CHAPTER 8

8 THE PALEOGENE LAND SURFACE & ITS SUBSEQUENT RIFTING

8.1 THE PALEOGENE LAND SURFACE IN SUNDALAND

8.1.1 The stratigraphic record in C and NW Kalimantan and W Sarawak shows that by the end of the Mesozoic, Cretaceous ophiolites and overlying turbidites together with a large volcano-plutonic complex had been added to the Paleozoic-Mesozoic cratonic part of the SE Asian plate. The term "Sundaland", used strictly to define the landmass of SE Asia which stood above sea level during periods of low sea level in the Pleistocene, has been redefined by Hutchison (1989,1992) as an acceptable term to describe the continental south-east Asian arm of the Eurasian Plate.

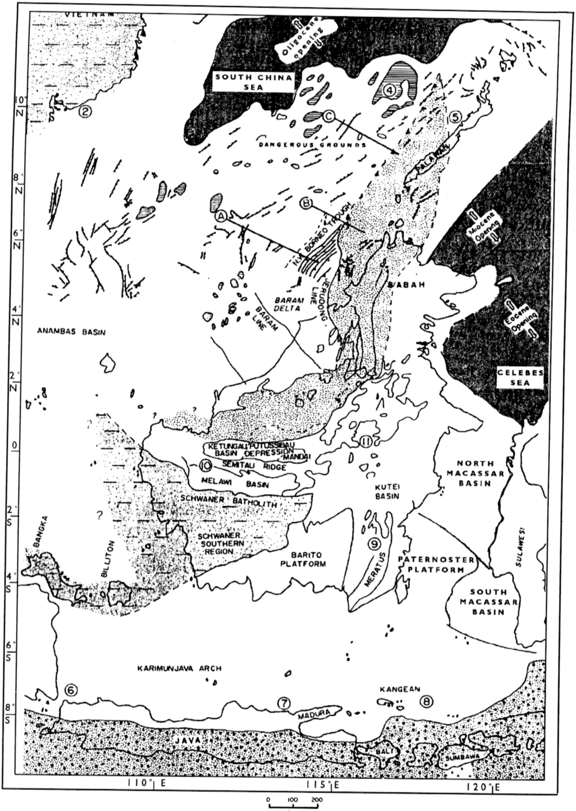
8.1.2 The western part of Sundaland comprising the pre-Cenozoic basement of Sumatra and Peninsular Malaysia is composed of Paleozoic and Mesozoic rocks and is largely cratonic (Hutchison,1989) whereas the eastern part (Borneo to W Sulawesi) consists predominantly of Cretaceous ophiolite, mélange and turbidite with volcanics and granitoids accreted onto the craton (Pieters & Supriatna,1990). The southern margin is taken to lie through the middle of Java island to Kangean and thence north-eastwards to include the western arm of Sulawesi.

8.1.3 The area now occupied by the Rajang Group formed an early Cretaceous - late Eocene turbidite basin and represented a gulf or marginal basin to the Pacific Ocean and called appropriately the "Danau Sea" (Haile,1994). Taylor & Hayes (1983) refer to the basin as being floored by

Mesozoic oceanic crust and remnants of the Mesozoic oceanic crust are found in the Boyan and Lupar zones as well as along Mersing Line in N Sarawak (Hutchison,1975a; Williams *et al.*,1986). During the Cretaceous, southward subduction at the Boyan-Lupar zones resulted in closure of the Danau Sea and generation of the Schwaner Mountains Cretaceous volcano-plutonic arc (Hutchison,1994). At the end of the Cretaceous, an extensive land surface was developed incorporating the South China Sea, Java Sea and seas E of Borneo together with the uplifted Schwaner Mountains and cratonic Sundaland, Vietnam and China which have persisted as land to the present. The extent of the land surface is shown in Fig 8.1. The evidence for such an extensive land mass is described by Hutchison (1992) from the study of a large number of stratigraphic sections throughout SE Asia and southern China (Fig 8.2). The rifting episodes which took place, often in the Paleogene mark the beginning of the breakup of the Paleogene landmass and the development of graben filled initially with continental deposits provides key evidence for a widespread land surface across much of Sundaland.

8.2 THE PALEOGENE LAND SURFACE IN BORNEO

8.2.1 Offshore NW Borneo and Palawan, the southern sector of the South China Sea basin is composed of attenuated continental crust (Taylor & Hayes,1980) confirmed from the dredged samples (Kudrass *et al.*,1986). Oil wells drilled on the Reed Bank and offshore NW Palawan show Cretaceous and older Basement rocks overlain unconformably by con-glomerates and carbonates with minor volcanics (Fig 8.2). The oldest samples



Marginal basins

Major horst on Paloecene landmass

Highland area s which persisted as land

Late Cretaceous through Oligocene Turbidite Basin (Rajang Group)

Cenozoic slope sediments

Ⓐ—— Seismic section

② Location of stratigraphic section

Thrust front

Trench

Normal fault

Fig 8.1 Paleocene landmass of SE Sundaland and rift zones (modified after Hutchison, 1992)

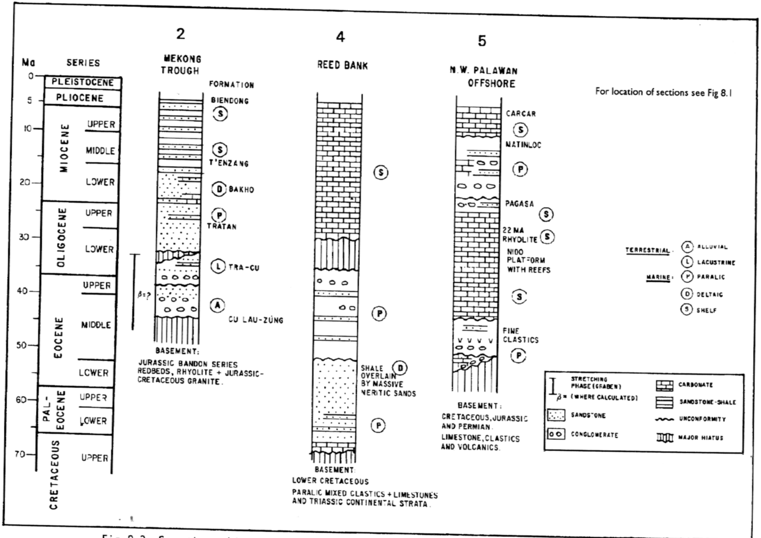


Fig 8.2 Stratigraphic sections of Cenozoic basins of the S China Sea area. (modified after Hutchison, 1992; 2 after Le(1986) 4 & 5 after Taylor and Hayes (1980), Hinz & Schluter (1985) & Holloway (1981)

collected from the Reed Bank are deltaic sandstones with a Triassic flora and fauna. Metamorphic rocks show K/Ar dates of late Jurassic-Lower Cretaceous. Widespread Oligocene -early Miocene carbonates were developed on the rifted continent and form clear reflectors (Hinz & Schluter, 1985). No detailed stratigraphy is published from below the platform carbonates but Holloway(1982) indicates the sediments are shallow water fine clastics. The NW Borneo - Palawan trough was interpreted by Hamilton (1979) as a remnant subduction trench which became dormant in the early Miocene. Seismic stratigraphy obtained across the Dangerous Grounds and Palawan Trough (see Chapter 1, Fig 1.6a,b) now shows well-defined, Oligocene-early Miocene platform carbonates dipping gently eastwards with a sedimentary cover derived from the Baram Delta Province. The carbonates and associated clastic are relatively undeformed indicating that the continental block beneath the southern part of the South China Sea is stationary. The sedimentary cover is being actively deformed by gravity tectonics; thrusts,growth anticlines, ponding and over-spilling of sediments away from the source. Therefore, the NW Borneo - Palawan Trough is not and has not been a convergent subduction system since the Oligocene. Hutchison (1993) concludes the sediments deposited to the SE of the Trough are loading and depressing the underlying attenuated continental lithosphere resulting in a landward dip to the Cenozoic cover.

8.2.2 The Paleocene landmass S of the Rajang basin comprised the uplifted Cretaceous Schwaner and Meratus Mountains complexes together with fragments of Upper Paleozoic rocks. The eastern margins of the landmass have been disrupted by the subsequent opening of the Celebes and Sulu Seas with associated faulting and rifting. In NW Java (Fig 8.3,column 6), the N-S grabens first received volcanic rocks belonging to the middle Eocene Jatibarang Formation (Adnan *et al.*,1991) which is locally contains oil. A major hiatus separates the Jatibarang from the lacustrine Talang Akar Formation succeeded by widespread Oligocene platform carbonates common throughout Java and eastern Borneo (see Chapter 9, Fig 9.25) (Gordon,1985). In NE Java (Fig 8.3 column 7), the middle Eocene - early Oligocene Ngimbang Formation rests with pronounced unconformity on pre-Cenozoic basement rocks and comprises conglomerates and coarse sandstones with coals overlain by shallow water limestones, marls and sands (Soeparyono and Lennox,1989). In the Kangean region (Fig 8.3, column 8), the base of the Cenozoic consists of Paleogene coarse clastics unconformably upon weakly metamorphosed Cretaceous metasediments and succeeded by coal-bearing sequences overlain by marginal marine sediments (Phillips *et al.*,1991). In the Java Sea, NE-trending horst and graben structures link Java to southern Borneo and oil wells drilled to basement indicate a variety of volcanic,plutonic and ophiolitic rocks probably of Cretaceous age (Bishop,1980). Cross sections show Paleogene to Eocene strata which begin with terrestrial lacustrine and fluvial sediments succeeded by shallow marine deltaic sequences and extensive Oligocene platform carbonates (Cater,1981 & see Chapter 9,Fig 38). Thus throughout Java and the Java Sea, the early Cenozoic history begins with terrestrial sedimentation or volcanism indicating the erosion and breakup of a Paleogene land surface.

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Attributes to Fig 8.3 opposite:

Stratigraphic column No 6 *after:*

Gordon,T.L. 1985 Talang Akar coals - Ardjuna sub-basin oil source. *Proc. 14th annual convention*, Indonesian Petroleum Association, Jakarta, 2, 91-120.

Reminton,C.U. & Pranyoto,U. 1985 A hydrocarbon generation analysis in northeast Java basin using Lopatin's method. *Proc. 14th annual convention*, Indonesian Petroleum Association, Jakarta, 2, 121-141.

Stratigraphic column No 7 *after:*

Soeparyona,N & Lennox,P.G. 1989 Structural development of hydrocarbon traps in the Cepu field, northeast Java, Indonesia. *Proc. 18th annual convention*, Indonesian Petroleum Association, 1, 139-156.

Stratigraphic column No 8 *after:*

Kohar,A. 1985 Seismic expression of Late Eocene carbonate buildup features in the JS25 and P.Sepanjang trend, Kangean Block, NE Java. *Proc. 14th annual convention,* Indonesian Petroleum Association, Jakarta, 1,437-452.

Phillips,T.L., Noble,R.A. & Sinartio,F.F. 1991 Origins of hydrocarbons, Kangean Block,northern Platform, offshore NE Java Sea. *Proc.20th annual convention*, Jakarta, 1, 637-655.

Stratigraphic section No 10 *after:* Pieters, *et al.*, (1987)

Stratigraphic section No 11 *after* Wain & Berod,1989 & Van de Weerd & Armin, 1992.

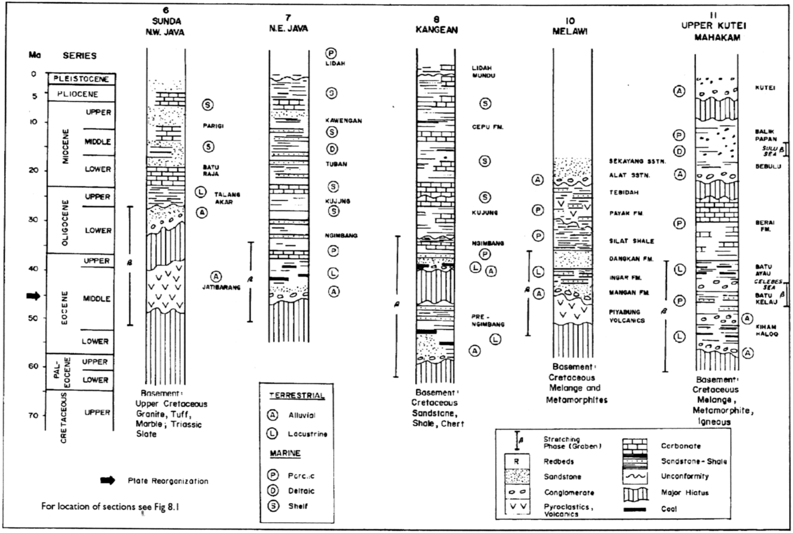

Fig 8.3 Stratigraphic sections of Cenozoic basins S of the Rajang Group in Borneo. (after Hutchison, 1992)
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8.2.3 A similar tectono-stratigraphic sequence is found in the southern half of Borneo Island. In the Melawi basin(Fig 8.3, column 10), the Piyambung Volcanics containing sanidine and quartz polymorphs testify to explosive eruption of air-fall tuffs and lie at the base of predominantly coarse grained sequences of rugose,continental deposits lying unconformably on a Cretaceous basement of ophiolite, mélange and metamorphic rocks. The Upper (West) Kutei basins (Fig 8.3, column 11) contains thick sequence of terrestrial sediments with the Oligocene Berai limestone similar to the widespread platform carbonates found in the Java Sea (Williams *et al.*,1986). The Kayan and Ketungau basins show similar characteristics; the middle Eocene Serantak Volcanics comprising felsic tuffs,dacitic dykes and stocks are located close to the Kayan basins. The lowest strata of the Ketungau basin contain basaltic sills and the late Eocene Muller Volcanics comprising basaltic - andesitic tuff, agglomerate breccia and pyroclastics lie on the SE margins of the Ketungau basin (Pieters & Supriatna, 1990).

8.2.4 In the Meratus area (Fig 8.4), Paleogene NW-SE grabens begin with the Tanjung Formation comprising basal conglomerates sandstones-,shales and coals, locally with basaltic tuffs and lavas which, in the Tanjung field, contain oil (Nayoan, 1981; Kusuma & Darin,1989). The sediments are thought to be either Paleocene (Kusuma & Darin,1989) or Eocene (van de Weerd & Armin, 1993). The basal conglomerates contain abundant chert derived from the Cretaceous ophiolite and deepwater sedimentary cover indicating a preponderance of these rocks exposed in the pre-Cenozoic land surface.Deposition in the narrow grabens gradually widens in the late Eocene

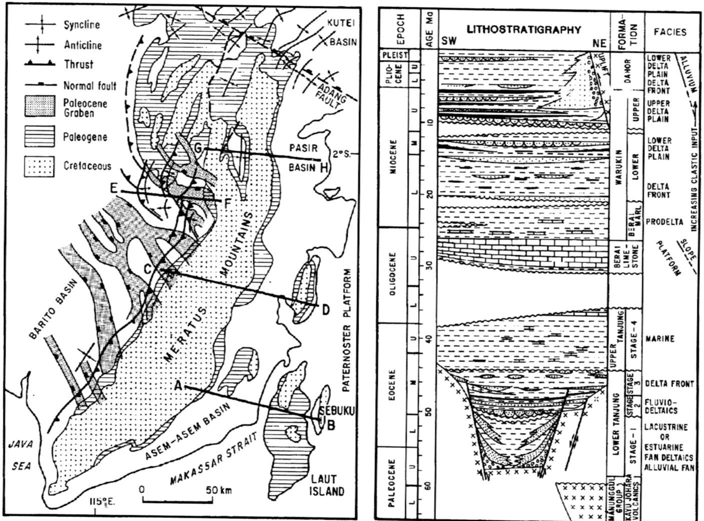

Fig 8.4 Paleogene grabens and lithostratigraphy of the Barito Basin, SE Kalimantan, based on Kusuma & Darin (1989) and Van de Weerd & Armin (1992). Cross sections in Fig 8.5. (after Hutchison, 1992)

and fully marine deltaic sedimentation occurs across much of SE Borneo forming the Cenozoic hydrocarbon-rich basins of Kutei,Barito, Asem-Asem and Pasir. Paleocene volcanics occur at the northern end of the Meratus chain at the base of the Tanjung Formation (see Chapter 5,Fig 5.2: volcanics marked Pev).

8.2.5 In SW Sulawesi, Cretaceous ophiolite and flysch sediments are overlain by the terrestrial Malawa Formation containing thin coals and locally,redbeds. The early Paleogene strata are overlain by the Tonasa Formation platform carbonate equivalent to the Oligocene Berai Limestone in Borneo and Java (Hassan,1981).

8.2.6 In northeastern Kalimantan, jasper conglomerate beds of the Lower Eocene Malinau Formation rest unconformably on deformed flysch sequences of the Upper Cretaceous Mentarang Formation and elsewhere the Upper Eocene Sebuku Formation containing the thin Sebuku limestone rests directly on the Mentarang Formation in outliers towards the Sabah border (Lefevre *et al.*,1982). Northeast Kalimantan including the Mangalihat Peninsular was a relatively stable area during the Paleogene with terrestrial or shallow marine deposition. In Sabah and offshore NE Kalimantan, extensional tectonics did not commence until much later in the early Miocene when lower alluvial floodplain deposition commenced in the circular basins of central Sabah including the coal-bearing Maliau basin. Offshore, the Tarakan basin seems to have commenced in the early Miocene as older deposits are unknown (van de Weerd & Armin,1993).

8.3 SUMMARY OF EARLY CENOZOIC TECTONICS IN BORNEO

8.3.1 The stratigraphic evidence described above indicates the breakup of a widespread Paleogene land surface beginning, in Borneo, with an early graben phase dated as Paleocene in the Meratus area. Paleocene limestones are virtually absent in Sundaland, especially in Borneo because most of the area was land at that time. The few Paleocene limestones occur on the flanks of the Mesozoic core of the Meratus mountains at the base of the Tanjung Formation (see Chapter 6, Fig 6.2) and are deposited unconformably on Cretaceous granite or volcanics. The early Cenozoic terrestrial sediments and, in places,volcanics were gradually succeeded by beginnings of deltaic sedimentation often with thin coals. More fully marine transgression is expressed in the widespread Oligocene limestones which developed as platform carbonates over a extensive areas from eastern Borneo to the Java Sea and Java island. The platform carbonates are absent further west where deposition was continental. Thus, there were no major rivers flowing eastwards during the Oligocene. Drainage was consistently to the W and NW into the Rajang deepwater.

8.3.2 Hutchison (1992) indicates a basement uplift in the Meratus Mountains area after the deposition of the Oligocene Berai Limestone (Fig 8.5). Van de Weerd & Armin (1993) indicate the Barito, Pasir and Asem-Asem basins were originally continuous throughout the period Oligocene - Middle Miocene. Uplift took place in the late-Miocene to Pliocene, expressed in the Dahor Formation exposed mainly in the Barito basin and on the E slopes

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Attributes for Fig 8.5 opposite

Cross Section A-B *after* Rustandi *et al.*, 1981

Cross Section C-D *after* Supriatna *et al.*, 1980

Cross Section E-F *after*

Kasuma,I & Darin,T. 1989 The hydrocarbon potential of the Lower Tanjung Formation, Barito Basin, SE Kalimantan. *Proc. 18th annual convention*, Indonesian Petroleum Association, Jakarta, 1, 107-138.

Cross Section G-H *after* Umar *et al.*, 1982

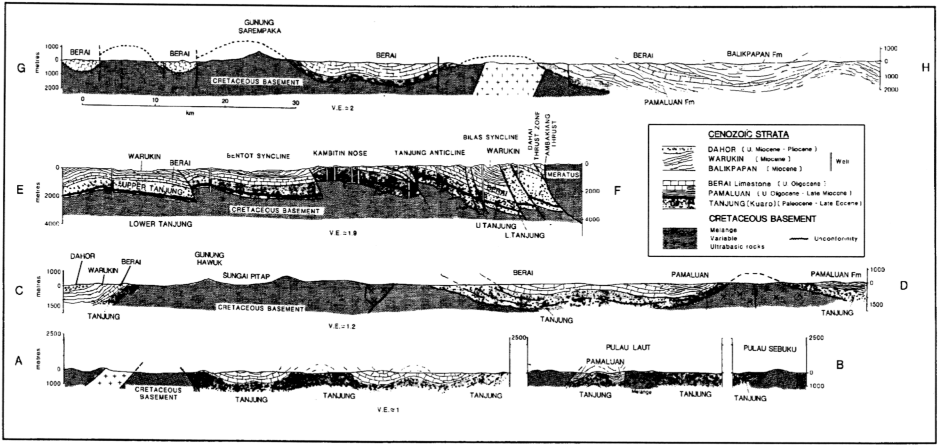

Fig 8.5 Cross sections across the eastern Barito Basin, Meratus Mountains the Pasir and Asem Asem basins.

(after Hutchison, 1992. Attributes on facing page.)

of the Meratus chain and containing pebbles of the Mesozoic ophiolitic rocks. Thrusting on the W flank of Meratus (Fig 8.5, section E-F) and encountered in the Tanjung oilfield is thought to be en expression of the late Cenozoic uplift (Hutchison, 1992). The cause of the uplift is unknown. Hutchison (1992) suggests the mélange in Meratus was formed during the Neogene uplift, analogous to the mélange developed in the Semitau ridge which was uplifted to divide the Ketungau,Melawi and Mandai basins which Williams *et al.*,(1986) suggests may have been linked originally as one basin in the Paleogene.

8.4 ORIGIN OF PALEOGENE RIFTING AND DEVELOPMENT OF CENOZOIC BASINS

8.4.1 The causes of the breakup of the Paleogene land surface by rifting have been attributed by Hutchison (1992) to the Eocene extrusion tectonics theory developed by Tapponier *et al.*,(1982,1986). The theory attempts to explain the radial mega-faulting associated with the collision and indentation of the Indian plate with the Eurasian plate judged to have taken place 45 Ma ago (Dewey *et al.*,1989). There was a world-wide major plate reorganisation at this time when Australia rifted from Antarctica (Veevers, 1984) and a new spreading system created at the Southeast Indian Ocean Ridge (Packham,1990). The faulting and rotational tectonics associated with the Yunnan syntaxis extend southeastwards to Sundaland which Hutchison(1992) suggests has been progressively oroclinally bent as a result of clockwise rotation imposed by indentation and extrusion tectonics (Tapponier *et al.*,1982, 1986). Clockwise rotation is confirmed by paleomagnetic studies on Cenozoic basins in Thailand and late Cenozoic basalts in E Peninsular Malaysia (Fuller *et al.*,1991). Such clockwise rotation probably does not extend to Borneo where anticlockwise rotation has been indicated (Haile *et al.*,1977; Schmidtke *et al.*,1990). Hutchison (1992) suggests the collision of Australia with the Banda arc affects the eastern, non-cratonic part of Sundaland and imposes anti-clockwise rotation and left-lateral shear on Borneo. The tectonic collisions registered in the Banda arc are currently under investigation and far from clear. Although the main Australian continent did not collide until 2.5 to 3 Ma ago, an earlier micro-continental collision took place between 10 and 7 Ma ago and an even earlier event at 38Ma in the Eocene (Richardson, 1993). The cause of rifting and breakup of the Paleogene land surface in Borneo is as yet incompletely resolved and further studies, particularly on the relative movements on basin margin faults, are required before a reasonable explanation can be made.

8.4.2 It is instructive to examine the distribution of Eocene rift basins through Sumatra, Java and Kalimantan (Fig 8.6). The pull-apart basins of Sumatra and western Java show a consistent long axis orientated N-S to NNE-SSW as predicted by Hutchison (1992, Fig 8). In Kalimantan, however, no such basins exist and the distribution of Eocene outcrop if more sporadic, especially around the Meratus area where presumably the Eocene has been eroded as the Meratus basement was uplifted.

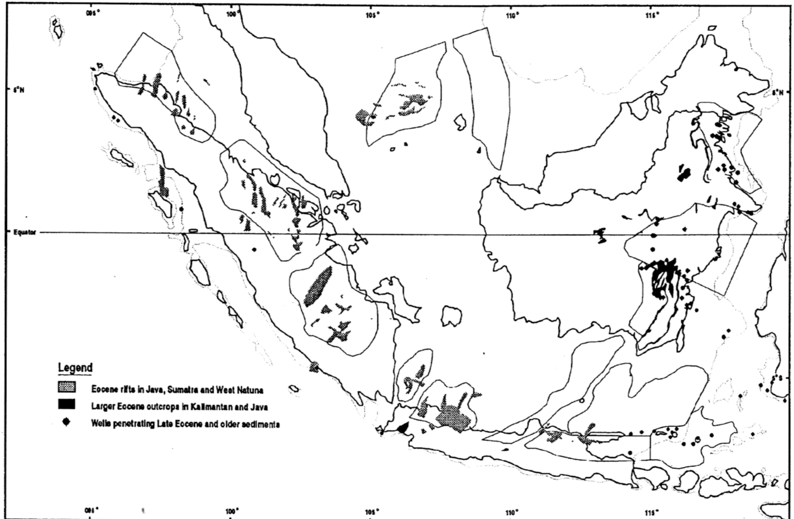

Fig 8.6 Eocene rift basins & areas of Eocene outcrop in Java & Kalimantan, Indonesia.
(after Courteney, in press)