DEPOSITIONAL ENVIRONMENT OF THE SAROLANGUN COALS, SOUTH SUMATRA BASIN

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Abstract

The Muaraenim Formation, a Late Miocene unit within the South Sumatera Basin, is included in some of the most significant coal resources in Indonesia. The upper part of the unit exposed in the Sarolangun Region, where it consists mainly of sandstone and shale, with relatively thin (< 1.5 m) coal beds. Lithofacies analysis of the outcropping strata indicates that deposition took place in a terrestrial to marine environment.

Microscopic analysis shows that the coal consists mainly of vitrinite maceral group (telovitrinite and detrovitrinite), with having a rare to sparse inertinite and minor liptinite and mineral matter. Palynological studies show abundant pollens, derived from mangrove vegetation that grew in a fresh water environment. The GI and TPI values, calculated from detailed maceral analysis, when plotted on similar diagrams to those developed by Diessel (1992) show the coals to have two different facies characteristics. Some of the coals, especially those having a high vitrinite content, show high TPI and relatively high GI values, suggesting that deposition was in upper delta plain and fluvial environments (wet forest swamp) with a relatively high rate of subsidence. Other coals have much lower TPI but higher GI values, indicating that peat was possibly developed in in a lower delta plain, with relatively slow subsidence conditions. Some coal samples also have high proportions of pyrite and other mineral matter, and thus it might have been deposited in more brackish environments. The change reflects the onset of marine transgression near the top of the Muara Enim sequence. Palynological analysis indicates the occurrence of fresh water and mangrove vegetation, supporting deposition in wet and possibly partly brackish conditions.

Keywords: Depositional environment, Sarolangun coals, South Sumatera Basin, Indonesia

S a r i

Formasi Muaraenim merupakan unit Miosen Akhir di Cekungan Sumatera termasuk paling signifikan sebagai cadangan batubara di Indonesia. Bagian atas dari Formasi Muaraenim yang tersingkap di daerah Sarolangun umunya tersusun oleh batupasir dan batulanau dengan lapisan tipis batubara (< 1.5 m). Analisis litofasies dari singkapan batuan tersebut menunjukkan pengendapan terjadi di lingkungan darat sampai dengan laut.

Analisis mikroskop organik menunjukkan batubara di daerah penelitian umumnya terdiri dari grup maseral vitrinit (telovitrinit dan detrovitrinit), degan jarang sekali maseral inertinit, serta sedikit sekali mseral liptinit dan kandungan mineral matter. Studi palinologi dari beberapa sampel menunjukkan kaya akan polen yang berasal dari tumbuhan mangrove yang tumbuh di lingkungan air tawar. Perhitungan lebih lanjut dari analisis maseral untuk GI and TPI yang di plot ke dalam Diagram Diessel (1992), mengindikasikan batubara di daerah penelitian memiliki karakteristik fasies yang berbeda. Beberapa sampel batubara, khususnya yang kaya akan vitrinit maseral, memperlihatkan harga TPI yang tinggi dan harga GI yang juga relatif tinggi, yang menunjukan kemungkinan di endapkan pada lingkungan upper delta plain sampail fluvial (wet forest swamp). Sedangkan beberap sampel lain memiliki angka TPI yang rendah dengan angka GI yang tinggi, menunjukkan lingkungan rawa kemungkinan di dataran delta bagian bawah pada saat penurunan cekungan yang relatif rendah. Beberapa sampel batubara juga tersusun oleh mineral pirit yang sangat tinggi yang kemungkinan mengindikasikan bahwa batubara tersebut telah diendapkan pada lingkungan berawa. Perubahan lingkungan pengendapan menunjukkan terjadinya genang laut pada bagian atas sekuen dari Formasi Muaraenim. Kemunculan dari beberapa spesies polen yang diduga berasal dari tumbuhan air tawar dan mangrove memperkuat asumsi bahwa batubara di daerah penelitian diendapkan pada kondisi basah atau pada sebagian berawa.

Kata kunci: Lingkungan Pengendapan, Batubara Sarolangun, Cekungan Sumatera Selatan, Indonesia.

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Introduction

Indonesian coal basins are divided into three types, foreland, intermountain, and deltaic types (Koesoemadinata *et al*, 1978). In the foreland basin and deltaic zones, coals were deposited within regression time, while the intermountain basin was deposited pre-transgression time.

The South Sumatera Basin is a sedimentary basin formed since the beginning of the Tertiary and developed through the Neogene (Bemmelen, 1949). In Tertiary tectonics of Sumatera, the South Sumatera Basin, can be defined as a back-arc basin, underlain unconformably by the pre-Tertiary basement rocks comprising metamorphics, volcanics, sediments and plutonics that are different in ages and provenances. De Coster *et al*, 1974, stated that the depositional cycles of South Sumatera Basin are catagorized into two phases, transgression and regression phase. Coal bearing successions of this basin are mostly deposited in regression cycles, such as Muaraenim and Airbenakat Formations.

The South Sumatera Basin consists of four sub-basins, namely, Jambi sub-basin, North Palembang sub-basin, Central Palembang Sub-Basin, and South Palembang Sub-basin (Bishop, M,G., 2001). The Sarolangun area is located in the Central Palembang Sub-Basin, covers the nortwestern part of South Sumatra Basin (Figure 1). Administratively, the Sarolangun area belongs to the Sarolangun Regency of Jambi Province.

The geological setting of Central Palembang Sub-Basin was initiated by deposition of a shallow marine-brackish (at the base), paludal, delta plain and non-marine environment, composed of sandstone, mudstones and coal beds (de Coster, 1974). However, the relationship between the sedimentological position of peat formation and the petrological composition of coals in this area do not known yet.

The aim of the paper is establish paleoenvironment of the study area based on organic facies gained from maceral analysis, which then supported by lithofacies and palynology analysis. The coal characteristics information obtained are based on coal petrology on several selected fresh outcrop hand samples of coal collected from the representative areas of the upper part unit of Muaraenim Formation.

Method

To attain the aims of the study, specific geologic field investigations and laboratory techniques were performed.

The field investigation has been focused in the Sungai Belati Coal (SBC) Coalfield and Lubuk Napal. The surface and sub-crop coal samples are collected for laboratory analysis purposes. The coal outcrops are well exposed to be observed, especially in the coal working face and coal excavation of the Sungai Belati Coalfield. Predominantly, the outcrops can be reached by walk and cars or motor-bikes.

The laboratory techniques deal with semi-quantitative organic petrology. Representative coal samples and non coal samples were collected from the upper part unit of the Muaraenim Formation. By using standard procedures, the coal samples were prepared as polished briquettes. The polished briquettes were prepared from crushed 1 mm-size samples representing each coal seam, which then mounted in epoxy resin. 16 polished briquettes from the Sarolangun coals were subjected to the organic petrology analysis, which was mainly focused on maceral identification and quantification. This is important to have better understanding of maceral and mineral matter characteristics due to depositional environmental analysis.

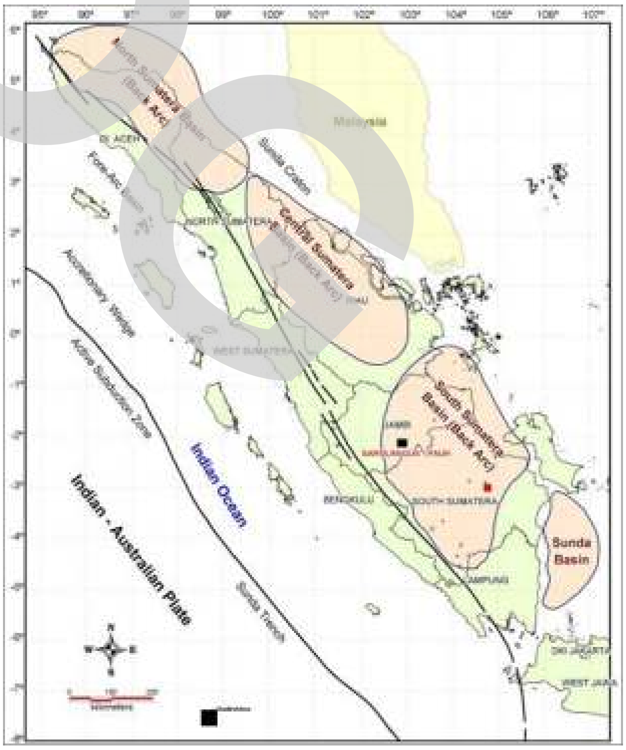

Figure 1. Back arc basin map in Sumatra and locality of the study area.

The maceral analysis based on 500 counts on each samples (including mineral matter) under reflected white light, was performed microscopically on polished briquettes sections. Ordinary white reflected light from a tungsten lamp and violet blue light from a highly pressure mercury lamp to initiate fluorescence were used for illumination, by using Leitz MPV-2 photomicroscope.

Most maceral determined are adopted from the International Committee for Coal Petrology (I.C.C.P., 1963 and 1971). Maceral analysis determines quantitatively the volume of organically derived, microscopically recognizable substances of coal, which are defined by their morphology and color.

Coal Geology

Lithofacies

Based on the field observation, the upper part unit of the Muaraenim Formation in Sarolangun Regency consists of sandstones, shale, and relatively thin coal beds (< 1.5 m). This unit is unconformably overlain by the Quaternary deposits of Kasai Formation.

Outcrop observation of the Sarolangun Coal unit generally consists of intercalated of fine-medium grained sandstone and light grey shale, and thin brown coal. Lithofacies interpretation may indicate that the Sarolangun Coal unit mainly divided into two facies, mire and flood basin (Figure 2). The lower unit of stratigraphic section is interpreted as mire facies. It made of thin coal bed covered by light grey carbonaceous shale at the top and bottom of coal seams, mostly made of flat bedding structures, whilst at the top of coal bed succession identified as flood basin facies, comprise erosive-based, fine- medium grained sandstone, with sedimentary structures, parallel lamination, ripple cross-lamination, and small cross bedding.

As mentioned previously, the lower part of section was deposited in the swamp area where the supply of the fine detritus and debris plant accumulated in the stable condition. The occurrence of fine to medium-grained sandstones with erosive-based and uneven sedimentary structures indicates the upper part of section is deposited as crevasse splay or channel. The further top of section consist of thick tufaceous claystone of Kasai formation, presumably this condition relates with the extensive volcanic activity in this area. Weimer in Diessel (1976) states that the alluvial and upper delta plain contains three coals producing sub-environment: (1) back-levee swamps, (2) abandoned channels, and (3) flood basin swamps. The overall depositional environment of Sarolangun coal is interpreted as an alluvial plain and or upper delta plain system.

Lithotypes

Two coal seams are well exposed in two areas that are SBC coalfield and Lubuk Napal (Figure 3). Coal characteristics from both areas indicate quite similar, but they are different in succession and thickness.

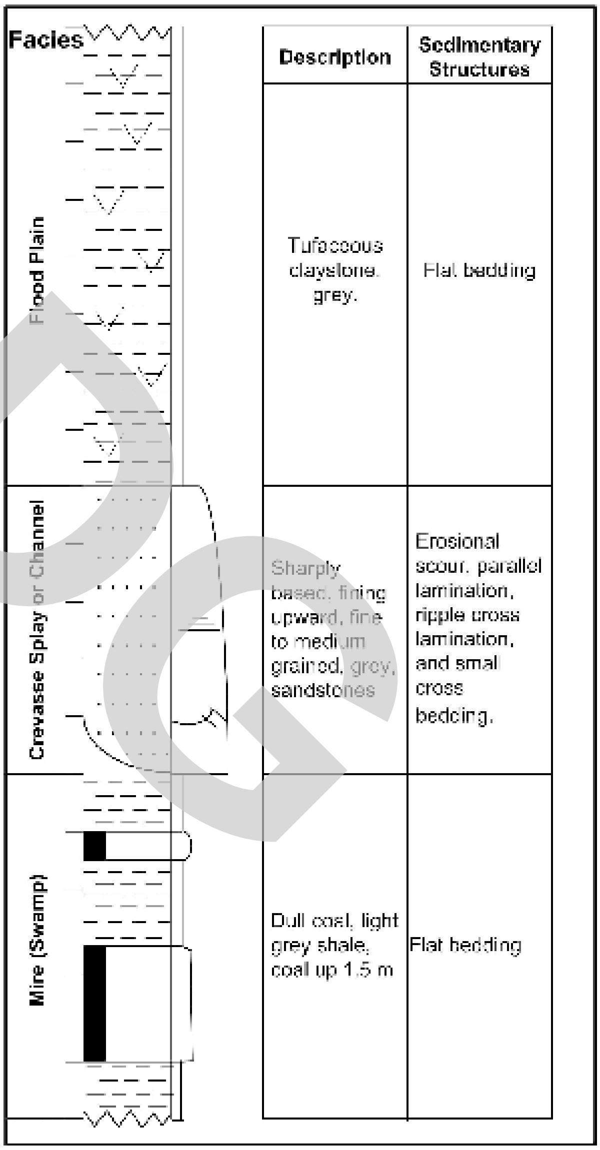

Figure 2. Lithofacies analysis of the Muaraenim Formation in the SBC Coalfield area.

Sungai Belati (SBC) coalfield

SBC coalfield area is not far from Sarolangun Town, approximately 15 km to the north (Figure 3). In the area, the coal seams form a slightly good outcrop and sub-crop, overlain by intercalations of sandstone and mudstone.

Characteristics of coal seam in this area are commonly dull - dull banded, blackish brown to brown in colour, brown in streak, rather hard, choncoidal to sub choncoidal fractures (Figure 4A), medium cleat, scattered of resin (0,1 mm – 3 cm). The coal is significantly categorised as low to moderate rank, having calorific value is about 3767 cal/gram, adb (Table 1).

Lubuk Napal Area

The region is located approximately 60 km to the northeast of Sarolangun Town (Figure 3). Coal section measurement was carried out in the Lubuk Napal area. Two coal seams in the area are exposed in the Monobegading River. The coal seams are typical dull to dull banded lithotypes (Figure 4B). However, the dominant lithotypes are dull banded. Megascopically, the coals are blackish brown in colours, brown in streak, slightly to highly cleated, resinous (2 mm – 2 cm), some coals have very thin layer of sulphur (0,1 – 0,2 mm), containing pyrites. The thickness of each coal sub-seam is less than 1.5 m. The coal ranges from moderate to high in rank about 3780 cal/gram to 4295 cal/gram, air dried basis; (Table 1).

Table 1. Calorific Values of the Sarolangung Coal

No	Sample code	Location	Calorific value
			Cal/gr, adb
1	06 TH 21E	Lubuk Napal	4196
2	06 TH 21F		3976
3	06 TH 22A		3886
4	06 TH 22B		4250
5	06 TH 22C		3950
6	06 TH 22D		3938
7	06 TH 22E		4117
8	06 TH 22F		4295
9	06 TH 22G		3952
10	06 TH 23		3780
11	06 TH 24	SBC	3767
12	06 TH 27A	Sungai Keruh dan Sungai Mengkua	3782
13	06 TH 27B		2803
14	06 TH 27 C		2742
15	06 TH 28		1225

Petrography of Coal

Maceral

Maceral analysis of the Sarolangun coals identified in white reflected light and fluorescence modes and also supported by photomicrographs are discussed within the paper. Maceral and mineral matter analyses of the coal (16 polished briquettes) were conducted to establish the maceral distribution and characteristics. Results of the proportions of maceral and mineral matter in each individual coals are presented in Table 2.

The maceral composition of the Sarolangun coals, predominantly, have consistently high proportion of vitrinite, with minor low amounts of exinite; a low inertinite constituent; and low to medium mineral matter content.

The SBC coals is characterised by the predominant vitrinite maceral group (up to 98.6%), mainly made up of telovitrinite (72%), with 70.8% of telocollinite and 1.2% of textinite , detrovitrinite (26%), with desmocolinite (24.6%) and minor of densinite (1.6%) and corpogelinite (2%). The exinite group (0.8%) includes cutinite (0.4%), sporinite (0.2%), and alginite (0.2%). However, the inertinite are absent in the sample from the SBC coals.

The maceral composition of Lubuk Napal coals is quite similar, consists of vitrinite group up to 93.8% with telovitrinite ranges from 28.6% to 59.6%, telocollinite (27.6% – 57.8%), textinite (0.4% - 4.6%), detrovitrinite (24.8% - 41.2%), densinite (0% - 35.2%), with minor of attrinite (0% - 15.2%), desmocollinite (0.6% - 28.2%), and gelovitrinite corpogelinite (0 – 2.6%). The inertnite group (2% - 13%) is essentially composed sclerotinite (1% - 8.8%), semifusinite (0 – 9.6%), inertodetrinite (0 – 3%), fusinite and macrinite are absent. The exinite group (2.8% - 18%) includes resinite (1.4% - 11.2%), sporinite (0 – 4.2%), cutinite (0 – 1.6%), suberinite (0 – 1.4%), alginite (0 – 1.8%), and liptodetrinite (0 – 2%).

Maceral characterization from SBC and Lubuk Napal are very similar under the microscope examination. General description of each macerals group is described in the following section.

Table 2. Petrographic Analysis Data of the Sarolangun Coal

NO.	SAMPLES	LOCATION	MACERAL (%)																						MINERALS (%)				
			TX	TC	TL	At	Dns	Dsm	DT	Crp	GL	V	Sp	Cu	Re	Sb	Alg	Lipt	EX	F	Sf	Sc	Intr	IN	Cly	Crb	PyF	PY	MM
1	06 TH 21A		0.4	33.2	33.8	2	25.2	8	35.2	1.2	1.2	70.2	4.2	1	11.2	0	0.8	0.6	18	0	1	3.4	0.6	5	1.4	1.6	1.6	0.4	5
2	06 TH 21B		1.8	47.7	49.5	4.4	24	1.6	30	2.3	2.3	81.8	0.8	1.2	4	0.4	0	0.4	6.8	0	2	4	0.4	6	1.2	1.4	1.2	0.4	4.2
3	06 TH 21C		1	27.6	28.6	4.4	31	3	38.4	3	3	70	2	1	6	0	0.4	0	9.4	0	3	5	1	9	2	1.4	1.2	0.4	5
4	06 TH 21D		2.2	44.2	46.4	4.6	26.4	3	34	0	0	80.4	1	0.6	3.4	0.4	1	2	8.4	0	0	8.8	0.6	9	2	0.4	0.6	0.8	3.8
5	06 TH 21E		1.8	57.8	59.6	2.4	17.2	5.2	24.8	1.2	1.2	85.6	0	3	1.4	0	1.2	1.4	7	0	0	3	0.4	3	1	1	1.6	0.4	4
6	06 TH 21F		0	40	40	2.2	33	3.4	38.6	0	0	78.6	0.8	0.4	3	0	0.4	0	4.6	0	3	4.2	1	8	1.8	1.2	0.8	1.6	5.4
7	06 TH 22A		0.4	46.4	46.8	1	28	3	32	1.6	1.6	80.4	0	1.4	3.6	1.4	0.4	0.4	7.2	0	4	5.2	2	11	0.4	2	0	0.6	3
8	06 TH 22B	Lubuk Napal	4.6	46.6	51.2	2	35.2	4.4	41.2	1.4	1.4	93.8	0	1.4	0.4	0	0.4	0.6	2.8	0	1	1	0	2	3.2	2.6	0	1	6.8
9	06 TH 22C		2.6	40.4	43	6.2	15	4.2	25.4	2.6	2.6	71	1.2	0.4	4	0	1.8	0.6	8	0	9.6	7	2.6	19	0.8	0.6	0.4	0.2	2
10	06 TH 22D		1	49.2	50.2	1.4	25.2	0.6	27.2	1.6	1.6	79	0.4	2	2.6	2	0.6	1.4	9	0	3	7.4	0.6	11	1.4	0.4	0	0.4	2.2
11	06 TH 22E		1	37.6	38.6	2.4	35	3.6	41	1	1	80.6	2.4	0	6.2	0.4	0.6	0	9.6	0	2	3.8	0.8	7	2	0.4	0	0.6	3
12	06 TH 22F		0.4	29.2	29.6	15.2	24	2	41.2	1.6	1.6	72.4	0.6	0.8	6.6	0.4	1	0	9.4	0	5	4.4	1.2	11	1.2	0.8	0	0.4	2,4
13	06 TH 22G		3.2	43.2	46.4	5.2	28.4	2.6	36.2	1.6	1.6	84.2	0	1.6	1.8	1	0.8	1.4	6.6	0	3	3.2	0.8	7	0.8	0.8	0	0.6	2.2
14	06 TH 23		1	40.4	41.4	3	29	3.4	35.4	0.6	0.6	77.4	0.4	1	3.6	0.6	0.6	0.6	6.8	0	4	5.6	3	13	1.4	0	0	0.4	1.8
15	06 AP 05 C		0.6	55.8	56.4	0	0	28.2	28.8	0.6	0	85.2	1.2	0.6	1.6	0	0	1.4	4.8	0	0	5	1	6	1.6	0.8	0.6	1	4
16	06 AP 01 C	SBC	1.2	70.8	72	0	1.6	24.6	26	2	0	98.6	0.2	0.4	0	0	0.2	0	0.8	0	0	0	0	0	0	0	0.2	0	0.2

Remarks:			
VITRINITE (V)	**EXINITE (EX)**	**INERTINITE (IN)**	**MINERAL MATTER (MM)**
TX: Textinite	Sp: Spronite	F: Fusinite	Cly: Clay
TC: Telocolinite	Cu: Cutinite	Sf: Semifusinite	Crb: Carbonate
TL: Telovitrinite	Re: Resinite	Sc: Scelrotinite	PyF: Pyrite Framboidal
At: Attrinite	Sb: Suberinite	Intr: Inertodetrinite	PY: Pyrite
Dns: Densinite	Alg: Alginite		
Dsm: Desmocolinite	Lipt: Liptodetrinite		
DT: Detrovitrinite			
Crp: Corpocolinite			
GL: Gelovitrinite			

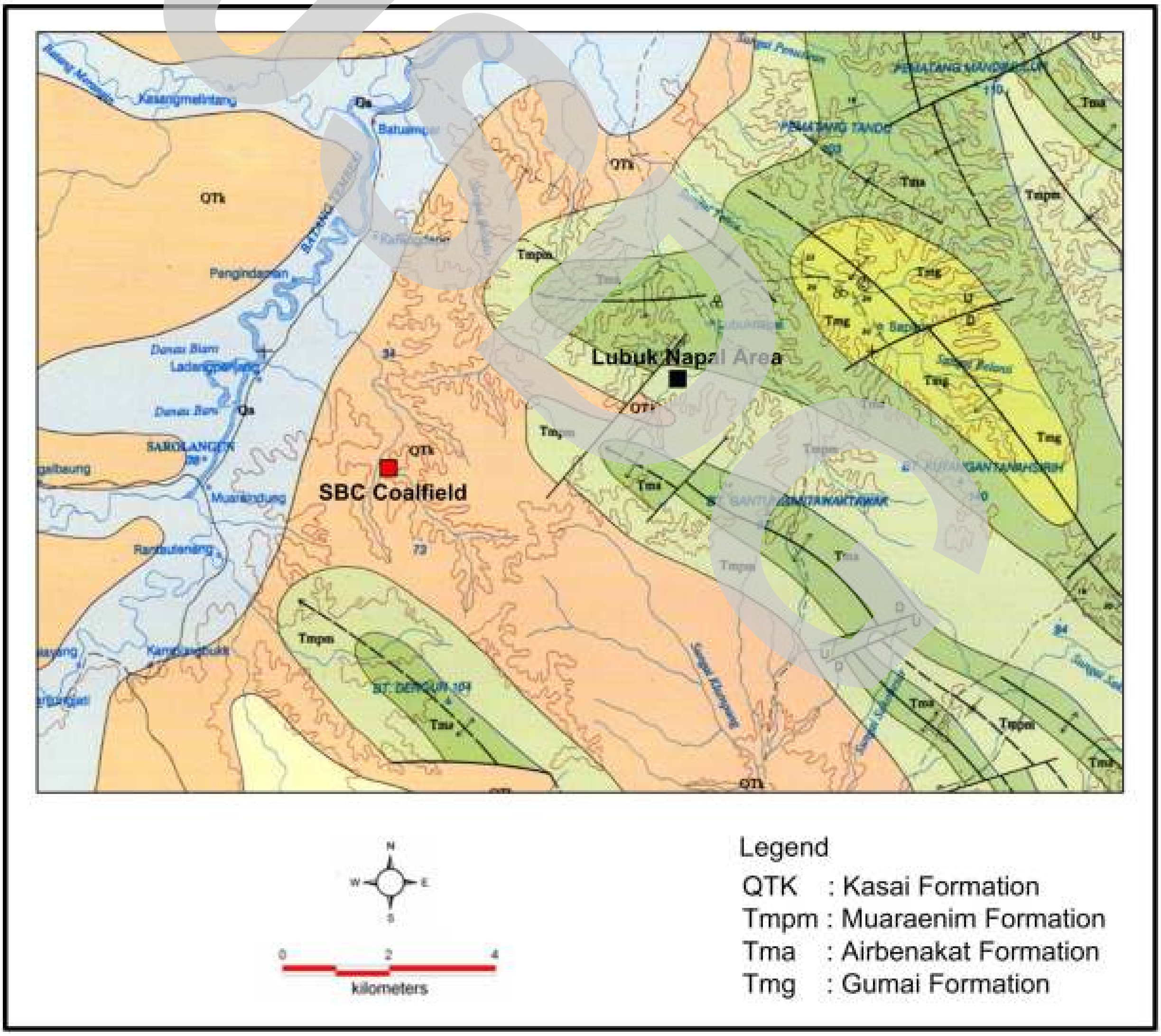

Figure 3. Geological map of the study area that shows location of SBC coalfield and Lubuk Napal Area, Sarolangun Quadrangle, South Sumatera (adopted from Suwarna *et al*., 1992)

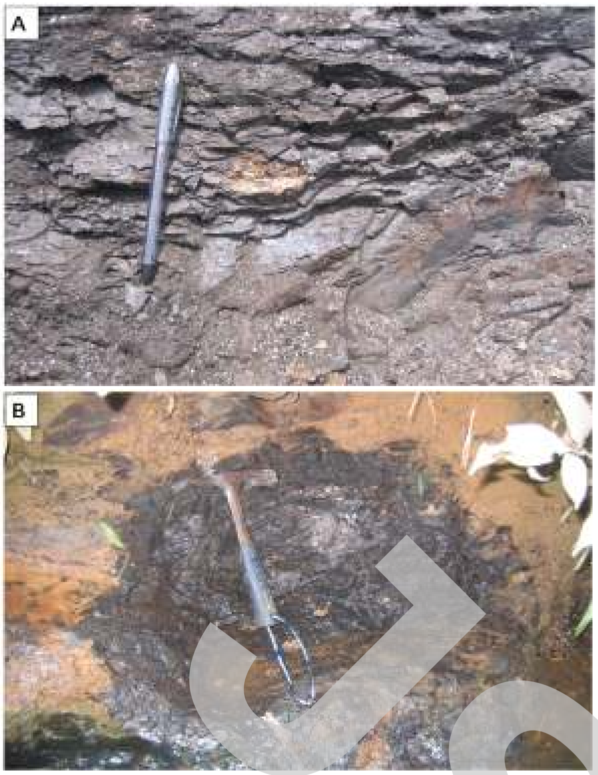

Figure 4. Coal lithotype of the Sarolangun coals, A: lithotype of 1.5 m coal seam from the Sungai Belati Coalfield, showing dull - dull banded, with choncoidal to sub choncoidal fractures; B: dull coals from the Monobegading River of the Lubuk Napal area.

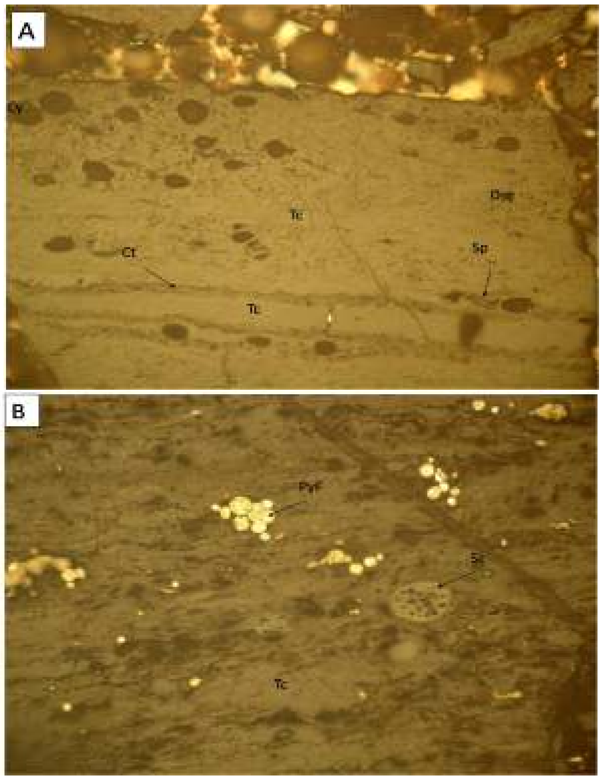

Figure 5. Photomicrograph of maceral analysis from the Sarolangun coals. (A) Telocollinite (Tc) associated with desmocolinite (Dsc), cutinite (Ct), sporinite (sp), clay minerals (Cy) within the SBC (Reflected light), Sample: 06 AP 01; (B) Showing telocolllinite (Tc) and sclerotinite (Sc), with framboidal pyrite (PyF), Lubuk Napal Coal, Sample: 06 TH 21D.

Vitrinite

Vitrinite is mainly composed of telovitrinite and detrovitrinite. Telovitrinite maceral shows a massive texture, with fairly uniform structures, light to dark grey colour, sometimes with desiccation cracks and transverse and oblique micro-cleats, in particular case in association with cutinite and sporinite (Figure 5A). Detrovitrinite is esentialy composed of desmocolinite and attrinite. Desmocolinite together with gelovitrinite are present as structureless groundmass. Corpocolinite included into gelovitrinite is usually present as discrete, with various shapes in sub-rounded to round.

Inertinite

Inertinite is composed of sclerotinite, semifusinite, inertodetrinite. Fusinite and macrinite are not observed. Sclerotinite is a common maceral of the group, originally derived from fungal with characteristics rounded to elongated shape (Figure 5B). Semifusinite occurs mainly as large lenses, bands or as isolated fragments, and it is generally associated with vitrinite and fusinite, and also pyrite. The presence of embedded tiny specks of inertodetrinite in the vitrinite, suggest that the inertodetrinite has undergone a high degree of degradation.

Exinite

Exinite consists of resinite, cutinite , sporinite, alginite , liptodetrinite, and suberinite. Resinite is a common maceral found as in situ cell filling or isolated body, rounded. Cutinite occurs as a dom, with commonly elongated shapes (Figure 5A). Like cutinite, sporinite found as dispersed organic matter (d.o.m), some has a lenses shape. Alginite origin from discrete alga bodies, it is found in either elliptical or spherical shapes.

Mineral Matter

The coal seams from both SBC and Lubuk Napal are characterized by very low to low amounts of mineral matter, comprising clay, pyrite and carbonates. Those three minerals are in similar amount, showing varieties values 0% - 3.2% (Clay), and 0% - 1.6% (Pyrite), and 0% - 2.6% (Carbonates). These are found with various size and modes of origin, and are mainly distributed within the macerals. The characteristics of each mineral from the optical miscroscope observation are described below.

Clay Minerals

Clay mineral in the Sarolangun coals (both SBC and Lubuk Napal area) are mostly found as small to large lenses and cell lumens within the telovitrinite macerals (Figure 5A). The massive lenses of the clay mineral within the maceral of coal seam may have been deposited into peat swamp by water or wind during the burial deposition of the organic matter (Ward, 2002).

Pyrite

Pyrite is found in two types, both framboidal and non framboidal modes (Figure 5B). Pyrite may infill or replace of coal macerals during the syngenetic deposition. The occurrence of pyrite is commonly associated with marine influence due to bacterial reduction of SO4 and precipitation of Fe sulphides in the peat swamp (Teichmuller and Teichmuller, 1979; Mackowsky, 1982).

Carbonates

Carbonates occur as crack or fissures infillings within the vitrinite macerals of the Sarolangun coals. This may indicate that the carbonates were commonly deposited in the second stage of the coalification, either in the syn-sedimentary or early diagenetic origin (Kortenski, 1992; Vassilev and Vassileva, 1996; Ward, 2002).

Palynological Analysis

Palynology analysis (Table 3), has been done on four samples collected from two areas. Two samples were collected from SBC coalfield and another two samples were collected from Lubuk napal area.

The palynology result on samples collected from SBC area shows the occurrence of *Palmaepollenites kutchensis, Florschuetzia trilobata, Acrostichum aureum* (sample No. 06 AP 01 A), and *Florschuetzia trilobata, Verrucatosporites usmensis,* and *Palmae Sp* (sample No. 06 AP 01 C). This may indicate that pollen originally derived from freshwater swamp. However, the Lubuk Napal coal units are composed of *Florschuetzia trilobata, Florschuetzia meridionales, Palmaepollenites kutchensis, Durio Sp, Retistephanocolpites williamsii, Cicatricosporites dorogensis* and *Verrucatosporites usmensis* (sample No. 06 AP 11), then *Florschuetzia meridionales, Durio Sp* and *Verrucatosporites usmensis* (sample No. 06 AP 05C). This may suggest that pollen from the Lubuk Napal coals unit were originally came from the backmangrove environment (Figure 6). These pollens maybe transported together with rock fragment to the basin and deposited in the peat swamp during the coalification.

Development of mangrove forest and freshwater swamp vegetation was close to a tidal environment influence. The back mangrove environment indicates that the final stage in the development of the mangrove and the beginning of the transition to a freshwater swamp. The freshwater environment is characterised by the presence of a freshwater swamp and lowland rain forest species, while brackish swamp elements are absent. Thus, the association of pollen assemblages above may indicate that the Sarolangun coals might be deposited wet environment, or mainly brackish condition.

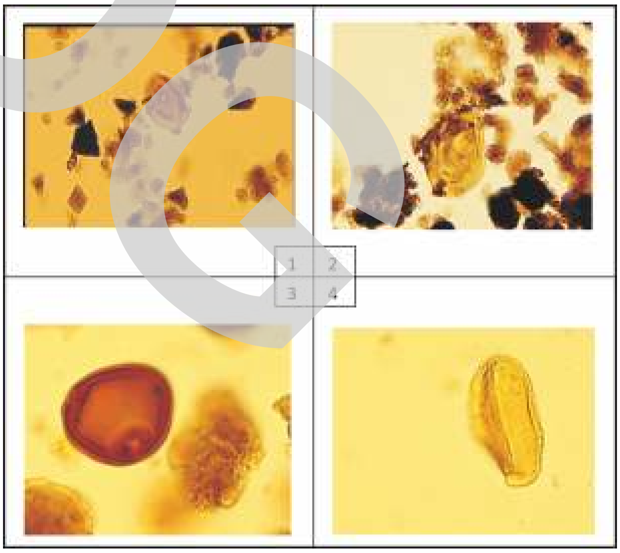

Figure 6. Photomicrograph pollen *Florschuetzia trilobata* (1), *Palmae Sp* 4), and *Durio Sp* (2,3), *its indicated the depositional environment of freshwater swamp and backmangrove depositional in the studies area.* Sample: (06 AP 01 C, Durio 06 AP 05 C, 06 AP 11).

Discussion

Coal facies

The term "mire" was used in the sense of Moore (1989) and McCabe (1987) as a habitat in which organic material, especially peat accumulation. The accumulation of peat formation is generally slowly sinking followed by subsidence event where mineral input is also nil or very small, in which the groundwater table keep abreast of peat formation. Such mires are called "topoganic "or "low moors". Only in areas of very high rainfall "ombrogenous" mires or "high more" which include "raised bogs" and "blanket bogs", may form above the groundwater table.

Coal facies is determinate based on maceral type and microlitotype. Diagnostic maceral as paleoenvironmental indicators are compared to remaining macerals. Tellinite and telocollinite, formed in a relatively high moisture conditions, are derived from partially gelified woody tissues. In spite of the structured inertinite (semifusinite and fusinite) as derived from woody vegetation, but it was under a relatively dry oxidizing condition. However, inertodetrinite, also having the same origin as semifusinite and fusinite, was originated from the disintegration of structured inertinite.

Futhermore, the abundance of vitrinite within the coal indicated that the coal was originated in a wet forest swamp environment (Bustin, *et al*., 1983), mainly from arborescent vegetation (Rimmer and Davis, 1988). A greater degree of degradation of woody tissue, mainly influenced by the type of vegetation, depth of water, pH, bacterial activity, and temperature of peat (Teichmuller, 1989) or mixed environmental conditions across the peat swamp may resulted in high content of degraded vitrinite.

Diesel (1986), introduced a model of "gelification Index" (GI) and a "Tissue Preservation Index" (TPI), based on the ratio of specific maceral combination. Both ratio indices can be used to determinate particular peat forming environment. The ratio formulated as follows :

GI = (Vitrinite + Macrinite) / (Semifusinite + Fusinite + Inertodetrinite)

TPI = (Vitrinite A + Semifusinite + Fusinite) / (Vitrinite B + Macrinite + Inertodetrinite).

A wet condition of peat formation is distinguished by highly GI and high TPI indices, whereas dry conditions lead to low TPI indices (Diessel, 1986). Coals deposited that contain rich of inertodetrinite, were deposited in piedmont plains where severe oxidation restricted the formation of telinite and telocolinite. Under conditions of falling water table, even structured inertinite will disintegrate to form insitu inertodetrinite, commonly couple with an increase in inherent ash and rather resistant sporinite. Inspite of coal deposited in upper delta plain and fluviatile environments are rich in vitrinite (wet forest swamp), but also in clastic clay minerals. Brackish coal deposited in a delta plain, partly as marsh peat, are distinguished by a high Gelification Index and a low Tissue Preservation Index, as well as by high amounts of pyrite and organic sulfur, due to a marine transgression.

Lamberson *et al*. (1991) explained that the high TPI and GI values in which content of vitrinite > inertinite and structured vitrinite > degraded vitrinite occurred in wet forest swamp of telmatic zone with rapid burial. However, the high GI and low-moderate TPI values are due to microbial attack conducted on coal precursor that was deposited in limited influx-clastic marsh (Figure 7). The coal exiting is characterized by vitrinite > inertinite, and degraded vitrinite > structured vitrinite.

Tabel 3. Palynological results of rock collected from Sarolangun Regency

No	Samples No.	Location	Pollen	Depositional Environment
1	06 AP 01 A	SBC	*Florschuetzia trilobata*	Freshwater Swamp
			Palmaepollenites kutchensis	
			Acrostichum aureum	
2	06 AP 01 C	SBC	*Florschuetzia trilobata*	Freshwater Swamp
			Verrucatosporites usmensis	
			Palmae sp	
3	06 AP 05 C	Lubuk Napal	*Florschuetzia meridionales*	Backmangrove
			Durio sp	
			Verrucatosporites usmensis	
4	06 AP 11	Lubuk Napal	*Florschuetzia trilobata*	Backmangrove
			Florschuetzia meridionales	
			Palmaepollenites kutchensis	
			Durio sp	
			Retistephanocolpites williamsii	
			Cicatricosporites dorogensis	
			Verrucatosporites usmensis	

Depositional environments

The ratio of specific maceral combination is used here as Diesel (1986) parameters. The petrographic indices of gelification index (GI) and tissue preservation index (TPI) are suitable to delineate the depositional environment system on the Sarolangun coals.

Table 4, shows that the TPI value from some coal samples (06 TH 21B, 06 TH 21D, 06 TH 21E, 06 TH 21F, 06 TH 22A, 06 TH 22B, 06 TH 22C, 06 TH 22D, 06 TH 22G, 06 TH 23, 06 AP 01C, 06 AP 05C) is around 1.1 – 2.9. This indicates the plant tissue is well preserved. Additionally another samples (06 TH 21 A, 06 TH 21C, 06 TH 22E, 06 TH 22F) indicate that moderate plant tissue is preserved, with low of TPI value for about 0.7 – 0.9. The GI value ranges from 5.9 – 58.6, indicates that the coals depositional environment was used to be a wet or sub-aqueous.

The combination result of GI and TPI values, were plotted into a diagram of Diessel, 1986 (Figure 7). The diagram shows that the Sarolangun coals were generally deposited in a wet environment area that was a marsh or fen to wet forest swamp environment under anoxic condition. The high GI and variety of TPI values show that the depositonal environment of the Sarolangun coals was a marsh or fen under limno-telmatic to telmatic (wet forest swamp). The Sarolangun coals have a high GI value, made up of most vitrinite, with minor content of semifusinite and inertodetrinite.

The marsh or fen depositional phases showed by samples 1, 3, 11, and 13, which are located close together on the diagram. Otherwise, eleven samples 2, 4, 5, 6, 7, 9, 10, 12 and 14, also plotted close together, indicate a stable telmatic (wet forest swamp). In addition one sample 8 (06 TH 22B) has a highest GI value.

The coal samples 06 TH 21F and 06 TH 22B, containing high mineral matter content are possible to be developed in marsh environment. A combination of desmocollinite (and gelovitrinite), and a little of telocollinite contents, shows that the coal is originated from soft tissues of shrubs within a marsh environment.

Both GI and TPI presented two coal facies characteristics. The high TPI and the high GI values, related with high vitrinite content, suggest that colas were deposited in an upper delta plain and in a fluvial environment (wet forest swamp). They are also represented a high rate of subsidence. On the other hand, a low TPI and high GI values, as well as a high amount of pyrite and other mineral matters, present in brackish coals, partly as marsh to fen peat, are due to a marine transgression, relatively in slow subsidence event.

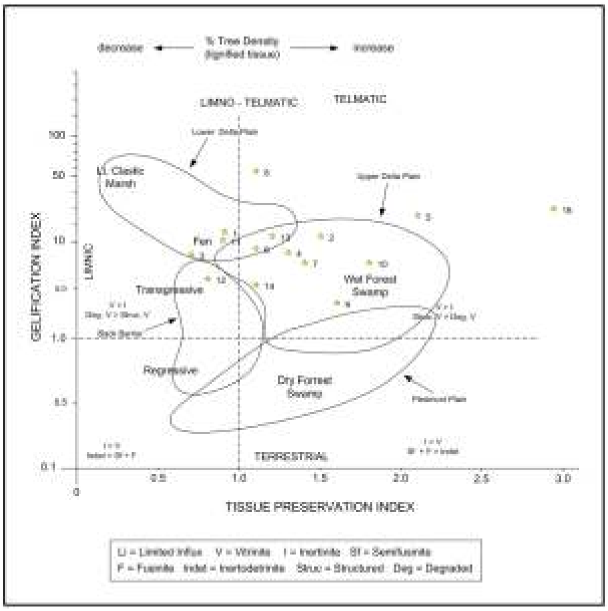

Figure 7. The diagram of coal Facies of the Sarolangun coal measures (based on Diessel's diagram, 1992), shows that the samples of predominantly a fen to wet forest swamp environment.

Table 4. Tissue Prservation Index (TPI) and Gelification Index (GI) of the Sarolangun Coals Used as Depositional Parameters.

No.	Samples No.	Location	TPI	GI
1	06 TH 21A	Lubuk Napal	0.9	14.04
2	06 TH 21B		1.5	13.6
3	06 TH 21C		0.7	8.1
4	06 TH 21D		1.3	8.6
5	06 TH 21E		2.2	25.2
6	06 TH 21F		1.1	9.4
7	06 TH 22A		1.4	7.5
8	06 TH 22B		1.1	58.6
9	06 TH 22C		1.6	3.7
10	06 TH 22D		1.8	7.4
11	06 TH 22E		0.9	12.2
12	06 TH 22F		0.8	6.8
13	06 TH 22G		1.2	12
14	06 TH 23		1.1	5.9
15	06 AP 05 C		1.9	14.2
16	06 AP 01 C	SBC	2.9	46.5

Based on GI and TPI value variation, the Sarolangun coals accumulated in marsh peatland from weakly to relatively strong decomposed shrub and grass tissues, under condition of microbial attack within moderate subsidence in limnic to limno telmatic setting, with relatively high detrital input. However, the latter coals were deposited in forested swamp (peatland) from weakly to relatively strong decompose woody tissues, under condition of moderate to rapid subsidence in telmatic zone. These conditions are also characterized by rapid burial, and mild to strong humification with strong gelification of plant tissues, occurring in the coal mire.

The coal facies diagram indicates that other coals fall within telmatic of forest swamp with a rapid burial condition. However, the latter coals occupy a limnic environment with limited influx-clastic marsh setting under a microbial attack condition. It represents that the Sarolangun coals are relatively deposited during the flooded area.

These results suggest that the Sarolangun coals night have been daposited in a marine transgression, with high to slow rate of subsidence. It indicated the ratio of accommodation space and peat production rate are balance. Futhehrmore the sedimentary supply was very slow, probably develoved progradational trend.

Conclusions

The coal bed are mainly characterized by high content of vitrinite (up to 98%), with minor low inertinite (0 – 19%), and exinite (0.8% - 18%). However, a low quantity mineral matter occurs, comprising a similar amount of clay minerals, pyrite and carbonates.

The lithofacies on vertical sequence analysis of the Sarolangun section, they are two facies identified. The lower part of section was deposited in a swamp area (mire) in the stable condition, whilst the upper part of section is deposited as crevasse splay or channel in flooding phase.

The pollen assemblage of the Sarolangun coals indicates that the sequence associated with development of mangrove forest and freshwater swamp vegetation, supporting deposition in wet and possibly partly brackish conditions.

The combination result of GI and TPI values indicates facies of the Sarolangun coals is ranges from a marsh to fen under limno-telmatic to telmatic, with high to slow subsidence rate.

A small amount of inertinite is indicative of the absence of severe oxidation during accumulation of the peat. The predominance of desmocolinite suggests that the main peat-forming plant communities were poor in stable lignin and rich in cellulose, probably dominant in herbaceous type with a smaller contribution from forest swamp type. This condition also supported by the sedimentary facies associations indicating a fluvial to shallow marine environment. The occurrence of the pyrite may also support that the peat growth were influenced by marine condition.

It can be concluded that based on organic facies gained from the maceral analysis, supported by associated sediment and pollen characteristics, the depositional environment of Sarolangun coals is transition of freshwater to marine environment.

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