COALIFICATION TREND IN SOUTH SUMATERA BASIN

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ABSTRACT

Similarities and differences in rank characteristics in the Bukit Asam coals within the South Sumatera Basin reflect their geological setting, particularly influence of the intrusion of andesite bodies and stratigraphic aspect. Rank variation was determined by vitrinite reflectance measurements of one hundred and thirty-four (134) coal samples. The higher vitrinite reflectance of the coals is a result of higher regional coalification level in the basin associated with the local and variable effects of igneous intrusions, as well as the greater cover/overburden. Philosophically, the higher the temperature, the more profound the alteration occurs; and the thicker the overburden, the more profound the rank occurs as well. The thermally affected coals have vitrinite reflectances between 0.69% (high volatile bituminous) and 2.60% (anthracite), whereas those of not affected are between 0.30% (brown coal) and 0.53% (sub-bituminous) according to the Australian classification.

Keywords : coal, rank, coalification, South Sumatera Basin

1. INTRODUCTION

The development from peat through the stages of brown coal (lignite), sub-bituminous and bituminous coals to semi-anthracite and anthracite is termed *coalification* (Stach *et al.,* 1982). The coalification process is determined primarily by rise of temperature and the time during which this takes place. Pressure retards chemical reactions during coalification. Proof of the strong influence that temperature has on the progress of coalification may be found in contact metamorphic coals. Moreover, it is clear that regions of particularly strong coalification have received additional heat from large intrusive igneous bodies in depth.

In many coalfields, dykes, sills and other types of igneous intrusion have invaded some of the seams and associated rocks (Chandra and Taylor, 1982). The heat from these intrusions (up to 1,000ºC) causes changes to occur in the coal. As usual, the higher the temperature, the more profound the alteration. Therefore, it may be possible to trace progressive alteration from completely unaffected coal away from the intrusion to the most strongly affected coal adjacent to the body of igneous rock. These effects of heat are local and variable, and geologically speaking, occur over a comparatively short period. This kind of alteration contrasts with the normal progression of rank, which is a regional and slow process in response to normal, rather than abnormal, upper crustal temperatures.

The Bukit Asam coalfield in the South Sumatera Basin (Darman and Sidi, 2000; Figure 1) having the same phenomena is a classical example where some of the seams were intruded by the andesitic bodies. Reflectance studies of the Bukit Asam coals indicate that the coals vary from brown coals to anthracite stages. Normally, rank increases with depth and geothermal gradient in the basin. The high rank exhibited by high vitrinite reflectances is due to proximity of the intrusion. The coals not affected by the contact alteration range between brown coal and sub-bituminous coal rank; whereas the thermally altered coals vary from high volatile bituminous to anthracite.

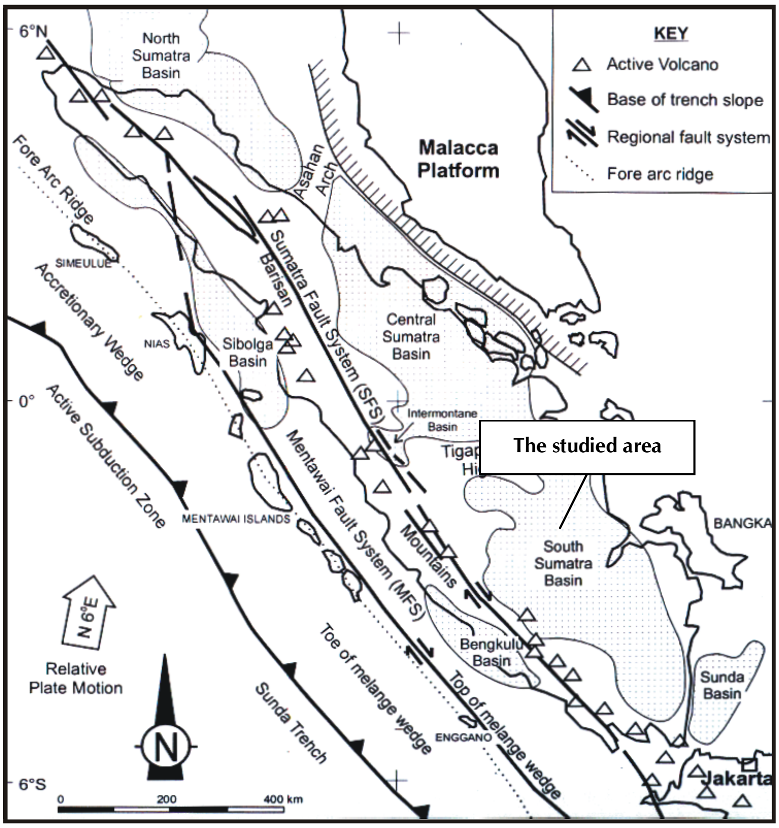

Figure 1. Tectonic setting of Sumatera showing the studied area at the South Sumatera Basin.

The purpose of the study is to present and interpret coalification data obtained from several exploratory holes and spot samples in the Bukit Asam coalfield within the South Sumatera Basin. The rank characteristics are determined by vitrinite reflectance measurements.

2. METHODS OF INVESTIGATION

One hundred and thirty-four (134) coal samples for the study were obtained from the Bukit Asam coalfield. Procedures, preparation, terminology and techniques used for the study are according to the Standards Association of Australia (1964, 1977 and 1983). The sample types were collected from core, cutting and spot samples. Eighty-eight (88) samples from borehole cores and cuttings were collected through the entire thickness of the seam. Forty-six (46) spot samples were collected from portions of in-situ exposures, including outcrop and open cut. All the samples were examined in the coal laboratory of R and D Centre for Mineral and Coal Technology, in reflected white light excitation. Macerals were determined in oil immersion in reflected plane polarised light at a magnification of x500. Polarised light was significant for the examination of thermally altered samples. An Orthoplan microscope, fitted with a Leitz Vario-Orthomat camera, which incorporates 5 to 12.5x zoom was used for all photography.

The measurements on vitrinite reflectance were carried out based on the Standards Association of Australia (1981). The polished blocks containing vitrinite free from scratches were selected for the measurements. The reflectance measurements were undertaken using a Leitz Orthoplan microscope fitted with a Leitz MPV photometer. The microphotometer was calibrated against a set of glass standards ranging in reflectance from 0.917% to 1.726% and a synthetic spinel of 0.413%. One hundred (100) measurements were obtained on each sample from which the mean random reflectance and the standard deviation were calculated. In addition, a total of 30 measurements were taken on each sample from which the mean maximum reflectance and the deviation were also calculated.

3. GEOLOGY

The structural development of Sumatera is generally attributed to the interaction of two major crustal plates, namely the Southeast Asian plate (Sunda Shield) and the Indian Ocean plate (Katili, 1973 and 1980; Pulunggono, 1976; Hamilton, 1979). This interaction caused strong deformation of the Mesozoic and Palaeozoic complexes of the Barisan Range, situated on the western side of the island. East of the Barisan Range, along the western edge of the Sunda Shield, a series of Tertiary foreland basins were developed, one of these being the South Sumatera Basin. In relation to coal deposition, the most important sedimentary basins are Palaeogene intermontane basins, Neogene backdeep and deltaic basins (Koesoemadinata, 1978).

In Sumatera, Tertiary transgression was commonly preceded by Palaeogene intermontane basin development (Ombilin Basin). Coal seams deposited within these basins are interbedded with lacustrine, fluviatile, alluvial plain and near shore deposits (Koesoemadinata, 1978; Eubank and Makki, 1981). The coal seams tend to be limited in lateral extent, but numerous seams are present within the coal measure sequence.

A Neogene basinal backdeep basin developed where marine clastic sedimentation occurred immediately above the Palaeogene sediments formed some local basal unconformities (Koesoemadinata, 1978; De Coster, 1974; Pulunggono, 1976). This marine sedimentation cycle terminated with a regression sequence where vast swampy areas developed, resulting in extensive coal deposits like in South Sumatera basinal area. The deposition of coal occurred in a paralic to limnic and brackish environment.

The Tertiary sediments in the Bukit Asam area were deposited in the South Sumatera Basin. The regional Stratigraphy of the South Sumatera coal province is described by Shell Mijnbouw (1978). Two periods of sedimentation took place, namely transgressive and regressive phases. The Telisa Group was deposited during the transgressive phase. The regressive phase resulted in deposition of the Palembang Group. A complete stratigraphic sequence for the South Sumatera Basin is illustrated in Figure 2 (Thamrin *et al.,* 1980).

The workable coal measures of the South Sumatera Basin are developed in the Muara Enim Formation, which occurs in the middle of the Palembang Group (Shell Mijnbouw, 1978; Koesoemadinata, 1978; Roeslan, 1984; Sukarsono, 1984). Thickness of this formation is 450-750 metres. De Coster (1974) and Shell Mijnbouw (1978) interpreted the formation as Late Miocene to Pliocene. The work of many authors, including Edwards and Glaessner (1947), Haan (1976), Roeslan (1984) and Sukarsono (1984; Figure 3) has revealed that six major coal seams and several thin coals (an aggregate thickness for all seams of 60-90 metres) are present in the Bukit Asam area. The thicknesses and terms of the seams and interseams are presented in Figure 3. The Bukit Asam coals are autochthonous in origin. Seat earths occur at the base of the seams.

4. RESULTS AND DISCUSSION

Vitrinite reflectance measurements were made on one hundred and thirty-four samples (Appendix 1). The vitrinite reflectances range from 0.30% to 2.60%. This wide range is due to the intrusion of the Pliocene-Pleistocene andesite body in the Suban area.

Vitrinite reflectance (Rvmax) of coal not affected by contact alteration ranges from 0.30% to 0.53%, but the Rvmax thermally altered coals ranges from 0.69% to 2.60%. Vitrinite reflectances between 0.40% and 0.50% are dominant at the Bukit Asam area. Figures 4 and 5 show isorank lines for the Mangus (A1+A2) and Suban (B1+B2) seams, respectively. It seems that the pattern of vitrinite reflectance variation over the Bukit Asam coalfield is similar for different seams. The main trend is for rank to increase towards the south of the area (in the vicinity of the andesite intrusion). There are a number of local departures from this trend. West of the Air Laya pit, for instance, the rank increases locally toward the location of RC 60 (Rvmax of Mangus seam: 1.35% and Suban seam: 1.71% proximal to RC 60). Sukarsono (1982) reported that specific energy of coal in this area is very high and total moisture is low (Table 1).

This reversal is presumably associated with local heating by igneous intrusions. The heating in this instance has been sufficiently slow and under such confining pressures as to produce an increase in the degree of coalification rather than carbonization. To the north (Banko area) and to the west (Air Laway area) of Bukit Asam, vitrinite reflectance decreases gradually (Rvmax ranging from

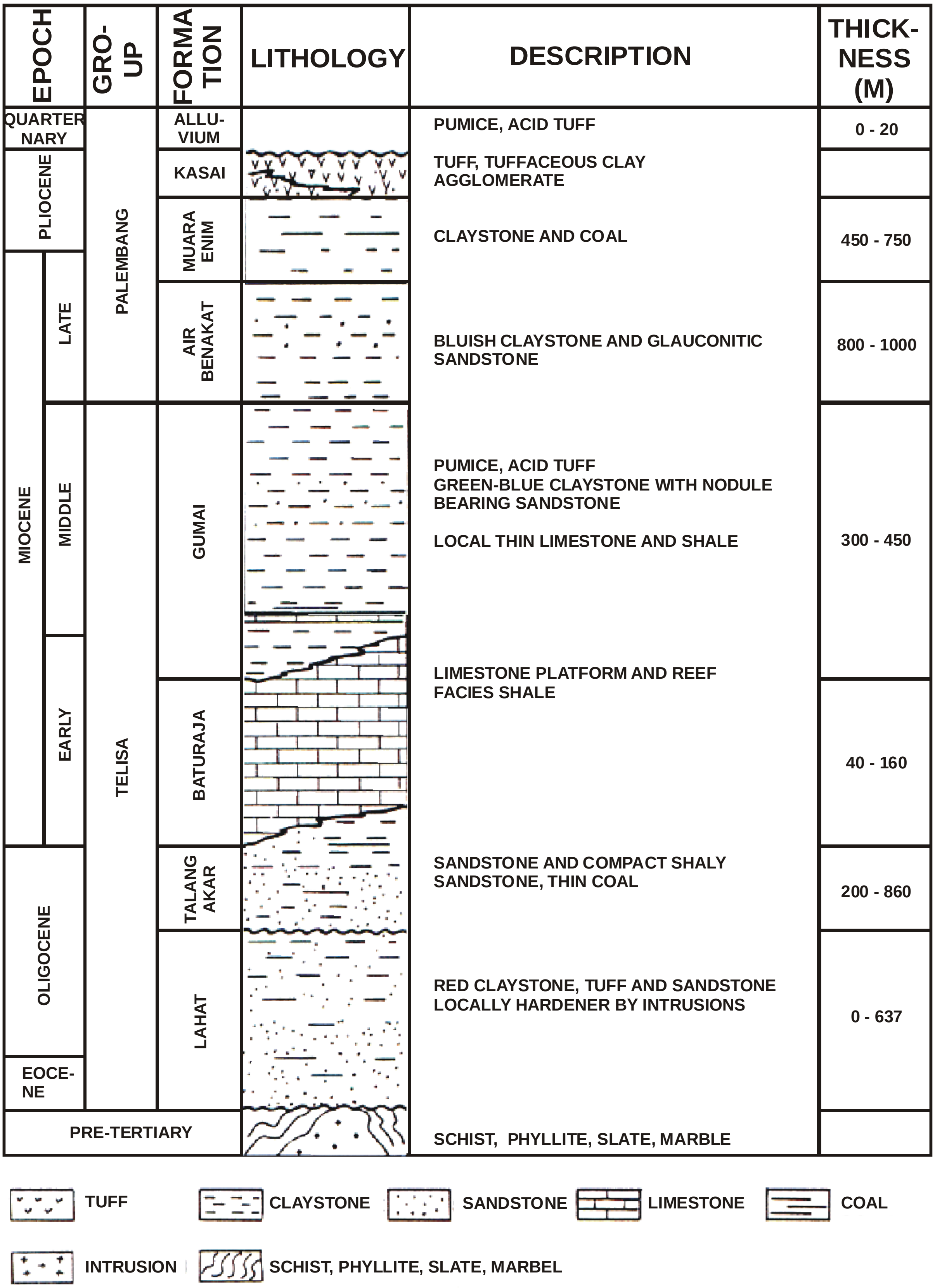

Figure 2. Stratigraphy of the South Sumatera Basin

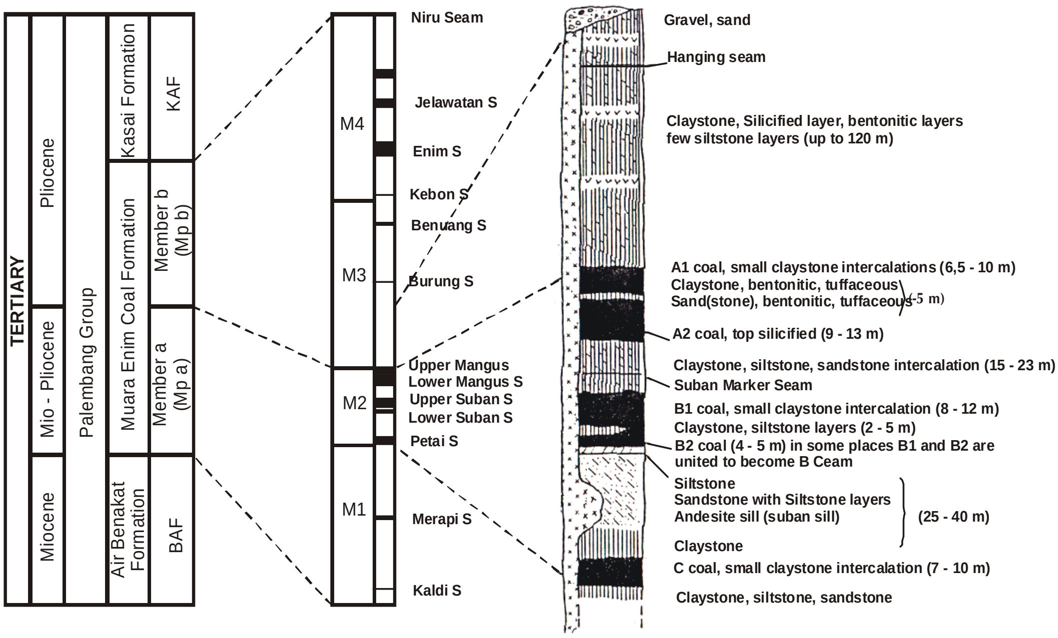

Figure 3. Stratigraphy of the Bukit Asam area

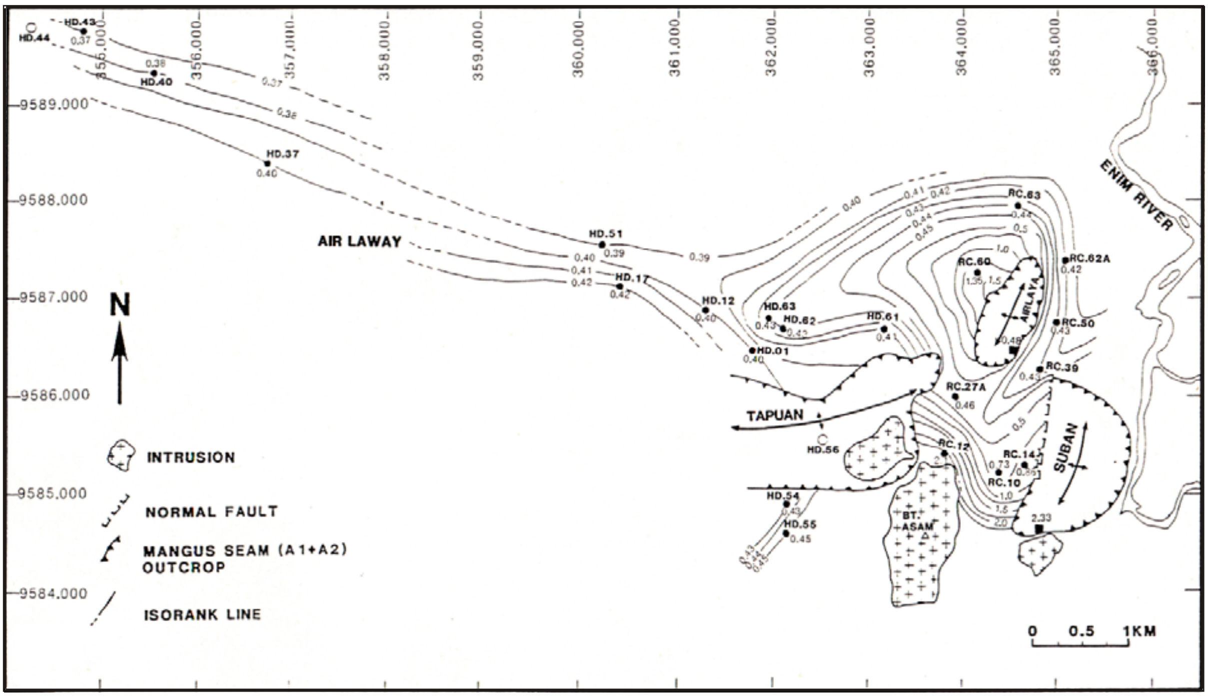

Figure 4. Variation in rank, expressed as vitrinite reflectance in Mangus seam (A1+A2) in the Bukit Asam coalfield

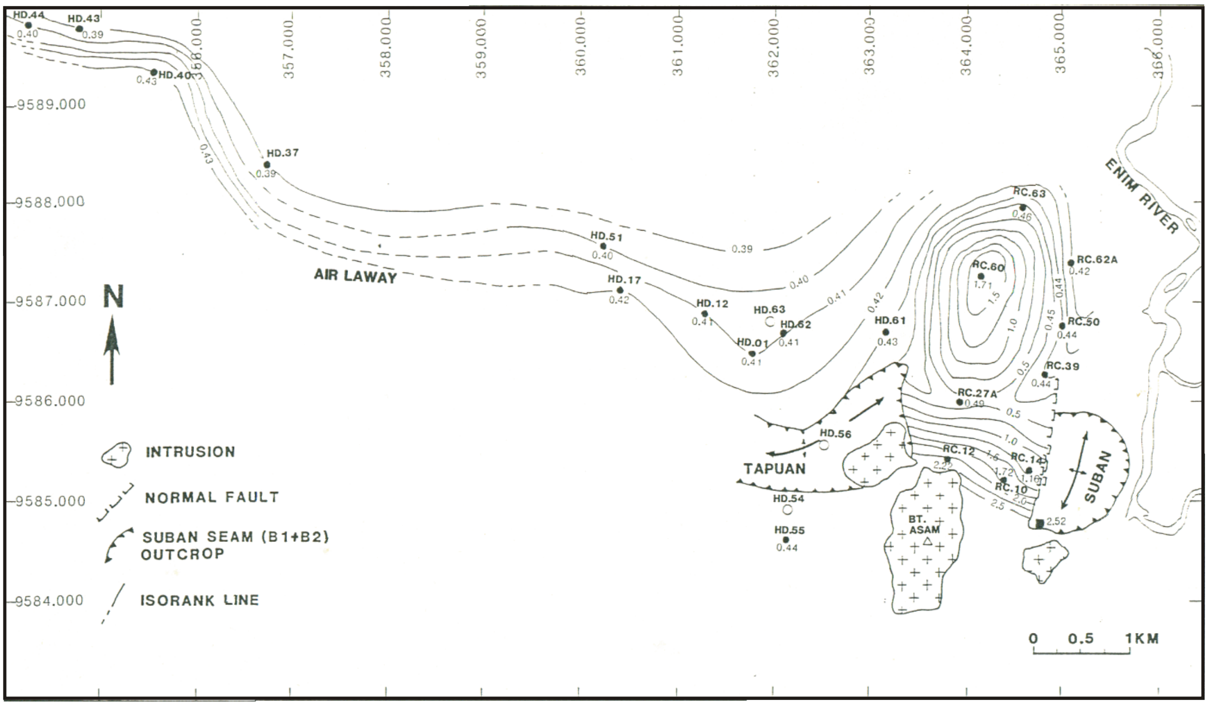

Figure 5. Variation in rank, expressed as vitrinite reflectance in Suban seam (B1+B2) in the Bukit Asam coalfield

Table 1. Specific energy and total moisture of the coal seams in RC 60

Location	Seam	Total Moisture (%)	Spesific Energy (kcal/kg)
RC 60, west of Air Laya	A1	9	6,69
	A2	4	7,116
	B1	7	7,384
	B2	9	6,249
	C	5	7,726

0.35% to 0.40%). The isorank lines of the Mangus and Suban seams in the vicinity of the andesite intrusion are shown in **Figures 6** and **7**. Vitrinite reflectance gradually decreases from south to north, although there is an increase locally in the Air Laya pit.

In stratigraphic aspect, vertical reflectance also shows a marked difference between the upper and lower seams. This difference may be due to differences in stratigraphic position and the effect of heating from the andesite intrusion. Individual vitrinite reflectance profiles show an increase in vitrinite reflectance gradient near the total depth (e.g. RC 27A and RC 50, Figure 8, and RC 10 and RC 14 boreholes, Figure 9). Vitrinite reflectance profiles from RC 27A and RC 50 show nearly rectilinear rank gradient. High rank gradients are present in RC 10 and RC 14. Curvature of the reflectance profile for RC 10 and RC 14 is pronounced and it is due to heating by the intrusion. Proximate analyses of the Bukit Asam coals (Sukarsono, 1982; Table 2) show that with increasing depth of burial, the specific energy becomes higher and total moisture decreases (i.e. the rank increases). A decrease in specific energy will occur however where vitrinite reflectance exceeds about 1.5% to 2.0%.

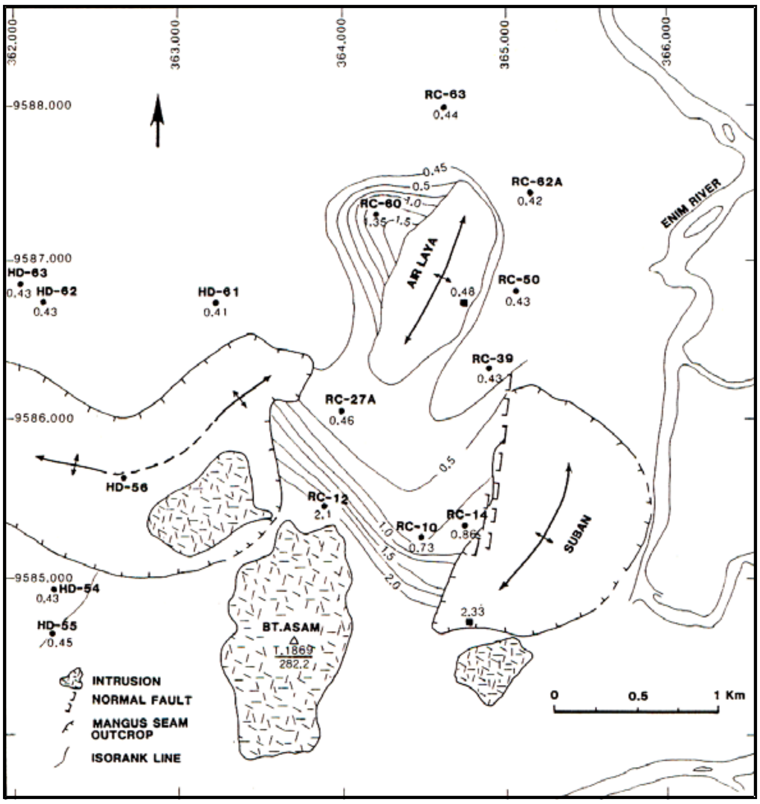

Figure 6. **Variation in rank, expressed as vitrinite reflectance in Mangus seam (A1+A2) in the vicinity of intrusion, Bukit Asam**

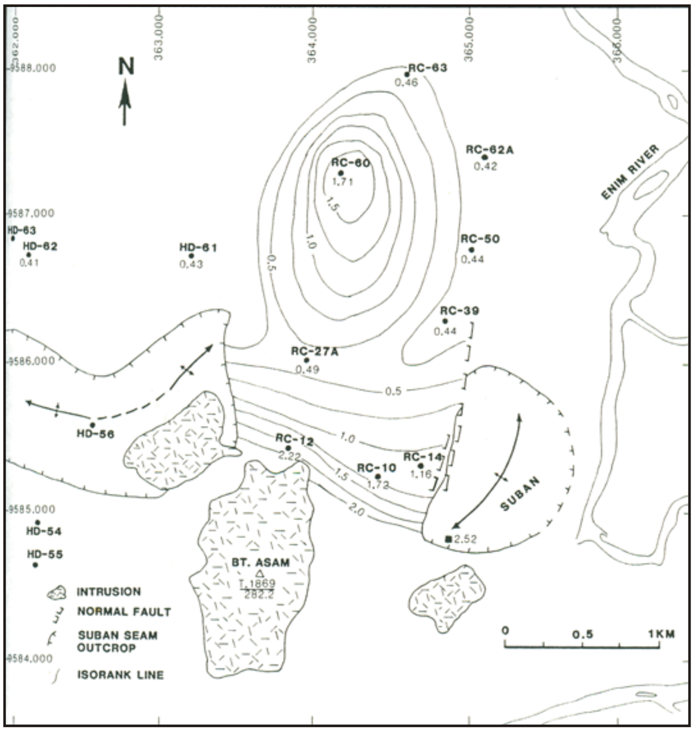

Figure 7. **Variation in rank, expressed as vitrinite reflectance in Suban seam (B1+B2) in the vicinity of intrusion, Bukit Asam**

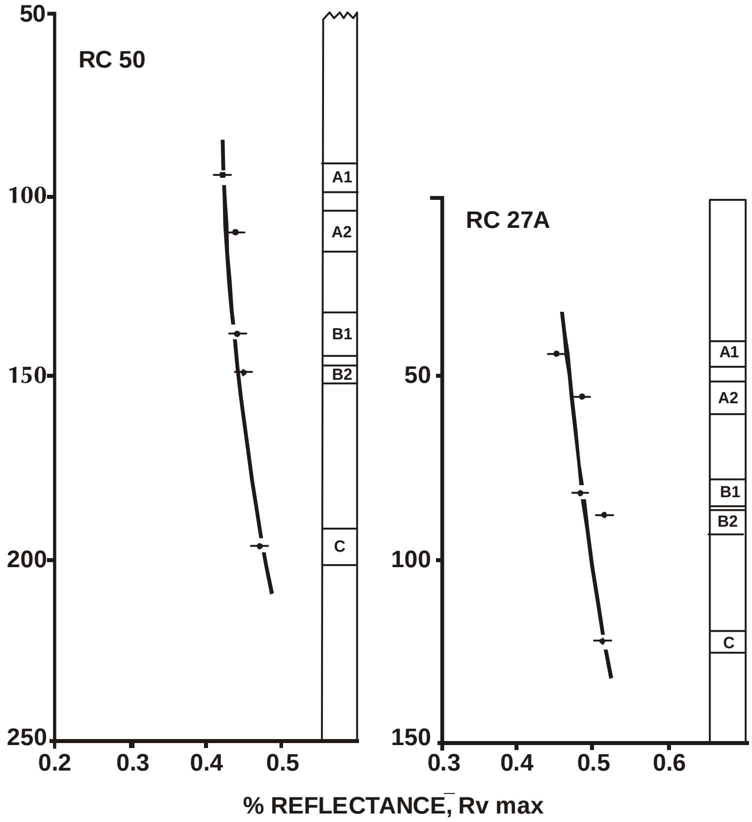

Figure 8. Depth-reflectance profile for RC 50 and RC 27A wells showing nearly rectilinear reflectance profile

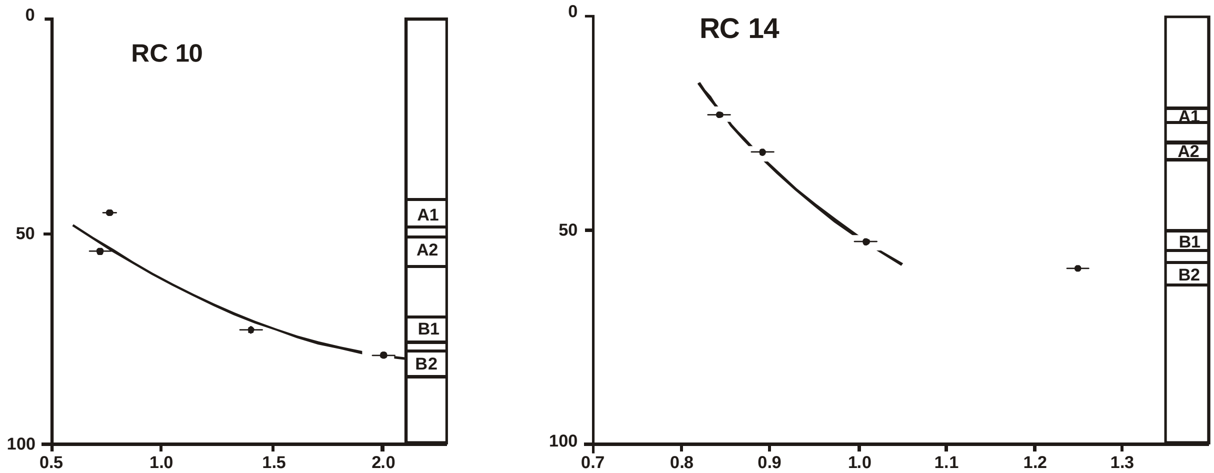

Figure 9. Depth-reflectance profile for RC 10 and RC 14 wells showing effects of underlying intrusion

Table 2. Specific energy and total moisture of some Bukit Asam coals

Location	Seam	Total Moisture (%)	Specific Energy (kcal/kg)	Rvmax (%)
	A1	21	5,507	0.42
	A2	22	5,616	0.44
RC 50	B1	21	5,823	0.44
Air Laya	B2	20	5,888	0.45
	C	19	5,692	0.47
	A1	6	7,330	0.77
RC 10	A2	5	7,637	0.69
Suban	B1	3	7,964	1.40
	B2	3	6,834	2.05

Some seams exhibit an increase in vitrinite reflectance from seam top to bottom. Vitrinite reflectance of A seam in the Air Laya pit, for instance, increases from 0.40% (at the top) to 0.47% (in the middle) to 0.49% (at the bottom).

5. CONCLUSIONS

The presence of the andesite intrusion in the Bukit Asam area has resulted in locally change rank of the coals. The coals affected by heat of the intrusion have higher ranks rather than those of not affected. The thermally affected coals have vitrinite reflectances between 0.69% (high volatile bituminous) and 2.60% (anthracite). Hence, it is possible to trace coalification trend from completely unaffected coal away from the intrusive bodies to the most strongly affected coal adjacent to the body of igneous rock.

In the perspective of stratigraphic aspect, vitrinite reflectance of the Bukit Asam coals indicate significant increases with depth, with the example of A seam in the Air Laya pit. It shows an increase from 0.40% (at the top), 0.47% (in the middle) to 0.49% (at the top). This is a regional process in response to the normal temperatures due to the pressure of thickness of the overburden. It is also assumed that the geothermal gradient in the basin has remained fairly constant throughout the coalification period.

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APPENDIX 1. Vitrinite reflectance data (the Australian standard)

No.	Location	Seam	Rvmax (%)	Range	Rank
1	Tapuan	Hanging	0.38	0.35-0.45	Brown coal
2			0.42	0.38-0.48	Sub-bituminous
3			0.41	0.37-0.46	Sub-bituminous
4	Banko	Hanging	0.36	0.30-0.41	Brown coal
5			0.38	0.34-0.43	Brown coal
6			0.49	0.43-0.54	Sub-bituminous
7	Air Laya o/c	A1	0.47	0.40-0.52	Sub-bituminous
8			0.46	0.40-0.51	Sub-bituminous
9	SE Balong Hijau o/c	A1	0.41	0.36-0.47	Sub-bituminous
10			0.41	0.36-0.52	Sub-bituminous
11			0.40	0.36-0.45	Sub-bituminous
12	SW Balong Hijau o/c	A1	1.73	1.67-1.77	Low-volatile bituminous
13			1.61	1.52-1.66	Low-volatile bituminous
14			0.42	0.37-0.49	Sub-bituminous
15	Muara Tiga o/c	A1	0.38	0.35-0.42	Brown coal
16			0.40	0.36-0.44	Sub-bituminous
17	Air Laway	A1	0.37	0.33-0.41	Brown coal
18			0.37	0.33-0.43	Brown coal
19			0.42	0.38-0.46	Sub-bituminous
20	Tapuan	A1	0.45	0.41-0.51	Sub-bituminous
21			0.41	0.38-0.47	Sub-bituminous
22	Air Laway	A1	0.43	0.39-0.47	Sub-bituminous
23			0.43	0.39-0.47	Sub-bituminous
24	Tapuan	A1	0.43	0.39-0.48	Sub-bituminous
25			0.39	0.35-0.42	Brown coal
26	Air Laway	A1	0.35	0.31-0.40	Brown coal
27			0.36	0.32-0.39	Brown coal
28			0.40	0.36-0.44	Sub-bituminous
29	Suban o/c	A1	2.34	2.29-2.44	Semi-anthracite
30			2.32	2.21-2.42	Semi-anthracite
31	Air Laya o/c	A1	0.41	0.37-0.47	Sub-bituminous
32			0.44	0.39-0.50	Sub-bituminous
33	Air Laya	A1	1.44	1.39-1.49	Medium-volatile bituminous
34			0.43	0.39-0.47	Sub-bituminous
35	Suban	A1	0.84	0.77-0.91	High-volatile bituminous
36	Bukit Asam	A1+A2	1.99	1.85-2.06	Low-volatile bituminous
37	Air Laya	A1	0.45	0.40-0.52	Sub-bituminous
38	Tapuan	A1	0.77	0.70-0.87	High-volatile bituminous
39	Air Laya	A1	0.42	0.38-0.46	Sub-bituminous
40			0.42	0.37-0.50	Sub-bituminous
41			0.44	0.41-0.49	Sub-bituminous
42			0.40	0.36-0.44	Sub-bituminous
43			0.37	0.33-0.42	Brown coal
44	Banko	A1	0.42	0.37-0.48	Sub-bituminous
45			0.41	0.35-0.47	Sub-bituminous
46			0.43	0.38-0.47	Sub-bituminous
47			0.45	0.39-0.52	Sub-bituminous
48	SW Balong Hijau o/c	A2	1.00	0.93-1.04	High-volatile bituminous
49			0.98	0.93-1.03	High-volatile bituminous
50			0.41	0.36-0.45	Sub-bituminous
51	Muara Tiga	A2	0.40	0.37-0.44	Sub-bituminous

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No.	Location	Seam	Rvmax (%)	Range	Rank
52			0.40	0.36-0.45	Sub-bituminous
53			0.40	0.36-0.47	Sub-bituminous
54	Air Laway	A2	0.42	0.37-0.47	Sub-bituminous
55			0.38	0.35-0.41	Brown coal
56			0.44	0.39-0.48	Sub-bituminous
57	Tapuan	A2	0.46	0.39-0.51	Sub-bituminous
58			0.43	0.38-0.48	Sub-bituminous
59	Air Laway	A2	0.41	0.38-0.45	Sub-bituminous
60			0.45	0.40-0.48	Sub-bituminous
61	Tapuan	A2	0.42	0.38-0.47	Sub-bituminous
62			0.39	0.36-0.42	Brown coal
63	Air Laway	A2	0.39	0.36-0.42	Brown coal
64			0.41	0.35-0.44	Sub-bituminous
65			0.40	0.36-0.44	Sub-bituminous
66	Suban o/c	A2	2.32	2.24-2.45	Semi-anthracite
67			2.18	2.10-2.23	Semi-anthracite
68			0.44	0.37-0.50	Sub-bituminous
69	Air Laya	A2	1.26	1.12-1.32	Medium-volatile bituminous
70			0.43	0.38-0.49	Sub-bituminous
71	Suban	A2	0.89	0.80-0.95	High-volatile bituminous
72	Air Laya	A2	0.48	0.43-0.55	Sub-bituminous
73	Tapuan	A2	0.69	0.61-0.75	High-volatile bituminous
74	Air Laya	A2	0.44	0.40-0.49	Sub-bituminous
75			0.43	0.38-0.47	Sub-bituminous
76	Muara Tiga o/c	B	0.44	0.39-0.49	Sub-bituminous
77			0.40	0.36-0.45	Sub-bituminous
78			0.39	0.36-0.42	Brown coal
79	Air Laway	B	0.43	0.38-0.47	Sub-bituminous
80			0.42	0.38-0.49	Sub-bituminous
81	Tapuan	B	0.44	0.39-0.51	Sub-bituminous
82			0.41	0.38-0.46	Sub-bituminous
83			0.40	0.37-0.44	Sub-bituminous
84			0.40	0.37-0.45	Sub-bituminous
85	Air Laway	B	0.39	0.31-0.40	Brown coal
86			0.41	0.37-0.45	Sub-bituminous
87			0.41	0.37-0.47	Sub-bituminous
88			0.43	0.39-0.48	Sub-bituminous
89			2.60	2.50-2.70	Anthracite
90	Suban o/c	B1	2.41	2.30-2.53	Semi-anthracite
91			2.55	2.47-2.63	Anthracite
92			0.43	0.39-0.49	Sub-bituminous
93	Air Laya	B1	1.70	1.64-1.75	Low-volatile bituminous
94			0.43	0.39-0.49	Sub-bituminous
95	Suban	B1	1.07	1.01-1.13	High-volatile bituminous
96	Bukit Asam	B1	2.19	2.09-2.29	Semi-anthracite
97	Air Laya	B1	0.48	0.41-0.59	Sub-bituminous
98	Tapuan	B1	1.40	1.34-1.52	Medium-volatile bituminous
99	Air Laya	B1	0.44	0.40-0.49	Sub-bituminous
100	Banko	B1	0.42	0.38-0.49	Sub-bituminous
101			0.53	0.43-0.64	Sub-bituminous
102	Air Laway	B2	0.43	0.39-0.49	Sub-bituminous

APPENDIX 1. Vitrinite reflectance data (the Australian standard)

No.	Location	Seam	Rvmax (%)	Range	Rank
103			0.49	0.42-0.56	Sub-bituminous
104	Air Laya	B2	1.72	1.66-1.78	Low-volatile bituminous
105			0.44	0.39-0.51	Sub-bituminous
106	Suban	B2	1.25	1.20-1.33	Medium-volatile bituminous
107	Bukit Asam	B2	2.25	2.17-2.35	Semi-anthracite
108	Air Laya	B2	0.51	0.44-0.57	Sub-bituminous
109	Tapuan	B2	2.05	1.97-2.12	Semi-anthracite
110	Air Laya	B2	0.45	0.40-0.52	Sub-bituminous
111			0.42	0.38-0.47	Sub-bituminous
112	Muara Tiga o/c	C	1.46	1.40-1.54	Medium-volatile bituminous
113	Muara Tiga	C	1.55	1.46-1.62	Low-volatile bituminous
114			1.53	1.48-1.58	Low-volatile bituminous
115			0.42	0.37-0.48	Sub-bituminous
116			0.43	0.38-0.47	Sub-bituminous
117			0.44	0.39-0.48	Sub-bituminous
118			0.47	0.41-0.54	Sub-bituminous
119			0.45	0.40-0.50	Sub-bituminous
120	Air Laway	C	0.89	0.81-0.97	High-volatile bituminous
121			0.42	0.38-0.47	Sub-bituminous
122			0.41	0.35-0.48	Sub-bituminous
123			0.45	0.39-0.50	Sub-bituminous
124			0.42	0.39-0.47	Sub-bituminous
125			0.45	0.40-0.51	Sub-bituminous
126	Air Laya	C	1.78	1.66-1.85	Low-volatile bituminous
127			0.45	0.39-0.50	Sub-bituminous
128	Bukit Asam	C	2.28	2.19-2.36	Semi-anthracite
129			0.51	0.46-0.58	Sub-bituminous
130	Air Laya	C	0.47	0.40-0.54	Sub-bituminous
131			0.43	0.38-0.50	Sub-bituminous
132			0.41	0.36-0.50	Sub-bituminous
133	Banko	C	0.41	0.37-0.47	Sub-bituminous
134			0.41	0.37-0.45	Sub-bituminous

Note: o/c – open cut