VITRINITE REFLECTANCE VARIATION OF OMBILIN COAL ACCORDING TO ITS PETROGRAPHIC ANALYSIS

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ABSTRACT

Rank and type variations of the Ombilin coals were studied by petrographic examination of thirty-six samples. The coals are mainly dominated by vitrinite and rare exinite, inertinite and mineral matter. Vitrinite macerals are dominated by detro- and telovitrinite. Cutinite, liptodetrinite and suberinite are the dominant exinite macerals in the coals. Inertinite macerals in the coals include sclerotinite, inertodetrinite and semifusinite. Mineral matter is rare in the coals consisting of clay and pyrite. The type differences largely reflect climatic influence and differences in peat conditions. The higher vitrinite reflectance of some of the coals is a result of igneous intrusion. The thermally affected coal has vitrinite reflectances between 3.39% and 4.69% indicating a coalification stage of anthracite; whereas the thermally unaffected coal is between 0.55% and 0.77% with ranks of sub-bituminous to high volatile bituminous, as classified by the Australian classification. The thermal effect has also an impact to the vitrinite content in the coals. The thermally affected coals contain 86-99% vitrinite, whereas the thermally unaffected coals contain 80-96% vitrinite. This is because in the thermally affected coals, exinite cannot be distinguished from vitrinite, and it appears to contain high proportion of vitrinite.

1. INTRODUCTION

Coals occur in most major Sumatera Tertiary sedimentary basins. The major known occurrences of coals are mainly confined to the Palaeogene Ombilin Basin (Ombilin coalfield) and South Sumatera Basin (Bukit Asam coalfield). The study is emphasised only in the Ombilin Basin that is an intermontane basin located approximately 100 km northeast of Padang, the Sawahlunto region, West Sumatera Province (**Figure 1**). Reflectance studies of the Ombilin Basin reveal that the coals range from sub-bituminous to anthracite stages. Normally, rank increases with depth of burial and geothermal gradient in the Sumatera coal bearing basins. However, some coal seams in the Ombilin coalfield are exhibit abnormally high vitrinite reflectances due to proximity of andesite intrusions. Ombilin coals which not affected by contact alteration are sub-bituminous (minor) to high volatile bituminous (major) rank, whereas thermally altered coals are anthracite. The higher rank of the coals compared to the surrounding coals in the coalfield is due to their different thermal history with higher temperatures acting over longer periods at Ombilin.

The aims of the study are to obtain an understanding of the following aspects:

- to determine type and rank characteristics of the Ombilin coals by making maceral analyses and reflectance vitrinite measurements.
- to establish the broad patterns of rank and type of the coals.
- to examine the implication of the petrographic data with respect to the presence of igneous intrusions in the coalfield.

The above aims of the study have been met by an integrated petrological study presented in the paper. The authors are solely responsible for the preparation of the coal samples and collection of petrological data.

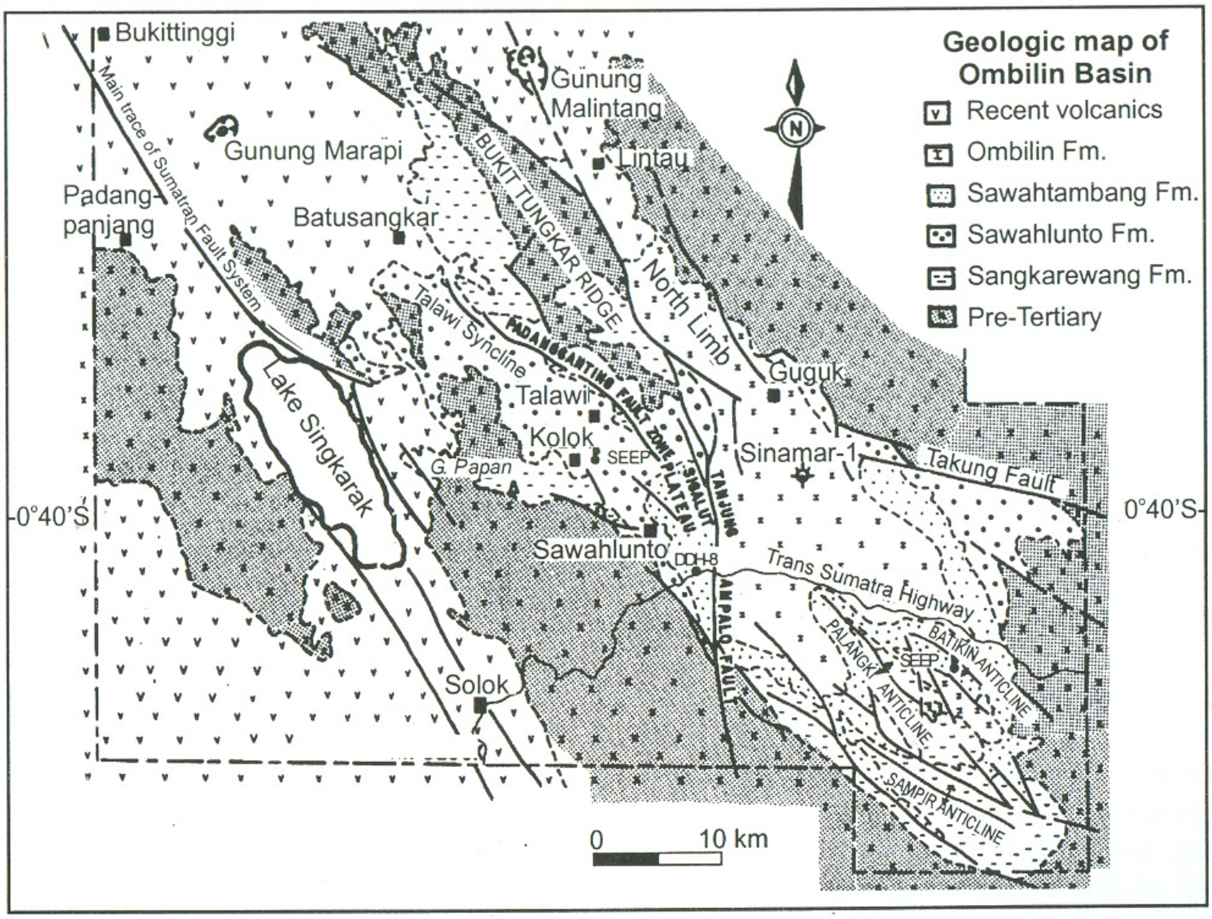

Figure 1. Ombilin intermontane Basin (Koning, 1985)

2. METHODOLOGY

Thirty-six coal samples consisting of 27 spot/outcrop and 9 core samples studied were obtained from the Tertiary Ombilin coalfield. The sampling was based on the procedure of the Standards Association of Australia (1964). The core samples were collected through the entire thickness of the seams. The spot samples were obtained from portions of insitu exposures, including outcrop and open cut. They were taken to examine reflectance and petrographic determination of the coals showing distinctive compositional features.

The method of preparation of polished particulate coals for microscopic analysis was carried out through crushing, embedding, grinding and polishing. All the samples examined were conducted in the coal laboratory of R and D Centre for Mineral and Coal Technology.

All samples were examined in both reflected white light and reflected ultraviolet light excitation. Maceral analyses were determined in oil immersion in reflected plane polarised light at a magnification of x500. Polarised light was essential for the examination of thermally altered samples. The exinite group of macerals were studied using ultraviolet light excitation at a magnification of x500. Fluorescence examination was carried out using a Leitz Orthoplan microscope. This system provides a combination of acceptable intensities, adequate colour separation of components and ease of switching from reflected white light to fluorescence mode (Cook, 1980). An Orthoplan microscope fitted with a Leitz Vario-Orthomat camera was used for all photography. Maceral analysis is based on counting of 500 points and the data are calculated as follows:

– mineral matter counted: %vitrinite+exinite+inertinite+mineral matter=100
– mineral matter free basis:

%vitrinite+exinite+inertinite=100

Reflectance measurements were carried out using a Leitz Ortholux microscope fitted with a Leitz MPV 1 microphotometer. The microphotometer was calibrated against synthetic garnet standards of 0.917% and 1.726% reflectance and a synthetic spinel of 0.413% reflectance. A galvanometer was set to provide a reading of one half the reflectance multiplied by 100. Reflectance measurements were made using incident light of 546 nm wavelength and oil immersion of refractive index 1.518 at a room temperature of 23°±1°C (Cook, 1982). One hundred (100) measurements were obtained from each sample from which the mean random reflectance and the standard deviation were calculated. Additionally, a total of 30 measurements were taken on each sample in which the mean maximum reflectance and the deviation were also calculated.

3. GEOLOGICAL SETTING

The Ombilin coalfield is located on the northwest margin of the Eocene Ombilin Basin in West Sumatera. The basin is structurally controlled by wrench fault, which is related to the Great Sumatera Fault Zone (De Coster, 1974 and Harsa, 1975).

The Palaeogene cycle of sedimentation in the Ombilin Basin represents the initial terrestrial phase of the Tertiary sequence (Koesoemadinata, 1978 and Eubank and Makki, 1981). The Palaeogene sequence was deposited in an intermontane basin, which developed at the beginning of the Tertiary when the pre-Tertiary landmass was block-faulted into grabens. The graben-like basin was filled from all sides by alluvial fans, whilst several lakes existed in the central basin. As the topographic relief decreased, the basin became an alluvial valley with meandering rivers followed by a braided river system, before it was folded and uplifted in the Early Miocene. A number of sub-parallel anti- and synclines are present in the basin, mostly bounded by major faults, which trend principally east-west, northeast-southwest and northwest-southeast (**Figure 2**). The coal measures occur in two stratigraphic units, namely the Sawahlunto Formation and the Poro Member of the Sawahtambang Formation (**Figure 3**). Three coal seams (A, B and C) occur in the Sawahlunto Formation. A detailed stratigraphic sequence of the coal measures is presented in **Figure 4**. Coal seams of the Poro Member of the Sawahtambang Formation are exposed on the southeastern part of the basin. The seams are very thin with thickness varying between 15 and 18 cm.

4. RESULTS

4.1 Coal type

Microscopic studies of 36 coal samples from four coal seams (A, B1, B2 and C) in the Ombilin coalfield show that those samples are composed largely of vitrinite and minor exinite with rare inertinite (**Table 1**). Slightly different maceral compositions exist between coal seams. For instance, vitrinite content increases slightly from A seam through to C seam. Thermally affected coals commonly contain vitrinite and rare inertinite, but it his no recognizable exinite. In the viewpoint of macroscopic studies, the coals are mostly dominated by brighter (clarain and vitrain) lithotypes.

a. Vitrinite
   Vitrinite content of the Ombilin coals (**Photo 1**) has a range between 82% and 99% (average 90%). Detrovitrinite forms a matrix for isolated thin bands of telovitrinite and exinite. The detrovitrinite matrix comprises >50% of the total vitrinite in most of the coal samples. Gelovitrinite (mainly corpovitrinite and porigelinite) occurs throughout the coals. They are commonly associated with suberinite.

b. Exinite
   Exinite content ranges from 1% to 9% (average 6%). Cutinite, resinite and liptodetrinite are the dominant exinite macerals, although suberinite and sporinite are dominant in some occurrences. Fluorinite, exsudatinite and alginate occur in few samples and are rare.

c. Cutinite (**Photo 1**) constitutes over 5% of some samples. It occurs mostly as thin-walled cutinite (tenuicutinite). The cutinite has weak to moderate intensity orange fluorescence. In some cases, it does not fluoresce. Suberinite constitutes up to 3% of some samples of the coals. It typically shows weak orange fluorescence, but in some cases does not fluoresce. Non-fluorescing suberinite is difficult to distinguish from vitrinite. Resinite is present in most of the samples, although its content is trace

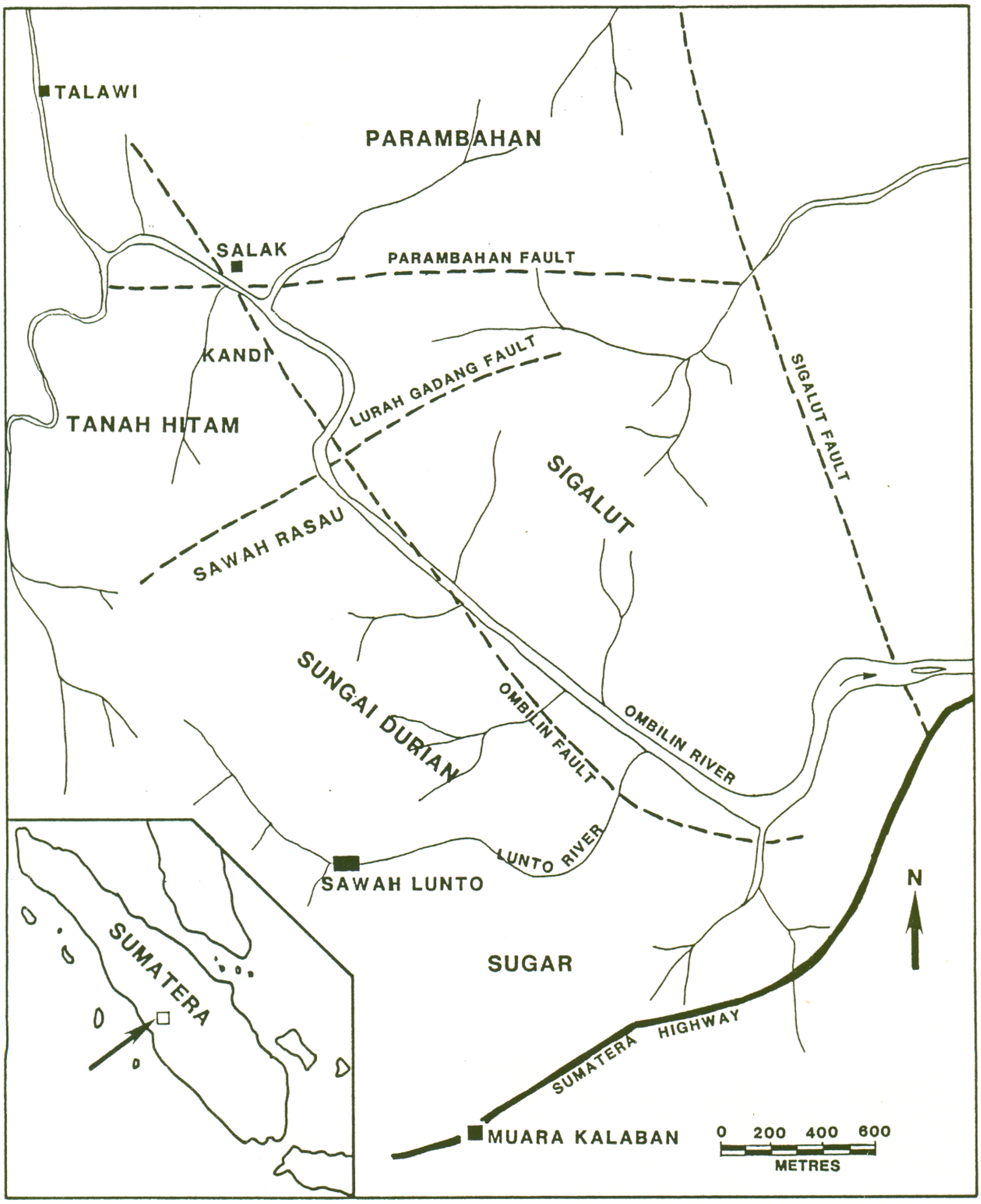

Figure 2. Regional geological structure in the Ombilin coalfield (Marubeni-Kaiser, 1971)

to 1%. The resinite occurs as discrete small bodies (<0.06 mm). It has greenish yellow to yellow fluorescence. Sporinite is dominant exinite maceral in some samples. It occurs mostly as miospores and pollen and is disseminated throughout the coals. The sporinite has yellow to orange fluorescence. Fluorinite is rare in the Ombilin coals. It has a greenish yellow fluorescence. Alginite is present in some samples. Its content is variable, varying from traces to 2%. Significant variation in exinite fluorescence colours exists between the samples. The alginate has yellow to orange fluorescence.

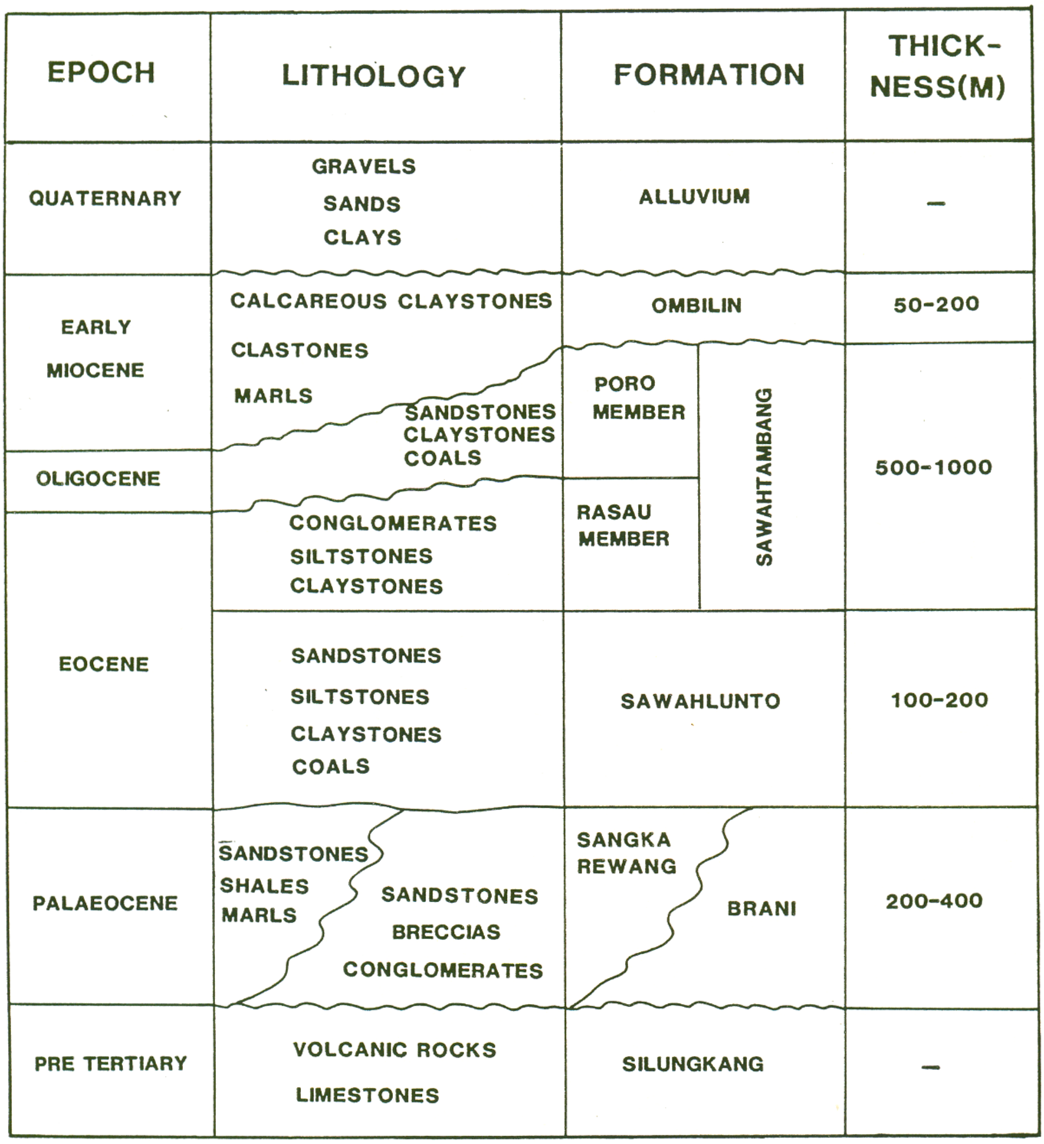

Figure 3. Stratigraphy of the Ombilin Basin (Roeslan, 1984)

d. Inertinite
Inertinite is a minor constituent in the samples. The inertinite content varies between a trace and 4% (average 2%). Sclerotinite (**Photo 2**) is the dominant inertinite maceral group and consists of sclerotia, single and twin celled teleutospores and teleutospores with three and four cells. Semifusinite takes place as thin layers and rarely as isolated lenses in a detrovitrinite matrix. Inertodetrinite constitutes 1% (average) of the coals. It occurs as angular and irregular forms disseminated throughout the coals.

e. Mineral matter
Mineral matter includes mainly clay and pyrite (**Photo 3**) and is rare in the Ombilin coals. It generally constitutes a trace to 4%, although some samples contain >6%. Most of the mineral matter occurs as pods disseminated throughout the coals. Framboidal pyrite is common in the thinner seam.

Based on the above Ombilin coal type, it can be highlighted that the exinite and inertinite contents of the coals are systematically related to the vitrinite content. The exinite and inertinite contents

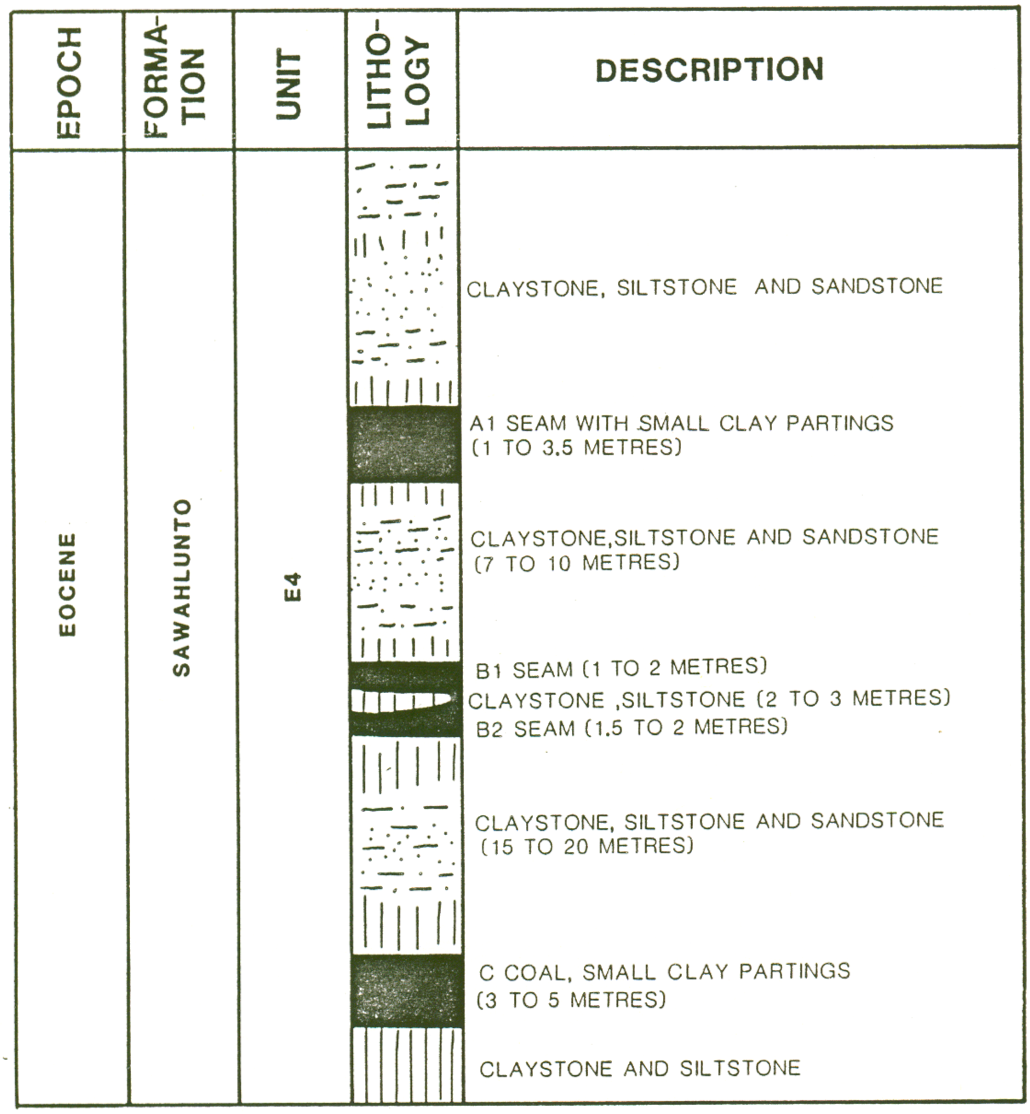

Figure 4. Stratigraphic sequence of the Ombilin coal measures (Marubeni-Kaiser, 1971)

decrease with the increase in vitrinite content. The exinite content is not related to the inertinite content.

4.2 Coal rank

Mean maximum vitrinite reflectance (Rvmax) values were obtained on thirty-six samples from the Sawahlunto Formation of the Ombilin coalfield (**Table 2**). The results are used to assess lateral and vertical variation. Most of the samples are high volatile bituminous rank (Rvmax of 0.62-0.77%), although one sample is sub-bituminous (Rvmax of 0.55%), according to Standards Association of Australia (1981). The low vitrinite reflectance value of some samples may be due to the presence of alginite (Hutton and Cook, 1980). The rank of the isolated coals in the Tanah Hitam open cut increases sharply into anthracite stage. This change is presumably associated with heating from a local intrusion.

Three coal layers are present in the Ombilin coalfield (from top to bottom: A, B and C seams), as mentioned in the previous chapter. Slight variation in vitrinite reflectance occurs laterally. The vitrinite reflectance of A seam for instance, decreases southwards from the Sawah Rasau un-

Table 1. Maceral composition of the coals

LOCATION	SEAM	VITRINITE (%)				INERTINITE (%)				EXINITE (%)				MM
		Tv	Dv	Gv	Tot	Sf	Scl	Inert	Tot	Res	Cut	Sub	Tot	(%)
Tanah Hitam o/c	A	47	33	5	85	-	tr	tr	tr	-	6	3	9	1
		21	57	10	88	-	-	-	-	-	1	tr	1	tr
		23	51	8	82	tr	tr	tr	tr	1	5	2	8	3
		23	50	13	86	tr	tr	tr	tr	tr	4	4	8	1
Sawah Rasau u/g	A	29	56	10	95	tr	tr	1	1	tr	1	tr	1	tr
		19	58	10	87	-	tr	tr	tr	tr	5	1	6	1
		37	49	10	96	-	1	1	2	tr	1	tr	1	-
		38	48	5	91	tr	2	1	3	1	2	tr	3	1
		24	51	9	84	tr	tr	1	1	1	1	1	3	3
Tanah Hitam o/c	B1	24	49	16	89	1	1	1	3	1	tr	tr	1	2
		19	58	13	90	tr	2	1	3	1	1	tr	2	1
Sawah Rasau u/g	B1	14	65	5	84	tr	1	tr	1	tr	4	tr	4	6
		23	60	9	92	tr	1	1	2	1	2	tr	3	1
Tanah Hitam o/c	B2	19	65	9	93	1	2	1	4	1	tr	tr	1	tr
		28	51	11	90	tr	1	1	2	tr	4	1	5	1
Sawah Rasau u/g		17	68	7	92	1	1	1	3	1	4	tr	5	tr
	B2	66	25	5	96	-	tr	tr	tr	1	1	tr	2	1
		19	61	5	85	tr	1	-	1	tr	3	-	3	3
		41	47	7	95	tr	-	1	1	1	1	1	3	tr
		42	49	1	92	tr	1	1	2	-	3	1	4	tr
		39	42	14	95	-	tr	-	tr	tr	3	tr	3	-
BH7 Parambahan	B	23	57	8	88	1	2	1	4	1	2	-	3	3
		26	54	6	86	1	2	1	4	tr	5	tr	5	3
		40	41	9	90	tr	2	1	3	1	2	1	4	2
		36	36	8	80	2	1	-	3	tr	3	2	5	11
		19	54	13	86	tr	3	3	6	1	1	1	3	1
Tanah Hitam o/c	C	35	53	6	94	-	tr	tr	tr	-	tr	2	2	tr
		33	50	8	91	-	1	2	3	-	1	3	4	-
		99	-	tr	99	1	tr	-	1	-	-	-	-	tr
		99	-	-	99	tr	1	-	1	-	-	-	-	tr
		20	62	6	88	1	1	tr	2	tr	1	tr	1	7
		33	55	5	93	tr	1	tr	1	1	2	1	4	-
Sawah Rasau u/g	C	26	48	18	92	tr	tr	tr	tr	tr	4	2	6	tr
		32	50	12	94	tr	tr	-	tr	1	3	1	5	tr
BH7 Parambahan	C	33	48	8	89	1	2	tr	3	1	3	tr	4	2
		38	45	8	91	tr	1	1	2	1	1	tr	2	4

Notes: Tv : telovitrinite, Dv : detrovitrinite, Gv : gelovitrinite, Sf : semifusinite, Scl : sclerotinite, Inert : inertodetrinite, Res : resinite, Cut : cutinite, Sub : suberinite, MM : mineral matter, Tot : total; o/c : open cut, u/g : underground

derground mine (**Figure 5**). Rvmax ranges from 0.62% to 0.71% in Sawah Rasau and 0.63% to 0.64% in Tanah Hitam. The slight differences may be due to depth of burial. The same trend exists for the B1, B2 and C seams. Vitrinite reflectance of the B and C seams increases to the north of the area (Parambahan). Rvmax of the B seam in the north ranges from 0.70% to 0.77% and for the C seam ranges between 0.75% and 0.77%.

Vitrinite reflectance of C seam increases locally in the Tanah Hitam open cut. Two polished blocks have Rvmax of 4.69% and 3.39% and both are classified as anthracite.

Vitrinite reflectance data from a shallow depth borehole (BH7) at Parambahan area shows that rank gradient increases with increasing depth (about 0.045% Rvmax/10 meters, **Figure 6**). In

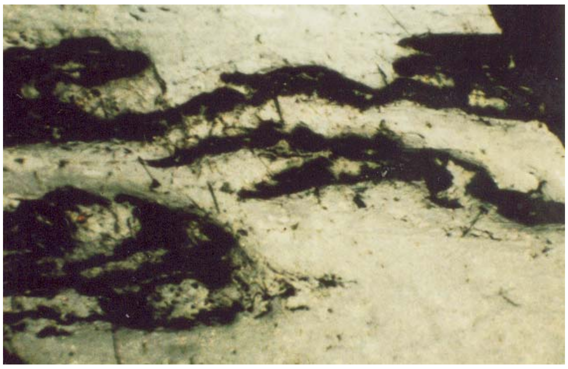

Photo 1. Telovitrinite (grey) and cutinite (black). B1 seam, Rvmax: 0.65%, field width: 0.28 mm, reflected white light

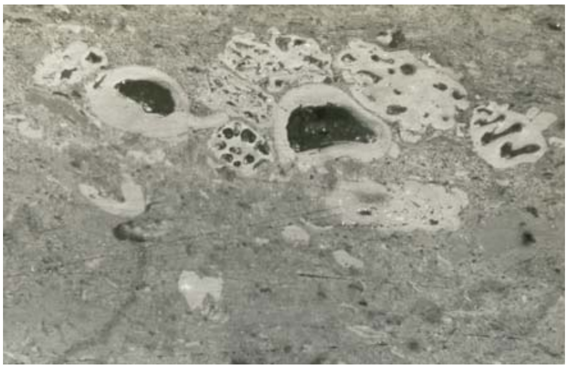

Photo 2. Sclerotinite (white) in detrovitrinite (grey), B seam, Rvmax: 0.70%, field width: 0.22 mm, reflected white light

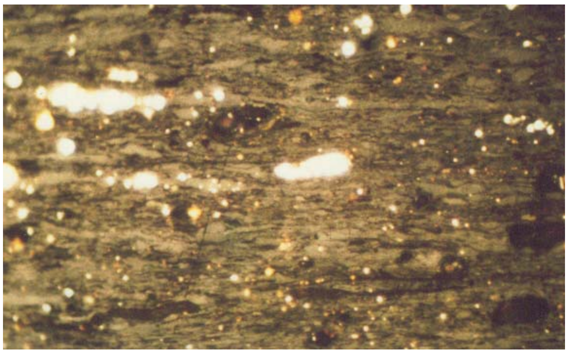

Photo 3. Pyrite (white), detrovitrinite (grey) and exinite (black), B1 seam, Rvmax: 0.55%, field width: 0.28 mm, reflected white light

the Sawah Rasau area, no significant vitrinite reflectance variation exists among A, B and C seams, but vitrinite reflectance for the two B seam splits indicates that lower B (B2) is slightly higher in rank than that of upper B (B1). Vitrinite reflectance increases slightly from A seam through to B and C seams in the Tanah Hitam open cut. Rvmax of A seam ranges from 0.63% to 0.64%. Vitrinite reflectance in places increases from top to bottom of the seam. Seam A in the Sawah Rasau underground mine, for instance, indicates an increase in vitrinite reflectance from 0.62% at the top through to 0.71% at the base.

5. DISCUSSION

Maceral compositions of the Palaeogene Ombilin coal samples are slightly different from each other. There is a factor affected the difference, that is intrusion (thermal) effect. In the thermally affected coals, exinite commonly cannot be distinguished from vitrinite. Thus, it appears to contain high proportion of vitrinite, which varies from 86% to 99%. However, the thermally unaffected coals contain 80% to 96% vitrinite. Exinite maceral is common in the coals unaffected by contact alteration with some samples containing up to 9% exinite. In contrast, the thermally affected coals have trace amounts of exinite. Cutinite and suberinite are prominent in some of the Ombilin coals in association with vitrinite.

Both thermally affected and unaffected coals contain rare inertinite with some samples containing up to 6%. In some cases, the coals with a low inertinite content have a relatively high amount of mineral matter. Cook and Johnson (1975) have suggested that this may be the result of peat ablation in relatively reducing decreasing quality of environments giving an unfavourable balance between the rate of accumulation of organic material and mineral matter.

The most obvious trend for the Ombilin coal is the decrease in the proportion of exinite and the increase in the proportion of vitrinite. Vitrinite in the coals unaffected by contact alteration consists of thick detrovitrinite matrix (up to 68% in some samples) interbedded with thin bands of telovitrinite. Vitrinite of thermally affected coals is mostly structureless, massive and containing few pores.

The dominance of vitrinite in the coals is indicates

Table 2. Rank of the coals (Australian standard)

LOCATION	SEAM	Rvmax (%)	RANGE	RANK
Tanah Hitam o/c	A	0.63	0.57-0.69	High volatile bituminous
		0.64	0.59-0.70	High volatile bituminous
		0.62	0.54-0.70	High volatile bituminous
		0.68	0.62-0.74	High volatile bituminous
Sawah Rasau u/g	A	0.71	0.60-0.72	High volatile bituminous
		0.64	0.58-0.70	High volatile bituminous
		0.67	0.60-0.74	High volatile bituminous
		0.68	0.60-0.82	High volatile bituminous
		0.62	0.57-0.69	High volatile bituminous
Tanah Hitam o/c	B1	0.64	0.57-0.69	High volatile bituminous
		0.64	0.56-0.70	High volatile bituminous
Sawah Rasau u/g	B1	0.55	0.46-0.63	Sub-bituminous
		0.65	0.59-0.71	High volatile bituminous
Tanah Hitam o/c	B2	0.68	0.61-0.75	High volatile bituminous
		0.64	0.59-0.71	High volatile bituminous
		0.71	0.66-0.80	High volatile bituminous
Sawah Rasau u/g	B2	0.71	0.61-0.80	High volatile bituminous
		0.62	0.54-0.71	High volatile bituminous
		0.71	0.65-0.78	High volatile bituminous
		0.7	0.64-0.78	High volatile bituminous
		0.72	0.67-0.78	High volatile bituminous
BH7 Parambahan	B	0.75	0.70-0.81	High volatile bituminous
		0.76	0.72-0.87	High volatile bituminous
		0.77	0.69-0.83	High volatile bituminous
		0.77	0.72-0.82	High volatile bituminous
		0.64	0.56-0.73	High volatile bituminous
		0.63	0.57-0.67	High volatile bituminous
Tanah Hitam o/c	C	0.62	0.57-0.66	High volatile bituminous
		4.69	4.59-4.77	**Anthracite**
		3.39	3.30-3.51	**Anthracite**
		0.68	0.60-0.79	High volatile bituminous
		0.64	0.59-0.75	High volatile bituminous
Sawah Rasau u/g	C	0.7	0.65-0.77	High volatile bituminous
		0.68	0.61-0.75	High volatile bituminous
BH7 Parambahan	C	0.75	0.69-0.84	High volatile bituminous
		0.77	0.73-0.81	High volatile bituminous

Notes: o/c-open cut, u/g: underground

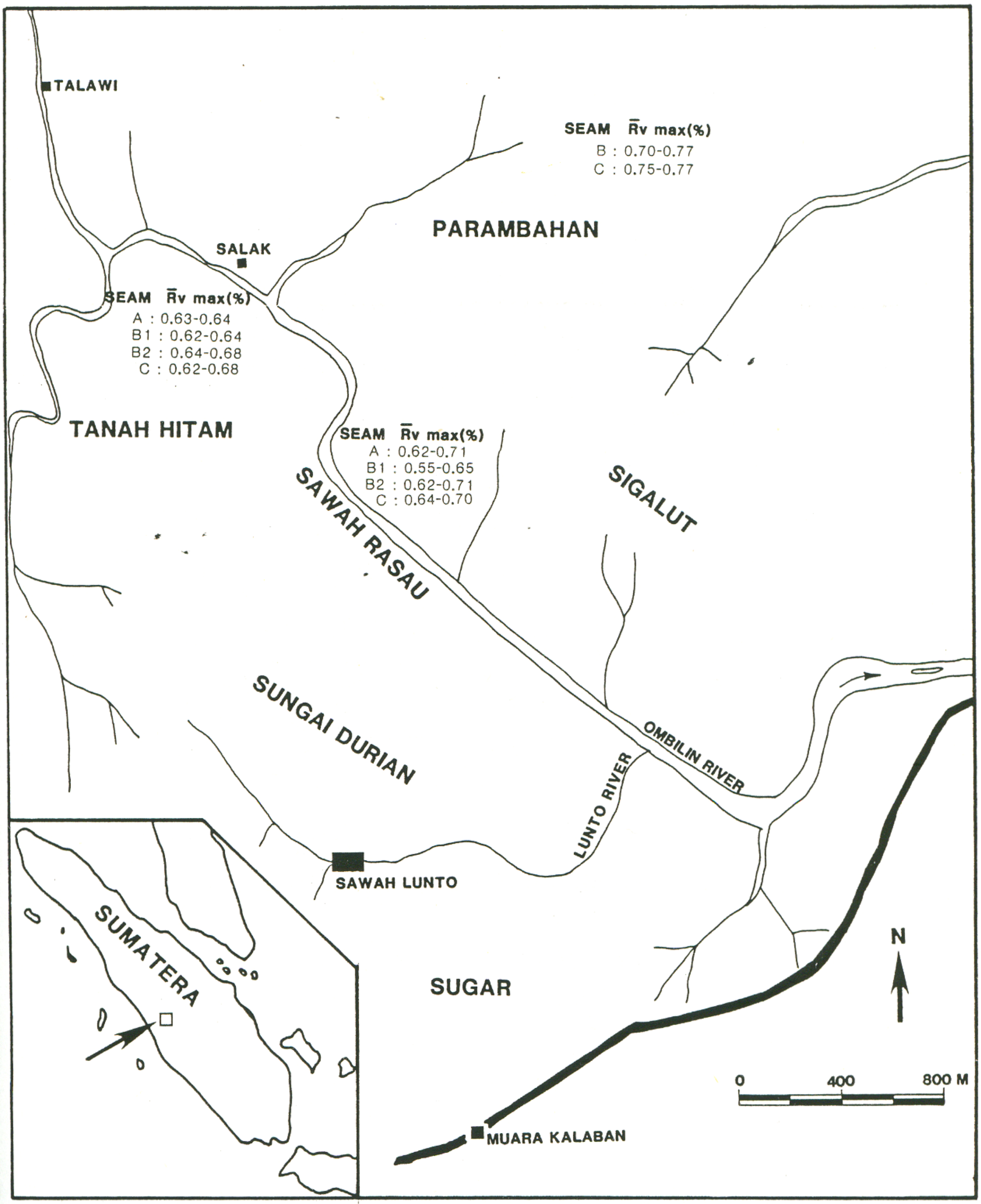

Figure 5. Ombilin coalfield showing variation of vitrinite reflectance

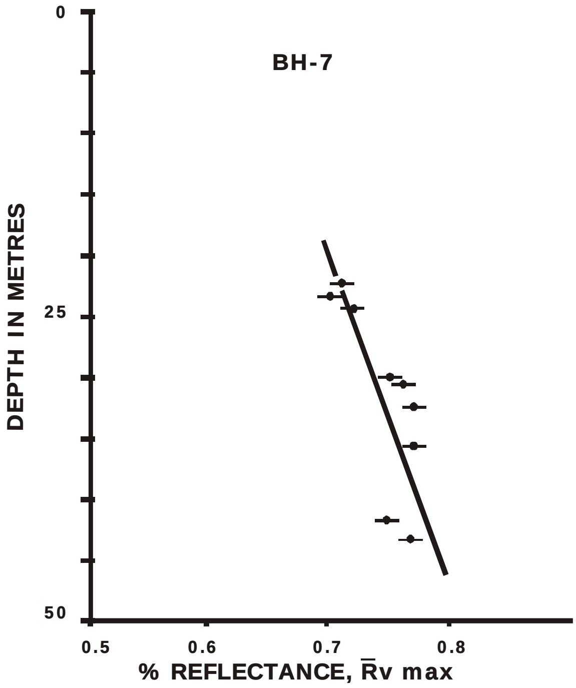

Figure 6. Depth-reflectance profile for BH7 well in Ombilin coalfield

of forest type vegetation in humid tropical zone, without significant dry events throughout. Vitrinite-rich coal in some cases has a high content of mineral matter. Many seams deposited in areas of rapid subsidence have both a high vitrinite content and a high mineral content present as discrete dirt bands (Cook, 1975); Shibaoka and Smyth, (1975).

In the viewpoint of rank, the Ombilin coals exhibit variable vitrinite reflectances, despite its geological history, apparently because of variable tectonic and igneous intrusion factors. The coals consist of thermally affected and unaffected coals. The thermally unaffected coals have vitrinite reflectances 0.55-0.77%, whereas the thermally affected ones are 3.39-4.69%, with ranks of sub-bituminous to high volatile bituminous and anthracite, respectively. In the area of the thermally altered coals, a more rapid and thorough alteration has occurred where bodies of igneous rock have intruded the Tertiary sequences. As a result, coal of lower rank has been metamorphosed to anthracitic rank.

6. CLOSING MARKS

The coal type and rank characteristics of the Palaeogene Ombilin coals, based on thirty-six samples, indicate the influence of geological setting. The coal type differences reflect the influence of peat environment and climate. Vertical and lateral rank variation characteristics result from contrasting burial and palaeotemperature histories. The palaeoclimate of the Ombilin area throughout the Palaeogene was humid and tropical. The development of Ombilin peats was associated with the establishment of tropical forest.

Macroscopically, the Ombilin coals can be characterised as brighter (clarain and vitrain) lithotypes. Microscopically, vitrinite is the dominant maceral in the coals containing mostly detrovitrinite and telovitrinite with minor gelovitrinite. This indicates the coals were deposited in wetter marsh areas during the peat formation. Exinite is common in the coals with cutinite as the dominant maceral in some occurrences. Inertinite is rare in the coals and sclerotinite is the dominant inertinite maceral. This indicates that the coal depositional environment was a reducing condition. Mineral matter is also rare in the coals comprising mainly clay and pyrite.

Vitrinite reflectance of the Ombilin coals show significant increases with depth. Some seams exhibit an increase in vitrinite reflectance from seam top to bottom. The coal seams are locally altered by igneous activity that has resulted in a wide range of higher rank coals (Rvmax of 3.39-4.69%, anthracite rank). In the proximity of the intrusion, very high lateral and vertical rank gradients are present.

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