Indonesian Journal of Geology, Vol. 8 No. 4 December 2013: 205-214

Stratigraphy and Tectonics of the East Ketungau Basin, West Kalimantan during Palaeogene

Stratigrafi dan Tektonika Cekungan Ketungau Timur, Kalimantan Barat selama Paleogen

SUYONO

Centre for Geological Survey, Geological Agency, Ministry of Energy and Mineral Resources
Jln. Diponegoro No.57 Bandung, Indonesia

Corresponding Author: suny_96@yahoo.com
Manuscript received: October 24, 2013, revised: November 11, 2013, approved: December 12, 2013

ABSTRACT

East Ketungau Basin is one of frontier basins in Indonesia. Some of these basins, especially those in eastern Indonesia, have been identified to possess potential of oil and gas. The existing publications of geological fieldworks and extensive exploration in the East Ketungau Basin are limited. The detailed sedimentological and biostratigraphical studies of the sedimentary succession will be used to reconstruct the tectonic and palaeogeographical history of the basin. The sedimentary Mandai Group consists of three facies such as mudstone facies, clean sand facies and alternation between thinly coal seam, coaly shale, and claystone facies. However, each facies characterizes depositional environment of barrier- island and associated strand-plain systems.

Keywords: East Ketungau Basin, Palaeogene, Mandai Group

ABSTRAK

Cekungan Ketungau Timur merupakan salah satu cekungan perbatasan di Indonesia yang beberapa di antaranya telah teridentifikasi memiliki potensi minyak dan gas, terutama di Indonesia bagian timur. Publikasi yang tersedia tentang penelitian geologi di lapangan dan eksplorasi ekstensif di Cekungan Ketungau Timur sampai saat ini masih terbatas. Penelitian sedimentologi dan biostratigrafi terperinci mengenai runtunan batuan sedimen akan digunakan untuk merekonstruksi sejarah tektonika dan paleogeografi cekungan tersebut. Sedimen Kelompok Mandai terdiri atas tiga fasies, yaitu fasies batulumpur, fasies pasir bersih, dan perselingan antara lapisan batubara tipis, serpih batubaraan, dan fasies batulempung. Namun, setiap fasies memiliki karakteristik lingkungan pengendapan barrier-island dan sistem asosiasi pantai-dataran.

Kata kunci: *Cekungan Ketungau Timur, Paleogen, Kelompok Mandai*

INTRODUCTION

West Kalimantan is a frontier area for many natural resources of conventional and unconventional potential such as economic mineral, coal, and hydrocarbon especially in the Ketungau and Melawi Basins. Geologically, the northern part of West Kalimantan can be divided into several geological provinces, *i.e.* South China Sea Basin to the west and northwest, Rajang Accretionary Prism to the north, and Schwaner Mountains to the south. The basin is bounded by the longitudes 112° 30' to 114° and 0° to 1° North latitude (Figure1).

The subsequent rotational history of Kalimantan, concerning its relative position is still a matter of debate-interpretations including "no rotation" (Lee and Lawyer, 1995), "clockwise rotation" (Rangin *et al*., 1990), "counter clockwise rotation" (Haile

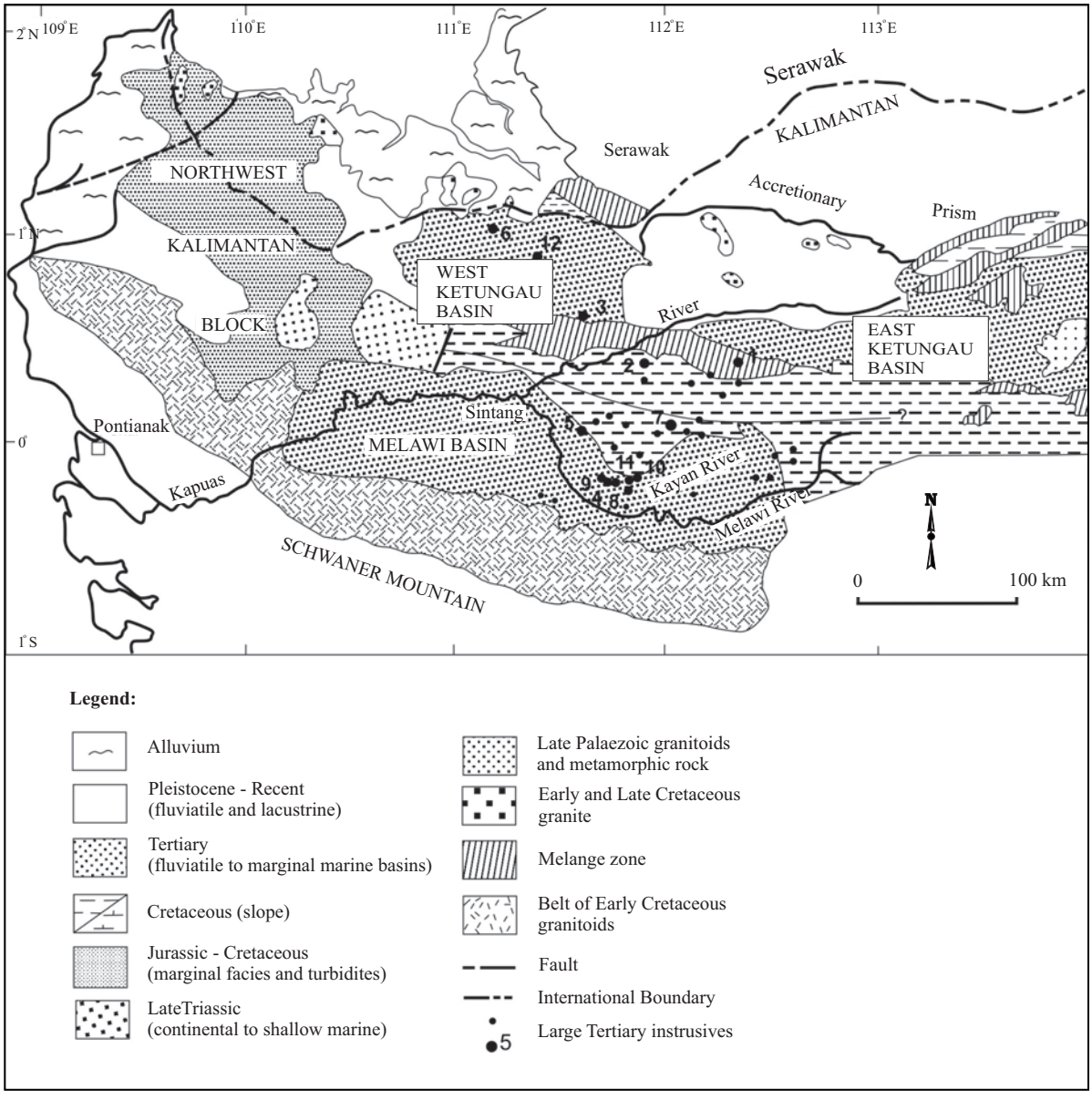

Figure1. Location and regional geological map of the Melawi and Ketungau Basins (modified from Williams and Harahap, 1987).

et al., 1978; Hamilton, 1979; Hall, 1996; Charlton, 2000; and Tjia, 2012), and "mixed rotations" (Briais *et al*., 1993 in Hall, 1996). The recent publication by Tjia (2012) assumed that Kalimantan did not experience a progressive counter clockwise rotation during the Cenozoic, whereas the dynamics of the spreading of the South Sea China Basin, the strong west-verging Pacific Plate, the northward progression of the Indian Ocean-Australian Plate, and possibly extrusion of continental Southeast Asia appear to have impacted the region differently at different times of the Cenozoic.

This paper will describe the geology, stratigraphy, and tectonic setting of the East Ketungau Basin of the West Kalimantan region during Palaeogene, on the basis of detailed sedimentological and biostratigraphical data. All samples belonging to the East Ketungau Basin were collected during the Center of Geological Survey (PSG) fieldwork in 2009 and 2010.

Methodology

Accomplishing the purpose of the study, specific geological investigation and laboratory analyses were carried out. Then, the study was focused on the stratigraphic analysis of each member of Mandai Group, with logging sections using geological compass and GPS. Basically, each facies of the Mandai Group was selected for a representative section, which was supported by collecting rock samples for laboratory analysis, such as pollen and foraminifera analysis, rock-eval pyrolysis, and GC-MS analysis in order to acquire ages and depositional environments in this basin. The paleontologic analysis was conducted at GSI paleontology laboratory, whilst the last two analyses were carried out at LEMIGAS laboratory. Following standard procedures. The detailed sedimentological and biostratigraphical studies of the sedimentary succession led to the construction of an updated stratigraphy of the East Ketungau Basin.

Geological Outline

The palaeogeographic evolution of East Ketungau Basin between Late Cretaceous and Early Tertiary still remains to be debated, such as foreland basin (Pieters *et al.*, 1993) and related subduction process (William and Harahap, 1987).

The author assumes that the East Ketungau Basin (or Mandai Basin) was formed by the collision between the Schwaner Arc and Eurasian Plate during Late Cretaceous until Early Tertiary, and it is interpreted as a fore arc basin, whereas the Schwaner Mountains I - type granitoid belt is a magmatic arc. The Boyan melange is situated in the south and the Sarawak Accretionary Prism in the north (would be consistent with subduction). Pieters *et al.* (1993) named the clastic deposits that filled the Palaeogene sedimentary basins in eastern North West Kalimantan as the Mandai Group.

Fieldwork of the Mandai Group was carried out between 2009 and 2010 along Sebilit, Boyan, Mentebah, and Semangut Rivers. Sandstone and mudstone facies in this area are gently dipping northward and unconformably overlay the Selangkai Group and other basement rocks in the Putussibau and border of the Sintang Quadrangles.

Stratigraphy and Tectonics

Stratigraphy

The Mandai Group was firstly defined by Pieters *et al.* (1993), comprising medium-to fine-grained sandstone, mudstone, siltstone, and locally coal seam which crop out in the Mandai River.

The recent fieldwork of the basin suggests that the Mandai Group sediments were divided into three facies, from lower to upper parts as mudstone facies, clean sandstone facies, and alternating sandstone and mudstone with locally coal seam.

In the upstream area of the Sebilit River, the East Ketungau Basin sediments are dominated by mudstone facies consisting of siltstone, fine-grained sandstone, and mudstone representing the lower part of the Mandai Group. Its exposure can also be found along the upstream area of the Boyan River, Mentebah, and road cuts between Sebilit and Boyan Rivers. A detailed stratigraphic section of the lower part of mudstone facies is characterized by an alternation of dark grey shallow marine, silty mudstone and very fine-grained well sorted sandstone (Figure 2a). Furthermore, the upper part of mudstone facies is dominated by parallel laminations of grey to reddish siltstone and claystone with thin carbonaceous layers (Figure 2b). Generally, the mudstone facies has bedding dips between 15^{o} - 33^{o} to the north and northeast.

The analysis results of foraminifera,ichno fossil, and palinology (Table 1) supported by rock-eval pyrolysis and GC - MS mode results (Figures 3 and 4), tend to show a shallowest open marine-transitional-anoxic to sub-oxic lacustrine depositional environment. This facies is approximately 150 m thick in the upstream area. The mudstone facies is correlated with Kantu Formation in the West Ketungau Basin.

The 'clean sand' facies is found in the middle part of the Palaeogene Mandai group sediments, characterized by white to brown quartz sandstone, medium- to coarse- grained well sorted sandstone showing massive and well bedded sandstone, with scour structure, cross stratification, and locally shows mudrapes. The sequence is well exposed in Boyan Rivers, Nangapayang Hill, and Mentebah Rivers. The lower part of clean sand facies is dominantly composed of cross-bedding ranging from 20-30 cm representing a medium scale (Conybeare and

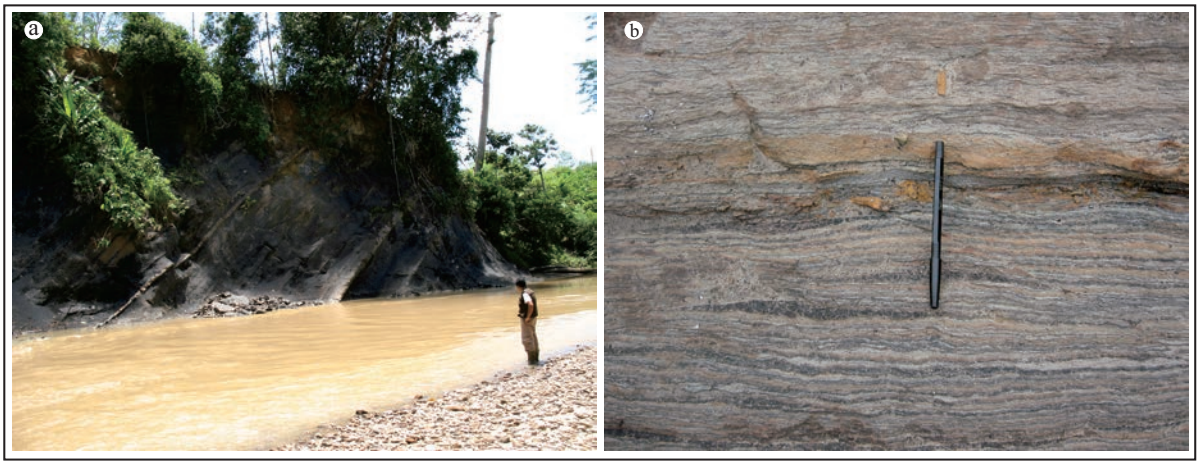

Figure 2. Photograph of lower part of Mandai Group sediments. a. Alternating dark grey silty mudstone and very fine-grained well sorted sandstone. b. Parallel laminated grey to reddish grey siltstone and claystone with thin carbonaceous layers.

Crook, 1986). This sand body (sand bar) is mainly formed in the upper part of the 'clean sand' facies. This facies conformably overlies the mudstone facies and is correlated with Tutoop Sandstone in the West Ketungau Basin. The thickness of this sequence is around 150 m in Nangapayang Hill, Simpangsuruk Subregency.

Due to the occurrence of *Rosalia* and *Skolithos* ichnofossil (Table 1), the sequence was probably deposited as a barrier bar in a tidal environment. The direction of paleocurrent in the sandstone facies ia to northwest, north, and northeast directions. The source of clean sand facies (Figure 5) possibly is Schwaner granite and metamorphic basement from the Schwaner Mountain.

The alternating sandstone and mudstone with thin coal seams conformably overlies the 'clean sand' facies, and forms the upper part of the Palaeogene sediments of Mandai Groups. This facies is dominated by bedded medium- to fine- grained sandstones and in some areas it is also characterized by the presence of siltstone and mudstone with parallel lamination and thin coal seams (Figure 6). The sequence is distributed along the downstream area of Boyan, Sebilit, and Mentebah Rivers, and in a low area nearby Nangasuruk region.

The stratigraphic section on the northern side of Sebilit and Boyan Rivers shows an alternating dark grey parallel laminated siltstone and planar foreset laminae of fine-grained sandstone in the lower part of this sequence (Figure 7). Additionally, the flaser and lenticular beddings were also exposed in adjacent area of Sebilit Rivers (Figure 8). These sedimentary structures appear to have been formed particularly on tidal flats and in subtidal environments, where conditions of current flow or wave action causing sand depositions alternate with slack-water conditions when mud is deposited (Boggs, 2010). The depositional environment of these sequences is a tidal flat area from supratidal to intertidal zone. The sedimentary unit is correlated with the Ketungau Formation in West Ketungau Basin.

The upper sequence of this facies is predominantly composed of alternating thin coal seam, coaly shale, and claystone. The sequence is exposed at a hill cut behind a local farm in Tanjung Harapan Village, Nangasuruk Subregency. Commonly, the dip of banded coal and coaly shale facies varies between 10^{o} - 32^{o} to the northeast. This section was interpreted as a marsh tidal flat until subtidal estuary environment with occasional low energy transport.

Tectonic Evolution

The paleogeography of Western Indonesia during Cretaceous - Early Tertiary (Figure 9) can be explained when the Schwaner granitoid Mountain and the highly deformed ophiolite and oceanic rocks as tectonic melange and broken formation from Sambas in the West to Mangkaliat in the East were formed due to westward subduction of South China Sea Plate beneath margin of Eurasian Plate.

Table 1. Paleontology Analysis of the Mudstone Facies of the Mandai Group

No	Location	Foram		Pollen	Ichno fossil	Depositional Environment
		Planktonic	Benthic			
1	09/MH/08			*Ilexpollenites* *Podocarpus* *Pteris* type *Verrucatosporites* *Palmaepollenites kutchensis* *Tricolporites* *Spinizonocolpites echinatus*		backmangrove
2	09/MH/11			*Avicennia* type Psilate trilete *Verrucatosporites* *Tricolporites* *Triporites*		mangrove
3	Downstream Sebilit Rivers, sample code: 09/ NO/ 17			1 Reticulate pollen 6 Trilete spore 1 Malvaceae 1 Grass pollen	*Thalassonoides* *Cylindrichnus* and *Palaeophycus*	Estuary or inter tidal
4	Upstream Boyan Rivers, sample code: 09 /MH /06		*Dentalina* sp., *Nonion* sp., *Lenticulina* sp., *Rectoglandulina comatula, Lagena lateralis, Marginulina marginuloides, Pseudonodosaria* sp., *Nodosaria* sp., *Lagena gracillina, Lenticulina* sp., *Oolina globosa*			Inner shelf – shallow middle shelf
5	Simpang Suruk Crossroad to Nangapayang Hill, sample code: 10 NO 30	*Acarinina soldadoensis (P.5 - P.9), Globigerina velasconensis (P.4 -P.6), Morozovella aequa (P.4 - P.6), Planorotalites pseudomenardii (P.4), Morozovella angulata (P.3 - P.4).*	*Quinqueloculina* sp., *Sigmoilopsis* sp., *Nodosaria* sp., *Uvigerina* sp., *Textularia* sp., *Anomalinella* sp., *Ammodiscus* sp., *Lagena* sp		*Rosalia, Skolithos*	Inner Shelf to shallowest open marine, age of this facies is late paleocene (Thenetian)
6	10 NO 27		*Lagena* sp, *Quinqueloculina* sp., *Sigmoilopsis* sp., *Ammodiscus* sp, *Anomalinella* sp., dan *Eponides.*,			Inner Shelf to shallowest open marine

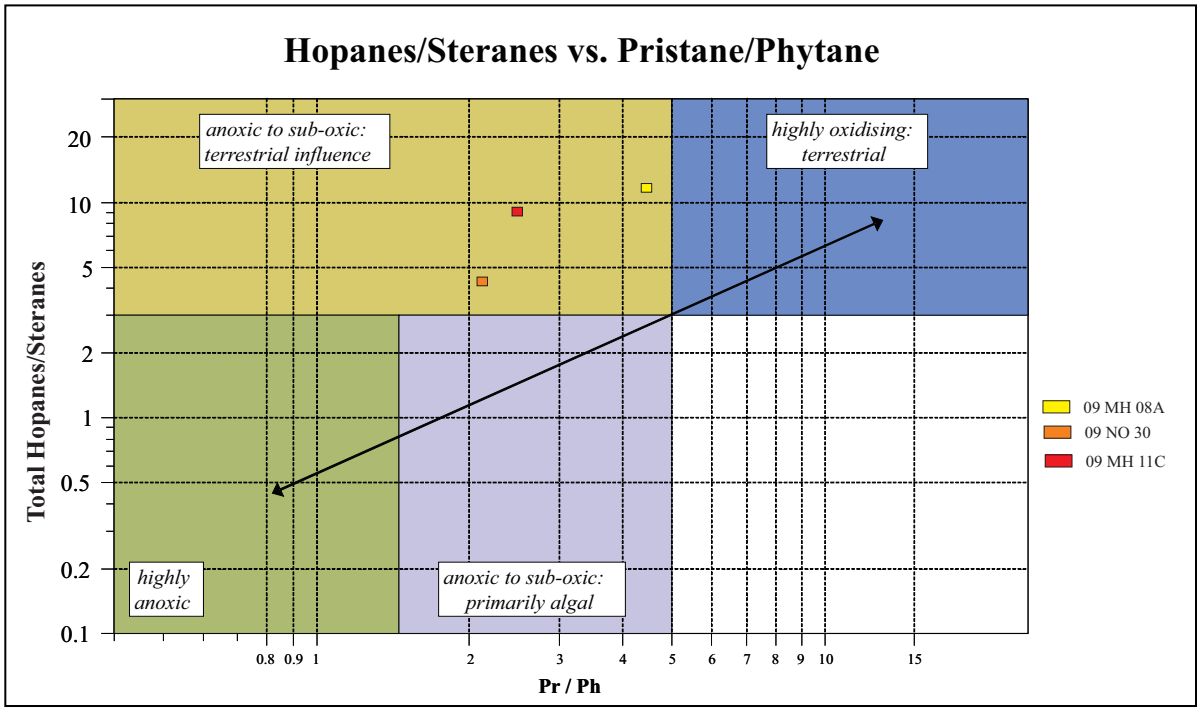

Figure 3. Ratio of hopanes/steranes *vs.* Pr/Ph, showing anoxic to sub-oxic condition of mudstone facies of the Mandai Group (Hermiyanto and Suyono, 2011).

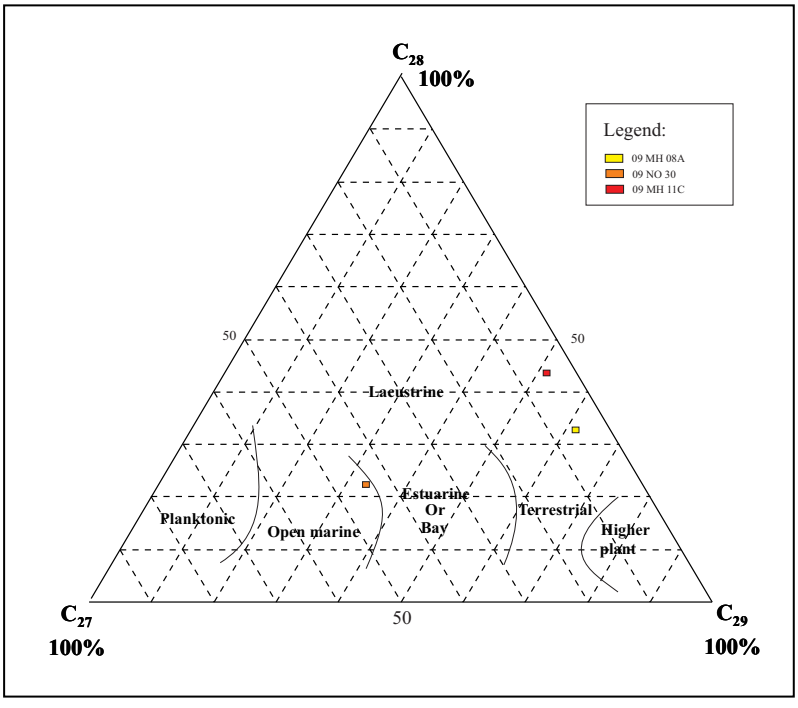

Figure 4. Ternary diagram of sterane that shows depositional environment of fine sediments of Mandai Group (Hermiyanto and Suyono, 2011).

Figure 5. Photograph of clean sand deposits possibly derived from Schwaner granite and metamorphic basement of Schwaner Mountains middle part of Mandai Group.

Figure 7. Photograph of alternating dark grey parallel laminated siltstone and planar foreset laminae of fine- grained sandstone of the upper part of Mandai Group.

Figure 6. Photograph of parallel laminated siltstone and mudstone with thin coal seam of the upper part of Mandai Group.

Figure 8. Photograph of flaser and lenticular bedding of upper part of Mandai Group cropping out at adjecent area of Sebilit River.

In the Sintang (Heryanto *et al*., 1993) and Putussibau (Pieters *et al*., 1993) geological maps, the Boyan Melange is widely exposed from Nanga Tepuai to Boyan. The melange consists of fragments and blocks of sandstone, chert, schist, serpentinite, mudstone, diorite, basalt, and limestone embedded in a highly cleaved and pervasively sheared chloritized pelitic matrix (Harahap, 1995).

During Late Cretaceous to Early Tertiary, two phases of sedimentation occurred in the East Ketungau Basin. The first phase of sedimentation was present throughout the Late Cretaceous when the shallow to deep marine Selangkai Formation filled fore-arc basins of West and East Ketungau depressions. The Selangkai Formation and Busang Complex are interpreted as the basement of the East Ketungau Basin. The Mandai Group unconformably overlies the Selangkai Formation during Early Tertiary in the East Ketungau Basin, following 50° of anticlockwise rotation of Kalimantan (Tjia, 2012) and an extensional phase at the north side. The last deformation in western Kalimantan may be represented by the Sintang Intrusive which was derived from an arc magmatism and produced by melting of the young South China Sea crust in the Late Oligocene to Early Miocene (Hartono and Suyono, 2006).

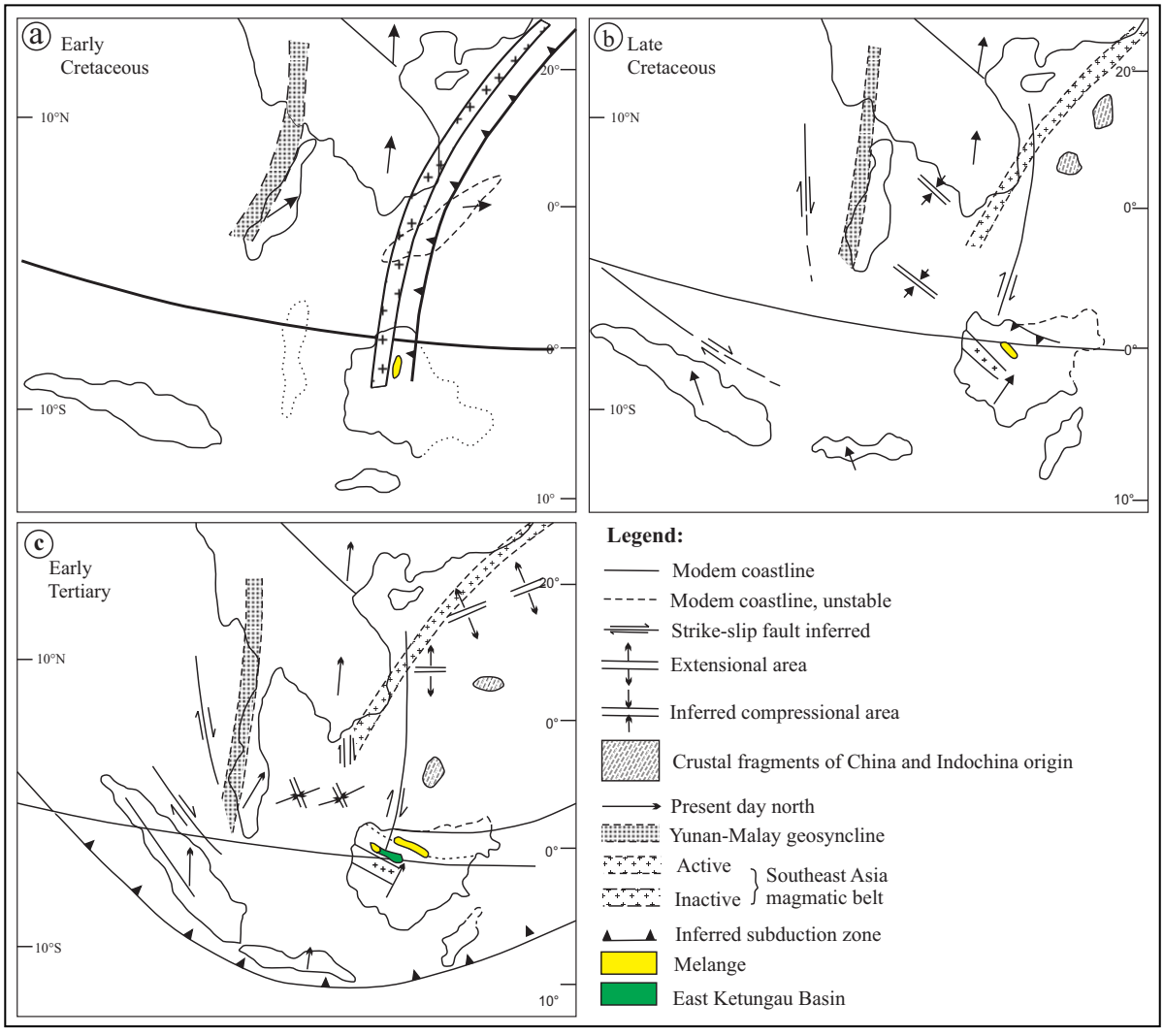

Figure 9. Paleogeographic recontructions showing a major N-W transform fault during the Late Cretaceous and Early Tertiary in NW Borneo (modified from Taylor and Hayes, 1983).

Discussion

Based on present data, the stratigraphy and tectonic history of West Kalimantan from Early Cretaceous to Tertiary suggest the development of the East Ketungau Basin including West Ketungau and Melawi Basins started during the Palaeogene.

During the Palaeogene, the Kantu Formation, Tutoop Sandstone, and Ketungau Formation accumulated in the western part of the Ketungau Basin. During this period, the eastern part was predominantly being filled by the deposition of the Mandai Group sediments with mudstone facies, 'clean sand' facies, and alternating sandstone and mudstone facies with thin coal seams (Figure 10).

The Mandai Group sediments consist of three facies where each facies has a typical characteristic depositional environment of barrier- island and associated strand-plain system. The three facies can be elaborated as follows:

The mudstone facies is typically parallel laminated grey to reddish siltstone and claystone with thin carbonaceous layers and alternation of dark grey shallow marine silty mudstone and very- fine grained well- sorted sandstone. The rock sequence which is rich in trace fossils, pollen, and foramin-

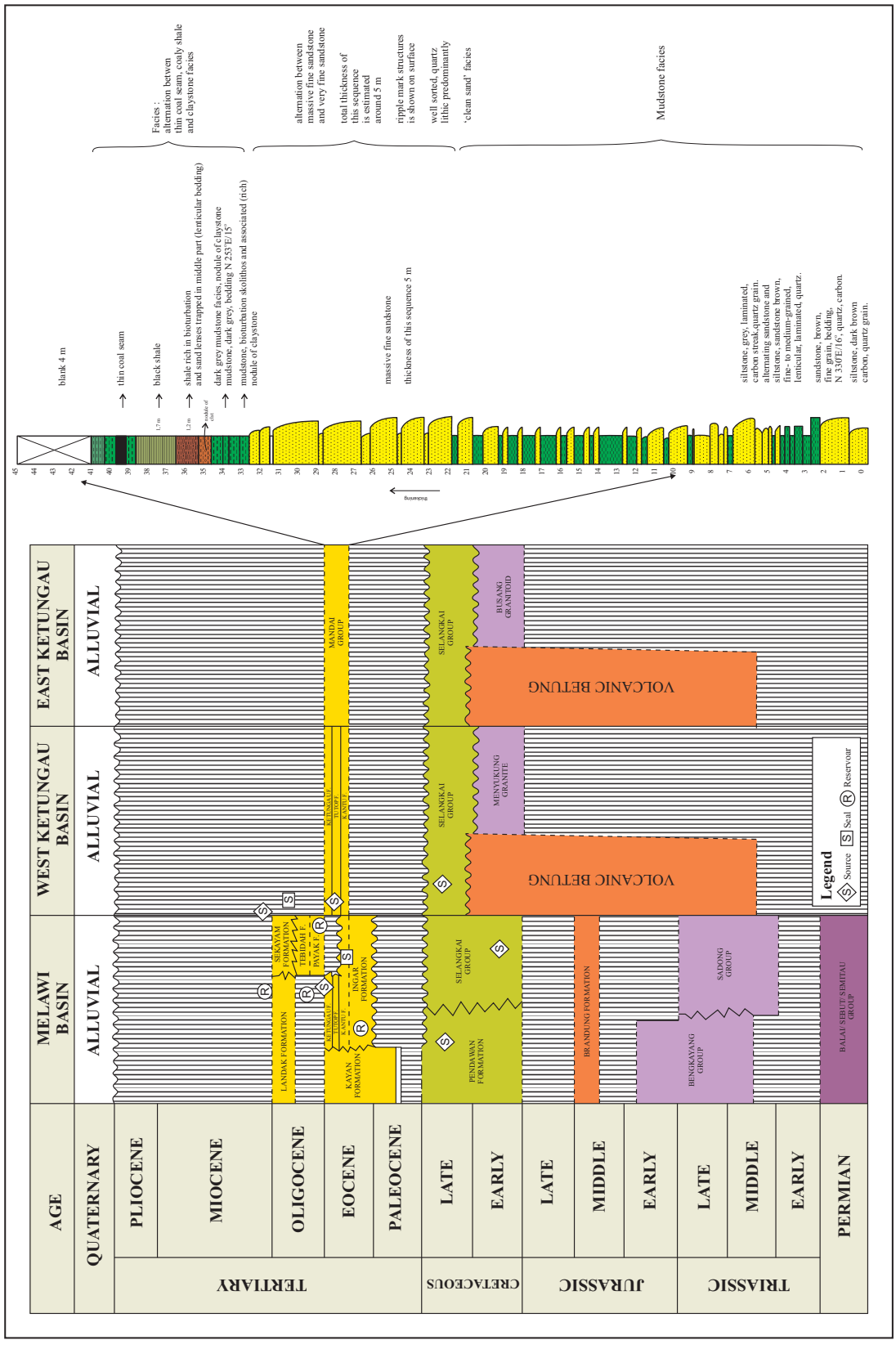

Figure 10. Stratigraphic Column of the Mandai Group Sediments at East Ketungau Basin and compared with West Ketungau and Melawi Basins

ifera, indicates a shallow open marine to a subtidal lagoon environment.

The 'clean sand facies' being the middle part of Mandai Group sediments is characterized by white to brown quartz sandstone, medium- to coarse-grained and well-sorted sandstone showing massive and well bedded sandstone, with scour structure, cross stratification, and locally mud drapes develops. This facies was deposited as a barrier bar sequence, in a tidal flat environment, exposed to wave-action and storm currents with occasional high energy transport.

The alternation between thin coal seam, coaly shale, and claystone facies forms the upper part of the Mandai Group sediments. This section is interpreted as a marshy tidal flat up to subtidal lagoon environment with occasional low energy transport.

Conclusion

The East Ketungau Basin was formed from the Late Cretaceous to the Late Eocene, when the fore-arc sediments of the Selangkai Formation was filling this basin. The Mandai Group sediments which consist of the mudstone facies in lower part, 'clean sand' facies in the middle, and alternating thin coal seam, coaly shale, and claystone facies as the upper part unconformably overlies the Selangkai Formation. The three facies of this group suggest as barrier island deposits associated with a depositional strand plain system.

In addition, the stratigraphic succession of the East Ketungau Basin has similar characteristic and lithologic distribution as the West Ketungau Basin and Melawi Basin in the south. Those formations overly the Pre-Tertiary Selangkai Formation during Palaeogene.

Finally, seismic and other geophysical studies of the Gunung Menyukung area need to be carried out in order to correlate the stratigraphy between the West and East Ketungau Basins and the tectonic events of the Boyan and Lubuk Antu mélanges.

Acknowledgments–It would not have been possible to finish this paper without the assistance of the working group responsible for the Indonesian Sedimentary Basin Atlas, Centre for Geological Survey (Pusat Survei Geologi) and reviewers of the Indonesian Journal of Geology. Thanks are due to Dr. R. Sukhyar and Dr. Yunus Kusumabrata for a permission to publish this paper.

References

Boggs, Jr., S., 2010. *Petrology of sedimentary rocks*, Second Edition. Lambridge University Press, Cambridge, 612pp.

Charlton, T.R., 2000. Tertiary evolution of the eastern Indonesia collision complex. *Journal of Asian Earth Sciences,* 18, p.603-631.

Conybeare, C.E.B. and K.A.W. Crook., 1986. Manual of sedimentary structures. *Bureau of Mineral Resources Australia Bulletin*, 102, p.327.

Haile, N. S., 1978. 'Reconnaissance palaeomagnetic results from Sulawesi, Indonesia and their bearing of the palaeogeographic reconstruction'. *Tectonophysics*, 46, p.77-85.

Hall, R., 1996. Reconstructing Cenozoic SE Asia. In: Hall, R. and Blundell, D.J., (Eds.), *Tectonic evolution of Southeast Asia, Geological Society of London*, p.153-184.

Hamilton, W. 1979. Tectonics of the Indonesian Region. U.S. *Geological Survey Professional Paper*, p.345-1078.

Harahap, B.H., 1995. The Boyan melange West Kalimantan, origin and tectonic environment. *Bulletin of the Geological Research and Development Centre*, Bandung.

Hartono, U. and Suyono, 2006. Identification of Adakite From The Sintang Intrusive in West Kalimantan. *Journal of Geological Resources*, 16, p.173-178.

Hermiyanto, G.M. and Suyono, 2011. Organic Geochemistry and Rock Eval Pyrolysis of Eocene fine Sediments, East Ketungau Basin, West Kalimantan. *Indonesian Journal of Geology*, p.95-104.

Heryanto, R., William, P.R., Harahap, B.H., and Pieters, P.E., 1993. *Geology of the Sintang Sheet area, scale 1 : 250.000*. Geological Research and Development Centre*, Bandung*.

Lee, Y. T. and Lawyer, A. L., 1995. Cenozoic plate reconstruction of Southeast Asia. *Tectonophysics*, 251, p.85-138.

Pieters, P.E., Surono, and Noya, Y., 1993. *Geology of the Putussibau Sheet area, scale 1: 250.000*. Geological Research and Development Centre, Bandung.

Rangin, C., Dahrin, Pubellier, R M., and the Tethys working group, 1990. A simple model for the tectonic evolution of Southeast Asia and Indonesia region for the past 43 m.y. *Geology Society of France*, 6, p.889-905.

Taylor, B. and Hayes, D.E., 1983. Origin and history of the South China Sea Basin. The tectonic and geologic evolution of southeast Asia Seas and island, part 2. In: Hayes, D.E. (Ed). *Geophysical Monographs of American Geophysic Union, Washington,* 27, p.23-56.

Tjia, H.D., 2012. The Paleo-Orientations of Northwestern Borneo and Adjacent South China Sea Basin. *Indonesian Journal of Geology*, 7, p.67-76.

Williams, P.R. and Harahap, B.H., 1987. Preliminary Geochemical and Age Data From Postsubduction Intrusive Rocks, Northwest Borneo. *Australian Journal of Earth Sciences,* 34, p. 405-415.