CHAPTER III

SUBSURFACE GEOLOGY OF THE HUA HIN BASIN

The knowledge on the subsurface geology of the Hua Hin basin is basically obtained from geological data and geophysical logs of the Phetchaburi-1 well and ground seismic reflection survey of approximately 1,000 line-kilometres (Fig 3 a). The geological data are essentially composed of lithological logs, cutting and sidewall core descriptions. The geophysical logs include 4 parameters, namely, caliper, gamma ray, spontaneous potential and resistivity.

Information obtained from seismic reflection survey reveals that the maximum depth of the Hua Hin basin, from the sea floor to the present pre-Tertiary basement, is over 5,000 metres. The stratigraphic framework of Hua Hin basin can be initially subdivided into 3 depositional sequences on the basis of sequence boundaries and seismic patterns which observed on seismic reflection sections or the seismic stratigraphy. The three boundaries of these sequences are the important markers which are used to correlate the depositional sequences thorough the Hua Hin basin and the Upper Gulf of Thailand (Figs. 3 b & 3 c). The pre-Tertiary basement reflector is the lowest marker indicating the lowest boundary of these Cenozoic sequences with the onlapping character of reflections to acoustic basement. This marker is defined as the angular unconformity. The pre-Tertiary basinal basement rocks are believed to be the Permain limestone, clastic sediments of Permo-Carboniferous and undifferentiated Mesozoic clastic sediments. The middle and upper markers are within

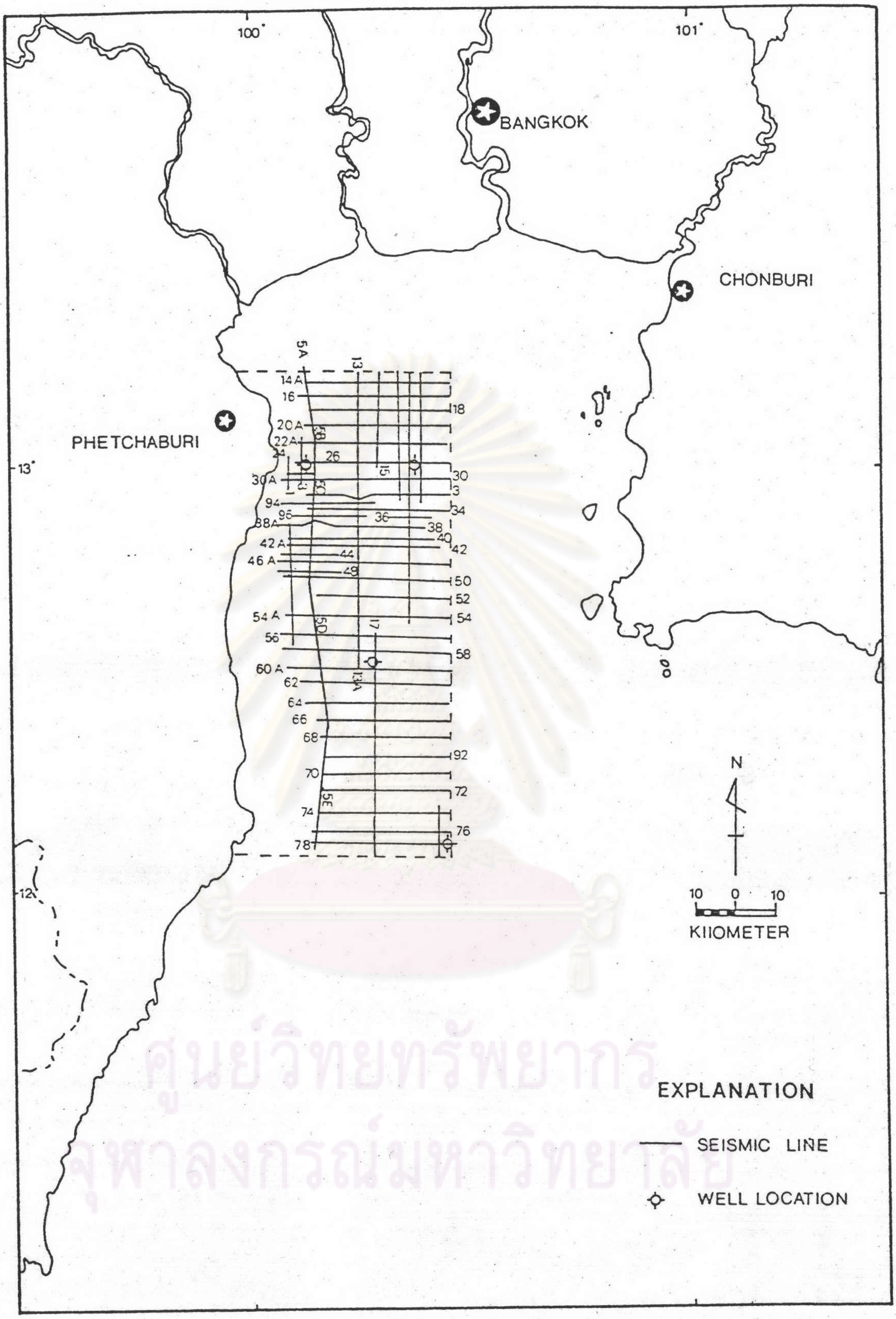

Figure 3. a Seismic lines covering the study area and well locations.

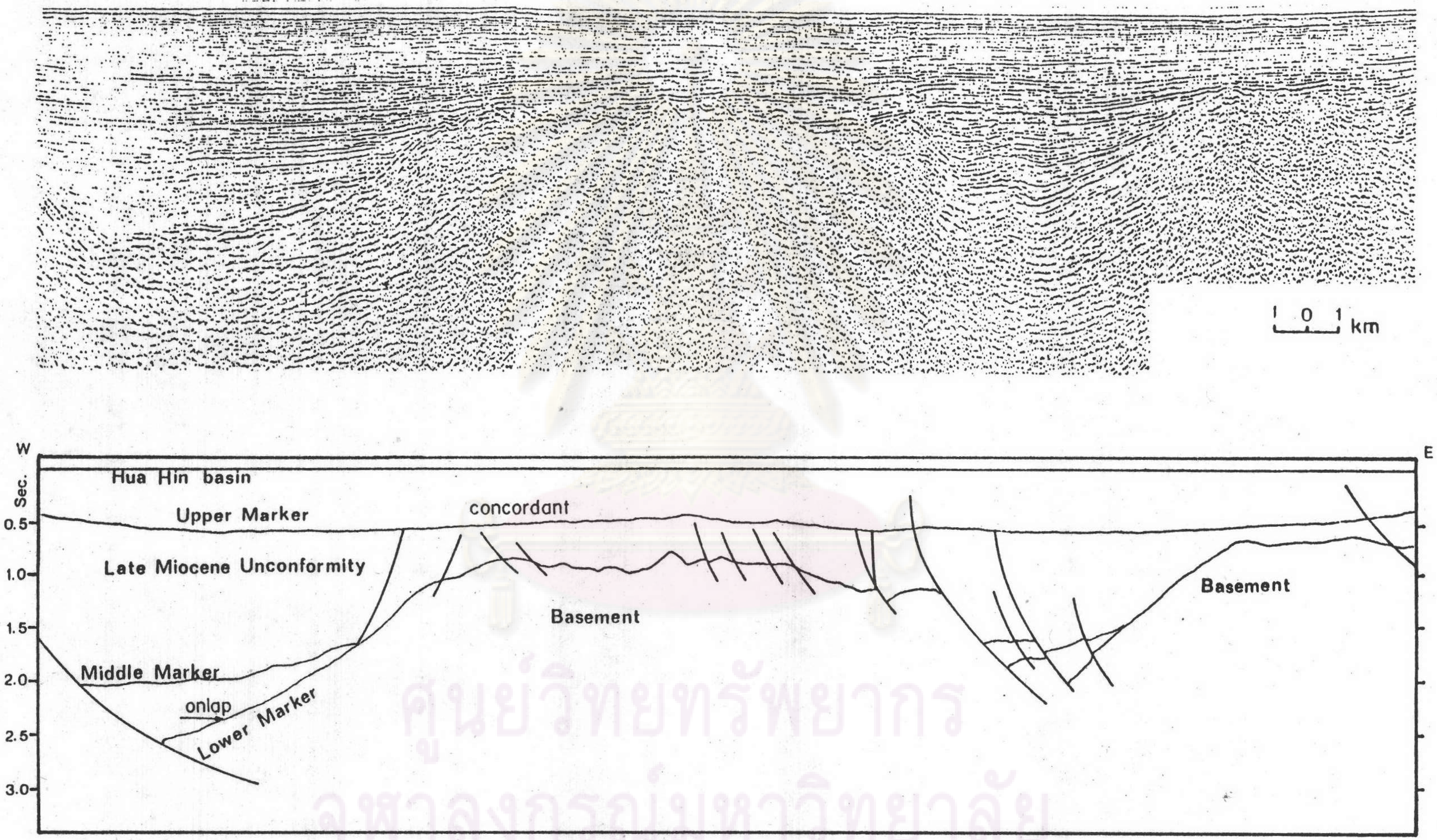

Figure 3. b Seismic section and geological section along the E-W direction (seismic line no.34, see Fig.3.a for location) of the Hua Hin basin showing the three markers.

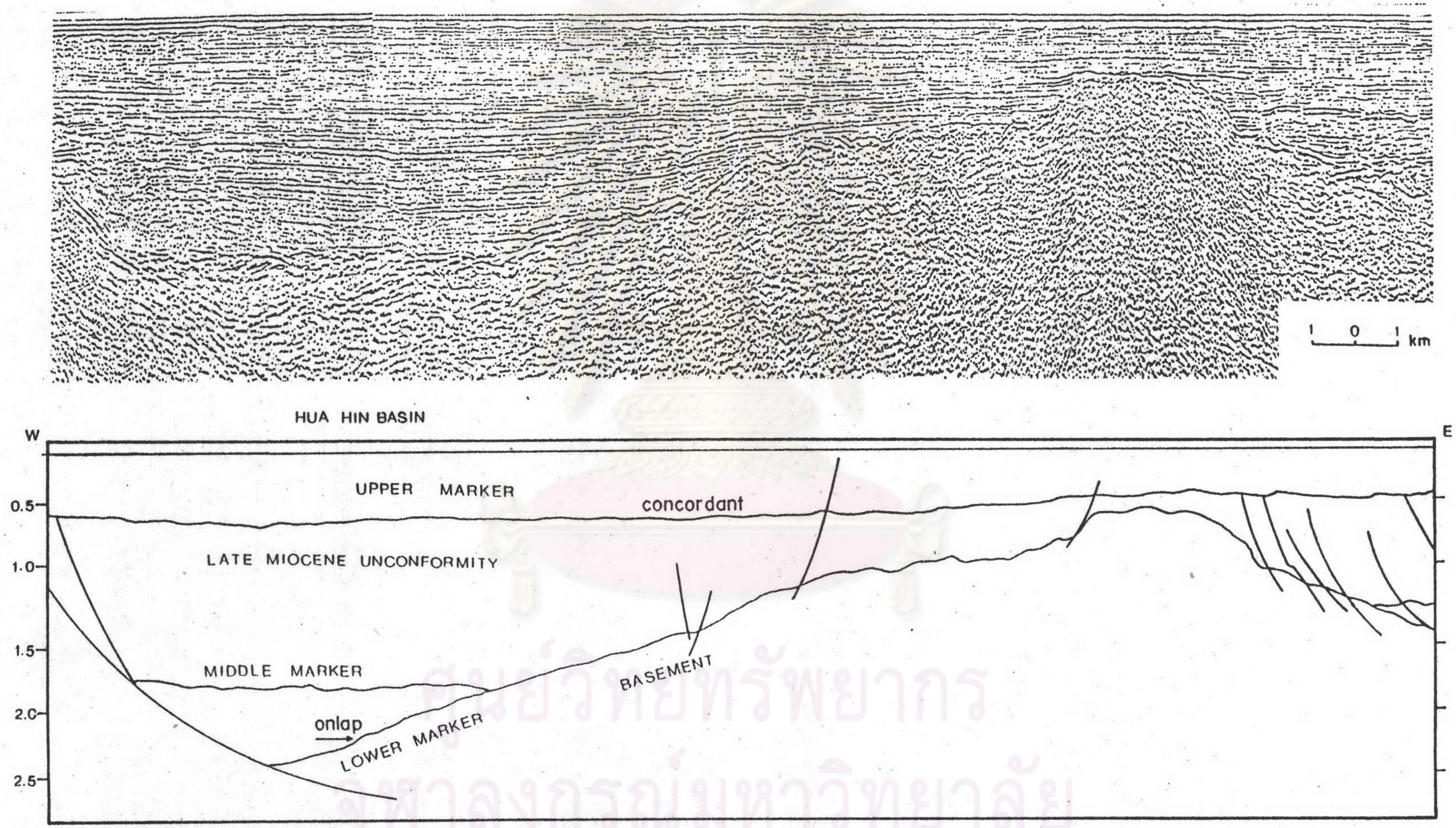

Figure 3. c Seismic section and geological section along the E-W direction (seismic line no. 40, see Fig.3.a for location) of the Hua Hinbasin showing the three markers.

the Cenozoic sequences. The middle marker shows onlapping to or conforming with the top of the lowest sequence, and shows onlapping to acoustic basement at the edge of basin. The marker can be reliably correlated by strong reflection characteristics and exhibits slightly erosional truncation. This marker is defined as angular unconformity. The upper marker is rather conform with the upper boundary of the middle sequence and is defined as the disconformity. As the matter of fact, the upper marker is rather difficult to define then the geological interpretation is necessary to correlate the top sequence along the Hua Hin basin. Generally, this marker is well known as, the Late Miocene unconformity, a regional unconformity in most of Tertiary basins in Thailand. The unconformity indicates the cessation of major rifting of most Tertiary basins and commonly marks by the die out of the faults which in turn have close relations with the development of Tertiary basins in Thailand. Therefore, in Hua Hin basin, the upper marker is the unconformity which is defined by the extinction of the faults that mark the intermission of major rifting of the Hua Hin basin.

The top depositional sequences of the Hua Hin basin can be further subdivided into two intervals considering from the information of geological data. The two interval was separated by the marine transgression unconformity?. The uppermost part of the Hua Hin basin was filled by the sediments of marine origin which resulted of the influence of the marine transgression. During the marine transgression the erosion surface may be formed because of the action of current and wave. Therefore, the sedimentary sequences of the Hua Hin basin can be eventually subdivided into 4 sedimentary units (Fig.

3 d).

3.1 The Sedimentary Units of Hua Hin Basin.

The sedimentary units of the Hua Hin basin are correlated from the integration of geological data, geophysical logs and ground seismic survey interpretation.

These 4 sedimentary units in the Hua Hin basin are informally referred to in this study as, units A,B,C, and D in ascending order (Fig. 3.1 a).

3.1.1 Unit A

The unit A is the lowermost sequence of Cenozoic rocks which overlies unconformably the pre-Tertiary basement in the Hua Hin basin and is overlain unconformably by the unit B. The unit A is distributed only in the lowest part of the basin with varying thicknesses according to the shape of basin. This unit is relatively widely distributed in the southern part as compared with that of in the northern part of basin. This is due to the broad shape of the southern basin. The maximum thickness of this unit located in the southern part of basin, is approximately 2,800 metres. The overall geometry of this unit is therefore concluded to be wedge-lens shaped. The general seismic reflection parameters in this sequence are high to low amplitude and fair to poor continuity, whereas the high amplitude and fair to good continuity are the characteristics in the upper part.

Due to the fact that only a few hundred metres of Phetchaburi-1 well have penetrated this unit, therefore lithological

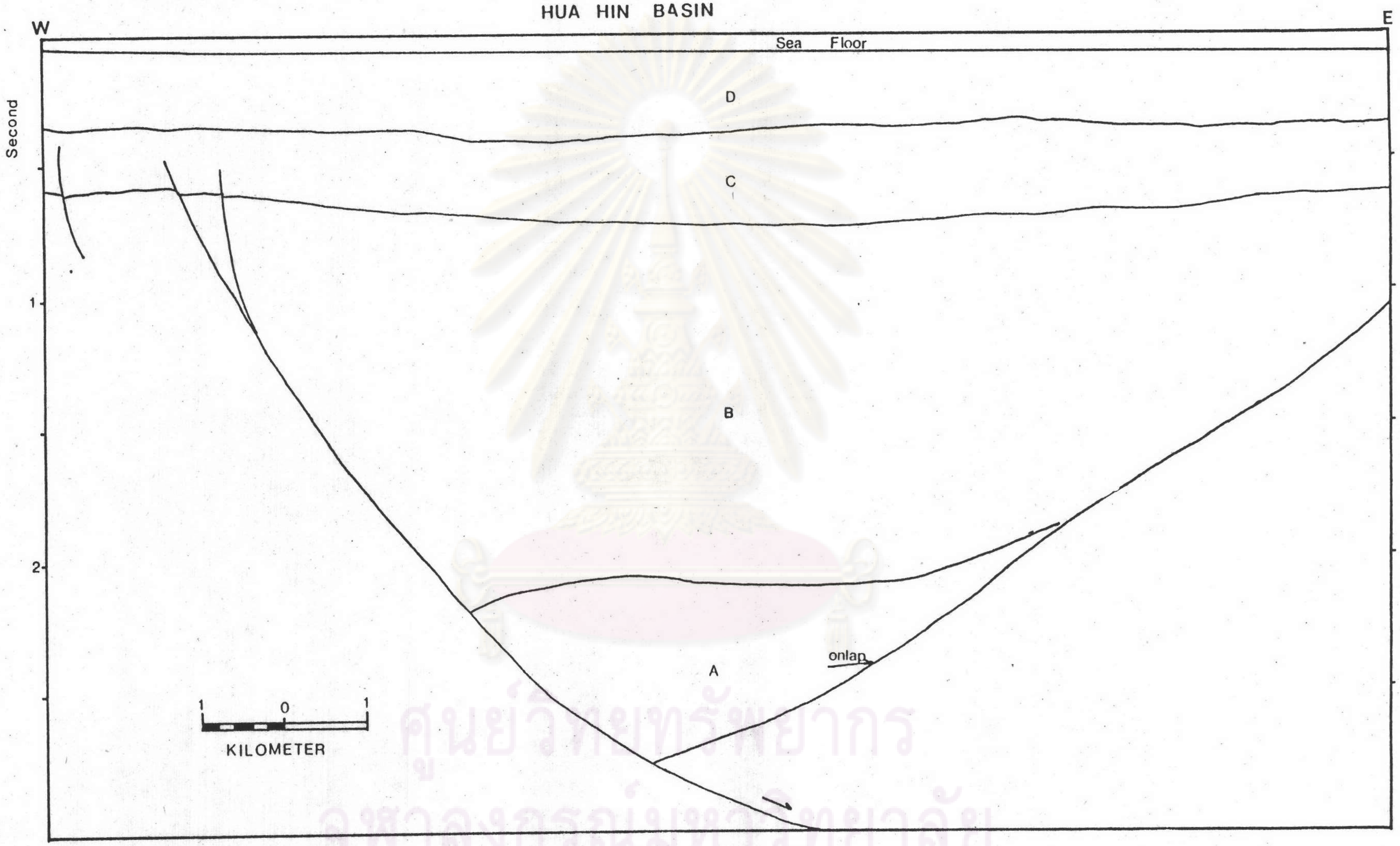

Figure 3. d Seismic section line no. 96 (see Fig.3.a for location), showing the sedimentary units in the Hua Hin basin.

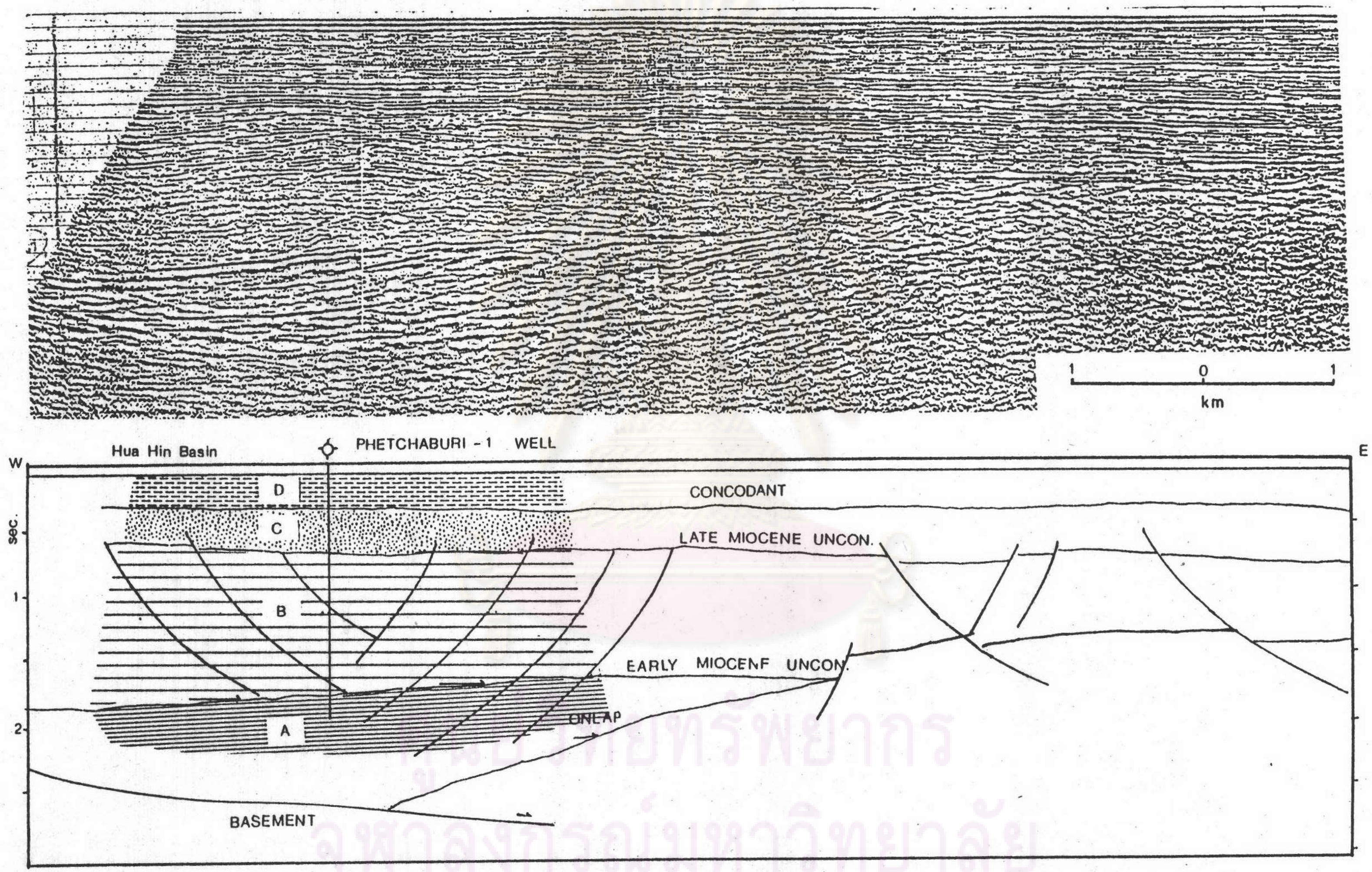

Figure 3.1 a Seismic section line no. 26a (see Fig. 3.a for location), showing the sedimentary units in the Hua Hin basin.

characteristics of this unit is accordingly limited, and represents only the uppermost portion.

The unit A can be subdivides into 2 subunits on the basis of lithological characteristics as follows:

(a) Subunit A-1

This subunit is the lower portion of the unit A which have been penetrated approximately 50 metres. The lithology of this part is mainly grey, dark grey shale, minor reddish brown shale and calcareous shale interbedded with thin-bedded limestone.

On the whole, the lithology of this unit is mainly limestone-shale interbedding in the upper part and is presumably mainly dark shale interbedded with thin-bedded limestone in the lower part.

(b) Subunit A-2

The uppermost portion of this unit is extremely thick and composing of limestone-shale intercalation with minor sandstone. The thickness of this portion is approximately 390 metres. The lithology of this portion is characterized by red , yellowish brown, purplish grey to dark grey shale, grey, whitish grey, greyish green, red, pink and light brown microcrystalline limestone, calcareous shale and medium-to fine- grained sandstone. The thickness of shale layers is approximately 5 to 30 metres whereas that of the limestone layer is approximately 2 to 12 metres.

The characteristics of the unit A is summarized in Figure. 3.1.1.

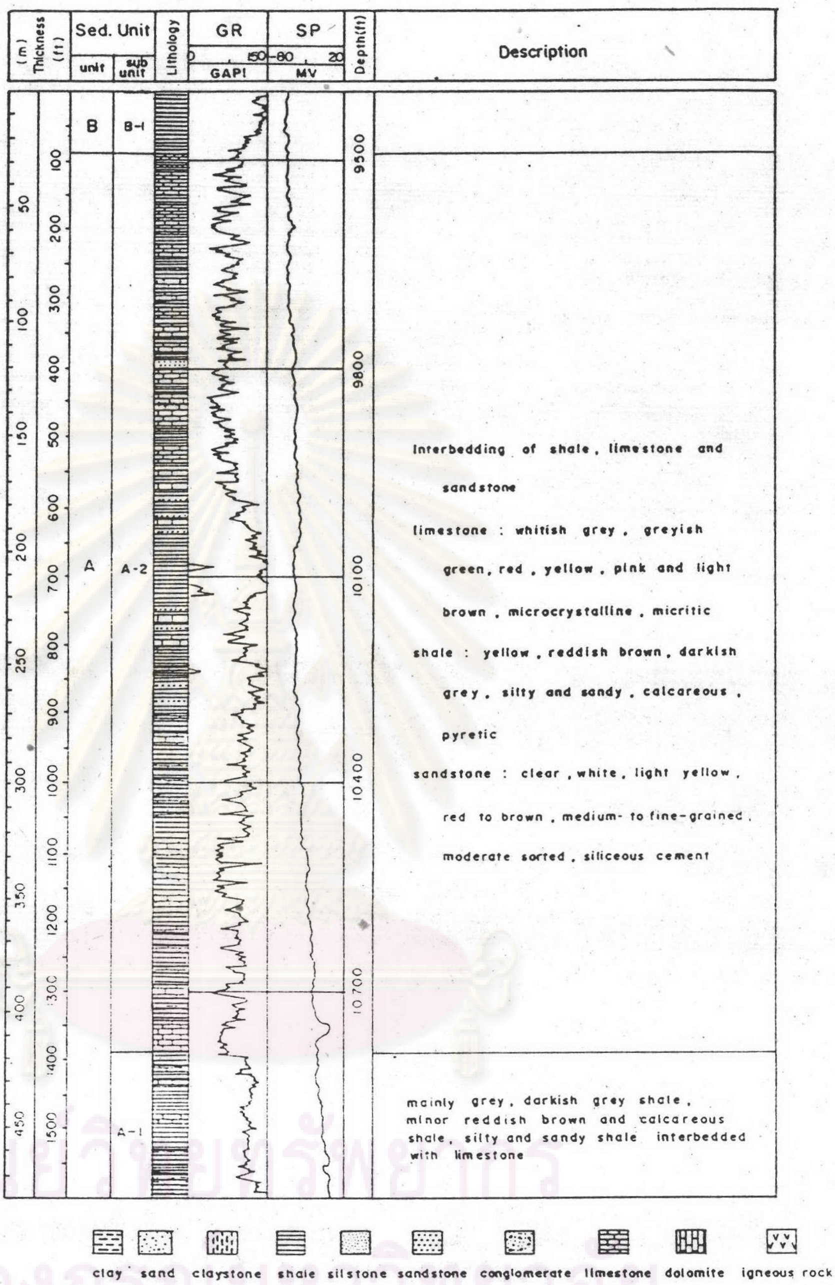

Figure 3.1.1 Lithological and geophysical characteristics of the Unit A, Hua Hin basin.

3.1.2 Unit B

The unit B unconformably overlies the unit A. This unconformity, is defined as the middle marker and is used as the lower boundary of the unit B throughout the Hua Hin basin. The unit B is conformably underlain the unit C. The distribution of the unit B is wide-spread throughout the basin with varying thicknesses. The overall geometry of the unit B is considered to be sheet drape to wedge shape or tabular. The average thickness of this sequence is approximately 1,200 metres with maximum thickness of about 1,500 metres. In general, the seismic reflection configuration of this unit is subparallel to parallel with fair to good continuity and low to high amplitude.

The unit B can be subdivided into 11 subunits on the basis of lithological. They are described in ascending order as follows:

(a) Subunit B-1

The subunit B-1 is approximately 500 metres thick sequence of shale, limestone and sandstone interbedding. The shale layers, 2 to 10 metres thick, are generally reddish brown colour and slightly calcareous, silty and sandy shale in some parts. The limestone layers, 1 to 10 metres thick, are characterized by light grey, whitish brown to red, with microcrystalline texture. The sandstone layers, 1 to 10 metres thick, are characterized by fine- to medium-grained. In addition, there are dolomite, with trace of coal in some parts of this sedimentary portion.

(b) Subunit B-2

The subunit B-2 is characterized by the intercalation of reddish brown, red, brown, sandy and calcareous shale, siltstone, sandstone, with the sand/clay ratio of 1:1. The total thickness of this intercalation is estimated to be 120 metres. The thickness of shale and siltstone layers are 3 to 12 metres, whereas that of the sandstone layers are 1 to 15 metres. The sandstone generally varies in colour, coarse- to medium-grained, and angular to subangular.

(c) Subunit B-3

This subunit is mainly light brown to reddish brown shale, silty, sandy and calcareous shale interbedded with coarse- to fine-grained sandstone, angular to subangular with trace of limestone and dolomite fragments in some part. The sand/clay ratio of this subunit is 1:1.

(d) Subunit B-4

The subunit B-4 is characterized by the 70 metres thick of red ,brown to light yellow shale interbedded with coarse-to medium-grained sandstone, with the sand/clay ratio of 1:1. The thickness of sandstone layers is 5 to 10 metres, whereas the thickness of shale layers is 2 t0 12 metres.

(e) Subunit B-5

This subunit is almost exclusively shale layers of totally 140 metres thick. The lithological characteristics of shale is red, brown, pale yellow. Besides, the coarse- to medium-grained sandstone layers are present with thickness of approximately 1-2 metres in some parts. The sand/clay ratio is 2:3.

(f) Subunit B-6

The subunit B-6 is characterized by approximately 120 metres thick of reddish brown, light yellow, silty and sandy shale interbedded with medium-grained sandstone and conglomeratic sandstone, and with limestone, dolomite fragments in some parts. This subunit reveals the sand/clay ratio of 1:1.

(g) Subunit B-7

This subunit is the thick yellow to reddish brown shale, silty and sandy in some parts with some limestone and dolomite fragments. the sand/clay ratio of this subunit is 1:2. The total thickness of this subunit is approximately 80 metres.

(h) Subunit B-8

The unit B-8 is characterized by yellow, reddish brown shale, silty and sandy shale interbedded with very coarse- to fine-grained sandstone, some dolomite, limestone and lithic fragments. The sand/clay ration of this subunit is 1:1. The total thickness of this subunit is approximately 150 metres.

(j) Subunit B-9

This subunit is the thick light brown, yellow to red claystone, silty ,sandy and minor sandstone. The sand:clay ratio of this unit is 1:5.The total thickness of this subunit is approximately 150 metres.

(k) Subunit B-10

The subunit is characterized by claystone interbedding with sandstone, with the sand/clay ratio of 1:1. The total thickness of this subunit is approximately 350 metres. The claystone layers of 4 to 70 metres thick are generally light brown, yellow to red colour. The sandstone layers of 3 to 15 metres thick are characterized by the associations of different grain sizes , subangular to subrounded, moderately sorted, with clay matrix and calcareous cement.

(l) Subunit B-11

This subunit is the interbedding of sandstone with the intercalation of dolomite and clay of approximately 100 metres thick in the lower part. The characteristics of the dolomite layers are mainly white to light brown to pink and microcrystalline texture, whereas the clay layer are generally light brown to reddish brown, silty and calcareous. The sandstone layers are characterized by white ,yellow, pink and grey colour mainly of clear quartz, fine- to coarse-grained , subrounded to rounded and mostly moderately sorted. The upper part of this subunit is a thick bedded of light brown clay with approximately 60 metres thick.

The characteristics of the unit B is summarized in Figure. 3.1.2.

3.1.3 Unit C

The unit C unconformably overlies the unit B. The unconformity underlies the unit C is the Late Miocene one and is conformably underlain unit D which is the uppermost sequence of Hua

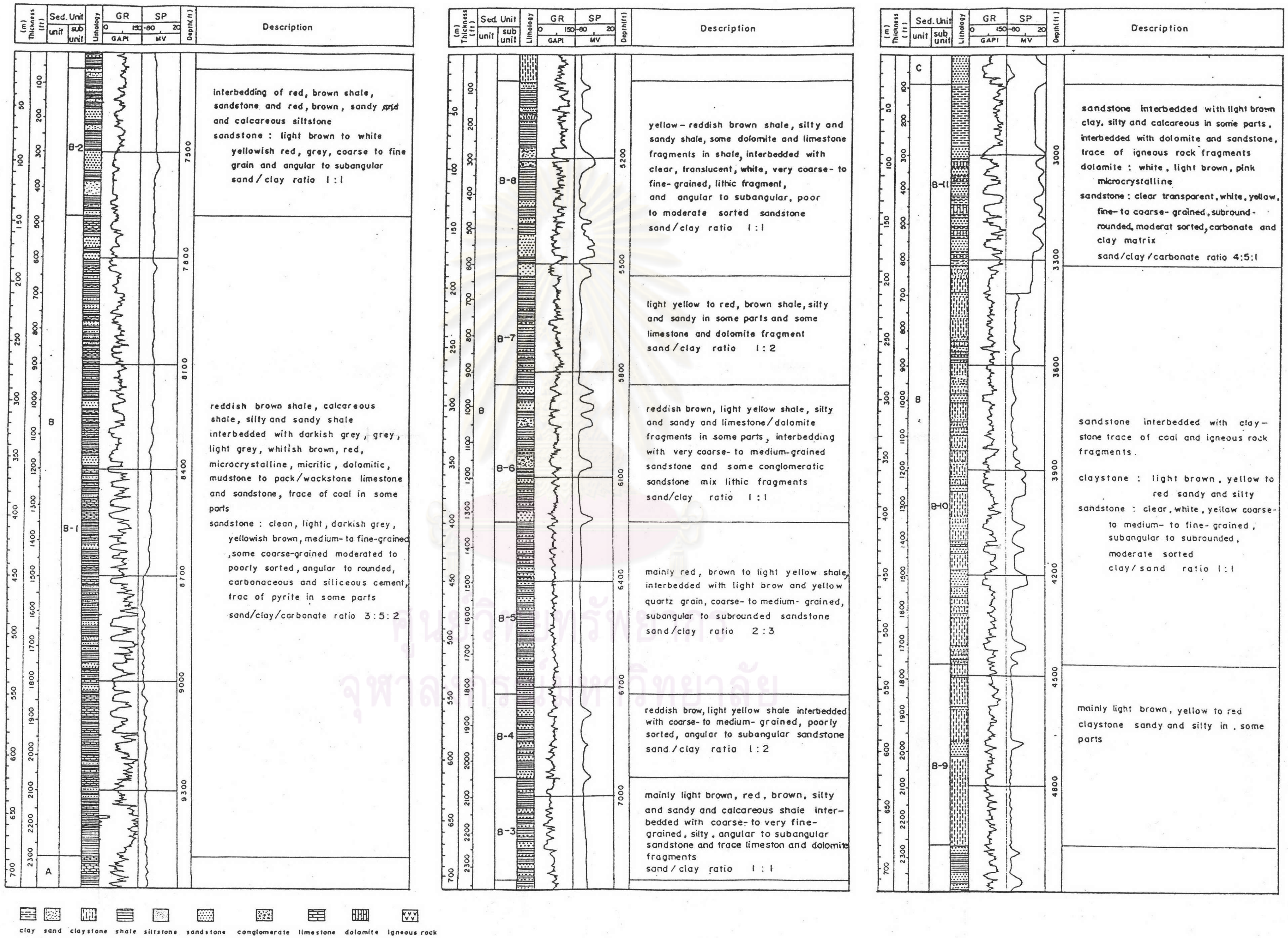

Figure 3.1.2 Lithological and geophysical characteristics of the Unit B, Hua Hin basin.

Hin basin. The total thickness of this unit is approximately 500 metres and the unit is distributed wide-spreadly throughout the Hua Hin basin. The overall geometry of the unit C is considered to be tabular or sheet.

In general, the reflection configuration of this unit is parallel with fair to good continuity and low to high amplitude. The unit is uniformly distributed throughout the area with very little tectonic disturbance.

The unit C is characterized by thick layers of sandstone and clay intercalation, with the sand/clay ratio of 1:1. The sandstone layers of 5 to 30 metres thick are consisting of clear and white quartz, medium- to coarse-grained, moderately sorted and subangular to subrounded. The clay layers of 2 to 50 metres thick are generally light brown to brown colour with trace of micas.

The characteristics of this unit is illustrated in Figure. 3.1.3.

3.1.4 Unit D

The unit D is the uppermost sedimentary sequence of the Hua Hin basin which conformably overlies the unit C and distributed wide-spreadly throughout the Hua Hin basin. The total thickness of this sequence is approximately 400 metres but no record of the sediments below seabed to 100 metres. The overall geometry of the unit D is considered to be the tabular or sheet.

On the whole, the general reflection configuration is parallel with fair to good continuity and low to moderate amplitude.

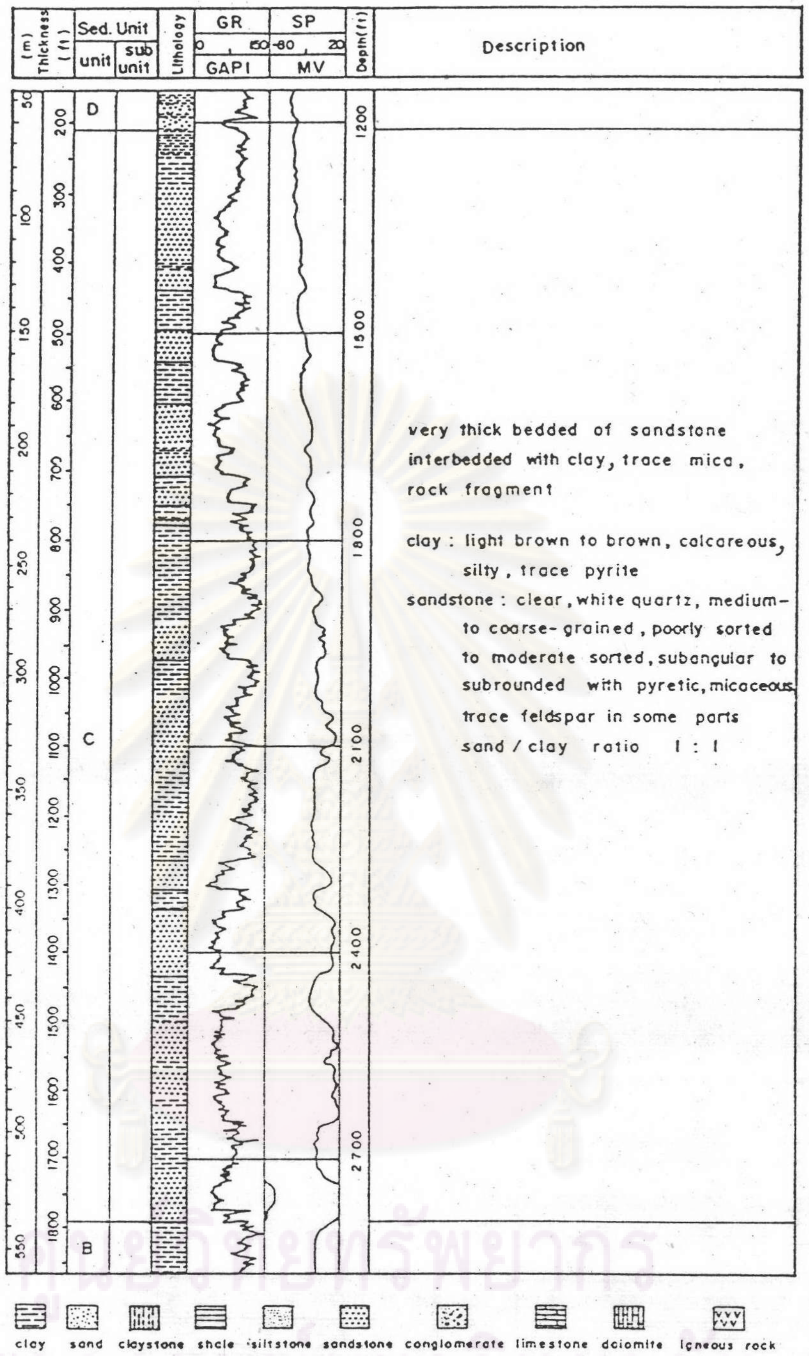

Figure 3.1.3 Lithological and geophysical characteristics of the Unit C, Hua Hin basin.

This unit is uniform distributed throughout the area..

The unit D is essentially characterized by unconsolidated clay essentially and sand interbedding, with the sand/clay ration of 1:1. The lithological characteristics of sand are clear and white quartz, light brown to pale yellow, with different grain-size association ,subangular to subrounded, and moderately sorted. The thickness of sand layer varies from 5 to 20 metres. The clay is generally light brown, brownish yellow to pale brown, silty and calcareous in some parts.

The characteristics of this unit is illustrated in Figure. 3.1.4.

3.1.5 Palynological Evidences and Age Determination

Information regarding palynology obtained from the report of the palynological analysis of Phetchaburi-1 well, of Pecten International Company, are defined from the study of cutting and sidewall core samples. All in all, most samples are examined barren of marine fossils. From sidewall core at 3,086 feet depth, the pollens of Gramineae, Quercus, Alnus, Pinus, Picea, Tsuga,Castanea, and rare Florschuetzia levipoli are identified and referred to as Miocene in age. Between the depth range of 9,420 to 10,830 feet, the study from composite ditch cutting contains few pollens, they are, Stenochlaena laurifolia, and Florschuetzia levipoli/semilobate representing Miocene in age. Within the interval of 10,980 to 11,007 feet depth, the pollens of Classopollis classoides, Circulina parva, Classopollis, Spherioollenites scabratus, Proxapertites sp., and Verrucosisporites sp. are identified and considered to be of Late

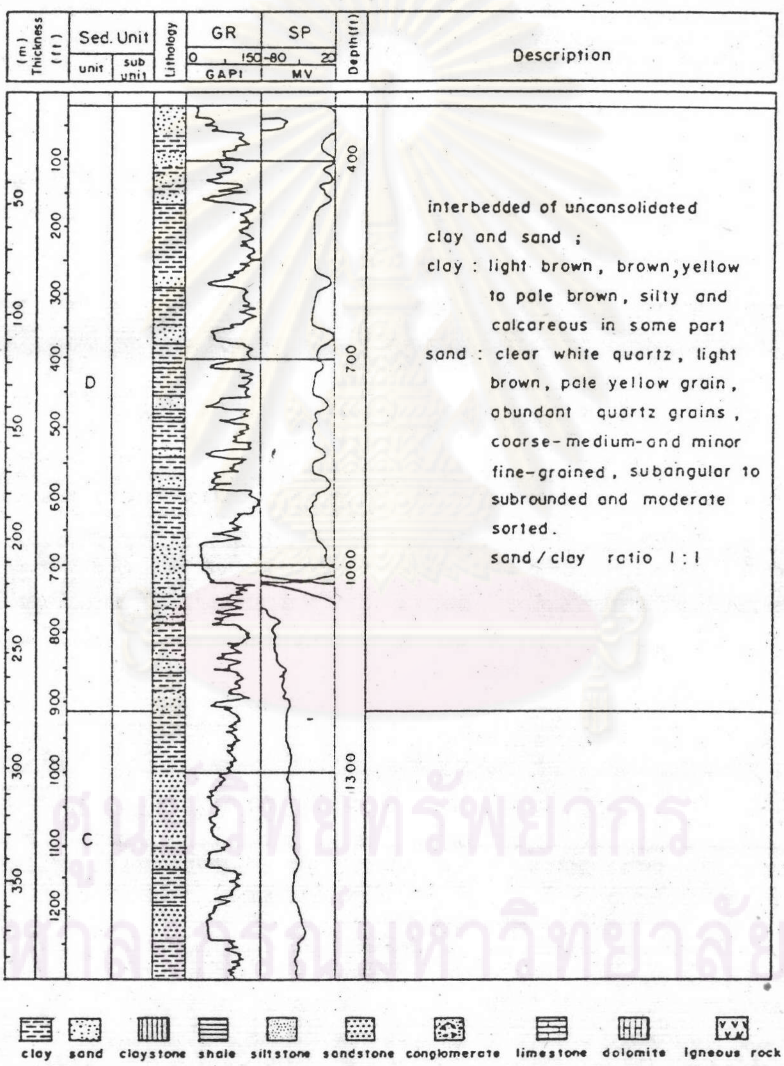

Figure 3.1.4 lithological and geophysical characteristics of the Unit D, Hua Hin basin.

Cretaceous in age.

To sum up, the unit A contains both Late Cretaceous and Miocene pollens. Therefore, the Late Cretaceous pollens are possibly of reworked origin. In addition, the Miocene pollens are represented in the unit B . However, there are no record of palynological evidence in unit C and D (Fig. 3.1.5).

3.2 Geological Structures

The development of Tertiary basins of the Gulf of Thailand is considered to be related with the opening of the Gulf that related to the plate motions of India toward Asia during Late Cretaceous to Early Tertiary. The movements of these plates are believed to be caused of the activities of the major fault zones in the SE Asia. The interaction of these faults may be the cause of the formation of Cenozoic basins in the Gulf. The major fault zones, which are believed to be closely related to the development of the Cenozoic basins in the Upper Gulf, are Three Pagodas fault zone, Ranong-Khlong Marui fault zone and Pranburi Hua-Hin fault zone. The structural elements of the Upper Gulf considered from the Cenozoic basins are many directions of normal fault, roll-over and antithetic faults. The Cenozoic basins in the Upper Gulf of Thailand are believed to develop at the same time by same cause due to similar structural elements. The Hua Hin basin is a small basin in the Upper Gulf. Therefore, the information of this basin integrated with the interpretation of regional structural framework can be referred to as the structural evolution of the Cenozoic basins in the Upper Gulf of Thailand.

SEDIMENTARY UNIT	AGE
D	—
C	—
B	MIOCENE
A	MIOCENE — (? LATE CRETACECUS)

Figure 3.1.5 The age determination from the palynological evidence of the sedimentary units in the Hua Hin basin.

3.2.1 Structural Framework of the Upper Gulf of Thailand

In general, most of basins in the Upper Gulf of Thailand comprise of a series of approximately N-S trending elongate grabens, half- grabens and horsts. Many geologists, such as, Woollands and Haw (1976), Lian and Bradley (1986), Tappoiner (1986), Polachan (1988),and Charusiri (1989) believed that the formation of these basins are related to the development of the major faults, namely, Ranong-Khlong Marui fault in the Thai- Malay peninsula, the Three Pagodas fault on the edge of the Gulf and the Pranburi-Hua Hin fault along the western coast of the Gulf (Fig.3.2.1).

3.2.1.1 The Three Pagodas Fault Zone (TPFZ)

The TPFZ is a NW to SE trending and extends from Burma across the Thai-Malay Peninsula through on the western edge of the Gulf of Thailand. The age and the sense of movement of the TPFZ is uncertain. Bunopas (1981), believed that the motion of the TPFZ was sinistral and was active during Jurassic to Cretaceous by the evidence of significant left-lateral offset of various rocks in western Thailand. Nutalaya and Rau 1984, used the evidence of dextral offset of mountain ridge in the western of Thailand and Burma then concluded that the sense of movement of TPFZ was right-lateral in Tertiary age but were reactivated in Quaternary. Tappoiner (1986), suggested that the Gulf of Thailand was formed by sinistral movement of the TPFZ and changed the sense of movement to dextral during Late Cenozoic using the evidence of earthquake in SE Asia. O'leary (1989), concluded that the TPFZ was certainly active during Mesozoic and moved left-lateral as considering from the basement structure along

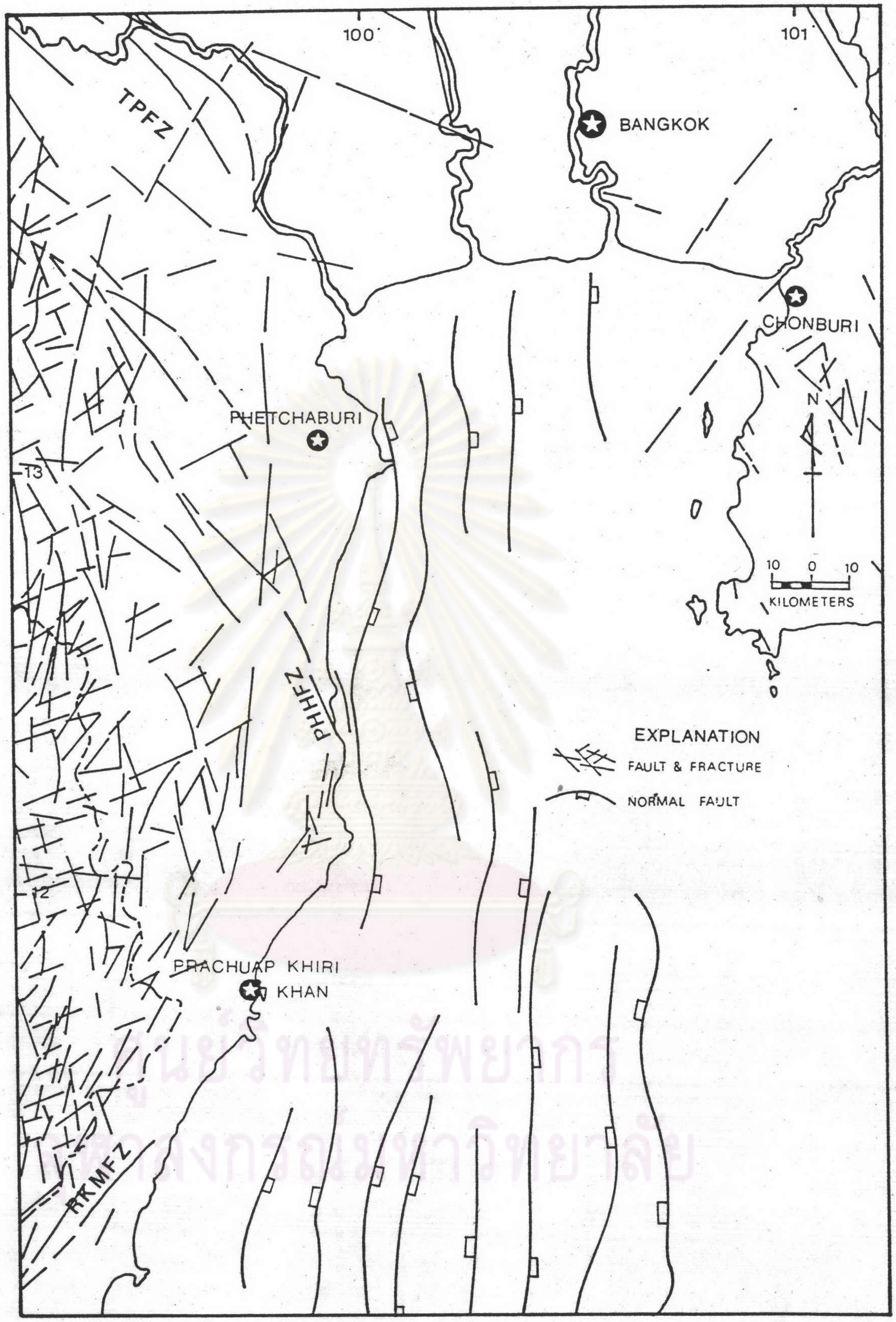

Figure 3.2.1 The structural framework of the Upper Gulf of Thailand. (after Nutalaya & Rau,1981 and DMR 1981,1988)

this fault. Consequently, the collision of India with Asia was the cause of reversal of movement of TPFZ from sinistral in Mesozoic to dextral in Tertiary. The major dextral movement on TPFZ is believed to have occurred in the Eocene to Early Oligocene and it resulted in large-scale dextral shear stress in the block between this fault. This shear stress may be expected to cause the extension of the Tertiary basins in this region. Polachan (1988), attempted to compare the structural model of the Gulf of Thailand and Mergui basin. He further suggested that the TPFZ was a dextral wrench fault similar to the Mergui fault zone in the Mergui basin which was active during Tertiary. Polachan and Sattayarak (1989), concluded that the TPFZ was left-lateral in Triassic, using the evidence from the offset of Permo-Triassic granitic belts in western Thailand, and changes to right-lateral in Oligocene time. The dextral movement of the TPFZ is the result in the interpretation of dextral shear model of the crystal block between the TPFZ. They suggested, that the Gulf is pull-apart basin and formed by dextral simple shear tectonics associated with the NW to SE and N-NE to S-SW conjugate wrench faults. Therefore, the NW to SE trending fault is TPFZ with dextral movement.

To sum up, the TPFZ was initially sinistral movement during Triassic to Cretaceous, and possibly changed the sense of movement to dextral in Oligocene.

3.2.1.2 Ranong-Khlong Marui Fault Zone (RKMFZ)

The RKMFZ is oriented in the N-NE to S-SW direction which cut obliquely across the Thai Malay Peninsula. The Ranong and Khlong

Marui faults lie at the western part of the Gulf of Thailand and perhaps merge together at the northwestern edge of the Gulf in the north and the distance between them increase southwardly. The sense of movement and age of RKMFZ is very controversial. However, some geologists suggested interesting information about RKMFZ. Garson et.al., (1976), suggested that RKMFZ has a sinistral movement during Late Jurassic to Late Cretaceous by the evidence of the offset sinistral of the Late Carboniferous to Triassic granites with a total displacement of at least 200 kilometres. Puttapiban and Suensilpong (1978), concluded that the RKMFZ may be moved before the Tertiary but were later sinistrally reactivated during Tertiary from the evidence of the offset of Tertiary pegmatite dykes sinistrally in Phuket area. Bunopas and Vella (1983a&b), proposed that the faults are the dextral movement during Late Cretaceous to Early Tertiary by the evidence of E to W spreading of the Gulf of Thailand at that time. Polachan (1989), studied in Mergui basin and shows clear evidence of sinistral movement of the RKMFZ. The offsets of the ridge in the western and southern of Mergui basin are the result of RKMFZ which have been active during Oligocene to the present.

As the result, the movement along RKMFZ is at least twice and remain active until the present. Presumably these faults developed during Late Jurassic to Early Cretaceous by sinistral movement and moved dextrally during Late Cretaceous to Early Tertiary. After all, during Oligocene to present the faults are later reactivated with sinistral movement again.

3.2.1.3 Pranburi Hua-Hin Fault Zone (PHHFZ)

Charusiri (1989), defined PHHFZ and studied the geology, mineralization and geochronology of this area in detail. The PHHFZ lies in the west of the Gulf of Thailand, the west of the Hua Hin basin, and located very close to the coastline in the igneous and metamorphic complex which are distributed in Pranburi- Hua Hin area. The Pranburi-Hua Hin area is located in Amphoe Cha Am and Amphoe Pranburi, Changwat Prachaub Khirikhan. This area is widely accepted as representing a large cataclastic zone (Pongsapich, Vedchakauclana and Pongprayoon, 1980; Charusiri, 1989). This cataclastic zone was developed in Precambrian and Lower Paleozoic rocks is believed to be a part of Shan Thai craton. There are three major sets of fractures and faults or lineaments in the area, namely , N to S, NW to SE and N-NE to S-SW. The fractures occur in the Upper Paleozoic sedimentary rocks, metamorphic complex and granitic terranes distributed in this area. The NW to SE trending fracture system occurs in the north of the area and N-NE to S-SW direction fracture system appears in the south. The direction of the fault system clearly reflects as a rather good foliation in the metamorphic complex exposed very close to the coastline in this area.

In fact, this area is composed of the complex rocks, and the oldest rock unit is believed to be Precambrian age. The cataclastic zone and metamorphic complex in this area show many strong deformations. In general, the sense of movement and age of this fault zone are controversial. Incidentally, this fault may change the sense of movement and other reactionary through. However, the evidence of direction of movement of mineral fragments in mylonite samples and several cataclastic features in the major fault zone from the NE-SW foliation show that the sense of movement of PHHFZ is actually right-lateral. The development of right lateral movement of PHHFZ has been caused by the collision of India and Asia during the Eocene time (55 Ma).

Few geologists suggested the age of PHHFZ, such as, Dheeradilok et al. (1983) defined Carboniferous age : Pongsapich et al. (1983) assigned pre-Permo -Carboniferous, and Putthapiban and Suensilpong (1978) considered that the PHHFZ is of Eocene age. In other words, the age of cataclastic rocks of these faults varies between 33.5 to 36 Ma (Charusiri, 1989). Subsequently, from the radiometric data of PHHFZ, the late major faulting was active during Late Eocene to Early Oligocene (33.5-36 Ma) which is believed to be closely related to the initial opening of the Gulf of Thailand (Bunopas and Vella,1983a and Charusiri, 1989).

Moreover, the radiometric data of the granite bodies in the vicinity of the PHHFZ about 5 to 10 kilometres, reveal that the age increases away from the fault zone within the range of 44.8 to 66.2 Ma. These data suggest that the emplacement of granite bodies may have occurred during the Eocene age concurrent with the collision of India and Asia. In addition, the age of the similar granite, from the zone of tin-tungsten deposit in this area, is between Late Oligocene to Early Miocene (21 Ma) possibly indicating the last major deformation in this area.

Besides, Tertiary andesitic and rhyolitic dykes with minimum age about 17-19 Ma are exposed in this area. This can be referred to as the youngest effect during Miocene events.

In conclusion, in this area there are Pranburi-Hua Hin foliated granitoid rocks that are may be Precambrian or Early Paleozoic in age and the emplacement of granites which is identified as Early Eocene age (50 to 55 Ma). During Late Eocene to Early Oligocene (33-36 Ma), the transcurrent Pranburi-Hua Hin fault was active, thereafter a subsequent tectonic event occurred during Late Oligocene to Early Miocene (21-17 Ma).

3.2.2 Structural Elements of the Upper Gulf of Thailand

Structures of the upper Gulf of Thailand have been recognized from a study of seismic sections in this area. There are few small basins in the upper Gulf,such as, Hua Hin basin, Sakhon basin, Pak Nam basin and N-Western basin. Three sets of faults occur in the upper Gulf,namely, NW to SE, NE to SW and N to S (Fig.3.2.2). These faults are the synsedimentary faults which developed at the same time as deposition of the Late Paleogene sediments. Besides, roll-over and antithetic faults usually occur on the hanging-wall of these normal faults.

3.2.2.1 NW to SE, NE to SW and N to S normal faults

The NW to SE, NE to SW and N to S direction normal faults are revealed to scatter throughout the upper Gulf of Thailand. These faults are mainly developed along the western margin of small basins in the upper Gulf and the orientation of these small basins are hence controlled by these faults. Most of these faults are tilted block-fault dipping towards the east direction. These faults are listric

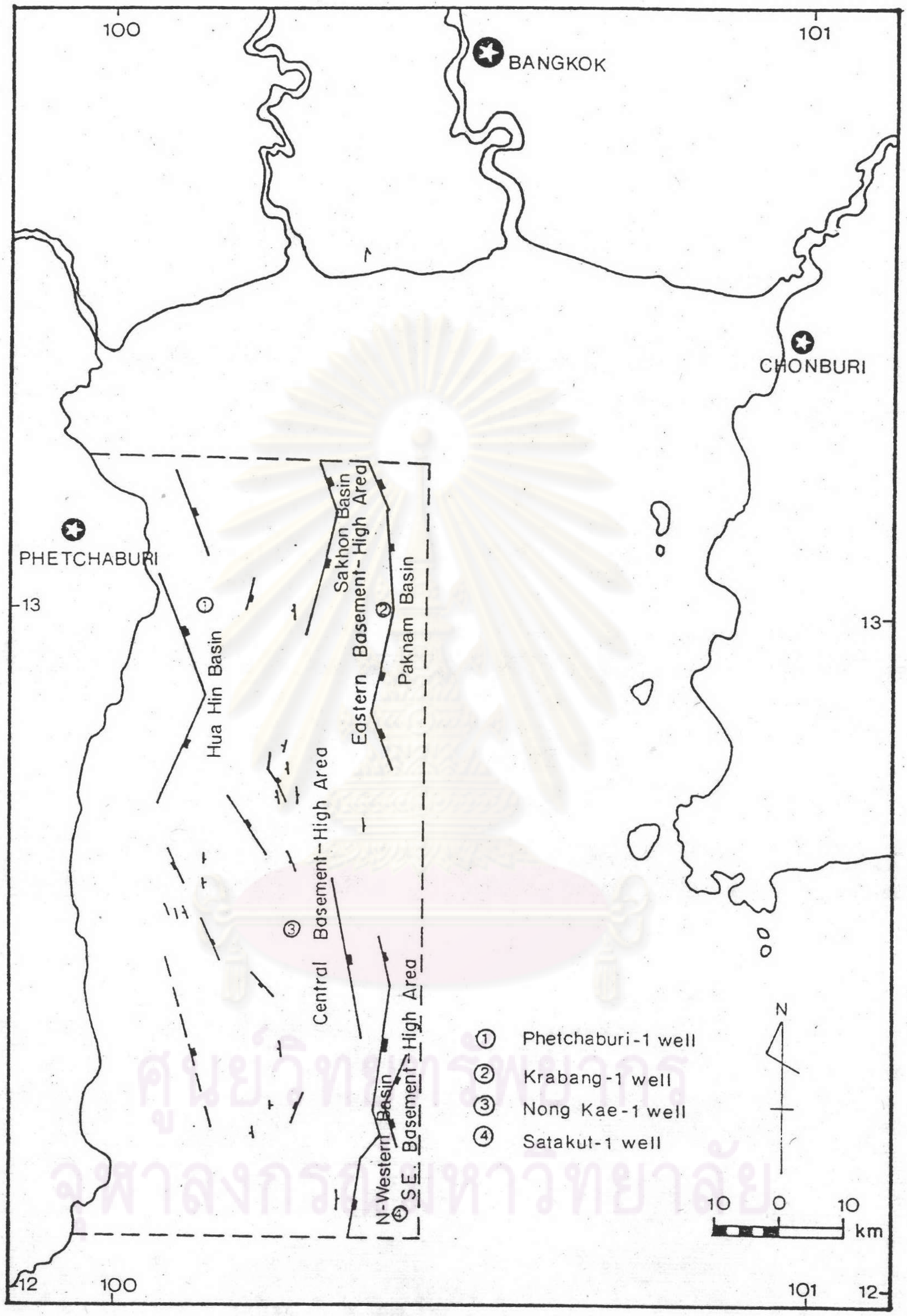

Figure 3.2.2 The structural elements of the Upper Gulf of Thailand. 1:Krabang-1 well,
2:Phetchaburi-1 well
3:Nong Kae-1 well
4:Sattakut-1 well

normal faults which have controlled the development of these small basins. These faults are believed to be active during Oligocene to Miocene, and usually died out towards the Late Miocene unconformity. The development of these faults are possibly closely related to the Three Pagodas, Ranong- Khlong Marui and Pranburi- Hua Hin fault zones and plate motions of India toward Asia. Therefore, the activities of these normal faults should be developed at the same time with the activities of the PHHFZ, TPFZ,and RKMFZ. These faults are probably the result of movements of these major fault zones. Palachan(1988), suggested that the development of N to S Tertiary basins in the Gulf of Thailand can be explained in terms of a major transtensional shear cople resulting from the oblique plate convergene of India moving toward Asia by develop as a result of the complex movement of the NW to SE trending right lateral fault (TPFZ) and the NNE to SSW trending left lateral conjugate faults(RKMF) during Early Tertiary. In the Upper Gulf of Thailand, the development of these listric normal faults were believed to be the result of the collision of India and Asia and the interactions of TPFZ and RKMFZ. The Pranburi-Hua Hin fault is the only fault which has been clearly dated. Therefore, the development periods of these faults are possibly defined according to the PHHFZ activities. All in all, these listric normal faults initially developed at Late Eocene/Early Oligocene play important role in the formation of small basins in the Upper Gulf. The deposition of sediments in these basins are believed to commence at once after the basin formation. Thereafter, the last event of movement in PHHFZ was active during Early Miocene then the unconformity of the depositional sequences in small basins are accordingly considered to be Early Miocene in age. Finally, the activities of these faults died out during the Late Miocene.

3.2.2.2 Roll-over and antithetic faults

Roll-over is among one of important features associated with the listric normal faults (Bealey 1985). It develops in the hanging wall of listric normal fault and is revealed along the curvature of the listric normal fault in cross section. The normal movement along a curved fault plane tends to pull the blocks apart as well as to displace them vertically. Therefore the antithetic fault produces result of adjustments to fill the incipient gap by rupture and develops in the updip direction of the listric normal faults. To sum up, the roll-over and antithetic faults response to the same force and develop because of the curvature of the fault plane at depth (Hamblin 1965). In the Upper Gulf of Thailand, the roll-over and antithetic faults are clearly present in the sequence between the Early Miocene Unconformity and Late Miocene Unconformity (Fig. 3.2.2.2).

3.2.3 Geological Structures of the Hua Hin Basin

Information obtained from the seismic reflection survey reveals that the configuration of the pre- Tertiary basement of Hua Hin basin within the study area is elongated mainly in the N-NW to S-SE (Fig. 3.2.2). The basin is approximately 10-15 kilometres wide and 100 kilometres long. There are 3 main sub-basins with the maximum depth from sea floor to present pre- Tertiary basement of over 5,000 metres. These sub-basins are aligned along the western coast of the Upper Gulf. The northern and southern sub-basins are both aligned in the N-NW to S-SE whereas the middle sub-basin has a crescentic shape

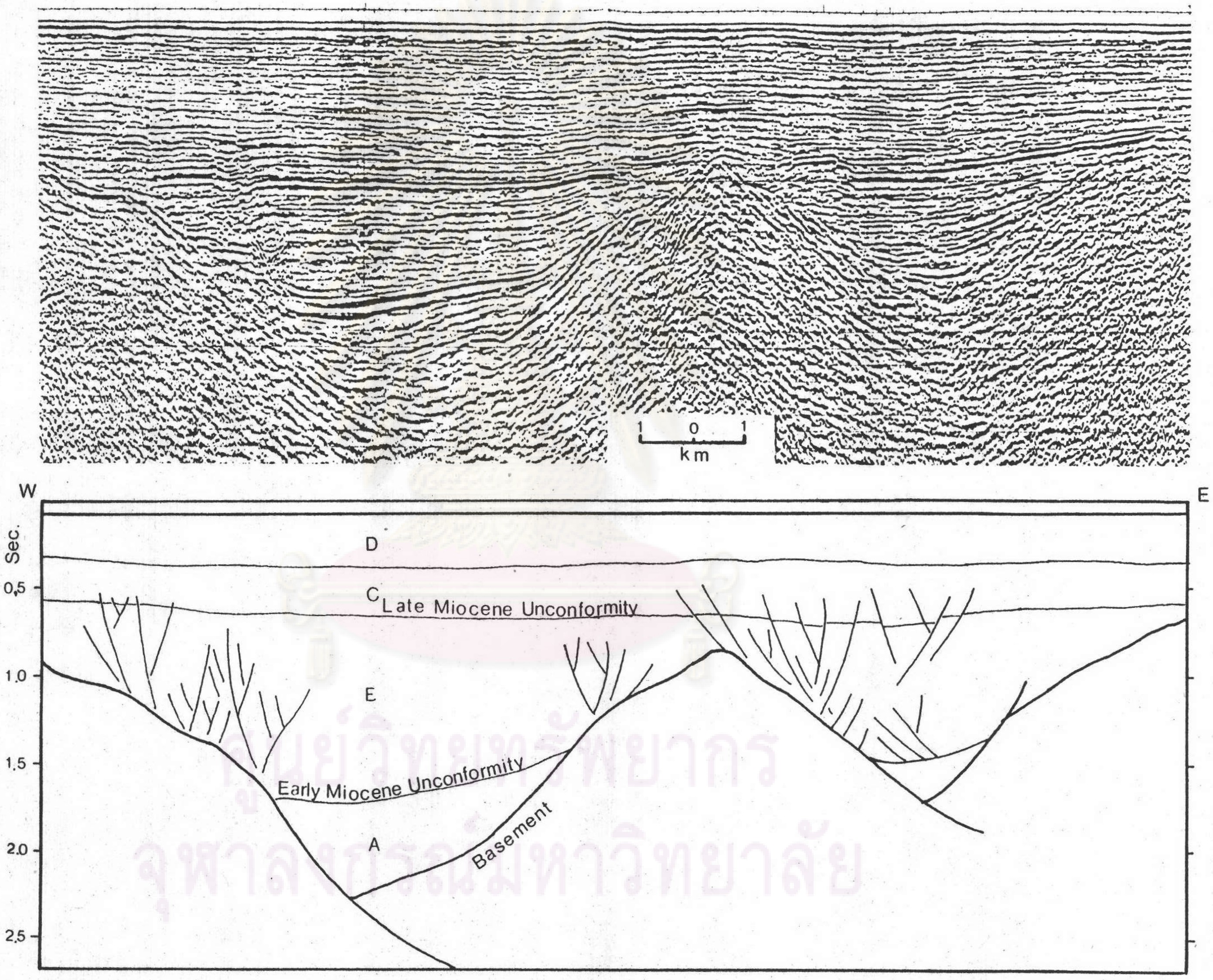

Figure. 3.2.2.2 Seismic section (line no. 22A)showing the roll-over and antithetic faults in the Upper Gulf of Thailand.

convexing towards the western direction of basin. The northern and middle sub-basins are smaller in size than the southern sub-basin which is the widest and have maximum depth about 5,900 metres.

Seismic sections show that the formation and deposition in these sub-basins are controlled by the listric normal faults (Figs. 3.2.3 a-d). These listric normal faults can be categorized into three sets, they are, NW to SE, NE to SW and N to S. Among these three fault sets, the major ones are the NE to SW and NW to SE directions. The development of these faults is closely related to the movement of the Pranburi-Hua Hin, Three-Pagodas and Ranong-Khlong Marui fault zones. In Hua Hin basin, roll-over is usually developed in the hanging wall of listric normal faults on the western margin. The antithetic faults are often present in the sequence between the Early Miocene unconformity and Late Miocene unconformity in the northern part of the Hua Hin basin.

3.2.4 <u>Structural Evolution of the Hua Hin Basin</u>

Due to the fact that, the listric normal faults are controlled by the movement of TPFZ, RKMFZ, and PHHFZ; therefore the movement of these three fault zones are closely related to the formation of the Hua Hin basin. These major fault zones are believed to be the effect of plate motions of India toward Asia during Late Cretaceous to Early Tertiary. Even though the collision of India and Asia has been in progress since the Early Cretaceous, but the Hua Hin basins in is considered to has developed during the Oligocene time because of the transcurrent of PHHFZ was active during Eocene/Early Oligocene and the representing of the oldest sediment in the Upper

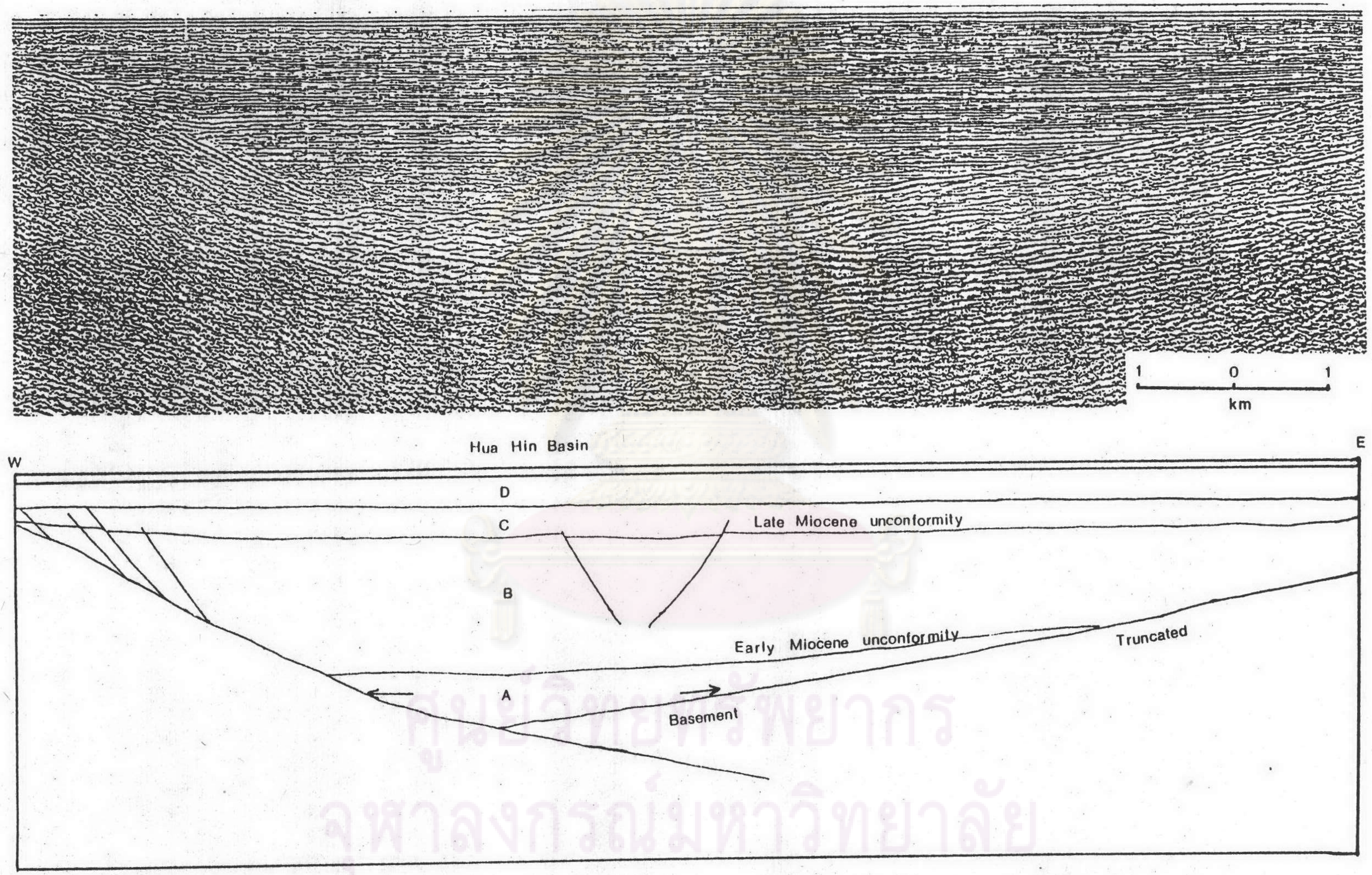

Figure 3.2.3 a The seismic section and geological section along the E-W direction (seismic line no. 94, see Fig 3.a for location) of the Hua Hin basin showing the depositional and structural controls.

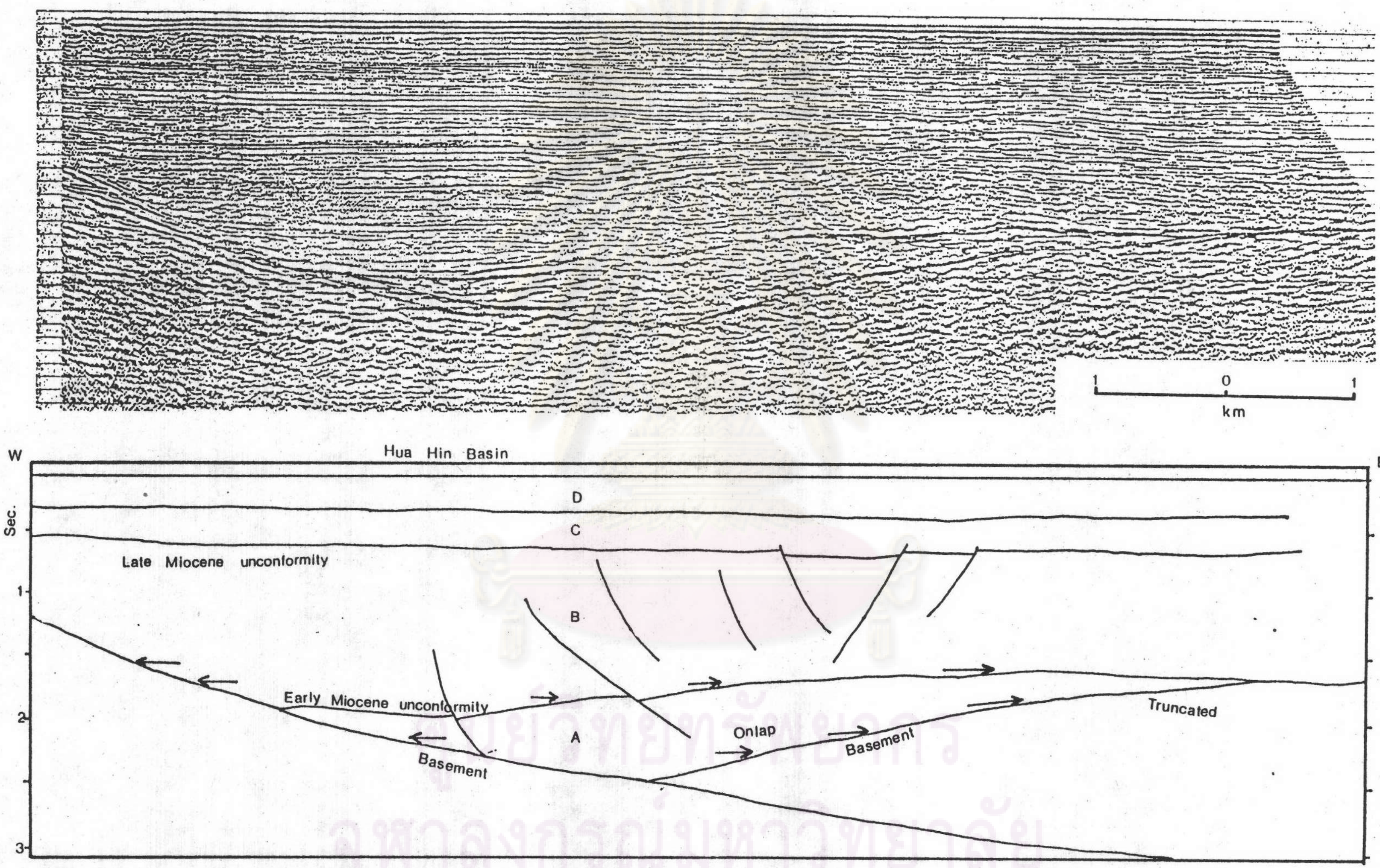

Figure 3.2.3 b The seismic section and geological section along the E-W direction (seismic line no. 24, see Fig.3 a for location) of the Hua Hin basin showing the depositional and structural controls.

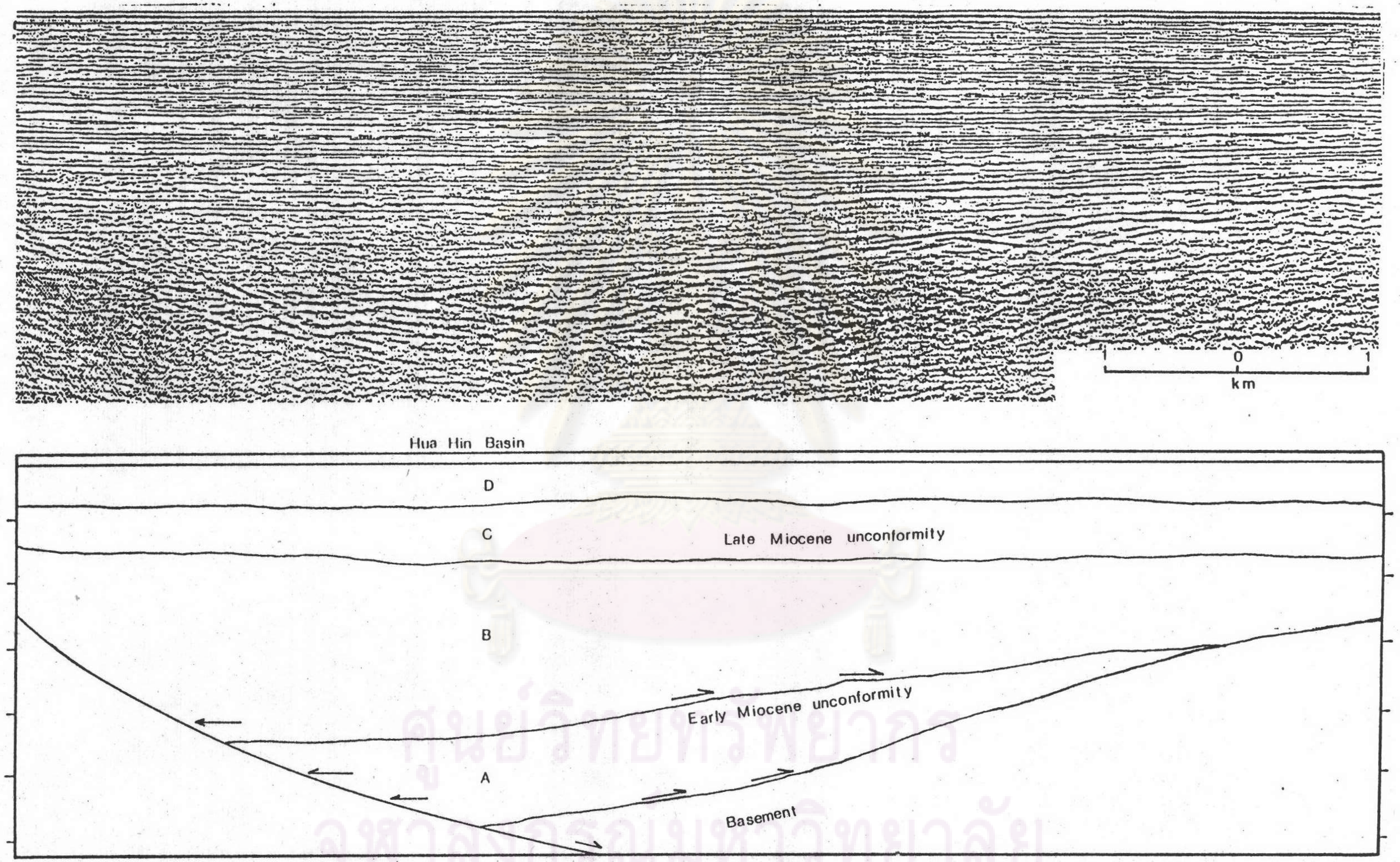

Figure 3.2.3 c The seismic section and geological section along the E-W direction (seismic line no.16, see Fig. 3.a for location) of the Hua Hin basin showing the depositional and structural controls.

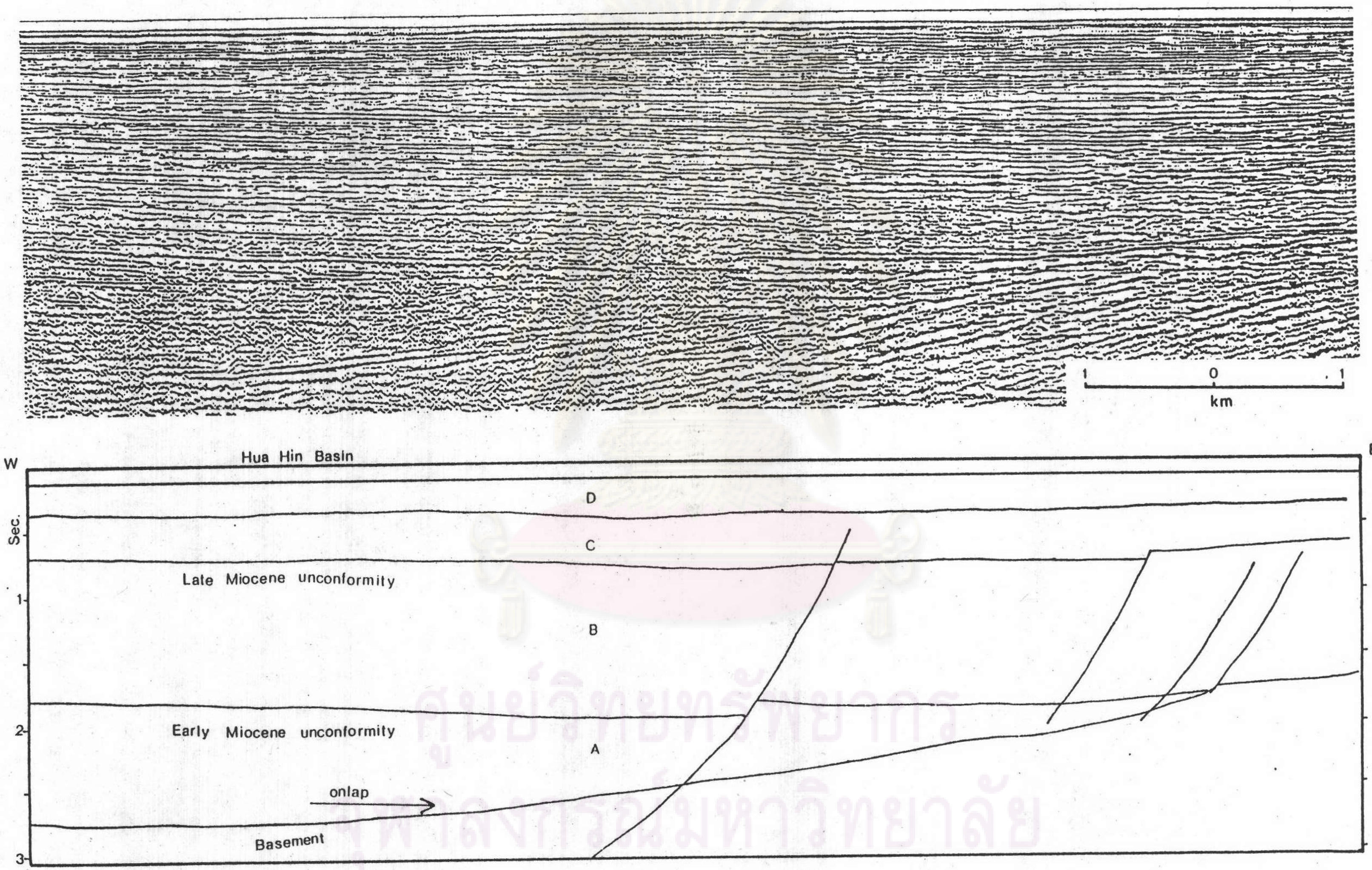

Figure 3.2.3 d The seimic section and geological section along the E-W direction (seismic line no.64, see Fig. 3.a for location) of the Hua Hin basin showing the depositional and structural controls.

Gulf is only defined as Eocene/Oligocene in age.

Because the PHHFZ is located very close to and lies parallel with the Hua Hin basin, therefore the listric normal faults on the western margin of the basin are considered to be initially developed during the major faulting of Pranburi-Hua Hin transcurrent fault. Besides, the directions of this fault are similar to the major trending faults in the Hua Hin basin. The PHHFZ is also the only fault zone in this region where the ages of movements are clearly identified. The major movement of PHHFZ was during Early Oligocene age (33-36 Ma), and the subsequent tectonics was active in this area during Early Miocene (21-17 Ma). Besides, the major activities of the plate motions in this region were active at that time. In addition, some Tertiary basins in adjacent areas show similar structural framework to that of the Hua Hin basin and are considered to be developed during the similar geological time.

The information on seismic sections and sedimentary sequences in Hua Hin basin was used to erect a structural evolution of the basin. The structural history of the basin can be summarized into 3 episodes, they are, Early Oligocene to Late Oligocene-Early Miocene, Early Miocene to Late Miocene, and Late Miocene to Holocene.

3.2.4.1 Early Oligocene to Late Oligocene-Early Miocene

There are three fault sets which were developed in the Hua Hin basin at the same time, they are, N-NW to S-SE, N-NE to S-SW and N to S normal faults (Fig. 3.2.4.1). These faults control the directions of the sub-basins in the Hua Hin basin. All fault sets were active at the beginning of the development of the basin in the

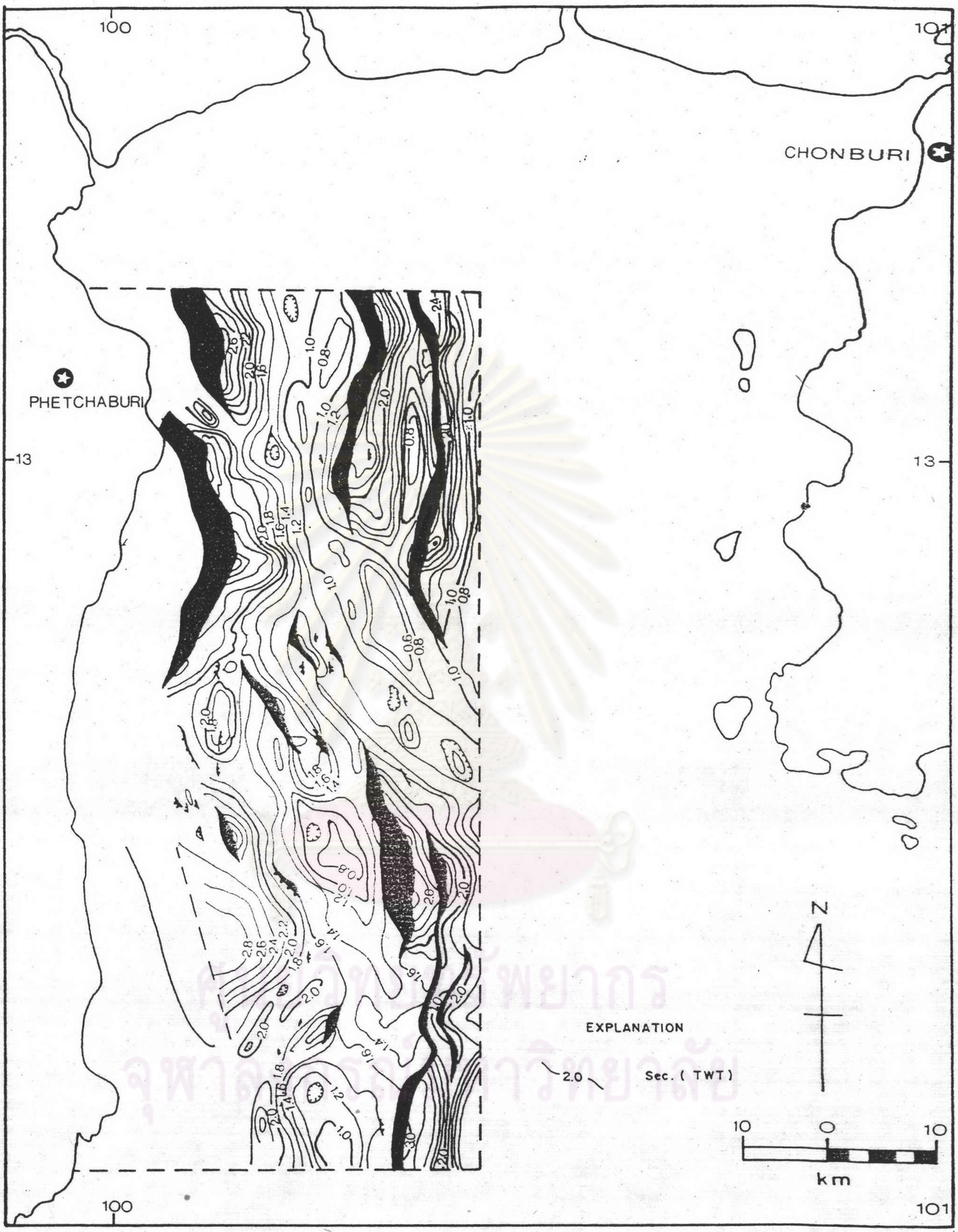

Figure 3.2.4.1 The structural map of the basement of the Hua Hin basin.

Early Oligocene (33-36 Ma). Some Tertiary basins in Thailand, such as, Phitsanulok basin (Knox and Wakefield, 1983), Suphanburi basin (O'leary and Hill, 1989), Pattani basin (Lian and Bradley, 1986), are believed to be formed during Late Cretaceous to Early Tertiary and the oldest sediments are of Oligocene age. The Indo-Himalayan collision is the major cause of Mae Ping and Three Pagodas faults movements that were active during Early Tertiary time (O'leary and Hill, 1989).

In the Hua Hin basin the half-grabens with intervening basement high area were formed by rotation fault blocks. The N to S rifting extended progressively southward during Early Oligocene as shown by the relatively broader shape of the southern sub-basin. Sediments were deposited at only the deepest part of the half-grabens characterized by the shale interbedding with limestone which is referred to the unit A in Hua Hin basin. The Oligocene sediments thicken westward indicating that the half-grabens depocenting in the west.

During Late Oligocene to Earliest Miocene, the renewed uplifting was marked by local unconformity in the top of sedimentary unit A in the Hua Hin basin. The deformation was strongest in the northern sub-basin and relatively weaker in the middle and southern sub-basins. The uplifting may be the result of the subsequent tectonics in the PHHFZ (23-16 Ma.). The sea-floor spreading in the Andaman sea is the cause of uplift and erosion in the Mergui basin during earliest Early Miocene (Polachan, 1989). Therefore, the late tectonic activity in the major fault zone and the sea-floor spreading of Andaman sea may be the result in the renewed uplifting of Hua Hin basin represented by the Late Oligocene -Early Miocene unconformity and the listric normal faults continued to move.

3.2.4.2 Early Miocene to Late Miocene

During the Early Miocene time, the Hua Hin basin continued to subside and was accumulated by the thick sequence of the interbedding of shale ,limestone and sandstone which is referred to the B sequence. The basin depocenter was likely to be located in the west along the normal fault which controlled the subsidence of basin. The roll-over and antithetic faults was clearly developed during this time (Fig. 3.2.4.2).

At the end of Early Miocene, the drifting stage of sea- floor spreading of Andaman sea was the cause of a compressional regime in the Mergui basin represented by as the unconformity. Towards the end of Early Miocene, the unconformity is clearly present in the Mergui basin. In the Hua Hin basin, this compressional regime may be the result in the termination of half-graben faulting and the influence of the clastic sediments deposited in the upper portion of the unit B. Then the lower portion of the unit B was possibly accumulated during Late Oligocene /Early Miocene to the end of Early Miocene.

The end of Early Miocene to Late Miocene, the Hua Hin basin continued to subside by the relatively slower extension rate than in the previous time. The upper portion of the unit B was deposited which are characterized by the interbedding of sandstone, shale, clay, dolomite and limestone. The faulting was died out at the Late Miocene time. The roll-over and antithetic faults were also ceased during this time. The Late Miocene unconformity of Tertiary basins of

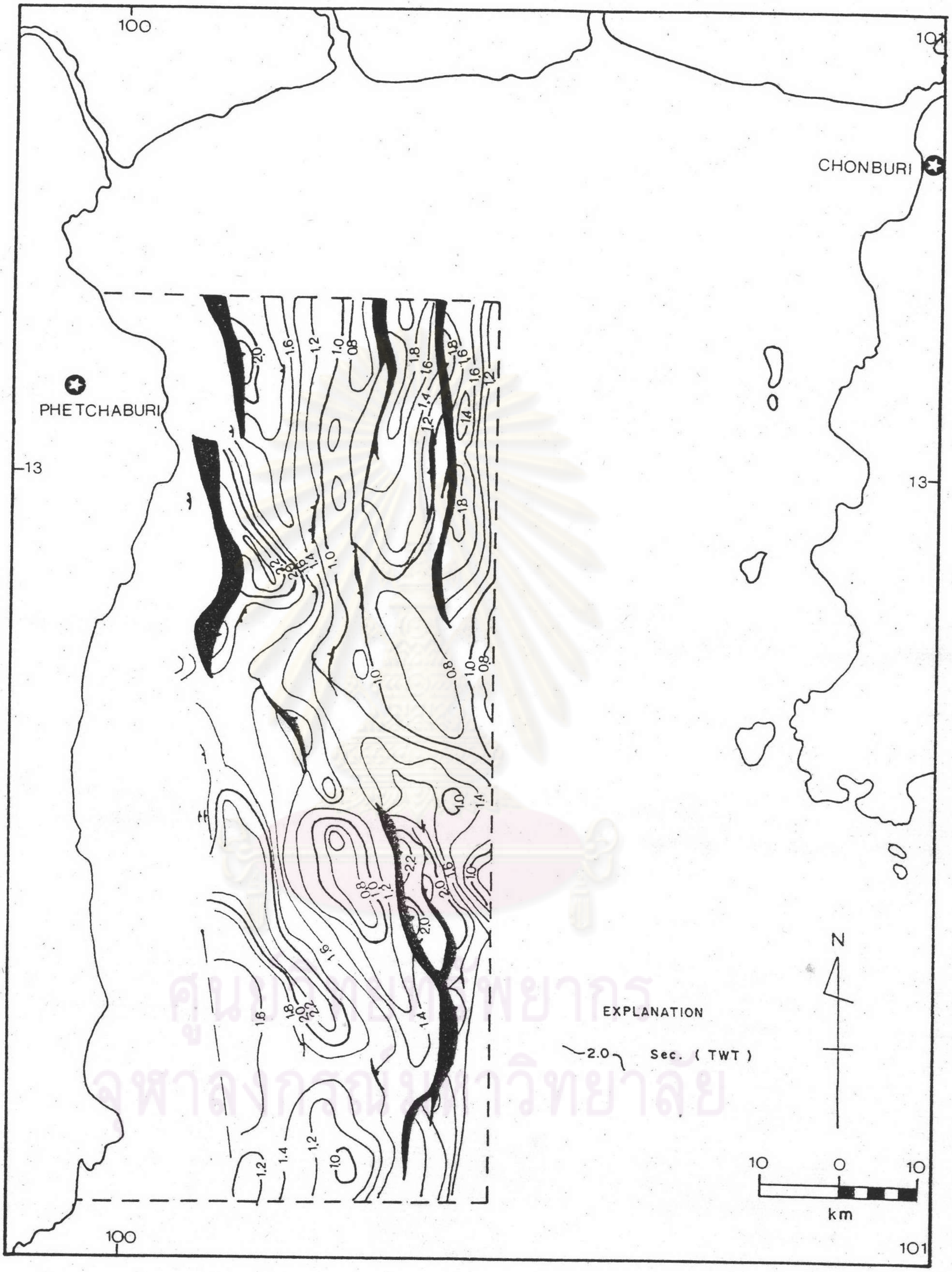

Figure 3.2.4.2 The structural map of the Early Miocene age.

Thailand and adjacent areas is defined by the information from high alumina- alkali basalts which are widely distributed in southern Indochina, northern, southeastern and central Thailand (Bunopas,1983). The Late Miocene basalts indicate the climax of E to W extensional tectonics in this region. Barber (1985) suggested that the northward movement of Australia to collide with SE Banda Arc and the subduction of the Pacific plate and India ocean are the major cause of the compressional regime with represented by the Late Miocene unconformity in this region. Therefore, in the Hua Hin basin the unconformity between units B and C is defined as Late Miocene in age.

3.2.4.3 Late Miocene to Holocene

As the matter of fact, most of normal faults of the Hua Hin basin was ceased during the Late Miocene time, therefore the unconformity should be defined at that time. Thereafter, the slow subsidence has dominated tectonic activities in this area. The rifting of the Gulf of Thailand and Chao Phraya basin was ceased during the Pliocene caused by the orogeny of western Thailand and Burma as shown by the uplifting of mountains surrounding the Lower Central Plain (Nutalaya,1984). From the Late Miocene to Pliocene, the interbedding of sandstone and clay of the unit C was deposited.

The information of the marine transgression from the southern basins in the Gulf of Thailand ,namely, Malay and Pattani basins shows the timing of initial incursion of the sea in the Gulf as Eocene to Early Oligocene (Woolland and Haws, 1976; Lian and Bradley, 1986). In the Upper Gulf area, the depositional environment was shallow marine represented by the influence of the marine transgression during the Late Pliocene to Holocene.

The renewed subsidence was initiated during Late Pliocene and has been continued to Holocene time as presented by the block faulting in the Lower Central Plain (Nutalaya, 1984). Some of the faults in the Upper Gulf remain active during the time, and control both the present-day topography of the sea floor of this area and the main drainage lines in the Lower Central Plain continuously to the Upper Gulf area. The poorly consolidated sediments have been buried more than 2,000 metres in the Choa Phraya basin during Late Pliocene to present. During the Pleistocene time, the major marine regressions of world-wide glaciations have effected the shallow seas that cover the SE Asia area. The study of Bangkok soft clay reveal that the last trasgression took place during the Middle Holocene. Thereafter, the Lower Central Plain emerged a few metres from the sea, this activity should be the last tectonic evidence related to the tectonic activities in the Hua Hin basin. During Pliocene to Holocene the interbedding of unconsolidated sand and clay has been deposited in the Hua Hin basin which is referred to as the unit D. The unit D is accumulated under the shallow sea environment.

3.3 <u>Sedimentary Facies Analysis</u>

The sedimentary units of some Cenozoic sediments of the Hua Hin basin earlier described in this study serve as a fundamental basis for the sedimentary facies analysis. The sedimentary facies is defined in descriptive term as a certain volume of rock that can be characterized by a set of features, such as grain size, geometry and structure, that distinguish it from other rock units (Anderton,1985). The interpretative term of sedimentary facies is a label summarizing the interpretation of the processes and environments of deposition of a certain rock unit. The sedimentary facies analysis is the description and classification of any body of sediments followed by the interpretation of its processes and environment of deposition. A group of related sedimentary facies, considered to be genetically or environmentally is facies association which is used to represent related depositional environments or depositional system.

As a matter of fact, only the Phetchaburi-1 well had penetrated sedimentary of the Hua Hin basin in addition to the seismic of totally 700-1000 line-kilometres, therefore the subsurface data for sedimentary facies analysis are very limited. Most sedimentary facies from this study are referred to from this well. Besides, some sedimentary facies of each sedimentary sequence of the Hua Hin basin may not be present in the Phetchaburi-1 well, and consequently could possibly be missing from this study. The sedimentary facies is used to the reconstruction of depositional environment which could be synthesized to formulate the depositional system from facies association. Despite the fact that some sedimentary facies are unknown, the interpretation of depositional system is not critically affected.

The detailed subsurface geological analysis has allowed the distinction of the sedimentary units within the Hua Hin basin as previously described. Each of the sedimentary units is considered in terms of sedimentary facies for further uses in the reconstruction of depositional environment. The sedimentary facies in this study is characterized by 3 main parameters, they are: lithology, sedimentary structure, some aspects of external geometry and fossil.

The foregoing discussion will be focusing upon the descriptive and the interpretative sedimentary facies, respectively.

The lowermost sedimentary unit of Cenozoic sediments in the Hua Hin basin is the unit A which unconformably overlies the pre-Tertiary basement rocks. The unit A is analyzed in terms of sedimentary facies A and the subsurface geological data available for the analysis of this unit is confined within the uppermost 440 metres thick from the penetration of drill-hole where the maximum thickness of the facies A is approximately 2,800 metres. The lithology of the facies A is characterized by the interbedding of shale with limestone and occurrences thin-bedded of sandstone in some parts. The pollen of Classopollis classoides, Circulina parva, Classopollis jardinei, Spheripollenites scabratus, Proxapertites sp., and Verrucosisporites sp. are present in this sedimentary facies (Pecten,1984). The overall geometry of this facies is wedge-shaped or wedge-lens-shaped and rest in the lowermost part of the basin. The characteristics of the facies A is summarized and presented in Figure.3.3.a.

Overlying unconformably the unit A is the unit B which is generally characterized by the interbedding of shale , limestone and siltstone in the lower part and the series of fining upward sequence from sandstone or siltstone to shale intervening with the thick sequence of shale, calcareous shale in the upper part. There are 2 sedimentary facies in this unit ,namely, sedimentary facies B1 and B2

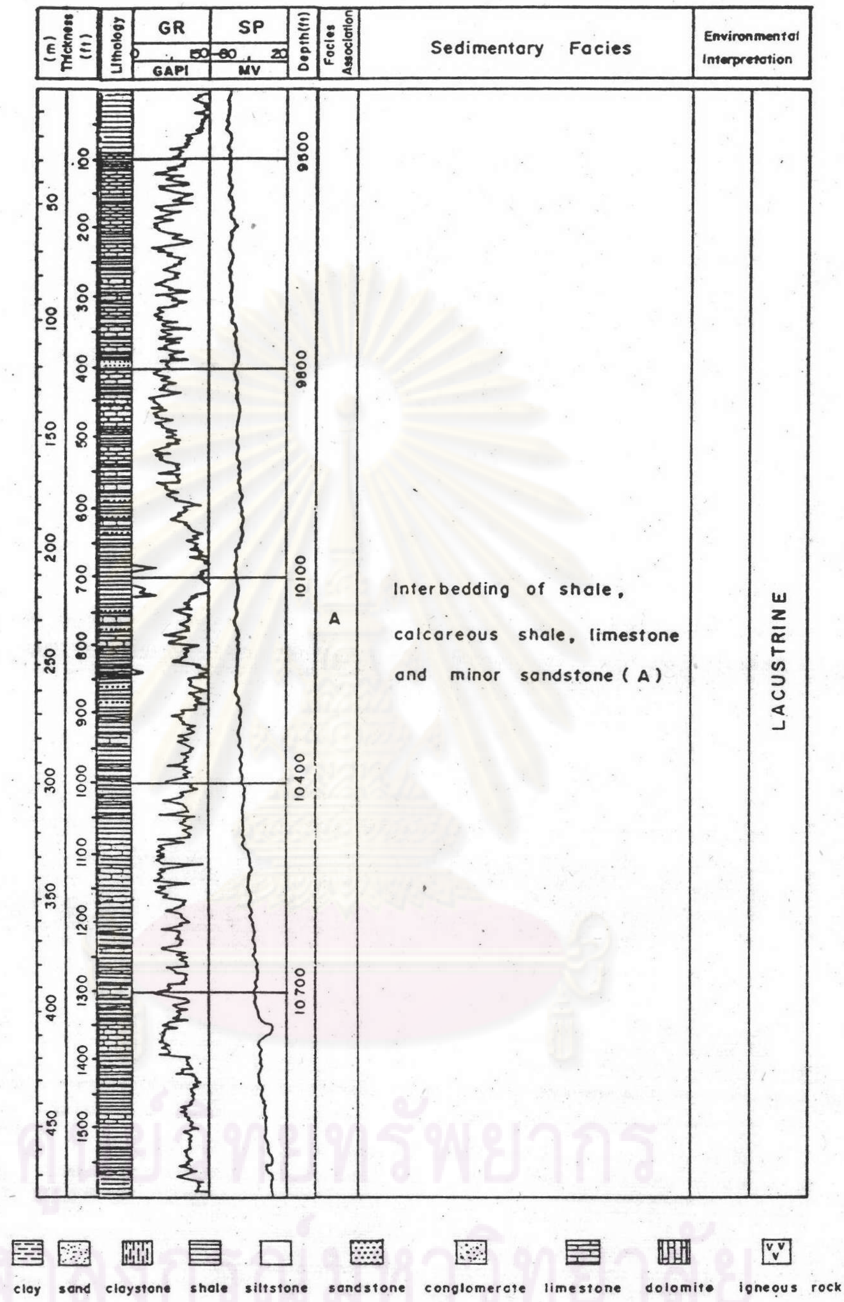

Figure 3.3 a Summarized the depositional environment of Facies association A.

in ascending order. The sedimentary facies B1, with approximately 500 metres thick, unconformably overlies the top of the interbedding of limestone and shale of sedimentary facies A. The external geometry of this facies is considered to be sheet-draped to wedge-shaped. The lithological characteristics of this facies are mainly interbedding of shale, limestone and sandstone. The pollens of Stenochlaena laurifolia and Florschuetzia levipoli/semilobate are present in this sedimentary facies(Pecten,1984). Overlying the sedimentary facies B1 is 1,300 metres thick of sedimentary facies B2. The overall geometry of this facies is sheet-draped to wedge-shaped or tabular. The sedimentary facies B2 is represented by thick succession of the series of fining-upward sequences from sandstone, siltstone to shale intervening with the thick sequence of shale/claystone, calcareous shale/claystone, sandy, silty shale/claystone minor sandstone and dolomite/limestone, with the sand/clay ratio off 1:1. In this sedimentary facies is represented by pollens of Gramineae, Queercus, Alnus, Pinus, Picea, Tsuga, Custanea and Florschuetzia levipoli(Pecten,1984). The characteristics of the facies association B is summarized and presented in Figure.3.3.b.

The unit C is separated from the unit B by the Late Miocene unconformity. The unit C is represented by the sedimentary facies C. The sedimentary facies C is mainly characterized by the series of fining upward sequence of sandstone and clay with the sand/clay ratio of 1:1. The overall geometry of this facies is tabular or sheet covering over the study area. the facies is approximately 500 metres thick. The characteristics of the facies C is summarized and presented in Figure.3.3.c.

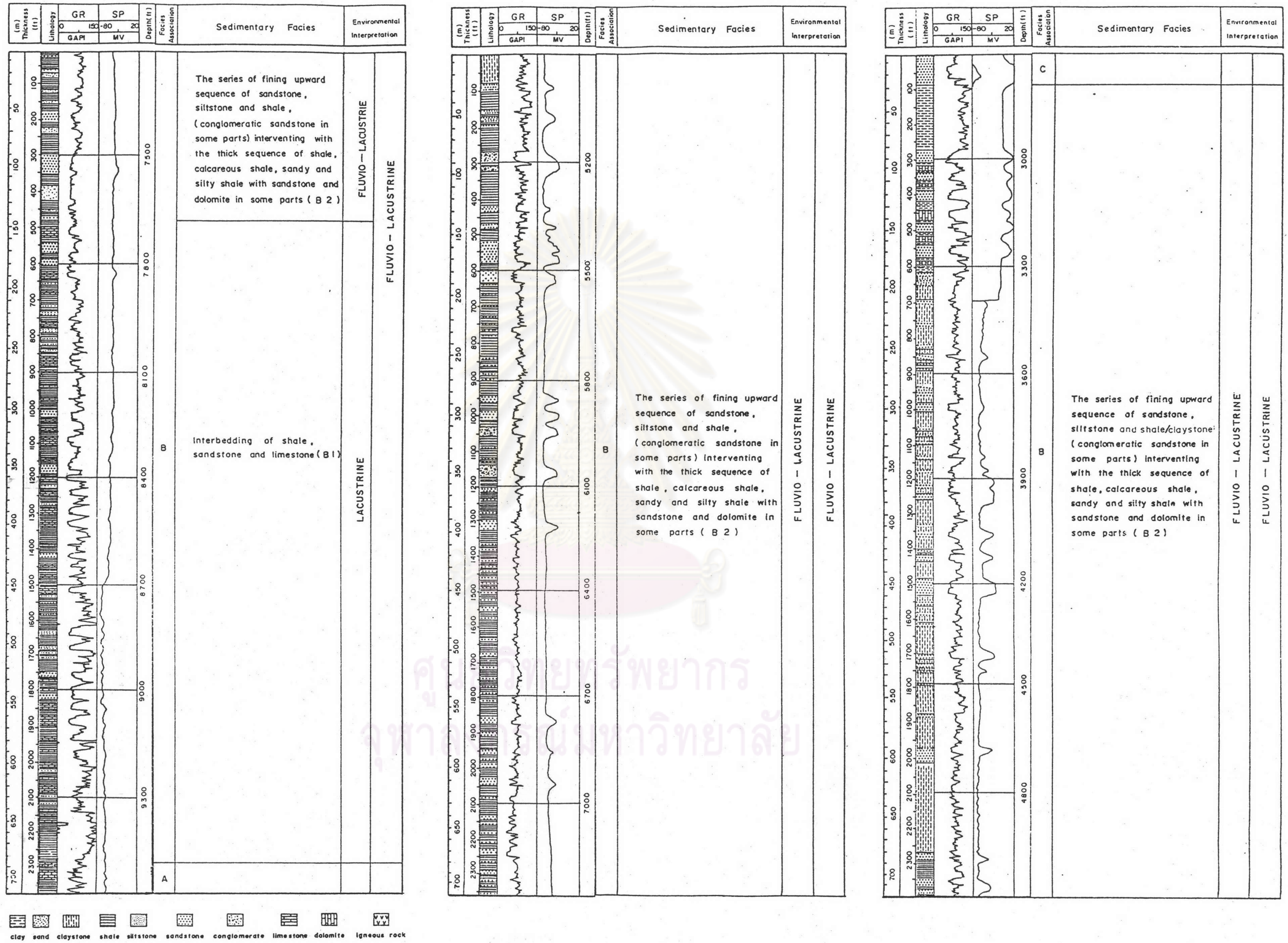

Figure 3.3 b Summarized the depositional environments of Facies association B.

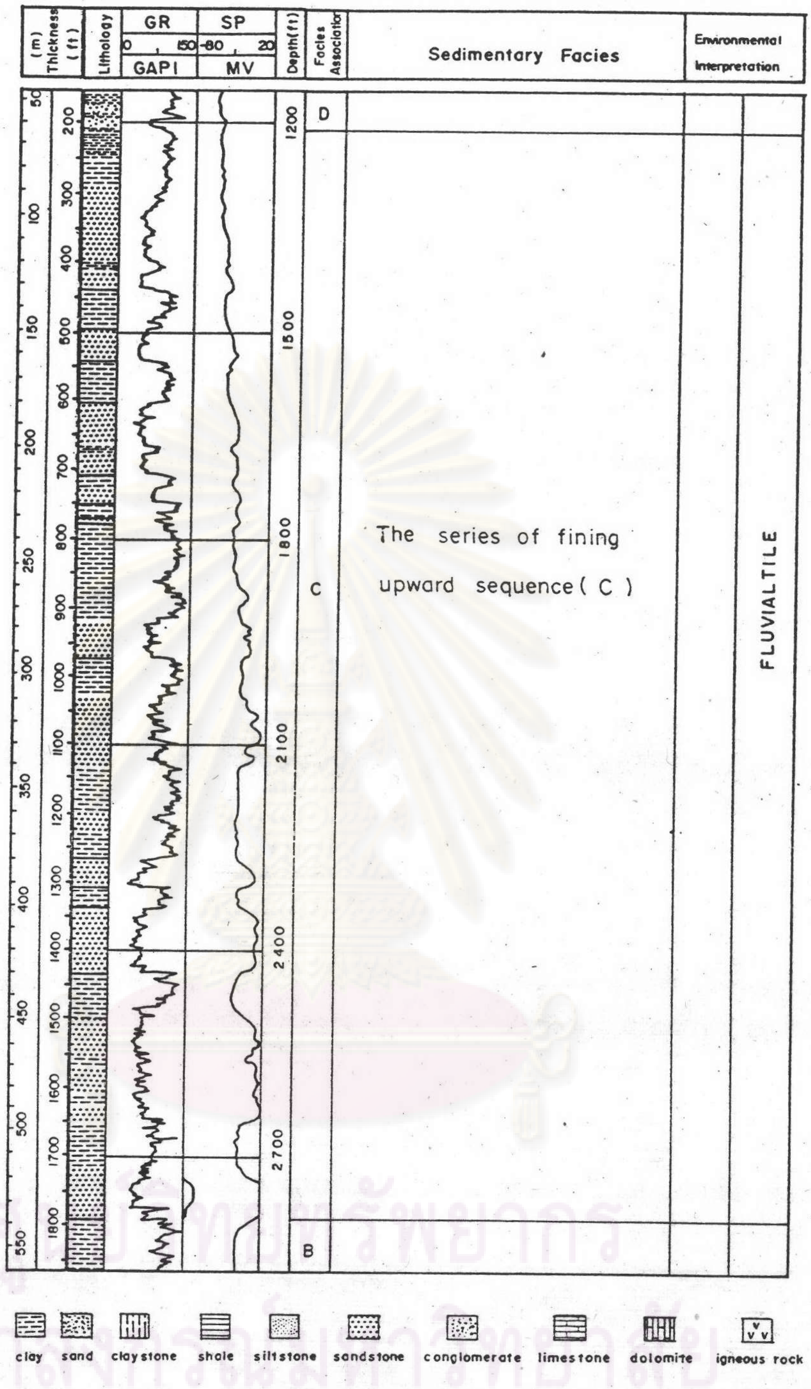

Figure 3.3 c Summarized the depositional environments of Facies association C.

The uppermost unit of sedimentary sequence within Hua Hin basin is the unit D which unconformably? overlies the unit C and is represented by the sedimentary facies D. The sedimentary facies D is characterized by association of sand and clay with the sand/clay ratio of 1:1. The facies is approximately 400 metres thick. The overall geometry of the unit D is tabular covering over the study areas. The characteristics of sedimentary facies D is summarized and presented in Figure.3.3.d.

3.4 Proposed Depositional Model

The sedimentary facies within the Hua Hin basin have been analyzed for the interpretation of depositional environments. The characteristics of each sedimentary facies, namely, lithology, sedimentary structure, external geometry and fossil are used to compare with the appropriate facies models. Consequently, all possible depositional environments are defined from the analogous study of sedimentary facies concerned with the facies models. All in all, the depositional environment is concluded from the detailed analysis of all possible depositional environments into the most possible one.

3.4.1 Depositional Environment of Facies A

As a matter of fact, the Hua Hin basin was developed as the half-graben and has been subsided during the deposition of facies A. The Hua Hin basin was formed by the listric normal fault, during rapid subsidence to form the graben, and the sedimentary facies associated faults, such as, alluvial fan, talus, etc. may be deposited in the basin. The sedimentation of Cenozoic sediments in

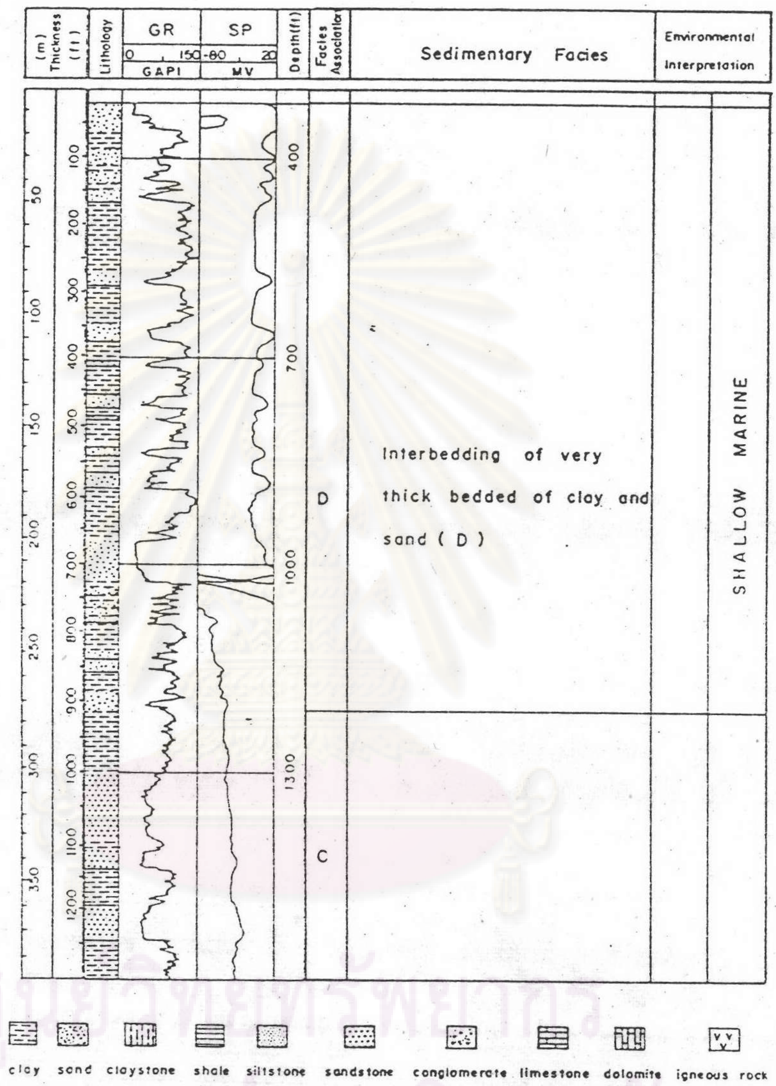

Figure 3.3 d Summarized the depositional environment of Facies association D.

the Hua Hin basin under the present investigation began under the lacustrine environment. The sedimentary facies A as compared with the facies models of Picard and High (1972 and 1981), Reading (1979) and Davis (1983) is interpreted the lacustrine sediments and represented by well laminated of shale interbedded with limestone and minor sandstone. The maximum thickness of the sedimentary facies A is approximately 2,800 metres. The sedimentary facies A is the lowest part of the Cenozoic sequence which was deposited only in deep part of the Hua Hin basin. During the rapid subsidence the initial sedimentation in the Hua Hin basin was the sedimentary facies which associated faulting. Afterthat, the Hua Hin basin was under the lacustrine environment which resulted from the rapid subsidence and caused by high extension regime during the time.

The characteristics of facies A and the environmental interpretation are summarized and presented in figure 3.3. a.

3.4.2 <u>Depositional Environment of Facies Association B</u>

After the lacustrine sedimentation of the sedimentary facies A, the Hua Hin basin was uplifted because of the compression regime in the region. This caused the erosion and tilting of the facies A. The unconformity between facies A and facies B is assigned as the Late Oligocene to Early Miocene age earlier discussed in 3.2.4. During the deposition of facies B, the area of Hua Hin basin was extended wide-spreadly in the upper part and the deep half- graben configuration was abandoned. This is believed to have the influence on the fluvialtile sedimentation in the upper sequence of the facies association B.

The lacustrine sediments of the sedimentary facies A is overlain by the lacustrine sediments of sedimentary facies B1. The sedimentary facies B1, as compared with the facies models of Kukal (1971), Picard and High (1972 and 1981), Reading (1979) and Potter (1980) is considered to be the lacustrine sediments represented by the interbedding of well laminated of shale, limestone and sandstone. The thickness of the sedimentary facies B1 is approximately 500 metres. Therefore, after the deposition of sedimentary facies A followed by the uplifting and erosion, the Hua Hin basin was again subsided and continued to be deposited under the influence of lacustrine environment of facies B1. The subsidence was presumably the result of movement of the listric normal fault which control the development of this basin. The many episodes of subsidence are represented by the medium-grained clastic influx under the influence of high energy regime in this facies than that of the facies A. The subsidence rate was rather slow in the upper part of the facies B1 and consequently the basin was gradually silting up toward the top of this facies.

After the deposition of sedimentary facies B1, the area of Hua Hin basin was filled up by the approximately 1,300 metres thick of the sedimentary facies B2. This sedimentary facies is represented by a series of fining-upward sequence intervening with the shale/claystone interbedded with minor sandstone and/or carbonate rocks. A series of fining-upward sequence of this sedimentary facies, as compared with the facies models of Allen (1964), Walker (1984), Reading (1978), Selley (1980), Miall (1982) and Davis (1983) is concluded to be the channels and banks of high sinuosity meandering stream of fluvialtile environment. On the other hand the shale/claystone interbedded with minor sandstone and carbonate rocks of this sedimentary facies B2, as compared with the facies models of Petersen et al., (1963), Muller and Irion (1969), Picard and High (1972,1981), Reading (1979), Potter (1980) and Davis (1983), is concluded to be lacustrine environment. Therefore, during the deposition of facies B2, the Hua Hin basin had undergone many episodes of subsidence and silting up as represented by several cycles of fluvio-lacustrine sediments.

In short, during the deposition of the facies association B the area of Hua Hin basin had been slowly subsided under the influence of the decreasing extension rate in this region. During the time when lower portion of this facies was deposited under the lacustrine environment, the configuration of the Hua Hin basin was characterized as a half-graben. After this, the half-graben of the basin was filled up and the deposition of the upper portion of this facies was deposited under the fluvio-lacustrine environment, throughout the Hua Hin basin and other areas in the Upper Gulf of Thailand. The major faulting in the Hua Hin Basin was terminated at the end of the deposition of the facies association B of fluvio-lacustrine environment.

The characteristics of facies association B and their environmental interpretation are summarized and presented in Figure 3.3. b.

3.4.3 Depositional Environment of Facies C

The facies C unconformably overlies the facies association B. This Late Miocene unconformity is well-known and widely distributed in the SE Asia indicating the time of final E to W extension of the Cenozoic basins in this region. After the end of deposition of the facies association B, the Hua Hin basin and adjacent area were characterized by rather flat topography and the facies C was uniformly deposited under tectonically quiescence to slow subsidence episodes throughout the Upper Gulf of Thailand.

The sedimentary facies C is characterized by the series of fining upward sequence of sandstone and clay and the overall geometry of this facies is tabular-shaped. The sedimentary facies C as compared with the facies models of Allen (1965), Walker (1984), Reading (1979), Selley (1980) and Davis (1983) is defined to be the channels and banks of meandering stream of the fluvialtile environment.

The characteristics of the facies association C and the environmental interpretation is summarized and presented in Figure 3.3 c.

3.4.4 Depositional Environment of Facies D

The uppermost facies of Cenozoic sediments in the Hua Hin basin is the facies D. After the uplifting during the Pliocene, the renewed subsided was initiated at the Late Pliocene to Pleistocene time with evidence in the Lower Central Plain (Nutalaya, 1984). The facies D was deposited under the slow rate of subsidence in the area of Hua Hin basin during Pliocene to Holocene. As a matter of fact, the Tertiary sedimentation throughout the SE Asia was influenced by the episodes of transgressions and regressions. From the study of Beddoes (1980), the first marine transgression was defined during Eocene to Early Oligocene, followed by the second widespread marine transgression in this region during Late Oligocene to the end of Early Miocene time. Afterthat, the Middle Miocene regression occurred and followed by minor transgression in Upper Middle Miocene. The episode of maximum regression was defined during Late Miocene to Early Pliocene and followed by the Early Pliocene transgression. Throughout the Pliocene to Holocene, there are several periods of fluctuation of the sea level in SE Asia which would have caused regressions and transgressions in the basins in this region (Hutchison, 1986). The major marine regression of world-wide glaciations during the Pleistocene time have effected the shallow sea in the SE Asia. The initial marine transgression in the southern part of the Gulf of Thailand was define during Eocene to Early Oligocene (Woolland & Haw, 1976 ;and Lian & Bradley,198) and the incursion of the sea in the Northern part of the Gulf was considered to be during Early Pliocene (Pradidtan,1990). The timing of the initial incursion of the sea in the Lower Central Plain is unknown but the last marine transgression in the Lower Central Plain is defined as Middle Holocene (Somboon, 1990). The marine fluctuation in SE Asia during Middle Paleogene to Holocene are summarized and presented in Figure 3.4.4.a. To sum up, the sedimentation in the Hua Hin basin and adjacent area was influenced by the marine fluctuations during Pliocene to Holocene.

Time				Sea level change in SE Asia	Depositional Unit in the Hua Hin basin
Quat.	Pleisto.	Holocene		Transgression	D
		Pleistocene		Regression	
Tertiary	Neogene	Pliocene		Transgression	
		Miocene	Late	Regression	C
			Middle	minor transgression	B
				Regression	
			Early	Transgression	
	Paleogene	Oligocene	Late		A
			Early	Regression	—
		Eocene		Transgression	—

Figure 3.4.4 a The eustatic changes in sea level of SE Asia.
(after Beddose, 1980)

The sedimentary facies D is characterized by the interbedding of clay and sand. Evidences from the sedimentation during Pliocene to Holocene in Chao Phraya basin in the Lower Central Plain in the north and Western basin, Chumporn basin, Pattani basin as well as Malay basin in the southern indicate the marine transgression (Pradidtan. et. al, 1990). Therefore, the sedimentation of facies D was concluded to be under the marine environment. The sedimentary facies D, as compared with the facies models of Heckel (1972), Reading (1979), Selley (1980), Miall (1982) Davis (1983), Galloway & Hobday (1983), Walker (1984) and Klein (1985), MeCave (1985), Fraser (1989) are considered to be the shelf-clay and wave /tidal current-sand which were deposited under the shallow marine environment.

The characteristics of sedimentary succession has been summarized and presented in Figure 3.3.d.

In general, the Hua Hin basin had been developed under tectonic influences, such as, the extension, the major faulting, and the sea-floor spreading in this region. These activities combined with other factors, namely, climate, source of sediments, etc. within this area, affect the sedimentation in the basin. To sum up, the Cenozoic sedimentary sequences of the Hua Hin basin was initially deposited under the lacustrine environment at the lowest part of the basin which formed the deep half-graben. Thereafter, the upper part of basin was filled up by the fluvio-lacustrine environment. Consequently, the fluvialtile sediments were wide-spreadly deposited over the Hua Hin basin and other area in the Upper Gulf of Thailand. Finally, the marine sediments were accumulated in the uppermost part of basin and adjacent areas (Fig. 3.4.4.b).

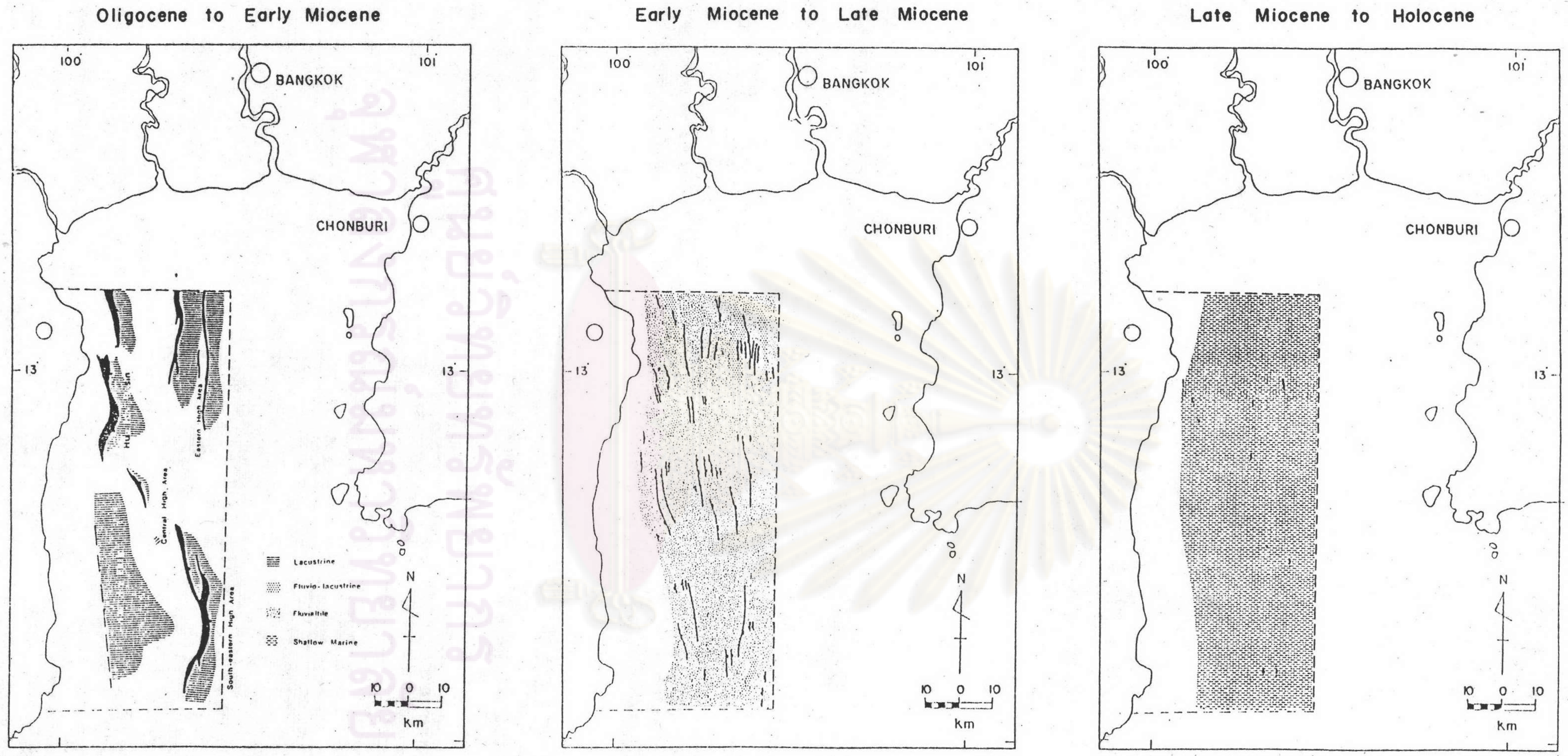

Figure 3.4.4 b Facies maps of the study area.

3.5 The Hua Hin Basin Model

In conclusion, from the previous investigations on the Tertiary basins in the Gulf of Thailand, there are three main ideas about the development of these basins. The first idea is defined during 1974 to 1987 by many geologists, such as, Achalabhuti (1974,1980, 1981, Paul and Lian (1975), Bunopas (1980), Mitchell (1985), Gatinsky (1986), Hutchison (1986) and Prididtan (1987). It is believed that the development of the Tertiary basins in the Gulf is concluded to be the result of the plate motions in SE Asia during the Late Cretaceous to Early Tertiary. The activities of plates in SE Asia were closely related to the movements of India toward Asia, the sea-floor spreading, rifting and emplacement of granites in this region. Most of geologists defined these basins as the rift basin model. However, few geologists, such as, Mitchell (1985) and Hutchison (1986) classified these basins as the back-arc basin model. During 1986 to 1988, few geologists, such as, Hutchison (1986), Lian and Bradley (1988) and Polachan (1988), suggested the new idea about the construction of these basins. This is the second idea which is believed that the Tertiary basins in the Gulf of Thailand are the shear basin model or continental wrench basin model forming by the interaction of wrench faults. Finally, during 1987 to 1989 the combination of the first and second ideas is formulated into the third idea by many geologists, such as, Daly, Hooper and Smith (1987), Chinbunchorn, Pradidtan and Sattayarak (1989) and Polachan and Sattayarak (1989). In this idea, the development of the Tertiary basins in the Gulf of Thailand are the result of the plate motion in SE Asia during Late Mesozoic to Early Cenozoic combined with the interactions of wrench faults in this region. These basins are classified as the rift/ pull apart basin model.

On the whole, most sedimentary basins develop in the series of many stages with each stage is a response to a particular tectonic setting at different geological time. Therefore, a mature basin may have a complex tectonic history with a diverse assemblage of structural styles and sedimentary fill. For the purpose of interpreting modern and ancient sedimentary basin, a series of basin models are suggested and described the depositional systems, geological structures, geometry and tectonic setting for each one. These basin models are a powerful tool for interpreting the regional plate tectonic history.

There are several excellent classifications of basin models that have been used in this study, such as, Miall (1984), Ingersoil (1988), that are presented in Tables 3.5a & 3.5b. As noted for the study, the many basins have undergone two or more development stages. The each stage has a different tectonic setting, structural style and depositional system.

The structural style of the Hua Hin basin is dominated by mainly N-NW to S-SE, N-NE to S-SW and N to S normal faults, accompanied by the antithetic faults and roll-over. The normal faults control the development of the Hua Hin basin and influence the configuration of the basin. The basin is elongated mainly in the N-NW to S-SE trend. The basin is approximately 9-10 kilometres wide and 100 kilometres long is aligned along the west coast of the Upper Gulf of Thailand from Phetchaburi to Prachuap Khirikhan provinces. The

Table 3.5 a Classification of the types of sedimentary basin. (after Miall,1984)

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1. Divergent margin basins
    - Rift basins
        - Rifted arch basins
        - Rim basins
    - Ocean margin basins
        - Red sea type
        - Atlandtic type
    - Aulacogens and failed rifts
2. Convergent margin basins
    - Trenches and subduction complexes
    - Forearc basins
    - Interarc and backarc basins
    - Retroarc basin
3. Transform and transcurrent fault basins
    - Basin setting
        - Plate boundary transform fault
        - Divergent margin transform fault
        - Convergent margin transcurrent fault
        - Suture zone transcurrent fault
    - Basin type
        - Basin in braided fault systems
        - Fault termination basins
        - Pull-apart basins in en echelon fault systems
4. Basins developed during continental collision and suturing
    - Foreland basins
    - Peripheral basins
    - Intra-suture embayment basins
    - Associated transcurrent fault basins
5. Cratonic basins

Table 3.5 b Basin Classification.
(after Ingersoll 1988)

Divergent setting

- Terrestrial rifts valley
- Proto-oceanic rift
- Continental rises and terraces
- Failed rifts and aulacogens
- Intracatonic basins
- Oceanic basins
- Oceanic islands

Convergent setting

- Trenches
- Trench-slope basins
- Forearc basins
- Intra-arc basins
- Interarc and backarc basins
- Retroarc foreland basins
- Remnant ocean basins
- Peripheral foreland basins
- Piggyback basins
- Foreland intermontane basins

Transform setting

- Transtensional basins
- Transpressional basins
- Transrotational basins

Hybrid settings

- Intracontinental wrench basins
- Successor basins

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major normal faults which controlled the formation of the basin lie on the west of the basin corresponding to the depocentic features in the west. The faults are the listric normal fault which is believed the effect of the inter actions and movements of the transcurrent faults in the area. They are, Pranburi- Hua Hin, Three- Pagodas and Ranong- Khlong• Marui faults. The activities of these transcurrent faults are believed to be caused by the plate movement in this region. The collision of India with Asia was the main cause of the formation of these transcurrent faults during the Late Cretaceous to Early Tertiary. Afterward, the tectonics of the plate motions, such as, sea-floor spreading, rifting and uplifting were still active during that time and are the result in the changing sedimentation in this basin. The sedimentary facies associated faulting were deposited during the same time of basin forming. Afterthat, the sediments of lacustrine environment were accumulated in the lower sequence of basin. Thereafter, the middle sequence of basin was represented by the fluvio- lacustrine sediments. Then the fluviatile sediments were deposited over the area in the Upper Gulf and is finally covered by the shallow marine sediments.

Upon comparing the Hua Hin basin with the basin models of Miall (1984), Baillie (1987), Ingersoil (1988), it concluded that the Hua Hin basin had been developed in many stages. At the Late Mesozoic to Early Cenozoic, the plate collisions in the SE Asia produced the compression shear stress in this region which caused by the activities of major transcurrent faults. Transtensional stage and back arc stage possibly developed at that time. Subsequently, the cratonic crust attenuations are represented by the rifting stage with extension stress regime. During the rifting stage, the effects of shear and compressional, extensional stress are represented by the activities of transcurrent faults, subsequently plate collision and sea- floor spreading.

As a result, the Hua Hin basin may be initially developed as transtentional or back arc basin models. However, there is no evidence of magmatic arc and back arc sedimentation, therefore at that time the basin was possibly classified as the transtensional basin model. Then the subsequently tectonics were active represented by the rifting stage combined with the transtensional stage. Therefore, in the present investigation, the mature Hua Hin basin is concluded to be the rift/ transtensional basin or associated transcurrent fault basin.