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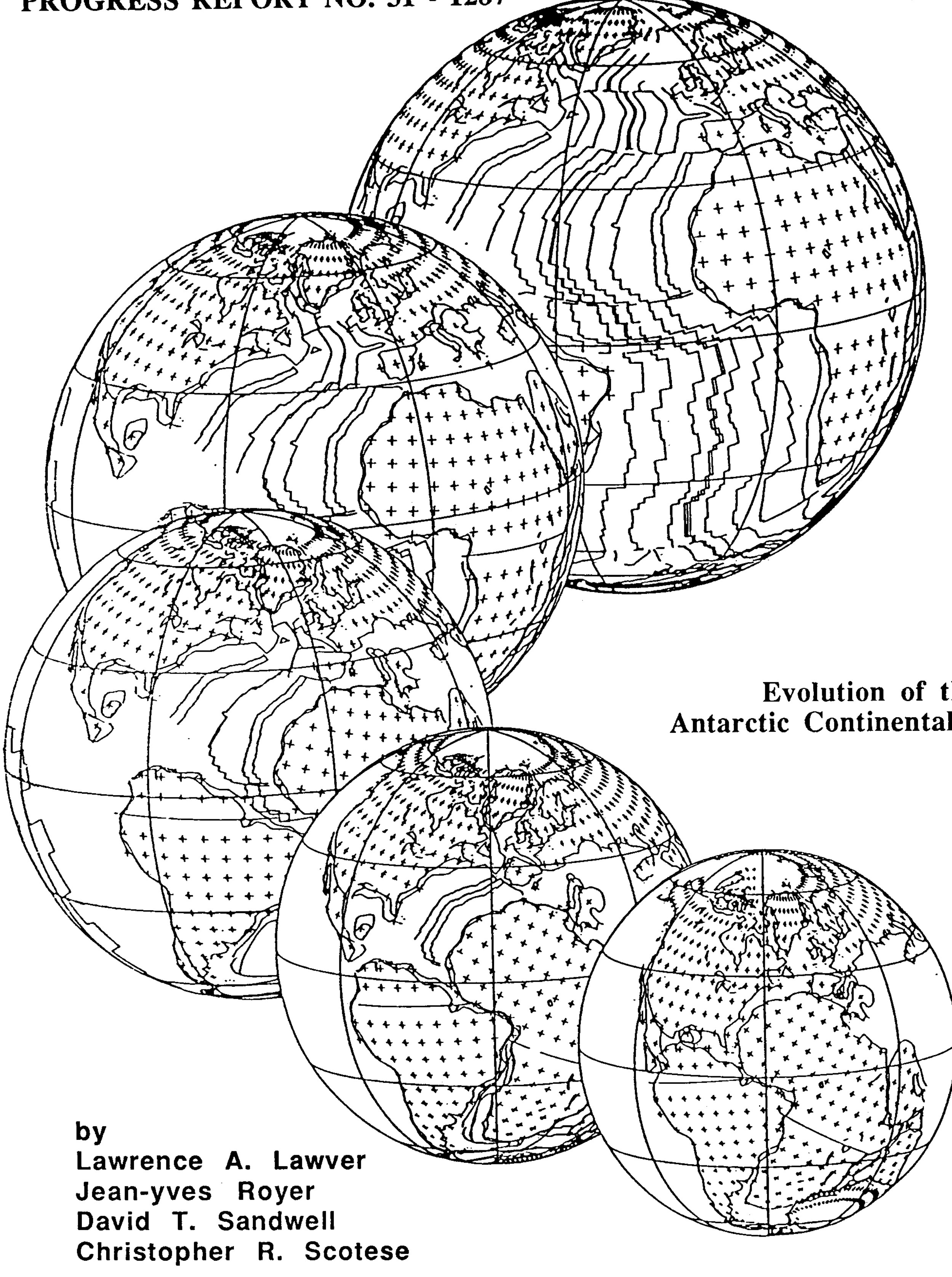
PROGRESS REPORT NO. 31 - 1287



Evolution of the Antarctic Continental Margins

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EVOLUTION OF THE ANTARCTIC CONTINENTAL MARGINS

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With the exception of the Pacific facing margin of West Antarctica between Thurston Island and the tip of the Antarctic Peninsula, all of the continental margins of Antarctica are either rifted passive margins or sheared transform margins. The exception was a convergent margin where subduction was active from prior to the breakup of Gondwanaland until very recently. Starting in the southwestern Weddell Sea which rifted as part of a back-arc basin connected with back-arc spreading in the Rocas Verdes Basin of southern South America during the Middle to Late Jurassic (~170 Ma), the continental margins of Antarctica seem to young clockwise. A sheared margin along the Explora Escarpment between 25°W and 10°W connected the southwestern Weddell Sea rifting with contemporaneous rifting in the Mozambique Basin. This resulted in a Middle Jurassic rifted passive margin along Dronning Maud Land. East of the Gunnerus Ridge at 35°E, Sri Lanka and India rifted off of Antarctica sometime between 129 Ma and 118 Ma. Rifting between Australia and Antarctica, stretching in the Ross Sea Embayment and rifting between the Campbell Plateau--Chatham Rise and Marie Byrd Land, all started about 95±5 Ma. The convergent margin on the Pacific margin of the Antarctic Peninsula stopped active subduction in the west at about 50 Ma, with the most recent subduction about 5 Ma off the South Shetland Islands. The only presently active continental margin on the Antarctic Continent is a short section of left lateral transform fault along the tip of the Antarctic Peninsula. Very young volcanism in the Ross Sea region may indicate that a new continental margin is in the initial stages of formation.

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INTRODUCTION

The reconstruction of an early Mesozoic Gondwanaland (Figure 1) indicates that most of the present day margin of Antarctica was bounded by other continental masses. With the exception of West Antarctica, which was a subduction margin from Thurston Island to the tip of the Antarctic Peninsula during part of the period since break-up, the rest of the Antarctic margin was formed either as a rifted passive margin or as a sheared transform margin.

The identified marine magnetic anomalies that record the initial break-up of Gondwanaland (Figure 2) are observed in the Mozambique Basin (Segoufin, 1978, Simpson et al., 1979) and in the Western Somali Basin (Segoufin and Patriat, 1980). Recently Cochran (in press) has extended the initial breakup to the North Somali Basin as well. The oldest anomaly identified by Cochran in the the Western Somali Basin is M22 (152 Ma--Palmer, 1983). There is sufficient room between the identified anomalies and the continental margin of Madagascar in the south and Africa in the north to extend seafloor spreading as much as 300 kilometers beyond both M22 to the north and to the south. This translates to as much as 20 million years of seafloor spreading prior to the first identified anomaly in the West Somalia Basin if a constant spreading rate is assumed. In the Mozambique Basin, the anomalies older than M16 (142 Ma) are not well identified but upwards of 300 km of seafloor exist that is presumably older than the tentativiely identified M22 anomaly. Again this might imply that seafloor spreading commenced as early as 170 Ma.

DRONNING MAUD LAND/AFRICA

The conjugate magnetic anomalies to those in the Mozambique Basin were found by Bergh (1977) near the Astrid Ridge off Dronning Maud Land. Bergh (1987) identified magnetic anomalies M0 (118 Ma) to M11 (134 Ma) but other anomalies are clearly visible between M11 and the continental margin of Dronning Maud Land. Even so, there is at most 100 km between what might be M22 and the margin, representing only 6 to 7 million years of additional seafloor spreading prior to 152 Ma. Bergh calculates the same spreading rate of 15 mm/year (half-rate) for anomalies M1 (122 Ma) to M5 (127 Ma) as Segoufin (1978) found in the Mozambique Basin. Bergh (1987) presents two scenerios for the Mesozoic opening of the Mozambique Basin; one fits the Astrid Ridge against the Mozambique Escarpment while the other matches it with a fracture zone suggested by Simpson et al. (1979) about 100 km to the east of the Mozambique Escarpment at 25°S to 28°S. Since the Mozambique Escarpment is not only steep, >27° in some places, but is parallel to the general direction of opening of the Mozambique Basin, it is assumed to be a sheared margin that was produced by the seafloor spreading in the Mozambique Basin.

Worldwide, the average angle of the continental slope is 4° (Kennett, 1982). Strike-slip transform margins generally have very steep slopes, as much as 45° while subduction margins which may be steep in places, nearly always have obvious subduction related features. Rifted passive margins usually have gentle slopes of 4° or less. If the Mozambique Escarpment is a sheared margin, it is reasonable to ask what was sheared off of it. The East Antactic margin, known as the Explora Escarpment, from about 10°W to about 25°W also has a very steep slope. A SEABEAM survey by *R/V Polarstern* (Barker, Kennett, et al., in press) between 13°30'W and 15°W revealed a continental slope of 45°. The strike of this margin is roughly parallel to the direction of spreading recorded by the anomalies to the east of Astrid Ridge (Bergh, 1987). The Explora Escarpment between 10°W and 25°W may have been the conjugate sheared transform margin to the Mozambique Escarpment. If that is correct, then the reconstruction of Gondwanaland by Lawver and Scotese (1987) is too tight for a Middle Jurassic fit, particularly considering the position of Madagascar with respect to Africa.

Scrutton et al. (1981) and Rabinowitz et al. (1983) both suggest a looser fit of Madagascar with Africa based on the original work of Bunce and Molnar (1977). In addition, Battail et al. (1987) make the point that during the Late Permian and Early Triassic, Madagascar was obviously separated from Africa by a marine barrier. Reeves et al. (1987) produce an identical fit for Madagascar and Africa as Lawver and Scotese (1987) but suggest that active rifting in a triple junction centered on the Kenyan coast may have begun as early as Permo-Carboniferous, contemporaneous with the initial Karoo deposition. After a very slow initial rifting, onset of seafloor spreading occured during Middle Jurassic as evidenced by the encroachment of marine conditions from the north. Reeves et al. (1987) suggest that the stretching on the three limbs of the triple junction resulted in the Northeast-Southwest opening of the now-buried Anza Trough in Kenya and the southeastward motion of Madagascar away from Africa along the north-south Mombasa margin and the northeast-southwest Somalia margin. When the actual opening of the Somali Basin began, the Anza Trough failed, and north-south opening occured as part of the two plate break-up of Gondwanaland. It may be reasonable to assume that the initial Permo-Carboniferous rifting along the Mombasan coast as discussed by Reeves et al. (1987) extended south along the southeast coast of Africa. This slow extension may have produced the Mozambique Plateau between the eastern margin of the Falkland Plateau and the Explora Coast.

Kristoffersen and Haugland (1986) discuss the geophysical evidence for the East

Antarctic plate boundary in the Weddell Sea. While they discuss the possibility that the Explora Escarpment section of the East Antarctic margin between 12°W and 19°W represents a sheared margin overprinted by rifting, they connect it with the colinear Andenes Escarpment that extends to 40°W and suggest that both escarpments were formed by rifting. As noted above, the 45° slope of the Explora Escarpment is more indicative of a sheared margin than a rifted margin. As suggested by Lawver et al. (1985) the sheared margin of Dronning Maud Land only operated as such from break-up (170 Ma) to anomaly M12 (136 Ma) time when separation between South America and Africa (Figure 3) resulted in a triple junction that replaced the original two plate break-up between West (South America/Africa) and East Gondwanaland. Consequently we propose that the Explora Wedge was first rifted during the pre-breakup extension and then sheared between 170 Ma and 136 Ma and finally rifted once more. The older, initially rifted Explora Wedge (older than 170 Ma) was sliced off during the shearing period and is now represented by the deep sediments landward of the Explora Escarpment and those left behind on the Mozambique Ridge. The Andenes Escarpment is undoubtedly related to the younger rifting event (136 Ma to present) that produced much of the seafloor in the Weddell Sea.

Many researchers have discussed the problem of the overlap of the Antarctic Peninsula with the Falkland Plateau in Gondwanaland reconstructions (Dalziel and Elliot, 1982; Lawver et al., 1985; Dalziel et al., in press). The most reasonable solution seems to be a clockwise rotation of the Antarctic Peninsula with respect to East Antarctica during the early stages of break-up since any overlap problem disappears by M0 (118 Ma) time according to Lawver et al. (1985). Such a scenerio is supported by paleomagnetic data from the Ellsworth Mountains, the Antarctic Peninsula, and Thurston Island (Grunow et al., 1987a,b). If the Late Jurassic--Early Cretaceous opening of the Mozambique Basin was translated along the Explora Escarpment to the southwesternmost Weddell Sea, earliest opening of the Weddell Sea would have resulted in a clockwise rotation of the Peninsula with respect to East Antarctica. In contrast, if the Weddell Sea opened in a north-south direction since prior to anomaly M25 (156 Ma) time, as suggested by LaBrecque and Cande (1987) and LaBrecque and Barker (1981) , then it is difficult to produce clockwise rotation of the Antarctic Peninsula between break-up and M0 time. As Gondwanaland breaks up with opening in the Somali Basin, Mozambique Basin and southwestern Weddell Sea, the Antarctic Peninsula is assumed to slide along the western edge of the tip of South America. Since there is no geological evidence to support such a sheared margin, it is premature to assume that that is what actually happened.

ENDERBY LAND--QUEEN MARY LAND/SRI LANKA--INDIA

The next major event to affect the continental margin of present-day Antarctica was the rifting of India/Sri Lanka from East Antarctica between 35°E and 95°E (Figure 4). The Proterozoic Shillong Plateau in northeastern India (present location 27°N, 94°E) is considered to be the easternmost point of Lesser India that must be fit against East Antarctica. With the location of Australia fit to Wilkes Land constrained by GEOSAT data (Sandwell and McAdoo, in press) and the location of Sri Lanka/Lesser India constrained by the Gunnerus Ridge (Lawver et al., 1985), the very western tip of the Naturaliste Plateau fits against the Shillong Plateau. This assumes that there has been no motion between the Naturaliste Plateau and Australia since break-up. Marine magnetic anomalies immediately northwest of Naturaliste Plateau have been dated as M0 to M5 (118 Ma to 127 Ma) by Veevers et al. (1985). To the southwest, a triangular area of crust bounded by the NNW-SSE trending Naturaliste fracture zone on the northeast, the WNW-ESE trending Diamantina fracture zone on the south and the Dirck Hartog ridge on the west may be the one region where magnetic anomalies formed at the Antarctica-India boundary could be found. If as postulated by Markl (1974) that the Dirck Hartog Ridge is an abandoned spreading center, then the anomalies in the triangular region should be similar in age and distance from the spreading center as the anomalies off Naturaliste Plateau. In contrast, if Naturaliste Plateau is not a continental fragment older than the initial break-up (Coleman et al., 1982) then M5 (127 Ma) may not be the age of the break-up of India/ Antarctica. South of the Argo Abyssal Plain (15°S, 112°E) the magnetic anomalies closest to the Continent-Ocean Boundary (COB) are identified as M9 or M10 (129 to 130 Ma). In the Argo Abyssal Plain to the north the oldest identified anomalies are older than 160 Ma (Heirtzler et al., 1978). While it is clear that whatever rifted off northwest Australia was not part of Greater India, whatever rifted off western Australia from 15°S to the Naturaliste Plateau may have been attached or partially attached to Lesser India. The difference in total spreading between M9 and M5 time is only 230 kilometers. Such an offset could have taken place on a few strike-slip faults in Greater India. Livermore and Vine (in press) present a similar scenerio for the early evolution of the Indian Ocean but argue that some other block, perhaps Tibet rifted off western Australia rather than Greater India. We suggest that the difference of only a few million years in age, makes it unlikely that whatever rifted off western Australia was totally unattached to Lesser India.

Space problems with East Antarctica, Madagascar and Africa preclude India moving away from Antarctica at M10 (130 Ma) time or earlier (Lawver et al., 1985; Livermore and Vine, in press). If the M5 anomalies off the Naturaliste Plateau indicate initial India/Antarctica spreading in the east then the active spreading center off western Australia may have initiated westward propagation of the rift. Without identifiable magnetic anomalies off Enderby Land or off the east coast of India, the exact age of the seafloor spreeading between India/East Antarctica can not be determined to closer than M5 to M0 (127 to 118 Ma). Rifting between Sri Lanka and India started in the Early Cretaceous (130 Ma, unreferenced timescale) according to Katz (1978) based on geological work in Sri Lanka. Katz (1978) suggests as much as 200 km of separation between Sri Lanka and India resulting in the formation of the NE-SW Cauvery-Palk Basin in the Gulf of Mannar. This rifting probably occurred contemporareous with the initiation of rifting between India and East Antarctica. If the major plate rifting was propagating westward it may have bypassed the Cauvery-Palk Basin rifting to join the Mozambique Basin rifting, separating Sri Lanka from Antarctica, instead of leaving Sri Lanka as part of Antarctica if the Cauvery-Palk Basin rifting had been successful. As the westward propagation reached the Mozambique Basin the transform motion along the Davie Ridge/fracture zone stopped and seafloor spreading in the Somali Basin ceased.

WILKES LAND/AUSTRALIA

Cande and Mutter (1982) revised the identification of seafloor spreading anomalies between Australia and Antarctica. They suggested that spreading could be separated into two distinct phases--breakup to anomaly 20 (45 Ma) at 4.5 mm/year, and anomaly 20 to present at 22 to 38 mm/year (half-rate). Very slow spreading in regions of continental breakup frequently produce confused magnetic signatures because of high sedimentation blanketing the spreading centers. Cande and Mutter (1982) concluded that breakup and initial rifting could have occurred anytime between 110 Ma and 90 Ma (Figure 5).

Veevers (1986) put the age of the breakup as mid-Cretaceous (95±5 Ma) based on seismic data from the Australian margin. There is a short mid-Cretaceous lacuna in the Otway Basin between the block-faulted Early Cretaceous rift-valley sediments of the Otway group and the overlying relatively unfaulted Late Cretaceous Sherbrook group (Veevers, 1986). While Veevers (1986) was able to clearly identify the COB on the Australian margin, he had only limited data on the conjugate Antarctic margin. With the recent GEOSAT data (Sandwell and McAdoo, in press), the COB gravity anomaly is now clearly delineated on the Antarctic margin as well. In fact, the meanderings of the COB on the Australian margin at 118°E, 120°E, 124°E and 126°E, are mirrored in the GEOSAT gravity anomaly on the Antarctic margin at 110°E, 115°E, 123°E and 127°E. In addition the GEOSAT derived gravity anomalies clearly show the tracks that Tasmania and the Tasman Rise followed off the Antarctic margin. It is clear that the initial slow rifting of Australia away from Antarctica had a certain westward component as evidenced by the GEOSAT anomalies.

ROSS SEA/NEW ZEALAND/MARIE BYRD LAND

Marine magnetic anomalies have been identified off New Zealand in the Southwest

Pacific as anomaly 32 (72 Ma) by Stock and Molnar (1987). In addition to the seafloor spreading that occurred to the west between Australia and Antarctica, seafloor spreading was active in the Tasman Sea from prior to anomaly 33 (76 Ma) time according to Stock and Molnar (1982). Stretching in the Ross Sea during Late Cretaceous has been suggested by Cooper and Davey (this volume), Bradshaw (this volume), and Fitzgerald et al. (this volume). They variously date the extension as Paleocene (Bradshaw), Late Mesozoic "early-rift" (Cooper and Davey), and Late Cretaceous--Early Cenozoic (Fitzgerald, et al.). Bradshaw discusses the convergent Gondwanide margins in northeast Australia and New Zealand that continued to develop in the Early Cretaceous but "ended abruptly about 100 Ma, probably due to the oblique convergence and collision of the Pacific-Phoenix Ridge." He also states that the evidence for rifting and extension between Antarctica and New Zealand date back to "more than 100 Ma", which suggests that the subduction of the Pacific-Phoenix Ridge to the north, may have been a major factor in the initiation of the extension and rifting between New Zealand and Antarctica.

In the reconstruction of Gondwanaland shown in figure 1, 40-50% extension between Marie Byrd Land and East Antarctica has been assumed (Lawver and Scotese, 1987). This extension coincides with earliest rifting between Australia/East Antarctica but seems to predate the Southwest Pacific seafloor spreading (Stock and Molnar, 1987). Bradshaw (this volume) indicated that extension seems to have started near the Antarctic-Indian-Australian triple junction and spread eastwards, being older south of Australia than in the Tasman region and youngest in the Ross Sea. It is possible that the Ross Sea embayment represents a failed rift and that the seafloor spreading then propagated between Marie Byrd Land and Campbell Plateau--Chatham Rise to join the active spreading to the east.

The GEOSAT-derived gravity anomalies shown in figure 6 indicate that the prominent Udintsev fracture zone (50°S, 210°E to 65°S, 240°E) can be extended into the Antarctic margin at Pine Island Bay between Thurston Island and Marie Byrd Land. The northern extension of the Udintsev fracture zone continues to the northeastern point of Chatham Rise. This confirms that the Grindley and Davey (1982) reconstruction of New Zealand in Gondwanaland is essentially correct. The relatively fast spreading between the Pacific and Antarctic plates (36 mm/year half-rate; Stock and Molnar, 1987) and the moderately fast spreading in the Tasman Sea (21 mm/year half-rate; Hayes and Ringis, 1973) contrast sharply with the very slow spreading between Antarctica and Australia (4.5 mm/year; Veevers, 1986) and the stretching in the Ross Sea that was occurring at the same time. The four areas all suggest roughly the same time for initiation of stretching and seafloor spreading where it occurred. Since seafloor spreading died out in the Tasman Sea just before the major increase in spreading rate between Antarctica and Australia, a suggested scenerio for this very complicated region is that seafloor spreading was propagating slowly eastward as suggested by Veevers (1986) between Antarctica and Australia. At the same time spreading between Antarctica and the Pacific plate was propagating westward since there appears to be slightly more room between Chatham Rise and Marie Byrd Land than there is between Campbell Plateau and western Marie Byrd Land. The Pacific-Antarctic seafloor spreading continued into the Tasman Sea with two triple junctions producing changes in ridge orientation. The eastern one resulted in stretching in the Ross Sea region while the other formed the intersection of the spreading centers between the East Antarctic, Australian and Pacific plates with two relatively fast spreading ridges and one very slow one (Antarctic/Australian).

CONVERGENT MARGIN--PINE ISLAND BAY TO ANTARCTIC PENINSULA

The Cenozoic subduction history of the Pacific margin of the Antarctic Peninsula was discussed by Barker (1982). As mentioned above, Bradshaw (this volume) discusses the convergent Gonwanide margin in northeast Australia and New Zealand that was active in the Early Creataceous but that ceased about 100 Ma. Barker (1982) shows this subduction boundary between the Phoenix and the remnant of the Gondwana plate at 100 Ma as a continuous subduction zone from northwest of 'New Zealand' to the tip of the Antarctic Peninsula. Since there are no identified magnetic anomalies immediately off of West Antarctica between the Udintsev fracture zone and the Tharp fracture zone, it is not possible to speculate as to the timing and nature of this boundary but we assume that it was probably a subduction boundary until sometime between 100 Ma and 80 Ma.

Anomaly 31 (70 Ma) is identified more than 1000 km offshore of Thurston Island, so it can be assumed that seafloor older than anomaly 34 exists seaward of Thurston Island. Since the conjugate seafloor to that off Thurston Island extends more than 1000 km past the Chatham Rise to the Kermadec Trench region there is no real space problem that would necessiate continued subduction. Conversely, since there is on-going subduction at the Kermadec Trench, it can be assumed that some seafloor was subducted beneath the Thurston Island region. Unlike the seafloor north of the Tharp fracture zone where it is documented (Cande et al., 1982) that a Phoenix--Antarctic spreading center was subducted at the plate margin resulting in a cessation of subduction (Barker, 1982), the undated older (probably Cretaceous Quiet Zone) anomalies between the Udintsev and Tharp fracture zones do not imply when subduction ceased since we can not be sure that an active spreading center was subducted.

If the magmatic activity in the Trans-Antarctic Mountains (TAM) can be related to subduction along the Pacific margin of Gondwanaland then subduction was occurring prior to 175 Ma (Dalziel et al., in press). From the Tharp fracture zone northwards, Barker (1982) dates the cessation of subduction by the age of the oldest identified magnetic anomalies offshore and the age of the Magmatic rocks of the Antarctic Peninsula. Subduction ceased about anomaly 21 time (49 Ma) between the Tharp and Heezen fracture zones, about anomaly 6 time (25 to 20 Ma) between the Heezen and Anvers fracture zones and within the last 5 to 8 million years for the remainder of the Antarctic Peninsula.

CONCLUSION

The present-day Antarctic plate boundary is far removed from the Antarctic continental margin except in the immediate vicinity of the northern tip of the Antarctic Peninsula. The continental margin of the Antarctic Peninsula has had the longest history of tectonic complications of any of the Antarctic margin in the last 175 million years. Prior to the breakup of Gondwanaland it was a westward facing subduction margin. Back-arc basin seafloor spreading in the Rocas Verdes region of southern South America, extension between the Antarctic Peninsula and East Antarctica coupled with the intrusion of Jurassic magmas along the TAM and in Southern Africa, and seafloor spreading in the North and Western Somali Basins and the Mozambique Basin, all resulted in the two plate breakup of West and East Gondwanaland. At anomaly M12 time (135 Ma), South America and Africa broke apart resulting in a complete reorganization of spreading in the Weddell Sea. The previously rifted then sheared Explora Escarpment once again became a rifted margin that connected with the Andenes Escarpment to as far west as 44°W (Kristoffersen and Haugland, 1986).

While rifting in the Mozambique Basin may have contributed to some extension between India and Sri Lanka in the present-day Gulf of Mannar between anomaly M10 time and M0 time, major rifting between India and Antarctica probably started in the east and propagated westward between M5 to M9 time (127 to 130 Ma) and M0 time (118 Ma). It is impossible to bracket the breakup between India and Antarctica any closer than 129 to 118 Ma. With the breakup of India and East Antarctica, seafloor spreading stopped in the Somali Basin. The clockwise rotation of the Antarctic Peninsula with respect to East Antarctica stopped, leaving Marie Byrd Land as perhaps the only part of continental Antarctica not in its present day location. Marie Byrd Land reached its present position with respect to Antarctica by stretching of the Ross Sea Embayment region during the Late Createaceous and early Cenozoic.

By 100 Ma, Gondwanide subduction beneath Northeast Australia and New Zealand abruptly stopped (Bradshaw, this volume) and initial stretching premonitory to seafloor spreading was beginning between Antarctica, Australia, New Zealand and Marie Byrd Land. By anomaly 34 time (82 Ma) the last of the rifted passive margins of present-day

Antarctica had formed opposite Australia and New Zealand. On-going subduction continued along the Antarctic Peninsula coast until almost 5 million years ago off the South Shetland Islands. At approximately 30 million years ago seafloor spreading began in the Scotia Sea which bounds the northern tip of the Peninsula with a left-lateral transform fault (Barker and Dalziel, 1983). While the tectonic evolution of the Antarctic continent seems to be almost complete, it may in fact be starting all over again with the recently active extension in the Ross Sea region (Cooper and Davey, this volume).

Acknowledgements This paper has not been read or reviewed by anyone including the junior authors, consequently they should not be held accountable for any statements made herein. The final acknowledgments will be much different than these. This is the University of Texas, Institute for Geophysics contribution no. 0000.

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Figure 1. Early Mesozoic reconstruction of Gondwanaland based on Lawver and Scotese (1987). AP = Antarctic Peninsula, MBL = Marie Byrd Land, SNZ = South New Zealand, NNZ = North New Zealand. Continental blocks are reconstructed to a fixed East Antarctica. The Antarctic Peninsula has been rotated with respect to East Antarctica.

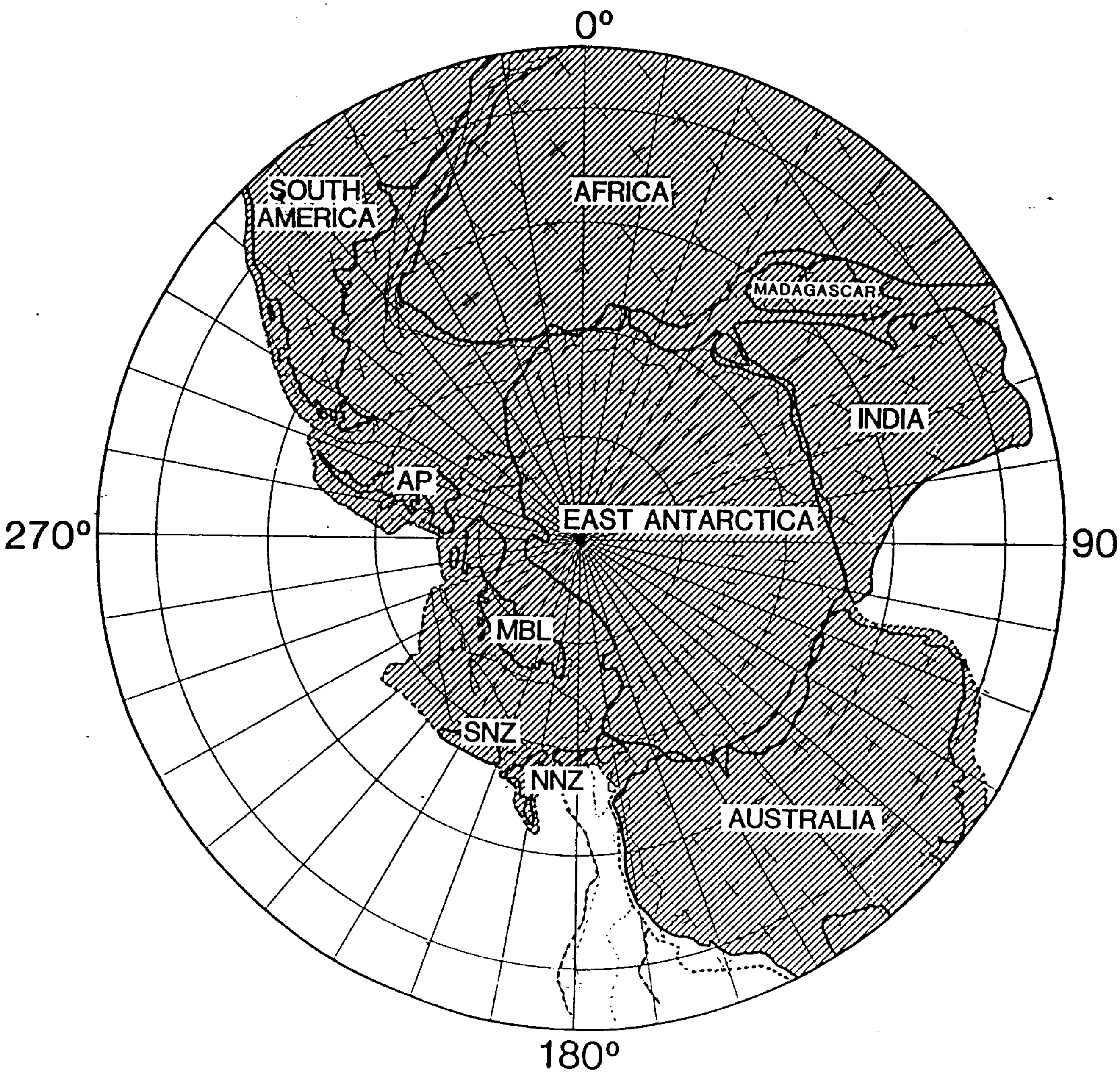
Figure 2. Magnetic anomaly M15 time (140 Ma) reconstruction of West Gondwanaland (South America--Africa) and East Gondwanaland. Seafloor spreading has taken place in the Somali Basin, Mozambique Basin, and Southwestern Weddell Sea. A sheared transform margin has occurred along the Explora Escarpment. SB = Somali Basin, MB = Mozambique Basin, SwWS = Southwestern Weddell Sea, ME = Mozambique Escarpment, EE = Explora Escarpment.

Figure 3. Magnetic anomaly M10 time (130 Ma) reconstruction of Gondwanaland. Rifting has started in the South Atlantic between South America and Africa producing a reorganization of the seafloor spreading in the Weddell Sea at M12 (132 Ma) time.

Figure 4. Magnetic anomaly M0 time (118 Ma) reconstruction of Gondwanaland. Rifting between India and Antarctica has begun with the cessation of seafloor spreading in the Somali Basin. West Antarctica with the exception of Marie Byrd Land has assumed its present day geographic location with respect to East Antarctica.

Figure 5. Magnetic anomaly A30 time (70 Ma) reconstruction of Gondwanaland. Stretching between Marie Byrd Land and East Antarctica has produced the Antarctic continental mass as it is presently configured. Rifting between Australia and Antarctica has begun as well as rifting between South New Zealand and Marie Byrd Land.

Figure 6. Summary chart of present-day Antarctica showing the continental blocks that rifted off of Antarctica and the time of the rifting. Chart shows the GEOSAT-derived gravity anomalies (Sandwell and McAdoo, in press). The prominent Udintsev fracture zone can be seen at 60°S, 235°E. The tracks marking the northward path of Tasmania are easily seen at 60°S, 150°E. Undulations in the continental-edge gravity anomaly along the Wilkes Land margin mirror the continental slope of Australia.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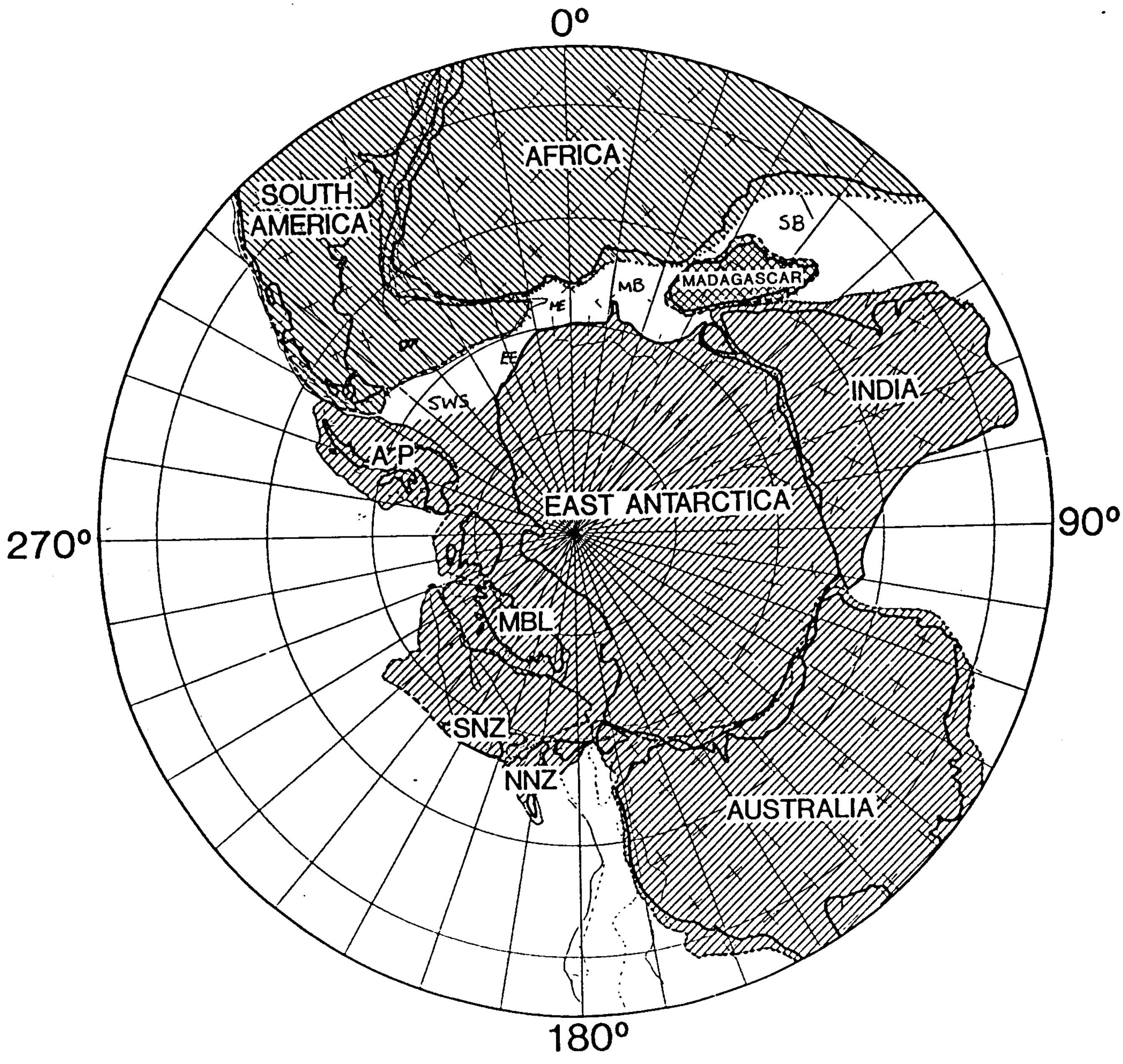
MBL
SNZ
NNZ
AUSTRALIA
180°

Fig 1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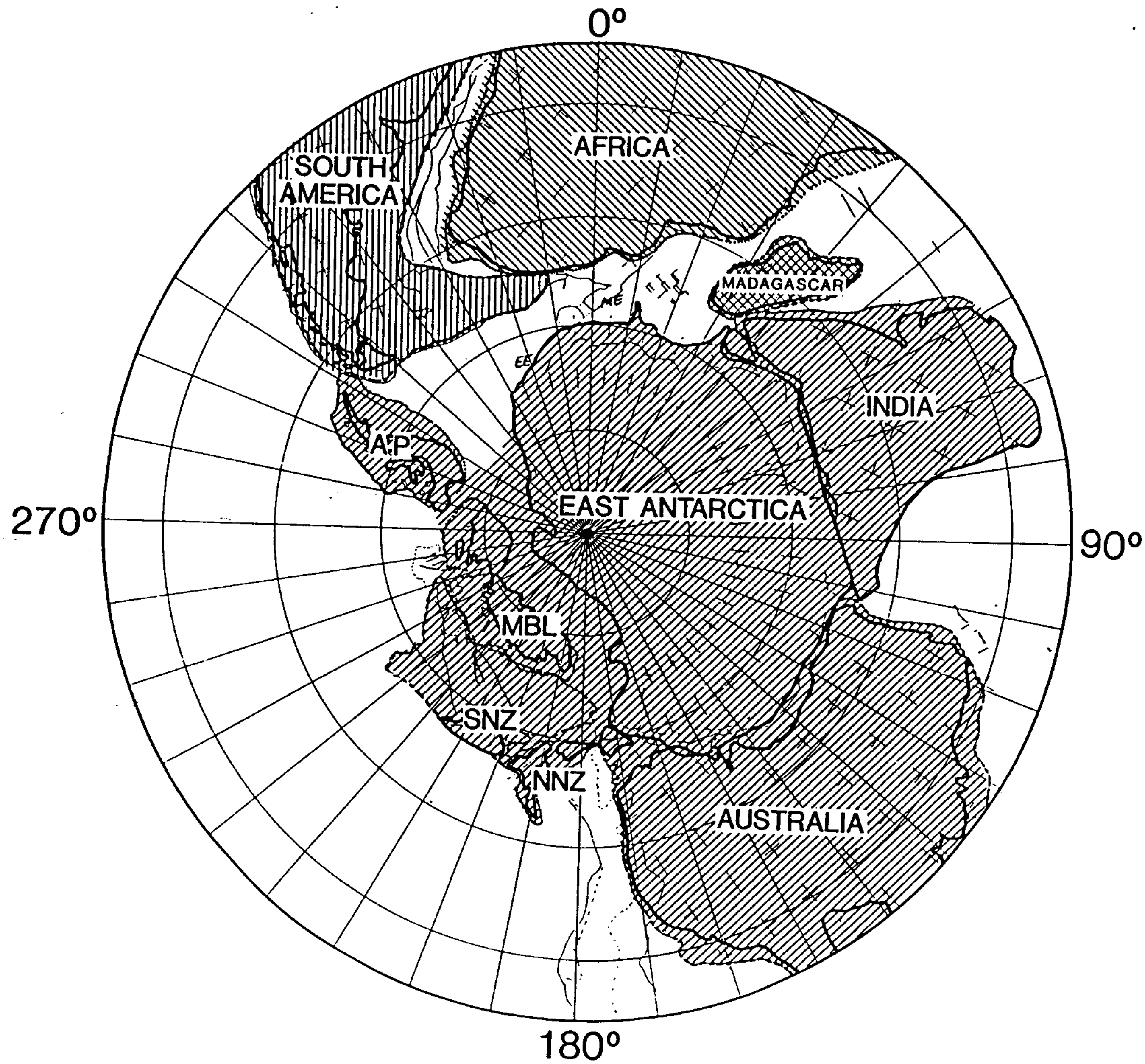
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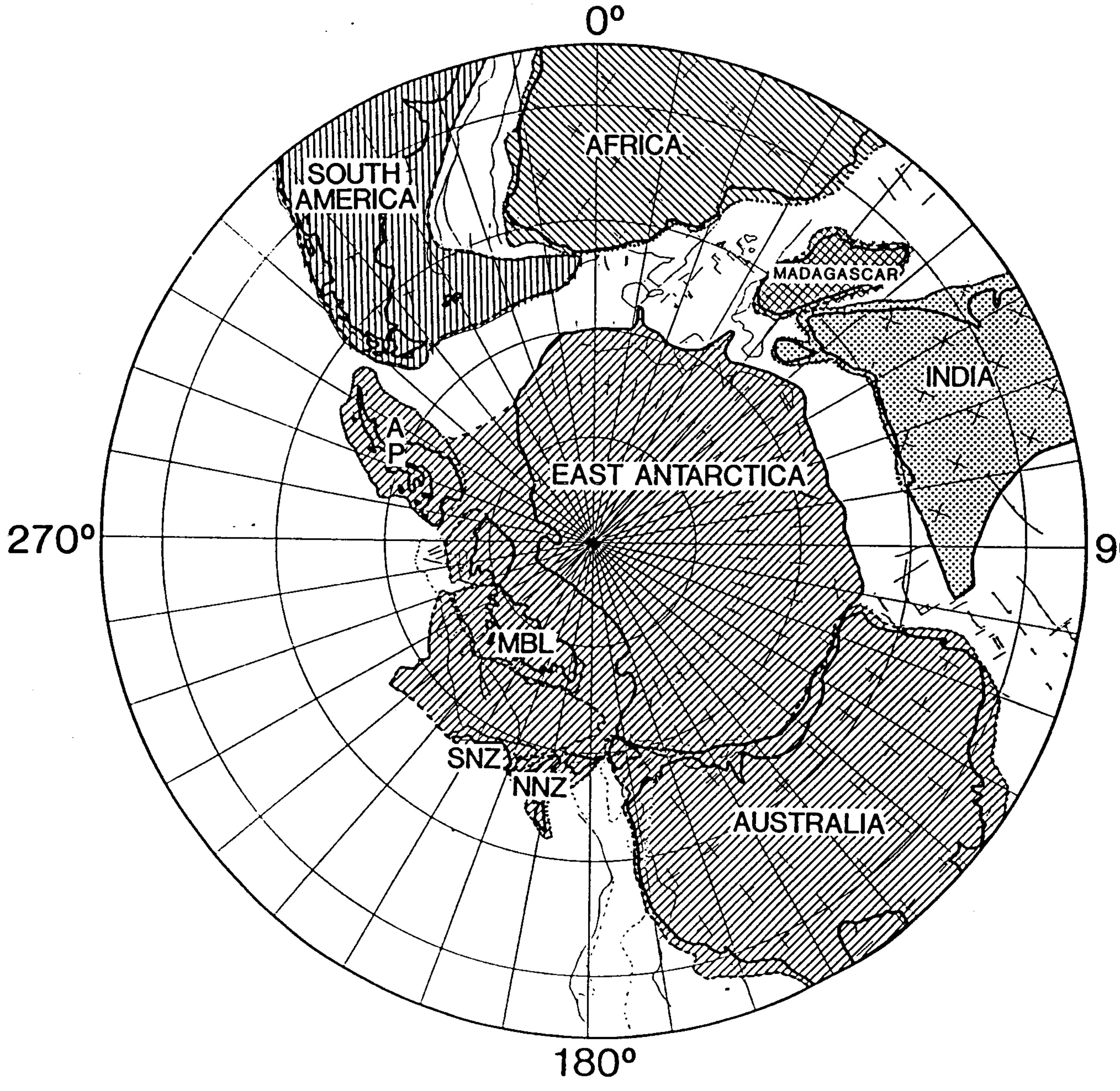
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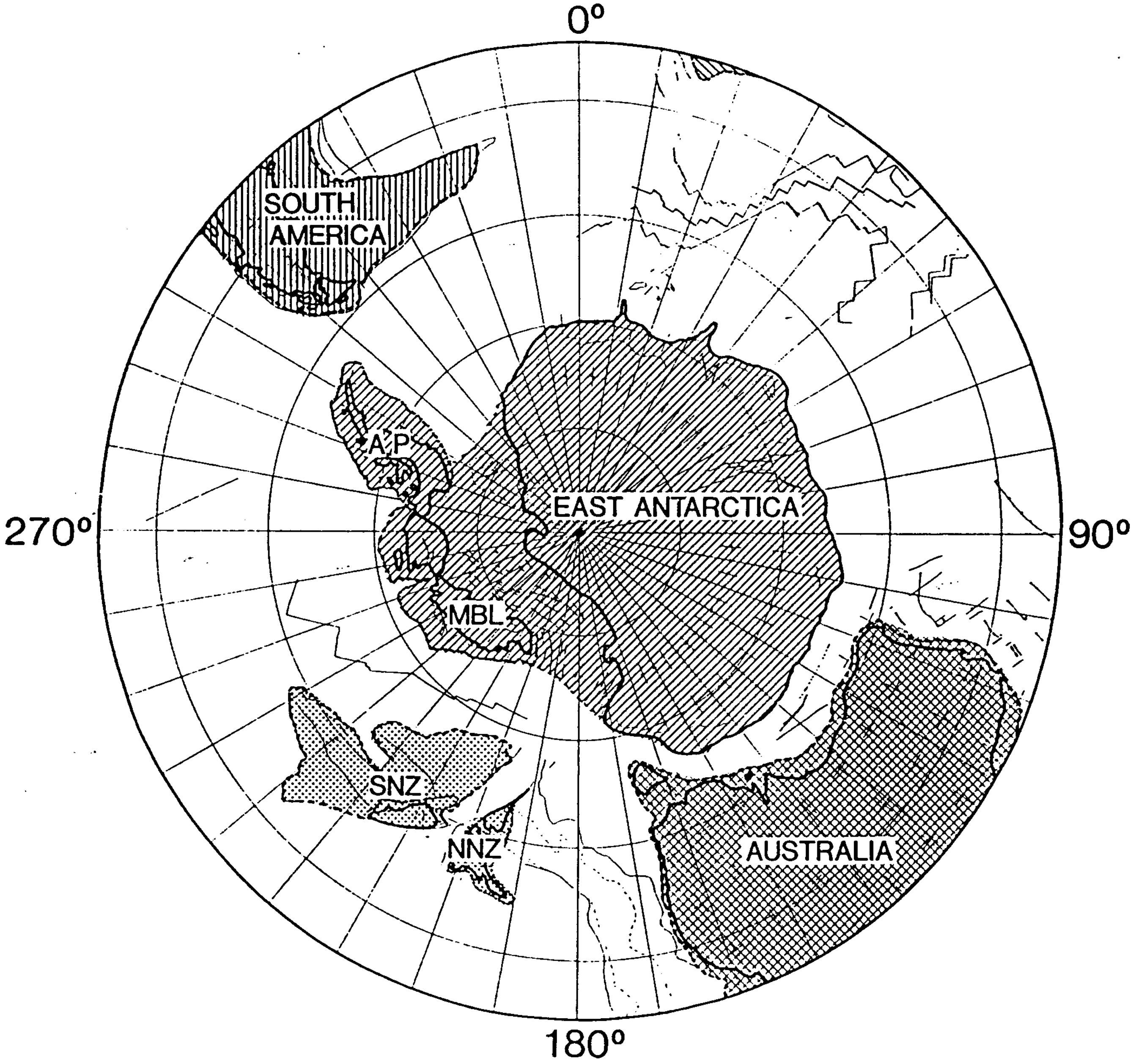
Fig 4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Sheet 18, Descending GEOSAT Passes

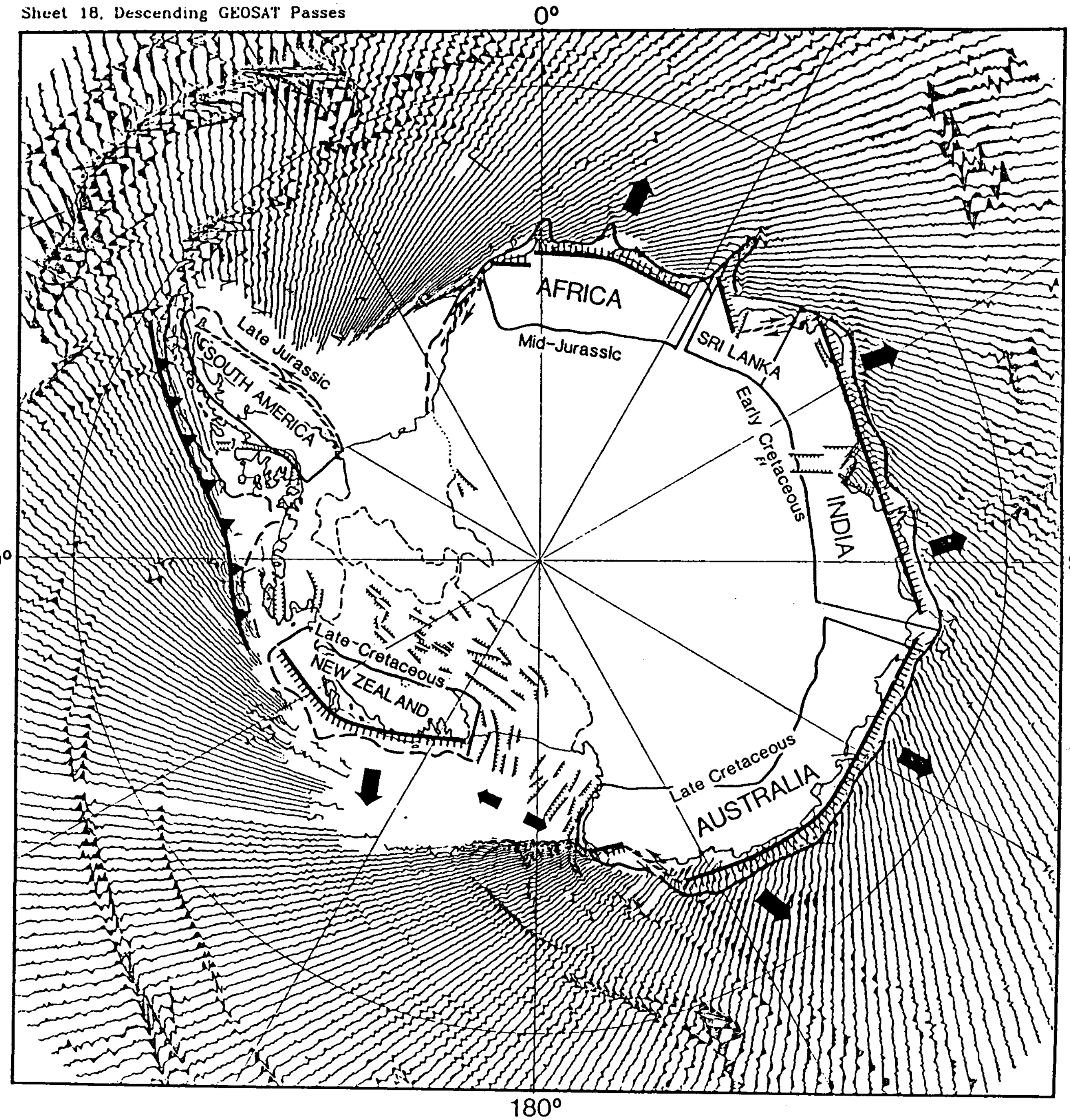

Fig 6