

Depositional Environment of Fine-Grained Sedimentary Rocks of the Sinamar Formation, Muara Bungo, Jambi

Lingkungan Pengendapan Batuan Sedimen Berbutir Halus Formasi Sinamar, Muara Bungo, Jambi

M. H. HERMIYANTO ZAJULI and H. PANGGABEAN

Geological Agency
Jln. Diponegoro 57 Bandung 40122, Indonesia

ABSTRACT

The research area is situated in the northwestern side of South Sumatra Basin, which is a part of Muara Bungo Regency, Jambi Province. The Oligocene Sinamar Formation consists of shale, claystone, mudstone, sandstone, conglomeratic sandstone, and coal-seam intercalations. This research was focused on fine sedimentary rock of Sinamar Formation, such as shale, claystone, and mudstone. Primary data were collected from SNM boreholes which have depths varying from 75 m up to 200 m, and outcrops that were analyzed by organic petrographic method, gas chromatography-mass spectrometry (GC-MS) of normal alkanes including isoprenoids, and sterane. The dominant maceral group is exinite, composed of alginite (3.4 - 18%), and resinite (1.6 - 5.6%), while vitrinite maceral consists of tellocolinite 0.4 - 0.6%, desmocolinite 0.4%, and vitrodetrinite 8.4 - 16.6%. Organic petrography and biomarker analyses show that organic materials of shales were derived from high plants and algae especially *Botryococcus* species. *Botryococcus* and fresh water fish fossil, found in the shale indicate a lacustrine environment.

Keywords: Sinamar Formation, Oligocene, organic petrography, biomarker, lacustrine, Muara Bungo

SARI

Lokasi penelitian terletak di sebelah barat laut Cekungan Sumatra Selatan yang secara administratif berada di wilayah Kabupaten Muara Bungo, Provinsi Jambi. Formasi Sinamar terdiri atas serpih, batulempung, batulumpur, batupasir, dan batupasir konglomeratan serta sisipan batubara yang berumur Oligosen. Penelitian ini difokuskan pada batuan sedimen halus Formasi Sinamar yaitu serpih, batulempung, dan batulumpur. Data primer berasal dari sumur SNM yang mempunyai kedalaman 75 m sampai 200 m, dan singkapan batuan yang dianalisis berdasarkan metode petrografi organik, Kromatografi Gas-Spektrometri Massa (GC-MS) alkana normal termasuk isoprenooidnya, dan data sterana. Eksinit sebagai kelompok sub-maseral utama pada serpih Formasi Sinamar tersusun oleh maseral alginit (3,4 - 18%) dan resinit (1,6 - 5,6%), sedangkan maseral vitrinit terdiri atas sub-maseral telokolinit sebanyak 0,4 - 0,6%, desmokolinit 0,4%, dan vitrodetrinit 8,4 - 16,6%. Analisis petrografi organik dan biomarker memperlihatkan bahwa bahan organik serpih Formasi Sinamar berasal dari tumbuhan tinggi dan alga khususnya jenis *Botryococcus*. *Botryococcus* dan fosil ikan tawar, yang ditemukan di Serpih Formasi Sinamar mengindikasikan serpih tersebut diendapkan pada lingkungan lakustrin.

Kata kunci: Formasi Sinamar, Oligosen, petrografi organik, biomarker, lakustrin, Muara Bungo

INTRODUCTION

The Sinamar Formation occurs in Sumatra, at a particular area nearby the northwestern tip of South

Sumatra Basin. The sequence of Sinamar Formation consists of shale, claystone, siltstone, and thin intercalation of sandstone and coals deposited in a fluvial-deltaic environment (Rosidi *et al.*, 1996).

The stratigraphic sequences and tectonics of the Sinamar Formation are nearly similar to the Talangakar and Lemat Formations of South Sumatra Basin, the Sangkarewang Formation of Ombilin Basin, and the Pematang Formation (Brown Shale) of the Central Sumatra Basin which all formations have potential of oil and gas in Sumatra.

The subject of this research is the fine-grained sedimentary rock of Sinamar Formation distributed in Muara Bungo area (Figure 1), whilst data of the research area comprise geochemistry data including biomarker (Gas Chromatography and Gas Chromatography Mass Spectrometry) and maceral composition (organic petrography).

This study reveals the role of fine-grained rocks as a potential source rock of the Sinamar Formation. Moreover, the Talangakar and Lemat Formations are famous for their role to be potential source rocks in South Sumatra Basin. Thus, this research is focused on identifying fine-grained sedimentary rocks of the Sinamar Formation as the possible alternative potential for hydrocarbon source rock in South Sumatra Basin.

The objective of this research is to identify the depositional environment of fine-grained sedimentary rocks of the Sinamar Formation based on organic matter and geochemical characteristics. Depositional environment, organic matter, and geochemistry characteristics of the Sinamar Formation will be correlated in the future with the Talangakar, Lemat, Sangkarewang, and Pematang Formations that have been proven to have a source rock potential for oil and gas.

METHOD

The primary data collected during the fieldwork including observation, measurement, and rock sample collection both outcrop and core samples, have geochemical characters corresponding to be source rocks.

The core data were supplied by a coal mining company of the PT. Kuansing Inti Makmur (KIM), having the coal mining concession, particularly in the Muara Bungo area, South Sumatra Basin. Organic petrography analysis was carried out in

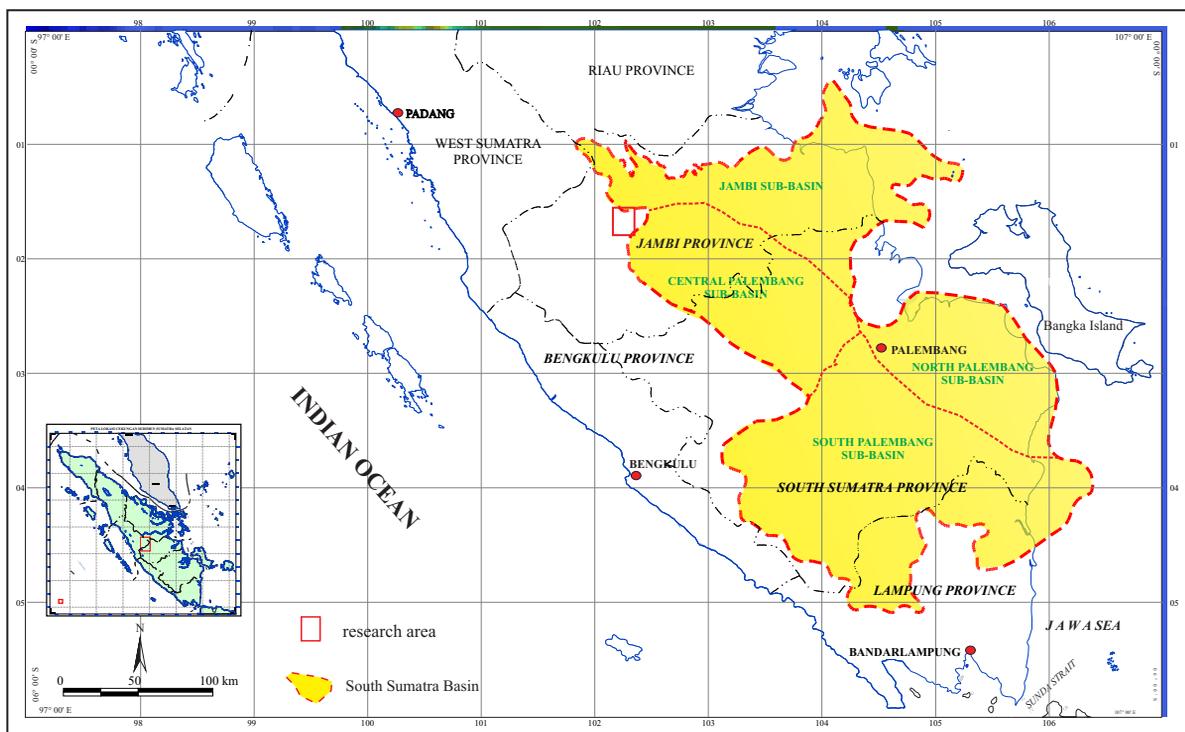


Figure 1. South Sumatra Basin showing Research locality, Muara Bungo area.

Centre for Geological Survey laboratory, Geological Agency, Bandung, while Gas Chromatography-Mass Spectrometry/GC-MS analysis was performed in Lemigas, Jakarta.

GEOLOGICAL SETTING

Previous study on regional geology was carried out by Van Bemmelen (1949), who investigated the Ombilin and Central Sumatra Basins, especially on their basin constructions having potential on the coal deposits. Furthermore, the Centre for Geological Survey (previously the Geological Research and Development Centre) had completed a systematic geological mapping work of 1: 250,000 scales in Painan Sheet and northeastern part of Muarasiberut (Rosidi *et al.*, 1996), Solok Sheet (Silitonga and Kastowo, 1995), and Rengat Sheet (Suwarna *et al.*, 1994).

Tectonically, the area of this study is situated in an intermountain basin (Figure 2), bordered by

the eastern flank of Barisan Mountains and Barisan Mountain Anticline of South Sumatra Basin. The flank of Barisan Mountains extend to the northwest - southeast having elevation of 150 m up to thousands of meters above sea level (De Coster, 1974).

In general, the geological structure developed in the studied area are anticline and syncline with some strike-slip fault structures. The anticline and syncline structures have a trend pattern of northwest - southeast. They have affected all rock units in the area to form fold structures (De Coster, 1974).

Strike-slip fault in the eastern part of area intersects several rock units of the Sinamar and Rantaukil Formations. This strike-slip fault is in a west-east direction. The fault crossing fold axis was presumably formed post anticline-syncline folds.

Stratigraphy of the studied area, expressed in the geological map of Painan Sheet (Figure 3), comprises Oligocene to Miocene rock units (Figure 4). The oldest rock unit is the Oligocene Sinamar Formation conformably overlain by the Rantaukil Formation. The Sinamar Formation consists of conglomerate and

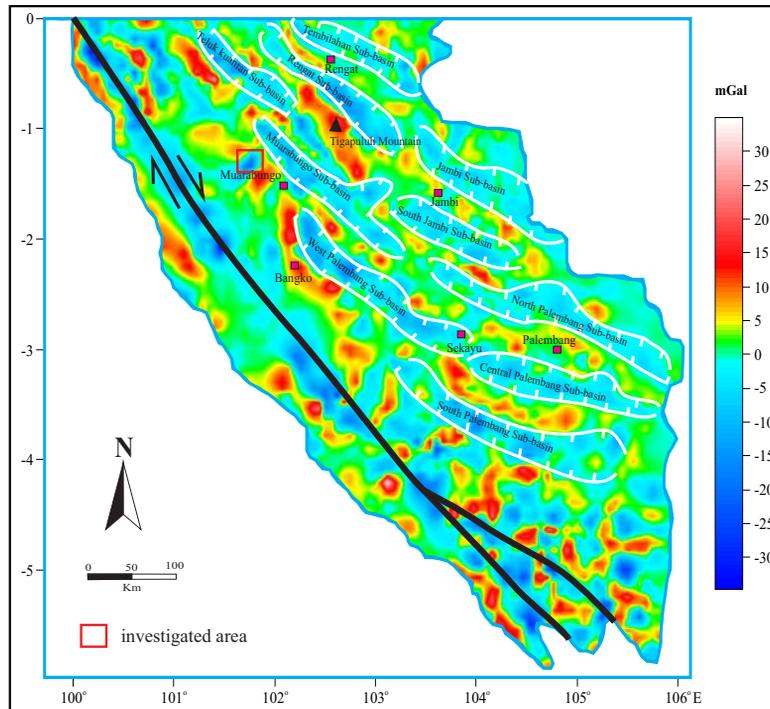


Figure 2. South Sumatra Sub-basin pattern based on a moving average analysis of gravity analysis (Setiadi and Widijono, 2010) shows 10 sedimentary sub-basins identified *i.e.*, North, Central, South, and West Palembang Sub-basins, also North and South Jambi Sub-basins, Muarabungo Sub-basin, Telukkuantan Sub-basin, Rengat Sub-basins, and Tembilihan Sub-basin.

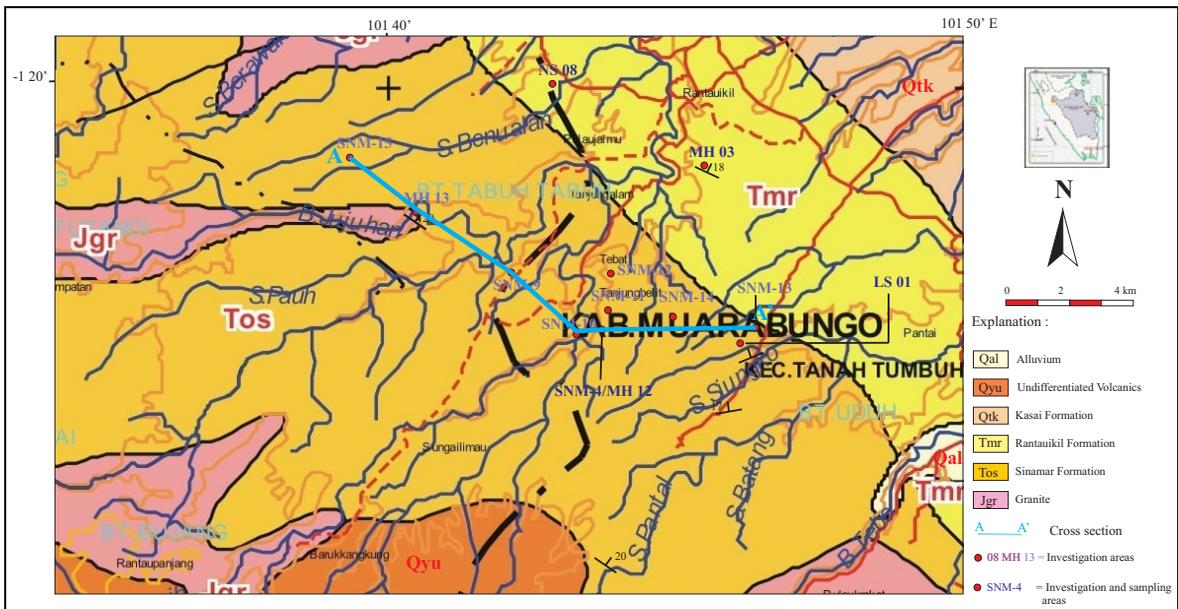


Figure 3. Geological map of investigated area showing distribution of the Sinamar Formation (Rosidi *et al.*, 1996).

AGE		JAMBI SUB-BASIN (Pertamina, 1992)	PAINAN SHEET (Rosidi <i>et al.</i> , 1996)	
QUARTENARY		Alluvium	Alluvium	
		Kasai Formation	Kasai Formation	
TERTIARY	NEOGENE	PLIOCENE		
		MIOCENE	Late	Muaraenim Formation
			Middle	Airbenakat Formation
		Early	Gumai Formation	Rantaukil Formation
	PALEOGENE	OLIGOCENE	Talangakar Formation	Sinamar Formation
			Lahat Formation	
		EOCENE		
		PALEOCENE		
PRE-TERTIARY		Mem. of. Condong Mentulu Formation Mentulu Formation Gangsai Formation	Granite Barisan Formation Palepat Formation	

Figure 4. Stratigraphic correlation of Jambi Sub-basin (Pertamina, 1992) and Painan Sheet (Rosidi *et al.*, 1996).

conglomeratic quartz sandstone in its lower section, succeeded by blackish grey claystone having thickness that varies from 2 m to 5 m, intercalated by coal seam of 20 cm thick. The formation is composed of claystone and pebbly sandstone in the upper section, and shale with intercalation of coal seams of 30 cm up to 700 cm in thickness in the uppermost part. The age of the formation is Oligocene and the thickness is 750 m (Rosidi *et al.*, 1996).

The Oligocene-Miocene Rantauikil Formation is dominated by claystone, tuffaceous sandstone, calcareous sandstone, marl, and thin limestone lenses. The Plio-Pleistocene Kasai Formation overlying the Rantauikil Formation consists of tuff, pumiceous tuff, and tuffaceous sandstone. Alluvium deposit consists of gravel, pebble, sand, and mud. Currently, the alluvium was deposited due to river abrasion (Rosidi *et al.*, 1996).

Figure 4 explains a comparison between the stratigraphy of Jambi Sub-basin and the investigated area, Sinamar. The comparison purpose is to confirm that the Sinamar Formation differs with the Talangakar Formation of South Sumatra Basin, although their ages are virtually similar and their location areas are almost close together.

RESULT

The primary data used were gained from the outcrop observation and rock sampling during fieldwork. The laboratory analysis was performed on rock samples collected from cores of borehole and some outcrops. Six boreholes samples collected, are SNM-4, SNM-9, SNM-10, SNM-11, SNM-13, and SNM-15. All those boreholes have a total depth ranging from 75 m to 200 m, and the drilling activity was carried out by a coal mining company, PT Kuansing Inti Makmur (PT KIM), as one of the exploration activities in the investigated area. Rock samples collected were taken from selected outcrop namely 08 MH 13 and core from SNM-4 well which were close to sampling location of 08 MH 12. The laboratory analyses executed were eight rock samples for organic petrography, and three samples for geochemistry method of Gas Chromatography-Mass Spectrometry (GC-MS).

Shale, coal, sandstone, and claystone can be found at location 08 MH 13 (Figure 5). Typical

fresh water fish fossil of 20 cm length and 15 cm width and a large size of trunk having a length of 22 m and diameter of 90 cm (Figure 6) also occur in this location. Samples for organic petrography analysis of the shale of Sinamar Formation collected from borehole SNM-4 (08 MH 12R) indicates that the main composition of organic matter consists of 14.4% vitrinite maceral of all vitrodetrinite types and mineral matter of 83.6% clays and 2% pyrite (Table 1). Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) analyses conducted on the same shale sample and location are shown in Table 2.

Organic petrography analysis on the shale of Sinamar Formation at 08 MH 13 location (Table 1) shows that the main composition of the organic matter consists of vitrinite maceral group ranging from 9.4 % to 17.0 %, with exinite of 9.0% up to 20.6%, whilst inertinite of typical inertodetrinite is 0.4%. The vitrinite maceral group is composed of sub-group maceral of telocollinite 0.4% - 0.6%, desmocollinite 0.4%, and vitrodetrinite 8.4% - 16.6%, while maceral of exinite consists of maceral sub-group of resinite 2.0% - 5.6% and alginite 3.4% - 18.0%. Mineral matter comprises clays ranging from 58.4% to 77.0%, carbonate of 2.6% - 4.0%, and pyrite from 0.6% to 5.0%. Alginite maceral is mostly typical *Botryococcus* as shown in 08 MH 13C and 08 MH 13A samples (Figure 7). Exinite content is larger than vitrinite indicated in samples 08 MH 13C, 08 MH 13E, and 08 MH 13E2.

The main organic matter composition of claystone is exinite (11.2%) consisting of resinite 1.6% and alginite 9.6%, whilst vitrinite maceral is 10.8% comprising telocollinite 0.4%, desmocollinite 0.8%, and vitrodetrinite 9.6%. Mineral matter comprises 76% clays, 1.4% carbonate, and pyrite of 0.6 %.

DATA ANALYSIS

Origin of Organic Matter and Depositional Environment

The origin of organic matter content is determined by a biomarker analysis, while depositional environment of the fine-grained sedimentary rocks of Sinamar Formation has been determined from the data of organic matter and geochemistry characters.

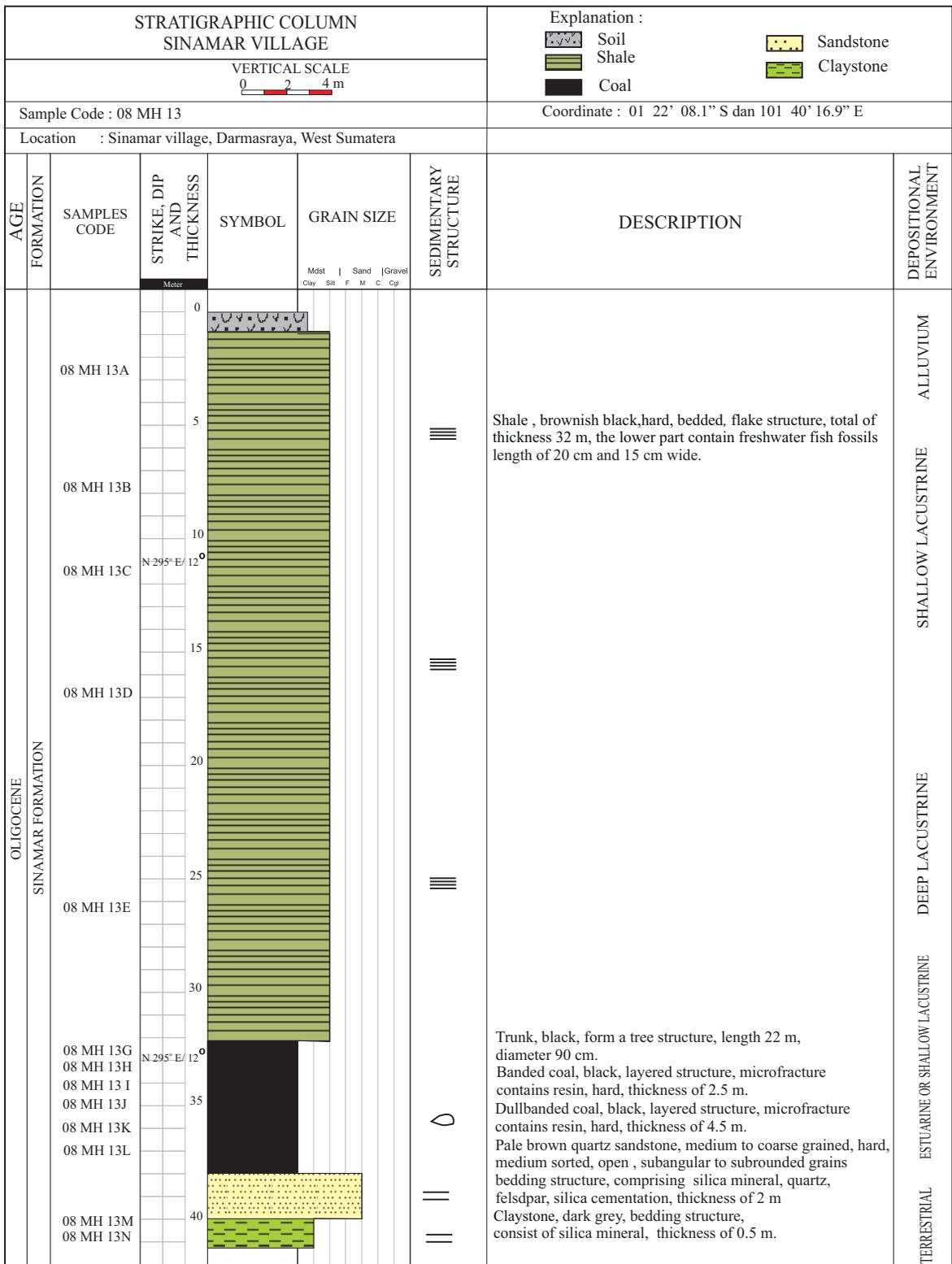


Figure 5. Stratigraphic Column in 08MH13 location, showing claystone, sandstone, coal, and shale beds at the top succession.



Figure 6. An outcrop of shale bed containing fresh water fish fossil (left) and wood trunk (right), at 08MH13 location.

Table 1. Result of Organic Petrography on Shale and Claystone of the Sinamar Formation

No	Sample Code	Lithology	Maceral (%)								Mineral Matter (%)							
			Tc	Dc	Crp	Vd	V	Re	Alg	E	Sf	Idt	I	Cl	Pi	Carb	MM	
1	08 MH 12 R	Shale (BH)	-	-	-	14.4	14.4	-	-	-	-	-	-	-	83.6	2.0	-	85.6
2	08 MH 13 A	Shale (OC)	0.4	-	-	16.6	17.0	5.6	3.4	9.0	-	-	-	67.0	3.0	4.0	74.0	
3	08 MH 13 C	Shale (OC)	-	0.4	-	16.4	16.8	2.6	18.0	20.6	-	-	-	58.4	1.6	2.6	62.6	
4	08 MH 13 D	Shale (OC)	0.4	0.4	-	14.6	15.4	2.0	7.0	9.0	-	-	-	68.0	5.0	2.6	75.6	
5	08 MH 13 E	Shale (OC)	0.4	0.6	-	8.4	9.4	2.0	10.6	12.6	-	0.4	0.4	77.0	0.6	-	77.6	
6	08 MH 13 E2	Claystone (OC)	0.4	0.8	-	9.6	10.8	1.6	9.6	11.2	-	-	-	76.0	0.6	1.4	78.0	

Explanation :

Tc : Telocollinite	V : Vitrinite	Sf : Semifusinite	MM : Mineral Matter	BH : Borehole
Dc : Desmocollinite	Re : Resinite	Idt : Inertodetrinite	Py : Pyrite	OC : Outcrop
Crp : Corpocollinite	Alg : Alginite	I : Inertinite	Carb : Carbonate	Cl : Clay
Vd : Vitrodetrinite	E : Exinite			

The scope of depositional environment discussion is restricted to the rock and stratigraphic sequence analyses.

Origin of Organic Matter

The origin of organic matter can be concluded from the ratio of numerous organic chemical parameters, such as normal alkane isoprenoid, sterane, and triterpane. Generally, isoprenoid used is pristane/phytane (Pr/Ph), and Carbon Preference Index (CPI). Sterane can be used as a photosynthetic biota indicator of terrestrial and water environment. Triterpane is commonly derived from bacteria, often applied as a depositional environment and diagenetic indication. A combination of normal alkane, sterane and triterpane data, will designate information of the organic facies system (Peters and Moldowan, 1993).

Peters and Moldowan (1993) stated that the ratio of Pr/Ph greater than 3.0 indicates that it has a tendency to be a terrestrial source of typically high plant organic matter, where as the ratio of pristane/nC17 having a value of larger than 0.6 shows that the origin of organic matter, is terrestrial high plants.

A plot of pristane/phytane *versus* hopane/sterane values (Figure 8) shows that samples 08 MH 13 B and 08 MH 13 E have the organic matter of typical algae origin with concluding to be anoxic to suboxic conditions. The shale of Sinamar Formation at 08 MH 13 location (Table 1) shows that the maceral of exinite consists of maceral sub-group of resinite 2.0% - 5.6%, alginite 3.4% - 18.0%. The maceral composition of 08 MH 13 significantly indicates

Tabel 2. Result of Gas Chromatography and Mass Spectrometry on Shale Rocks of the Sinamar Formation

GC and GC-MS Analysis	Sample Code			
	SNM-4/08 MH 12R (shale)	08 MH 13B (shale)	08 MH 13E (shale)	
Ratio of n-alkane	Pristane/phytane	6.43	3.57	1.80
	Pristane/nC17	1.70	1.53	5.13
	Phytane /nC18	0.43	0.22	3.20
	Carbon Preference Index (CPI) 1	1.72	1.13	1.43
	Carbon Preference Index (CPI) 2	1.97	0.73	0.45
Ratio of Triterpane	C30 Moretane/C30 Hopane	1.25	0.25	0.40
	22S/(22S+22R)C31	0.14	0.56	0.24
	Tm	4379548	253963	4924907
	Ts	441344	40160	2119932
	C29/C30 Hopane	0.66	1	2.86
Ratio of Sterane	20S/(20S+20R)C29	0.15	0.42	0.15
	C27 sterane	4	35	53
	C28 sterane	22	23	18
	C29 sterane	74	42	29
	C29 $\alpha\alpha\alpha$ R	333706	23868	665958
	C29 $\alpha\alpha\alpha$ S	1893929	32393	3706247
	C29 $\alpha\beta\beta$ R	601917	26325	1963239
	C29 $\alpha\beta\beta$ S	372882	14754	572087
Ratio of Aromatic	DNR-1	5.44	1.06	5.62
	TNR-1	1.11	1.61	0.74
	MPI-1	0.31	0.54	0.43
	MPI-2	0.45	0.64	0.49
	Rc1	0.58	0.72	0.66
	Rc2	2.12	1.98	2.04
	Ro1	0.73	0.85	0.73
	Ro2	0.98	0.89	0.74
	F1	0.40	0.46	0.40
	F2	0.29	0.27	0.23
	Total Hopane / Sterane	6.7	13.6	16.67

high algae content. It is consistent to the result of ratio of hopane/sterane *versus* pristane/phytane representing the derivation of the organic matter.

Depositional Environment

Depositional environment can be interpreted from results of field data, organic petrography, and

biomarker analyses. From field data, for instance, it can be interpreted by discovering fresh water fish fossil within shale rock, while organic petrography is to find out the maceral composition, especially the present of *Botryococcus* within shale. Furthermore, the biomarker data includes the ratio of isoprenoid parameters, such as pristane/phytane (Pr/Ph), pristane/nC17, and phytane/nC18.

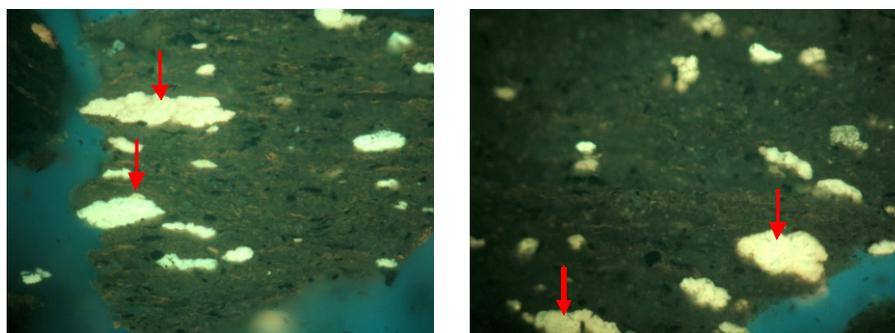


Figure 7. Typical alginite maceral (*Botryococcus*) (red arrows) from samples of 08 MH 13A (left) and 08 MH 13C (right).

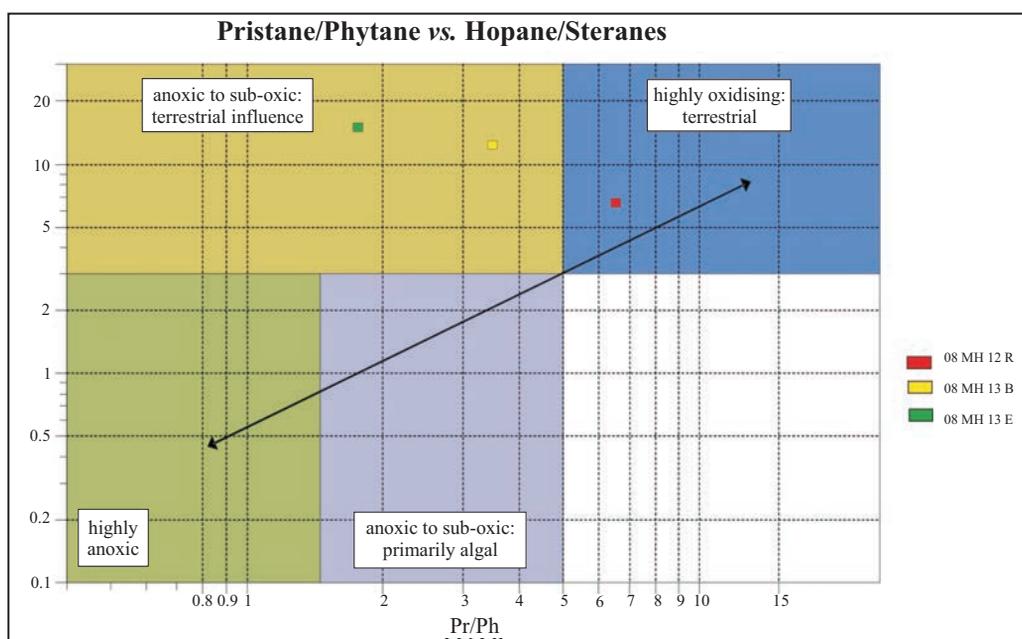


Figure 8. Diagram of pristane/phytane (Pr/Ph) versus hopanes/steranes, showing depositional environment of samples of 08 MH 12R, 08 MH 13B and 08 MH 13E.

Botryococcus and fresh water fish fossils discovered within the shale bed at 08 MH 13 location are common characteristics of a lacustrine depositional environment (Tissot and Welte, 1984). The *Botryococcus* is a typical algae classified into sub-maceral of tellalginite of alginite maceral that is commonly deposited in a fresh water area (Tissot and Welte, 1984).

The sedimentary structure of shaly rock was the result of sedimentation in a medium of a tranquil water current condition. Hence, the shale bed of Sinamar Formation explains that it was the result of a depositional process in a lacustrine environment.

The depositional environment, based on biomarker especially sterane, can be expressed in using cross-plot of C27, C28, and C29 in a triangle diagram (Figure 9). The diagram of C27, C28, and C29 of 08 MH 13B, 08 MH 13E, and 08 MH 12R samples indicated that 08 MH 13B was derived from an estuarine environment or shallow lacustrine, while 08 MH 13E was an open marine or deep lacustrine, and 08 MH 12R sample was of typical terrestrial. In most cases, all samples of 08 MH 13 labels indicate that the shale was deposited in a lacustrine environment, whilst sample of 08 MH 12R was a terrestrial environment.

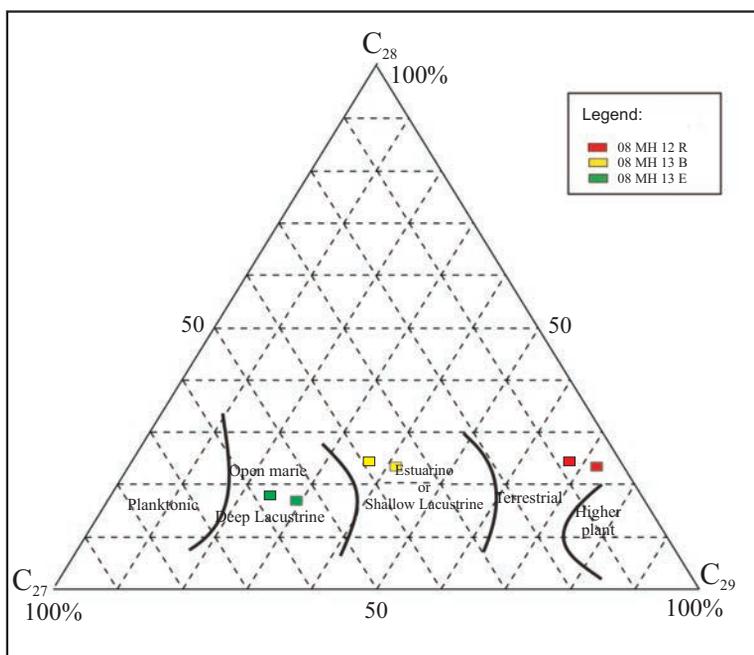


Figure 9. Triangle diagram of C27, C28, and C29 steranes according to Huang and Meinschein (1979, in Waples and Machihara, 1991), showing depositional environment of samples 08 MH 12R, 08 MH 13B, and 08 MH 13E.

Based on the maceral composition, in particular the sample 08 MH 13 indicates that algae content is significantly high ranging from 3.4 % to 18.0% (Table 1). Furthermore, the triangle diagram of C27, C28, and C29 shows that sample 08 MH 13 was derived from a shallow to deep lacustrine environment. The lacustrine environment indication is also supported by maceral composition of mainly algae of typical *Botryococcus*.

Based on this data analyses, the Sinamar Formation was deposited in a lacustrine environment that was distinctive result with the previous work suggesting a fluvio-deltaic environment (Rosidi *et al.*, 1996). According to them, the Tertiary sedimentary rock of Sinamar Formation unconformably underlying the Pre-Tertiary, rock was deposited in a fluvio-deltaic environment having age of Oligocene.

DEPOSITIONAL MODEL OF THE SINAMAR FORMATION

Generally, the Sinamar Formation is composed of three lithologic units namely conglomeratic sandstone, sandstone, and claystone in the lower

section. In the middle section, it is characterized by alternating shale, claystone, mudstone, and coal; and sandstone and claystone in the upper section. Alternating shale, claystone and mudstone are found in shallow wells of SNM-12, SNM-10, and SNM-11, while the most prominent rocks of sandstone, conglomeratic sandstone and claystone in SNM-15, SNM-14, and SNM-13. SNM-12, SNM-10 and SNM-11 are located in central part of the investigated area, and other wells are situated in the margin part of the area (Figure 3).

Stratigraphically, the 08 MH 13 sample is situated below the 08 MH 12R sample as collected in the investigated area. The 08 MH 13 sample is in the lower part of the middle section of Sinamar Formation comprising alternated shale and coal. This situation shown in the cross-section of A-A' (Figure 10) indicates that the lower part where the 08 MH 13 is located has been occupied by sandstone beds which are the lowermost section unit of the Sinamar Formation. The 08 MH 12 sample is situated in upper part of the middle section unit of the Sinamar Formation. The presence of sandstone and claystone beds in the upper section at SNM-4 or 08 MH 12 locations confirms that 08 MH 12 sample is

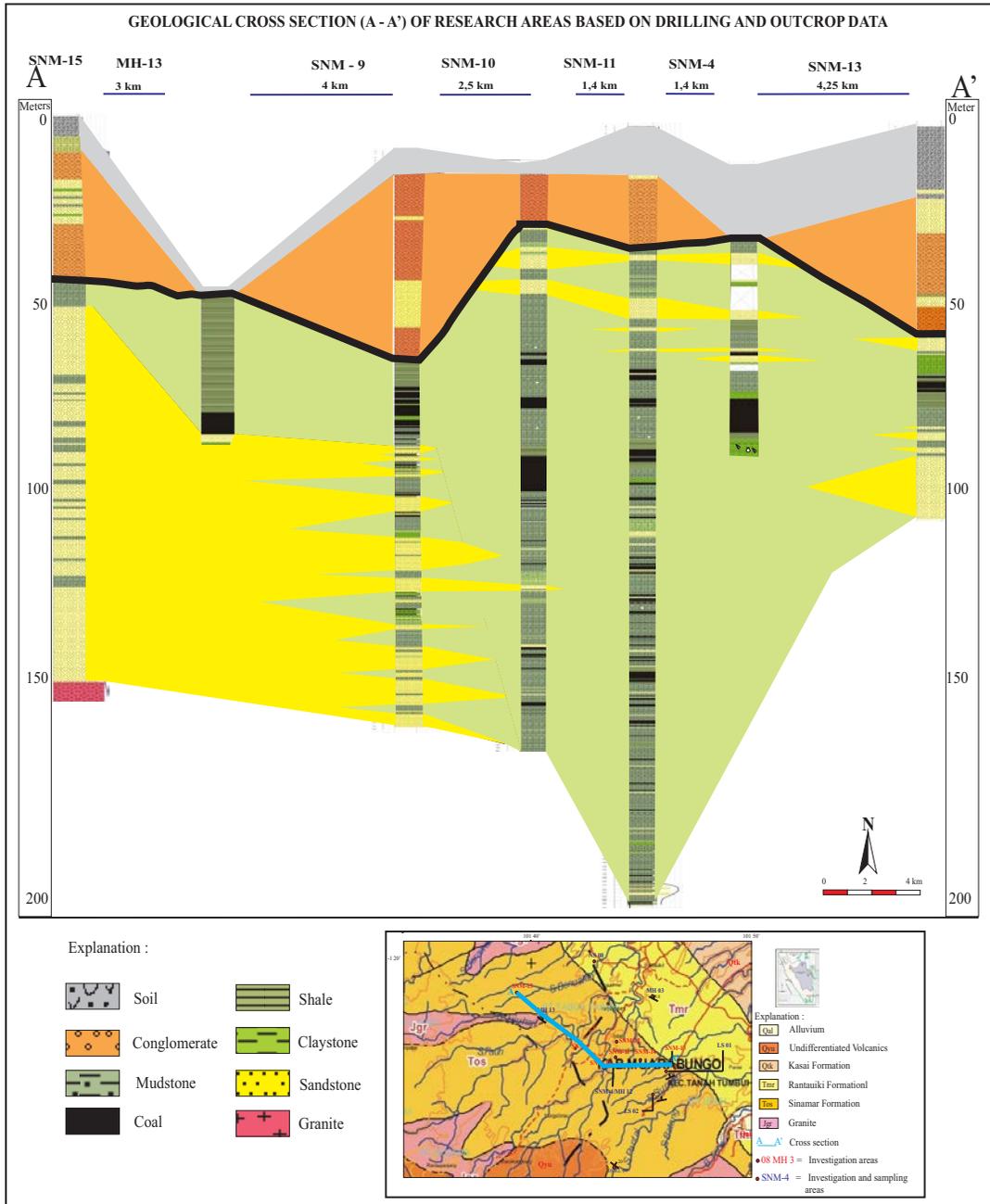


Figure 10. Geological cross-section of A-A', representing lithologic correlation, and fine-grained sedimentary layer to be prominent in the middle part section.

situated in the upper part of the middle unit section of Sinamar Formation.

The cross-section A-A' (Figure 10) shows that the margin area consists of interbedded sandstone-claystone. The interbedded fine-grained sediments are prominent in the middle part of section of the

investigated area. It can be interpreted that the middle part of the investigated area is also the central part of the basin where the fine-grained sedimentary rocks of the Sinamar Formation were deposited. The alternating fine-grained sediments have been deposited during a tranquil current as the characteristics

of a lacustrine deposit. In the basin margin, it is characterized by sedimentary rocks penetrated by SNM-15, SNM-14, and SNM-13 wells.

Figure 10 represents interbedding conglomeratic sandstone and claystone at the edge of cross-section dominated by quartz lithology composition of a typical non-marine. The cross-section A-A' is restricted to the Jurassic granite rock in the southeast and northeast areas. The existing conglomeratic sandstone (Figure 11) is thought to be derived from the Jurassic granite. The presence of graded structure in lower part of SNM-15, SNM-13 wells, and 08LS01 outcrop indicates that the deposition has been controlled by a gravity process. In the western margin of the basin, the cross-section A-A' denotes that conglomeratic sandstone was the dominant sediments in the lower part, while towards the upper part

the claystone alternation is a prominent rock. At the edge of the basin, it seems to be interfingered with alternating fine-grained sedimentary rocks situated in the central part. Thus, this picture confirms the occurrence of alluvial fan deposit in the edge of investigated area.

Based on the cross-section A-A', the geological map and depositional environment of the fine-grained sediments of Sinamar Formation, a lacustrine depositional environment model can be described in the investigated area (Figure 12). Thus, the lacustrine sedimentary rock might have been deposited along the alluvial fan sediments. In the stratigraphy column, the edge of investigated area represents the existence of quartz sandstone interbedded with shale as indicative of the rocks deposited in the same time. In the central part of the



Figure 11. Outcrop of conglomeratic sandstone at location LS02, a close-up of the outcrop (right).

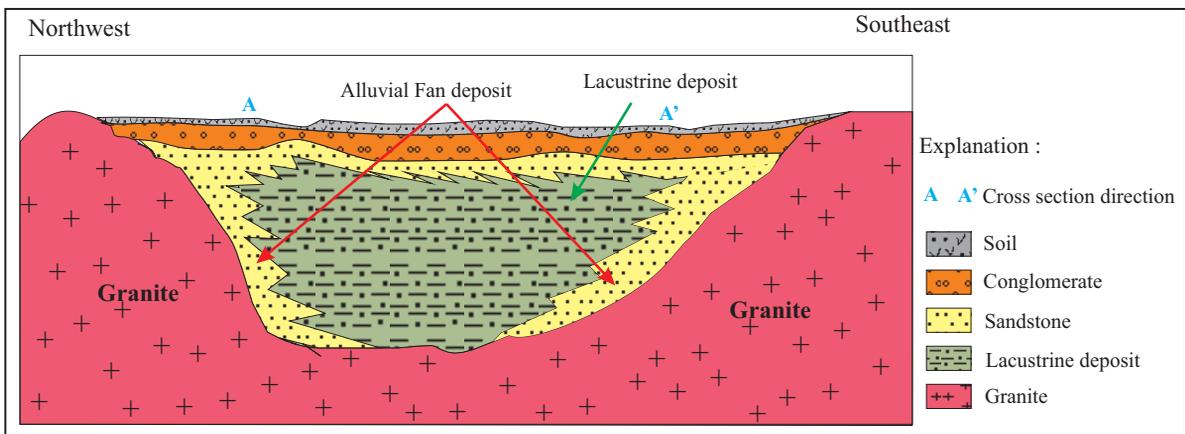


Figure 12. A cross-section model of lacustrine deposit in the investigated area.

investigated area, the SNM-10 and SNM-11 columns show that alternating sandstone and shale seems to be relatively reducing. Therefore, the distribution of sandstone only reached the margin of the basin.

DISCUSSION

Generally, *Botryococcus*, fresh water fish fossil, and wood trunk were found in the 08 MH 13 sample suggesting that the shale of Sinamar Formation was deposited in a lacustrine environment. Biomarker analysis shows that 08 MH 13 sample tends to be deposited in a lacustrine environment with an anoxic condition. The wood trunk found in the upper part of coal seam (08 MH 13G) suggests that the coal seam was deposited in a estuarine or shallow lacustrine or swamp environment. In contrast, sample 08 MH 12 was deposited in a terrestrial environment with an oxic condition.

The depth of lacustrine environment is depicted by the anoxic condition of rock sample. While the oxic zone is an open condition represented by the stratigraphic position of sample 08 MH 12 above sample 08 MH 13. The anoxic and oxic conditions were indicated by the biomarker analysis, especially the ratio of pristane and phytane (Pr/Ph), as a condition affected by a water level change.

At a condition for the period of high water level, water volume increased influencing the reduce of oxygen resulted in an anoxic condition. In contrast, at the decrease water level condition, oxygen penetrated into water resulting in an oxic situation. The distinction result between sample 08 MH 13 and 08 MH 12R indicate a change of facies sediment from lacustrine into terrestrial environments. These changes include anoxic conditions leading to the oxic one which can be explained by the changes in lake water level from high to low. This condition occurs due to the process of regression during the facies change from a lacustrine into terrestrial condition.

The continuous alternating fine sedimentary rocks and thicker beds in the middle part of section A-A' shows that a continuous sedimentation process has occurred within a water condition of low current. An unceasing sedimentation can occur by a continuous supply of sedimentary clastics. A thicker bed

indicates that a combination of sedimentary supply and subsidence coincides to occur with a relatively a long period.

The organic petrography analysis result indicates that exinite content is larger than vitrinite as found in samples 08 MH 13C, 08 MH 13E, and 08 MH 13E2. The exinite content occurring in the fine-grained sedimentary rock is partly composed of alginite, especially *Botryococcus* type and a small amount of resinite, cutinite, and sporinite. The presence of dominated alginite sub-macerals suggests that the sediments tend to have been deposited in a fresh water, especially a lacustrine environment.

TST (Transgressive System Tract) began to occur above the erosional (ravinement surface) or limit sequence (sequence boundary). TST at the sites characterized by the presence of a mixture of grains of coarse sediments and mollusc fragmentation is high enough that is interpreted from the remnants of earlier sediments. Upwards, fossil obviously disappears. Biomarkers analyses (pristane and phytane) show anoxic conditions correlated with TST on 08 MH 13 location.

HST (Highstand System Tract) occurs when a rising sea level (in research are analogous to the lake water level) is relatively slow compared to the TST, causing sediment supply to be relatively equal to the average living accommodation. This marks the transgression ends and begins to be continuous towards regression. Regression deposition, formed when sediment supply is greater than its accommodation space is a hallmark of the late HST (highstand Systems Tract). The HST at the investigated area characterized by the deposition process is a repeated deposition of mudstone and claystone. Based on these characteristics, the HST are found at the upper and bottom of SNM-11.

LST (Lowstand System Tract) consists of deposits of the oldest type 1 depositional sequence, namely type 1 depositional sequence formed when sea level drops (analogous to the lake water level) relatively, with no regard to shoreline physiography of the basin. The characteristics of LST at the studied area is the presence of coal deposits in the mudstone and shale at all locations, except the SNM-15. The analysis of biomarkers (pristane and phytane) shows oxic conditions at the time the lake water level lacking in.

CONCLUSIONS

The presence of *Botryococcus* algae, fresh water fish fossil, wood trunk, and the result of triangle diagram of sterane C27, C28, and C29 for shale samples indicates that the main natural character of the Sinamar Formation was a result of the deposition in a fresh water lacustrine environment. The shale of Sinamar Formation has been formed by a facies change from a lacustrine into terrestrial condition. The coal seams (08 MH 13G,H, I, J, K, and L) were derived from an estuarine environment or a shallow lacustrine. Lowstand system tract is characterized by the presence of coal deposit.

Conglomeratic sandstones found in the studied area were a product of depositional processes in an alluvial fan that was coincident with the deposition of the fine-grained sediments of Sinamar Formation. It confirmed that all lithological sections of the fine-grained sediments of the Sinamar Formation were deposited in a lacustrine environment by various fluctuated surface levels of water.

The thicker bed of sedimentary clastics indicates that a combination sedimentary supply and subsidence coincide to occur with a relatively long period. This condition is caused by the highstand system tract process.

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