

## CHAPTER II

### Regional Geology

#### 2.1 Regional Distribution of Triassic Rocks

##### 2.1.1 Introduction

Study on Triassic rock sequence in Thailand is quite important since these rock sequences occur several kinds of depositional environments. As it has been considered by several workers (Bunopas, 1981; Charusiri, 1989; Chaodumrong, 1997; Metcalfe, 1997). Two microcontinental continents (Shan-Thai and Indochina, Bunopas and Vella, 1992) and two intervened tectonic units (Lampang-Chiang Rai and Nakhon Thai oceanic blocks, Charusiri et al., 2000). The aim of this section is to compile Triassic rock sequence of the country in order to visualize their paleoenvironments.

##### 2.1.2 Historical Backgrounds

In the old days (before 1960) much of work for Triassic rocks were focused mainly on paleontological studies. Emphasis was placed on the Triassic fossils in northern Thailand as reported by Høgbom (1914), Lee (1923), and Heim and Hirschi (1939).

Subsequently, Triassic fossils from the Kamawkale Limestone in the Thailand and Myanmar border between Tak and Kanchanaburi Provinces (see Figure 2.1), were studied by Gregory (1930), Weir (1930), Trauth (1930), and Pia (1930). Assemblage of fossils, i.e., algae, corals, brachiopods, bivalves, and ammonoids have yielded the age of Late Triassic (Norian).

In the first geological map (Brown et al., 1951) published by the co-operation between United States Geological Survey and Royal Department of Mines (Department of Mineral Resources at present), marine Triassic sequence including Kamawkale Limestone was assigned belonging to the Khorat Series (LaMoreaux et al., 1959 and Chalichan and Bunopas, 1954) so called Khorat Group by Ward and Bunnag (1964).

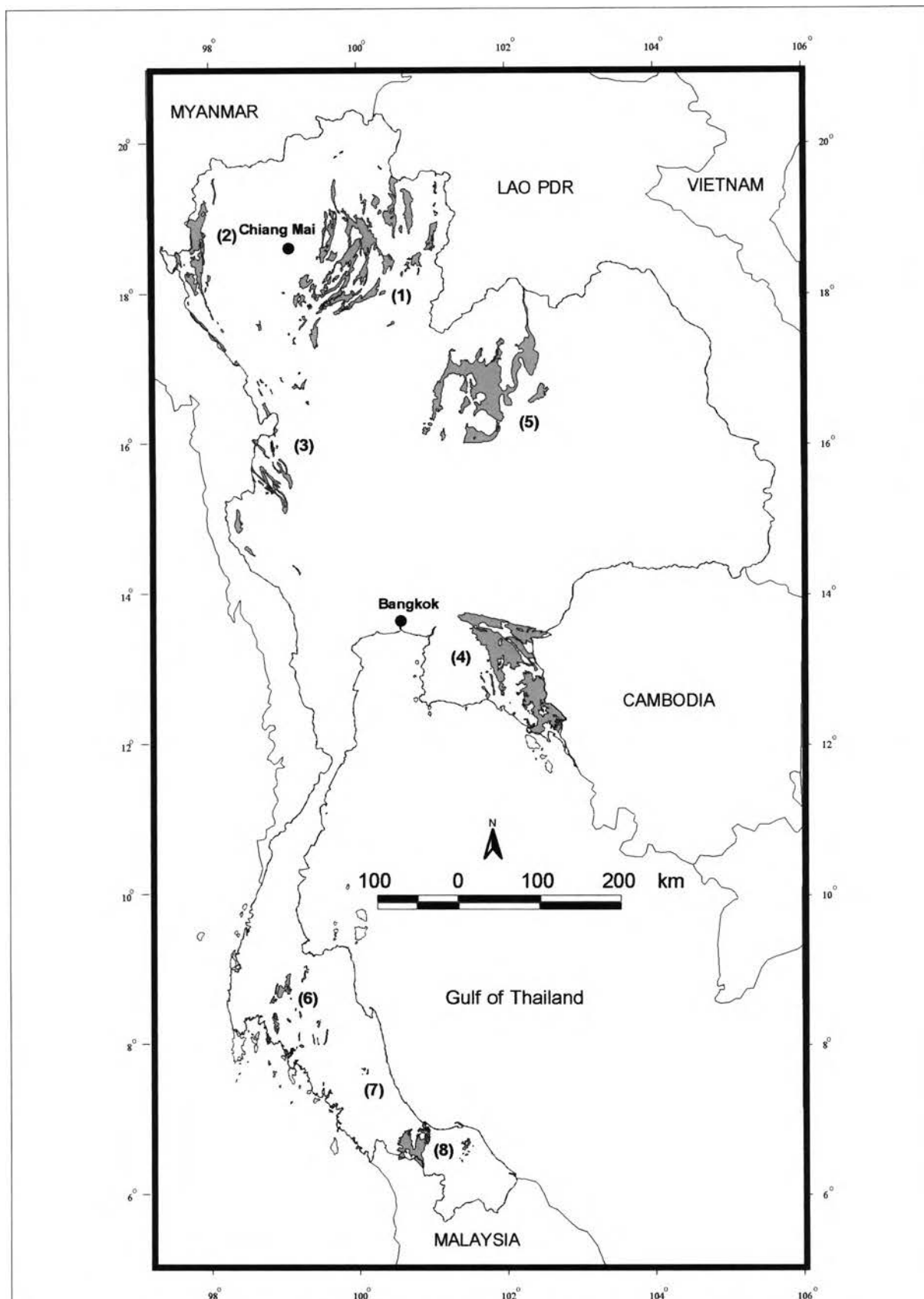


Figure 2.1 Map of Thailand showing distribution of Triassic sedimentary rocks (modified after Department of Mineral Resources, 1999). (1) Lampang-Phrae-Uttaradit-Nan area, (2) Mae Hong Son area, (3) Mae Sot-Thong Pha Phum area, (4) Chantaburi-Rayong-Sra Kaew area, (5) Loei-Phetchaburi-Khon Khaen area, (6) Trang-Krabi area, (7) Phattalung area, (8) Songkhla area

However, based on their studies, all the rock sequences were deposited on continental environments and they also applied their collective term "continental red beds of Mesozoic age".

The Khorat Group proposed by Ward and Bunnag (1964) was applied only rocks deposited in continental environments within the Khorat Plateau.

Ward and Bunnag (1964) also reported Triassic ammonoids in Mae Moh District, Lampang Province. These fossils and their associated rocks were studied in detail by Pitakpaiwan (1955), and later on these fossils were re-examined by Kummel (1960) and reconfirmed the Triassic age between Anisian and Carnian. Almost the same time, Kobayashi and Tokuyama (1959) reported Triassic fossils from northern and southern parts of Thailand. The Triassic fossil bivalve (*Halobia* sp.) were reported at Denchai station (km. 60), east of the location where Pitakpaiwan (1955) reported. In the south, the Triassic bivalves (e.g., *Daonella* sp.) were observed by Kobayashi and Tokuyama (1959) in Na Thawi district, Songkhla Province.

Buravas (1961) studied coral fossils in limestone lens in the Pha Kan area, Lampang Province. The fossil corals including *Thecosmilia* sp., *Margarosmilia* sp., *Conophyllia* sp. gave the age of Late Middle to Late Triassic.

In 1964, Department of Mineral Resources with the co-operation of German Geological Mission launched a geological mapping project at scale of 250,000 and northern Thailand was first selected for this project. Triassic rocks which are distributed in northern Thailand are stemmed from careful investigations on macrofossils by Piyasin (1972, 1975) and Bunopas (1976), and microfossils by Piyasin (1971), Baum et al. (1970), von Braun and Jordan (1976), Hagen and Kemper (1976), and Kemper et al. (1976).

Kiriwat and Suensilpongs (1964) reported Triassic marine sedimentary sequence at Ban Tha Si, Lampang. Pitakpaiwan et al. (1969) in his collective studies on fossils of northern and northeastern Thailand, also reported the name "Lampang Group" without detailed description for the marine Triassic rocks in several parts of the country in his geological map scale 1:1,000,000. This allowed Piyasin (1972) to use the term "Lampang Group" for marine Triassic rocks at Ban Tha Si. These Triassic rocks include

basal conglomerate, red sandstone, limestone, and gray flysch strata. By the same time Chonglakmani (1972) made the first detailed study in the Lampang Basin of northern Thailand. Ban Tha Si was selected for his study, with different routes from those of Piyasin (1972). Similar fossils were reported with more assemblages than those of the earlier works. The marine Triassic rock sequences, particularly in Lampang and Phrae Basins were later studied extensively by Chonglakmani (1983), Chaodumrong (1992, 1993), Charusiri et al. (1994), and Chaodumrong and Burrett (1997) (see more detail in later section)

Triassic sequence in southern Thailand commenced much than those of the north . Ridd and Wainwright (1969) first proposed the Phattalung Group for sequences of rocks exposed to the east of Phattalung Province. The rock strata include principally sandstone and conglomerate which occurred in Mesozoic. Grant-Mackie et al. (1980), with the corporation of geologists at Prince Songkhla University, made a detailed study on Triassic stratigraphy in the Saba Yoi and Na Thawi areas of Songkhla Province. Later on, Igo et al. (1988) discovered conodont and radiolaria in limestones at Khao Chiak, in Phattalung Province. These limestones with karstic topography was earlier mapped as Ratburi Limestone of Permian age. Sashida and Igo (1992) reconfirmed the Triassic occurrence for both conodont and radiolarian fossils with more detailed assemblage. By the same time, Fontaine and Tantiwanit (1992) reported Triassic bivalves (mostly *Daonella* sp.) at THE northwestern part of Khao Tao, Phang Nga Province. The first marine dinosaurs-Ichthyosaur was discovered by French and Thai geologists in dolomitic limestone near the road at Khuan Khanun District, about 14 km north of Phattalung city (Buffetaut and Suteenthorn, 1993; Fontaine et al., 1993). This marine dinosaur yields the age of Early Triassic (Buffetaut et al., 1994). Ampornmaha (1995) proposed the name "Chaiburi Formation" for sequences of limestones and dolomite containing abundant Triassic conodonts from small isolated hills and mountains nearby Chaiburi Town of Phattalung Province.

In eastern Thailand, Sivabawon et al. (1976) first introduced the Phong Namron Formation for sedimentary sequences containing interbedded graywacke and mudstone exposed mostly near the Thailand-Cambodia border of Chantaburi and Trad Provinces. Hada et al. (1990) reported radiolarian fossils in chert beds at Laem Ngob District, Chantaburi Province and assigned the age of Middle Triassic.

### **2.1.3 Distribution and Paleoenvironments**

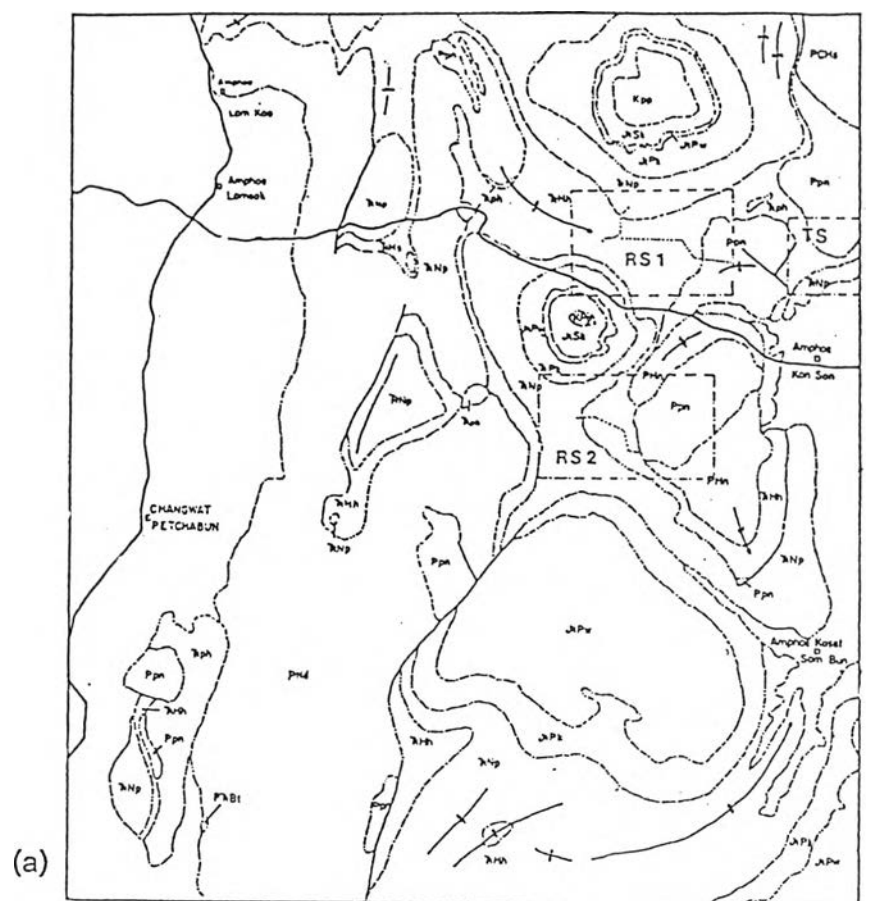
Based upon our compilation on geologic and paleontologic works of Triassic rocks, the map showing distribution on Triassic sediments in Thailand is herein proposed (Figure 2.1). The map is mainly modified from the geologic map of Thailand published by Department of Mineral Resources (1999). As shown in Figure 2.1, Triassic sediments are widely exposed in almost all regions of Thailand except in the main northeastern region. Eight major areas are recognized including (1) Lampang-Phrae-Uttaradit-Nan area, (2) Mae Hong Son area, (3) Mae Sot-Thong Pha Phum area, (4) Chantaburi-Rayong-Sra Kaew Area, (5) Loei-Phetchabun-Khoa Khaen area, (6) Trang-Krabi area, (7) Phattalung area, and (8) Songkhla area. These Triassic sediments are believed to have occurred in both marine and non-marine (or continental) environments (see Chonglakmani, 1999).

#### **2.1.3.1 Continental Deposits**

The Triassic sedimentary rocks which deposited in non-marine environments belong to the Khorat Group –i.e., Huai Hin Lat Formation and Nam Pong Formation

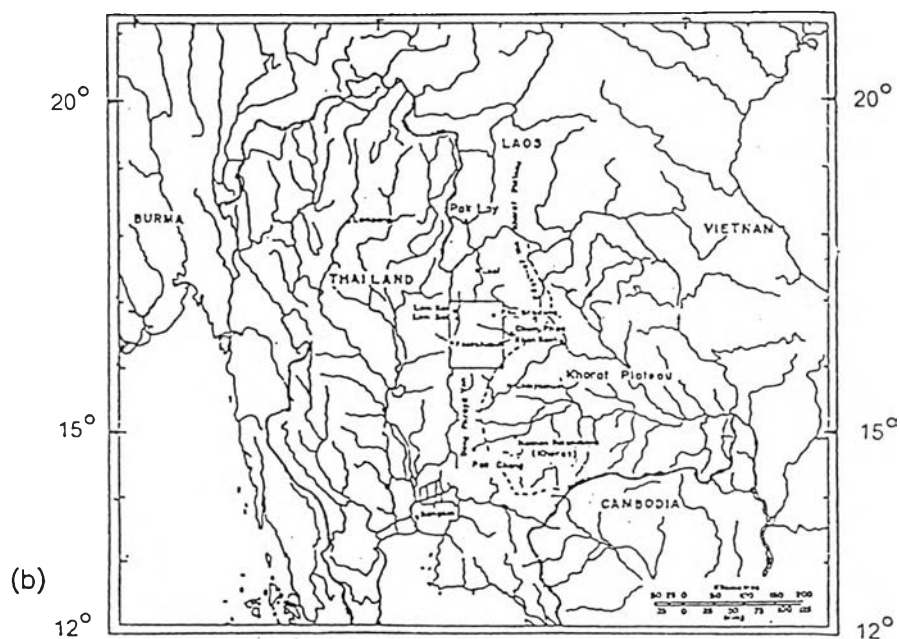
##### **2.1.3.1.1 Huai Hin Lat Formation**

Iwai et al. (1966) proposed the Huai Hin Lat Formation for a sequence of sedimentological strata which its type section exposed along the Huai Hin Lat stream course (Figure 2.2) about 18 km southeast of Ban Phra Nokkhao, Chum Phae District, Khon Khaen Province. The Huai Hin Lat Formation is assigned to be the oldest rock sequence of the Khorat Group with the range of thickness between 100 and 900 m. (average about 250 m). This formation lies unconformable over sediments of Permian to Triassic? Clastics of the Nam Duk Formation and Permian limestones of the Ratburi Group and conformably under the Nam Pong Formation (Chonglakmani & Sattayarak, 1978, (see Figures 2.2 and 2.3). The Huai Hin Lat Formation consists of three members, based on the systematic stratigraphic study of Chonglakmani and Sattayarak (1978). The oldest member is called the Sam Khaen member which mainly comprises gray basal conglomerate (about 50 m-thick) with interbedded lens or beds of limestone and sandstone (Figure 2.4). The middle member is Dat Fa member (about 500 m thick)



(a)

95°                      100°                      105°



(b)

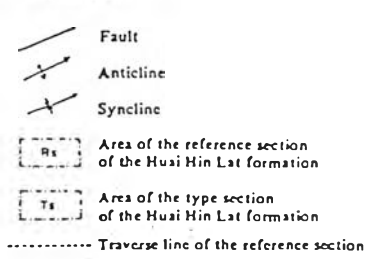
Figure 2.2 (a) Geological map of the Petchabun-Phu Kradung area.







(b) Index map of study area.

	MEMBER	FORMATION	GROUP	AGE
<b>Oa</b>	Alluvial deposit			QUATERNARY
<b>Ot</b>	Terrace gravel, Talus, Colluvial deposit			
UNCONFORMITY				
<b>KPp</b>	Sandstone, white, pale orange, pebbly, pebbles of quartz, chert and red siltstone, sandstone, white, cross-bedded, with some shale and conglomerate beds.	PHU PHAN		LOWER-MIDDLE CRETACEOUS
<b>JRsk</b>	Sandstone, reddish brown, micaceous siltstone, gray, brown, reddish brown, lime-noduled conglomerate shale, purplish brown, brick red.	SAO KHUA		MIDDLE-UPPER JURASSIC
<b>JRp</b>	Sandstone, white, pink, orthoquartzite, cross-bedded, massive, pebble layering in the upper bed with some reddish brown and gray shale.	PHRA WTHAN		LOWER-MIDDLE JURASSIC
<b>JRpK</b>	Shale, brown, reddish brown, purplish red, micaceous siltstone, sandstone, brown, gray, micaceous, cross-bedded with some lime-noduled conglomerate.	PHU KRADUNG	KIIBORAT	LOWER JURASSIC
<b>JRp</b>	Sandstone, reddish brown, brown, cross bedded, laminated conglomerate, pebbles of red siltstone, quartz, quartzite, chert with brown to reddish brown shale and siltstone.	NAM PHONG		RHAETIAN
<b>Dim</b>	Shale, sandstone, limestone, gray diorite, tuff and agglomerate.	I MO		TRIASSIC
<b>TRHh</b>	Basal conglomerate, sandstone, gray, reddish brown, shale, gray to black, reddish brown, calcareous, limestone, agillaceous.	HUAI HIN LAT		CARNIAN-NORIAN
<b>TRh</b>	Tuff, agglomerate, rhyolite andesite. With some sandstone and conglomerate beds.	PHO HAI		
UNCONFORMITY				
<b>Pnd</b>	Shale, gray to black Sandstone, yellowish brown, fine-grained, limestone, lense and bedded. Highly disturbed.	NAM DUK		LOWER-MIDDLE PERMIAN
<b>Pnn</b>	Shale, gray, sandstone, yellowish brown, limestone, lense and bedded.	HUA NA KHAM	RATBURI	
<b>Ppn</b>	Limestone, gray, massive, chert, black, noduled or thin bedded, with some shale.	PHA NOK KHAO		
<b>PCHh</b>	Sandstone, shale, gray, yellowish brown, chert, black, red, milky, pink, banded to massive, limestone, gray, thick bedded.	HUAI SOM		LOWER PERMIAN-CARBONIFEROUS
IGNEOUS ROCKS				
<b>TRBI</b>	Diorite, andesite, stock, dyke.	BO THAI INTRUSIVES		PERMO-TRIASSIC

**SYMBOLS**



 Fault  
 Anticline  
 Syncline  
 Area of the reference section of the Huai Hin Lat formation  
 Area of the type section of the Huai Hin Lat formation  
 Traverse line of the reference section

(c)

Figure 2.2 (cont.)

(c) Legend of box (a).

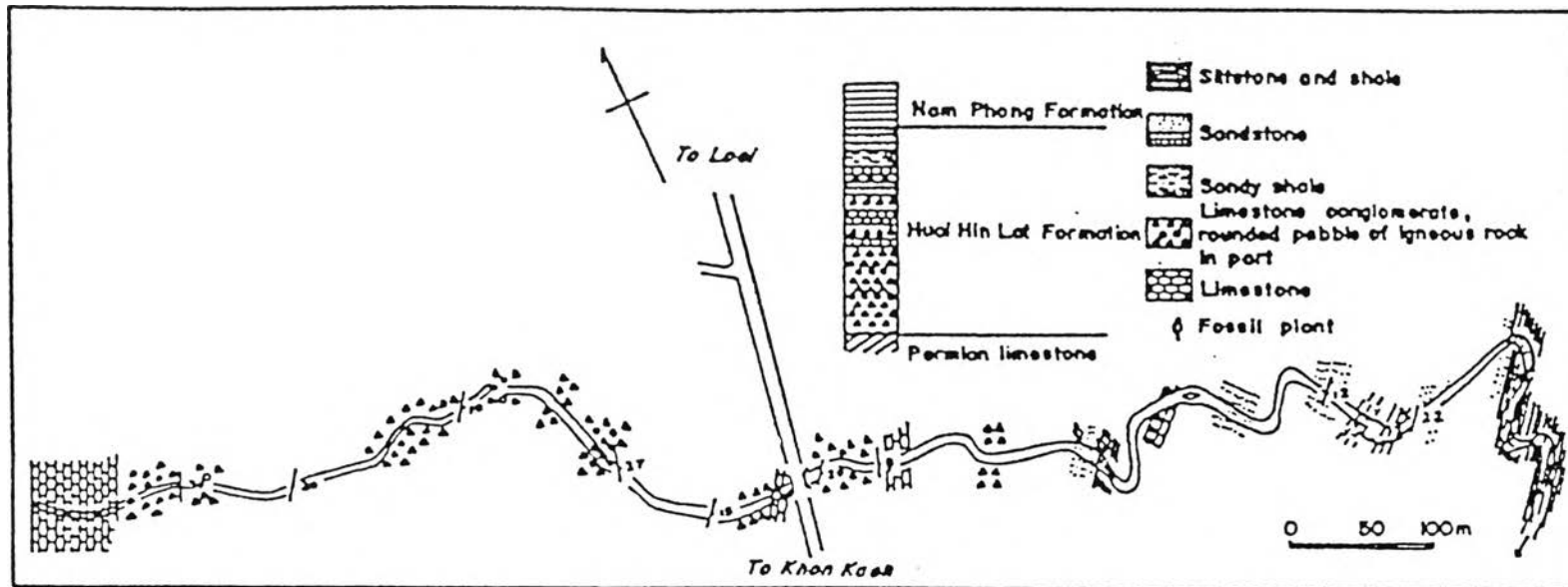


Figure 2.3 Map diagram showing lithostratigraphic type section of the Huai Hin Lat Formation (after Iwai et al., 1966).



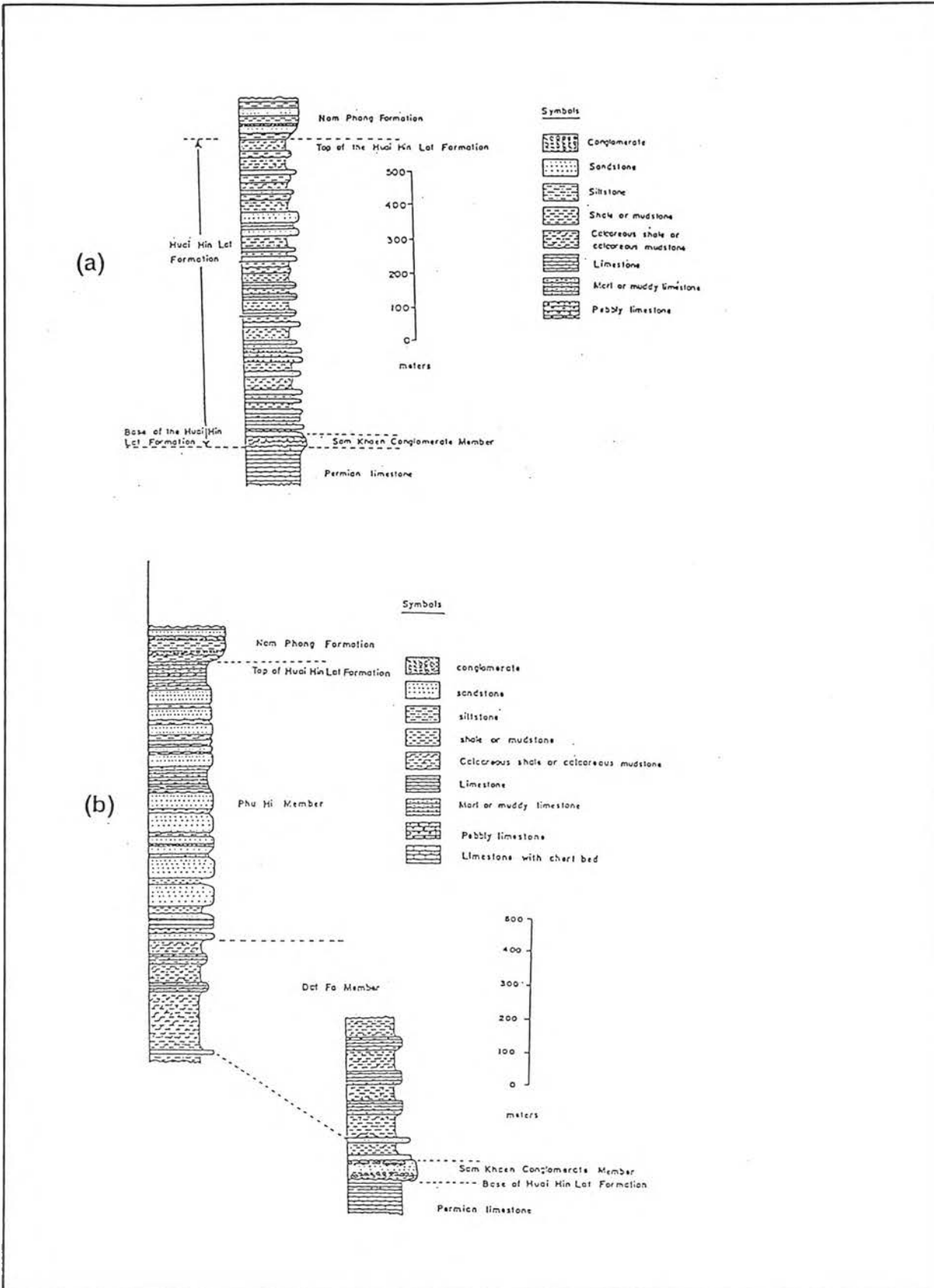


Figure 2.4 (a) Lithostratigraphic reference section of the Huai Hin Lat Formation, Nam Phrom Dam Section (Chonglakmani and Sattayarak, 1978), (b) Lithostratigraphic reference section of the Huai Hin Lat Formation, Ban Dat Fa section (Chonglakmani and Sattayarak, 1978).

which is marked at the top and bottom by thick beds of reddish brown sandstone and is largely composed of interbedded reddish brown to gray calcareous shale and mudstone with grayish black marl or muddy limestone. The youngest member is I Mo member (about 400 m-thick) consisting chiefly of gray sandstone and shale interbeds with intercalated grayish black to greenish gray marl in the middle part. Fossils (*Cladophlebis* sp., *Cclathropteris* cf. *Meniscoides* Brongniart, *Pterophyllum* sp., *Equisetites arenaceous* (Jaeger) Schenk, *E. naitoi* Kon'no, *Neocalamites* cf. *Hoerensis* (Schimper) Haile, *Todites goeppertianus* (muenster) Krasser, *Nilssonia thailandica* Kon'no and Asama, n. sp., *Anomozamites minor* (Brongn.) Nathorst, *Elatocladus* sp., *Ovalipollis lunzensis*, *Cycadopites carpentieri*, *Alisporites* sp., *Zebrasporitesfimbriatus*, *Cumerosporites* sp., *Concavisporites lunzensis*, and *Verrucosporites* sp.) of the Huai Hin Lat Formation indicate the age of Late Triassic (about Carnian to Norian and possibly Rhaetian, see (Chonglakmani and Sattayarak, 1978). Maneechai (1994), based upon his stratigraphic mapping in areas around Pak Chong to Sri Kae Districts, Nakhon Ratchasima Province, discovered Norian nonmarine to brackish fossils (*Euestheria mansuyi*) in marl beds.

#### 2.1.3.1.2 Nam Phong Formation

The Nam Phong Formation was proposed by Ward and Bunnag (1964) with a type section about 1,465 m at Ban Nam Phong, Phu Kradung District, Loei Province. However, the thickness of the formation can vary considerably from 100 m to 1,500 m. The formation consists principally of thick, resistant, reddish brown siltstone with mainly sandstone in the middle part and interbedded mudstone at top. Fossils (such as *Estaria* sp., see Chonglakmani and Sattayarak, 1978) indicate the age of Rhaetian. We consider that the clastic sediments of the Nam Phong Formation deposited at the beginning in the intermountain basin, then changed the environment to meandering stream with intense and violent currents and ended up with alluvial deposition in the relatively dry tropic environment.

#### 2.1.3.2 Marine Deposits

Most of marine sediments are extensively found in the west, northwestern, east, and southern Thailand (see Figure 2.1).

#### 2.1.3.2.1 Nam Pat Group in Uttaradit, northern Thailand

The Nam Pat Group was proposed by Bunopas (1981) as a sedimentary rock unit of Triassic age with a type section at the eastern side of Sirikit Dam in Uttaradit Province. The Group can be divided into 3 formations with lateral facies changes from each other. Based on subsequence stratigraphic correlation. Meesook et al. (2000) newly proposed two formations for the Nam Pat Group namely the Huai Lat Formation (Lower) and the Bo Khong (upper) with exclusion of a limestone rock unit (mapped as the lower formation or Tr<sub>1</sub> by Bunopas, 1981).

The Nam Pat Group has the overall thickness of 1,400 m and essentially consists in the lower part of greenish gray conglomerate with abundant clasts of volcanics and some of sandstone, limestone, granite, chert, and quartz, and in the upper part of thick sequence interbedded blackish to greenish gray sandstone with mudstone showing well-defined graded bedding and Bouma sequence. Conodont fossils (*Fachychladina* sp.) indicate the age of Early Triassic mainly thin- to thick-bedded, blackish gray limestone with sandstone and mudstone interbedded at the bottom part. Fossils-*Unionites* sp. and *Costotaria goldfussimansuyi* found in these limestone lens strata indicate the age of Middle Triassic. We interpret that the Nam Pat Group was deposited in the deep marine environments during Early to Middle Triassic.

#### 2.1.3.2.2 Lampang Group in Lampang-Phrae area, northern Thailand

Piyasin (1972) introduced the Lampang Group for Triassic marine sedimentary rocks found in areas around Lampang Province with the thickness up to 5,000 m (Meesook, 2000) and consisting of 5 formations at Ban Tha Si, Amphoe Mae Moh. Numerous studies have been done afterward in terms of lithostratigraphy (Liengsakul, 1979), biostratigraphy (Chonglakmani, 1981), paleoenvironment (Chaodumrong and Burret, 1992) and geologic/tectonic setting (Charusiri et al., 1994).

Based upon more detailed stratigraphic mapping and correlation, the Lampang Group consists of 7 formations from older to younger as Phra That Formation, Pha Kan Formation, Hong Hoi Formation, Doi Long Formation, Pha Daeng Formation, Kang Pla Formation, and Wang Chin Formation. The last two formations were additionally proposed by Chaodumrong and Rao (1992). The Lampang Group mostly

expands within 2 major basins namely Lampang and Phrae Basins (Figure 2.5) covering a large region in Lampang, Phrayao, Phrae, Nan and Uttaradit Provinces. Chaodumrong and Burrett (1997) found the Lampang basin occurred earlier than Phrae Basin. The Lampang Basin consists of 5 rock formations (from Phra That to Pha Daeng Formations). Several bivalves including *Daonella*, *Posidonia*, *Paratrachyceres*, *Costotaria*, and *Claraia* indicate Lower to Middle Triassic (Kraiskabian to middle Carnian). The Phrae Basin composites 3 rock formations (from Pha Daeng to Wang Chin Formations). Fossils as *Halobia*, *Posidonia* and *Palaeocardita* give the age of Middle to Late Triassic (or middle Carnian to Norian).

Most rocks of the Lampang Group lie unconformably over volcanic rocks of Permo-Triassic age and limestones of Permian age. The sediments of the Lampang Group lies under the continental red beds of Jurassic to Cretaceous age with both unconformable and conformable contacts.

According to our recent investigation and Meesook et al. (2000), the Lampang Group with the conformable contact with the overlying group occurred in the middle part of the basin.

A) Phra That Formation took its name from Phra That Muang Kham Pagoda about 11 km southwest of Lampang city. The type section is along the road from Ngae to Song District, Lampang Province. Both volcanogenic and non-volcanic rocks ranging in thickness from 90 to 650 m are reported by Chaodumrong and Burrett (1992). Conglomerates are observed in the lower part and then interbedded with gray, grayish green and light to reddish brown sandstone and shale, with abundant fossils of *Claraia intermedia* and ammonite-*Ophioevas* (Chaodumrong and Burrett, 1993) indicating that the lower part of the formation is characterized by red-colored coarse-grained clastics and the upper part by green- to gray-colored, fine-grained clastics.

B) Pha Kan Formation was named by Piyasin (1972) with the type section at Doi Chang Mountain east of Mae Moh mine, Mae Moh District, Lampang. Its type section leads Chonglakmani (1981) to propose the term Doi Chang for the formation name. The Formation with the thickness ranging from 250 to 600 m consists mainly of massive to thick bedded gray mudstones containing abundant bivalves and brachiopods with few algae and crinoids. The upper part of the sequence is

T R I A S S I C	B A S I N G R O U P	Lampang Basin			Phrae Basin	
		Sop Prap- Ngao-	Chae Hom- Pha Yao-	Lampang Chiang Ra	Phayao-Ngao Long-Wang Chin	
Upper	L A M P A N G				Wang Chin Fm	Thu Tap Huai Chan Mae Lu SS Phu Tap
					Kang Pa Fm	
					Pha Daeng Fm	
Middle	A N G	Doi Long Fm				
		Hong Hoi Fm	Mae Dum SS	Huai Muang Tha Si		
Lower	G	Pha Kan Fm	Muang Khan Chang Grab	Cave Temple		
		Wiang Sawan				
		Phra That Fm				

(a)

Figure 2.5 (a) Stratigraphic columnar sections of the Lampang Group in Lampang and Phrae Basins, (b) Stratigraphic correlation of rock sequences in Lampang and Phrae Basins, (c) Part of map of Thailand showing location of the basins studied by modified from Chaodumrong and Burrett (1992).

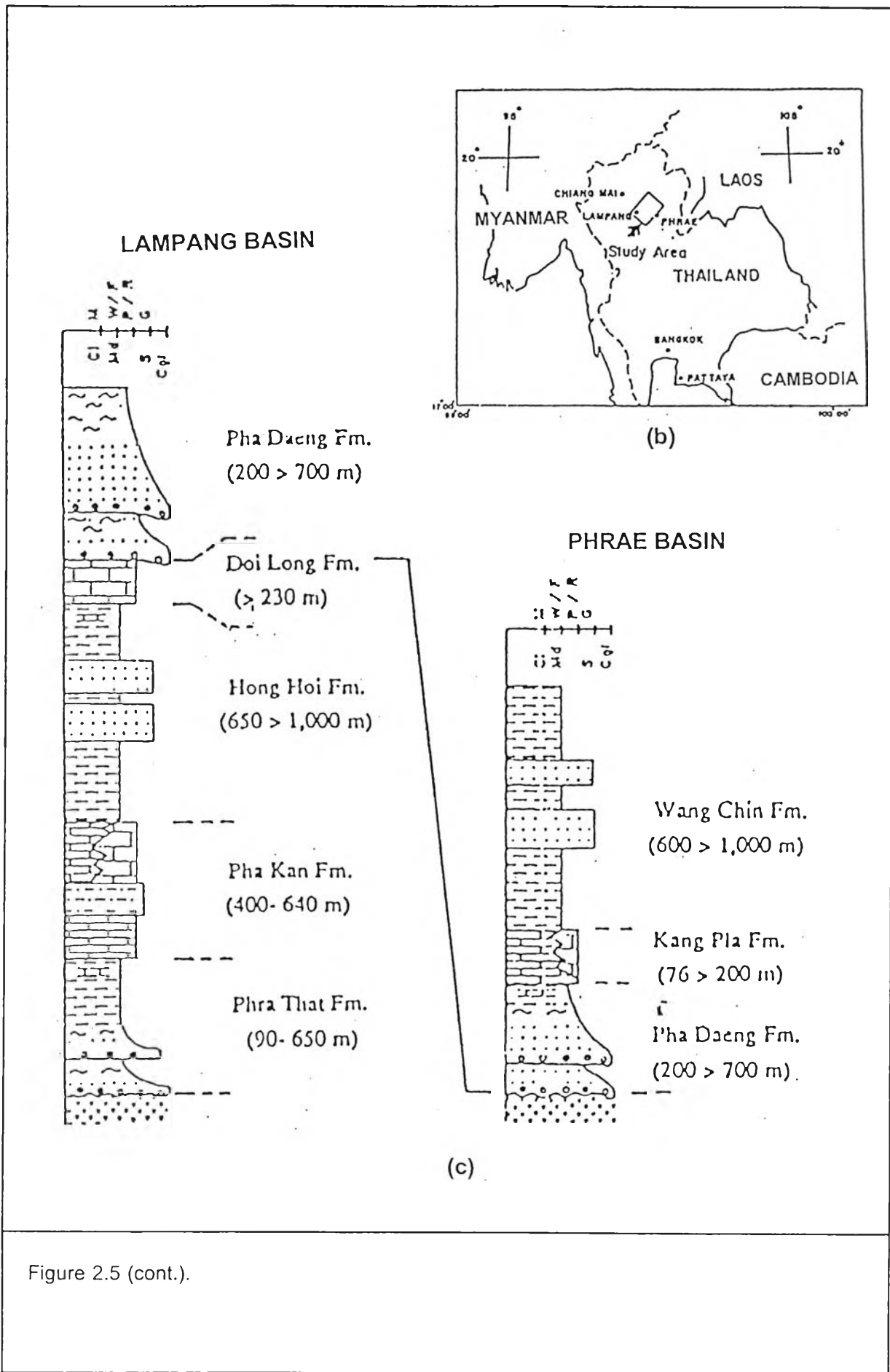


Figure 2.5 (cont.).

characterized by gray to green sandstone and shale. Middle Triassic is proposed for the age of the Pha Kan Formation (Charusiri et al., 1994).

C) Hong Hoi Formation which the name is taken from Hong Hoi stream (at Ban Dong, Lampang) near a road from Ngao to Lampang. The formation with the varying thickness of 1,200 to 1,900 m consists largely of gray alternating beds of sandstone and shale with some intercalation of conglomerate and limestone. Important fossils including *Halobia* and *Daonella* with some brachiopods and ammonites indicate the age of the Hong Hoi Formation as Middle Triassic.

D) Doi Long Formation takes its name from Huai Doi Long stream course, east of Ban Tha Si, Mae Moh District, Lampang. The formation has the thickness ranging from 230 m to 400 m and consists mainly of light gray to dark gray micritic limestone with abundant fossils and bioturbation. The *Ostrea*-like bivalves and brachiopods-*Cuneirhynchia* sp. suggest Middle to Late Triassic for the age of the Doi Long Formation. Charusiri et al. (1994) believed that the formation occurred locally, formed as lens-shaped strata, and changed laterally with the underlying the Hong Hoi Formation. In the upper part, the Doi Long Formation grades vertically into gray to reddish brown limestone conglomerate.

E) Pha Daeng Formation with the thickness of 500 to 600 m comprises well-beds of largely micaceous sandstone, siltstone, and shale with thin coquina limestone. In the lower part, conglomerate beds with graded and cross-bedded sandstone are dominant, with abundant clasts of limestone and a few of rhyolite, quartzite and slate. Chonglakmani (1972) reported fossils of *Hettangia* in siltstone sorting upon basal conglomerates. Several workers including Piyasin (1972) and Charusiri et al. (1994) considered that the Pha Daeng Formation took place in the non-marine environment, but a few (Chaodumrong, 1993. Chaodumrong and Burrett, 1997) believed that the formation was deposited in the marine environment.

F) Kang Pla Formation is composed largely of gray, bedded limestones with thickness of 76 to 200 m. The formation is interpreted to have been deposited in the shallow environment (Chaodumrong and Rao, 1992).

G) Wang Chin Formation (originally referred to Mae Thang Formation by Piyasin, (1972) comprises chiefly shale with graywacky sandstone interbedded in the middle part and conglomerate with mainly volcanic clasts in the lower part. The formation containing *Daonella* and *Halobia* bivalves (at Huai Mae Tik) varies in thickness from 600 to 1,000 m. The Wang Chin Formation is believed to have occurred in the deeper and outer shelf environment (Chaodumrong and Rao, 1992)

#### 2.1.3.2.3 Mae Sariang Group

This sedimentary rock unit is exposed restrictedly in a narrow and long basin between Mae Sariang District (in the south) and Mae Hong Son city (in the north). Baum et al. (1970) first studied rocks of the Mae Sariang Group and reported that the unit consists of sandstone, shale, and limestone. Bunopas (1981) first proposed the name Mae Sariang Group (Figure 2.6) and stated that the type section of the Mae Sariang Group is at the western part of the road between km 5 to km 10 from Mae Hong Son city to Mae Sariang District. In his brief description, the Mae Sariang Group consists of 50 m-thick conglomerate unit in the lower part, 700 m-thick, interbedded, gray shale/siltstone and sandstone, and 100 m-thick sandy shale.

Tofke et al. (1993) made a detailed study on 3 sequences of Triassic sedimentary rocks along the road from Mae Sariang to Mae La Noi districts. They reported that these Triassic rocks consist mainly of red, green, gray ribbon chert beds in the lower sequence, with radiolarian fossils and intercalation of claystone and siltstone. Each chert bed is about 10 cm-thick. The middle sequence is composed largely of pelagic limestone ranging in color from reddish to greenish and light to dark gray. Individual beds do not exceed 10 cm, and the overall thickness is about 20 m. Radiolarian and shell fragments are found only in the light gray limestone bed along the road at km 119.625, Highway 108. The upper sequence is regarded as turbidite sequence mainly containing graded to crossed-bedded siliciclastic strata of sandstone intercalated with shale. The Individual range in thickness from 5 to 20 cm and sometimes attain up to 100 cm. These three sequences have the overall thickness of more than 100 m. Well-preserved bivalves found in interbedded shale indicate the age of Middle to Late Triassic (Ladinian to Carnian).



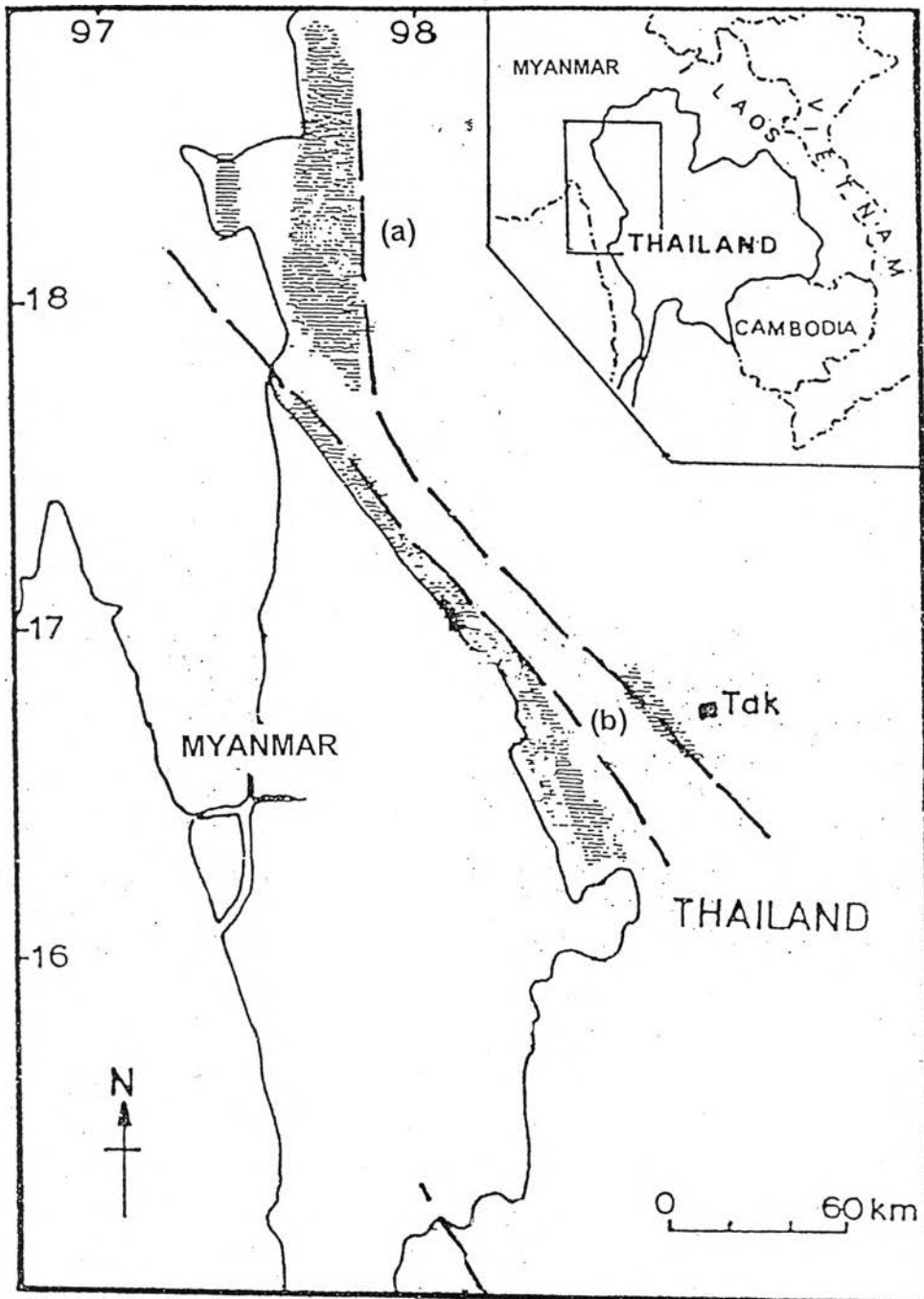


Figure 2.6 Map of western Thailand showing distribution of Triassic sediments of the Mae Sariang Group; (a) (Bunopas, 1976) and the Mae Moei Group; (b) (von Braun and Jordan, 1976).

Very recently Meesook et al. (2000) summarized that marine sedimentary rocks of Triassic age in Mae Hong Son province unconformably overlies Paleozoic sequences and underlies Jurassic-marine sequence. The overall thickness of the Mae Sariang Group attains up to 220 m, and the group consists chiefly of ribbon with interbedded claystone and thin limestone in the lower part. In the upper parts, the group is characterized by Bouma sequence of conglomerate, sandstone and shale beds with graded beds and fining upward sequence. Clasts in conglomerate beds include chert, metamorphic rocks, and granites. Important fossils, such as *Halobia comata*, *Posidonia* sp., *Halobia styriaca* Mojs, *Daonella* cf. and *Sumatrensis* Volz, indicating the age of Middle Triassic.

#### 2.1.3.2.4 Mae Moei Group in northwestern Thailand

This sedimentary rock unit proposed by von Braun and Jordan (1976) for Mesozoic sedimentary sequence is exposed in Mae Moei and Mae Sot areas of western Thailand (Figures 2.6 and 2.7). The Mae Moei Group consists of two major units—the Lower and the Upper Units. Two sections were stratigraphically studied in detail by von Braun and Jordan (op. cit.), —one along Kamawkale gorge of the Mae Moei River (Figure 2.8) and the other along Huai Hin Fon stream at the Tak-Mae Sot highway (Figure 2.8).

For the Huai Hin Fon section, the oldest rock sequences studied overlie unconformably the Permian sediments at km 67.5 road from Tak to Mae Sot. These sequences are called the Pang Manora Sandstone (390 m-thick) consisting mainly of yellow to red sandstone and shale in the upper part, gray to red sandstone in the middle, and poorly sorted limestone conglomerate in the lower. The younger unit is the Mae Pa Luang Shale (470 m-thick) consisting of red to gray shale with *Myoshoria* sp. and *Gonodon* aff. *mellingii* fossils and thinly bedded sandstone and limestone intercalation. The almost top sequence is the Huai Hin Fon Limestone (680 m-thick) consisting of clayey to silty limestone, and the topmost sequence is the Huai Hin Fon Shale (770 m-thick) composed mainly of greenish gray siltstone, shale, and sandstone with *Posidonia* in the upper part and dark gray shale with ammonoids in the lower part.

For the Mae Moei section, three sections were recognized. The lower sequence largely of 900 m-thick greenish gray shale with interbedded sandstone in the lower part. This sequence is almost similar to those of the Pang Manola Sandstone and

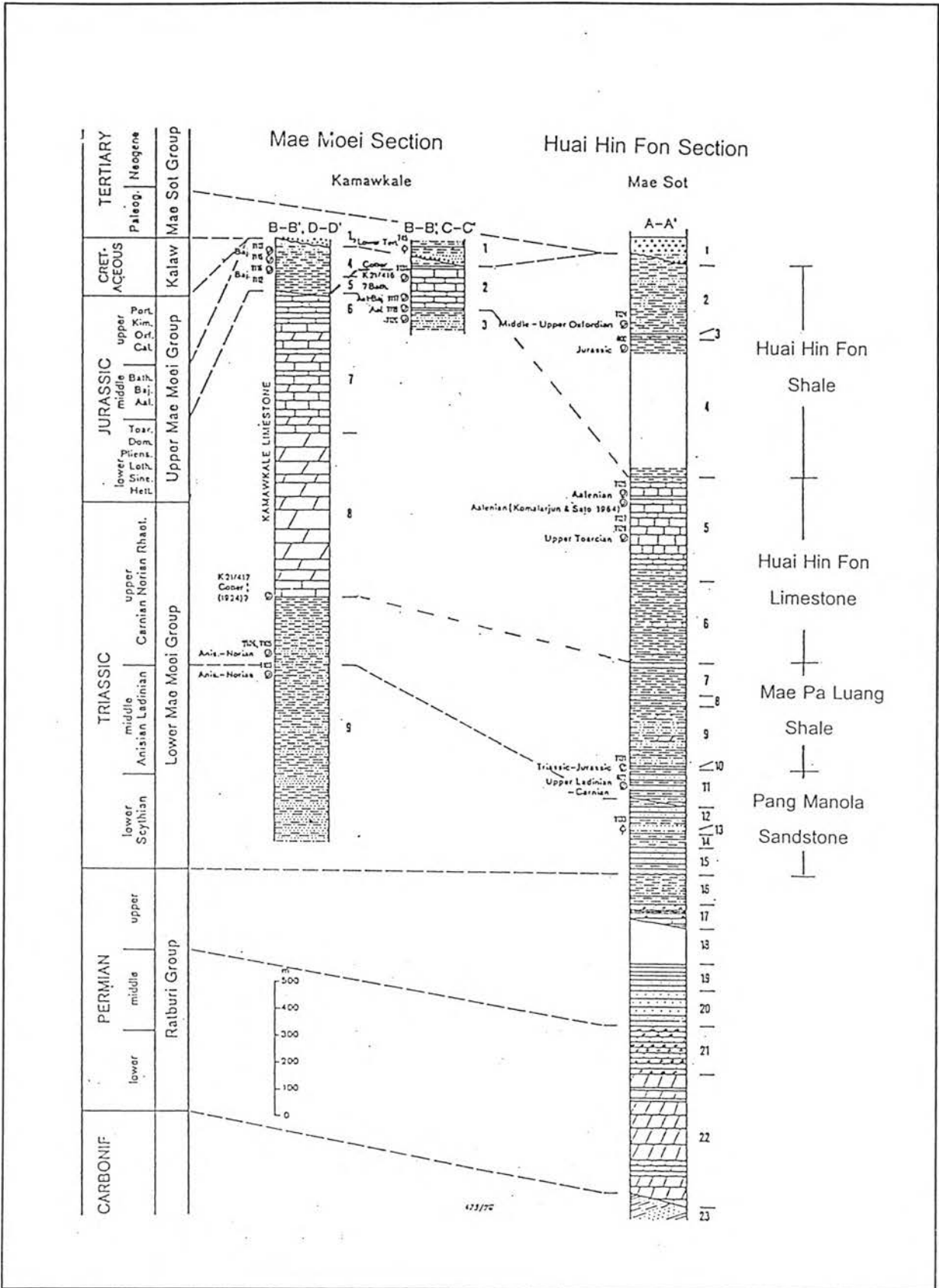


Figure 2.7 Composite stratigraphic columns, Kamawkale and Mae Sot areas (von Braun and Jordan, 1976).

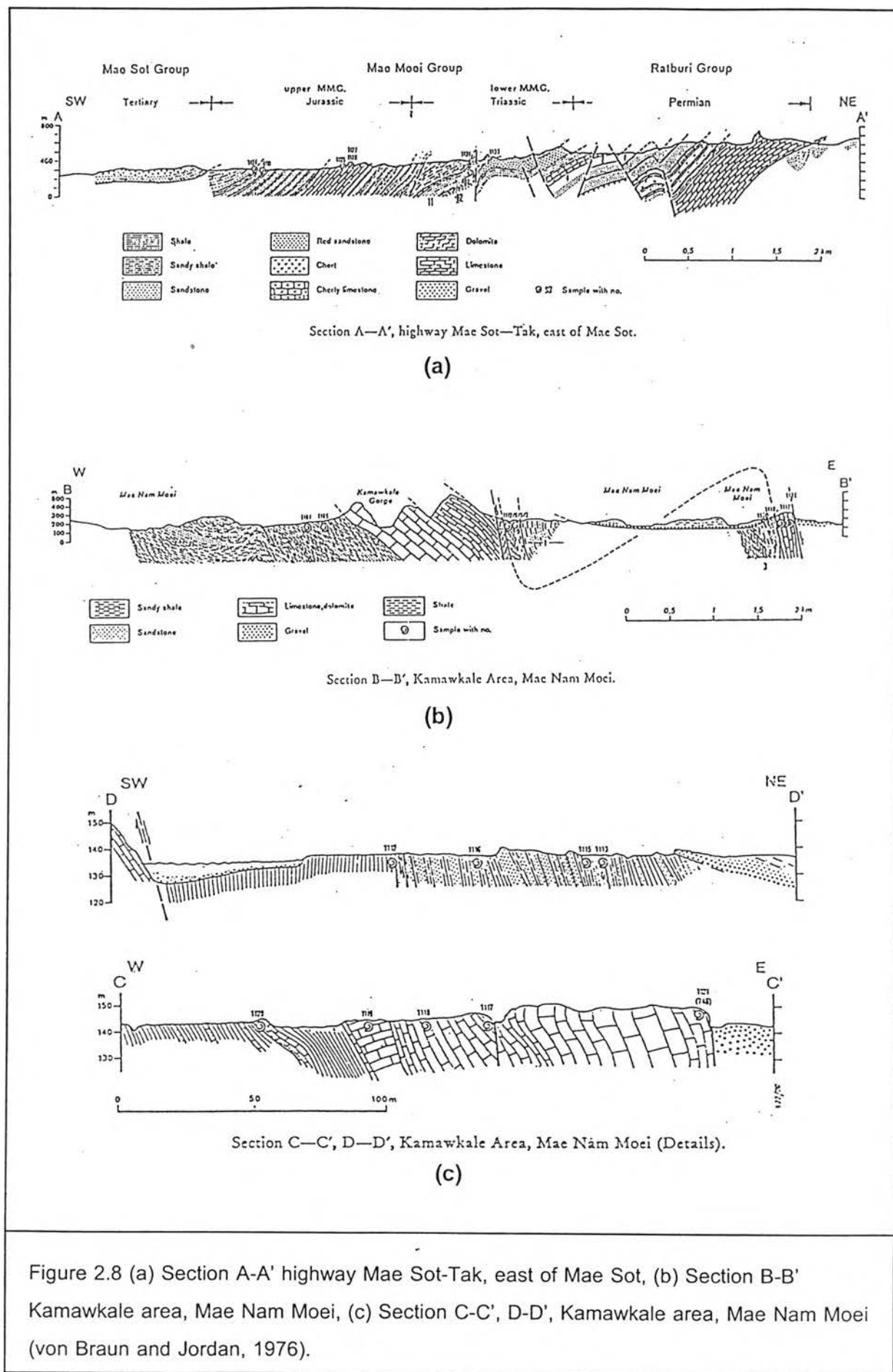


Figure 2.8 (a) Section A-A' highway Mae Sot-Tak, east of Mae Sot, (b) Section B-B' Kamawkale area, Mae Nam Moei, (c) Section C-C', D-D', Kamawkale area, Mae Nam Moei (von Braun and Jordan, 1976).

the Mae Pa Luang Shale of the Huai Hin Fon section. *Halobia* and *Posidonia* bivalves and ammonidia fossils in shale suggest the age of Late Triassic. The middle sequence is characterized by the Kamawkale Limestone with the age subsequently proved as Jurassic similar to the of the Huai Hin Fon Limestone. The upper sequence is dominated in the lower part by 235 m-thick, red conglomerate with poorly sorted of chert, volcanic, limestone, sandstone and quartz rock fragments and intercalated with sandstone and limestone beds. In the upper part (140 m-thick), the sequence becomes interbedded gray mudstone and sandstone with abundant fossils of *Daonella samatrenis* Volz, suggesting the age of Middle Triassic.

#### 2.1.3.2.5 Tak Group in the Tak area, northern Thailand

This sedimentary stratigraphic unit was proposed by Bunopas (1976) for a Triassic sequence of 400 m-thick sedimentary strata exposed as narrow and long outcrops in the western part of the east-dipping Lansang thrust fault, about 12 km west of Tak city. The Tak Group comprises mainly red beds of conglomerates interbedded with sandstone and gray beds of sandstone, limestone, and shale. Fossils-*Daonella sumatriensis*-suppggest the age of Ladinian (Middle Triassic).

#### 2.1.3.2.6 Si Sawat Limestone in Kanchanaburi, western Thailand

Kemper et al. (1976) proposed the Sri Sawat Limestone for a stratigraphic unit consisting largely of Triassic to Jurassic limestone (Figure 2.9) exposed in areas of Si Sawat District, northwest of Kanchanaburi Province. The type-section of the Sri Sawat Limestone is at Huai Chongkrong stream course parallel with the road from Si Sawat to Noen Sawan, about 6 km west of Si Sawat town.

Meesook et al. (2000) stated that these Triassic sedimentary rock exposed in Si Sawat (Figure 2.10) and Thong Phaphum Districts of Kanchanaburi Province have the overall thickness attaining up to 200 m. The rock sequences include light to dark gray, thick-bedded limestone strata with red siltstone, mudstone and sandstone beds at the top part. (Table 2.1).

Abundant fossils of bivalves-*Posidonia* sp. and *Daonella* sp. in shale/mudstone and conodonts-*Neogondella mombergensis*, *Neospathodus aegaeus*

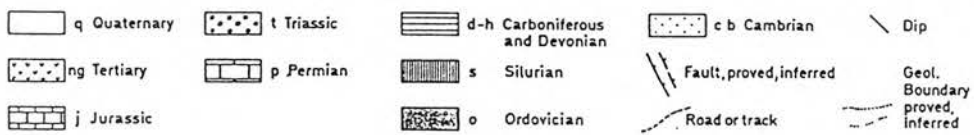
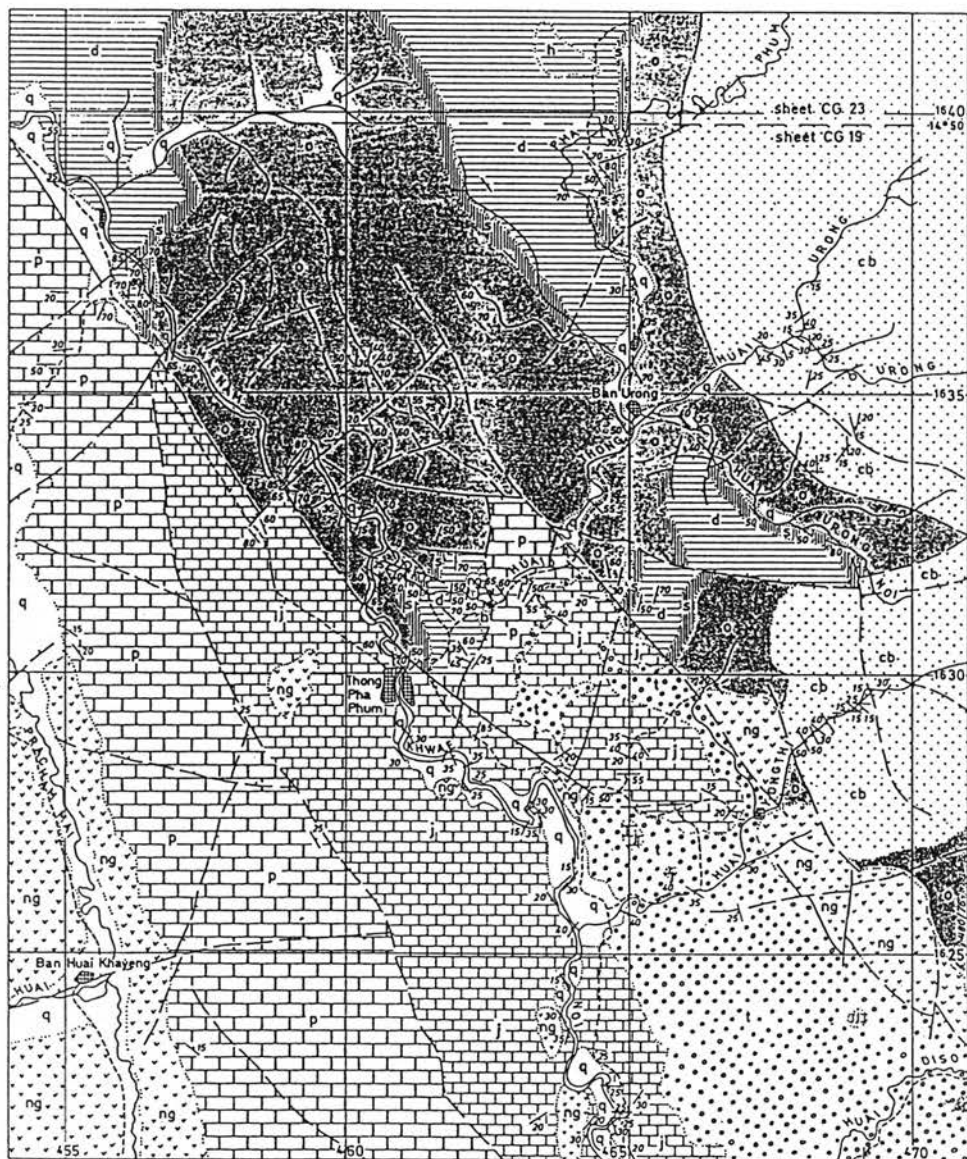


Figure 2.9 Geological map of Thong Pha Phum area (Hagen and Kemper, 1976).

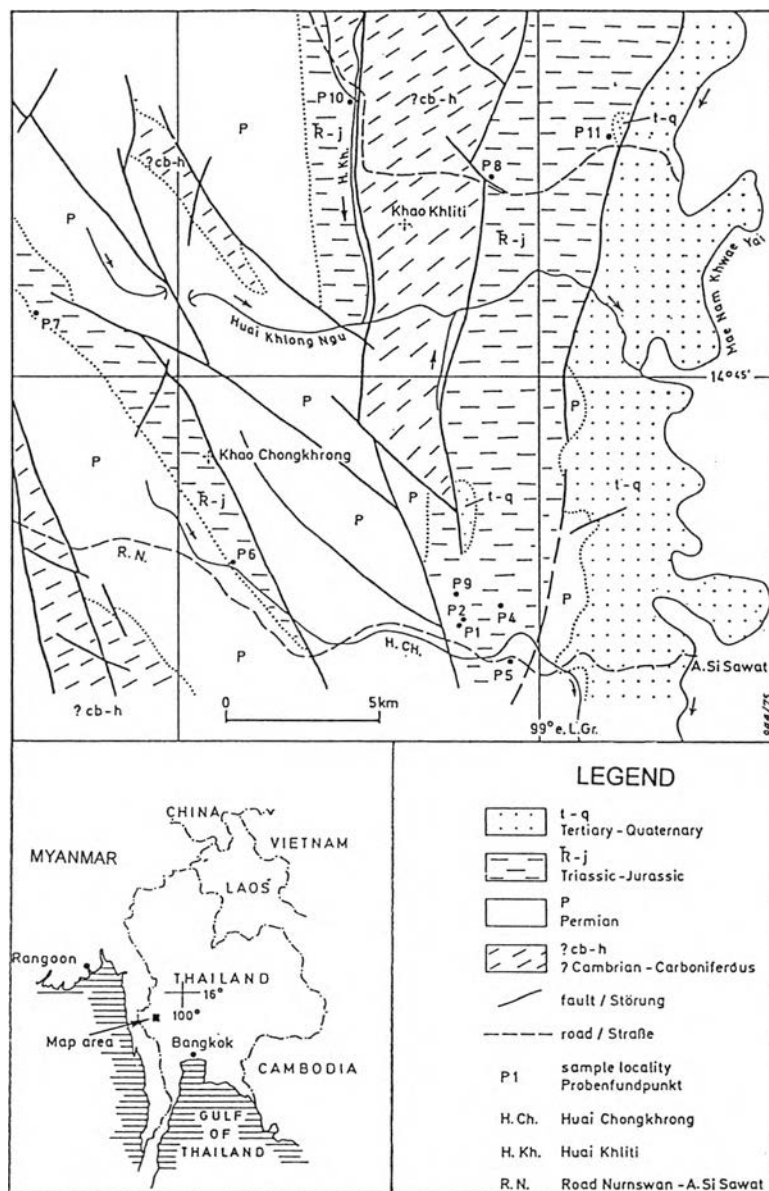


Figure 2.10 Generalized geological map of the area northwest and west of Si Sawat (Kemper, Maronde, and Stoppel, 1976).

Table 2.1 Stratigraphic column of the area of investigation (not to scale), (Kemper, Maronde, and Stoppel, 1976).

		Thong Pha Phum Area	Si Sawat Area		Fossils	
CRETACEOUS			no proof			
JURASSIC	Malm	U	no proof	no proof		
		M		?	light brown grey and light grey limestone; red conglomerate	foraminifera ( <i>Kurnubia</i> ), algae, gastropods, brachiopods
		L	? ?	?		
	Dogger	U		?		
		M			light brown grey limestone	foraminifera ( <i>Lucasella</i> , <i>Haurania</i> etc.) algae
	Lias	L				
U		~ 300 m	?			
M				middle to dark grey limestone	foraminifera ( <i>Orbitopsella</i> )	
TRIASSIC	Rhaetian	L				
		M			partly red sandstone, shale, marl and limestone	no fossils
		U			light to dark grey limestone	conodonts foraminifera ( <i>Involutina</i> ), calc. algae ( <i>Boucina</i> ), brachiopods, corals
	Norian					
	Carnian	± 200 m				
	Ladinian					
Anisian				light to dark grey limestone	conodonts	
	Scythian					
PERMIAN				grey limestone	partly rich in fossils	



(Bender), *Gondolella cf. constricta* (Mosher and Clark) in limestone, indicate late Early Triassic (Anisian) age. However, younger conodonts such as *Epigondolella abneptis* (Kuckriede) indicate early Late Triassic (Norian) age.

#### 2.1.3.2.7 Marine Triassic rocks of THE Kanchanaburi area

In the southern part of western Thailand, particularly west of Kanchanaburi city, Triassic strata were reported to be exposed along the northwest-trending Three Pagoda Fault (Bunopas and Vella, 1992). Triassic strata are mainly limestone with interbeds of sandstone, shale, and marl. The overall thickness of this rock unit is about 200 to 300 m. *Halobia* and *Daonella* bivalve fossils and microfossils indicate the age of Middle to Late Triassic.

#### 2.1.3.2.8 Marine Triassic rocks of southern Thailand

Triassic sedimentary sequences in southern Thailand are widely exposed in 2 main areas of the Songkhla and the Phattalung Provinces. Based upon the detailed investigation in Songkhla province by Grant-Mackie et al. (1980), Triassic rock sequence can be grouped into 4 units based upon stratigraphic correlation. The oldest unit is the Suan Cham Formation with the thickness of 1,700 m consisting of siltstone and graded-bed sandstone, probably deposited in shelf environments. The overlying unit is the Chedi Formation (or Mi Kiat Formation). Conglomerate (500 m-thick) comprises a thick sequence of quartz conglomerate with intercalation lens-shaped medium-grained sandstone, suggesting being deposited in deeper shelf environment. The younger unit is the Klong Kon Formation with the overall thickness of 600 m. This formation consists of thickly bedded, gray micritic limestone, partly dolomitized. Conodonts in this limestone indicate the age of Anician (late Early Triassic) similar to that of the Pha Kan Formation (Lampang Group). The occurrence of foraminifera fossils in limestone strata suggest the deposition was in Middle to Late Triassic age. The youngest unit is the Sani (or Na Tha Wi) Formation consisting largely of siltstone, fine-grained quartzitic sandstone, black chert, and fine-grained conglomerate with the thickness of 3,000 m to 4,300 m. in Na Thawi District (Songkhla). The occurrences of *Daonella sumatrenis* Volz bivalve at Klong Kam stream along the Highway no. 42 and *Daonella multilineata* (Jones) in the siltstone bed of the lower Na Thawi Formation, suggest the age of Late Triassic for the Sani

Formation. This formation can be correlated with the Semanggol Formation in northwestern mainland Malaysia.

The more recent study by Ampornmaha (1995) in Phattalong Province indicates that most of the rock sequence are limestone strata with the total thickness of 400-500 m (see Figure 2.11). Paleontological datings on conodonts extracted from limestones indicate the age ranging from Early to Late Triassic. Ampornmaha (1995) also introduced the new formation as the Chaiburi Formation for the Triassic limestones around the Phattalong area (Figure 2.11). The Formation has the thickness of about 500-m and consists of 3 members and 5 microfacies (Figure 2.12). The Phukhaothong Dolomite Member is the oldest member consisting mainly of massive to thick-bedded dolomite with *Neospathodus kummeli* and *Neospathodus waageni* (Sweet) middle Early Triassic conodonts and thin-bedded of bioclastic mudstone. The Chiak Limestone Member is the middle member comprising variably thick-bedded of limestones with chert lamination, lens and nodules and *Neospathodus timorensis* (Nogami), *Neospathodus kockeli* (Tatge), and *Neohindeodella bulgarica* (Budurov and Stefanou) Middle Triassic conodonts. The youngest member is the Phanomwang Limestone member consisting of reef limestone and coral buildups with abundant Late Triassic fossils such as calcisponges, scleractinian corals, mollusks, echinoids, crinoids, foraminifers, and others. All the recognized facies and members studied indicate deeper to shallower marine environments through times. Ampornmaha (1995) suggested that the collision of Shan-Thai plate and Indochina may have occurred nearly deposition of these Triassic carbonates.

Triassic rocks were reported to occur in two other areas in southern Thailand. Thick-bedded limestone containing Late Triassic *Daonella* and *Posidonia* bivalves were observed to overlie black carbonate beds at Khao Tao, Phang Nga Province (Fontaine and Tantiwanit, 1992). In Nakhon Si Thammarat Province, Raksaskulwong et al. (1989) reported the Triassic clastics of the Sai Bon Formation clearly observed at small hills near Ban Sai Bon and Khao Khaeo mountains, Khao Khom and Khao Lakchang mountains to the east of Klong Thom District. The Sai Bon clastics lie unconformable on the Ratburi Limestone of Permian age at Ban Long Khao and Khao Khico, Phanom District of Surat Thani Province. The up to 110 m-thick Triassic strata comprise mainly brownish red siltstone with fine-grained sandstone and mudstone in the upper sequence and dolomitic limestone in the lower sequence.

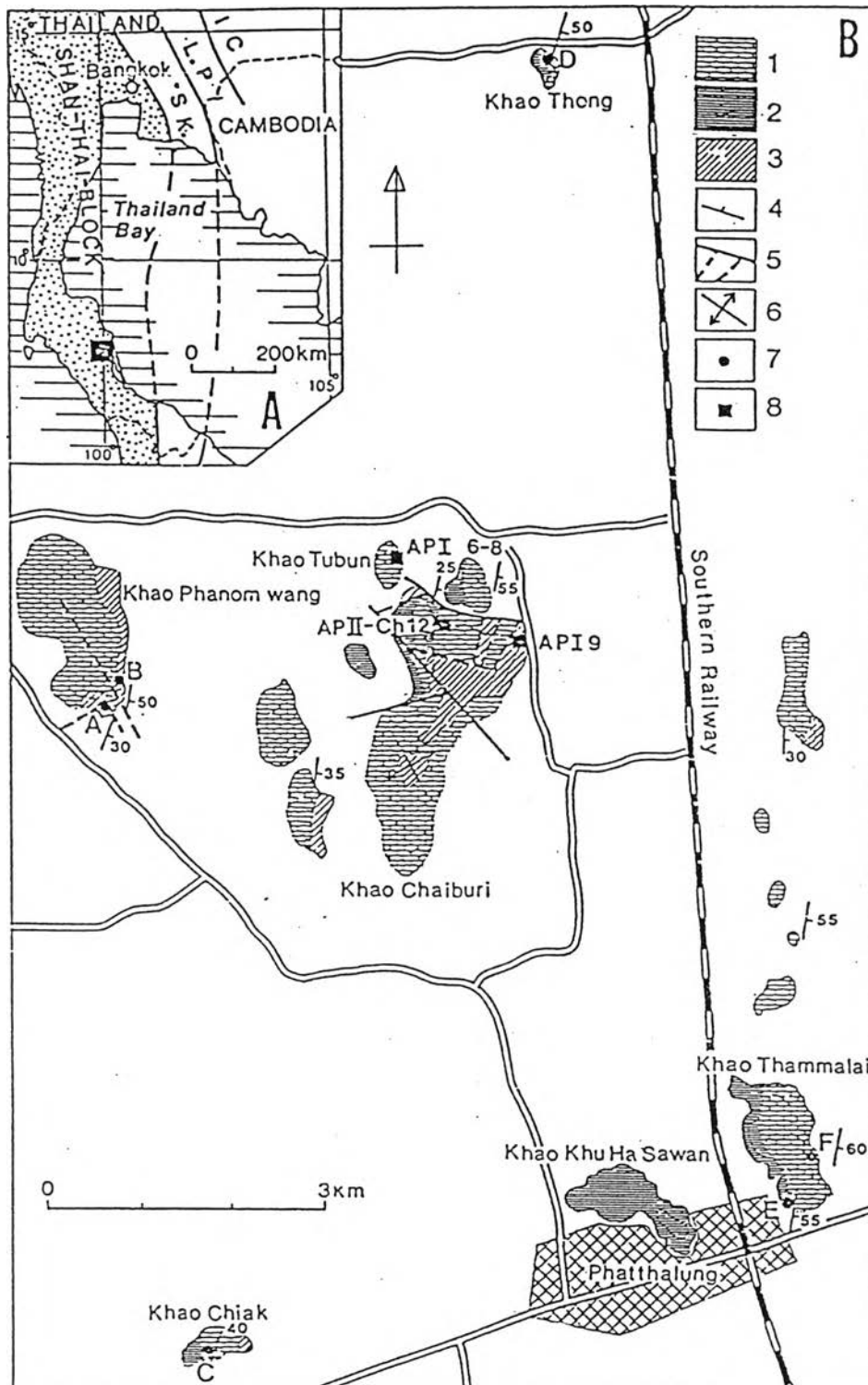


Figure 2.11 Simplified geological map of the Chaiburi Formation in the Phattalung area, Peninsular Thailand (Ampornmaha, 1995). (1) Phukhaothong Dolomite Member, (2) Chiak Limestone Member, (3) Phanomwang Limestone Member, (4) strikes and dips, (5) faults, (6) anticline, (7) stratigraphic section A-F, (8) additional carbonate samples

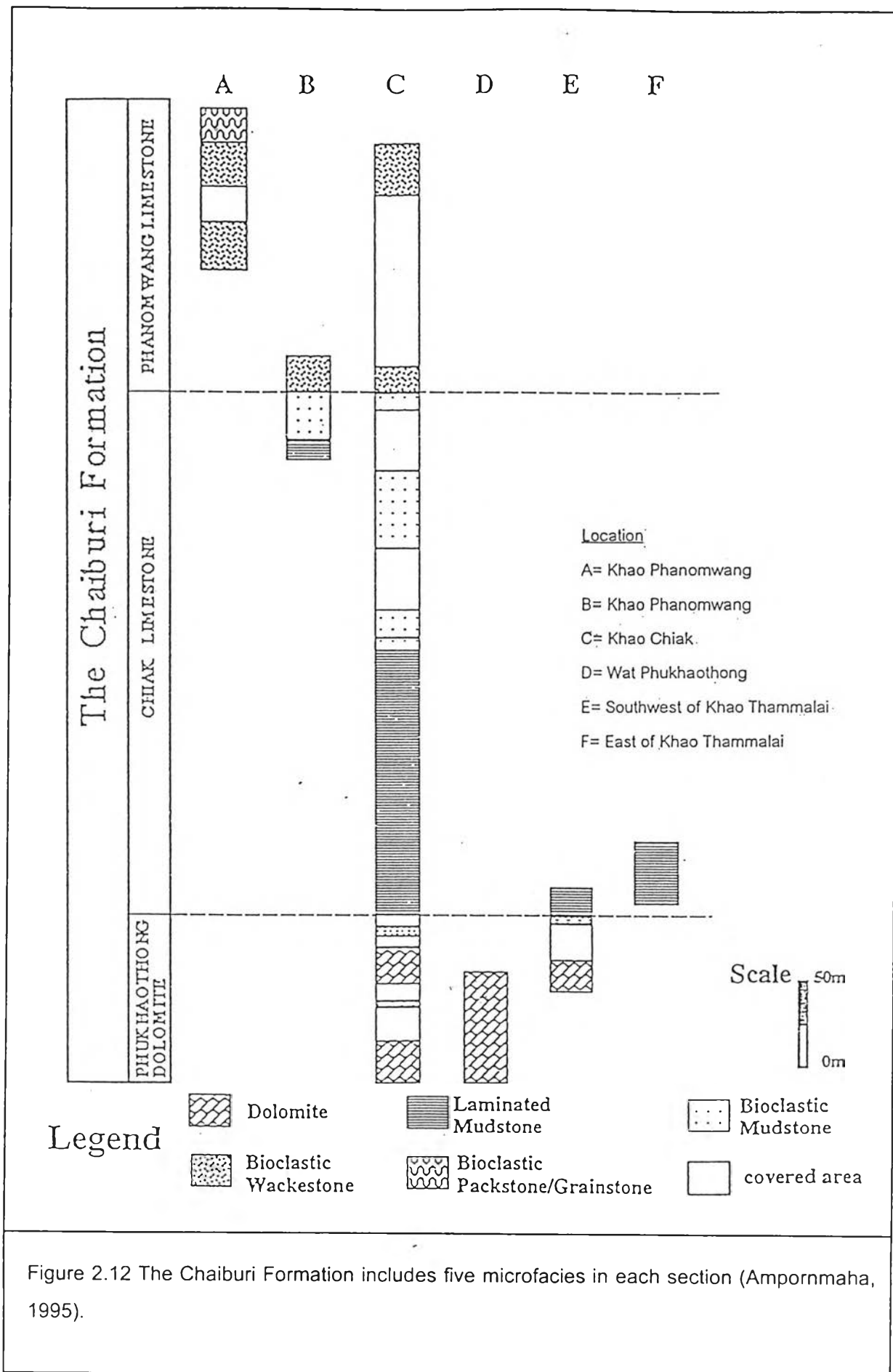


Figure 2.12 The Chaiburi Formation includes five microfacies in each section (Ampornmaha, 1995).

Fossils-pelecypods (*Plaeocardis* sp.), gastropods, and plants, supported the age of Late Triassic (Raksaskulwong et al., 1989).

#### 2.1.3.2.9 Marine Triassic rocks of Eastern Thailand

In eastern Thailand marine Triassic rocks can be divided into 4 formation (Meesook et al., 2000) and are herein collectively or loosely called “the Chantaburi Group”.

The oldest formation is the Sookpaiwun Formation with the type section at Khao Sookpaiwun, east of Rayong city and the overall thickness of more than 100 m. The Formation consists largely of gray, blackish gray and pinkish brown oolitic to pisolitic limestone with strong deformation. Fossils including foraminifera-*Meadrospira pusilla* Ho and *Glomospira tenuifistula* Ho and algae-*Aeolissacus tintiuniforis* Misik in limestones suggest the age of Early to Middle Triassic (Fontaine and Suthectora, 1997).

Younger than the Sookpaiwun Formation is the Noen Po Formation (Chaodumrong, 1992) with its type section at Khao Noen Po, west of Chantaburi Province. Most rocks of this formation are mudstone interbedded with volcanoclastic sandstone. The overall thickness is about 250 m.

The next formation is the Pong Nam Ron Formation (Sivabaworn et al., 1976) which good exposures are at Klong Pogn Nam Ron, Pong Nam Ron District, Chantaburi Province. The rocks were observed in the northwest-southeast trend from Wang Nam Yen District, Sra Khao Province southward to east of Trad. The formation is composed largely of thin- to thick-bedded, partly overturned and cleaved graywacke and mudstone with conglomerate intercalation (Figures 2.13 and 2.14). Lateral variation is quite clear with the coarser clasts to the east and finer clasts to the west, conformably with pebble imbrications and cross-bedding orientation clearly observed at Klong Pong.

The occurrence of abundant volcanic clasts and fusulinid-bearing limestone and the alternating bed of turbiditic sandstone and shale of Bouma sequence, lead us to suggest. The Pong Nam Ron Formation took place as submarine fan environment deposited in an active margin nearby continents.

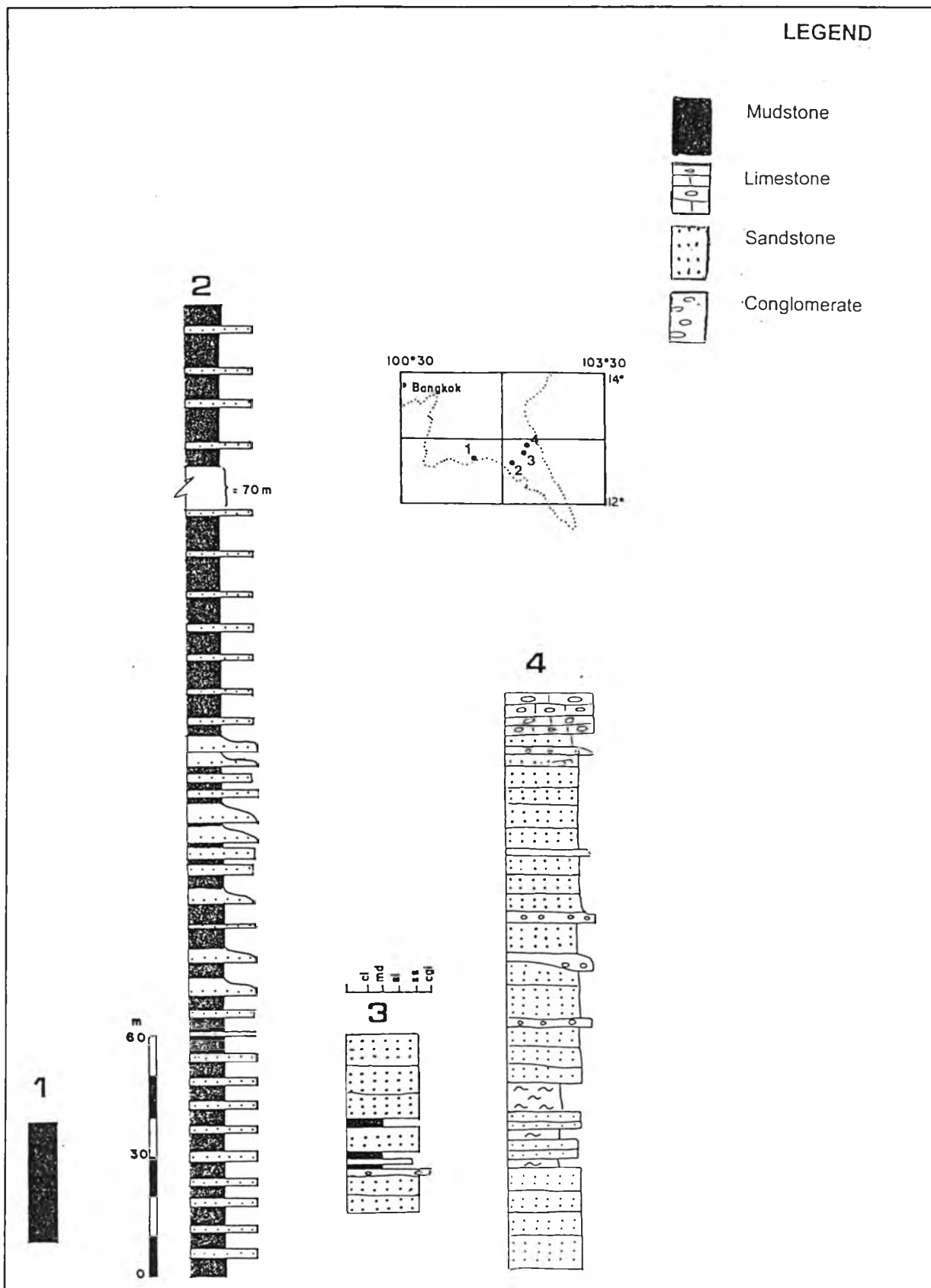
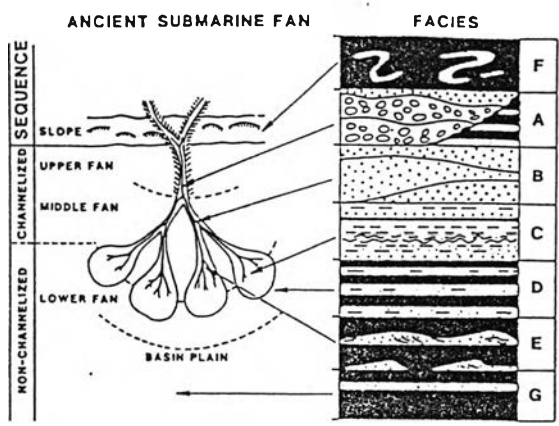


Figure 2.13 Stratigraphic sequence of the Pong Nam Ron Formation in eastern Thailand (Phonprasit and Prasomsub, 1984). 1. Ban Tha Rua, 2. Noen Puyai Yua, 3. Khao Klua, and 4. Klong Nam Ron.

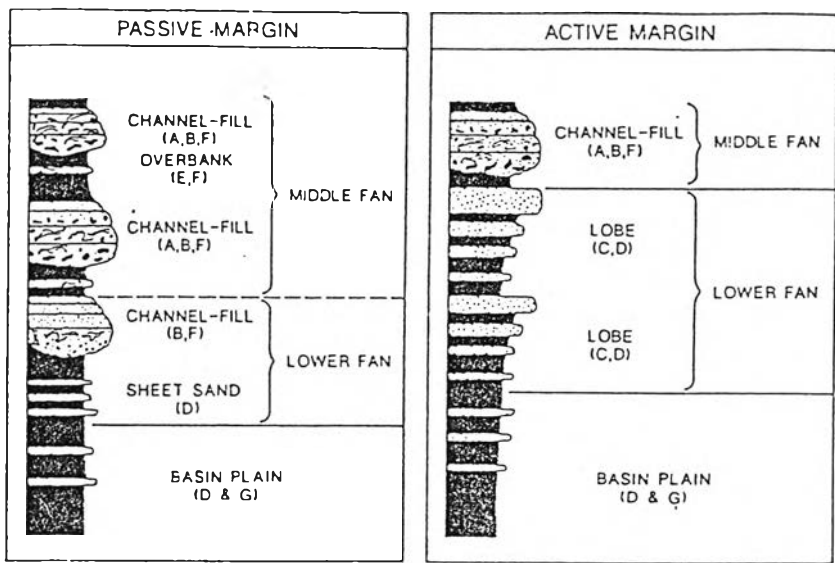


**DISTRIBUTION OF FACIES**

FACIES	ENVIRONMENT				DEPOSITIONAL PROCESSES
	SLOPE	UPPER FAN	MIDDLE FAN	LOWER FAN	
A	█	█			DEBRIS FLOWS, LIQUIFIED FLOWS
B		█	█		DEBRIS FLOWS, LIQUIFIED FLOWS, TURBIDITY CURRENTS (HIGH ENERGY)
C			█		TURBIDITY CURRENTS
D			█	█	TURBIDITY CURRENTS (LOW ENERGY)
E		█	█		LIQUIFIED FLOWS, TURBIDITY CURRENTS, TRACTION CURRENTS (?)
F	█	█	█		SLUMPS, DEBRIS FLOWS
G				█	PELAGIC & HEMIPELAGIC SEDIMENTATION

(a)

**TURBIDITE FACIES**



(b)

Figure 2.14 (a) Submarine fan and its facies distribution at continent margin (Mutti and Ricci Lucchi, 1972), (b) Turbidite sequences observed in the passive and active margin (Shanmugam and Moiola, 1988).

The youngest formation is the Noen Puyai Yua Formation (Chaodumrong, 1992) with the overall thickness of 250 m consisting of well-bedded grayish black to gray mudstone/shale interbedded with gray, partly graded and volcanogenic sandstone. The volume shale-sand ratio of 2:1 and internal structure led us to consider that the Noen Phayai Yua Formation was deposited in the outer-fan facies of turbidite sequence (Shanmugam and Moida, 1988) of an active margin.

## 2.2 Regional stratigraphy of the study area

The following stratigraphic subdivision and their nomenclature follow those adopted and established by the Department of Mineral Resources that appear in the 1:1,000,000 Geological Map of Thailand published in 1999.

The Changwat Mae Hong Son is underlain by rocks ranging in age from Cambrian to Recent (Figure 2.15). The geology of the region has been described previously by various workers i.e., Toriyama (1944), Brown et al. (1951), Konishi (1953), Pitakpaivan (1955), Sithiprasasna (1959), Pitakpaivan et al. (1964), Pitakpaivan (1965), Kobayashi and Igo (1966), Stoppel (1966-1969), Baum and Koch (1968), Braun (1969), Wolfart (1969), and Department of Mineral Resources (1999). Stratigraphic sequence in the western and eastern parts consists mainly of Paleozoic rocks. The description of those rock units are given below from the oldest to the youngest.

2.2.1 Cambrian rocks in Mae Hong Son province is called "Pha Bong Quartzite" by Bunopas (1981) for quartzite exposed Pha Bong Dam, in Mae Hong Son town. The Pha Bong Quartzite consists of 700 m-thick thinly to thickly bedding, gray to light brown quartzite.

2.2.2 Ordovician rocks herein belong to the Thung Song Group for blackish gray to light gray limestone with thin to thick beds, locally with greenish gray marble. The overall thickness is about 100 m. Several Early to Middle Ordovician conodont fossils were found in limestone including *Acontiodus* sp. indet (Stoppel, 1967, 1982), *Protopanderodus* cf. *P. giganteus* (Sweet & Bergstrom), *Scolopodus* sp. indet. and *Walliserodus ethingtoni* (Fahraeus).



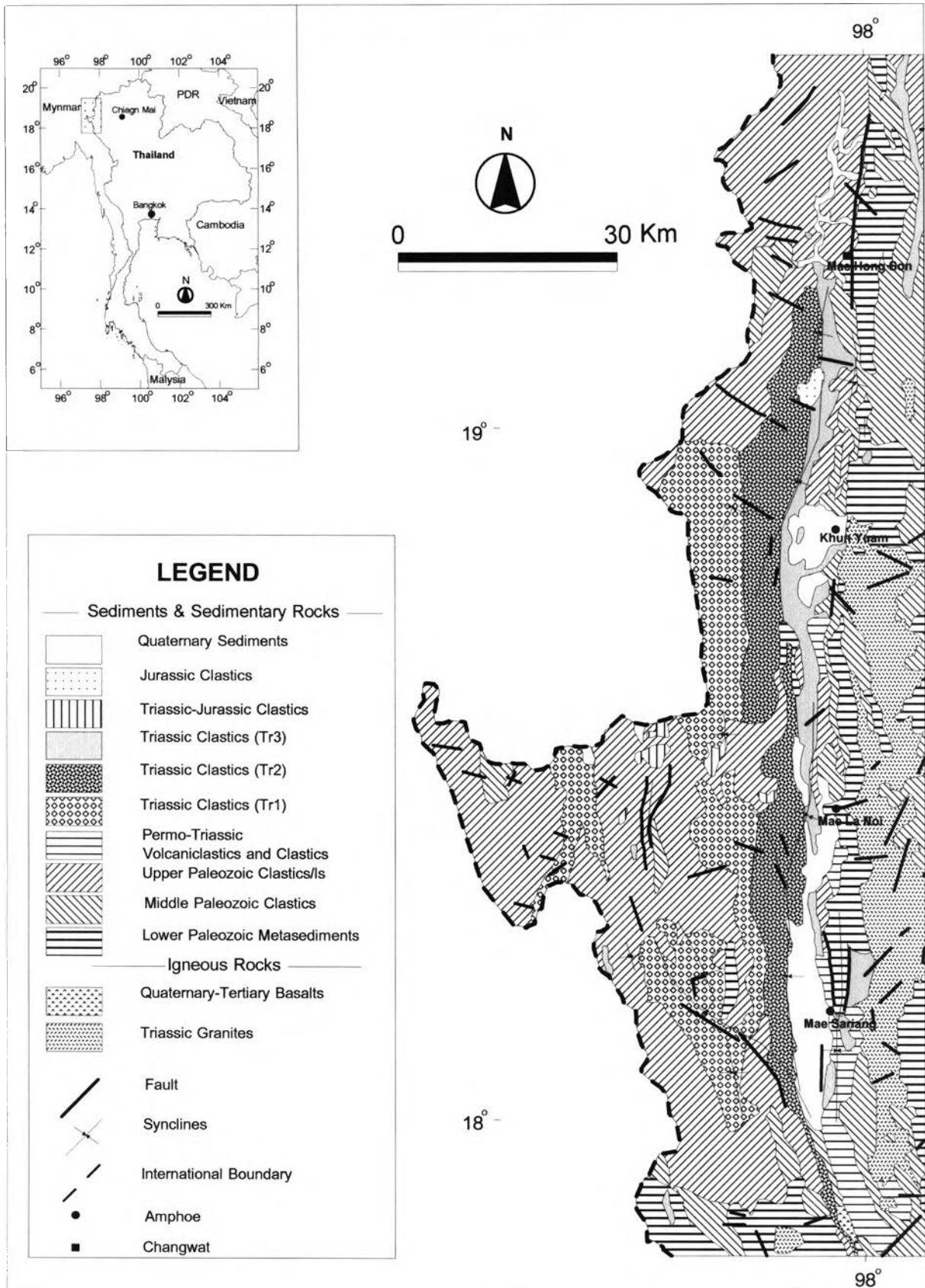


Figure 2.15 Regional geologic map of Mae Hong Son area showing area. (modified from Charusiri, et al., 1994; Department of Mineral Resources , 1999; this study).

2.2.3 The lower Paleozoic strata was mostly observed to the eastern part of the Mae Hong Son town. Silurian-Devonian rocks are called the "Mae Hong Son Group" by Bunopas (1981). The group consists of shale and sandstone with chert beds and limestone lens in shale. The minimum thickness is about 1,000 m. Several conodonts in limestone including *Trichonodella* sp. indet., and *Walliserodus santiclairi* Cooper, indicate Late Silurian-Early Devonian (Stoppel, 1967, 1982) age, and *Angulodus walrathi* (Hibbard), *Belodella triangularis* (Stauffer), and *Ozarkodina plana* (Huddle) indicative of Middle Devonian age (Stoppel 1967, 1982)

2.2.4 Carboniferous sediments are called the "Mae Tha Group" (following Piyasin, 1972) with the overall thickness of 400 m and consisting of two formations. The Lower formation comprises mainly gray to dark gray coarse-grained sandstone, dark gray shale and light green to gray chert, locally with limestone interbedded with shale. The upper formation consists of dark gray shale with intercalated gray siltstone and greenish gray sandstone. In some areas the sequence is characterized by siltstone and chert beds. The upper formation which lies over the lower formation is assigned to the Middle Carboniferous age whereas the lower formation is assigned to the Early Carboniferous.

2.2.5 Permian rocks is herein named the Ngao Group for sedimentary rocks. The overall thickness is about 200 m. The lowest formation is the Kiu Lom Formation which consists of gray fine-grained sandstone in the lower part, gray to greenish brown chert and shale in the middle and shale in the upper. Several foraminifera (as *Verbeekinidae*, *Schwagerininae*, and *Pachyphloia* sp.) indicate the age of Permian.

2.2.6 Permo-Triassic sediments are found in the Mae Hong Son area, particularly at Ban Huai Lan and Ban Mae La Luang, eastern side of the Nam Mae Yuam River from south of Mae Sariang to Sob Moei District. This unnamed unit consists mainly of sandstone, tuffaceous sandstone, argillaceous limestone, metarhyolitic to metaandesite tuffs; shale metalimestone lens, chert, shale, and oncolitic limestones.

### 2.2.7 Triassic sediments

Detailed stratigraphy of the Triassic rock is described in section 2.1 and will not be repeated herein.

### 2.2.7 Jurassic rocks

Jurassic strata in Changwat Mae Hong Son are included in the Huai Pong Group. The Huai Pong Group is named after the village of Ban Huai Pong, Amphoe Muang, Changwat Mae Hong Son. The group is proposed by Meesook (1994). Jurassic strata overly the marine Triassic Mae Sariang Group of Bunopas (1981) and underly Quaternary strata. The Huai Pong Group can be divided into three formations, namely in ascending order, the Pa Lan Formation, Mai Hung Formation, and Kong Mu Formation. The Huai Pong Group is approximately 200 meters thick.

The type locality of the Pa Lan Formation is situated between km 8 and km 9 on the unsealed road connecting the Mae Sariang-Mae Hong Son high way to Ban Pa Lan and Ban Klang. This formation is characterized by regular alternations of gray mudstones with subordinate thin-bedded sandstones. The formation has a total thickness of approximately 90 meters in its type section. Fossiliferous mudstones and siltstones of this formation are rich in bivalves and rare in ammonites. The stage is placed below limestones of the Mai Hung Formation containing foraminifera (*Timidonella* sp.) of Aalenian age. Evidence of the Early Toarcian is provided by ammonites *Dactyloceras* sp. with *P. (Parvamussium) donaiense* Mansuy and *P. (Parvamussium) palanicus* found in the lower part of the Pa Lan Formation.

The type locality of Mai Hung Formation is located at a limestone cave, about 1.5 km along the trace SSE of Ban Mai Hung. This formation is characterized by well-bedded sandy limestones with oncolites at the base and fossiliferous calcareous siltstone and massive-gray in the middle portion; the top part is sandy limestone grading into sandstone of the overlying Kong Mu Formation. This formation is approximately 40 meters thick in its type section. The type locality of the Kong Mu Formation is located at Doi Kong Mu, about 4 km south of Ban Pa Lan and 1 km southwest of the type section of the Mai Hung Formation. This formation consists mainly of fine- to medium-grained

arkosic sandstone. The basal beds are slightly calcareous, grading up from the sandy limestone of the underlying Mai Hung Formation. The Kong Mu Formation has a total thickness of approximately 65 meters in its type section.

Aalenian strata consist of well-bedded to massive gray limestones and sandstones of the Mai Hung and the Kong Mu Formations. A small lens of limestone intercalated in the Mai Hung Formation contains *Timidonella* sp. (foraminifera). The sequence is conformably underlain by Toarcian mudstones and siltstones of the Pa Lan Formation.

2.2.8 Quaternary sediments consists of 4 deposits, namely; high terrace deposits, middle terrace deposits, low terrace deposits, and alluvial deposits.

2.2.8.1 High terrace deposits consist of 50 m-thick gravel bed with clasts of quartzite, sandstone, limestone, chert, granite, and quartz. The maximum size of clasts is about 40 cm. Well roundness is very characteristic and mud matrix and cement are fine sand, silt, and clay. In some areas, the unit is well-observed by thick-bedded laterite. Age of the unit is assigned to a Pleistocene.

2.2.8.2 Middle terrace deposits are about 80 m-thick and consist of thin-beds of laterite, gravels, and silt.

2.2.8.3 Low terrace deposits are about 30-40 m-thick and consist of laterite soil, sand, and gravel with some silt and clay.

2.2.8.4 Alluvial deposits are about 30 m-thick and consist of sand, gravel, and clays for mud by action of river surface.

## **2.3 Igneous rock**

Granite is the only plutonic rock exposed in this area. It is widely distributed in the central and eastern parts of the area and intrudes the Cambrian rocks in Triassic Period (Charusiri et al., 1992). Typically this rock is medium- to coarse-grained, porphyritic, foliated, biotite granite grading to fine-grained, biotite-muscovite granite.

The volcanic igneous rocks are surprisingly not found in this area.

#### **2.4 Geological Lineament**

Lineaments are traced from NASA LANDSAT-5 TM (09/02/1988) on the scale of 1:250,000. Three major groups of them are distinguished in the investing area (Figure 2.16). The first group shows clearly in the direction of N-S and NNW-SSE, particularly the fault zone of N-S direction (Mae Hong Son-Mae Sariang fault zone). It passes through Mae Hong Son, Khun Yuam, Mae La Noi and Mae Sariang. The second direction of the lineaments are northeast and southwest, they are observed dominantly in the eastern part of Mae Nam Yuam particularly in Amphoe Khun Yuam and Amphoe Mae La Noi. some are present in the west of Mae Nam Yuam. The third zone of lineaments are distributed weakly all over the area with the direction of E-W.

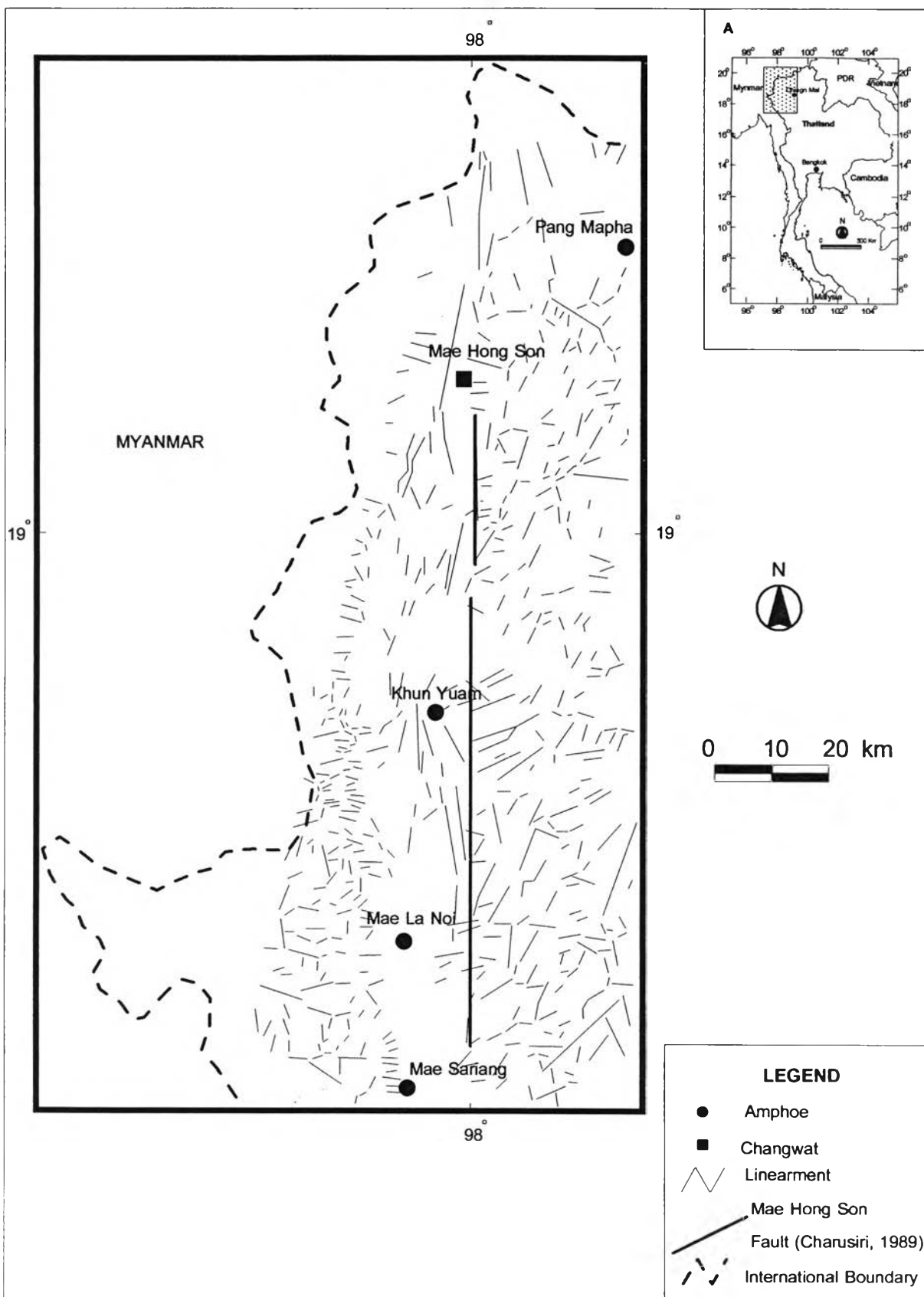


Figure 2.16 Major structure and geologically linearment from Lansat TM5 imageries.