CHAPTER II

GEOLOGY AND STRATIGRAPHY

The study area is situated in three districts including Amphoe Ta Khli, Amphoe Tak Fa and Amphoe Phrayuha Khiri, eastern part of Changwat Nakhon Sawan. Carbonate map of the study area is map sheet: Changwat Nakhon Sawan, ND 47-3, scale 1:50,000 (DMR, 1995) and is illustrated in Figure 2.1. The rock in the study area consists of Permian carbonate rock of the Tak Fa formation of Saraburi Group (previously names as Ratburi Group) ranging in age from Lower to Middle Permian (Yakhtashian-Kungurian).

2.1 General Geology

The Saraburi Group

Bunopas (1981) and Hinthong *et al.* (1985) erected Saraburi Group, for the sequence of limestone and clastic rocks occurring on the Indochina terrane i.e. on the eastern side of lower Chao Phraya central plain from south of Nakhon Sawan, passed U-thai Thani to Saraburi, and also on the western edge of the Khorat Plateau from Loei, south to Saraburi. The Saraburi Group was previously mapped as the Rat Buri Group (Brown *et al.*, 1951; Javanaphet, 1969; Nakornsri, 1977). Later in 1992, Bunopas generalized the stratigraphic name for Thailand into seven longitudinal stratigraphic belts based on tectonic provinces and evolution concept of the Shan-Thai and Indochina terranes. He also located the Saraburi Group in the VI belt (Figure 2.2 and Table 2.1).

In order to serve a background of the present study, general stratigraphy of Saraburi Group on the Chao Phraya central Plain has been reviewed as follows:

The Saraburi Group in Nakhon Sawan-Lop Buri area

According to previous investigation of Nakornsri (1977, 1981), the Saraburi Group in the Nakhon Sawan-Lop Buri area is subdivided into 2 formations on the basis of their lithology and fossils assemblages. Two formations are composed of the Tak Fa formation and Khao Luak formation, in ascending order.

(1) Khao Luak formation

The Khao Luak formation consists of well-bedded, green and grey sandstone, brownish-grey shale and thin limestone bands. The beds generally strike N-S and dip into both east and west. Overturning of strata is found locally. This formation exposed in a long narrow trend of more or less N-S direction at Lop Buri area. Fossils found in this formation indicated the Lower Permian (Sakmarian to Artinskian).

(2) Tak fa formation

The type section is located at Amphoe Tak fa, Changwat Nakhon Sawan. This formation consists mainly of massive locally to well bedded fossiliferous limestones, grey to bluish grey limestone; sandstone and shale. Fossils found in this formation are fusulinoideas, brachiopods, corals, ammonoids and bryozoans. Fusulinoidean species *Verbeekina verbeeki* and *Parafusulina* sp, indicated Middle Permian age. They are commonly found in this formation. In the Changwat Nakhon Sawan map sheet, Tak Fa formation is exposed at three isolated groups of hills characterized by karst topography in Amphoe Ta Khli, Amphoe Tak Fa and Amphoe Phrayuha Khiri, eastern part of Changwat Nakhon Sawan. This formation ranges from Artinskian to Kungurian. It is bounded by unconformity in the upper part.

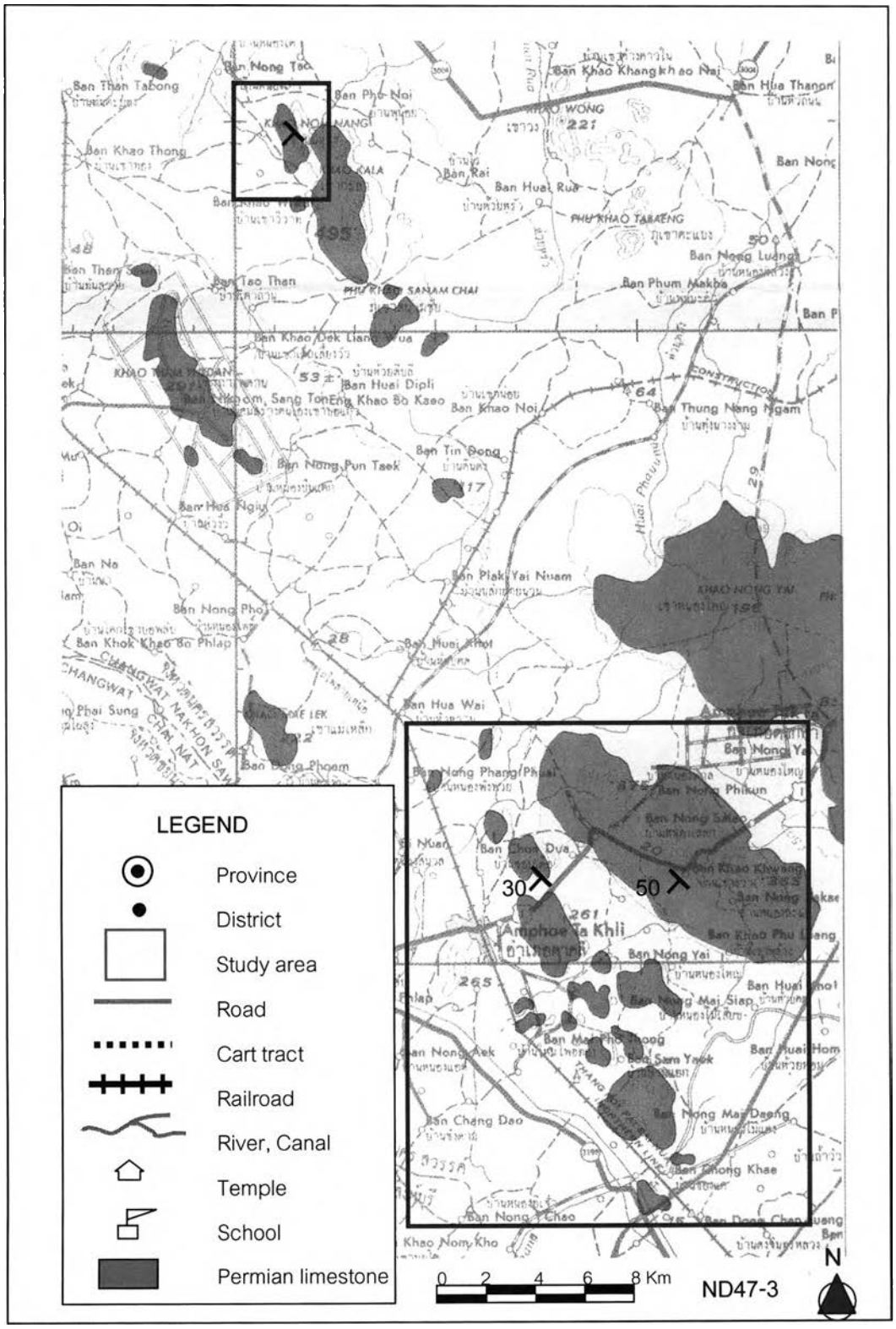


Figure 2.1 Carbonate map of Changwat Nakhon Sawan 1:50,000 (DMR, 1995).

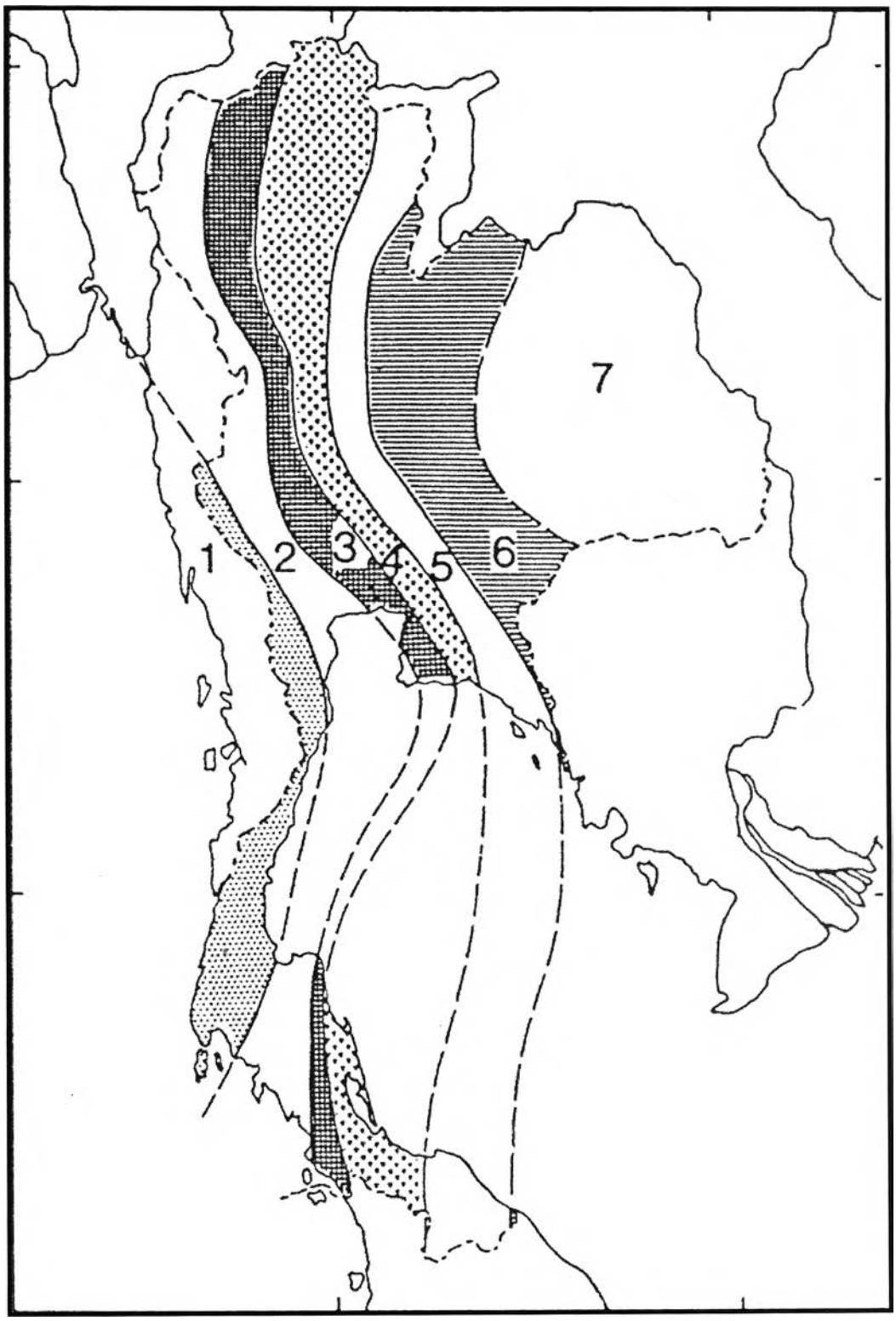
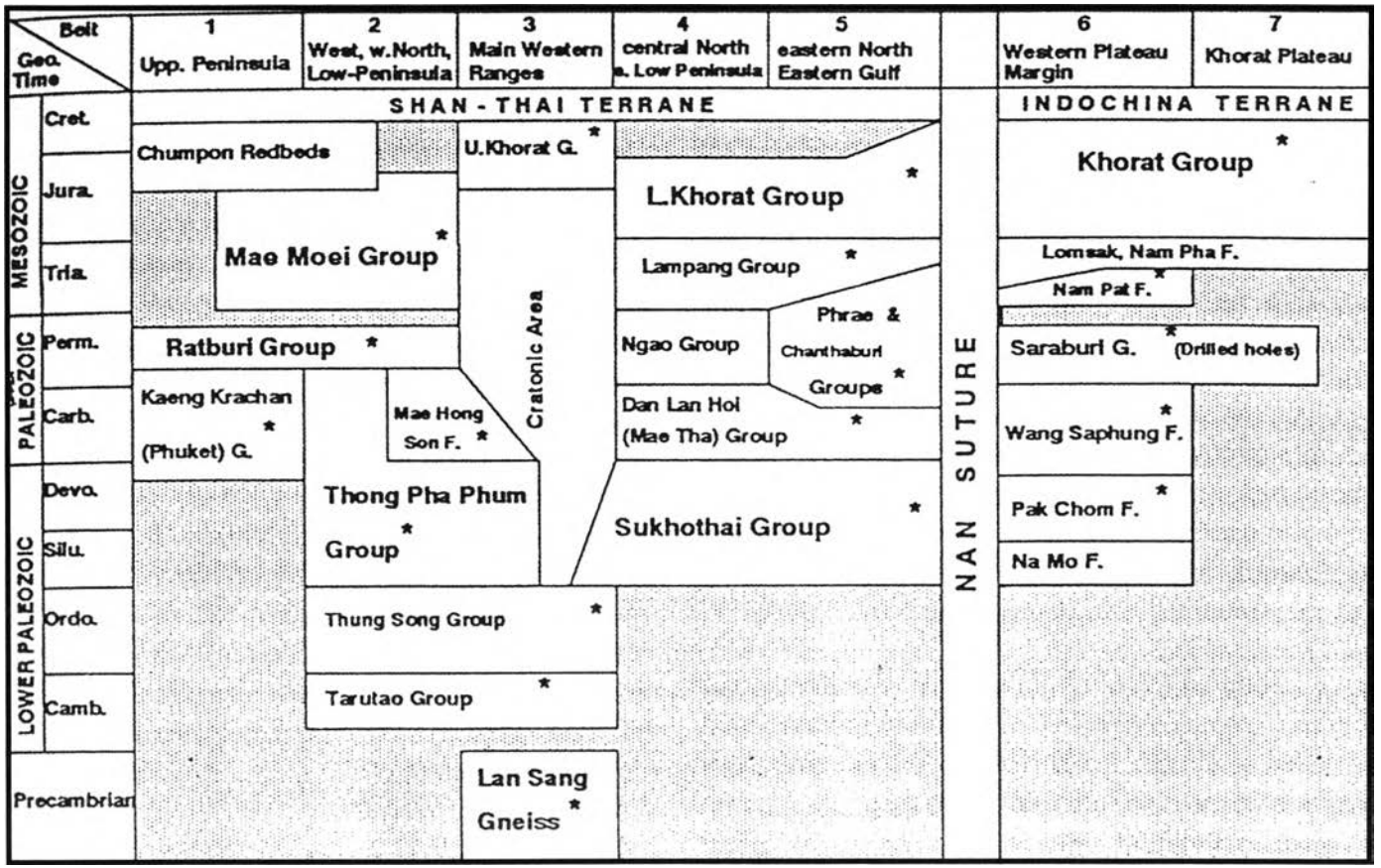


Figure 2.2 Seven longitudinal stratigraphic belts of Thailand: 1-5 on Shan-Thai and 6-7 on Indochina terranes (Bunopas, 1992).

Table 2.1 Generalized stratigraphic nomenclatures for Thailand within the seven stratiraphic belts on Shan-Thai and the Indochina cratons divided by the Nan Suture. Name with (*) are adopted by the DMR in new 1:2,500,000 geologic map.



The Saraburi Group in Saraburi area

The Saraburi Group in Saraburi area is composed of six formations: Phu Phe, Khao Khwang, Nong Pong, Pang Asok, Khao Khad and Sab Bon in ascending order (Hinthong *et al.*, 1985). These formations are described as follows:

(1) Phu Phe Formation

The Phu Phe Formation consists mainly of pinkish grey to very dark grey limestone with chert in tabular nodules parallel with bedding and partially intercalated with slate shale at some part. Their base was upthrusted on the Sab Bon Formation (metasedimentary rocks). The type section is located at Khao Phu Phe and Khao Krom Thang, km 131-132, east of Friendship Highway, totally 593 m thick. Fusulinoideas found in this formation indicated Sakmarian age such as *Pseudoschwagerina* cf. *toriyamai*, *Pseudoschwagerina turbida*, *Pseudoschwagerina* sp., *Paraschwagerina* sp., *Pseudofusulina* sp., *Minojaponella* sp., *Schubertella* sp., *Triticites* cf. *ellipsoidalis*.

(2) Khao Khwang Formation

This Formation consists of black, dark to light grey limestone with chert nodules, locally dolomitic, intercalated with pinkish brown and greenish grey shale, sandstone, tuffaceous sandstone and volcanic rocks. The type section is located at Khao Khwang, Changwat Saraburi, totally 490 m thick. Fusulinoideas discovered from this formation indicated Sakmarian age such as *Charaloschwagerina* sp., *Paraschwagerina* sp., *Pseudoschwagerina turbida*, *Pseudodoliolina* sp.

(3) Nong Pong Formation

The Nong Pong Formation is characterized by banded grey to greenish grey limestone, dark grey to grayish brown shale, grey to very dark grey, thin to thick bedded limestone, interbedded with brownish grey shale. In middle part, the rocks consist of grey to brown shale interbedded with grey to dark grey limestone grading upward to well bedded, grey limestone. And in upper part, the rocks consist of grey to brownish grey shale intercalates with grey to dark grey limestone. The total thickness of this

formation is 673 m. The type section is located at east of Khao Khwang. Fusulinoideas found in this formation are *Cancellina* sp., *Neofusulina* sp., *Pseudodoliolina* sp., *Pseudofusulina* sp., *Thailandina buravasi* and *Verbeekina* sp. They indicated Artinskian to Kungurian age.

(4) Pang Asok Formation

The Pang Asok Formation is devided into 3 parts: lower, middle and upper parts. In Lower part, the rocks consist mainly of greenish grey to pale reddish brown sandstone, intercalated with shale, pale reddish brown shale, interbedded with ligh greenishgrey arkosic sandstone, pale reddish brown shale, intercalated with brownish grey limestone. In middle Part, the rock is mostly grey to greyish brown shale. In upper part, the rocks are brown to dark grey shale, slaty shale, intercalated with greenish grey lenticular arkosic sandstone. The type section of this formation is located at Pang Asok village, near Pang Asok railway station, totally 366 m thick. Fossil is rarely found in this formation.

(5) Khao Khad Formation

The Khao Khad Formation consists of very dark grey to black limestone, recrystalline and argillaceous limestone and dolomite, nodular and bedded chert intercalated with shale and sandstone, rare volcanic rocks, locally marble and calcsilicate rocks. The type section of this formation is located at Khao Khad, Amphoe Phra Phuttabat Changwat Saraburi: Its thickness is about 1812 m. Fossil are abundant in this formation such as fusulinoideas, brachiopods, gastropods, ammonoids, bryozoans and crinoid. They indicate Artinskian to Kungurian in age. More than 100 species of fusulinoideas in this formation were reported by Toriyama (1975) and Titirananda (1976). They suggested that the Khao Khad Formation can be correlated with Tak Fa formation in the Lop Buri-Nakhon Sawan area.

(6) Sap Bon Formation

The Sap Bon Formation is characterized by grey to brown tuffaceous sandstone, siltstone, shale and chert intercalated with grey limestone. In upper part of the formation, the rocks consist of light grey to dark grey, thin-bedded, recrystalline limestone interbedded with light brown to rusty brown shale and siltstone. The type section is located at Ban Sap Bon Teak Plantation, Bon Sok Luk and Huai Sap Tai, Amphoe Muak Lek Changwat Saraburi. The total thickness is 1,103 m. *Agathiceras* sp. is usually found in this formation. *Pseudofusulina* sp., *Colania* cf. *douvillei*, *Neoschwagerina* cf. *magaritae* and *Minojapanella* sp. found in this formation indicate Kungurian to Wordian.

2.2 Geology and stratigraphy of the study area

The study area is located within Tak Fa formation of Saraburi Group (Nakornsri, 1976). The study area covers 12 localities: 2 stratigraphic sections (Khao Look Klone and Khao Noi) and 10 isolated samples (Figure 2.1, 2.3 and 2.4). The rocks are mainly composed of thickly bedded and massive limestones.

2.2.1 Khao Look Klone (Location KLK)

Khao Look Klone is a quarry in Amphoe Ta Khli. The strata were measured at the east of Khao Look Klone (UTM 648700 E 1690400 N) where the limestones are good exposures and continuous sequence. The mainly strikes of bedding are 125^{o} and dipping 30^{o}to the southwest direction. The stratigraphic section of Khao Look Klone is shown in Figure 2.5. The thickness of the section is approximately 42 m. I systematically collected the carbonate sample every 1 m through the section. The rocks are composed of thin to thick bedded, dark grey bioclastic wackestone to packstone intercalated with thin black shale in some part especially in lower part. Fusulinoideas are abundant only in lower and middle parts. They are very rare in the upper part. The distribution of fusulinoideas at Khao Look Klone shows in Figure 2.7. They are *Staffella* sp., *Pseudostaffella* sp., *Nankinella* sp., *Schubertella* sp., *Ozawainella* sp. and *Pseudofusulina* sp. These fusulinoideas indicate Yakhtashian or Artinskian age.

Moreover, the carbonate rocks also contain smaller foraminifers, algae, crinoid and shell fragments.

2.2.2 Khao Noi (Location KN)

The carbonate strata in the western part of Khao Noi (UTM 653000 E 1690400 N) were measured. The attitudes of beddings are 170° strike and 50°dip to southwest direction. The Khao Noi section is about 25 m thick (Figure 2.6). In this section, I systematically collected the carbonate sample every 1 m through the section. The rocks are composed of thick to very thick bedded, bioclastic wackestone to packstone. They are prolific with fusulinoideas, algae, smaller foraminifers, crinoids and shell fragments. Fusulinoideas were found abundantly throughout the section. The distribution of fusulinoideas at Khao Noi shows in Figure 2.8. They are *Misellina* sp., *Maklaya* sp., *Neothailandina* sp., *Pseudofusulina* sp., *Chusenella* sp., *Neofusulinella* sp., *Schubertella* sp. and *Nankinellla* sp. The occurrence of Misellina indicates Bolorian or Kungurian (early Middle Permian).

According to previous investigation, *Misellina* were found at Khao Phlong Phrab, Changwat Saraburi (Toriyama *et al.*, 1974) indicate Artinskian age. Later Dawson and Racey (1993) report fusulinoidean assemblage zone from Saraburi Limestone, *Misellina* zone indicate Bolorian age. Wielchowsky and Young (1985) reported *Misellina termieri* (Deprat) and Misellina confragaspira (Leven) from Phu Pha Daeng. These indicate Artinskian age.

Due to ten localities are not continuous exposures of limestone and some localities are covered by vegetation, thus, the sampling method of ten isolated localities of carbonates yielding fusulinoidea is random isolated sample (hand specimen) of each locality.

Ban Hua Khao (Location TK 1)

The isolated hill of Ban Hua Khao (UTM 650000 E 1692100 N) is light grey limestones. They are abundant fossil such as fusulinoideas, brachiopods and ammonoids. Microscopically, the rock is bioclastic wackstone. It is composed of seven

fusulinoidean genera: *Pseudofusulina* sp., *Parafusulina* sp., *Yangcheinia* sp., *Pseudodoliolina* sp., *Neothailandina* sp., *Afghanella* sp. and *Neoschwagerina* sp. These fusulinoideas indicate Murgabian or Wordian. They were found together with shell fragments, smaller foraminifers and algae. The interior of bioclasts have been occluded by sparry calcite.

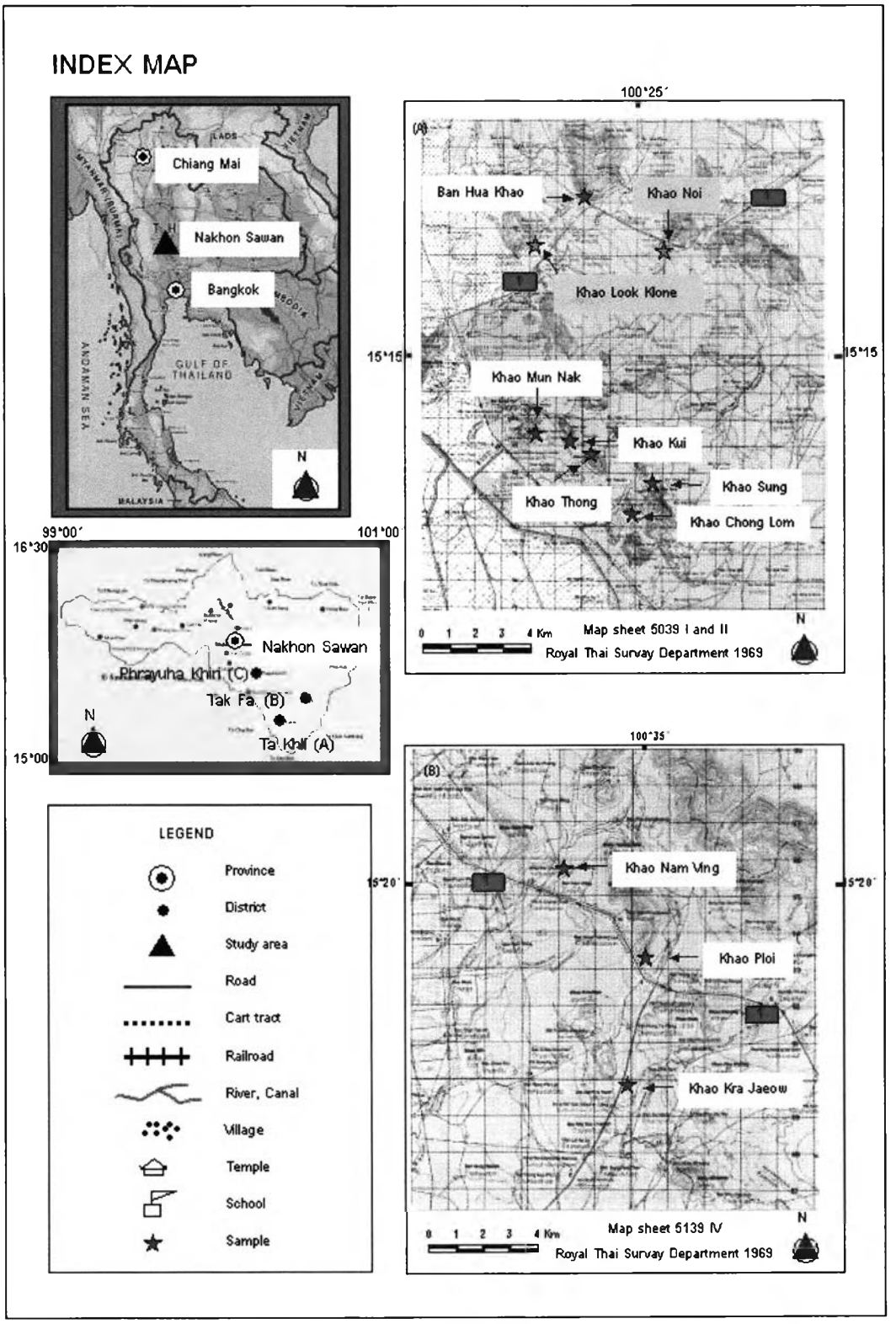


Figure 2.3 Topographic map of the investigated areas.

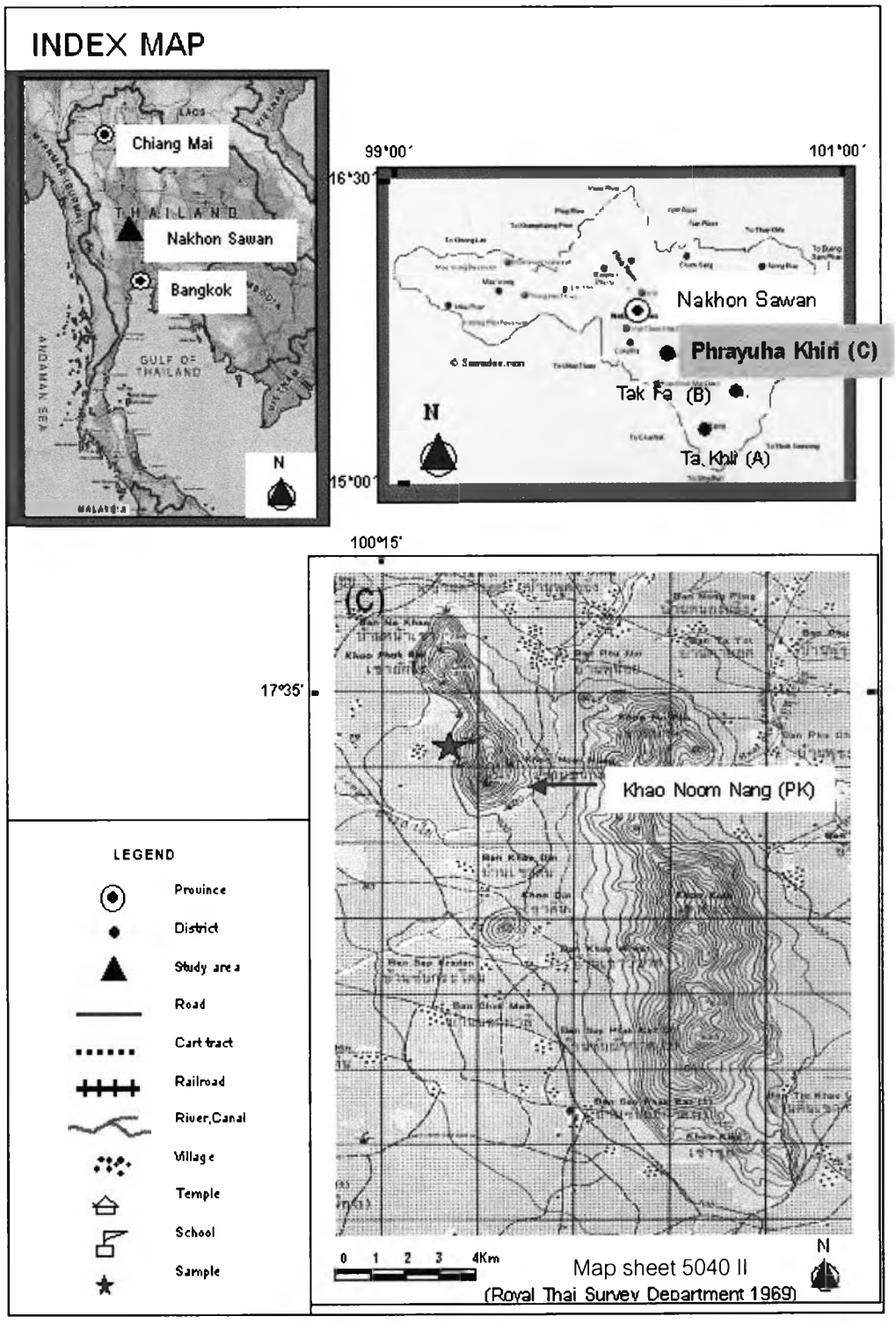


Figure 2.4 Topographic map of the investigated area.

Figure 2.5 Khao Look Klone section.

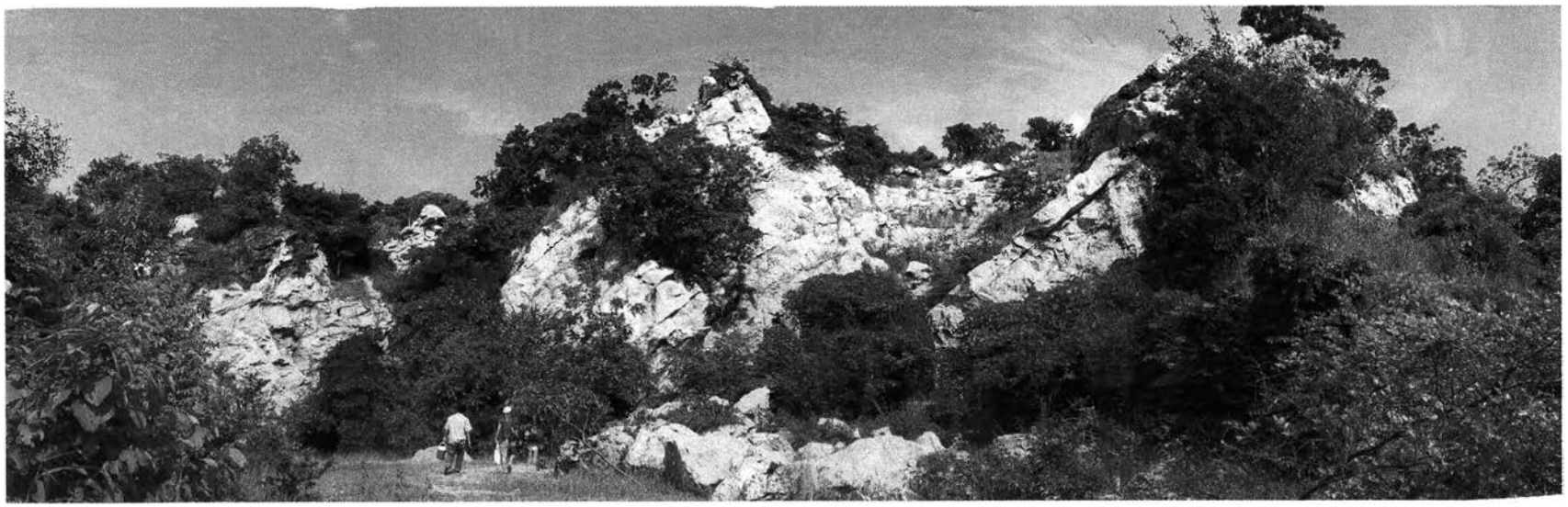


Figure 2.6 Khao Noi section.

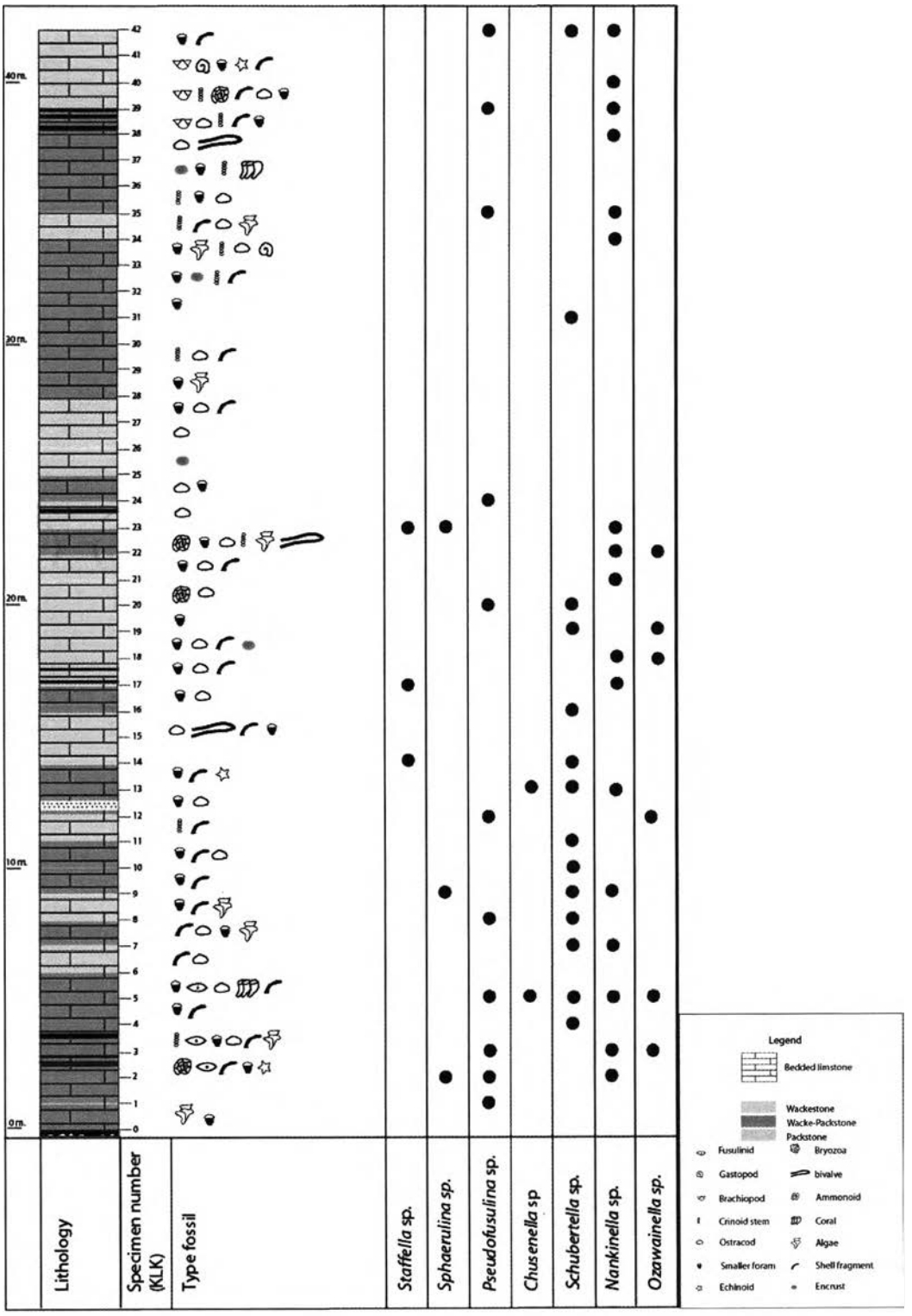
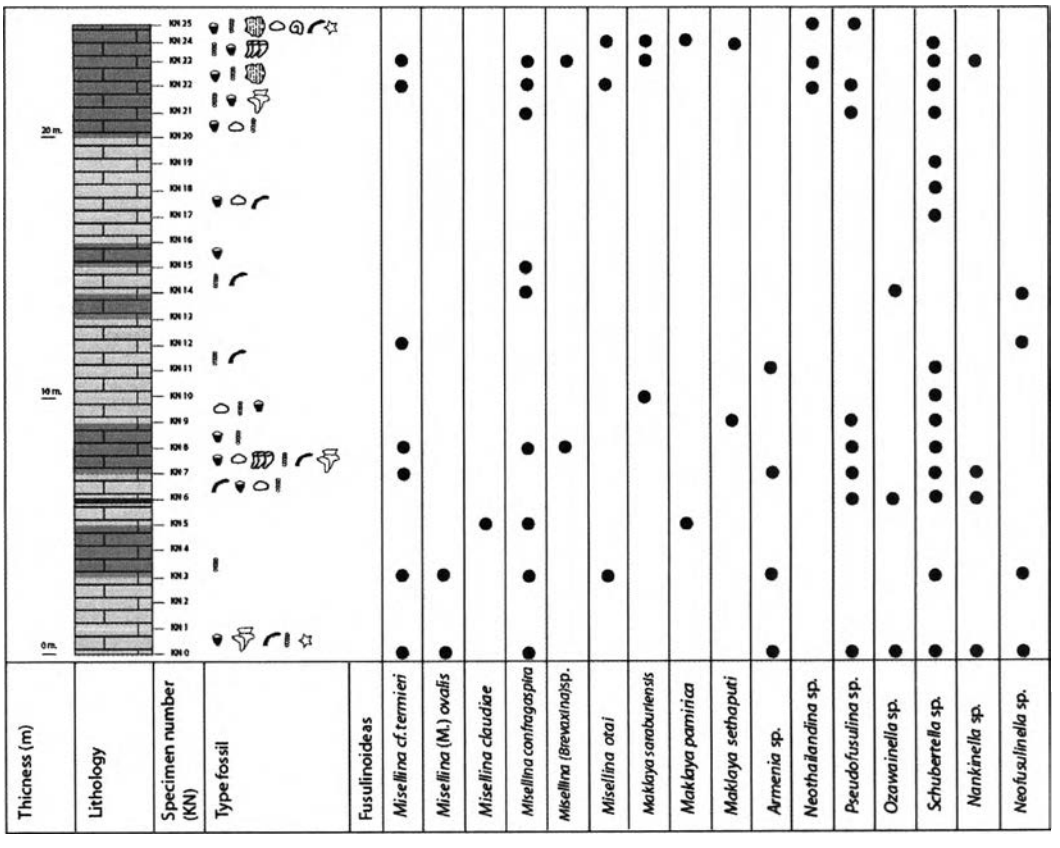


Figure 2.7 Stratigraphic section and distribution of fusulinoidean fauna from Khao Look Klone section.



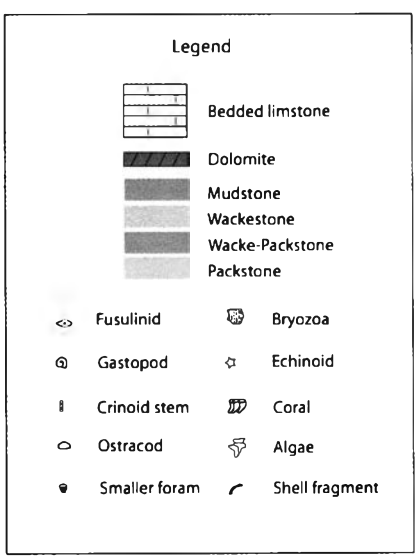


Figure 2.8 Stratigraphic section and distribution of fusulinoidean faunas from Khao Noi section.

2.2.3 Khao Mun Nak (Location TK 2)

The isolated hill of Khao Mun Nak (UTM 648100 E 1683500 N) is characterized by medium grey limestone. Fossils found in the outcrop are fusulinoideas and corals. Microscopically, the rock is bioclastic wackstone to packstone. It consists of Murgabian or Wordian fusulinoidea such as *Pseudofusulina* sp., *Parafusulina* sp., *Pseudodoliolina* sp., *Verbeekina verbeeki* and *Afghanella* sp. They were found together with smaller foraminifers and algae.

2.2.4 Khao Kui (Location TK 3)

The isolated locality at Khao Kui (UTM 649500 E 1683200 N) is medium grey limestone. The fossils found in this limestone are fusulinoideas and crinoids. Microscopically, the rock is bioclastic wackstone. Its contains only two genera of fusulinoidea: *Chusenella* sp. and *Lepidolina* sp. Smaller foraminifers and algae were also found. *Lepidolina* is the characteristic fauna of Midian. Therefore, the carbonate yielding *Lepidolina* sp. in this locality is Midian or Capitanian (upper Middle Permian) age.

2.2.6 Khao Thong (Location TK 4)

Small isolated hill at Wat Khao Tong (UTM 650400 E 1682800 N) is medium grey limestone. Microscopically, the rock is bioclastic wackstone to packstone. It consists of fusulinoidea three species belong to *Pseudofusulina* sp., *Chusenella* sp. and *Lepidolina* sp. These fusulinoideas indicate Midian or Capitanian. They were found together smaller foraminifers.

2.2.7 Khao Sung (Location TK 5)

The isolated locality at Khao Sung (UTM 652500 E 1681800 N) is medium grey limestone. The fossils found in this limestone are fusulinoideas. Microscopically, the rock is bioclastic wackstone. It consists of Kubergandian or Roadian age fusulinoidea such as *Pseudofusulina* sp. and *Skinnerella* sp. Smaller foraminifers were also found.

2.2.8 Khao Chong Lom (Location TK 6)

The isolated locality at Khao Chong Lom (UTM 651900 E 1680600 N) is characterized by light grey limestone. Fossils found in the outcrop are fusulinoideas. Microscopically, the rock is bioclastic wackstone. It consists of three genera of fusulinoidea: *Chusenella* sp., *Verbeekina verbeeki* and *Lepidolina* sp. The carbonate yeilding *Lepidolina* sp. in this locality is Midian or Capitanian age. They were found together with smaller foraminifers.

2.2.9 Khao Nam Ving (Location TF 1)

The isolated locality at Khao Nam Ving (UTM 667900 E 1696000 N) is medium to dark grey limestone. They are abundant fossil such as fusulinoideas, gastropods, corals and anatoconcha. Microscopically, the rock is bioclastic wackstone. It is composed of six fusulinoidean genera: *Pseudofusulina* sp., *Pseudofusulina* sp., *Verbeekina* sp., *Yangcheinia* sp., *Neoschwagerina* sp., *Afghanella* sp. The age of this limestone is Murgabian or Wordian age based on fusulinoidea. They were found together with crinoids.

2.2.10 Khao Ploi (Location TF 2)

The isolated locality at Wat Tam Porn Sawan (UTM 670500 E 1693000 N) is characterized by medium grey limestone. Fossils found in the outcrop are fusulinoideas. Microscopically, the rock is bioclastic wackstone to packstone. It consists of Midian or Capitanian fusulinoidea: *Chusenella* sp. and *Lepidolina* sp. Algae, shell fragment and smaller foraminifera were also found.

2.2.11 Khao Kra Jaeow (Location TF 3)

The isolated hill of Khao Kra Jaeow (UTM 669600 E 1690700 N) is dark grey limestone. They are abundant fossil such as fusulinoideas, gastropods, corals and crinoids. Microscopically, the rock is bioclastic wackstone. It is composed of three fusulinoidean genera: *Colania* sp., *Neoschwagerina* sp. and *Sumatrina* sp. These fusulinoideas indicate Midian or Capitanian age.

2.2.12 Khao Nom Nang (Location PK)

The isolated locality of Khao Nom Nang (UTM 636600 E 1722200 N) is medium gray, thick-bedded limestone with NW-SE strike and dipping W. In the field, the fusulinoideas can generally be observed. Microscopically, the rock is bioclastic wackstone. It is consists of *Verbeekina* sp., *Sumatrina* sp. and *Colania* sp. These fusulinoideas indicate Midian or Capitanian age.