CHAPTER 13

13 CONCLUSIONS

13.1 CORRELATION OF PALEOZOIC & MESOZOIC STRATIGRAPHY OF BORNEO WITH SE ASIA

13.1.1 Introduction

13.1.1.1 The stratigraphic record in Borneo shows that originally, proto-Borneo was composed essentially of Permo-Carboniferous ocean floor, represented by the Pinoh Metamorphics, Tuang Formation and Kerait Schist. The allochthonous Devonian limestones have been exposed by tectonism in a mélange belt associated with closure of the Mesozoic Danau Sea. They originated possibly from the Indo-China plate where Devonian limestones occur in Vietnam. The Devonian limestones are associated tectonically with areas of andesite, granodiorite and schist of unknown age which may be derived also from the Indo-China plate. Radiometric dating of the igneous rocks associated with the limestone may provide clues to the origin of the assemblage.

13.1.2 Stratigraphic correlation between Borneo and China & Indochina

13.1.2.1 The other Paleozoic- early Mesozoic rocks occur mostly as coherent strata located S of the Lupar zone in W Sarawak and NW Kalimantan. The fusulinid-bearing Carbo-Permian inliers (Balaisebut Group) associated with Permo-Triassic igneous and metamorphic rocks at the western end of the Busang - Murong Crescent and the Permo-Triassic rocks at both ends are in a critical position within the tectonically complicated Boyan zone. It seems possible that the Carbo-Permian sediments are derived from fragments of the South China and/or Indochina continental blocks which rifted from Gondwana-Land in the Paleozoic (Metcalfe, 1990); included with those fragments is the warm-water fusulinid limestone of the Terbat Formation. Paleolatitude plots show that South China was in the tropics during the Carboniferous-Permian (Metcalfe,1991, Fig.2). The Upper Triassic Serian and Sekadau Volcanics and perhaps the Jagoi granite represent an old island arc association marginal to the rifted South China and/or Indo-China continental blocks. Tate (1991a) has suggested that the mineralogy of the igneous and metamorphic rocks in the Permo-Triassic inliers may show that they are derived from oceanic crust. The Luconia Platform, Reed Bank and Dangerous Grounds represent the original continent which was part of continental China and the dredged samples of Jurassic rocks similar to those found in South China (Hinz & Schluter,1985a,b)

13.1.2.2 Thus, the rift, drift and accretion of the Pre-Cambrian and Paleozoic elements of the South China and Indochina blocks was completed by the late Paleozoic and , together with the North China block, were *already in tropical latitudes forming part of what Gatinsky et al.,(1984) has* termed Cathaysia-Land on which characteristic Late Carboniferous- Permian tropical Cathaysian floras developed. The Late Carnian - early Norian Kruisin flora of the Triassic Sadong Formation shows some affinity with the Triassic Anchau basin in SW China and the Norian Tonkin flora of north Vietnam (Kon'no,1972). The Upper Jurassic Kedadom Formation contains bivalve faunas identical to the Upper Jurassic- lowest Cretaceous Torinosu fauna of Kyushu, Shikoku and NE Honshu, Japan (Tamura & Hon,1977).

13.1.2.3 There is abundant evidence to indicate a clear correlation between the Paleozoic-early Mesozoic stratigraphy of Borneo and the China and Indochina continental blocks.

13.1.3 Stratigraphic correlation between Borneo and the western part of Sundaland

13.1.3.1 The pre-Cenozoic geology of Borneo has no counterpart in areas to the west where the Paleozoic and Mesozoic stratigraphies and paleo-environments of Sumatra and Malaya are entirely different. In Sumatra, interpretation is difficult as most data is derived from oil wells. The "Greywacke" and "Quartzite" terranes (Hutchison,1993) lie W of the Paleotethys suture zone and show inherent Gondwanan characteristics of cold-water faunas and *Glossopteris* floras which have nothing in common with Borneo. The Lower Paleozoic comprises the Mutus "assemblage" (Hutchison,1993) and although the assemblage contains some elements of oceanic crustal material, it is considered to be older than the Carbo-Permian rocks in Borneo.

13.1.3.2 Structural trends along the eastern side of Malaya, Singapore through Bangka and Billiton Islands as well as Sumatra trend north-south in the N and bend oroclinally eastwards towards the S so that in Billiton, the structural grain of the Permo-Triassic rocks is E-W (Hutchison, 1993). The trend does not continue further E into southern Borneo. The rocks exposed at the SW tip of Borneo comprises the Matan Complex on Pulau Bawat and Pulau Cempedak and the Ketapang Complex onshore (Sudana & Jamal,1989). The Matan Complex on the Kendawangan Quadrangle sheet is described as lithic tuff, dacitic tuff, crystal tuff and lava interbedded with meta-sandstone,-siltstone and -claystone. The Ketapang Complex is here described as comprising quartz sandstone, tuffaceous quartz sandstone meta-quartz sandstone,-siltstone and -shale. Although major structures mapped in the NE sector of the Quadrangle trend roughly E-W similar to the structural grain in Billiton, the age of the successions in SW Borneo is younger than Permian. On Billiton island, there is well-documented evidence which indicates there is no stratigraphy older than Permian and the latter is intruded by Triassic granites (Van Bemmelen,1949; Jones, *et al.*, 1977) . In Borneo Island, no Triassic granites have been found which intrude Permian rocks. The only Permian rocks of similar lithology in Borneo are found in restricted outcrops of the Terbat Formation in Sarawak and the fusulinid limestones of the Balaisebut Group in Kalimantan. The nearest Triassic granites eastward occur in Sula Island and they are related to New Guinea from where they have been translated westwards along the major Sorong transcurrent fault in northern New Guinea (Hutchison,1989).

13.1.4 Stratigraphic correlation between Borneo and the southern part of Sundaland

13.1.4.1 There are no Permian carbonates of Asian affinity in Timor; the Timor Permian has faunas characteristic of the Permian of Perth, W. Australia which show a paleoenvironmental change from cold to warm water species during the Permian - Triassic Eras. The Australian part of

Gondwana began to rift in the Permian indicated by pillow lavas with a rift signature below the Permian Limestone on Timor and the Australian continent began its northward movement into the tropics during the Triassic. Moreover, the geology on Sumba island, Indonesia, comprises rocks with continental affinity related not to Australia but to Java and Sulawesi. (A.J. Barber, GSM Technical talk, Kuala Lumpur , 15 September,1994). The Permian faunas in Borneo therefore are likely to be related to Asian (Cathaysian) rather than Gondwana species.

13.1.4.2 Thus, the stratigraphy of Borneo island can be linked to Cathaysian China & Indochina. The subsequent geological evolution of Borneo island is related largely to tectonic movements connected with the rifting of continental China/Indochina and Mesozoic subduction of a late Paleozoic-Mesozoic ocean termed by Haile (1994) the "Danau Sea".

13.2 THE DANAU SEA,CRETACEOUS SUBDUCTION & ACCRETION TO SOUTHEAST SUNDALAND

13.2.1 Subduction began in the late Jurassic-Lower Cretaceous with the development of a N-facing trench dipping away from the South China-Indochina continent and an island arc approximately 200km to the S of the subduction zone (now seen as the Schwaner Mountains plutonic arc association) . The intervening ground between the subduction zone of the island arc system and the China block in the N was occupied by a deep ocean basin floored by Jurassic - Lower Cretaceous chert, distal turbidites and ?pillow lavas/serpentinites of a ?Paleozoic age. The spreading centre which created the Paleozoic oceanic crust was presumably that which caused China to separate from Gondwana Land and located in the southern hemisphere.

13.2.1.1 A succession of turbidites accumulated on the ocean floor underlain probably by Permo-Carboniferous oceanic crust between the S China block and the subduction zone from Upper Cretaceous through to Eocene (now seen of the Rajang Group) and derived from major rivers flowing off the S China - Indochina continent - perhaps the proto-Mekong which flowed across what is now the SW sector of the South China Sea. In order to accumulate vast thickness of sediments in a deep basin, there must be major sources on the margin of a large continent. The continent is Cathaysian South China-Indochina, which, because of the post-glacial rise in sea level, is presently submerged and lies beneath much of the area of the present day South China Sea (see Chapter 1, Fig 1.2).

13.2.1.2 The gradual closing of the Permo-Carboniferous ocean and approach of the subduction zone/island arc to the South China block resulted in thrusting and crustal shortening of the area occupied by the Danau Sea so that the Rajang Group turbidites were squeezed into a thick accretionary prism comprising a thrust stack perhaps several kilometres thick and accreted onto the Paleozoic Borneo.

13.2.1.3 Isolated islands marginal to the South China block comprised Triassic granites (Jagoi) around which the Bau Limestone developed in relatively narrow peripheral shallow water with deep water turbidites of the Pedawan Fm close by.

13.2.1.4 Approximately 200 km beyond the Cretaceous subduction trench, a volcano-plutonic arc intruded I-type granitoids and associated volcanics into a core composed of older rocks (Jurassic and pre-Jurassic granitic(Jagoi), volcanic(Serian) and metamorphic rocks (TuangFm.). A narrow zone of carbonates (Bau Limestone) were deposited around the protruding Jagoi granite hills in the Serikin area. At no great distance from the coral reef zone, the submarine topography deepened rapidly with steep slopes marking the edge of deep water in which turbidites and collapse/storm surge deposits accumulated as the Pedawan Formation. The Pedawan Fm has not been described in reconnaissance mapping as a deep water deposit and only recently have deep water features been recognised (Azhar Hj Hussin ,1991). In eastern Sabah, similar shallow carbonate shoals were deposited on uplifted turbidites and oceanic crust as the limestones of Madai-Baturong (Leong,1979; Hutchison, 1989).

13.2.1.5 Thus, by the end of the Cretaceous, Sundaland had additional accretionary material comprising the Rajang Group and Schwaner Mountains plutonic-arc complex with uplifted oceanic crust accreted onto the continental margin of Sundaland, forming an enlarged land area which remained stable, enabling the formation of a Paleocene land surface. At the same time, some of the Jurassic - Lower Cretaceous oceanic crust in eastern Sabah was uplifted.

13.2.1.6 Closure of the Permo-Carboniferous ocean floor with the accretionary prism and subduction zones sandwiched between Schwaner Mountains volcanic-plutonic arc and the S China Block (Luconia block etc) resulted in termination of subduction at the Mesozoic-Cenozoic boundary and the initiation of subduction of the present day Indonesian island arc marked by the Eocene Jatibarang Formation in N Sumatra.

13.2.1.7 Hutchison (1996) has reviewed the evidence for subduction at the Boyan/Lupar zones and has resolved an earlier problem concerning reconciliation of the ages obtained from the Rajang Group especially the Crocker Formation with the Cretaceous radiometric dates obtained from the granitoids in the Schwaner Mountains. By separating the younger Oligocene West Crocker Formation from the rest of the (older East) Crocker Formation, Hutchison (1996) has clarified the apparent confusion in Sabah where there are two successive turbidites successions. The East Crocker (?Upper Cretaceous - Eocene) is the equivalent of the Rajang Group in central Sarawak and forms a continuous belt of accretionary prism created during Cretaceous subduction but bent subsequently into a NW-facing orocline. However, there is no satisfactory explanation for the sharp twist of the East Crocker succession into the "Sulu" trend in northern Sabah. The West Crocker represents an Oligocene deep water succession whose shallower equivalents are the Temburong Formation in Brunei (Tate,1996) and the Kelabit Formation in N Sarawak (Haile,1962).

13.2.2 Haile (1994) has introduced the term "Danau Sea" for the Mesozoic oceanic plate consumed at the trench. The Danau Sea closure has almost completely consumed and removed the Mesozoic ocean floor by subduction and only fragments brought up along the Lupar and Boyan zones remain as visible testament to the former ocean. There is no Proto-South China Sea (*i.e.* the area between Borneo and present day China) earlier than Oligocene when spreading commenced to generate new oceanic crust. If the Danau Sea was of similar dimensions to the present day South China Sea, i.e. 2250 km across, the ocean would have been consumed in less than 40 My assuming a rate of 6 cm/year. The Rajang Group probably extends beneath the Miri zone shown by the presence of (?thrust-bound) inliers at Mulu and Temala and hence the subcrop width is perhaps of the order of 500 km. If the Danau Sea had undergone crustal shortening say, by 50%, at least 1000 km of oceanic crust was consumed in less than 20 My. Cretaceous subduction may not, however, have been continuous but episodic, as Ru and Piggot (1986) have indicated for the Oligocene spreading of the South China Sea. No evidence remains for a spreading centre in the Danau Sea. Subduction was probably dipping away from the South China-Indochina continent. In East Asia, the Manila trench located in the NE sector of the present South China Sea is the only example of a subduction zone dipping *away* from a continent. The trench dips eastward and the South China Sea is being subducted beneath the Pacific ocean. At its northern end, Taiwan is colliding with the edge of the South China continent. Probably because of the collision, subduction has just ceased at the Manila trench and the prevailing convergent tectonics have been transferred to the Philippines arc-trench system which is very young with a subduction zone dipping steeply *west-wards*. Hutchison (1989) remarks that the present-day situation in the Philip-pines is a rare event in time where an orogenic zone is bounded on both sides by simultaneously active and opposed arc-trench systems.

13.2.3 The Lupar line does not separate areas of differing geology for on a larger regional scale, there are turbiditic sequences (eg Pedawan -

Selangkai Formations) further to the S and W. Turbidites are not only restricted to the Rajang basin. The term *Lupar Line* now seems to be outdated and its earlier use based on a relatively restricted area mapped in great detail in W Sarawak (Tan,1979) and extrapolated somewhat arbitarily over a wide area has been superceded as a result of recent mapping in Kalimantan. A rather better term "***Danau suture***" is suggested to express the broad belt of ultrabasic rocks associated with mélange extending from the Natuna Islands in the west through the Lupar valley and crossing central Kalimantan almost to the east coast. The Lupar Line as originally conceived does not continue far into Kalimantan. The Lupar Line should be renamed "***Lupar fault***" as it is probably a major synsedimentary fault in the early history of the basin and delineating the NE margin of the Ketungau basin in Sarawak. The fault was initiated and active during the Eocene as the vertical beds S of the fault belong to the Eocene Silantek Formation.

13.2.4 Geographically, the distribution of land and ocean begins to approach the present day configuration, with the Australia plate already detached from Antarctica and beginning its traverse across the Indian ocean to collide with Indonesia, a process happening at the present time in Timor-Wetlar and probably the cause of the Pliocene cordierite-bearing granites in Ambon.

13.3 THE INDIA - EURASIA COLLISION AND THE RIFTING & DEVELOPMENT OF CENOZOIC SEDIMENTARY BASINS IN BORNEO

13.3.1 Hutchison (1992b) has described the Paleogene land surface in SE Asia and its subsequent breakup commencing at about 45my BP and caused by the collision of the Indian and Eurasian plates. In Borneo Island, the breakup resulted in the formation of initially alluvial basins - Melawai, Barito (Tanjung Fm), Ketungau, Mandai. In a very few places (W Meratus and ? Banggi island,N Sabah) Paleocene limestone accumulated in shallow marine areas on the margins of the enlarged continent. Rift-connected Eocene explosive vulcanism and intrusion is known in the Lupar valley, the Bukit Mersing area (Arip volcanics) and andesitic and rhyolitic explosive vulcanicity (Nyaan Volcanics - Piyambung tuff) in Kalimantan.

13.3.2 Further N in central and N Sarawak, Brunei and SW Sabah, deposition commenced either with shallow marine limestones (e.g. at the base of the Nyalau Formation) or shallow marine (Kelabit & Temburong Formations grading into deep water turbidites of the Oligocene West Crocker Formation).

13.3.3 The South China block was still in existence (as the Penian High) and provided the source of the thick Oligocene sands (Nyalau Fm.) but the uplifted Rajang Group was more or less peneplaned allowing coal and other shallow water sedimentary deposits to be formed on an unconformity.

13.3.4 The reactivated West Baram Line - Jerudong Line-Morris fault provided the local tectonic framework for the development of the proto

Baram and Baram Delta basin during the late Oligocene - early Miocene.

13.3.5 Spreading in the South China Sea which commenced in the Oligocene terminated in late Miocene. The initiation of Middle Miocene rifting and spreading in the Sulu Sea as well as another Middle Miocene surge in the continued opening of the South China Sea had a major tectonic impact on depositional sequences throughout Borneo.

13.3.6 The collision of India with Eurasia provided the indentation - extrusion pattern so prominently shown in the geology of SE Asia today. Major fault patterns in SE Asia are attributed to the indentation-extrusion model (Fig 13.1) (Wood,1985). The collision had a profound effect on major structural margins and boundaries within Borneo Island - notably to modify the sutures marking the site of former subduction zones, so that the Lupar zone is now primarily a major fault marking the edge of the Ketungau basin - with vertical strata uptilted during or soon after deposition.Similarly, the Boyan Zone is largely fault restrained; N-dipping steep thrust faults have been recognised on seismic traverses across the Boyan zone. The Bukit Mersing Line is probably another major thrust fault which has brought chert and oceanic crust fragments to the surface, generating a mélange in the process.

13.3.7 The collision resulted in clockwise rotation of strike ridges in the Rajang - Embaluh Groups so that in western Borneo, the strike is WNW. The paleomagnetic reconstructions indicating anticlockwise rotation of Borneo since the Cretaceous cannot be reconciled.

13.3.8 Areas of very high gravity anomalies suggest oceanic crustal rocks lie close to the present day surface and in E Sabah (Darvel Bay)

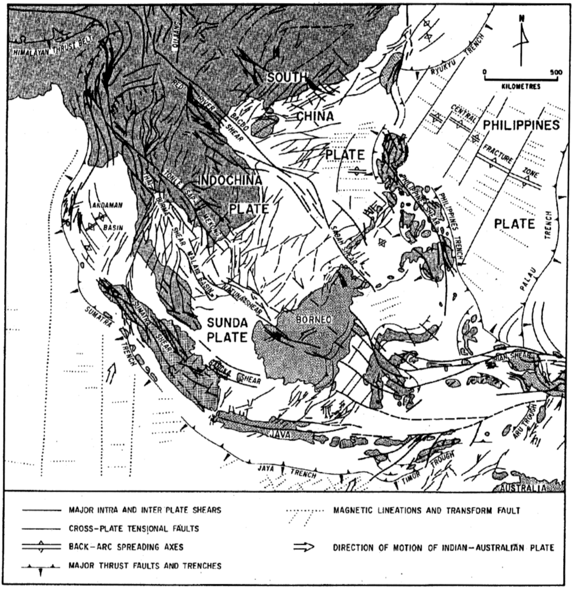

Fig 13.1 Major fault patterns in SE Asia. The predominant NW - SE shears are attributed to the indentation collision of India with Eurasia in the early Cenozoic. (from Wood, 1985)

and SE Kalimantan (Meratus), oceanic rocks created at depths of the order of 6 km are now exposed. Elsewhere, in the Kapuas Lakes in NW Kalimantan and lakes in the onshore part of the Mahakam delta (Kutei basin)in the E, the anomaly is the same order of magnitude and areal dimensions but oceanic rocks are not exposed. The mechanism whereby relatively small areas of oceanic crust of the order of 500 Km^2 are uplifted seems to be fault and thrust related but the structural mechanics are unknown . The onshore metamorphic rocks W of Darvel Bay have no roots and possibly lie on a thrust whereas in Darvel Bay, the thrust may lie much deeper. Upwelling of the asthenosphere could provide the necessary stresses to develop thrusting of the upper mantle and also the exceptional subsidence for the major basins Kutei and Baram to accumulate up to 16 km of sediment. The alleged fragment of oceanic crust lying within the major depocentre of the Kutei basin is a curious anomaly for which there is presently no feasible explanation.

13.3.9 The origins of sedimentary basins and subsequent basin inversion continue to be debated and many issues remain unresolved. The low-grade sericite-pyrite metamorphism seen in the Temburong Formation in Brunei seems to be due to loading possibly accompanied by slightly increased heat flow. Recently published studies on low-grade metamorphism (Roberts *et al.*, 1996) indicate that "metamorphism is essentially the result of heat flux associated with an extensional phase of basin evolution, i.e. pre-deformational". Basin inversion of Cenozoic sedimentary basins in Borneo and throughout SE Asia in general appears to have commenced at about 25Ma (Middle Miocene) during a period of extensional tectonics in the Sulu and South China Seas with compensatory compression elsewhere in SE Asia. Computer reconstructions of the East Natuna basin (Ginger *et al.*,1993) indicate that basin inversion can occur soon after basin fill is complete and that crustal shortening of about 19% can create a mountain chain several thousand metres high.

13.4 AN OVERALL STRUCTURAL FRAMEWORK FOR BORNEO ISLAND

13.4.1 The Anambas orocline and its counterpart in Borneo

13.4.1.1 The gross regional structural pattern of Sundaland exhibits a broad orocline of Permo-Triassic rocks in a wide,curvilinear belt extending from Thailand, Malaya and Sumatra to Billiton island. Van Bemmelen (1949,1970) labelled the curved parallel trendlines in Sundaland as the Anambas Mountain System comprising the Natuna, Anambas, Karimata, Tin belt and Karimundjawa zones (abbreviated to "Anambas orocline"). The age of the oroclinal deformation is presumed to be later than the orogeny which produced the structures within the zones (Hutchison,1993). The bending of the Anambas orocline is related possibly to the northwards progression of the Indian plate and subsequent collision with the Eurasian plate in the early Eocene. Such indentation would be expected to cause Borneo Island to be rotated *clockwise* and hence inconsistent with the observed *anticlockwise* rotation (derived mainly from paleomagnetic analysis of Cretaceous rocks).The "***Danau suture***" and its accretionary prism of Rajang Group sediments show a similar oroclinal bend to the broader Anambas zone and is aligned WNW in Sarawak, E-W in Kalimantan and NNW towards Natuna Island possibly becoming N-S towards the Con Som basin offshore the Mekong delta. Two belts of gravity highs offshore W Sarawak and NW Kalimantan follow similar curved trends and they appear to stop against an ENE-WSW linear feature about 30 km N of Natuna but the nature of the abrupt termination is unknown. The ENE-WSW linear feature may be an older,reactivated transcurrent fault.

13.4.2 Major tectonic lineaments in Borneo

13.4.2.1 A dominant NE to NNE structural grain is especially prevalent in NW Borneo and probably extends throught most of the western part of Borneo Island. NNE faults are the site of major gold deposits in central Kalimantan at Kelian and a recent discovery at Busang, 300 km NNW of Samarinda (Far East Economic Review,21st March,1996). In the Lian Cave area to the W of the Keningau valley, isolated reef limestones overlie basalts within the predominantly turbiditic sequences of the Oligocene West Crocker Formation (Abdul Mubin,1989). The reef appears to have formed as an atoll on top of an extinct volcano and its location along a major NNE-trending fault testifies to deep-seated tectonic activity. The fault was reactivated in the early Quaternary and together with a parallel fault further E, formed the intermontane Keningau valley. Other NNE-trending faults separating the extensive circular basins in central Sabah are also deep-seated, indicated by diorites intruded along their length. McManus & Tate (1976) suggested the NNE fault structures in NW Borneo replicated deep transcurrent faults aligned in the same direction as the Cretaceous transcurrent faults in the oceanic crust of the eastern part of the Indian Ocean plate (Veevers,1984). Many offshore oilfields in Brunei and NW Borneo show a preferred NE axial trend and seismic surveys fequently show flower structures which seem to converge at depth into a NE-trending fault lineament (Tate,1991b).

13.4.2.2 A WNW - ESE tectonic lineament is probably extant across Borneo from the Baram Line in the NW to the Mangkalihat Peninsula in the SE. The lineament probably marks the northeastern edge of one or more continental blocks at depth. Both the Luconia shaols and Mangkalihat have been stable for considerable periods in the early - mid Cenozoic and there is a recorded high heat flow in Luconia Province. The lineament also appears to delineate the northerly extent of antimony mineralisation as well as the locus of Middle Miocene tin-bearing granitoids in central Kalimantan. The Mersing Line and Balingian Shear Zone (Tate, *in press*) also show elements of a WNW direction. Offshore SW Sarawak, half graben are bounded by WNW faults.

13.4.2.3 In SE Borneo, the Adang fault is another major WNW-trending structure which has controlled sedimentation in the Kutei basin at least from the Oligocene and probably earlier (Fig 13.1). Wood (1985) links the Adang fault with the Lupar fault and Natuna Shear creating a major tectonic lineament across central Borneo. The rift-related early Cenozoic basins in central Kalimantan may also have been influenced by the Adang lineament although the trend of the basin margins is more equatorial.

13.5 WHAT LIES BENEATH BORNEO ISLAND?

13.5.1 Hamilton's (1979) premise of a lost continent in the region between Australia and SE Asia may yet be proved to be correct. The presence of tin in central Borneo and antimony mainly in Sarawak suggests there is a continental source beneath central Borneo. Isotopic analysis of Late Cretaceous sediments in SW Sulawesi and Sumba Island show that they do not match other rocks either in eastern Indonesia or northern Australia and suggest that fragments of Sundaland occur as far south as Sumba Island (Vroon *et al.*,1994).

13.5.2 There is increasing evidence to suggest parts of the Australian continent have collided with and been subducted beneath the southeastern extremity of Sundaland. Bergman *et al.*,(1996) report new field and laboratory evidence from western Sulawesi comprising new K-Ar, Ar^{40}-Ar^{39}, Rb-Sr and Nd-Sm isotopic data which suggest Cretaceous to Eocene crystallisation of granitoid intrusives and Oligocene-Miocene obduction. Other Rb-Sr, Nd-Sm and Upb isotope studies show parental source rocks of the Miocene granitoid melts were derived from the late Proterozoic-early Paleozoic crustal and mantle assemblages with signatures typical of rocks belonging to the Australian-New Guniea tectonic plate. Bergman *et al.*,(1996) have suggested a new model of Miocene continent-continent collision between Australia and Sundaland with Australian continental lithosphere subducted beneath southeast Sundaland. Fission track and isotope data constrain the magmatism, cooling and denudation history at 113Ma. The model envisages the Makassar Strait as a deep foreland basin bounded on both sides by converging Neogene thrust belts (see cross sections in Fig's 8.5 & 9.30). The new model is in contrast to earlier models suggesting Cenozoic oceanic spreading or continental rifting. However, thrusts along the W margin of Meratus (Fig 8.5) dip steeply to the east. There is no evidence of shallow westerly inclined thrusts advocated in the Bergman *et* *al.*,(1996) convergent thrust model and the relationship between SE Borneo and Sulawesi remains incompletely explained . The late Miocene magmatic arc in W Sulawesi is considered by Bergman *et al.*, (1996) also as a product of continent-continent collision in constrast to previously held views of normal ocean-continent or ocean-ocean subduction arcs.

13.5.3 The new geochemical data provide important evidence of Australian impingement into Sundaland. Similar isotope and radiometric age determinations would be worthwhile in Borneo, especially on all post-Mesozoic igneous rocks in order to clarify their genetic origin and give an indication of what lies beneath Borneo. The antimony-tin mineralisation suggests that a fragment of continental China-Indochina lies beneath Borneo, at least for central Sarawak and NW Kalimantan. Antimony, mercury,arsenic and tin are found in abundance in SW China; the Dachang deposits in Jiangsu Province (Fu *et al.*,1993) occuring as hydrothermal replacement of shallow water, stromatoporoid Devonian sediments with a Yenshanian granitoid at depth contains more reserves of tin than the whole of SE Asia . The tin-tungsten antimony-deposit at Gejiu (Kochiu) in Yunnan Province has produced already more tin than the total output from SE Asia (Peng & Cheng,1988). Clearly the South China Block is the world's largest tin-antimony province. The antimony-arsenic-mercury mineralisation in West and Central Sarawak as far north as the West Baram Line *is possibly remobilised from a rifted continental block derived from South China;* the high heat flows in Luconia Province indicate continental material at depth and the continental block continues eastward to the contiguous Rajang basin. Additional heat flux caused by collisional and thrust tectonics associated with the closure of the Danau Sea would remobilise relatively low temperature hydrothermal mineralisation contained within the rifted continental block.

13.5.4 Perhaps a fragment of the Australia-New Guniea plate has managed to penetrate into SE Borneo and lies below Meratus, if future studies show that the isotopic signatures of the Miocene or later igneous rocks correlate with the Australian signatures obtained from SW Sulawesi.

13.5.5 The geology of Borneo Island is now known with a fair degree of precision. Future research should be directed towards geochemical and isotope studies of post-Mesozoic igneous rocks as well as deep seismic surveys to indicate the deep crustal structure beneath Borneo. The causes of sedimentary basin formation and inversion may be then plausably explained.

13.5.6 It is appropriate to close this thesis as it began with a reference to William Hamilton who published in 1979 an extraordinary erudite, monumental account of the Indonesian Region explaining much of the geology of SE Asia including Borneo Island in plate tectonic terms, a relatively new Earth Theory at that time. Some of Hamilton's models have been subsequently criticised but nevertheless, his power of observation, deduction and foresight is an inspiration to all who work on the geology of the Region.