

CHAPTER III



PETROGRAPHIC CLASSIFICATION OF CARBONATE ROCKS AND FUSULINACEAN ASSEMBLAGES

Limestones in the eastern part of Changwat Loei belong to the Saraburi Limestones* (Bunopas, 1992). These limestones contain rich and well preserved organic remains such as fusulinids, brachiopods, corals, etc. Limestone samples collected from twelve localities of the study area were used for paleontologic study of fusulinids to determine geologic age and for petrographic analyses to indicate the depositional environment. A total of 13 genera of fusulinids were identified from the rock samples. The fusulinid genera and other faunas are listed in Table 7. The rock types of these carbonate rocks are dolomitic limestone to grainstone. The classification is based on Dunham (1962) and Folk (1959, 1962). The percentages of various grain types also presented in the appendix. The content of the faunas, the composition of carbonate rocks together with their classification are respectively described, as follows :-

Pha Mo (Location TCM 94-1)

The isolated hill of Pha Mo shows dark grey, thick-bedded limestones with a NS strike and dipping W. In the field, the fusulinids can generally be observed.

* Saraburi limestones is distributed on the west of Khorat Plateau margin and eastern part of the Central Plain.



Table 7 (continued)

Sample No.	<i>Triticites</i> sp.	<i>Daixina</i> sp.	<i>Pseudoschwagerina</i> sp.	<i>Jigulites</i> sp.	<i>Darvasites</i> sp.	<i>Pseudofusulina</i> sp.	<i>Parafusulina</i> sp.	<i>Yangchienia</i> sp.	<i>Verbeekina</i> sp.	<i>Chalaroschwagerina</i> sp.	<i>Panirina</i> sp.	<i>Schubertella</i> sp.	<i>Sphaerulina</i> sp.	<i>Tubiphytes obscurus</i> Maslov	<i>Pseudovermiporella</i> sp.	<i>Bacnella</i> sp.	<i>Pachyptota</i> sp.	<i>Epimastopora?</i> sp.	<i>Globivalvulina</i> sp.	<i>Caminia</i> sp.	<i>Protomichelina</i> sp.	<i>Crassiparietiphyllum</i> sp.	Giant pelocypod
TCM 94-9-20																							X
TCM 94-9-21								X					X			X		X					
TCM 94-9-22						X	X																
TCM 94-9-23													X	X		X							
TCM 94-9-24						X																	X
TCM 94-9-25						X																	
TCM 94-9-26															X								X
TCM 94-9-27													X	X								X	
TCM 94-9-28													X	X					X				
TCM 94-9-29													X						X				
TCM 94-9-30					X	X							X			X							
TCM 94-10 L.					X	X							X								X		
TCM 94-10 M.														X									
TCM 94-10 U.					X	X		X				X					X			X			
TCM 94-11-1											X												
TCM 94-11-2											X												
TCM 94-11-3													X	X									
TCM 94-11-6											X		X	X									
TCM 94-11-7											X	X							X				
TCM 94-11-9											X			X					X				
TCM 94-11-10											X	X	X	X					X				
TCM 94-11-14											X	X		X									
TCM 94-11-15					X																X		

L = Lower part, M = Middle part, U = Upper part

Microscopically, the rock is bio-pelmicritic wackestone. It comprises prominently only *Triticites* sp. together with shell fragments, pseudo-algae (*Tubiphytes obscurus* Maslov), crinoids, smaller foraminifers, calcispheres and peloids. The interior of bioclasts have been occluded by sparry calcite. The age of this limestone is Late Kassimovian to Early Gzhelian based on *Triticites* sp. The microscopic texture of this limestone is present in figure 8.

Pha Mo Noi (Location TCM 94-2)

The isolated hill of Pha Mo Noi is a massive limestone. In the field, fossils are not observed with the naked eyes. This rock is a dolomitic limestone based on result from XRD. But microscopically, it is a bio-pelmicritic wackestone (Figure 9) and contains only *Triticites* sp., associated with shell fragments, pseudo-algae (*Tubiphytes obscurus* Maslov), crinoids, smaller foraminifers and peloids. The interior of bioclasts have been occluded by sparry calcite. The age of this limestone is Late Kassimovian to Early Gzhelian based on *Triticites* sp.

Phu Khao (Location TCM 94-3)

The Phu Khao location consists of dark grey, thick-bedded limestones interbedded with friable clastic rocks. These limestone beds are conformable with the Pha Mo area based on structural ground. The detailed stratigraphic study of this location was made. A measured section is shown in figure 10. The abundant fossils, especially fusulinids can be observed extensively in these limestone beds (Figure 11). Five samples are collected from this location. They are samples no. TCM 94-3-1, TCM 94-3-2, TCM 94-3-4, TCM 94-3-5 and TCM 94-3-6. The content of the faunas, carbonate rocks and ages of each sample can be respectively mentioned as follows :-

1. Sample no. TCM 94-3-1

The rock type of this limestone sample, is biomicritic wackestone. It consists of *Triticites* sp., *Daixina* sp, in association with pseudo-algae (*Tubiphytes obscurus* Maslov), smaller foraminifers (*Pachyphloia* sp.), crinoids and shell fragments (Figure 12). Some bioclasts have been encrusted by pseudo-algae or lime mud and occluded by sparry calcite in the interior. The grains have no arrangement. The age of this limestone is Gzhelian based on *Daixina* sp.

2. Sample no. TCM 94-3-2

This rock is underlain by sample no. TCM 94-3-1. Microscopically, this specimen is biomicritic wackestone. The fauna assemblage comprises fusulinids in genus *Daixina*, together with pseudo-algae (*Tubiphytes obscurus* Maslov and *Bacinella* sp.), shell fragments, crinoids and smaller foraminifers (Figure 13). The allochems are not oriented. Some bioclasts have been encrusted by pseudo-algae or lime mud and occluded by sparry calcite in the interior. The age of this limestone is Gzhelian based on *Daixina* sp.

3. Sample no. TCM 94-3-4

The faunas occur in biomicritic wackestone (Figure 14). They are composed of fusulinids (*Daixina* sp.), associated with pseudo-algae (*Tubiphytes obscurus* Maslov and *Epimastopora?* sp.), smaller foraminifers, shell and crinoid fragments. They are supported by carbonate mud and contain sparry calcite cement. All of allochems have no orientation and some intragranular voids have been occluded by sparry calcite. The age of this limestone is Gzhelian based on *Daixina* sp.

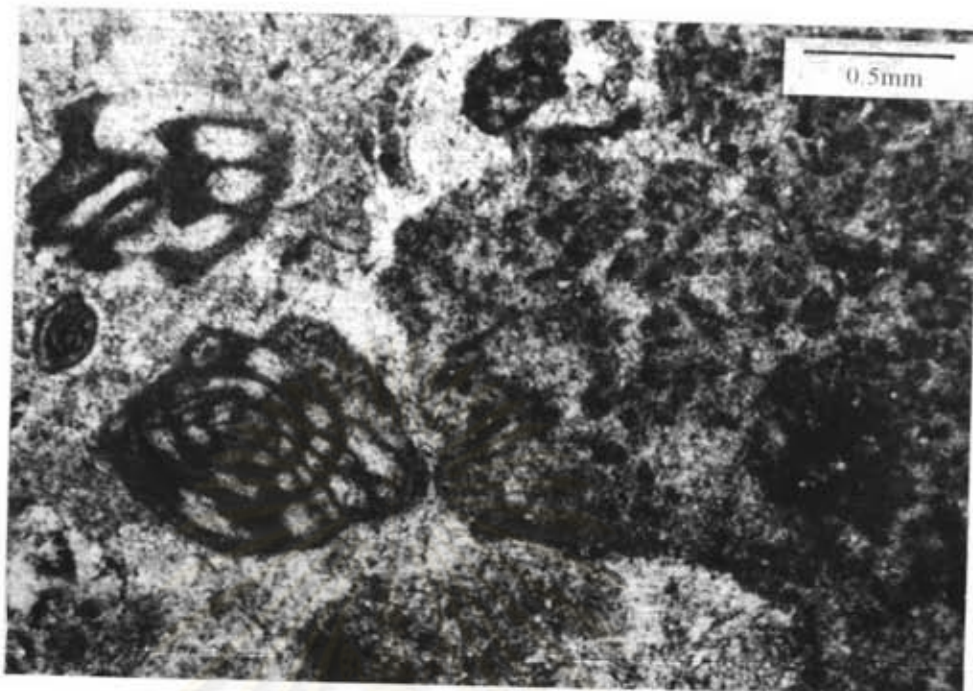


Figure 8 Photomicrograph of Pha Mo sample showing matrix supported with some fragments of fusulinids in bio-pelmicritic wackestone.



Figure 9 Photomicrograph of Pha Mo Noi sample showing shell fragments with sparry calcite cement.

Metres above base

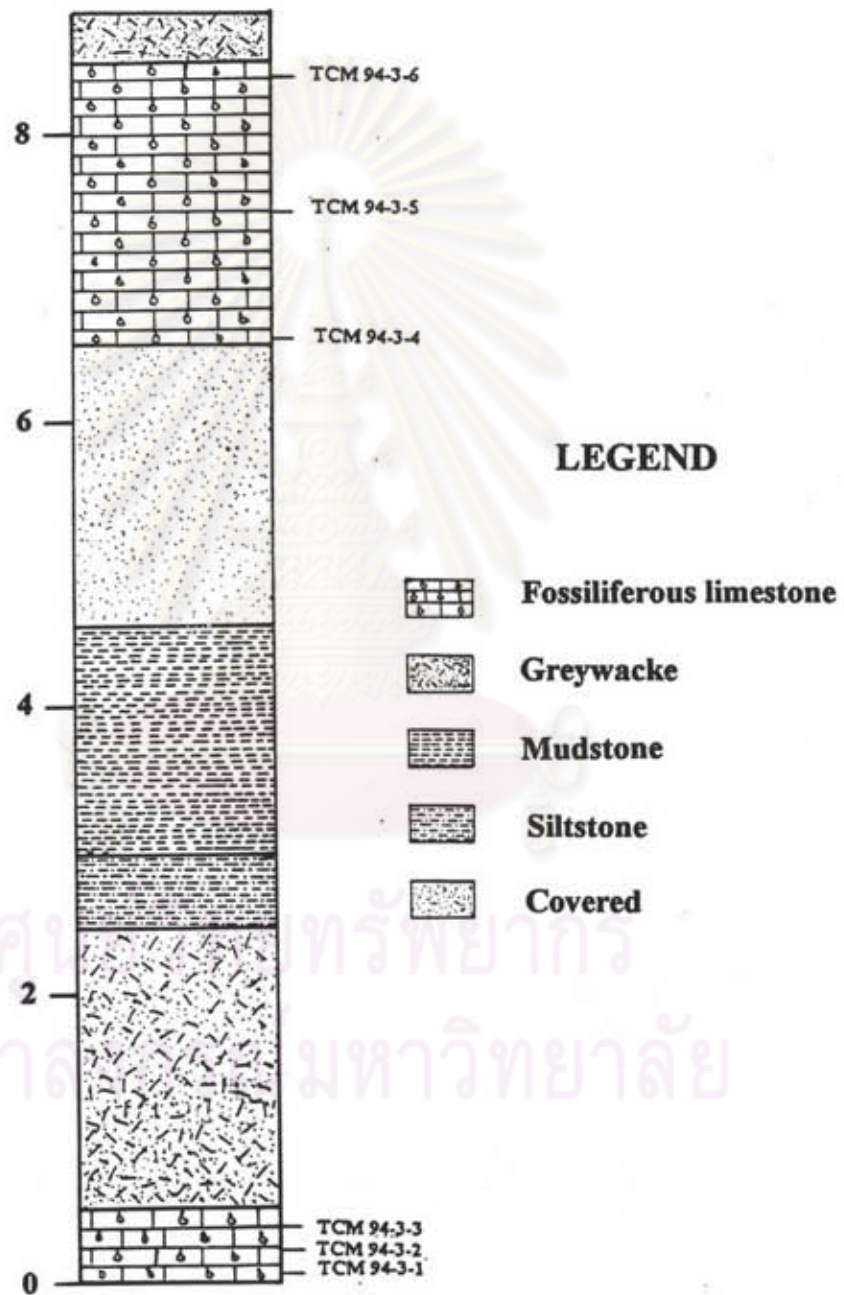


Figure 10 Measured section and sample locations of Phu Khao.

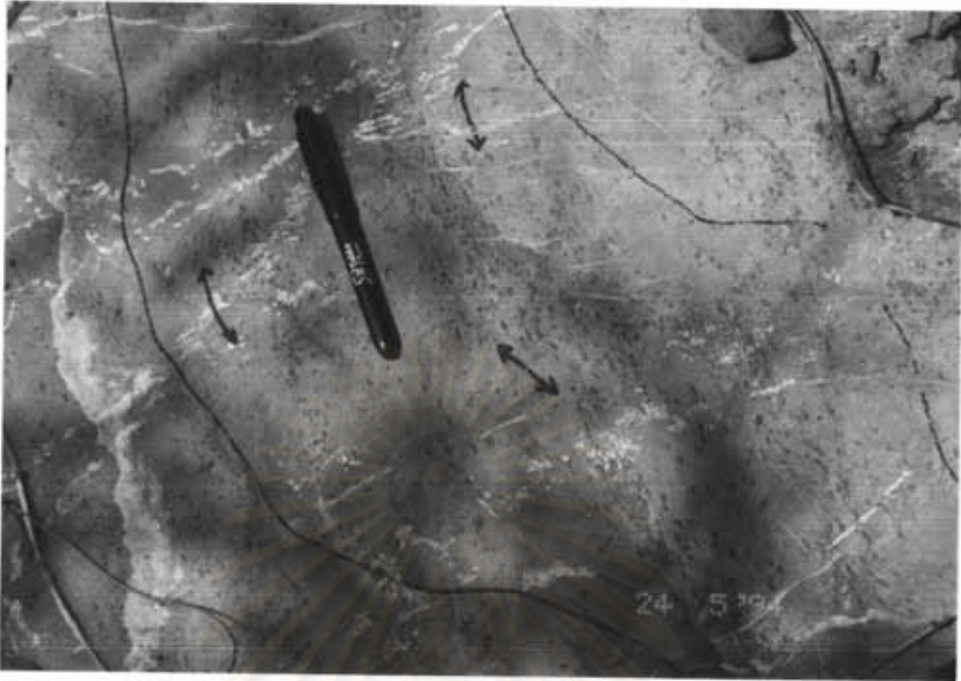


Figure 11 The abundant of fusulinids in fossiliferous limestone beds at Phu Khao.

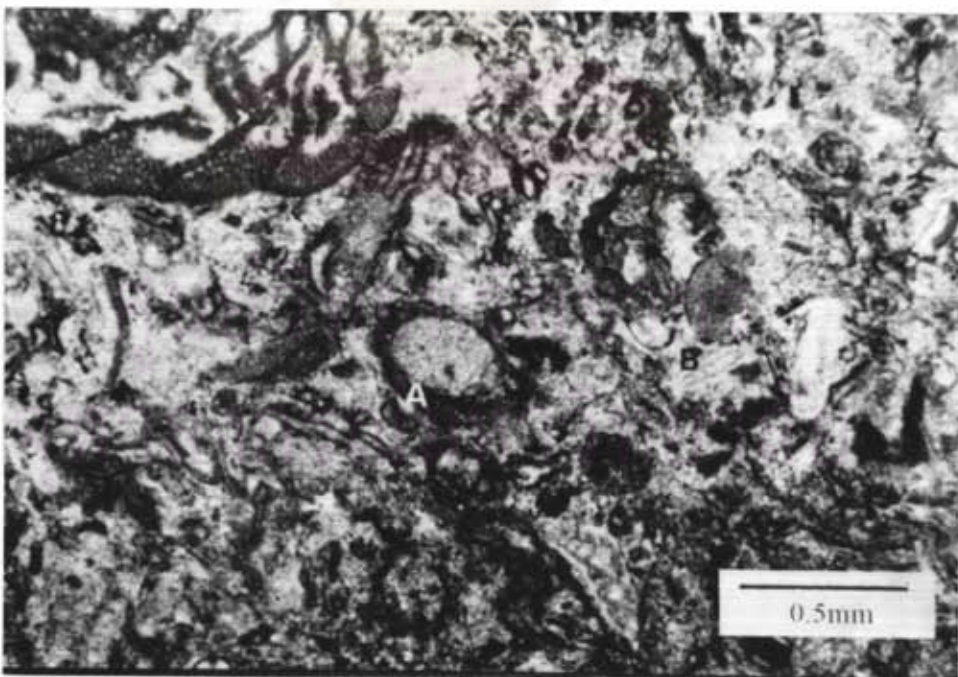


Figure 12 Photomicrograph of TCM 94-3-1 showing A) Pseudo-algae, B) *Pachyploia* sp.

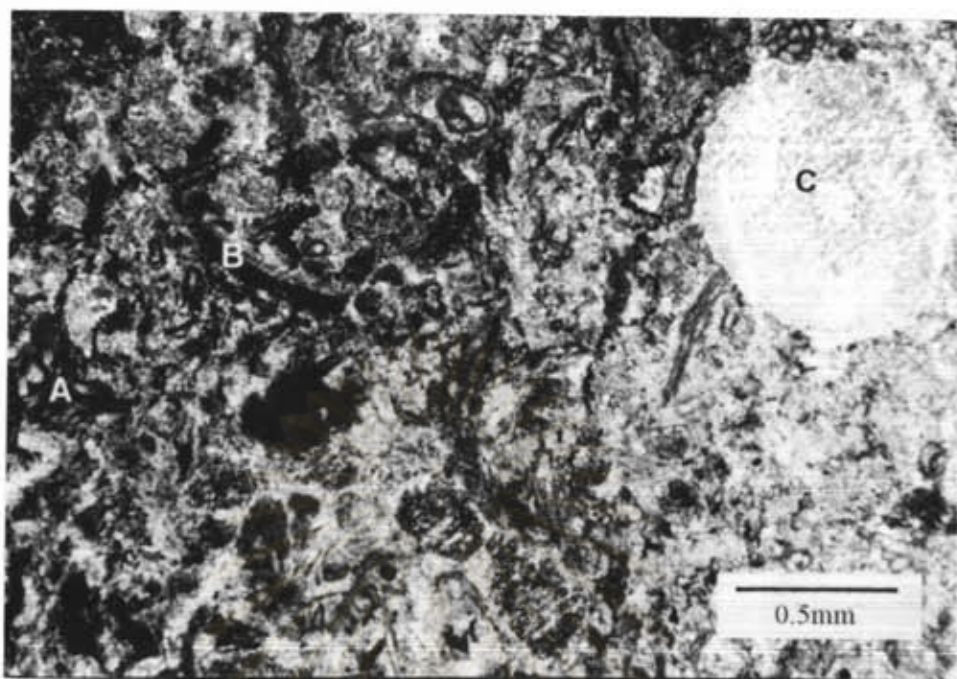


Figure 13 Photomicrograph of TCM 94-3-2 showing bioclasts with matrix supported in biomicritic wackestone. A) Pseudo-algae, B) Shell fragments, C) Crinoid plate.

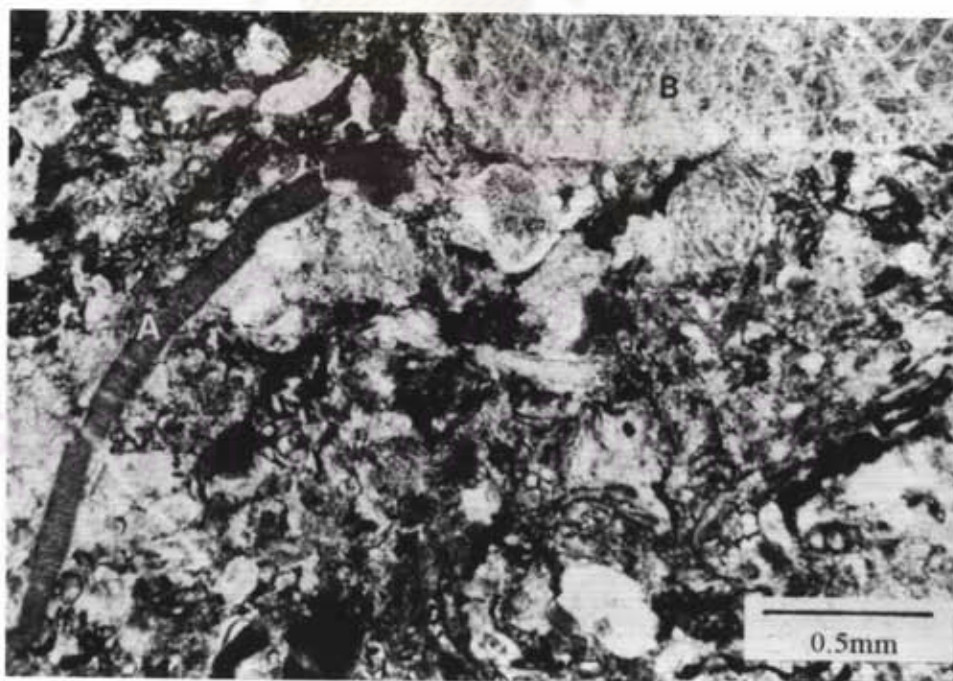


Figure 14 Photomicrograph of TCM 94-3-4, showing many types of bioclasts. A) Pseudo-algae (*Epimastopora?* sp.), B) Crinoid debris.

4. Sample no. TCM 94-3-5

This limestone bed contains abundant fusulinids. Microscopically, this rock is biomicritic wackestone (Figure 15). The faunas contain fusulinids (*Triticites* sp. and *Daixina* sp.), pseudo-algae (*Bacinella* sp.), shell fragments, smaller foraminifers and crinoids. The small fragments of pseudo-algae are generally distributed in this sample. Some bioclasts have been encrusted by pseudo-algae and occluded by sparry calcite in the internal structure, for example, in gastropods, chambers of fusulinids, etc. The grains show no orientation. The horizon corresponds to Gzhelian based on *Daixina* sp.

5. Sample no. TCM 94-3-6

In thin sections, the rock type is packstone (Figure 16). The faunas of this sample comprise fusulinids (*Daixina* sp. and *Pseudoschwagerina* sp.), together with dominant pseudo-algae (*Bacinella* sp.), calcispheres, smaller foraminifers, shell and crinoid fragments. They are cemented by sparry calcite and contain less carbonate mud. Some bioclasts, especially crinoid plates have been encrusted by pseudo-algae. Furthermore, most of the grains are surrounded by carbonate mud. Sparry calcite occluded the interior structure of gastropods and fusulinid chambers. All of allochems are not oriented. An Asselian age is inferred to this limestone based on *Pseudoschwagerina* sp.

The measured section and ages of this rock unit are concluded in figure 17.

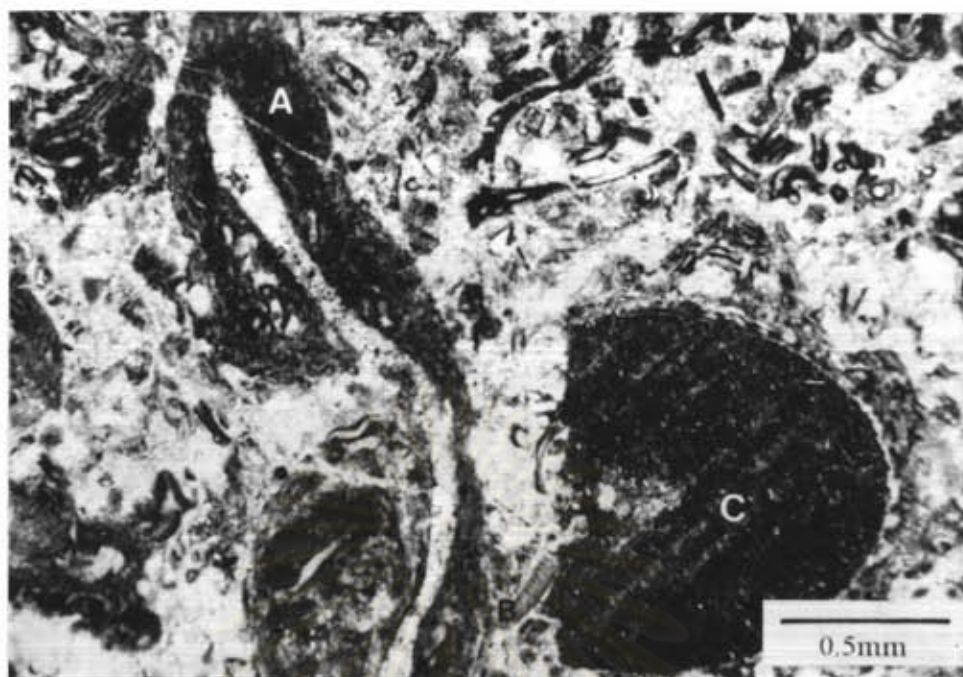


Figure 15 Photomicrograph of TCM 94-3-5, showing bioclasts with mud-supported and sparry calcite cement in biomicritic wackestone.

A) *Bacinella* sp., B) *Epimastopora?* sp., C) Crinoid debris.

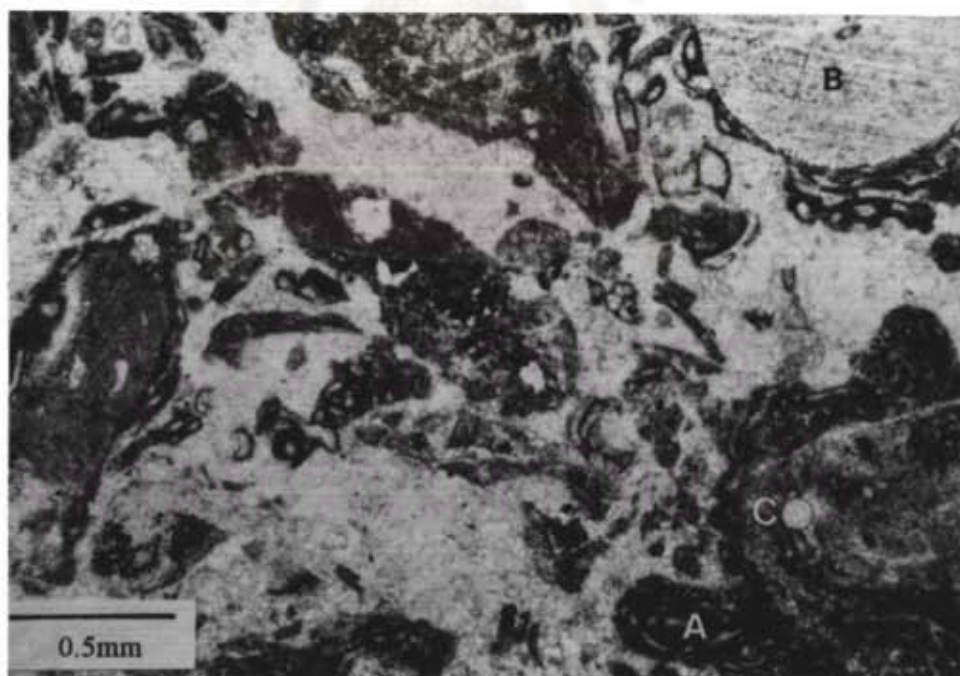


Figure 16 Photomicrograph of TCM 94-3-6, showing some bioclasts and sparry calcite cement in this limestone.

A) Pseudo-algae (*Bacinella* sp.), B) Crinoid plate, C) Calcisphere.

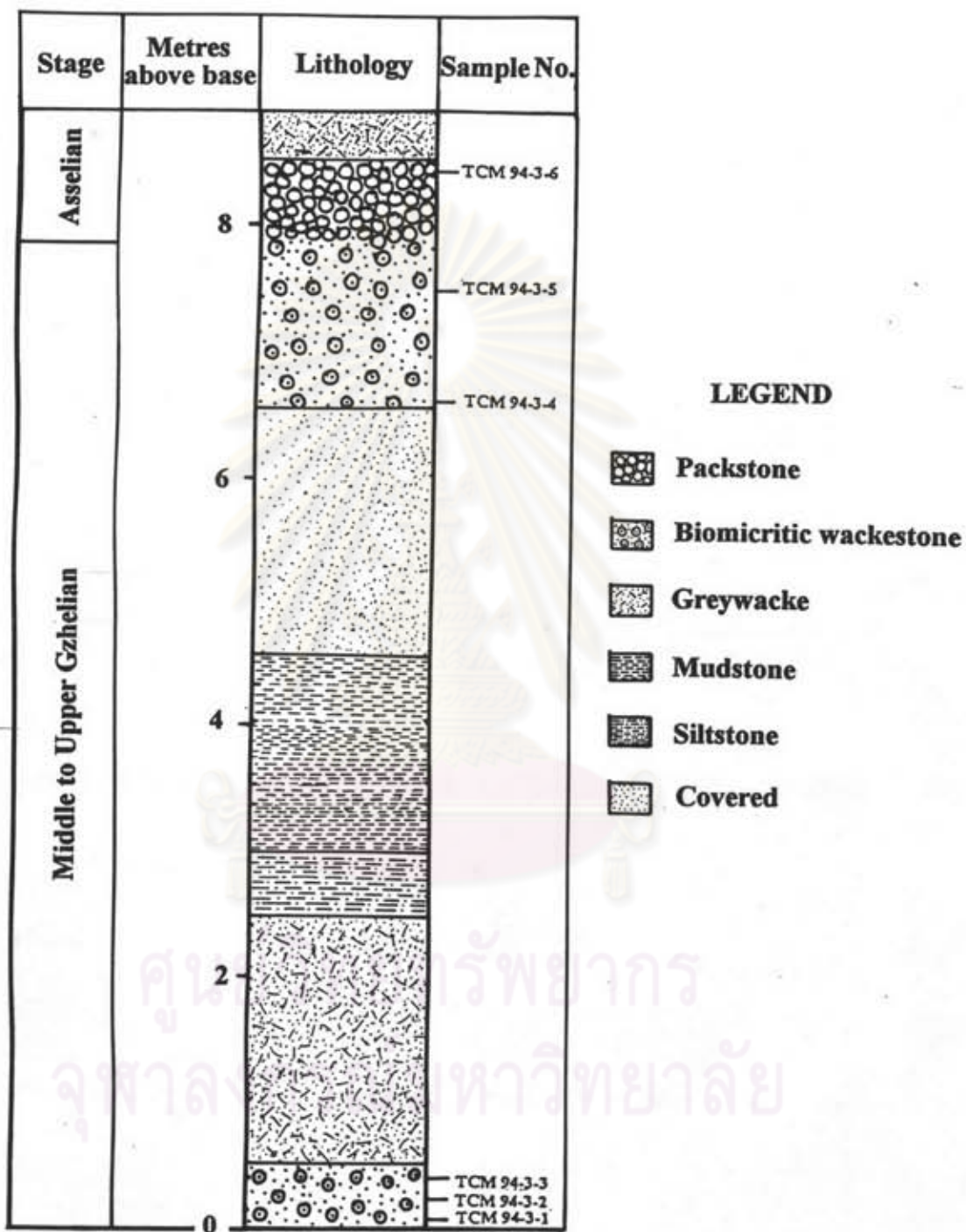


Figure 17 The measured section and ages of Phu Khao.

* The age of this section is based on the Stage scale in the Mediterranean-Alpine fold belt (see Table 1-1, page 8).

Km 30+050 along Changwat Loei-Amphoe Na Duang road (Location TCM 94-4)

This outcrop is at Km 30+050 along Changwat Loei-Na Duang road and is similar to the Phu Khao area (Location TCM 94-3). It is dark grey, thin-bedded limestones interbedded with clastic rocks. This location stratigraphically overlies the TCM 94-3 sequence. The strike direction of beds is NNW-SSE and dipping to the west. Detailed stratigraphic study and samples collection in this area were made (Figure 18). These limestones contain abundant fossils especially fusulinids (*Pseudoschwagerina* sp.). The kind of fauna, classification of limestone and geologic age in each bed can be respectively described from lower to upper beds as follows :-

1. Sample no. TCM 94-4-1

The rock is argillaceous limestone. Microscopically, it is packstone (Figure 19) and consists dominantly of pseudo-algae (*Bacinella* sp., *Tubiphytes obscurus* Maslov and *Epimastopora?* sp.), calcispheres, fusulinids (*Daixina* sp. and *Pseudoschwagerina* sp.), smaller foraminifers, shell and crinoid fragments. The pseudo-algae fragments are extensively distributed and tightly compacted. The rather complete and a few twisted fusulinid tests are also observed. Some bioclasts have been encrusted by pseudo-algae and occluded by sparite in their interior. Most grains have no arrangement. This rock is cemented by sparite with less carbonate mud. The age is Asselian based on *Pseudoschwagerina* sp.

2. Sample no. TCM 94-4-2

Microscopically, the rock type of limestone is biomicritic wackestone. It comprises predominantly pseudo-algae (*Bacinella* sp., *Tubiphytes obscurus* Maslov and *Epimastopora?* sp.) together with fusulinids (*Schubertella* sp.), shell fragments, smaller foraminifers, crinoid debris and calcispheres (Figure 20). They are supported by carbonate mud and contain sparry calcite cement. Bioclasts have been encrusted by pseudo-algae and occluded by sparite in the internal structure. Most grains are non-aligned. This rock is considered to be Asselian in age based on *Pseudoschwagerina* sp. that are found in the lower and upper beds of this sample.

3. Sample no. TCM 94-4-3

The rock type of this limestone sample is biomicritic wackestone (Figure 21). The sample contains both complete and incomplete fusulinid tests of the genera *Triticites*, *Daixina* and *Pseudoschwagerina*, which are also associated with prominent pseudo-algae (*Tubiphytes obscurus* Maslov and *Bacinella* sp.), shell fragments, smaller foraminifers, crinoid debris and calcispheres. In some bioclasts of fusulinids, shell fragments and crinoid plates have been encrusted by pseudo-algae and their interiors have been occluded by sparite. Most grains have not been aligned. The intergranular voids are supported by calcareous mud and contain sparry calcite cement. The age of this limestone is Asselian based on *Pseudoschwagerina* sp.

4. Sample no. TCM 94-4-4

The rock type of this limestone is biomicritic wackestone (Figure 22) which consists of complete fusulinids together with some broken fusulinid tests

Metres above base

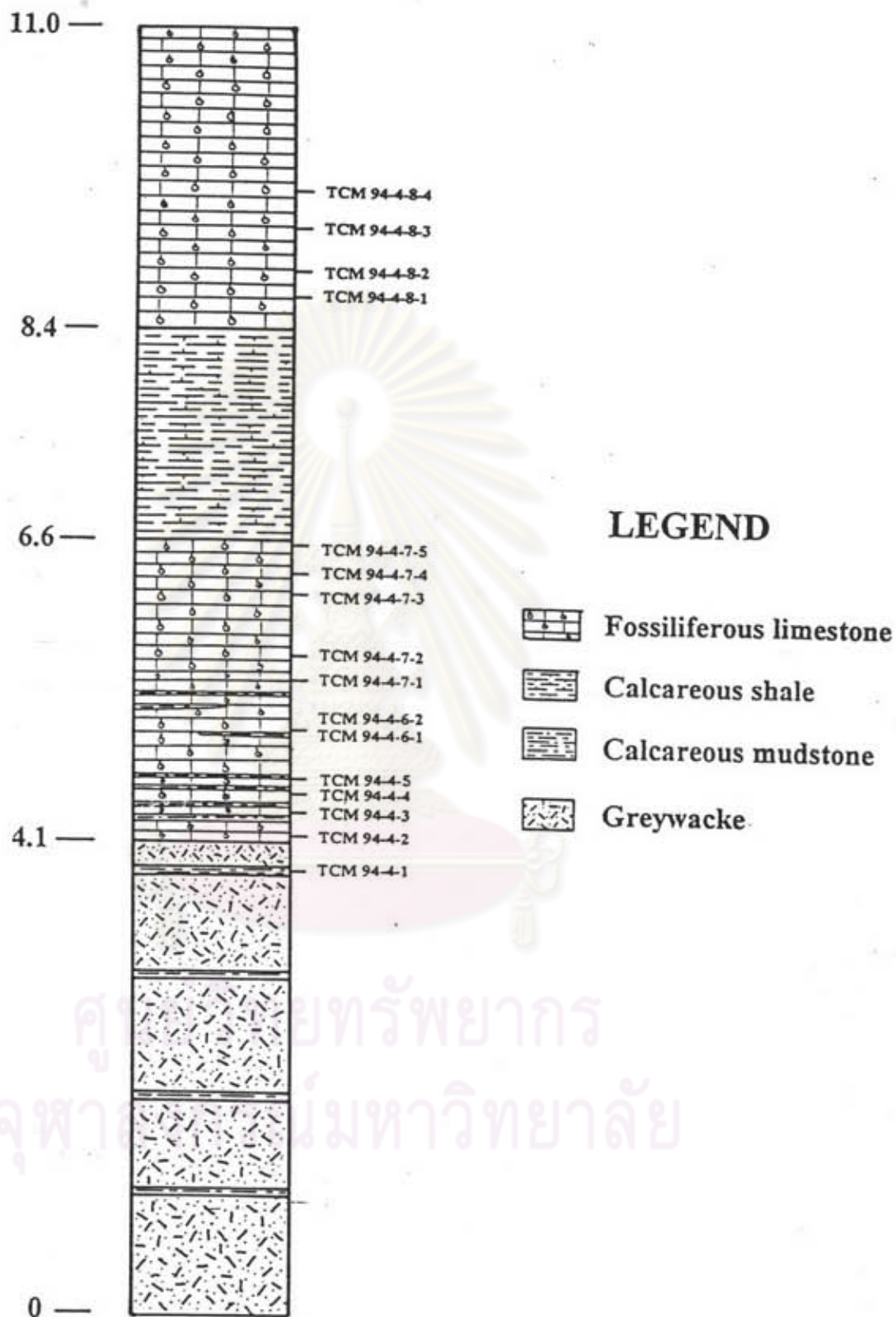


Figure 18 Measured section and sample locations of TCM 94-4.

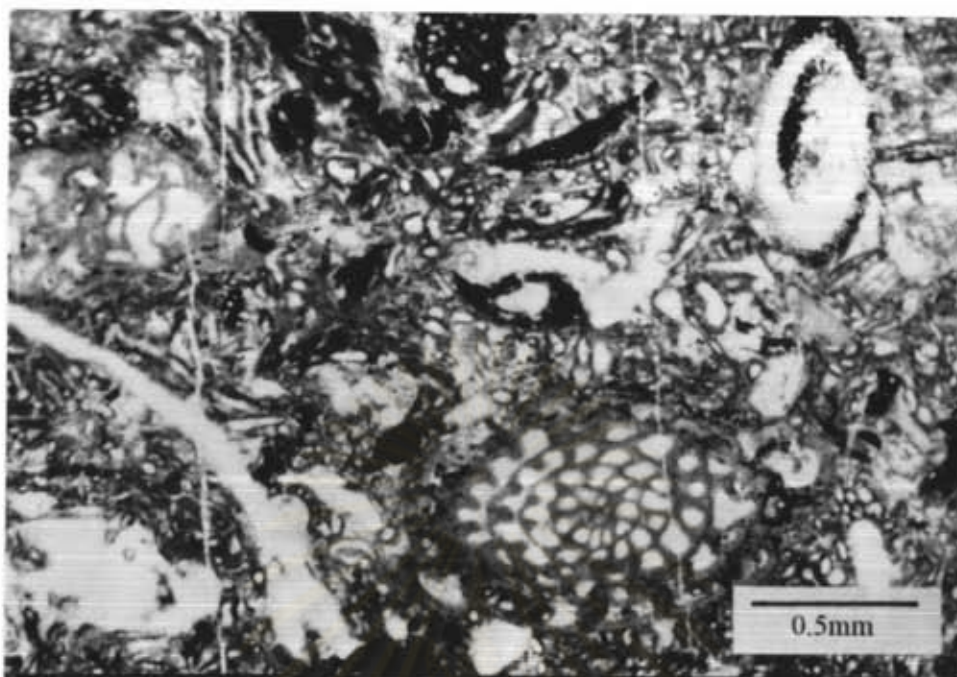


Figure 19 Photomicrograph of TCM 94-4-1, showing packed grains of bioclasts in packstone.

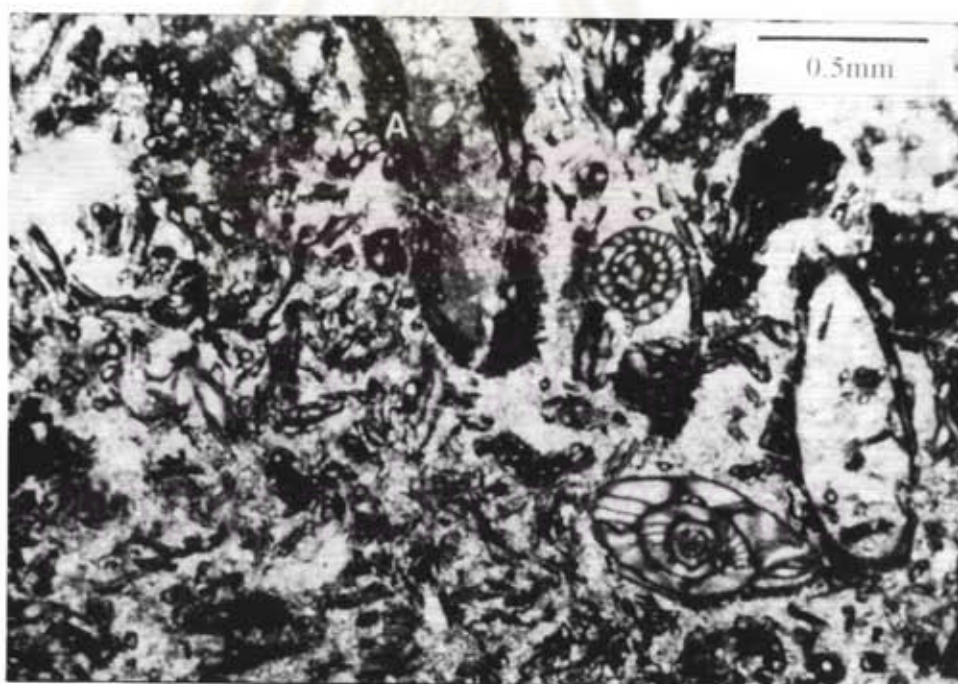


Figure 20 Photomicrograph of TCM 94-4-2, showing the grains of *Bacinella* sp.(A), *Schubertella* sp., *Tubiphytes obscurus* Maslov and mud-supported in biomicritic wackestone.

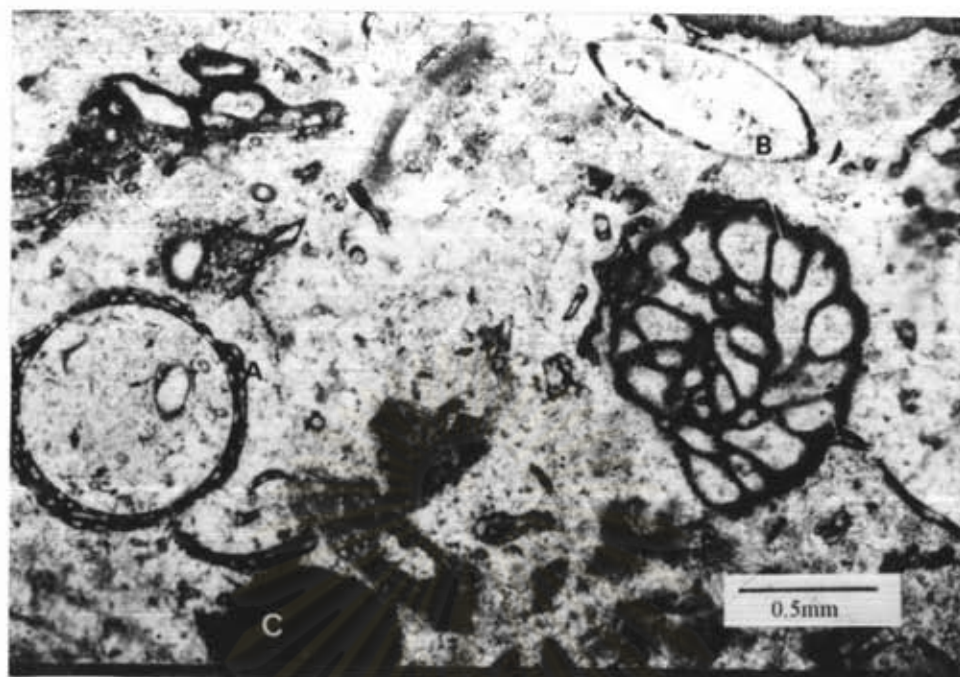


Figure 21 Photomicrograph of TCM 94-4-3, showing A) *Bacinella* sp., B) ostracod shell, C) *Tubiphytes obscurus* Maslov in biomicritic wackestone.

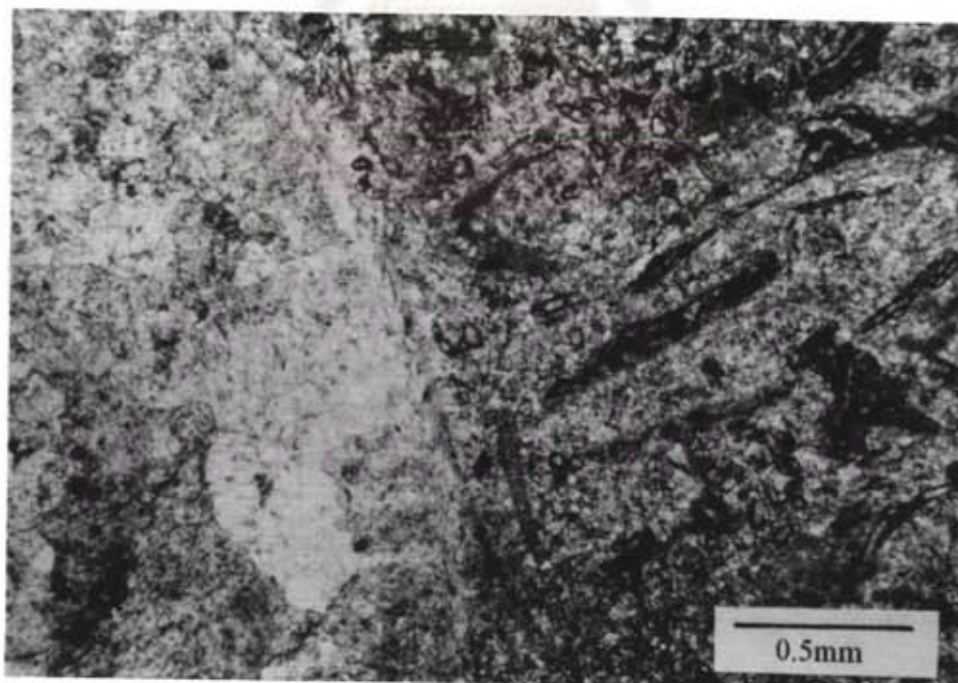


Figure 22 Photomicrograph of TCM 94-4-4, showing the bioclasts in biomicritic wackestone. Brachiopod shell is on the left.

belonging to the genera *Jigulites* and *Pseudoschwagerina*, associated with pseudo-algae (mostly *Bacinella* sp. and *Tubiphytes obscurus* Maslov), shell fragments (dominantly of brachiopods and ostracods), crinoid debris, smaller foraminifers and calcispheres. Some bioclasts of fusulinid tests and shell fragments have been encrusted by pseudo-algae. The chambers of fusulinids and the interior of brachiopod shells are filled with sparry calcite. Arrangement of bioclasts are not observed. This sample belongs to Asselian based on *Pseudoschwagerina* sp.

5. Sample no. TCM 94-4-5

Thin sections of rock sample show biomicritic wackestone (Figure 23). The rock is composed of pseudo-algae (*Tubiphytes obscurus* Maslov and *Bacinella* sp.), fusulinids (*Pseudoschwagerina* sp.), shell fragments, smaller foraminifers, crinoids and calcispheres. They are supported by abundant carbonate mud with sparry calcite cement. Sparry calcite within the interior of large bioclasts are observed. Most grains are non-aligned. The age of this sample is Asselian based on *Pseudoschwagerina* sp.

6. Sample no. TCM 94-4-6

This location is represented by the samples no. TCM 94-4-6-1 and TCM 94-4-6-2. These two samples are the same in composition and occur in biomicritic wackestone (Figure 24). They consist predominantly of pseudo-algae (*Tubiphytes obscurus* Maslov and *Bacinella* sp.). Both of complete form and fragment of fusulinids belong to *Pseudoschwagerina* sp. Smaller foraminifers, shell fragments and crinoid debris are also found. These rocks are mud-supported with sparry calcite cement. Most grains are not in alignment. Some bioclasts have been encrusted by pseudo-algae.

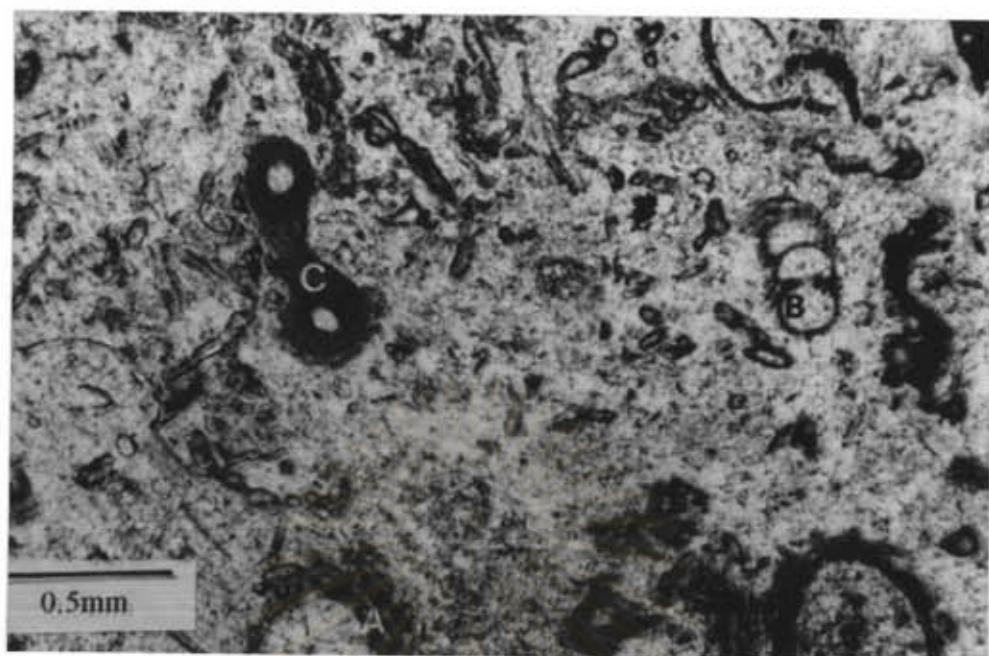


Figure 23 Photomicrograph of TCM 94-4-5, showing the bioclasts in biomicritic wackestone. *Bacinella* sp. (A), Smaller foraminifer (B), *Tubiphytes obscurus* Maslov (C).

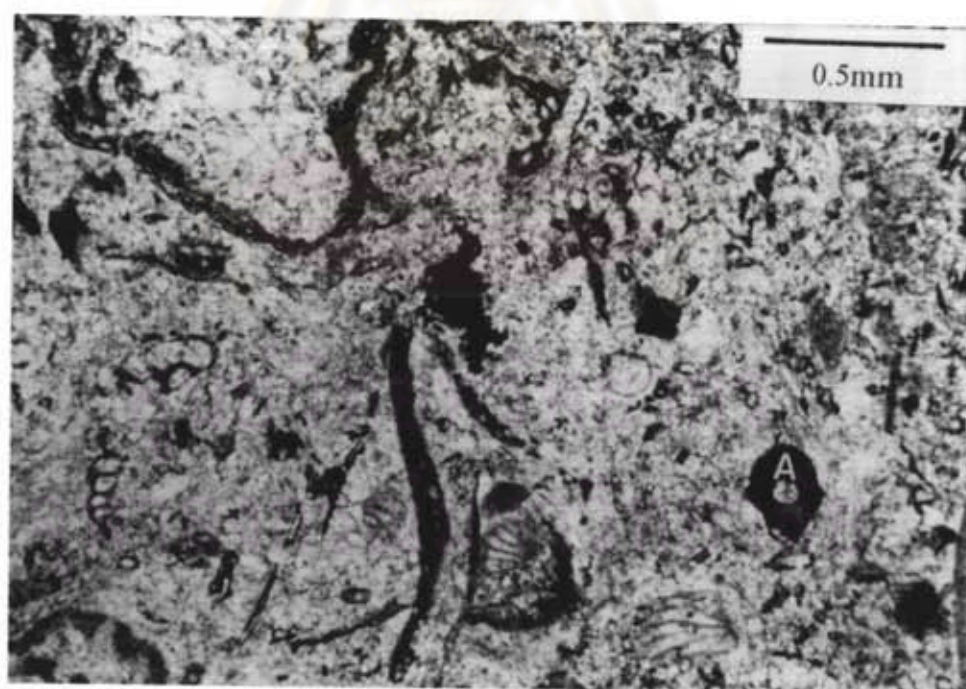


Figure 24 Photomicrograph of TCM 94-4-6, showing the bioclasts with mud-supported in biomicritic wackestone. (A) *Tubiphytes obscurus* Maslov.

Sparry calcite is common in the fusulinid tests and shell cavities. *Pseudoschwagerina* sp. in this sample indicate an Asselian age.

7. Sample no. TCM 94-4-7

Thin sections of samples no. TCM 94-4-7-1 to TCM 94-4-7-5 are similar in their compositions. These samples exhibit biomicritic wackestone and comprise dominantly mud-supported carbonate with bioclasts and calcite cement (Figure 25). The faunal assemblage containing pseudo-algae (*Tubiphytes obscurus* Maslov and *Bacinella* sp.) is commonly observed. Furthermore, fusulinids in the genus *Pseudoschwagerina*, smaller foraminifers, shell and crinoid fragments are also present. The age of this limestone is Asselian based on *Pseudoschwagerina* sp.

8. Sample no. TCM 94-4-8

This limestone location includes samples no. TCM 94-4-8-1 to TCM 94-4-8-4. The thin sections of these samples are rather similar in texture but they differ in the amount of bioclast which is the highest percentage in the sample no. TCM 94-4-8-3. The rock type of these samples is biomicritic wackestone. They comprise dominantly mud-supported carbonate with minor bioclasts and calcite cement (Figure 26). The faunal assemblage contains fusulinids (*Pseudoschwagerina* sp.) together with pseudo-algae (*Tubiphytes obscurus* Maslov and *Bacinella* sp.), smaller foraminifers (*Globivalvulina* sp.), shell fragments and crinoid debris. Some bioclasts are filled with sparite. The age of this limestone is Asselian based on *Pseudoschwagerina* sp.

The measured section and age of this rock unit are concluded in figure 27.

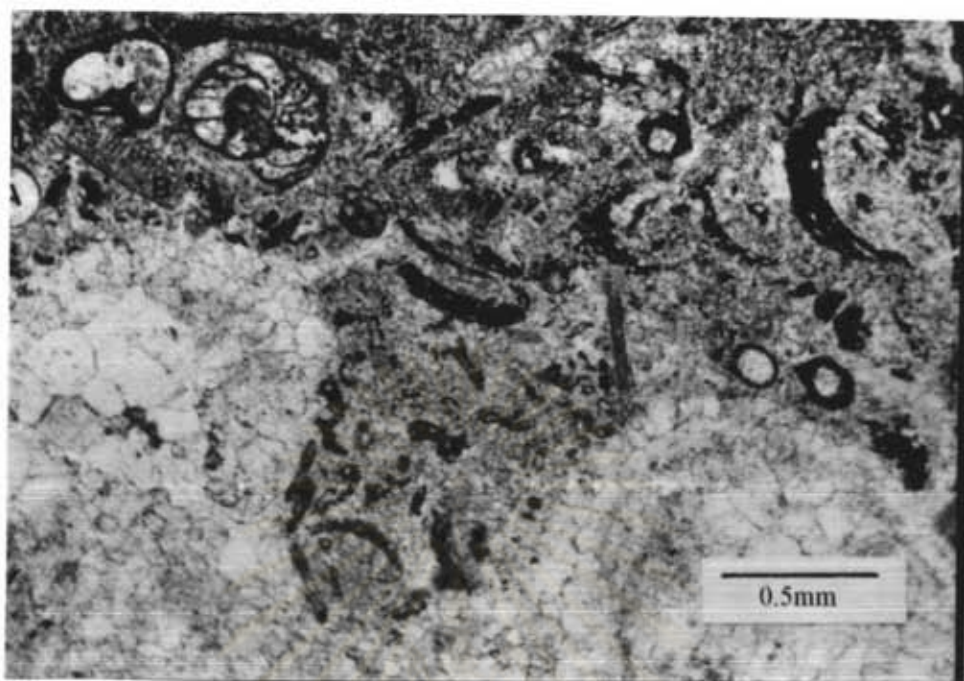


Figure 25 Photomicrograph of TCM 94-4-7, showing the bioclasts with matrix supported in biomicritic wackestone. A) Calcsphere, B) *Epimastopora?* sp. Brachiopod shell is on the bottom.

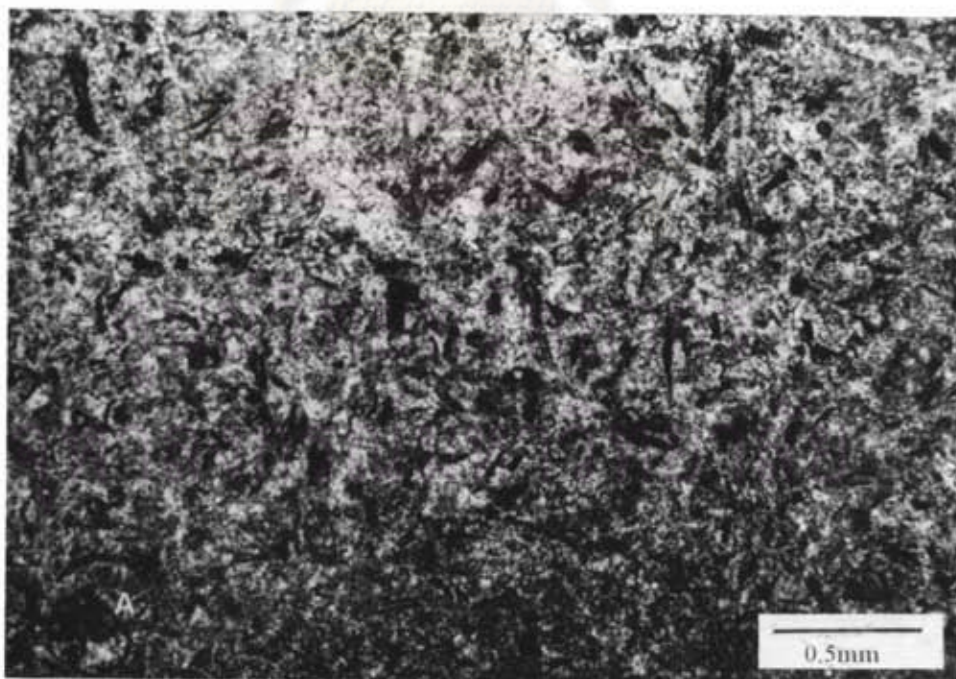


Figure 26 Photomicrograph of TCM 94-4-6, showing the bioclasts with mud-supported in biomicritic wackestone. (A) *Globivalvulina* sp.

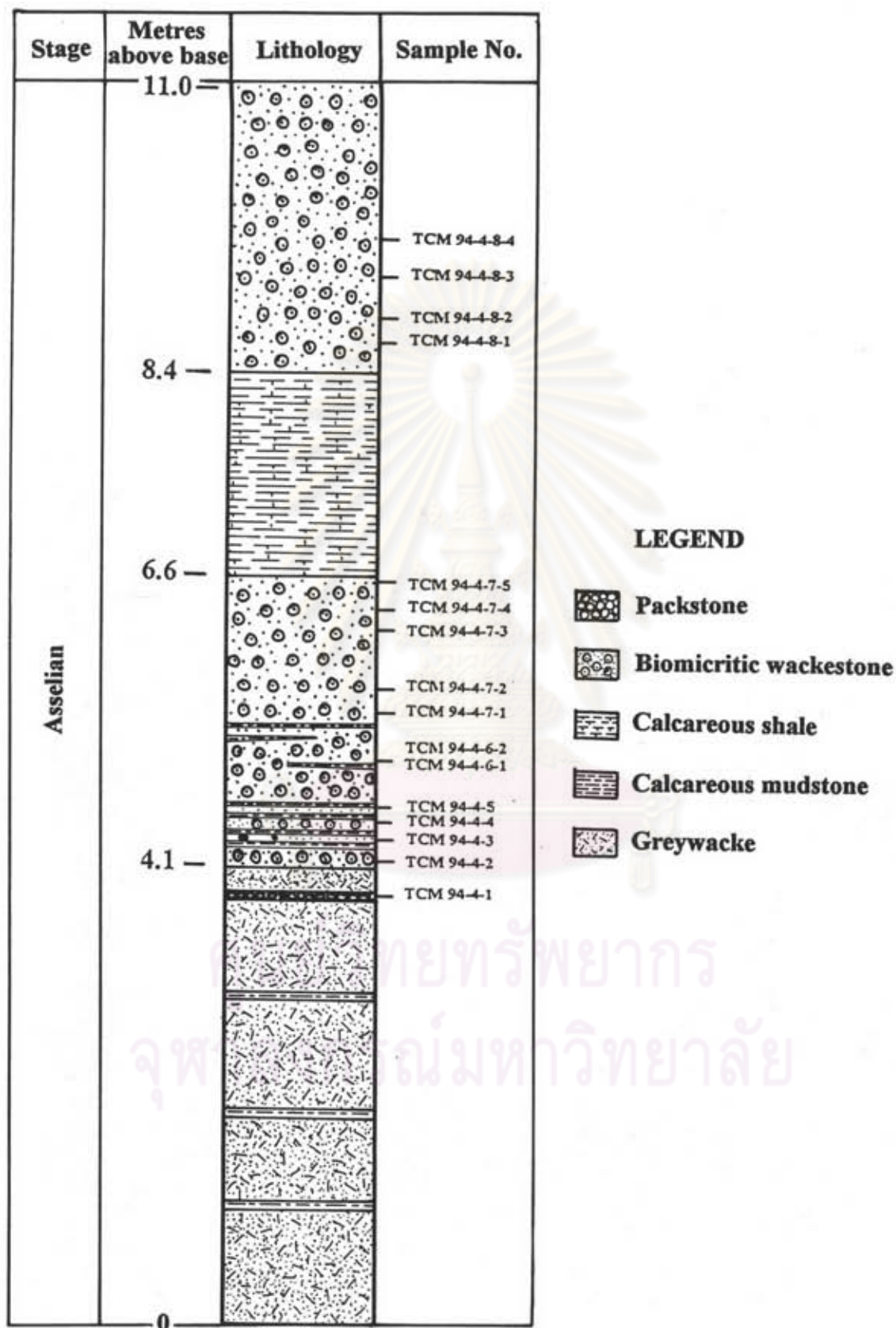


Figure 27 The measured section and age of Location TCM 94-4.

* The age of this section is based on the Stage scale in the Mediterranean-Alpine fold belt (see Table 1-1, page 8).

Road from Ban Na Din Dam to Ban Nam Suai Tha Sawan

The road from Ban Na Din Dam to Ban Nam Suai Tha Sawan consists of 4 localities viz. Location TCM 94-5 (grid reference 028313), Location TCM 94-6 (grid reference 054312), Location TCM 94-7 (grid reference 055309) and Location TCM 94-8 (grid reference 069298). Their petrographic and paleontologic analyses are respectively explained as follows :

1. Location TCM 94-5

This outcrop is in a small limestone hill, showing thick-bedded limestone unit. Strike and dip direction are in NE-SW and W respectively. The occurrences of foreslope talus and stromatolitic boundstone are considered to be a reef zone. The talus composition in thin section comprises oolites, peloids, shell fragments, fusulinid (*Triticites* sp.), crinoids plates and intraclasts. The clasts are poorly sorted and ranging from < 1 mm to >10 mm in size. This rock is mud-supported with calcareous cement. The occurrence of *Triticites* sp. indicates Late Kassimovian to Early Gzhelian.

2. Location TCM 94-6

The limestone is exposed in an isolated hill which is trending NW-SE parallel to the bedding and dipping to SW. No fossils are observed in this rock. This rock is dolomitic limestone based on XRD result and photomicrograph of this sample is present in figure 28.

3. Location TCM 94-7

The limestone is exposed on the ground surface. This station is not far from Location TCM 94-6. It contains some fossils, especially corals. The rock type of this sample is biomicritic wackestone (Figure 29). It contains corals, belonging to *Caninia* sp. (Jirawanwasana, 1995). Pseudo-algae, shell fragments and crinoid debris are also observed but fusulinid is not found. The age is Asselian to Sakmarian based on *Caninia* sp. (Jirawanwasana, 1995).

4. Location TCM 94-8

The limestone is exposed in a small hill, trending NW-SE and dipping to SW direction. This exposure has the same attitude of bedding as those of Location TCM 94-6. Oncoliths can be noted in the field. Microscopically, the rock type of this specimen is grainstone (Figures 30 and 31). It is composed predominantly of fusulinids together with smaller foraminifers, shell fragments, crinoid debris, peloids and calcareous cement. Fusulinids belong to *Jigulites* sp., *Darvasites* sp. and *Daixina* sp. which indicate an Early Permian age based on *Darvasites* sp. Some fusulinid tests are surrounded by carbonate mud. Furthermore, oncolites are also found and their nucleus are shell fragments and fusulinid tests. Most of the grains are not in alignment.

Wat Sunantharam (Location TCM 94-9)

Small isolated hill at Wat Sunantharam (Location TCM 94-9) is composed of dark grey, thin- to thick-bedded limestones, trending NW-SE and dipping to the E. Fossils are not observed in the lower part. In the middle part, limestone breccia is found (Figure 32). The fossils are observed in clasts of limestone breccia. The fossils of

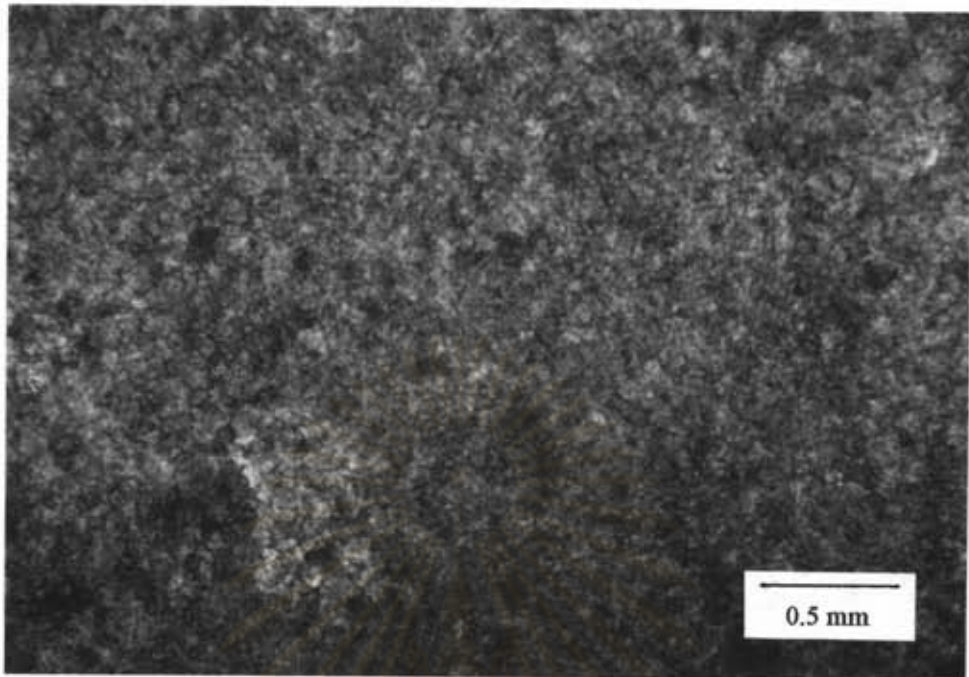


Figure 28 Photomicrograph of TCM 94-6, showing dolomitic limestone.

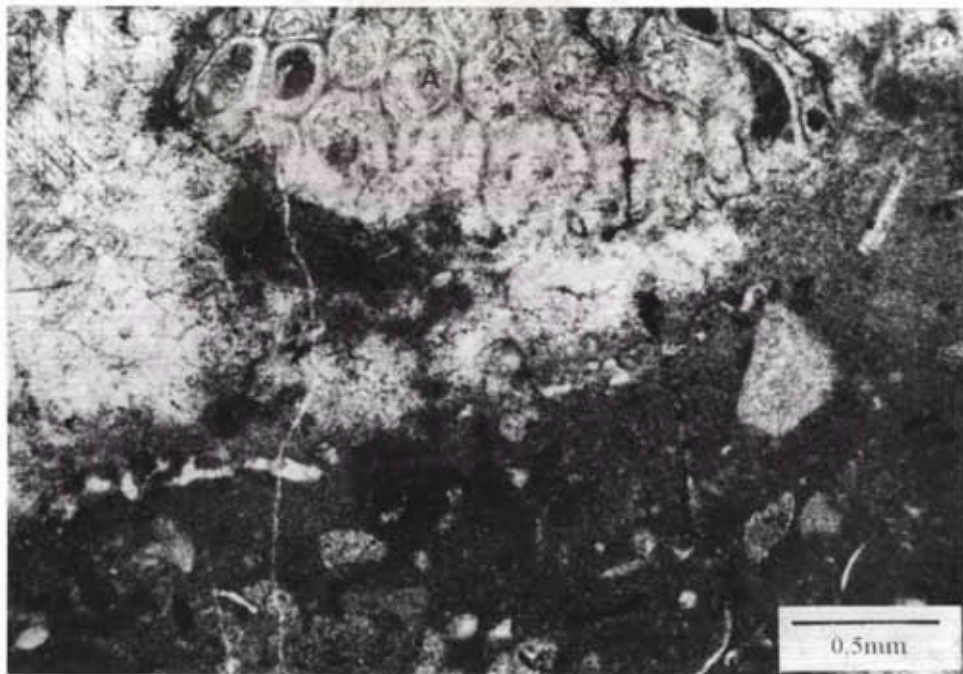


Figure 29 Photomicrograph of TCM 94-7, showing coral *Caninia* sp.(A), shell fragments with mud-supported in biomicritic wackestone.

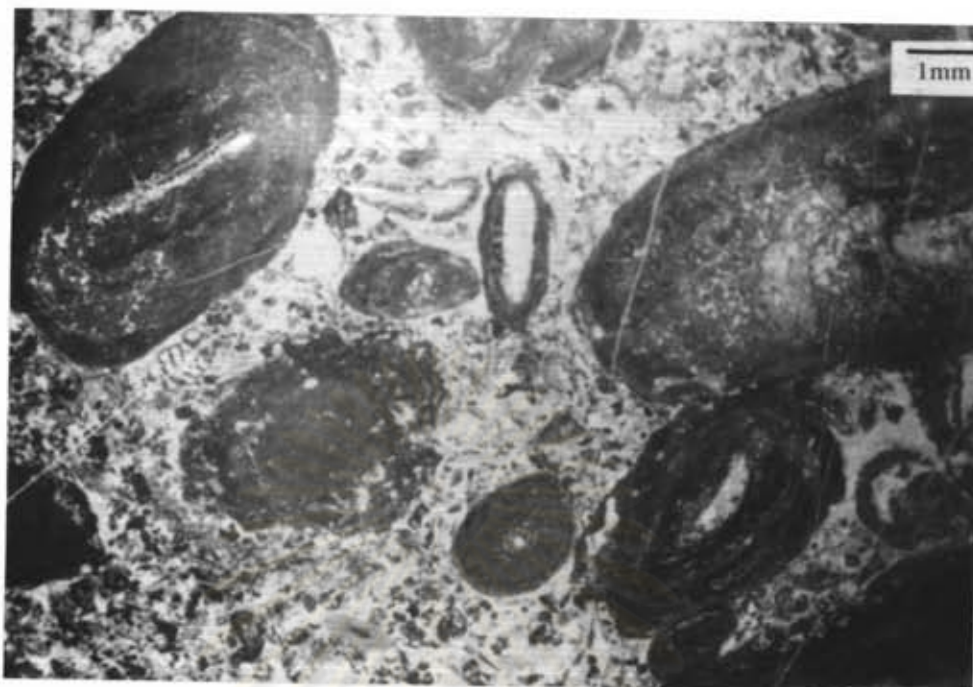


Figure 30 Photomicrograph of TCM 94-8, showing oncoliths with shell fragments and fusulinid tests formed as nucleus.



Figure 31 Photomicrograph of TCM 94-8, showing fusulinids in grainstone.

upper beds are abundant and comprise fusulinids, corals, giant pelecypods (Figure 33) and crinoids. Chert nodules are found in some limestone beds. Detailed stratigraphic study is carried out (Figure 34). Thirty rock samples were collected from the field, but twenty-four specimens were selected for petrographic and paleontologic analyses. The eight specimens in the lower part, four specimens in the middle part and ten specimens in the upper part were taken for detailed description. These samples are respectively identified from the lower to upper beds as follows :-

1. Sample no. TCM 94-9-1

This sample is micritic limestone. Microscopically, its composition is predominantly carbonate mud. Thin to thick veins of calcite are generally observed. Based on XRD result, the rock is dolomitic limestone. The age is estimated to be Bolorian? based on stratigraphy.

2. Samples no. TCM 94-9-2, TCM 94-9-3, TCM 94-9-4, TCM 94-9-5, TCM 94-9-9, TCM 94-9-10 and TCM 94-9-11.

These rocks show micritic limestone (Figure 35). They are lithologically similar and comprise prominently carbonate mud and calcareous cement. Fossils are less than 10% or absent. Calcite veins are rare to common. The geologic age is estimated to be Bolorian? based on stratigraphy.

3. Sample no. TCM 94-9-13

The sample is the limestone breccia which were collected from the middle part of this location. The rock type is packstone and comprise predominantly broken

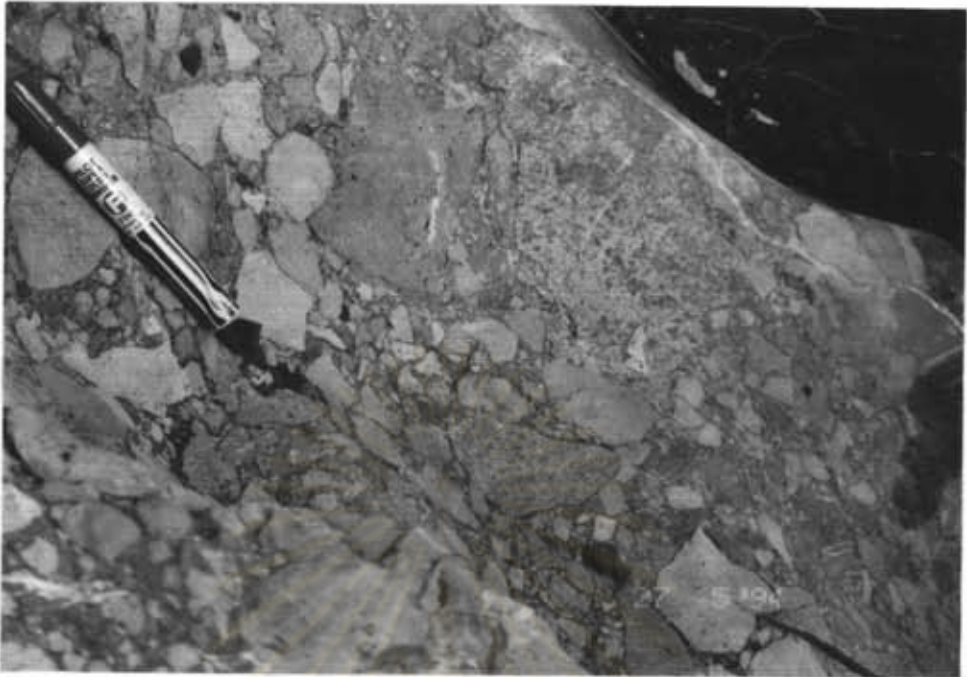


Figure 32 The limestone breccia shows poorly sorted and angular clasts at Wat Sunantharam.



Figure 33 The fragments of giant pelecypods at Wat Sunantharam.

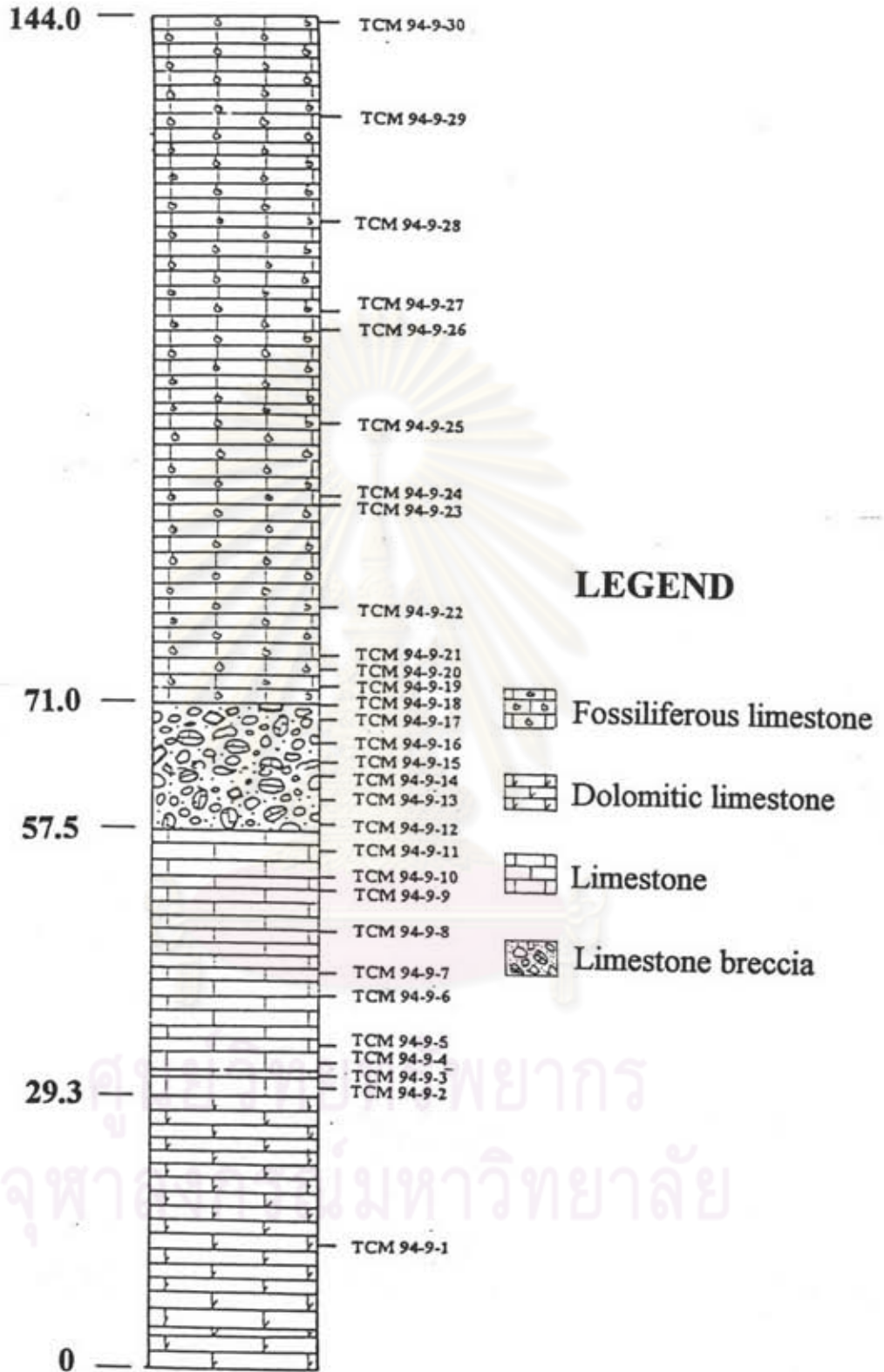


Figure 34 Measured section and sample locations of Wat Sunantharam.

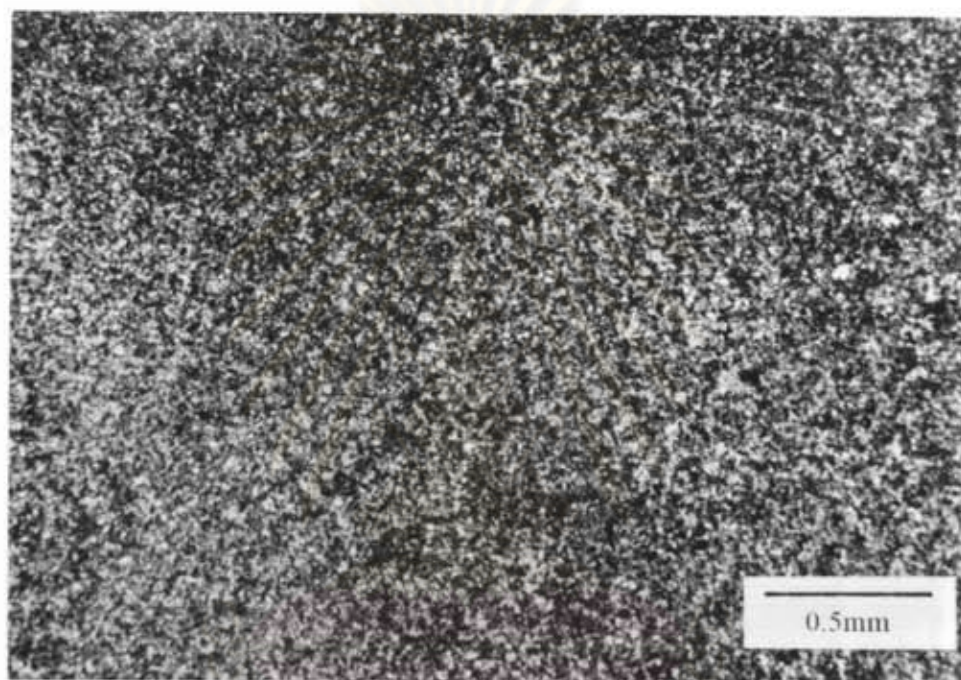


Figure 35 Photomicrograph of TCM 94-9-9, showing micritic limestone.

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shell fragments (< 0.1 to 2.0 mm in size), together with fusulinids and smaller foraminifers and rock fragments. Fusulinids belong to *Pseudofusulina* sp. The interior of bioclasts have been occluded by sparry calcite. The rock fragments are composed of micritic limestone and fossiliferous limestone grains which contain shell fragments of ostracods and fusulinid (*Pamirina* sp.). They are poorly sorted, sub-rounded to angular. This sample contains less mud-supported and shows packed grains. Many types of the particle contact are observed viz. point contact, concavo-convex contact, tangential contact and sutured contact. The sample shows the irregular to high-amplitude peaked stylolites with residual clay film.

4. Sample no. TCM 94-9-15

This specimen is limestone breccia. Microscopically the rock type is biomicritic wackestone and contains dominant shell fragments associated with pseudo-algae, crinoid debris, fusulinids and smaller foraminifers. Fusulinids yield *Yangchienia* sp. Pseudo-algae comprises mostly *Tubiphytes obscurus* Maslov. Smaller foraminifers yield *Pachyploia* sp. and *Globivalvulina* sp. This limestone is mud-supported with sparry calcite cement and contains some chert grains.

5. Sample no. TCM 94-9-16

The sample is limestone breccia. Microscopically, the rock type is packstone. It consists of the complete tests of fusulinids together with broken shell fragments, smaller foraminifers, calcispheres, pseudo-algae and crinoids. Fusulinids are composed of *Parafusulina* sp. and *Yangchienia* sp. Pseudo-algae belongs to *Tubiphytes obscurus* Maslov. Sparry calcite within chambers of fusulinids and shell

fragments are observed. The packed grains are not oriented. The irregular stylolites are generally found. Most of the contacts are sutured and tangential types.

6. Sample no. TCM 94-9-17

The specimen is limestone breccia. The rock type is packstone which comprises shell fragments, fusulinids, crinoids and smaller foraminifers (*Pachyploia* sp.) Fusulinids are both of broken and complete tests which yield *Parafusulina* sp., *Pseudofusulina* sp. and *Yangchienia* sp. This limestone contains the packed grains and is less mud-supported with calcareous cement. The grains show various types of contacts viz. point contact, concavo-convex contact, tangential contact and sutured contact. The sample shows irregular stylolites with residual clay film. Some fragments and chambers of fusulinids tests are filled by sparite. Calcite veins are generally found.

Remarks : In the field, the samples no. TCM 94-9-13 to TCM 94-9-17 are poorly sorted limestone breccia and contain chert nodules. No fossils in the matrix of this rock is observed. The author presumed that the limestone breccia is a secondary deposit filled in cavity. The age of this rock is estimated to be Kubergandian based on *Yangchienia* sp.

7. Sample no. TCM 94-9-19

This sample is dark grey limestone with chert nodules. Microscopically, it belongs to packstone which contains mainly shell fragments together with fusulinids, crinoid debris and smaller foraminifers. Fusulinids contain *Yangchienia* sp. and *Pseudofusulina* sp. This limestone is less mud-supported and contains sparry calcite cement. The grains are not oriented. They show various types of contacts viz. point

contact, concavo-convex contact, tangential contact and sutured contact. This rock occasionally shows the irregular to high-amplitude peaked stylolites with residual clay films (Figure 36). Sparry calcite filled in some shell fragments and chambers of fusulinids. Calcite veins are normally found. The age of this bed is referred to Kubergandian based on *Yangchienia* sp.

8. Sample no. TCM 94-9-20

In the field, the rock is dark grey limestone and giant pelecypods are observed in this bed. Microscopically, the rock is packstone (Figure 37) and composed of large pelecypod shells, less carbonate mud and sparry calcite cement. The orientation of shell fragments are parallel with bedding. Other fossils are not found. Sparite occluded within all of fragments. Calcite veins are occasionally observed. The age is inferred to Kugergandian based on *Yangchienia* sp. that is found in the lower and upper beds of this sample.

9. Sample no. TCM 94-9-21

This limestone is dark grey. Fusulinids and chert nodules are present. Microscopically, two rock types can be distinguished. They are biomicritic wackestone and grainstone. Fusulinids (*Verbeekina* sp.) together with pseudo-algae (*Tubiphytes obscurus* Maslov), shell fragments, smaller foraminifers (*Pachyploia* sp. and *Globivalvulina* sp.), crinoids and peloids are found in these types. Most of the grains are not oriented. The allochems in grainstone are moderately sorted, sub-rounded to rounded. Sparite filled in some bioclasts. Calcite veins are occasionally observed. Kubergandian age is referred to this limestone based on *Yangchienia* sp. that is found in the upper bed.

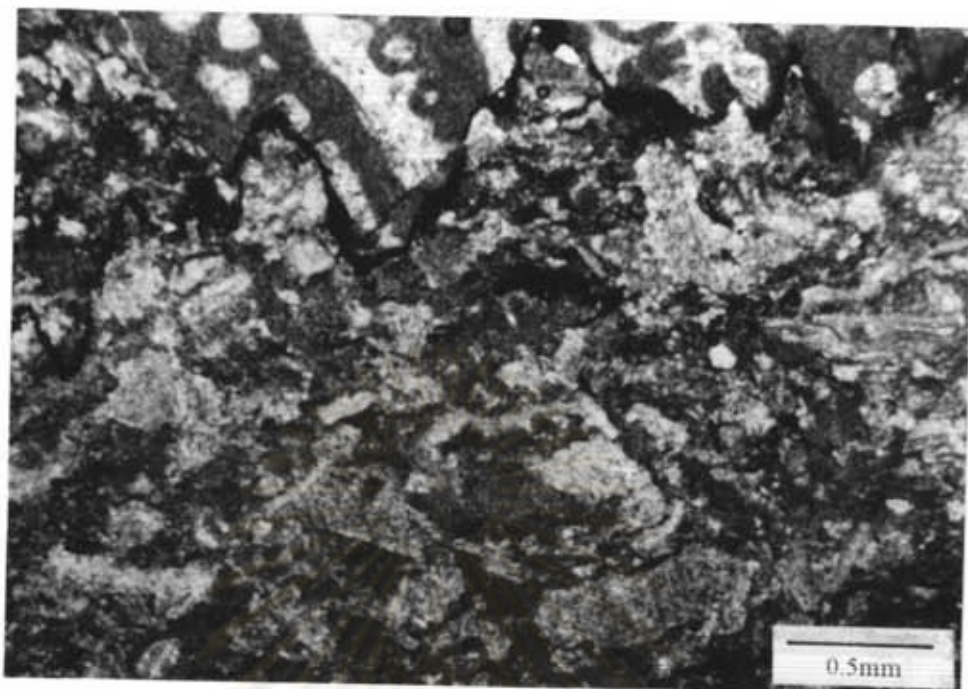


Figure 36 Photomicrograph of TCM 94-9-19, showing packed bioclasts and stylolite in packstone.

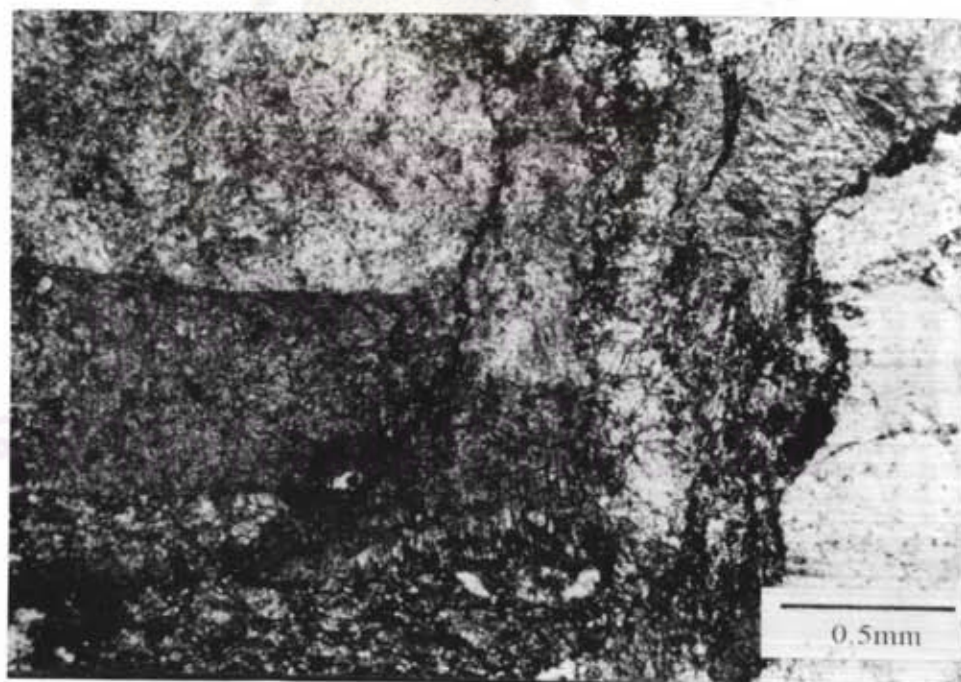


Figure 37 Photomicrograph of TCM 94-9-20, showing packed shell fragments of giant pelecypod in packstone.

10. Sample no. TCM 94-9-22

The sample is dark grey limestone which contains fusulinids and chert nodules. In thin section, this limestone is packstone and consists of shell fragments together with fusulinids and crinoids. Fusulinids belong to *Parafusulina* sp. and *Yangchienia* sp. Some fusulinid tests are replaced by silica and some bioclasts are unidentified because their internal structures are also destroyed by replacement. The packed grains are not oriented. Dissolution along the contact of grains are observed. Many types of grain contact can be distinguished viz. point contact, concavo-convex contact, tangential contact and sutured contact. The sample occasionally shows the irregular stylolites with residual clay films. Calcite veins are generally found. The age is Kubergandian based on *Yangchienia* sp.

11. Sample no. TCM 94-9-23

The limestone is dark grey. Shell fragments and crinoid stems are present. Microscopically, the specimen belongs to biomicritic wackestone. It is composed prominently of shell fragments, crinoid stems, pseudo-algae and smaller foraminifers. Fusulinids are not found in this sample. Pseudo-algae comprises *Pseudovermiporella* sp. and *Tubiphytes obscurus* Maslov and smaller foraminifers (*Pachyploia* sp.). Calcite veins are occasionally found. Kubergandian age is inferred to this limestone based on *Yangchienia* sp. in sample no. TCM 94-9-22 and coral (*Crassiparietiphyllum* sp.) in sample no. TCM 94-9-27.

12. Sample no. TCM 94-9-24

This rock type is packstone, containing giant pelecypod shells and chert nodules. It is composed predominantly of shell and crinoid fragments together with fusulinids and smaller foraminifers. Fusulinids (*Parafusulina* sp.) are replaced by silica. Some bioclasts are unidentified because their internal structures are destroyed by replacement. The packed grains have no orientation. Large and small calcite veins are commonly noted. The age is referred to Kubergandian based on *Yangchienia* sp. in sample no. TCM 94-9-22 and coral (*Crassiparietiphyllum* sp.) in sample no. TCM 94-9-27.

13. Sample no. TCM 94-9-25

The sample is a dark grey limestone containing chert nodules. Microscopically, this specimen is packstone and contains prominent shell fragments, crinoid stems and fusulinids. Fusulinids belong to *Parafusulina* sp. Some fusulinid tests are broken and recrystallized. The allochems are not aligned. This limestone occasionally shows the irregular stylolites with residual clay films. The age of this limestone belongs to Kubergandian based on *Yangchienia* sp. in sample no. TCM 94-9-22 and coral (*Crassiparietiphyllum* sp.) in sample no. TCM 94-9-27.

14. Sample no. TCM 94-9-26

The specimen is a dark grey limestone containing fragments of giant pelecypods. In thin section, the rock type belongs to packstone. This rock is composed dominantly of packed large pelecypod shells associated with occasional pseudo-algae (*Pseudovermiporella* sp.). Fusulinid is not found. The orientation of shell fragments

are parallel with bedding. Sparry calcite is filled in shell fragments. The Kubergandian age is referred to this limestone based on *Yangchienia* sp. in sample no. TCM 94-9-22 and coral (*Crassiparietiphyllum* sp.) in sample no. TCM 94-9-27.

15. Sample no. TCM 94-9-27

The sample is a dark grey limestone. Microscopically, this limestone belongs to biomicritic wackestone. It contains prominent shell fragments and pseudo-algae together with corals, crinoid stems, smaller foraminifers and calcispheres. Fusulinid is not observed in this sample. Pseudo-algae comprises *Pseudovermiporella* sp. and *Tubiphytes obscurus* Maslov. Corals contain *Crassiparietiphyllum* sp. indicating a Kubergandian age. (Jirawanwasana, 1995). Calcite veins are occasionally found.

16. Sample no. TCM 94-9-28

The rock is dark grey limestone. Microscopically, this specimen is oolitic grainstone. It is composed dominantly of pseudo-algae associated with shell fragments and smaller foraminifers. Pseudo-algae belongs to *Pseudovermiporella* sp. and *Tubiphytes obscurus* Maslov. Smaller foraminifers contain *Globivalvulina* sp. Fusulinid is not found in this rock. Oolites generally show concentric structure (Figure 38) commonly with smaller foraminifers as nucleus. Large shell fragments are filled by sparite. Calcite veins are generally found. The age is referred to Kubergandian or Murgabian.

17. Sample no. TCM 94-9-29

The dark grey limestone with some chert nodules can be observed in the handspecimen. In thin section, this rock type is biomicritic wackestone. The pseudo-algae, shell fragments, crinoid stems and smaller foraminifers are commonly observed in this sample but without fusulinid. Pseudo-algae comprises *Tubiphytes obscurus* Maslov. Smaller foraminifers contain *Globivalvulina* sp. Calcite veins are occasionally found. Kubergandian or Murgabian age is inferred to this limestone.

18. Sample no. TCM 94-9-30

The sample is dark grey limestone with fusulinids, gastropods, crinoid stems and chert nodules. Microscopically, the rock type is bio-pelmicritic wackestone. The dominant of fusulinids together with shell fragments, pseudo-algae, smaller foraminifers and peloids are found in this rock. Fusulinids consist of *Parafusulina* sp. and *Pseudofusulina* sp. Pseudo-algae comprises *Tubiphytes obscurus* Maslov and *Bacinella* sp. Fusulinids and peloids are generally observed (Figure 39). Some shell fragments are filled by sparite. Calcite veins are commonly present. This limestone belongs to Kubergandian or Murgabian age.

Based on corals (*Crassiparietiphyllum* sp.) in sample no. TCM 94-9-27 indicate Kubergandian age and fusulinids (*Parafusulina* sp. and *Pseudofusulina* sp.) in uppermost bed of this location (samples no. TCM 94-9-30) are long-ranging. The samples no. TCM 94-9-28 to TCM 94-9-30 stratigraphically overlie the sample no. TCM 94-9-27. So the estimated age of samples no. TCM 94-9-28 to TCM 94-9-30 may be Kubergandian or Murgabian.

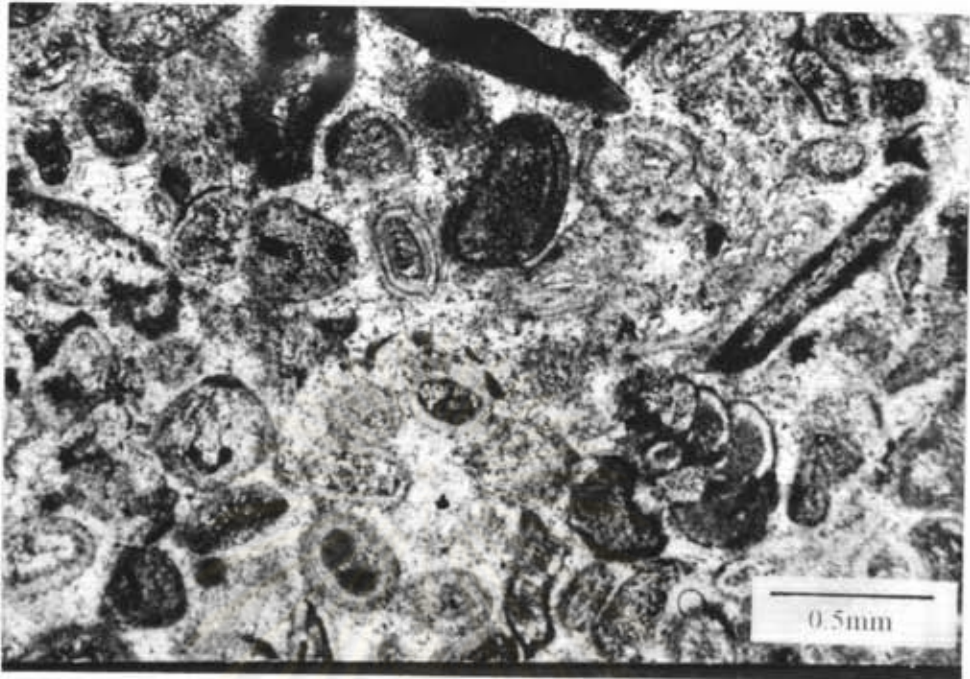


Figure 38 Photomicrograph of TCM 94-9-28 showing oolids in grainstone.

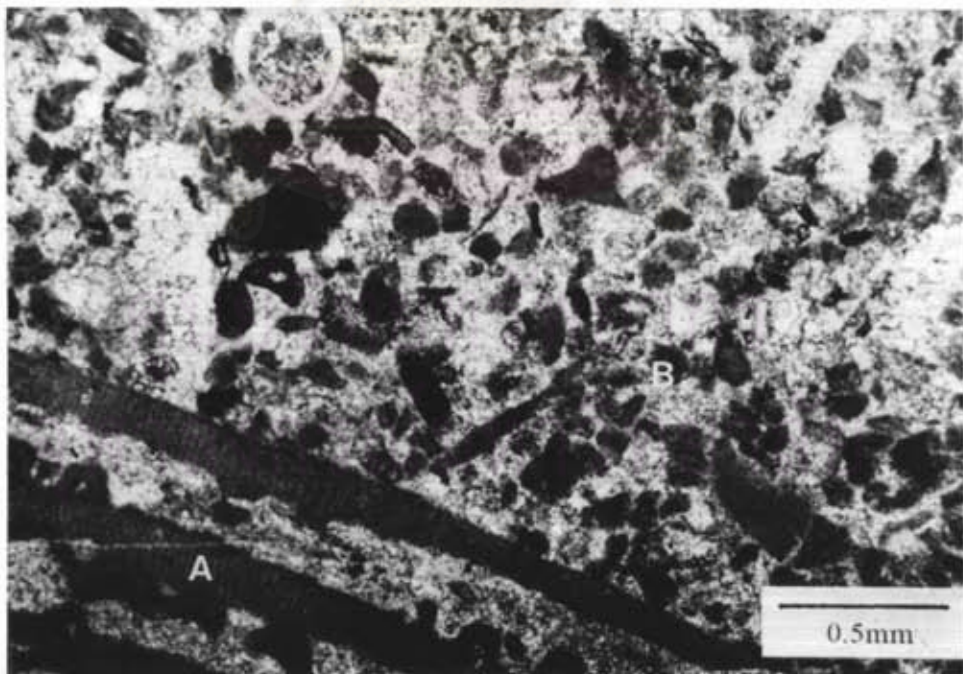


Figure 39 Photomicrograph of TCM 94-9-30 showing bio-pelmicritic wackestone. A) Wall of fusulinid, B) Peloid

The measured section and ages of this rock unit are present in figure 40.

Along Amphoe Wang Saphung-Changwat Nong Bua Lamphu highway

Along this highway 3 locations at Km 15+080, grid reference 099164 (Location TCM 94-10) and Km 17+080, grid reference 118167 (Location TCM 94-11) and grid reference 118166 (Location TCM 94-12) were studied. Their petrographic and paleontologic results are respectively explained as follows :

1. Location TCM 94-10

The large isolated hill contains dark grey thick-bedded limestones which trends east-westerly and dips to the north. This location stratigraphically underlies the TCM 94-11 sequence. Three levels of this limestone outcrops, lower, middle and upper parts, were collected for petrographic and paleontologic studies. The stratigraphy and sample collection in this location were not carried out in detail. Fusulinids, corals and chert lens are generally observed in the lower part. In the middle part, pseudo-algae and chert nodules are found extensively. Fusulinids, corals and chert lens are also present in the upper part. The detail of these parts are respectively described from the lower to upper parts as follows :

1.1 Location TCM 94-10 in the lower part

The handspecimen is dark grey limestone with fusulinids, corals and chert lens. Microscopically, the rock type is biomicritic wackestone. It contains abundant fusulinids (*Pseudofusulina* sp. and *Parafusulina* sp.) together with pseudo-algae (*Tubiphytes obscurus* Maslov), corals (*Protomichelinia* sp.), calcispheres,

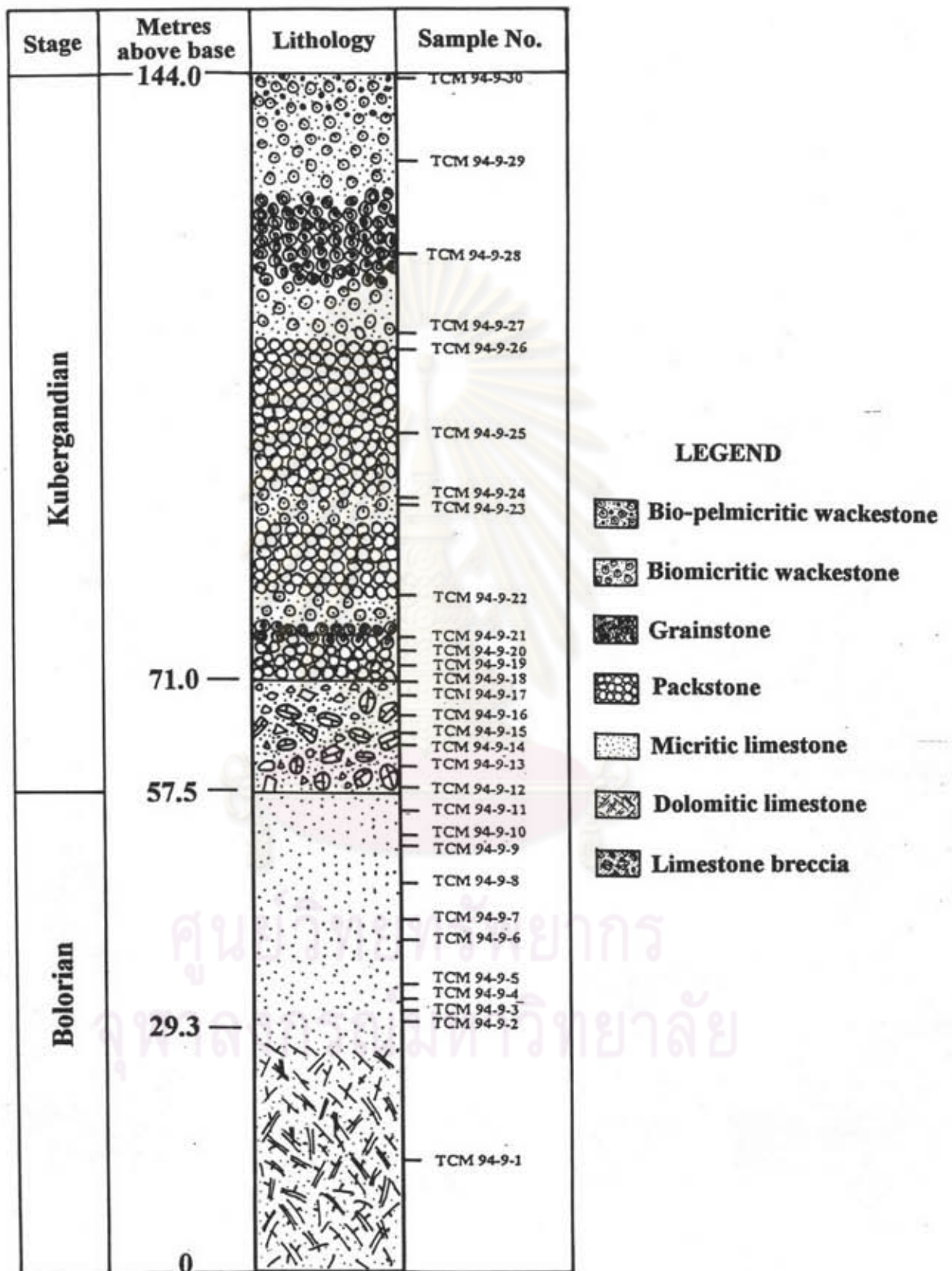


Figure 40 The measured section and ages of Wat Sunantharm.

* The age of this section is based on the Stage scale in the Mediterranean-Alpine fold belt (see Table 1-1, page 8).

crinoid debris, shell fragments and smaller foraminifers (Figure 41). The small shell fragments are also present in this sample. Sparry calcite occluded in the internal structure of bioclasts. Quartz grains are generally observed. The allochems have no orientation. The geologic age of this part is indicated by coral (*Protomichelinia* sp.) and fusulinid (*Chalaroschwagerina* sp.) which are found in the upper part of this location, belonging to Yahtashian.

Remark : Protomichelinia sp. is described by Jirawanwasana (1995).

1.2 Location TCM 94-10 in the middle part

This limestone is dark gery with pseudo-algae, crinoid stems and chert nodules. In thin section, the rock is biomicritic wackestone. It consists predominantly of pseudo-algae (*Pseudovermiporella* sp.) associated with shell fragments, crinoid debris and smaller foraminifers. Quartz grains are generally found (Figure 42). The allochems do not exhibit orientation. The age is referred to Yahtashian based on fusulinid and coral that are found in the lower and upper parts.

1.3 Location TCM 94-10 in the upper part

The sample is dark grey limestone. The fusulinids, corals and chert nodules can be observed. Microscopically, the rock is biomicritic wackestone. It comprises fusulinids (*Pseudofusulina* sp., *Parafusulina* sp. and *Chalaroschwagerina* sp.), together with pseudo-algae (*Epimastopora* ? sp. and *Tubiphytes obscurus* Maslov), coral (*Protomichelinia* sp.), shell fragments, crinoid debris and smaller foraminifers. The small shell fragments are occasionally distributed in this sample.

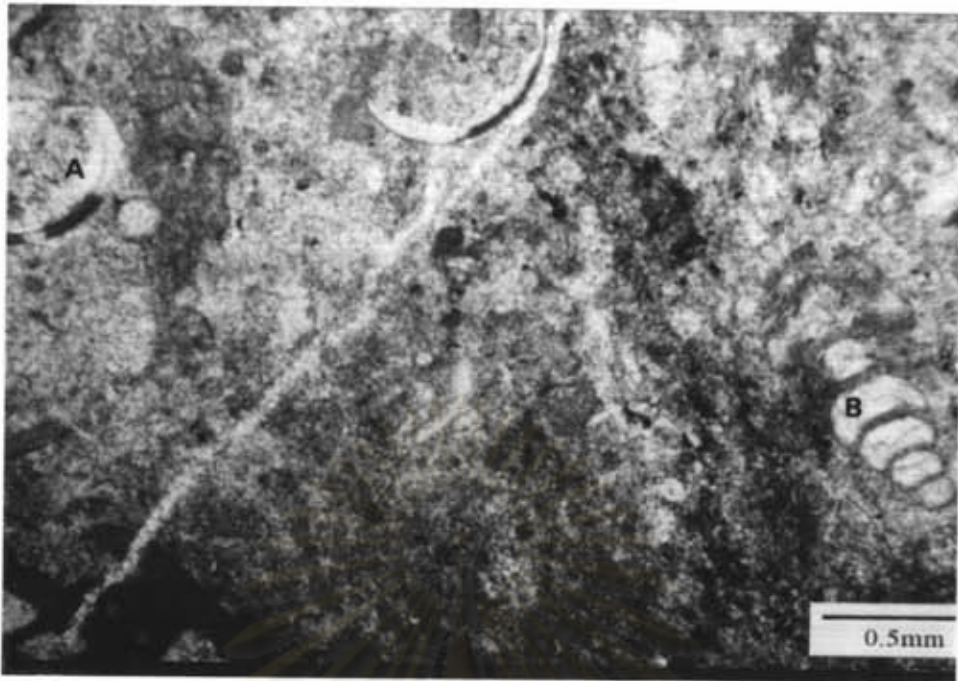


Figure 41 Photomicrograph of TCM 94-10 (lower part), showing bioclasts with carbonate mud in biomicritic wackestone. Ostracod shell (A), Smaller foraminifer (B)

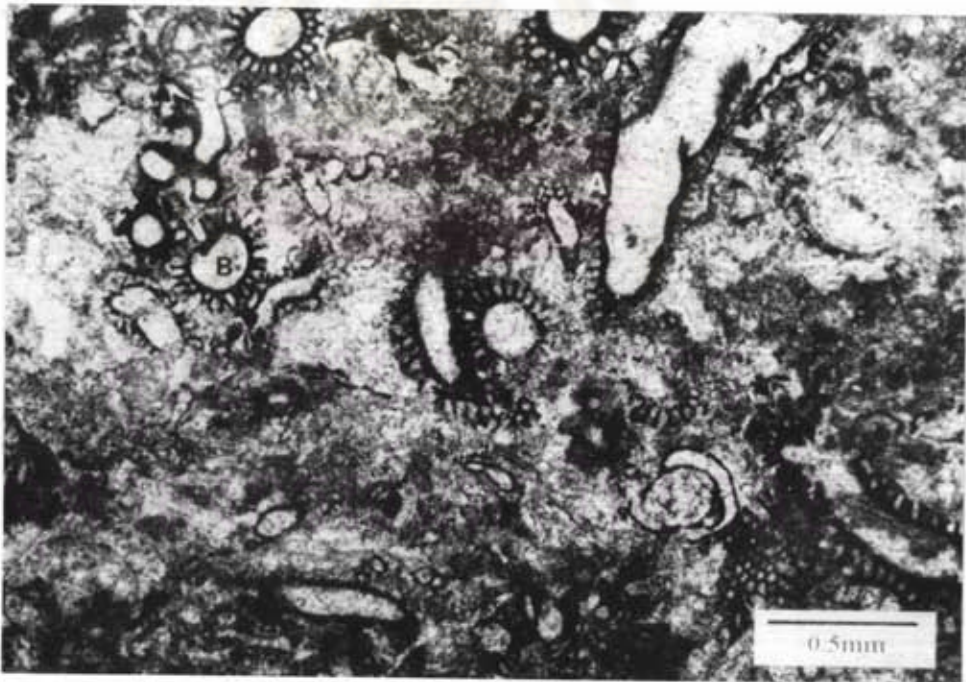


Figure 42 Photomicrograph of TCM 94-10 (middle part), showing bioclasts with carbonate mud in biomicritic wackestone. *Pseudovermiporella* sp. (A and B)

Sparry calcite occluded in the interior structure of bioclasts. Quartz grains are commonly found. The allochems are not aligned.

Remarks : *Chalaroschwagerina* sp. is identified by Ueno (Personal communication, 1995).

2. Location TCM 94-11

This outcrop is in a small hill consisting of dark grey, thick-bedded fossiliferous limestones. The strike of the beds is NW-SE and the dip is to the NE. This location stratigraphically overlies the TCM 94-10 sequence. In the lower part of this sequence (samples no. TCM 94-11-1 to TCM 94-11-14), gastropods and giant pelecypod fragments are clearly seen but fusulinids are not observed by naked eyes. In the upper part (sample no. TCM 94-11-15), fusulinids are larger than those of the lower part and corals can be observed from handspecimens. Detailed stratigraphic study and sample collections were carried out in this area (Figure 43). Nine samples for petrographic and paleontologic analyses are respectively described from the lower to upper beds as follows :

2.1 Sample no. TCM 94-11-1

The rock is dark grey limestone. Microscopically, the limestone is bio-pelmicritic wackestone. It contains predominantly peloids together with calcispheres, shell fragments, smaller foraminifers and fusulinids. Peloids are rounded to sub-rounded. Fusulinid tests are small and complete. They comprise predominantly *Pamirina* sp. Calcispheres are generally distributed in this samples. Calcite veins often

Metres above base

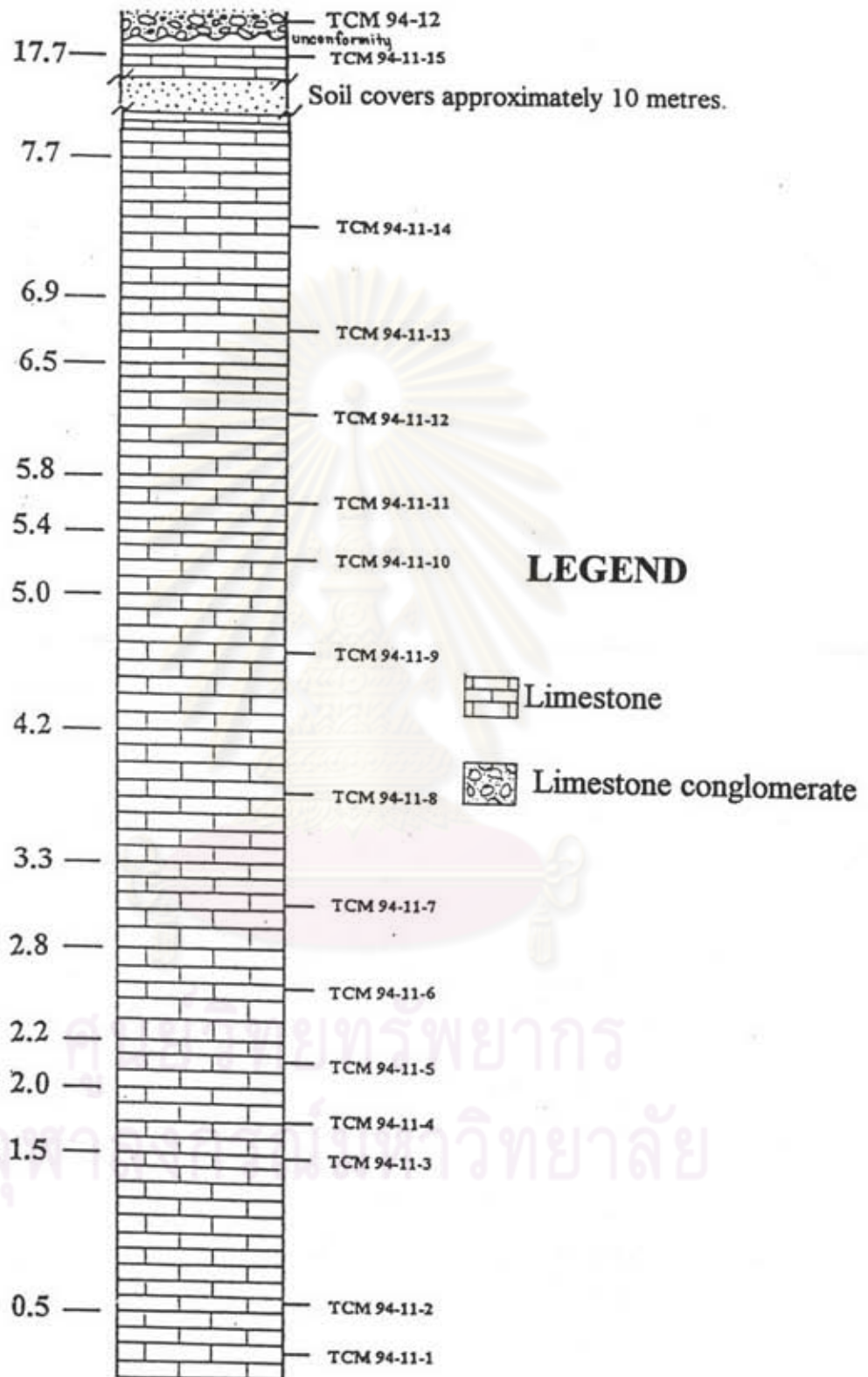


Figure 43 Measured section and sample locations of TCM 94-11.

occur. The bioclast cavities are filled by sparite. This limestone is Yahtashian in age based on *Pamirina* sp.

2.2 Sample no. TCM 94-11-2

The handspecimen is dark grey limestone. Fossils can not be observed by naked eyes. Microscopically, the rock type is bio-pelmicritic wackestone which is composed predominantly of peloids associated with calcispheres, shell fragments, smaller foraminifers and fusulinids. Peloids are also rounded to sub-rounded resembling the previous sample. Fusulinids are small and complete in shape. They comprise dominantly *Pamirina* sp. Calcispheres are preserved but their quantity are less than the previous sample. Sparry calcite is common within bioclasts. Calcite veins are also observed. The Yahtashian age is referred to this limestone based on *Pamirina* sp.

2.3 Sample no. TCM 94-11-3

The sample is dark grey limestone. Fossils can not be found by naked eyes. In thin section, the rock type is biomicritic wackestone. It contains calcispheres, pseudo-algae (*Pseudovermiporella* sp. and *Tubiphytes obscurus* Maslov), shell fragments, smaller foraminifers. Calcispheres are abundant and can be observed throughout this rock. Pseudo-algae is occasionally found. Sparite within bioclasts commonly occurs. Small calcite veinlets are also noted. This sample is Yahtashian in age based on *Pamirina* sp. that is found in the lower and upper beds of this sample.

2.4 Sample no. TCM 94-11-6

The rock is dark grey limestone and contains gastropods and fragments of giant pelecypods. Microscopically, this sample is biomicritic wackestone, containing pseudo-algae (*Tubiphytes obscurus* Maslov and *Pseudovermiporella* sp.) in association with fusulinids (*Pamirina* sp.), shell fragments, crinoid debris, smaller foraminifers and calcispheres. Large and small calcite veins generally occur. Sparite within shell fragments is also observed. The age of this limestone is Yahtashian based on *Pamirina* sp.

2.5 Sample no. TCM 94-11-7

The sample is dark grey limestone containing gastropods. Microscopically, the rock consists dominantly of bioclasts in bio-pelmicritic wackestone. Bioclasts contain peloids together with fusulinids (*Pamirina* sp. and *Schubertella* sp.), shell fragments, smaller foraminifers (*Globivalvulina* sp.) and calcispheres. Peloids are rounded to sub-rounded. This limestone is mud-supported and contains sparry calcite cement. Calcite veins are generally found. Sparite within shell fragments is also noted. The rock is Yahtashian in age based on *Pamirina* sp.

2.6 Sample no. TCM 94-11-9

The sample is dark grey limestone containing gastropods and fragments of giant pelecypods. In thin section, this limestone is biomicritic wackestone. It contains abundant shell fragments associated with fusulinids (*Pamirina* sp.), pseudo-algae (*Pseudovermiporella* sp.), smaller foraminifers (*Globivalvulina* sp.) and calcispheres. The limestone is mud-supported and contains sparry calcite cement.

Sparite filling in shell fragments are observed. The grains are arranged parallel with limestone bed. The limestone is Yahtashian in age based on *Pamirina* sp.

2.7 Sample no. TCM 94-11-10

The handspecimen is dark grey limestone containing gastropods and giant pelecypod fragments. Microscopically, the rock is biomicritic wackestone. It is composed dominantly of calcispheres together with fusulinids (*Pamirina* sp. and *Schubertella* sp.), pseudo-algae (*Tubiphytes obscurus* Maslov and *Pseudovermiporella* sp.), smaller foraminifers (*Globivalvulina* sp.) and shell fragments. Calcispheres are commonly distributed in this rock. Calcite veins are small and occasionally found. The shell fragments are filled by sparite. In some part of thin section, carbonate mud and shell fragments are arranged nearly parallel with the limestone bed. Its age is Yahtashian based on *Pamirina* sp.

2.8 Sample no. TCM 94-11-14

The sample is a dark grey limestone containing gastropods and giant pelecypod fragments. Microscopically, this limestone is biomicritic wackestone which comprises dominantly shell fragments together with fusulinids (*Pamirina* sp. and *Sphaerulina* sp.), pseudo-algae (*Pseudovermiporella* sp.), calcispheres and smaller foraminifers. They are mud-supported and contain calcareous cement. Calcispheres and smaller foraminifers are distributed occasionally in this sample. Shell fragments have been occluded by sparite. Calcite veins are small and occasionally found. The Yahtashian age is inferred to this limestone based on *Pamirina* sp.

2.9 Sample no. TCM 94-11-15

The sample is a dark grey limestone. Fossils and chert lens can be observed by naked eyes. Microscopically, the rock type is biomicritic wackestone. It contains fusulinids (*Pseudofusulina* sp.), corals (*Protomichelinia* sp.), shell fragments and smaller foraminifers. Some bioclasts are recrystallized, so they are difficult to identify. Large and small calcite veins are generally found. This rock is mud-supported and contains calcareous cement. The shell fragment cavities and fusulinid chambers are filled by sparite. The limestone age is estimated to be Yahtashian based on coral (*Protomichelinia* sp.) because fusulinid (*Pseudofusulina* sp.) is long-ranging that can not indicate the certain age.

The measured section and age of this rock sequence are concluded in figure 44.

3. Location 94-12

The rock exposure is composed of massive limestone conglomerate. This limestone conglomerate is clearly observed at Km 17+080 and opposite of the previous location on the highway from Amphoe Wang Saphung to Changwat Nong Bua Lamphu. The clasts of limestone conglomerate contain some faunas. This conglomerate unconformably overlies the Permian limestone. From the field evidence and the stratigraphic position, this rock can be correlated with the conglomerate of Huai Hin Lat Formation.

Microscopically, the limestone clast is composed of grains of micritic and fossiliferous limestones together with peloids, carbonate mud and calcareous cement.

The grains of micritic and fossiliferous limestones are poorly sorted and they are rounded to angular. Fossiliferous limestone grains consist of the fragments of fusulinids associated with shell fragments, pseudo-algae, smaller foraminifers and calcispheres. Fractures in this sample are generally found and have been occluded by sparry calcite. The age of the limestone conglomerate is Late Triassic.



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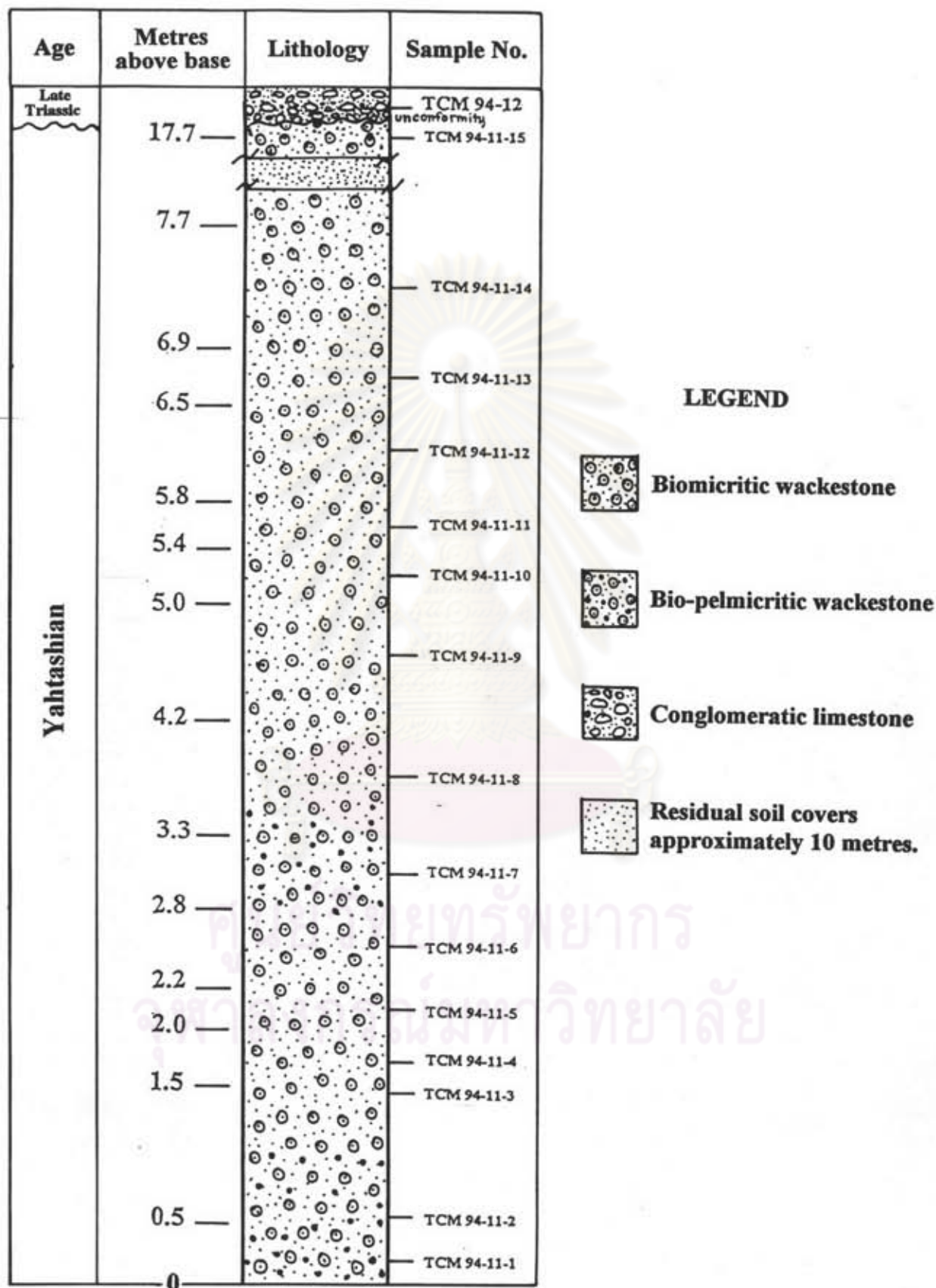


Figure 44 The measured section and ages of Location TCM 94-11 and TCM 94-12.

* The age of this section is based on the Stage scale in the Mediterranean-Alpine fold belt (see Table 1-1, page 8).