

## CHAPTER II

### GEOLOGY

In order to understand the geology of the study area, the general background in regional geology, stratigraphy and paleontology of the area must be fully reviewed. The following discussion will be divided into three parts as firstly, a review of the regional Permian stratigraphy throughout Thailand; secondly, a regional geology of the study area; and thirdly, the geology of Khao Lamphean.

#### 2.1 Regional Permian Stratigraphy

Nakornsri (1976 and 1981) and Yavichai (1993) reported the age of rocks found in the present study area as the Permian Period. The most widespread and economic important carbonate rocks throughout Thailand are Permian age. They are distinctly characterized by carbonate-clastic sequences that were obviously deposited in marine environments. They are predominantly composed of carbonate rocks with relatively less abundant shale, sandstone and cherts. Because of their diverse lithology, and fauna assemblages they have been mapped into many different lithostratigraphic unit by many geologists as shown in the Figure 1.1.

Recently, the Department of Mineral Resources [DMR] has conceded at least four formal names for the Permian successions in Thailand (Raksaskulwong, 2002) according to their geographic distribution and geological setting.

In brief, they are generally referred to as Ratburi Group in Lower Western and Southern Province; Ngao Group in the Northern and Upper Western Province; Chantaburi Group in the Eastern Province; and Saraburi Group in the Northeastern Province or the Loei-Petchabun Ranges as illustrated in Table 2.1.

##### 2.1.1 Ratburi Group

Age (Ma)	Period	Northern & Upper Western		Loei - Phetchabun Ranges		Eastern		Lower Western & Southern	
		Group	Formation	Group	Formation	Group	Formation	Group	Formation
245	Triassic	Lampang					Pong Nam Ron		Si Bon Chai Buri
	Upper Permian		Huai Tak		Sap Bon (Nam Duk) Khao Khad		Khao Chakan (Khao Ta Ngok)		Urn Luk Phanom Wang
		Middle Permian	Ngao	Pha Huat	Saraburi	Pang Asok (Hua Na Kham) Nong Pong (E-Lert)			Ratburi
285	Lower Permian		Kiu Lom		Khao Khwang (Nam Ma Ho Ran, Pha Nok Khao) Phu Pha		Sra Kaeo (Wang Nam Yen)		Khao Phra (Ko Yao Noi)
	Carboniferous	Dan Lan Hoi (Mae Tha, Phrae)			Wang Sa Phung (Huai Som)				Kaeng Krachan (Phuket)

Table 2.1 Lithostratigraphic correlation of the Permian succession in Thailand (Raksasulwong, 2002).

Javanaphet (1969) first named the Ratburi Group for Permian-Carboniferous limestones and their associated clastic successions throughout Thailand. Later on, Bunopas (1981 and 1992) limited the Ratburi Group only to the Permian successions that occurred in the stratigraphic belt No. 1-2 of the Shan-Thai microcraton (Figure 1.5).

Recently, Harrison et al. (1997) carried out an investigation on the Ratburi Group occurred in the vicinity of Suratthani Province, southern Thailand, and divided it into four formations in ascending orders as follows;

#### Thung Nang Ling Formation

This formation is composed of dark-pale gray, medium to thickly-bedded fossiliferous limestone which conformably overlaid the Permo-Carboniferous clastic rocks of Kaeng Krachan Group. The thickness of this formation is about 80 meters.

#### Phap Pha Formation

It consists of dark gray thinly to medium bedded limestone, interbedded with calcareous mudstone and shale. Chert nodules are occasional form in the limestone. The thickness of the formation is about 200 meters.

#### Phanom Wang Formation

This formation comprises mainly coarse-grained, medium bedded limestone, dolomitic limestone and light gray dolomite. Chert nodules are commonly formed and oriented parallel to the bedding planes. The thickness of this formation is about 80 meters.

#### Um Luk Formation

The formation consists predominantly of light gray, dense, very thickly-bedded limestone. The thickness of the formation is about 200 meters.

Fontaine and Suteethorn (1988) discussed the ages of the limestone in Ratburi Group range from the middle of Murghabian to late Permian in the upper part, which was discovered the index forams, *Shanita* sp.



The fusulinids are found in low diversity encountered East Thailand. Corals are restricted to few localities and many are solitary that indicate harsh conditions.

### 2.1.2 Ngao Group

The Permian rocks found in northern region had been formerly mapped as the Ratburi Group. Subsequently, Bunopas (1981 and 1992) proposed the Ngao Group for the Permian successions that were located in the Northern and the Upper Western Province or in the stratigraphic belt No.4 (Figure 1.5).

Previously, Piyasin (1972) divided the so-called Permian Ratburi Group in Lampang area into 3 formations in ascending order as follows:

#### Kui Lom Formation

This formation overlies conformably Carboniferous strata, the Dan Len Hoi Group, and is composed of clastic and pyroclastic sediments intercalated by thinly bedded limestone. Lower Permian fossils were found in limestone, shale and sandstone, however the important faunas are fusulinids such as *Triticites* sp. and *Pseudoschwagerina* sp. which indicating Lower Permian age. The thickness of the formation is more than 200 meters.

#### Pha Huat Formation

The lower part of this formation consists predominantly of thickly bedded recrystalline limestone intercalated by tuffaceous sandstone that is overlain by very thickly-bedded limestone containing chert nodules and found fusulinids, *Neoschwagerina* sp., indicating the Middle Permian age. The thickness of the formation is about 600 meters.

#### Huai Tak Formation

This formation comprised of shale and mudstone intermittently intercalated by thinly bedded sandstone, limestone and conglomerate. In addition, the limestone contains of fusulinids such as *Palaeofusulina sinensis* and *Colaniella parva* indicating Late Permian



(Sakagami and Hatta, 1982; Ishibashi et al., 1994). The thickness of the formation is about 760 meters.

### 2.1.3 Chantaburi Group

Bunopas (1981 and 1992) proposed that the Permian strata in eastern region, situated in the stratigraphic belt No. 5 (Figure 1.5), is referred to as the Chantaburi Group and furthermore subdivided them into two formations in ascending order as follows:

#### Srakaew Formation

The formation consists of radiolarian chert, limestone and composite mélangé assemblages with ophiolite and ultra-mafic rocks. The radiolarian in the chert beds indicates the age of Middle to Late Permian (Sashida and Nakornsri, 1997)

#### Khao Chakan Formation

The formation consists of very thickly bedded fossiliferous limestone containing the fusulinids, namely, *Cancellina nipponica*, *Neoschwagerina simplex*, *Yabeina* sp. and *Lepidolina* sp., and corals i.e., *Pseudohuanggia* sp., *Waagenophyllum* sp., *Multimurinus* sp. and *Ipciphyllum* sp. indicating middle Permian age (Fontaine and Salyapongse, 1997).

In addition, Chaodumrong (1992) also subdivided the Chantaburi Group into two formation, namely Wang Nam Yen formation in the lower part and Khao Ta Ngog formation in the upper part.

### 2.1.4 Saraburi Group

Bunopas (1981) proposed the Saraburi Group for the carbonate-clastic sequences cropped out in the eastern part of the lower Chao Phraya central plain, extending approximately in north-south direction along the western edge of the Korat Plateau from Loei to Saraburi. This area is commonly referred to the Loei fold-belt (Bunopas and Vella, 1983) as well as the Phetchabun fold and thrust belt (Wielchosky and Young, 1985). It is

worthy to mention that the Saraburi Group was formerly mapped as a part of the Ratburi Group (Brown et al., 1951; Javanaphet, 1969; Tittirananda, 1976; Bunopas, 1976; Nakornsri, 1976 and Hinthong, 1981).

In brief, the lower part of the Saraburi Group is composed mainly of greenish gray, well bedded sandstones interbedded with gray shale, and some intercalation of thinly bedded limestone. The upper member is composed predominantly of medium-very thickly bedded limestone commonly rich in fossils, in parts containing elongated chert nodules, and occasionally some intercalation of fine-grained sandstone, shale and bedded chert. Base on the evidences of important faunas such as fusulinids, brachiopods and corals indicate that the age of the Saraburi Group ranges from the Lower to Middle Permian.

Moreover, they not only conformably overlies either the Upper Carboniferous carbonate-clastic, the so-called Wang Sa Phung Formation, in some places, the volcanic-clastic of Huai Som Formation, they also unconformably underlie the Triassic (Huai Hin Lat Formation) or Permo-Triassic volcanics.

#### 2.1.4.1 The Saraburi Group in Saraburi area

The greater part of Saraburi Group occurs mainly in Saraburi province extending to the southern part of Lop Buri province and also Amphoe Pak Chong, Nakorn Ratcha Sima province. Mainly investigation of the Permian rocks regarding to geology, sedimentology and stratigraphy were previously carried out by Lee (1923), Brown et al. (1951), Beeser and Abele (1963), Borax and Stewart (1966), Tittirananda (1976), Wielchowsky and Young (1984), Hinthong et al. (1985), Sawata, (1985), Phothong (1985), and Thambunya (1999).

However, lithostratigraphic classification established by Hinthong et al. (1985) has still been widely recognized. Accordingly, the Saraburi Group in this area was divided into six formations in ascending order as follows:

##### Phu Phe Formation

It is the lowest part of Saraburi Group, consisting of gray to very dark gray, thick to very thickly bedded limestone with nodular chert and some intercalations of slaty shale in the lower part. The limestone contains the Lower Permian (Asselian to Sakmarian) fusulinids, namely, *Pseudoschwagerina* sp. and *Triticites* sp. It is noteworthy to point out that this formation upthrusts onto the Sup Bon formation which is the younger formation (Borax and Steward, 1966; Hinthong, 1985 and Phothong, 1985). The thickness of the formation is about 600 meters.

#### Khao Khwang Formation

It is composed of dark to light gray, thick to very thickly bedded limestone with numerous nodular chert. In places, it was dolomitized and associated with tuffaceous sandstone. Its fossil assemblage includes brachiopods, bryozoa, crinoid stem and fusuline indicating the age of lower Permian (Asselian to Sakmarian). Thus, this formation exhibits a lateral facies-change related to the Phu Phe formation. The thickness of the formation is about 490 meters.

#### Nong Pong Formation

The formation is composed chiefly of shale interbedded with thinly bedded limestone or argillaceous limestone, containing some intercalation of chert. Besides, the limestone lenses occurred at the upper horizons. Some fossiliferous beds contain ammonoids, *Agathiceras* sp. and fusulinids indicating Artinskian to Kungurian (lower Middle Permian) age. The thickness of the formation is about 670 meters.

#### Pang Asok Formation

The formation consists mainly of greenish gray shale and slaty shale containing locally, gray sandstone and limestone lenses. The limestone lenses contain fossils of bivalves, crinoid stems and fragments of corals, *Yatsengia* sp. indicating Roadian (lower Middle Permian) age (Madee, 1997 and Noipow, 1999). The thickness of the formation is about 360 meters.



### Khao Khad Formation

The formation comprises light gray thinly bedded to very thickly bedded limestone containing a lot of chert nodules and abundant fossils, and locally interbedded with shale, sandstone and conglomeratic limestone. Many paleontological works were described from fossiliferous limestone including fusulinids (Toriyama et al., 1969; Pitakpaiwan et al., 1969; Ozawa, 1970 and Titirananda, 1976), corals (Sukiyama, 1982; Fontaine, Sattayarak and Suteethorn, 1994) and ammonoids (Siriteerasarn, 1997), and pointed out that the age of the formation is ranging from upper Lower Permian (Artinskian to Kungurian) to upper Middle Permian (Capitanian or Midian). The thickness of the formation is about 1,800 meters.

### Sap Bon Formation

It is the upper most lithostratigraphic formation consisting of pale brown-gray interbedded shale, siltstone, minor amount of sandstone, with local intercalation of dark gray limestone and chert. The rocks were, in places, usually metamorphosed to slaty shale, phyllite and schist. Base on the identification of ammonoids, *Agathiceras* sp., it indicates the age of Sap Bon Formation as Kungurian to Kazanian. The thickness of the formation is about 1,100 meters.

#### 2.1.4.2 The Saraburi Group in Loei - Nong Bua Lamphu area

The Saraburi Group is widely cropped out in the east and south of Loei province and extend into Nong Bua Lamphu province. Its sedimentological and stratigraphic studies were previously carried out by Bleakly et al. (1965), Charoenprawat and Wongwanich (1976), Charoenprawai et al. (1984), Wielchowsky and Young (1984), Kozar et al. (1992), Homrareun (1995) and Assavaphachara (1998).

Thus, lithostratigraphic classification established by Charoenprawat et al. (1984) are widely conceded. Accordingly, the Saraburi Group in this area was divided into 3 formations in ascending order as follows:

### Nam Mahoran formation

The formation comprises gray thickly bedded limestone containing black nodular or thinly bedded chert, and intercalations of thinly bedded, gray shale. Some fossiliferous beds contain fossils of algae, coral, brachiopods, crinoid stems and fusulinids, indicating Gzhelian (Late Carboniferous) to Murgabian (lower Middle Permian) age. The thickness of the formation is more than 500 meters.

#### E-Lert formation

It is composed of brown-gray shale, yellowish brown sandstone and thinly bedded, dark gray limestone and chert. The sediments also show cross-bedding and wavy laminations of probably Bouma - sequence (Altermann, 1989). The ammonoids, *Agathiceras* sp., in the shale and fusulinids, *Parafusulina* sp., in the limestone not only indicate Asselian to Kubergandian age but also suggest that the formation might be interfingering to the Nam Maholan formation and can be correlated with the Pang Asok Formation in Saraburi Area (Assavaphachara, 1998 and DMR, 2001).

#### Pha Dua formation

This formation is composed of thinly bedded brown to brownish micaceous sandstone, siltstone and shale containing plant fossils. The ammonoid, *Agathiceras* sp., found in it indicates the Kazanian (middle Middle Permian) age. The formation could be correlated with the Sap Bon Formation in Saraburi area (Department of Mineral Resources, 2001)

#### 2.1.4.3 The Saraburi Group in the Phetchabun - Chaiyaphum area

Permian successions in Phetchabun and Chaiyaphum area are not similar to the Saraburi Group in Saraburi area regarding to their lithology and fossil assemblages. Many stratigraphic investigations were carried out by many workers such as, Chonglakmani and Sattayarak (1984), Chonglakmani et al. (1979), Altermann (1989), and Chutakositkanon (1999).

However, lithostratigraphic classification established by Chonglakmani and Sattayarak (1984) has still been widely recognized. Accordingly, the Saraburi Group in this area was divided into three formations in ascending order as follows:

#### Pha Nok Khao formation

The formation is comprised of thickly to very thickly bedded, gray limestone, containing black nodular or thinly bedded chert and thinly bedded shale intercalation. The formation could be correlated with Nam Mahoran formation in Loei area (Assavaphachara, 1998 and Charoentitirat, 2003) and Khao Khwang Formation in Saraburi area (Department of Mineral Resources, 2001). The limestone contains fusulinids and corals indicating the Lower to Middle Permian age.

#### Hua Na Kham formation

It consists of gray shale, yellowish brown sandstone and some limestone lenses. Its age is referred to be middle Permian. It might be correlated with the Pang Asok Formation in Saraburi Area and the E-Lert formation in Loei Area (Assavaphachara, 1998 and DMR, 2001).

#### Nam Duk formation

It is composed of interbedded sequence of gray to dark gray shale with minor brownish sandstone, and thinly bedded, and show characteristics of Bouma - sequence (Altermann, 1989). The limestone contains fusulinids of Middle Permian age.

#### 2.1.4.4 The Saraburi Group in Lop Buri - Nakorn Sawan area

The Permian rocks in this area were formerly studied and recognized as Ratburi Group (Nakornsri, 1976 and, 1981). They were divided into 2 formations according their difference in lithology and fossil assemblage as follows;

#### Khao Luak Formation

This formation is composed mainly of greenish to gray, well-bedded sandstone, brownish-gray shale and limestone bands. The limestone contains very rare coral fossils, *Psuedohuangia* sp., and fusulinids, *Verbeekina verbeeki*, both indicate the lower Middle Permian age.



### Tak Fa formation

The formation comprises predominantly of gray to bluish gray, medium to very thickly bedded fossiliferous limestone containing chert nodules and minor amount of sandstone and shale. The fossils are very abundant including brachiopods (Yanagida, 1964), bryozoa (Sakagami, 1975) and fusulinids *Neoschwagerina* sp., *Pseudodoliolina* sp. and *Sumatrina annae* (Pitakpaiwan, 1966, Toriyama and Pitakpaiwan, 1973) which indicate lower Middle Permian age. Accordingly, it can be suggested that the Tak Fa formation is interfingering to the Khao Luak formation.

The abovementioned stratigraphic nomenclature of the Saraburi Group occurred in different areas in central and northeastern regions of the Loei-Petchabun mountain range. Their correlation can be summarized and illustrated in Table 2.2.

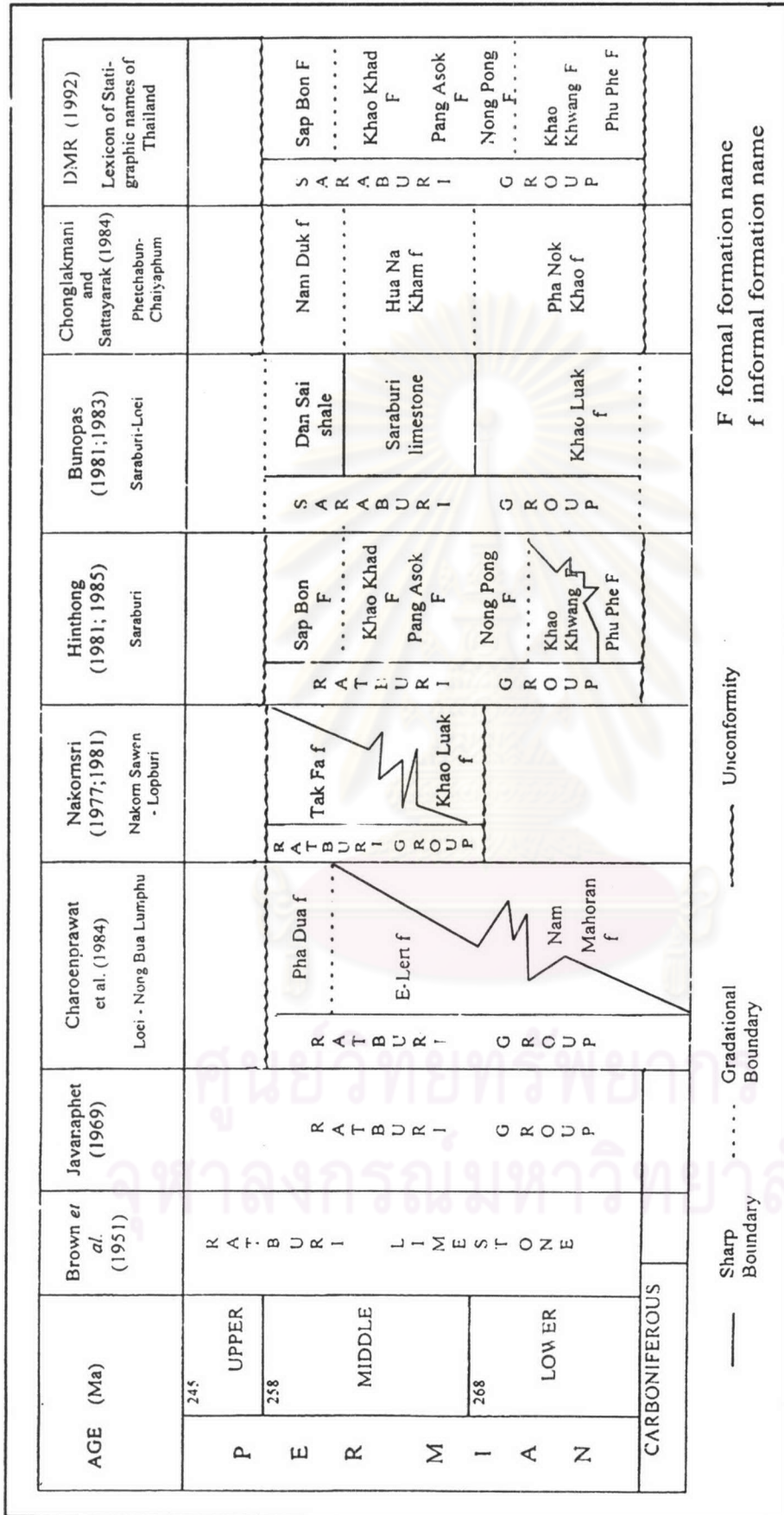
2.1.5 Regional facies variation of the Permian Saraburi Group in the Northeastern and Central Thailand.

Wielchosky and Young (1985) presented the variation of regional facies of the carbonate and siliciclastic rocks within the Permian "Petchabun fold and thrust belt" (synonym of the Loei fold-belt) in the Northeastern and Central Thailand.

They reported various carbonate facies in six environments, including marginal marine, restricted platform, platform interior, outer platform, basin margin and basin plain including three environment of siliciclastic facies representing of deep, shallow, and marginal marine environments.

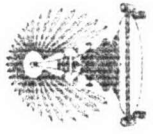
Furthermore, the report concluded a model of regional facies variation of the Petchabun fold and thrust belt as shown in Figure 2.1.

The proposed model comprise of two platforms, namely, Pha Nok Khao platform and Khao Khwang platform in shallow marine environments being separated by Nam Duk basin of deep sea environments.

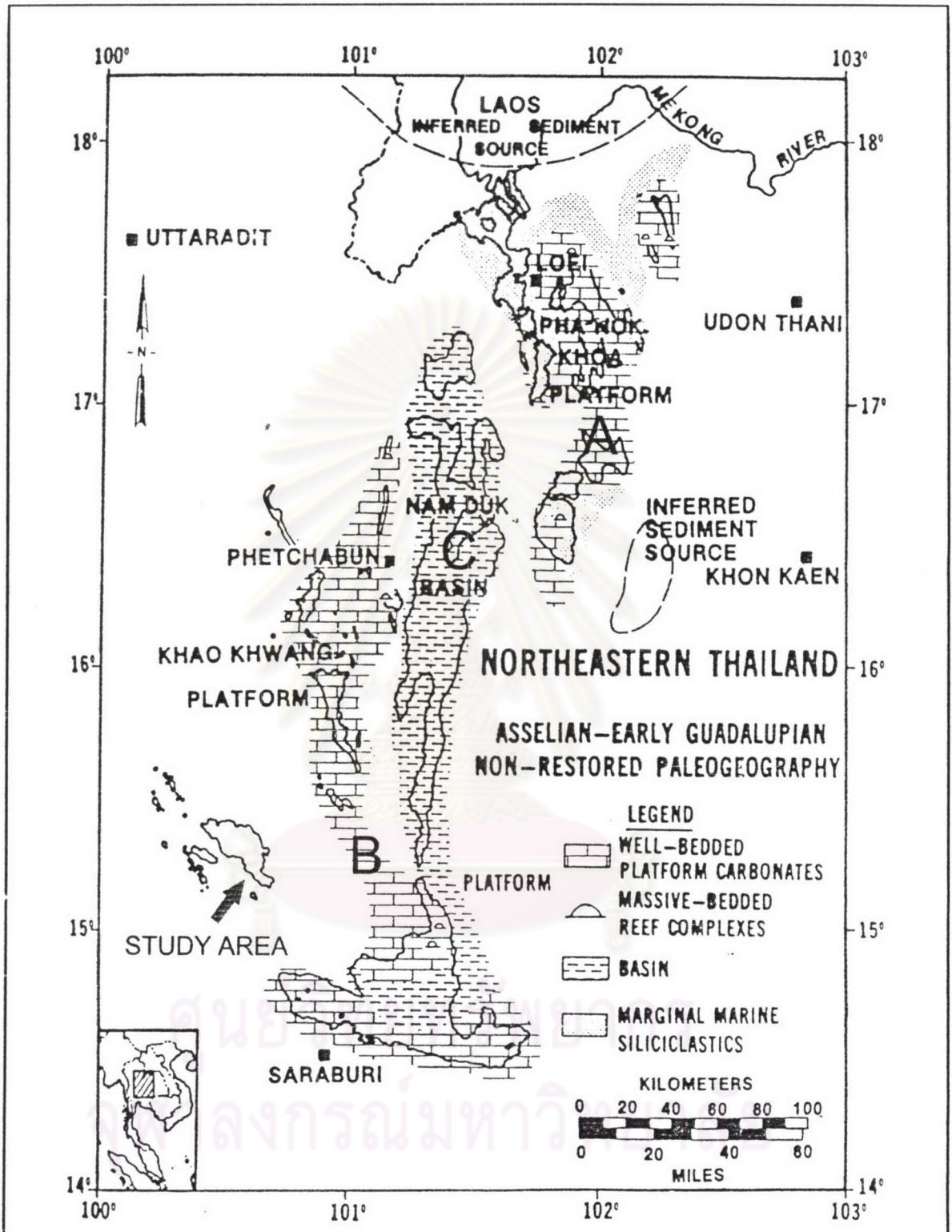


INITIAL MICROFACIES AND LITHOSTRATIGRAPHY OF PERMIAN CARBONATE SEDIMENTS IN THE VICINITY OF KHAO LAMPHEAN, AMPHOE NONG MUANG, CHANGWAT LOPBURI.

Table 2.2 Lithostratigraphic correlation of the Permian rocks in Central and Northeastern regions (Modified after Assavapatchara, 1997).







INITIAL MICROFACIES AND LITHOSTRATIGRAPHY OF PERMIAN CARBONATE SEDIMENTS IN THE VICINITY OF KHAO LAMPHEAN, AMPHOE NONG MUANG, CHANGWAT LOPBURI.

Figure 2.1 The model of regional facies variation in Permian Phetchabun fold and thrust belt (After Wielchosky and Young, 1985) showing the Pha Nok Khoa Platform(A), the Khao Khwang Platform (B), and the Nam Duk Basin (C).





Pha Nok Khao Platform (A) is in the northern part, which cover the Loei - Nong Bua Lamphu area and eastern part of the Phetchabun - Chaiyaphum area. It is distinctive depositional basin of the platform carbonates such as the Nam Mahoran Formation and Pha Nok Khao Formation which are characterized of very thickly bedded fossiliferous limestone and their faunas indicate Upper Carboniferous(only in Nam Mahoran) to Middle Permian age.

Khao Khwang Platform (B) is situated in the southern part, which covers the Saraburi-Lop Buri area and western part of the Phetchabun Area. It is also depositional basin of platform carbonate rocks that is represented by very thickly bedded fossiliferous limestone. Unlike the Pha Nok Khao Platform, almost faunas in the Khao Khwang Platform indicate only Permian period age, Lower Permian in the Phu Phe Formation and Khao Khwang Formation, and Middle Permian in the Tak Fa formation and Khao Khad Formation.

However, the western part of the Phetchabun area, which is previously mapped as Pha Nok Khao Formation is included as a part of the Khao Khwang Platform. However, recent information were reported that few localities of them belong to Carboniferous and Upper Permian age (Chonglakmani and Fontaine, 1992).

Nam Duk Basin (C) covers the central part of the Phetchabun- Chaiyaphum area. It includes the basin margin and basin plain environments which are characterized by thinly bedded chert, limestone and clastics showing some characteristic of the Bouma - sequence. The Nam Duk Formation is the best evidence to represent the basin. Other units may include the Khao Luak formation, Nong Pong Formation and Pang Asok formation.

Chonglakmani and Fontaine (1992) mentioned that the Khao Khwang Platform (Phetchabun-Lam Narai Platform) and Pha Nok Khao Platform (Loei Platform) were shallow marine environments situated in the continental margin of the Indochina Plate during Carboniferous until the beginning of middle Permian. At the outset, the Nam Duk Basin were deepening which is a consequence of an extension of the margin. Later on because of the movement change, compression appeared during Middle Permian and the Nam Duk

Basin turned to be shallow marine before that a general emergence transformed the whole region into land in the Upper Permian resulting to marine fossils of this age have never been found. On the contrary, plant imprints and fossil wood have been discovered (Kono, 1964; Asama, 1966; and Chonglakmani and Fontaine, 1992).

In addition, they concluded schematic Permian stratigraphic column of the Khao Khwang Platform in Phetchabun – Lam Narai area as shown in Figure 2.2.

The Khao Lamphean area is situated in the west of the area which is assigned as the Khao Khwang Platform. By initial examination of the lithology, stratigraphy and fossils, it is probable that the present study area is included as a part of Khao Khwang Platform.

## 2.2 Regional Geology of the Study Area

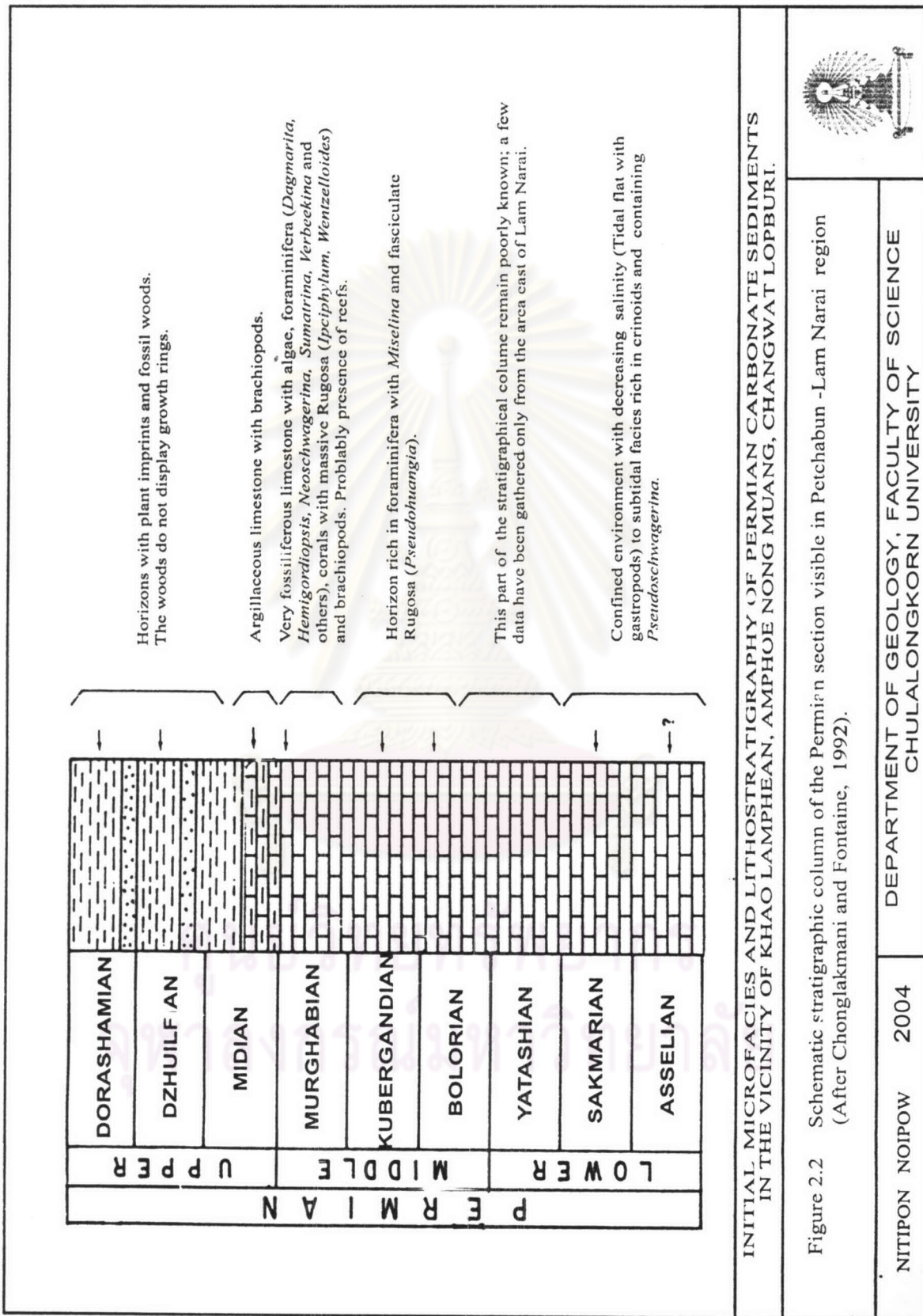
The present study area is located in a geological map scale 1: 250,000 sheet ND 47-4: Amphoe Ban Mi (Nakornsri, 1976, 1981).

Subsequently, the Department of Mineral Resources [DMR] published a detailed geological map with the scale of 1: 50,000 of Lop Buri area as shown in Figure 2.3, aiming at exploring and evaluating the potential of economic mineral deposits in this area (Yavichai, 1993). According to this work, twelve rock units consist of 2 sedimentary rock units, 2 metamorphic rock units, 7 igneous rock units and an unit of unconsolidated sediments. They were described in detail as follows;

### 2.2.1 Sedimentary rock units

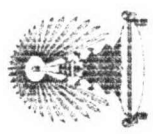
Khao Khok Unit ( $P_{1st}$ ) consists of gray to dark gray, bedded limestone with chert nodules and chert beds. The limestone contains abundant fossils of fusulinids, corals, brachiopods bryozoa and algae, indicating Lower to Middle Permian age (Pitakpaiwan, 1973). The Khao Khok Unit can be correlated to the Tak Fa formation of Nakornsri (1976 and, 1981).





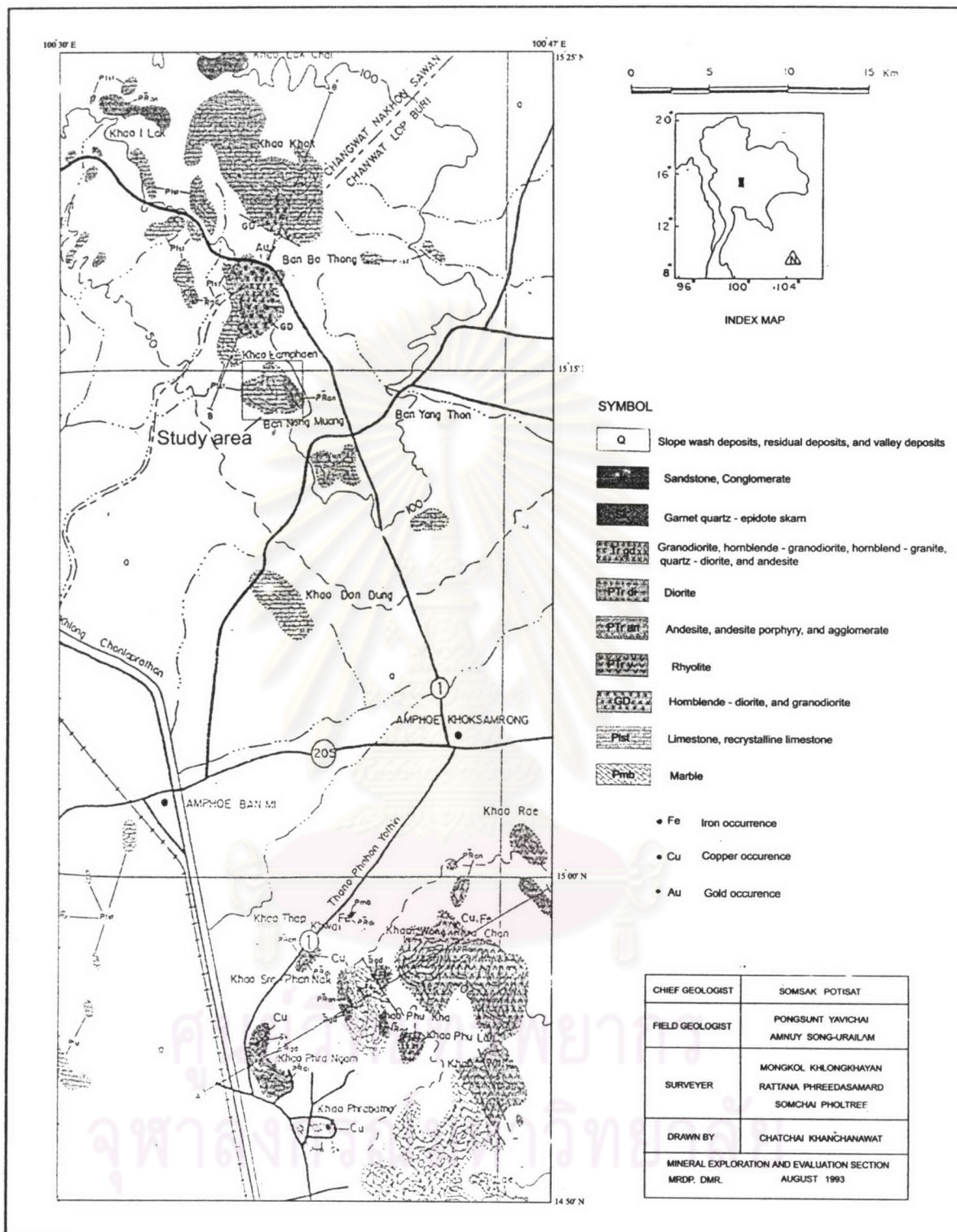
INITIAL MICROFACIES AND LITHOSTRATIGRAPHY OF PERMIAN CARBONATE SEDIMENTS IN THE VICINITY OF KHAO LAMPHEAN, AMPHOE NONG MUANG, CHANGWAT LOPBURI.

Figure 2.2 Schematic stratigraphic column of the Permian section visible in Petchabun -Lam Narai region (After Chonglakmani and Fontaine, 1992).



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INITIAL MICROFACIES AND LITHOSTRATIGRAPHY OF PERMIAN CARBONATE SEDIMENTS IN THE VICINITY OF KHAO LAMPHEAN, AMPHOE NONG MUANG, CHANGWAT LOPBURI.

Figure 2.3 The geological map of Lop Buri - Khok Samrong area (Yavichai, 1993).



Wat Mai Sophim1 Unit (Jr) consists of conglomerates at the lower part and sandstone at the upper part. The conglomerates are composed of poorly sorted quartz and chert pebbles being embedded in sand matrix. The sizes of pebbles range from 0.5 to 5 centimeters in length. The sandstones are reddish brown to greenish gray orthoquartzite. The unit usually occurs as narrow belts of less than 10 meters thickness, overlaying the older limestone and chert. Thus, the unit is reported to be Jurassic age (Nakornsri, 1976).

## 2.2.2 Igneous rock units

Khao Wong Phra Chan Unit ( $PTr_{an}$ ) consists predominantly of andesite of various types such as, fine-grained andesite, andesite porphyry and andesitic agglomerates. The rock is commonly greenish gray to dark gray colors, porphyritic and composed of plagioclase phenocrysts. At the type locality, Khao Wong Phra Chan, the andesitic agglomerates have been found overlaying the andesite porphyry. Its pebbles are composed mainly of andesite and a rarity of chert and shale fragments. The andesites also occur in fractures of the country rock as dikes or sills, sometime showing flow structures. The unit is reported to be Permo-Triassic in age (Hinthong, 1985).

Khao Lak Chai Unit ( $PTr_v$ ) consists predominantly of rhyolite. Its is greenish gray to pale brown, fine-grained and clearly shows flow structures. The unit is reported to be Permo-Triassic in age (Hinthong, 1985).

Khao Sapan Nak Unit ( $PTr_{di}$ ) is medium to coarse-grained diorites, which found in narrow zone, and usually associated with quartz diorite and hornblende granite veins. The unit is inferred to be Permo-Triassic in age (Hinthong, 1985).

Khao Pui Lon unit ( $Tr_{gd}$ ) is an assemblage of undifferentiated plutonic rocks that are composed of medium to coarse-grained hornblende diorite, hornblende-biotite granite and hornblende granodiorite, hornblende granite and quartz diorite. The age of unit is questionably either Triassic (Nakornsri, 1976) or Permo-Triassic (Hinthong, 1985).



Huai Pong unit ( $Tr_{an}$ ) consists dominantly of fine-grained andesites that occur as veins in the older rocks such as the marbles of Khao Phra Ngam unit and the hornblende diorite of Khao Pu Lon unit. Because of their cutting into the Triassic rocks, the unit may probably be Post- Triassic age.

Wat Mai Sophim2 Unit ( $An$ ) is composed of fine-grained, greenish gray to green andesitic tuff that overlie the Jurassic sedimentary rocks of Wat Mai Sophim1 unit. Thus, the unit may probably be post-Jurassic age.

Ban Bo Thong unit ( $Gd$ ) consists of medium to coarse- grained hornblende granodiorite and diorite that locally show porphyritic texture of hornblende and plagioclase feldspar phenocrysts. Because of cross cutting evidences to the Jurassic rocks, the unit may probably post-Jurassic in age.

### 2.2.3 Metamorphic rock units

Khao Phra Ngam unit ( $P_{mb}$ ) is white and pale gray marbles or crystalline limestone of the Khao Khok unit ( $P_{lst}$ ). Its contacts with the plutonic rocks have usually been metasomatically metamorphosed to be skarns where iron and copper deposits have been discovered.

Skarn unit ( $Sk$ ) is medium to course-grained, garnet-quartz-epidote-pyroxene-(wollastonite/diopsite)-calcite skarn containing quartz veinlets in their fractures. Additionally, their minor varieties are fine-grained, occasionally containing malachite and azurite in their fractures.

### 2.2.4 Unconsolidated Quaternary Sediments unit (Q)

The unconsolidated, Quaternary, sediments unit is commonly found at hill slopes and flood plain that cover approximately 70% of the area. The sediments are composed of colluvium sediments, residual, laterites and the alluvium sediments in flood plain.



From the comparisons, the carbonate successions found in the present study are remarkably similar in lithologic characters and associated fossils to the Khao Khok unit ( $P_{1st}$ ) which consists dominantly of bedded limestone with abundant fossils indicating Lower to Middle Permian age.

## 2.5 Geology of Khao Lamphean

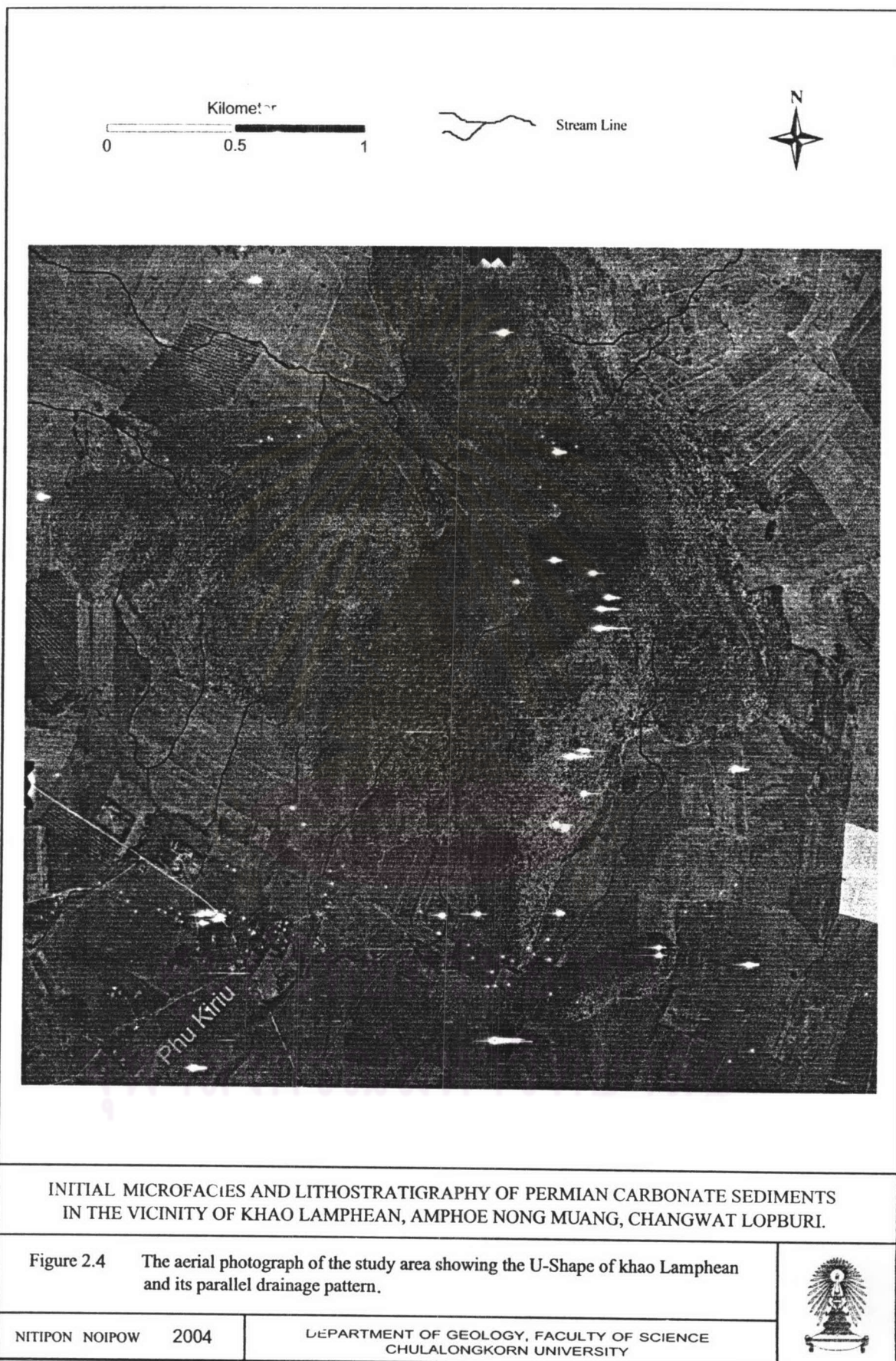
The study area is almost a square-shape, covering approximately 10 square kilometers, mountainous area which is occupied by an isolated hill namely Khao Lamphean. The Khao Lamphean is a karstic limestone hill with the U-shape like geometry that is orientating in the northwest-southeast direction. It is about 2 kilometers wide and 2 kilometers long with elevation about 470 meters (above MSL.) in its peak. It is surrounded by unconsolidated soil of rolling terrane with the average elevation of 200 meters (above MSL.).

The area is almost entirely covered by thin, mixed deciduous forest that mainly consists of bamboo trees in hilly areas being surrounded by areas of mixed crop fields in the hill slope and rolling plain.

The drainage system is obviously divided into two parts following its U-shape character. The inside drainage pattern displays a parallel pattern and Phu Sai is the main stream flowing northwestwardly. Whereas, the outside drainage pattern shows a parallel character. In the northeastern part they flow northeastwardly to Huai Phu Kachom, but in the southwestern part they flow southwestwardly to Phu Khiriu as illustrated in Figure 2.4.

### 2.3.1 General lithology

The limestones in the study area are well bedded as thinly to very thickly bedded with their average thickness of 0.5-2 meters. Generally their lithology are characterized by light gray to dark gray (predominantly dark gray) fossiliferous limestones. The grains are subrounded to sub-angular and quite well sorted. Their grain sizes range from fine to





coarse-grained with their majority being equivalent to sand and finer grain sizes, but occasionally granule and small pebble sizes are found as shown in Figure 2.5.

Microscopically, it almost represents by micritic rocks and can be identified as sparse biomicrite and packed biomicrite (Folk, 1959, 1962). The major grain components are bioclasts of which various marine fauna fragments, namely, forams, algals, ostracods, corals, bryozoans, echinoderms, some shell fragments and some other grains such as peloids.

Besides, argillaceous limestone were locally found especially in the western part of the study area. The siliceous rock locally occurred either as elongated and nodular black cherts. They scatter throughout the succession. Moreover rare evidences of dolomitic limestone are locally discovered as small pockets in the limestone.

### 2.3.2 Geological structure

The general structure of the limestones is characterized by gently inclined beds which almost regularly dipping to WSW direction. The strike directions commonly vary from  $165^{\circ}$ - $180^{\circ}$  and dip angles can be measured from  $5^{\circ}$ - $20^{\circ}$  with majorities of  $10^{\circ}$ - $15^{\circ}$ .

This seems to be a normal limb of an board anticline, which its fold axis orientates in the NNW-SSE direction probably being located in somewhere to the northeast of the study area. It is consistent with the suggestion of Phothong (1985) that explained the implication between major geological structures of the Saraburi Group in Saraburi - Lop Buri area and the overturn synclines-anticlines.

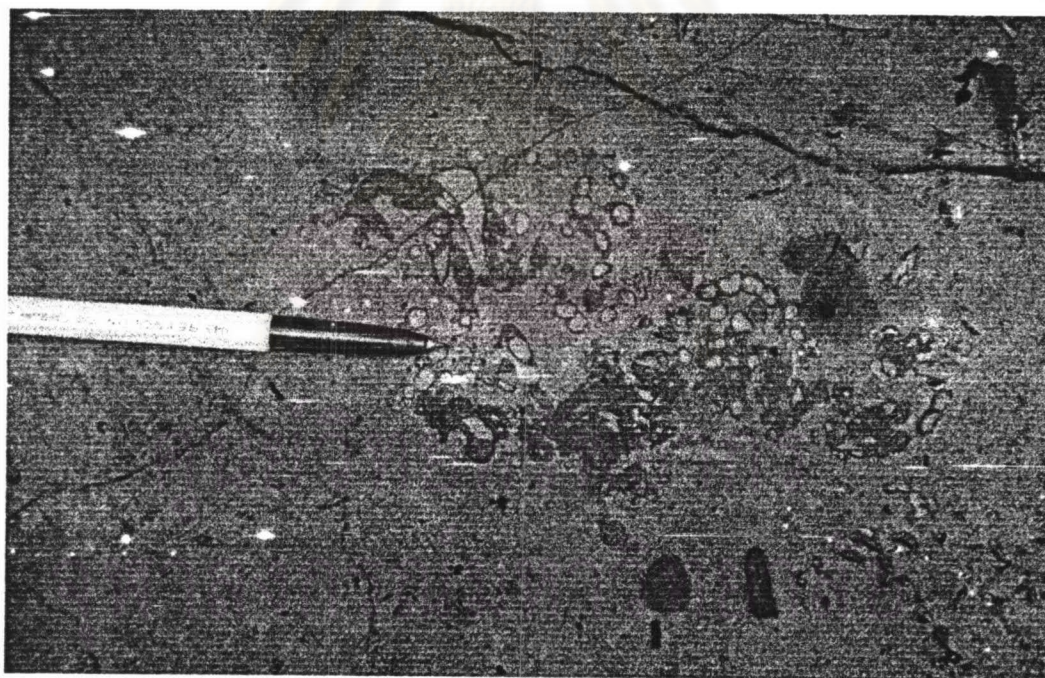
In addition, some minor warping occurred locally, as chevron-style symmetric syncline and anticline, at Ban Chon Muang to the southern part of the study area. The axis of folding plunges with low angle, about  $20^{\circ}$ , to the southern direction (Figure 2.6). Its hinge area is clearly angular and the rock around the hinge area was fractured, some beds were dislocated by a minor fault with its displacement of less than 1 meter. Fractures and joints in



(a)



(b)



**Figure 2.5** The characteristics of carbonate successions in study area; major strata characteristic of medium to thick-bedded with average thickness 0.5-1 meters (a), the eminent lithology of gray to dark gray fossiliferous micritic limestone (b) (grid ref. 743847).



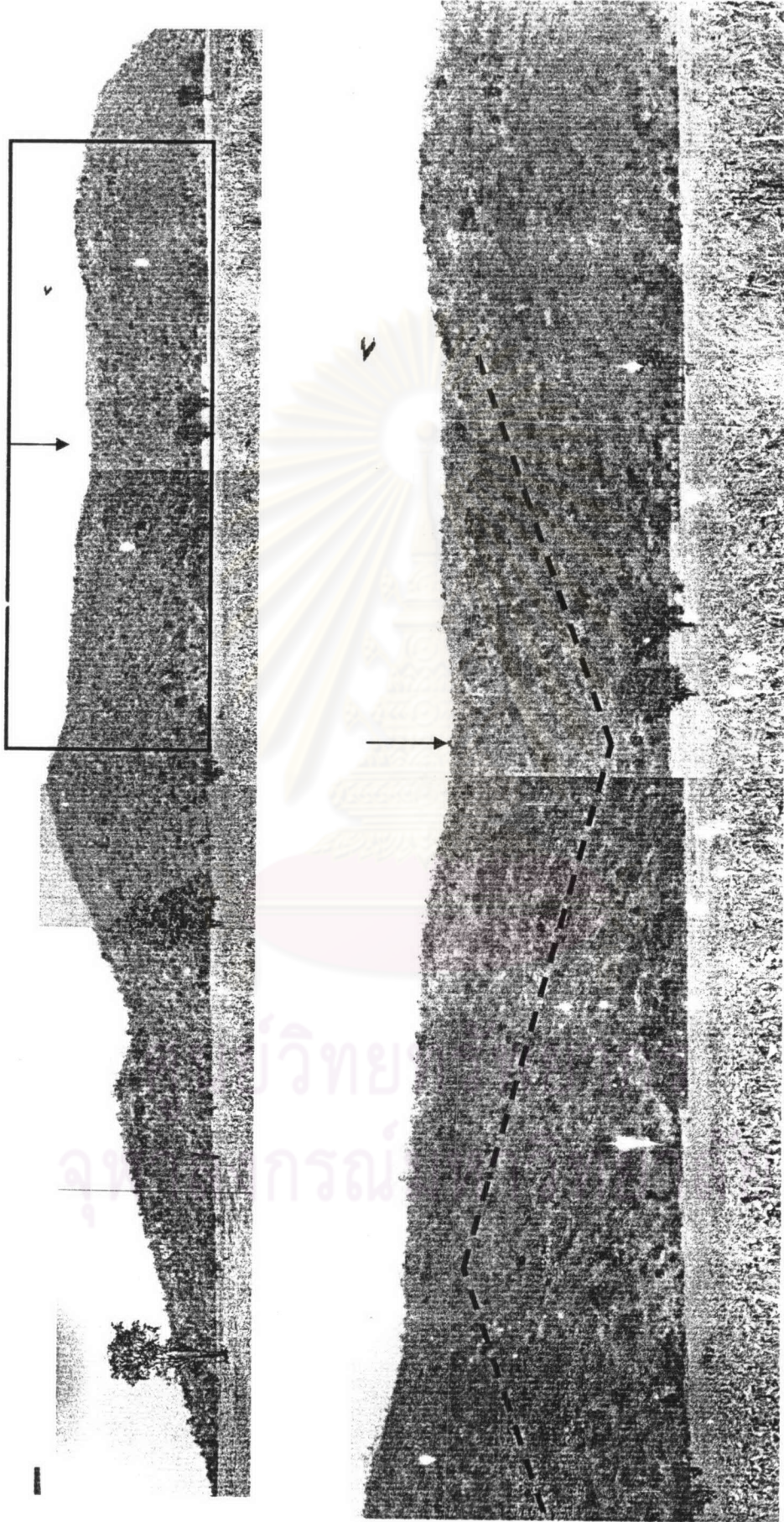


Figure 2.6 Chevron-style, minor folding at Ban Chon Muang located in the southern part of the study area (Photograph looked north).

the rocks are relatively rare. Accordingly, a summarized structural map of the study area is illustrated in Figure 2.7.

### 2.3.3 Faunas

The limestone in the study area are abundant in many types of fossils. The fossil assemblage comprises mainly of shallow marine faunas such as corals, algals, forams, gastropods, bivalves and brachiopods (Figure 2.8).

The most abundant faunas are the foraminifera including both of smaller forams and fusulinids. The fusulinids are very good index fossils in Permian Period and the excessive works from many Permian localities around the study area are excellent references. The fusuline assemblage is distinctively associated with middle Permian fusulinacean of the Family Neoschwagerininae and Verbeekinae.

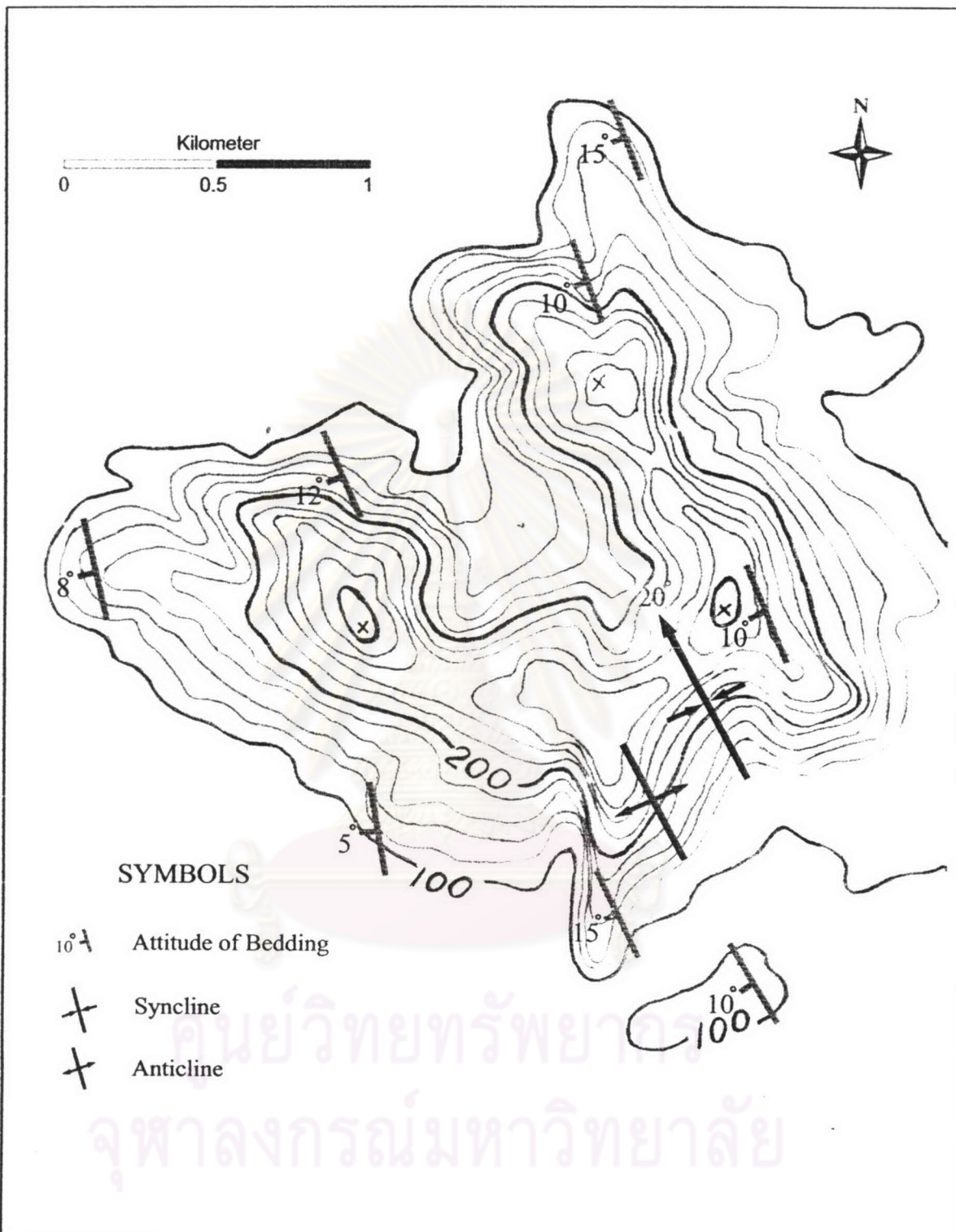
The corals are quite well preserved consisting dominantly of massive rugose corals, some fasciculate rugose and tabulate corals, which are commonly found in the middle Permian strata of Thailand.

The details of studying faunas will be present in Chapter III.

### 2.3.4 Stratigraphic Nomenclature

Stratigraphically, the limestones of Khao Lamphean were previously mapped as the Tak Fa formation (Nakornsri, 1977, and 1981) and later as Khao Khok rock unit (Yavichai, 1993) of Lower to Middle Permian age. However, the Permian carbonate rocks in the present study may be referred to as the Tak Fa formation and conceded in the Saraburi Group. The upper boundary of the formation was reported to be uncomformably underlying Permo-Triassic volcanic rocks that was distinctly found at Wat Mai Sophim (Fontaine and Suteethorn, 1994 and Yavichai, 1993), 10 km. to the north of the study area, but there is no evidence of the younger and older units discovered in the present investigation.





INITIAL MICROFACIES AND LITHOSTRATIGRAPHY OF PERMIAN CARBONATE SEDIMENTS IN THE VICINITY OF KHAO LAMPHEAN, AMPHUE NONG MUANG, CHANGWAT LOPBURI.

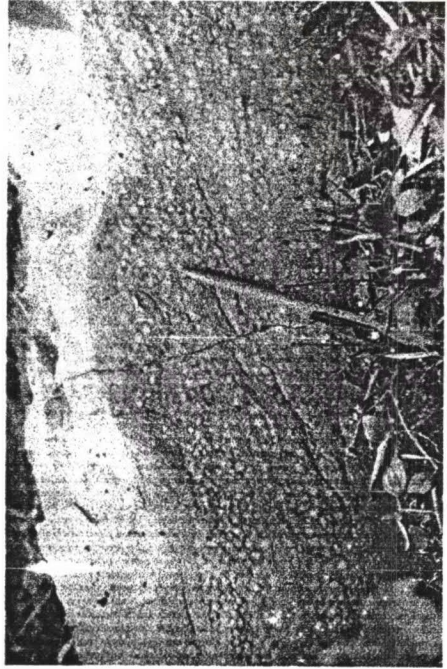
Figure 2.7 The structural map showing some minor warping and attitudes of bedding observed in the study area.



(b)



(a)



(d)



(c)

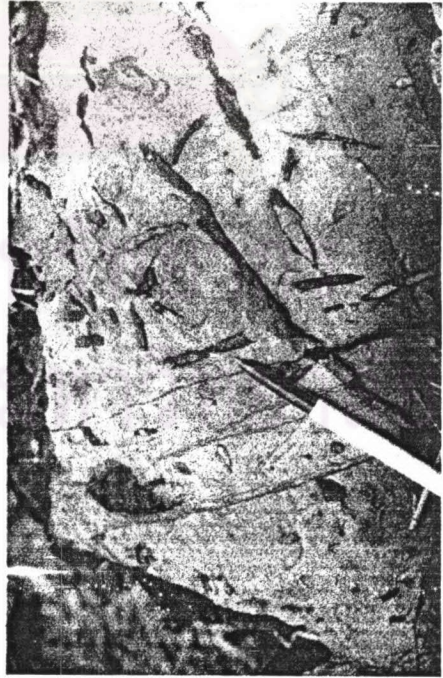


Figure 2.8 The major faunas found in the study area; fusulinids of various species occurred in grain supported fabrics (a), massive rugose corals (b), branched algae (c), giant bivalves (d).



Furthermore, there is an evidence of the younger andesitic dike occurring in the eastern part of the study area. The dikes crosscut into the Permian rocks at low angle. These volcanic dikes of andesitic compositions were previously reported to be the Permian-Triassic volcanics of the Khao Wong Phra Chan Rock Unit (Yavichai, 1993). Unfortunately, the contact between the dike and its country rock is not clearly observed due to covering of top soil.

Accordingly, a preliminary geological map of the study area, prepared by the initial field information is illustrated in Figure 2.9.



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