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A REVISED RECONSTRUCTION OF GONDWANA

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A revised reconstruction of Gondwana is presented. It is based on previous reconstructions that were geologically well constrained as well as utilizing marine magnetic anomalies as additional constraints. Three areas of conflicts, namely the position of Madagascar, the location of India/Sri Lanka and the overlap of the Antarctic Peninsula with the Falkland Plateau are discussed. An interactive graphics terminal was used to minimize continental overlap while reducing obvious gaps between pre-breakup Gondwanide components. Poles and angles of rotation were determined directly from the terminal for the optimum fit.

DuToit first proposed a model for the reconstruction of the southern continents in 1937. As our knowledge of the earth has increased, aided by the discovery and correlation of marine magnetic anomalies the models of Gondwana have evolved. In our reconstruction, we have used marine magnetic anomalies to position the reconstructed pieces of Gondwana and have utilized an interactive graphics terminal to then produce the best fit and to generate the poles of rotation and angles of rotation required to make our reconstruction of Gondwana. We have relied on previous reconstructions for those parts of the southern continent, that can be well constrained geologically. We have also taken into consideration continental stretching that precedes initial rifting to produce a closer fit of the pieces of Gondwana. Our revised reconstruction bears a striking resemblance to that presented by DuToit (1937).

Until recently three areas have produced controversy regarding reconstructions of Gondwana. These are; the location of Madagascar with

respect to Africa, the fit of Sri Lanka and India with East Antarctica and the overlap of the Antarctic Peninsula with the Falkland Plateau (a recognized continental fragment). Recent identifications of marine magnetic anomalies in the Somali Basin have confirmed the northern fit of Madagascar with the Somali-Kenya coast of northeast Africa (Segoufin and Patriat, 1980; Rabinowitz et al., 1983). Rotation of Sri Lanka closed with southern India (Katz, 1978) produces a pre-breakup configuration of India/Sri Lanka that fits tightly into the Lutzow-Holm Bay region of Enderby Land and a remarkable fit of the Indian coastline with Enderby Land, East Antarctica (see figure 1). The closures of South America with Africa (Ladd, 1974; Rabinowitz and Labrecque, 1979) and Australia with East Antarctica have generated only minor controversy and are used with only slight modifications in our proposed reconstruction.

Using the marine magnetic anomalies identified in the Somali Basin, in the Mozambique Basin (Segoufin, 1978; Simpson et al., 1979) and off East Antarctica (Bergh, 1977) as constraints on the closure of Africa/Madagascar to East Antarctica and suggested lineaments between Madagascar and India (Katz and Premoli, 1979) produces a reasonable fit of Africa/Madagascar/India/Sri Lanka with East Antarctica. Further evidence for the position of India/Sri Lanka in Gondwana is given by the juxtaposition of Charnockite localities in Southern India and Enderby Land (Grew, 1982a,b). Grindley and Davey (1982) presented a comprehensive reconstruction of New Zealand/Australia/Antarctica which we have used with only minor modifications. Consequently with the closure of South America/Africa/Madagascar with India/Sri Lanka/East Antarctica/Australia and the fit of New Zealand/Australia/Antarctica the only circumpolar pieces of Gondwana that are not well constrained are the pieces of West Antarctica.

Our pole of rotation for Australia fitted to Antarctica is different from those of Norton and Molnar (1977) and Griffiths (1974) but not quite as extreme as the McKenzie and Sclater (1971) pole that simply relied on a computer generated least-squared fit of the coastlines. Since Griffiths (1974) attempted to align the Bowers group of North Victoria Land with the Dundas Trough of Tasmania, more recent workers (Cooper et al., 1983) have concluded that there is insufficient geological evidence to require an exact paleo-alignment. By shifting the Australia fit slightly clockwise with respect to Antarctica, the Tasman Rise can be treated as a relatively rigid piece of the Australian plate and does not have to be rotated with respect to Australia as it does in the Norton and Molnar (1977) and Griffiths (1974) models.

Reasonable assumptions regarding the partial closure of Marie Byrd Land, West Antarctica with East Antarctica can be made based on assumed crustal stretching in such areas as the Marie Byrd Basin and the Ross Sea area. The bedrock surface map of Antarctica (Drewry, 1983) as well as the Deep Sea Drilling Project results (Hayes, D. E., Frankes, L. A., et al., 1975) both give the impression that the area beneath the Ross Sea and the Ross Ice Shelf and extending to the Ellsworth Mountain region is an area of horsts and grabens vaguely similar in appearance to the Basin and Range province of the western United States. We assume that the crust between East Antarctica and Marie Byrd has been stretched about forty to fifty per cent.

Identified marine magnetic lineations in the Tasman Sea were used to rotate Lord Howe Rise/North Island of New Zealand closed to Australia (Weissel et al., 1977). Anomalies in the Southwest Pacific can be used to close Campbell Plateau/South Island of New Zealand with Marie Byrd Land (Molnar et al., 1975). By assuming the partial closure of the Ross Sea,

the revised position of Australia with respect to Antarctica and the closure of North New Zealand/Lord Howe Rise with Australia then South Island New Zealand/Chatham Rise/Campbell Plateau fits into the space available (see figure 2). To restore the Campbell magnetic anomaly on the Campbell Plateau to the Stokes magnetic anomaly on South Island requires the closure of the Bounty Trough between the Chatham Rise and the Campbell Plateau as Grindley and Davey (1982) have suggested. Such a closure produces a tight fit between the Chatham Rise/Campbell Plateau and Marie Byrd Land similar to that proposed by Grindley and Davey (1982).

The above constraints on the reconstructions of Gondwana leave only a small area into which the remaining pieces of West Antarctica must fit. Previous reconstructions of Gondwana have resorted to three different solutions with regards to the fit of the pieces of West Antarctica. The first solution has been to ignore the problem and to simply show the Antarctic Peninsula overlapping the Falkland Plateau (Norton and Sclater, 1979). An alternative solution has been to place the Antarctic Peninsula on the Pacific side of South America (Barron et al., 1978). While there is no marine magnetic data to dispute this conclusion, geological data seems to imply that the westward facing tip of South America fronted an active subduction zone during the period 120 to 165 Ma, the period for which an overlap must be considered a problem (Lawver et al., 1985). The third solution has involved a counter-clockwise rotation of the Peninsula (Dalziel and Elliot, 1982). From data presented by Grunow et al. (this volume) concerning the paleomagnetic position for the pieces of West Antarctica, constraints can be placed on the amount of rotation that the Antarctic Peninsula could have undergone if the paleomagnetic results are strictly adhered to. While our revised version of Gondwana does not use

the new poles determined by Grunow et al. (this volume) we do use their conclusion that the Antarctic Peninsula and the Ellsworth Mountains/Whitmore Mountains, were roughly in the same position with respect to each other during the Jurassic as they are now. We have moved the Ellsworth Mountains block and the Whitmore Mountains block slightly closer together based on presumed graben-like structures indicated on Drewry's bedrock map of Antarctica. The location of the pieces of West Antarctica with the exception of Marie Byrd Land is tentative at best so we have left them outlined by a lightweight line to distinguish them from what we feel are the better constrained parts of Gondwana. Other non-constrained pieces, primarily those north of the main pieces of Gondwana are also shown with a lightweight line since we do not have marine magnetic anomaly identifications that constrain them nor do we know their exact pre-breakup configuration.

Our revised reconstruction is shown in figure 3. We have kept Africa fixed and plotted the reconstructed pieces in a mercator projection. The advantages of plotting it fixed to Africa and using a Mercator projection is twofold. First the continents remain recognizable to those use to seeing the world plotted with a Mercator projection. Secondly, the pieces that are not controversial are plotted without much enlargement while the more poorly positioned pieces of New Zealand and West Antarctica are enlarged so that some of the controversial areas are easier to decipher. We feel that the major problems with our revised reconstruction of Gondwana are the placement of the pieces of West Antarctica as well as the relative position of the whole assemblage. Figure 4 shows the revised position of the pieces of West Antarctica superimposed on a present-day West Antarctica held fixed to East Antarctica.

The table lists the poles of rotation that we used to produce the

reconstruction shown in figure 3. Since we choose to have Africa remain fixed, the poles are listed as rotations of the pieces to Africa or are listed as being rotated to another plate, fixed to that plate and then the package of plates are rotated to Africa. To change the location of Gondwana with respect to the present reference frame, it would only be necessary to change the rotation pole for Africa.

If figure 3 is compared to DuToit's (1937) reconstruction of Gondwana (see figure 5), the most obvious difference is the location of Antarctica with respect to Africa. Other than that, the location of Madagascar with respect to Africa has not changed although its location has produced debate during the last twenty years, and India/Sri Lanka/East Antarctica have remained in approximately the same configuration. The fit of Australia to East Antarctica as well as South America to Africa are easily recognizable. It is interesting to note that the reconstruction of Gondwana has not been greatly revised in the past fifty years.

Our revised reconstruction of Gondwana places constraints on the area in which the pieces of West Antarctica can be placed. The paleomagnetic results of Grunow et al. (this volume) indicates that there may be a major break between the Peninsula and Marie Byrd Land since our reconstruction indicates that Marie Byrd Land cannot have been rotated in the simple fashion that is suggested for the Peninsula and the Ellsworth and Whitmore Mountains. Further work, particularly in the region between the Antarctic Peninsula and Marie Byrd Land, is needed.

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Table 1. ROTATION POLES FOR JURASSIC GONDWANA FIT

PLATE	LAT.	LONG.	ANGLE	WITH RESPECT TO
AFRICA	90.0	0.0	0.0	HELD FIXED
SOUTH AMERICA	45.5	-32.2	58.2	AFRICA
INDIA	-4.44	16.74	-92.77	EAST ANTARCTICA
SRI LANKA	-13.67	31.11	-107.14	EAST ANTARCTICA
AUSTRALIA	-1.58	39.02	-31.29	EAST ANTARCTICA
MADAGASCAR	-17.13	165.57	47.64	EAST ANTARCTICA
ANTARCTIC PENIN.	73.87	108.59	-41.79	EAST ANTARCTICA
ELLSWORTH MTN.	72.64	100.37	-37.44	EAST ANTARCTICA
WHITMORE MTN.	72.55	97.64	-39.73	EAST ANTARCTICA
THURSTON IS.	62.27	21.84	13.27	EAST ANTARCTICA
MARIE BYRD LAND	62.27	21.84	13.27	EAST ANTARCTICA
NORTH NEW ZEALAND	43.0	-68.2	40.6	EAST ANTARCTICA
SOUTH NEW ZEALAND	64.4	-38.8	74.05	EAST ANTARCTICA
CHATHAM RISE	63.72	-33.05	80.77	EAST ANTARCTICA
EAST ANTARCTICA	-7.78	-31.42	51.11	AFRICA
FLORIDA	63.0	-17.5	80.3	AFRICA
CENTRAL EUROPE	64.3	147.3	20.6	AFRICA
IBERIA	50.0	3.3	-27.0	CENTRAL EUROPE
ARABIA	26.5	21.5	-7.6	AFRICA
IRAN/TURKEY	2.02	36.9	-24.6	ARABIA
TIBET	-43.0	0.5	8.0	INDIA

Figure Captions

Figure 1. Reconstruction of Africa/Madagascar/India/Sri Lanka/East Antarctica. Africa is held fixed in a present day reference frame. On continental fragments other than East Antarctica, heavy line is present day coastline. On East Antarctica, the heavy line represents the northern most extent of basement outcrops or the boundary of the Trans-Antarctic Mountains taken from Drewry (1983). Lightweight line is 2000-meter contour. 5 X 5 degree tick marks are pre-rotation present day latitude and longitude grid marks. Where present day extent of continental block is unknown (ie. northern bounday of India), the continental outline is left as a lightweight line. SL=Sri Lanka, LHB=Lutzow Holm Bay, AI=Amery Iceshelf.

Figure 2. Reconstruction of New Zealand/Marie Byrd Land/East Antarctica /Australia modified from Grindley and Davey (1983). Continental outlines as in figure one. Dashed lightweight line is presumed continental part of Lord Howe Rise (LHR). T=Tasmania, SNZ=Southern New Zealand, NNZ=Northern New Zealand.

Figure 3. Reconstruction of Gondwana. Continental outline as in figure one. Poles for reconstruction to Africa fixed in a present day reference frame are given in Table 1. WM=Whitmore Mountains, EM=Ellsworth Mountains, TI=Thurston Island block, NNZ=Northern New Zealand, SNZ=Southern New Zealand attached to Campbell Plateau, M=Madagascar, and T=Tasmania.

Figure 4. The pieces of West Antarctica held fixed to East Antarctica in a present-day reference frame (light lines) are superimposed on the revised positions of the pieces of West Antarctica in a pre-break up reference frame (heavy lines). The inset figure is taken from Grunow et al., this volume, and illustrates the clockwise rotation of the Antarctic Peninsula, the Ellsworth and Whitmore Mountains.

Figure 5. Reproduction of figure 7 of DuToit's book, "Our Wandering Continents" (1937). "Reassembly of Gondwana during the Paleozoic Era. The space between the various portions was then mostly land. Short lines indicate the pre-Cambrian or early Cambrian "grain". Diagonal ruling shows the "Samfrau" Geosyncline of the late Paleozoic. Stripping marks our regions of late Cretaceous and Tertiary compression. (Lambert's Equal Area Polar Projection)".

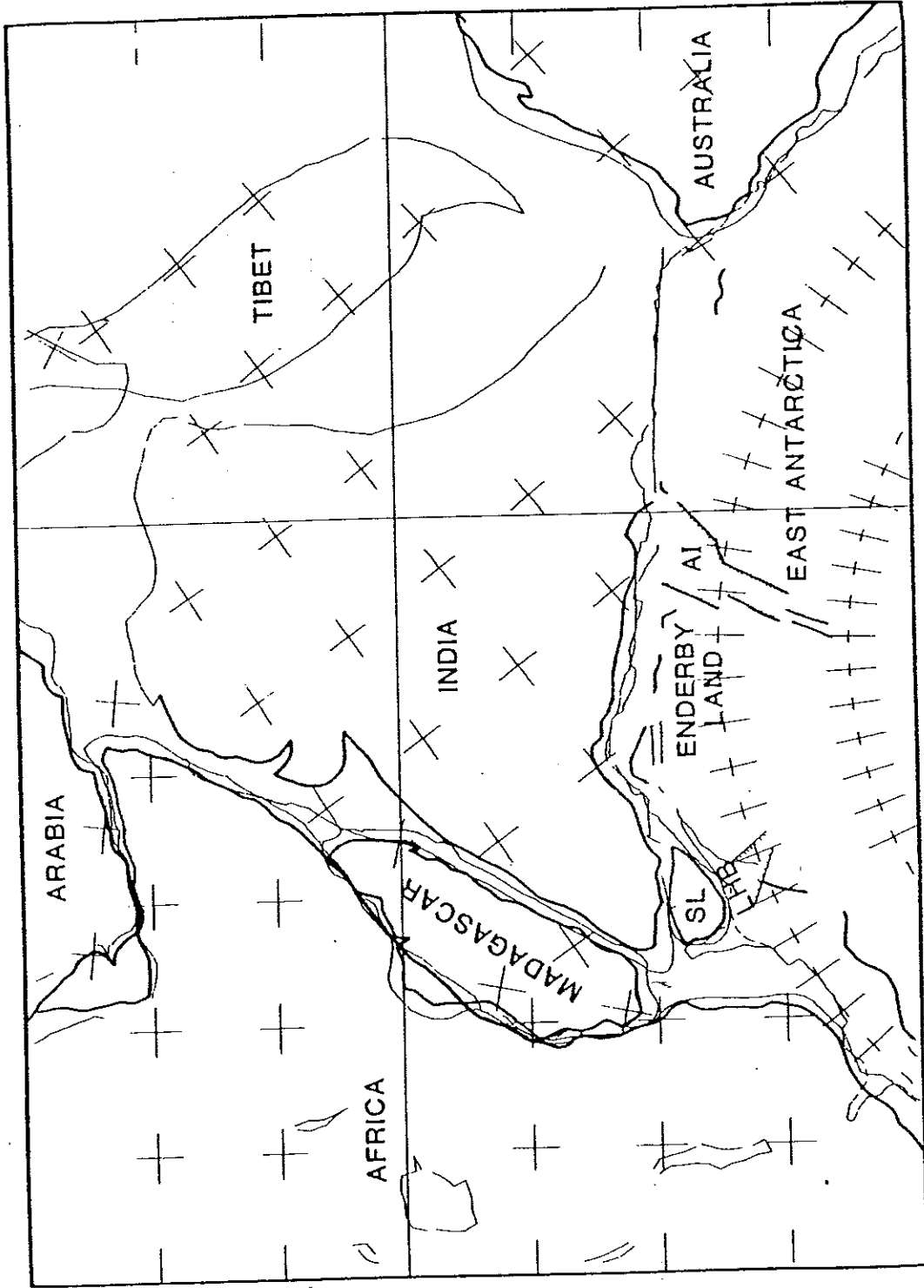


Figure 1

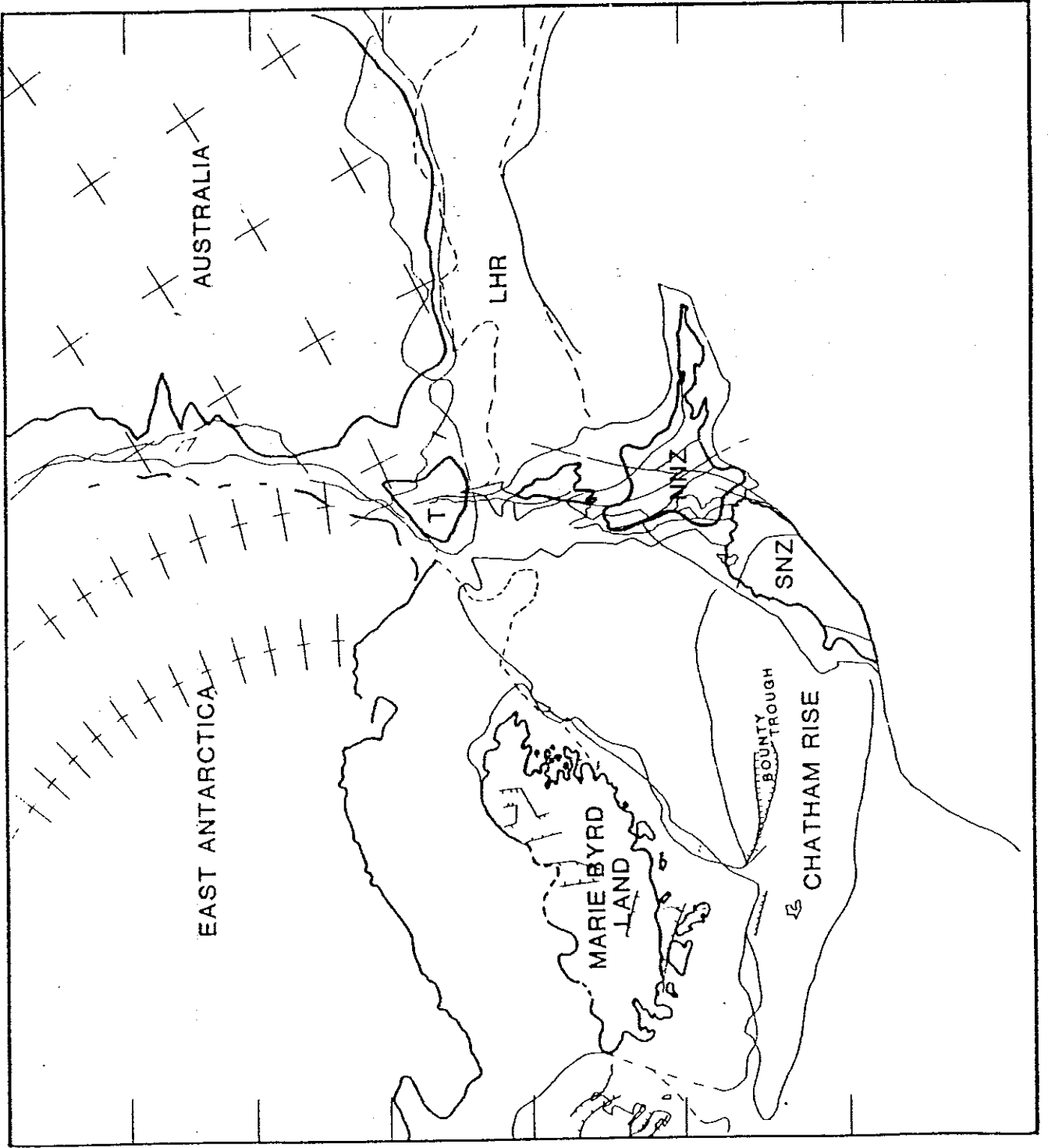


Figure 2

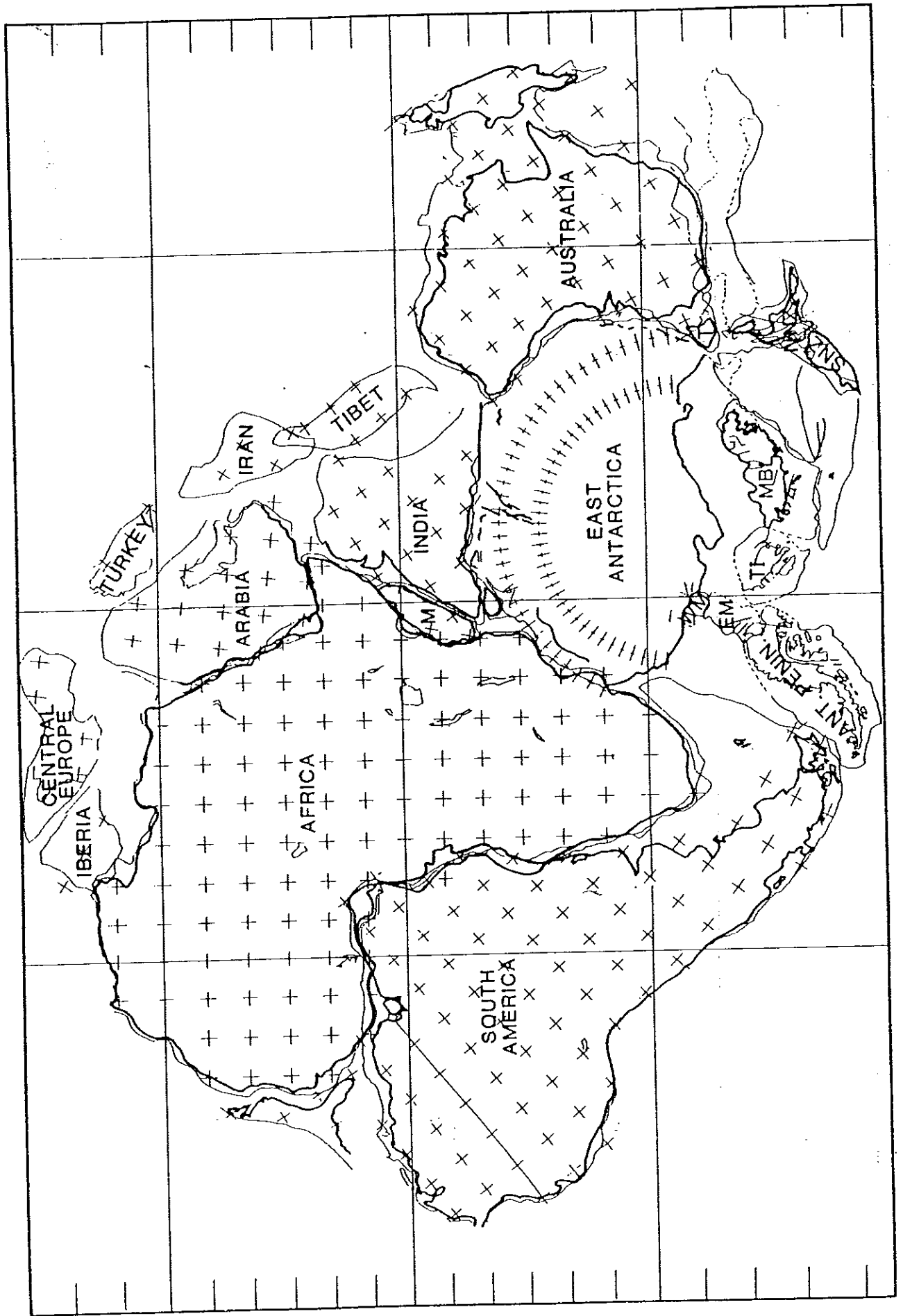


Figure 3

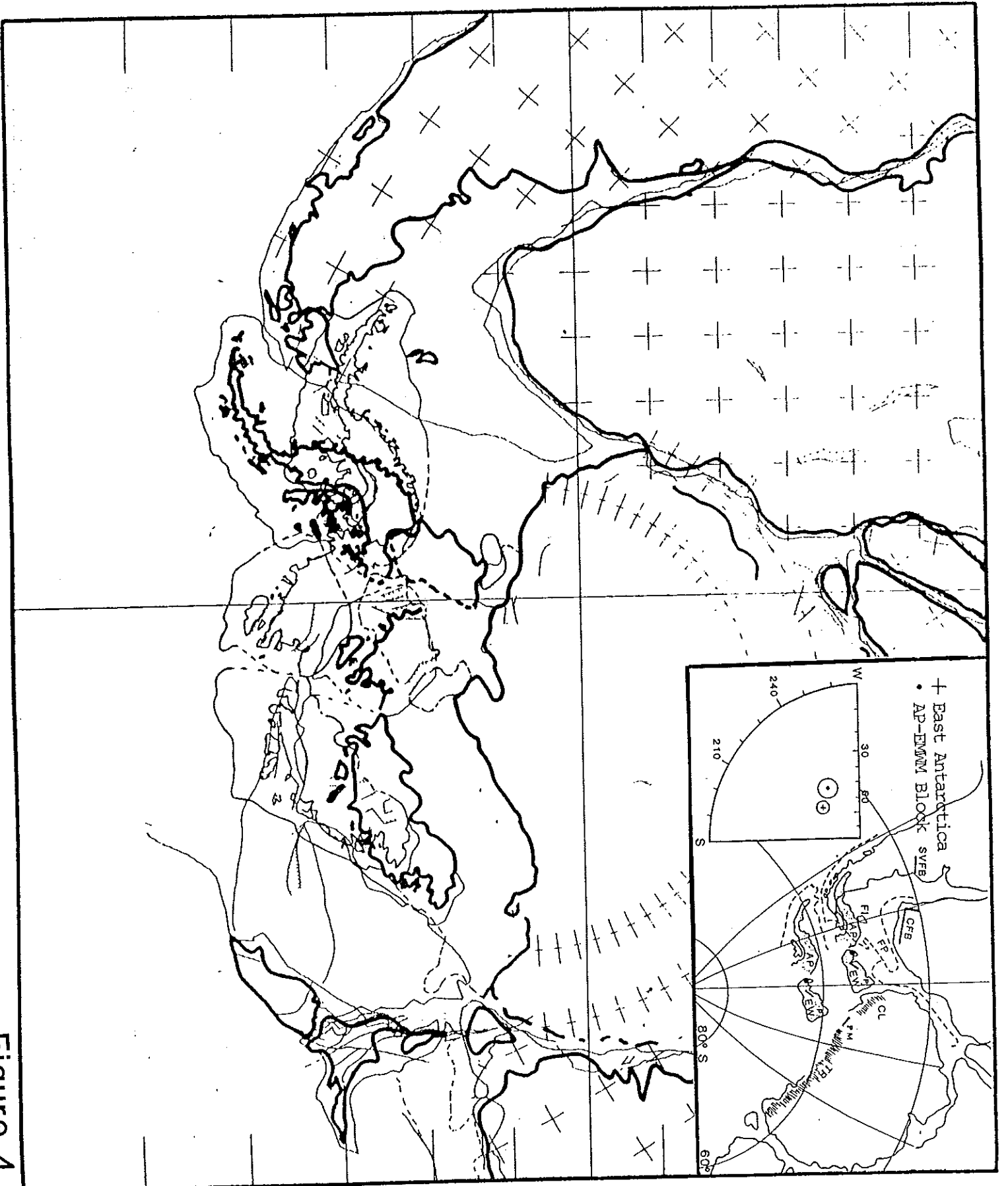


Figure 4

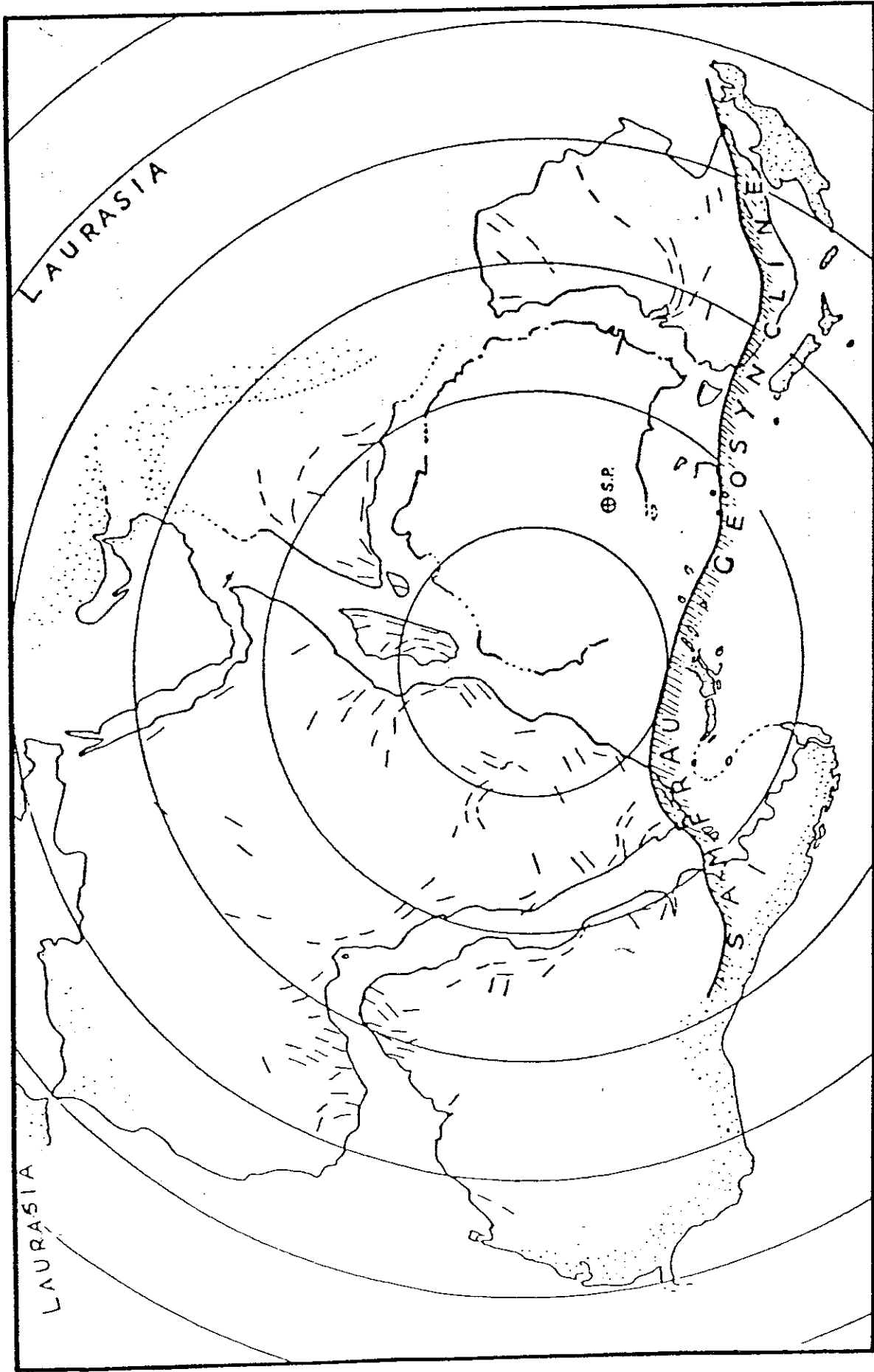


Figure 5