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An appraisal of the tectonic evolution of SW Borneo constraints from petrotectonic assemblage and gravity anomaly

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Abstract: Evidences derived from petrotectonic assemblages strongly support that early crust of SW Borneo has evolved from depleted basaltic to enriched andesitic composition of intra-oceanic subduction melts. Tectonic model suggests that early crust of SW Borneo has undergone delamination and sinking through spontaneous instability due to rupture and resulting downwarping. Due to intrusion and lateral spreading of hot upper mantle, lower crust has undergone heating and partial melting resulted in the extrusion of primitive tholeiitic magma into the overlying basins. East-West trending Pre-Carboniferous inlier surrounded by Cretaceous intrusives and volcanics occurring in the Schwaner Mountains of SW Borneo mark the beginning of the collision episode in the Cretaceous. Occurrence of widespread oceanic rock assemblages, ophiolites, meta-sedimentary and igneous rocks in a NW-SE spatial zone signify derivation from paleo-ocean basin closure and evolved with suture zone, continental arc and an accretionary prism. Deformed Cretaceous flysch forming an accretionary complex occur as an extensive, dominantly Tertiary accretionary wedge to the north. Bouguer gravity response revealed a subduction trench and trench migration due to indentation of Luconia micro-continent on to the SW Borneo peri-continent edge after subduction had ceased. Tatau high in front of the Miri trench bear witness of an important collisional tectonics fed by igneous activities. Sibu high represents a segment of Luconia Block. Collision and subduction between Luconia micro-continent and SW Borneo peri-continent have evolved "Sarawak Suture" and "Continental Arc".

Keywords: Early crust, petrotectonic assemblage, gravity anomaly, tectonic evolution, SW Borneo

INTRODUCTION

Borneo occupies a central position in the Sundaland promontory of SE Asia. Shallow Sunda Shelf in the south and west separates Borneo from Sumatra, Java, Indochina, peninsular Malaysia and Thailand (Figure 1). Although no literature or political demarcated SW Borneo is recognized, the boundary of SW Borneo is chosen arbitrarily in this study based on the map of Sundaland proposed by Hall & Wilson (2000). SW Borneo is chosen for study where pre-Carboniferous rocks and Cretaceous intrusive rocks occur to understand its tectonic evolution history which is a longstanding jigsaw puzzle. Secondly, a good account of both primary and secondary data acquisition have been possible from field study and literature survey respectively that helped to select SW Borneo for study. Figure 1 demonstrates the study area that marks the regions of primary and secondary data acquisition respectively. SW Borneo is believed to be the oldest continental fragment of Borneo that became part of Sundaland assembly. Sundaland, the continental core of Southeast Asia, is an assemblage of the continental fragments/blocks derived mainly from Gondwanaland during Early Late Palaeozoic-Late Mesozoic. Information derived from Geological Map of Borneo (Tate, 2002), the continental basement of SW Borneo consists of pre-Carboniferous crystalline slate, hornfels, phyllite, schist, gneiss and migmatite and overlain mainly by clastic sediments of Late Carboniferous to Cretaceous age.

Tectonic evolution of Borneo has long been a subject of vigorous geological debate. Borneo has undergone tectonic activities almost throughout its geologic history. However, today Borneo is relatively stable with little seismicity, no

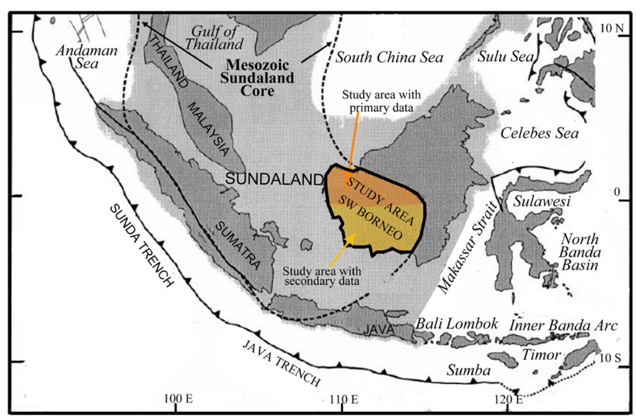

Figure 1: Borneo occupies a central position in the Sundaland promontory of SE Asia. Shallow Sunda Shelf in the south and west separates Borneo from Sumatra, Java, Indochina, peninsular Malaysia and Thailand. SW Borneo marks the present study area.

active volcanoes and small number of Quaternary volcanoes. Despite low elevation of Borneo island there are large and deep sedimentary basins of SW Borneo those have undergone sedimentation since at least early Mesozoic. A Jurassic Gondwana origin for SW Borneo was previously ruled out on the basis of Cathaysian faunas those are known from the Carboniferous–Lower Permian Terbat Limestone in the Sarawak–Kalimantan border (Sanderson, 1966; Metcalfe, 1985) and was considered part of the SW Borneo basement (Metcalfe, 1988). Taylor *et al.* (1990) opined that SW Borneo (Borneo Core) was derived from NW Australia in Jurassic based on the nitrogen-defect aggregation studies of diamonds from Kalimantan. However, SW Borneo is the only region of Borneo where oldest rocks belong to pre-Carboniferous occur as basement metamorphic complex. Being a fascinating region, SW Borneo has been described with various palaeo-geographic forms and positions in the scores of publications earlier but tectonic evolution of Borneo remained a puzzle. Tectonic appraisal of SW Borneo is the subject matter of the present study.

MATERIALS AND METHODS

Present study is focused on to reveal tectonics of SW Borneo wherein multi-dimensional primary data specially pertaining to petrotectonic assemblages and gravity anomaly data, and secondary data from literature survey were the bases for the study. An extensive literature survey from scores of publications provided a good background of geological information of the region. Geological Society of Malaysia released a CD-ROM on the Geology of Borneo Island compiled by Robert B. Tate (2001) of Geological Society of Malaysia provides a good account of geological background of SW Borneo. Geological Report 1 of Sematang and Lundu area of West Sarawak prepared by E. B. Wolfenden and N. S. Haile from the Geological Survey Department of British Territories in Borneo (Wolfenden & Haile, 1963) and the Geological Report 16 of Kuching area of Sarawak prepared by Denis Tan Ngoh Kiat of the Geological Survey of Malaysia (Tan, 1993) provide valuable information. In addition, information from published work by Williams *et al.* (1988 and 1986), Tan (1986), Hamilton (1979), Van Bemmelen (1949), CCOP–IOC (1981) and Hutchison (2005) are added to the study. Detailed geological study was conducted on 84 outcrops covering an area between 01°N – 02°N latitudes and 109°E – 112°E longitudes in SW Borneo. In addition, gravity data have been acquired covering same area between 01°N – 02°N latitudes and 109°E – 112°E longitudes using Sodin WS 410 gravity meter (Figure 2 inset). Wilford (1965) first recorded gravity data in west Sarawak but data are not available in the public domain. Geological Society of Malaysia published a CD-ROM entitled "Geology of Borneo Island" compiled by Robert B. Tate (2001) of Geological Society of Malaysia includes a gravity map of Tatau and offshore Balingian region of Sarawak Borneo that was initially included in the Transect VII (CCOP–IOC, 1992) (Figure 2 inset) representing contour map of Bouguer anomaly values of Tatau and offshore Balingian region. Bouguer map of CCOP–IOC (1992) was digitized and the gravity values at each grid point of 3 km x 3 km grid-cell was determined. Bouguer anomaly value of each grid point is then reduced to a base station having gravity value 145.3 mGal located at 1.6°N, 110.4°E. Thus, a regional Bouguer anomaly map of SW Sarawak is prepared for interpretation.

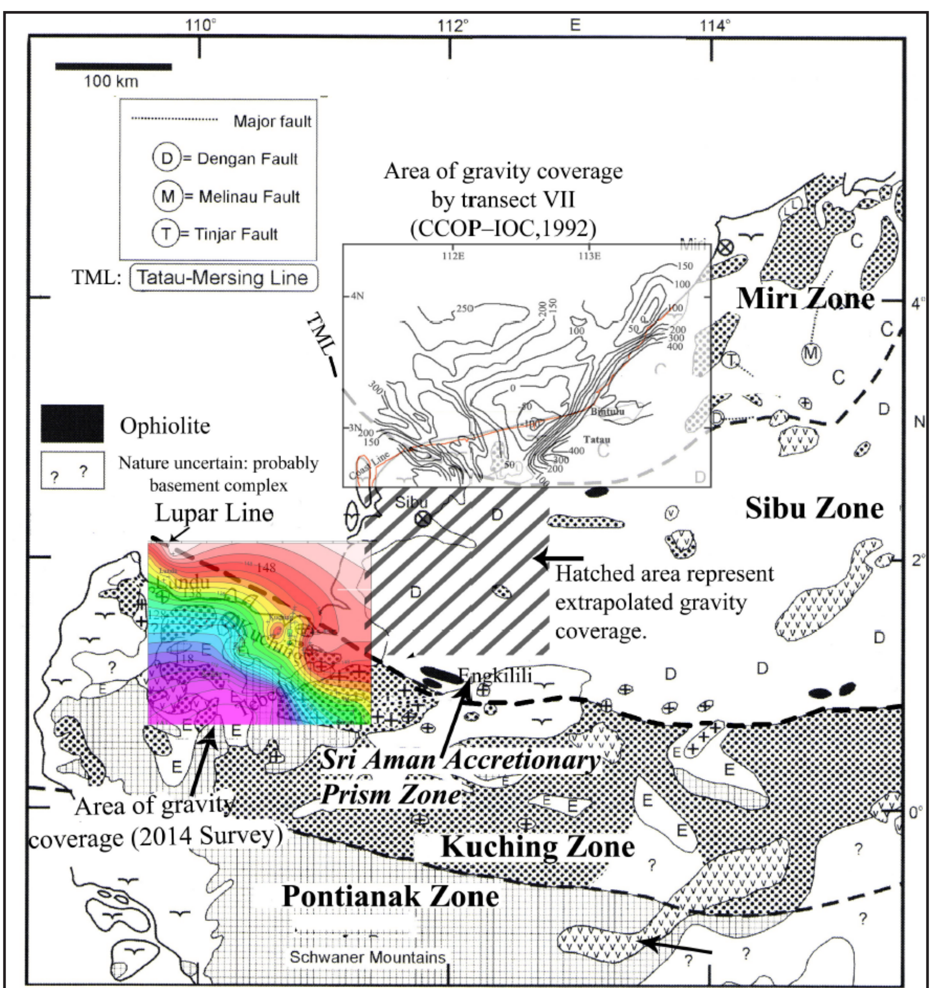

Figure 2: Bouguer anomaly map of SW Sarawak prepared from data acquired during present gravity survey (colored) and from the CCOP–IOC, 1992 gravity map (black & white contour values). Hatched area represents interpreted Bouguer anomaly map shown in the Figure 7 from extrapolated gravity. Structural zones of NW Borneo from Hutchison (2005).

GEOLOGICAL BACKGROUND

Morphotectonic settings of the Geological Map of Borneo (Tate, 2002) allowed Borneo Island to divide in: i) West Borneo Block (Borneo Core) where oldest rocks of the continental basement and widespread igneous rocks of Lr Cretaceous to Miocene in addition to metasedimentary rocks of mostly Tertiary period occur in the Schwaner Mountains; and two prominent basins viz., Melawi Basin and Ketungau Basin occupy an intrinsic position separated by Boyan melange; ii) North Borneo Block characterizes by the Meso-Cenozoic sediments with intense igneous intrusions; iii) East Borneo Block represents dominantly metasedimentary rocks of Cretaceous to Miocene in the Sabah orogen and metasedimentary rocks of Jurassic to Miocene in the Meratus Mountains. Most intrinsic feature of the Schwaner Mountains is the occurrence of east-west trending Pre-Carboniferous sedimentary rocks as a narrow inlier surrounded by the Cretaceous intrusives and volcanics. According to Hamilton (1979), Hutchison (1989) and Metcalfe (1996) Borneo has a Palaeozoic continental core in West Borneo surrounded by ophiolitic island arc and microcontinental crust accreted during the Mesozoic. The Palaeozoic of West Borneo Block is represented mainly by metamorphic rocks of Carboniferous to Permian age. Cretaceous granitoid plutons and associated volcanic rocks have intruded metamorphic rocks occur in the Schwaner Mountains of Borneo (Williams *et al*., 1988). Also in West Sarawak there is a belt of Cretaceous granitoid intrusions. Cretaceous granite is also reported from offshore drilling of the Sunda Shelf (Pupilli, 1973). In the North Borneo Block deep marine sediments of the Upper Cretaceous–Eocene Rajang Group form much of the Mountains and Crocker Ranges. Bedding dips in the Rajang accretionary complex is generally southward, while the complex as a whole becomes younger northward. The complex is interpreted as a series of thrust slices formed by the accretion at a subduction trench (Honza *et al*., 2000). The Rajang Group is unconformably overlain by the Eocene to Lower Miocene Crocker turbidites and mudstones (Hutchison, 1996; van Hattum, 2005). The Crocker Fan (Crevello, 2001) is the largest volume of deep marine Paleogene sediment in a single basin of SE Asia. Sedimentation of the Crocker Fan terminated in the Early Miocene during an early phase of the Sabah Orogeny (Hutchison, 1996). This resulted in a major unconformity, the Top Crocker Unconformity (TCU) which Hall *et al.* (2008) marked a collision event. However, above geological background does not provide any conclusive history of tectonic evolution of SW Borneo.

PETROTECTONIC ASSEMBLAGES AND TECTONIC SIGNIFICANCE

Rock assemblages due to tectonic activities are observed in the scores of outcrops during geological field study. Rock assemblages that characterize plate boundaries or specific plate interior settings are known as petrotectonic assemblages (Dickinson, 1971). Petrotectonic assemblages carrying imprints of tectonic derivations are found to occur in the several outcrops located in the WNW–ESE trending about 200 km long transect between Lundu (1°45'49"N 109°51'54"E) in the west and Engkilili (Sri Aman) (1°10'28"N 111°28'10"E) in the east. According to Coleman (1977) ophiolite complex represent fragments of older oceanic crust that have been tectonically emplaced in the suture zone of the continental orogenic belts. In a completely developed ophiolite complex such as the Troodos complex in Cyprus (Moores & Vine, 1971), the rock types are: a) ultramafic rocks usually having metamorphic-tectonic fabric, b) low-K tholeiitic gabbros and diabases commonly showing cumulus textures, c) low-K tholeiitic sheeted diabase dyke complex, and, d) low-k tholeiitic flows, commonly pillowed. Three kinds of materials can be added to ocean basins viz., fine sediments, turbidites, and lavas of which pelagic limestones and cherts are the most common sediments overlying ophiolites (Siever, 1978). Large bodies of broken and sheared rocks of different origins, known as melange, a subduction complex, also occur (Silver & Beutner, 1980) in the ophiolite zone. Some blocks may compose graded graywackes, chert and carbonates. Back-arc assemblages ranging from deep-sea sediments mixed with quartz-rich sediments, shales and carbonates to terrestrial conglomerates and arkoses occur depending on whether an ocean basin or continent existed behind an arc (Condie, 1982). Petrotectonic assemblages of rises and ocean basins come to view on land only where slabs of upper oceanic lithosphere are incorporated as thrust slices within or above subduction zones at convergent plate junctures. The contrasting petrotectonic assemblages characteristic of convergent plate junctures are those made in the arc-trench systems. Table below (Table 1) provides a list of petrotectonic assemblages found in the geological outcrops located scatteredly in the long transect of about 200 km long between Lundu and Sri Aman of SW Sarawak. List of several petrotectonic assemblages are given in the Table 1 with their locations (coordinates) shown in the Figures 3A to 3G.

Preceding discussion on the characteristics and tectonic significance of petrotectonic assemblages lead to infer that NW-SE trending about 200 km long linear zone between Lundu and Sri Aman of SW Sarawak in SW Borneo signify a 'Suture' and hence is given a name "Sarawak Suture" (Figure 3). Since a suture is evolved due to the closure of an ocean / sea basin and collision between two different continental blocks derived from different origins, in the present study a paleo-ocean / sea basin, most likely proto-South China sea, is believed to have occurred between SW Borneo and Luconia continental blocks. Rock assemblages in the suture zone maintain a linear trend in their occurrence. Khan *et al.* (2017) have also identified a linearity in the occurrence of igneous intrusive rocks of Oligo-Miocene age in parallel to the linearity of occurrence of petrotectonic assemblages. Igneous intrusive rocks showing a linearity likely to represent a continental arc zone derived from subduction melts. In addition to petrotectonic assemblages tabulated in the Table 1, more rock assemblages such as serpentinite

Table 1: Petrotectonic assemblages found in the geological outcrops in SW Sarawak of SW Borneo.

Name of the rock assemblages	Location names	Location (Co-ordinates)	Reference
Pillow basalt and sheeted basalt	Sri Aman	1°10’28”N 111°28’10”E	Figure 3 panel A
Chert	Sri Aman and Simunjan	1°09’46”N 111°27’42”E and 1°04’18”N 110°56’21”E	Figure 3 panel B and C
Sheeted dyke with columnar structure	Taman Matang Jaya (Jalan Matang) and Kota Padawan	1°38’53”N 110°11’07”E and 1°26’02”N 110°19’43”E	Figure 3 panel D. Inset columnar dyke at Kota Padawan.
Sheeted basalt with flow and pillow structures	Lundu	1°45’49”N 109°51’54”E	Figure 3 panel E
Serpentinite	Serian and Simunjan	1°08’28”N 110°34’09”E and 1°11’06”N 110°53’19”E	Figure 3 panel F and G

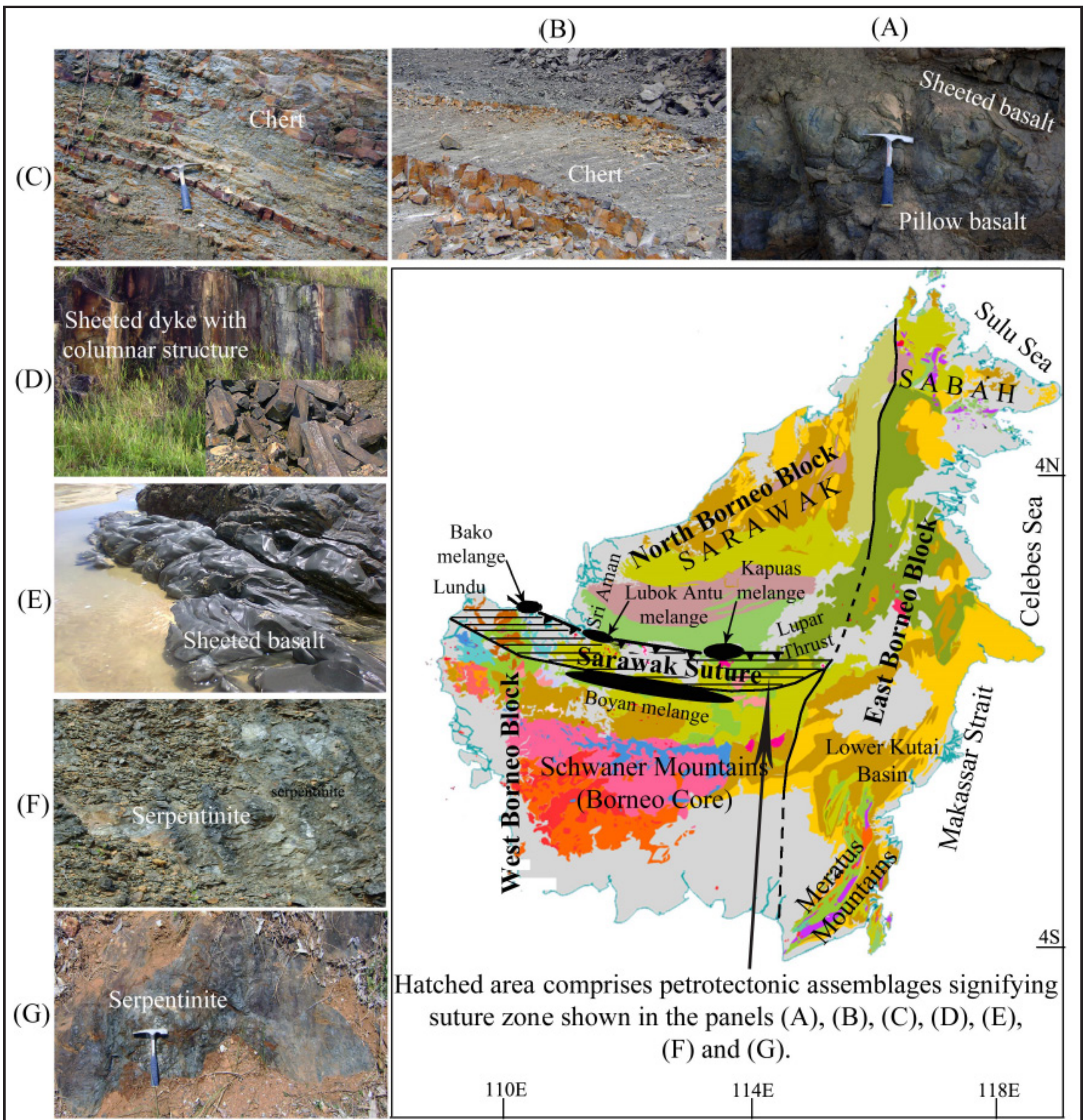

Figure 3: Petrotectonic assemblages signify suture zone that occur along the boundary between West Borneo Block and North Borneo Block bounded by Boyan melange to the south and Bako - Lubok Antu - Kapuas melange zones to the north. Suture zone rock assemblages such as pillow basalt, sheeted basalt, chert, sheeted dyke and serpentinite are shown in the seven panels A to G. Geological map of Borneo redrawn from Tate (2002).

occur at several locations having coordinates 01°07’54”N 110°33’06”E, 01°09’49”N 110°32’57”E, 01°09’14”N 110°39’06”E and 01°09’43”N 110°39’02”E. Chert have been found in several locations having geographic locations 01°26’57”N 110°15’40”E, 01°09’49”N 110°32’57”E and 01°11’29”N 110°55’50”E. Occurrence of fault rocks i.e., tectonic melange, fault breccia and mylonite, those signify fault zone have also been observed in the locations 01°37’55”N 110°27’00”E, 01°38’38”N 110°27’04”E, 01°40’31”N 110°27’28”E, 01°11’29”N 110°55’50”E, 01°16’45”N 110°25’52”E, 01°07’30”N 111°36’25”E, 01°09’14”N 110°39’06”E, 01°09’43”N 110°39’02”E, 01°07’33”N 111°36’57”E respectively (Figures 4A-4J). Tectonic melange also have been found near Bako township with a name “Bako melange” (Figure 3). Williams *et al.* (1986) have identified Lubok Antu and Kapuas melange zones. All these melange zones occur along north vergence thrust faults coinciding uniquely with the Lupar Line. Boyan melange that trends WNW-ESE separated Melawi Basin from Ketungau Basin in West Kalimantan (Trail *et al*., 1984). Field evidence of thrust fault at Bako (Figures 5A; 5B), and near Lubok Antu (Figures 5C; 5F) suggests that Bako, Lubok Antu and Kapuas melange occur due to thrust fault those coincide well with the “Lupar Line”. Hence, Lupar Line may be considered as a zone of series of thrust faults. Similarly, field evidences collected from north of Boyan melange along Malaysia-Indonesia border at Tebedu in SW Sarawak revealed an intra-formational deformation and faulting due to north-south compression with north directed thrusting (Figures 5D; 5E). This thrust is given local name “Tebedu Thrust”. Field evidences of thrust fault with geographic locations are given in the Figure 5. Finally, above “Sarawak Suture” and the “continental arc” have been identified to occur in a linear zone where oceanic petrotectonic assemblages i.e., ophiolite, chert, fault rocks, melange, igneous intrusive and extrusive rocks bounded by series of thrust faults trending WNW-ESE occur inter-mixing across 200 km transect between Lundu to the west and Sri Aman to the east (Figure 6).

INTERPRETATION OF BOUGUER GRAVITY

In order to determine crustal structure and tectonics of SW Borneo, observed Bouguer gravity were measured values have been calculated at 80 gravity stations located in the study area covering an area between 01°N – 02°N latitudes and 109°E – 112°E longitudes. Bouguer gravity of Tatau and offshore Balingian area taken from CCOP-IOC, 1992 and Bouguer gravity acquired in the present study are used to prepare a regional Bouguer gravity map which covers a substantial portion of the study area.

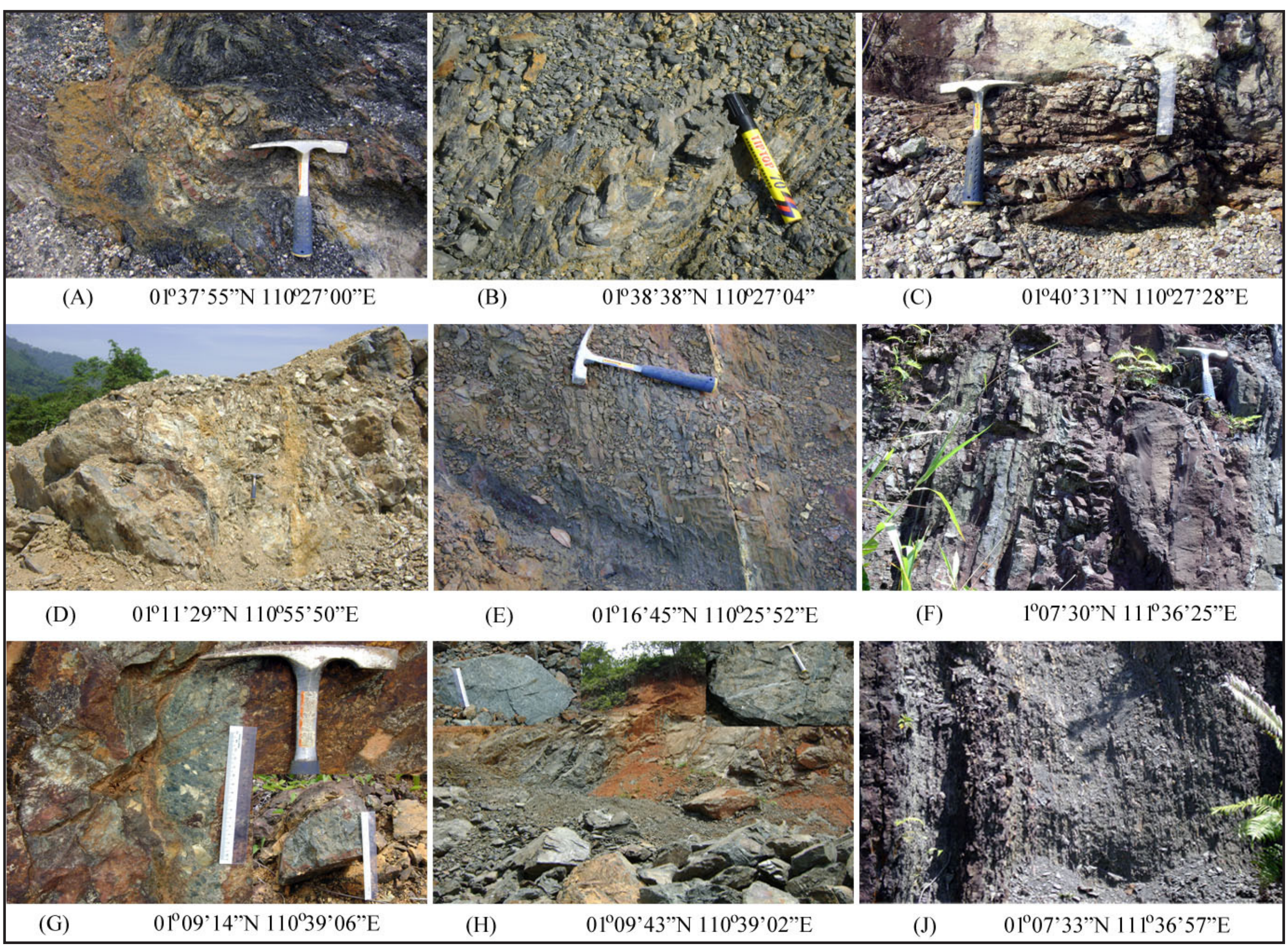

Figure 4: Tectonic melange, fault breccia and mylonite those typify fault zones are shown in the panels A to J.

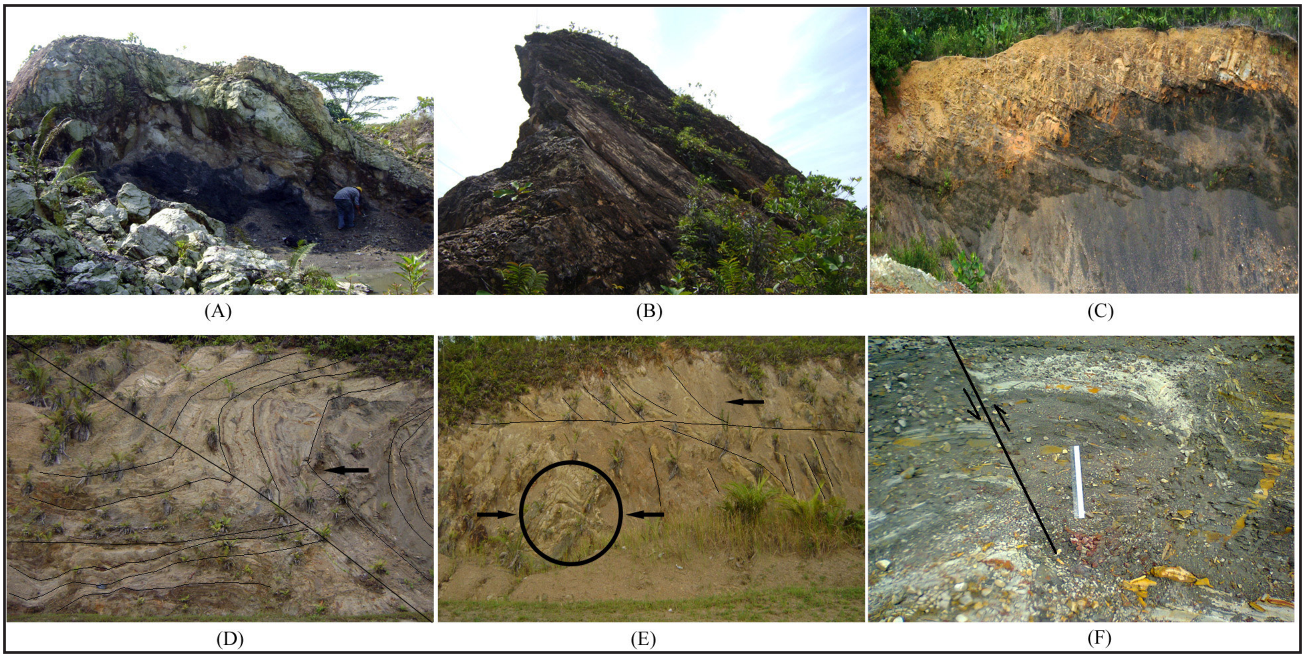

Figure 5: Field evidence of north directed thrust faulting at Bako, Sri Aman and Tebedo of SW Sarawak. (A) Location Bako 01^{0}40'31"N 110^{0}27'28"E, bedding plane strikes N70^{0}E-S70^{0}W, dips S20^{o}E. (B) Location Bako 01^{0}37'55"N 110^{0}27'00"E, bedding plane strikes N70^{0}E-S70^{0}W, dips S20^{0}E. (C) Location Sri Aman 01^{0}09'46"N 111^{0}27'42"E, bedding plane strikes East-West, dips South. (D) Location Tebedu 01^{0}04'01"N 110^{0}22'27"E. Observer facing east finds lower part of the exposure strikes North-South while upper part strikes NW-SE suggesting intra-formation deformation by rotation and over-ridding of the beds. (E) Location Tebedu 01^{0}04'16"N 110^{0}22'34"E. Observer facing east finds similar situation as of panel D with additional small scale over-turned folding shown in the circle. (F) Location 01^{0}22'31"N 110^{0}19'36"E, 3 km NE of Kampung Punau. Roll-over structure with thrust faulting.

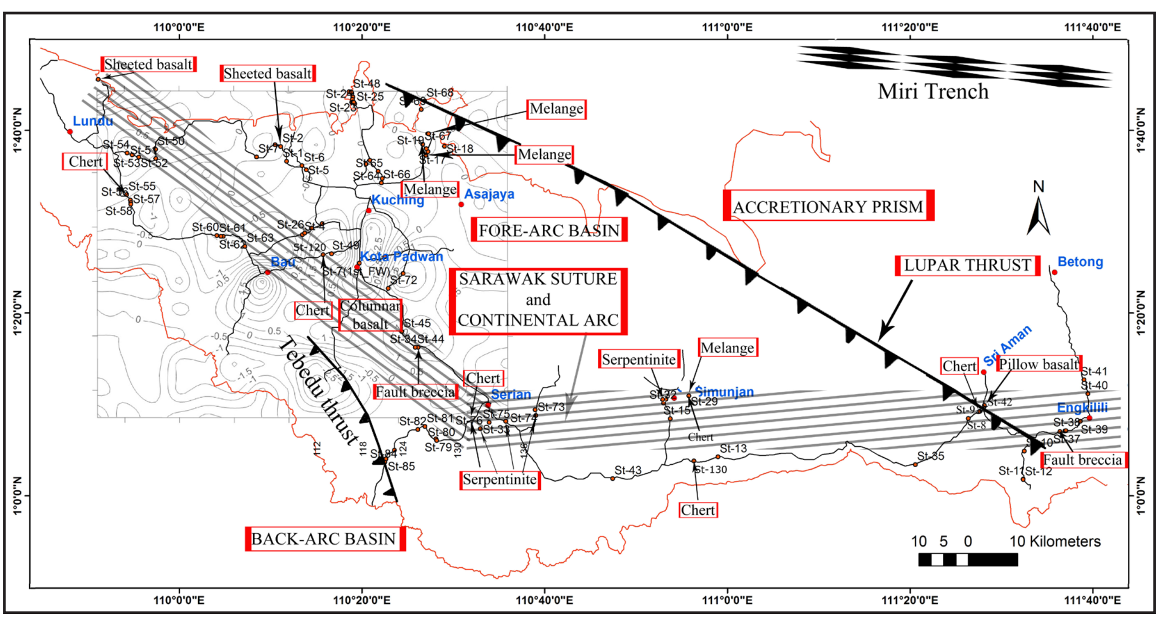

Figure 6: Plate-tectonic classification of the collision margin of SW Borneo and North Borneo showing suture zone, continental arc, trench, accretionary prism, fore-arc basin and back-arc basin.

Since positive Bouguer anomaly is related to high density structure and negative Bouguer anomaly is related to low density structure, the Bouguer gravity map (Figure 7) shows several structural highs and lows. NE-SW elongated tongue-shape depression of SW Sarawak is extended towards southwest as a sloping basement into deeper basin zone. Bouguer anomaly pattern on the on-shore portion of SW Sarawak demonstrates progressively negative values towards southwest suggesting a southwest sloping basement / basin-floor and deeper basin zone (Khan *et al.*, 2017). The deeper basin zone with increasing sediments thickness is likely to be the part of Melawi Basin (Figure 8). Further shown in the Figure 7 high positive Bouguer anomaly values of Tatau region in excess of +350 mGal signify a basement high evolved due to the intrusions of high density ultramafics derived from subduction melts. On the otherhand,

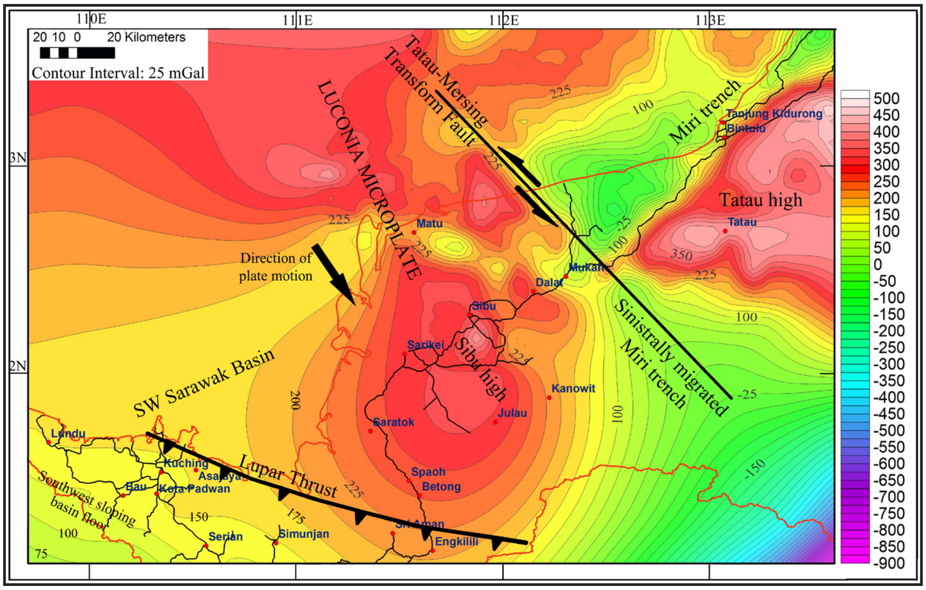

Figure 7: Interpreted Bouguer anomaly map showing crustal structure and mass distribution in the region of SW Borneo and North Borneo demonstrating NE-SW trending tongue-shape depression, Miri trench, Tatau high, Sibu high and transform fault and sinistral trench migration.

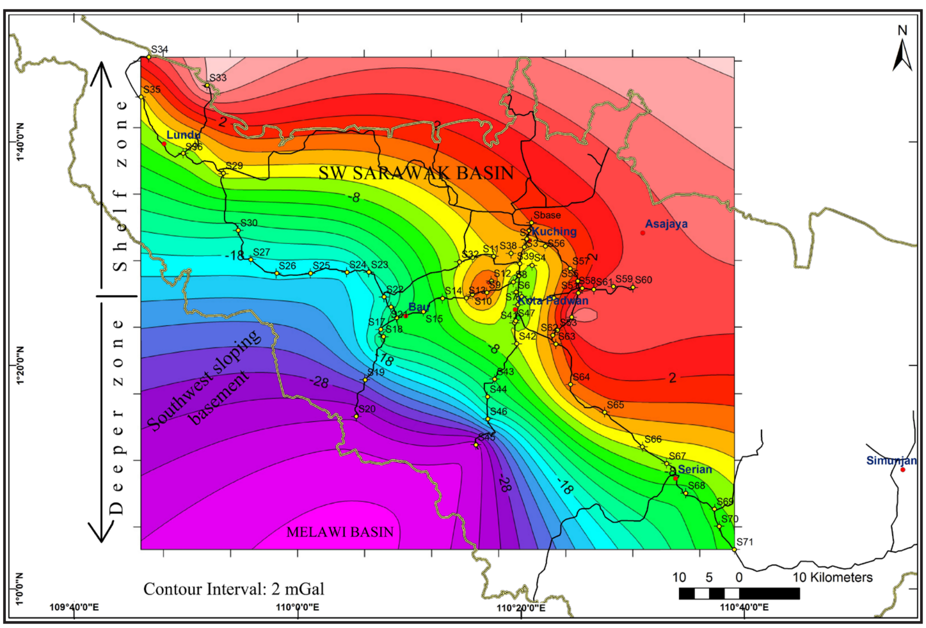

Figure 8: Bouguer anomaly map of SW Sarawak showing southwest directed sloping basement and basin floor; and deeper basin zone of Melawi basin.

very high positive Bouguer anomaly values in excess of +300 mGal of Sibu region is interpreted as an extension of Luconia micro-plate that also intruded by high density ultramafics. ENE-WSW trending high negative Bouguer anomaly values occurring north of Tatau high is due to the Miri trench wherein elongated contour pattern of Bouguer anomaly values in excess of –100 mGal is interpreted a trench having approximately 11 km thick sediments deposition. Characteristic Bouguer anomaly values of a trench in a subduction zone varies between -100 to -150 mGal (Condie, 1982). Subduction of Luconia micro-plate under SW Borneo block has initiated during Cretaceous resulting widespread Cenozoic volcanics from subduction melt. A sinistral transform fault is inferred that coincides well with popularly known "Mersing Line". Genesis of this sinistral transform fault is not clearly understood but a prominent shift of the gravity anomaly contour of Miri trench is clearly envisaged that suggests an indentation of Luconia microplate after ceasing of subduction in the Miri trench (Figure 7).

TECTONIC EVOLUTION OF SW BORNEO

Envision of stratigraphic framework, rock types and terrain pattern derived from Geological map of Borneo (Tate, 2002; Figure 9) suggests three distinct morphotectonic pattern that help to demarcate Borneo Island as SW Borneo, North Borneo and East Borneo. However, pre-Carboniferous crystalline basement overlain by Late Carboniferous - Cretaceous sediments suggest that early crust in SW Borneo has been evolved by the process of intra-oceanic subduction wherein melting enriched oceanic crust within a subduction zone produced juvenile continental crust. According to Gazel *et al.* (2015) thin oceanic crust can form by the process of decompression

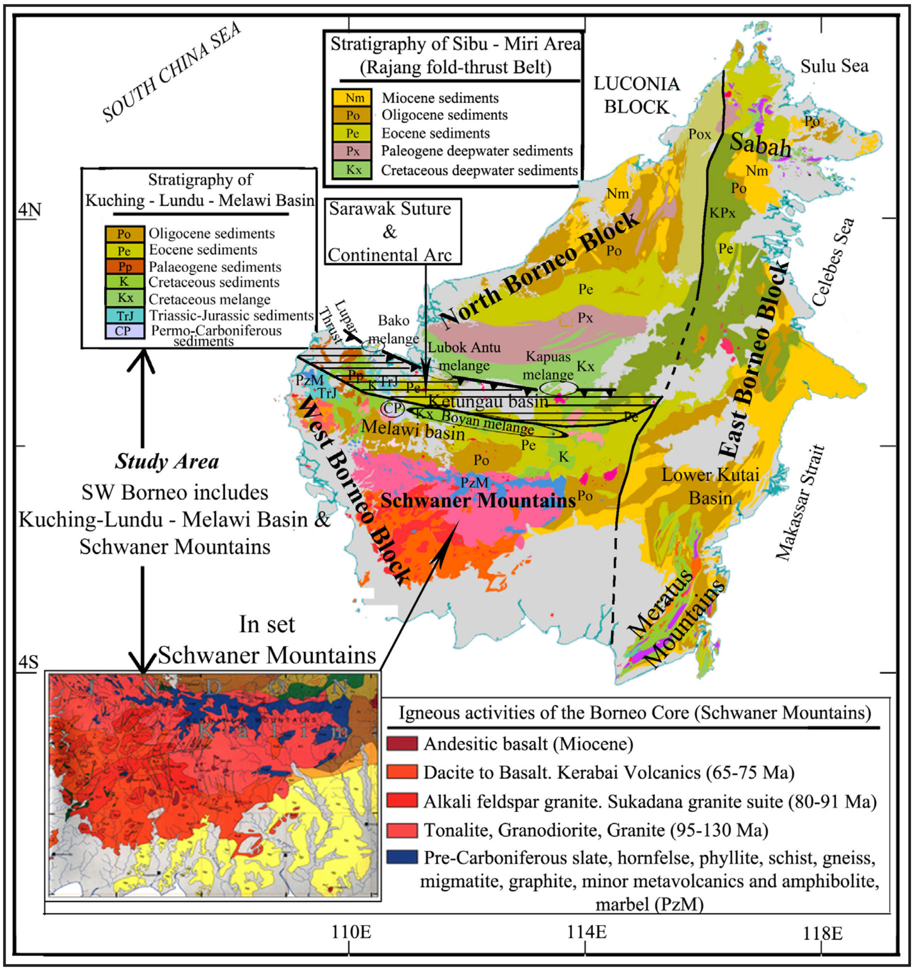

Figure 9: Geological map of Borneo suggests three morphotectonic zones based on rock types and terrain pattern (Redrawn from Tate, 2002).

melting of the upper mantle at mid-ocean ridges and juvenile continental crust of depleted basaltic to enriched andesitic composition may form from magma erupted above intra-oceanic subduction zones. It is further interpreted that juvenile lower crust had undergone delamination and sinking through spontaneous instability due to rupture and resulted downwarping to form an inland basin in SW Borneo where Late Carboniferous - Cretaceous sediments have been deposited. Intrusions and lateral spreading of hot upper mantle resulted juvenile crust to undergo heating and partial melting that subsequently formed primitive tholeiitic magma extruded into the overlying basins. Occurrence of andesitic basalt, dacite and granodiorite in Schwaner Mountains signify its derivation from primitive tholeiitic magma. In addition, hot lower crust might have been attenuated due to the ductile spreading.

Most intrinsic feature of SW Borneo is the east-west trending Pre-Carboniferous rocks that occur as inlier surrounded by the Cretaceous intrusives and volcanics (Figure 9). Crust melting granitoids intruded in the low-grade regional metamorphic rocks during Early Cretaceous in SW Borneo. An inlier may appear from a ‘tectonic window’, a geologic structure form by erosion on a thrust system when an erosional hole is created in the nappe. Since inlier is not a suture, it is interpreted that early crust (pre-Carboniferous crystalline basement) below Melawi Basin and Schwaner Mountains must have undergone downwarping, delamination, sinking and melting producing Early Cretaceous intrusions of tonalite, alkali granite and granodiorite from lower crust melt into the overlying basin. Further, occurrence of Boyan melange to the north of Schwaner Mountains comprising sheared argillic to phyllitic matrix of clast ranging from a few centimeter to several kilometer in diameter is characterized by tectonic melange of Cretaceous age. Further to the north of Boyan melange zone of SW Borneo, an extensive occurrence of oceanic rock assemblages including ophiolites and other volcanic rocks along 200 km long transect between Lundu to the west and Sri Aman to the east strongly support the existence of a plaeo-ocean basin that eventually was closed due to the collision of two continental blocks. Presence of tectonically transported oceanic assemblages such as turbidites, chert, serpentinite, pillow basalt, sheeted basalt and other oceanic assemblages within the accretionary complex represents a zone of collision. The prevailing tectonic status strongly recommends collision between northern peri-continental shelf of SW Borneo and Luconia micro-continental block. Paleo-ocean basin subducted below peri-continental shelf of SW Borneo that formed “Sarawak Suture” and continental arc zone. Normally, volcanic arc should occur in the back-arc zone behind a suture but in the present case both occur within a single tectonic zone. Genesis of such mixed zone should account for the greater angle of the subducting slab and the greater thickness of the sediments of the accretionary prism. Hence at the time when subduction was ceased the subducting slab attained much steeper angle intruding subducting melts within the suture zone. Miri trench marks the oceanward edge of the subduction zone. Further shown in the Figure 7 high positive Bouguer anomaly values of Tatau region in excess of +350 mGal signify a basement high evolved due to the intrusions of high density ultramafics derived from subduction melts. On the otherhand, very high positive Bouguer anomaly values in excess of +300 mGal of Sibu region is interpreted as an extension of Luconia micro-plate that also intruded by high density ultramafics. ENE-WSW trending high negative Bouguer anomaly values occurring north of Tatau high is due to the subduction trench (Miri trench) wherein elongated contour pattern of Bouguer anomaly values in excess of –100 mGal is due to a trench having approximately 11 km thick sediments deposition. Subduction of Luconia micro-continent under SW Borneo block was initiated during Cretaceous resulting widespread Cenozoic volcanics from subduction melt. A sinistral transform fault coinciding well with popularly known "Mersing Line" is observed from a prominent shift of the gravity anomaly contour of Miri trench. Genesis of this sinistral transform fault suggests an indentation of Luconia micro-continent after the ceasing of subduction in the Miri trench. Prevailing geotectonic status lead to propose a tectonic model of SW Borneo where all the tectonic elements i.e., suture, continental arc, accretionary prism, fore-arc basin and back-arc basin have been evolved (Figure 10).

CONCLUSIONS

Primitive juvenile crust of SW Borneo have evolved from intra-oceanic subduction melts wherein melting enriched oceanic crust within a subduction zone produced juvenile continental crust composed of pre-Carboniferous crystalline slate, hornfels, phyllite, schist, gneiss and migmatite. Meanwhile, lower crust went under the process of delamination and sinking through spontaneous instability due to rupture and resulted downwarping to form several inland basins including Melawi Basin where Late Carboniferous - Cretaceous sediments have been deposited. Tholeiitic magma due to lower crust melting and lateral spreading extruded into the overlying basins as andesitic basalt, dacite and granodiorite. Occurrence of pre-Carboniferous rocks as inlier surrounded by the Cretaceous intrusives and volcanics in Schwaner Mountains and the occurrence of Tebedu Thrust signify a collision episode during Cretaceous time. Closure and exhumation of Melawi Basin resulted ceasing of subduction of Luconia micro-continent beneath the peri-continental shelf of SW Borneo. Melawi Basin and Ketungau Basin separated by Boyan melange occupied an intrinsic tectonic position wherein Ketungau Basin was formed in the arc proper zone. Petrotectonic assemblages such as serpentinite, sheeted dyke, pillow basalt, chert and graywackes comprising ophiolites, fault rocks, igneous intrusives and several thrust faults all occur in a WNW-ESE trending zone which characterizes a suture. Although a Cretaceous collision between Luconia block and Borneo basement is inferred the ceasing of subduction came in Miocene resulting in the formation of Sarawak Suture, continental arc and trench migration. Andesitic volcanics ejected into the arc proper zone in Miocene. Tatau High in

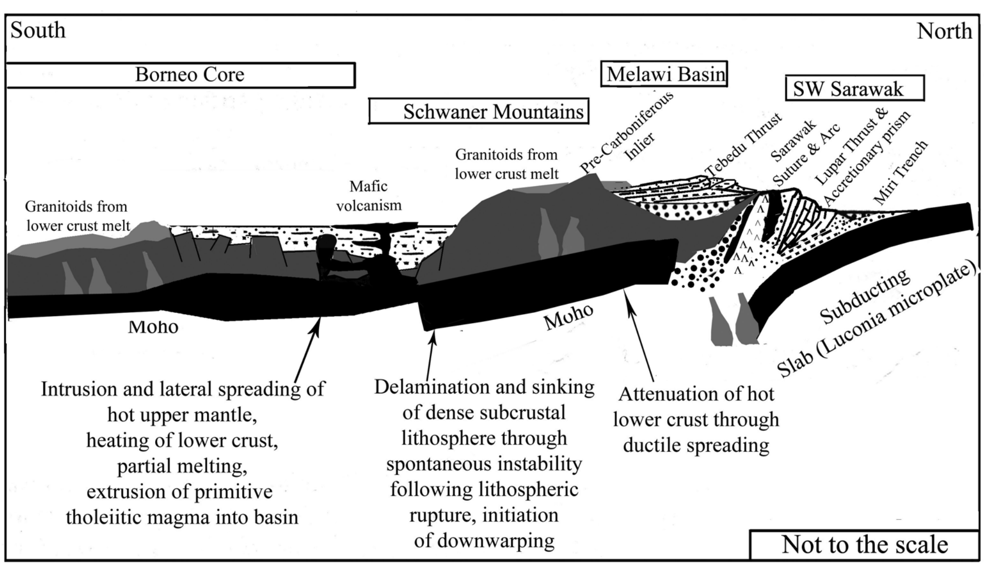

Figure 10: Proposed tectonic model along north-south cross-section across SW Sarawak - Melawi Basin - Schwaner Mountains - Borneo Core. Model shows crustal development by depleted basaltic to enriched andesitic composition of subduction melts wherein lithosphere had undergone delamination and sinking through spontaneous instability and resulted downwarping. Due to intrusion and lateral spreading of hot upper mantle, crust had undergone heating and partial melting resulting in extrusion of primitive tholeiitic magma into the overlying inland basins. Closure and exhumation of inland basins formed terrains of Schwaner Mountains and Melawi Basin. Tebedu Thrust, Sarawak Suture, Continental Arc, Lupar Thrust, Accretionary Prism and Miri Trench have evolved due to convergence, subduction and collision of SW Borneo and Luconia.

front of Miri trench signify a basement high due to invasion of high density ultramafics derived from subduction melts. Proposed tectonic model of SW Borneo exhbits all the tectonic elements of a conversing plate margin such as suture, continental arc, accretionary prism, fore-arc basin and back-arc basin.

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