CHAPTER V

COAL GEOLOGY

It is the known fact that a sedimentary basin is an area of the earth's crust that is underlain by the thick sequence of sedimentary rock. Besides, coal commonly occurs in sedimentary basin and is absent from intervention of igneous and metamorphic rocks.

Coal, a solid fossil fuel, is formed from plant derived organic remains plus some non-organic minerals. It is a heterogeneous soft material and composes of more than 50 percent by weight of organic matter. The first large sources of plant matter giving rise to enormous coal reserves did not appear before the Carboniferous and in this system the first important coal deposits have been preserved. The Upper Carboniferous is the "bituminous-coal period" that the Gymnospermae of the plant kingdom is dominated in those distant times (Diessel, 1982). Ever since the Angiospermae first appeared in Triassic time, underwent a rapid development and dispersed all over the places. A large amount of coal also developed in the Tertiary and the greatest thickness is known from this period.

The geological factors which determine the occurrence of coal deposits are :

a) Type of basin ; geologically and graphically environments, and basin development.

b) Appearance of land plants in geological time.

c) Accumulation and preservation of plant remains.

d) The level of water in the basin and/or the distance from the edge of the basin of the deepest part.

e) Chemistry of the water in the basin which effect to the blooming of organism and plants.

f) Diagenesis, or surface or near surface transformation of the coal remains.

g) Types of overburden material and effect of post depositional tectonism and

h) Coalification under the action of mechanical stresses and temperatures.

Increased demands for energy in the face of diminishing supplies of readily available liquid hydrocarbons have turned the attention of energy industries to coal. Many characteristics of coal bands, namely, thickness, continuity, quality, etc. can be attributed to the environments in which the peat beds accumulated and to the tectonic setting at and after the time of deposition. Therefore, a knowledge of depositional environments and tectonic influences should be in the exploration and development of economic coal bodies.

An attempt has, therefore, been made in the present study to focus some detailed study on the coal in the Tertiary sedimentary sequence of the Li basin. The geology of coal in this study covers various aspects, namely, stratigraphic position, characteristics and geometry of coal seams, coal petrography, coal rank and proposed coal depositional model. Details on each of the aforementioned aspects will be discussed as follows :

5.1 Stratigraphic Position, Characteristics and Geometry of Coal Seams

The coal measures of the Li basin is characterized as 2 coal seams of Ban Hong and Ban Mae Long Formations except in the Ban Na Sai-Ban Mae Wang sub-basin that characterized by 1 coal seam. The characteristics of each coal seam or band from bottom to top of each sub-basin are as follows :

5.1.1 Ban Pu Sub-Basin

The Ban Pu coal can be divided into 2 seams, namely, the lower and the upper coal seams. The two coal seams are lying between the fine-grained sedimentary units (Figure 3.1.1).

The lower coal seam of the Ban Pu area is characterized by thick coal bed. This coal seam overlying conformably the very fine- to very coarse-grained sand with clay matrix. It is brownish black to black, consist of dull and medium bright interbanded, massive, and sub-conchoidal fracture. Evidence from a few boreholes show that it is widely distributed in the Ban Pu area with the thickness varies from a few metres to about 30 metres. Due to its great quantity and shallow depth, this seam has extremely high economic value at present.

The upper coal seam lies over the medium hard, high plasticity, light olive gray clay. The seam is of low quality with great amount of parting. The coal appears as dusky brown colour, hard, dull to medium bright. Partings are characterized by light olive gray clay to olive gray clay which is mediumly hard, high plasticity, with muddled up of some sand and silt. This is probably due to the unstable depositional environment of the basin. In Ban Pu area, the thickness of this coal seam is generally variable. It is thinning westwardly with thickness of about 14 metres in the eastern margin to 1 metre in the western margin.

In the northern and eastern parts of the Ban Pu sub-basin, the coal seam crops out beneath the bounded pre-Tertiary rocks and is present at greater in depth southwardly. Because of high quality of the lower coal seam and its thickness, the western flank of the sub-basin was mined out and possibly using selective mining in the eastern flank of the sub-basin.

5.1.2 Ban Hong Sub-Basin

The coal seam of Ban Hong sub-basin is divided into two major coal seams and one split seam (Figure 3.1.2). The major coal seams are named as the upper coal seam and the lower coal seam. The lower coal seam is characterized by thick coal bed with the small amount of partings. This coal seam overlying the silt and clay. It is characterized by brown to black colour, hard, good brightness with the average thickness of about 12 metres.

The upper seam of the major coal seam is overlain by the sediments of silt, fine- to coarse grained sand with muddled up of some gravel. The seam is consist of hard coal, brown to black colour with some clay parting. There is a little amount of clay partings in the lower part of this upper coal seam and increasing upwardly. This is probably due to the unstable depositional environment of the basin. The average thickness of this upper coal seam, excluding partings, is about 6 metres.

The sedimentary sequence overlying the major coal seams is the split coal seam comprising of unconsolidated sediments with thin bedded coals and carbonaceous material intercalation containing leaves fossil. The coal intercalating zone is consist of two sub-zones, the lower sub-zone and the upper sub-zone. The lower sub-zone consists of a series of thin bedded coal with clay partings. Some of coal bands are of high quality but limited in continuation. The average thickness of the lower sub-zone is about 10 to 15 metres. The upper sub-zone is similar to the lower sub-zone with approximately 10 metres in average thickness. The continuation of both sub-zones is poor, mostly graded into coaly and carbonaceous materials. It also appears that the splitting seam and parts of the upper coal seam are eroded during Quaternary age.

Based on the geological and geophysical drill-hole data, cross-sections, structures and interpretation, there is a reason to conclude that the maximum thickness of the coal seam is in the middle part and the thickness decreases toward the north, east and west directions and eventually thinning out. The coal seam still extends toward the southern part of the sub-basin.

5.1.3 Ban Mae Long Sub-Basin

The coal seam of Ban Mae Long sub-basin can be divided into two seams (Figure 3.1.3). The lower coal seam is characterized by thin coal bed intercalated with a great amount of partings through the coal sequence. This coal seam overlying the brownish gray to gray clay with muddle of sand. The coal is characterized by brownish black to black colour, dull to bright band, hard but brittle.

Partings are characterized by brownish gray to dark gray coaly clay. This is probably due to the unstable depositional environment of the basin.

The sedimentary sequence overlying the lower coal seam is the thick sequence of brownish gray to gray clay with sand in the middle part.

The upper coal seam of the Ban Mae Long sub-basin is characterized by a thick coal bed with small amount of parting, lying over the very thick clay sequence. It comprises of hard and soft coal interbanded. The hard coal is characterized by brownish black to black colour, bright, sub-resinous luster, brittle and sub-conchoidal fracture. The soft part is characterized by brownish black colour, dull and brittle. Partings are brownish gray to gray clay, brownish black coaly clay and carbonaceous shale. This coal seam shows a relatively better quality than the lower coal seam. Due to its suitable quality, this coal seam shows extremely economic value at present.

Based on the geological and geophysical drill-hole data, correlation from the geological cross-section and interpretation, it appears that the geometry of the coal seam in the Ban Mae Long sub-basin is as follows :

In the northern and eastern parts of the Ban Mae Long sub-basin, the coal was deposited as a thick coal sequence both for upper and lower coal seams. The coal beds dip towards in the western direction. The coal seams are present through the central part of the basin, and the continuity is controlled by fault.

In the northern end of the sub-basin, the coal seams are oriented with the strike of northwest - southeast direction and the dipping angle is higher than that of the central portion.

Follow the direction of western part of the sub-basin, the coal seams are thinning and eventually pinch out corresponding to the increasing in depth. The lower coal seam is rather flat towards the west direction.

In the southern part of the Ban Mae Long sub-basin, the upper coal seam extends over a relatively wider area and then thinning out, whereas the lower coal seam covers smaller area and finally pinches out. However, both seams show a tendency to pinch out towards the basement-high structures.

5.1.4 Ban Pa Kha Sub-Basin

The nature of Ban Pa Kha coal deposit generally characterized by the presence of two coal seams, namely, the lower coal seam and the upper coal seam (Figure 3.1.4). The lower coal seam shows the sand, clay and organic clay partings. Towards the upper portion of this lower coal seam, 3 - 8 metres thick of clean and massive coal is a typical characteristics. The lower coal seam is generally characterized by brownish black to black colour, bright in most part, hard with sub-conchoidal fracture. The overall thickness of the lower coal seam varies between 15 to 20 metres, with the average cumulative coal thickness of approximately 10 metres. The area underlain by a relatively thick lower coal seam is located in the eastern and western parts of the deposits.

The sediments lie between the two coal seam are characterized by grayish brown to brown clay commonly intercalated with oil shale in the lower part. The upper coal seam is consist of coal bed with clay partings. The upper coal seam is generally characterized by brown to black colour, dull, commonly interbedded with coaly clay and clay of varying thickness. The coal seam thickness varies between 10 to 15 metres, whereas the average cumulative thickness of the solid coal is approximately 7 metres. This coal seam is distinctively different from the lower coal seam by the extensive intercalation of thin beds or lamination of light gray clay. It is possible to separate the upper coal seam from the lower coal seam by means of different geophysical signatures. The area underlain by a relative thick upper coal seam is located in the southwestern part of the existing mine pit where 8 - 10 metres thick of coal are discovered. The area underlain by a relatively thin coal of 1 - 4 metres thick extends towards the southwestern part of the sub-basin.

Basically, the geological cross - sections are correlated from the geological and geophysical information and necessary data. It is considered that the thicknesses of both coal seams along the east - west direction are in most part consistent except those overlying the horst structure which are relatively thinner. For the upper coal seam, there is a tendency of higher degree of seam splitting and lateral facies change from coal to oil shale southwardly. For the lower coal seam, the thickness gradually increases southwardly and then almost abruptly decreases and eventually thinning out towards the most southern part of the area.

It is the fact that the average strike of coal seams varies slightly from northwest to northeast with a very gentle dipping angle. Both coal seams are generally dipping toward the main Li basin with inclination angle of up to 20 degrees.

5.1.5 Ban Na Sai - Ban Mae Wang Sub-Basin

The nature of the coal deposit at Ban Na Sai - Ban Mae Wang sub-basin is characterized by the presence of only 1 coal seam (Figure 3.1.5). The coal seam appears as brownish black colour, dull with some bright band, loose to dense in massive bed of lower part, brittle, irregular to planar fracture, commonly interbedded with very fine- to fine grained sand and clay partings. The typical characteristic of the coal seam is water saturated in the coal mass. The coal bed lies sub-horizontally striking in the northeast direction and dipping towards the southeast or northwest directions. The average thickness of the coal seam is approximately 4 metres.

Due to the limited geological and geophysical drill-hole data, the interpretation on coal deposit less reliable. It is deduced that the coal was deposited in fault-block faulting.

In the southern part of the mine pit, the coal shows low degree of partings with a tendency of increasing parting to the north. The coal seam is present at the shallow depth in the north and dipping towards northern part. It is not clear that the coal seam extends northwardly or absent.

Generally, the coal deposit of Ban Na Sai-Ban Mae Wang sub-basin extends from the eastern part through the western part and is absent in the central part.

It is the fact that the coal quality of Ban Na Sai - Ban Mae Wang sub-basin is relatively inferior than those of the others because of higher degree of partings, impurity such as sulphide mineral, high moisture and volatile matter. This is probably due to the unstable depositional environment of the basin, the low degree of coalification, and the action of surface water.

5.2 Coal petrography

It is said that types and ranks of coal are dependent on the types of the parent material and geological concerns. Pressure and temperature are considered the eminent factors on coalification. After deposition, through sinking and locally moving of the basin, coal is upgraded. The deeper the sink, the higher grade of coal is obtained.

Parent matter of coal consist of several parts of plants, such as the woody tissue, resin, spore, pollen, algae and even phytoplankton. In petrology, these matters are classified into three maceral groups, namely, vitrinite, exinite or liptinite and inertinite.

Cook and others (1982) examined, by means of petrography, a few specimens from several small northern basins, including the Li basin. This study indicated that all coals were rich in vitrinite and detrovitrinite (attrinite, densinite, ultinite). The majority of the vitrinite is referable to densinite. Exinite was abundant in the coal dominated by liptodetrinite and cutinite. Sporinite and resinite were less abundant but locally prominent. Inertinite found as sclerotinite was a minor component in all specimens. And as for reflectance, all coal specimens fell into the brown coal rank.

In the present study, the samples are collected from 5 main sub-basins. The 10 pellets are prepared for coal petrographic study, using point counting method. Generally, the characteristics of the coal within the Li basin under the reflected light, compared with rocks, is that the vitrinite likes groundmass and the inertinite likes grains scatter in the groundmass. The inertinite is dark, while vitrinite is medium bright. The exinite is clearly characterized by grain, very bright under the reflected light. The shape of inertinite maceral is sub-rounded to rounded but the exinite and vitrinite have uncertain shape.

It is clearly seen that all coal mainly consist of vitrinite. Liptinite or exinite and inertinite are the minor components. It is also noticed that in 3 main sub-basins, namely , Ban Pu, Ban Hong and Ban Mae Long sub-basins, the exinite component is more abundant than inertinite. On the contrary, the Ban Pa Kha and Ban Na Sai-Ban Mae Wang coals consist of more inertinite group than exinite group. It is noted that the coal mass usually consists of mineral matter of mainly quartz, pyrite and clay minerals. The macerals composition of 5 main sub-basins including mineral matter is summarized in Table 5.2.1.

5.3 Coal rank

The categorization of coals by degree of metamorphism is known as rank classification. The changes in rank result mainly from

Table 5.2.1 The maceral composition of coal within the Li basin

Composition	Inertinite (%)	Vitrinite (%)	Exenite (%)	Mineral matter (%)
Ban Pu sub-basin	8.78	73.85	12.38	4.99
Ban Hong sub-basin	6.57	58.57	19.92	14.94
Ban Mae Long sub-basin	8.00	76.40	8.40	7.20
Ban Pa Kha sub-basin	9.40	76.40	6.80	7.40
Ban Na Sai-Ban Mae Wang sub-basin	17.40	62.40	10.00	10.20

the weight of overlying sedimentary rock, the heat produced by depth of burial, time, structural deformation, chemistry of the water and biochemical actions, all of which contribute to progressive compaction. Most rank classification systems are based on the following four changes that occur with increased metamorphism. These changes, as determined by laboratory tests, are : (1) decrease in the amount of volatile matter yielded during destructive distillation; (2) increase in heat value (calorific value) until the volatile matter content has decreased to between 14 and 22 percent, after which the heat value decrease also; (3) increase in carbon content; and (4) decrease in hydrogen content. In this study, the standard classification of coal by ranks (ASTM D 388 - 77) has been used. This classification is based on fixed carbon and calorific value (expressed in kcal./kg) calculated to the mineral - matter - free basis. The high - rank coals are classified according to fixed carbon on the dry basis; the low rank is classified according to calorific value on the moist basis.

In this study, the representative analyses of coal samples from boreholes scattering over main part of the study area have been selected for coal rank determination. The proximate analytical data are obtained from the Ban Pu Coal Co.Ltd. and the Lanna Lignite Co.Ltd.. Analytical data of Ban Pu sub-basin are obtained from 8 boreholes of totally 48 samples, Ban Hong sub-basin are obtained from 36 boreholes of totally 242 samples, Ban Mae Long sub-basin are obtained from 45 boreholes of totally 197 samples, Ban Pa Kha sub-basin are obtained from 127 boreholes of totally 619 samples and Ban Na Sai-Ban Mae Wang sub-basin are obtained from 41 boreholes of totally 81 samples (Table 5.3.1). These data include heat value or calorific value, ash content , moisture content, volatile matter, fixed carbon and sulphur content. The calorific value of mineral matter free, on moist basis is obtained from equation of Parr Formulas is as follows :

$$\text{Moist, Mn - free Btu.} \quad \frac{\text{Btu} - 50S}{100 - (1.08A + 0.55S)} \times 100$$

where

Mn = mineral matter

Btu = British thermal units per pound (calorific value)

A = percentage of ash, and

S = percentage of sulphur

The calculation of calorific value of any coal seams in each sub-basin , namely, Ban Pu, Ban Hong, Ban Mae Long, Ban Pa Kha and Ban Na Sai, have been carried out from 48, 181, 105, 176 and 81 samples, respectively. The final evaluation reveals that the modal value of calorific value of the coal seam from Ban Pu area falls within the range of lignite-A (Figure 5.3.1.a). The coal seams of Ban Hong area fall within the range of lignite-A to sub-bituminous-C (Figure 5.3.1 b). However, some of them fall within the rank of sub-bituminous-B. The upper coal seam in Ban Mae Long area falls within the range of sub-bituminous-C to sub-bituminous-B, some of them fall within the rank of sub-bituminous-A to high volatile C bituminous and the lower coal seam falls within the rank of lignite-A to sub-bituminous-C, some of them fall within the rank of sub-bituminous-B (Figure 5.3.1 .c). The upper coal seam in Ban Pa Kha area falls within the range of sub-bituminous -C, some of them fall within the

Table 5.3.1 Number of drill-holes and samples for coal quality proximate analysis in 5 main sub-basins of the Li basin

Areas	Number of drill-holes	Number of samples
Ban Pu sub-basin	8	48
Ban Hong sub-basin	36	242
Ban Mae Long sub-basin	45	197
Ban Pa Kha sub-basin	127	619
Ban Na Sai-Ban Mae Wang sub-basin	41	81

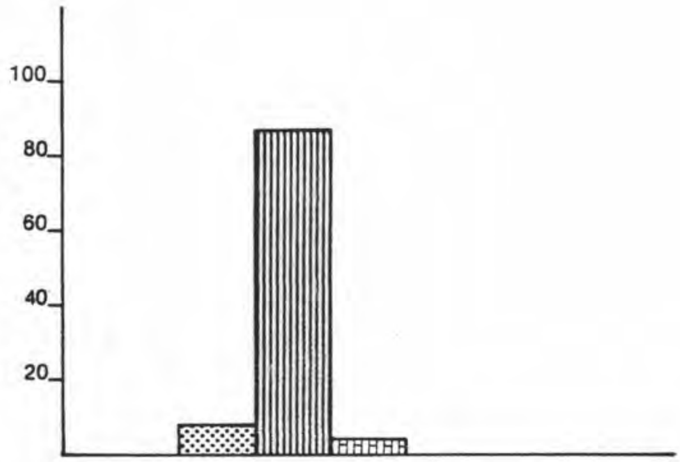

Figure 5.3.1.a Histogram showing calorific values of coal samples of Ban Pu sub-basin after Parr Formulas treatment.

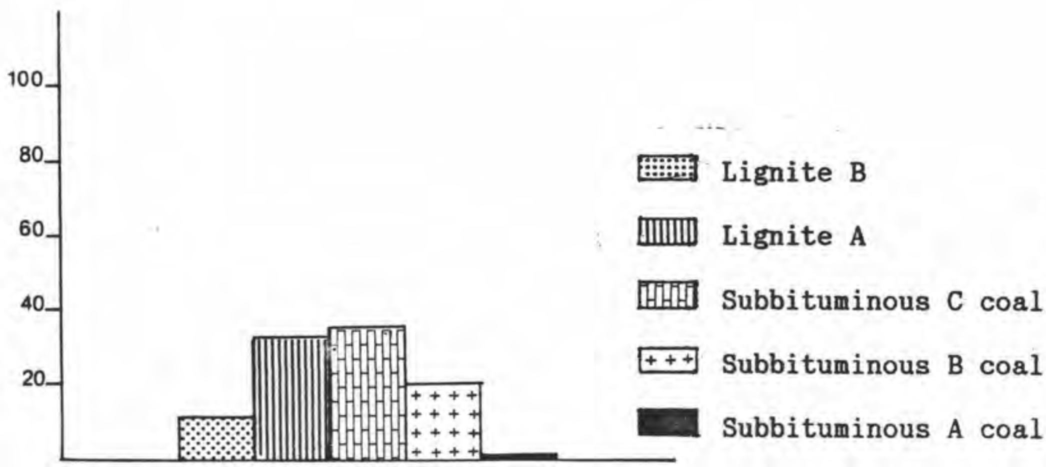

Figure 5.3.1.b Histogram showing calorific values of coal samples of Ban Hong sub-basin after Parr Formulas treatment.

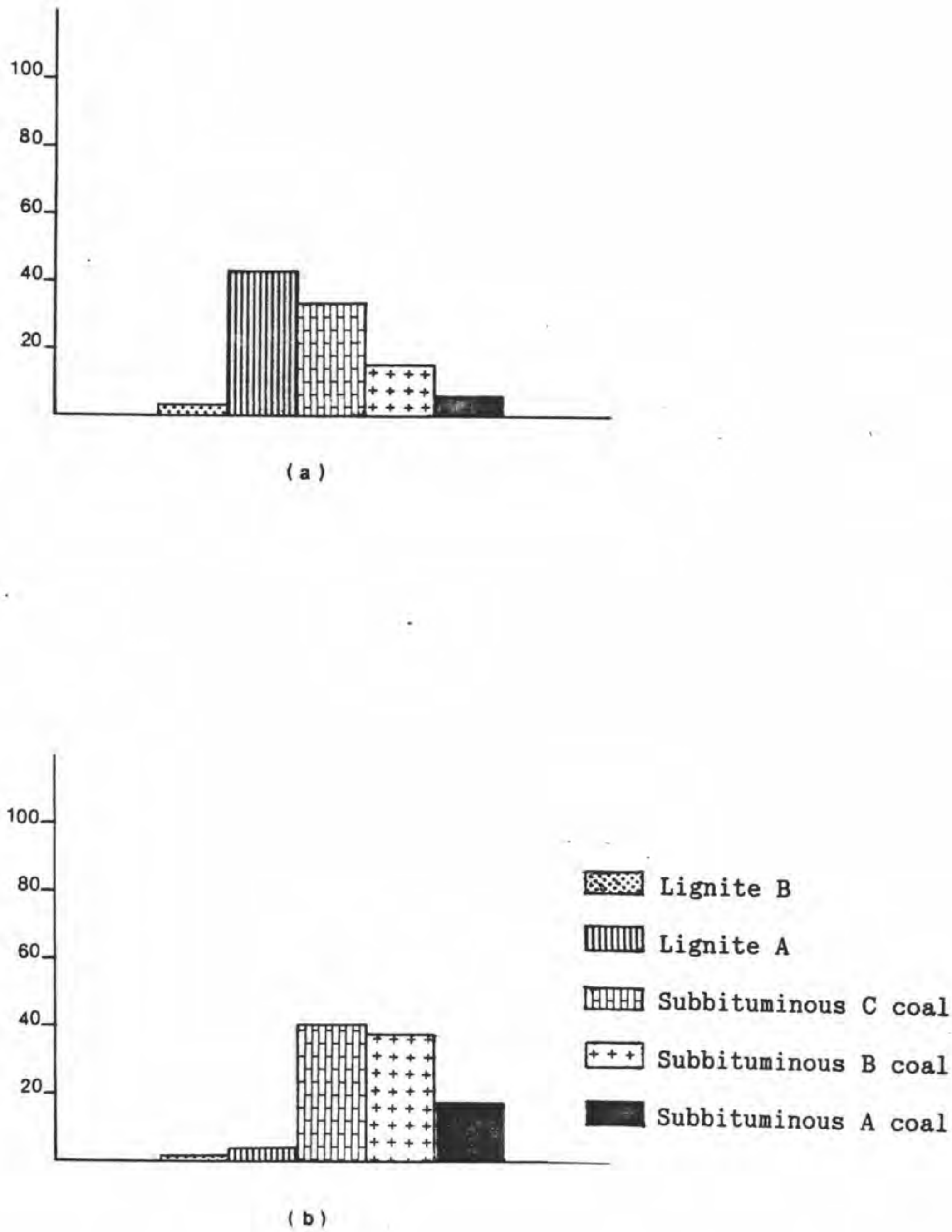

Figure 5.3.1.c Histogram showing calorific values of coal samples of Ban Mae Long sub-basin after Parr Formulas treatment.

a) lower seam b) upper seam

range of lignite-A and sub-bituminous-B, and the lower coal seam falls within the range of sub-bituminous-A to high volatile-C bituminous, some of them fall within the rank of sub-bituminous-B (Figure 5.3.1 d). The coal seam in Ban Na Sai-Ban Mae Wang area falls within the rank of lignite-A, some of them fall within the rank of lignite-B and sub-bituminous-C (Figure 5.3.1 e). For general name, coal of Li basin is concluded to be lignite to sub-bituminous. The average proximate analysis of coal in any sub-basins is shown in Table 5.3.2.

Detailed information regarding the coal ranks of 5 main sub-basins of the Li basin are presented in Figure 5.3.2.

5.4 Proposed coal depositional model

Generally, the coal deposit within the Li intermontane basin is proposed to be a limnic coal which the water level was controlled by local conditions. This means inland coal swamps or basins which never has any connection with the sea. Evidence of fossil records supports non-marine origin. The floras of *Alnus* sp. and *Fagus* sp. were classified by Endo (1964, 1966). These floras indicate the paleo-climate of peat accmulation to be temperate humid climate (Bouška, 1981). This coal deposit usually shows a relatively limited number of seams with restricted areal extent, but individual seam is frequently very thick. The relatively thick coal measures of limited lateral extent also indicate the limnic coal deposited in fault-bounded basins. The thick coal seam also indicate the dense plant community and/or continuous moderately subsidence of the basin.

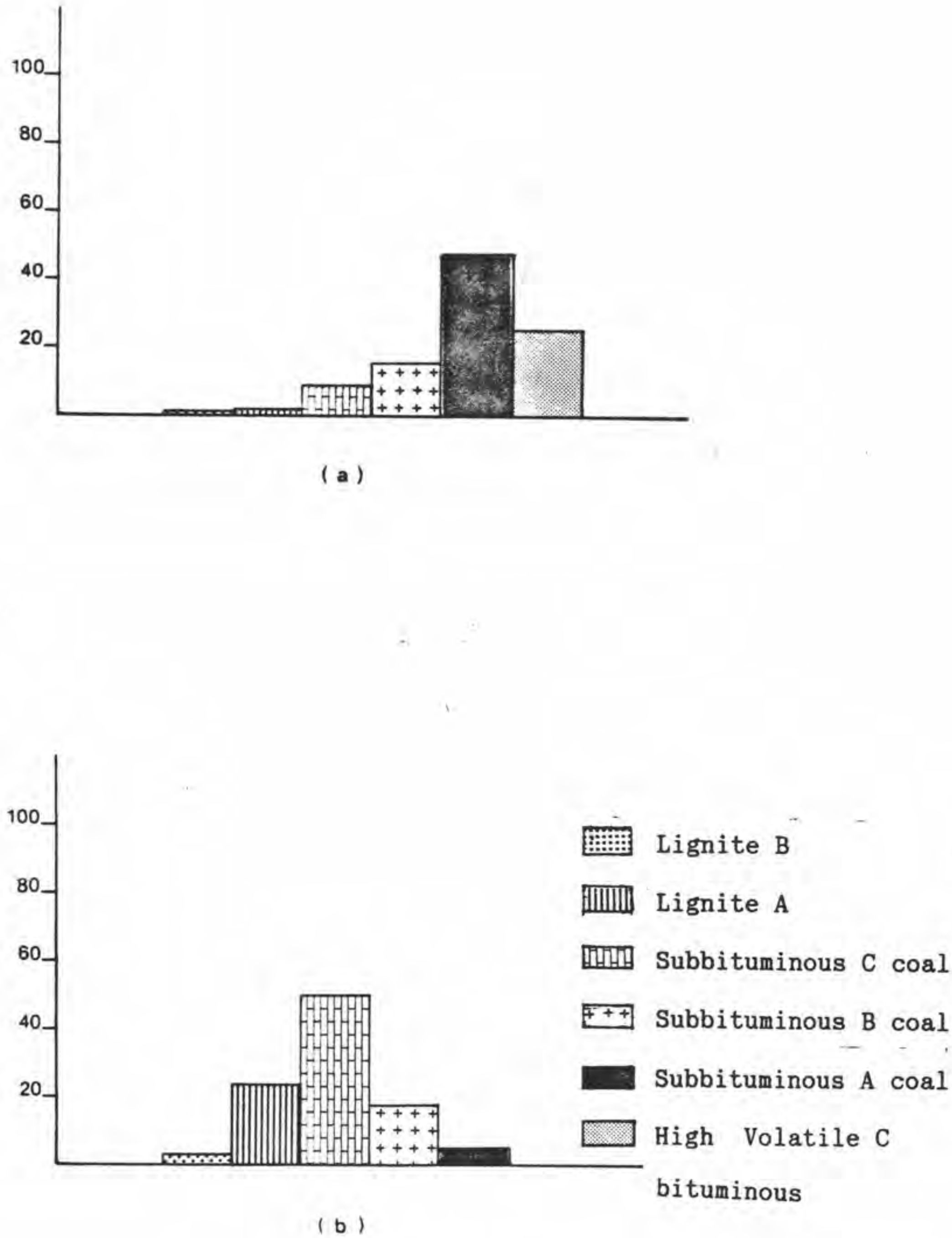

Figure 5.3.1.d Histogram showing calorific values of coal samples of Ban Pa Kha sub-basin after Parr Formulas treatment.

a) lower seam b) upper seam

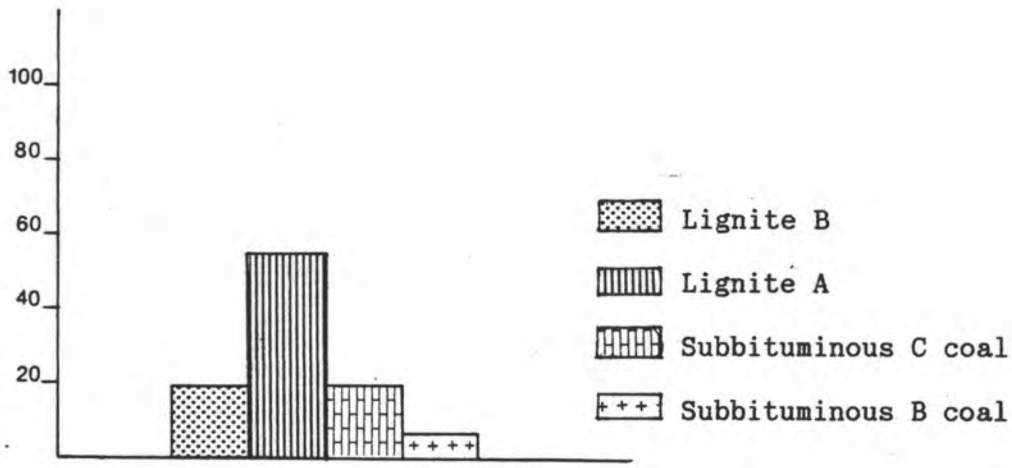

Figure 5.3.1.e Histogram showing calorific values of coal samples of Ban Na Sai-Ban Mae Wang sub-basin after Parr Formulas treatment.

Table 5.3.2 Proximate analysis of coals within the Li basin.

sub-basin		M.(%)	V.(%)	A.(%)	FC.(%)	S.(%)	CV.(kcal./kg.)
Ban Pu	Ar.	21.46	33.03	15.12	30.39	1.71	4,065.71
Ban Hong	Ar.	30.23	29.47	13.70	25.70	0.93	3,599.00
	Ad.	12.06	37.02	17.31	32.18	1.16	4,542.00
	Db.		42.30	19.41	36.82	1.33	5,186.00
Ban Mae-Long (UC.)	Ar.	35.67	28.71	9.17	26.45	0.29	3,699.00
	Ad.	11.21	39.65	12.62	36.52	0.40	5,067.00
	Db.		44.65	14.20	41.15	0.44	5,708.00
(LC.)	Ar.	30.98	24.07	24.29	20.67	0.45	2,888.00
	Ad.	5.66	32.90	33.13	28.31	0.62	3,952.00
	Db.		34.88	35.13	29.99	0.66	4,189.00
Ban Pa-Kha (UC.)	Ad.	7.5	34.45	29.52	28.54		
	Db.		38.05	30.25	31.60	1.97	4,876.77
(LC.)	Ad.	11.60	37.36	13.27	37.77		
	Db.		42.24	15.31	42.40	1.05	6,059.72
Ban Na Sai	Ad.	13.97	34.96	22.60	28.477	2.85	3,990.00

Note : M.= Moisture , V.= Volatile matter , A.= Ash content , FC.= Fixed Carbon , S.= Sulphur , CV.= Calorific Values , Ar.= As recieve basis, Ad.= Air-dry basis, Db.= Dry basis.

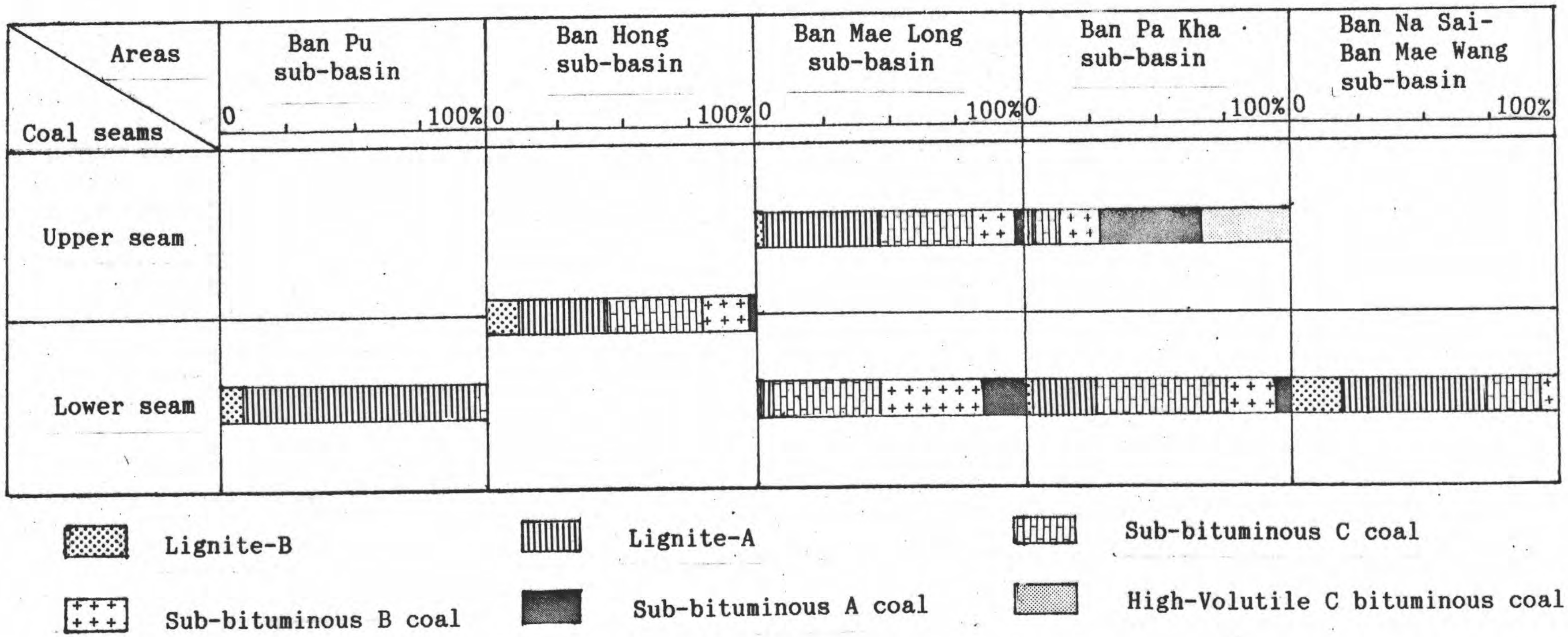

Figure 5.3.2 Detailed information of the coal ranks of the Li basin

Autochthonous coals develop from plants which after death form peat in situ. The coal in Li basin is proposed to be autochthonous coal. There are many evidences which support this suggestion, they are: wide distribution, considerable thickness of coal without parting interruption, gradational contact at the lower boundary, presence of coal stumps in growth position at Ban Pu Mine by Pol Chaodumrong (1982). According to the hypothesis of allochthony, the coal seam should be stratified with alternations of coarse- and fine-grained material corresponding to the alternations of floods and low water periods of river flowing into the lake. Moreover, almost of the coal seams in any sub-basins are covered by the metres of lacustrine clay which are practically devoid of coal seam. In terms of allochthony, it is difficult to see why the inflowing rivers, after having carried plant material into the lake for hundreds of years, suddenly stopped doing this and brought in only inorganic matter. However, evidence of abundant coal flakes which are present close to coal bands is concluded to be hypautochthonous coal. The hypautochthonous peat and sediment were deposited whereas the basin is slowly subsided.

The microscopic study of the macerals of coal in all sub-basins indicate that the vitrinite maceral is most abundant (Table 5.2.1). The vitrinite is the preservation of stems, roots and leaves of wood, periderm and leaf mesophyll tissues, some cell fillings including grass and reeds (Cook, 1975 ; Starch, 1982 ; and Bustin and others, 1983). It is indicated that peat is accumulated in the stagnant, highly toxic waters that protected the organic material from extensive biochemical decay [reducing environment] (White, 1973;

Tasch, 1960) and/or deposited in areas that underwent greater subsidence than the surrounding area [deep-basin type] (Smith, 1968 ; Cook, 1975 ; and Shibaoka and Smyth, 1975).

For the coal-bearing Li basin, it is suggested that peats were accumulated within the tectonic basin or fault-bounded basin where low-lying areas underwent greater subsidence than the surrounding area. The peat is accumulated in the suitable condition with preservation of vitrinite. Plants are concluded to be woods, branchs, grass and reeds. It is suggested that the plants were grown in moor type environment with temperate humid climate.

In detailed, proposed coal depositional models of coal-bearing sub-basin within the Li basin are conformable to the Tertiary coal exploration model of Thailand constructed by Chaiyudh Khantaprab (1985). The relationships between the subsidence and coal swamp deposition of 5 main sub-basins are shown in Table 5.4.1.

Due to the fact that the depositional environment of the coal seam in the Ban Na Sai-Ban Mae Wang sub-basin is the calcium rich one. The sediments contain considerable amount of calcareous substance with spot and cement appearance. The coal deposit in this sub-basin indicates the calcium-rich swamp. The calcium-rich water must have been leached from the surrounding swamp areas as well as limestone basement rocks which are exposed in the southern and southwestern parts of the Li basin. The coal-bearing sedimentary sequences elsewhere in the northern part of Thailand such as Mae Teep basin, Mae Moh basin, etc. show evidence of the solutioning of calcareous material.

Table 5.4.1 The relationships between the subsidence and peat swamp deposition of 5 main sub-basins of the Li basin

	Ban Pu sub-basin	Ban Hong sub-basin	Ban Mae Long sub-basin	Ban Pa Kha sub-basin	Ban Na Sai-Ban Mae Wang sub-basin
Sedimentary unit	Fault movement rapid subsidence Compaction of sand slow subsidence Compaction of clay moderate subsidence	Compaction of sand&clay low-moderate subsidence	Fault movement rapid subsidence	Fault movement rapid subsidence	
Upper coal seam	Fault movement rapid subsidence	Compaction of sand slow subsidence	Compaction of peat moderate subsidence	Compaction of peat moderate subsidence	
Sedimentary unit	Fault movement rapid subsidence Compaction of sand slow subsidence Compaction of clay moderate subsidence	Compaction of sand slow subsidence Compaction of clay moderate subsidence	Fault movement rapid subsidence	Fault movement rapid subsidence	Fault movement rapid subsidence
Lower coal seam	Compaction of peat moderate subsidence	Compaction of peat moderate subsidence	Fault movement rapid subsidence	Compaction of peat moderate subsidence	Compaction of peat moderate subsidence

In conclusion, the coal of the Li basin is concluded to be mainly of autochthonous coal, plant materials are grown in the swamp. In the case of thick coal band, the prolonged reducing coal-swamp environment coupled with the continuous subsidence of the depositional basin are believed to be the major controlling factors. Addition of water to the swamp should be fed by sluggish stream that carried only medium- to fine-grained sediments as indicated by a few medium-grained clastic rocks in the parting of the sub-basins. The peat bogs of the Li basin must have a suitable subsiding rate which preserved the remaining plant materials in reducing environment, because the rapid sudsidence during sedimentation results generally in abrupt variation in coal-seam geometry, whereas slower subsidence rates favour greater lateral continuity. If the subsidence rate is too slow, plant materials would be rotted or decomposed and no plant matters were preserved. Of course the whole basin must not have the same subsiding rate, indicates by the different thickness of coal seams or bands and different thickness of partings. Gastropods and bioturbation are commonly present in the clay layers indicating the shallow-water environment. The presence of some coal flakes within the partings also indicates some shifting or erosion of plant materials within the basin.