

PETROGRAPHIC AND CHEMICAL CHARACTERIZATIONS OF COALS FROM HONGSA COAL MINE, XAYABOULY PROVINCE, LAO PDR

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Abstract

This study presents the details of petrographic and chemical characterizations of the Cenozoic coal from the Hongsa coal mine, Xayabouly Province, Lao PDR. Eighty-nine samples from a drill core consist mainly of lignite, carbonaceous clays, and clays. From the petrographic study, the Hongsa coals are dominated by huminite, followed by liptinite, and the very few funginite of the inertinite group. They show both features of humic and sapropelic coals. A moderate amount of mineral matters are silica and clay minerals. Based on maceral and mineral assemblages, they indicate a forest swamp environmental setting with a moderate amount of sediments supplied by low-energy water flow. Moreover, the characteristics of maceral preservation indicated the depositional environment was an anoxic condition with low oxidation. The limnotelmatic environment points to the deposition of peat between an open moor and a wet-forest moor environment. According to a chemical analysis, the coals are classified as lignite A and lignite B with high ash content and low sulfur.

Keywords: Petrography, macerals, Hongsa coal mine, Lao PDR, Cenozoic basin

Introduction

Hongsa coal mine in the Hongsa Basin, Hongsa district, Xayabouly province, Lao PDR is located about 81 km northwest of the provincial capital and situated close to the Thai/Lao border at Huai Kon village, Chaloen

Prakiat district, Nan province, approximately 34 km northeast of the border checkpoint (Figure 1). The basin is roughly triangular-shaped and sub-elongated in ENE-WSW direction to the long axis about 12 km and the

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average short axis about 5 km (Figure 2). The concession covers an area of about 60 km² (Hofmann *et al.*, 2008). The basin is bounded by latitudes 19° 39' N and 19° 43' N, longitudes 101°14' E and 101° 24' E. The coal mine is recognized as one of Lao's major energy



Figure 1. The location map of the Hongsa coal deposit (a red circle) in Xayabaly Province, Lao PDR, 34 km northeast of the Huai Kon border checkpoint, Nan province

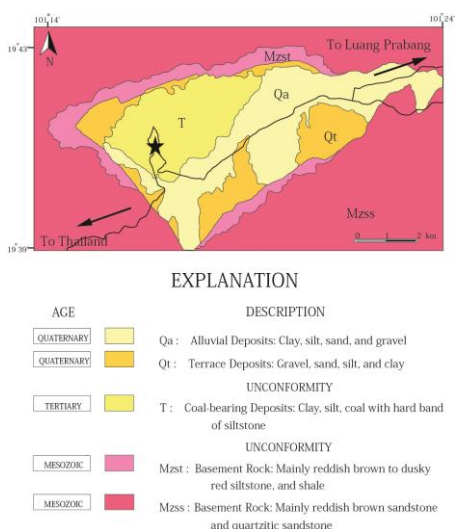


Figure 2. Geologic map of the Hongsa Basin. Coals in the Hongsa coal mine (black star) belong to Tertiary or Cenozoic age (T) (modified from Hofmann *et al.*, 2008)

resources. The development of mining operations commenced in mid-2015 with 436.9 million tons of lignite reserves extracted (Hongsa Power, 2019), supplying three mine-mount thermal power plants. The plans to excavate approximately 370.8 million tons of lignite reserves during its 25-year operation, reaching a capacity of 14.3 million tons per year (Phusuwan *et al.*, 2015).

The Hongsa Basin is an intermontane basin composed of fine-grained clastic sediments and coal seams which have a cumulative thickness of over 100 m (Vilaihongs and Areesiri, 1997). Tertiary sediments in Lao PDR, including the Hongsa Basin, were characterized by non-marine deposition over all the areas during the Himalayan orogeny since 58 Ma (Jain, 2014). Extensional movements of Late Neogene produced small intermontane pull-apart basins which became filled by fresh-water sequences and lignite beds at this time. The northern edge of the basin is bound by a set of faults trending ENE–WSW, while the western edge of the basin is bound by NW–SE trending normal fault (Hofmann *et al.*, 2008). The strata generally dip to the center of the mine with complex fault systems that can be recognized in the mine. The approximate timing of deposition in the Hongsa Basin is about 35 to 2 million years ago (Oligocene to Pliocene) (Morley and Racey, 2011).

The basement rock of the Hongsa Basin consists of Mesozoic sedimentary rocks, predominantly terrestrial red sedimentary rocks. This basin was filled with the Tertiary sediments, which are mainly comprised of light-gray silty clay, but also include clay with some siltstone hard bands and coal-bearing sequences. The uppermost is Quaternary sediments comprise of alluvial clay, silt, sand, and gravel of the Mekong River and its tributaries, and have been covered by recent soil and lateritic sand (General Department of Geology and Mines of Vietnam, 1988) (Figure 2).

The Cenozoic succession of Hongsa coal mine has been subdivided into 8 rock units by Hofmann *et al.* (2008), the succession from top to bottom are as follows (Figure 3):

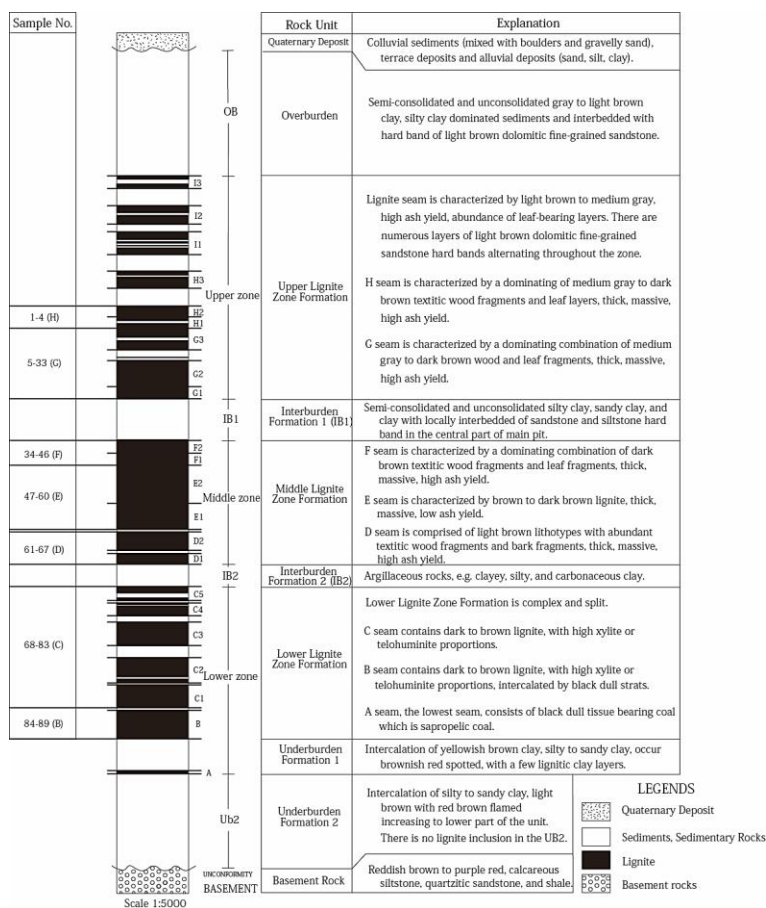


Figure 3. Stratigraphic sequence of the Hongsa coal deposit and sample number (modified from Hofmann *et al.*, 2008)

Overburden (OB) is the uppermost unit that consists of semi-consolidated and unconsolidated sediments. It is dominated with gray to light brown clay, silty clay interbedded with hard bands of light brown dolomitic fine-grained sandstone. This unit contains lens-like coal of different thicknesses on several levels. The thickness of the OB is up to 150 m in the central part of the main basin.

Upper Lignite Zone Formation or Upper Zone is divide into 3 seams: G, H, and I seams, which normally separated by clayey sediments. The lignite is characterized by light brown, high ash content, an abundance of leaf-bearing layers. There are numerous layers of light brown dolomitic fine-grained sandstone hard bands alternating through the zone.

Interburden Formation 1 (IB1) composes of semi-consolidated and unconsolidated silty clay, sandy clay and clay. They locally interbedded sandstone and siltstone hard band in the central part of the main basin. The thickness of the IB1 unit varies from less than 1 m up to 60 m.

Middle Lignite Zone or Middle Zone is divided into 3 seams: D, E, and F according to their qualities and lithotypes. F seam is characterized by a dominating combination of dark brown textitic wood fragment and leaf fragment, thick massive, high ash. E seam has high shares of detritic lignite and bark. It is characterized by a brown to dark brown coal, thick to massive, and low ash content. D seam is characterized by abundant textitic wood

fragment and bark fragment, light brown lithotype, thick massive, and high ash content.

Interburden Formation 2 (IB2) comprises clayey lignite and silty and carbonaceous clay. There are numerous hard bands in the central basin. The thickness varies from less than 1 m up to 60 m.

Lower Lignite Zone Formation or Lower Zone shows complex structures and split coals. It is divided into 3 seams: A, B, and C seam. The C seam contains dark to brown lignite with high xylite or humotelinite proportions. B seam appears as same as C seam but intercalated by black dull strats. A seam is the lowest seam and consisting of black dull tissue bearing coal with the sapropelic coal. The thickness is usually 1 m or less.

Underburden Formation (UB) is divided into two units: UB1 and UB2. The UB1 overlay the A seam and is characterized by intercalation of yellowish-brown clay, silty to sandy clay. They commonly occur brownish red spotted with few lignitic clay layers. The UB2 consists of silty to sandy clay, light brown with red-brown flamed increasing to the lower part of the unit.

The purpose of this study is to access the variation in maceral and mineral compositions of Hongsa coal by using petrography and chemistry and to discuss the depositional condition during an accumulation.

Materials and Methods

Sample Collection and Preparation

Eighty-nine samples were collected from a drill core of HS well from the central part of the Hongsa Basin, at the depths between 14.35 and 204.55 m of H seam to B seam (Figure 3). We have no sample from the A seam because the drill core was not exceeded. The 89 samples, which are representative, were analyzed by standard instruments and procedures. The samples consisted mainly of lignite, carbonaceous clays, and clays. They were crushed and subjected to petrographic and chemical analyses. The petrographic analysis was accomplished in a laboratory of the Department of Geological Sciences,

Chiang Mai University. The samples were crushed in a size of less than 1 mm and were impregnated with epoxy resin and packed in rubber tubes under the standard condition of coal sample preparation. The samples were examined with both white light and UV-excitation microscopy. For the maceral analysis, the line to line and point to point distance was maintained 0.4 mm for petrographic analysis, and 500 points of each sample were counted. The coal maceral groups and subgroups were classified based on the International Committee for Coal Petrology System 1994 (ICCP, 2001; Sýkorová *et al.*, 2005; Pickel *et al.*, 2017).

The basic chemical analysis was carried out by the Hongsa coal mine laboratory. The samples were crushed into powder less than 250 μm for proximate analysis to find out the contents of moisture, volatile matter, ash, and fixed-carbon. The method followed the ASTM D5142-09 (ASTM International, 2009), using a Thermogravimetric Analyzer (TGA701). The sulfur content was conducted with a Sulfur Determinator (SC632). The calorific value analysis was carried out using an Automatic Calorimeter (AC500), followed by the ASTM D5865 (ASTM International, 2013).

Results and Discussion

Petrographic Composition

The Hongsa coal is low-rank coal which contains all three maceral groups, huminite, liptinite, and inertinite. The most abundant maceral in all coal seams is huminite, which mainly consists of ulminite and textinite of telohuminite, densinite and attrinite of detrohuminite and gelinite and corpohuminite of gelohuminite. The second most dominant maceral is liptinite, generally consisting of cutinite, resinite, sporinite, liptodetrinite and suberinite. The inertinite shows low content, less than 1% of the total macerals, including the only funginite (Table 1). The lack of inertinite group in these coals indicate no experience of a forest fire.

The prominent huminite macerals in all seams are generally gelified woody cell

Table 1. Organic composition of samples from Hongsa coal deposit

Seam	Sample No.	Depth (m)	Lithology	Total Hum	Total Lip	Inert	MM	Remark
					%			
H	1-4	14.35-21.95	CL, L1CL, CBCL	20.8-48.7	17.0-49.6	0.0	29.6-37.7	Tel > Det = Gel Cu and Lipt are dominant.
G	5-33	21.95-88.70	CL, L1CL, CBCL, LI, CLLI	6.1-87.0	3.8-51.0	0.0	5.0-88.6	Tel > Det > Gel Cu and Lipt are dominant.
F	34-46	95.85-115.00	CL, L1CL, CBCL, LI, CLLI	9.0-72.4	7.0-38.3	0.0-0.7	1.8-63.0	Tel = Det = Gel Cu > Sp = Lipt
E	47-60	115.00-140.10	CL, L1CL, CBCL, LI	15.1-76.5	11.7-46.2	0.0	5.0-61.6	Tel > Det > Gel Cu > Lipt > Sp > Re
D	61-67	140.10-154.35	CL, L1CL, CBCL, LI	38.4-66.8	13.0-52.8	0.0-0.2	8.2-41.8	Tel = Det > Gel Cu > Re = Lipt
C	68-83	154.35-188.70	CL, L1CL, CBCL, LI, CLLI	7.2-90.6	3.7-45.3	0.0-3.9	4.0-60.5	Tel = Det > Gel Cu > Sp = Lipt > Re
B	84-89	188.80-204.55	CL, L1CL, CLLI, LI	45.7-75.5	6.5-50.9	0.0	3.3-47.9	Tel > Det Cu and Lipt are dominant.

Abbreviations: CL; clays, CBCL; carbonaceous clays, LI; coal (lignite), L1CL; lignitic clays, CLLI; clayey lignite, Hum; huminite, Lip; liptinite, Inert; inertinite, MM; mineral matter, Tel; telohuminite, Det; detrohuminite, Gel; gelohuminite, Cu; cutinite, Lipt; liptodetrinite, Sp; sporinite, Re; resinite.

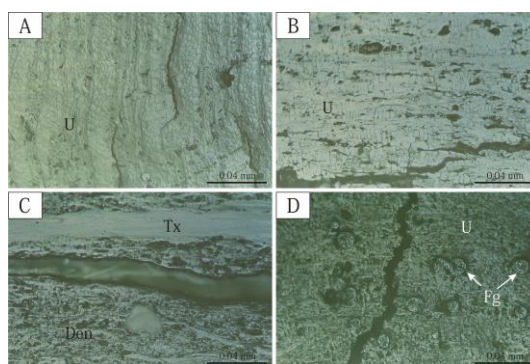


Figure 4. (A) Ulminite (U) from parallel section of wood in lignite from B seam. (B) Ulminite (U) from perpendicular section of wood in lignite from B seam. (C) Densinite (Den) as a groundmass with the white band of textinite (Tx) in lignite from F seam. (D) Funginite (Fg) associated with ulminite (U). All photomicrographs are shown in white light

structure of ulminite (Figures 4(a), 4(b) and 6(a)), densinite (Figures 4(c), and 6(c)), and textinite (Figure 4(c)). Gelinite as a groundmass can be found in some seams. These suggest that plant biomass underwent coalification under a reducing environment, which is a suitable environment for coal preservation. The oxidation was less occurred during deposited. In the liptinite group, cutinite has a well-preserved morphology and clear cuticular ledges (Figures 5(a), 5(b), and 5(c)). These indicate a mildly-reducing to the strongly-reducing depositional environment. The cutinite morphology, small bands with appendages and cuticular ledges, suggested the leaf may come from a tropical forest (Ratanasthien *et al.*, 1999). Resinite is found

associated in both telohuminite, typically in textinite, and ulminite. Rounded bodies of resinite display orange to yellowish-orange colors under fluorescent light (Figures 5(a) and 5(b)). Resinite shows the corrosion of surfaces and or the higher reflecting oxidation rims suggest the aerobic conditions, either oxygenated water, probably result from basin shallower or a peat surface exposed (Teichmüller, 1982). There is a high content of sporinite present in some seams, embedded in a groundmass of densinite, liptodetrinite and mineral matters. Sporinite usually shows bright yellow under fluorescent light, with a lens-shaped form due to the compression and lining along the bedding plane (Figure 5(d)), or sub-rounded form with some ornament

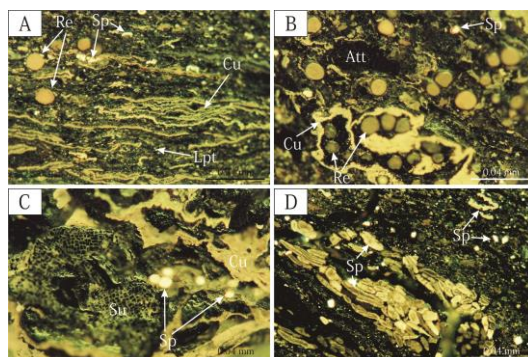


Figure 5. (A) Long cutinite (Cu) with cuticular ledges, with yellowish orange resinite (Re), bright whitish yellow sporinite (Sp), and liptodetrinite (Lpt) in groundmass of densinite in lignite from H seam. (B) Yellowish orange round-shaped of resinite (Re) with convolute long cutinite (Cu) and sporinite (Sp) in groundmass of densinite in lignite from D seam. (C) Green net-like suberinite (Su) with cutinite (Cu) and sporinite (Sp) in groundmass of densinite in clays from G seam. (D) Lens shaped sporinite (Sp) parallel to bedding plane in groundmass of densinite in lignite from G seam. All photomicrographs are shown in UV-excitation

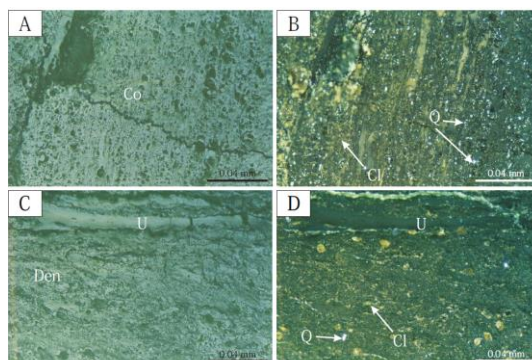


Figure 6. (A) The woody cell of corphuminite (Co) in white light show homogeneous massive with high amount of cavities and fissures) (B) Cross polarized light show high amount of mineral matters, clay minerals (Cl) and quartz (Q) filled in the cavities and the fissured from D2 seam (C) Ulminite (U) associated with densinite (Den) in white light (D) Cross polarized light show small amount of mineral matters in the wood textures from F2 seam

(Figures 5(b) and 5(c)). Suberinite shows pale greenish-yellow (Figure 5(c)) to reddish-brown net-like structure and reddish-brown sheath. Liptodetrinite displays as small fragments derived from other liptinitic material, such as cutinite, sporinite, resinite, and sporinite. The presence of liptodetrinite suggested they were transported from the origin and deposit with subaquatic coals or sapropelic coals (Stach *et al.*, 1982). The

association of these liptinite macerals indicates deposition in a forest swamp setting (Ratanasthien *et al.*, 1999) or mire (Rydin and Jeglum, 2013). Funginite (Figure 4(d)) originated from fungal spores, sclerotia, mycelia, and other fungal tissues that can survive in unaccommodating environments such as waterlogged or toxic conditions (ICCP, 2001). It is the only inertinite maceral found in the Hongsa coal-bearing formations and with

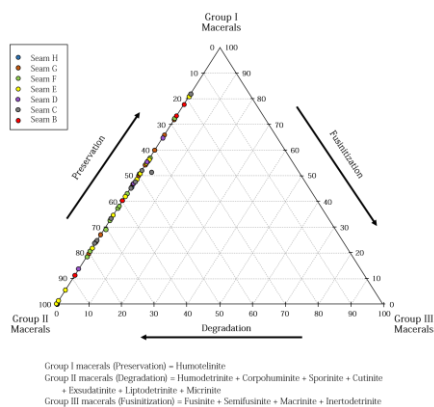


Figure 7. Genetic group coal facies diagram of the Hongsa samples base on maceral composition (modified from Stanton *et al.*, 1987; Moore *et al.*, 1990; Rimmer *et al.*, 2000; Edress *et al.*, 2018)

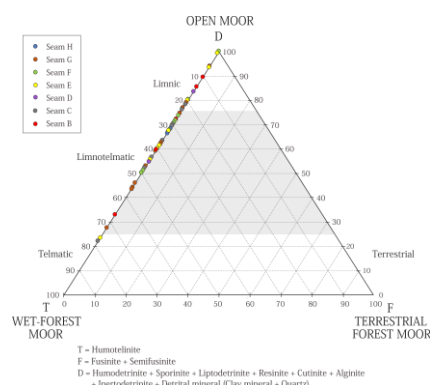


Figure 8. TDF coal facies diagram of the Hongsa samples base on maceral composition (modified from Diessel, 1982; Edress *et al.*, 2018)

deficient concentrations in only the F, D, and C seams. It usually has moderate reflectance and round shape, and its cell cavities are generally filled with mineral matters. Funginite is found only in the Tertiary coal.

Mineral matters consist mainly of quartz and clay minerals (Figures 6(b) and 6(d)). They present in a somewhat low to a moderate amount, and very low content of pyrite was observed. Mineral matters, mainly associated with coal, are present in low to high amounts

related to the lithology. Clay mineral and quartz are dominated and found in cracks, cavities, and fissures of wood texture. The occurrence of mineral matters indicates that they were impregnated from muddy water. These may take place during deposition from syn-depositional or early diagenetic processes in the form of authigenic and epigenic minerals (Ward, 2016)

The low pyrite content in the samples indicates that there was no significant influence from marine or volcanic sources during the deposition. This evidence support that the organic-rich sediments were deposited within a freshwater environment (Price and Casagrande, 1991).

Genetic Group (GI II III) Coal Facies Diagram

The genetic group coal facies diagrams were gradually developed (Stanton *et al.*, 1987; Moore *et al.*, 1990; Rimmer *et al.*, 2000; Edress *et al.*, 2018). This diagram represents the condition of peat during the deposition whether it was preservation, fusinitization, or degradation. The maceral from Hongsa coal mine fallen in the area between the maceral Group I and Group II with a tendency to be closer to Group II (Figure 7). This suggests the dominance of processes between preservation and degradation corresponds to the complete cutinite shape and corrosion of resinite rims.

TDF Coal Facies Diagram

The TDF diagram of coal facies was initially proposed by Diessel (1982) and later modified by Edress *et al.* (2018). This diagram is a petrographic approach to paleoenvironment reconstruction. The higher T values indicate a moist-forest moor environment. The higher F values point to a terrestrial forest moor environment, and higher D values reflect an open moor environment. The studies samples in a TDF coal facies diagram are positioned in the left line of a triangle, between an open moor and a wet-forest moor environment (Figure 8) and mainly fall in a field of limnotelmatic condition, followed by a limnic state. Only two samples reached a telmatic condition of a wet-forest

moor environment. Considering the major condition, the limnotelmatic zone is permanently covered with shallow water down to a water depth of 2 m, which is around the limit for rooted vegetation (Diessel, 1982). These suggest the basin was a change of history of deposition by inundating probably by subsidence or influx of water.

ABC Coal Facies Diagram

The ABC coal facies diagram was originally proposed by Mukhopadhyay (1989) and later modified by Edress *et al.* (2018). It is a graphic presentation of maceral assemblages to determine the peat-forming

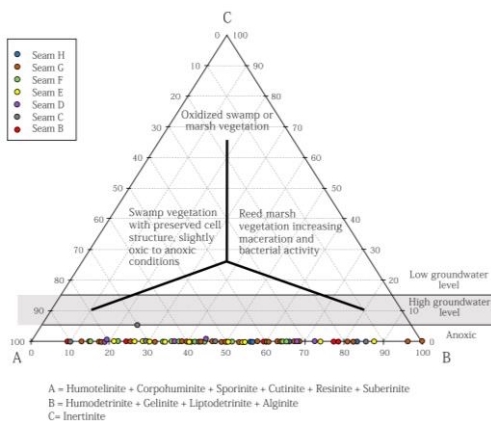


Figure 9. ABC coal facies diagram of the Hongsa samples base on maceral composition (modified from Mukhopadhyay, 1989; Edress *et al.*, 2018)

environments from coal compositions. The apices of a ternary diagram display different combinations of maceral types that form under similar conditions (Mukhopadhyay, 1989). Almost all of the Hongsa coal samples fall within the area of stagnant anoxic conditions and the water table is permanently above the surface of deposition (Figure 9). Only one sample, however, reaches the state of high groundwater level.

Proximate Analyses, Calorific Value, and Sulfur Content

Proximate analysis of samples from the HS well in their as-received basis are shown in Table 2. The moisture of all samples ranges from 13.08 to 47.73% (average 30.02%). The ash yield indicates a broad range of 10.56-81.56% (average 41.34%). The volatile matter yield and fixed-carbon content vary between 4.60-31.80% (average 19.59%) and 0.35-22.05% (average 9.040%), respectively.

The calorific value ranges from 0.01 to 13.95 MJ/kg (average 6.72 MJ/kg). The minimum value of sulfur content is 0.04%, while the maximum is 1.22% with an average of 0.53%. According to the classification of coals by rank based on calorific value (ASTM International, 1990), coals in the Hongsa Basin is ranked lignite B (less than 14.7 MJ/kg) to lignite A (14.7-19.3 MJ/kg). These ranks are based on ash yields (as-received basis) lower than 25%. As presented in Table 3, it was found that their volatile matter yields are higher than 59% but lower than 66% (dry, mineral-matter-free basis) and their fixed-

Table 2. Results of proximate, calorific value and sulfur content of the Hongsa coal

Seam	Sample No.	Lithology	AS-RECEIVE BASIS					%S
			M (wt.%)	A (wt.%)	VL (wt.%)	FC (wt.%)	HV (MJ/kg)	
H	1-4	CL, L1CL,	28.02-32.46	38.13-54.22	14.68-20.72	3.08-8.77	3.10-7.28	0.23-0.61
		CBCL	(~31.07)	(~44.96)	(~17.84)	(~6.13)	(~5.24)	(~0.48)
G	5-33	CL, L1CL, CBCL,	13.08-45.78	20.44-81.56	4.60-25.63	0.35-14.72	0.01-10.39	0.04-1.01
		LI, CLLI	(~29.70)	(~47.24)	(~16.24)	(~6.82)	(~5.00)	(~0.45)
F	34-46	CL, L1CL, CBCL,	20.88-36.88	15.29-65.39	10.38-30.54	1.78-19.39	1.71-13.05	0.19-0.88
		LI, CLLI	(~29.64)	(~38.76)	(~21.34)	(~10.27)	(~7.48)	(~0.54)
E	47-60	CL, L1CL,	19.98-47.73	10.56-67.09	10.91-31.80	1.78-22.05	2.00-13.95	0.14-0.97
		CBCL, LI	(~31.71)	(~36.46)	(~21.27)	(~10.57)	(~7.81)	(~0.56)
D	61-67	CL, L1CL,	21.54-34.60	19.31-57.56	14.71-29.79	3.49-16.81	3.11-12.42	0.25-0.68
		CBCL, LI	(~29.81)	(~35.01)	(~23.67)	(~11.51)	(~8.78)	(~0.55)
C	68-83	CL, L1CL, CBCL,	15.10-46.61	14.90-70.41	11.31-28.54	0.98-19.27	0.16-12.73	0.10-0.88
		LI, CLLI	(~30.59)	(~37.98)	(~21.27)	(~10.15)	(~7.56)	(~0.53)
B	84-89	CL, L1CL,	17.96-39.21	15.96-68.26	10.74-26.84	1.60-18.00	1.85-12.04	0.29-1.22
		CLLI, LI	(~26.49)	(~43.75)	(~20.06)	(~9.71)	(~7.14)	(~0.88)

Abbreviations: CL; clays, CBCL; carbonaceous clays, LI; coal (lignite), L1CL; lignitic clays, CLLI; clayey lignite, M; moisture, A; ash yield, VL; volatile matter yield, FC; fixed-carbon content, CV; calorific value, %S; %Sulfur content, ~; average.

carbon contents are higher than 34% but lower than 41% (dry, mineral-matter-free basis). The results show a range of gross calorific values from 10.67 to 16.51 MJ/kg in a moist, mineral-matter-free basis, considered to be lignite B and lignite A. This coincided with a rank stage of soft brown coal (Tissot and Welte, 1978) and correspond to the mean random vitrinite reflectance (Rm) of 0.25-0.30% that measured by Künstner and Schneider (1986). The low vitrinite reflectance of the Hongsa coals also indicates the lignite rank of coal (Senftle *et al.*, 1993). The average trends in moisture, ash yield, volatile matter yield, fixed-carbon, heating value, and sulfur content on the as-received basis from the upper H seam to the

lower B seam are shown in Figure 10. Common trends include an increase in volatile matter yield, fixed-carbon content, and heating value, which reverses the pattern for the ash yield. However, the relationship between a rank of coal and burial depth is uncertain and hard to identify.

Conclusions

Coal petrographic characters of Hongsa coals suggested that the main composition of coal originated from wood texture (vitrinite or huminite). The woody cell structures was gelified. The high resistance liptinite consists

Table 3. Ranks of coal based on those ash yield (as-received basis) lower than 25%

Sample No.	Seam	VL (%)	FC (%)	Gross CV (MJ/kg)	Rank of coal
		(dry, mineral-matter-free basis)	(moist, mineral-matter-free basis)	(moist, mineral-matter-free basis)	
5	G	64.65	35.35	12.87	Lignite B
11	G	63.52	36.48	13.86	Lignite B
20	G	64.82	35.18	11.97	Lignite B
34	F	61.17	38.83	12.90	Lignite B
39	F	63.90	36.10	15.20	Lignite A
43	F	62.80	37.20	14.33	Lignite B
46	F	61.22	38.78	14.60	Lignite B
47	E	59.05	40.95	16.14	Lignite A
48	E	63.71	36.29	15.18	Lignite A
49	E	62.61	37.39	11.97	Lignite B
51	E	62.78	37.22	13.26	Lignite B
56	E	65.40	34.60	14.23	Lignite B
57	E	63.22	36.78	16.09	Lignite A
59	E	63.15	36.85	14.83	Lignite A
62	D	63.52	36.48	15.60	Lignite A
63	D	64.03	35.97	16.51	Lignite A
78	C	64.89	35.11	12.29	Lignite B
80	C	62.16	37.84	10.67	Lignite B
82	C	59.66	40.34	16.04	Lignite A
83	C	61.85	38.15	14.56	Lignite B
85	B	59.86	40.14	14.33	Lignite B

Remark: Lignite B calorific value less than 14.7 MJ/kg, Lignite A calorific value 14.7-19.3 MJ/kg (ASTM International, 1990)
 Abbreviations: VL; volatile matter yield, FC; fixed-carbon content, CV; calorific value

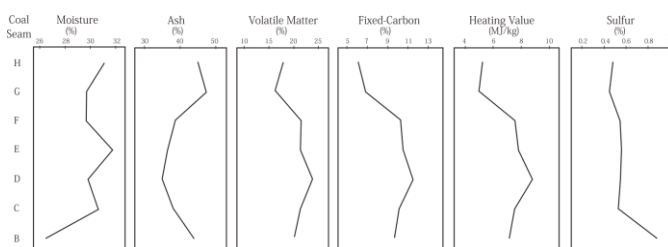


Figure 10. Seam profiles of average moisture, ash yield, volatile matter yield, fixed-carbon content, heating value, and sulfur content of Hongsa coal

of cutinite with well-preserved cuticular ledges, resinite with corrosion of surfaces, sporinite, liptodetrinite, suberinite and a few alginite. Funginite of inertinite is found negligible. The organic-rich sediments were deposited in an anoxic condition in the mire in the seasonal tropics, with low oxidation. The coals are predominantly by the succession from freshwater mostly in the limnetic condition. Fine-grained mineral matter (silica and clay minerals) penetrated the wood textures also indicate they were impregnated from muddy water, and deposit during syn-depositional or early diagenetic processes. The maceral and mineral assemblages reflect a forest swamp environmental setting with a moderate amount of sediments supplied by low-energy water flow. Based on the chemical study, the Hongsa coals were classified as lignite B to lignite A with high ash content and low sulfur that is positive for environment.

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