

CHAPTER 3

LITHOSTRATIGRAPHY OF THUNG YAI-KHLONG THOM AREA

The strata in any sedimentary sequence can be subdivided on the basis of their physical characteristics, fossil content or their time relationships. Accordingly, three kinds of units have been established. They are lithostratigraphic units, biostratigraphic units and chronostratigraphic units. In this study, the sedimentary sequences have been classified on the basis of lithostratigraphy. A lithostratigraphic unit is a body of rock strata which is unified by consisting dominantly of a certain lithological type, or combination of lithological types, or by possessing other impressive and unifying lithological features.

3.1 Stratigraphic classification and nomenclature

In this study, an attempt has been made to classify sedimentary sequences in the Thung Yai-Khlong Thom area into different lithostratigraphic units in order to fulfill the sedimentological purpose of the study. Boundaries separating lithostratigraphical units may be placed at transition, abrupt and erosional contacts, which in return reflect the changes of conditions of depositional environment.

The ultimate objective of subdividing the strata is to identify all of them and then to assemble a framework of non-overlapping units for designating hierarchies of lithostratigraphic units employed in the present study to cover the group, the formation and the lithofacies. However, with regard to the nomenclature of lithostratigraphic units, informal names have been used for the purpose of tentative reference.

The Trang Group is in a very confusing state with the earlier proposed name of the Trang Formation (Nakanart and Mantajit, 1983) having the type location within wildcat wells in the Andaman Sea. The Trang Formation consists of laminated shale, laterally change to argillaceous limestone and grade to glauconitic siltstone in Middle Miocene. The previous lithostratigraphic nomenclature schemes used for the Trang Group (Table 2.4) are those of Raksaskulwong (1994). Under the present study the lithostratigraphic nomenclature of non-marine Mesozoic rock in the Thung Yai-Khlong Thom area is accordingly proposed as “Trang group”.

In order to establish the lithostratigraphy of the Trang group, totally 17 sections have been measured in details and many other nearby localities have also been investigated. The lithostratigraphic units are described and defined as suggested in the International Stratigraphic Guide (Hedberg, H.D.,1994) and detailed measured rock sections, distributed throughout the this study area, are graphically represented using the keys from Selly (1996) (Figure 3.1), and attitudes of beds, fractures and faults are expressed in terms of dip direction/dip angle.

3.2 Measured sections

This study embraces two parts, namely, the field investigation and the laboratory work. During the field investigation, about 150 rock samples have been collected from 17 measured sections around the Thung Yai-Khlong Thom area (Figure 3.2), as follows:

- Section A at Khlong Min (grid reference 497974, map sheet 4825 II)
- Section B at Khlong Min to Khao Nam Daeng (grid reference 500970 to 507970, map sheet 4825 II)
- Section C at Khlong Min (grid reference 508001, map sheet 4825 II)
- Section D at Khao Tao (grid reference 514042, map sheet 4825 II)
- Section E at Ban Ao Tong (grid reference 457728, map sheet 4824 I)

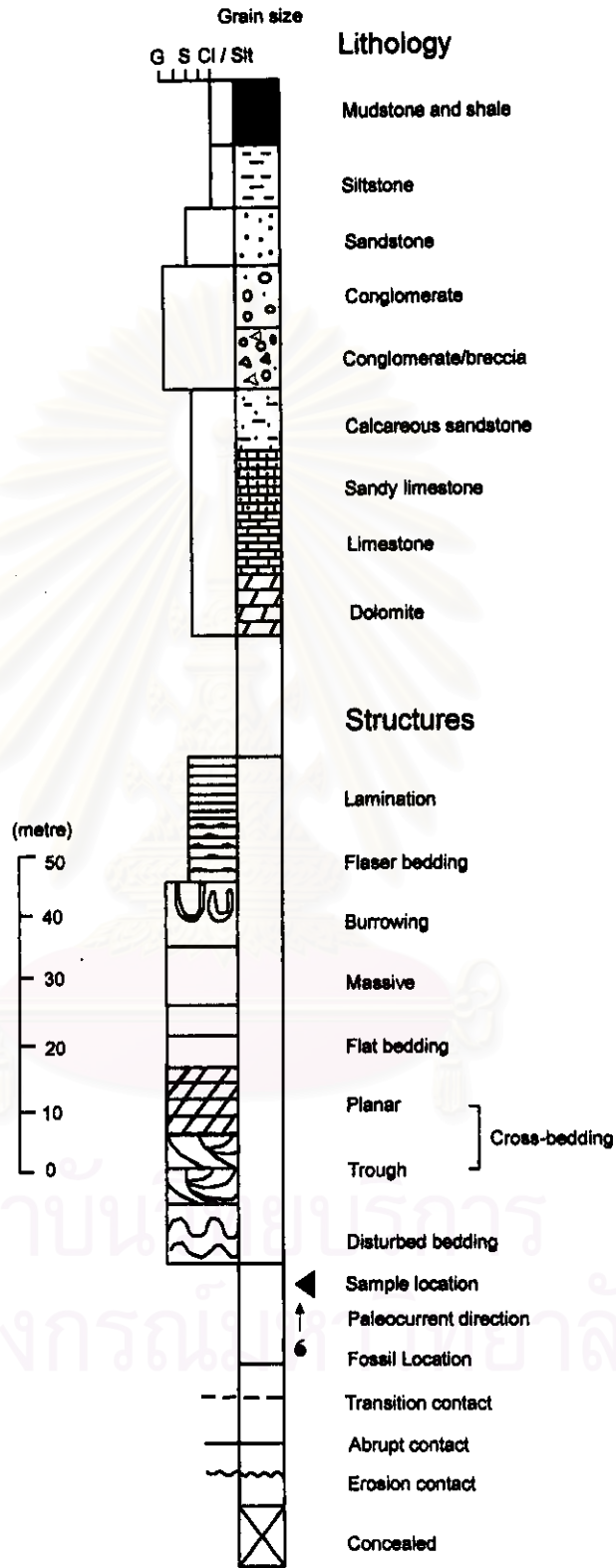


Figure 3.1 Detailed measured sections, illustrated throughout the thesis, are drawn using the above keys (modified from Selley, 1996)

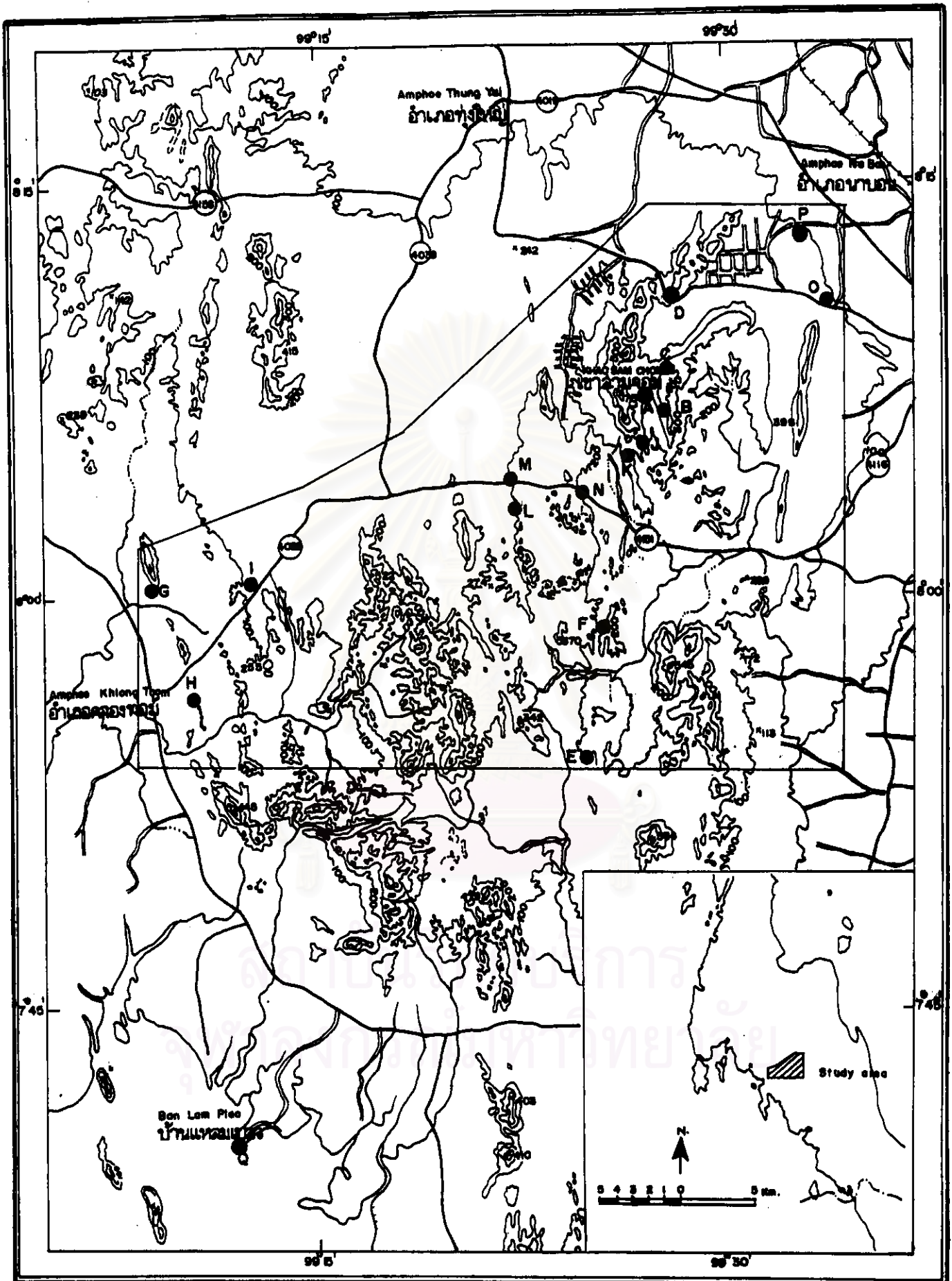


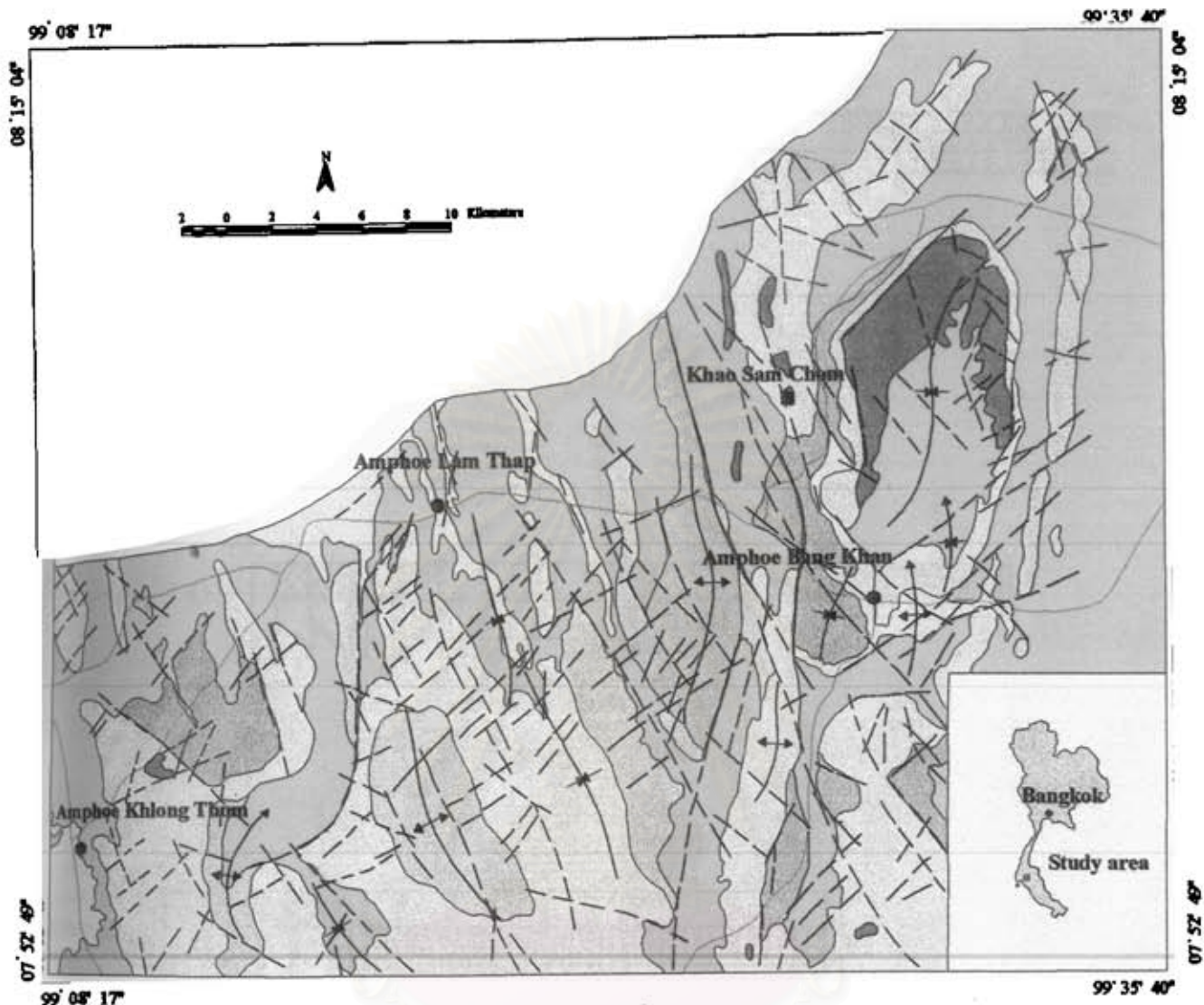
Figure 3.2 Location map of measured sections

- Section F at Lam Thap (grid reference 473805, map sheet 4824 I)
- Section G at Lam Thap (grid reference 165847, map sheet 4825 III)
- Section H at Lam Thap (grid reference 177773, map sheet 4824 IV)
- Section I at km.10 Lam Thap-Khlong Thom road no. 4038 (grid reference 232841 to 229837, map sheet 4824 IV)
- Section J at the southern part of Khao Sam Chom (grid reference 49794, map sheet 4825 II)
- Section K at the southern part of Khao Sam Chom (grid reference 497940, map sheet 4825 II)
- Section L at Khuan Sanai (grid reference 414895, map sheet 4825 II)
- Section M at Khuan Sanai (grid reference 413913, map sheet 4825 II)
- Section N at Khuan Sanai (grid reference 451915, map sheet 4825 II)
- Section O at km.13 Thung Yai-Thung Song road no. 4108 (grid reference 608041, map sheet 4825 II)
- Section P at Khao Khom (grid reference 596093, map sheet 4925 III)
- Section Q (reference section) at Laem Pleo (grid reference 224476, map sheet 4824 III)









The topography of the study area is generally high mountainous and undulating landforms, the maximum elevation is at Khao Sam Chom (754 metres MSL). The Thung Yai-Khlong Thom area is between latitudes $7^{\circ}52'49''$ N to $8^{\circ}15'04''$ N, and longitudes $99^{\circ}08'17''$ E to $99^{\circ}5'40''$ E. There exists several complete sections of the Trang group with good continuity at the Ban Mab Ching, Khlong Min, Ban Ao Tong and Laem Pleo, respectively (Figure 3.3).

Section A

Section A is located at Khlong Min, Ban Mab Ching about 20 kilometres west of Thung Song, Nakhon Si Thammarat. The total thickness is approximately 186 metres and 28 rock samples have been collected from mudstone intercalated with fossiliferous limestone. The attitude of bedding at this measured section generally dip direction and dip angle is $090/45$ as shown in Table 3.1 and Figures 3.4 and 3.5.



EXPLANATION

-  Floodplain deposits; Sand, silt and clay.
-  Colluvium deposits; Sand, silt, clay and gravel.
-  Phun Phin formation; Sandstone, fine-grained, red-maroon with x-bedding, siltstone and fanglomerate.
-  Sam Chom formation; Conglomerate, conglomeratic sandstone with clast support.
-  Lam Thap formation; Arkosic sandstone, thick bedded, brown to yellowish brown; conglomeratic sandstone, dense with *Unio sp.*
-  Khlong Min formation; Mudstone, sandstone, marl and limestone with fossiliferous beds
-  Sai Bon formation; Siltstone, red-maroon with sandstone, limestone and limestone lense.
-  Ratburi Group; Limestone, dark gray, massive to bedded.

SYMBOLS








-  Boundary
-  Fault, Fracture
-  Anticline
-  Syncline
-  Road
-  Reservoir
-  Amphoe

Figure 3.3 Geological map of the study area.

Legends

-  Mudstone and shale
-  Siltstone
-  Sandstone
-  Conglomerate
-  Conglomerate/breccia
-  Calcareous sandstone
-  Limestone
-  Dolomite
-  Lamination
-  Flaser bedding
-  Planar } Cross-bedding
-  Trough }

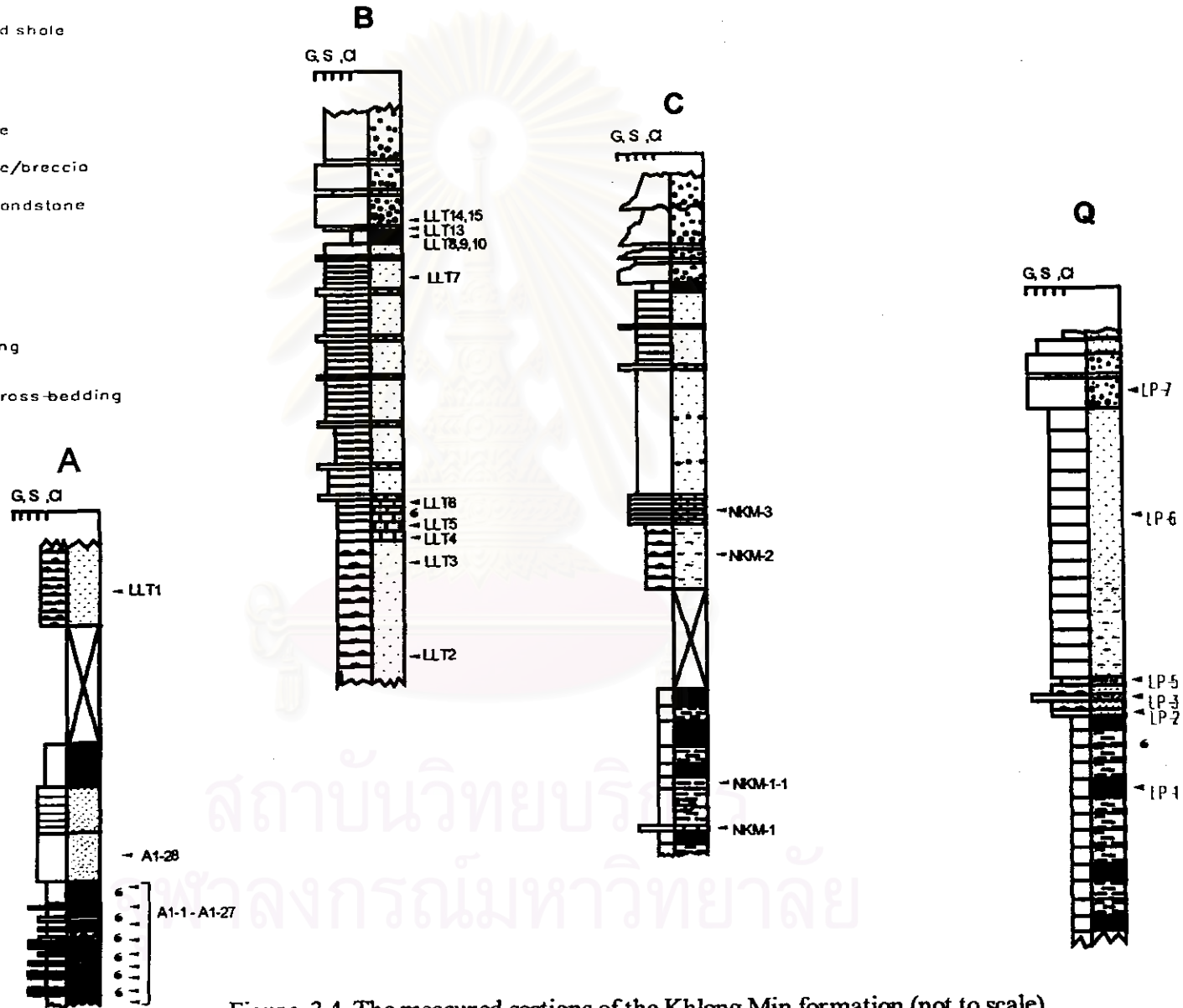


Figure 3.4 The measured sections of the Khlong Min formation (not to scale)

Table 3.1 Measured section A, grid reference 497974 (4825 II)

Section of sedimentary rocks of the Trang group, Khlong Min formation, Thung Song of Nakhon Si Thammarat.

Date 28/5/40

Khlong Min formation (Type section)

Thickness (m.)

(185.6 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (soil cover)
0.4	1	Mudstone, light gray, with abundant fossils, bedding 110°/35°, sample No. A1-1
0.25	2	Shale, grayish black to brownish black, moderately <i>Estheria</i> sp. at 0.45 m, sample No. A1-2
0.5	3	Shale, brownish black, abundant plant remains, moderately <i>Estheria</i> sp., Ostracod and <i>Modiolus</i> sp. at 1.0-1.05 m, sample No. A1-2
0.65	4	Shale, light gray, high weathering, rare <i>Modiolus</i> sp. at 1.37 m, sample No. A1-3
0.35	5	Shale, grayish black, abundant <i>Modiolus</i> sp. at 2.0 m, sample No. A1-4
0.2	6	Shale and peaty mudstone, brownish black, rare <i>Estheria</i> sp. at 2.2 m, sample No. A1-5
0.35	7	Mudstone, light gray, high weatering, with yellowish brown mottle, moderately <i>Lopha</i> sp. at 2.62 m, sample No. A1-6
0.1	8	Limestone lenses, gray, moderately fossils especially <i>Lopha</i> sp.
0.70	9	Mudstone, light gray, moderately weathering, yellow mottle
0.10	10	Limestone lenses, gray with abundant fossils
0.55	11	Mudstone, light gray, moderately weathering, mottle yellow, moderately Ostracod, <i>Eomiodon</i> sp. and <i>Lopha</i> sp. at 3.65,3.78 m, sample No. A1-7
1.4	12	Shale, greenish gray, abundant <i>Myrene</i> sp., <i>Ursivirus</i> sp. and <i>Jurassicorbula</i> at 4.3 m., and 5.35 m., bedding 100°/30°, sample No. A1-8
0.6	13	Mudstone, light gray, moderately mottle, with limestone lenses, sample No. A1-9
0.05	14	Mudstone, peaty, grayish black
0.30	15	Mudstone, light gray to gray, rare fossils
0.05	16	Mudstone, peaty, grayish black
0.45	17	Mudstone, light gray to gray, rare fossils
0.10	18	Limestone lenses, gray with abundant fossils
0.20	19	Mudstone, light gray to gray, rare fossils
0.10	20	Limestone lenses, gray with abundant fossils

Table 3.1(cont.) Measured section A

Thickness(m)	Unit No.	Description
0.20	21	Mudstone, light gray to gray, rare fossils
1.10	22	Shale, greenish gray, with vertebrate at 7.85 m. and abundant Ostracod, and <i>Ursivirus</i> sp. at 8.25-8.33 m., sample No. A1-10
0.8	23	Shale, greenish gray; siltstone interlayered, rare Ostracod and peaty increasing upward at 9.35-9.4 m.
1.20	24	Argillaceous limestone interbedded with mudstone, thin-bedded, containing moderately vertebrate and abundant <i>Lopha</i> sp., <i>Modiolus</i> sp., <i>Protocardia</i> sp., sample No. A1-11
0.30	25	Shale, reddish to brownish black, rare <i>Modiolus</i> sp.
2.0	26	Calcareous shale, gray, rare fossils, sample No. A1-12
0.5	27	Siltstone and very fine-grained sandstone with limestone lenses, light gray, moderately mottle, yellowish brown, sample No. A1-13/1
0.15	28	Shale, light gray, abundant vertebrates, <i>Rugosus</i> sp., <i>Eomiodon</i> sp., <i>Isognomon</i> and <i>Lopha</i> sp., sample No. A1-14
0.15	29	Sandstone, very fine-grained, yellowish brown with shell fragment layers at 13.65 m.
0.40	30	Siltstone and mudstone interbedded, light gray, moderately reddish brown to yellowish brown mottle
0.80	31	Calcareous shale, gray, with gypsum crystals, rare vertebrate and abundant fossils (invertebrate), sample A1-15
0.40	32	Argillaceous limestone, light gray to gray, thin-bedded, rare fossils
0.80	33	Calcareous shale, gray, with gypsum crystals, with vertebrate and abundant fossils (invertebrate), weathering increasing upward
0.50	34	Argillaceous limestone, light gray, abundant fossils increasing upward mainly <i>Lopha</i> sp., sample No. A1-16
0.75	35	Sandstone, very fine-grained, yellowish brown to brown, rare <i>Lopha</i> sp. and <i>Modiolus</i> sp., sample No. A1-17
1.15	36	Siltstone, light gray to gray, rare <i>Neomiodon</i> sp.
0.95	37	Siltstone, yellowish gray, coarsening upward with sample No. A1-18
0.05	38	Sandstone, fine-grained, yellowish brown and borrow fill, sample No. A1-19
0.15	39	Mudstone, brownish gray, peaty.
2.45	40	Mudstone, light gray to gray, moderately <i>Neomiodon</i> sp., <i>Myrene</i> sp. and <i>Ursivirus</i> sp. with limestone lenses, sample No. A1-21
0.05	41	Sandstone, fine-grained, yellowish brown, sample No. A1-22
0.05	42	Mudstone, gray, peaty
0.13	43	Sandstone, very fine-grained, thin-bedded with sample No. A1-23
2.07	44	Shale, light gray to gray, rare <i>Eomiodon</i> sp. at 24.5 m., abundant shell fragments at 24.4 m., sample No. A1-24
1.15	45	Mudstone, light gray with moderately yellowish brown mottle
0.20	46	Limestone, gray, abundant fossils with sample No. A1-25/1

Table 3.1(cont.) Measured section A

Thickness(m)	Unit No.	Description
1.0	47	Siltstone and calcareous mudstone, brownish black, abundant organic matters, abundant shell fragment layers at upper part, sample No. A1-26
0.50	48	Shale, brownish black, abundant organic matters
0.20	49	Shale, gray, fossiliferous
2.75	50	Oil shale, brownish black and peaty increasing at lower part, bedding 105°/45°, with sample No. A1-26
1.3	51	Mudstone, brownish black, moderately <i>Unio</i> sp., Ostracod, <i>Myrene</i> sp. and <i>Ursivirus</i> sp. at 31.8 m., with sample No. A1-27
2.7	52	Shale, brownish black, rare fossils
0.1	53	ditto
18.0	54	Sandstone, very fine-grained, yellowish brown, interbedded with siltstone at lower part and decreasing upward, sample No. A1-28
15.0	55	Sandstone, fine-grained, maroon to reddish brown, calcareous and caliche, very rare fossils
18.0	56	Mudstone interbedded with laminated siltstone, maroon to grayish brown
110	-	(concealed probably siltstone, marl and mudstone)

**A****B**

Figure 3.5 The location of measured sections. (A) Section A at Khlong Min (grid 497974, 4825 II); (B) Section B at Khlong Min (grid 500970, 4825 II).

Section B

Section B is located approximately in the southeast of section A of totally 150 metres thick. Four rock samples have been taken from the lower part. They consist of siltstone, mudstone, marl, and limestone beds with vertebrate fossils. The 3 samples collected from upper limestone bed contain abundant *Modiolus* sp. and plant remains. The general trend of strata is 080/40 (dip direction/dip angle) as shown in Table 3.2 and Figure 3.5

Section C

Section C is located at the escarpment in the eastern part of Khlong Min approximately 300 metres south of the section A. The sequence is characterised by siltstone, calcareous sandstone and limestone underlying the conglomerate and conglomeratic sandstone in the upper part. The total thickness is approximately 174 metres, 5 rock samples have been taken from the lower part and 6 samples from the upper part. The attitude of bedding is 085/40 (dip direction/dip angle) as shown in Table 3.3 and Figure 3.6.

Section D

Section D is situated at Khao Tao, road no.4110 , km. 22 to km. 25 from Thung Yai to Thung Song, Nakhon Si Thammarat. This section is the stratotype of the Lam Thap formation represented by thick-bedded arkosic sandstone, siltstone interbedded with sandstone and mudstone. The total thickness is 197.3 metres and 8 rock samples have been collected from this measured section. The attitude of bedding is 150/25 (dip direction/dip angle) as shown in Table 3.4 and Figures 3.7 and 3.8.

Section E

Section E is located at Ban Ao Tong, Wang Vi Set, Trang. This measured section is along the road no. 4225 from Bang Khan to Ban Kaun Kun of Sikao, Trang. It consists of arkosic sandstone, siltstone interbedded with sandstone, mudstone and conglomerate. The total thickness is approximately 195 metres, and 7 rock samples

Table 3.2 Measured section B, grid reference 500970 to 507970 (4825 II)

Section of sedimentary rocks of the Trang group, Khlong Min formation, Lam Thap formation and Sam Chom formation, Thung Song of Nakhon Si Thammarat

Date 28/1/42

Khlong Min formation, Lam Thap formation and Sam Chom formation (Type section)

Thickness (m.)

(150 metres)(From bottom to top)

Thickness(m)	Unit No.	Description
60	1	Sandstone, fine-to medium-grained, yellowish brown with flaser bedding, sample Nos. LLT2 and LLT3
10	2	Limestone, gray, thin-bedded with plant fragments and <i>Modiolus</i> sp., sample Nos. LLT4, LLT5 and LLT6
60	3	Sandstone intercalated with onglomerate, brownish yellow-light brown, medium-grained, with sample No. LLT7
2.5	4	Siltstone, orangish red to reddish brown, mod. to high weathering with sample Nos. LLT8, LLT9 and LLT10
0.5	5	Sandstone, light brown, medium-grained, with cross-bedding (010°/30°), bedding 055°/20°, sample No. LLT13
>15	6	Conglomerate, yellowish brown, and clast-supported, gravel-pebble size clasts of quartz, chert, volcanic rocks and sandstone, grade-bedding, and sandstone lenses, sample Nos. LLT14 and LLT15 escarpment of Khao Nam Daeng

Table 3.3 Measured section C, grid reference 508001 (4825 II)

Section of sedimentary rocks in the Trang group, Khlong Min formation, Lam Thap formation and Sam Chom formation, Ban Mab Ching, Thung Song of Nakhon Si Thammarat

Date 25/3/42

Thickness (m)

(174 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
>2	1	Siltstone, maroon, calcareous
3	2	Mudstone, grayish brown with caliche
1	3	Limestone, light gray, thin-bedded with sample No. NKM-1
9	4	Siltstone and limestone lenses, maroon, abundant vertebrates, with sample No. NKM1-1
2	5	Siltstone, maroon
19	6	Siltstone, maroon interbedded, with mudstone, gray with abundant plant remains
23	7	Concealed (soil cover)
15	8	Sandstone, calcareous, yellowish brown with flaser bedding, sample No. NKM-2
7	9	Limestone interbedded sandstone, gray to grayish brown, abundant wood fragments and bivalve (<i>Modiolus</i> sp.), sample No. NKM-3
60	10	Sandstone, conglomeratic sandstone, medium-grained, graded bedding, well sorted, and fining upward sequence
3	11	Mudstone, reddish brown
>30	12	Conglomerate and thin-bedded sandstone, brown to yellowish brown, matrix-supported, clast composes of quartz, chert and rock fragments, with cross-bedding very common



**Figure 3.6 The measured section C at Khlong Min (grid
508001, 4825 II)**

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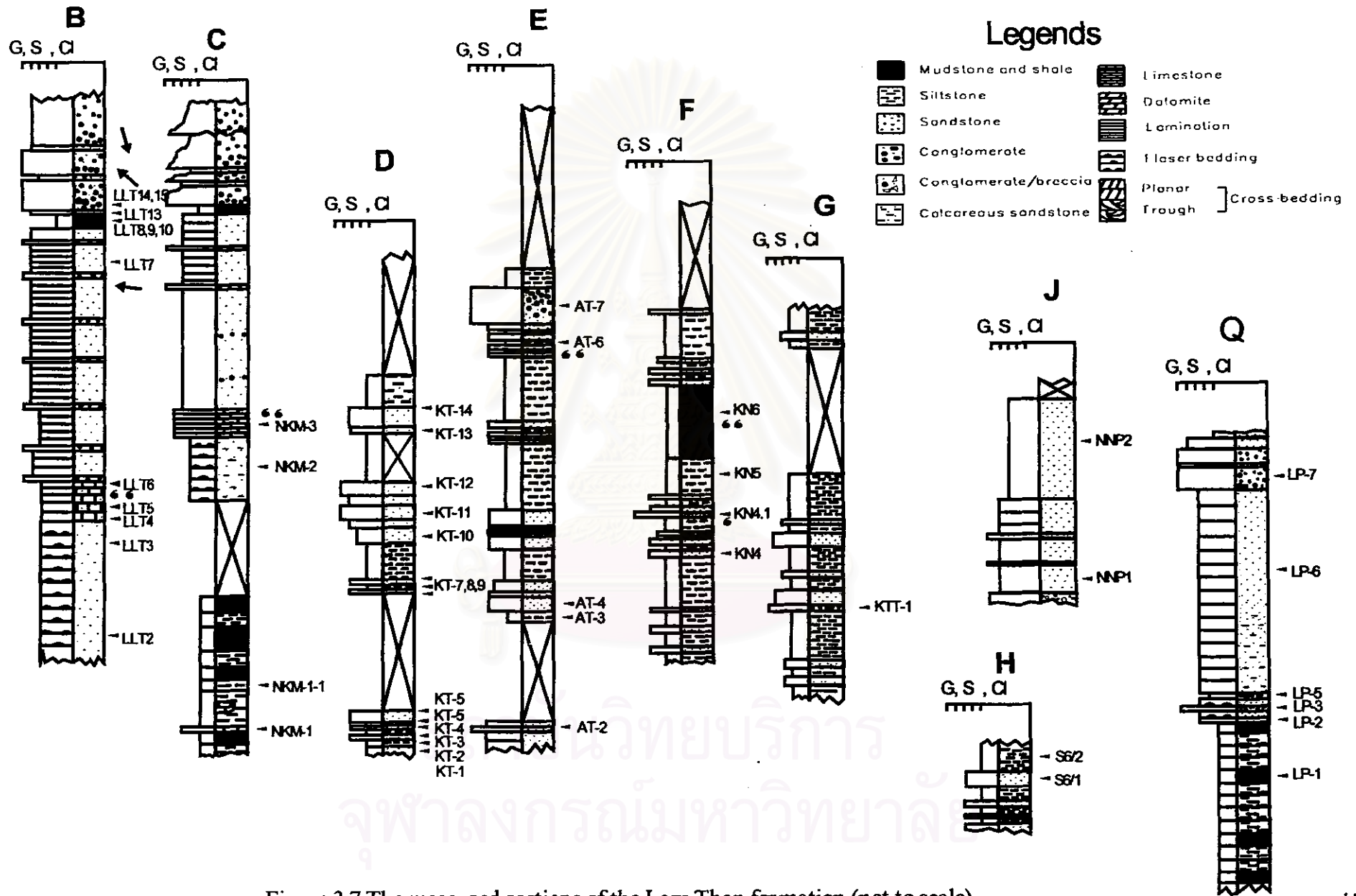


Figure 3.7 The measured sections of the Lam Thap formation (not to scale)

Table 3.4 Measured section D, grid reference 514042 to 520040 (4825II)

Section of sedimentary rocks of the Trang group, Lam Thap formation measured along Thung Yai-Thung Song road no. 4110 from km. 22 to km. 25 to Thung Yai of Nakhon Si Thammarat.

Date 3/3/41

Thickness (m.)

(197.3 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (soil cover)
2.5	1	Sandstone, light brown to pale reddish-brown, medium-grained, thick-bedded, bedding $155^{\circ}/20^{\circ}$ in dip direction/dip angle, sample No. KT-1
2	2	Siltstone, reddish brown to maroon, sample No. KT-2
1.35	3	Sandstone, light brown, medium-grained, thick-bedded, bedding $155^{\circ}/30^{\circ}$, sample No. KT-3
4	4	Siltstone, maroon, interbedded with sandstone, medium-bedded, sample No. KT-4
4	5	Sandstone, yellowish brown, medium-bedded, bedding $145^{\circ}/20^{\circ}$ and $150^{\circ}/25^{\circ}$, sample No. KT-5 at bottom and No. KT-6 at the top bed.
40.5	6	concealed interval (probably siltstone interbedded with sandstone)
1.30	7	Sandstone, light brown, thick-bedded, sample No. KT-8
2	8	concealed interval (probably siltstone)
2	9	Sandstone, light brown, fine-to medium-grained, thick-bedded, sample No. KT-9
12.5	10	concealed interval (probably siltstone)
5.6	11	Sandstone, light brown to yellowish brown, fine-grained, thick-bedded, sample No. KT-10
3	12	Sandstone, yellowish brown, thick-bedded.
5	13	Sandstone, light brown, medium-to coarse-grained, thick-bedded, sample No. KT-11
3	14	Sandstone, light brown, medium-to coarse-grained, thick-bedded.
4.5	15	Sandstone, light brown, medium-to coarse-grained, thick-bedded with flaser bedding, sample No. KT-12
17.3	16	concealed interval (probably siltstone)
2	17	Sandstone, light brown, medium-to coarse-grained, thick-bedded.
4.80	18	ditto and sample No. KT-13 and 14 bedding $130^{\circ}/25^{\circ}$
>50	19	concealed (soil cover probably siltstone interbedded with sandstone)

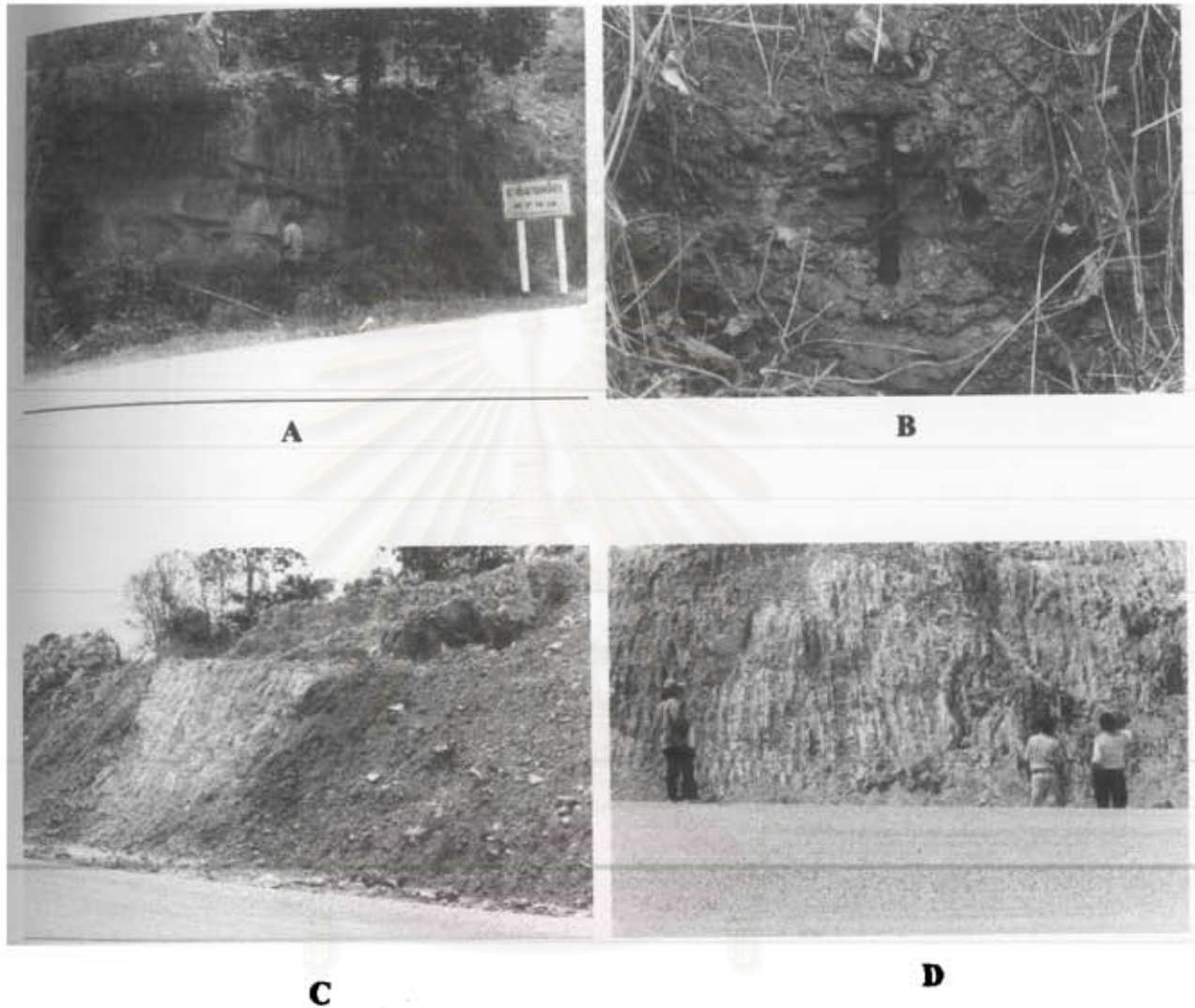


Figure 3.8 The location of measured sections. (A, B) Section D at Khao Tao, km. 22 to 25, road no. 4110 (grid 514042, 4825 II); (C, D) Section E at Ban Ao Tong along road no. 4225 (Grid 457728, 4824 I).

have been collected from this measured section. The attitudes of bedding are 085/45 and 275/70 (dip direction/dip angle) as shown in Table 3.5 and Figure 3.8.

Section F

Section F is situated at Ban Bang Prik, Bang Khan, Nakhon Si Thammarat. This measured section is along the new road cut from Bang Khran to Ban Noen Din Daeng of Lam Thap, Nakhon Si Thammarat. It is represented by arkosic sandstone, siltstone interbedded with sandstone, mudstone and conglomeratic limestone. The total thickness is 104.4 metres and 6 rock samples have been collected from this measured section. The attitude of bedding is 087/70 (dip direction/dip angle) as shown in Table 3.6 and Figure 3.9.

Section G

Section G is situated at Khao Thang, Khlong Thom of Krabi. This measured section is along the road cut from Lam Thap to Khlong Thom (grid reference 165847, 4825 III, Figure 3.10). It represents siltstone, conglomeratic sandstone, and siltstone interbedded with sandstone. The conglomeratic sandstone is matrix-supported, containing subangular, gravel to pebble size clasts of quartz 20%, sandstone 20% and chert 5%. The total thickness is 94.4 metres, and 1 rock sample has been collected from this measured section. The attitude of bedding is 260/70 (dip direction/dip angle) as shown in Table 3.7.

Section H

Section H is situated at quarry of Khuan Wai Daeng, Khlong Thom of Krabi. It consists of arkosic sandstone, siltstone interbedded with sandstone, mudstone. The total thickness is approximately 43 metres, and 2 rock samples have been collected from this measured section. The attitudes of bedding are 267/50 and 265/50 (dip direction/dip angle) as shown in Table 3.8 and Figure 3.11.

Table 3.5 Measured section E, grid reference 457728 (4824 I)

Section of sedimentary rocks of the Trang group, Lam Thap formation, Ban Ao Tong road no. 4225, Sikao of Trang

Date 13/3/42

Lam Thap formation (Type section)

Thickness (m.)

(195 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (sea)
5	1	Sandstone, light brown, medium-grained, well sorted, intensely fractured, thick-bedded, quartz and dark minerals composition, sample No. AT-1
0.5	2	Conglomerate and conglomeratic sandstone, light brown, clast-supported, subangular, gravel-pebble size clasts of composition; quartz 20%, sandstone 20% and chert 5%, bedding $260^{\circ}/40^{\circ}$, fault plane $240^{\circ}/80^{\circ}$, sample No. AT-2
30	3	concealed interval (probably siltstone)
4	4	Siltstone, grayish brown-reddish brown, highly weathered with sample No. AT-3
4.5	5	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, interbedded with siltstone, light brown, sample No. AT-4
5	6	Sandstone, fine-to medium-grained, very loose, sample No. AT-5
10	7	Siltstone, gray to greenish gray, interbedded with mudstone and flaser bedding, bedding $085^{\circ}/80^{\circ}$
3.5	8	Sandstone, medium-grained, light gray to brown
1.5	9	Siltstone, gray to greenish gray, interbedded with sandstone, thickening upward
2	10	Sandstone interbedded siltstone, grayish brown
5	11	Arkosic sandstone, medium-grained, yellowish brown
20	12	Siltstone, maroon
7	13	Siltstone interbedded with sandstone, thin-bedded, yellowish brown to brown
20	14	Siltstone, maroon
10	15	Sandstone, medium-grained, grayish brown, interbedded with siltstone, moderately fern-like leaves, sample No. AT-6
11	16	Conglomerate, clast-supported, contains gravel-pebble size clast of quartz, chert and sandstone, sample No. AT-7
6	17	Siltstone, reddish brown, highly weathered
>50	18	concealed

Table 3.6 Measured section F, grid reference 473805 (4824 I)

Section of sedimentary rocks of the Trang group, Lam Thap formation, near Ban Bang Prik(2) and Khlong Bang Khan, Bang Khan of Nakhon Si Thammarat

Date 3/3/41

Lam Thap formation

Thickness (m.)

(104.4 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (soil)
>20	1	Siltstone interbedded with sandstone, light brown to yellowish brown, highly fractured, medium-bedded, quartz and dark mineral composition
2	2	Sandstone, medium-grained, yellowish brown-light brown, thin-bedded, bedding $087^{\circ}/70^{\circ}$ with sample No. KN4
2	3	Siltstone, maroon
3	4	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, interbedded with siltstone, reddish brown
3	5	Siltstone, maroon
0.4	6	Conglomeratic limestone, brown to grayish brown, thin-bedded with vertebrate and bivalve (<i>Unio</i> sp.), sample No. KN4.1
15	7	Siltstone, reddish brown to maroon, interbedded with sandstone, maroon, fining and thinning upward sequence
20	8	Mudstone, grayish brown, moderately fern-like leaves with sample No. KN6
14	9	Siltstone interbedded with sandstone, maroon
>25	10	concealed (probably siltstone)

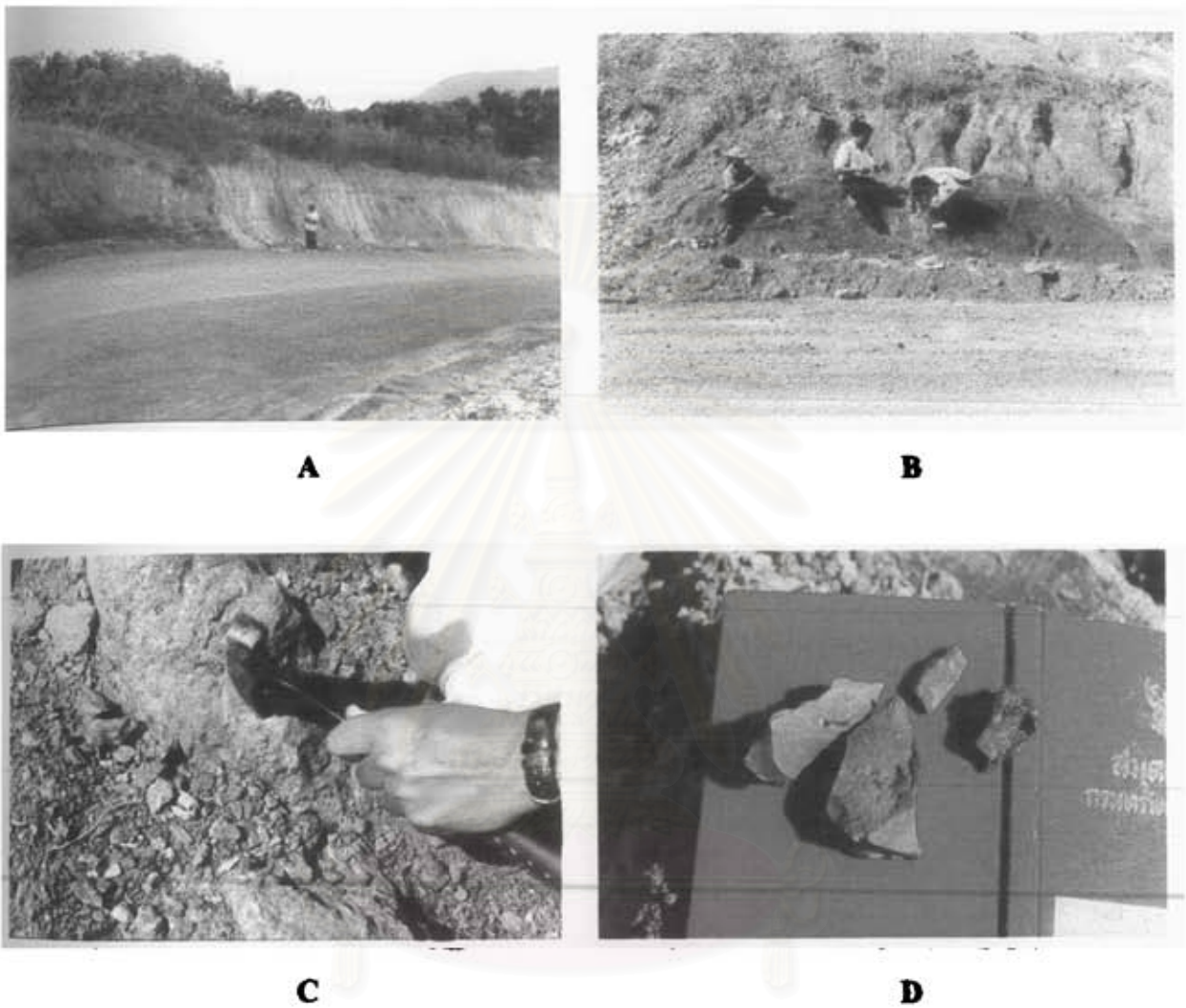


Figure 3.9 The location of measured section E at Ban Bang Prik (Grid 457728, 4824 I).

(A, B) Siltstone interbedded with sandstone; (C) Thin-bedded conglomeratic limestone with *Unio* sp.; (D) fern-like leaves.

Table 3.7 Measured section G, grid reference 165847 (4825 III)

Section of sedimentary rocks of the Trang group, Lam Thap formation, at Khao Thang, Khlong Thom of Krabi

Date 10/3/41

Lam Thap formation

Thickness (m.)

(94.4 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (soil)
20	1	Siltstone interbedded with sandstone, light brown to yellowish brown, high fracture, thick-bedded, quartz and dark mineral composition
0.4	2	Conglomeratic sandstone, light brown, matrix-supported, subangular, gravel-pebble size clast composition; quartz 20%, sandstone 20% and chert 5%
4.5	3	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, bedding 260°/70°
5	4	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, with sample No. KTT-1
10	5	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, interbedded with yellowish brown to reddish brown siltstone
3	6	Sandstone, medium-grained, very dense
15	7	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, interbedded with siltstone, maroon, fining upward and thinning upward sequences
30	8	concealed
2	9	Siltstone, maroon
1.5	10	Sandstone, grayish brown, medium-grained
>3	11	Siltstone, maroon concealed



**Figure 3.10 The location of measured section G(grid 165847, 4825 III)
at Khao Thang, Khlong Thom of Krabi.**

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Table 3.8 Measured section H, grid reference 177773 (4824 IV)

Section of sedimentary rocks in the Trang group, Lam Thap formation, Khuan Wai Daeng, Khlong Thom of Krabi

Date 11/5/40

Lam Thap formation

Thickness (m.)

(29 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
>2	1	concealed (soil) Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, bedding 267°/50°
1.5	2	Siltstone, maroon
1	3	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, interbedded with reddish brown siltstone
2.5	4	Siltstone, maroon
2	5	Sandstone, medium-grained, yellowish brown
5	6	Siltstone, maroon
5	7	Sandstone, medium-grained, yellowish brown to light brown, thin-bedded, bedding 265°/50°, sample No. S6/1
>10	8	Siltstone, grayish brown with sample No. S6/2 concealed (probably siltstone)

**A****B**

Figure 3.11 The location of measured section H at quarry of Khuan Wai Daeng(A and B)(Grid 177773, 4824 IV), Khlong Thom of Krabi.

Section I

Section I is located along the road no. 4038 from Lam Thap to Khlong Thom of Nakhon Si Thammarat and Krabi. It is characterised by very fine-grained red-reddish brown sandstone, and conglomerate/breccia commonly displaying planar and trough cross-beddings. The total thickness is 101.71 metres, and 3 rock samples have been collected from this measured section. The attitudes of bedding and cross-bedding are 270/30, 255/50 and 250/30 and 265/35 (dip direction/dip angle) as shown in Table 3.9 and Figures 3.12 and 3.13.

Section J

Section J is located at new road cut, south of Khao Sam Chom (grid reference 497944, map sheet 4825 II). It consists of yellowish brown arkosic sandstone and conglomeratic sandstone in the lower part gradually passing upward to the fine-grained sandstone, reddish brown, well sorted, medium-bedded with abundant mica flakes. It is totally 69 metres thick, and the attitude of bedding is 250/35 (dip direction/dip angle) as shown in Table 3.10 and Figure 3.13.

Section K

Section K is situated in the south of Khao Sam Chom (grid reference 497940, map sheet 4825 II). It is represented by fine-grained sandstone, reddish brown and conglomerate/breccia with common graded bedding. It is totally 744.4 metres thick and the attitude of bedding are 065/55 and 250/35 (dip direction/dip angle) as shown in Table 3.11 and Figure 3.14.

Sections L, M, N, O, and P (representing the sequences underlying the Trang group)

Sections L, M, N, O, and P represent the Triassic sequences (Sai Bon formation). Sections L, M, and N are situated at Khuan Sanai, section O at km. 13 Thung Yai-Thung Song road no. 4108, and section P at Khao Khom.(grid reference 605085, map sheet 4825 II). It consists of reddish brown sandstone, siltstone, mudstone, fossiliferous limestone, dolomite and limestone lenses with fossils of *Plaeocardita* sp., ammonite, brachiopod and plant remains. The total thickness is 50

Table 3.9 Measured section I, grid reference 232841 to 229837 (4824 IV)

Section of sedimentary rocks in the Trang group, Phun Phin formation measured along a road cut at road no. 4038 km.10, Khlong Thom of Krabi.

Date 28/2/41

Thickness(m)

(101.71 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
5.8	1	concealed (soil cover) Sandstone, orangish red, fine-to medium-grained, well sorted, thick-bedded, show small white spots on the surface, bedding $260^{\circ}/50^{\circ}$ and planar cross bedding $270^{\circ}/30^{\circ}$, $250^{\circ}/40^{\circ}$, $255^{\circ}/50^{\circ}$, and $255^{\circ}/35^{\circ}$, sample No. P-1
9.7	2	Sandstone, orangish red to reddish brown, medium-grained, well sorted, thick-bedded, bedding $255^{\circ}/85^{\circ}$ and planar cross bedding $250^{\circ}/35^{\circ}$, $245^{\circ}/70^{\circ}$, $265^{\circ}/35^{\circ}$, $285^{\circ}/10^{\circ}$, $290^{\circ}/35^{\circ}$, $282^{\circ}/45^{\circ}$, and $272^{\circ}/35^{\circ}$, fracture $085^{\circ}/80^{\circ}$, $131^{\circ}/85^{\circ}$, and $294^{\circ}/85^{\circ}$
0.12	3	Sandstone, orangish red to reddish brown, very fine-grained, composes of abundant feldspar
4.3	4	Sandstone, orangish red to reddish brown, medium-grained, well sorted, thick-bedded, composes of quartz and feldspar, bedding $250^{\circ}/55^{\circ}$ and $255^{\circ}/45^{\circ}$ and planar cross bedding $275^{\circ}/35^{\circ}$ and $260^{\circ}/40^{\circ}$
5.20	5	Sandstone, orangish red to reddish brown, medium-grained, fresh, thick-bedded, bedding $247^{\circ}/50^{\circ}$ and planar cross bedding $270^{\circ}/25^{\circ}$, $270^{\circ}/30^{\circ}$, $274^{\circ}/25^{\circ}$, and $274^{\circ}/22^{\circ}$
5.26	6	Sandstone, orangish red to reddish brown, medium-grained, fresh, thick-bedded, bedding $250^{\circ}/50^{\circ}$
6.4	7	Sandstone, orangish red to reddish brown, medium-grained

Table 3.9 (cont.) Measured section I

Thickness(m)	Unit No.	Description
1.8	8	Sandstone, orangish red to reddish brown, medium-grained, moderately weathered, composes of abundant feldspar increasing downward, thick-bedded, bedding 255°/50°
4.8	9	Sandstone, orangish red to reddish brown, very fine-grained, composes of abundant feldspar, bedding 257°/50° and 250°/55°
0.65	10	ditto
1.90	11	ditto
1.70	12	ditto
4.8	13	ditto
3.8	14	ditto
0.25	15	Conglomerate, clast-supported, cobble to pebble size, mainly quartz, sandstone, and chert, poor cemented, trough and planar cross beddings
0.7	16	Sandstone, orangish red to reddish brown, very fine-grained
5.2	17	ditto
4.23	18	ditto
6.10	19	Sandstone, with cross-bedding 300°/30°
3.0	20	Conglomerate/breccia with clast-supported
1.0	21	Sandstone, orangish red to reddish brown, very fine-grained
25	22	Conglomerate/breccia, clast-supported, cobble to pebble size clasts mainly quartz, sandstone, and chert, poor cemented, trough and planar cross beddings concealed (soil cover)

- ### Legends
-  Mudstone and shale
 -  Siltstone
 -  Sandstone
 -  Conglomerate
 -  Conglomerate/breccia
 -  Calcareous sandstone
 -  Limestone
 -  Dolomite
 -  Lamination
 -  Flaser bedding
 -  Planar] Cross-bedding
 -  Trough] Cross-bedding

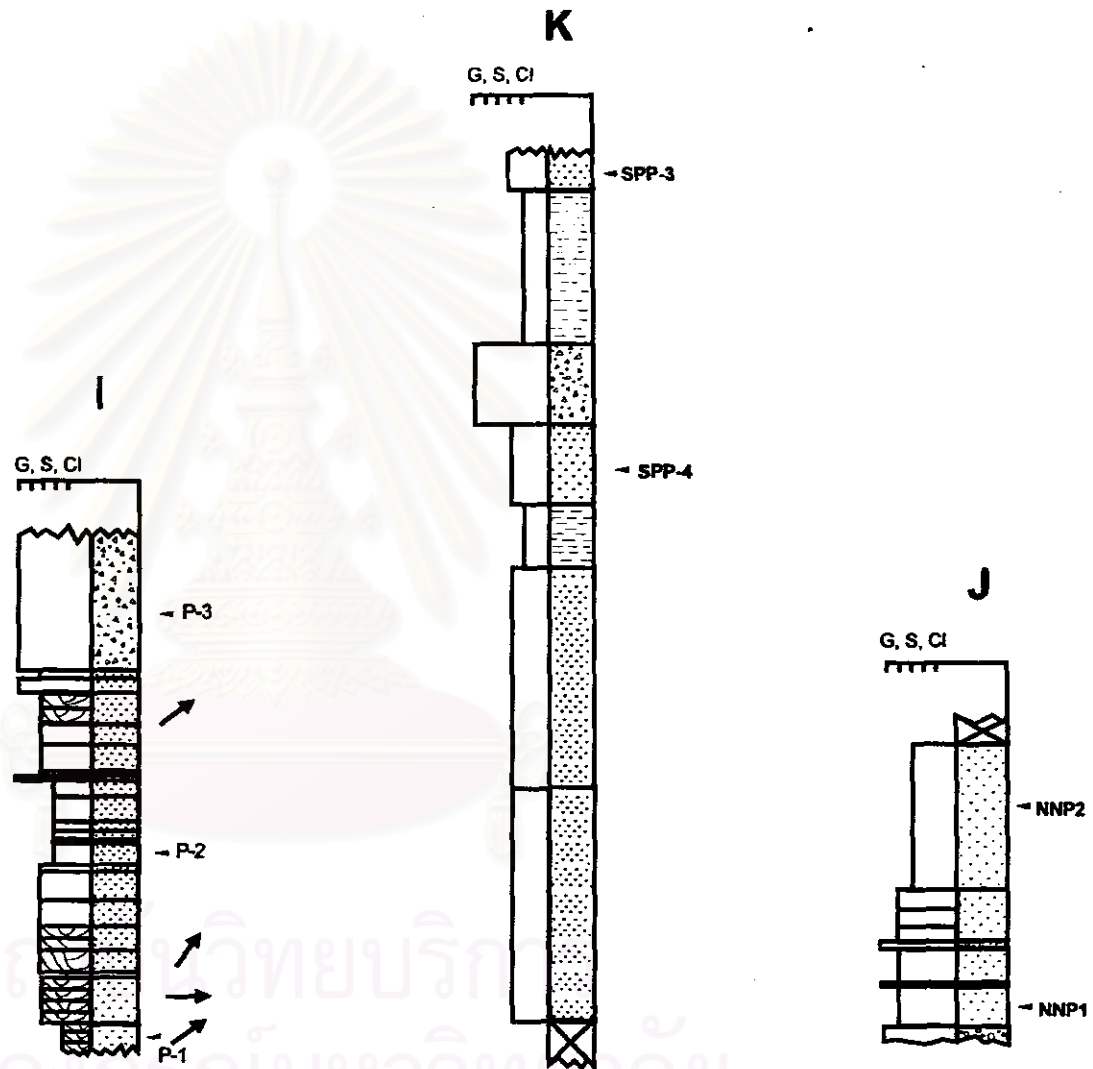


Figure 3.12 The measured sections of the Phun Phin formation (not to scale)

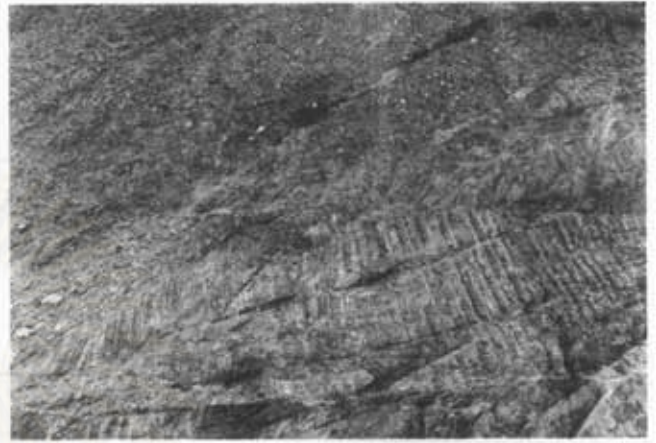
**A****B****C****D**

Figure 3.13 The location of measured sections. (A, B) Section I at km. 10 road no. 4038 (Grid 232841, 4824 IV); (C, D) Section J at southern part of Khao Sam Chom (grid 497944, 4825 II).

Table 3.10 Measured section J grid reference 497944 (4825 II)

Section of sedimentary rocks in the Trang group, Phun Phin formation overlies on Lam Thap formation, southern part of Khao Sam Chom, Nakhon Si Thammarat

Date 14/3/42

Contact between Lam Thap formation and Phun Phin formation

Thickness (m.)

(69 metres)(From bottom to top)

Thickness(m)	Unit No.	Description
>2	1	concealed (soil) Conglomeratic sandstone, brown, matrix-supported, clasts consists of quartz, chert, rock fragments.
32	2	Sandstone and conglomeratic sandstone, medium-grained, yellowish brown with sample No. NPP-1
>35	3	Sandstone, fine-grained, reddish brown with mica flakes, graded bedding, sample No. NPP-2 concealed (soil cover)

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Table 3.11 Measured section K, grid reference 497940 (4825II)

Section of sedimentary rocks of the Trang group, Phun Phin formation measured along a new road cut in the southern part of Khao Sam Chom, Thung Yai of Nakhon Si Thammarat.

Date 4/3/41

Thickness (m)

(774.4 metres) (From bottom to top)

Thickness(m)	Unit No	Description
		concealed (soil cover)
26.8	1	Sandstone, reddish brown, fine-grained, thick-bedded, bedding $055^{\circ}/85^{\circ}$, sample No. PP1-1
22.5	2	Sandstone, reddish brown, fine-grained, thick-bedded, bedding $055^{\circ}/85^{\circ}$, interbedded with siltstone, reddish brown to maroon.
38.8	3	Sandstone, reddish brown, fine-grained, thick-bedded, interbedded with siltstone, reddish-brown to maroon, sample No. PP1-2
10.5	4	Sandstone, reddish brown, fine-grained, thick-bedded.
7.2	5	Sandstone, reddish brown, fine-grained, thick-bedded with lamination, bedding $065^{\circ}/55^{\circ}$, sample No. PP1-3
64.2	6	Siltstone, maroon, lamination.
19.5	7	Conglomerate, reddish brown, matrix-supported, very loose, clast of sandstone, chert, quartz, cobble size average.
19.5	8	Sandstone, reddish brown, very fine-grained, thick-bedded, sample No. PP1-4
15.5	9	Siltstone, maroon, lamination.
57.4	10	Sandstone, reddish brown, very fine-grained, thick-bedded
57	11	Sandstone, reddish brown, very fine-grained, thick-bedded, bedding $250^{\circ}/35^{\circ}$.
315	12	concealed interval (probably siltstone)
140	13	Sandstone, reddish brown, very fine-grained, thick-bedded concealed (soil cover)

**A****B**

Figure 3.14 The location of measured section K (Grid 497940, 4825 II). (A) At southern part of Khao Sam Chom; (B) The fine-grained sandstone with rip-up clasts of mudstone.

metres of section L, 68 metres of section M, 70 metres of section N, 53 metres of section O, and 107 metres of section P as shown in Table 3.12-16 and Figures 2.5 and 3.15.

Section Q

Section Q is located at Laem Pleo, Ban Bo Muang, Khlong Thom of Krabi. This measured section is along the coast of Laem Pleo (Figure 3.2). It consists of calcareous siltstone and mudstone, conglomeratic limestone, calcareous sandstone, siltstone interbedded with sandstone and conglomerate with vertebrate fossils. The total thickness is 65.25 metres, and 7 rock samples have been collected from this measured section. The attitudes of bedding are 020/10 and 150/30 (dip direction/dip angle) as shown in Table 3.17 and Figure 3.16.

3.3 Composite section

Under the present study, an attempt has been made to combine and correlate the sedimentary sequences of all 12 measured sections of Trang group. Because of the Trang group is composed of Khlong Min, Lam Thap, Sam Chom and Phun Phin formations deposited under the transitional and fluvial environments, therefore, the sedimentary sequence has been subdivided into lithofacies. The combined section of the Trang group is divided into 9 lithofacies based on lithological characteristics, and the synthesis of combined section is illustrated in Figure 3.17.

The total thickness of the Trang group based on 12 measured sections, varies from 65 to 1,145 metres thick whereas the total thickness of the combined section is approximately 400 metres. The lateral facies change of the fluvial sediments, structural complication, and the correlation are believed to be the reasons of this thickness reduction of the combined section of the Trang group.

Table 3.12 Measured section L, at Khuan Sanai, grid reference 414895 (4825II)

Section of sedimentary rocks in the Sai Bon formation measured along a new local road cut in Khun Sanai, Amphoe Thung Yai, Nakhon Si Thammarat.

Date 5/3/41

Thickness(m)

(50.5 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
>5.5	1	Concealed (soil cover probably dolomitic limestone) Sandstone, quartzitic sandstone, yellowish brown, well cemented, well sorted, thick-bedded
10	2	Mudstone, fossiliferous limestone and shale, dark gray to gray with fossils of coral and <i>Paleocardita</i> sp., bedding 260°/35°, sample KS-1
4	3	Sandstone, quartzitic sandstone, yellowish brown, well cemented, well sorted, thick-bedded, sample No. KS-2
10	4	Mudstone, fossiliferous limestone and shale, dark gray to gray with fossils of coral and <i>Paleocardita</i> sp., bedding 260°/35°, sample KS-3
4	5	Sandstone, quartzitic sandstone, yellowish brown, well cemented, well sorted, thick-bedded
8	6	Mudstone, fossiliferous limestone and shale, dark gray to gray with fossils of coral and <i>Palaeocardita</i> sp., bedding 260°/35°, sample KS-4
2	7	Sandstone, quartzitic sandstone, yellowish brown, well cemented, well sorted, thick-bedded, sample No. KS-5
>7	8	Mudstone, fossiliferous limestone and shale, dark gray to gray with fossils of coral and <i>Palaeocardita</i> sp. Concealed (soil cover) (contact between Lam Thap fm./ Sai Bon fm., probably mudstone interbedded with limestone thickness about 177 metres)

Table 3.13 Measured section M, grid reference 413913 (4825 II)

Section of sedimentary rocks of the Triassic rock (Sai Bon formation), road cut at Khuan Sanai, Khlong Thom of Krabi

Date 5/2/42

Thickness (m)

(68 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (soil covers)
>3	1	Dolomitic limestone, and dolomite, light gray to gray
12	2	Limestone, very thick-bedded, light gray
7	3	Siltstone and mudstone, gray to brownish gray, with bivalve fossils and plant remains
4	4	Calcareous sandstone, thin-bedded with parallel bedding type
3	5	Siltstone, maroon to reddish brown interbedded with well stratified fine-grained sandstone
1.5	6	Conglomerate, gray with clast-supported
12	7	Siltstone, maroon to reddish brown interbedded with well stratified fine-grained sandstone
5	8	Sandstone and quartzitic sandstone, brown to yellowish brown
>22	9	Siltstone, maroon to reddish brown interbedded with well stratified fine-grained calcareous sandstone and with paleosol? concealed (soil covers)

Table 3.14 Measured section N, grid reference 451915 (4825 II)

Section of sedimentary rocks of the Triassic rock (Sai Bon formation), at eastern part of Khao Na Pu, Bang Khan of Nakhon Si Thammarat

Date 1/3/42

Thickness (m)

(72 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
>20	1	concealed (soil covers) Limestone, light gray to gray, thin-to thick-bedded with abundant fusulinid
27	2	Siltstone, calcareous sandstone with limestone lenses, well stratified and fining upward sequence
>25	3	concealed (soil covers, probably siltstone and mudstone)

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Table 3.15 Measured section O, grid reference 608041 (4825 II)

Section of sedimentary rocks of the Triassic rock(Sai Bon formation), road cut outcrop at road no. 4110 km.13, Khao Chong Sai Ngam, Thung Song of Nakhon Si Thammarat

Date 4/2/42

Thickness (m)

(53 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
>4	1	concealed (soil covers) Siltstone, maroon, interbedded with fine-grained sandstone in the lower part
0.3	2	Conglomeratic sandstone, brownish gray with matrix - supported
2	3	Sandstone, thick-bedded, fine-grained, and calcareous cemented
3	4	Siltstone and mudstone, gray to brownish gray
0.5	5	Conglomeratic limestone, gray to brownish gray, matrix - supported
3	6	Siltstone, maroon to reddish brown interbedded with well stratified fine-grained sandstone
1.5	7	Conglomerate, gray with clast-supported
3	8	Siltstone, maroon to reddish brown
2	9	Sandstone and quartzitic sandstone, brown to yellowish brown
4	10	Siltstone, maroon to reddish brown interbedded with well stratified fine-grained calcareous sandstone and with paleosol?
>20	11	concealed (soil covers)

Table 3.16 Measured section P, grid reference 596093 (4925 III)

Section of sedimentary rocks of the Triassic rock (Sai Bon formation), at Khao Khom, Thung Song of Nakhon Si Thammarat

Date 6/3/42

Thickness (m)

(120 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (soil covers)
>30	1	Dolomitic limestone, and dolomite, light gray to gray
30	2	Limestone, very thick-bedded, light gray
4	3	Conglomeratic limestone, light gray, with matrix-supported, clast mainly of limestone, sandstone and chert, average granule to cobble size
16	4	Concealed interval (probably siltstone and sandstone)
>40	5	Siltstone, maroon to reddish brown interbedded with well stratified sandstone and conglomeratic limestone; sandstone, medium-grained, well cement and well sorted
		concealed (soil covers)

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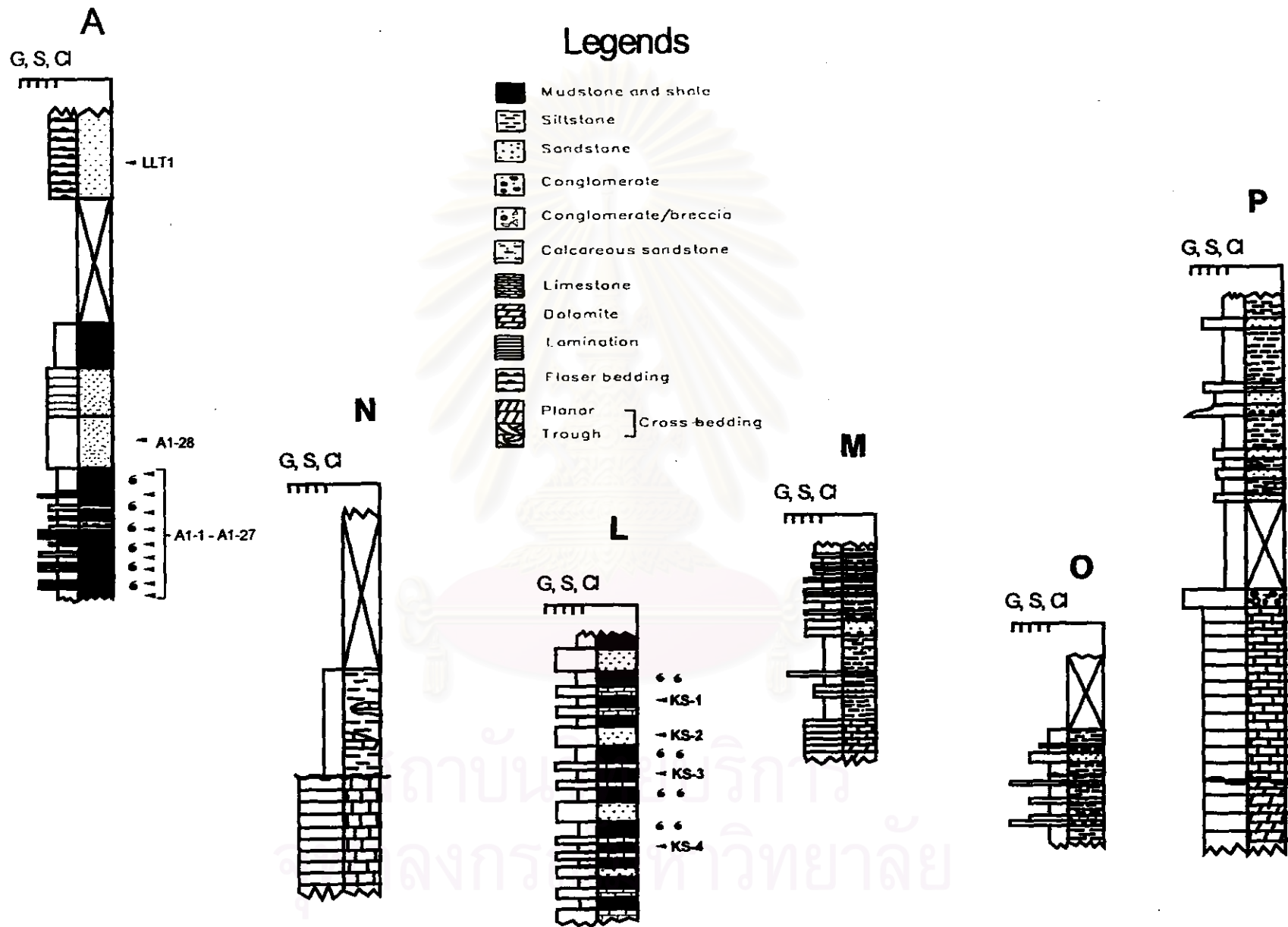


Figure 3.15 The measured sections of the Sai Bon formation (not to scale)

Table 3.17 Measured section Q (reference section), grid reference 224476 (4824 III)

Section of sedimentary rocks of the Trang group, Khlong Min formation, Lam Thap formation, and Sam Chom formation at Laem Pleo of Ban Bo Muang, Khlong Thom of Krabi

Date 20/3/42

Khlong Min formation, Lam Thap formation, and Sam Chom formation (reference section)

Thickness (m.)

(65.25 metres) (From bottom to top)

Thickness(m)	Unit No.	Description
		concealed (sea)
>25	1	Calcareous mudstone and siltstone, gray to dark gray, thin-bedded with lamination, bedding $020^{\circ}/10^{\circ}$ and $150^{\circ}/30^{\circ}$, at upper part small amount of petrified woods, chert nodules, and andesite dike(0.2 m. thick), sample No. LP-1
0.5	2	Calcareous sandstone, greenish gray, well stratified, thin-bedded and lamination, bedding $025^{\circ}/25^{\circ}$, sample No. LP-2
1.0	3	Calcareous sandstone, brownish gray, medium-bedded, with hummocky structure.
0.5	4	Limestone conglomerate, brownish gray, clast-supported, gravel size with some fragments of vertebrate fossils, sample No. LP-3
0.75	5	Calcareous sandstone, fine-to medium-grained, brownish gray, bedded with flaser bedding
0.5	6	Mudstone, gray, containing firm-like leaves, sample No. LP-5
30	7	Sandstone, fine to medium-grained interbedded with siltstone, reddish brown, thin-bedded, calcareous at lower part, sample No. LP-6
>7	8	Conglomerate, reddish brown to yellowish brown, and clast-supported of mainly quartz, chert, volcanic rock(feldspar) and petrified woods, moderately cemented, sample No. LP-7

**A****B****C****D****E**

Figure 3.16 Measured section Q at Laem Pleo (grid 224476, 4824 II). (A) Showing the lithostratigraphic sequence and conglomerate slump from upper part; (B) Folding at lower part; (C) With abundant petrified woods; (D) Hummocky structure; (E) Slump structure.

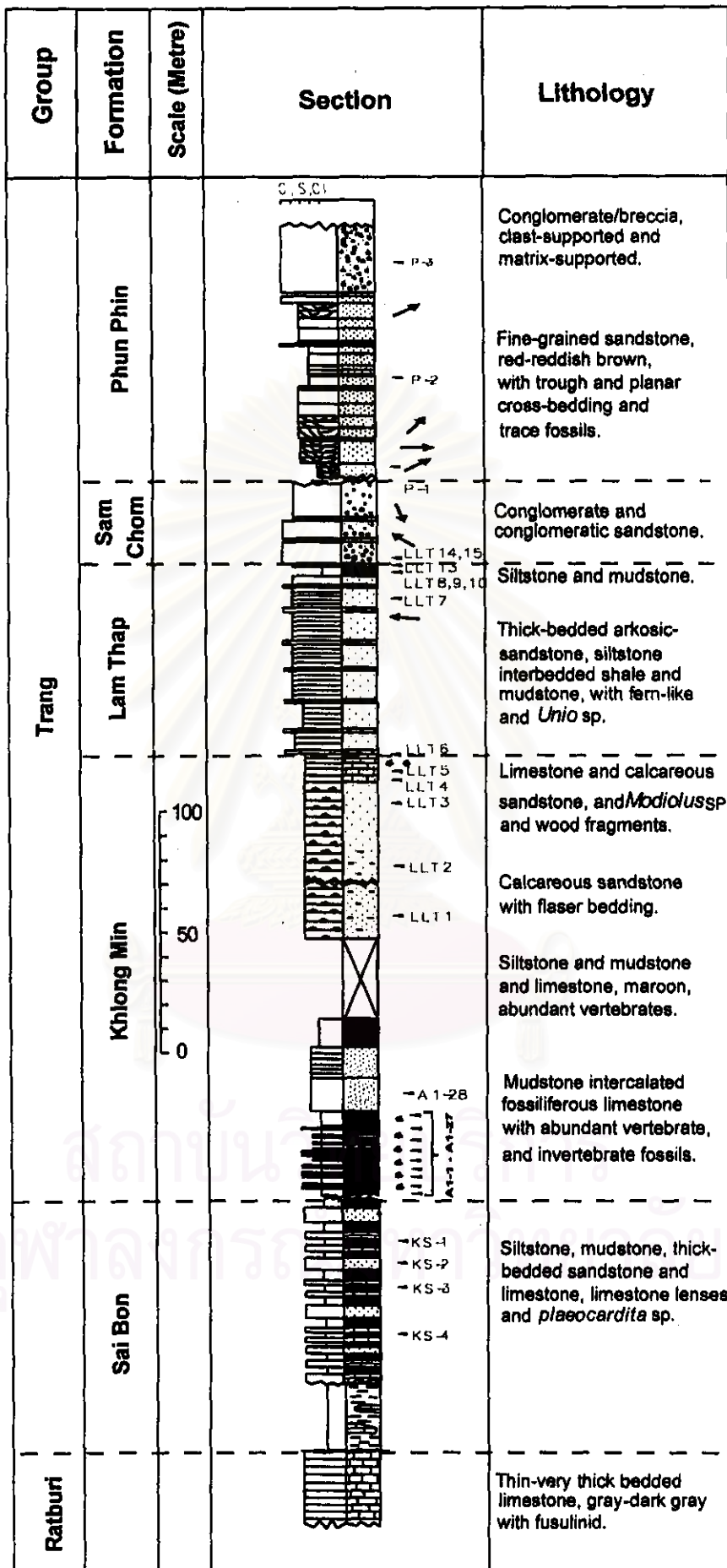


Figure 3.17 Composite section of the Trang group

3.4 Stratigraphy

Raksaskulwong (1994) proposed the non-marine Mesozoic rocks in this area as well as other neighbouring areas as Trang group. It consists of reddish brown shale, sandstone, conglomerate and reddish brown fine-grained sandstone of totally 760 metres thick. This sequence unconformably overlies the Triassic rocks. They are exposed in the area of Wiang Sa of Surat Thani, Thung Yai of Nakhon Si Thammarat, Khlong Thom of Krabi, and Wang Vi Set of Trang.

The geology of the region has been described previously by various workers i.e. Kobayashi&Tokuyama (1959), Hayami (1960), Javanaphet (1969), Snansieng et al. (1977), Grant-Mackie et al. (1978), Udomratn et al. (1981), Asama et al. (1981), Raksaskulwong et al. (1989), Prasomsap et al. (1989), Chaimanee et al. (1990), Meesook and Grant-Mackie (1994), Raksaskulwong (1994), Buffetaut et al. (1994) and Geology students of CU (1996, 1998) etc.. The stratigraphic sequences in the central part consist mainly of thin-to very thick-bedded limestone known as the Ratburi Group. The western and eastern parts are mainly non-marine Mesozoic rocks (Figure 3.3). The area is predominantly underlain by sedimentary rocks of different ages ranging from Permian to Quaternary. Some volcanics and shallow intrusive rocks are exposed along the north-western margin of the Sin Pun basin and eastern margin of the Krabi basin (Raksaskulwong et al., 1989).

In this study, a newly proposed non-marine Mesozoic lithostratigraphy rocks in ascending order is as follows: Khlong Min formation, Lam Thap formation, Sam Chom formation, and Phun Phin formation, respectively. The Khlong Min formation consists of 4 lithofacies; the mudstone intercalated with fossiliferous limestone, siltstone, sandstone and fossiliferous limestone with abundant vertebrate and invertebrate fossils. The fossil assemblages reflect lagoonal environment during lower Middle Jurassic, with gradual change of depositional environment from transitional to fluvial. The Lam Thap formation consists mainly of 2 lithofacies; the thick-bedded arkosic sandstone, and siltstone interbedded with shale with fern-like leaves, trace

fossils, bivalve of *Modiolus* sp. and *Unio* sp. indicating Upper Jurassic to Lower Cretaceous. The rocks were deposited in floodplain and alluvial fan environments. The Sam Chom formation predominantly consists of conglomerate, conglomeratic sandstone and poorly cemented coarse-grained sandstone of alluvial fan origins. The Phun Phin formation consists of 2 lithofacies; the fine-grained sandstone and conglomerate origins with trough and planar cross-beddings reflecting braided stream and debris flow origins. Stratigraphically and paleontologically (Asama, 1981; Chonglakmani, 1990; Zuoqi, 1993; Meesook and Grant-Mackie, 1994; Buffet et al. 1994; Jumnonghai, pers. comm., 1999), the age of the Trang group should be assigned as lower Middle Jurassic to Upper Cretaceous. The total thickness is from 65 to 1,145 metres. The correlation charts of all measured sections are presented in Figures 3.18, 3.19, 3.20, and 3.21.

Trang group

It is proposed in this study to subdivide the Trang group into 4 formations in ascending order as follows; Khlong Min formation, Lam Thap formation, Sam Chom formation and Phun Phin formation, respectively.

Khlong Min formation

(a) *Definition:* The Khlong Min formation refers to the sequence between sandstone and limestone of the Sai Bon formation (Upper Triassic) and arkosic sandstone and siltstone of the Lam Thap formation. It is exposed locally at Khlong Min, Ban Mab Ching (Ban Thang Luang map sheet, 4825 II), Ban Prak Paek, Khlong Tae Pa northwest of Khlong Thom (Figures 3.19 and 3.22) and Laem Pleo of Ban Bo Muang. The lower part of the formation consists generally of mudstone intercalated with fossiliferous limestone and maroon siltstone interbedded with thin-bedded limestone and abundant fossils of vertebrates, conchostracan (*Estheria*), bivalves, gastropods, ostracods and pollens. In the upper part of the formation, the colour is yellowish gray to gray. It composes mainly of calcareous sandstone, fine-to medium-

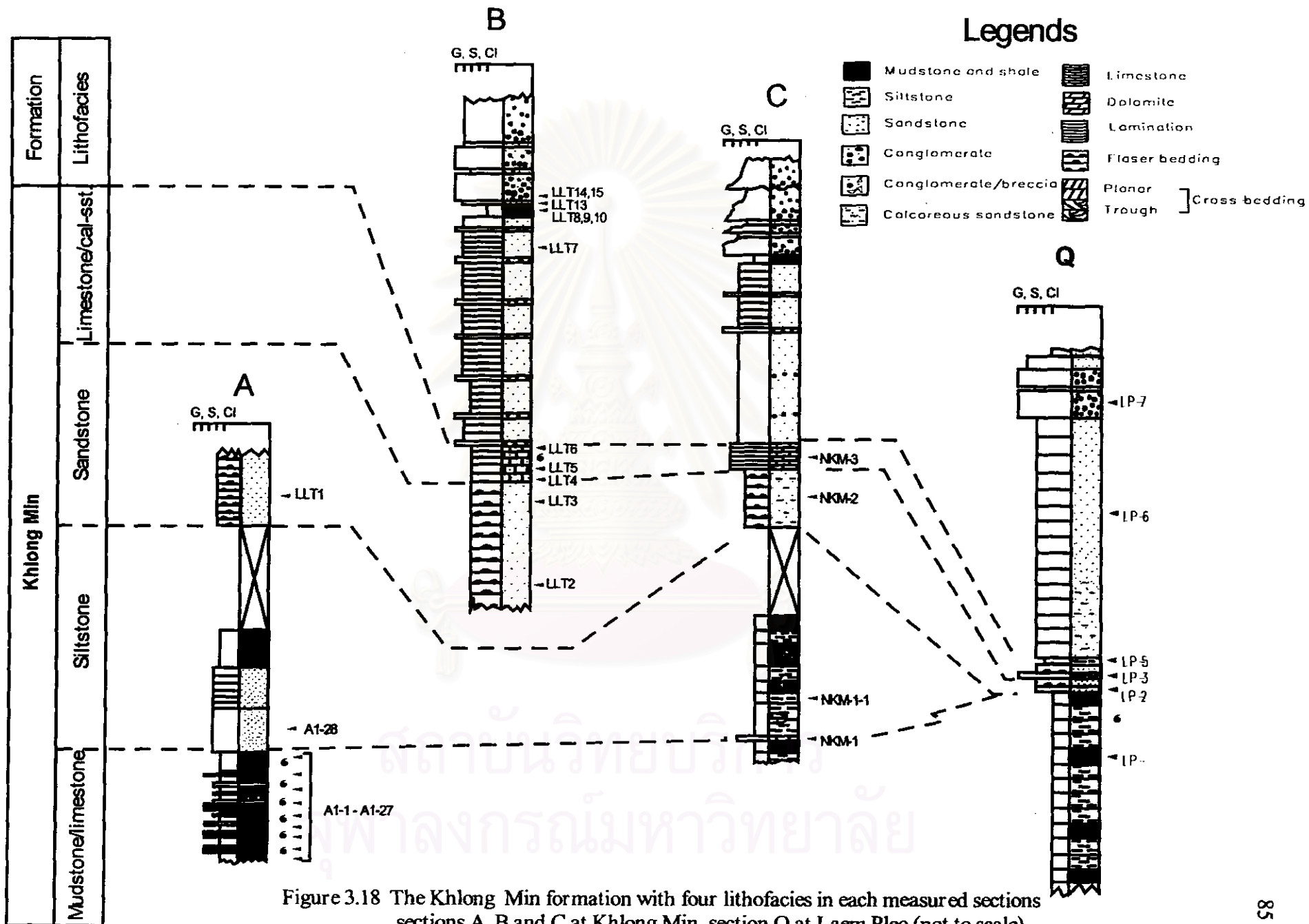


Figure 3.18 The Khlong Min formation with four lithofacies in each measured sections A, B and C at Khlong Min, section Q at Laem Pleo (not to scale)

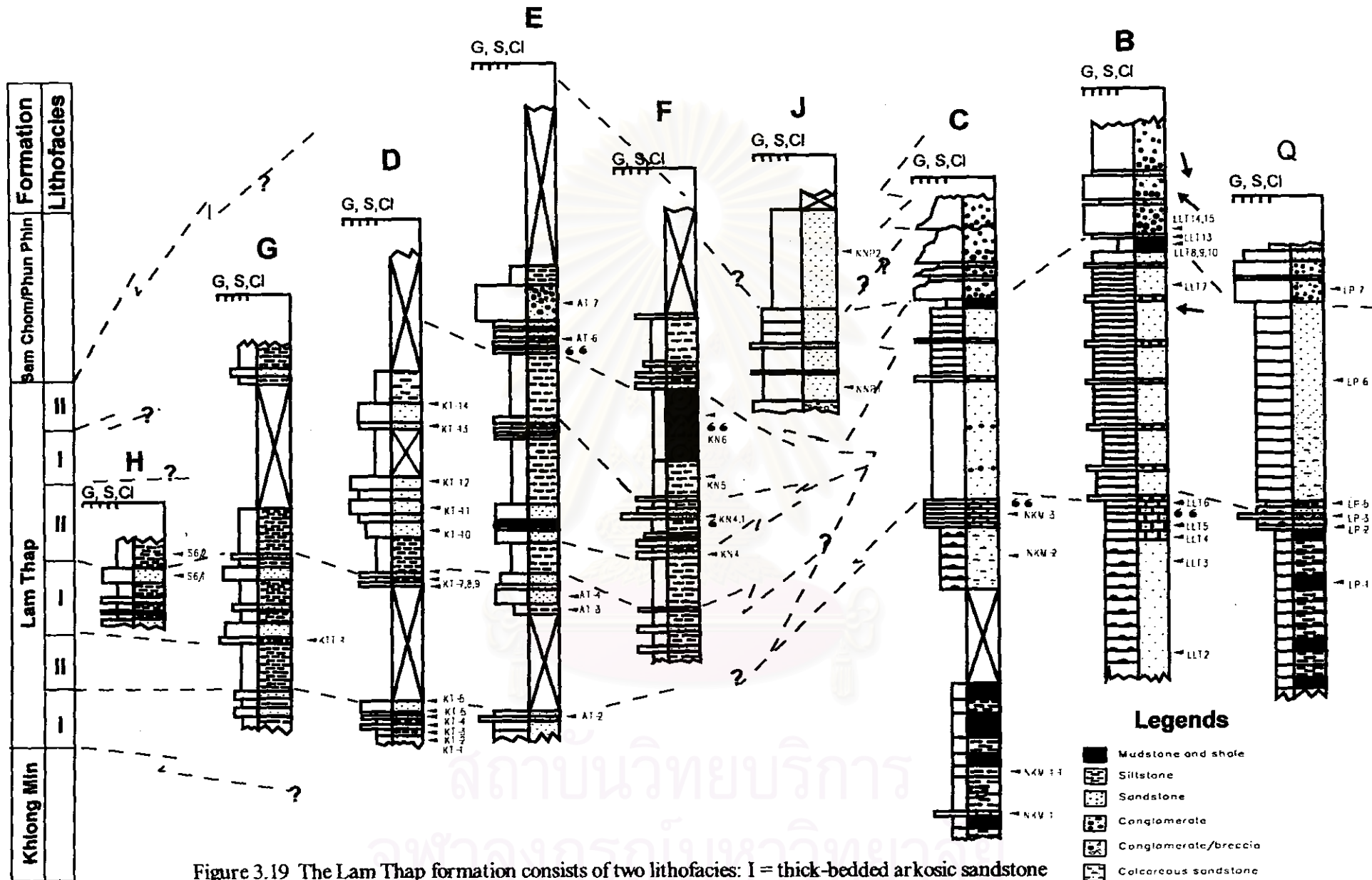


Figure 3.19 The Lam Thap formation consists of two lithofacies: I = thick-bedded arkosic sandstone and II = siltstone interbedded shale and mudstone; sections B and C at Khlong Min, sections F, G and H at Lam Thap, section D at Khao Tao, section E at Ban Ao Tong section J at south of Khao Sam Chorn, section Q at Laem Pleo (not to scale)

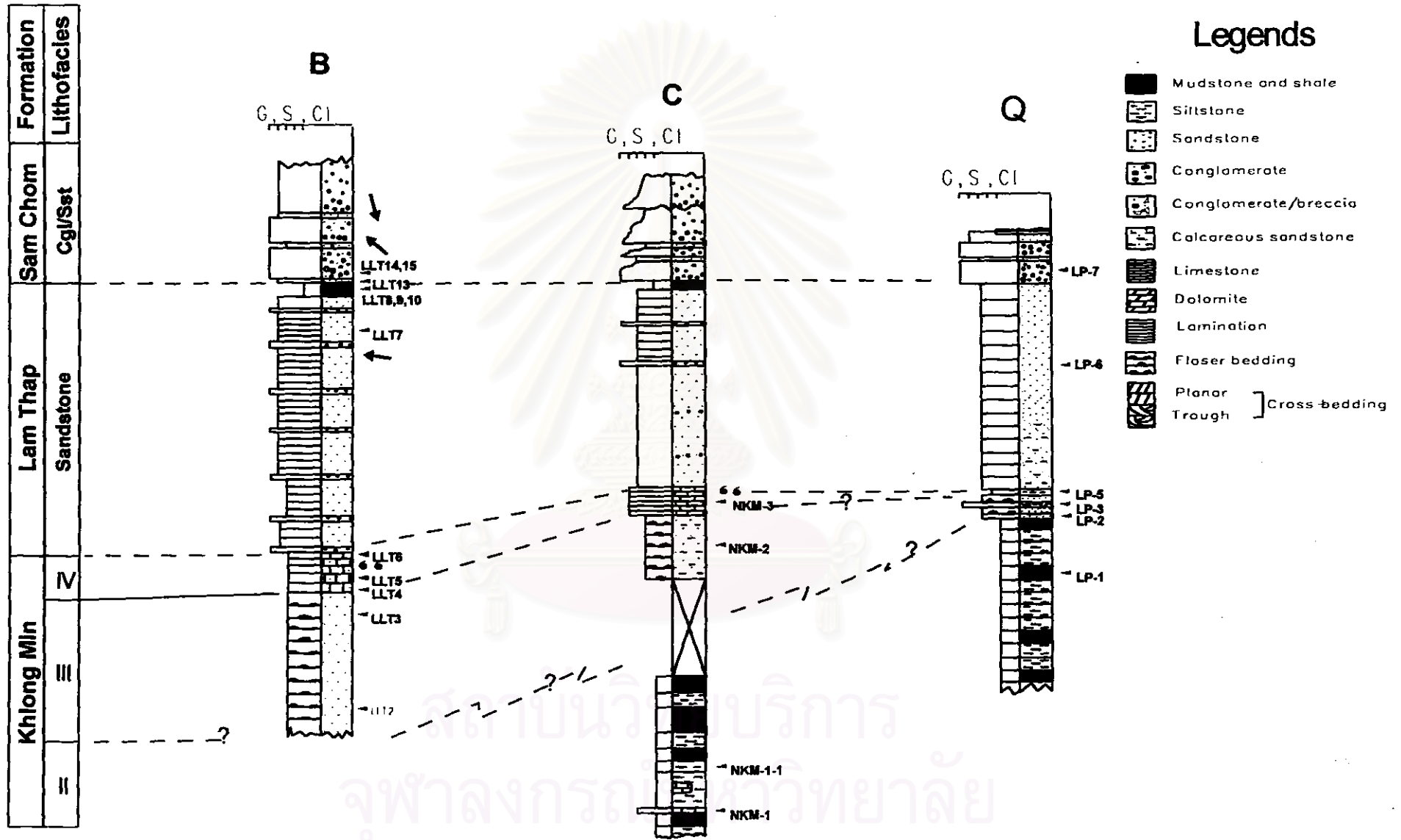


Figure 3.20 The Sam Chom formation correlation with measured sections B, C and Q; sections B and C at Khlong Min and section Q at Laem Pleo (not to scale)

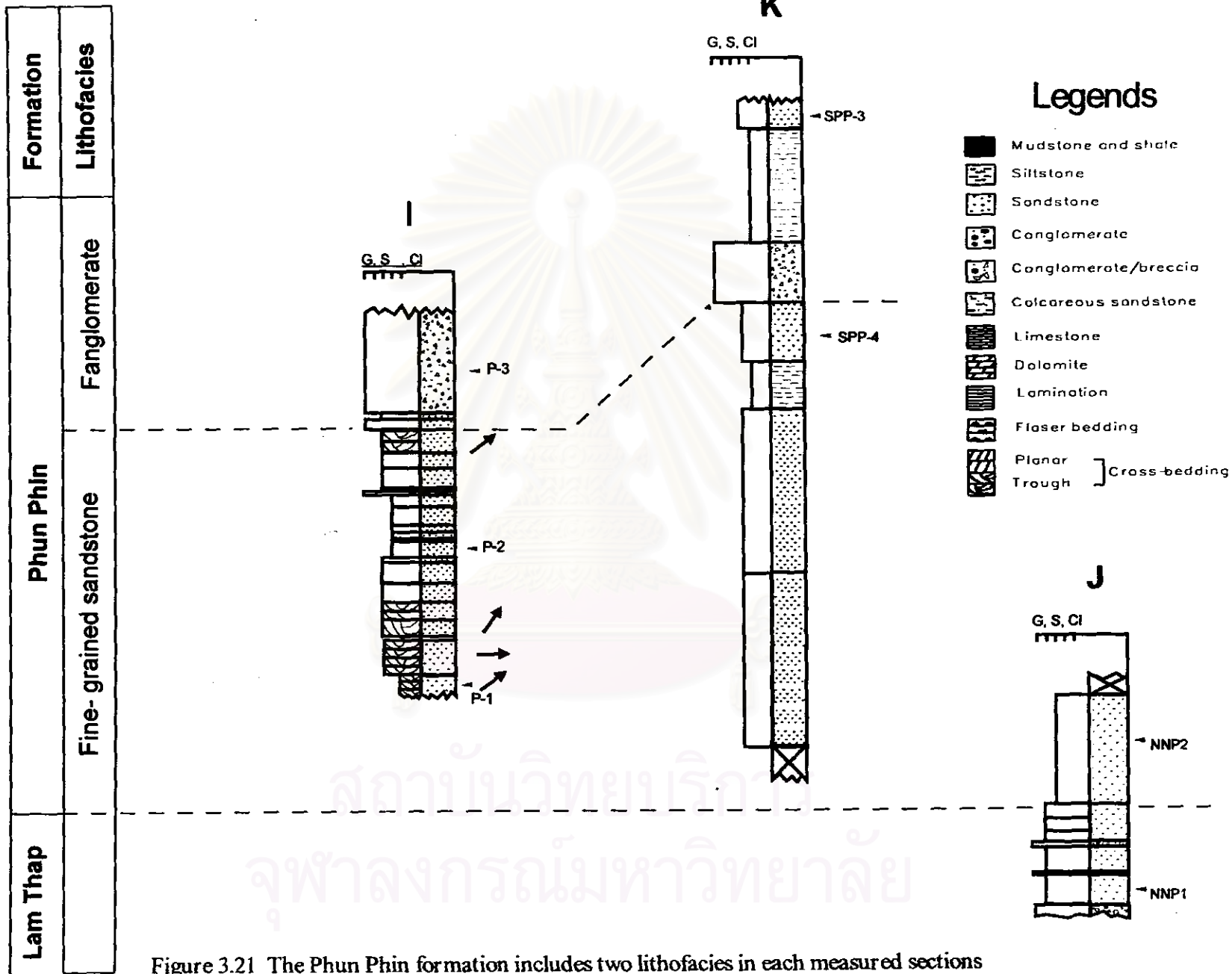


Figure 3.21 The Phun Phin formation includes two lithofacies in each measured sections (not to scale)



Figure 3.22 Khlong Min formation(lithofacies I), showing well stratified limestone at Khlong Tae Pa, northern part of Khlong Thom.

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grained with flaser bedding and thin-bedded limestone with wood fragments and bivalve of *Modiolus* sp.

(b) *Lithology*: The Khlong Min formation mainly consists of 4 lithofacies: the mudstone intercalated with fossiliferous limestone, siltstone, sandstone and fossiliferous limestone in ascending order as follows:

I. *Mudstone intercalated with fossiliferous limestone lithofacies*:

The mudstone intercalated with fossiliferous limestone lithofacies from the lower part of the formation (Figure 3.23). The lithofacies are commonly characterised by mudstone intercalated with thin-bedded fossiliferous limestone and bituminous jets. The fossiliferous limestone is commonly intercalated by mudstone, and the limestone is microscopically designated as biomicrite. Mudstone consists of fine-grained bioclasts and shell fragments which are partly cemented with gray to dark gray micrite matrix.

This lithofacies contains abundant fossils such as; *Estheria*, ostracods (*Darwinulla* sp.), sporepollens (*Classopollis* sp.), vertebrates etc. (Figure 3.24) and commonly hummocky structures (Sections A and Q).

II. *Siltstone lithofacies*:

It is mainly characterised by siltstone and biomicrite (Figures 3.25), reddish-brown to maroon, mottled texture and caliche are also common. The upper part of this lithofacies generally consists mainly of gray mudstone intercalated with thin-to medium-bedded limestone. Fossils, particularly vertebrate of hybodont shark, *Lepidotes*-like actinopterygians, lungfishes etc. (Buffetaut et al., 1994).

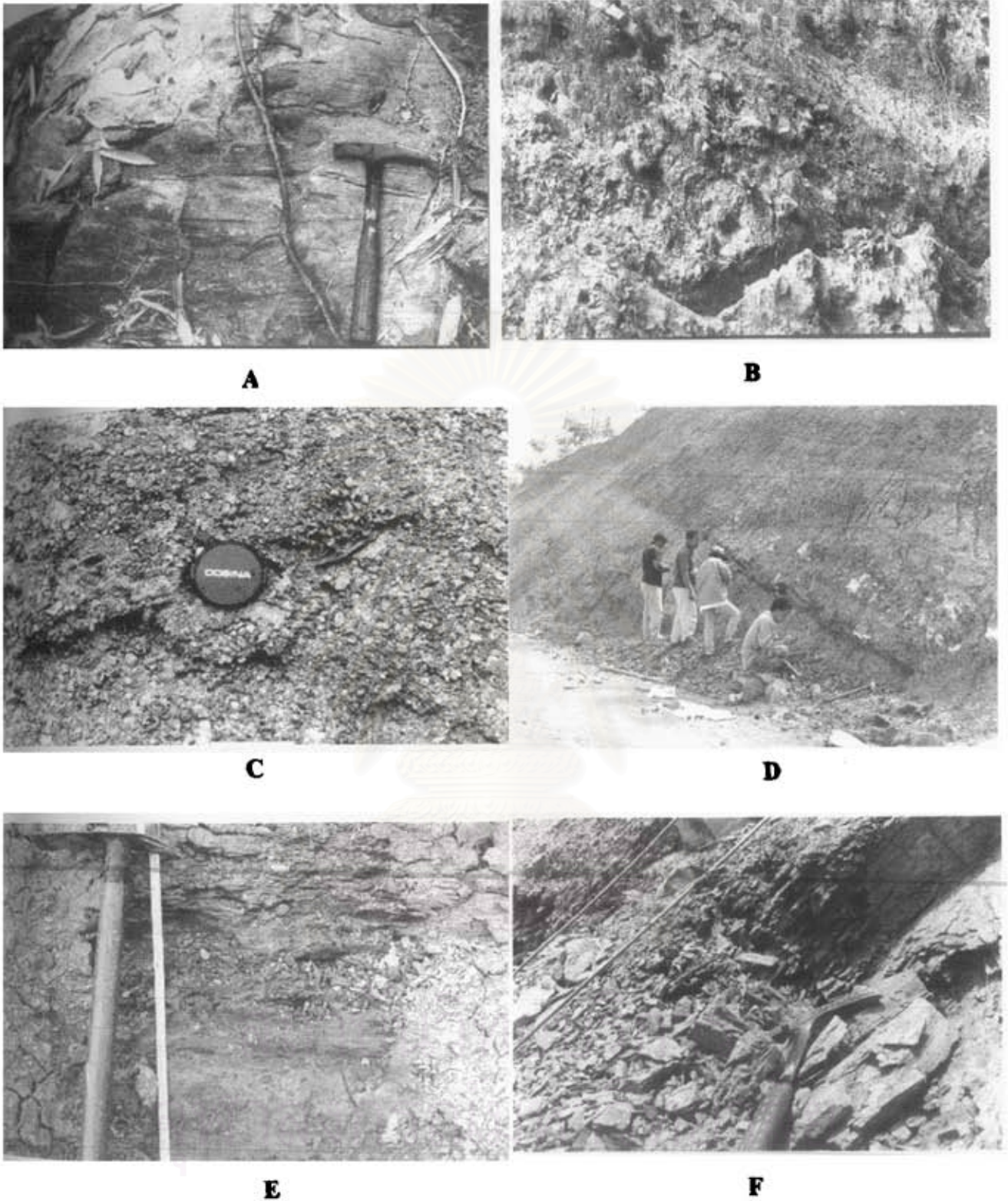


Figure 3.23 The Khlong Min formation (lithofacies I), (A) Hummocky structure; (B, D) Mudstone intercalated with fossiliferous limestone; (C) Conglomeratic limestone with clast-supported; (E) With fining upward sequence; (F) Mudstone and shale with abundant fossils of invertebrates.

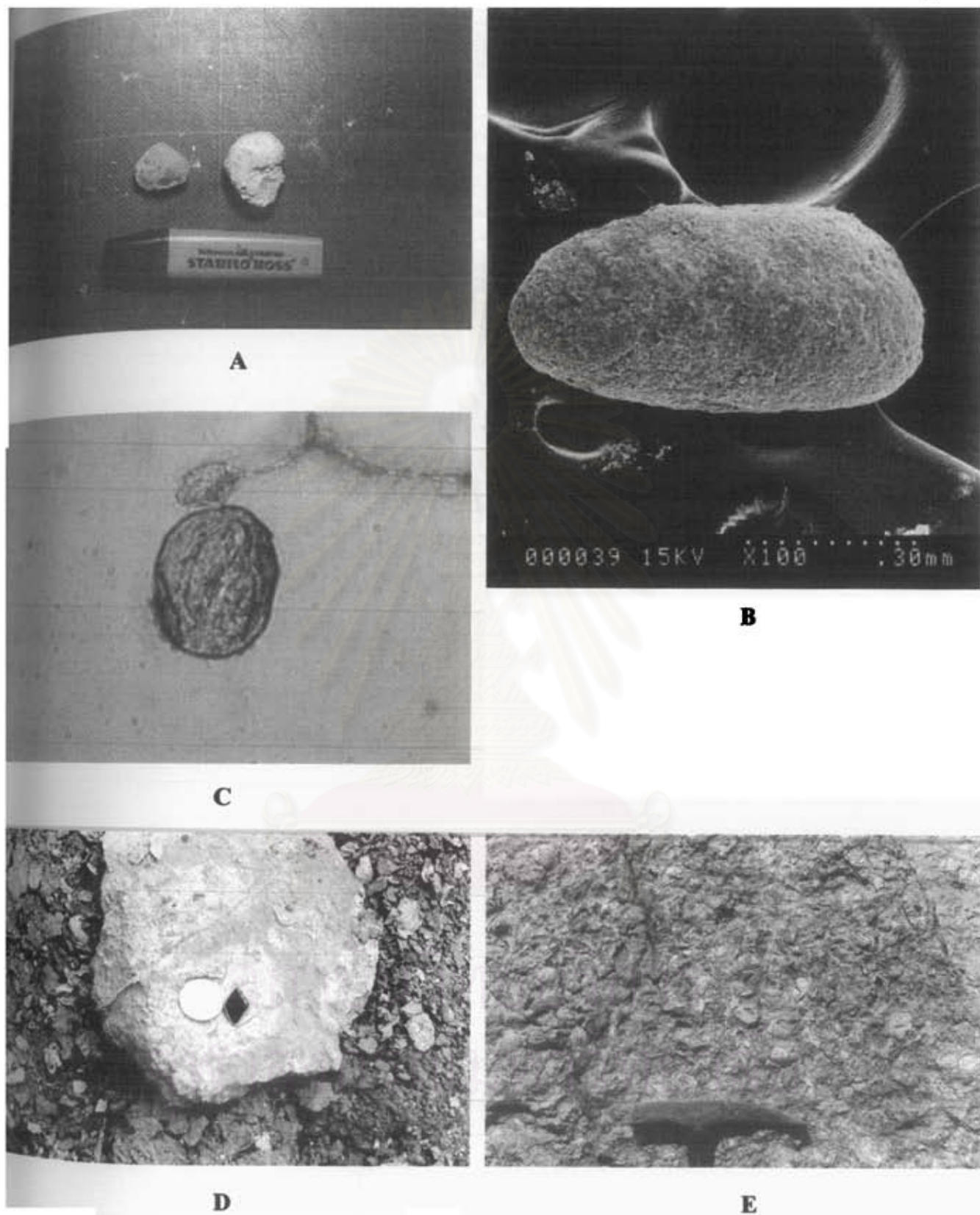


Figure 3.24 Fossils of the Khlong Min formation (lithofacies I). (A) Fossils of lithofacies I; (B) *Darwinulla* sp.; (C) *Aggerella circumtexta* sp.; (D) *Lepidotes* fishes; (E) Fossiliferous limestone with *Lopha* sp.

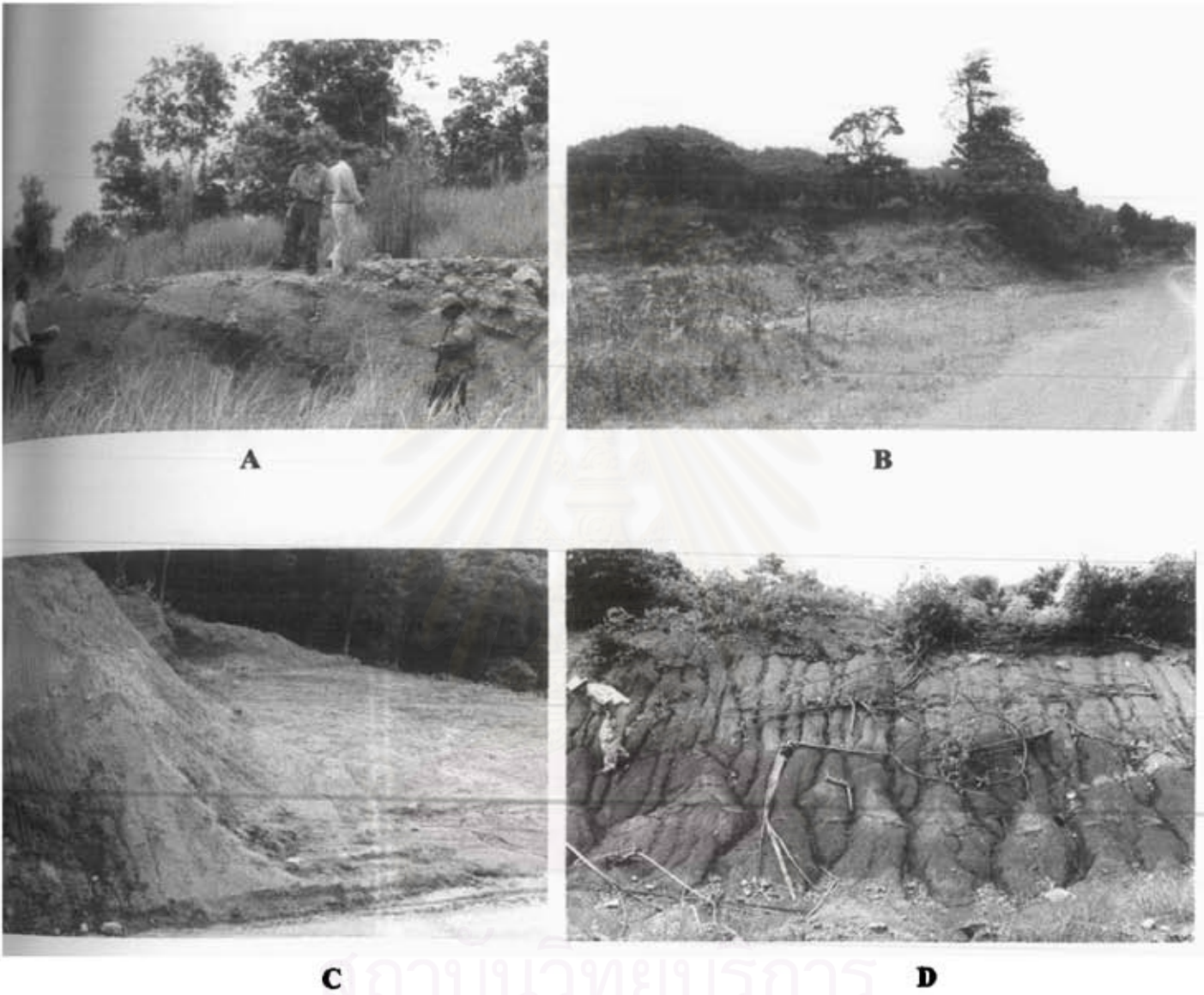


Figure 3.25 The Khlong Min formation (lithofacies II), (A) Siltstone with thin-bedded limestone, section C; (B) Siltstone, yellowish brown, section A; (C, D) Siltstone, maroon with abundant fossils of *Unio* sp.

III. *Calcareous sandstone lithofacies:*

This lithofacies overlies siltstone lithofacies with gradational contact. It is mainly calcareous sandstone, yellowish brown, medium-grained, well sorted with common flaser bedding (Figure 3.26). Petrographically, this lithofacies consists of calcareous sandstone and limestone. The sandstone composes mainly of quartz, feldspar and minor amount of rock fragments with calcareous cement. Most of quartz are fine-to medium-grained, subrounded and moderately sorted with iron oxide coating.

IV. *Fossiliferous limestone lithofacies:*

The thickness of this lithofacies ranges from 6 to approximately 10 metres. (Figure 3.18, Section B). It is characterised mainly by limestone interbedded with calcareous sandstone, medium-grained, well sorted with flaser bedding. The light gray-gray limestone beds contain abundant wood fragments and bivalve of *Modiolus* sp. (Figures 3.18 and 3.27). The calcareous sandstone consists of quartz, feldspar and rock fragments. Most of quartz are fine-grained, subangular to subrounded, and well sorted. Most of the grains are cemented by calcite and abundant opaque minerals.

(c) *Thickness:* The thickness ranges from 58 to approximately 116 metres. The measured sections at Khlong Min of Ban Mab Ching and Laem Pleo of Ban Bo Muang are 116 metres and 58 metres, respectively (Figure 3.19). At Khlong Min of Ban Mab Ching area, the thickness as measured by previous author (Raksaskulwong, 1994) is different, 75 metres.

(d) *Contact:* The Khlong Min formation unconformably overlies the marine Triassic sequence based on the presence locally basal conglomerate at the north of Khao Khom, grid reference 605085, map sheet 4825 II (Figure 3.28). The basal conglomerate with matrix-supported and clast are made up mainly of sandstone, quartz, limestone and chert. The marine Triassic rocks are composed of calcareous

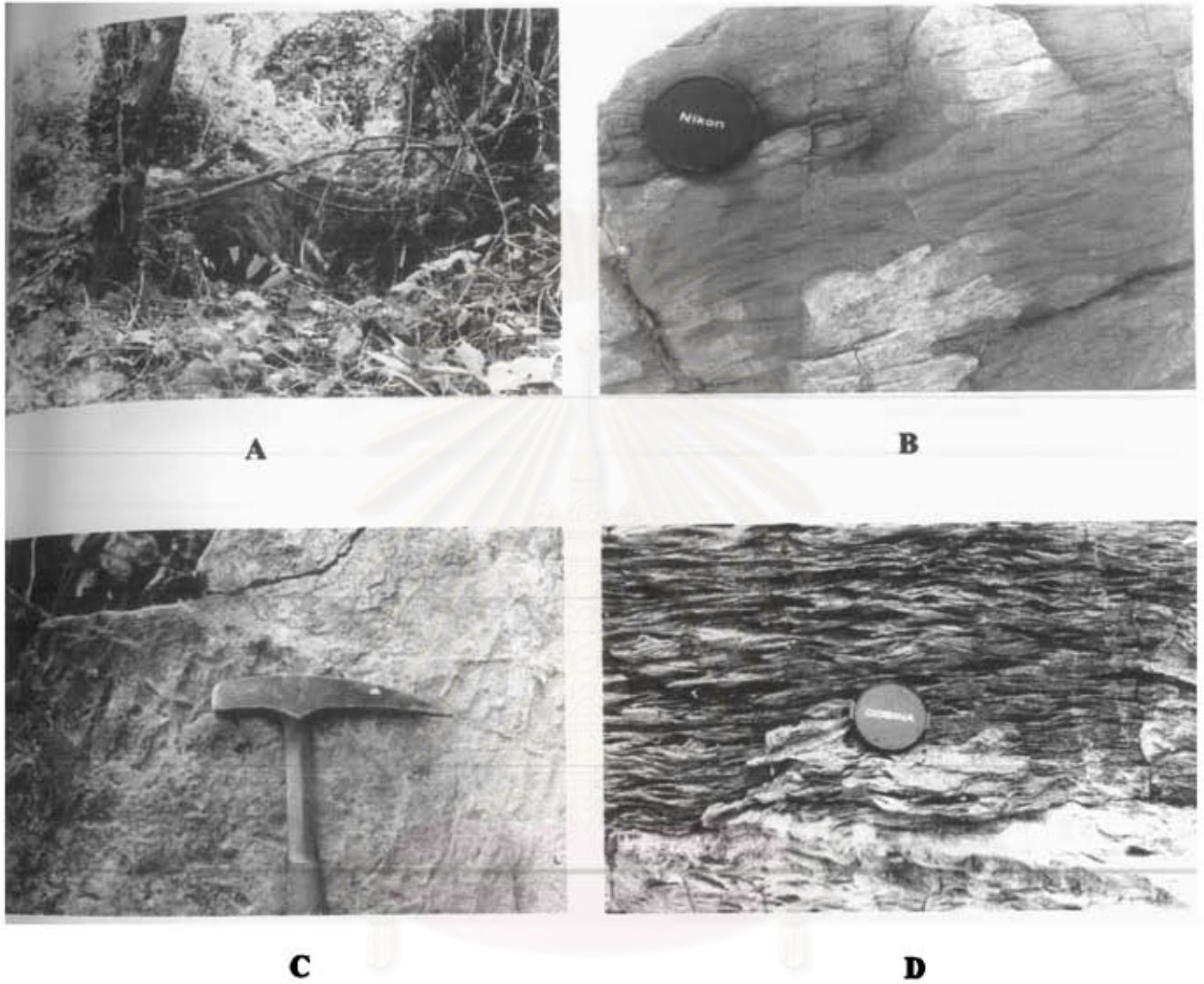


Figure 3.26 The Khlong Min formation (lithofacies III), (A, B) Calcareous sandstone with flaser bedding, section B; (C, D) Calcareous sandstone with flaser bedding, section Q.



A



B

Figure 3.27 The Khlong Min formation (lithofacies IV), (A) Limestone interbedded with calcareous sandstone; (B) Abundance of wood fragments and bivalve of *Modiolus* sp.

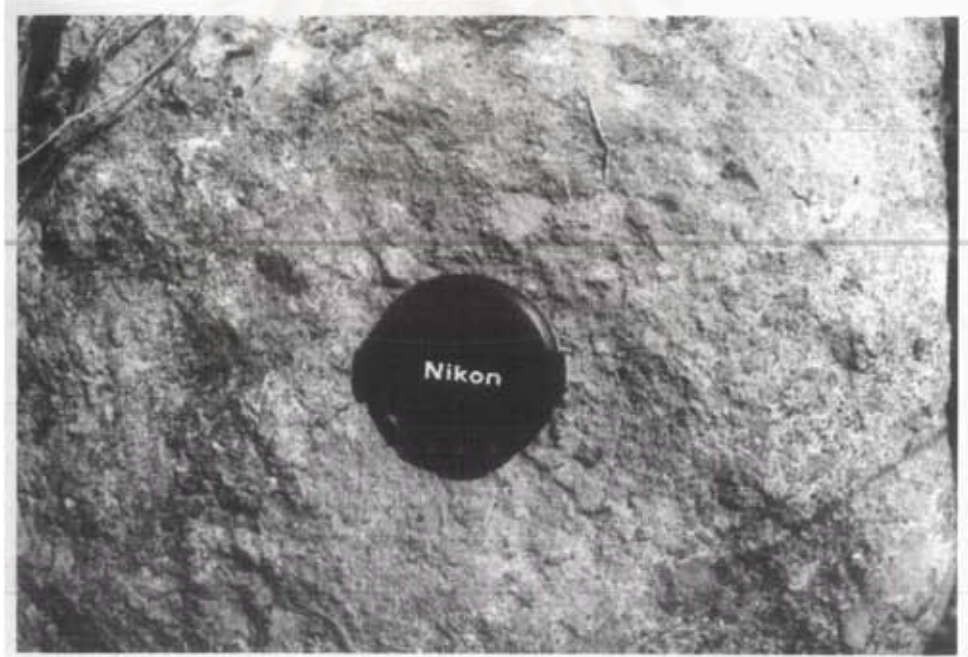
**A****B**

Figure 3.28 The basal conglomerate with matrix-supported at Khao Khom (grid 605085, 4825 II).

siltstone, reddish-brown to maroon, with thin-bedded limestone and limestone lenses with abundant fossils. This formation conformably underlies the Lam Thap formation of sandstone and siltstone.

(e) *Paleontology and age*: The age ranges from lower Middle Jurassic at Khlong Min of Ban Mab Ching, because the mudstone intercalated with fossiliferous limestone in the lower part of this formation contain the Ostracod (*Darwinulla* sp., Jumnonngthai, pers. comm., 1999) (Figure 3.24 and 3.29), sporopollens of *Classopollis* (86.18% of the total amount) and *Dicheiopollis* (4.25%) of Cheirolepidaceae (Zuoqi, 1999) of Late Jurassic age while siltstone interbedded with limestone contains vertebrates of hybodont sharks, *Lepidotes*-like actinopterygians, lungfishes, temnospondyl amphibians, mesosuchian crocodilians, and cryptodiran turtles (Buffateut et al., 1994) of Jurassic age. The upper fossiliferous limestone beds contain wood fragments and abundant *Modiolus* sp. (Meesook, pers. comm., 1999).

(f) *Reference locality*: The sequence at the type locality of Khlong Min, Ban Mab Ching is not completely cropped out. Therefore, additional reference locality is proposed in this paper at Laem Pleo of Ban Bo Muang, Khlong Thom, (Section Q) to produce the complete type-section.

Lam Thap formation

The Lam Thap formation takes its name from Amphoe Lam Thap of Nakhon Si Thammarat, proposed by Raksaskulwong (1989). The lithostratigraphic columns from the measured section are shown in Figure 3.19.

(a) *Definition*: The synonym of this formation is Chumphon red beds formation (Raksaskulwong, 1994) and Lang Khao formation (Department of Geology Chulalongkorn University, 1998). The Lam Thap formation is a predominantly arkosic sandstone and siltstone units, divided into 2 lithofacies. In some areas, the formation is made up of almost thick-bedded arkosic sandstone (Figure 3.19, sections

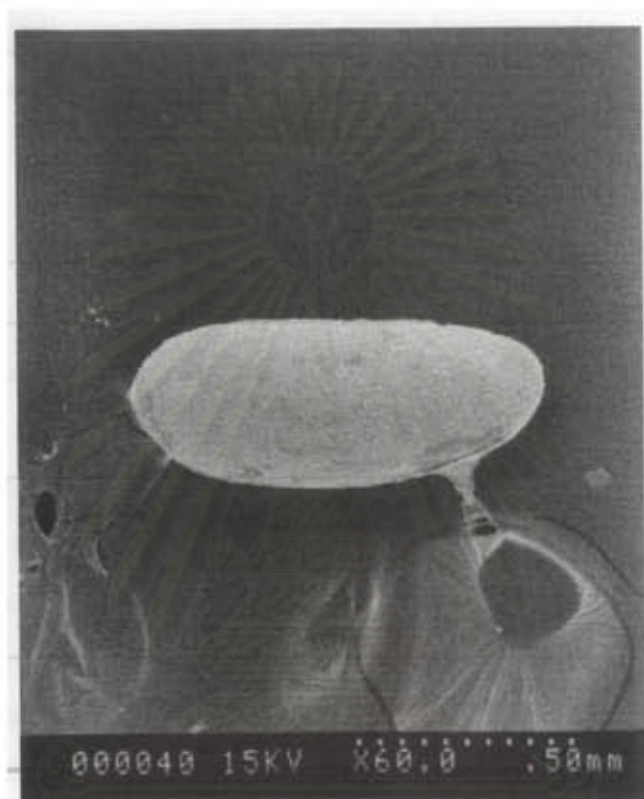


Figure 3.29 Ostracod (*Dawinulla* sp.) from the mudstone (lithofacies I), the Khlong Min formation.

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B, C and Q). On the other hands, it is characterised by siltstone, mudstone interbedded with sandstone and conglomeratic sandstone in some areas (Figure 3.19, sections D, E, F and H) with common fining upward and, in some areas, thinning upward sequences. The Lam Thap formation conformably overlies the Khlong Min formation and is conformably overlain by the Sam Chom formation. However, in some places it may be conformably overlain by the Phun Phin formation (Figures 3.21 and 3.30, Section J).

(b) *Lithology*: The Lam Thap formation consists of 2 lithofacies: the thick-bedded arkosic sandstone, and siltstone interbedded with shale. Relationships among the lithofacies are shown in Figure 3.19.

I. Thick-bedded arkosic sandstone lithofacies:

It consists of arkosic sandstone and conglomeratic sandstone, yellowish brown, well sorted and subangular to subrounded, thin-to thick-bedded (Figure 3.31) with graded bedding and planar cross-bedding (Figure 3.31). The lateral facies changes are very common. In the study area, this facies crops out mainly in Khao Tao (Figure 3.19, Section D), Khao Yan Yao, Khao Chong Din and Khao Khiam. The arkosic sandstone composes mainly of quartz, feldspar and rock fragments with siliceous and ferrugeneous cements. Most of the clasts are fine-to medium-grained and well sorted.

II. Siltstone interbedded with mudstone lithofacies:

This lithofacies is characterised by alternating beds of siltstone, shale, and thin-bedded sandstone (Figures 3.19, and 3.32). The colour of siltstone and shale are reddish brown to maroon. The sandstone is laminated to medium-bedded and medium-grained. Shale is gray to brownish gray with abundant fern-like leaves (Figure 3.19, Section E and 3.33), and the bivalve of *Unio* sp. (Meesook, pers. comm.,1999) (Figure 3.19, Section F and 3.33).



Figure 3.30 The Phun Phin formation conformably overlies the Lam Thap formation at southern part of Khao Sam Chom, section J.

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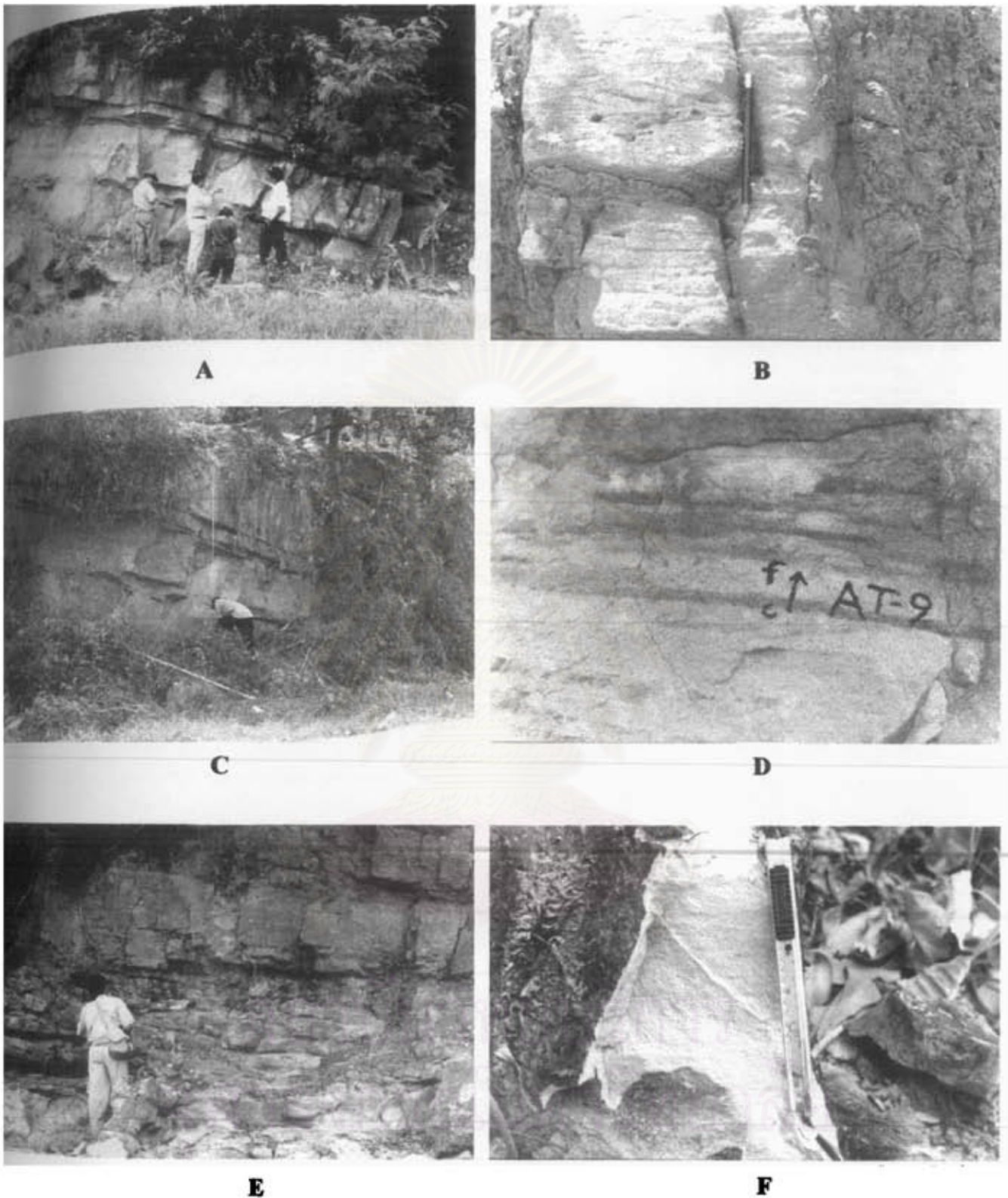


Figure 3.31 The Lam Thap formation (lithofacies V). (A, C) Thick-bedded arkose at Khao Tao, section D; (B, D and F) Showing planar cross-bedding and fining upward sequence; (E) Thick-bedded arkose at Laem Pleo, section Q.

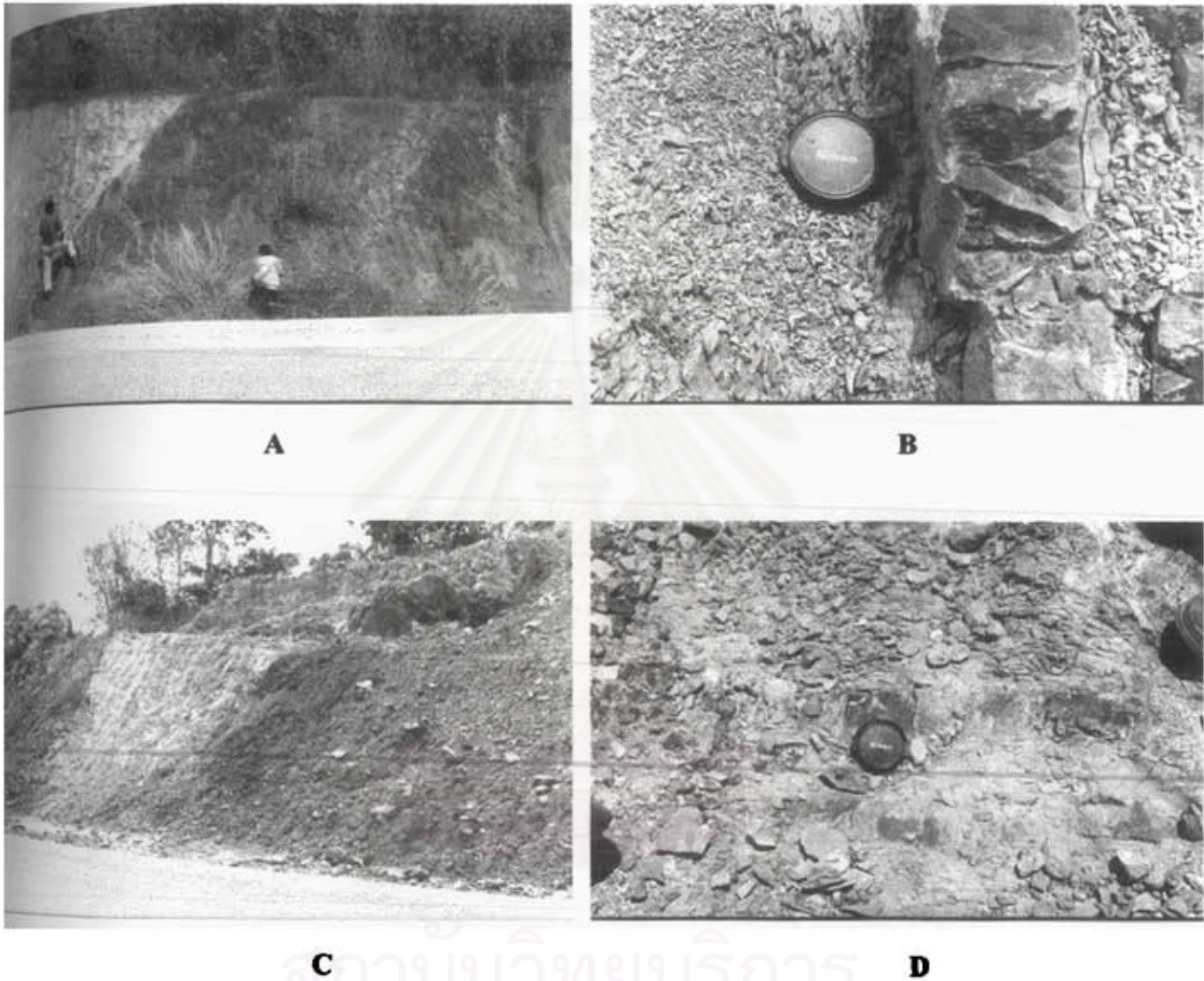


Figure 3.32 The Lam Thap formation (lithofacies VI). (A, C) Siltstone interbedded with shale, showing fining upward sequence; (B) Showing load cast; (D) Mudstone with fern-like leaves at Ban Ao Tong.

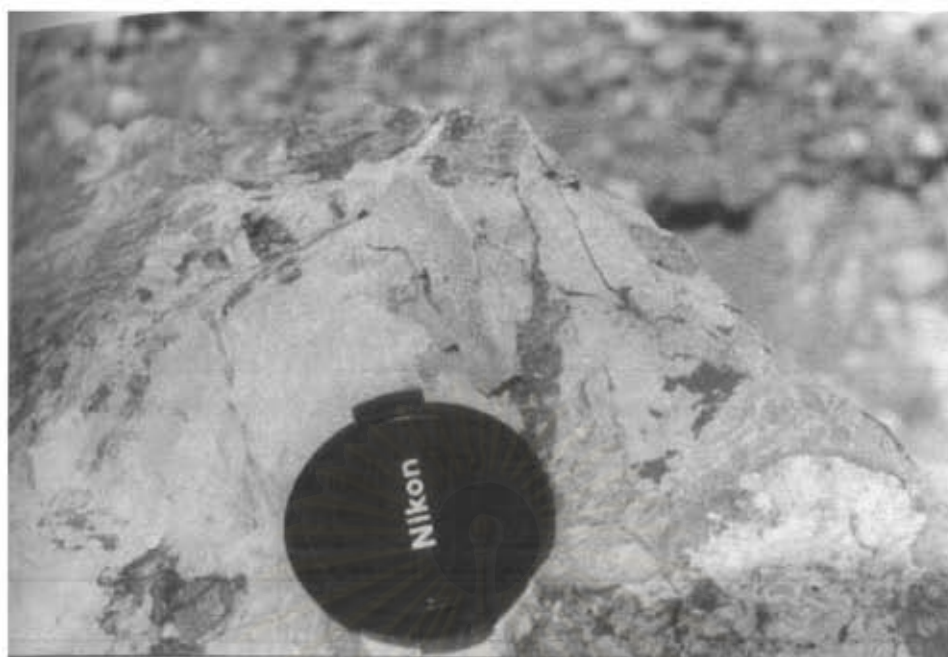
**A****B**

Figure 3.33 The Lam Thap formation. (A) Fern-like leaves, section E;
(B) *Unio* sp., section F.

(c) *Thickness*: The thickness ranges from 30 to 197 metres. The thickness of 60 metres was measured at the Khlong Min (Section B), 30 metres at the Laem Pleo of Ban Bo Muang (Section Q), and 197 metres at Khao Tao section (Section D).

(d) *Contacts*: The Lam Thap formation conformably overlies the Khlong Min formation and conformably underlies the Sam Chom formation at Khlong Min of Ban Mab Ching.

(e) *Paleontology and age*: Shale and siltstone of Section E (Road cut Road no. 4225, Bang Khan–Ao Tong) contain the fern-like leaves (Figure 3.33). Asama et al.(1981) identified and described 6 species of plant fossils. They belong to Filicales, Beunettitales and Coniferales indicating the early Early Cretaceous age.

The thin-bedded conglomeratic limestone of Section F (Figures 3.33) contains fossils of bivalves and vertebrates. These bivalves are similar to *Unio* sp. of the Sao Khua Formation of the Khorat Group identified by Meesook (pers. comm.,1999). Therefore, the *Unio* sp. of Lower Cretaceous may be correlated to the Sao Khua Formation of the Khorat Group.

(f) *Reference section*: The measured section at Laem Pleo of Ban Bo Muang (Section Q) and the Bang Khan section (Section F).

Sam Chom formation

With regard to Raksaskulwong (1994) who proposed the name Sam Chom formation to represent conglomerate and conglomeratic sandstone. The lithostratigraphic columns of the measured sections are shown in Figures 3.19 and 3.34.

(a) *Definition*: The Sam Chom formation is that sequence lying between the Lam Thap and Phun Phin formation. It consists mainly of conglomerate, medium-

**A****B**

Figure 3.34 The Sam Chom formation. (A) Conglomerate with sandstone lenses, section Q at Laem Pleo; (B) Conglomerate with sharp contact overlies the Lam Thap formation (grid 570019, 4825 III)

grained sandstone, and conglomeratic sandstone with matrix-supported, clasts contain mainly of quartz, chert, red sandstone, and volcanics with clast size varies from granule to boulder (Figures 3.35).

The type locality of the formation is situated at Khao Nam Daeng and Khao Sam Chom, Nakhon Si Thammarat (Figure 3.35).

(b) *Lithology*: It is characterised by conglomerate, conglomeratic sandstone and thin-to medium-bedded sandstone.

Conglomerate are matrix-supported and clasts are made up mainly of quartz, chert, sandstone, and some volcanics (Khuan Chanai, Khao Nam Daeng and Laem Pleo) and size varies from 0.2-50 centimetres (Table 3.18). The sandstone is yellowish brown to light gray, thin-bedded, and medium-grained, consisting mainly of quartz, feldspar and dark minerals with common graded bedding, and usually shows sharp contacts with overlies mudstone, siltstone of reddish orange to reddish brown. The lowerest part of this formation is marked locally by medium-bedded sandstone (Figure 3.36).

(c) *Thickness*: The 15 metres thick sequence was measured at Khao Nam Daeng, 100 metres at Khao Sam Chom, and 7 metres thick at Laem Pleo of Ban Bo Maung. However, the measured thicknesses differ markedly from previous estimates of 140 metres by Raksaskulwong (1994).

(d) *Contact*: The Sam Chom formation conformably overlies the Lam Thap formation and underlies the Phun Phin formation.

(e) *Type Locality*: The Khao Sam Chom and Khao Nam Daeng east of Khlong Min are the type localities.

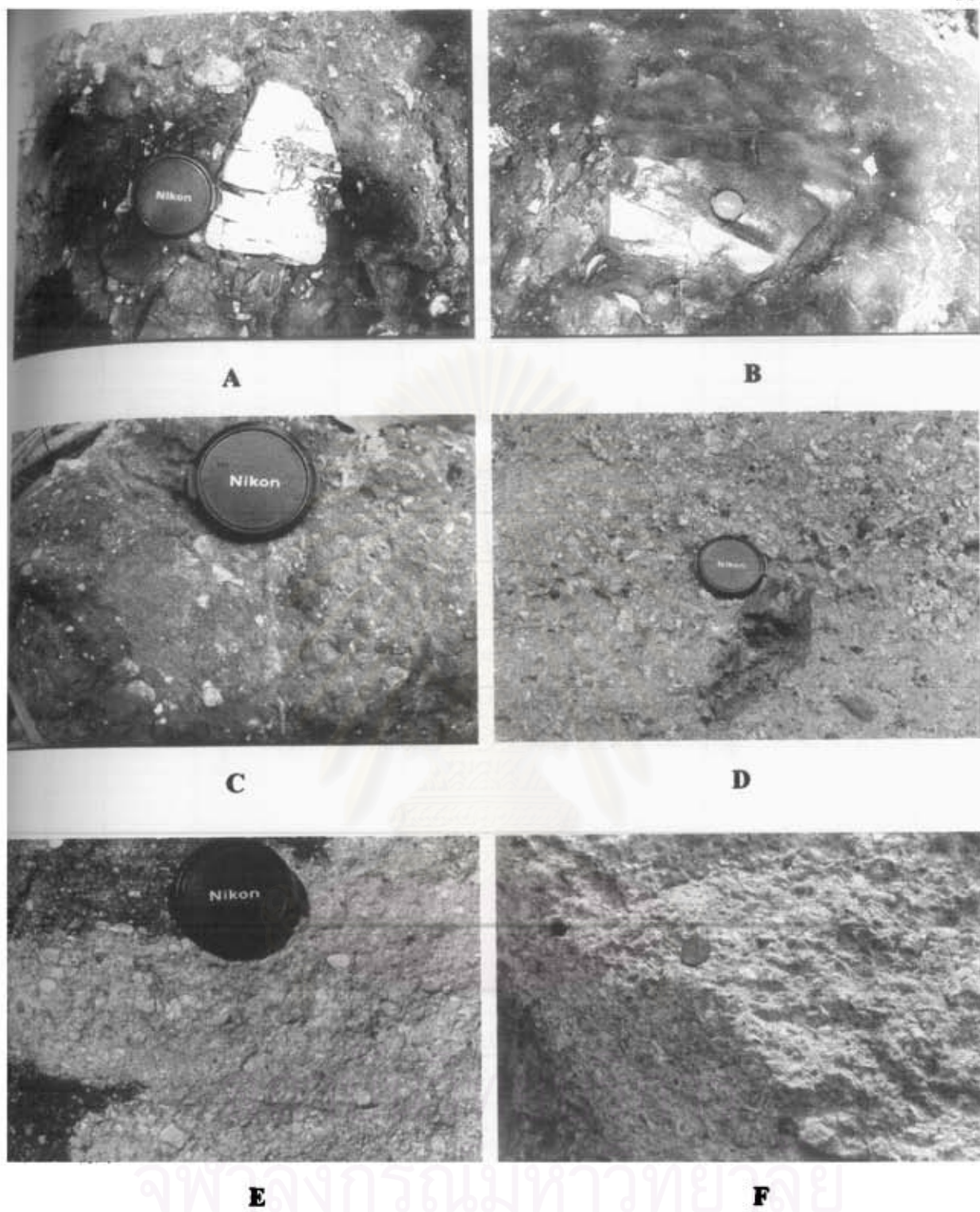


Figure 3.35 Clasts of the Sam Chom formation. (A, B, and C) At Khao Sam Chom; (D) At Laem Pleo; 3.35(E) At Khuan Chanai; (F) At Khao Nam Daeng.

Table 3.18 Summarised composition and size of conglomerate clasts of the Sam Chom and Lam Thap formations.

Formation	Location	Cement	Size (mm)	Compositions				
				Quartz	Chert	Sandstone	Volcanic rocks	Rock fragments
Sam Chom	Sam Chom	Moderately-well	Maximum	50	100	500	30	-
			Minimum	2	2	5	2	-
	Khao Nam Daeng	Moderately	Maximum	50	30	-	30	-
			Minimum	2	2	-	2	-
	Khuai Chanai	Moderately-well	Maximum	30	30	100	50	-
			Minimum	2	2	10	10	-
	Laem Pleo	Moderately-well	Maximum	40	50	-	50	-
			Minimum	2	2	-	10	-
Lam Thap	Ao Tong	Moderately-well	Maximum	30	40	50	-	10
			Minimum	2	2	2	-	2

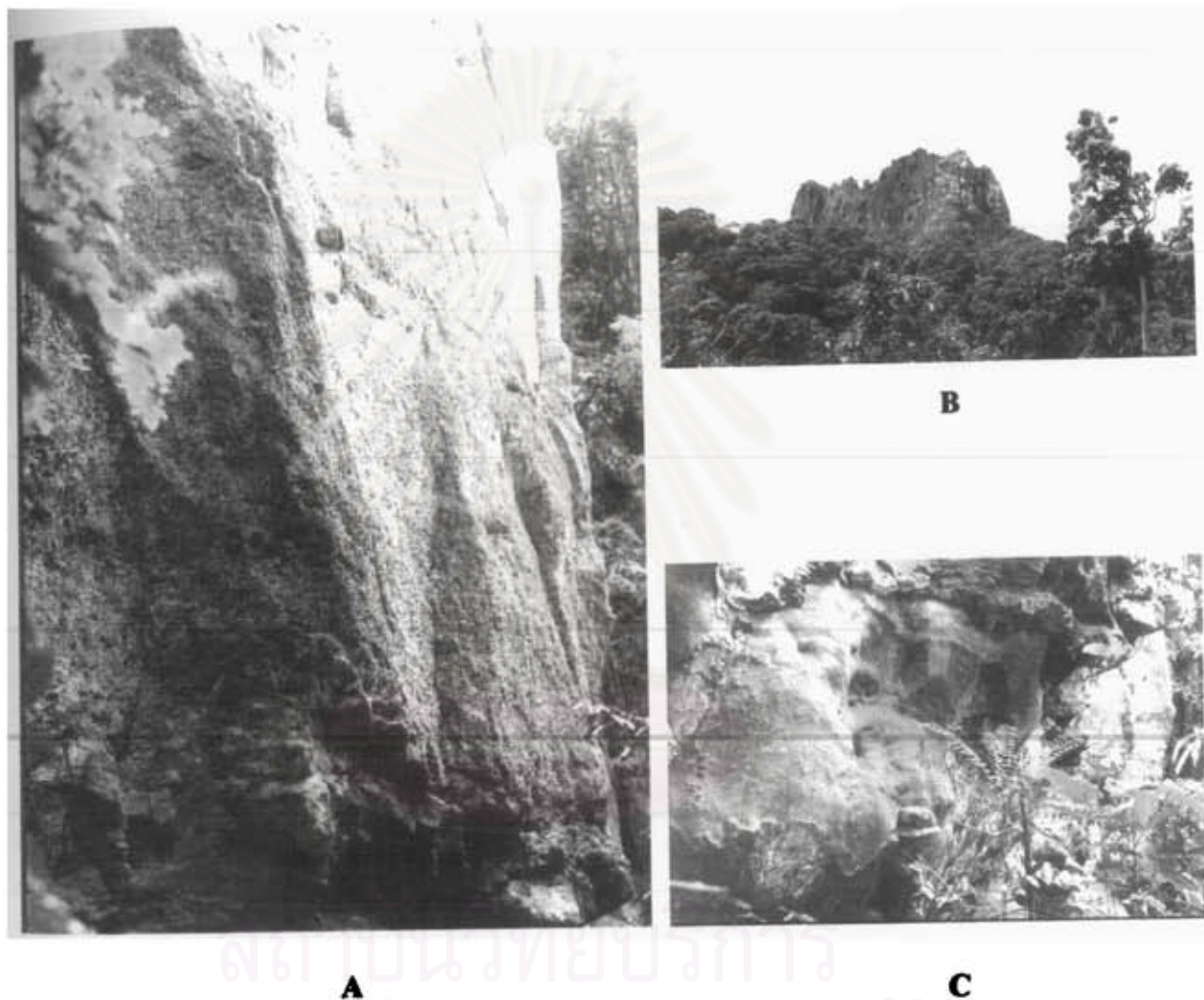


Figure 3.36 The Sam Chom formation. (A) At Khao Nam Daeng showing graded bedding; (B) Topography of Khao Sam Chom; (C) Siltstone underlies medium-bedded sandstone.

Phun Phin formation

The rocks of this formation in the Surat Thani area were mapped and named by Teeyapirat (1989).

(a) *Definition:* The Phun Phin formation predominantly consists of red to reddish brown fine-grained sandstone, conglomerate/breccia. It conformably overlies Sam Chom formation (Figure 3.37) and underlies Tertiary rocks. Raksaskulwong (1994) reported that the basal conglomerate of Tertiary deposits in the vicinity of Thung Yai area, particularly exposing along the margin of Sin Pun basin may overlies the upper part of the Phun Phin formation. But the contact between the basal conglomerate and the Phun Phin formation has not been revealed. Therefore, further investigation will solve this problem. The type locality is situated at km.10 road no. 4038 from Lam Thap to Khlong Thom. Planar and trough cross-beddings are predominant in this formation.

(b) *Lithology:* It is characterised by beds of fine-grained sandstone, red to reddish brown and conglomerate/breccia. The Phun Phin formation consists of 2 lithofacies: The fine-grained sandstone, and the fanglomerate.

I. Fine-grained sandstone lithofacies :

The 73 metres thick sequence is characterised at the lower part by mainly fine-grained sandstone and siltstone (Figure 3.38). The sandstone is composed of quartz in fine-grained matrix, and feldspar with ferrugeneous cement, medium-to very thick-bedded, parallel bed type, red to reddish brown, graded bedding, common planar and trough cross-bedding. The upper part of this lithofacies of approximately 20 metres thick, consists mainly of thin-to medium-bedded, reddish brown sandstone, and thin-bedded conglomerate with small to large planar cross-bedding, and locally bioturbated (Figure 3.39). Sharp contacts between fine-grained sandstone and conglomerate are common.



Figure 3.37 The Phun Phin formation unconformably overlies the Sam Chom formation at Khuan Chanai (grid 396634, 4824 I, SWW view).

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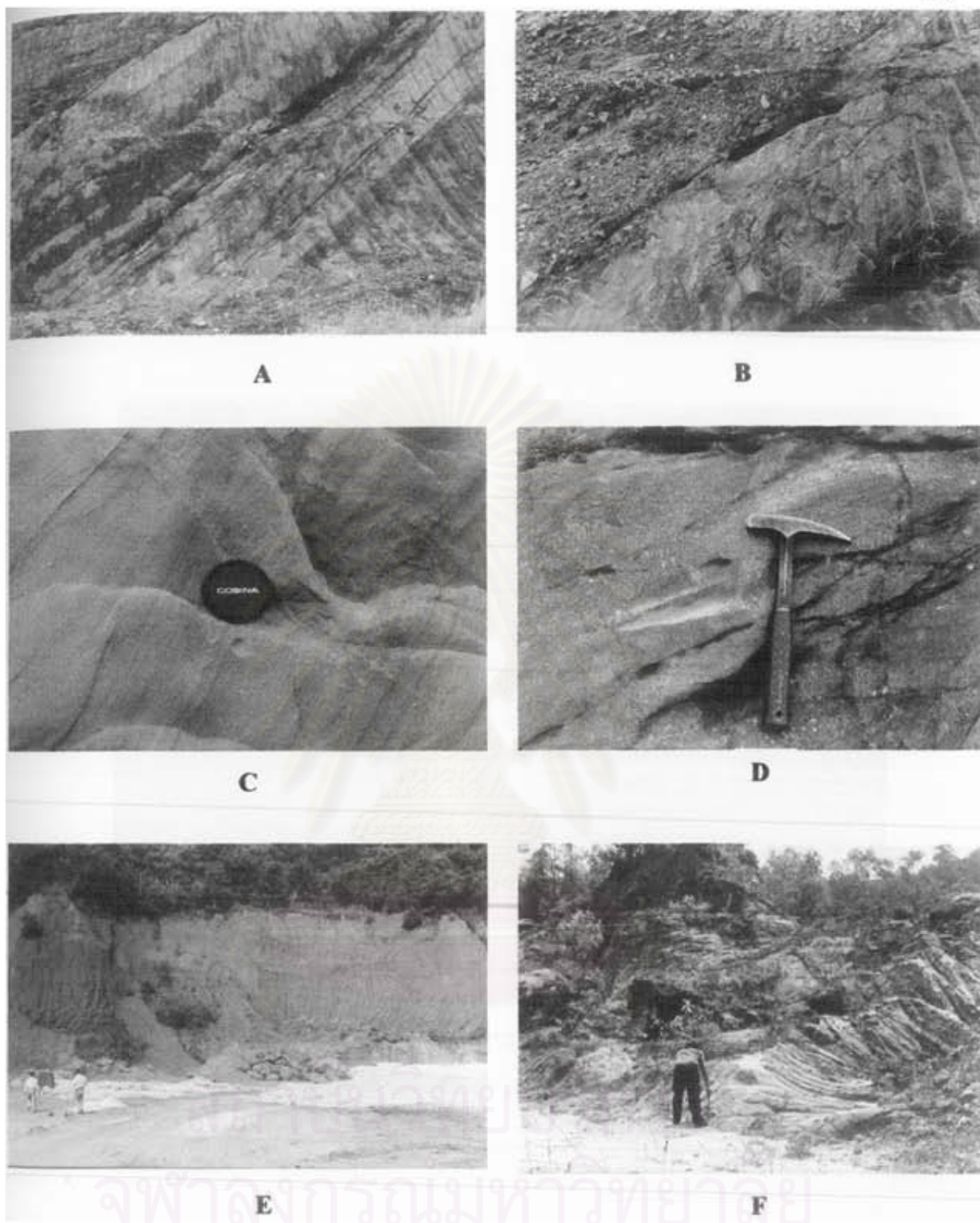


Figure 3.38 The Phun Phin formation (lithofacies VIII). (A) Thin-to very thick-bedded fine-grained sandstone, section I; (B) Showing sharp contact underlies the fanglomerate lithofacies (II); (C, D) Showing laminated and graded bedding; (E, F) The equivalent formation of fine-grained sandstone at Phun Phin, Surat Thani.



Figure 3.39 The bioturbation of fine-grained sandstone, northern part of Khao Na Daeng (grid 476747, 4824 I).

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II. *Fanglomerate lithofacies:*

The 28 metres thick sequence consists of conglomerate/breccia with both clast-supported and matrix-supported. Clasts are made up mainly of quartz, chert, quartzite, sandstone and rock fragments, angular to subangular, average granule to boulder size with maximum size of approximately 0.60 metres (Figure 3.40).

(c) *Thickness:* The thickness ranges from approximately 102 metres to 770 metres and possibly exceeding 1,000 metres thick at the south of Khao Sam Chom (Figure 3.41). However, the measured thicknesses differ markedly from previous estimate of 80 metres by Raksaskulwong (1994).

(d) *Contact:* Generally, it conformably overlies the Sam Chom formation and unconformably underlies the Tertiary rocks with the basal conglomeratic limestone of Tertiary deposits at Khao Raik Phon west of Sin Pun basin (Figure 3.42). However, in place where the Sam Chom formation is not developed, it overlies the Lam Thap formation, i.e, the new road cut south of Khao Sam Chom (Figure 3.19, Section J).

(e) *Paleontology:* Moderately common trace fossils in this formation, at the southern part of Ban Bang Khan (Figure 3.39).

3.5 Geological structures of the Thung Yai-Khlong Thom area

The regional geological structure of peninsular Thailand mainly orientates in the N-S direction for rocks ranging in age from Lower Paleozoic to Recent (Figure 2.9). The granites along the eastern part of the peninsular Thailand are mainly Triassic to Jurassic whereas those in the western part are Cretaceous to Tertiary (Charusiri, 1989)

The major geological structures include folds, fractures, and faults which mainly orientates in the north-south direction. The antiforms are restricted to

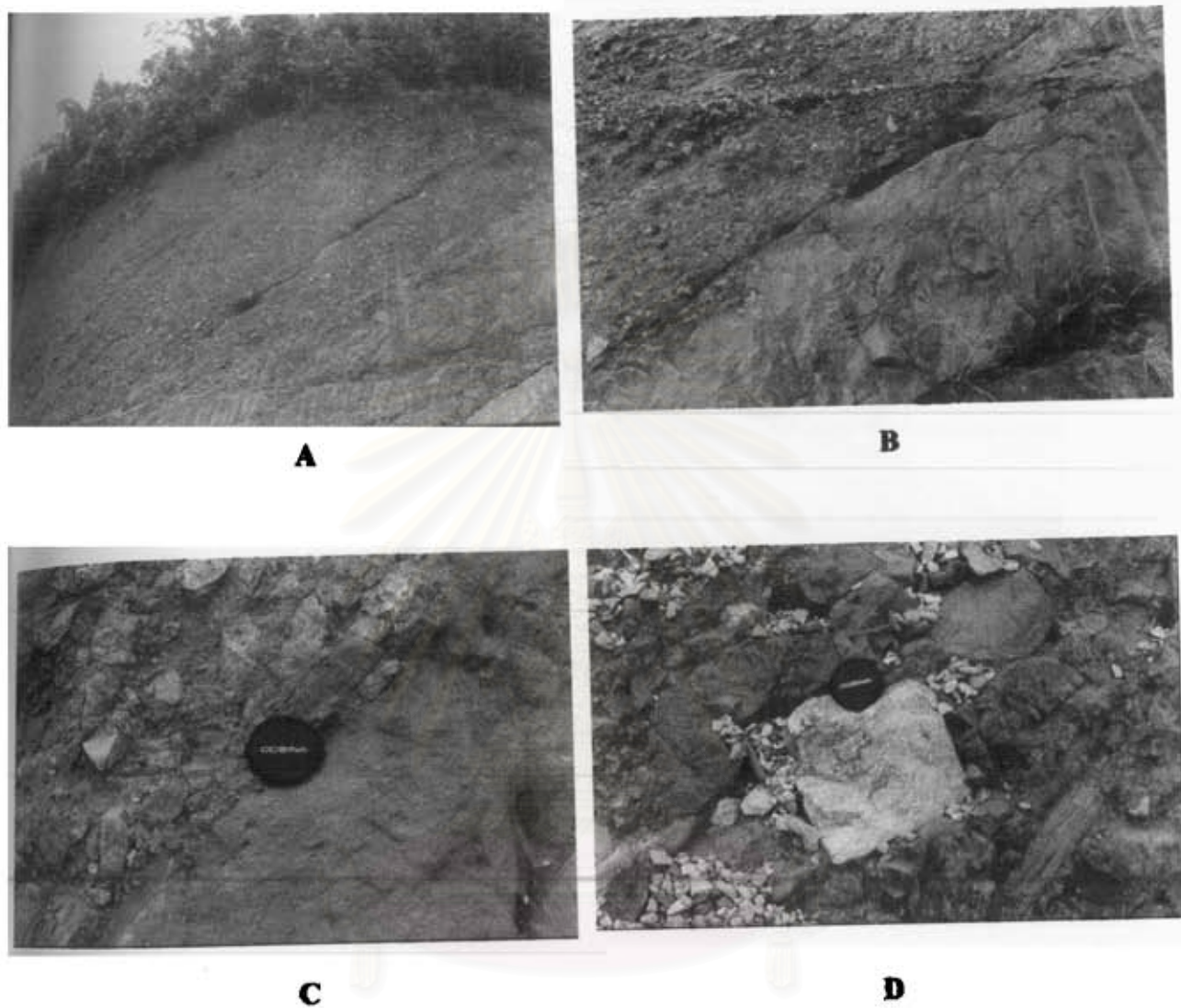


Figure 3.40 Fanglomerate lithofacies (IX), Phun Phin formation at km. 10 road no. 4038.
 (A, B) Showing sharp contact overlies the fine-grained sandstone lithofacies (I);
 (C, D) Clasts of conglomerate/breccia made up of quartzite, chert, sandstone and quartz.



Figure 3.41 The very thick sequence of the Phun Phin formation at south of Khao Sam Chom, section J.

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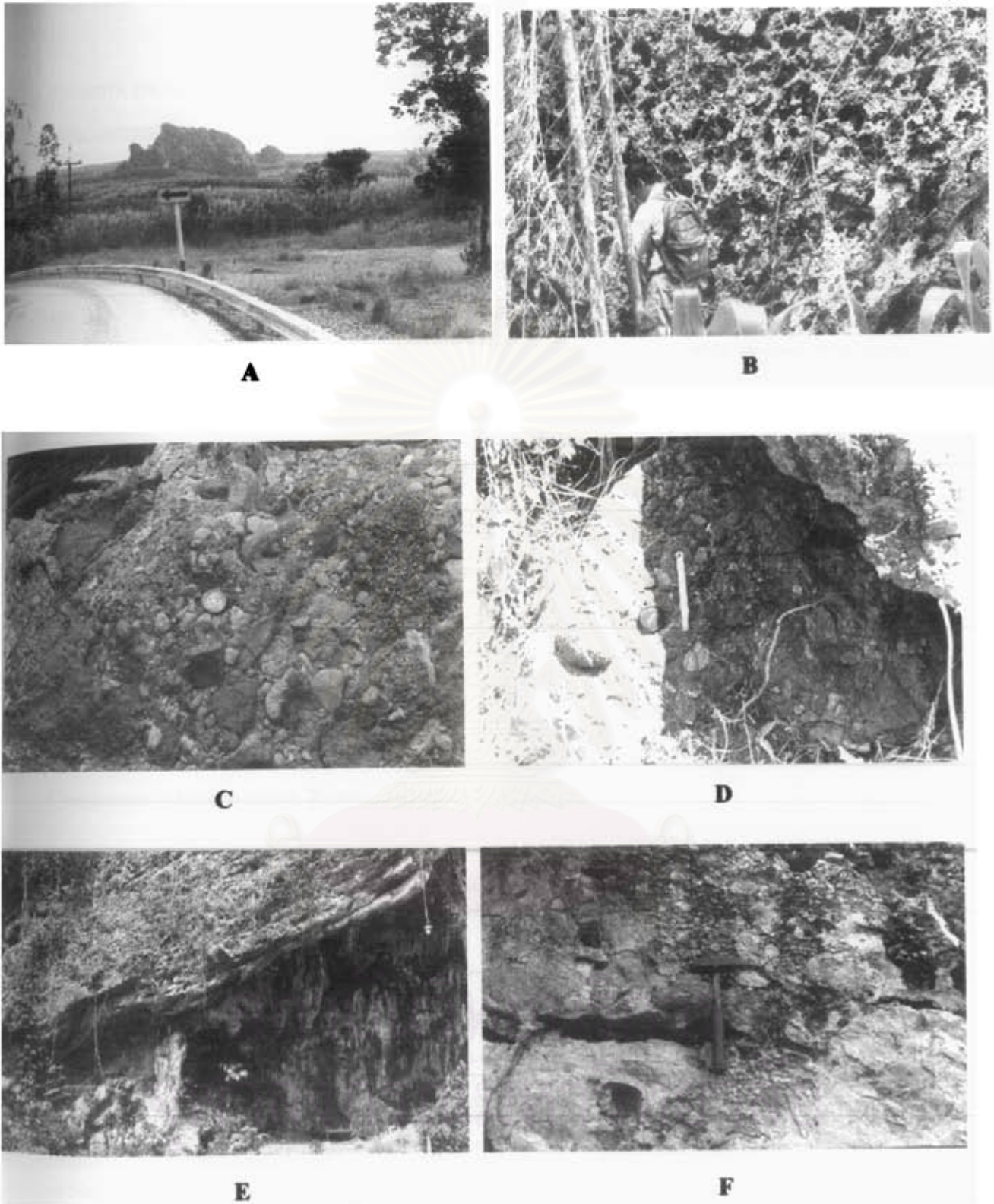


Figure 3.42 The basal conglomerate at Khao Riak Phon (grid 226117, 4825 III). (A) Khao Riak Phon; (B, C, D, E, and F) Conglomerate with matrix-supported, clasts made up of red sandstone, quartz and chert.

sediments peripheral to the granite plutons and are believed to be the result of granite emplacement.

The penetration of India into Asia caused the clockwise rotation of SE Asia, resulting increasing oblique subduction of the Indian Ocean Plate beneath the western edge of SE Asia (Charusiri, 1989). Thereafter, the movements along the strike-slip fault with the associated development of pull-apart basin in this region (Kosuwan, 1996). Wherever, the Ranong-Khlong Marui fault zone is inferred to has been active since Oligocene age.

According to the dextral shear model, the NW-SE Three Pagodas fault zone is the principal right-lateral strike-slip faults, whereas the NE-SW Ranong-Khlong Marui fault zones are conjugate left-lateral strike-slip faults (Polachan and Sattayarak, 1989). The left-lateral movement on the Three Pagodas Fault as shown by Bunopas (1981) were possibly caused by the E-W compression (present position) between the Shan-Thai and Indochina Plates in the Permo-Triassic time and reactivated in the Late Cretaceous where western Burma collided with Shan-Thai.

On the bases of the geological observations and the $^{40}\text{Ar}/^{39}\text{Ar}$ geochronological data, Charusiri (1989) suggested that the Three Pagodas (NW trending) fault was intensely active between 77 and 46 Ma, and the Ranong-Khlong Marui fault zones were probably also strongly active during the same period between 82 and 41 Ma.

Within the study area, various geological structures are measured and described throughout the area including beds, faults and fractures. After that, data of attitudes are compiled and analysed using Schmidt method of computing and equal area projection technique, and the "Dips 3.0" software.

Beds

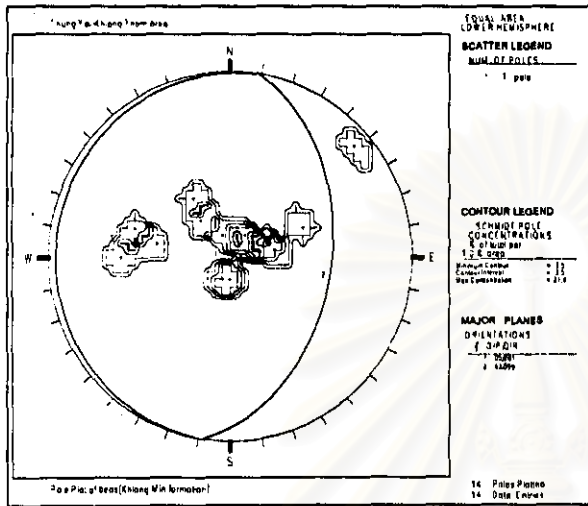
The bedding planes recognised in all outcrops of the study area are shown in Table 3.19. The major trend of bedding has a common NNW-SSE orientation. However, within the Lam Thap formation, the pole of bedding are quite variable as compared with other formations.

From the stereographic projection plots, two trends defined in the study area. Most of the dip angles are between 30-45 degree for all rock units, whereas the Permian rocks are between 10-40 degree. For the Triassic rocks, the dip angles are between 30-40 degree in the western part of the area, and 60-70 degree in the eastern part. The value of dip angles of the Khlong Min formation are about 30-55 degree. For the the Lam Thap formation, the average dip angle is approximately 25-70 degree. The value of dip angles of the Sam Chom formation are about 30-65 degree. For the Phun Phin formation, the average dip angle is approximately 50 degree in the southern part of the study area, and the gentle dip angle throughout in the north. The dip angle of all rock units are summarised in Table 3.20 and Figure 3.43.

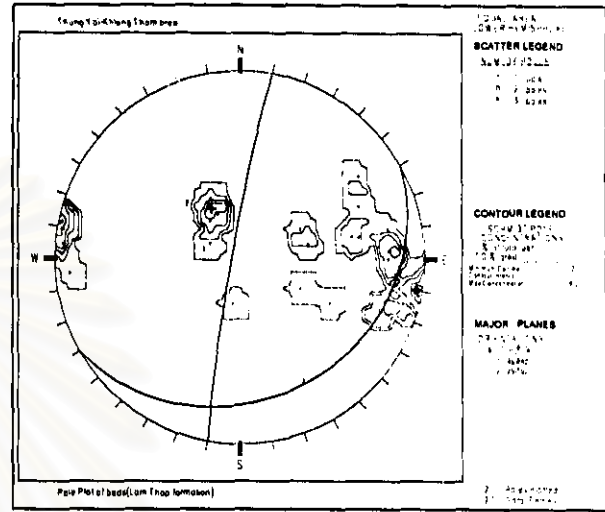
Faults

Evidences from the photogeological interpretation (Figure 3.44) indicate that there are three sets of faults in the study area, notably, the NE-SW, NW-SE, and E-W trendings. Among these, the NE-SW faults are most common. It is noted that the NW-SE and E-W faults have been offset by the NE-SW faults.

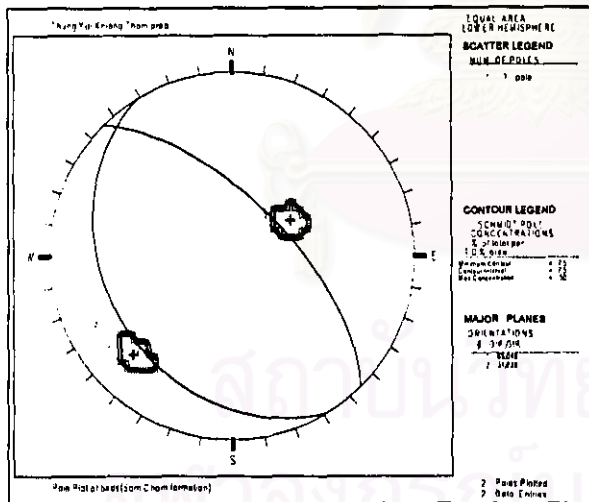
From the field investigations, the NE-SW faults mostly left-lateral strike-slip fault, whereas the NW-SE faults are right-lateral strike-slip fault, and the attitude of fault planes is shown in Table 3-19. The NW-SE fault line (refers to as F1 in Figure 3.44) is the eastern boundary between the Permian limestone of Khao Hin Som and Triassic rocks of the Sai Bon formation. The southwestern part of the study area, the



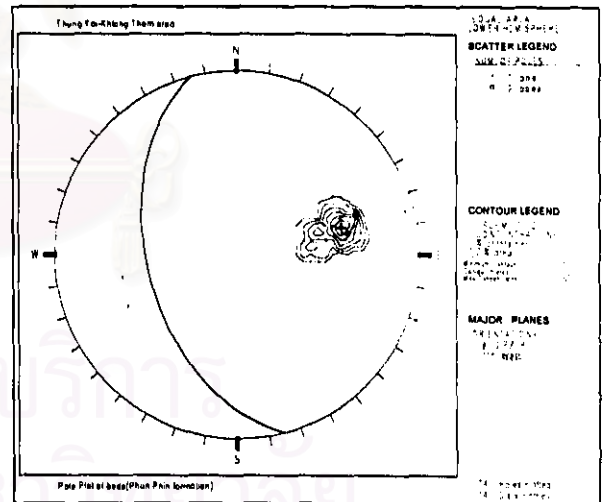
A



B



C

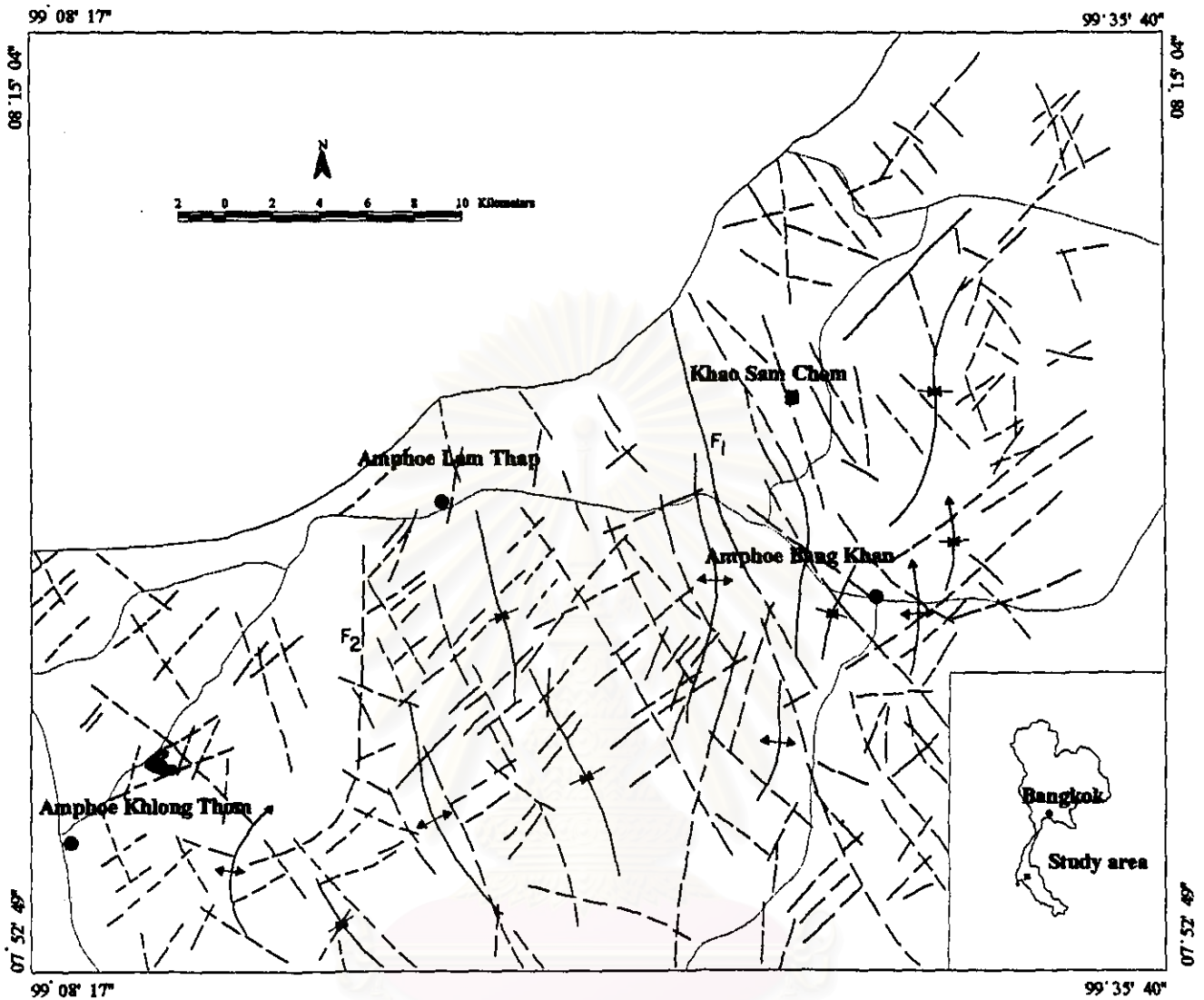


D

Figure 3.43 Schmidt method plotted. (A) Beds of the Khlong Min formation;

(B) Beds of the Lam Thap formation; (C) Beds of the Sam Chom formation;

(D) Beds of the Phun Phin formation.



SYMBOLS

- | | | | |
|--|-----------------|--|-----------|
| | Fault, Fracture | | Road |
| | Anticline | | Reservoir |
| | Syncline | | Amphoe |

Figure 3.44 Structural map of the Thung Yai-Khlong Thom area.

Table 3.19 Attitude of bedding, fracture and fault in the study area (dip direction/dip angle)

Group	Formation	Bed	Fracture	Fault
Trang	Phun Phin	250/55, 255/45, 275/40 260/40, 256/85, 260/55 090/15, 080/10, 090/40 240/60, 250/55, 255/45 255/55, 250/50, 247/50 260/52, 257/50, 055/85 065/85	180/80, 005/85, 194/85 185/85, 131/85, 000/90 200/80, 356/85	
	Sam Chom	055/20, 045/65, 240/30		045/65
	Lam Thap	275/85, 100/90, 270/70 268/70, 100/85, 285/85 100/85, 095/90, 285/80 005/20, 155/20, 155/30 145/20, 150/25, 110/15 260/55, 260/70, 260/30 245/30, 295/30, 235/65 260/50, 085/80, 275/75 290/75, 290/70, 295/45 290/70, 245/60	180/85, 190/70, 195/85 065/15, 015/85, 010/80 030/85, 190/75, 215/15 015/75, 160/70, 355/85 000/85, 135/20, 355/80 307/60, 010/75, 170/85 245/70, 170/85, 140/75 070/80, 295/80, 175/80 265/40, 105/35, 024/85 020/80, 020/80, 010/85 125/85, 105/90, 010/85 320/80, 210/70, 345/75	180/55, 085/55 335/85, 330/55 315/35, 240/15 240/80, 210/20 215/20, 235/25 105/05, 020/30 045/15, 045/30 090/10, 080/10 080/10, 080/10
	Khlong Min	245/45, 252/16, 237/10 090/50, 100/35, 105/45 230/80, 170/10, 265/20 020/10, 150/30, 145/20 245/35, 355/10, 160/15		
-	Sai Bon	260/35		
Ratburi	Permian	090/15, 080/10, 090/40 240/60, 250/55, 255/45	030/50, 155/75, 200/75 140/75, 170/85, 115/90	

Table 3.20 Showing the dip angle of different rock units

Group	Formation	Dip angle(degree)
Trang	Phun Phin	50(Western) and gentle (Eastern)
	Sam Chom	30-65
	Lam Thap	25-70
	Khlong Min	30-55
Triassic	Sai Bon	30-40
Permian	-	10-40
-	All rock units	30-70

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NE-SW curve fault line (refers to as F2 in Figure 3.44) is the boundary between Triassic rocks (dolomitic limestone and siltstone) and the rocks of the Lam Thap formation.

The rosette diagram plots (Figure 3.45) of fault planes in the study area show that the NE-SW, and NW-SE sets are the major fault system, whereas the E-W system is the minor fault system.

Fractures

From the field investigations, the fractures of the study area are mainly in NNE-SSW, NW-SE and E-W directions. All directions of fractures of rock formations (Khlung Min, Lam Thap, Sam Chom, and Phun Phin) are shown in Table 3.19.

The rosette diagram plots (Figure 3.46) of fractures in the study area, are diversify and very difficult to delineate than those of the faults. They can be assigned to NE-SW set which is the major fracture system of all formations except the fracture of the Phun Phin formation which is mainly of E-W set.

3.6 Petrography

In order to fully understand the lithological characteristics of the Trang group about 63 hand-specimen samples have been collected for detailed microscopic study. Locations of rock sample collected represent all formations and lithofacies (Figures 3.18-3.21). The thin-section examination is focussing upon the mineral composition, textures, and microstructures. The detailed petrographic descriptions of the representative samples are as follows:

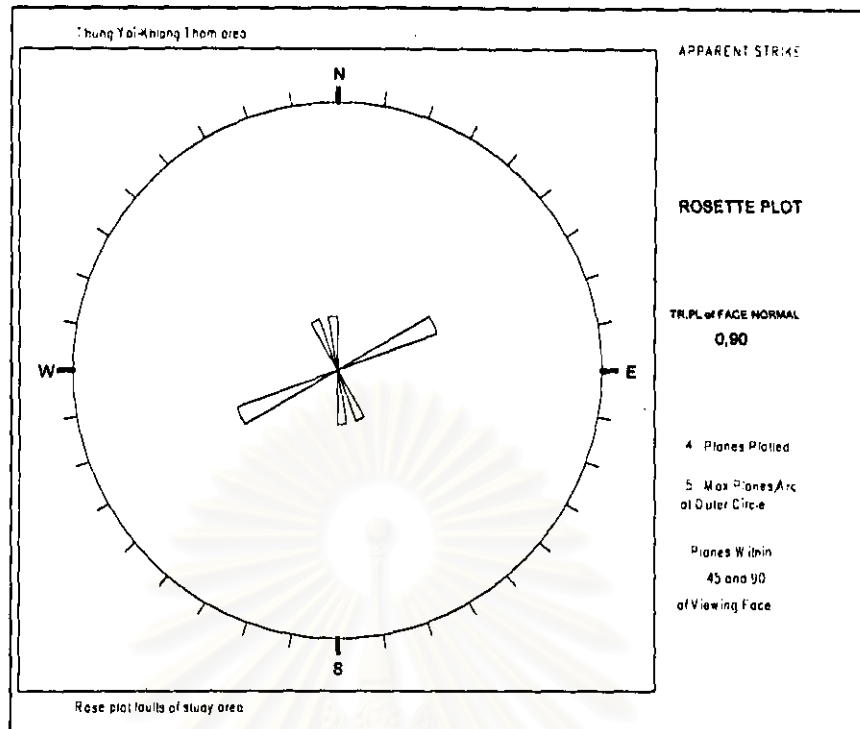


Figure 3.45 Rosette diagram plotted faults of the study area.

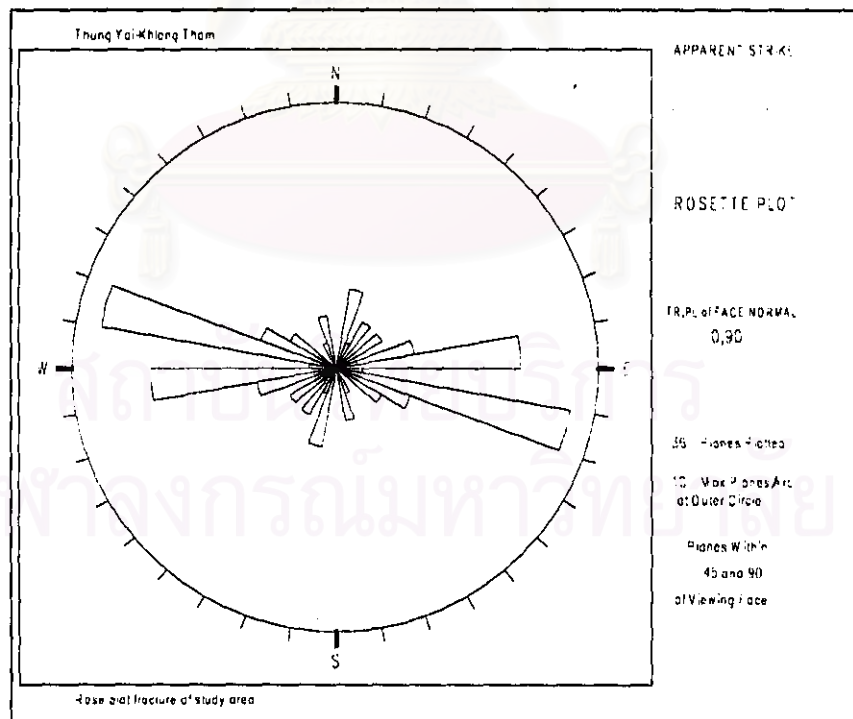


Figure 3.46 Rosette diagram plotted fractures of the study area.

Permian rocks

Microscopic studies of Permian rocks reveal that they are commonly biomicrite, and dolomite. The biomicrite is confined in thick-to very thick-bedded limestone at the lower part of succession of Permian limestone of Khao Ying Moo, and Khao Na Pu ranges. The dolomite is confined as isolated hill at the southern part of Khaun Hin Som of Ban Thang Luang map sheet (4825 II), and Khuan Wai Daeng of Ban Nua Khlong map sheet (4825 III).

The biomicrite (Folk, 1959; 1962) is characterised by the skeletal fragment of brachiopod, smaller foraminifers, fusulinaceans, and algae respective to the decreasing order of abundance (Figures 3.47).

Brachiopods and fusulinaceans are generally observed at the lower part of well-stratified limestone at Khaun Ying Moo and Khao Na Pu. Smaller foraminifers- *Pachyphloia* sp., *Langella* sp., *Climacammina ? sphacrica* are recognized from the same bedding of fusulinaceans. Fusulinaceous *Paraschwagerina* sp.(Figure 3.48), *Yangchienia* sp.(Figure 3.49), *Sumatrana annae* sp., and *Afghanella* sp.(Figure 3.50), and algae-*Tubiphytes obscurus* indicate the Murghabian-Midian age.

Triassic rocks

The Sai Bon formation is distributed throughout the study area, namely, Khuan Sanai, Ban Hui Nam Dam, southern part of Ban Dan, Khuan Wai Daeng, Khuan Na Na, Khao Chong Sai Ngam, Khao Khom, northwestern of Khao Khom, Khao Huai Bon, and Khuan Prak. It consists mainly of oolitic limestone, skeletal limestone, calcareous sandstone, siltstone with limestone lenses, and dolomite. The oosparite is confined in the well-stratified limestone of Khao Khom, whereas the dolomite is confined as monadnocks at the central part of the study area.

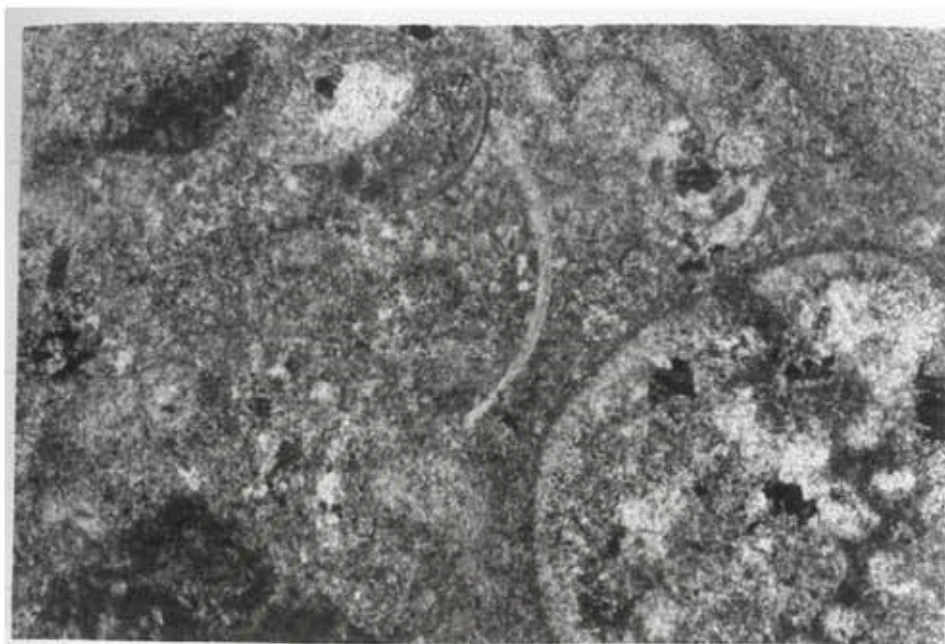


Figure 3.47 Photomicrograph of unidentified bioclasts of the Permian limestone at Khuan Ying Moo, crossed nicols , $\times 40$.

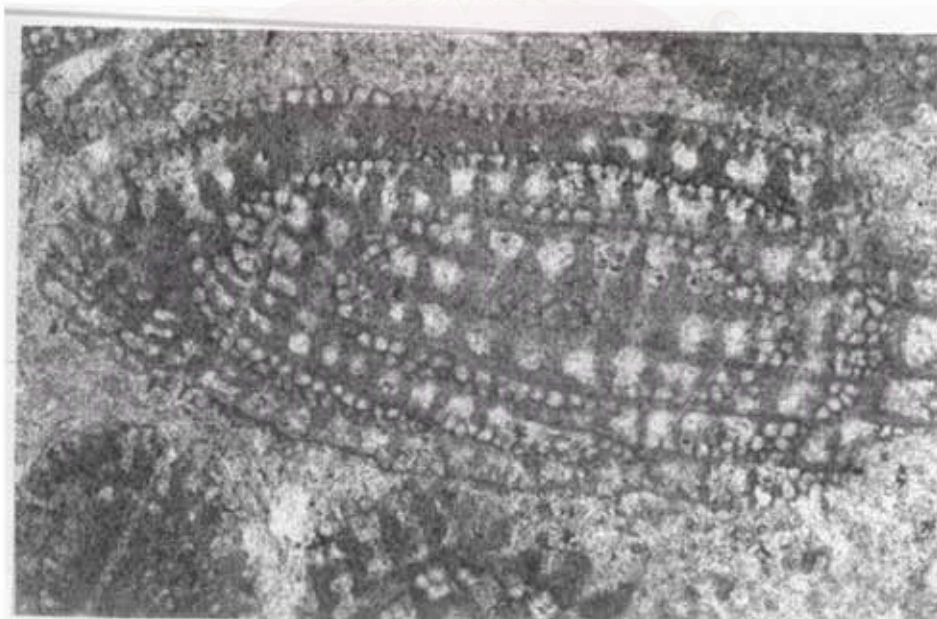


Figure 3.48 Photomicrograph of the Permian limestone at Khuan Ying Moo, showing fusulinid of *Paraschwagerina* sp., crossed nicols , $\times 40$.

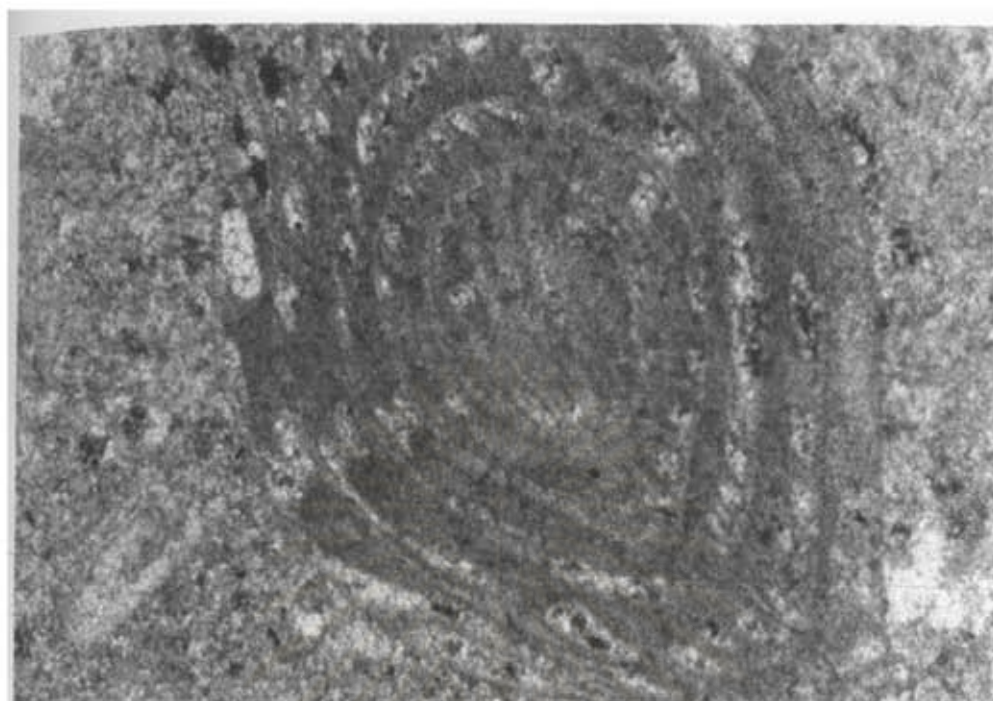


Figure 3.49 Photomicrograph of the Permian limestone at Khuan Ying Moo, showing fusulinid of *Yangchienia* sp., crossed nicols, $\times 40$.

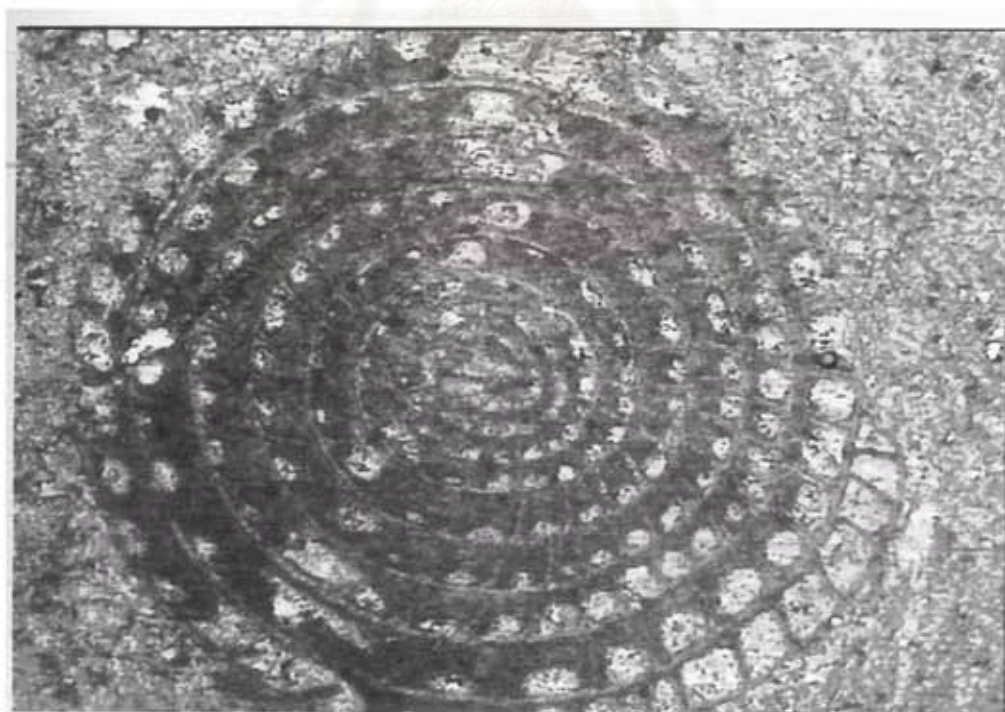


Figure 3.50 Photomicrograph of the Permian limestone at Kuan Ying Moo, showing fusulinid of *Afghanella* sp., crossed nicols, $\times 40$

Petrographically, the oolitic limestone is characterised by the allochems of mainly oolites, algal pellets, algal pisolite or oncolites, superficial oolites with sparry calcite cement. Therefore, the rock name is oosparite (Folk, 1959, 1962)(Figure 3.51).

The dolomite of the Sai Bon formation with the mosaic texture is shown in Figure 3.52.

Trang group

The detailed of petrographic study of the Trang group is focussing upon representative rock samples collected from measured sections under the present investigation. The lithofacies are defined on the bases of lithology, geometry, sedimentary structure, and fossils associations in order to reconstruct their depositional environments. The Trang group consists of 4 formations; Khlong Min formation, Lam Thap formation, Sam Chom formation, and Phun Phin formation in ascending order. The lithologies are named after the classification developed by Folk (1959, 1974), Dott (1964), and Pettijohn (1975). The lithofacies are summarized in Table 4.1.

Khlong Min formation

I. Mudstone intercalated with fossiliferous limestone lithofacies

The mudstone and limestone lithofacies are confined in the lower part of the Khlong Min formation (measured sections A, B and Q) and the lithology of this lithofacies characterised as biomicrite, biosparite, and intrasparite. The mudstone has been analysed using the XRD technique for the determination of mineral composition as shown in the Appendix A.2 and Figure A.2.

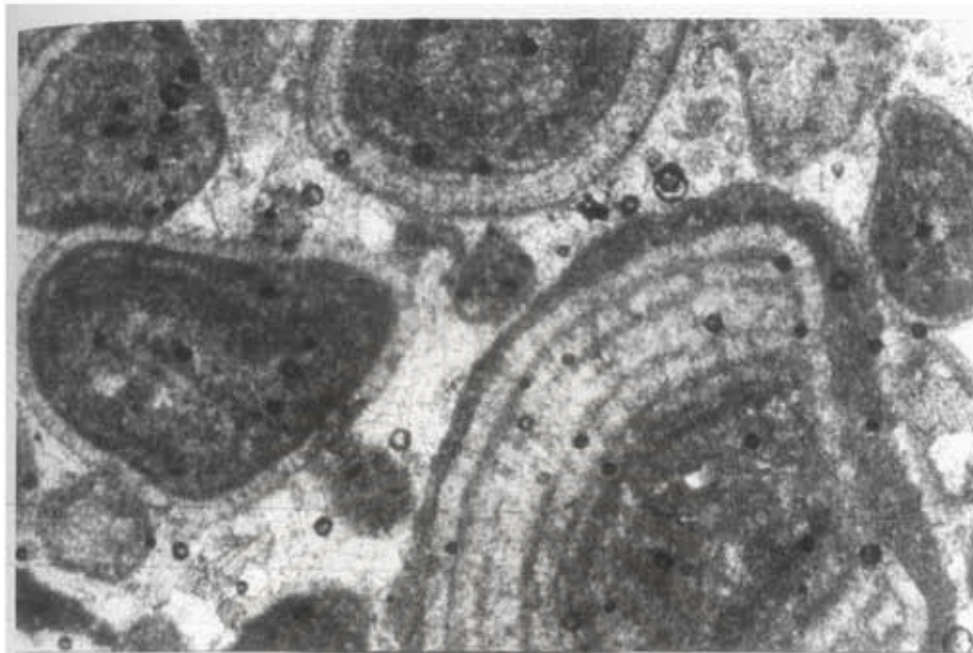


Figure 3.51 Photomicrograph of the Triassic oolitic limestone (MP3), showing mainly of oolites, algal pellets, with sparry calcite cement, crossed nicols, $\times 40$.



Figure 3.52 Photomicrograph of dolomite (the Sai Bon formation, KN1-7), showing mosaic of anhedral dolomite which replaced in the original limestone, crossed nicols, $\times 40$.

Petrographically, biomicrite composes mainly of bioclasts of brachiopods, smaller foraminifers and algae (Figures 3.53 and 3.54, samples KMN-1 and A1-25/1 of section A). Smaller foraminifers-*Classopolis* sp. indicate Middle Jurassic.

The biomicrite is consisting mainly of bioclasts of brachiopod with preferred orientation due to compaction (Figure 3.55, sample PT-1 at Ban Phru Toei).

The lower part of this lithofacies from the measured section Q consists of calcareous mudstone and calcareous sandstone interbedded with limestone (intrasparite). The calcareous sandstone consists mainly of fine-grained, angular to subangular, moderately sorted, quartz cemented by calcite (Figure 3.56, sample LP-1). The accessory minerals are muscovite and sericite.

The intrasparite is consisting mainly grains of rounded to subrounded carbonate mud (0.4-1.5 millimetres) (Figure 3.57, sample LP-3, measured section Q), with embedded silt-sized, rounded to subrounded quartz cemented by sparry calcite.

II. Siltstone lithofacies

This lithofacies is mainly consisting of reddish-brown to maroon siltstone interbedded with well bedded light gray biomicritic limestone and well exposed at Khlong Min in the western part of Thung Song, Nakhon Si Thammarat.

Petrographically, biomicrite (Figure 3.58, sample KMN-2, of measured section A) is consisting of abundant ostracod-*Darwinulla* sp. (Figure 3.24), and smaller foraminifers indicating brackish to fresh water environments, of Jurassic age.

III. Calcareous sandstone lithofacies.

The calcareous sandstone lithofacies composes mainly of yellowish brown fine to medium-grained sandstone with calcareous cement and flaser bedding

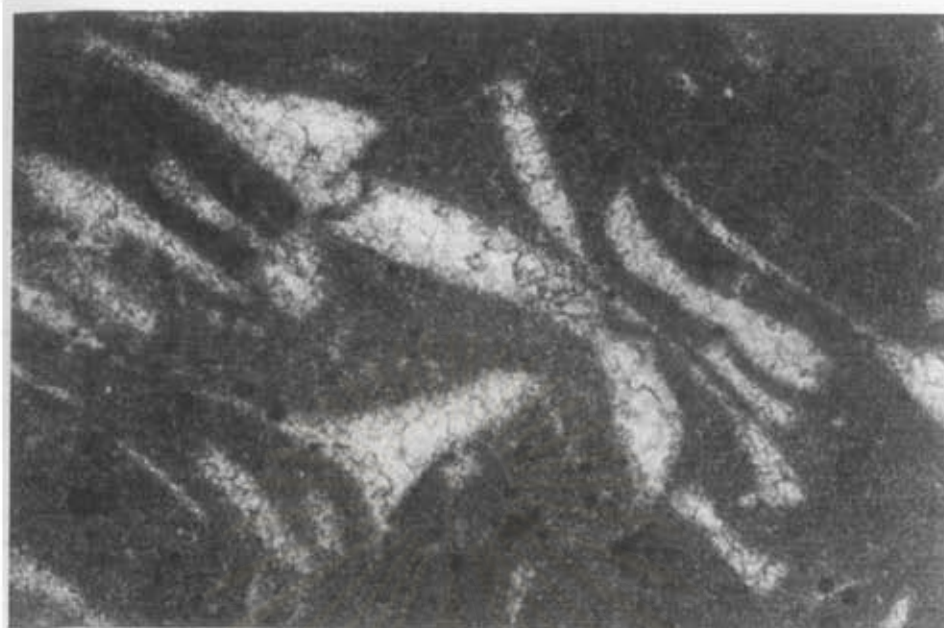


Figure 3.53 Photomicrograph of the fossiliferous limestone lithofacies (I), the Khlong Min formation (KMN-1), showing biomicrite consisting of undifferentiated bioclasts with micrite envelopes infilled with neomorphic spar, crossed nicols, $\times 40$.



Figure 3.54 Photomicrograph of biomicrite (the Khlong Min formation, A1-25/1), undifferentiated bioclasts showing micrite envelopes infilled with neomorphic spar, crossed nicols, $\times 40$.



Figure 3.55 Photomicrograph of biomicrite (the Khlong Min formation, PT-1), showing preferred orientation of bioclasts with micrite envelopes infilled with neomorphic spar, crossed nicols, $\times 40$.

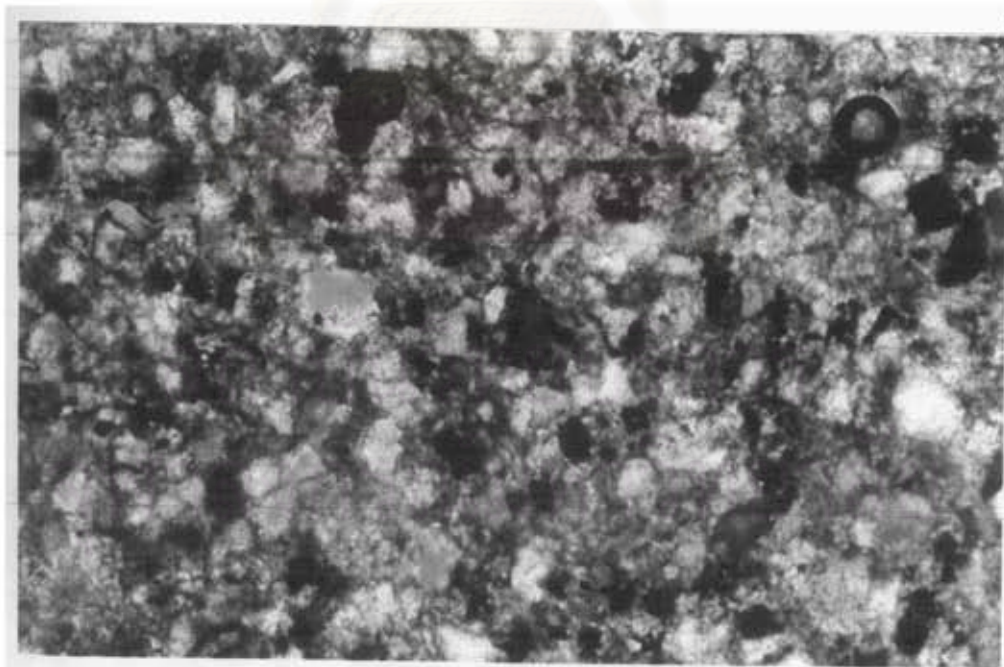


Figure 3.56 Photomicrograph of calcareous sandstone of the Khlong Min formation, LP-1 (section Q), consisting mainly of very fine quartz sand embedded in calcareous cement with accessory minerals of muscovite and sericite, crossed nicols, $\times 40$.

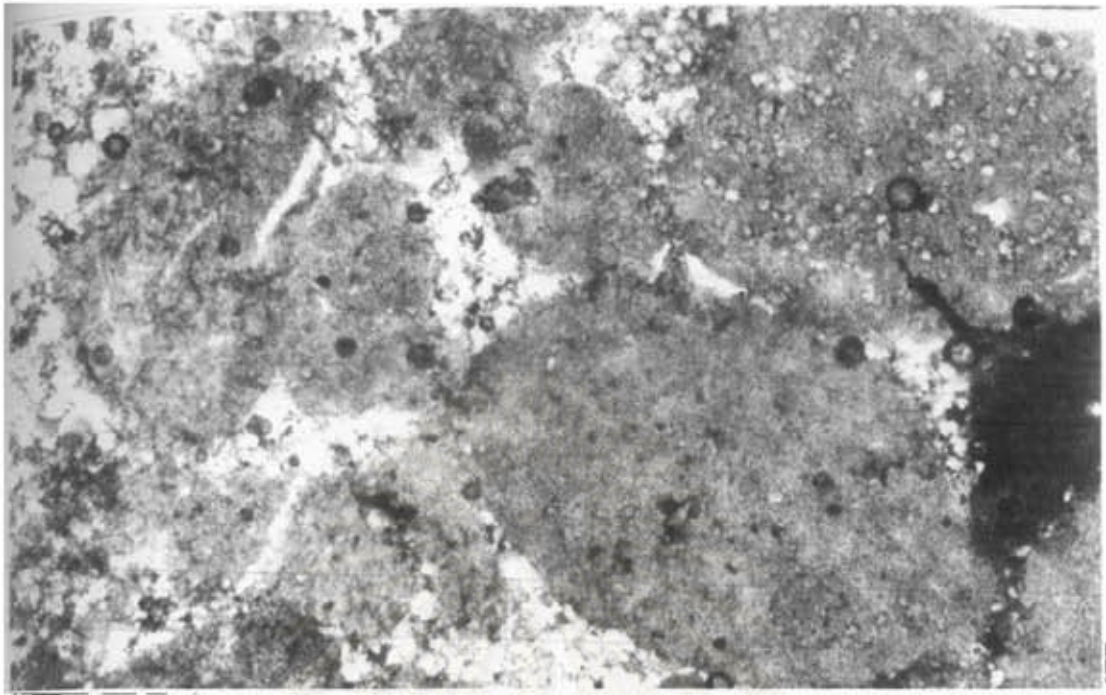


Figure 3.57 Photomicrograph of intrasparite of the Khlong Min formation, LP-3 (section Q), consisting mainly of rounded to subrounded intraclasts of micrite (0.4-1.5 m.), abundant silt-sized detrital quartz with sparry calcite cement, crossed nicols, $\times 40$

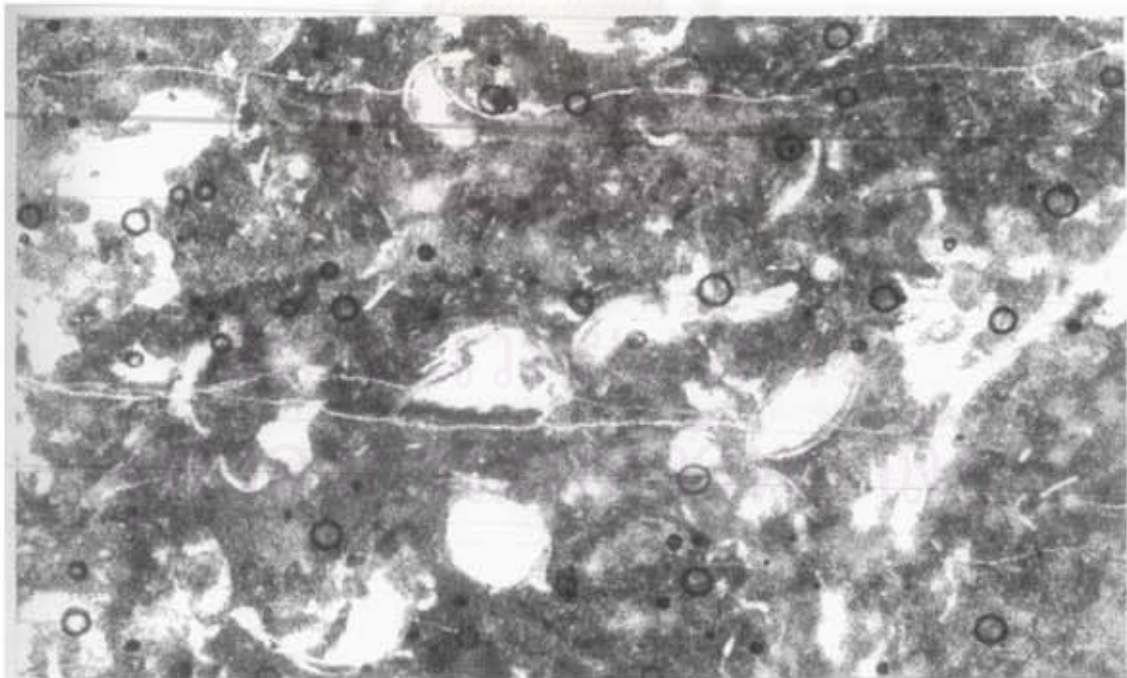


Figure 3.58 Photomicrograph of biomicrite (KMN-2) in the Khlong Min formation (lithofacies II), showing ostracod skeletons infilled with sparry calcite cement embedded in carbonate mud matrix, crossed nicols, $\times 40$

structure. The calcareous sandstone sample is obtained from flaser bedding sandstone of this lithofacies of measured section A and sample no. KMN-1.

Petrographically, calcareous sandstone (Figure 3.59, sample KMN-5) contains clastic texture and mainly of quartz (60%), feldspar (5%) and rock fragments. Most of quartz are fine-grained, subangular to angular with calcareous cement.

The distribution of calcareous sandstones are common in this lithofacies of the Khlong Min formation, i.e. at Khlong Min (measured sections A, B), and at Laem Pleo of Ban Bo Muang (measured section Q) and the thickness varies considerably from place to place.

IV. Fossiliferous limestone lithofacies

Microscopic studies of this lithofacies are confined to calcareous sandstone interbedded with fossiliferous limestone with abundant bivalves of *Modiolus* sp., and wood fragments. The distribution of those rocks are commonly found at Khlong Min (measured sections B and C).

Megascopically, light gray to gray colour and fossiliferous with abundant bivalves of *Modiolus* sp., and wood fragments (Figure 3.27) are common.

Petrographically, calcareous sandstone shows clastic texture of mainly quartz (50%), feldspar, and rock fragments with calcareous cement. Most of quartz are fine-grained and moderately sorted.

Lam Thap formation

The Lam Thap formation can be petrographically distinguished as arenite and arkose. This formation consists of 2 lithofacies; the thick-bedded arkosic sandstone

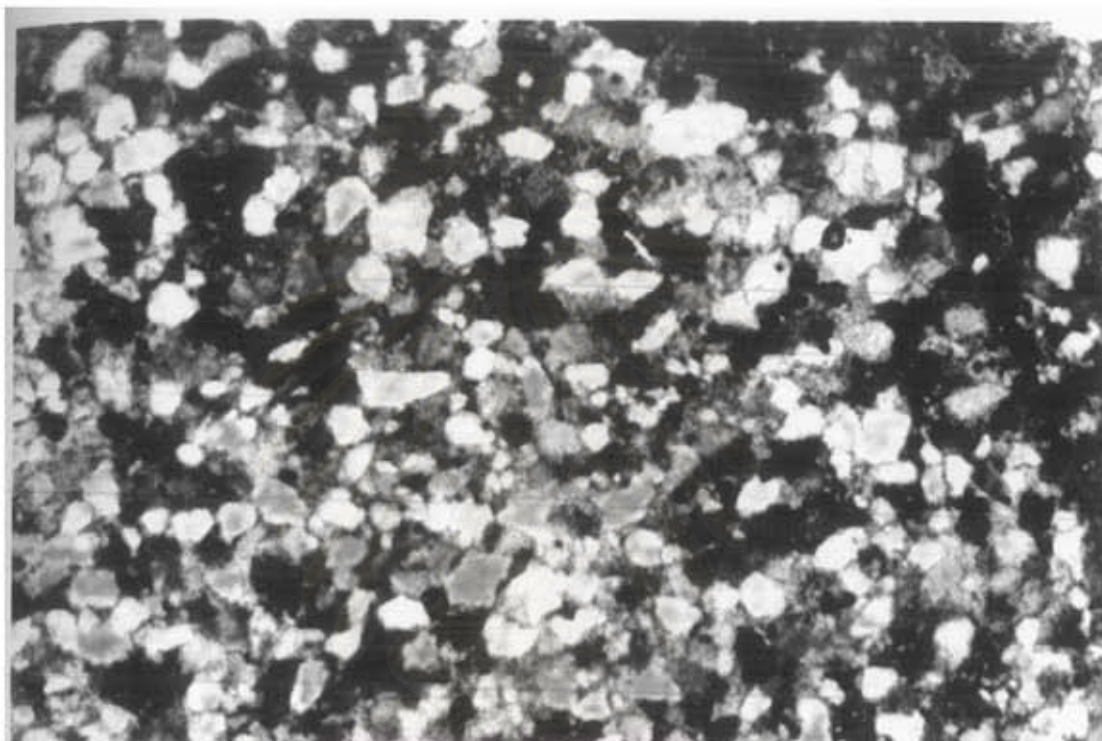


Figure 3.59 Photomicrograph of calcareous sandstone (KMN-5) in the Khlong Min formation (lithofacies III), showing mainly fine to very fine- grained, angular to subangular, moderately sorted quartz with minor amounts of feldspar and rock fragments cemented by calcite, crossed nools, $\times 40$.

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lithofacies and siltstone interbedded with mudstone lithofacies, and petrographic studies are as follows.

I. Thick-bedded arkosic sandstone lithofacies

The microscopic studies of this lithofacies is confined in thick-to very thick-bedded sandstone, yellowish brown to brown with cross-bedding and fining upward sequences. The distribution of this lithofacies is throughout the study area, especially in the northeastern and eastern part (measured section D).

Petrographically, arenite contains clastic texture of mainly quartz (70%), feldspar (10%), and rock fragments (15-20%) with siliceous cement (Figures 3.60 and 3.61). Most of quartz are fine-grained and type of contact is tangent. The accessory minerals are tourmaline and opaque minerals (Figure 3.61, sample KN 1-10).

The arkose is recognized from thick-bedded sandstone (sample LT 1-2, measured section C). It shows clastic texture and is composed mainly of quartz (70-80%), feldspar (15-20%), and rock fragments (5-10%) with siliceous and ferruginous cement (Figure 3.62, sample LT1-2, measured section C). Most of quartz are fine to medium-grained, subangular-angular and moderately sorted.

II. Siltstone interbedded with mudstone lithofacies

The siltstone interbedded with sandstone lithofacies is widely distributed with common lateral facies change. It consists of reddish-brown to maroon siltstone, gray mudstone interbedded with very well-bedded sandstone.

The orangish brown to yellowish brown siltstone from the uppermost bed of this lithofacies (measured sections B and C) has been analysed using the XRD technique for the determination of mineral compositions. The sample LSC-8 of measured section B contains quartz, kaolinite, and illite (Appendix A.2).

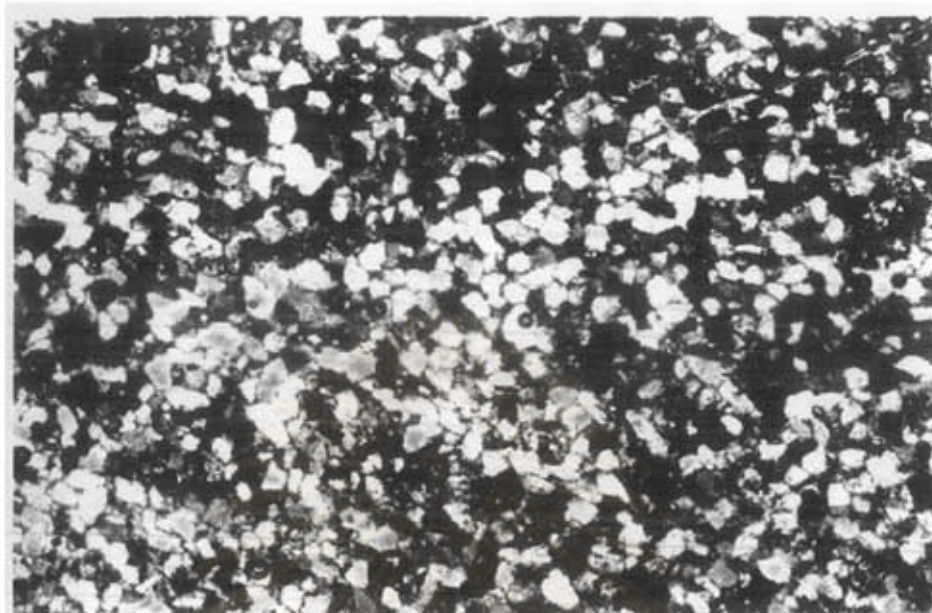


Figure 3.60 Photomicrograph of arenite (RLTM) in the Lam Thap formation (lithofacies V), showing mainly very fine-to fine-grained, angular to subangular, moderately sorted quartz with minor amounts of feldspar and rock fragments cemented by silica, crossed nicols, $\times 40$.

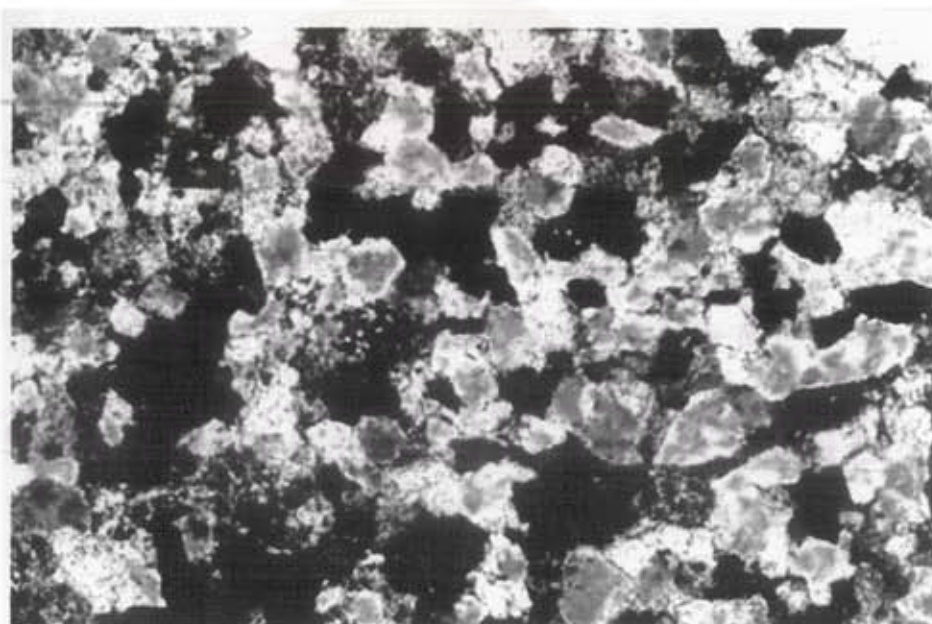


Figure 3.61 Photomicrograph of arenite (KN1-10) in the Lam Thap formation (lithofacies V), showing mainly fine to very fine grained, angular to subangular, moderately sorted quartz with minor amounts of feldspar and rock fragments, accessory minerals tourmaline and opaque minerals, cemented by silica, crossed nicols, $\times 40$.

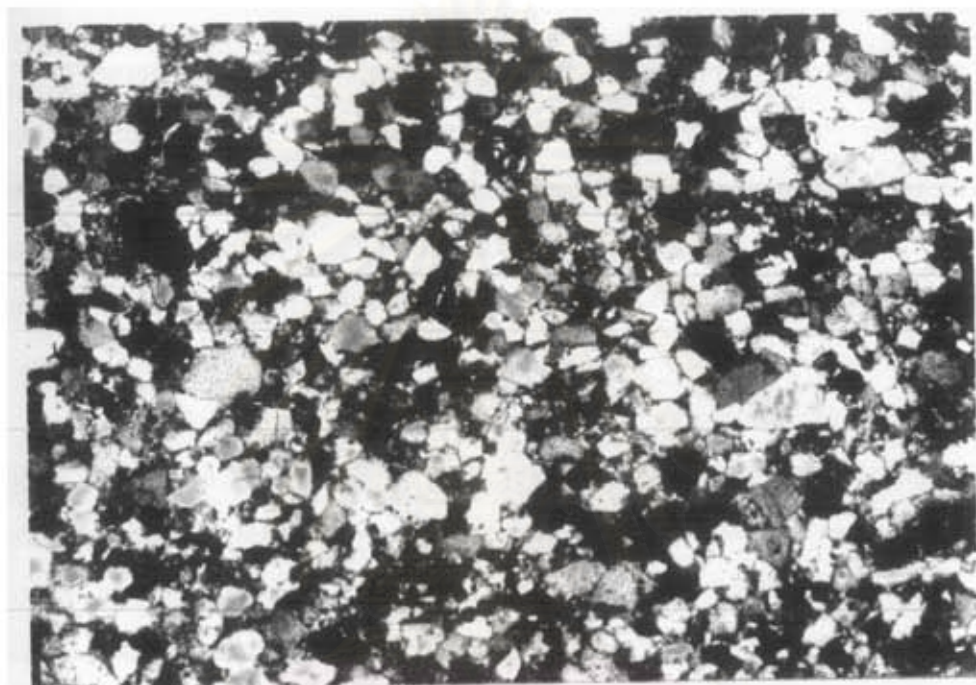


Figure 3.62 Photomicrograph of arkose (LT1-2) in the Lam Thap formation (lithofacies V), showing mainly fine to medium quartz of angular to subangular, moderately sorted with minor amounts of feldspar and rock fragments cemented by silica and iron oxides, crossed nicols, $\times 40$.

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Sam Chom formation

The Sam Chom formation consists of conglomerate and conglomeratic sandstone. The clasts compose mainly of quartz, sandstone, and chert with matrix-supported texture.

Petrographically, the conglomerate with mainly matrix-supported texture and clasts are made up of quartz, sandstone, and chert of average granule to cobble sizes. The chert is confined as clasts of conglomerate at Khao Sam Chom of Ban Thang Lung map sheet (4825 II). The chert composes mainly of very fine-to fine-grained, fibrous chalcedonic quartz with irregular orientation (Figure 3.63, sample NKM-11).

The medium-grained sandstone clasts of conglomerate at Khao Sam Chom (Figure 3.35, sample 376612) with average pebble to cobble sizes. The composition of sandstone clasts mainly consist of quartz, feldspar, and less of rock fragments with siliceous and ferrugeneous cements. The various types of lithology and size of clasts of conglomerate throughout the study area are shown in Table 3.10.

Phun Phin formation

I. Fine-grained sandstone lithofacies

The fine-grained sandstone lithofacies is mainly consisting of reddish-brown to red arenite and litharenite. The arenite is recognized in the lower and middle parts of successions at km.10, road no. 4038 from Lam Thap to Khlong Thom of Nakhon Si Thammarat and Krabi (measured section I).

Petrographically, the arenite mostly consists of quartz (50%), feldspar (7%), and rock fragments. The detrital grains are fine-grained, subangular to subrounded, well sorted, with ferrugeneous cement (Figure 3.64, sample PP-1).

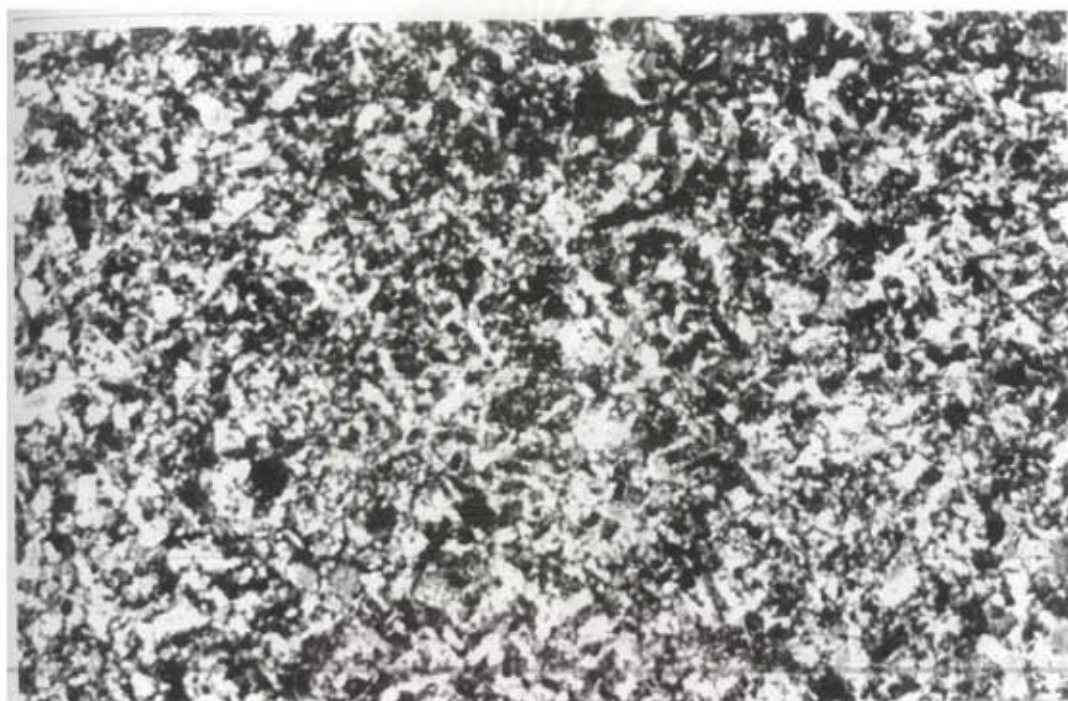


Figure 3.63 Photomicrograph of chert (NKM-11), clasts of conglomerate in Sam Chom formation, showing mainly fine to medium fibrous chalcedonic quartz with irregular orientation, crossed nicols, $\times 40$.

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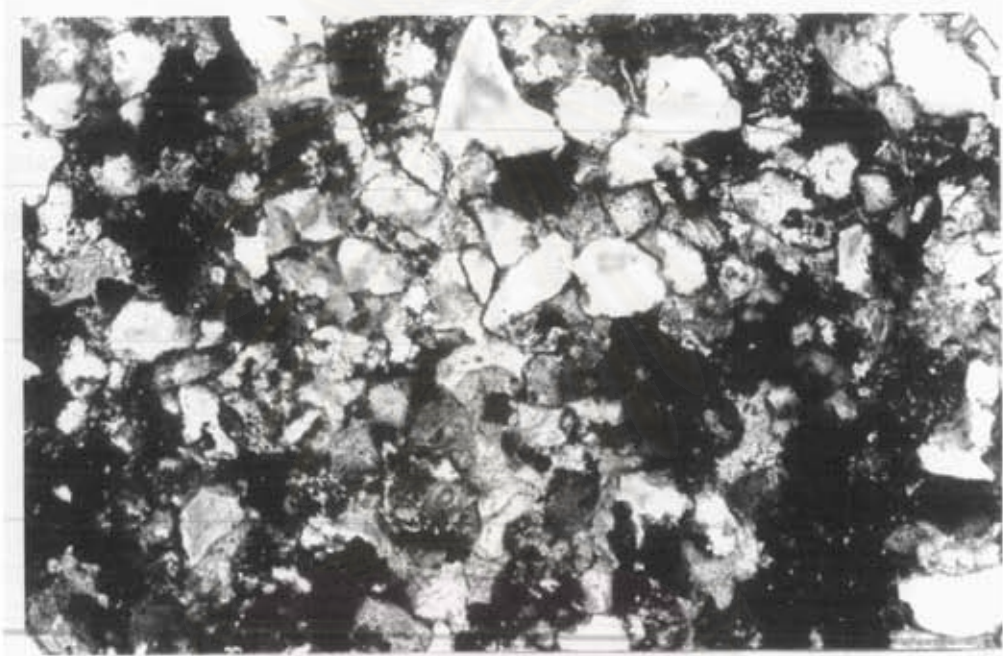


Figure 3.64 Photomicrograph of arenite (PP1) in the Phun Phin formation (lithofacies VIII), showing mainly fine-to medium-grained quartz of angular to subangular, moderately sorted, with minor amounts of feldspar and rock fragments cemented by iron oxides, crossed nicols, $\times 40$.

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The litharenite (Dott, 1964) is confined as red to reddish brown sandstone with commonly cross-strata at Phun Phin of Surat Thani (Figures 3.65 and 3.66, sample 383050). It is mainly consisting of quartz, feldspar, and rock fragments with single grain contact. The detrital grains are medium-to coarse-grained with ferrugeneous cement and the matrix contains abundant opaque iron oxides.

II. Fanglomerate lithofacies

The thick sequence which characterised the upper part of Phun Phin formation is mainly conglomerate/breccia with both clast and matrix-supported texture. The clasts are made up of quartz, sandstone, chert, quartzite, and rock fragments, respectively in the decreasing order of abundance.



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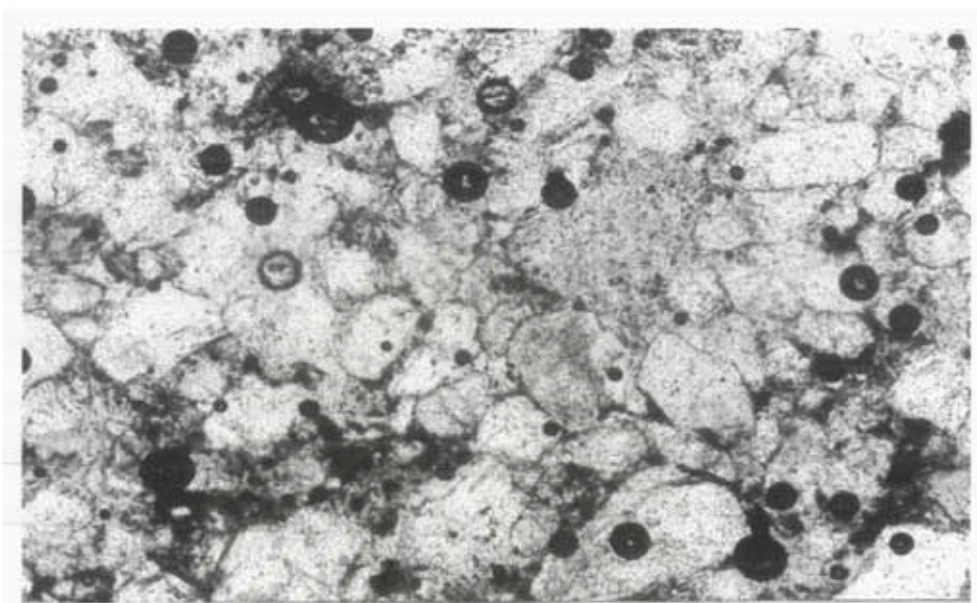


Figure 3.65 Photomicrograph of arenite (383050) in the Phun Phin formation (lithofacies VIII), showing mainly medium-to coarse-grained quartz of angular to subangular, moderately sorted, with minor amounts of feldspar and rock fragments(chert) cemented by iron oxides, uncrossed nicols, $\times 40$.

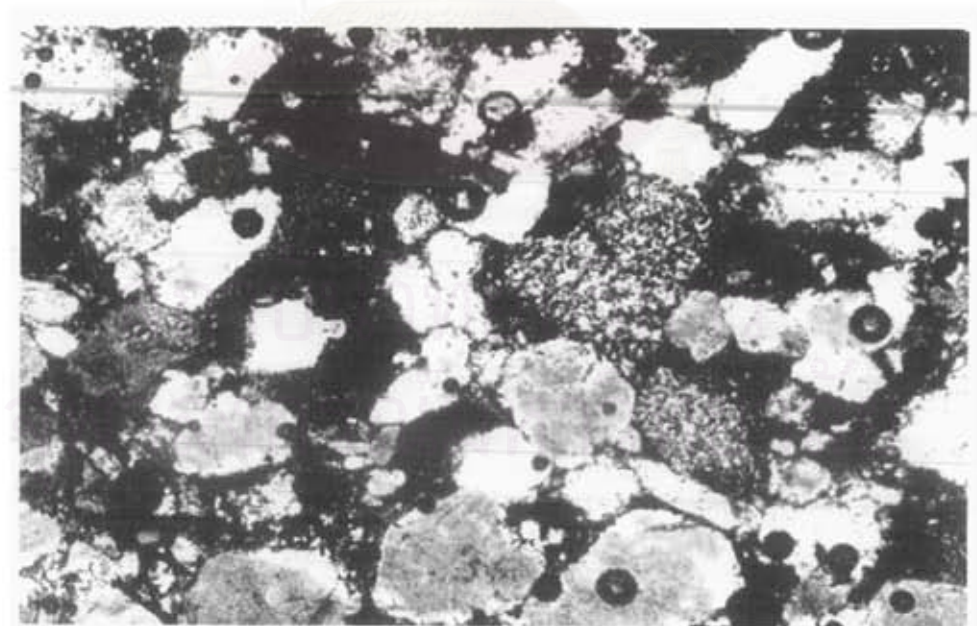


Figure 3.66 Photomicrograph of arenite (383050) in Phun Phin formation (lithofacies VIII), showing mainly medium-to coarse-grained of angular to subangular, moderately sorted quartz, with minor amounts of feldspar and rock fragments (chert) cemented by iron oxides, crossed nicols, $\times 40$.