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MESOZOIC TO CAINOZOIC PALAEOGEOGRAPHIC MAPS FOR THE EASTERN NEW GUINEA REGION

by

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Phanerozoic History of Australia Project

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1. INTRODUCTION

Sixteen time slice interpretative palaeogeographic maps of the eastern New Guinea region (Figure 1) were produced as part of the BMR-APIRA Phanerozoic History of Australia Project (1988-1991). The project is the successor to the BMR-APIRA Palaeogeographic Maps Project (1984-1987) which produced interpretative palaeogeographic maps of Australia for seventy time slices from the Cambrian to Recent (BMR Palaeogeographic Group, 1990; Bradshaw & Yeung, in press; Bradshaw & others, in prep.; Brakel & Totterdell, in prep.; Cook, 1988; Cook & Totterdell, 1991; Olisoff & others, in prep.; Totterdell & others, in prep.; Walley & others, 1990; Wilford & others, in prep.; Yeates & Mulholland, in prep.). The maps of Australia were plotted onto a present-day geographic base at a scale of 1:5,000,000. Interpretative maps for the Australian Plate margin produced for the current project were prepared for selected Mesozoic and Cainozoic time slices only (Table 1), using the Triassic/Permian boundary as a starting point. The maps were compiled at 1:10 000 000 scale and plotted on base maps depicting plate tectonic reconstructions for the appropriate time. The palaeogeographic maps for Australia were transferred onto these bases at the reduced scale. The time scale used is based on Harland & others (1982) for the Mesozoic, and Berggren & others (1985a, b) for the Cainozoic.

The palaeogeographic maps are based on the compilation and interpretation of a large body of published and unpublished geologic data for the New Guinea region; these are listed in a comprehensive bibliography in Chapter 6. Detailed data compilations in the form of stratigraphic summary columns and data maps have been summarised in Struckmeyer (1990, 1991b). For formation names used in this report, also refer to Struckmeyer (1990, 1991b) and Struckmeyer & others (1990).

The New Guinea Orogen (Figure 2) is the product of a number of plate tectonic processes that have affected the northern margin of the Australian Plate during

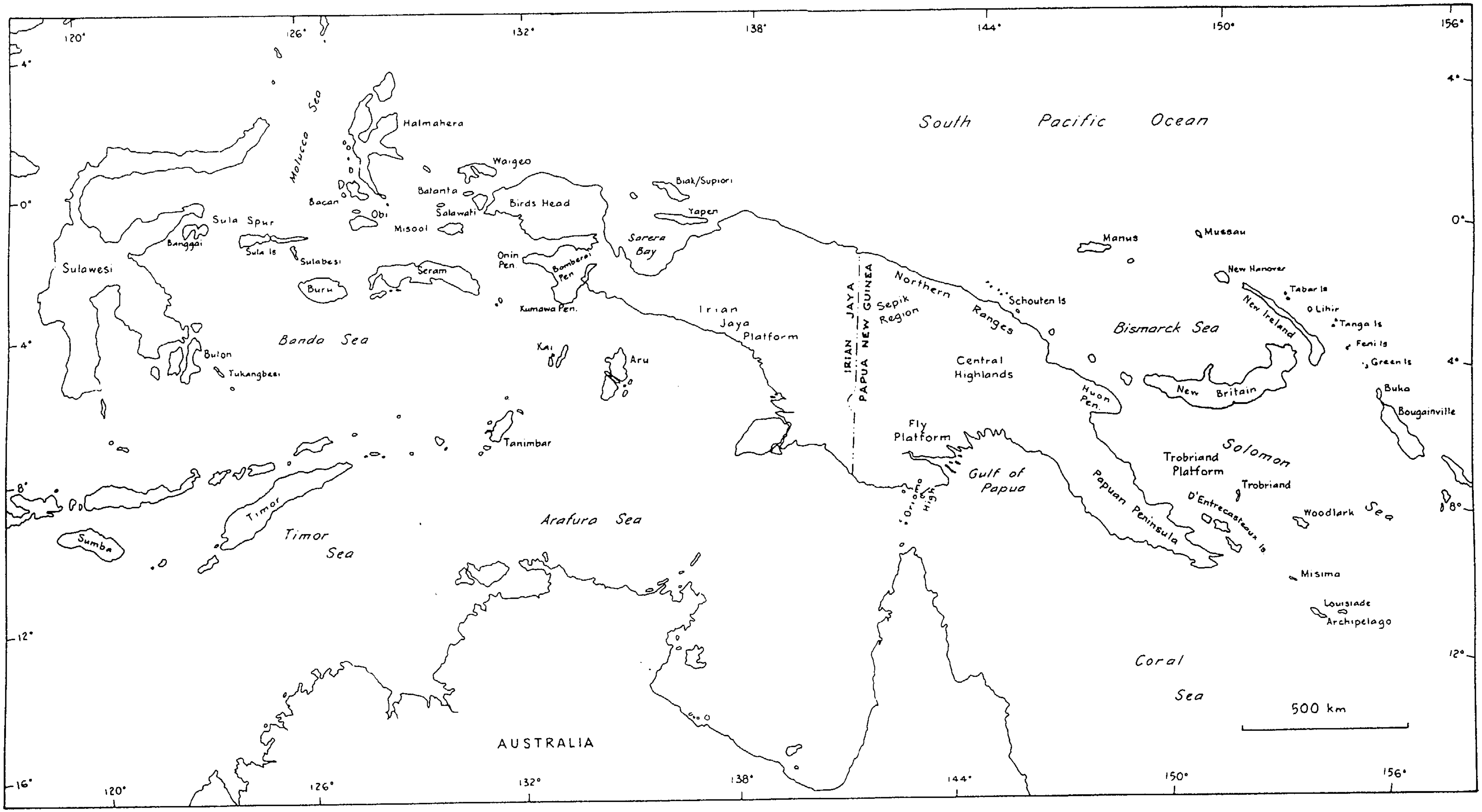


Figure 1: Location map for the New Guinea region.

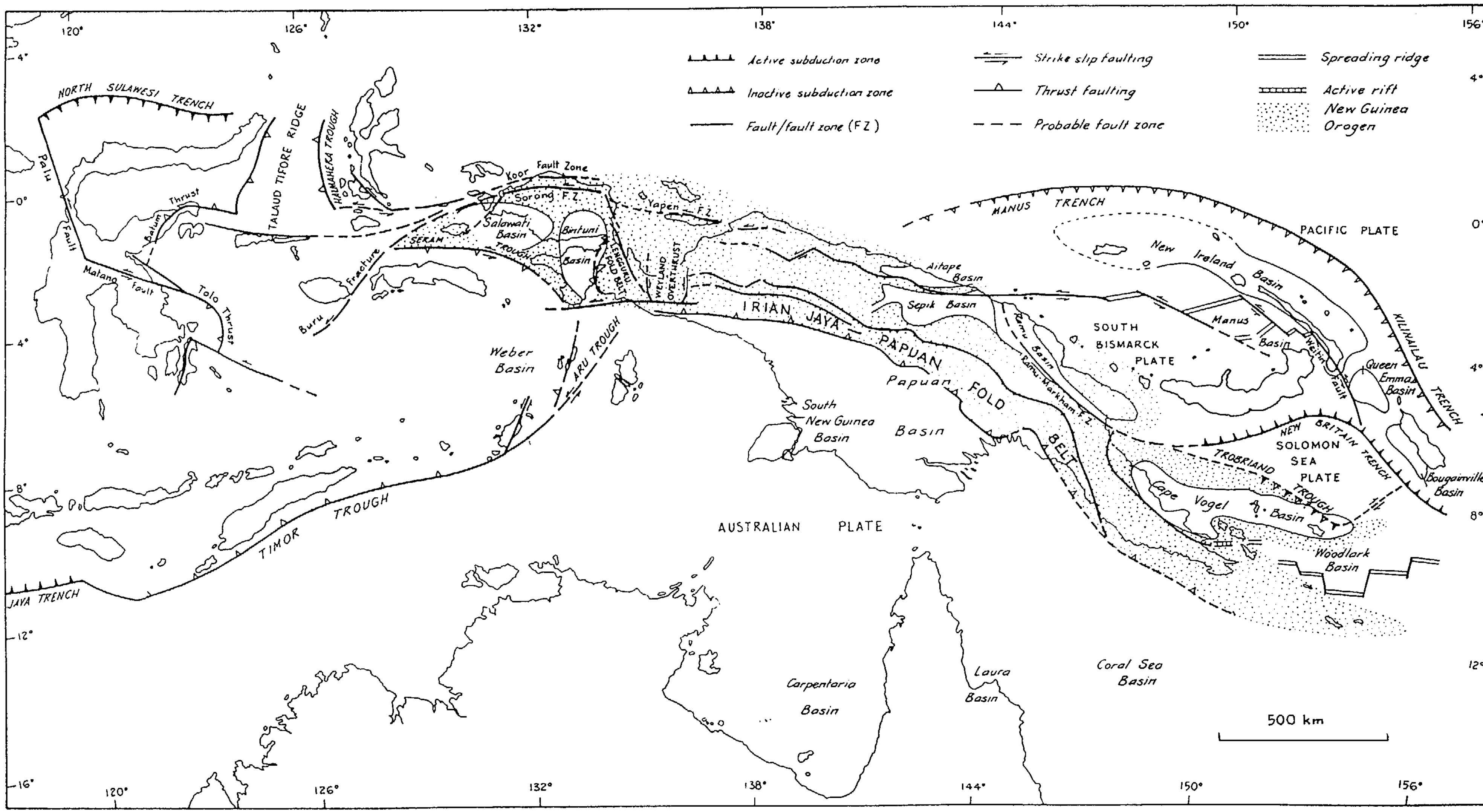


Figure 2: Present-day plate tectonic setting of the New Guinea region.

its Mesozoic to Cainozoic history. Reconstructions for the New Guinea area have been produced by a number of authors (e.g. Crook & Belbin, 1978; Kroenke, 1984; Pigram & Davies, 1987; Francis & Deibert, 1988; Audley-Charles, 1988; Francis, 1990). They differ considerably, both in the timing and mechanisms invoked, which may in part be ascribed to the sparsity of data in a geologically complex area. Thus, most of the models proposed are valid interpretations of possible scenarios of the plate tectonic development of the region within the geologic constraints provided by the data available. The plate tectonic reconstructions which were used as bases for the palaeogeographic maps presented here were developed in an attempt to integrate detailed reconstructions for the New Guinea region with similar reconstructions for other areas of the Australian Plate margin (Bradshaw & Ross, in prep.; Walley & Ross, 1991) by taking into account a global palaeomagnetic framework and the direction of movement of the major bounding plates. The computer-generated maps were produced using POMP (Paleoceanographic Mapping Project) digitising and plate tectonic reconstruction software. The plate tectonic reconstructions are discussed in detail in Struckmeyer (1991a) and Yeung & Struckmeyer (in prep.).

The maps in Figures 7 to 22 show coded palaeoenvironments (see legend in Table 2) plotted on the outline of tectonic components which moved relative to the Australian Craton during the Mesozoic to Cainozoic. The components are not identified in each of the palaeogeographic maps, but two plate tectonic reconstructions, for the Triassic and Late Oligocene, are given to identify the location of the various components (Figures 3 and 4), and two present-day location maps of the components are presented in Figures 5 and 6. Palaeolatitudes depicted on the palaeogeographic maps are based on the data base supplied with the PALEOMAP and Terra Mobilis™ (Denham & Scotese, 1988) software packages.

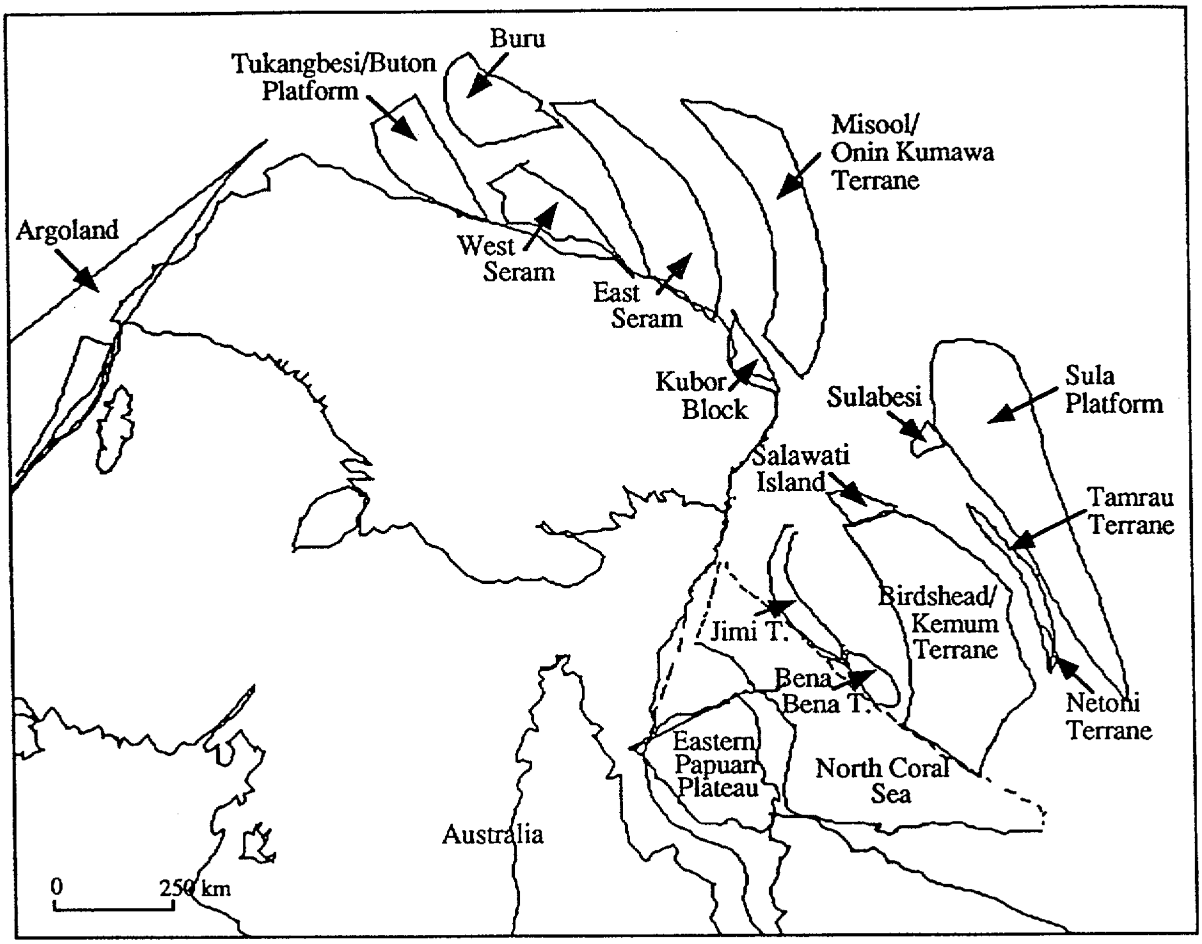


Figure 3: Plate tectonic reconstruction for the Late Triassic showing location of tectonic components.

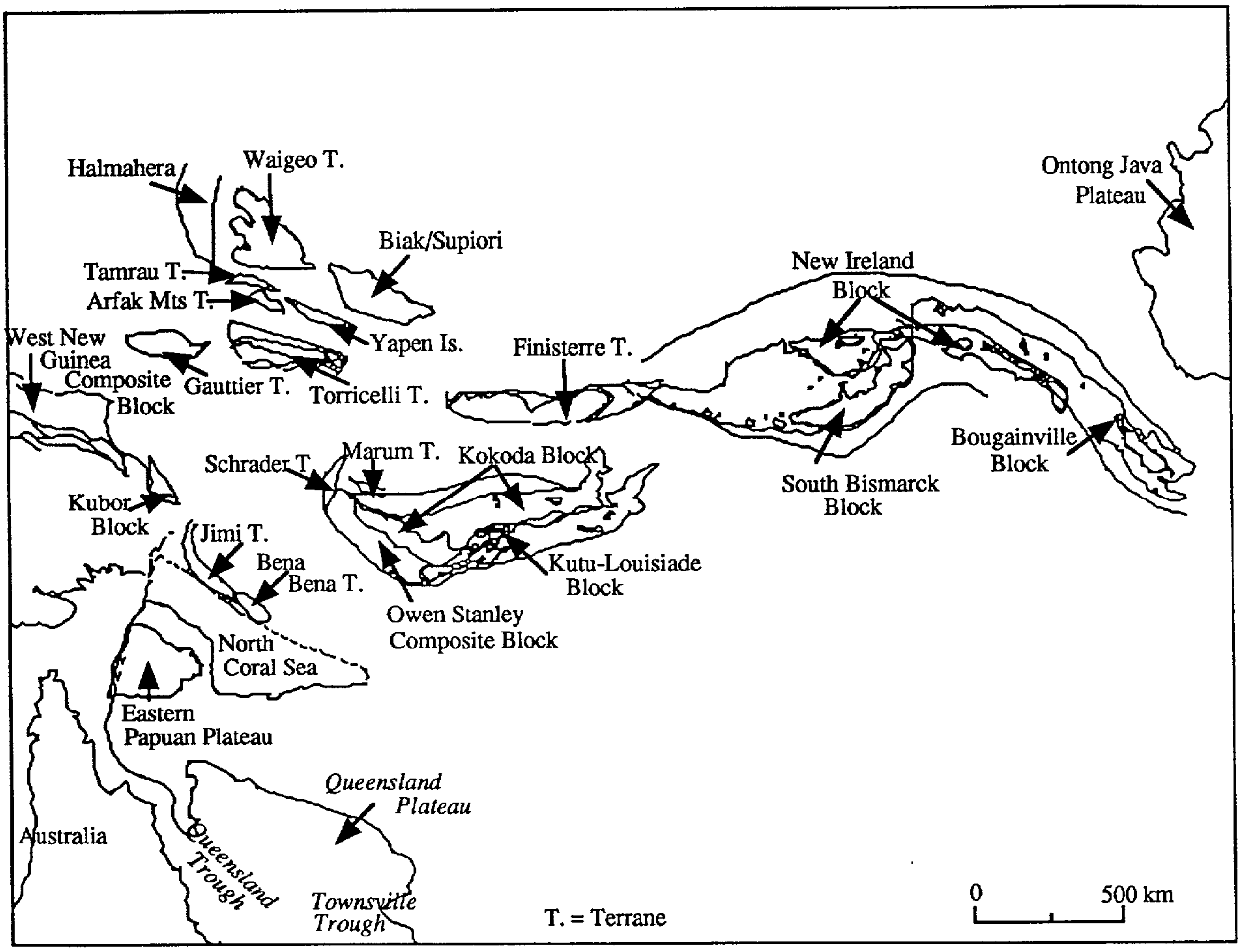
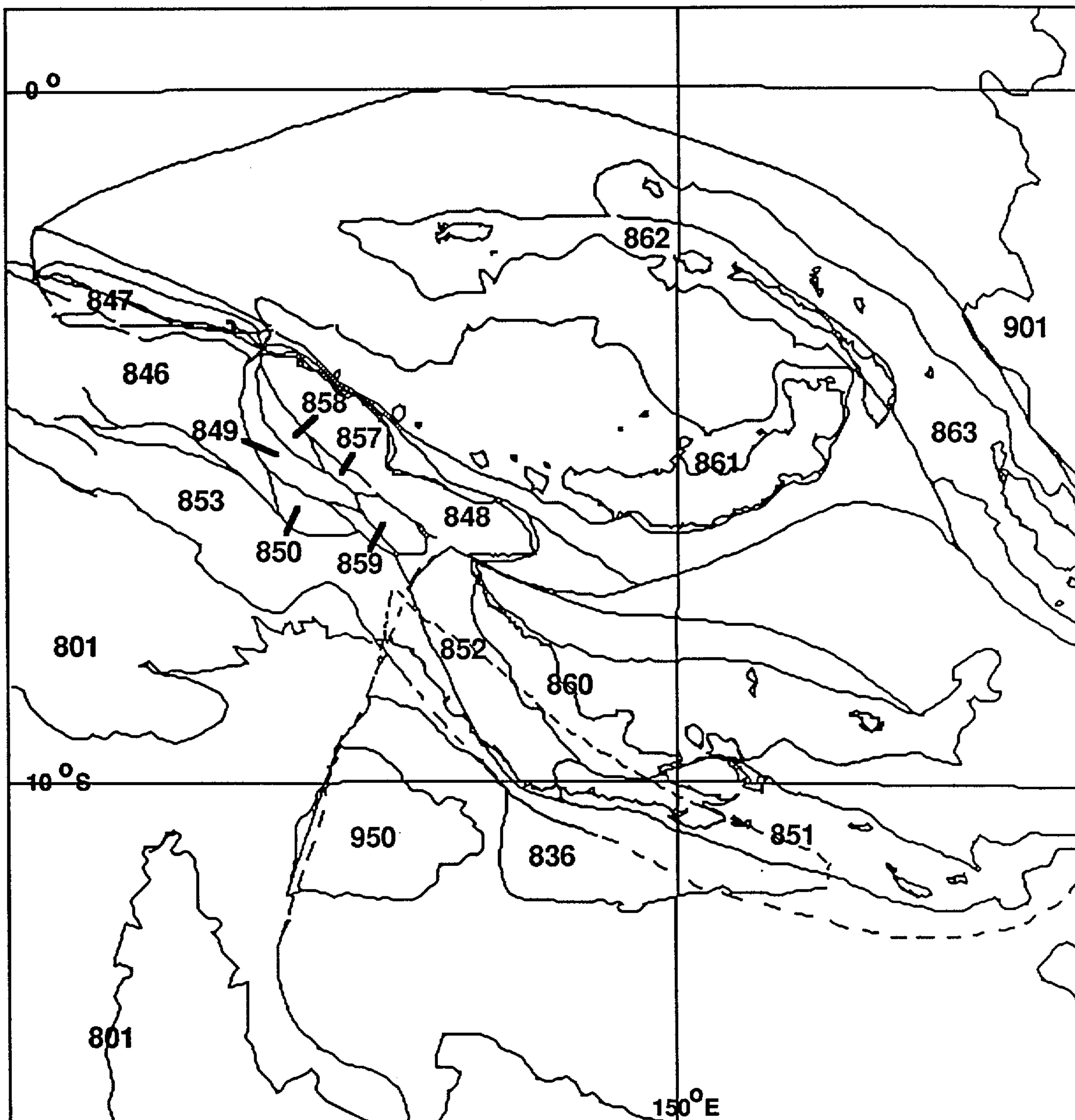


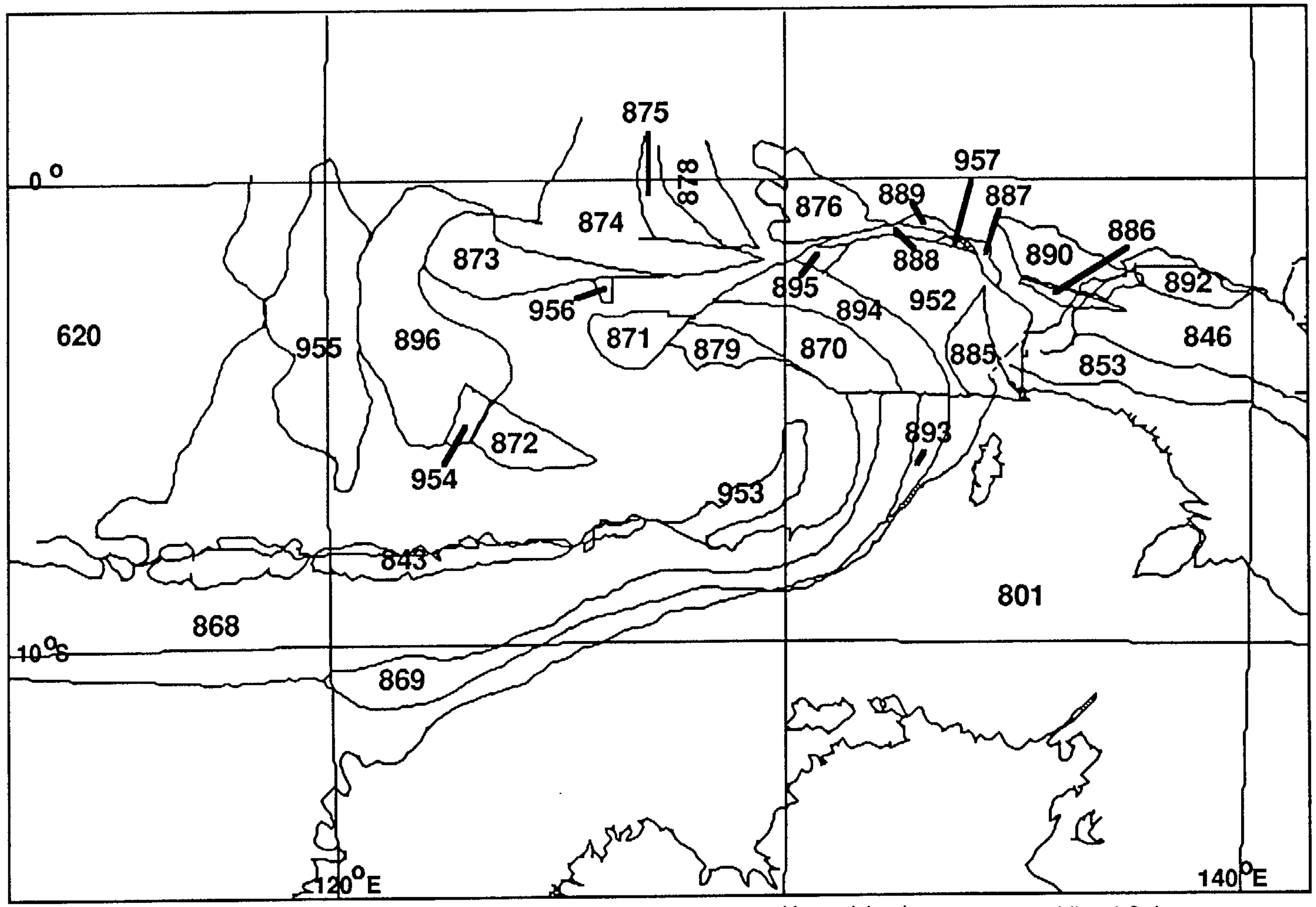
Figure 4: Plate tectonic reconstruction for the Late Oligocene showing location of tectonic components.



801 - Australia
836 - North Coral Sea
846 - West New Guinea Composite Block
847 - Torricelli Terrane
848 - Finisterre Terrane
849 - Jimi Terrane
850 - Kubor Block
851* - Kutu-Louisiade Block
852* - Owen Stanley Composite Block
853 - Papuan/Irian Jaya Fold Belt
857* - Marum Terrane
858* - Schrader Terrane
859 - Bena Bena Terrane
860* - Kokoda Block
861 - South Bismarck Block
862 - New Ireland Block
863 - Bougainville Block
901 - Ontong Java Plateau
950 - Eastern Papuan Plateau

* East New Guinea Composite Block

Figure 5: Tectonic components of the Papua New Guinea region.



620 - Borneo
801 - Australia
843 - Flores
846 - West New Guinea Composite Block
853 - Papuan/Irian Jaya Fold Belt
868 - Banda Volcanic Arc Complex
869 - Banda Para-autochthon
870 - East Seram
871 - Buru Island
872 - Tukangbesi/Buton Platform
873 - Sula Platform
874 - Molucca Sea Collision Complex
875 - Bacan Island
876 - Waigeo Terrane
878 - Halmahera
879 - West Seram
885 - Lengguru Fold Belt
886 - Yapen Island
887 - Arfak Mts Terrane
888 - Tamrau Terrane
889 - Tosem Terrane
890 - Biak/Supiori Islands
892 - Gauttier Terrane
893 - East Kai
894 - Misool/Onin Kumawa Terrane
895 - Salawati Island
896 - East Sulawesi
952 - Bird's Head/ Kemum Terrane
953 - Weber Split-off
954 - Buton
955 - West Sulawesi
956 - Sulabesi Island
957 - Netoni Terrane

Figure 6: Tectonic components of the Southeastern Indonesia region.

Table 1: Mesozoic to Cainozoic time slices (based on time scales of Harland & others [1982], Berggren [1969] and Berggren & others [1985a, b]).

TIME SLICE	AGE	MA
CAINOZOIC		
Cz 7	Quaternary	0 - 1.7
Cz 6a	Early Pliocene	3.0 - 5.0
Cz 4b	Early Miocene to earliest Middle Miocene	15.2 - 22.0
Cz 4a	Late Oligocene to earliest Miocene	22.0 - 30.0
Cz 2b	Late Eocene	36.5 - 40.0
Cz 1	Paleocene to Early Eocene	52.0 - 66.4
CRETACEOUS		
K 10b	mid-Campanian to mid-Maastrichtian	78.0 - 70.0
K 8	latest Albian to Cenomanian	99.0 - 91.0
K 4	Aptian	119.0 - 114.0
K 1	Berriasian to earliest Valanginian	144.0 - 137.0
JURASSIC		
J 8	Oxfordian to Kimmeridgian	162.0 - 150.0
J 5	mid-Bajocian	180.0 - 177.0
J 2	Pliensbachian to early Toarcian	200.0 - 191.0
TRIASSIC		
TR 5-6	Carnian to Rhaetian	231.0 - 213.0
TR 3-4	latest Anisian to Ladinian	239.0 - 231.0
TR 1-2	Scythian to Anisian	248.0 - 239.0

Table 2: Legend for Figures 7 to 22 (from BMR Palaeogeographic Group, 1990).

SYMBOL	ENVIRONMENT	WORKING DEFINITION
		LAND ENVIRONMENTS
LEU	unclassified	Areas with no preserved sediments of time slice age; interpreted as land.
LEE	erosional	Highlands; inferred from palaeocurrents, provenance studies, tectonic setting, presence of igneous intrusions, etc.
LDU	depositional, unclassified	No indication of specific environment; often includes subaerial volcanics.
LDF	fluvial	River deposits such as alluvial fans, braided and meandering channel deposits and coarser overbank sediments; also sand-dominated continental sequences with no evidence of aeolian or lacustrine deposition.
LDFL	fluvio-lacustrine	Low-energy river environments such as channels, overbanks, backswamps and shallow lakes on low-gradient flood plains; typically sheets of fine-grained sediments and coal.
LDL	lacustrine	Deposits of persistent lakes, typically finely laminated mud and sand frequently containing freshwater fossils.
LDG	glacial	Typically coarse, poorly sorted sediments, commonly with striated pebbles, cobbles, and boulders. Overall assemblage of sediments quite complex, ranging from aeolian sand flanking glaciers, river gravel, fine-grained mud with or without dropstones, to siliceous sediments.
		COASTAL ENVIRONMENTS
CDP	paralic	Coastal or marginal marine environments, e.g. lagoonal, beach, intertidal, deltaic. Range from coarse cross-bedded beach sand, through sand deposited in tidal deltas, to finely laminated organic sediment deposited in lagoons and estuaries (includes deltaic and intertidal-supratidal environments).
CDIS	intertidal-supratidal	Tidal zone, indicated by finely interlaminated fine and coarse detritus, herring-bone cross-bedding, flaser bedding, evidence of periodic exposure, etc.
CDD	deltaic	Indicated by thickness pattern, upward-coarsening sequences, and the mapped pattern of adjacent environments.
		MARINE ENVIRONMENTS
MU	unclassified	No indication of specific marine environment.
MVS	very shallow (0-20 m water depth)	Evidence of deposition above wave base and/or occasional emergence, e.g. oolites, cross-bedding.
MS	shallow (0-200 m water depth)	Continental shelf or flanks of volcanic islands, e.g. sand, mud and limestone containing fossils that typically lived in shallow water; includes young, active spreading ridges.
MBA	bathyal to abyssal (> 200 m water depth)	Deep-water deposition, e.g. condensed sequences, turbidites, monotonous shale; deeper-water organisms.
MA	abyssal (> 1000 m water depth)	Distal turbidite, clay, siliceous and calcareous ooze, ocean-floor basalt, etc.

2. MESOZOIC TO PALEOCENE

During the Mesozoic to Paleocene, the northern edge of the Australian Plate was a passive margin that experienced two major phases of extension, in the Triassic/Jurassic and in the Late Cretaceous to Early Eocene (Pigram & Panggabean, 1984; Symonds & others, 1984; Pigram & Davies, 1987; Struckmeyer & others, 1990; Struckmeyer, 1991a; Pigram & Symonds, in press). Figure 3 shows a reconstruction for the Late Triassic, when rifting and breakup to the north probably led to the detachment of part of the craton margin. The extensional event is indicated by the presence of a Triassic to Jurassic rift-drift sequence in the Papuan and South New Guinea Basins and on continental fragments which were detached from the margin later in the Mesozoic and now form part of eastern Indonesia. During the remainder of the Jurassic to the Early Cretaceous there was deposition of siliciclastic sag phase sediments along the northern margin of Australia (e.g. Pigram & Symonds, in press).

The second extensional event along the northeastern margin probably commenced in the middle Cretaceous and, in the Late Cretaceous to Paleocene, led to the detachment of continental fragments within an oblique, linked spreading system, as a result of the opening of the Coral Sea and an unnamed ocean basin to the north and northwest of the Coral Sea (Pigram, 1990; Struckmeyer, 1991a; Pigram & Symonds, in press). The Late Cretaceous to Paleocene extensional event was associated with uplift along the plate boundary in the eastern Papuan Basin that resulted in differential erosion of the Mesozoic sequences. Seafloor spreading continued until the Early Eocene, as indicated by magnetic lineaments in the Coral Sea Basin (Anomaly 24) and the presence of thrust slices of ophiolites of this age on the mainland of Papua New Guinea. Incipient subduction to the northeast of Australia may have occurred from the Campanian onwards.

2.1 Triassic (Figures 7-9)

During the Triassic, the northeastern margin of Australia was located at the southern edge of Tethys at palaeolatitudes of about 25 to 40 °S. The climate was generally warm and humid, probably monsoonal, with the wide extent of land in the Triassic during a time of low relative sealevel promoting aridity in the interior of the continent (Parrish & others, 1982).

In the Papuan Basin, the oldest Triassic rocks are granites of the Kubor Complex, which intruded Palaeozoic pelitic metamorphics in the Early to Middle Triassic (Page, 1976). The Kubor Complex and associated intrusives on the Jimi, Kemum and Netoni Terranes, and the Sula Platform probably formed erosional highs for at least part of the Mesozoic and provided a sediment source for adjacent areas. In the earliest Triassic (Figure 7), most of the Papuan Basin was probably emergent. Deep water marine environments were present in the Kubor Block region and the Jimi Terrane, as indicated by the dark shales of the Yuat Formation (e.g. Pigram, 1978; Francis, in prep.). They are probably time equivalents of the uniform shaly facies deposited across the Northwest Shelf during the Early Triassic (Bradshaw & others, 1988; Struckmeyer & others, 1990).

A depositional hiatus on Buton and western Seram during the Early Triassic probably indicates that these areas were emergent. They are here shown as a northwest-southeast trending land area with a shallow marine fringe to the south and north. A delta fed by rivers eroding the highs of western Seram and Tukangbesi/Buton may already have existed along the northeastern shore (Audley-Charles & others, 1979; O'Sullivan & others, 1985; Price & others, 1987), but dating of the Kanikeh Formation is poor. Deep water turbidites of the Keskain Formation were deposited on Misool (Pigram & others, 1982a, b).

A major regression occurred in the late Early Triassic. Time slices 3 and 4 (Figure 8) were characterised by restricted fluvial deposition in the southernmost and

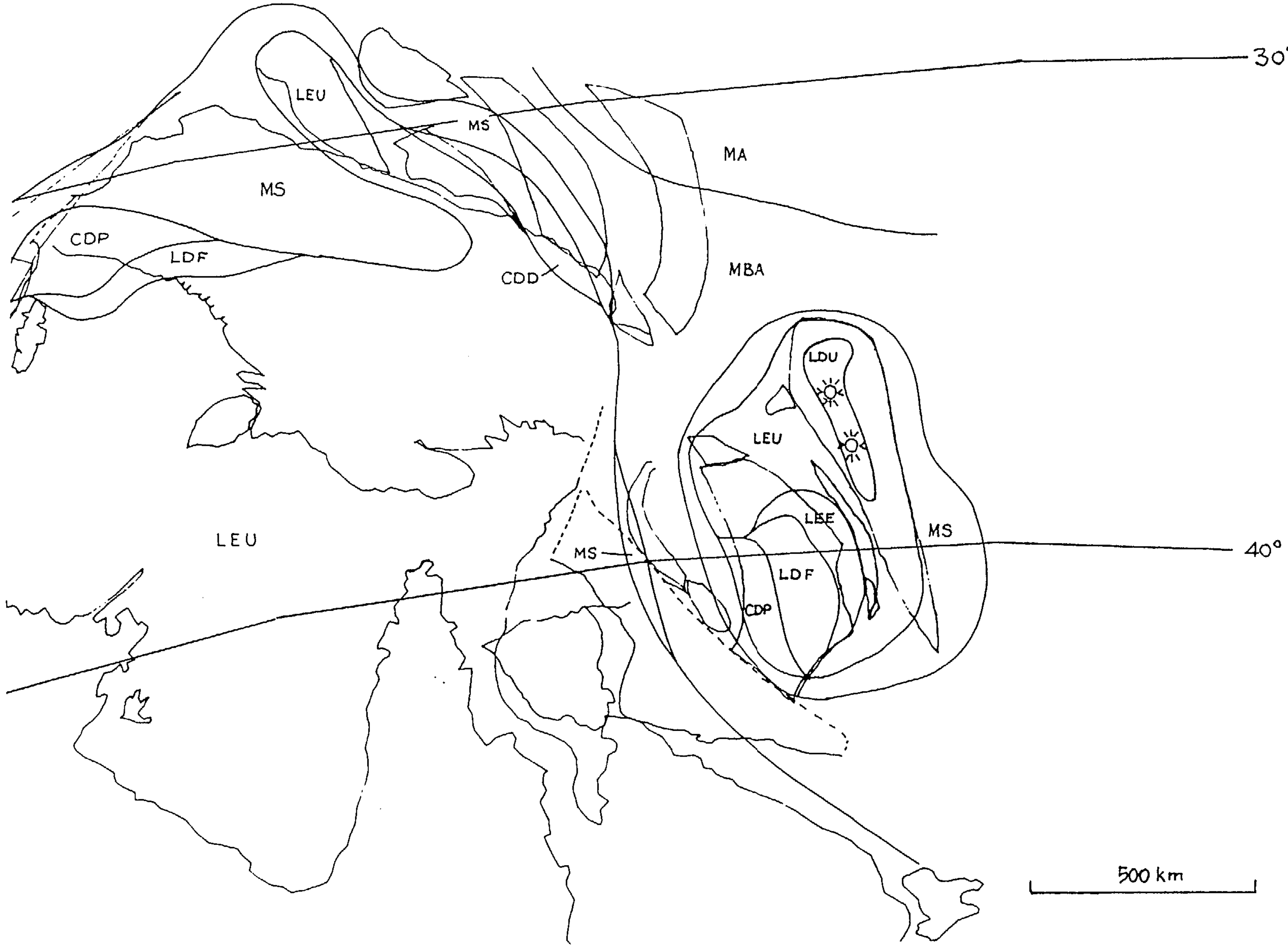


Figure 7: Early Triassic (Scythian to Anisian) palaeogeography (TR 1&2).

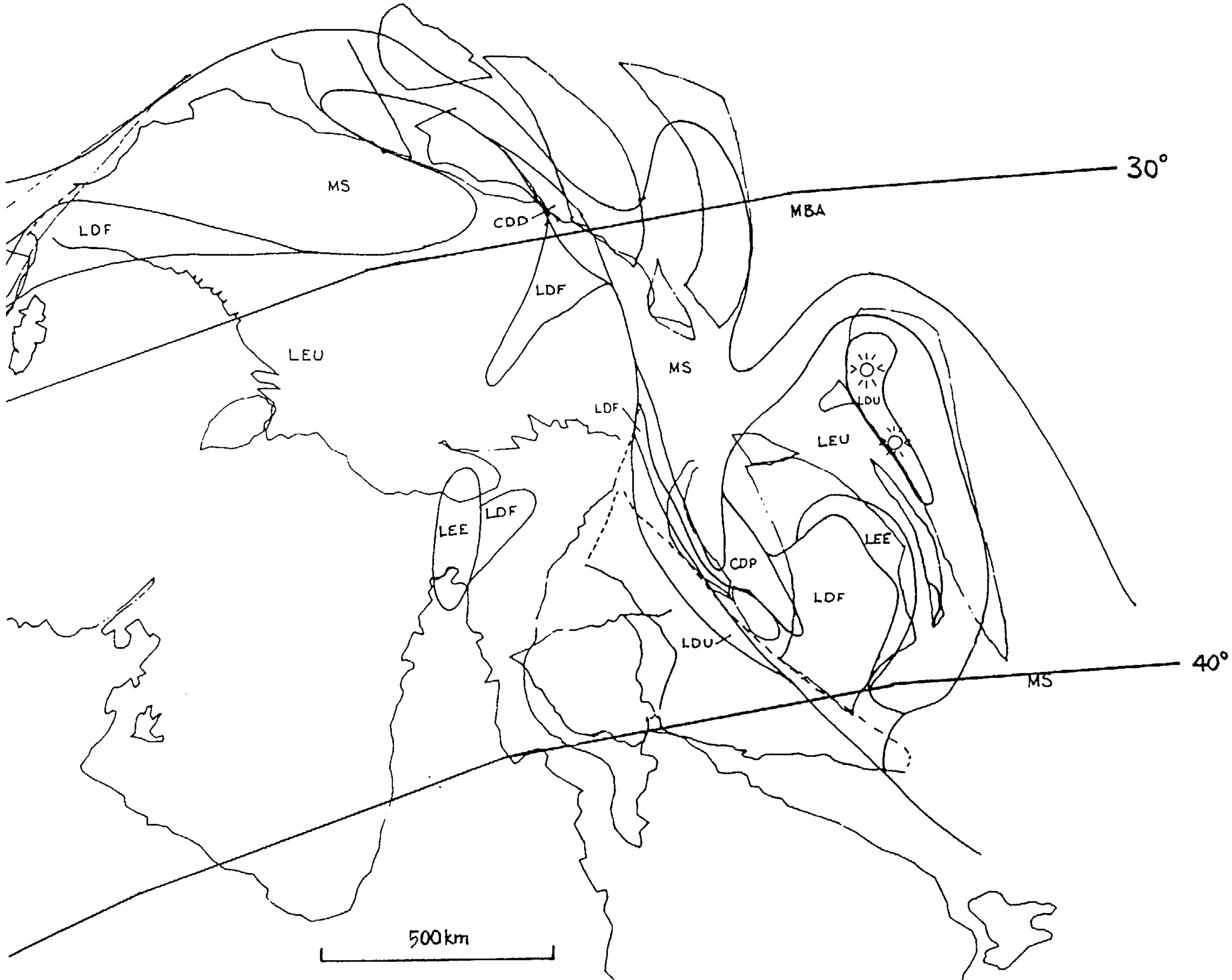


Figure 8: Middle Triassic (latest Anisian to Ladinian) palaeogeography (TR 3&4).

northwestern Papuan Basin, and shallow marine environments in the northeast, in the vicinity of the Kubor Block. On the Jimi Terrane, deposition occurred in fluvial to paralic and probably shallow marine environments with the accumulation of volcaniclastic sandstone, shale, conglomerate, redbeds and bimodal volcanics of the Kana Group (Pigram & others, 1987). Similar sediments of this age (Tipuma Formation) are present on the southern Birdshead/Kemum Terrane, where an extensive fluvial to paralic depositional system developed in the Triassic (Pigram & Sukanta, 1982; Pieters & others, 1985). These environments were probably continuous with those of the Jimi Terrane. Rift-related volcanism also occurred on the Sula Platform (Pigram & others, 1985a, b; Garrard & others, 1988), the Tukangbesi Platform (Koswara & Sukarno, 1986) and in southwestern Irian Jaya (Pigram & Panggabean, 1989), probably in terrestrial environments. In the northwestern part of the Tukangbesi/Buton Platform, sedimentation commenced with the deposition of the marine Winto Formation, a proven source rock (Davidson, 1991; Smith & Silver, 1991). In Seram, deposition of the deltaic Wakuku/Kanikeh Formation and its offshore equivalents (Saman Saman Formation) was well established by this time, while a slight shallowing of the depositional environments occurred in the Buru and Misool areas.

In time slices 5 and 6 (Figure 9), conditions in the northeastern part of the map area probably remained the same, although a marine incursion resulted in the deposition of carbonates (Nofanni Limestone) on parts of the Sula Platform (Pigram & others, 1985a, b; Garrard & others, 1988). Reefal and platform limestones developed on the Misool/Onin/Kumawa Terrane (Bogal Limestone, Lios Marl - Pigram & others, 1982a, b) and the Kubor Block (Kutu Formation - Bain & others, 1975; Skwarko & others, 1976; Francis & others, 1990; Francis, in prep). The reefs may have extended across the entire northern margin linking up with time equivalent Rhaetian reefs that developed on the northern Exmouth Plateau (Williamson & others, 1989). Fluvial environments in the northern Papuan and South New Guinea Basins became more extensive and the delta established in the earlier Triassic may have been fed by these rivers as indicated by continued deposition of the Wakuku/Karikeh Formation on southernmost

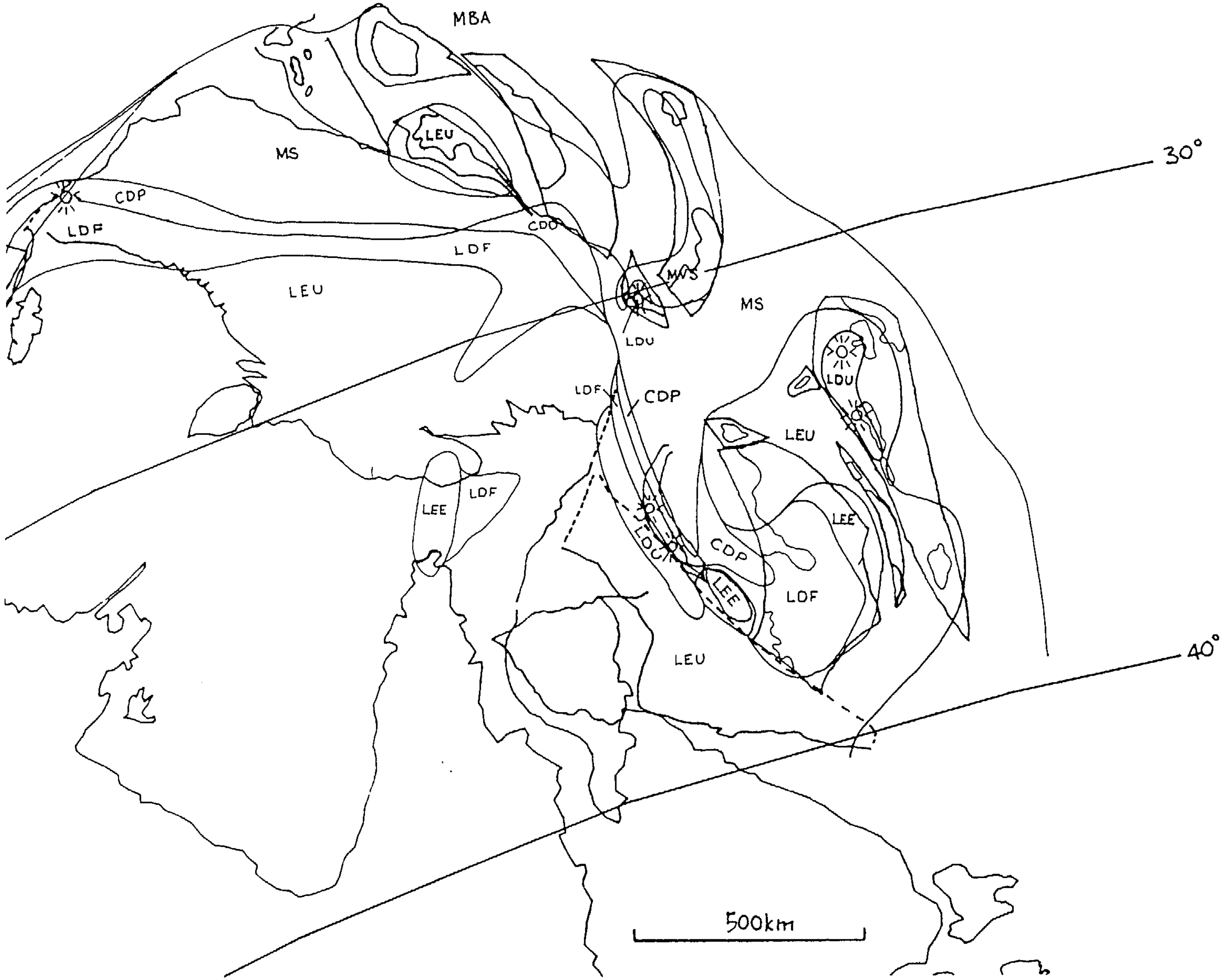


Figure 9: Late Triassic (Carnian to Rhaetian) palaeogeography (TR 5&6).

East Seram. However, most of the Seram and Buru areas were characterised by shallow marine environments with deposition of the Ghegan Formation (Fortuin & others, 1988; Tjokrosapoetro & Budhitrisna, 1982) and Manusela Formation (Price & others, 1987; O'Sullivan & others, 1985), both of which contain bituminous shales. On the Birdshead/Kemum Terrane, deposition of the red beds of the Tipuma Formation continued.

2.2 Jurassic

During the Jurassic, northeastern Australia was in low to middle latitudes. Monsoonal climates persisted in Gondwana; the dry interior zone remained extensive and coastal regions of Tethys still had a strongly seasonal climate (Parrish & others, 1982). Sedimentation along the northern Australian Plate margin was controlled by a change from the Triassic rift regime to one of breakup and ocean formation. This resulted in widespread Middle to Late Jurassic inundation of areas that were previously characterised by fluvial and paralic environments.

Early Jurassic - Pliensbachian to Toarcian (Figure 10)

In Papua New Guinea, an extensive river system developed on the southern Fly Platform and in the western Gulf of Papua as indicated by the presence, in a number of exploration wells, of a sequence of interbedded mudstone, sandstone and minor coal (Magobu Formation) deposited in fluvial to fluvio-lacustrine environments. On the Jimi Terrane, volcaniclastic sandstones, conglomerates, siltstones and mudstones of the Balimbu Formation and its equivalents accumulated in shallow marine environments that deepened to the north (Pigram& others, 1987). The presence of basic volcanics in the marine sequence gives a possible minimum age for ocean formation to the north of Australia. Continental fragments, which may have been present north of Papua New Guinea during the Triassic, had probably drifted northwards by this time (Pigram & Panggabean, 1984). The shallow marine environments in the vicinity of the Jimi Terrane probably extended northwestward, however, due to poor age

Figure 10: Early Jurassic (Pliensbachian to Toarcian) palaeogeography (J 2).

control and the structural complexity of the region, it is not clear whether deposition in the Late Triassic to Early Jurassic was continuous in some areas of the northern Papuan Basin. The Kubor Block may have been emergent during this time with a narrow fringe of paralic environments to the north on the Misool Terrane.

There is poor age control (?late Permian to ?Jurassic) for the Tipuma Formation on the Kemum Block; it is possible that this unit is entirely Triassic in age and that most of the region was emergent in the Early Jurassic. On the Sula Platform, red bed deposition in fluvial to paralic environments (Bobong and Kabauw Formations) commenced after the period of volcanism and minor limestone deposition in the Triassic (Pigram & others, 1985a; Garrard & others, 1988).

Middle Jurassic - Early to Middle Bajocian (Figure 11)

Deposition became more widespread with the transgression of the sea across the Kubor Block, parts of the present Papuan Fold Belt and Gulf of Papua, the Jimi Terrane and possibly the southern Birdshead/Kemum Terrane. Deposition of the marine fine-grained clastics of the Maril Shale and its equivalents may already have commenced in these areas. Remnants of the deeper water slope and basin sediments deposited in northern Papua New Guinea in the Middle Jurassic to middle Cretaceous are preserved in the West New Guinea Composite Block as low to medium grade metamorphic rocks of mostly pelitic origin. Intermediate to felsic intrusives of Late Jurassic to middle Cretaceous age that occur within this sequence may be related to initial extension between Papua New Guinea and the continental fragments that now form part of Eastern Indonesia.

In the southern Papuan Basin, coarse clastics sourced from land areas to the southwest accumulated in fluvial to fluvio-lacustrine environments on the Fly Platform and southwestern Gulf of Papua, and coarse to fine-grained sediments were deposited in paralic environments to the north and east of the river system. Locally, thin coal beds developed.

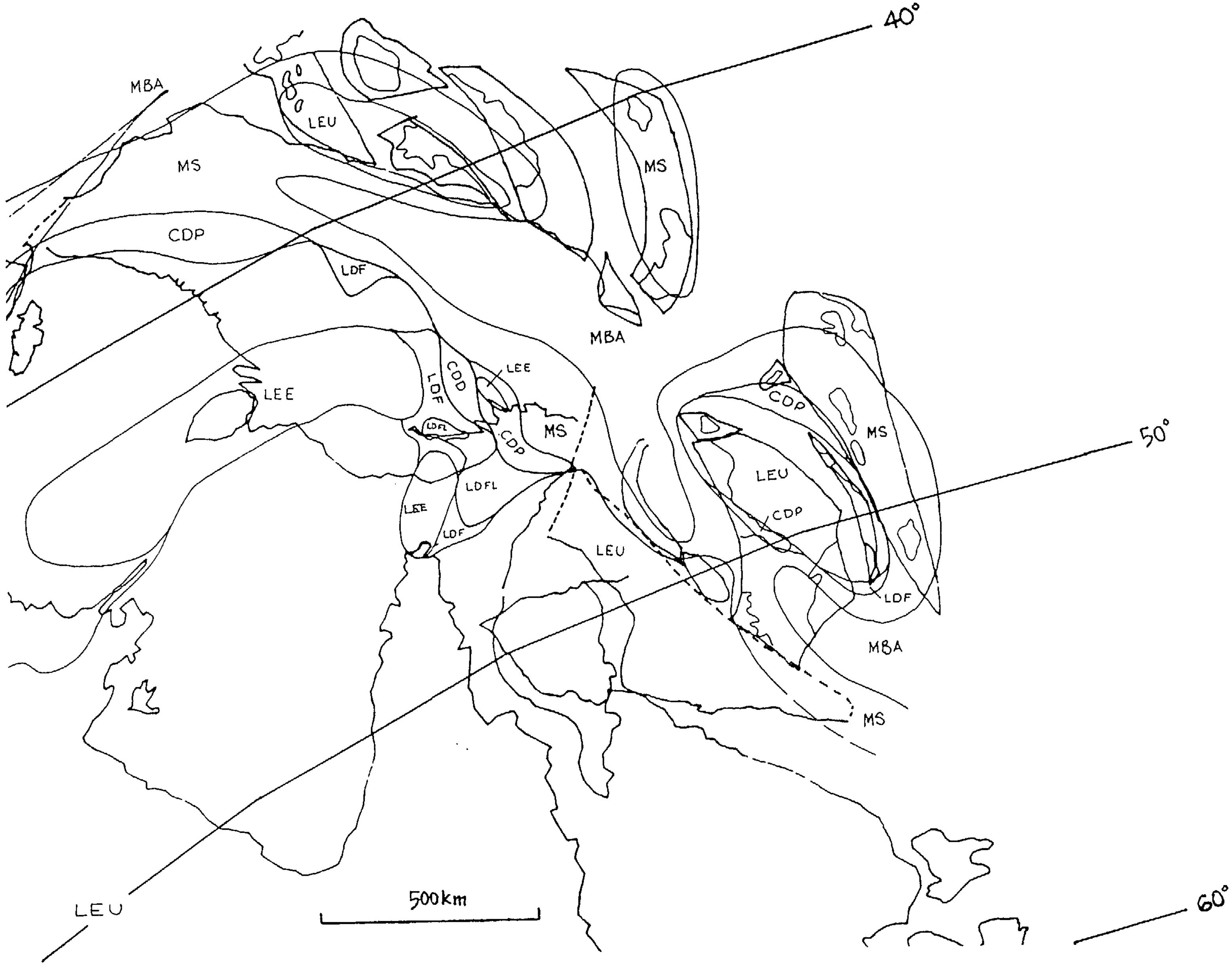


Figure 11: Middle Jurassic (Bajocian) palaeogeography (J 5).

On the Irian Jaya Platform, the marine transgression is indicated by a marked change from the fluvial to paralic and ?shallow marine coarse to fine-grained clastics of the Tipuma Formation to the claystones, mudstones and subordinate limestones of the lower Kembelangan Group (Visser & Hermes, 1962; Pigram & Panggabean, 1989; Dow & others, 1990). The greater part of the South New Guinea Basin remained emergent during this time.

Late Jurassic - Oxfordian to Kimmeridgian (Figure 12)

The Jurassic transgression reached its peak in time slices 7 to 8, when shallow marine environments were widespread in the Papuan Basin with extensive deposition of fine-grained clastics (Imburu Mudstone). These mudstones are likely to be an equivalent of the Maril Formation of the northern and eastern Papuan Basin, which consists mostly of shales deposited in bathyal environments on, and south of, the Kubor Block and the Jimi Terrane area. The shales are probably the major Mesozoic source rock interval of the region, and they are time-equivalents of the Dingo Mudstone, the principal source rock in the Northwest Shelf area (e.g., Bradshaw & others, 1988; Struckmeyer & others, 1990). Paralic environments stretched across the greater part of the Fly Platform and these environments extended southwards around the probably erosional Oriomo High into both the Carpentaria Basin and the Laura Basin, where they graded into fluvio-lacustrine environments. The North Coral Sea and Eastern Plateau components were probably emergent during this time, however, seismic data indicate that a small sedimentary basin may have been present on the northeastern Queensland Plateau during the Late Jurassic to Early Cretaceous (Symonds & others, 1984; P.A. Symonds, pers. com., 1991).

The Irian Jaya terranes were probably inundated during the Late Jurassic transgression with widespread deposition of fine-grained clastics in shallow to deeper water environments, which were later removed by erosion.

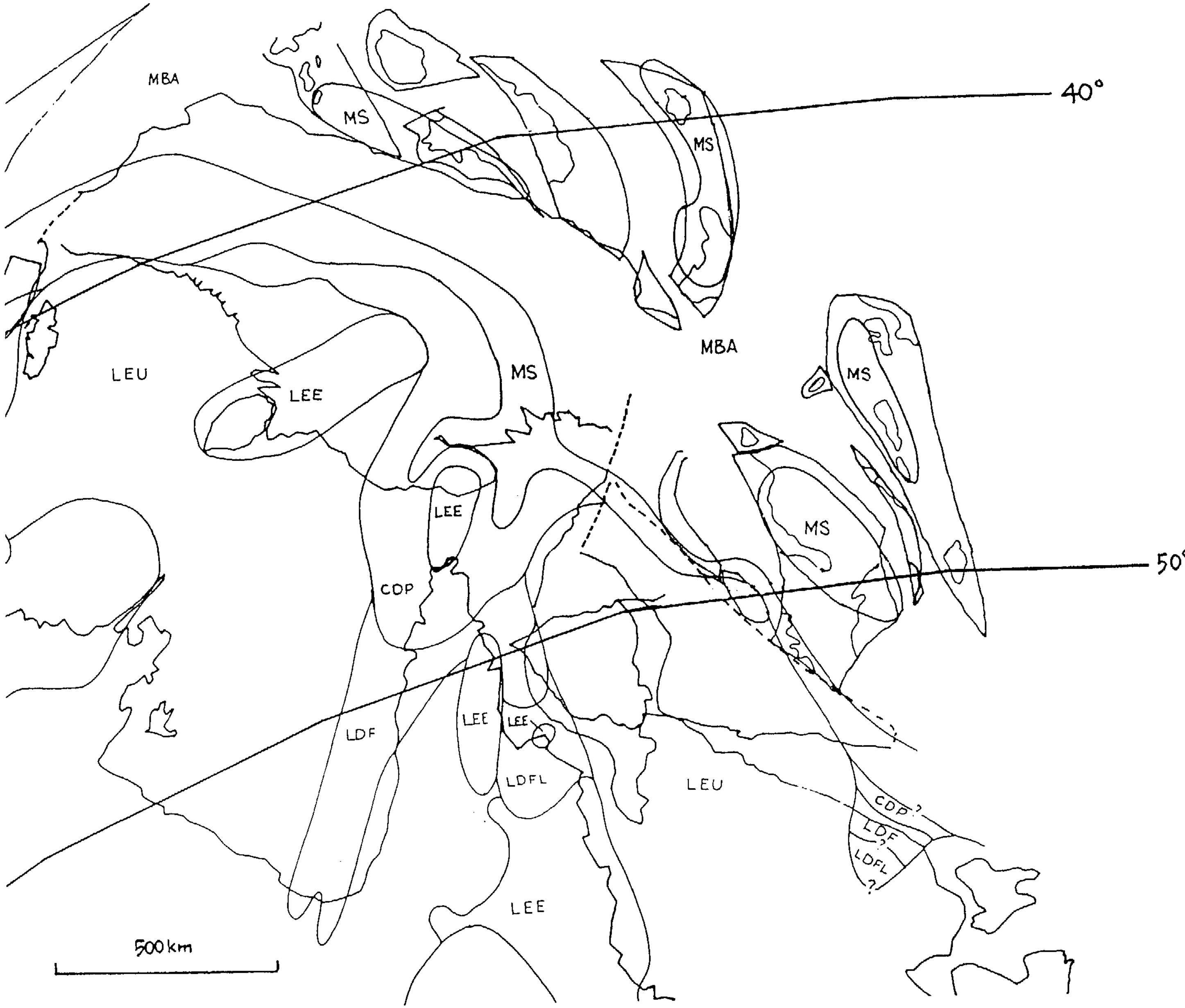


Figure 12: Late Jurassic (Oxfordian to Kimmeridgian) palaeogeography (J 8).

2.3 Cretaceous

Following Jurassic rifting and seafloor spreading along the northern Australian margin, the Early Cretaceous in this region was characterised by a more quiescent tectonic regime with continuing subsidence along the passive margin. The onset of a second phase of rifting in the mid-Cretaceous and subsequent ocean formation along the northern to northeastern plate margin resulted in extensive uplift across the region, and the detachment of continental fragments from the margin in the Late Cretaceous to Paleocene.

In the Early Cretaceous, the northern Australian Plate was located in middle latitudes ranging from 35 to 50°S. Commencement of the separation of Australia from Antarctica in the middle Cretaceous and associated rotation brought Australia into progressively lower latitudes. By the end of the Cretaceous, the northern part of the plate was located between approximately 20 and 35°S.

Early Cretaceous - Berriasian to earliest Valanginian (Figure 13)

In southern Papua New Guinea, the paralic fringe established in the Middle to Late Jurassic broadened during the latest Jurassic to Early Cretaceous. The greater part of the present Fly Platform and fold belt areas was characterised by a shore zone depositional system. Repeated minor transgressions and regressions caused the migration of beach, barrier-bar and channel-mouth facies, resulting in the deposition of quartzose sandstones (Toro Sandstone), which are the major reservoir rocks for hydrocarbons sourced by the underlying fine-grained Jurassic sediments. The Oriomo High remained emergent and probably provided a local sediment source. The paralic environments extended across the Carpentaria Basin and into the southeastern South New Guinea Basin, and a connection with the extensive fluvial system of the northern Eromanga Basin was established. To the north and the east, the Toro Sandstone grades into finer clastics deposited in shallow marine environments that deepened northwards, as indicated by continuing deposition of the Maril Shale/Kompiai Beds in the Kubor Block and Jimi Terrane areas. In some areas of the Gulf of Papua,

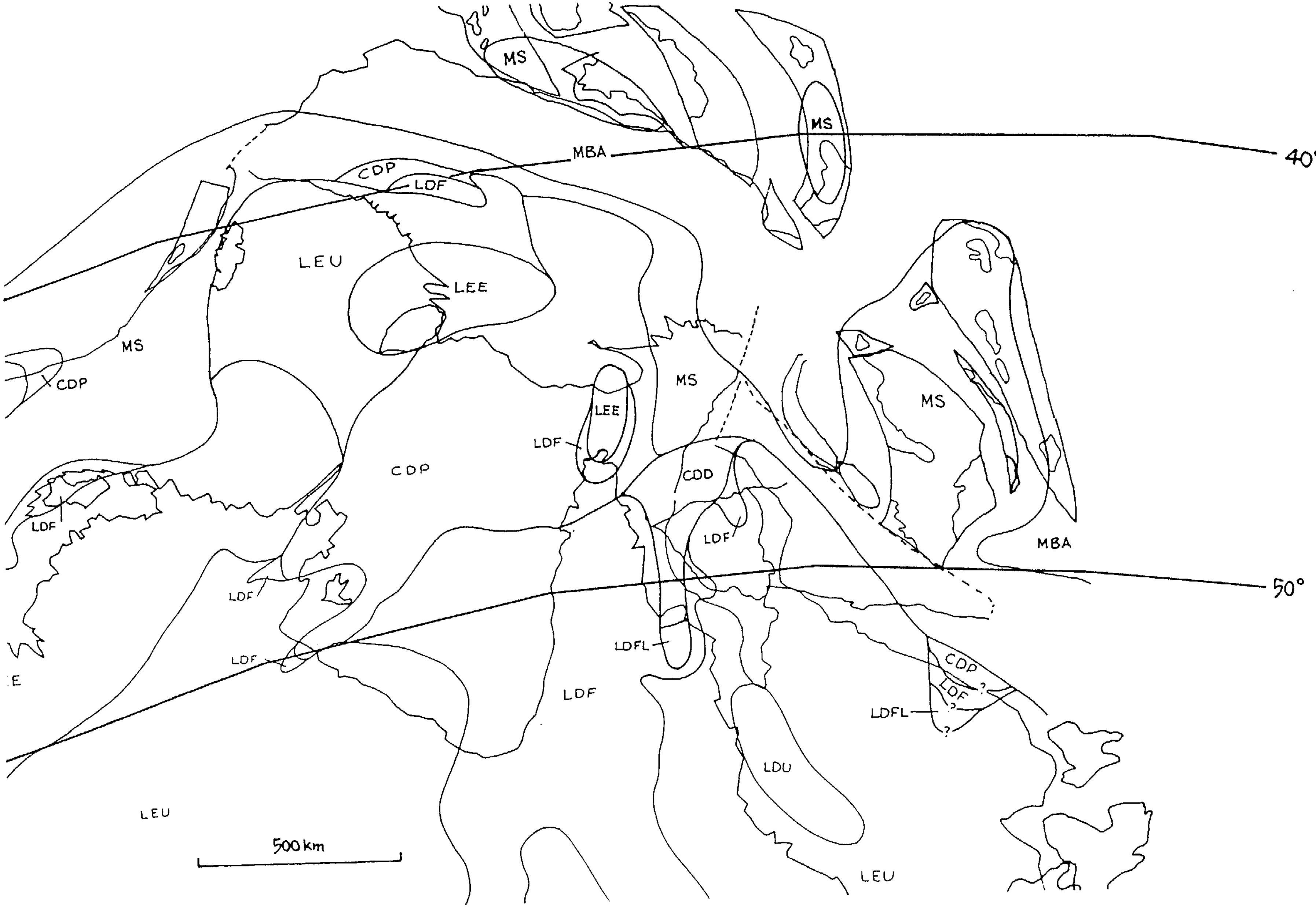


Figure 13: Early Cretaceous (Berriasian to Early Valanginian) palaeogeography (K 1).

particularly in its northwestern part, no Cretaceous rocks are preserved; this is probably due to Late Cretaceous to Paleocene uplift and erosion. Early Cretaceous rocks are also absent from the Kemum Block and the Netoni Terrane.

The paralic environments in the Papuan Basin extended into central Irian Jaya where beach and barrier bar deposits of the Woniwogi Sandstone are probably partly correlative with the Toro Sandstone. Similar to the Toro Sandstone, the Woniwogi Sandstone becomes more shaly to the north where it grades into undifferentiated marine sediments of the Kembelangan Group. Most of the South New Guinea Basin was still emergent and may have been connected with a land area to the southwest across the Arafura Sea .

Late Early Cretaceous -Aptian (Figure 14)

During the Early Cretaceous, Australia experienced a major inundation which culminated in the Aptian when extensive areas of the continent were covered by a shallow inland sea. Shallow marine environments were predominant in the Papuan Basin. Siltstones, mudstones and minor interbedded sandstones of the Ieru Formation were deposited across the basin during this time. To the north, deeper marine environments existed as indicated by dark grey to black shales. The presence of coarser-grained clastics in the latest Aptian succession in some areas of the basin may indicate a regressive period at this time. Basic to intermediate volcanics were extruded in mostly deep water environments in the Jimi Terrane area (Kumbruf Volcanics); they probably provided the source of volcanic detritus and tuffs within the Ieru Formation and its equivalents (Kerabi Formation, Kondaku Unit) in the Papuan Basin. Brown et al. (1980) suggested that the volcanics may be derived from a volcanic arc which developed over a subduction zone located to the north and northeast of the Papuan Basin. It is, however, possible that they are derived from volcanism associated with incipient rifting in the Coral Sea, which may have commenced as early as the Early Cretaceous (Taylor & Falvey, 1977; Symonds & others, 1984). Alkaline lamprophyre sills of Early to Late Cretaceous age, which intrude the Maril Shale southeast of the Kubor High area (Rogerson et al., 1988) and in the

Figure 14: Late Early Cretaceous (Aptian) palaeogeography (K 4).

northwesternmost Papuan Basin (Finlayson & others, 1988), may be related to this igneous phase (see also Struckmeyer, 1991b). The commencement of rifting in the Coral Sea as suggested by seismic data (Symonds & others, 1984; in prep.), is indicated on the map in Figure 14 by the presence of fluvial to paralic environments in the Townsville and Queensland Troughs and the proto-Coral Sea between the Queensland Plateau and the North Coral Sea component. Parts of the Queensland Plateau, Eastern Papuan Plateau and the North Coral Sea component were probably still emergent, but the widespread Aptian transgression very likely resulted in partial flooding of these areas and the partial encroachment of the sea into the rift grabens.

Marine environments that deepened to the north were also present in Irian Jaya, as indicated by the presence of mostly fine-grained clastics (Pinya Mudstone, undifferentiated Kembelangan Group). Part of the South New Guinea Basin was probably still emergent.

Middle Cretaceous - latest Albian to Cenomanian (Figure 15)

A further transgression occurred in the late Albian after the regressive phase that followed the Aptian peak of the Early Cretaceous inundation (Burger, 1986; Struckmeyer & Brown, 1990). In Papua New Guinea, deposition of the Ieru Formation continued across the basin in mostly shallow marine environments. Paralic conditions in the northwesternmost basin and on the southernmost Fly Platform suggest nearby land sources, indicating commencement of major regional uplift related to continuing extension in the north and northeast. Continuing granitic intrusive activity (e.g. Mt Victor Granodiorite on the Bena Bena Terrane) was probably also related to this extension. Several basement highs in the Gulf of Papua, and the onshore Papuan Basin, probably formed during this time, some of which provided locations for pinnacle reefs later in the Miocene.

Deep water environments were present in present-day northern and eastern Papua New Guinea. Extensive areas of the Queensland Plateau, Eastern Plateau

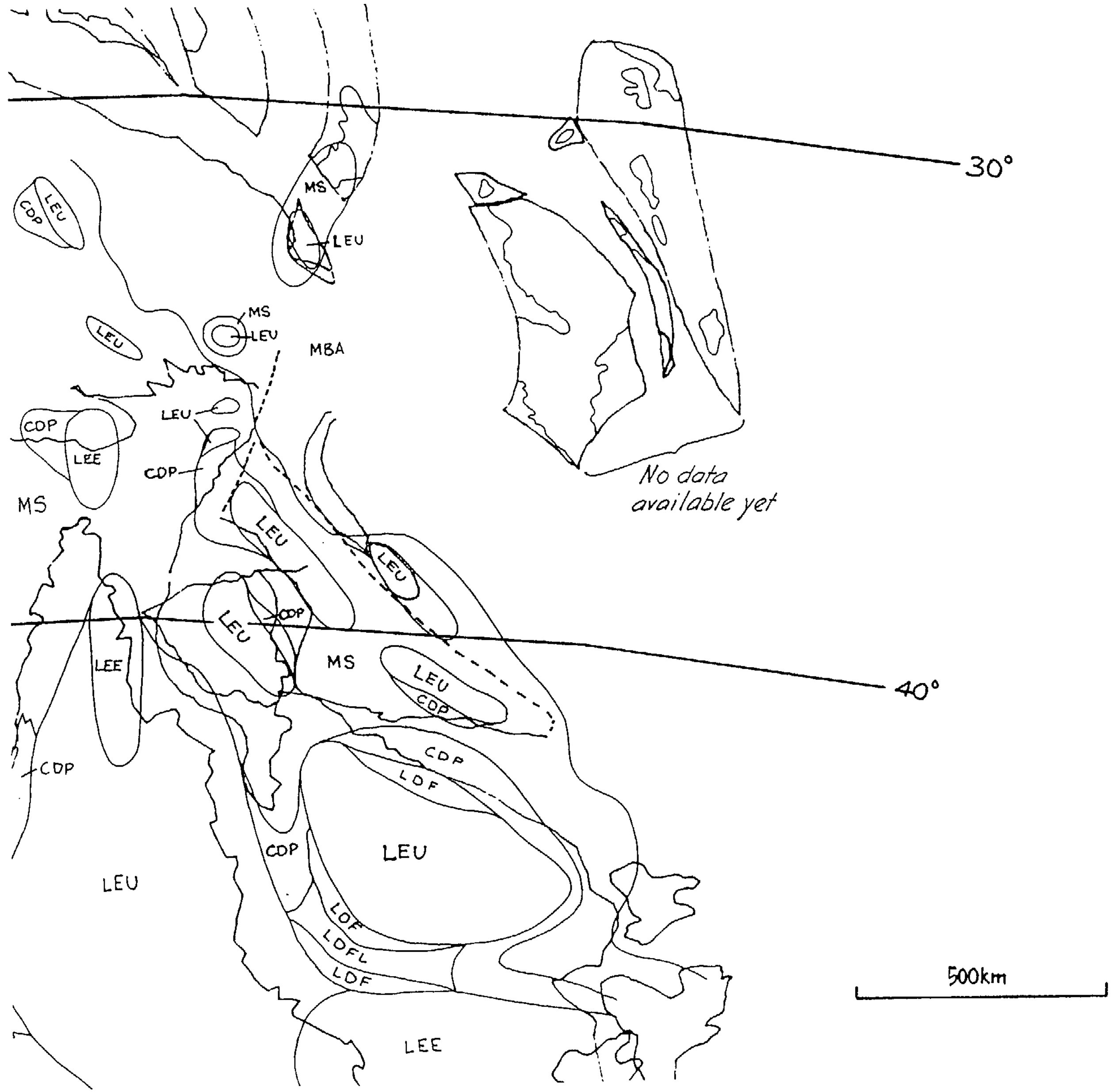


Figure 15: Middle Cretaceous (late Albian to Cenomanian) palaeogeography (K 8).

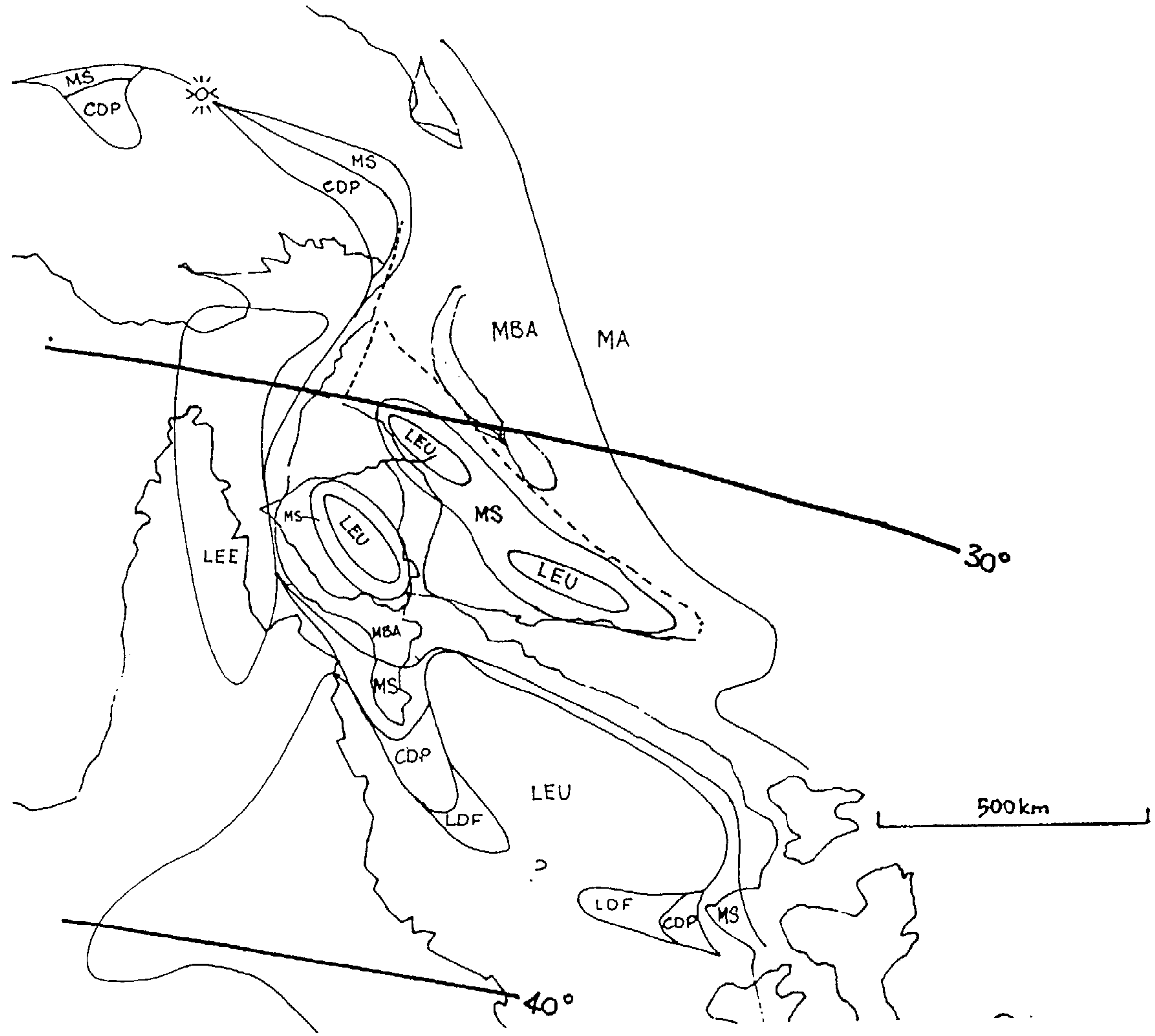


Figure 16: Late Cretaceous (mid-Campanian to mid-Maastrichtian) palaeogeography (K 10b).

and the North Coral Sea component were probably still emergent, but the sea may have encroached further into the grabens by this time. Oceanic crust probably formed in the developing ocean basin north of the North Coral Sea component with progressive northward movement of the Irian Jaya components. Remnants of this ocean basin of Late Cretaceous to Eocene age are preserved throughout the New Guinea Orogen as thrust slices of ultramafic to mafic rocks in association with bathyal-abyssal sediments.

Late Cretaceous - mid-Campanian to mid-Maastrichtian (Figure 16)

Regional uplift and differential erosion of upper Mesozoic sediments continued in the latest Cretaceous and extensive areas were probably emergent including most parts of the Papuan Basin and the southeastern South New Guinea Basin. Paralic environments characterised by the deposition of reworked, coarser grained sediments may have been present as a fringe around the emerging land areas, as indicated by the presence of the Pale Sandstone (Carman, 1987) at the top of the Ieru Formation in the northeastern Papuan Fold Belt area, and in the northwestern Papuan Basin. Deeper marine deposition of mostly fine-grained sediments and subordinate alkaline basaltic volcanics occurred in the vicinity of the Kubor Block (Chim Formation), the Jimi Terrane (Asai Shale) and the Bena Bena Terrane (Barabuna Beds). Conditions to the southeast, in the Coral Sea area, may have become increasingly marine with the onset of thermal subsidence related to seafloor spreading in the northern ocean basin. Paralic to fluvial environments may have been present in the Queensland and Townsville Troughs.

2.4 Paleocene (Figure 17)

The Late Cretaceous period of erosion and non-deposition in southern Papua New Guinea probably continued into the Paleocene as very few sediments of this age are preserved in the Papuan Basin. The Fly Platform and western Gulf of Papua were probably still emergent, with a narrow fringe of shallow marine environments in the present-day fold belt area; this is indicated by mostly coarse

Figure 17: Paleocene to Early Eocene palaeogeography (Cz 1).

grained clastics preserved in this area, which probably represent remnants of products of the Late Cretaceous to Paleocene erosional event. Seafloor spreading in the Coral Sea resulted in increased subsidence in the area and only some parts of the Queensland Plateau and the Eastern Papuan Plateau and North Coral Sea components may still have been emergent. Deep water pelitic sedimentation persisted in the Jimi Terrane area and present-day northern Papua New Guinea. Sea-floor spreading in the northern ocean basin continued and incipient subduction along the West Melanesian Trench (Manus-Kilinailau Trench) probably commenced in the latest Cretaceous to Paleocene, as evidenced by arc volcanics of this age on the Torricelli Terrane.

3. EOCENE TO RECENT

Increasing rates of northward movement of the Australian Plate from about 55 million years onward (Cande & Mutter, 1982) and a change in movement direction of the Pacific Plate from northward to westward approximately 45-42 million years ago (Clague & Jarrard, 1973), resulted in the conversion of the passive margin to a convergent margin and the formation of island arcs above two major, northward and southward dipping suduction zones to the north. The oblique collision of the Australian and Pacific Plates resulted in the successive accretion of allochthonous terranes of mixed, oceanic and island arc origin to the Australian Craton from the Oligocene onwards (e.g. Pigram & Davies, 1987; Struckmeyer, 1991a), the displacement of parts of the former passive margin, and the deposition of thick syntectonic sequences in the foreland (Pigram & others, 1989) and in basins forming between the accreting terranes.

3.1 Late Eocene (Figure 18)

In the Papuan Basin, deposition became more widespread during the Middle to Late Eocene, although most of the Fly Platform remained emergent. Sedimentation occurred in the northern and eastern Papuan Basin with the accumulation of a fringe of shallow water argillaceous to arenaceous carbonates

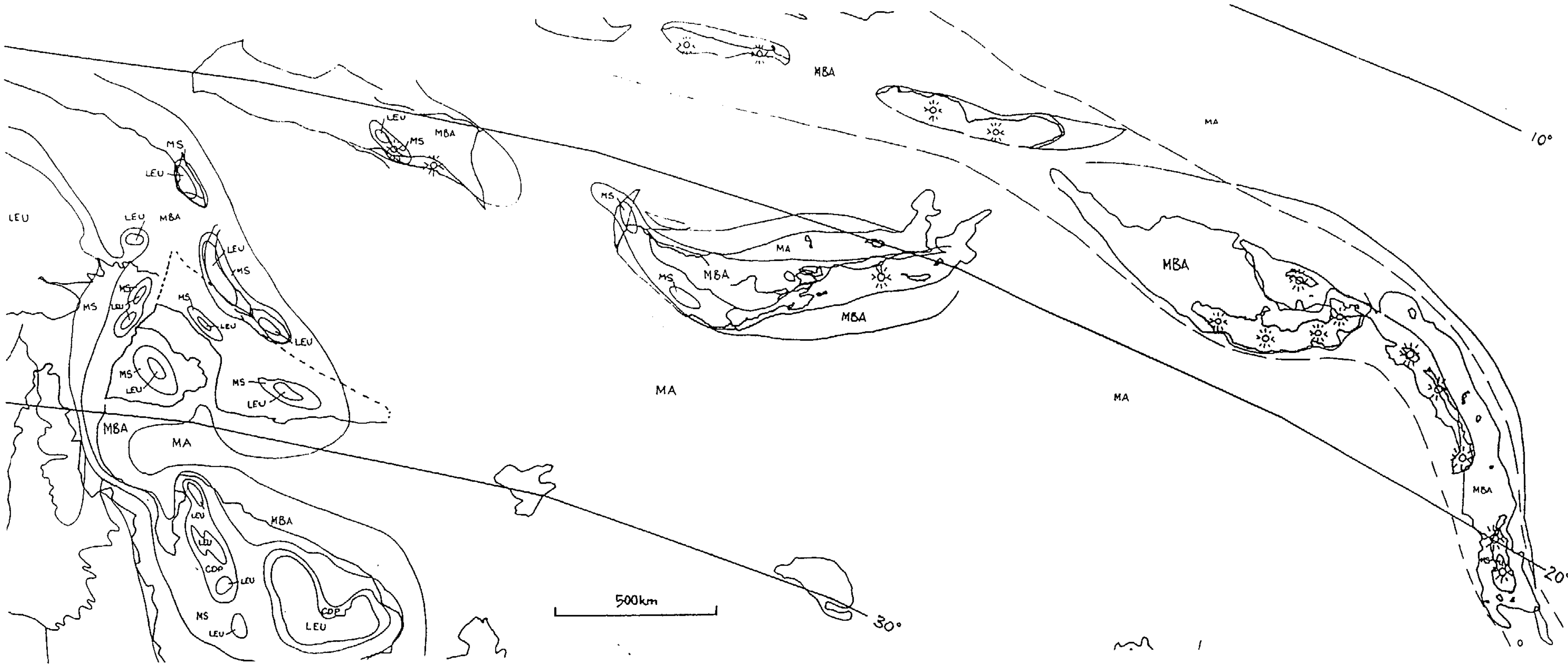


Figure 18: Late Eocene palaeogeography (Cz 2b).

(Mendi Group, Chimbu Limestone) around the emergent Fly Platform and emergent areas to the northeast and east. The shallow water carbonates grade into deeper water micrites, calcarenites and marls to the north and east (e.g. Nipa Group).

Distal Mesozoic to Palaeogene sediments of the Australian margin, oceanic crust and early arc-derived volcanics amalgamated above a northward dipping subduction zone; they would later form the composite terranes of mixed to oceanic affinity of central and eastern Papua New Guinea (i.e. West New Guinea Composite Block, East Papua Composite Block). For simplicity reasons, these composite blocks are shown in their present-day shape in Figures 4 and 18 to 21. However, they should be envisaged as gradually forming above the subduction zone by the scraping off of ocean floor sediments and the incorporation of fragments of oceanic crust. The Eocene age of deformation and metamorphism of these terranes is likely to reflect amalgamation of the terranes above the subduction zone. During the Eocene, palaeoenvironments across the amalgamating terranes were typically bathyal to abyssal, as indicated by the presence of a Middle to Late Eocene sequence of siliceous mudstone and argillite with occasional chert and interbeds of tuff and basaltic to andesitic lava (e.g. Gusap Beds, Paga Beds). However, gradually shallowing conditions in some areas are indicated by remnants of shallow water limestones of Late Eocene age.

The developing island arcs to the northeast were characterised by the extrusion of andesitic-basaltic lavas and associated tuffs, agglomerates and clastics in mostly deep water environments, although some subaerial edifices may have been present.

3.2 Late Oligocene to Early Miocene (Figure 19)

By the Late Oligocene to Early Miocene, initial collision of the West New Guinea Composite Block (WNGCB) had occurred, but subduction probably continued further to the east, thereby bringing the East Papua Composite Block closer to the margin. To the northeast, southwestward subduction continued along the West

Melanesian Trench with a string of island arc terranes trending NNW to SSE.

In the Papuan Basin, the Fly Platform and the western Gulf of Papua were again characterised by shallow marine carbonate platform sedimentation after a major depositional hiatus in the Early to Middle Oligocene related to the initial collision in the north. Barrier reefs developed on or near the platform edge (Borabi Reef Trend) and they may have extended to the north and northwest around the rim of the platform. Pinnacle reefs grew on basement highs along the slope and locally reached a stacked thickness of up to 1000m due to accelerated subsidence. These reefs are proven reservoirs for major gas accumulations (e.g. Pasca, Pandora fields). To the north and east of the carbonate platform, open shelf to deeper water carbonates and clastics were deposited. Thus, in the northern trough between the platform and the probably largely emergent Kubor Block, there was deep water turbiditic sedimentation sourced from both the carbonate platform to the south and emergent landmasses to the north.

The initial collision of the WNGCB is reflected in the presence of mostly fine-grained foreland deposits, which accumulated in shallow marine conditions in the westernmost part of the developing foreland basin, but mostly in bathyal environments to the southeast. Part of the composite block may already have been emergent by this time. The accreted block was characterised by widespread intrusions, most of which fall within the age range of 25 to 15 million years; they probably represent post-collisional igneous activity. The intrusions are associated with volcanics deposited in terrestrial to shallow marine conditions. The northern part of the developing Sepik Basin (Figure 2) was probably entirely deep marine as suggested by the presence of turbiditic sediments.

The East Papua Composite Block was located above the northeastward dipping subduction zone. Probable forearc basin deposits are preserved along the southwestern margin of the block. Related arc volcanics occur in the Cape Vogel Basin (Figure 2) - they were deposited in mostly bathyal water depths, although

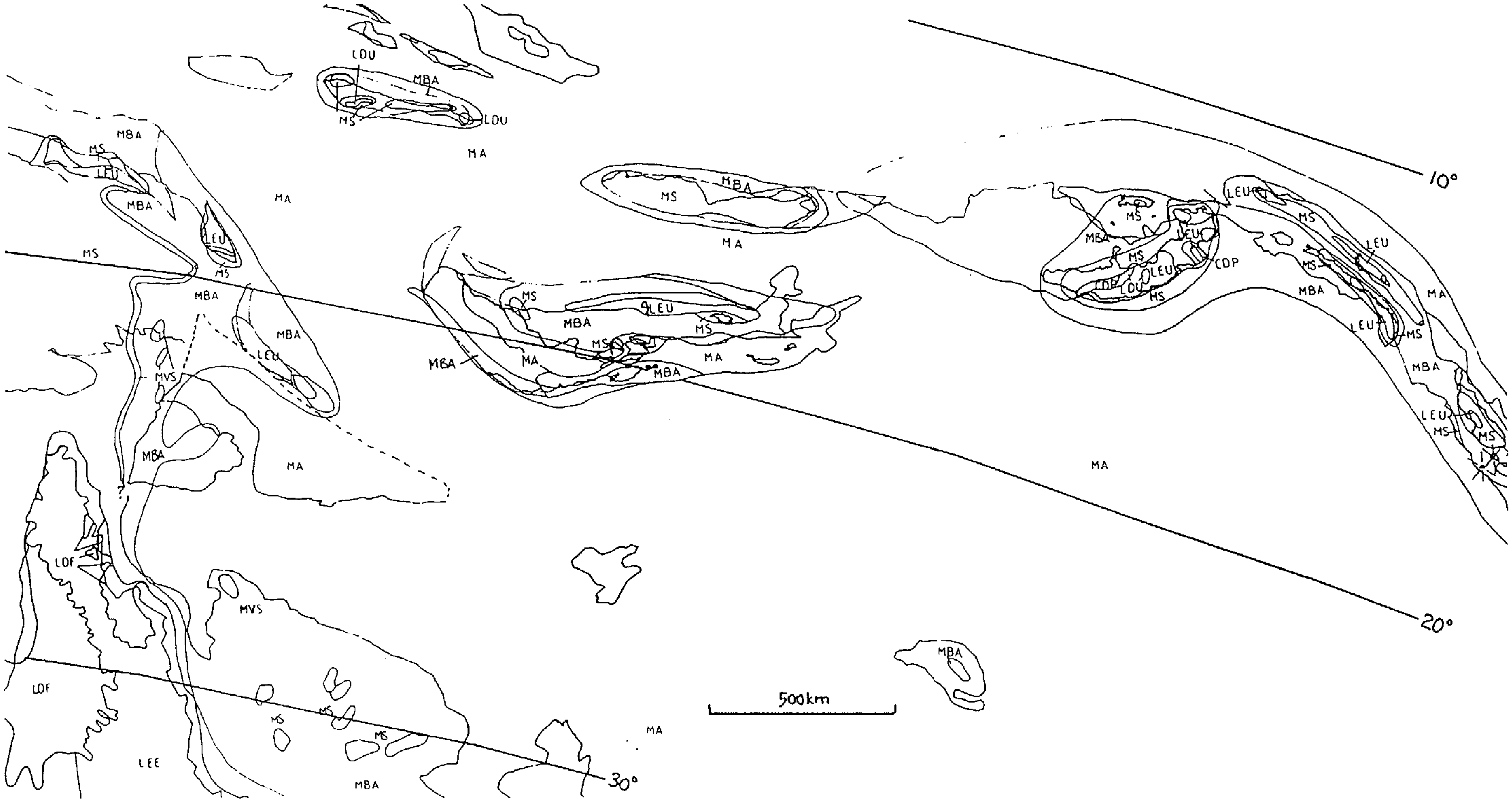


Figure 19: Late Oligocene to Early Miocene palaeogeography (Cz 4a).

locally shallow water carbonates developed. The volcanics thin to the north, indicating that part of the Trobriand Platform may have been emergent, possibly rimmed by a shallow water platform; some of the limestones associated with this environment are preserved on Woodlark Island.

Arc volcanism related to the West Melanesian subduction zone continued into time slice 4a and sedimentation of the associated volcanics and volcaniclastics occurred in mostly marine environments. The emergence of the island arc is indicated by conglomerates of this age on the southern Torricelli Terrane and the development of carbonate buildups in the Aitape Basin (Figure 2). These carbonate buildups could be an important reservoir for hydrocarbons sourced from Miocene to Pliocene sediments. On New Britain, up to 1000m of andesitic lava, tuff, conglomerate and minor limestone were deposited in subaerial, coastal and shallow marine environments. Part of New Ireland, and the southwestern New Ireland Basin may have been emergent to shallow marine, but deposition in the greater part of the offshore New Ireland Basin probably occurred under bathyal conditions.

3.3 Late Early to Early Middle Miocene (Figure 20)

A major plate tectonic event in Papua New Guinea during this time was the collision of the East Papua Composite Terrane which is here envisaged to have caused the northwestward displacement of the Jimi and Bena Bena Terranes and the onset of anticlockwise rotation of the Kubor Block. This is reflected in intensive syn- to post-collisional intrusive activity in the Middle to Late Miocene on these terranes. Co-magmatic volcanism is indicated by the presence, along the margins of the Bena Bena Terrane, of volcanics which were deposited in increasingly shallow marine conditions. Volcaniclastic turbidites accumulated in the marine trough south of the emergent landmasses.

Most of the East Papua Composite Block may have been emergent by time slice 4b. Arc-related volcanism had ceased and deposition in the Cape Vogel Basin was characterised by turbidites. Shallowing conditions in the south are indicated

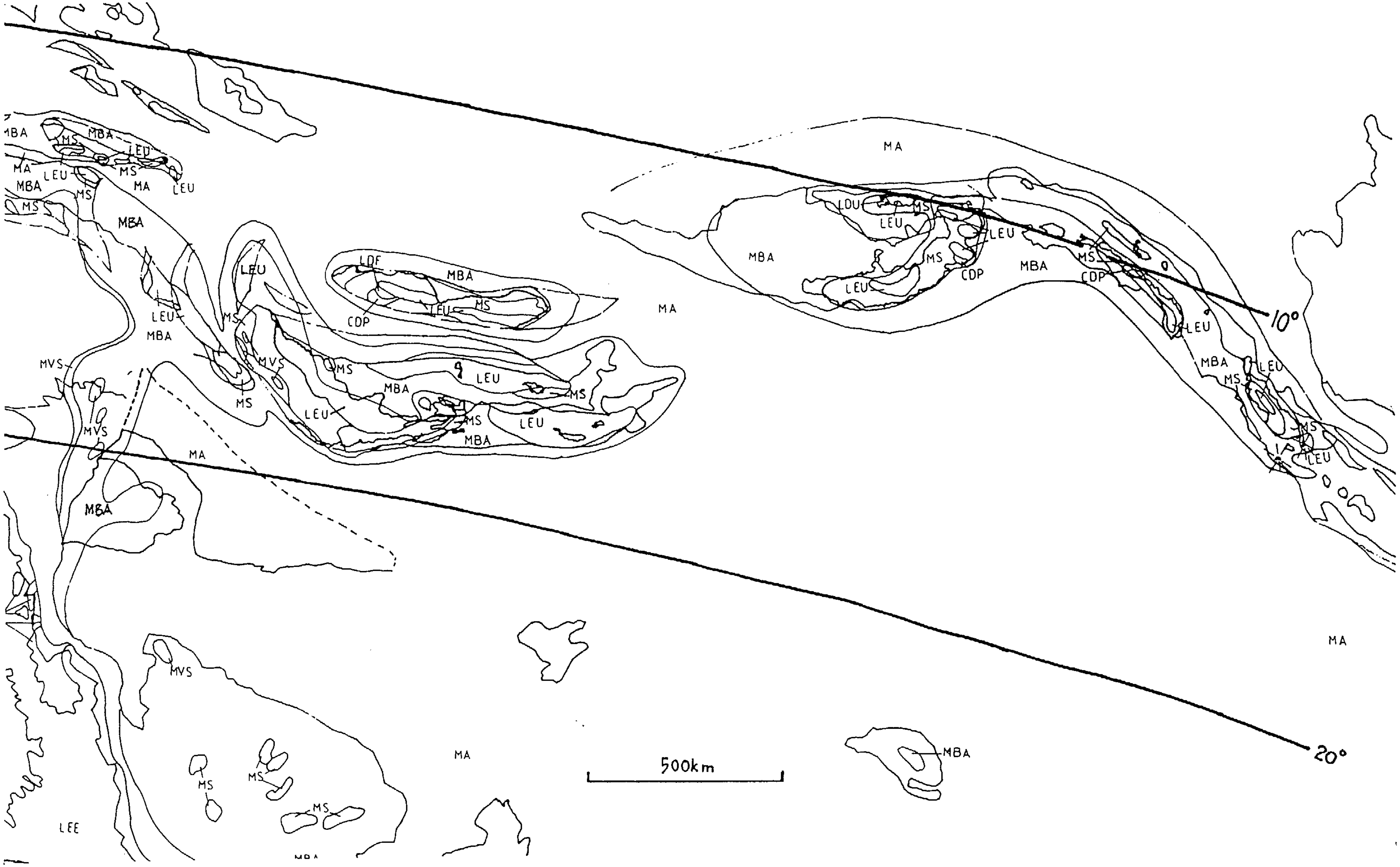


Figure 20: Late Early Miocene to early Middle Miocene palaeogeography (Cz 4b).

by the presence of shallow marine volcaniclastic sediments and reefal limestones along the southwestern and southern margins of the terrane.

In most of the Papuan Basin, reef and platform environments persisted, but foreland deposits in the north had encroached further south onto the platform. These deposits had become markedly coarser grained by this time. Gradual emergence in the southern Sepik area is evidenced by the presence of coastal deposits to the southwest and shallow marine conglomerates in the east. Shallow marine conditions in the southern Sepik Basin were probably more widespread than in time slice 4a.

The northern part of the Sepik Basin was still characterised by turbidite deposition, but the commencement of collision of the Torricelli Terrane may have resulted in generally shallowing conditions. Volcanism on the Torricelli Terrane continued into the Middle Miocene, probably related to northeasterly subduction of remnant Australian Plate oceanic crust. Fine-grained turbiditic sediments were also deposited in the central Aitape Basin, but reefs probably continued growing along the basin margins. Rapid southward deepening in the southern part of the Terrane probably indicates the location of the trench or suture.

The arrival of the Ontong Java Plateau at the West Melanesian Trench in latest time slice 4a time resulted in gradual cessation of volcanism along the former arc and these areas were now characterised by mostly shallow water carbonate deposition. Core areas of the islands were probably emergent, as indicated by fluvial to coastal deposits in some areas, for example on the Finisterre Terrane and in New Ireland. Carbonate deposition probably extended into the offshore basins, for example in the New Ireland and Bougainville Basins.

3.4 Early Pliocene (Figure 21)

By the Early Pliocene the Torricelli Terrane had accreted to the margin. The collision of the Finisterre Terrane had commenced in the Late Miocene,

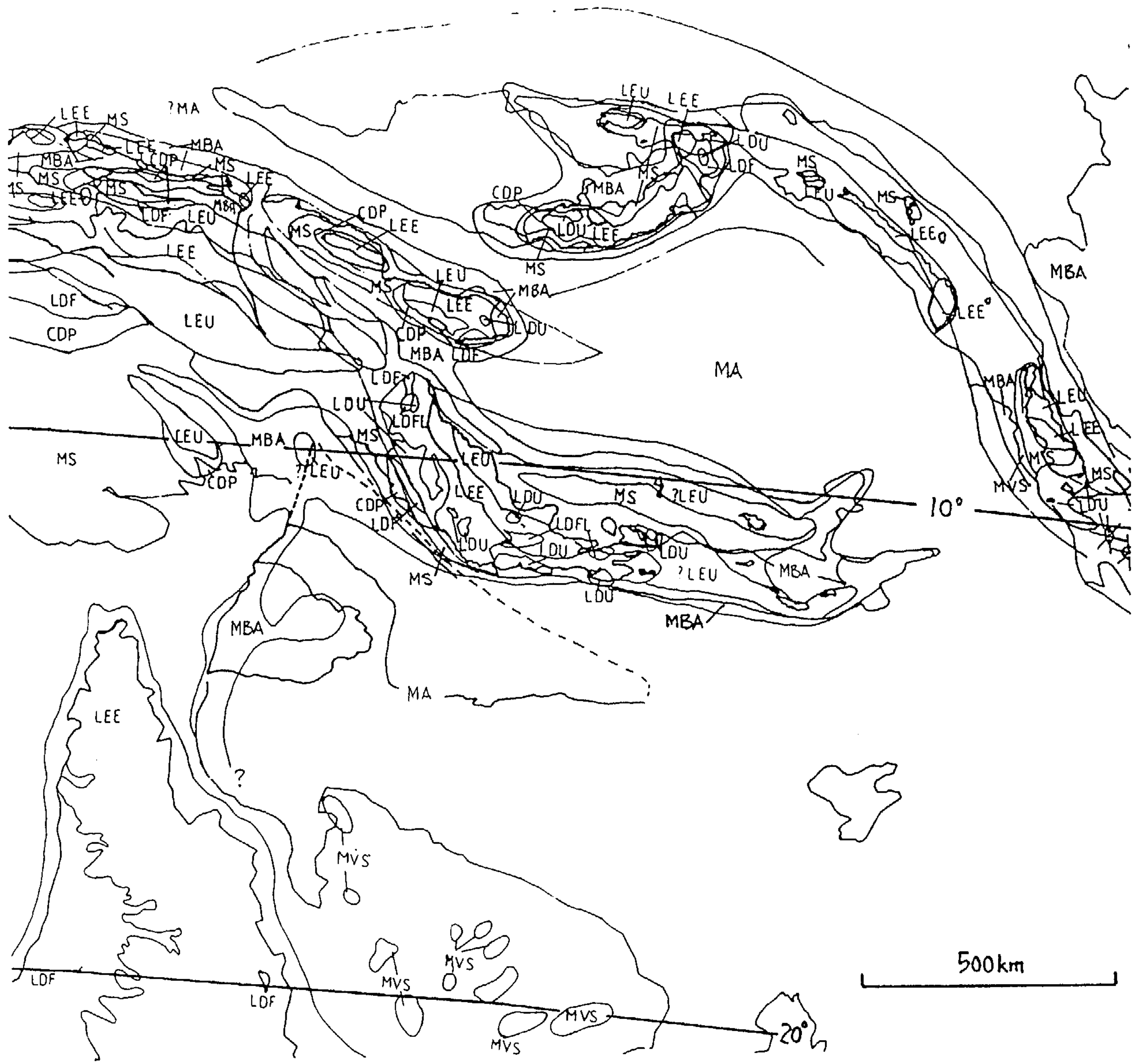


Figure 21: Early Pliocene palaeogeography (Cz 6a).

progressing eastwards, where a change in provenance in sediments of early Late Pliocene age indicates the onset of collision (Abbott & Silver, 1991). After the period of tectonic quiescence in the Middle Miocene in the northeastern arc region, arc reversal in the Late Miocene resulted in renewed volcanism on Bougainville, New Ireland and New Britain. The products of this volcanism are preserved as volcaniclastic sediments which were deposited in mostly shallow to deep marine environments. They provide a possible regional seal for the Miocene limestones.

In the Papuan Basin, the greater part of the Fly Platform and western Gulf of Papua were again inundated by a shallow sea, but the carbonate platform had by this time been buried by clastics shed from the northern emerging mountains. The sediments become finer towards the east and northeast grading into the shallow to deeper marine thick claystones of the Orubadi Beds. Occasional lenses and interbeds of detrital limestones wthin this sequence indicate commencing uplift of the Miocene carbonate platform in the northern part of the basin.

The greater part of central northern Papua New Guinea was probably emergent with a central chain of highlands, which reflect continued uplift and the development of the southern fold belt. Volcanism associated with this uplift commenced in the late Early Pliocene in the central fold belt area. In the northwestern Papuan Basin, thick coarse to fine clastics were shed from the highlands and were deposited in fluvial to coastal environments. Similarly, continuing uplift of the East Papua Composite Block is evidenced by extensive fluvial, coastal and marine foreland basin deposition along its southern margin, and preserved early Pliocene fluvial to fluvio-lacustrine deposits in the present-day ranges themselves. Extensive subaerial volcanism along the western and southern margins of the terrane was probably related to thrust loading and uplift.

In northern Papua New Guinea, most of the southern Sepik Basin was probably emergent, but with a coastal to shallow marine fringe in the northwest, and a deeper marine trough in the northeast. Deep marine conditions probably prevailed in the central Aitape Basin as indicated by an interbedded sequence of

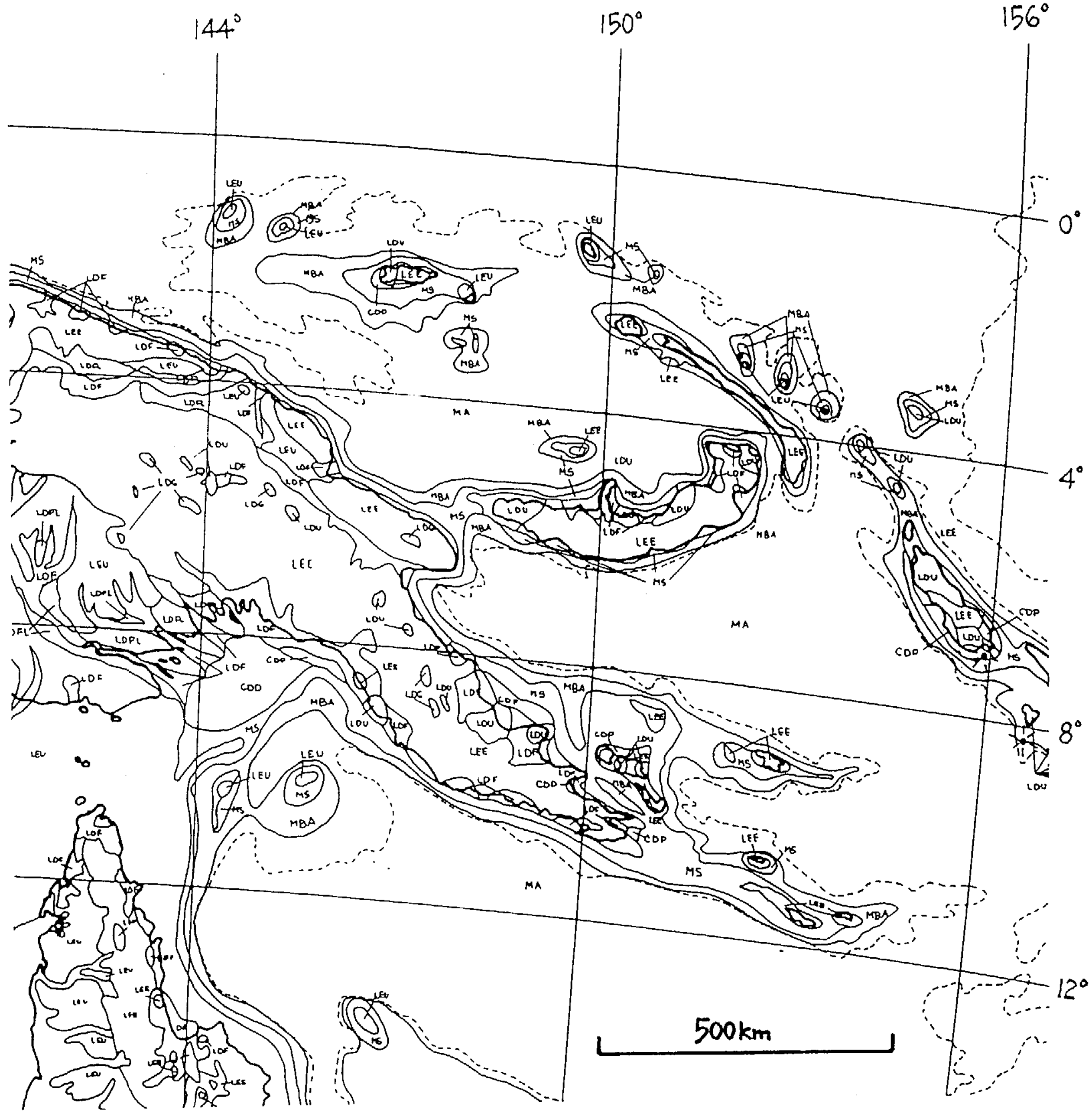


Figure 22: Late Quaternary palaeogeography (Cz 7 - late).

micaceous mudstone and graded lithic sandstone. The greater part of the accreting eastern Finisterre Terrane was emergent, with outcrops of the earlier arc volcanics providing the source for fluvial conglomerates of the syntectonic Leron Formation, which was deposited along their southeastern rim. These deposits become finer grained towards the west in the Ramu Basin, where fine- to coarse grained sediments were deposited in shallow to deeper marine environments.

3.5 Holocene (Figure 22)

The last map captures the major sealevel lowstand at approximately 18 000 years ago during the last major glaciation. The geography in the northern island chain and along the north coast was very similar to the present-day with slightly more extensive land areas and coastal fringes due to the sealevel fall. The fluvial system on the Fly Platform probably extended further eastwards with a large delta in the Gulf of Papua, whereas the southern rivers that now run into Torres Strait probably dewatered into a large inland lake postulated for the Gulf of Carpentaria (Smart, 1977; Langford, 1990). Glaciers developed along the central chain of highlands, mostly on the summits of the higher volcanoes.

4. CONCLUSIONS

In conclusion, the major aspects in the palaeogeographic development of the eastern New Guinea region during the Mesozoic to Recent can be summarised as follows:

During the Mesozoic to Paleocene, the northern edge of the Australian Plate was a passive margin which experienced two major phases of extension, in the Triassic/Jurassic and in the Late Cretaceous to Early Eocene. Triassic to Early Jurassic sedimentation occurred across a passive margin in depocentres that formed in response to initial extension. Fluvial to shallow marine volcaniclastics and redbeds were deposited in restricted areas in the Papuan and South New Guinea Basin and on continental fragments (Birdshead/Kemum

Terrane, Jimi Terrane) that were detached from the margin later in the Mesozoic. During the Middle to Late Jurassic, sedimentation along the northeastern Australian margin was controlled by a change from the Triassic rift regime to one of breakup and ocean formation, resulting in widespread inundation of the region. In southern Papua New Guinea, deposition continued in fluvial, paralic and shallow marine environments, whereas deeper marine shales accumulated in northern Papua New Guinea and also across the greater part of the Irian Jaya terranes. The earliest Cretaceous was characterised by widespread paralic to deltaic conditions, which resulted in the deposition of reservoir sandstones across the Papuan Basin and the Irian Jaya Platform. Increasing marine inundation during the Early Cretaceous led to the deposition of mostly fine-grained clastics throughout the region.

A second phase of rifting along the northern margin commenced in the mid-Cretaceous, resulting in extensive volcanism and intrusive activity. The onset of seafloor spreading in an unnamed ocean basin to the north of present-day Papua New Guinea in the Late Cretaceous led to the detachment of continental fragments that now form part of southeastern Indonesia. Ocean formation in the Coral Sea occurred in the latest Cretaceous to Early Eocene causing the northward movement of the North Coral Sea and Eastern Papuan Plateau components. Regional uplift associated with this extensional event occurred throughout the region in the Late Cretaceous to Paleocene resulting in widespread erosion of earlier Mesozoic sediments. Remnants of the erosional products are preserved in the present-day fold belt area.

Increasing rates of northward movement of the Australian Plate and a change in movement direction of the Pacific Plate from the Middle Eocene onwards led to the oblique collision of the two plates, the formation of island arcs above two major subduction zones, and the successive accretion of allochthonous terranes to the Australian Craton from the Oligocene onwards. On mainland Papua New Guinea, a carbonate platform developed in the northern and northeastern Papuan Basin, whereas the developing island arcs to the northeast were characterised by the extrusion of andesitic-basaltic lavas and the deposition of associated sediments in mostly deep water environments.

Carbonate platform and reef environments predominated in most of southern Papua New Guinea during the Late Oligocene to Middle Miocene, providing important reservoir facies for hydrocarbons sourced from Mesozoic and possibly Pliocene shales. The first collisional event along the northern margin occurred in the mid-Oligocene, resulting in initiation of foreland basin deposition in the northernmost Papuan Basin. At the same time, to the north and northeast, island arc volcanism continued above two major subduction zones in bathyal to shallow marine environments.

In time slice 4b time, carbonate deposition continued in most of the Papuan Basin, but clastic foreland basin deposition had encroached further southwards. The accretion of the East Papua Composite Block to the northeastern Australian plate margin caused the displacement of slivers of Australian craton. Uplift commenced in central northern New Guinea, while successor basins formed between the craton and the accreting terranes. The collision of the Ontong Java Plateau with the West Melanesian Arc caused the waning of volcanism and a tectonically quiescent period dominated by carbonate deposition throughout the region.

During the Early Pliocene burial of the carbonate platform by foreland basin deposits continued in the Papuan Basin. These sediments provide a seal for the limestone reservoirs. Collision of the Finisterre island arc terrane and the formation of the Papuan/Irian Jaya Fold Belt commenced, with associated trap formation. Arc reversal in the northeast resulted in the burial of the Miocene carbonates by thick volcaniclastic sequences.

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