LITOSTRATIGRAPHIC AND SEDIMENTOLOGICAL SIGNIFICANTS OF DEEPENING MARINE SEDIMENTS OF THE SAMBIPITU FORMATION GUNUNG KIDUL RESIDENCE, YOGYAKARTA

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ABSTRACT

Sambipitu Formation in the Southern Mountains plays an important role due to its stratigraphic position, between syn-volcanism and post- volcanism periods. The formation widely distributes along the southern slope of the Baturagung Mountains, Gunung Kidul Residence, Yogyakarta Province.

Stratigraphically, the Sambipitu Formation is conformably underlain by dominated unit of volcanic breccias of the Nglanggran Formation, and conformably overlain by dominated unit of marl of the Oyo Formation.

Based on detail section along the river of Ngalang, the Sambipitu Formation can be divided into Lower and Upper Members. The Lower Member is dominated by sandstone and siltstone, which is alternated by breccias. The Upper Member is dominated by siltstone and mudstone, which is intercalated by sandstone, marl and conglomerate. The Lower Member was deposited on an environment influenced by tidal current, which was highly affected by gravity flows of volcanic material. This deposition environment was getting deeper to be an inner shelf, where the Upper Member was deposited.

Furthermore, based on Rock-eval pyrolysis, TOC value of the Sambipitu Formation ranges from 0.08% to 0.43%, whilst the PY (potential yield) value less than 0.15 mg HC/g rock. Thus, on the basis of those two parameters, the Sambipitu Formation is included into oil prone source rock potential of poor category. Moreover, Tmax value of the Sambipitu Formation ranges from 226°C - 335°C, with the HI (hydrogen Index) value varies from 0 – 12. It indicates that this formation contains kerogen Type III. Therefore, the organic thermal maturation based on plotting of Tmax vs HI, this formation falls into an immature category.

Key word: Lithostratigraphy, volcanic material, tidal flat, inner shelf, and Sambipitu Formation.

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SARI

Formasi Sambipitu memegang peran penting karena posisi stratigrafinya yang terletak diantara perioda volkanisme dan pasca volkanisme. Formasi ini tersebar luas di lereng selatan Pegunungan Baturagung, Kabupaten Gunung Kidul, Provinsi Daerah Istimewa Yogyakarta. Formasi Sambipitu menindih selaras Formasi Nglanggran dan ditindih selaras oleh Formasi Oyo.

Berdasarkan penampang stratigrafi rinci sepanjang Sungai Ngalang, Formasi Sambipitu dapat dibagi menjadi: Anggota Bawah dan Anggota Atas. Anggota Bawah didominasi oleh perselingan batupasir dan batulanau, dengan sisipani breksi gunung api. Sedangkan Anggota Atas didominasi oleh batulanau dan batulumpur dengan sisipan batupasir dan konglomerat. Anggota Bawah diendapkan di lingkungan paparan pasang-surut yang dipengaruhi oleh pengendapan material gunung api. Paparan pasang-surut itu semakin dalam menjadi paparan dalam dimana diendapkan Anggota Atas.

Berdasarkan analisis Rock-eval pirolisis, nilai kandungan karbon total (TOC) serpih Formasi Sambipitu berkisar 0,08% – 0,43%, sedangkan Potential yield (kandungan cairan hidrokarbon) kurang dari 0,15 mg HC/g batuan. Berdasarkan dua parameter tersebut diatas, formasi tersebut termasuk kedalam kategori oil prone source rock, dengan kategori buruk (poor). Formasi Sambipitu mempunyai nilai temperatur maksimum (T_{max}) antara 226℃ - 335℃, dengan nilai HI (Hydrogen Index) kurang dari 12, menunjukkan formasi ini memiliki kerogen tipe III. Berdasarkan diagram temperatur maksimum (T_{max}) terhadap nilai indeks hidrogen (HI) bahan organik, kematangan organik dari formasi ini termasuk ke dalam tingkat belum matang.

Kata kunci: Litostratigrafi, material volkanik, paparan pasang-surut, paparan dalam, dan Formasi Sambipitu.

INTRODUCTION

The study was carried out based on outcrops of the Sambipitu Formation, mainly along the Ngalang River, which is one of the Oyo River tributaries. The river flows southward crossing the north flank of the Baturagung Mountains. This area is a part of the residence of Gunung Kidul, Yogyakarta Special Province, located in Southern Mountains

Southern Mountains is situated along the southern part of Jawa Island. The mountains are formed by mixture of clastic sediments, carbonates and volcanic materials. Stratigraphically, the Southern Mountains can be divided into three major periods of sedimentary processes, those are pre-volcanism, syn-volcanism and post-volcanism periods. Sambipitu Formation, named by Bothe (1929), is a lowest unit in the post-volcanism sequence. This formation is spread along the southern slope of the Baturagung Mountains (Figure 1).

Stratigraphically, the Sambipitu Formation is conformably underlain by dominated unit of volcanic breccia of the Nglanggran Formation (Figures 2 and 3). The formation is overlain by dominated unit of marl of the Oyo Formation. The lithostratigraphy of Sambipitu Formation indicates as transitional zone between the volcanic activity and carbonate sedimentary process, this formation is mixed by volcanic clastic and carbonate sedimentary products (Surono, et al, 1992).

Purposes of the study are to recognize lithological variation and to establish stratigraphic position of the Sambipitu Formation, related to sedimentological processes. The study also evaluates the organic maturity and their implication to the potential source of the formation.

Methods

Achieving the aims of the study, the fieldworks and laboratory activities were

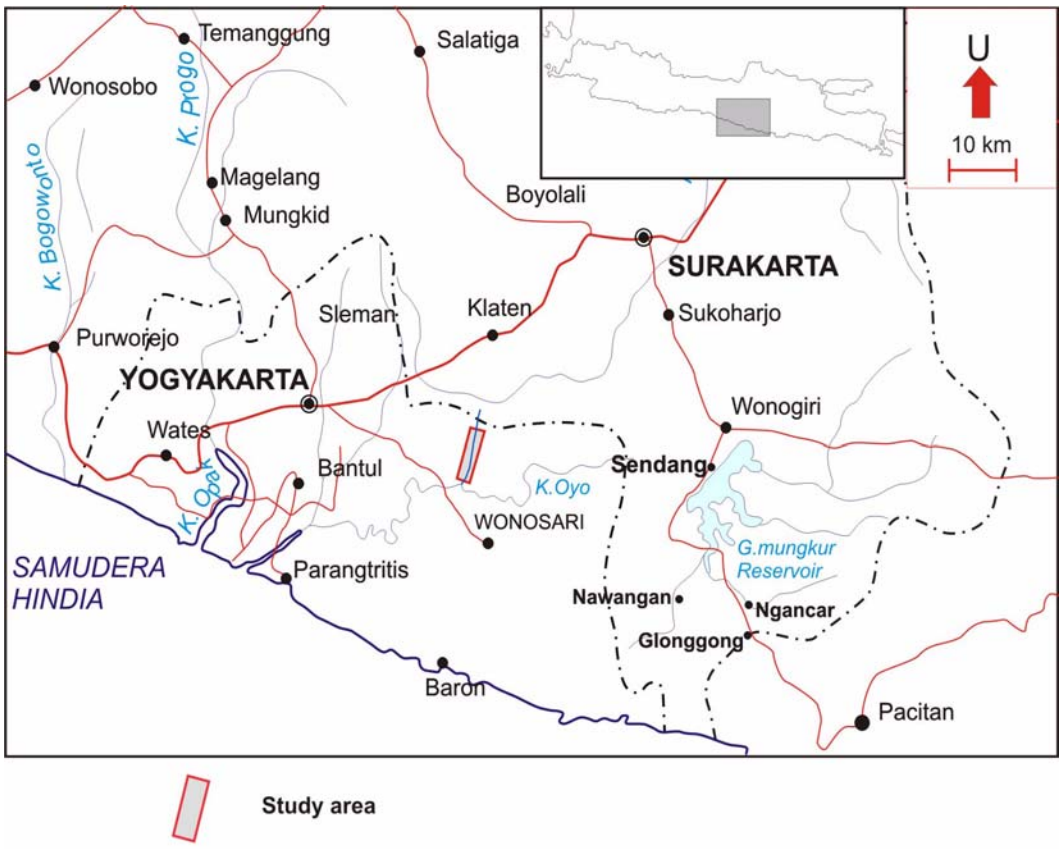

Figure 1. Location of the study area.

performed that is mainly used organic geochemistry of clastic sediments taken from the Sambipitu Formation. About 315 meters thickness of detail section had been done along the Ngalang River. The section crossed the Sambipitu Formation about 223 meters length (Figure 3). Petrographic and paleontological analyses have been carried out at the Geol*Labs*, Centre for Geological Survey, Agency of Geology; Bandung. For the purpose of hydrocarbon potential evaluation, six samples had also been analyzed by rock-eval method at "Lemigas" Laboratory, Jakarta

RESULTS

Field Features

The Ngalang River, which is a tributary of Oyo River, flows toward south and crosses the southern slope of the Baturagung Mountains. This river crosses a rough morphology in its upper course, that is mainly composed of tuff series of the Semilir Formation and volcanic breccias of the Nglanggran Formation. In the lower course of the river, lithologies consist dominantly of soft material, that are formed the Sambipitu and Oyo Formations. Consequently, the morphology is getting smoother and flatter at the lower course. The

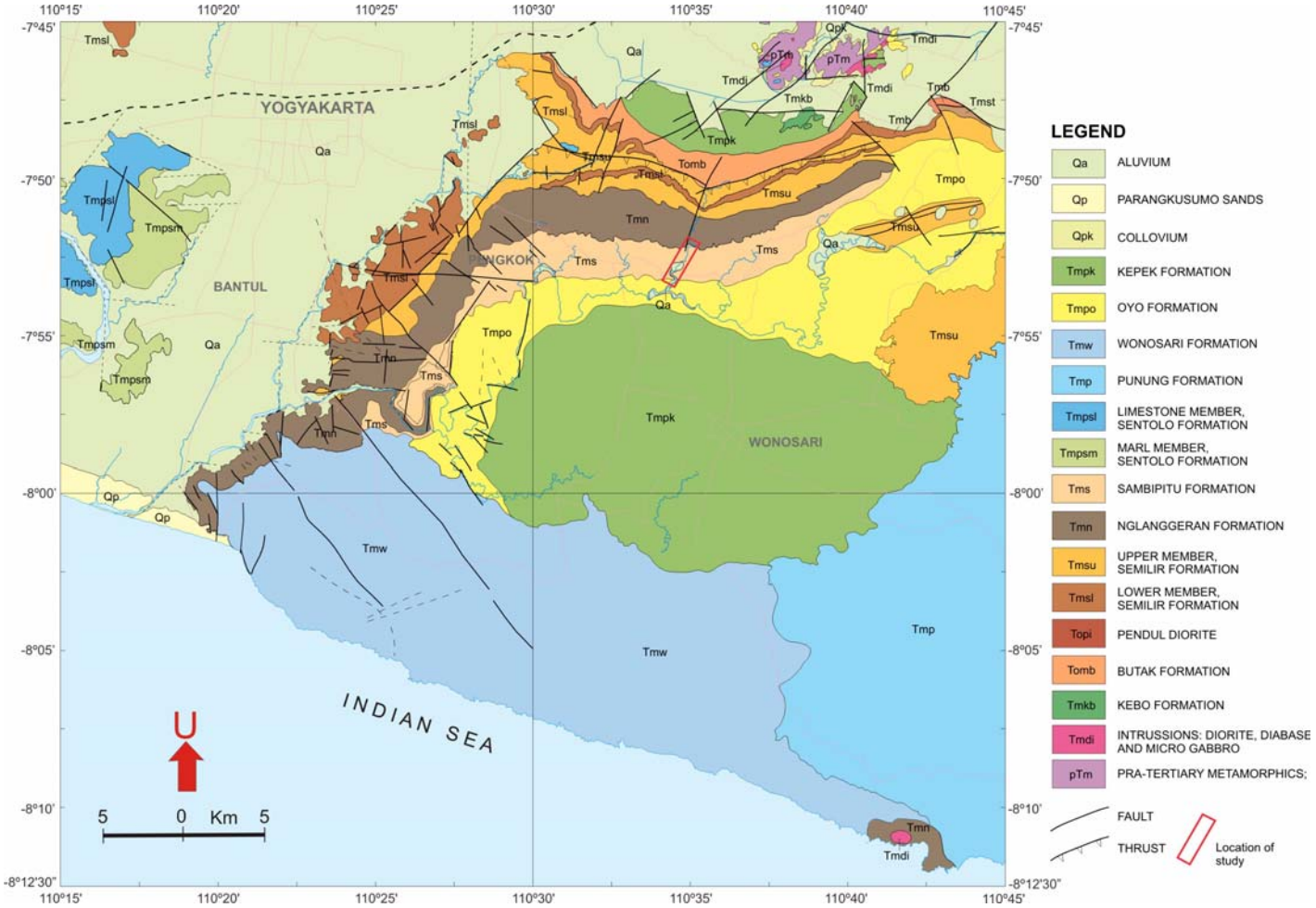

Figure 2. Geological map of the study area, simplified from Margono *et al*. (2009, in prep.) and Fakhruddin *et al.* (2009, in prep.).

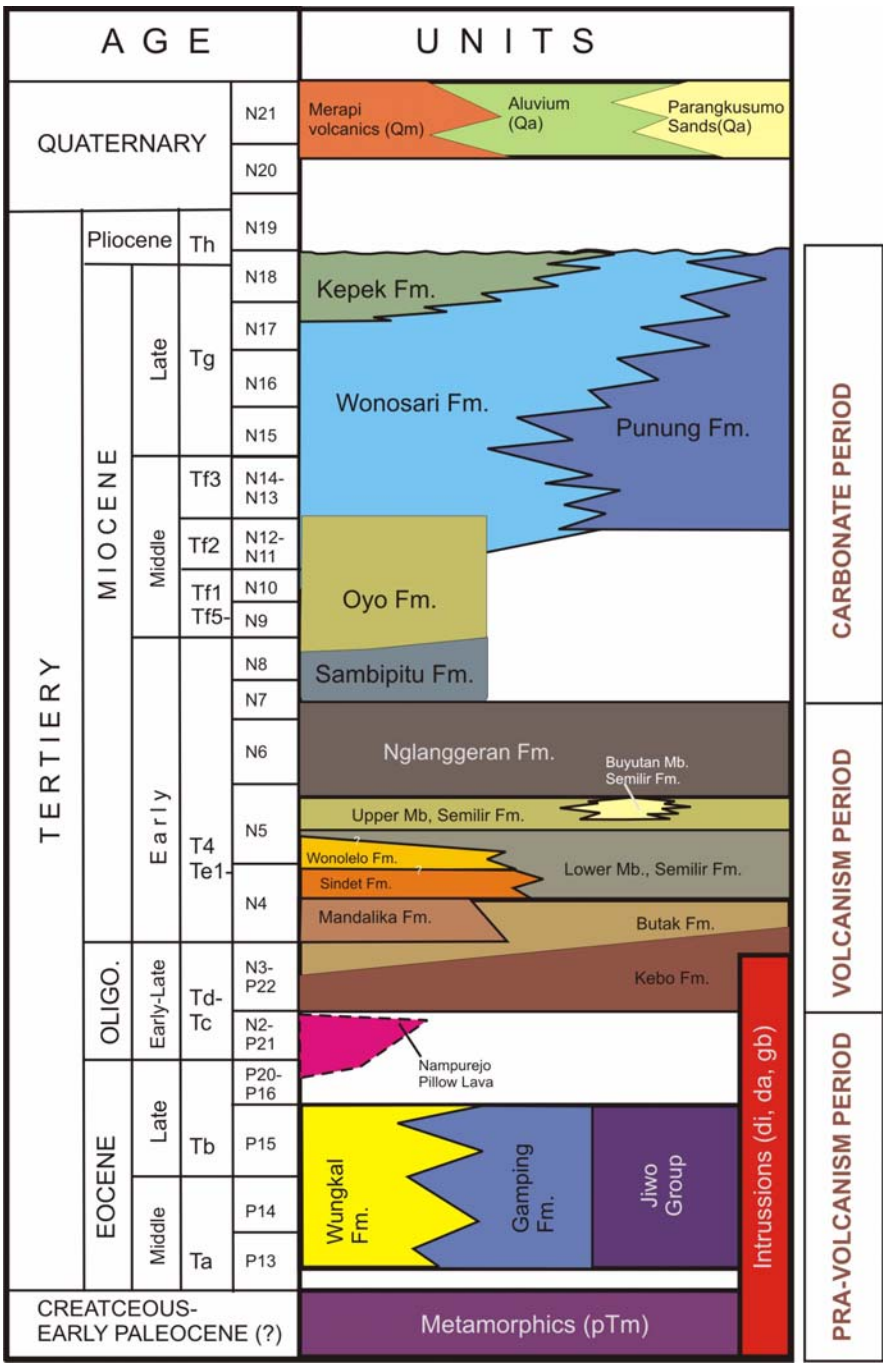

Figure 3. Stratigraphy of the study area.

selected section used for the present study had been done in this lower course.

The Ngalang River passes the Sambipitu Formation from its lowest to uppermost parts. Outcrops of the formation well exposes along the river banks and its base. Commonly, lithologies formed the Sambipitu Formation are well bedded, and thickness range from 0.2 to 4 meters. Dips of the beds commonly vary from 8^o to 15^o. Mostly, this river crosses bedding strikes of the formation. There are only few minor faults crossing the outcrops. During the dry seasons (May-August) the river only has a few water at its bottom.

Lithostratigraphy

Lithologically, the Sambipitu Formation can be divided into Lower and Upper Members (Figure 4). It is well cropped out along the Ngalang River and dominated by alternation of sandstones, siltstone, mudstone, and shale. The Lower Member is characterized by volcanic breccias intercalation. On the other hand, the Upper Member is indicated by conglomerate in the lower portion and calcareous sediments in the upper portion.

Lower Member of the Sambipitu Formation

The Lower Member (85 meters thickness) of the Sambipitu Formation is conformably underlain by Nglanggeran Formation, which is dominated by agglomerate and volcanic breccia (Figure 5). Sandstone and siltstone (mudstone or shale) appear as dominant portion in the lower part. Several beds of volcanic breccias intercalate the lower part.

Commonly, sandstones are grey, fine to coarse grained, well bedded, and 0.15 – 1.2 meters thickness. Their fragments are volcanic rocks, sub rounded-rounded and well sorted. However some beds, especially in the lower portion, are poorly sorted, pebbly and have coal fragments.

Siltstone, mudstone and shale are brownish grey to grey, and well bedded. Their thicknesses vary from few millimeter to 0.6 meter. Some very thin coal beds (<1 millimeter) have been found within the series.

Breccias are grey, composed of subangular to subrounded andesite fragments (5 to 20 centi meters diameter). The thicknesses of breccias are vary from 0.5 meter to 3.5 meters.

Sedimentary structures within the Lower Member are erosion surfaces, normal gradded, planar cross-beds, parallel lamination, wavy beddings, lenticular beds, bioturbations, and burrows. Erosion surface has been detected under sandstone layer. Coal, shale fragments and very thin layers of intercalated coals are found in some places.

Upper Member of the Sambipitu Formation

The Upper Member of the Sambipitu Formation is mainly consisted of a fine-grained sequence intercalated by conglomerate, marl and limestone in the uppermost part. Thickness of the Upper Member is about 138 meters (Figure 6).

Sandstones within the Upper Member of the formation are well bedded, and 0.2 to 1 meter thickness. Their fragments are mostly volcanic rocks, sub rounded to rounded and well sorted.

Similar to the Lower Member, siltstone, mudstone and shale within the Upper Member of the Sambipitu Formation are brownish grey to grey, and well bedded. Their thicknesses vary from few millimeter to 0.6 meter. Very thin coal layers (<1 mm) have been found within the member.

There are three beds of conglomerate in the Upper Member of the Sambipitu Formation. The conglomerate beds are underlain by erosion surfaces, and the thickness is about 1.3 meters. Their fragments are subrounded to rounded, fining upward, and dominated by volcanic materials.

Marl and limestones are very common intercalations in the upper portion of the Upper

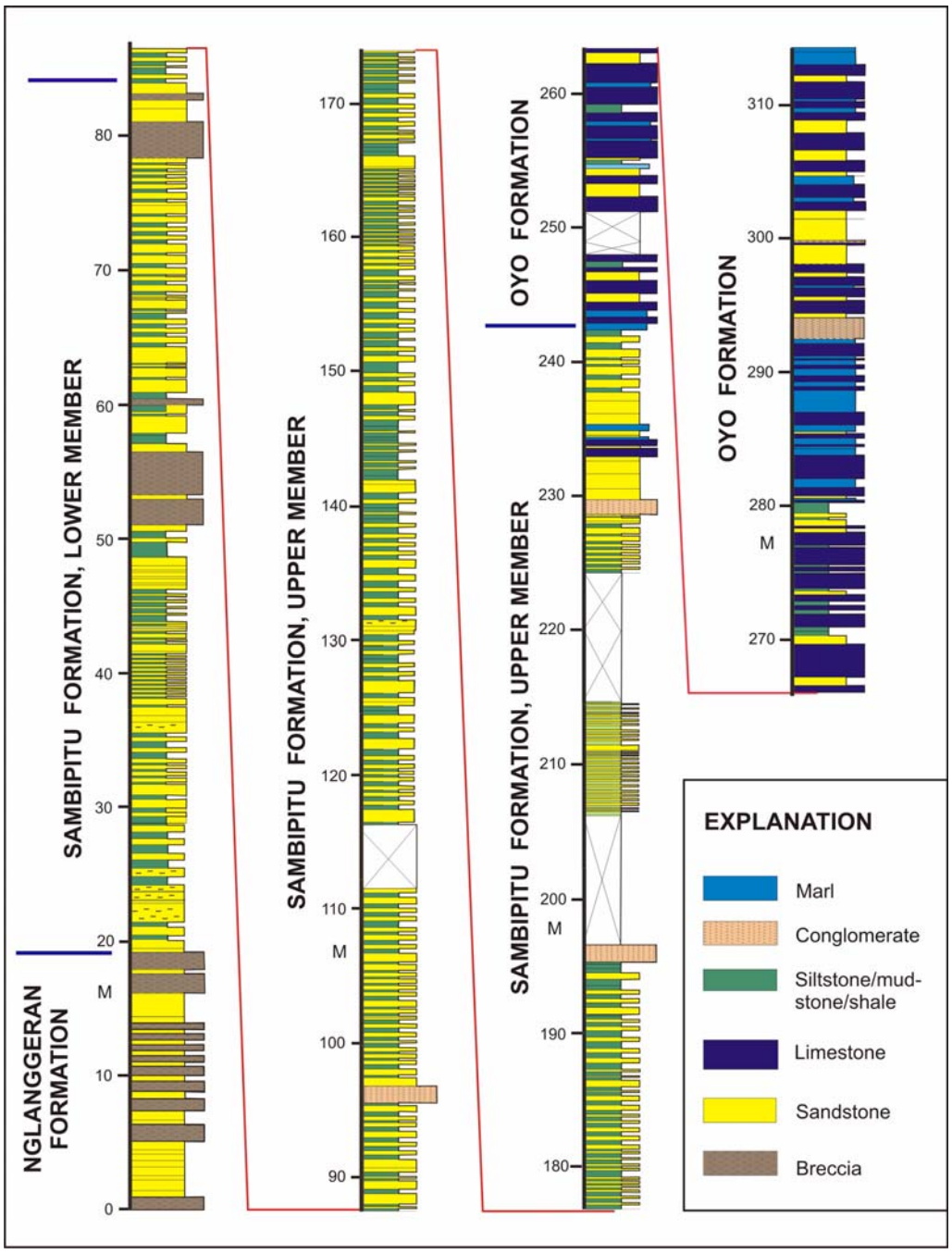

Figure 4. Relationship between the Sambipitu Formation with underlaying unit of the Nglanggeran and overlaying unit of the Oyo Formation.

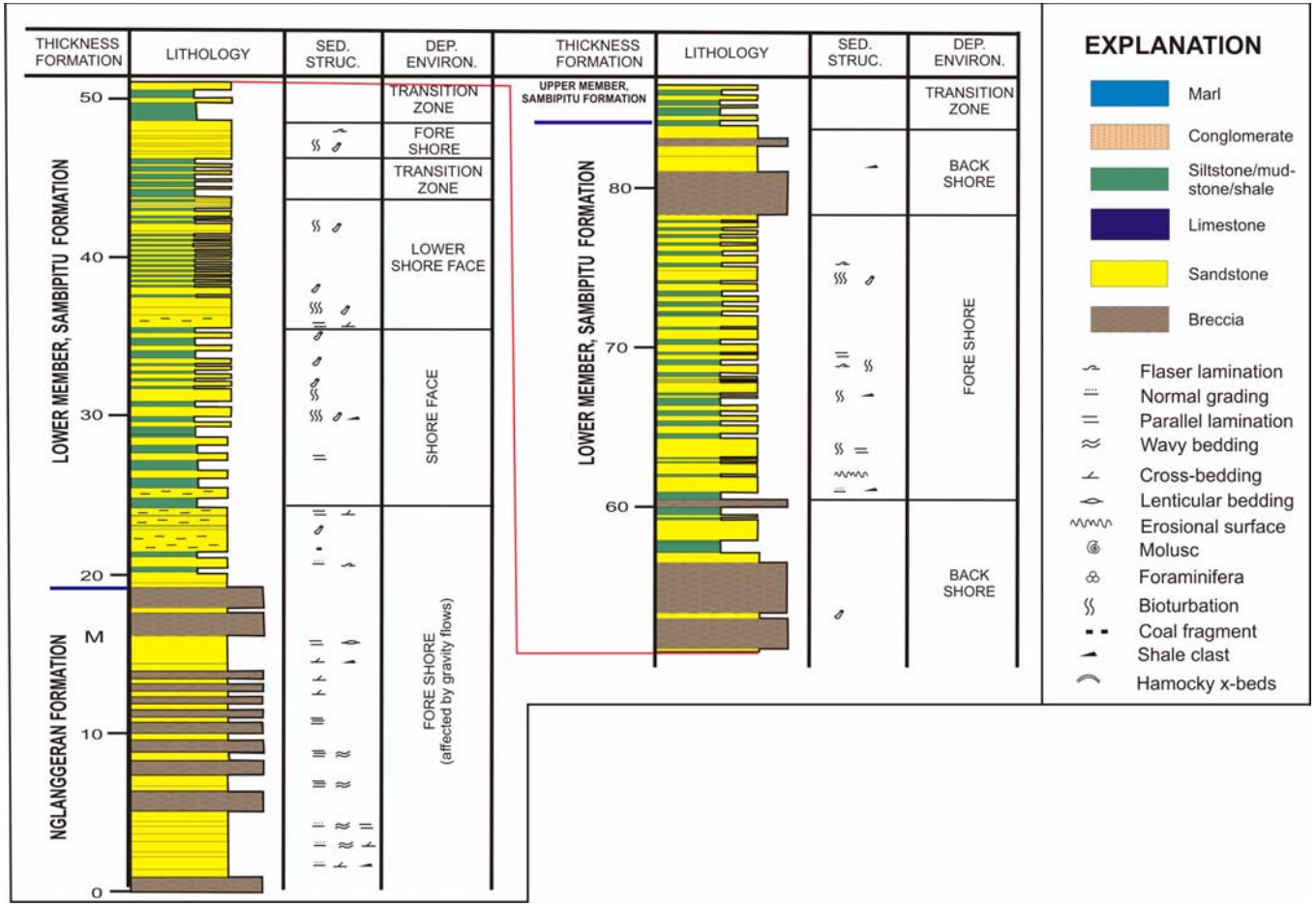

Figure 5. Lithological composation of the Lower Member of the Sambipitu Formation.

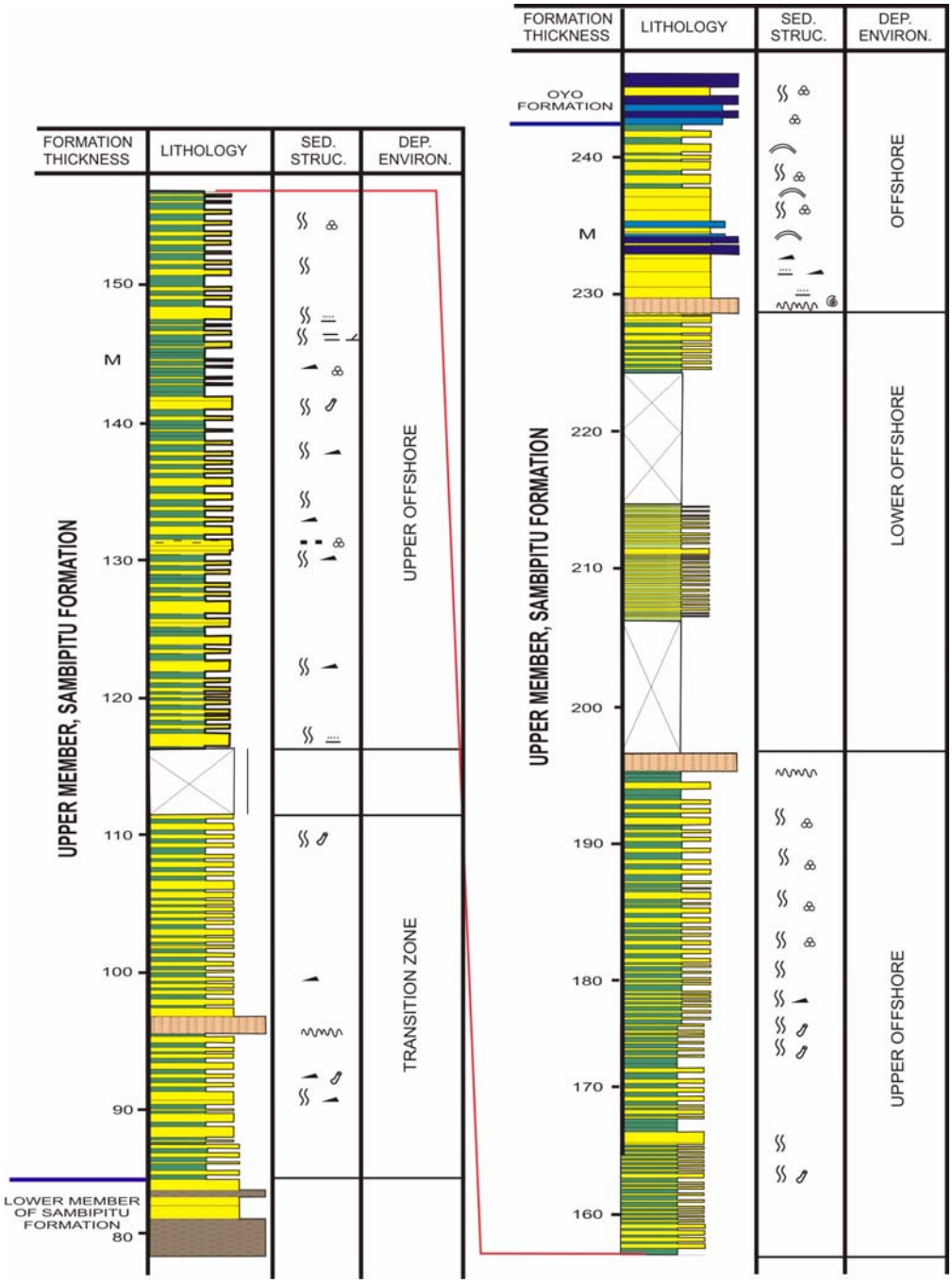

Figure 6. Lithological composation of the Upper Member of the Sambipitu Formation.

Member. They are well bedded and 0.2 to 0.60 meter thickness. The limestones are mostly white and wackstone type.

Sedimentary structures within the Upper Member of the Sambipitu Formation, are borrows, bioturbations, gradded bedding, shale clasts, planar cross-beds, parallel lamination, and erosion surfaces (Figure 6). Coal fragments and mollusks have been found, especially on erosion surfaces. Bioturbation and shale clasts have distributed to the entire part. Foraminifers are commonly existed, especially within the upper portion. Erosion surfaces take place underneath conglomerate beds and very thin intercalated layers of coal also found.

A g e

Fossil of the Lower Member of the Sambipitu Formation is rare but foraminifers found abundantly in the Upper Member. Based on paleontological analyzes of 11 samples from Upper Member (Table 1), it shows that the planktonic foraminifers, especially index fossil of *P. glomerosa* is classified as N8 age (latest Burdigalian–early Langhian) or latest Early Miocene. The Oyo Formation, which conformably overlies the member, has an age of N8 to N11 (latest Burdigalian to early Serravillian) or latest Early Miocene to Middle Miocene. On the other hand, Bothe (1929) determined this formation as Middle Miocene based on large foraminifers that are found very abundantly. It is, probably, he collected younger age for the formation. Moreover, according to *Suyoto (1992)* the age of the Sambipitu Formation of N7-N9 or Early – Middle Miocene based on small foraminifers. Therefore, it is very important to determine the contacts between the Sambipitu Formation and the both underlying and overlaying formations.

Samples taken from the Sambipitu Formation (Table 1) are located within the Upper Member. U-Pb dating of the Semilir Formation (Smyth *et al*., 2003) indicates that the formation has a 19-20 Ma ages. The Semilir and Nglanggran Formations were deposited in very short time, about one million years (Smyth *et al*., 2005). If this interpretation is right, the Lower Member of the Sambipitu Formation probably was started to be deposited in 17-18 Ma years or N7 (latest Burdigalian). However, Fakhruddin (2009), found first appearance of index pollen fossil (*Florschuetzia meridionalis*) that is interpreted as Late Burdigalian (similar to early N8). Thus, the age of the Sambipitu Formation is N7-N8 or latest Early Miocene.

Organic Maturity and Potential Source

Six samples were collected from the Ngalang River Section of the Sambipitu Formation for Rock-Eval pyrolysis analysis (Table 2). Based on Rock-Eval pyrolysis, total organic carbon (TOC) content of shale of the Sambipitu Formation varies from 0.08% to 0.43%. The Sambipitu shale has a potential yield from 0.01 to 0.15 mg HC/g rock. Plotting on the TOC versus Potential Yield on the Rad Diagram (1984), the Sambipitu Formation tends to indicate to be a poor source rock (Figure 8).

The maximum temperature (Tmax) data indicate that the Sambipitu Formation is characterized by the Tmax varying from 226°C to 335°C. Moreover, based on Hydrogen Index (HI), organic matter from the Sambipitu Formation having HI from 0 to 12 indicate a Type III kerogen. The maximum temperature (Tmax) versus Hydrogen Index (HI) diagram (Figure 7) shows that thermal maturity of the organic matter from the four formations tends to occur an immature zone.

Evaluating the results of the geochemical analyses conducted on mudstone and siltstone, it can be summarized that the Sambipitu Formation are strongly assumed as a poor potential for source rock of petroleum.

Table 1. Foraminifers within the Upper Member of the Sambipitu Formation and the Oyo Formation.

FORMATIONS	SAMPLES	ZONE	*Globigerinoides immaturus*	*G. scitula scitula*	*G. sacculifer*	*G. subquadratus*	*G. diminutus*	*G. sicanus*	*G. bisphericus*	*Globorotalia peripheroronda*	*G. continuosa*	*G. birnageae*	*G. siakensis*	*G. mayeri*	*G. praescitula*	*G. archeomenardi*	*G. praemenardi*	*G. obesa*	*G. peripheroacuta*	*G. lobata*	*G. peripheroacuta*	*Globigerina venezuelana*	*G. praebulloides*	*Globoquadrina praedehiscens*	*G. altispira*	*G. dehiscens*	*Praeorbulina transitoria*	*P. glomerosa*	*Orbulina universa*	*Hastigerina praesiphonites*	*Cassigerinella ciphoIensis*
FORAM ZONATION (Blow, 1969)				N9 - Res			N7 - N8	N8 - N9	N7 - N8	N6 - N10		N7 - N9			N5 - N9	N6 - N10	N10 - N12		N9 - N10	N11 - N12	N9 - N10			N3 - N6			N7 - N8	N8	N9 - Recent	N7 - N13	
Oyo Formation	06 RF 101 R1	N11	■			■			■				■					■							■						
	06 RF 101 Q					■				■	■	■	■	■							■								■	■	
	06 RF 101 N		■			■				■	■		■	■			■	■		■	■								■		
	06 RF 101 J	N10	■	■		■				■			■	■			■		■						■				■	■	
	06 RF 101 G		■			■				■				■			■				■				■	■			■		
	06 RF 101 D	N9	■		■					■				■				■				■	■		■				■	■	
	06 RF 101 A	N8	■			■	■		■	■	■		■										■		■			■			
	08 AP 79		■			■	■	■	■	■		■										■				■	■	■			
Upper Member Sambipitu Fm.	08 AP 70		■			■		■		■		■	■		■										■		■	■			
	08 AP 62		■		■	■	■	■	■			■	■	■	■							■	■		■	■				■	
	06 RF 102 G		■		■	■	■	■		■	■	■	■												■		■			■	
	08 AP 60		■		■	■	■		■			■	■	■								■			■		■	■		■	■
	08 AP 58					■			■		■	■	■	■		■		■				■	■		■						■
	08 AP 55		■		■	■					■	■	■	■				■					■		■	■				■	
	08 AP 50		■		■	■		■			■	■	■	■								■			■	■				■	
	06 RF 102 C												■	■																	
	06 RF 102 B		■		■					■		■	■									■		■	■			■		■	

SAMPLES	Nodosaria	Robulus	Cibicides	Amphistigena	Bullimina	Nonion	Uvigerina	Gyroidina	Bolivina	Eponides	Cassidullina	Rotalia	Operculina	Dentalina	Amphycarina	Sphaeroidina	Nonion	Pullenia	Lagena
ENVIRONMENT (Murray, 1991)			0 - 2000 m	0 - 130 m, coral reefs, lagoon	inner shelf - bathyal	0 - 180 m	100 - >4500 m	shelf - bathyal	inner shelf - bathyal	shelf - abyssal	shelf - abyssal		0 - 130 m, inner shelf, lagoon					outer shelf - bathyal	
06 RF 101 R1	■		■	■				■	■										
06 RF 101 Q																			
06 RF 101 N	■		■						■										
06 RF 101 J																			
06 RF 101 G																			
06 RF 101 D			■	■			■		■			■	■						
06 RF 101 A	■		■	■				■	■										
08 AP 79	■	■					■								■		■		
08 AP 70		■			■		■			■						■			■
08 AP 62	■	■			■				■										
06 RF 102 G								■	■										
08 AP 60		■			■		■			■							■	■	
08 AP 58										■									
08 AP 55	■	■			■				■		■				■	■			
08 AP 50		■	■		■		■	■						■					
06 RF 102 C																			
06 RF 102 B	■	■	■	■	■	■	■												

Table 2. Results of geochemistry analysis

NO	SAMPLE CODE	LITHOLOGY	TOC (%)	S1	S2	S3	PY	S2/S3	PI	PC	Tmax (^{0}C)	HI	OI	Tmax NDP
				mg/g										
1	08 AP 39	Claystone	0.25	0.06	0.00	0.19	0.06	0.00	1.00	0.00	335	0	77	NDP
2	08 AP 41	Claystone	0.43	0.03	0.05	0.20	0.08	0.25	0.38	0.01	285	12	47	NDP
3	08 AP 50	Claystone	0.08	0.00	0.00	0.02	0.00	0.00		0.00	255	0	26	NDP
4	08 AP 53	Sandstone	0.30	0.14	0.01	0.34	0.15	0.03	0.93	0.01	226	3	115	NDP
5	08 AP 55	Sandstone	0.25	0.01	0.00	0.14	0.01	0.00	1.00	0.00	243	0	56	NDP
6	08 AP 58	Claystone	0.26	0.03	0.00	0.17	0.03	0.00	1.00	0.00	285	0	66	NDP

TOC: Total Organic carbon
S1 : Amount of Free Hydrocarbon
S2 : Amount of Hydrocarbon released from kerogen
S3 : Organic carbon Oxide
PY : Amount of Total Hydrocarbons = (S1 + S2)
PI : Production Index = (S1/S1+S3)
PC : Pyrolysable Carbon
Tmax: Maximum Temperature (^{0}C) at the top of S2 peak
HI : Hydrogen Index = (S2/TOC) x 100
OI : Oxygen Index = (S3/TOC) x 100
NDP : No Determination Posibble

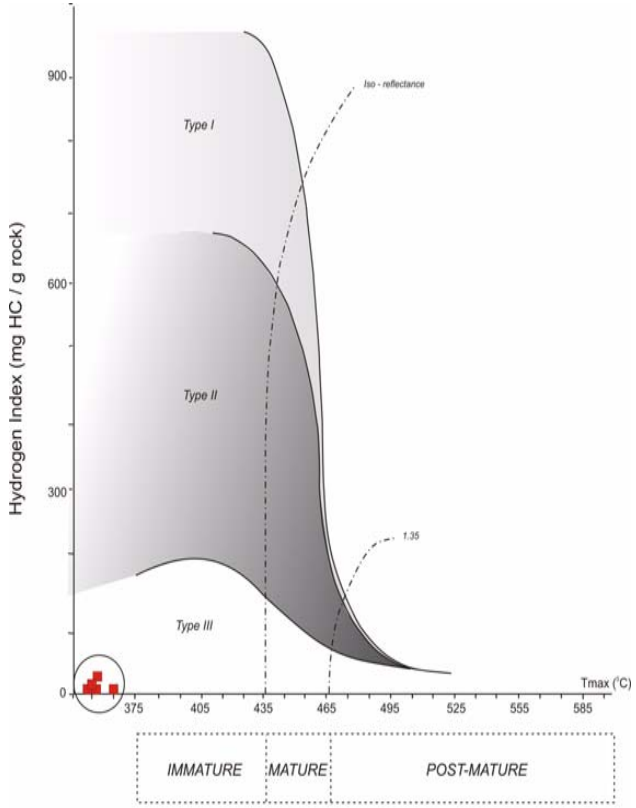

Figure 7. Diagram of Hydrogen Index versus Tmax showing kerogen type of the Sambipitu Formation.

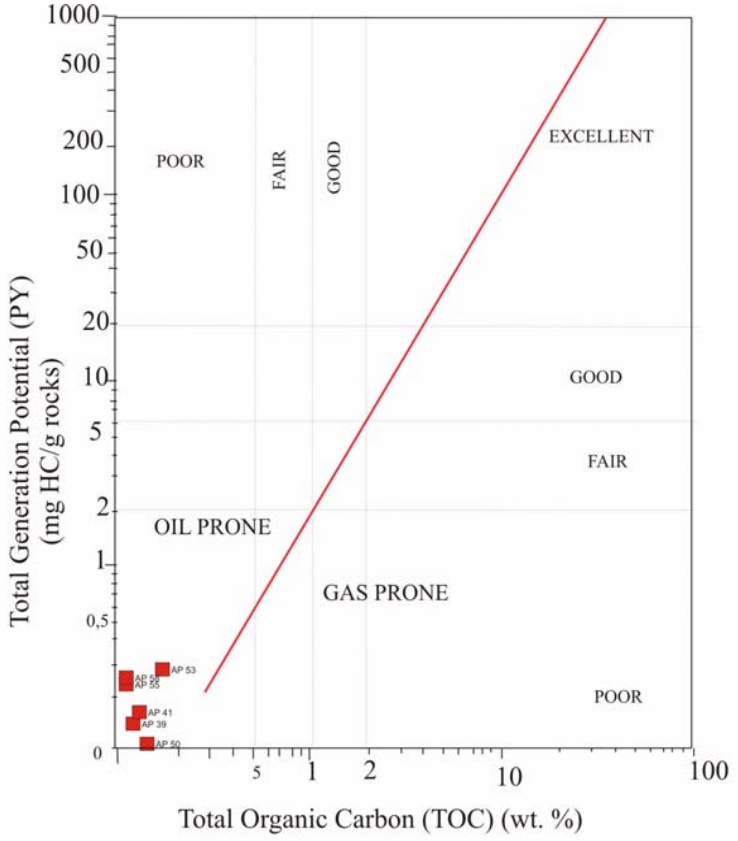

Figure 8. Diagram of TOC versus Pyrolysis Yeild (PY) showing hydrocarbon poor potential of the Sambipitu Formation.

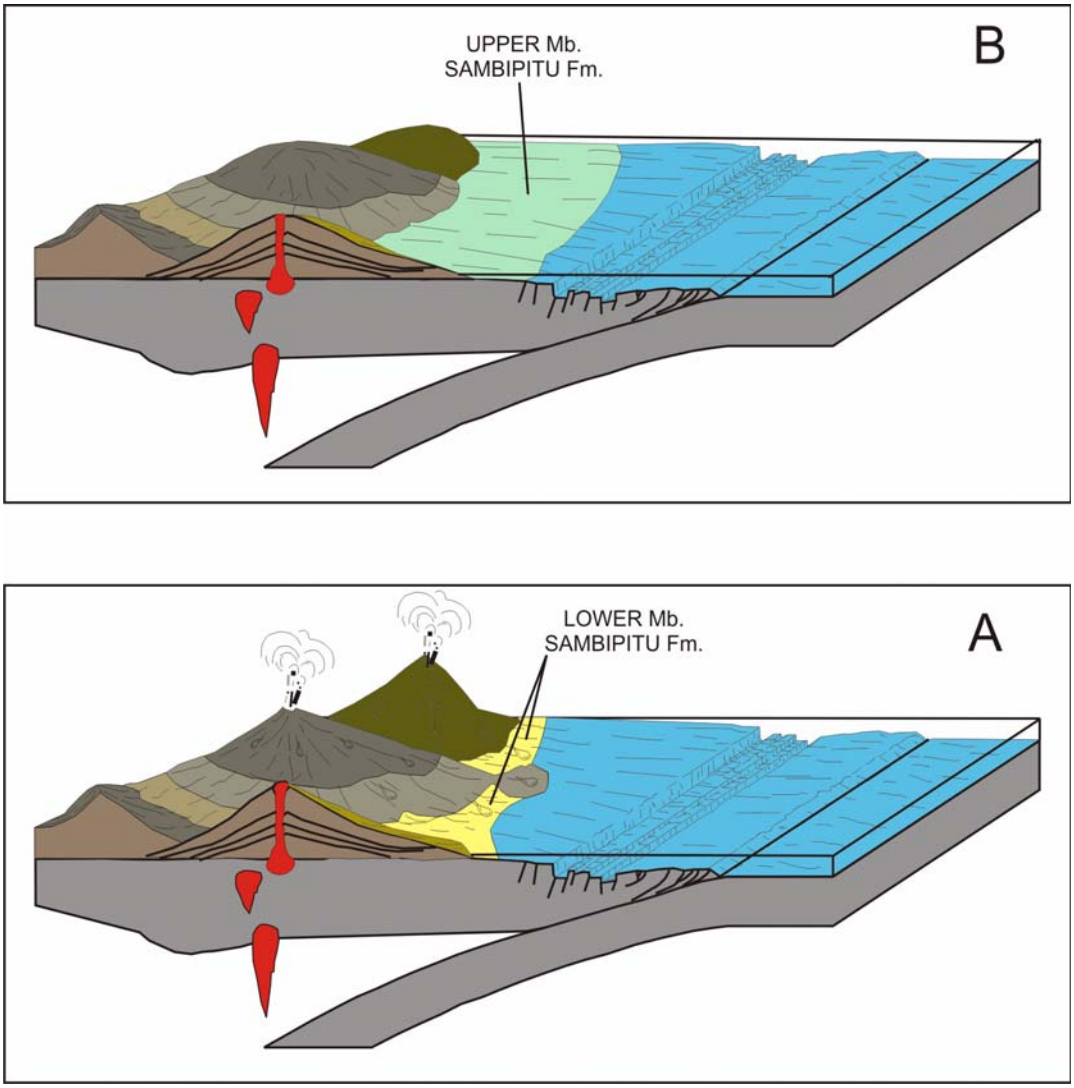

Figure 9. Sedimentological significant of the Sambipitu Fprmation.
A = the Lower Member, B = the Upper Member.

DISCUSSIONS

Lower Member

The Lower Member of the Sambipitu Formation is dominated by alternating between sandstones and mudstone (siltstone or shale) with intercalations of breccias (Figure 5). The pollen fossils of *Zonocostities ramonae*, *Florschuetzia trilobata* and *Acrosticum aureum* indicate that the member was deposited on a mangrove environment. The presence of tidal sedimentary structures (e.g. lenses bedding, flaser bedding and wavy bedding) indicate that the depositional environment was affected by tidal current (Collinson and Thomson, 1989). Ichno fossil study by Santy *et al*. (2007), support this interpretation.

Shale shell fragments and shale clasts, which are commonly found in the bottom of some layers in the member, may be as lag deposits on the floor of tidal channels. Mollusks and coal fragments, which are commonly found on some erosion surfaces, strongly support this interpretation. Thin layers of coal could be formed by mangrove vegetation which had abundantly grew on supra tidal.

Contacts between breccia and sandstone layers are distinct. It indicates that during the breccias deposition, volcanic activity was very strong. Volcanic materials, transported to the back shore environment, where the finer grained sediments were deposited. Due to the intense activity of volcanism, the volcanic material formed a steep slope and rough topography. Because of this features, the volcanic material moved downward as lahar or debris flows.

Based on some features above the depositional environment of the Lower Member of the Sambipitu Formation can be summarized that the member deposited influenced by tidal current and volcanic material debris flows (Figure 9A). Abundant bioturbations and trace fossils indicate that tidal current was moderate energy.

Upper Member

The Upper Member of the Sambipitu Formation is dominated by alternating between sandstones and mudstone (siltstone or shale) (Figure 6). Bioturbations are very abundant within the member. These indicate that during the deposition, current was moderate energy. Foraminifers are found abundantly, especially in the upper part. Based on the benthonic foraminifers such as *Amphistigina* sp., *Nonion* sp., and *Operculina* sp., (Table 1), it indicates that the Upper Member was deposited in inner shelf (0 to 130 meters). The foraminifers increase upwards showing that the depositional environment was deepening. Hummocky cross-stratifications occur in the upper part of the member show environment were affected by storms during its deposition.

The conglomerates dominated by volcanic fragment, shows that the material derived from distance sources. Probably the material was deposited on land before transported to the sea. This material probably derived from same area as volcanic material within the Lower Member. As assumed, during the time of the Upper Member deposition volcanic activity had ceased.

As mentioned, the Upper Member of the Sambipitu Formation was deposited in inner shelf which was deepening upward.

CONCLUSIONS

The Sambipitu Formation, which is underlain by the Nglanggran Formation and overlain by the Oyo Formation, can be divided into the Lower Member and the Upper Member. The Sambipitu Formation is dominated by various lithology such as sandstone, mudstone, shale and siltstone. The Lower Member is dominated by sandstones and by volcanic breccias intercalation. On the

other hand, the Upper Member is dominated by fine grained sediments and intercalated by conglomerate in the lower part and calcareous sediments in the upper part. The formation had been deposited during N7 to N8 or latest Early Miocene.

The Lower Member was deposited on a tidal current environment. Volcanic activities that resulted in steep topography brought breccias down to the above environment. This environment deepened offshore, where most of the Upper Member was deposited. During the deposition time of the Upper Member, carbonate material had developed well due to ceased volcanic activity.

The results of geochemical analyses of some samples, indicates that the Sambipitu Formation is strongly assumed to be poor potential for source rock of petroleum.

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