CHAPTER IV

DEPOSITIONAL ENVIRONMENTS

In general, coal-bearing sedimentary sequences have originated in several types of acient physiographic units. However, one of the most essential condition needed is the accumulation of peats and clastic sediments in swamps or marshes. Environments of somewhat stagnant water may be located in deltas, alluvial channels, lagoons, estuaries, coastal strips, and in central plain near the base lavel of erosion.

The accumulation of particular plant associations gives rise to peat bogs under certain diastrophic, climatic, and morphological conditions. Peat deposits are the geologically youngest deposit of caustobioliths, the coal deposits bring their fossil analoques. Essentially, three types of peat bogs are differentiated;

a) lowmoor

b) highmoor

c) transitional peat bogs

Lowmoor bogs develop in lowland by gradual overgrowing of marshes or water basins. They are fed both with surface and ground-water. The formation of lowmoor bogs depends on the balance of microbial decay of weathered plant material. Where microflora is capable of decomposing all material accumulated in one year into mineral components, humus cannot heap up and peat cannot develop. Since the lowmoor bogs are fed with ground water, which brings an abundance of dissolved nutritive substances, their vegetation cover differs from that of highmoor bogs. The vegetation is more varied; it is rooted under the water under level in soil generally enriched in nutrients, particularly Ca and K. In fossil lowmoor bogs two types are distinguished on the basis of the mode of plant matter accumulation;

a) stagnant peat bogs, formed by prolonged overgrowing of water body :

b) irrigation peat bogs, formed by increasing water-logging of the area. The development of the two types is often linked up and repeats itself cyclically. It is controlled predominantly by diatrophism and climate.

Highmoor bogs develop at higher elevations under cooler and more humid climatic condition. They grow on soils poor in nutrients or in basins with clayey impermeable bottoms, invariably above the ground-water table and are fed almost entirely with atmospheric water. Precipitations bring only few nutrients and the plant species are therefore represented by some grasses and sphagnum moss. The lower parts of sphagnum gradually die away and are transformed into true peat; the upper parts grow continuous and the bog may thus rise up to several meters above the ground-water table. The yearly accretions are small, of about 3-4 cm. In the midst of the bog, where the environment is most humid, the moss grows most rapidly and the bog is up heaved assuming a loaf-shaped form. The development of a highmoor bog is occasionally interrupted by period of drought, when so-called boundary horizon, rich in inorganic material wind-blown on its surface, are formed.

Transitional peat bogs representing a transition between the preceding types develop where a highmoor bog was forming on the lowmoor substrate. Essentially, progressive accumulation of plant material in a lowmoor bog will produce earthy to pure peat as long as the plant roots can reach the mineral substrate. Afterwards the plant association is replaced by associations which need only a minimum of inorganic matter, i.e. by the genus Sphagnetalia. The factors affecting the development stage are climatic, topographical and others. The character of the development of brown and bituminous coal deposits, both of Carboniferous and Tertiary age, was similar to that of present-day peat bogs except for the type of vegetation. The overgrowing of recent water bodies preceeding the formation of peat bogs repeats the infilling of water basins in Tertiary times or sea embayments and freshwater basins in Carboniferous (Fig. 4a). The nature of transitional peat bogs is inferable from the above type and depends on the development stage.

	Highmoor bog	Lowmoor bog
Origin	depending on precipitation, deterioration of climate	topogenous, depending on terrain configuration
Growth	rises above the ground surface, independently of ground water	grows only in water-logged basins
Peat-forming plants	sphagnum, cotton grass	sedge, reed, trees (willow, alder)
Nutrient content	very poor, lack of calcium (CaO 0.5 %, max. 0.8 %)	medium to rich (2–4 % CaO), $CaCO_3$ sometimes present
Reaction	acid, pH = 5–5.6 (may be even 3)	neutral or slightly alkaline, pH = 7–7.8 (sometimes also acid, pH > 4)
Vegetation	sparse, poor in species	luxuriant, rich in species
Ash	1–3 %	5–15 %

Figure 4a. Brief characteristics of peat bog types (from Bouska, 1981).

The coal-bearing depositional basins can be generally classified into 2 types, namely, paralic, and limnic. In the paralic basin, which is formed along the margin of the sea, numerous coal seams tend to be relatively regular over long distances with limited thickness. On the contary, the limnic basin or in land fresh-water basin tends to contain few coal seams with irregular geometry of relatively greater thickness.

The understanding of the coal depositional environments is beneficial not only to sedimentological aspects but also to the explorations of coal resources. The depositional history of coal-bearing sedimentary sequences in certain intermontane basin in particular is considered to be an important depositional model for other neighbouring intermontane basins. Besides, a number of exploration and production models for coal bearing sequences in various parts of the world is based on interpretation of sedimentary environments.

Detailed analysis of subsurface geology and stratigraphy based on three-dimensional field data obtained from three-dimentional open-cast coal mine data and borehole records have allowed the distinction of a number of sedimentary lithofacies which will be interpreted as depositional environments. Facies are important because their recognition and analysis provide the basis for an environmental interpretation of stratigraphic units. Generalizations based on comparative studies of several similar modern and ancient examples are often called facies models It has been suggested by Walker (1976) that a good facies model has four functions, besides being a generalization of a number of real examples.

a. It can serve as a norm, with which any real example can be compared .

b. It can serve as a framework and guide for future observations.

c. It can serve as a predictor in new geological situations.

d. It can serve as a basis for interpretation of the facies in terms of physical or chemical mechanisms.

However, only few existing facies models satisfied all of Walker's criteria. Further development and elaboration of the principal models remain one of the major joint tasks of sedimentology and stratigraphy.

Generally, the major controlling factors for the formation of large coal deposits are the suitable depositional environments previously outlined and the diastrophism which cause subsidence of the depositional basins.

Cyclic sedimentation is known to have existed in various geological periods. It is thought at present that cyclic sedimentation of coal-forming material is caused by diastrophic movements. The subsidence of a plain with coal-forming peat bogs is followed by either marine transgression or flooding to form the inland lake.

Regional subsidence leads to evolution of four types of basin:

a) Basins of geosynclinal systems

b) Basins on the platforms

c) Basins intermontane depressions

d) Basins of transitional regions.

Besides, the origin of cyclic sedimentation is also explained as due to climatic changes. Every glaciation represents a stage of extensive alluviation and formation of lakes and swamps. In the following interglacial stage the sea may spread over such coal-forming basin and deposit there clastic material with drifted plant remains and later on the marine limestone may develop. During the subsequent glaciation, the resumed sedimentation favourable to coal formation may begin again with the deposition of clastic sediments.

In conclusion, the accumulation of plant material depends on many factors which are basically controlled by diastrophism and climate. Diastrophic movements produce subsidence of some parts of the Earth's crust and upheaval of others, thus giving rise to source areas and sedimentary basins. The thickness of the basin filling and the cyclic structure of the basin are also affected by diastrophism. The climate governs the evolution and composition of vegetation, the groundwater conditions bring one of the major accessory factors. Environments suitable for the accumulation of plant material developed only at some places of the Earth, depending on the coarse of mountain ranges, climatic zone and on the evolution stage of fossil flora. Migration of the Earth's axis created favourable conditions for the formation of coal deposits even in the areas that are glaciated at present.

In this study, the term "lithofacies" or "sedimentary facies" denotes the collective character of any sedimentary rocks which denote record of its depositional environments. The subdivision of lithofacies or sedimentary facies is represented by sub-facies which characterizes the sedimentary unit deposited in the sub-environment. Facies association and facies sequence are groups of facies that occur together and are considered to be genetically or environmentally related. Therefore, the facies association and facies sequence represents a group of depositional environment or depositional system.

The relationships between different rank sedimentary records and depositional environments are illustrated in Figure 4b.

Sedimentary records	Depositional environment
Facies association/Facies sequence	Depositional system
Lithofacies/Sedimentary facies	Depositional environment
Sub-facies	Sub-environment

Figure 4b. The relationship between sedimentary records and depositional environments (Modified after Selley, 1980).

4.1 Formation and Characteristics of Depositional Krabi Basin

The Krabi depositional basin is believed to be formed by minor northeast-southwest faults movement and erosion towards the close of Mesozoic and probably in Early Tertiary time. As a consequence, a long and narrow graben extending in the northeast-southwest direction was formed and was succeeded by the deposition of sedimentary sequences of Krabi Group in the structural depression of older rocks.

The study area is a part of the graben filled Tertiary sediments of the Krabi Group. The depositional basin under the present investigation is considered to be basin intermontane depression caused by subsidence of the block faulting or graben (Fig. 4.1).

4.2 Lithofacies Analysis

Detailed subsurface geological analysis has allowed the distinction of a number of lithostratigraphic units of sedimentary sequences within Krabi basin as previously described. In the foregoing passage,

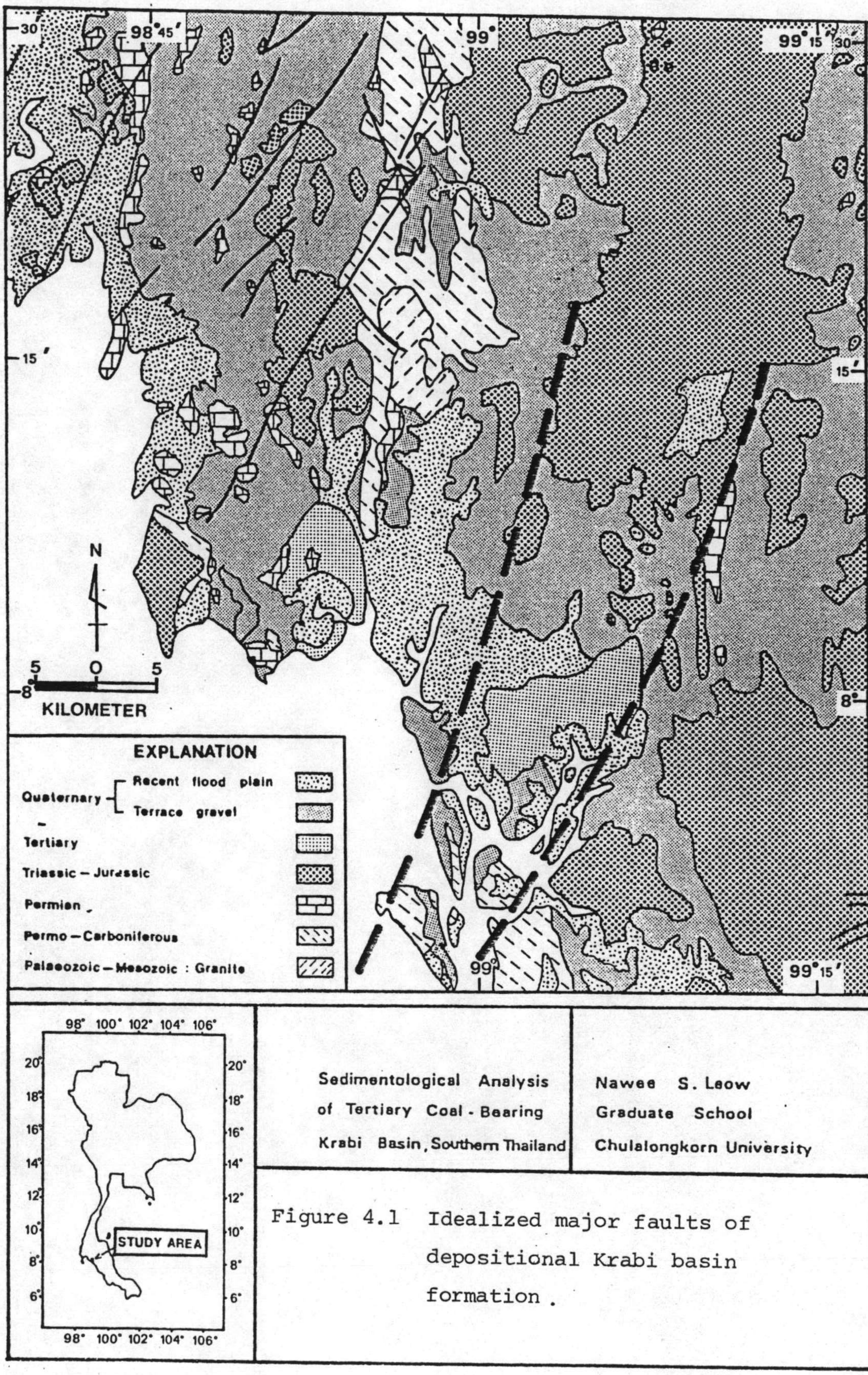


Figure 4.1 Idealized major faults of depositional Krabi basin formation .

differrent lithostratigraphic units earlier defined will be considered in terms of lithofacies for further uses in the reconstruction of depositional environments. The lithofacies in this study is characterized by four parameters, namely, lithology, geometry, sedimentary structure and fossil.

The lowest lithostratigraphic units of sedimentary sequences within Krabi basin is the A Formation which unconformably overlies the pre-Tertiary basement rocks. The subsurface geological data available for this analysis is confined within the uppermost 70 m. thick only. The lithology of A Formation is characterized by a series of fining-upward sequences from sandstone to claystone alternate with sandstone-claystone thinly interbedding. At least five cycles of fining-upward units and sandstone - claystone thinly interbedding have been recognized. The overall geometry of the A formation is tabular covering wide spreadly over the study area. The fining-upward units show the gradual change in grain size from sand to clay with maximum thickness of the whole unit less than 15 m., whereas the thinly interbedded sand-clay units show the flat lamination with overall maximum thickness of the unit of 20 m. It is noted that the change in lithology of both units are either transitional or abrupt. The characteristics of the facies association A are summarized and presented in Figure 4.2 a.

Overlying the A Formation is the B Formation which is mainly characterized by the lithological association of fine-grained clastic sediments, coal and some limestone. The lowest part of the B Formation, B1 Member, is represented by the sand, silt and clay. This lithofacies, which lies on top of the uppermost fine-grained clastics of the facies association A, is approximately less than 10 m. thick showing the fining - upward sequence from sand to clay and eventually passing

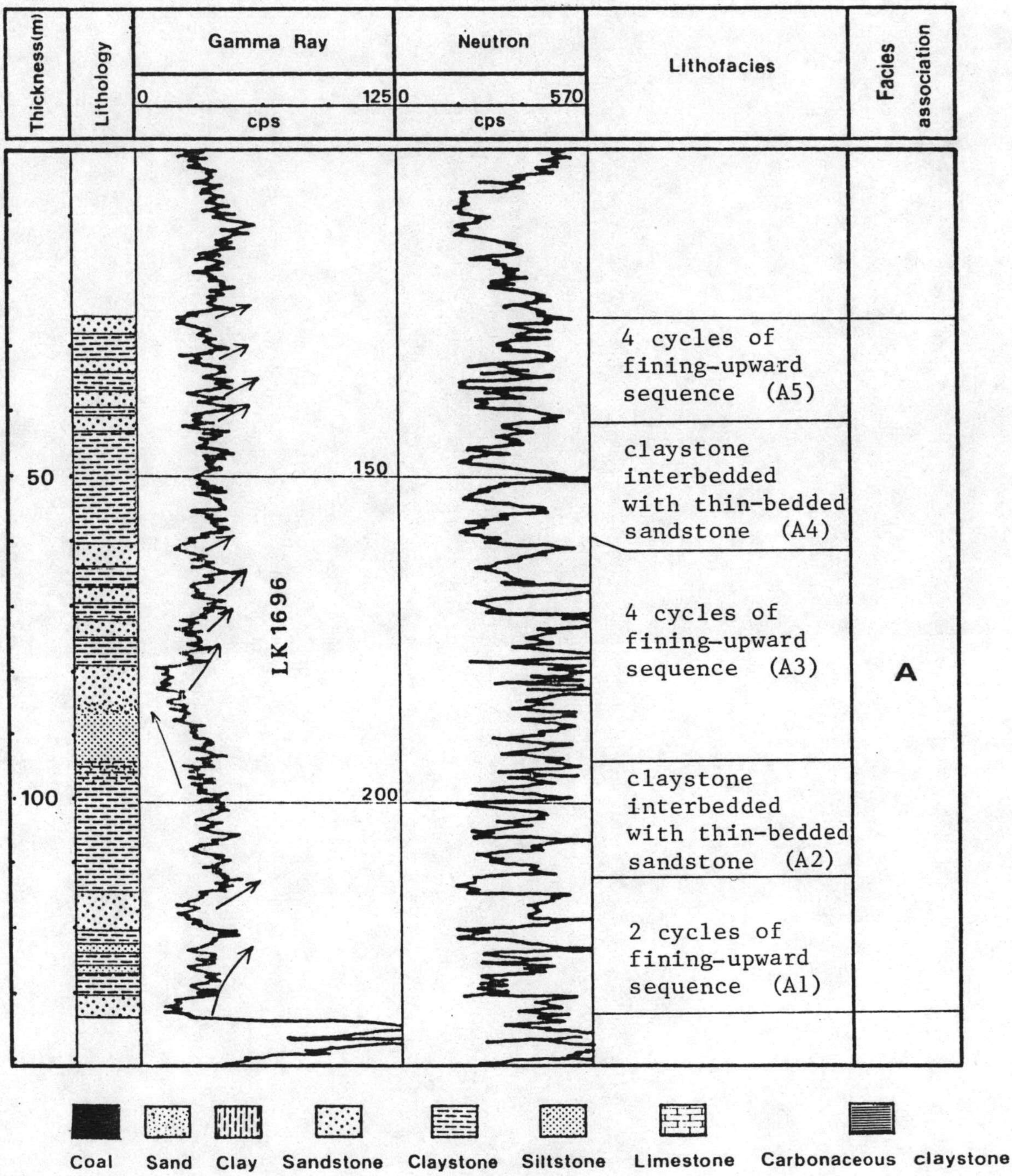


Figure 4.2 a The characteristics of facies association A.

upward into the coal of B2 Member with sharp contact. Therefore the sequence represents the under clay unit and is widely distributed with blanket or tabular geometry. The B2 Member represents the coal seam with clay and sandy clay partings of maximum 60 m. thick. This coal seam is also widely distributed with tabular geometry. It is noted that in the north-central part of the study area this coal seam splits into 2 main seams with the B3 Member of maximum 40 m. thick as a major parting in between. The lithological characteristics of B3 Member is mainly clay in the middle part with coarsening-upward and coarsening-downward. The overall geometry of this lithofacies is lens-shaped. The uppermost lithofacies of the facies association B is the B4 Member characterized by the interbedding of claystone to limestone or sandstone with average thickness of 20 m. The geometry of this lithofacies is tabular. This facies association B represents the major coal deposits of the study area. The characteristics of this facies association are summarized and presented in Figure 4.2 b.

The C Formation, with 60 m. thick, is generally characterized by the association of medium- to fine-grained clastics. The lowest part of the formation, the C1 Member, is characterized mainly by the claystone with abundant gastropods. In the lowest part of the lithofacies, there appears to be more influence of the medium- grained clastics gradually passing upwards into claystone associated with thin sandstone beds. The overall geometry of this lithofacies is tabular. Overlying the C1 Member is the thick succession of a series of fining-upward sequences of approximately 35 m. thick in the lowest part and approximately 30 m. in the uppermost part with 35 m. thick of claystone with abundant gastropods in the middle part. The claystone in the middle part is carbonaceous and contains thin sand interbedding. The

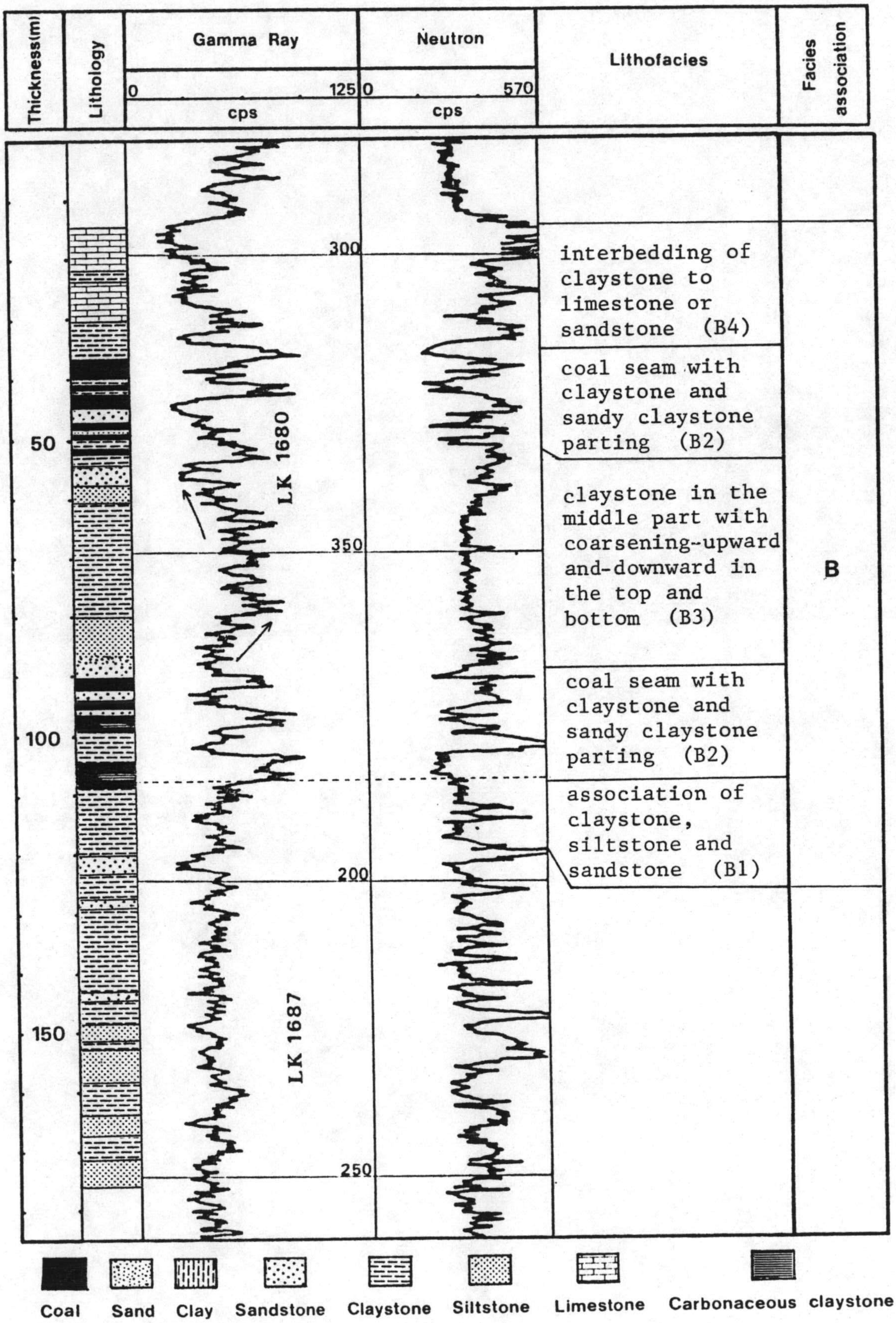


Figure 4.2 b The characteristics of facies association B.

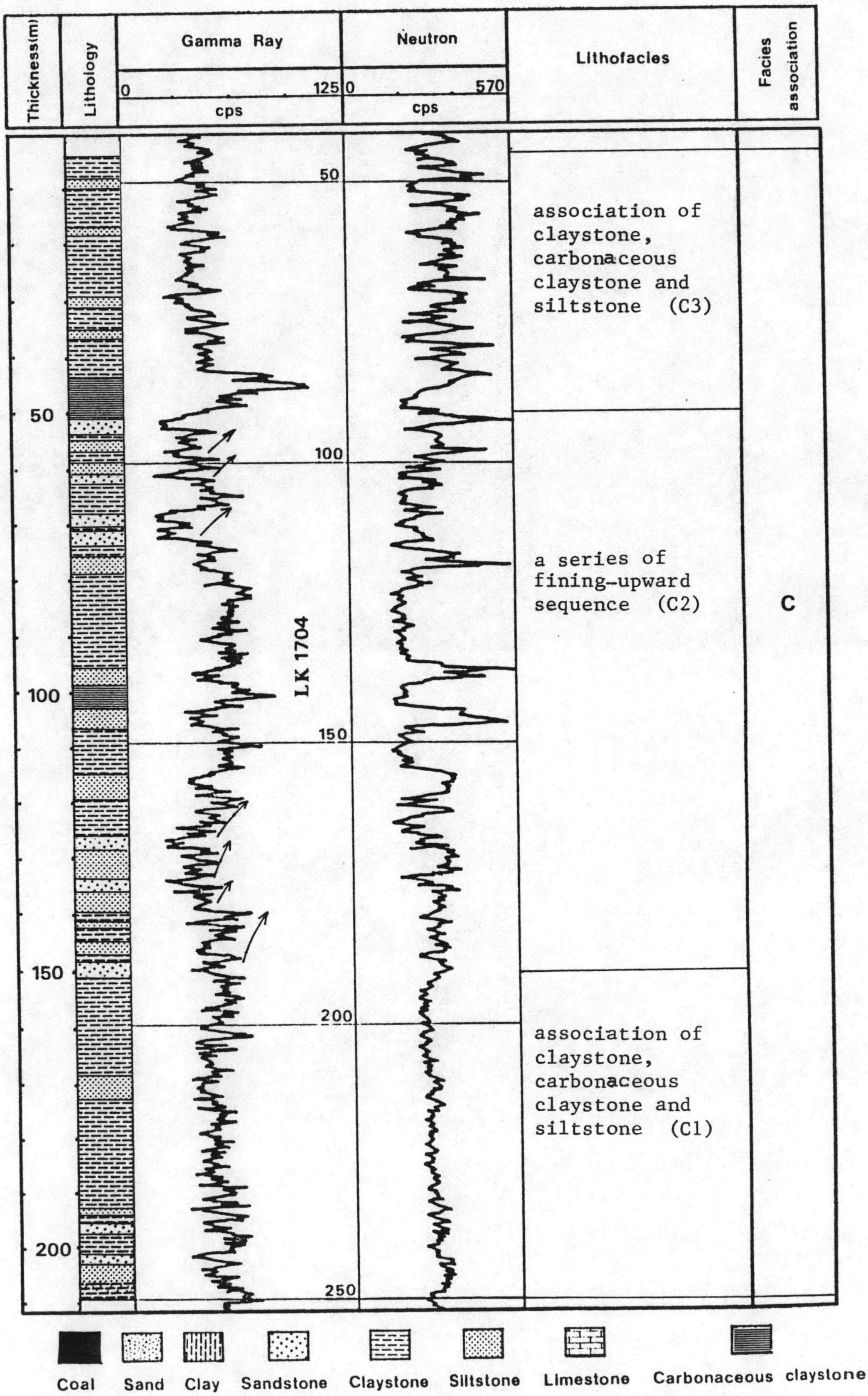


Figure 4.2 c The characteristics of facies association C.

geometry of this lithofacies is tabular. The uppermost member of the C Formation, C3 Member, is characterized by the association of claystone, carbonaceous claystone, and siltstone with abundant gastropods the thickness of this lithofacies is approximately 45 m. and geometry is considered to be tabular. The characteristics of the facies association C is summarized and presented is Figure 4.2 C.

In the northern part of the study area, the D Formation lies unconformably with erosional surface on the C Formation. The lower part of the formation is characterized by a series of fining- upward sequence of approximately 100 m. thick. At least 15 cycles of fining-upward sequence have been recognized. The lithology grades from sandstone to claystone, and the geometry of the whole sequence is considered to be prism. Overlying the thick fining-upward sequence is mainly claystone with rare gastropods of totally 35 m. thick. The geometry of the upper of a lithofacies is the lens-shaped. The characteristics of the facies association D is summarized in Figure 4.2 d.

The D Formation in the northern part of the study area shows the lateral facies change into the E Formation in the southern part of the study area. It is also noted that the E Formation lies conformably on the C Formation.

The lithofacies of the E Formation is generally characterized by alternating sequence of sandstone, siltstone, and claystone of totally 120 m. thick. The lower part of the formation, E1 Member, of approximately 60-100 m. thick is characterized by the alternating sequence of sand and clay arranged themself in 3 cycles of coarsening-upward characters. Each coarsening-upward sequence is approximately 20-30 m. thick. The overall geometry of this facies association is tabular with a tendency to be slightly thickening southwardly. The

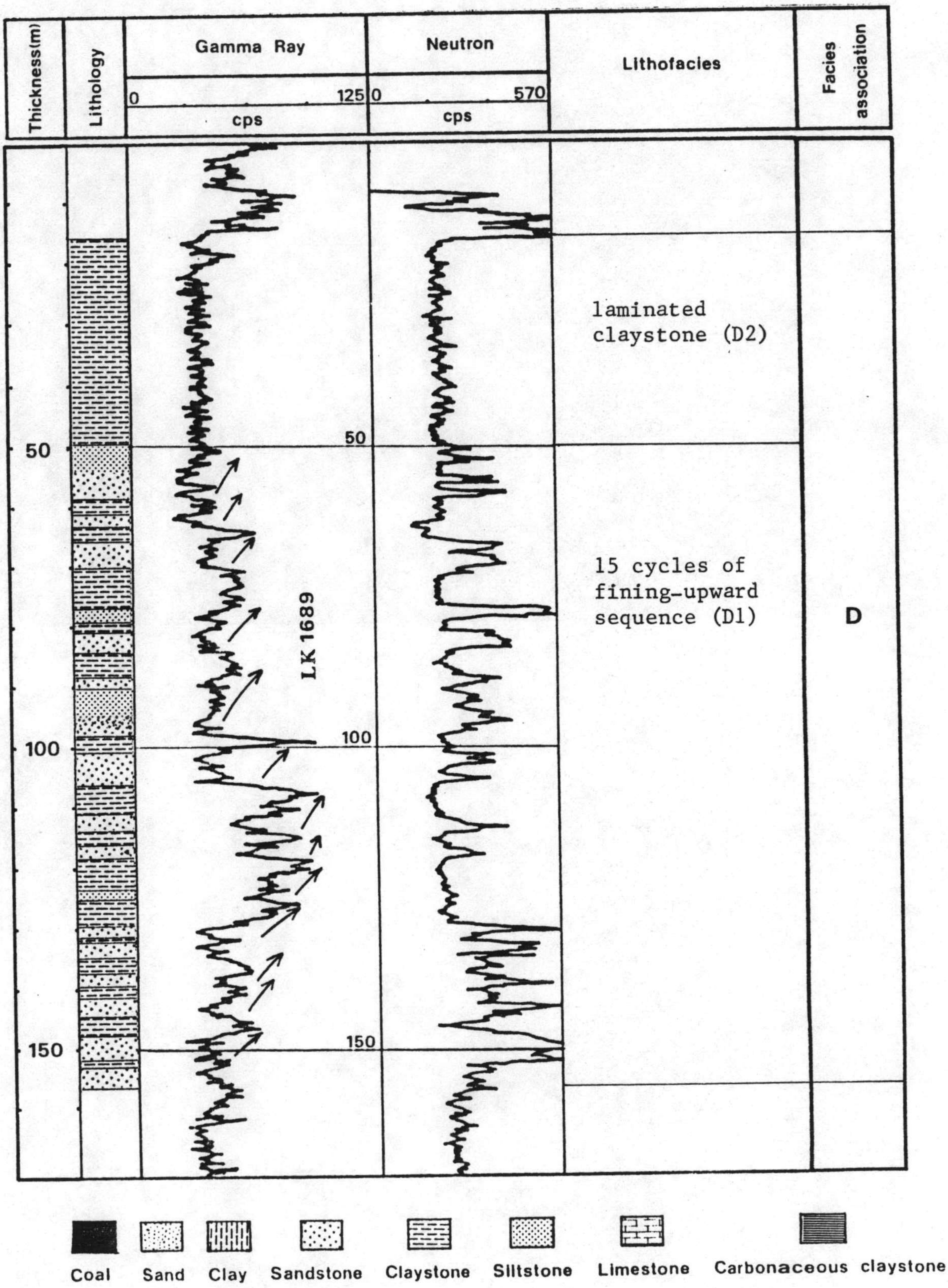


Figure 4.2 d The characteristics of facies association D.

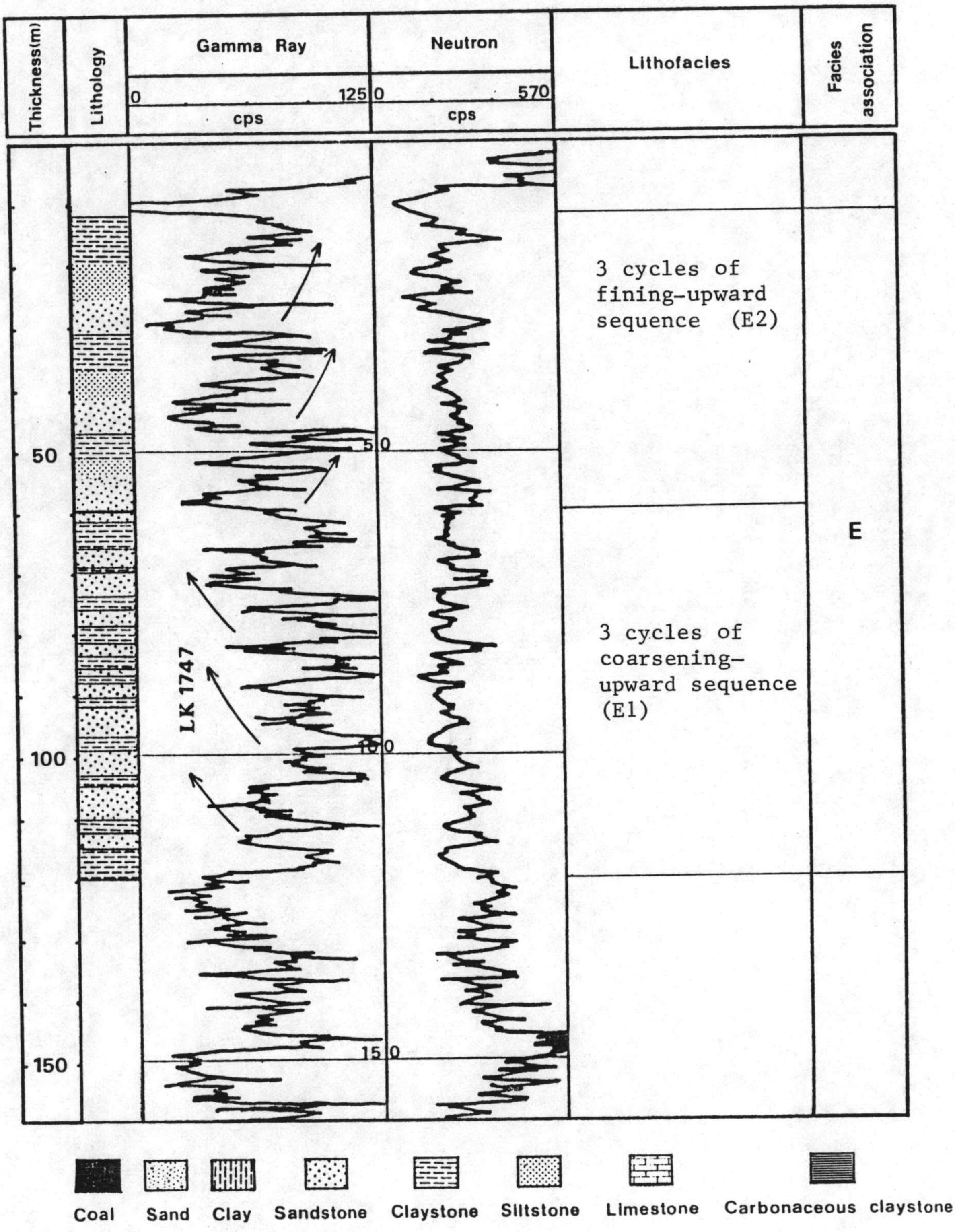


Figure 4.2 e The characteristics of facies association E.

upper part of the formation E2 Member, is clearly characterized by 3 cycles of fining-upward sequence of sand, silt, and clay. Each cycle or lithofacies is approximately 15-20 m. thick. The geometry of this facies association is wedge-shaped thickening southwardly. The Characteristics of lithofacies of the E Formation is summarized and presented in Figure 4.2 e.

The uppermost sedimentary sequence of Krabi basin is the undifferentiated Quaternary deposits with overall thickness ranged from 2-10 m. in the north to 20-50 m. in the south. The deposit is characterized by unconsolidated, reddish-brown clay, lateritic clay, sand, and gravel. At least 4 cycles of fining-upward sequence of gravel, sand, and clay have been recognized in these deposits. Each fining-upward sequence is approximately 15 m. thick. The geometry of the Quaternary deposits is blanket with a tendency to be thickening southwardly. The characteristics of this lithofacies of the Quaternary deposits is summarized and presented in Figure 4.2 f.

4.3 Proposed Depositional Model

In order to interprete the depositional environments of various lithofacies of the sedimentary sequences within Krabi basin, characteristics of each lithofacies, notably, lithology, geometry, sedimentary structure, and fossil have been prepared and summarized. These characteristics are used to compare and contrast with the theoretical facies models (Appendix E).

After that, all possible depositional environments are drawn from the analogous study of lithofacies concerned with the theoretical facies models. Final reconstruction of depositional environment is

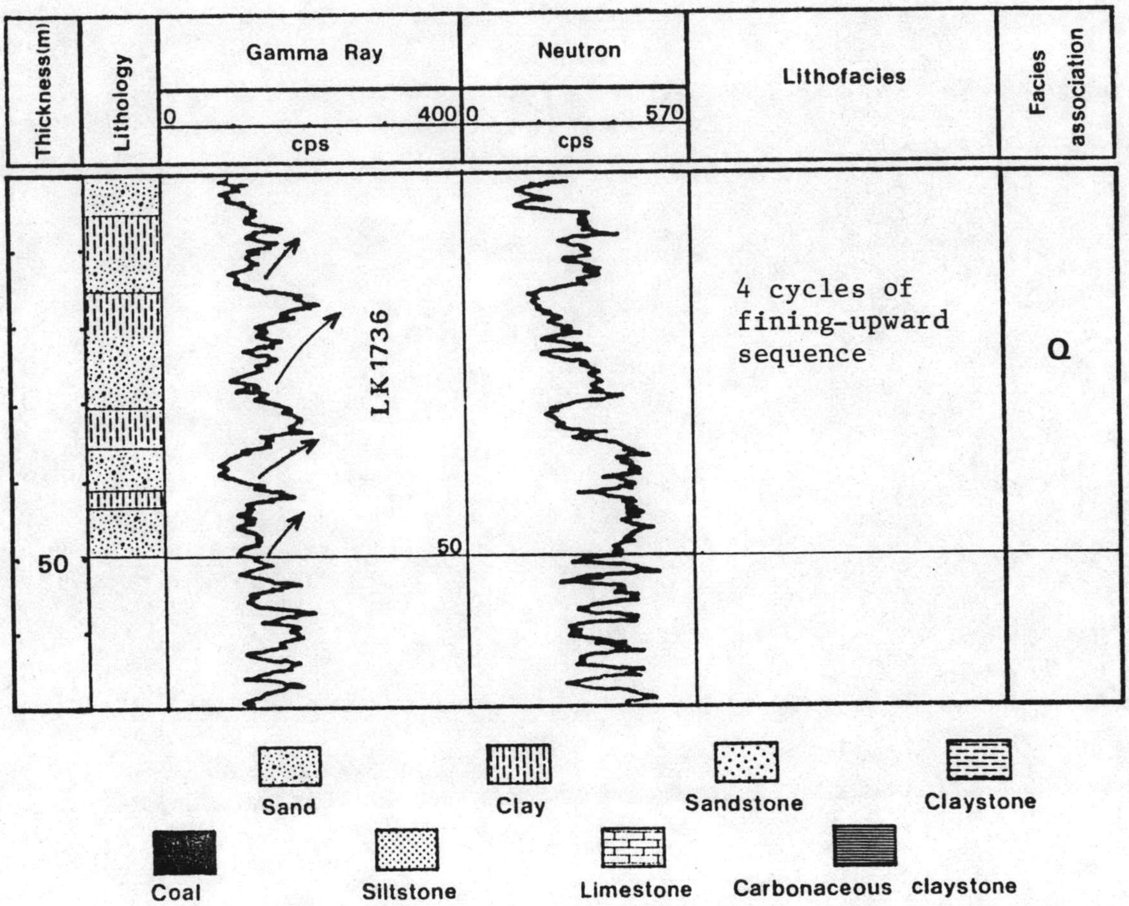


Figure 4.2 f The characteristics of Quaternary deposits.

concluded from the detailed analysis of all possible depositional environments into the most possible one. Procedures on this aspect are summarized in Table 4.3.

4.3.1 Depositional Environment of Facies Association A

The sedimentation of Tertiary sediments in Krabi basin under the present investigation began with the fluviatile environment which resulted in the deposition of fluvial lithofacies A1. The lithofacies A1, as compared with the studies by Sundborg (1956), Leopold et al (1964). Allen (1965), Collinson (1978), Miall (1978), and Selley (1980), shows at least two cycles of typical fining-upward fluviatile sediments of meandering stream. After the deposition of lithofacies A1, the environment is believed to be drastically changed from a fluviatile to lacustrine due to rapid subsidence. This rapid subsidence was presumably the result of the block-faulting of the depositional basin. As compared with the studies by Kukal (1971), Picard and High (1972), and Reading (1978), the lithofacies of lacustrine sediments -lithofacies A2- is characterized by the interbedding of clay and sand of approximately 15-20 m. thick. The uppermost part of the lithofacies A2 indicated that there is more influence of the silt influx. It is therefore concluded that the lacustrine environment had been gradually silting up towards the top of the lithofacies. After the silting up of the paleolake, sedimentation under fluviatile environment of presumably meandering river type had continued. At least four cycles of fining-upward sequence of silting up of paleolake. The lithofacies A3, therefore, embraces the silting up sequence and four fining-upward sequences. The total thickness of lithofacies A3 is approximately 35 m. Towards the end of sedimentation of lithofacies A3, the depositional environment had once again undergone rapid subsidence and became a

Table 4.3.1 Summarized interpretation of depositional environments of Krabi basin.

Facies assoc.	Litho-facies	Lithology: Color	Lithology: Lithological characters	Geometry: Geometry	Geometry: Thick. (m)	Geometry: Distribution	Sediment. structures	Fossils	Diagnostic characters	Possible depositional envi.: 1	Possible depositional envi.: 2	Possible depositional envi.: 3
Q		reddish-brown to grey	clay to sand rare conglomerate	blanket	10-15	over the basin	fining-upward sequences	-	associated with present environment +	meandering stream ★	braided stream	distributary channel on delta plain
E	E2	reddish-brown to grey	sandstone to claystone +	lens	10-20	only in southern part	fining-upward sequences	-	signature of geophysical log +	meandering stream	braided stream	distributary channel on delta plain ★
E	E1	reddish-brown to grey	claystone to sandstone and limestone	tabular	60-100	only in southern part	coarsening-upward sequences +	-	associated with upper unit +	delta front ★	lacustrine	tidal flat
D	D2	reddish-brown	claystone	Prism	> 35 +	only in northern part	laminated	rare gastropods	intermontain deposits and absent marine fossils +	lacustrine ★	tidal flat	-
D	D1	reddish-brown	claystone to sandstone and rare conglomerate	tabular	10-15	only in northern part	fining-upward sequences +	-	no diagnosis of delta in this area +	meandering stream ★	braided stream ★	distributary channel on delta plain
C	C3	grey	claystone	tabular	> 40 +	over the basin	laminated	abundant gastropods	absent marine fossils +	lacustrine ★	tidal flat	flood plain
C	C2	grey	claystone to sandstone	tabular	> 80 +	over the basin	laminated and some fining-upward sequences +	abundant gastropods	absent marine fossils +	fluvio-lacustrine ★	tidal flat	flood plain
C	C1	grey	claystone	tabular	> 55 +	over the basin	laminated	abundant gastropods	absent marine fossils +	lacustrine ★	tidal flat	flood plain
B	B4	greenish-grey to grey	claystone to sandstone and limestone +	tabular	> 20	absent in the central part	laminated	rare gastropods	absent marine fossils +	lacustrine ★	tidal flat	flood plain
B	B3	greenish-grey	claystone	lens +	30-40	only in the central part	laminated	rare gastropods	absent marine fossils +	lacustrine ★	tidal flat	flood plain
B	B2	black to dark grey	coal and claystone partings +	tabular	20-60	over the basin	coal interbedded with claystone	rare gastropods	absent marine fossils +	lacustrine coal swamp ★	tidal flat	flood plain
B	B1	grey to greenish-grey	claystone	blanket or tabular +	< 10	absent in the southern part	laminated, tendency to be fining-upward sequences +	-	absent marine fossils and +	lacustrine ★	tidal flat	flood plain
A	A5	grey to reddish-brown +	claystone to sandstone	tabular	< 10	over the basin	fining-upward sequences	-	sand/clay 1:1, no delta association +	meandering stream ★	braided stream	distributary channel on delta plain
A	A4	grey to reddish-brown	claystone	tabular	> 15 +	over the basin	laminated	-	absent marine fossils +	lacustrine ★	tidal flat	flood plain
A	A3	grey to reddish-brown +	claystone to sandstone	tabular	< 10	over the basin	fining-upward sequences	-	sand/clay 1:1 + no delta association	meandering stream ★	braided stream	distributary channel on delta plain
A	A2	grey to reddish-brown	claystone	tabular	> 15 +	over the basin	laminated	-	absent marine fossils +	lacustrine ★	tidal flat	flood plain
A	A1	grey to reddish-brown +	claystone to sandstone	tabular	< 10	over the basin	fining-upward sequences	-	sand/clay 1:1 + no delta association	meandering stream ★	braided stream	distributary channel on delta plain

+ Dominant ★ High confidence

Example; for the lithofacies D2 interpretation;

In lithofacies D2, the parameters, such as, lithology, geometry, sedimentary structure, and fossil, can suggest some possible depositional environments, including, lacustrine and tidal flat. The dominant parameters, such as, thickness of more than 35 m., absence of marine fossils, and intermontain-deposition indicate that the depositional environment of the lithofacies D2 is most likely to be lacustrine.

lake. This lacustrine environment, as compared with the studies by Reading (1978) and Selley (1980), is represented by the lithofacies A4 which is characterized by interbedding of sand and clay totally 15 m. thick. This paleolake was subject to silting up processes towards the end of deposition of lithofacies A4 and the depositional environment was gradually changing from lacustrine to fluviatile. The lithofacies A5 of at least four cycles of fining-upward sequence, as compared with the studies by Sundborg (1956), Leopold (1964), Allen (1965), Miall (1978), and Selley (1980), indicating sedimentation under the fluviatile environment of presumably meandering river types. The thickness of the lithofacies A5 is approximately 20 m.

Therefore, the sedimentary sequence of A Formation is analyzed in terms of lithofacies association of A1 to A5 representing the fluvio-lacustrine environments. The facies association A and environmental interpretation are summarized and presented in Figure 4.3.1.

4.3.2 Depositional Environment of Facies Association B

After the fluviatile sedimentation of lithofacies A5, as compared with the studies by Kukal (1971), Picard and High (1972), and Reading (1978), the area of Krabi basin was subsided and the depositional environment had changed to lacustrine environment. The lithofacies B1 which is the lower part of the B Formation suggests that they were deposited in lacustrine environment in lower part and the silting up the paleolake in the upper part. The overall thickness of this lithofacies is slightly greater than 10 m. and the geometry of this lithofacies is tabular. The sedimentary structure is mainly lamination of claystone, siltstone, and some sandstone.

As compared with the studies by Francis (1961) and Selley (1980), sedimentation in the area had continued after the silting up of

Thickness (m)	Lithologic column	Lithology	Geometry	Sedimentary structures	Fossils	Lithofacies	Facies association	Environmental interpretation		Major controlling factor: Subsidence – Loading	Faulting	Compaction	Silting up
		Grey to reddish-brown claystone, siltstone and sandstone	tabular	fining-upward sequence	-	A5	A	Fluvial	Fluvio - lacustrine				
50		Grey to reddish-brown claystone and sandstone	tabular	interbedding of claystone and sandstone	-	A4		Lacustrine					
		Grey to reddish-brown claystone, siltstone and sandstone	tabular	fining-upward sequence	-	A3		Fluvial					
100		Grey to reddish-brown claystone, siltstone and sandstone	tabular	claystone interbedded with sandstone and siltstone	-	A2		Lacustrine					
		Grey to reddish-brown claystone, siltstone and sandstone	tabular	fining-upward sequence	-	A1		Fluvial					

Figure 4.3.1 Summarized the depositional environment of facies association A.

paleolake in the intermittent subsiding coal swamp with some interruption of lacustrine sedimentation. This is characterized by a series of coal seam cycle with claystone and sandstone partings of varying thickness. The total thickness of lithofacies B2 is approximately 35 m. and the overall geometry of the lithofacies B2 is tabular.

After the coal swamp sedimentation in the uppermost part of lithofacies B2, the area had undergone gradual subsidence and the depositional environment, as compared with the studies by Kukal (1971), Reading (1978), Selley (1980), and Davis (1983), had accordingly changed from coal swamp to marginal lake sub-environment and eventually central lake sub-environment, respectively. This is indicated by the fining-upward sequence in lower part followed by laminated claystone interbedded with siltstone and sandstone in the middle part of the lithofacies B3. It is significant to note that the lacustrine sedimentation of lithofacies B3 partly occured in the central part of the basin and therefore partially interrupted the coal swamp deposition of lithofacies B2. The lacustrine sedimentation of lithofacies B3 did not effect the areas in the most northern, western, and southern parts,whereas the sedimentary sequence of lithofacies B2 in the central and eastern parts was interrupted by lithofacies B3. The geometry of lithofacies B3 is lens-shaped in between tabular geometry of lithofacies B2 where the lithofacies B2 overlies the lithofacies B3. The uppermost part of lithofacies B3 shows evidence of silting up the paleolake which is characterized by the coarsening-upward nature.

Finally, the uppermost part of the B Formation or lithofacies B4, as compared with the studied by Picard and High(1972), Reading (1978), and Davis (1983), shows typical lacustrine sediments of limestone interbedded with claystone and sandstone. Therefore the

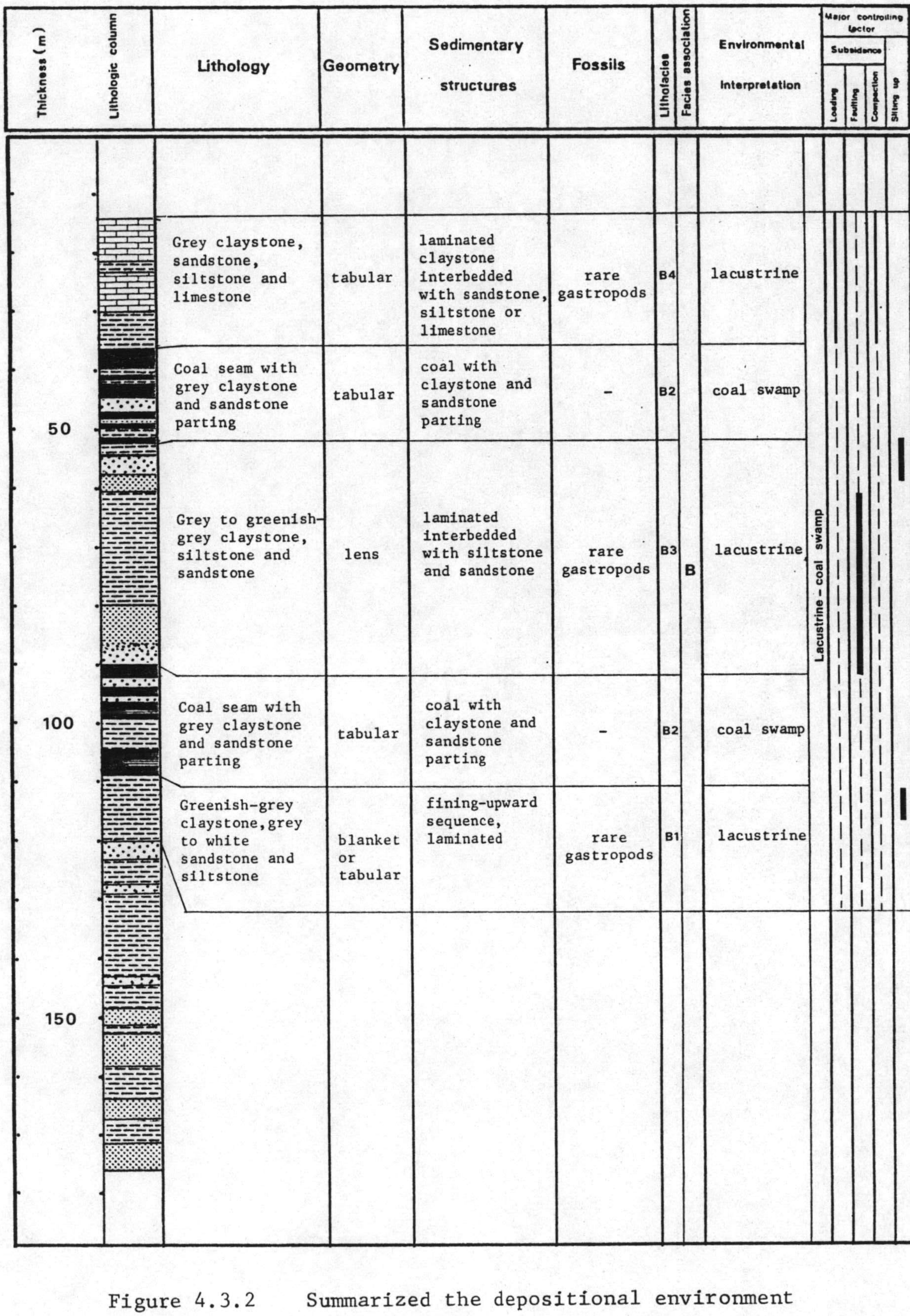


Figure 4.3.2 Summarized the depositional environment of facies association B.

depositional environment of lithofacies B2 in the coal swamp had progressively changed into lacustrine environment of lithofacies B4. This change is believed to be caused by gentle subsidence due to faulting. The thickness of lithofacies B4 is approximately 20 m. with overall tabular geometry.

The characteristics of facies association B and their environmental interpretation are summarized and presented in Figure 4.3.2.

4.3.3 Depositional Environment of Facies Association C

The lacustrine sedimentation of the lithofacies B4 was followed by the silting up of the paleolake which marks the lower part of lithofacies C1. The sequence of silting-up succession of approximately 15 m. thick was again followed by an extraordinary thick sequence of lacustrine sediments represented by laminated claystone and siltstone with sandstone in some parts. This long period of paleolake sedimentation is believed to be caused by the reactivation of the block-faulting coupled with compaction of the underlying sediments. Therefore, the approximately 40 m. thick of lacustrine sediments were deposited with penecontemporeneous subsidence. Besides, the abundance fresh-water gastropods also suggests the fresh-water lacustrine environment. In conclusion, the lithofacies C1, as compared with the studies by Picard and High (1972) and Reading (1978), represents the lacustrine sedimentation.

After the deposition of lithofacies C1, the paleolake was silting up followed by the fluviatile sedimentation of approximately 35 m. thick of the lower part of lithofacies C2. A series of fining-upward sequences indicate typical fluviatile sedimentation. Towards the end of the lower part of lithofacies C2, the depositional environment had changed from fluviatile to lacustrine environment caused by

Thickness (m)	Lithologic column	Lithology	Geometry	Sedimentary structures	Fossils	Lithofacies	Facies association	Environmental interpretation		Major controlling factor: Subsidence: Loading	Faulting	Compaction	Silting up
		Grey claystone, siltstone, sandstone and carbonaceous claystone	tabular	laminated claystone with influence of sandstone and siltstone	abundant gastropods	C3	C	lacustrine	Fluvio - lacustrine				
50		Grey claystone, siltstone and sandstone	tabular	laminated claystone with fining-upward sequence in lower and/or upper parts of the member	abundant gastropods	C2		lacustrine fluvial					
100													
150		Grey claystone, sandstone and siltstone	tabular	laminated claystone with more influence of sandstone and siltstone	abundant gastropods	C1		lacustrine					
200													

Figure 4.3.3 Summarized the depositional environment of facies association C.

subsidence. The 35 m. thick sequence of lacustrine sediments with abundant gastropods in the middle part of lithofacies C2 shows some evidences of the interruption of lacustrine sedimentation by the silting up sequence of approximately 10 m. thick. The upper part of the lithofacies C2 suggests that the sequences were deposited under the silting up of paleolake with some influence of fluviatile sedimentation. This uppermost sequence of lithofacies C2 is approximately 30 m. thick. In conclusion, the depositional environment of lithofacies C2, as compared with the studies by Kukal (1971), Picard and High (1972), Reading (1978), and Selley (1980), is interpreted to be fluvio-lacustrine ranging from fluviatile environment in the lower part and gradually passing upward to lacustrine environment and eventually terminated by silting up the active lake margin with clastic influx in the uppermost part.

The sedimentary sequence of the lithofacies C3, as compared with the study by Francis (1961), was deposited in the coal swamp environment followed by the lacustrine sedimentation caused by slow subsidence of the depositional basin with periodic influx of silt. The slow subsident rate is believed to be caused by the compaction of thick underlying sedimentary sequence. The 40 m. thick sequence of the claystone and siltstone with abundant gastropods strongly indicate the deposition in the slightly subsiding lacustrine environment.

The characteristics of facies association C and their environmental interpretation are summarized and presented in Figure 4.3.3.

4.3.4 Depositional Environment of Facies Association D

After the deposition of lacustrine sediments of the lithofacies C3, the northern part of Krabi basin had been abruptly uplifted, whereas the southern part of the basin was gently subsided. This is believed to

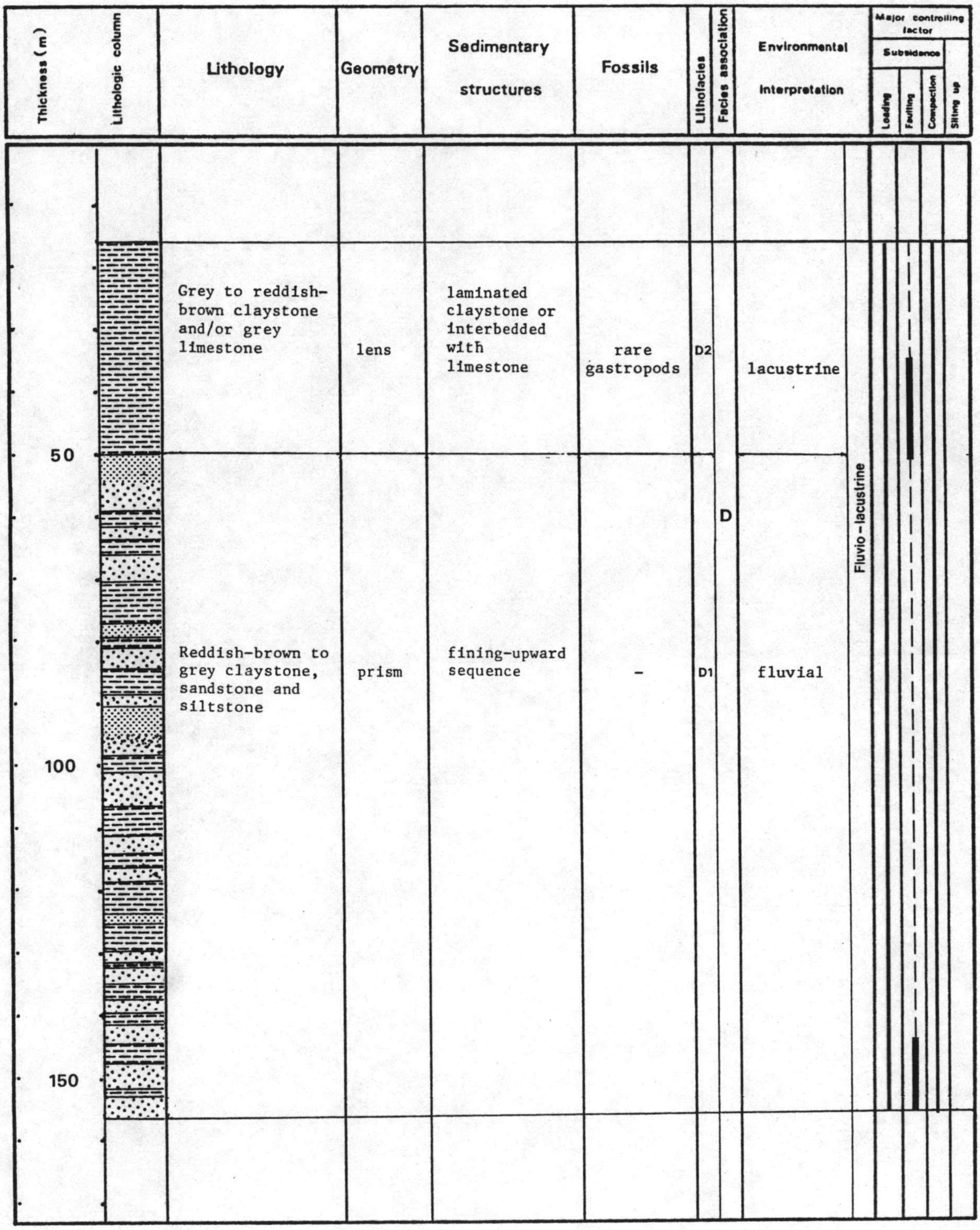


Figure 4.3.4 Summarized the depositional environment of facies association D.

be controlled by a series of northeast-southwest faulting in Late Tertiary. The sedimentary sequence of the lower part of facies association D -lithofacies D1- in the northern part of the basin is characterized by a series of fining-upward sequence of totally 100 m. thick. As compared with the studies by Walker (1976), Reading (1978), Selley (1980), and Davis (1983), this strongly suggests that the sediments were deposited under fluviatile environment in gentle subsiding basin or the fills of basin flanking by uplifted area.

The upper part of the facies association D -lithofacies D2- is characterized by laminated claystone, with rare gastropods, of approximately 35 m. thick. As compared with the studies by Kukal (1971), Picard and High (1972), and Davis (1983), this suggests that some parts of the depositional basin of fluviatile environment had been rapidly subsided and the depositional environment had accordingly changed into lacustrine. It is noted that the lacustrine sediments of lithofacies D2 is only confined within some block-faulted areas. Therefore, it is concluded that the lacustrine sedimentation occurred in the small graben of the alluvial plain. In conclusion, the facies association D indicates the fluvio-lacustrine environment.

The characteristics of facies association D and their environmental interpretation are summarized and presented in Figure 4.3.4.

4.3.5 Depositional Environment of Facies Association E

Farther south, the facies association D laterally changes into the facies association E of different characteristics.

The lower part of facies association E -lithofacies E1- is characterized by at least 3 cycles of coarsening-upward sequence of sandstone, siltstone, and claystone of totally 60-100 m. thick. This

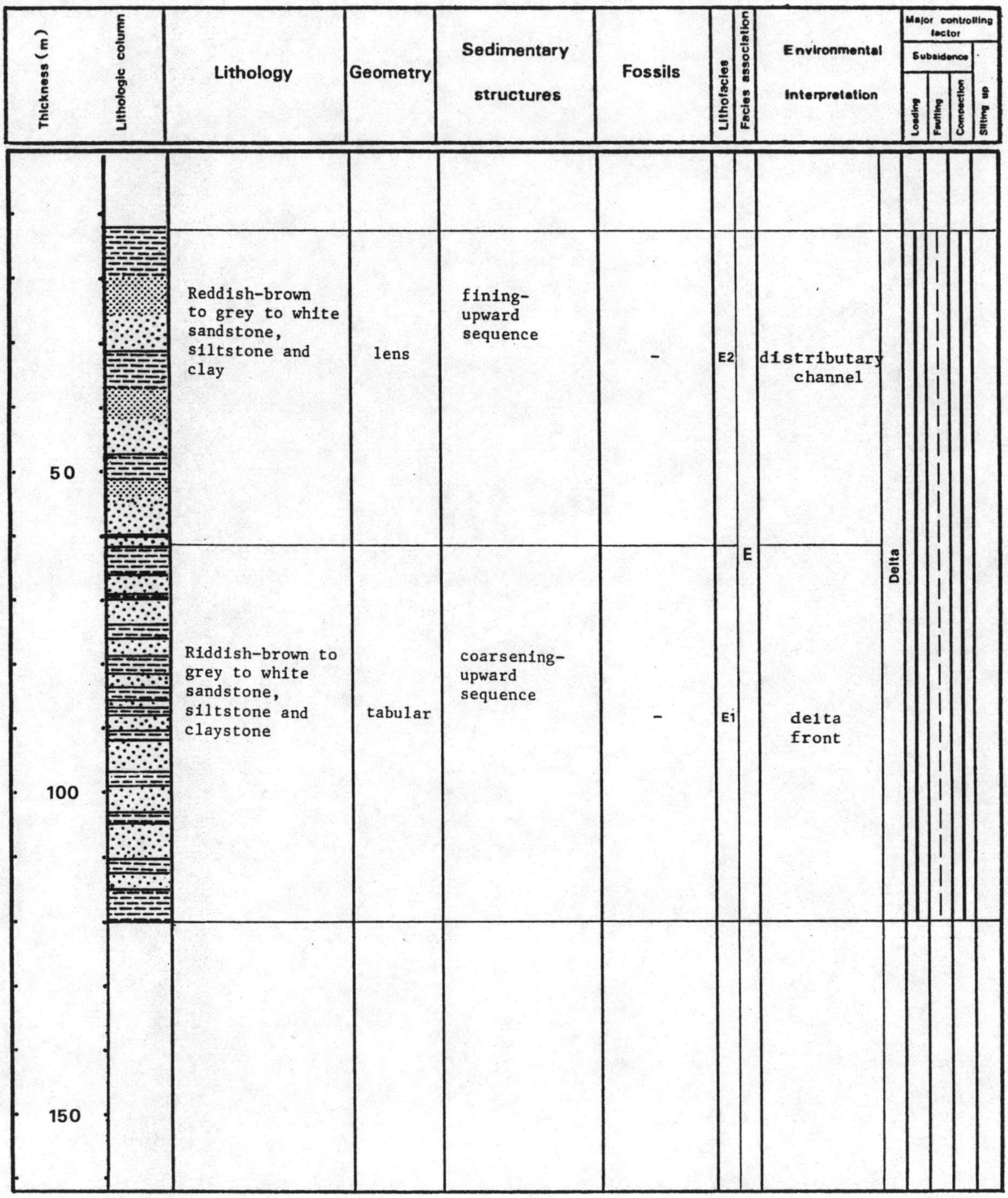


Figure 4.3.5 Summarized the depositional environment of facies association E.

lithofacies indicated the sedimentation in the delta front sub-facies of the deltaic environment, as compared with the studies by Fisher (1969), Walker (1976), Reading (1978), Selley (1980), and Davis (1983). Therefore, the fluviatile sediments of the lithofacies D1 in the north had laterally passed southwardly into the deltaic sediments of the lithofacies E1.

Overlying the lithofacies E1 is the lithofacies E2 of totally 50 m. thick. This lithofacies is characterized by at least 3 cycles of fining-upward sequence of sandstone, siltstone, and claystone. The lithofacies E2 is considered to represent the fluviatile sedimentation of the distributary channels on the upper deltaic plain, as compared with the studies by Fisher (1969), Walker (1976), Reading (1978), Selley (1980), and Davis (1983). The facies association E, therefore, suggests that the sediments were deposited in the upper part of the prograding deltaic sequence towards the southern direction.

The characteristics of facies association E and their environmental interpretation are summarized and presented in Figure 4.3.5.

4.3.6 Depositional Environment of the Quaternary Deposits

The Tertiary sediments of Krabi basin is overlain by a thin veneer of Quaternary deposits of approximately less than 50 m. thick. The lithofacies sequence is characterized by a series of fining-upward sequence with gravel, sand, silt and clay. As compared with the studies by Sundborg (1956), Leopold (1964), Allen (1965), Collinson (1978), Miall (1978), and Selley (1980), these sediments strongly suggest that they been deposited under the fluviatile environment of presently known Khlong Pakasai, Khlong Phela, and their tributaries. At least 4 cycles of fining-upward sequence have been recognized. The fluviatile deposits in the uppermost sedimentary succession of Krabi basin also confirm that the whole sequence represents the prograding shoreline in the gentle subsiding near shore basin.

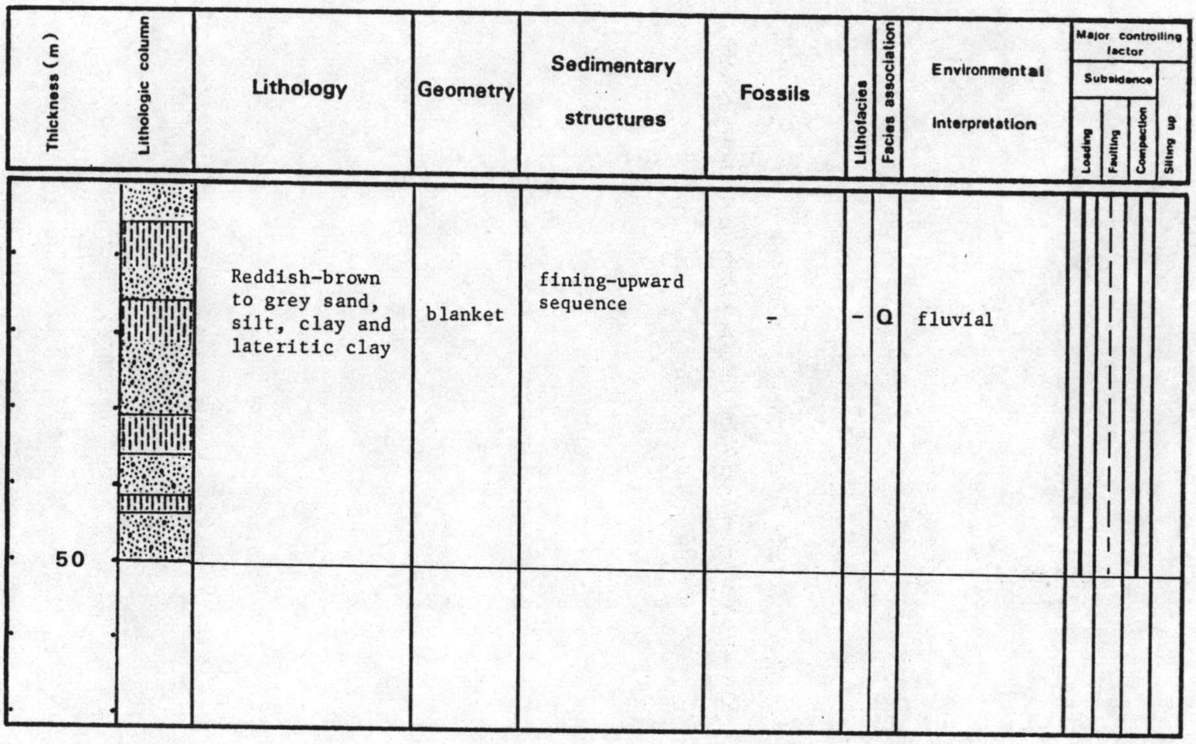


Figure 4.3.6 a Summarized the depositional environment of Quaternary deposits.

The depositional history of the Quaternary sedimentary sucession have been summarized and presented as model in Figure 4.3.6 a.

In conclusion, the coal-bearing Tertiary sedimentary sequences of Krabi basin mainly characterized by association of conglomerate, sandstone, siltstone, claystone/shale and coal are believed to be deposited in the fluvio-lacustrine and swamp environments in the lower part with fluvio-lacustrine, swamp, and deltaic environments in the upper part. The deposition of coal is interpreted to be the coal swamp associated with fresh-water lacustrine environments. It is also significant to note that subsidence was caused by tectonic movement or compaction or the combination of these two factors during the time of deposition as well as after deposition. In Late Tertiary, some parts of the depositional basin particularly the southern margin were partially inundated by marine transgression as indicated by deltaic sediments. The depositional history of Krabi basin has been active throughout the Quaternary Period when fluviatile sediments have been deposited as thin veneer covering the study area with varying thickness. The depositional models of Krabi basin are summarized in Figures 4.3.6 b and c.

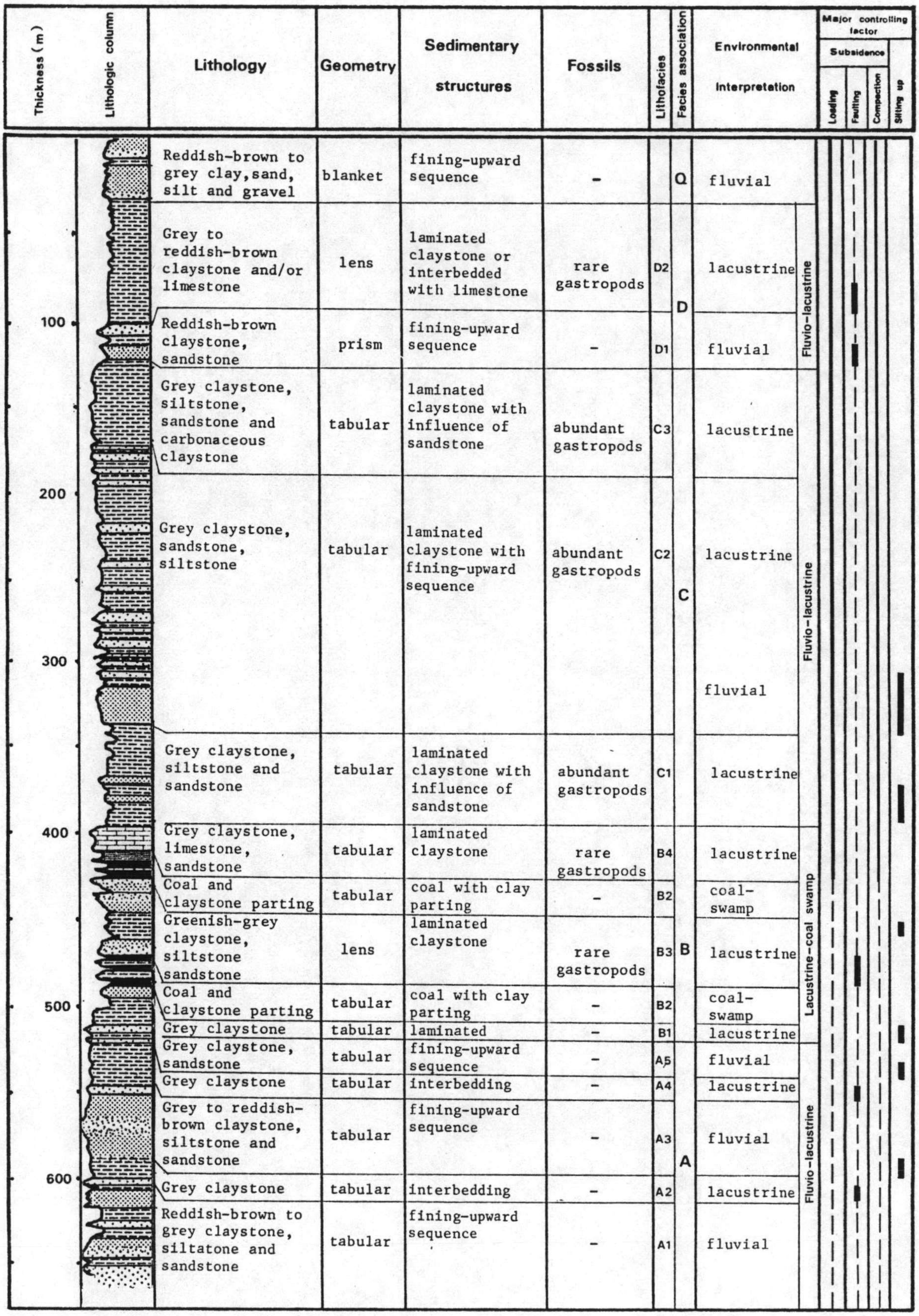
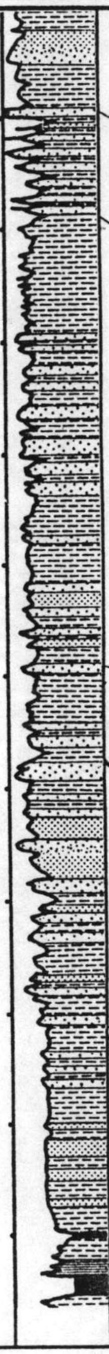


Figure 4.3.6 b Summarized the depositional environment of the Krabi sequence in the northern part of Krabi basin.



Thickness (m)	Lithology	Geometry	Sedimentary structures	Fossils	Lithofacies	Facies association	Environmental interpretation	
	Grey to reddish-brown clay, silt, sand, gravel and lateritic clay	blanket	fining-upward sequence	-		Q	fluvial	
100	Reddish-brown to grey sandstone, siltstone and claystone	lens	fining-upward sequence	-	E2	E	distributary channel	Delta
200	Reddish-brown to grey claystone, white sandstone, siltstone and limestone	tabular	coarsening-upward sequence	-	E1	E	delta front	Delta
300	Grey to greenish-grey claystone, siltstone and sandstone	tabular	laminated claystone with influence of siltstone	abundant gastropods	C3	C	lacustrine	Fluvio-lacustrine
400	Grey claystone, sandstone and siltstone	tabular	laminated claystone with fining-upward sequence in the lower part	abundant gastropods	C2	C	lacustrine fluvial	Fluvio-lacustrine
500	Grey claystone, sandstone and siltstone	tabular	laminated claystone with influence of sandstone and siltstone	abundant gastropods	C1	C	lacustrine	Fluvio-lacustrine
	Grey to greenish-grey claystone, sandstone, siltstone and limestone	tabular	laminated claystone interbedded with sandstone or limestone	rare gastropods	B4	B	lacustrine	Lacustrine-coal swamp
	Coal, grey claystone and sandstone	tabular	coal with clay and sand parting	-	B2	B	coal swamp	Lacustrine-coal swamp

Major controlling factor: Subsidence (Loading, Faulting, Compaction); Silting up

Figure 4.3.6 c Summarized the depositional environment of the Krabi sequence in the southern part of Krabi basin.