PROCEEDINGS, INDONESIAN PETROLEUM ASSOCIATION
Thirty-Ninth AnnualConvention & Exhibition, May 2015

THE MESOZOIC TECTONIC SETTING OF SE SUNDALAND BASED ON METAMORPHIC EVOLUTION

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ABSTRACT

Based on metamorphic evolution, tectonic setting of the Southeast Sundaland is marked by two tectonic sutures, which are partitioned by Paternoster micro-continent. The first is Jurassic accretionary remnant located to the west of the micro-continent and represents the existence of the Meratus Suture. The metamorphic belt extends offshore beneath the Java sea and extends northward to the Mangkalihat Peninsula or to western part of Central Sulawesi. Part of the Jurassic high-pressure belt had been overprinted toward medium pressure even thermal metamorphism during further geologic events toward the Cretaceous Barrovian even Buchan type metamorphisms. It was triggered by elevating heat flow as respon to the crustal thickening due to collision of the Paternoster against Sundaland in the early Cretaceous and subsequent Cretaceous calc alkaline magmatism.

The second is Cretaceous accretionary complex, located to the east of the micro-continent. It extends from Karangsambung in Java, Bantimala-Latimojong-Pompangeo in Sulawesi and surrounds eastern part of Paternoster Platform and West Sulawesi Continent. This subduction belt was a curve high-pressure metamorphic belt in Southeast Sundaland. High and ultra-high pressure metamorphic rocks of The BantimalaMelange Complex and The Luk Ulo Melange Complex together with their ophiolite are cropped out since early Late Cretaceous and Early Paleogene Periods respectively.

During Cretaceous Time, high temperature low pressure metamorphism occurred in The Meratus Mangkalihat Belt, on the contrary high pressure low temperature metamorphism was happened in the Karangsambung-Bantimala-Pompangeo Belt. Both metamorphic belts represent the Cretaceous paired metamorphic belts in Southeastern Sundaland which have been cropped out since early Late Cretaceous.

Keywords: Sundaland; Suture; High Pressure Low Temperature, High Temperature Low Pressure Metamorphism; Paternoster Platform; Paired Metamorphic Belts.

PRE-TERTIARY GEOLOGY OF SE SUNDALAND

Pre-Tertiary geology of Southeast Sundaland is tightly connected to subduction of Meso-Tethys oceanic crust beneath southeast Eurasia continental plate. Sundaland is the continental core in SE Eurasia, including peninsular Malaysia, Thailand, SW Borneo, Sumatra and Java and is a composite region of fragments that rifted from Gondwanaand drifted northward in different times, and then accreted to the Eurasian continent during the Late Palaeozoic to Cenozoic. They were responsible for continental growth along southern and southeastern margin of Sundaland (Katili, 1972; Audley Charles et al., 1976; Metcalfe, 1996; Wakita, 1996; Hall, 2009).

The oldest rocks of the Sundaland are the Upper Paleozoic -Early Mesozoic metamorphic basements in central and west Kalimantan (Supriatna et al., 1993; Rusmana&Pieters, 1993; Heryanto et al., 1993; Pieters et al., 1993 ; Abidin et al., 1993; Sanyoto&Pieters, 1993; Amiruddin& Trail, 1993; Supriatna et al., 1995; Margono et al., 1995), Upper Paleozoic and Triassic granitic and metamorphic rocks in Bangka-Belitung Islands (Katili, 1972; Hamilton, 1979; Katili& Hartono, 1983; Hall, 2009). The Early-Late Mesozoic granite, volcanics in Western Kalimantan, Southern Sumatra and western part of Java Sea illustrate magmatic activity during the time. In the same time, the Sundaland was surrounded by the accretionary complexes of various

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ages (Katili, 1972; Hamilton, 1979; Wakita, 1996, Parkinson et al, 1998). Those tectonic events had been demonstrated sophistically by serial of metamorphic evolution in this region. High temperature metamorphism occur in the surrounding magmatism while high-ultra high pressure occur in the subduction zone. Both types of metamorphism may present juxtaposing in certain region, in the relative similar time span, which is called paired metamorphic belts.

Paired Metamorphic Belts

Paired metamorphic belt was firstly introduced by Miyashiro, (1961). It refers to contrast different baric factor controlling metamorphisms that are bordered by median line of abrupt fault contacts or un-metamorphosed rocks between the two contrasting belts. His idea was inspired by spatial distribution and relationship between metamorphic belt of andalusite-sillimanite type or low-pressure intermediate group and metamorphic belt of jadeite-glaucophane type with high-pressure intermediate group that are located side-by side and of similar age in Japan.

The occurrence of paired metamorphic belts generally represents subduction and magmatism evidents, either active continental margin or island arc setting which occur limitedly during Phanerozoic Eon (Miyashiro, 1973; Winkler, 1974; Brown, 2009;2010). To tribute the Miyashiro's work and contribution to the tectonic development based on metamorphic petrology, Brown, (2009; 2010) reveals his idea to extend the Miyashiro's original concept of "paired metamorphic belt" from the simple pairing of subductions along circum-Pacific accretionary orogens to be pairing of subduction to collision orogenic system. He puts a wider view of this concept to the continental amalgamation during earth history which is designated by former subduction followed by collision convergene in the end of the continental crust formation.

This paper will concern on geo-thermobarometry properties, U-Pb SHRIMP zircon results and physical and spatial distribution of the metamorphic rocks over SE Sundaland.The purpose of this paper is to clarify the occurrences of tectonic units in Southeast Sundaland using metamorphism approach and correlate spatially those units to reconstruct its tectonic setting.One by one tectonic unit will be correlated according to its similarities and different. They might compose significance tectonic settings of Sundaland during Mesozoic Era especially during Cretaceous Period. Contributions based on metamorphic evolution wish to furnish the available Southeast Sundaland tectonic setting.

METHODS

This work is based on fieldwork done on 2009-2012 in some accretionary complexes in SE Sundaland: West and South Kalimantan; Central Java; South Sulawesi. Data collected from this work had been processed and analyzed in some Laboratories, such as in the GeoLab, Centre for Geological Survey of Indonesia, Bandung; in the XRF and EPMA laboratory, University of Kiel, Germany and in Acme Analytical Laboratories (Vancouver) Ltd, Canada, in Zircon geochronology SHRIMP II at Centre of Isotopic Research of VSEGEI in Saint Petersburg, Russia.

MESOZOIC TECTONIC SETTING OF SE SUNDALAND BASED ON METAMORPHISM

Metamorphic Evolution and Tectonic Events

Discussing of metamorphic evolution of SE Sundaland tectonic setting is closely related to the occurrence of paired metamorphic belts in this region from time to time.Occurrence of Mesozoic paired metamorphic belts in Indonesia was initially stated by Miyashiro (1961). East Sulawesi Ophiolite together with glaucophanitic schist was assumed as the Mesozoic outer arc/belt and the western parallel belt of granitic together with biotite schist located to the west of Median Tectonic Line was the inner arc/belt of the paired in western Central Sulawesi. His interpretation is nowadays argued because the latest data sets compiled from the regions have shown different facts. The Pompangeo Schist Complex which represents high-pressure metamorphism in eastern part of the Central Sulawesi has Aptian isotopic ages (Parkinson et al, 1998) while low-pressure high-temperature metamorphic rocks in western Central Sulawesi occurred in a range of 15 – 3 Ma (Parkinson et al, 1998; Sukamto, J.D. Obradovich in Hamilton, 1979). The latest metamorphism is contemporaneous with Miocene and Pleistocene magmatic activities (Priadi et al., 1994; Bergman et al., 1996; Polve et al., 1997, 2001). Other metamorphic complexes of western Central Sulawesi consist of the Malinoquartzo-feldspatic mica schists and gneisses of Early Carboniferous ages; the Palu biotite schists and gneisses, amphibolite, amphiboliticschists and gneisses.They contain granulite, eclogite and peridotitic slices along the Palu-Koro fault zone of Permo-Triassic ages and the Karossa metapelite of uncertain age (van Leeuwen and Muhardjo, 2005).

Based on those data, the assumsion that central Sulawesi was pair Cretaceous metamorphic belt is remaining uncertainty. The paired metamorphic belts as contrasting baric type belts: High and low, pressure types, distributed side by side of contemporaneous belts may not be exist in Central Sulawesi but some other localities in Southeast Sundaland region may specify its present in the region.

High-pressure metamorphism followed by emplacement of ophiolite indicating outer arc/belt might occur in many places in southeast Sundaland. In Java, high-pressure rock together with dismembered ophiolite are found in the Luk Ulo Melange Complex which may spread-over Bayat area east of Yogyakarta and distributed over Cileteuh in western Java. In Sulawesi, Cretaceous high-very high-pressure metamorphic complexes are present not only in the BantimalaMelange Complex but also in the Latimojong mountain, Pompangeo Schist Complex and Mekongga Complex (Sukamto, 1986; Parkinson et al., 1998; Miyazaki et al., 1996; Bergman et al., 1996; Soesilo, 1998).

On the other hands, Cretaceous granite outcrops are found onshore and offshore along southeast Sundaland margin(Figure1B). Along offshore north of western Java sea basin, oil well drilling found Cretaceous granite-diorite of 106 – 64 Ma to the west and 88 Ma to the east of Java Sea while granite of 94 -58 Ma are found in deep onshore well in northwest Java basin (Hamilton, 1979). In Southeast Kalimantan, Dirk and Amiruddin, (2000) report various granites are found and designate certain affinities. Permo-carbonifereous syn-collisional granites are found in Lumo area of northwestern Meratus Range while to the east, the nearby Jurassic plagiogranite are cropped out in Purui Dalam, east of Buntok. Huge Cretaceous Volcanic Arc granite, diorite and gabbro are found in the centre of the Meratus Range as well as in Pulau Laut Island. Indication of high temperature metamorphism contemporaneously correlated with Cretaceous magmatic activities in Southeast Sundalandis only indicated onshore in Meratus Range of southeast Kalimantan.

Palaeogeographic position of Kalimantan and Sulawesi before Makassar Strait rifting (Situmorang, 1982; Guntoro, 1998) designates the Cretaceous high-pressure BantimalaMelange Complex was sticked along southern margin of Southeast Sundaland and between both complexes is reliable to be arc trench gap distance. The Paternoster platform located between the Meratus and the BantimalaMelange Complexes borders both metamorphic belts.

a. Jurassic HP metamorphic belts

Two localities indicating Jurassic high-pressure metamorphism are detected in Southeast Sundaland margin. Blueschist outcrops of 180-165 Ma are found in southern Meratus Range in South Kalimantan (Wakita et al., 1998) while the other assumed high-pressure metamorphic terrane is in eastern Sabah, Northeastern Kalimantan, presents as blocks and boulders of glaucophane-talc schist, eclogite, garnet-kyanite schist, corundum-pyrope amphibolite and garnet pyroxenite within Miocene boulder beds (Parkinson et al., 1998)(Figure 1A). These outcrops has been assumed as paired with high temperature metamorphic unit of Pinoh Formation and Cretaceous Kuayan Volcanic Formation in Schwahner Mountain(Figure 3A).

In the Meratus complex, part of the Jurassic high pressure low temperature metamorphic rocks had been overprinted toward medium pressure and temperature metamorphism during further geological event (Figure 2). It was triggered by elevating heat flow due to the crustal thickening and Cretaceous calc alkaline magmatism in this complex. The later geologic events initiated part of the Jurassic HP metamorphic rocks modified toward the Barrovian even Buchan type metamorphisms in The Meratus Complex during Cretaceous Time (Figure 3C).

b. The Paternoster vs Sundaland collision.

Finding of high grade metamorphic rock e.g. garnet amphibolite (Rustandi et al, 1995) in the Meratus Complex might be significance for tectonic setting of this region. Soesilo, 2012 reports detail analysis of high-grade rocks from Kusan area, eastern slope of Meratus that shows existance of high pressure garnet granulite; garnet amphibolite; amphibolite. Mineral assemblage of Garnet granulite are K feldspar + garnet + clinopyroxene + hornblende ± plagioclase ± rutile ± ilmenite ± zoisite. The free ortho pyroxene bearing assemblage does not fix either granulite or eclogite facies assemblage (IUGS-SSMR Smulikowski et al., 2003) because of lack orthopyroxene for the granulite but contains plagioclase which does not belong to eclogite. It is fit to transitional pressure zone between eclogite and granulite facies of high-pressure influences during high grade metamorphism (Pattison, 2003).

Occurrence of granulite facies might indicate some different tectonic settings: (1) crustal –thickening processes driven by converging plate movement, (2) large intrusion in the base of the continental crust, (3) magma loading in higher crustal level, (4) extensional tectonic setting (Appel et al., 1998). Soesilo, 2012 reports that pressure of about 9.55 up to 12 kbar and temperature of 765° - 900°C had been attained during peak metamorphism of the garnet granulite and they show clockwise P-T loop from indicating eclogiticprotolith. The U-Pb SHRIMP of its zircon yield 136.8 ± 3.6 million(Figure 2). This phenomenon encourages interpretationof crustal thickening during generation of the granulite.

Field data show outcrop of garnet granulite adjacent to peridotite. Monnier et al., (1999) indicates that Meratus peridotites represent a fragment of subcontinental / suboceanic lithosphere. They characterizes transitional plate as product of continental rifting. The overriding Radiolarian bearing sediments above the ultramafic indicates that it is older than middle Jurassic (Wakita et al., 1998).While Yuwono et al., 1988 assume that the ultramafic as obducted slice of the crust above Alino Formation. The obduction produced infra-ophiolitic metamorphic sole.

All these data tend to designate collision occurred in the Meratus Complex. Transitional plate in the passive margin had been pushed by collision of the Paternoster micro-continent and had been obducted over southeastern Sundaland margin since Early Cretaceous Time. Oceanic-continental converging plate movement of active continental margin had modified to be continent-continent collision, which generated crustal thickening and sutures(Figure 3C).

c. Cretaceous HPLT metamorphic belt

Cretaceous high-pressure rocks in Southeast Sundaland are widespread in many localities. They are cropped out in Karangsambung area, Central Java, in Bantimala and Latimojong Mountain South Sulawesi, in Pompangeo Mountain Central Sulawesi and in Mekongga-Rumbia Southeast Sulawesi. In southwestern Central Java dismembered ophiolite together with high-pressure metamorphic rocks are cropped out at Karangsambung area, about 30 km north of Kebumen District and is known as the LukUloMelange Complex. Tourmaline blueschist, epidote blueschist, epidote eclogite, amphibole epidote eclogite, lawsonite eclogite, jadeite-glaucophane quartz rock together with quartz-phengite-garnet schist/gneiss, phyllite and amphibolite constitute this complex (Soesilo, 2012). Their metabasite inherites tholeiite and shoshonitic basalt protolith of Enriched type MORB and Oceanic Island Basalt while their metapelite/psammite derived from clay and greywacke protolith. Pressure up to 27.21 kbar and temperature up to 628°C under a thermal gradient of 5.6 - 6.1°C.km-1 had influenced metabasite. On the other hands, the metapelite and metapsammite were adapted with pressure of 14.85-21.1 kbar and temperature of 382°-435°C under geothermal gradient of 5.3°-6.9°C/km and prevailed 56.4-80.2 km depth. Clockwise P-T paths have been displayed by metapelite/psammite and metabasite which wasdesignated similar prograde and retrograde trails(Figure 2). K-Ar and U-Pb SHRIMP zircon age dating of the LukUlo high-pressure rocks yield 125 – 101 Ma or Barremian up to Albian ages.

In South Sulawesi Early Cretaceous high-very high-pressure metamorphic rocks present together with ultramafic rocks in the Bantimala Melange Complex. They are constituted by amphibole eclogite, epidote amphibole eclogite, epidote eclogites; lawsonite eclogite, zoisite blueschist, tourmaline blueschist, lawsonite blueschist, epidote blueschists, phyllitic blueschist, greenschist, phyllitic greenschist, piemontite phyllite and graphite phyllite (Soesilo, 2012). Eclogite out crops are generally located to the west, which toward east is continuously followed by lower pressure facies of blueschist and greenschist. Pressure up to 30.62 kbar and temperature 670°C had influenced Bantimala's eclogite (Figure 2). During metamorphismeclogite suffered geothermal gradient of ~ 6.5° – 7.4ºC/km and prevailed depth of 83.5 - 104 km. Protolith of eclogite and blueschist indicate E type MORB, oceanic Island Basalt and Calc Alkaline island arc rocks. The mixing protolith support an interpretation of overriding island arc and oceanic crust protolithhad been subducted within this complex. Based on zircon SHRIMP geochronology the generation of mid oceanic ridge protolith was 296 ± 2 Ma whilethesubduction metamorphism represented convergent orogen during 137 – 106 Ma with P-T paths indicate Fransiscan loops. To the north of Bantimala region, in Latimojong Mountain, high-pressure metamorphism was also formed. They are represented by glaucophane-lawsonite schist, crossite-epidote metabasite (Gisolf, 1917; Parkinson et al., 1998) of calc alkaline protolith of blueschist (Soesilo, 1998). Muscovite of Latimojong mica schist yields K-Ar ages of 128, 123 and 114 Ma (Bergman et al., 1996).

Distribution of Cretaceous high-pressure metamorphic rocks extends over Central Sulawesi. In the Pompangeo Mountain, Central Sulawesi Cretaceous high-pressure rocks are found and it is known as the Pompangeo Schist Complex. Parkinson et al., (1998) reported that it is predominantly represented by shallow marine, continental origin of phyllitic marble, calcareous phyllite, graphitic schist, quartzite and metaconglomeraterocks which were influenced by temperature up to 450°C and pressure 10 – 12 kbar. The high-pressure rocks are associated with subcontinental lithospheric mantle rocks which accomplished peak metamorphism under 22 and 28 kbar and temperature at 1030 – 1100 °C. They consist of garnet peridotite and garnet-clinopyroxene granulite of Cretaceous time (Kadarusman& Parkinson, 2000).

d. Cretaceous HTLP metamorphic belt

In the Meratus Complex, south Kalimantan, two among three terranes located in the complex indicate thermal influence predominating metamorphism during Cretaceous time. It is represented by high temperature metamorphic rocks and hornfels cropped out in the Batangalai region, to the north of the complex and high-pressure granulite found in the Kusan region, to the east of central Meratus. High temperature low pressure metamorphism had occurred in the Meratus Complex during Cretaceous Period. Soesilo, 2012 reports that they were controlled by geothermal gradient of 33°-46° C/km which produced temperature up to 535°C due to magmatic arc environment. Such thermal regime had had been suffered by the mica quartz schist/gneiss located to the north of the complex. High heat-flow emanated by Cretaceous calc alkaline granite, diorite and leucogabbro of the Batangalai intrusions changed geothermal gradient to be 78°-88°C/km and elevated temperature up to 640°C and pressure below 4 kbar which lead to be aureole zone of Potassium feldspar-cordierite hornfels subfacies formation(Figure 2). U-Pb zircon age of the metapelite and leucogabbro are 118.3 ± 2.6 Ma and 115 ± 2 Ma respectively (Soesilo, 2012; 2014). The U-Pb dating is consistent with previous K-Ar age dating of the magmatic rocks which range 131 – 71 Ma (Sikumbang and Heryanto, 1994; Yuwono et al., 1988; Wakita et al., 1998).

The granulite terrane located to the centre of the complex which is located among Manjam and Sampanahan ophiolites consists of amphibolite; garnet amphibolite; granulite and garnet granulites. Soesilo, 2012 reports that mineral assemblage of the granulite and Grt granulite indicate high-pressure granulite which represents transitional zone between normal granulite (Coutinho et al,2003; SCMR nomenclature) and eclogite. Temperature achieved up to 900°C and pressure of 9.55 – 12 kbar with geothermal gradient between 19.4 – 23.6 °C/km(Figure 2). Its clockwise P-T-t loop designates crustal thickening process thatwas interpretedly driven by collision of Paternoster micro continent with southeast Sundaland margin. Subduction metamorphism that produced blueschist had ceased just the collision started and slowly exchanged high-pressure metamorphism with relatively higher temperature caused by continental crust thickening since 136.8 ± 3.6 Ma(Figures 1A & 3B-C).Furthermore,since late Early Cretaceous Epoch this region had been controlled by high temperature metamorphism because of increasing heat-flow by magmatic emanation.

Cretaceous acidic magmatic activities are also recorded from offshore along Java Sea and onshore deep drill holes in North West Java basin. The magmatic activities may be followed by contemporaneous high temperature metamorphism to surrounding wall-rocks but current collecting data from Java Sea and north western Java basin drill cores have not sufficiently affirmed the status of metamorphic regime.

e. Cretaceous paired metamorphic belts

Cretaceous high-very high-pressure metamorphic rocks together with dismembered or in-complete ophiolite occurs in the LukUloMelange Complex; the BantimalaMelange Complex; the Latimojong Mountain; Pompangeo Schist Complex and Mekongga-Rumbia Mountain. They may represent outer arc/belt of Cretaceous high-pressure belt, which is extend relatively East-West, concave southernward by the time, before counter-clockwise rotation of Southeast Sundaland with little latitude change, since late Mesozoic and before the late Miocene (Hamilton, 1979; Fuller et al., 1991 in Hall, 1996).

Otherwise, Cretaceous high temperature low-pressure metamorphism simultaneously had been carried out in the Meratus Range whilst high heat flow had originated from Cretaceous calc alkaline intrusions. The subsequent high temperature low pressure metamorphism in the Meratus Complex had overprinted previous high-pressure metamorphic rocks during Jurassic Period. During this Period Meratus represents as inner arc/belt of the paired metamorphic belts in Southeast Sundaland margin(Figure 3C-D). Prior to its generation, the collision between Paternoster micro-continent and Southeast Sundaland margin took places and caused crustal thickening in the Meratus Complex in early Valangian Stage.

Mesozoic Tectonic Setting of Southeast Sundaland

Jurassic subduction that produced blueschist in the Meratus Complex remains controversy for the geology of main land of Sundaland. Geologic record collected from Schwaner Mountain or surrounding region indicates the no existence of Jurassic high temperature metamorphic rocks. The only indication has been drawn by Amiruddin and Trail (1993) about the occurrence of the Pinoh metamorphic unit in the Schwaner Mountain which contains andalusite, cordierite, biotite, and occasionally garnet and sillimanite. These assemblages represent high temperature influenced metamorphism. Unfortunately, no isotopic ages collected from this metamorphic rocks but they put this suite in Carboniferous – Triassic ages. The only indication come from volcanogenic formation, which is close to the Jurassic age ofKuayan Formation which is located to the south of TumbangManjul and Tewah and to the north of Pangkalanbuun and Sampit. It consists of breccia of andesite and basalt; lava, tuffaceous sandstone and tuff (Margono et al., 1995; Sumartadipura and Margono,1996; Hermanto et al., 1994; Nila et al., 1995). The lithology illustrates the existence of the calc alkaline volcanic product.

Although rather imprecise, the calc alkaline volcanic products of Kuayan Formation and high temperature indicating Pinoh Metamorphic Unit in the Schwaner Region might paired with penecontemporaneous Jurassic high pressure metamorphic rocks of the Meratus Complex. Those contrasting characters may represent Brown's (2009; 2010) wider view of paired metamorphic belts of Jurassic Period. Indeed it is needed to get radiometric ages of Pinoh metamorphic rocks to ensure that it will contributes to Jurassic geology of the Sundaland.

Soesilo, 2012 reports, the Meratus' metamorphic rock geochemical data present of oceanic crust and back-arc spreading MORB protoliths. It is interpreted as back arc spreading oceanic crust formation between Paternoster and Sundaland continents (Monnier et al., 1999) at least before Middle Jurassic (Wakita et al., 1998). Whilst Gondwana break-up had been occurring and being followed by formation of Ceno-Tethys, its northward movement pushed both back arc oceanic crust and micro-continents to underflow beneath Sundaland margin during Early Jurassic time. The Jurassic subduction ceased when collision of Paternoster against Sundalandstarted in the beginning of Early Cretaceous(Figure 3 B). The collision had generated thickening crust and produced high-pressure granulite in Meratus. In another place, new Cretaceous subduction took place to the south of (behind) the Paternoster platform. Subduction accommodated northward compression of the Ceno-Tethys movement beneath Paternoster micro-continent. High-pressure metamorphism of Proto Bantimala complex occurred contemporaneously with collision of the Paternoster againstSundaland in Early Cretaceous. Calc alkali magmatism beneath MeratusSuture had been produced and had elevated gradient geothermal of overriding region. In the Meratus Complex, this situation had exchanged former cool subduction environment toward high temperature magmatic environment and was commenced on 131 million years ago. Quartz rich shelf sediments metamorphosed under previous high-pressure condition had been adjusted to high temperature metamorphism.Contact metamorphism generated pyroxene hornfelsfacies on 118 – 115 million years ago and had influenced up to the end of Cretaceous time (71 million years ago).Along Cretaceous Period those belts were paired metamorphic belts (Figures 3A-D).

The occurrence of the Paternoster micro-continent has emplaced the Meratus and Bantimala sutures in different time spans and regions. Meratus suture belong to the Jurassic accretionarycomplex which partly suffered subsequent high temperature overprinting exchange while the Bantimala suture belong to Cretaceous accretionary complex. During Cretaceous Period, partially melting of Bantimala' oceanic slab generated high temperature metamorphism in the Meratus Complex (Figure 4 Above). Outcrops of the Cretaceous paired metamorphic belts have been exposed on the earth surface since early Late Cretaceous. Exhumation had been triggered by many geological events: compression caused by the collision, faulting caused by buoyancy of the subducting Paternoster micro-continent (Satyana et al., 2008), extensional movement and pull-apart structure (Sikumbang, 1986), excavating by rapid denudation of tropical climate (Hall and Nichol, 2003) in the Meratus side and the low angle corner of flow melange mechanism (after Cloos, 2003).

CONCLUSIONS

1. Meratus-Mangkalihat and Karangsambung-Bantimala-Latimojong-Pompangeo Belts are different sutures in different time spans and regions. Both sutures are partitioned by Paternoster micro-continent. Paternoster platform is separated micro-continental block from main Kalimantan and East Java South Sulawesi Block.

2. Meratus Complex belongs to the Jurassic suture which partly suffered subsequent high temperature overprinting in Cretaceous Period while the Luk Ulo Melang Complex in Central Java, Bantimala Melange Complex, Latimojong and Pompangeo Schist Complex in Sulawesi belong to Cretaceous suture.

3. High pressure belt of Meratus Complex might paired with Kuayan Volcanic and Pinoh Metamorphic Formations in Schwaner Mountain during Jurassic Period while during Cretaceous Period, high temperature metamorphic belts of Meratus Complex is paired metamorphic belts with high pressure metamorphic belt of Bantimala Melange Complex.

ACKNOWLEDGEMENT

Authors wish to thank Niko Asia Ltd (formerly Black Gold Energy Ltd.) for financial support during completion of the research. This topic was the first author's dissertation at ITB which was sandwiched by University of Kiel Germany. Supports were also available from the SFB 754 Subduction Related Fluid Research of Kiel University Germany and from The UPP Chevron-ITB. For all supports, the authors sincerely appreciate.

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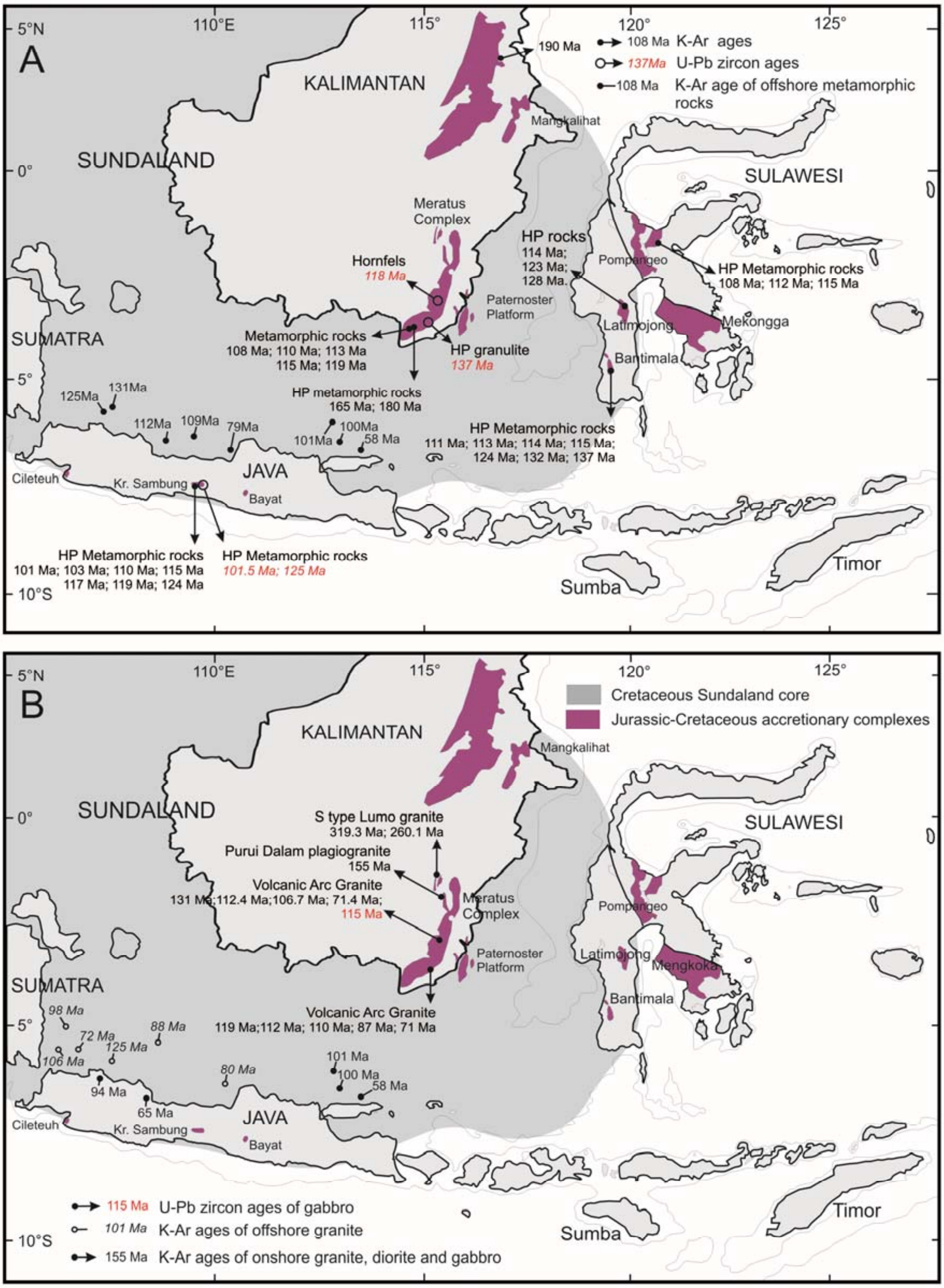

Figure 1 - Distributions of metamorphic rock ages (Above) and magmatic rock ages (Below). Almost of metamorphic rock are Cretaceous ages except in Meratus Complex and Mangkalihat which are available Jurassic ages. Cretaceous Volcanic Arc Granite are cropped out in Meratus Complex, which is penecontemporaneous with Cretaceous high pressure metamorphic rocks in BantimalaMelange Complex. K-Ar ages collected from Hamilton, 1979; Parkinson et al, 1998; Sikumbang, 1986; Dirk and Amiruddin, 2000 while U-Pb zircon SHRIMP ages are earned from Soesilo, 2012.

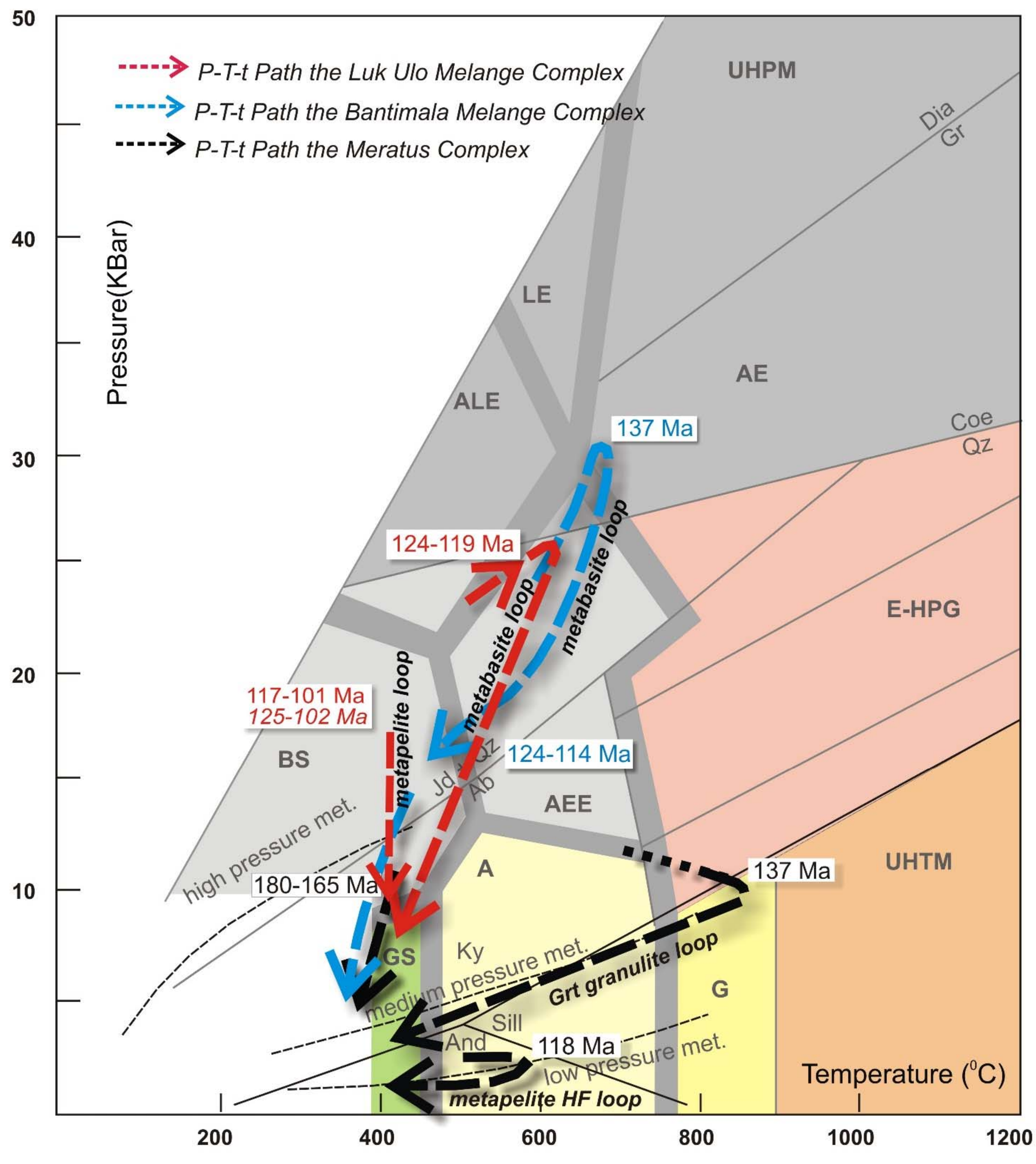

Figure 2 - P-T-t paths of the Jurassic and Cretaceous metamorphic belts in Southeast Sundaland. Jurassic Meratus high pressure metamorphic loop shows blueschistfacies exchanged toward greenschist and its character resemble with LukUloMelange, BantimalaMelange Complexes although occurred in different period. Subsequently the HP rocks had been influenced by high geothermal gradient due to collision of Paternoster and Sundaland, as well as further Cretaceous magmatism. BS=blueschistfacies, AEE = amphibole-epidoteeclogitefacies, ALE = amphibole-lawsoniteeclogitefacies, LE=lawsoniteeclogitefacies, AE=amphibole eclogitefacies, UHPM= ultrahigh-pressure metamorphism. E-HPG = medium temperature eclogite–high-pressure granulite metamorphism. G = granulite facies metamorphism, whereas UHTM = the ultrahigh-temperature metamorphic part of the granulite facies.

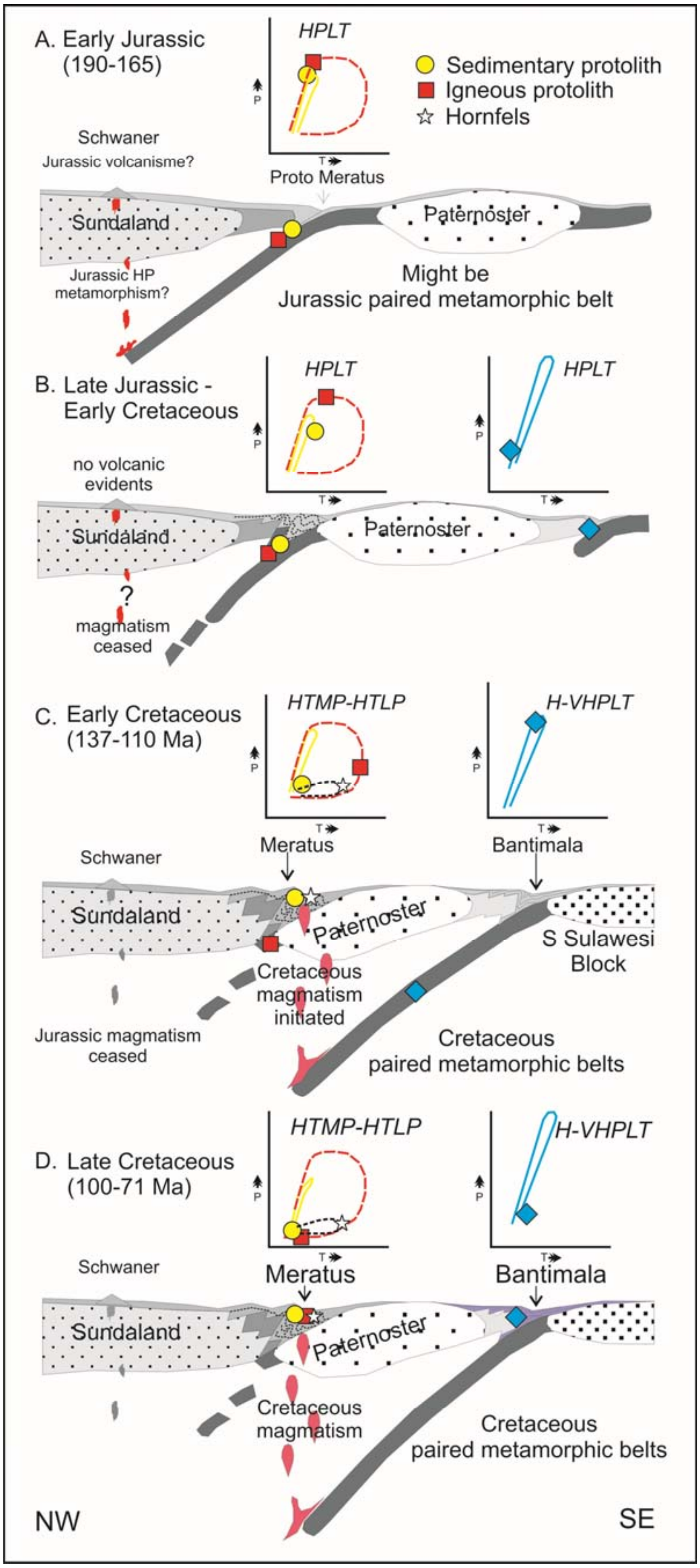

Figure 3 - Cartoon showing Mesozoic tectonic evolution of Southeast Sundaland margin and apparent Mesozoic metamorphic loops. HPLT = high pressure low temperature; HTMP=high temperature medium pressure; HTLP=high temperature low pressure; H-VHPLT= high-very high pressure low temperature.

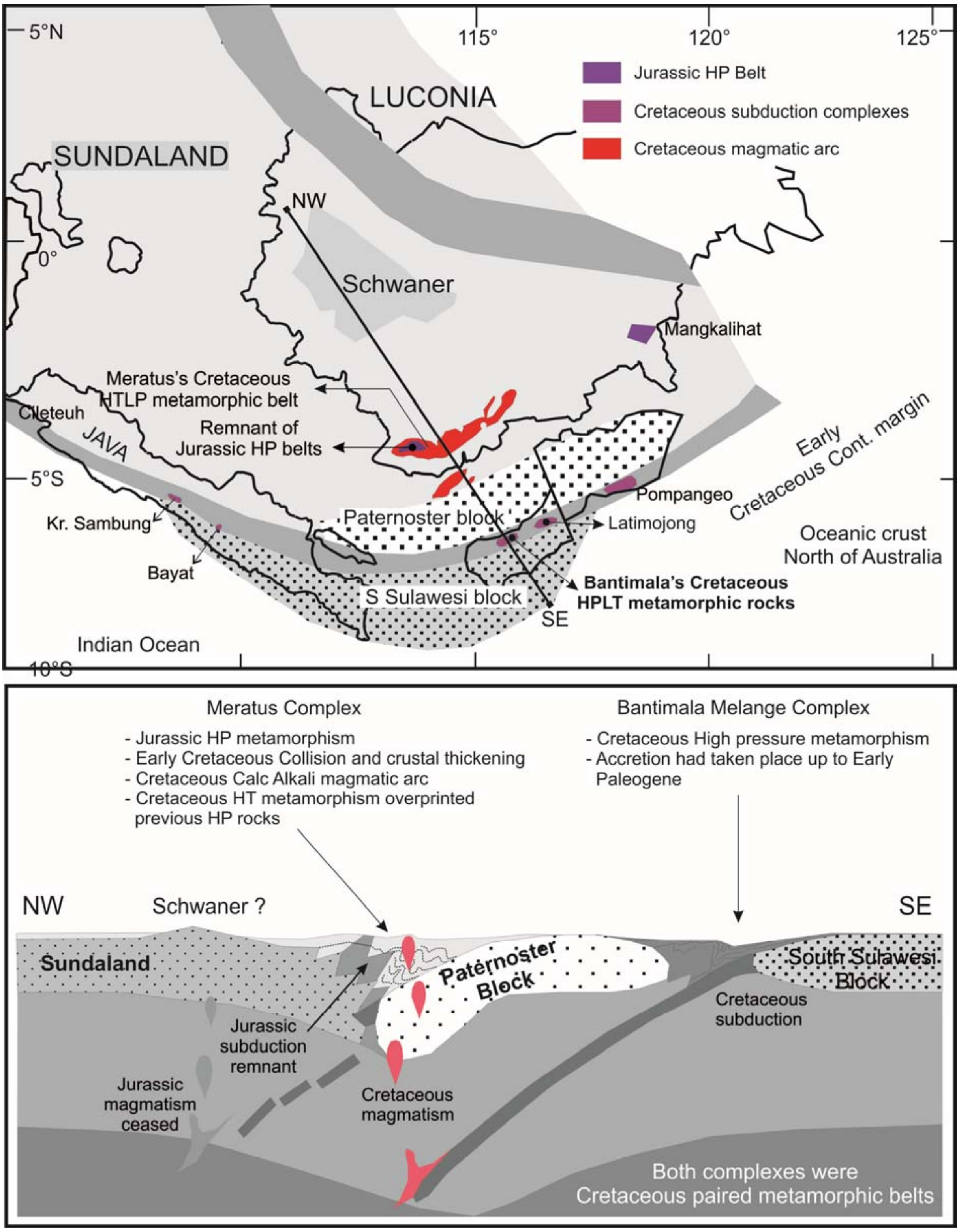

Figure 4 - Above is phisiographic configuration of Southeast Sundaland during Cretaceous Period (Modified from Hall, 2009). NE-SW geological cross section isdrawn in figure below. Cartoon showing tectonic evolution of Late Cretaceous of Southeast Sundaland margin (below). Paternoster micro-continent has partitioned Meratus Jurassic HP belt and Bantimala Cretaceous HP belt. Due to its exchange toward high temperature metamorphism, Meratus HT metamorphic rock had been paired metamorphic belt with juxtaposed Bantimala HP metamorphic rocks during Cretaceous Period.