CHAPTER 5

5 CRETACEOUS VOLCANO-PLUTONIC ROCKS

5.1 SCHWANER MOUNTAINS

5.1.1 Introduction

5.1.1.1 Granitoid plutons and associated volcanics occupy an extensive area in the Schwaner Mountains in central and western Kalimantan and form the largest area of granitic rocks in Borneo. Their distribution is illustrated in Fig 5.1. Radiometric dating of rocks show that the ages fall into four groups (Williams *et al.*,1988). Those belonging to the I-type granites (Chappell & White,1974) form the bulk of the determinations between 130 and 100Ma (Lower Cretaceous). Potassic granites show a maximum at about 87Ma (mid-Upper Cretaceous) and occur in the SW. The Schwaner Mountains volcanics from a younger spread of ages between 65-75Ma. Lower Cretaceous granites intrude the Pre-Carboniferous Pinoh Metamorphics which appear as a series of rafts within the pluton.

5.1.2 Lower Cretaceous granitoids (Kl1)

5.1.2.1 The Laur and Sepauk granitoids of Lower Cretaceous age occur widely in the Pontianak-Nangataman, Nangapinoh (Pieters & Sanyoto,1989) and Tumbangmanjul quadrangles and the Alan granite of the same age in Long Pahangai (Fig 5.1). The Laur and Sepauk granitoids are closely associated and form the larger part of the Schwaner Batholith. Petrologically, the Laur is a monzonite and Sepauk a tonalite - granodiorite and K-Ar radiometric ages obtained from the Sepauk and Laur plutons are in the 130-95 Ma range. The granitoids are calc-alkaline and I-type in character and

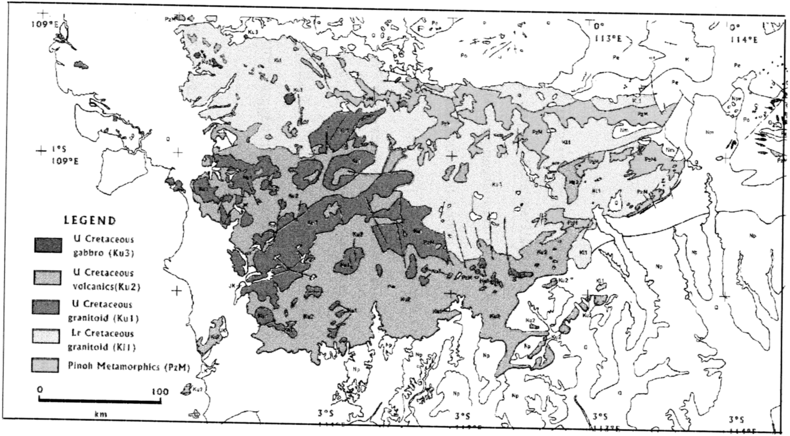

Fig 5.1 Distribution of Pinoh Metamorphics & Cretaceous granitoids & associated volcanics, Schwaner Mountains, C & W Kalimantan. (after Pieters & Supriatna, 1990)

emplaced at mid-crustal levels over an area of 600 km long and 180 km wide. They were formed from igneous material near the base of the crust during subduction in the Lower Cretaceous. The Alan granite intrudes altered volcanic rocks of unknown age and lies within disturbed zones. K-Ar radiometric ages range from 121-130 Ma but the genetic origin is unclear.

5.1.2.2 In NW Kalimantan, the Mensibau Granitoid (Kl2) Fig 5.2 occurs widely in W Sanggau and Singkawang and forms an extension to the large Schwaner Batholith. It varies in composition from hornblende-biotite granodiorite to tonalite. K-Ar dates range from 95-125Ma and geochemical analyses indicate a calc-alkaline, I-type composition (JICA,-1982, Suwarna *et al.*,1989). The Biwa Gabbro forms numerous stocks and plugs in Nangataman and Nangapinoh, the largest of which forms G. Biwa (0° $35'$S, 110°E). The Biwa Gabbro intrudes the Mensibau Granodiorite and also perhaps the Raya Volcanics. A K-Ar radiometric age of 87.9 Ma (Haile, *et al.*,1977) suggests the intrusions are Late Cretaceous.

5.1.2.3 The Lower Cretaceous Menyukung granite (Kl3) which occurs in two isolated small intrusive masses in the Kapuas Lakes District in Sintang quadrangle is an unusual alkali felspar granite, rich in K-felspar, accessory ilmenite and trace element tin. Anomalous tin values occur in streams draining the two main granite bodies suggest that the granite is a member of the S-type, ilmenite series (Chappell & White, 1974). The nearest tin-bearing granites lie almost 500 km to the E and are Miocene. One radiometric determination gives an age of 125Ma; the granite intrudes the Danau Mafic Complex.

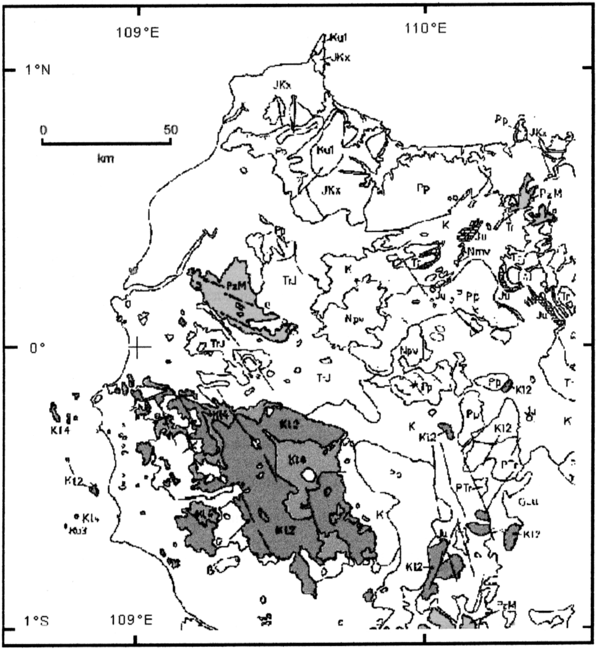

Fig 5.2 Distribution of Pinoh Metamorphics, Cretaceous granitoids & associated volcanic rocks, N.W.Kalimantan & W Sarawak. (after Tan, 1982 & Pieters & Supriatna,1990)

PzM Pinoh Metamorphics
Kl4 Upper Cretaceous Volcanics
Kl2 Upper Cretaceous granitoids

5.1.3 Lower Cretaceous volcanics (Kl2)

5.1.3.1 The Raya Volcanics form a suite of altered basalt-andesite-dacite intrusives and associated pyroclastic deposits occurring widely in Singkawang and extend E to Sanggau (Fig 5.2). A K-Ar radiometric date from a single sample yielded an age 106Ma, suggesting that the volcanics are probably Lower Cretaceous. Trace element analyses (Harahap, 1987) show that the Raya Volcanics have a typical island-arc association and are probably co-magmatic with the Mensibau Granodiorite (Suwarna *et al.*,1989). The Betung Volcanics in Sintang are dated on one pyroxene sample (98Ma) but field characteristics suggest similarities with the Upper Triassic Serian Volcanics.

5.1.4 Upper Cretaceous Volcanics (Ku2)

5.1.4.1 The Bunga basalt and Kerabai volcanics which were formerly considered as part of the "Matan Complex" in Ketapang comprise a wide variety of compositional and eruptive types ranging from andesite to basalt with dacite, trachy-andesite, rhyodacite and rhyolite and quartz keratophyre. Geochemically the basic varieties of the Bunga basalt are high K/Na, calc-alkaline basalts suggesting that the Bunga basalt formed in a mature, volcanic-arc setting. The rocks have yielded Upper Cretaceous radiometric ages. The age and 250-300km separation from the Lubok Antu - Kapuas melange suggests that they are more likely to be linked with Lubok Antu - Kapuas rather than the Boyan subduction zone. An arc-trench distance of 200-300 km is of the correct order, according to modern examples (Hutchison, 1975). Alternatively, perhaps the paired subduction lies to the SE in subduction zones of the Meratus area but the arc-trench separation is much greater.

5.1.4.2 The Kerabai Volcanics (Ku2) (Fig 5.1) are a suite of Upper Cretaceous volcanics and subvolcanics which crop out extensively in S Nangataman, SW Nangapinoh, Ketapang and Tumbangmanjul quadrangles. They consist of lava, lava breccia, pyroclastics, and shallow intrusive dykes and sills and stocks and are composed of andesite, dacite-granodiorite, monzonite and basalt-gabbro. Chemically, they plot in the same fields as the Sukadana Granite suite and are probably co-magmatic. Stratigraphic relationships indicate an age younger than the emplacement of the Sepauk Tonalite and Laur Granite although isotopic analyses indicate the granites are about 15 Ma older than the volcanics.

5.1.5 Upper Cretaceous granitoids (Ku1)

5.1.5.1 Upper Cretaceous granitoids and related volcanic rocks occur in the Schwaner Batholith in Pontianak - Nangataman, Nangapinoh and Ketapang and comprise the Sukadana Granite Suite and Kerabai Volcanics. The Sukadana granitoids are widely distributed in the southern part of the Schwaner Mountains and form igneous masses of batholithic dimensions and a distinct NE alignment as well as smaller plutons and stocks. Petrologically, they range from rare gabbros and diorites to abundant quartz monzonites, monzogranite and syenite to alkali-felspar granite and syenite. Chemically and mineralogically, the rocks are predominantly calc-alkaline with hornblende and ortho- pyroxene. Riebeckite was reported by van Bemmelen (1939) but De Keyser & Rustandi (1989) found arfvedsonite in one of their thin sections and suggested that van Bemmelen's riebeckite may also be arfvedsonite. In plotting all available analyses of the Sukadana Granite Suite, De Keyser & Rustandi conclude that although chemically the analyses fall narrowly within the alkali-calc series, mineralogically the rocks belong to the calc-alkali series as there is abundant common hornblende and orthopyroxene. Trace element analyses show no definite trends. The Sukadana granitoids are typical I-type, magnetite series granites and De Keyser & Rustandi (1989) suggest they may have formed by partial melting of a fractionated basic igneous source in the lower crust. Radiometric ages obtained mainly from K-Ar determinations supplemented by few U/Pb dates range mostly in the Upper Cretaceous.

5.2 WEST SARAWAK

5.2.1 Upper Cretaceous granitoids

5.2.1.1 A number of Upper Cretaceous granitoids forming relatively small, isolated intrusions occur in an arcuate belt 75-100 km wide from Tg. Datu on the border in the west to the Nieuwenhuis Mountains in the east. In Sarawak, they comprise the adamellite intrusions at Tg. Datu and Tinting Bedil, the granodiorites at Sebuyau (Lupar estuary) and Gading, near Lundu (Fig 5.3). Smaller bodies of gabbro are sometimes present. The Tinting Bedil intrusion contains hornblende and magnetite and is possibly an I-type granitoid. K-Ar radiometric ages range from 75-101Ma (Kirk, 1965). The Pueh intrusion straddles the border region in the NW; it intrudes the Serebang Formation with the development of a hornfels zone. The granite contains xenocrysts of cordierite (Fig 5.4 a,b) and garnet and bright red biotite

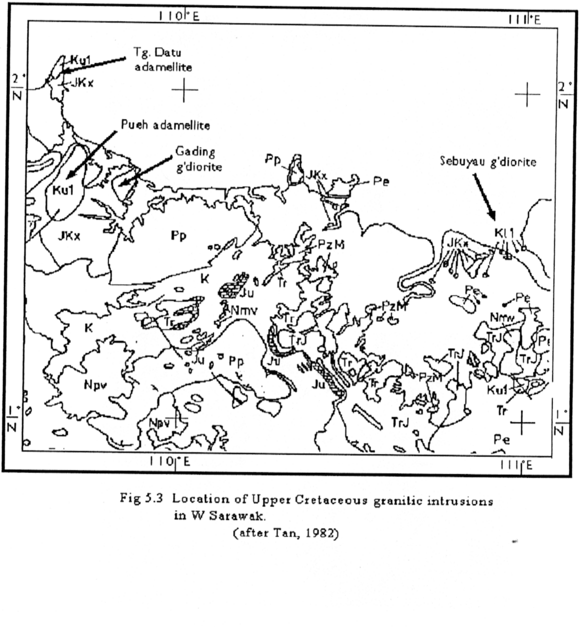

Fig 5.3 Location of Upper Cretaceous granitic intrusions in W Sarawak.
(after Tan, 1982)

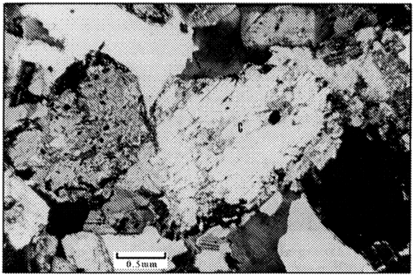

Fig 5.4a Large (2mm in length) almost hypidiomorphic cordierite crystal in coarse-grained adamellite. Pueh, W. Sararwak. (from Sophee Sulong, 1994)

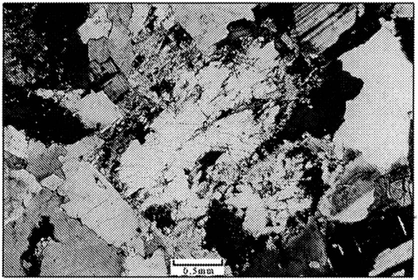

Fig 5.4 b Another sub-hypidiomorphic grain of cordierite rimmed by muscovite in coarse-grained adamellite. Pueh, W. Sararwak. (from Sophee Sulong, 1994)

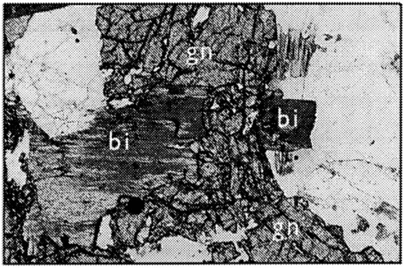

Fig 5.5a Euhedral red biotite and garnet intergrowth, Pueh adamellite, Pueh, W Sarawak.
(after Sophee Sulong, 1994)

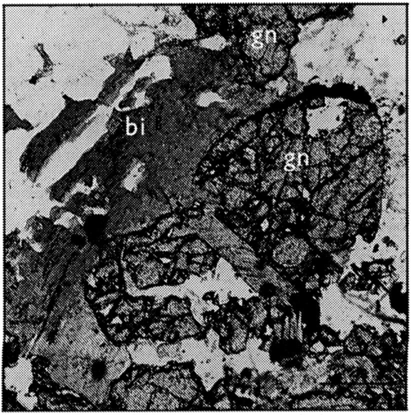

Fig 5.5b Red biotite and garnet intergrowth, Pueh adamellite, Pueh, W Sarawak.
(after Sophee Sulong, 1994)

intergrowths (Fig 5.5 a,b) and idiomorphic muscovite with accessory tourmaline (Sophee Sulong,1994). Kirk (1968) comments there is little variation in texture except for a porphyritic marginal facies on the SE margin. There are pegmatitic veins with tourmaline as well as leucogranite and aplite veins. The intrusion has plenty of sedimentary inclusions in various stages of digestion. Strong shearing affects the E margin where there is a fault contact with the Serebang Formation.

5.2.1.2 The Tg. Datu intrusion 25 km N of the Pueh pluton is composed of orthoclase up to 6mm, plagioclase sometimes zoned with interior of andesine An 28, microperthite and bright red biotite. Normative corundum is 3.9.

5.2.1.3 Two chemical analyses are available of the Pueh intrusion and a third of the Tg. Datu intrusion which is probably the same rock type (Kirk,1960) and another eight from the Pueh intrusion (Sophee Sulong,1994). Unfortunately the localities of the samples collected by Sophee Sulong are not recorded precisely and their position in relation to the contact with the Serebang country rocks is unknown. Both the Pueh and Tg. Datu adamellites are peraluminous with primary muscovite, biotite and normative corundum. They are both S-type granites in the classification of Chappel & White (1974).

5.2.1.4 The textures shown by cordierite in thin sections (Fig 5.4 a,b) show a roughly xenocrystic relationship with the other components of the adamellite , raising an important question of origin. The cordierite could come from three sources - in the restite minerals following crystallization from a S-type granite where melting of Al-rich sediments (pelitic and semi-pelitic materials) has occurred during the evolution of the granite from a continental source; contamination by granite magma intruding pelitic sediments and absorption of xenoliths during the upward rise of magma, or thirdly, Al-rich country rock xenoliths which have contaminated an otherwise normal I-type granite. For example, the cordierite granite in Ambon in the Moluccas, is thought to have been formed by melting at depth of the Australian continent which is being subducted below the Indonesian island arc system (Hutchison & Jezek,1978; Hutchison, 1989). The hypidiomorphic texture of the granite and presence of perthite suggests a depth of emplacement of the order of 10-12 km. The presence of numerous sedimentary inclusions in various stages of digestion suggests that the adamellite has been formed either by melting of continental crust containing pelitic sedimentary rocks or the intrusion has penetrated sediments on its upward trace. The samples containing cordierite appear to have been collected from the marginal zone of the pluton and therefore the presence of cordierite is subject to certain reservation that it has come from xenoliths of digested envelope. If, however, there are indeed numerous xenoliths throughout the pluton as perhaps Kirk (1968)implies, the origin could well be crustal anatexis of continental material. The xenocrystic nature of the few grains of cordierite of comparable size to other major minerals in the thin section would support melting and assimilation of pelitic country rock at depth.

5.2.1.5 A single K/Ar radiometric age obtained on biotite from the Pueh adamellite (monzogranite) gave 80.6 Ma (Upper Cretaceous)(Bladon, 1989).

5.2.1.6 Elsewhere in Kalimantan, small, late Cretaceous granitoid bodies appear to be related t o those in W Sarawak. The Era granite (75Ma) and the minute Pesinduk altered granodiorite occur in Kapuas and the Topai hornblende - biotite granite (76Ma) in the Long Nawan quadrangle (Baharuddin & Andimangga, 1989) in the NE. Williams, *et al.*,(1988) has noted that the small granitic bodies of late Cretaceous age form a discontinuous arcuate belt parallel to the regional trend of the melange belts. The rocks are generally biotite monzogranite or syenogranite and show no evidence of deformation. The convergent ages of all the intrusions and somewhat similar chemistry suggest they are all genetically related but the relationship is with the melange belts and granitoid batholiths further south remains unclear. Perhaps a trace element study would resolve the issue.

5.3 PRESENT-DAY CRUSTAL HEAT FLOW

5.3.1 Hutchison (1989) remarks on the present high heat flow of the SE Asian region and the preponderance of hot springs, particularly in the Sinoburmalaya part. Hot springs in west Borneo appear to be limited in extent or have not been recorded on the recently published preliminary geological maps as only two hot springs are shown, one in the Jagoi granite (109° 58'E, 1°17'N) and the other in northern Putussibau (113°20'E,00°57'N). In west Sarawak, eight hot springs are reported from seven areas between Serian and Lundu (Sulong Enjop,1990). Four are associated with faults adjacent to the

Serian volcanics, three are in Bau Limestone/Pedawan Formations and one at Lundu is close to the Pueh granodiorite intrusion. Those at Paku, ENE of Bau and Senah, 32km S. of Bau are thought to be associated with limestone and igneous rocks at depth (Wilford,1955, Wilford & Kho,1965). The waters are mostly calcium bicarbonate with a temperature range from 32-69°C. The geothermal gradient map (Rutherford and Qureshi,1981) has no data between Pontianak and Singapore. High heat flows (3° - 3.5°/100 ft) occur in the South China Sea, E of Natuna and in the Java Sea, S of Belitung Island; the Luconia Platform is moderate (2°-3°/100 ft) and the Barito Basin mostly low (1°-2°/100 ft). The apparent rarity of present day thermal activity, particularly in the largely granitic Schwaner Mountains, suggests that this part of Borneo may be geothermally cooler than the Sunda platform further west.

5.4 MERATUS MOUNTAINS

5.4.1 Lower Cretaceous volcanics

5.4.1.1 There appear to be no Lower Cretaceous volcanic rocks *sensu stricto* in the Meratus mountains area. Sikumbang (1986) describes the Pudak Formation belonging to the Alino Group as containing a chaotic assemblage of volcaniclastic deposits together with limestone blocks passing upwards into graded and stratified sequences of similar material with additionally radiolarian mudstones. No radiometric ages are avaiable for the volcanic components and there seems to be no source for the volcanic material visible at the present exposure level.

5.4.2 Upper Cretaceous volcanic rocks

5.4.2.1 Volcanic, volcanoclastic and sedimentary strata belonging to the Manunggul Group occur in a trough along the central axis of the Meratus Mountains. Quite extensive areas underlain by the Haruyan Member of the Pitap Formation (Kph) occur in the NW part of the Meratus Mountains, particularly the Amuntai,Bandjermasin and Sampanahan quad-rangles. Smaller outcrops occur in the Kotabaru quadrangle. [Note:Sikumbang,1986 refers to the Pitanak Volcanic Formation, a synonym for Haruyan Member]. The distribution of the Haruyan Member and Pitanak Formation is shown in fig 5.6. The Haruyan Member consists of lava flows of pyroxene basalt,amygdaloidal basalt and polymict breccia (?agglomerate). A K/Ar radiometric age of 72.6 Ma was obtained from a total rock sample from Amuntai and although the total rock is slightly altered, the value is regarded as a minimum age (Bladon *et al.*, 1989). The author suspects the ages of the Haruyan Member and Pitanak Formation may be older than published and the evidence is discussed in Chapter 6.

5.4.3 Upper Cretaceous granitoids

5.4.3.1 The distribution of Upper Cretaceous granitoids in SE Borneo is shown in Fig 5.6. The plutonic rocks at the southern end of the Meratus Mountains have been studied in detail by Sikumbang (1986) where they occur in two prominent NE-trending mountain ranges, the Tambak-Tamban Range in the NW and, separated by the Manunggul Basin, a smaller body, the Kintap granite in the middle of the Manjam Range facing the Java Sea. The Kintap Granite is an I-type, K-felspar biotite granite which intrudes both the Meratus ophiolites and the Lower Cretaceous Alino Group

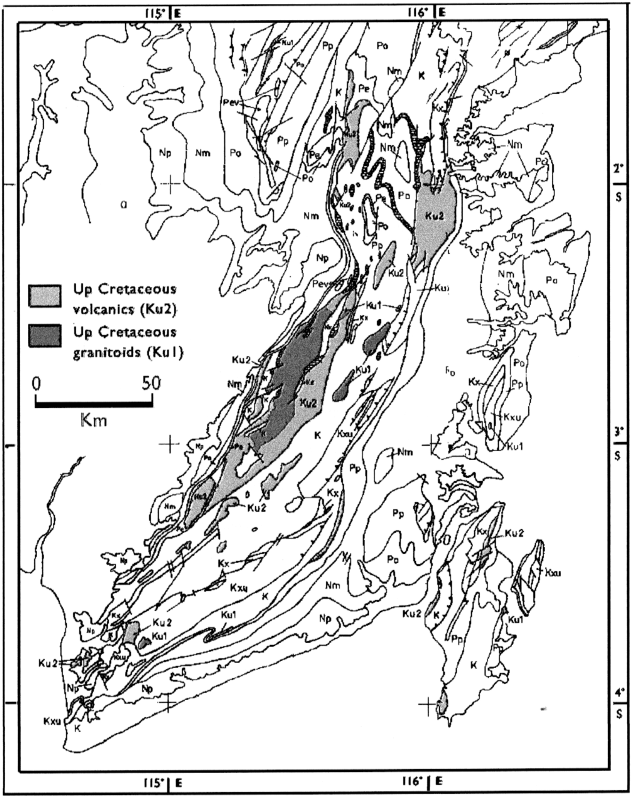

Fig 5.6 Distribution of Cretaceous granitoids & associated volcanics, Meratus Mountains area, SE Borneo

(after Sikumbang,1989 & various authors) volcano-clastic sediments and is dated radiometrically (whole rock K/Ar) at 95.3Ma. The Rimuh Plutonic Complex in the Tambak-Tamban Range comprises a gabbro-diorite-granodiorite-granite assemblage of uncertain origin which, in the opinion of Sikumbang (1986) may be an early batholith or leuco-melanocratic rocks derived from the Meratus ultrabasic rocks, presumably by sub-seafloor metamorphism. There are no radiometric determinations and the age of the Complex is assumed to be Upper Cretaceous because diorite intrudes Lower Cretaceous limestones and pebbles of diorite, granodiorite and granite as well as clasts of Pitanak Volcanics occur in the Upper Cretaceous Pamali breccias. The Rimuh Plutonic Complex is associated with and surrounded by the Pitanak Volcanic Formation which comprises amygdaloidal porphyritic plagioclase andesite lavas and volcanoclastics. Unfortunately there is no petrographical or geochemical data to link the Pitanak Volcanics with the Rimuh plutonic rocks and Sikumbang (1986) assumes a genetic connection from field relationships. The Rimuh pluton continues northeastwards for about 100km in a long,narrow pluton. On the Amuntai Sheet (1713), the granite is positioned in the Lower Cretaceous but on the adjacent Sampanahan Sheet (1813) it is classified as Upper Cretaceous.

5.4.3.2 In comparison with the Schwaner batholiths, the areal extent and hence volume of granitic rocks in the Meratus Mountains region is small, less than one fiftieth of the size. There is therefore some scepticism regarding the origin of the Meratus granites. The subduction hypothesis advocated by Sikumbang is questionable. There is no significant accretionary prism of comparable size to the Rajang Group and the paucity of quartz and other continental-derived materials excludes a continental collision. The strike-slip nature of the thrust sheets of ophiolite and the presumed steeply dipping nature of those thrusts has apparently obliterated any evidence of the origin of the ophiolites. Thus, Sikumbang's reconstructions in cross sections, (Sikumbang,1986, Fig 204) are untenable.

5.4.3.3 An alterative explanation is required; perhaps some if not all the granitic rocks in the Meratus Mountains area were formed by transpressional crustal melting; there is clearly evidence of strike-slip movement in the region. Transpressional tectonics coupled with relatively high heat flow could have resulted in limited melting of the lower crust to yield relatively small, long and narrow bodies associated with major shear zones. Examples of such granitoids occur in Normandy in NW France and the Donegal granite in Ireland. No geochemical or petrographic data area available to support transpressional melting and until such data become available, the matter remains inconclusive.

5.4.3.4 The Meratus Mountains has had repeated uplift and submergence; in the Late Cretaceous, the Cretaceous oceanic floor was uplifted to exposure with erosion and deposition of the Pamali breccia. An extensional phase during the Paleogene - early Miocene created the Barito-Pasir-Asem depocentres which were assumed to have been one connected basin (Van de Weerd & Armin,1993). Renewed uplift is alleged to have commenced in the Middle Miocene during a compressive phase probably as a result of the westward thrust of Sulawesi caused by the impingement of the Australian continent into the Banda Sea (Letouzey *et al.*,1990). Evidence of thrusting of Western Sulawesi towards SE Borneo is also indicated by Bergman *et al.*, (1996).