CRETACEOUS OROGENIC GRANITE BELTS, KALIMANTAN, INDONESIA

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ABSTRACT

Two types of Cretaceous Orogenic Granite-Belts are able to be recognized in Kalimantan, which tend to show characteristics of Cordilleran and Caledonian Granite-Types.

The Cordilleran Granite-Type consists of huge granitoid batholiths known as the Schwaner, Ketapang and Singkawang batholiths. This granite type comprises tonalite and granodiorite, and minor granite *sensu stricto*, predominantly owning calc-alkaline to slightly alkaline composition. The granitioids are also metaluminous and slightly peraluminous which probably due to the assimilation of magma stopping. Genetically, the granite is an I-type which was formed during a subduction of oceanic crust material beneath a continental margin. Those plutons were emplaced during a longer period, ranging from 86 to 129 m.a or from Early to Late Cretaceous.

The Caledonian Granite-Type comprises isolated smaller plutons of Pueh Granite, Manyukung Granite, Era Granite, Topai Granite, Nyaan Granite, Alan Granite, Kelai Granite and Sangkulirang Granite. This granite type consists of granite *sensu stricto* and granodiorite, having calc-alkaline and alkaline and also metaluminous and peraluminous compositions. They belong to I-type and S-type granites, suggesting that in the area, different magma sources had been generated. The I-type granite was derived from partial melting of igneous rock whereas the S-type one was derived from anatexis of sedimentary rocks of continental crust. These plutons were emplaced within a relatively short time, ranging from 74.9 to 80.6 m.a or Late Cretaceous.

Keywords: Cretaceous Orogenic Belts, Cordilleran and Caledonian Granite types.

SARI

Dua tipe Jalur Granit Orogen Kapur dapat diketahui di Kalimantan, yang cenderung memperlihatkan ciri-ciri tipe Granite Kordilera dan tipe Granite Kaledonia.

Jalur Granit Kordilera terdiri dari batolit granit berukuran sangat besar yang dikenal sebagai batolit Schwaner, Ketapang dan Singjkawang. Jenis granit ini terdiri dari tonalit, granodiorit dan sedikit granit (sensu stricto), kebanyakan berkomposisi calc-alkalin sampai agak alkalin. Batuan granit tersebut umumnya juga berkomposisi metaluminus dan sedikit peraluminus yang barangkali disebabkan oleh adanya proses asimilasi "magma stopping". Secara genesa granit ini bertipe I yang terbentuk pada saat penghunjaman suatu kerak samudera terhadap suatu tepi lempeng benua. Tubuh pluton tersebut telah ditempatkan dalam waktu nisbi atau relatif panjang yang berkisar dari 86 sampai 129 juta atau dari Kapur Awal sampai Kapur Akhir.

Jalur Granit Kaledonia terdiri dari tubuh-tubuh pluton terisolasi berukuran kecil yaitu : Granit Pueh, Granit Manyukung, Granit Era, Granit Topai, Granit Nyaan, Granit Alan, Granit Kelai dan Granit Sangkulirang. Jenis granit ini terdiri dari granit (sensu stricto) dan granodiorit, berkomposisi calk-alkalin dan alkalin dan juga metaluminus dan peraluminus. Batuan granit tersebut merupakan granit tipe I dan tipe S yang memberikan dugaan bahwa di wilayah ini terdapat sumber magma yang berbeda. Granit tipe I berasal dari peleburan batuan beku sedangkan tipe S berasal dari peleburan batuan sediment di kerak bumi. Tubuh intrusi tersebut telah ditempatkan dalam waktu yang lebih pendek berkisar dari 74,9 sampai 80,9 juta tahun yang lalu atau Kapur Akhir.

Kata Kunci : Jalur Orogenik Kapur, Tipe Granit Kaledonian dan Kordilera.

INTRODUCTION

This paper was presented in the 2nd International Symposium of the International Geoscience Programme (IGCP) Project 507 : *Paleoclimates of the Cretaceous In Asia and their global correlation* undertaken in August 20-21, 2007 in Seoul National University, South Korea. The aim of the programme is to gather paleoclimatic information and important clues to understand what caused changes in paleoclimate in Asia during Cretaceous including tectonic activity, relative sea-level change and igneous activity.

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The used geological and geophysical data in this paper are obtained from the Centre for Geological Survey's Data Base as result of the Indonesia Australia Geological Mapping Project (1983 - 1995) including paleomagnetism measurement in Kalimantan, mainly in the West and East Kalimantan. The project was a joint project between Geological Research and Development Centre (GRDC) of Indonesia (Geological Survey Institute) and Bureau Mineral Resources (BMR) of Australia (AGSO nowadays).

Alot of Cretaceous granitic plutons are exposed in Kalimantan, Indonesia. Those granitoid plutons could be separated into two groups. The first, in the south forms granite batholiths whereas the other, in the north forms an isolated granite- belt. On the basis of tectonic setting and characteristics of orogenic granitic rock of Pitcher (1982) on both granite pluton groups belong to Cordilleran orogenic granite-type and Caledonian orogenic granite-type respectively (Table 1).

The presence of both Cretaceous orogenic granite types and also volcanic rocks in the region confirms that magmatic and volcanic activities have been generated in the region, which were probably related to subduction and or collision between northern oceanic crust (Proto South China Sea) and southern continental crust during Early to Late Cretaceous. Related to that Cretaceous tectonic activities, a forearc basin has been formed as Proto- Tertiary Basins consisting of Proto Melawi-Ketungau Basins in the west, Proto Kutai Basin in the east and Proto Barito Basins in the southeast. These basins were filled by Cretaceous transgressive shallow to deep marine silisiclastic and carbonate sediments and regressive fluvio-deltaic sediments.

Paleomagnetism measurements have been done to reconstruct position of Kalimantan during Mesozoic and Tertiary and the result has been published (Sunata and Wahyono, 1987)

The main objective of this paper is to understand paleoposition and tectonic activity of Kalimantan during Cretaceous, including magmatic and sedimentation -activities occurred in the island.

OROGENIC GRANITIC TYPE

Pitcher, 1982 (*in* Eric, 1986) classified orogenic granitic rocks. Two of them consist of Cordilleran type and Caledonian type. The I-Cordilleran type is the most common group of granitic rocks which are generally emplaced into seismically active continental margins. They form huge, linear, composite batholiths in which their initial $^{87}Sr/^{86}Sr$ ratios are usually less than 0.706 and tend to contain porphyry Cu,Mo mineralization. The dominant rock is usually tonalite.

The I- (Caledonian) type of granitic rocks are considered to be emplaced at the time of uplifting and decompression which occurs after the closure of an ocean basin. The granite is characterized by and initial $^{87}Sr/^{86}Sr$ ratio between 0.705 and 0.709. The dominant rock types are in the range of granodiorite-granite, but these rocks are often associated with minor intrusive bodies of hornblende diorite, gabbro and ultramafic rocks of the Appinite-type. Furthermore, the other characteristics of these orogenic rocks are shown in Table 1.

Tabel 1. Orogenic Granitic Rocks (Pitcher, 1982)

Pacific type	Cordilleran type	Caledonian type	Himalayan type
Subduction beneath and oceanic island arc	Subduction of oceanic materials beneath a continental margin	Uplift and relaxation immediately after the closure of an ocean	Continent - continent collision
Small composite or zoned stocks	Huge composite batholiths	Discrete multiple intrusions	Large bodies of autochthonous granite, migmatites and local stocks
Essentially evolved from a mantle-derived magmas that usually belongs to either the island arc tholeite or calc-alkali series	Calc-alkali parental magmas, plus assimilation of continental crustal materials	Calc-alkali parental magmas plus anatexis of continental crustals materials	Large scale anatexis of continental crustal materials
Tonalites	Tonalite, granodiorite and granites	Granodiorite and granites	Leucogranites and granites
Plutonism is generally short-lived	Plutonism is episodic and extend over a long period	Plutonism is generally short-lived	Plutonisms of moderate duration

GEOLOGY

The generalized Cretaceous geology and tectonic setting of Kalimantan is presented in Figure 1.

The accretionary prism belt in the north is named as Sambas-Mangkaliat Accretionary Prism toe (Amiruddin,2000b). It comprises sedimentary rocks overlying oceanic crust, ophiolite, deformed to tectonic mélange and or broken formation. This belt was intruded by those isolated small granite plutons, distributed from the Sambas Quadrangle in the west (West Kalimantan) to the Muara Wahau in the east. More to the north of this prism is occupied by sedimentary gravity flow including turbiditic deposits of Embaluh Complex (Emmichoven (1939) or Embaluh Group (Pieters *et al*, 1993a) which is Cretaceous-Eocene in age.

Another accretionary prism toe is also present in the south east, which in this paper is named Meratus Accretionary Prism-Toe. The prism is composed of mafic - ultramafics, granite, deep sea sediments and mélange, which are intruded by some isolated Cretaceous granitoid plutons, distributed from the south to the north along the western part of the Meratus Ridge. The granitoid plutons mainly consist of Batang Alai Granite and Hajawa Granite.

The isolated granite plutons intruding the Sambas - Mangkaliat Accretionary Prism Toe, in the north comprise Pueh Granite, Manyukung Granite, Era Granite, Topai Granite, Nyaan Granite, Alan Granite, Kelai Granite and Sangkulirang Granite.

The huge granite batholiths in south west consist of Schawaner Batholith, and Ketapang Batholith whereas in the northwest is Singkawang Batholith (Amiruddin, 2000) These granite batholiths intruded basement of Permocarbon regional metamorphic rocks, forming dynamo-thermal metamorphic rocks.

The Cretaceous basins in this paper were initially named by proto the name of Tertiary basins, due to their superimposed positions.

The proto- Ketungau and Melawi, Madi and West Kutai Basins were filled by Cretaceous shallow to deep marine sediments of Selangkai (Heryanto, 1993, Pieters *et al*., 1993) and Pedawan Formations in the lower part and fluvio-deltaic deposit of Kayan Sandstone in the upper part (Supriatna *et al*.1993). Orbitulina Limestone are also present in places.

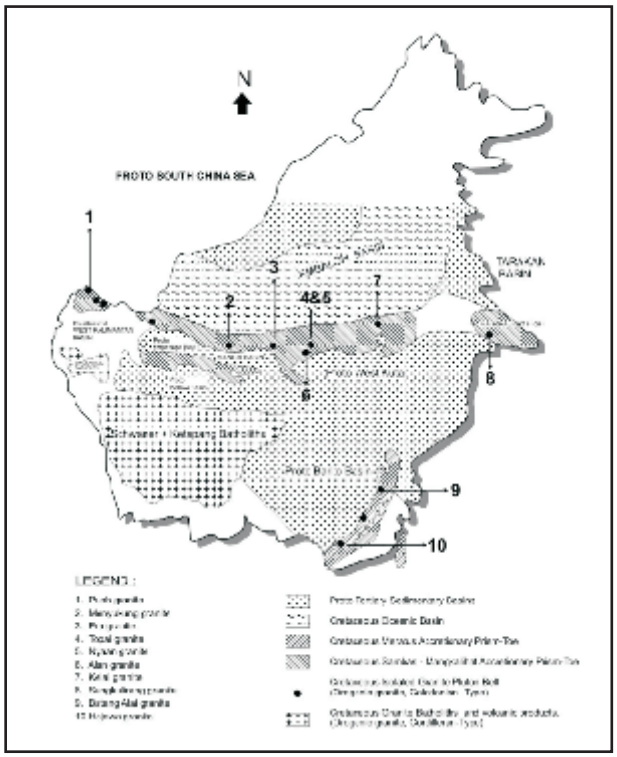

Figure 1. Cretaceous Tectonic Setting of Kalimantan (After Amiruddin, 2000b)

The Proto Barito Basin was probably filled by Cretaceous Carbonate deposit of the Batununggal Formation, Sub marine volcano deposits of Haruyan Formation and sub marine fan sediment of Pitap Formation (Heryanto, 2000a,b).

PALEOMAGNETISM

Sunata and Wahyono (1987) and Wahyono and Sunata (1987) reconstructed hypothetically the development of paleogeography of Kalimantan during Mesozoic to Tertiary on the basis of paleomagnetic measurement data, as shown in Figure 2 and from the reconstruction we enhance an approximate position of the Cretaceous of Kalimantan as presented in Figure 3.

The position of Kalimantan in Early Triassic was to the north Equator on latitude of 18.77 N, however, during Late Triassic it moved to the south of equator in 10.7 S. In Jurassic time, it moved to the north closer to the equator with the length of island was northwest-southeastward; after that since Early Cretaceous to Eocene the position of Kalimantan was still in equator, but the length of island was east-west direction. In Oligocene to Miocene, the island has been anticlockwise rotated about 45˚, resembling to the present day position.

Hall (1997) reconstructed Cenozoic Tectonics of SE Asia and Australasia, in which at 50 Ma or end Early Eocene, the Indian Plate moved northward and subducted into South East Eurasia Plate forming a subduction zone parallel to Sumatera, Java and Kalimantan. The Kalimantan to the north is bordered by Proto South China Sea which is underlain by a oceanic crust (Figure 4).

Panggabean *et al*, 2007 modified Paleogeography of Indonesia during Cretaceous - Early Tertiary. They reconstructed the position of Kalimantan was in equator region, whereas Sumatera is also near equator with its position was almost parallel to the equator line shown in Figure 5.

Katili (1989) modified lineament of Cretaceous subduction zones in Kalimantan. The subduction zone was in Southeast Kalimantan through Meratus and Pulau Laut ophiolites and they were blocked by Paternoster Fault in the north. The Subduction belt continue to Northwest ward through Kembayan and Natuna ophiolite.

CALEDONIAN OROGENIC GRANITIC ROCKS OF KALIMANTAN

Sambas - Mangkaliat Isolated Granite Belt

This orogenic granite type forms an isolated pluton - chain, extending from Sambas (West Kalimantan) in the west up to Mangkaliat region (East Kalimantan) in the east. It comprises Pueh Granite, Manyukung Granite, Era Granite, Topai Granite, Nyaan Granite, Alan Granite, Kelai Granite, and Sangkulirang Granite (Amiruddin, 2000b).

The granite plutons commonly are felsic and comprise granite (*sensu stricto*), granodiorite and minor adamelite. These plutons are mostly calc-alkaline and minor alkaline and also metaluminous to peraluminous in composition. This calc-alkalic and metaluminous composition is consistent to the presence of Ca-plagioclase, biotite and hornblende in the rocks. The alkaline and peraluminous composition is consistent to the presence of quartz, albite, K- feldspar, biotite and garnet which are more aluminous than biotite. The characteristics of those granitoids are summarized in Table 2 and Figures 6 and 7.

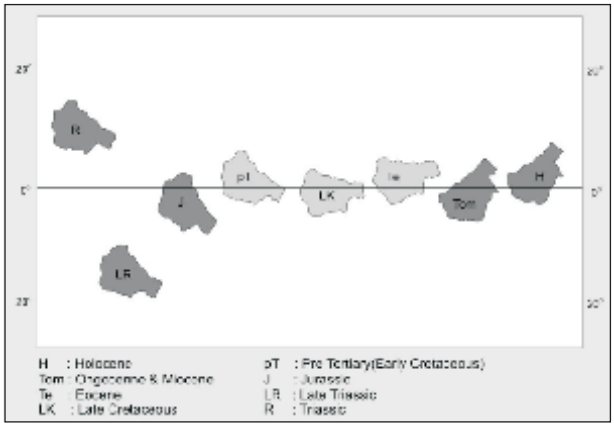

Figure 2. Hypothetical Paleolatitude of Kalimantan during Mesozoic to present day (From Sunata and Wahyono, 1987).

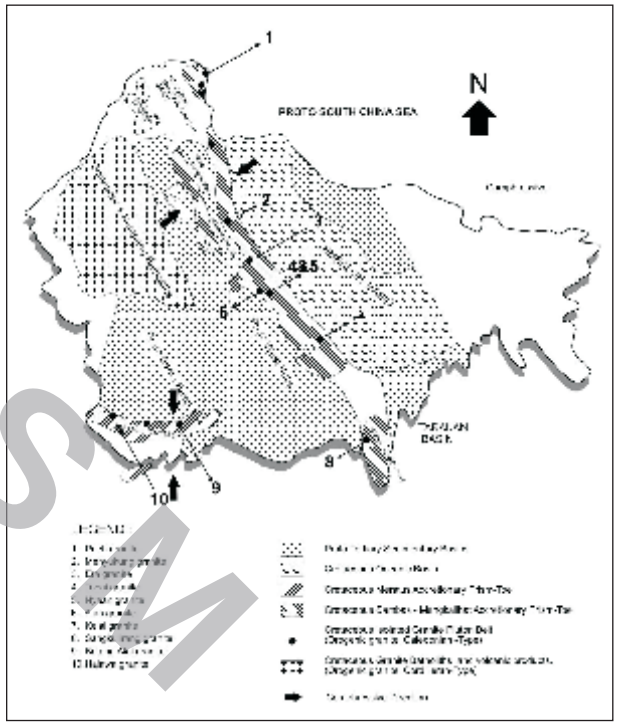

Figure 3. Approximate position and geology of Kalimantan during Cretaceous.

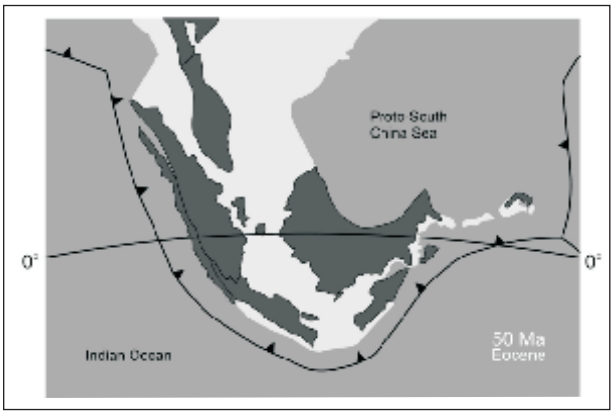

Figure 4. Eocene (50 m.a.) tectonic setting of South Asia (from Hall, 1997).

Those geochemical and mineralogical properties indicate that those granite plutons are mostly I-type granite and minor S-type (Amiruddin, 2000b). They form a belt consisting of multiple discrete intrusions which are distributed from West to East Kalimantan.

These granites were relatively emplaced in short time span live during Late Upper Cretaceous, at least from 74.9 m.a to 80.6 m.a. The presence of the I and S - types reflect different parental magmas. The I-type was derived from partial melting of calc-alkaline igneous rock in the lower crust or upper mantle, whereas the S-type resulted from partial melting of a sedimentary rocks source in a continental crust, probably generated during late Upper Cretaceous collision activity.

Meratus Isolated Granite Belt

Another orogenic granite belt is generated along western part of Meratus Mountains in the south east Kalimantan. It consists of isolated granite–plutons of Batang Alai Granite and Hajawa Granite. These granite plutons intruded Meratus accretionary prism belt composed of mafic - ultramafics, granite, deep sea sediments and mélange.

The Batang Alai Granite mostly comprises granite (*sensu.stricto*), tonalite, thronjemite and granodiorite and minor more mafic rocks such as diorite and gabbro. These are consistent to felsic to intermediate

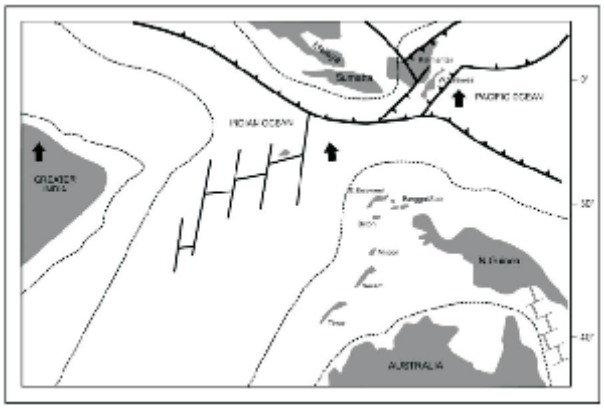

Figure 5. Paleolatitude of Kalimantan and Sumatera during Cretaceous to Early Tertiary (Panggabean *et al*, 2007).

and more mafic compositions. The felsics are alkaline to calc-alkaline. The intermediate is metaluminous to more metaluminous and more calcic. The age of this granite is 101,00 ± 2.6 m.a. to 118,61 ± 1.45 m.a. or Albian (near border between Lower to Upper Cretaceous).

The Hajawa Granite consists of diorite, diorite quartz, tonalite and granite sensu stricto. The rocks are calc-alkaline to alkaline, metaluminous except granite (sensu stricto) is peraluminous. The age of this granite is 70.962 ± 0.49 m.a. to 87.148 ± 1.81 m.a or Upper Cretaceous. These granite plutons mostly show characteristics of I-type granite although S-type granite is also present (Dirk and Amiruddin, 2000).

Table 2. Characteristics of The Caledonian Orogenic Granite Types In Kalimantan (Amiruddin and Andi Mangga, 1999; Amiruddin, 2000b; Dirk dan Amiruddin, 2000)

Plutons	Rock Type	Acidity	Alkalinity	Alumina saturated	K-Ar Dating m.a.
Singkawang	**Mangkaliat Belt**				
Pueh Granite	adamellite, granite, monzogranite	intermediate	calcalkaline	slightly peraluminous	80 ± 0.6
Menyukung Granite	granite, granodiorite	felsic-intermediate	alkaline-calcalkaline	peraluminous-metaluminous	–
Era Granite	granite, granodiorite	felsic-intermediate	alkaline-calcalkaline	slightly peraluminous-metaluminous	74.9 ± 2 to 78.6 ± 0.8
Topai Granite	granite, granodiorite	felsic-intermediate	alkaline-calcalkaline	peraluminous-metaluminous	75.9 ± 0.9 to 77.5 ± 0.3
Nyaan Merah Granite	granite	felsic	alkaline	peraluminous	–
Alan Granite	granite, granodiorite	felsic-intermediate	?alkaline-calcalkaline	?peraluminous-metaluminous	–
Kelai Granite	granite	felsic	?calcalkaline	metaluminous	–
Meratus	**Belt**				
Batang Alai Granite	granite (s.s), tonalite, and granodiorite diorite and gabbro	felsic-intermediate to more mafic	alkali-calcalkaline and more calcic	metaluminous to more metaluminous	101.00 ± 2.6 to 118.61 ± 1.45
Hajawa Granite	diorite, diorite kuarsa, tonalite and granite sensu	intermediate-felsic	calcalkaline-alkaline	metaluminous to peraluminous	70.962 ± 0.49 to 87.148 ± 1.81

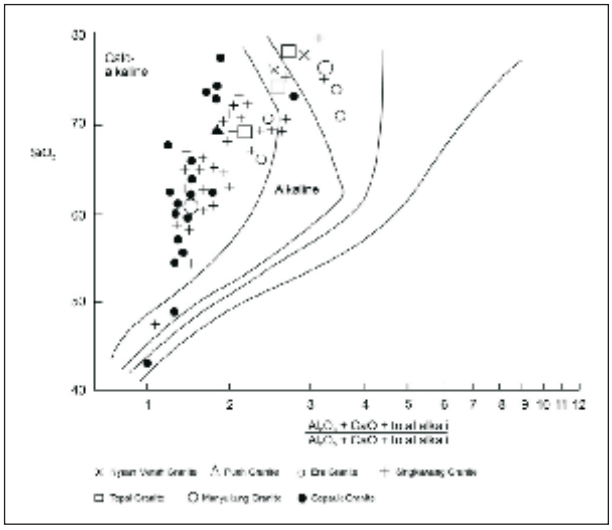

Figure 6. Analyses of rock samples of the isolated granite and granite batholiths plotted on the Alkalinity ratio variation diagram (After Amiruddin, 2000b).

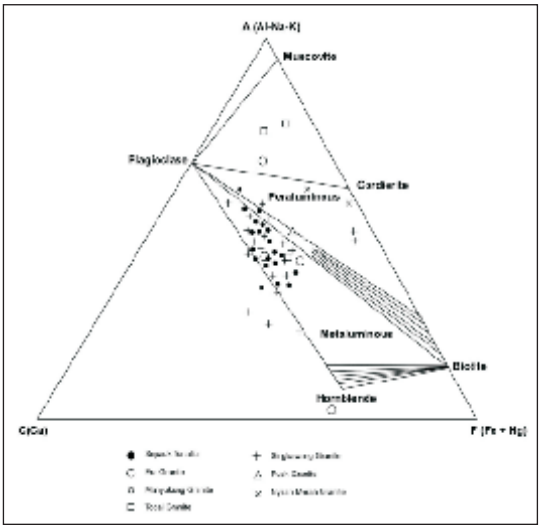

Figure 7. ACF plot diagram for granite plutons and batholiths inWest to East Kalimantan (After Amiruddin, 2000b).

Cordilleran Orogenic Granite-Type

This orogenic granite-type is represented by Schwaner, Ketapang and Singkawang batholiths (Amiruddin 2000c).

The Schwaner batolith comprises Sepauk Tonalite and Laur Granite. The Sepauk Tonalite is dominantly composed of tonalite, granodiorite and minor granite (*sensu stricto*). The granitoids of the Sepauk Tonalite are mostly intermediate and minor felsic, and they are mostly calc-alkaline and minor alkaline. The rocks are also metaluminous to weakly peraluminous. This compositions are supported by mineralogy content comprising ca-plagioclase, biotite and more mafic minerals e.g. hornblende and or pyroxene. No more aluminous minerals than biotite.

The Laur Granite consists of monzogranite, granodiorite and syenogranite; rare tonalite, quartz diorite and diorite. Those rocks contain perthitic microcline and/or orthoclase, plagioclase (An_{10-30}), quartz, and biotite and/or hornblende; accessory minerals are iron oxide, sphene, apatite, zircon and tourmaline.

The Singkawang batholith is to northwest of the Schwaner batholith, consisting of Mount Sebiawak Granodiorite, Mount Raya Granite, Mount Selantar Granodiorite and Tiang quartz-diorite. Those granitoid rocks mainly comprise tonalite, quartz diorite, granodiorite and granite containing quartz, plagioclase, hornblende and more mafic minerals in various proportion. Geochemically, those rocks are mostly intermediate to felsic, although some mafic rocks are also present such as quartz bearing gabbro. They are metaluminous and calc-alkaline. This composition is consistent to their mineralogy contents.

The Ketapang batholith is to southwest of the Schwaner batholith. It is composed of Sukadana Granite, and Sangiyang Granite. The Sukadana Granite mainly comprise monzogranite, syenogranite and alkali-feldspar granite; minor granodiorite, tonalite, quartz diorite and diorite. Those rocks are generally leucocratic with 90-100% felsic minerals, composed of plagioclase (An_{10-50}), K-feldspar (orthoclase, minor microcline) and quartz. Minor mafics: hornblende, biotite and rare pyroxene, some alkali-feldspar granites contain riebeckite and arfvedsonite. Geochemically, the rocks are felsic to intermediate, mostly metaluminous, less commonly peraluminous, tend to be alkali-calcic, minor peralkaline. The Sukadana Granite belongs to I-type granite, however, in places A-type granite are probably also present with evidence of those alkalic amphiboles content and the peralkaline rock composition. Tectonically, the I-type granite suite is commonly Volcanic Arc Granite which is related to the subduction activity, whereas the A-type Granite is probably related to extensional tectonics or post subduction intrusives. The age of the Sukadana Granite is Late Cretaceous on the basis of K-Ar, Rb-Sr, and U-Pb dating (Amiruddin, 2000c).

The field relationship between granite bodies to the adjacent rocks indicates that these granite batholiths in West Kalimantan represent contact aureole granite. This relationship indicates these granites were emplaced distally from source rocks. It is equivalent to mesozone granite expressing approximate depth of emplacement about 7 - 16 km. This is also consistent with the Oxidation Coefficient reflecting deep environment of emplacement. This granite is characterized by a normally discordant contact between country rocks and intrusive bodies.

PROTO TERTIARY BASINS

In this paper, the proto Tertiary basins are probably divided into proto Melawi-Ketungau Basin, proto Barito Basin and proto West Kutai Basin. The three basins are probably related each other.

Proto Melawi-Ketungau Basin

The proto Melawi Ketungau Basin was filled by Cretaceous continental shelf and slope deposits of Pedawan Formation (Supriatna *et al*., 1993) which is the equivalent to shallow - deep marine Selangkai Formation (William and Heryanto, 1986) and Kayan Sandstone (Muller, 1968 in Supriatna *et al.*, 1993).

The Pedawan Formation in Sanggau sheet is composed of sandstone, siltstone, mudstone, shale, locally slaty shale, some limestone and tuff, commonly calcareous, locally carbonaceous and tuffaceous. The limestone : beds up 3 m thick, associated with calcareous sandstone and mudstone, locally pyritic, fossiliferous. The fossil content comprises ammonites, belemnites, pelecypods, orbitolinids, worm tubes and plants. The thickness over 2000 m . Zeijlman van Emmichoven, 1939 (in Supriatna *et al*., 1993)also recorded fossils from oolitic limestone found in Pade River and comprise radiolaria, corals, *Pholadomia* sp. and *Reineckia anceps*. From a marly sandy shale contains rich fauna of pelecypods: *Pecten* sp, *Ostrea* sp., cf. *Cardium* and *Astarte borneensis* Vogel and from a marly clay-shale : *Mytilus* sp., *Astarte borneensis* Vogel and *Exelissa septemcostata* Vogel.

The Selangkai Formation (William and Heryanto, 1986) in Sintang sheet is composed of calcareous, intercalated sandstone, minor limestone, pebbly mudstone; commonly severely deformed. Fossil content from 11 samples of sandstone and mudstone comprise *Lenticulina* sp, *Nodosaria* sp., *Eponides diversus*, *Heterohelix globulosa*, *Globigerinelloides aspera, Globotruncana linneiana, Rotalipora* sp. cf., *R.green hornensis, Heterohelix striata, Saracenaria* sp., indicating the rocks are a Turonian age. Seven samples of limestones contain *Orbitolina scutum* indicating a Cenomanian age. Two samples contain Cretaceous radiolarian.

The Kayan Sandstone is composed of fluvio-deltaic deposits of quartz-feldspar and quartz-lithic sandstone, pebbly siltstone, shale and conglomerate intercalations; minor coal, silisified and pyritized wood. Late Cretaceous to early Tertiary Pollen is also present in Sarawak (Muller, 1968 in Supriatna *et al*, 1993).

The Paniungan Formation consists of calcareous shally mudstone intercalated by thin sandstone, deposited in outer shelf. It contains Molusca: *Cylindrites* sp. (Sikumbang, 1986 in Heryanto, 2000) recorded Lower Cretaceous spore (Palynomorph) content in this formation comprising *Cicatricosisporites, Coronatispora, Klukisporites, Leptolepidites, Verrucosisporites, Cyanthidites, Classopolli, and Eucommidites*. These spores were usually derived from tropical or equator region (DR. Polhaupessy, *pers. communication* 2007).

The Batununggal Limestone comprises upper-Early Cretaceous Orbitolina limestone, bioclastic limestone and calcarenite deposited in continental shelf. It is probably similar to this of orbitolina limestone of the Selangkai Formation deposited in proto Melawi-Ketungau Basin.

The Pitap Group consists of Continental slope deposit of Pudak Formation and submarine fan sediment of Keramaian Formation. Those sediments contain resedimented fragments from Paniungan Formation. and Batununggal Limestone, which were probably product of sedimentary gravity flow including turbiditic mechanisms. The age of the Pudak Formation may be Late Cretaceous. However. Robinson *et al*, 1996 (in Heryanto 2000) recorded microflora and nanopanktons comprising *Fasciculitus aubertae, Sphenolithus anrrhapus, Hornibrookina australis and Photosphaera plana* indicating *Discoaster multira diatus Zone* which is Late Paleocene age.

Proto Kutai Basin

The proto Kutai Basin was filled by Cretaceous Selangkai Group which is continuation of this in proto Melawi basin in the west. This unit is composed of mudstone, sandstone, siltstone; minor conglomerate,

limestone; rare coal; commonly calcareous and carbonaceous. Fossils found in this formation comprise large foramniferas: *Orbitolina scutum* which indicates a Cretaceous (possibly Cenomanian) age. Other fossils consist of indeteterminate benthonic foraminifera, miliolids and fragments of coral, algae, pelecypods and echinoids. The fossils are shallow marine fauna (Pieters *et al*., 1993a).

Cretaceous Tectonic Development

Pieters *et al*. (1993a) and Amiruddin (2000b) considered that during Early Cretaceous, the ophiolite and associated oceanic sedimentary rocks (Kapuas and Danau Mafic Complexes) in West - East Kalimantan were deformed into an accretionary wedge during southward subduction on the Northeastern Plate (proto South China Sea) beneath a continent (Sunda Land) in the south , forming highly deformed ophiolite and oceanic rocks as tectonic mélange and broken formation which were developed from Sambas in the west to Mangkaliat in the East . The subduction was followed by the formation of a large continental - margin magmatic arc which are exposed as Schwaner, Ketapang and Singkawang Batholiths and also volcanic rocks (Figure 8 A).

During the Late Cretaceous, the Northeastern Plate continuously moving southwards caused part of the continental crust (proto South China Sea) of the Northeastern Plate collided with continental crust of the Southern Continental Plate (Figure 8B). This collision gave rise to an uplifting of the accretionary prism and also anatexis (partial melting of continental crust and mantle producing granitic magma. After the decrease of these compressive and uplifting forces, they were followed by the release of stress, forming extensional ruptures which were the ways for emplacement of granitic magma.

This scenario above could explain how the formation of the orogenic granite belt developing in Meratus Complex. In this case, during Lower Cretaceous, the oceanic crust of Indian Plate move to the north and subducted into the Southeast marginal Eurasia Plate forming a subduction zone which is a highly deformed terrain and mixing zone of oceanic and continental rocks forming mélange and or broken formation in the region (Figure 9A). This subduction was also followed by magmatic and volcanic arc activities increasing formation of various plutons of Schwaner and Ketapang batholiths, associated with extrusive rocks. During Aptian to Upper Cretaceous the Indian Plate move continuously northward causing a collision between Eurasia and India continental Plates producing an accretionary prism followed by partial melting of continental and oceanic rocks. This partial melting or anatexis generates more basic or more calcic granite rock, intruded as isolated plutons in the west of Meratus Complex (Figure 9B).

DISCUSSION AND CONCLUSION

On the basis of paleomagnetic data, during Cretaceous, the hypothetical paleo latitude of Kalimantan have been in equator region with tropical condition. This position is also confirmed by the presence of Lower Cretaceous-tropical spora (Palynomorph) in the Paniungan Formation, comprising *Cicatricosisporites, Coronatispora, Klukisporites, Leptolepidites, Verrucosisporites, Cyanthidites, Classopolli, and Eucommidites*. The presence of Orbitolina Limestone and bioclastic limestone in those proto-Tertiary basins indicate that the carbonate rock was deposited in warm and clean environment which is usually occurred in tropical regions.

Two Cretaceous orogenic granite belts can be recognized in Kalimantan, namely as Caledonian Type-Orogenic Granite and Cordilleran Type-Orogenic Granite.

The Caledonian type occupy subduction and or collision complex, generated in Sambas-Mangkaliat Complex in the north and also in Meratus Complex in the southeast. This granite type occupying Sambas-Mangkaliat complex is commonly felsic and comprises granite (*sensu stricto*) and granodiorite. These plutons are calc-alkali to alkaline and metaluminous to peraluminous in composition. They form a belt consisting of multiple discrete intrusions. Genetically it is a I-type granite. These granites were generally emplaced in short time span live during Late Cretaceous time, at least from 74.9 m.a. to 80.6 m.a. Whereas, this orogenic type occupying Meratus Complex is felsic-intermediate to more mafic. It is dominantly calc-alkaline to more calcic although alkalic-calcic are also present. It is consistent to mataluminous and more metaluminous composition although peraluminous composition is also present. This orogenic type was emplaced during Albian (near border Lower and Upper Cretaceous) to Maastrichtian or Upper Cretaceous. The rocks belong to I-type granite.

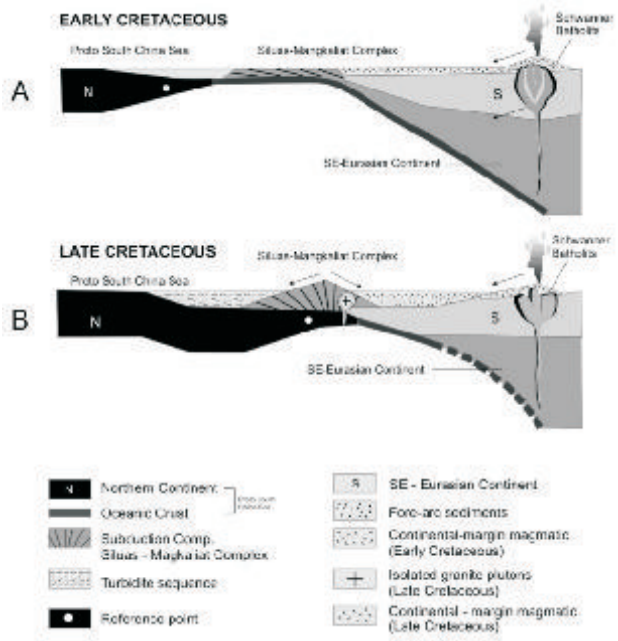

Figure 8. Compressive tectonic activities during Early (A) and Late (B) Cretaceous related to formation of granite orogenic belts and fore arc basin of the proto Melawi - Ketungau and proto Kutai Basins in the northern part Kalimantan (Pieters *et al*, 1993a and Amiruddin, 2000b).

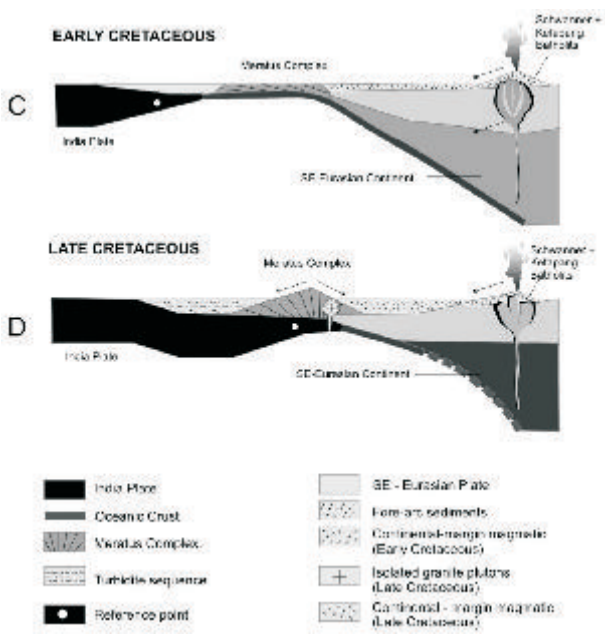

Figure 9. Compressive tectonic activities during Early (A) and Late (B) Cretaceous related to formation of orogenic granite belt and fore arc basin of proto Barito Basin in the southeastern Kalimantan (this paper)

The Cordilleran type consists of huge batholiths comprising Schwaner, Ketapang and Singkawang batholiths and occupy the southwestern part of Kalimantan. The Schwaner and Singkawang batholiths are dominantly composed of intermediate rocks such as tonalite, quartz diorite and granodiorite and minor granite (sensu stricto) with mostly calc alkali composition. It is consistent to metaluminous composition. It is a I-type granite.

The Ketapang batholith is slightly different in composition. It is composed of monzogranite, syenogranite and alkali-feldspar granite; minor granodiorite, tonalite, quartz diorite and diorite. Those rocks are generally leucocratic, mostly alkali-calcic composition and minor peralkaline although calcalkali composition is also present. The alumina saturation of rocks indicate that the rocks are metaluminous and minor peraluminous.

The granite plutons are mostly I-type, however, the presence of some alkali-feldspar granites contain riebeckite and arfvedsonite indicate the A-type granite is also present in this batholith.

The presence of double subduction belts and double magmatic belts in Kalimantan suggest that the formation of those tectonic elements are related to compressive activities occurring in two directions. The first, Northeast - South west plate movement and the second in the north-south directions. These tectonic activities produce the Caledonian Orogenic Granite Belt along Sambas-Mangkaliat belt and along Meratus Mountain (Subduction or Collision zones) and more distal forming Cordilleran orogenic granite occupying magmatic and volcanic arc of Schwaner, Ketapang and Singkawang batholiths.

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