



## PERMIAN LITHOSTRATIGRAPHY OF THE SHAN-THAI TERRANE IN THAILAND: REVISION OF THE KAENG KRACHAN AND RATBURI GROUPS

Pol Chaodumrong<sup>1</sup>, Wang Xiangdong<sup>2</sup> and Shen Shuzhong<sup>2</sup>

<sup>1</sup>, Department of Mineral Resources, Bangkok 10400, Thailand

<sup>2</sup>Nanjing Institute of Geology and Palaeontology, Nanjing 210008, P.R. China

### ABSTRACT

*Permian strata of the Shan-Thai terrane in Thailand consist of the clastic sequence of the Kaeng Krachan Group and the conformably overlying carbonate sequence of the Ratburi Group. However, the constituent formations of the former were used in different ways, while formation names in the latter are in an initial stage and only applied in limited areas. During the last few years, detailed stratigraphic and paleontological work and reviews from Kanchanaburi through southern Thailand have been carried out. As a result, the lithostratigraphy of both the Kaeng Krachan and Ratburi Groups are revised. The Kaeng Krachan Group, ranges in age from the Asselian to Kungurian and consists of 5 formations, in ascending order, the Laem Mai Phai, Spillway, Ko He, Khao Phra and Khao Chao. The Ratburi Group ranges in age from the Roadian to Wuchiapingian and comprises 5 formations, in ascending order, the Thung Nang Ling, Khao Muang Krut Sandstone, Phap Pha, Phanom Wang, and Um Luk. In most areas, the group commences with thin to medium bedded limestone of the Phap Pha Formation and is conformably overlain by massive limestone of the Um Luk Formation. The Permian stratigraphy of the Kaeng Krachan and Ratburi Groups can be traced widely from Malaysia, through peninsular Thailand, Myanmar, West Yunnan, to Lhasa.*

**Key words:** Permian lithostratigraphy, Kaeng Krachan Group, Ratburi Group, hiatus, Shan-Thai terrane, glaciomarine, dropstone

### INTRODUCTION

The purpose of this paper is to clarify the stratigraphy of the Kaeng Krachan and Ratburi Groups. During the last few years, we have investigated in detail 22 measured stratigraphic sections as well as reviewed the published paleontology on the Kaeng Krachan (also called Phuket Group) and Ratburi Groups from Kanchanaburi southward to Phuket. The term Kaeng Krachan is used and subdivided differently by various authors. For example, the "Khao Phra Formation" of Piyasin (1975), Raksaskulwong and Wongwanich (1993), and Department of Mineral Resources (1999) have different meanings (Table 1). In order to minimize nomenclatural confusion, it is necessary to revise the stratigraphic classification of the Kaeng Krachan Group by following the guidelines in the International Stratigraphic Guide (Hedberg, 1976). The carbonate sequence of the Ratburi Group, on the other hand, has long been mapped as a single unit without subdivision into constituent formations. Chaodumrong et al. (1998) were the first to demonstrate that the carbonate sequence of the Ratburi Group could be subdivided into formations and mapped on 1:50,000 scale. Later, Chaodumrong, et al. (2004) showed that stratigraphic units of both groups are mappable and correlate able across the Shan-Thai terrane which had been implemented in geological maps at 1:50,000 scale of southern

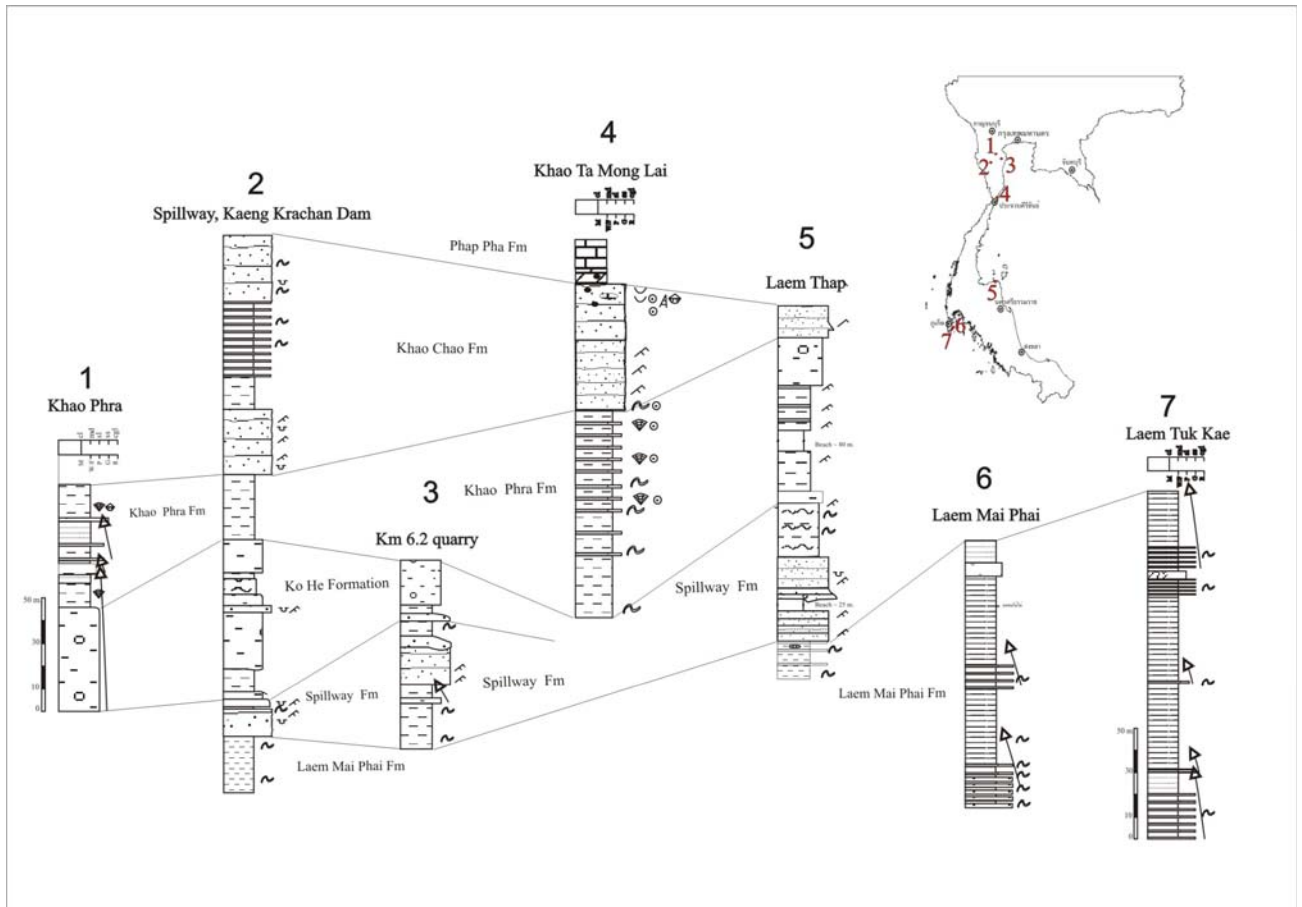
Thailand accomplished in 2005 (e.g. Boonkanpai, 2005) after the great tragedy tsunami in December 26, 2004.

### PROPOSED LITHOSTRATIGRAPHIC NOMENCLATURE FOR THE KAENG KRACHAN GROUP

The name "Kaeng Krachan Group" of Piyasin(1975) is favored here due to it being widely used. It is redefined here as that sequence of thin to medium bedded sandstone and mudstone, pebbly rocks, mudstone and quartz-rich sandstone, ranging in age from Asselian to Kungurian (Lower Permian) outcropping in the Shan-Thai terrane. Its lower boundary has not been observed, and it is overlain conformably by carbonates of the Ratburi Group. It consists of 5 formations, in ascending order, the Laem Mai Phai, Spillway, Ko He, Khao Phra and Khao Chao (Table 1 and Fig. 1). However, the Spillway Formation occurs locally. Lower part of the group was deposited by gravity flow sediments, possibly in submarine fan environment, in outer shelf and basin plain areas under glaciomarine conditions as indicated by abundant *Cruziana* ichnofacies and rare dropstones. The upper part was shallow marine with occasional storm deposits.

*Table 1 Stratigraphic nomenclature development of the Kaeng Krachan Group*

Piyasin (1975)		Hills (1989)		Raksaskulwong and Wongwanich(1993)		Dept Mineral Resources(1999)		This Paper	
Gr	Fm	Gr	Fm	Gr	Fm	Gr	Fm	Gr	Fm
Kaeng Krachan	Khao Chao 270-760 m	Phuket	Ao Loh Dalum	Kaeng Krachan	Khao Phra 120 m	Kaeng Krachan	Khao Chao	แก่งกระจาน (Kaeng Krachan)	เขาเจ้า Khao Chao
	Khao Phra 344-520 m		Ko Lon		Ko He 120 m		Khao Phra		เขาพระ Khao Phra
	Huai Phu Noi 205-480 m		Laem Mai Phai		Spillway 120 m				เขาเส Ko He
			Khao Wang Kradat 104 m				Laem Mai Phai	สปีลเวย์ Spillway	
								เขื่อนไม่ไฟ	



*Figure 1 Lithostratigraphic correlations of the Kaeng Krachan Group*

## Laem Mai Phai Formation

The name Laem Mai Phai Formation of Hill(1989) is adopted here. It is well exposed on the Phuket island where it is 120 meters thick at its type section at Ban Laem Mai Phai. It is characterized by at least 2 cycles of fining upward sequences that were deposited by turbidity currents. Thin bedded sandstone and mudstone with sandstone to mudstone ratio around 2:1 to 1:1 occurred in the lower part of the sequence (Fig. 2a). Bedding consists mostly of wavy and parallel type. Bioturbation of *Cruziana* ichnofacies are common in this part (Fig. 2b). Sandstone decreases in proportion upward and changes to

laminated mudstone in the upper part of the sequence (Fig. 2c). There are occasional slumped beds and rare dropstones (Fig. 2d). Raksaskulwong and Wongwanich (1993) reported “distorted brachiopod” as *Spirifer* sp. and *Spinomartinia* sp. from eastern side of the Laem Mai Phai and assigned to be Early Carboniferous- Early Permian. However, these fossils were identified from many places in southern Thailand and Malaysia to be Early Permian (Grant, 1976; Waterhouse, 1981; Shi et al., 1997, 2002; Chaodumrong et al., 2004). Therefore, the age of this formation belongs to the Lower Permian.



**Figure 2** Photos showing characteristics of the Kaeng Krachan Group: a) Thin bedded sandstone and mudstone, b) Planolites, same location as Fig. 2a, c) Laminated mudstone, and d) Dropstone

## Spillway Formation

The Spillway Formation (Raksaskulwong and Wongwanich, 1993) is a 120 meters thick sequence of laminated mudstone and thin to medium bedded sandstone. The bedding is of usually wavy and nonparallel type (Fig. 3a). Sedimentary structures such as load cast, bioturbation, slump, hummocky cross bedding and

lonestone can be observed. It overlies conformably the Laem Mai Phai Formation, and is well exposed at its type section at Kaeng Krachan Dam, but elsewhere is of limited distribution. Age of this formation is determined from stratigraphic ground to be Lower Permian.

## Ko He Formation

Pebbly rocks are typical of the Kaeng Krachan Group. The Ko He Formation (named after "He island" of Phuket province) of Raksaskulwong and Wongwanich (1993) overlies conformably either the Spillway Formation or Laem Mai Phai Formation (where the Spillway was absent), and is characterized by an over 125 meters thick sequence of mainly pebbly rocks (Fig. 3b) or diamictite with subordinate, intercalated mudstone and sandstone. It is poorly sorted, with clasts generally less than 10%, and a matrix consisting of silty mud to muddy sand. Clasts are mostly smaller than 2 cm, and consist mainly of quartzite, quartz, sandstone, limestone, marble, granite and gneiss. Brachiopod *Costatumulus* sp. at Khao Nang Hong of Phangnga province may indicate a Sakmarian-Artinskian age.

## Khao Phra Formation

The Khao Phra Formation differs from the original name proposed by Piyasin (1975) in that it lacks predominant pebbly rock sequence. Its type section is at Khao Phra in Phetchaburi province, where it overlies conformably the Ko He Formation. It is a 340+ meters thick sequence of mudstone, laminated mudstone, siltstone and sandstone (Fig. 3c). Faunas are often observed and indicate a Sakmarian-Artinskian age, including bryozoans: *Fenestella* sp., *Polypora* sp. (Sakagami, 1968);

brachiopods from Khao Than of Chumphon province: *Stereochia koyaonensis* Waterhouse, *Spiriferellina modeta* Waterhouse, *Spinomartinia prolifera* Waterhouse, *Chonetinella andamanensis* Waterhouse, *Cleiothyridina seriata* Grant, at Khao Phanom of Krabi province: *Spinomartinia prolifera* Waterhouse, *Demonedys tricorporum* Waterhouse, *Costatumulus* sp., *Linoproductus* sp. (Chaodumrong et al., 2004), and crinoids.

## Khao Chao Formation

Quartz-rich sandstone, ranging in composition from quartz arenite to subarkose, is a typical characteristic of the upper part of Kaeng Krachan Group and had been reported from many places in southern Thailand. This paper follows Piyasin (1975) in separating this sandstone sequence as the Khao Chao Formation lying conformably on the Khao Phra Formation. It is characterized by a sequence of quartz-rich sandstone, shale, siltstone and mudstone. Beds of tuff, limestone, thin shells (Fig. 3d) and crinoid stems are observable in the upper part of the formation. Brachiopod: *Meekella bisculpta* Grant, and *Costatumulus* sp. were identified in white sandstone of Chumphon province (Shi et al., 2001), and *Marginifera* sp. at abandoned quarry opposite to the Khao Phu Liap of Kanchanaburi province (Chaodumrong et al., 2004), and indicate a Sakmarian-Artinskian age.

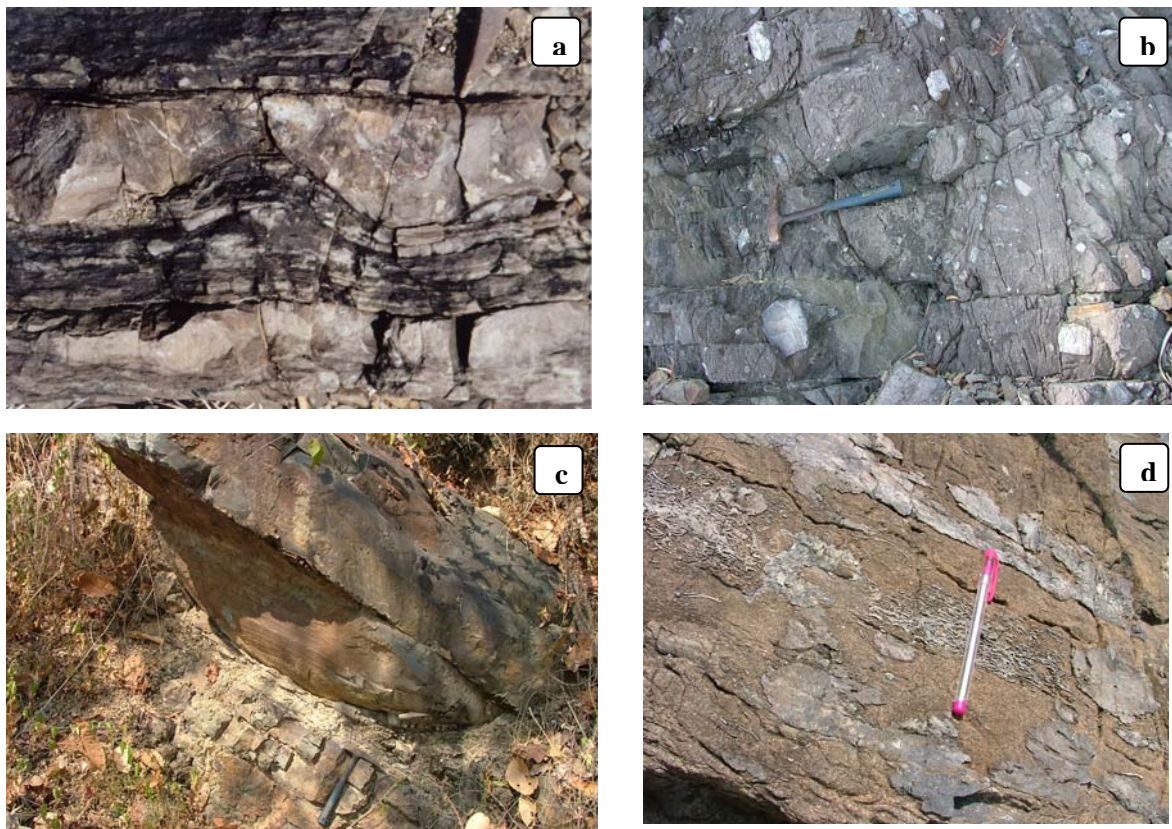


Figure 3 Photos of the Kaeng Krachan Group, a) Load cast in the Spillway Fm, b) Pebbly sandstone in the Ko He Fm, c) Laminated mudstone in the Khao Phra Fm, and d) Thin shell beds in the Khao Chao Fm.

## PROPOSED LITHOSTRATIGRAPHIC NOMENCLATURE FOR THE RATBURI GROUP

The Permian limestone sequence in the Thai peninsula has long been mapped as a single unit as the Ratburi Group without division into constituent formations (e.g. Department of Mineral Resources, 1999), and a type section was not proposed. During carbonate resource mapping in Surat Thani area, Chaodumrong et al. (1998) subdivided the limestone sequence into formations, using their physical characteristics and lithofacies criteria such as lithology, type of bedding, intercalation of clastic rocks and presence of chert. It also shows that each subdivided formation exhibits similar chemical and mechanical properties. Later, Chaodumrong et al. (2004) amended the

stratigraphy of the Ratburi Group to consist of 5 formations, in ascending order the Thung Nang Ling, Khao Muang Krut Sandstone, Phap Pha, Phanom Wang, and Um Luk. In most areas, the group commences with thin to medium bedded limestone of the Phap Pha Formation and is conformably overlain by massive limestone of the Um Luk Formation (Fig. 4). Faunas, in general, are rare and low diversity, but local can be abundant. Replacement dolomite can be observed in all formations, and many places showing strong dolomitization. The Ratburi Group lies conformably on the Kaeng Krachan Group, and was deposited from the Roadian to the Wuchiapingian (Middle to Late Permian) on a shallow marine, low energy, epeiric carbonate platform.

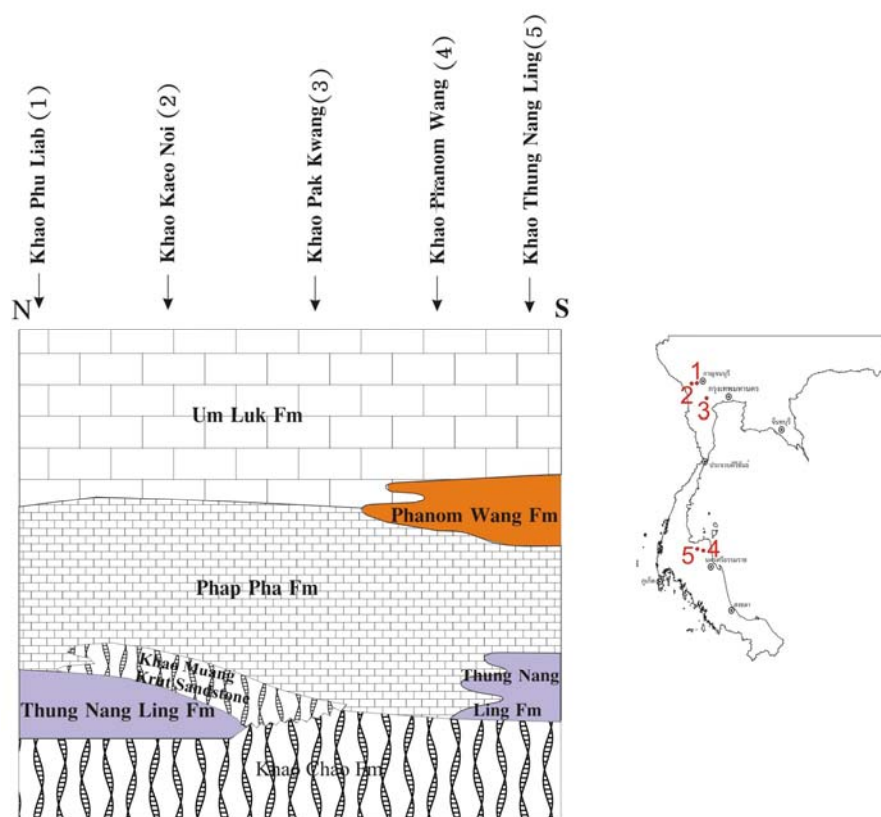


Figure 4 Simplified stratigraphic relationship within the Ratburi Group

### Thung Nang Ling Formation

Thung Nang Ling Formation takes its name from "Khao Thung Nang Ling" in Surat Thani province. It is that 80 meters thick sequence of thick bedded, gray skeletal packstone and grainstone (Fig. 5a) with minor shale and sandstone. It occurred locally. Crinoid stems are common to abundant. Coral: *Euryphyllum* sp. (at Khao Kaeo Yai of Kanchanaburi province), and *Marginiferid* gen. et sp. indet. (at Khao Kaeo Noi of Kanchanaburi), suggests a Wordian (Middle Permian) age.

### Khao Muang Krut Sandstone

Khao Muang Krut Sandstone is that 50 meters thick sequence, cropping out at "Khao Kaeo Noi" in Kanchanaburi province, of quartz-rich sandstone (quartz arenite-subarkose), shale and mudstone with limestone increase in proportion up sequence. Fossils are common; brachiopods include *Stereochia litostyla* Grant, *Derbyia scobina* Grant, *Neospirifer* sp., and corals include: *Verbeekiella* sp., *Lophophyllidium* sp., and Wordian (Middle Permian) in age.

## Phap Pha Formation

Phap Pha Formation takes its name from "Khao Phap Pha" in Surat Thani province. It is, 200 meters thick, characterized by thin to medium bedded, gray wackestone to lime mudstone, and interbedded thinly layer shale (Fig. 5b). Few fossils are observable but include the coral: *Sinopora* sp. (Fontaine et al., 2003), and the fusulinids at Khao Kaeo Noi *Pseudofusulina* sp., *Yangchienia* sp., the brachiopods at Khao Kaeo Noi *Stereochia litostyla* Grant, at Khao Phu Liap *Spiriferellina* sp., *Marginifera* sp. which may indicate a Middle Permian (Wordian) age.

## Phanom Wang Formation

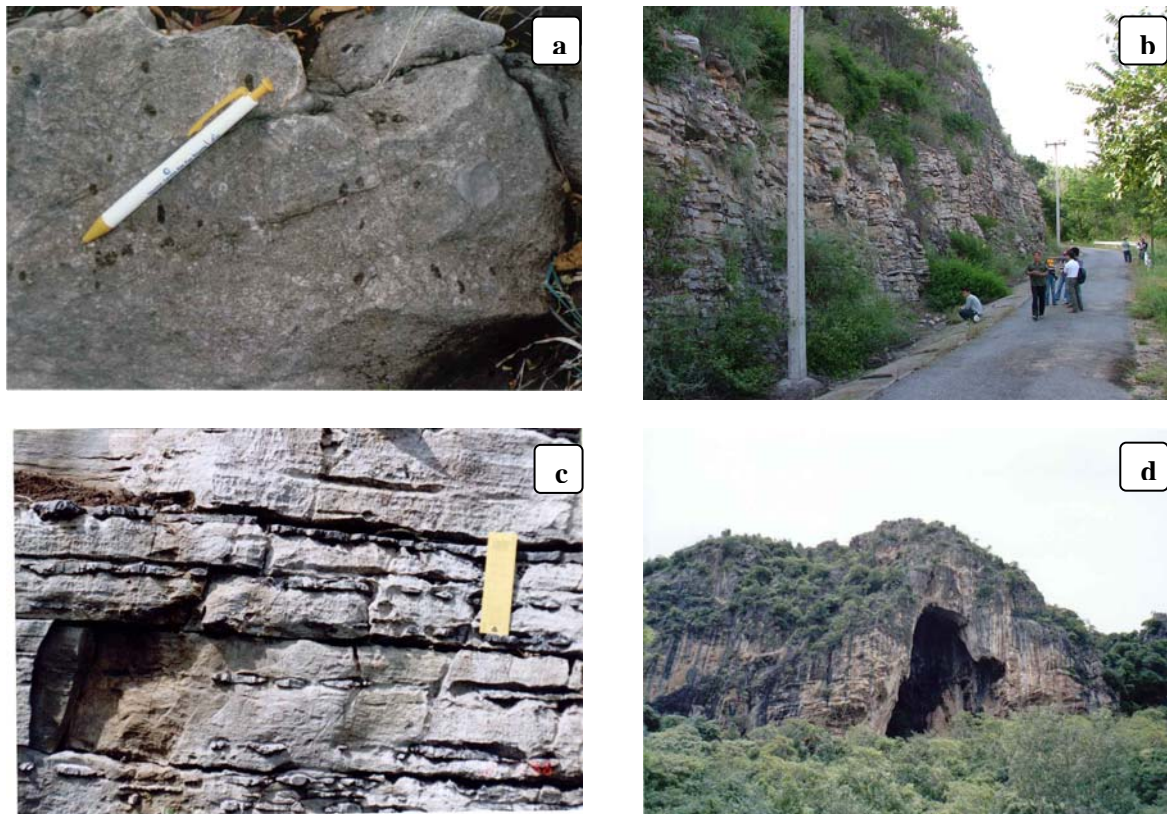
Phanom Wang Formation is that 80 meters thick sequence of medium to thick bedded, gray limestone (mainly wackestone to packstone) and intercalated chert nodule and lens (Fig. 5c). It is well exposed at Khao Phanom Wang temple in Surat Thani province, but elsewhere has a limited distribution.

## Um Luk Formation

Um Luk Formation (Fig. 5d) is that 200 meters thick sequence of thickly bedded to massive, gray to light gray limestone (mainly lime mudstone to packstone). Fauna are rare and low diversity. The fusulinids: *Eopolydiexodina* sp. and *Yangchienia* sp. are found in the lower part of the formation and indicate a Middle Permian (Murghabian), while *Shanita* sp. (Dawson et al., 1994) indicates Late Murgabian to early Dzhulfian age.

## CONCLUSIONS

The lithostratigraphy of the Kaeng Krachan Group is revised to consists of 5 formations, namely, the Laem Mai Phai, Spillway, Ko He, Khao Phra and Khao Chao. It is overlain conformably by carbonate sequence of the Ratburi Group that comprises 5 formations, namely, the Thung Nang Ling, Khao Muang Krut Sandstone, Phap Pha, Phanom Wang, and Um Luk. The Tha Ma Dua Sandstone of Bunopas (1992) that claimed to be the uppermost stratigraphic unit of the Ratburi Group is regarded here as Mesozoic red beds.



**Figure 5** Photos showing rocks of the Ratburi Group, a) Crinoidal grainstone or encrinite of the Thung Nang Ling Formation, b) Thin to medium bedded limestone of the Phap Pha Formation, c) Thin bedded limestone and chert in the Phanom Wang Formation, and d) Massive limestone of the Um Luk Formation lies conformably on thin bedded limestone of the Phap Pha Formation.

What is the age of the base of the Kaeng Krachan Group? It has long been mapped as Carboniferous-Permian Period based on evidence of Piyasin (1975) who reported "not well preserved specimen" as Upper Devonian *Chonetes* sp. from Huai Phu Noi Fm (equivalent to Laem Mai Phai Fm of this paper), and Upper Carboniferous *Fenestella* sp. and *Polypora* sp. from Khao Chao Fm; and Raksaskulwong and Wongwanich (1993) who reported "distorted specimen" as Early Carboniferous- Early Permian *Spirifer* sp. and *Spinomartinia* sp. from eastern side of the Laem Mai Phai (equivalent to Laem Mai Phai Fm of this paper). However, Piyasin (1975) ignored the "Upper Devonian *Chonetes* sp." when he assigned the age of the Kaeng Krachan Group as only Carboniferous (see entitle of the paper). On the other hand, the *Fenestella* sp. and *Polypora* sp. (e.g. Sakagami, 1968, 1973), *Spirifer* sp. and *Spinomartinia* sp. (Grant, 1976; Waterhouse, 1981; Shi et al., 1997; Chaodumrong et al., 2004) were clearly identified as Early Permian. Therefore, it is no doubt that the Kaeng Krachan Group belongs to Lower Permian. In fact, after a review of published paleontological documents (brachiopods, corals, bryozoans, fusulinids and foraminifera) over the last 30 years of various researchers, there has been no Late Carboniferous fossil documented in the Thai Peninsula (Chaodumrong et al., 2004), except Dill et al. (2005) who reported age of the Ratburi Group

from foraminifera as Upper Carboniferous to Middle Permian, that is strongly contrasted with this paper. However, the faunas as mentioned above strongly indicate the age of the Ratburi Group ranging from Middle to Upper Permian. Our studies also suggest a hiatus on the Shan-Thai terrane during Late Carboniferous. Evidence from large dropstones in the Laem Mai Phai Formation strongly supports a glaciomarine depositional environment (Fig. 6) while *Cruziana* ichnofacies are typical of shelf environments. This is consistent with occurrences of temperate to cool brachiopod: *Sulciplica*, *Kitakamithyris*, *Vacunella*, *Cancrinelloides*, and cool water coral: *Euryphyllum* of Late Asselian in pebbly mudstones of Kaeng Krachan Group from the Phi Phi and Muk islands (Waterhouse, 1982). The Shan-Thai terrane was rifted from the Gondwana probably not later than Early Permian as indicated by occurrence of pebbly rocks and the cool water faunas. The pebbly rocks were deposited in the rift basin by debris flow process. They were derived from the Gondwana as suggested by similarity of clasts in the pebbly rocks and the tillites in northwest Australia (Hills, 1989). Shallow marine environment continued in the upper part of the Kaeng Krachan Group through the epeiric carbonate platform of the Ratburi Group.

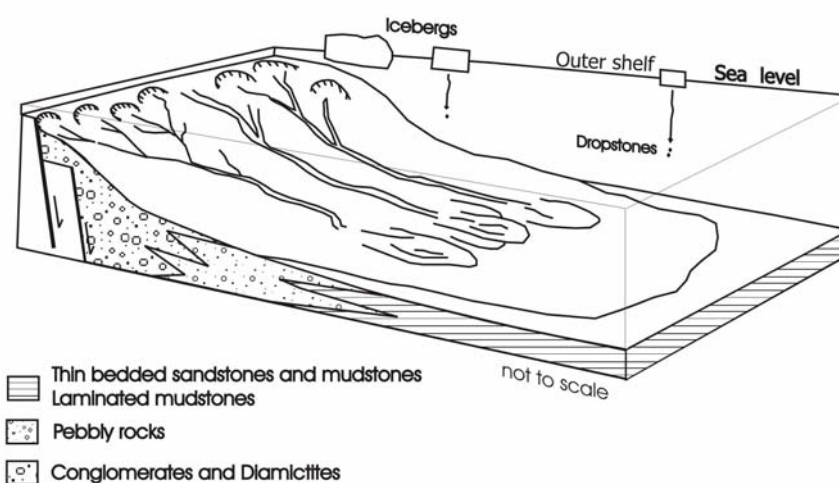


Figure 6 Depositional model of the Kaeng Krachan Group.

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