

## WORKSHOP ON STRATIGRAPHIC CORRELATION OF THAILAND AND MALAYSIA

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### PALEOZOIC SUCCESSION IN THAILAND

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**ABSTRACT** The whole sequence of Paleozoic rocks which mainly of marine origin are outcropping outside the Khorat Plateau, both in Shan-Thai and Indochina microcontinents, or cratons. The Cambrian and Ordovician outcrops are closely associated with the Precambrian in the Western Belt, on the Shan-Thai cratonic fragment. The total thickness of Cambro-Ordovician sandstone and limestone exceeds 1,600 m.

Silurian-Devonian rocks are differentiated into several facies belts from west to east. Fossiliferous carbonate shelf facies and continental derived clastic shale and sandstone of graptolite-tentaculite facies conformably overly Ordovician limestone and conformably underly Upper Paleozoic rocks outcrop in the lower Peninsula and west of the Western Mountains from Kanchanaburi to Mae Hong Son. East of the Western Mountains, the eastern Gulf, and in the Sukhothai Fold Belt, three facies belts are recognised; from west to east, 1, back-arc basin facies consisting of graptolitic black shale and bedded chert and occasional limestone are found at Fang, Lampang, east Kanchanaburi, Rayong, and Yala in the south Peninsula; 2, volcanic arc facies consisting of metavolcanics and meta-agglomerate and fine grained tuffs crop out at Chiangrai, Lampang, Tak, Nakhon Sawan in north and western Thailand, at Rayong in the eastern Gulf and probably at south Narathiwat in the Peninsula; 3, fore-arc, chiefly the arc-trench gap deposits consisting of marble, and bedded cherts occur at Sukhothai and Nakhon Sawan, and Rayong-Chantaburi in the eastern Gulf, and the trench facies consisting of flysch-like low grade metasediments are found at Nan, immediately west of the Pha Som Ultramafic Belt. Silurian-Devonian rocks at Loei which are the oldest Paleozoic outcrops of Indochina Craton on the Thai side consist of shelf sandstone, shale and limestone.

Carboniferous rocks in the Sukhothai Fold Belt consist of

varying lithologies and thickness from west to east in the West, the North, the eastern Gulf, and the Peninsula. At places marine shelf sedimentation continued in the west and flysch type sediments in the east, but with local unconformities. In the middle part of the fold belt pronounced unconformities on the Silurian-Devonian rocks are overlain by thick volcanic agglomerates and possibly marine red-beds underlying Lower Permian limestone. Carboniferous volcanic rocks are relatively rarer than in the Silurian-Devonian sequence and are represented by agglomerate and tuffaceous rocks with minor shallow acid to basic intrusive rocks near Phrae. West of the Western Mountains, west of the eastern Gulf and west of the Peninsula passive continental margin sediments continued into Carboniferous period and consisted of shale sandstone and minor chert beds, but local paralic red-beds occur. The mainly Carboniferous to Lower Permian pebbly mudstones occur further to the west. Carboniferous sediments which are fossiliferous in the upper part occur in the environs of Loei and Phetchabun and are thicker from east to west, changing from massive limestones to a more sandy shaly limestone facies.

Permian rocks are dominantly limestones. The limestones are possibly of different ages in the Western Mountains, the Sukhothai Fold Belt and the Loei Fold Belt. The Permian in the Sukhothai Fold Belt contains minor tuffaceous rocks. The Permian sequence in all areas are mainly Lower to Middle Permian. The early Upper Permian rocks, mainly shale, sandstone and thin limestone are found at places in Lampang, in the Sukhothai Fold Belt, and in the Loei Fold Belt at Loei and Phetchabun.

## INTRODUCTION

Early Paleozoic sandstone and limestone are exposed in the Western Province only (Fig. 1). Their general trends are mainly north-south. Thick Middle Paleozoic sediments and volcanic rocks are widespread to the east of the western mountains (in Sukhothai Fold Belt). In contrast, thinner Middle Paleozoic rocks west of the western mountains (in western part of the Western Province) and west of the Eastern Province (in Loei Fold Belt) contain no significant volcanic assemblage. Upper Paleozoic arenites, argillite and carbonates are found adjacent to Middle Paleozoic rocks but also spread farther to the east and the west, in all major geological provinces.

Three main geological provinces are immediately obvious (Bunopas, 1981). In the middle, separating the other two, is a north-south trending fold belt of middle Paleozoic to lower Mesozoic marine sediments. The other two are fragments of ancient continent with crystalline Precambrian basement rocks. The three may be designated as Western Province, Central Province and

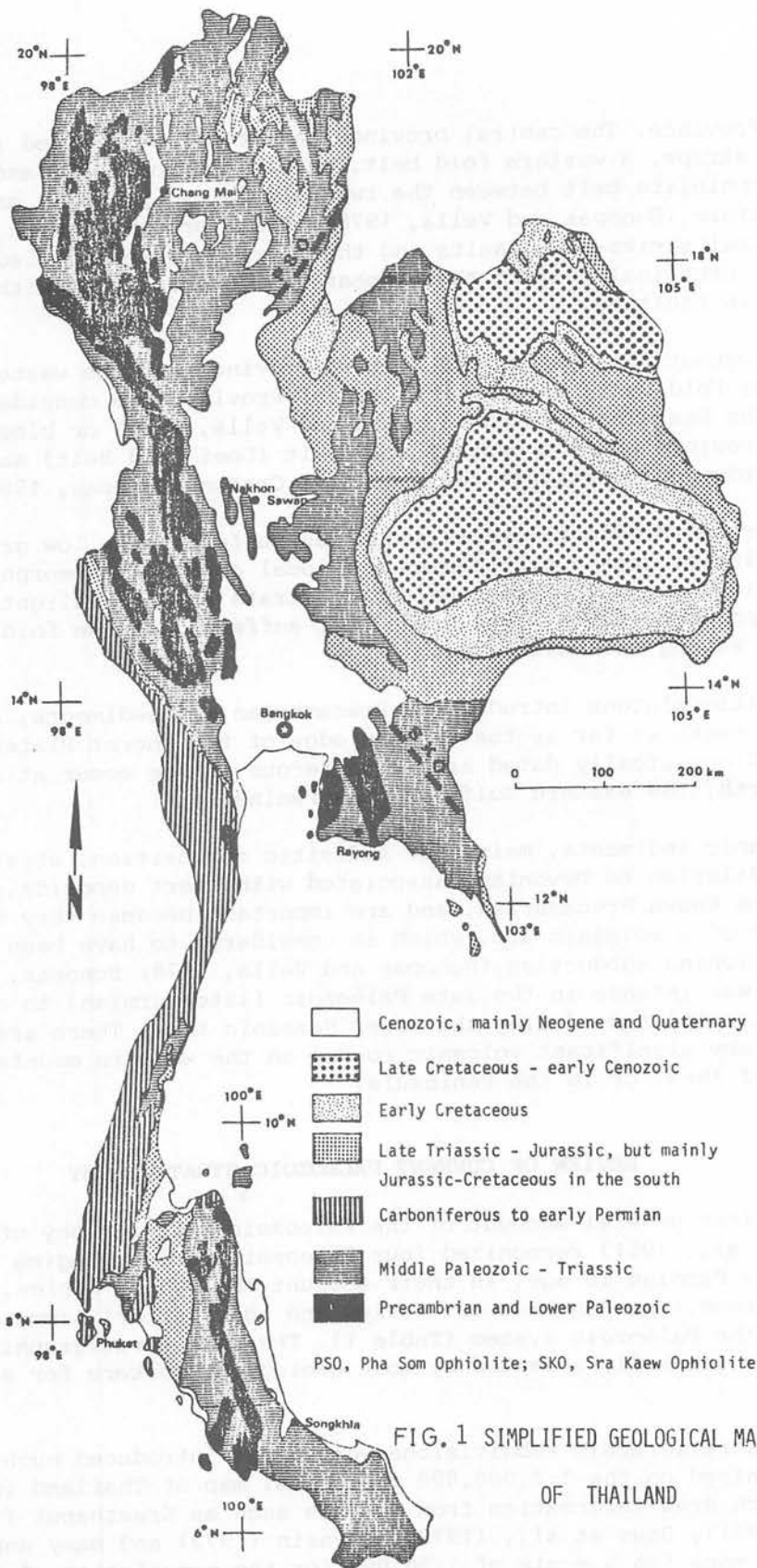


FIG.1 SIMPLIFIED GEOLOGICAL MAP  
OF THAILAND

Eastern Province. The central province can itself be divided into three parallel strips, a western fold belt, an eastern fold belt and a discontinuous ophiolite belt between the two fold belts, probably marking the Nan Geosuture (Bunopas and Vella, 1978). These provinces were dislocated by sinistral strike-slip faults and their trends were modified by sinistral oroclinal bending that appears to be associated with the strike-slip faulting.

Throughout this paper, the Western Province and the western fold belt (Sukhothai Fold Belt) west of the Central Province are considered to constitute the Shan-Thai Craton (Bunopas and Vella, 1978) or block; and the Eastern Province and the eastern fold belt (Loei Fold Belt) east of the Central Province constitute the Indochina Craton (Bunopas, 1981) or block.

Lower and Middle Paleozoic sequences suffered only low grade regional metamorphism of greenschist facies and local contact metamorphism adjacent to granitic bodies. The Upper Paleozoic strata are only slightly metamorphosed (zeolite-phrenite-pumpellyite grade) but suffered intense folding and developed strong fold cleavage.

Granitic plutons intruded the Precambrian metasediments, and the Paleozoic rocks as far as the western edge of the Khorat Plateau. Granite bodies radiometrically dated as Carboniferous in age occur at a few places in the north, the eastern Gulf, and the Peninsula.

Volcanic sediments, mainly of andesitic composition, stratigraphically dated as Silurian to Devonian, associated with chert deposits, lie to the east of the known Precambrian, and are important because they indicate the initiation of a volcanic arc, which is considered to have been caused by westward dipping subduction (Bunopas and Vella, 1978; Bunopas, 1981). Volcanism was intense in the late Paleozoic (late Permian) to early Mesozoic (early Triassic) and during the lower Mesozoic time. There are no volcanic rocks (or any significant volcanic rocks) on the western mountains or to the west of them, or in the Peninsula.

#### REVIEW OF CURRENT PALEOZOIC STRATIGRAPHY

The first general account of the Paleozoic stratigraphy of Thailand (Brown, et al., 1951) recognized four Paleozoic series ranging from Cambrian to Permian in age. In their account the Phuket Series, the Thung Song Limestone, the Kanchanaburi Series and the Ratburi Limestone represent the Paleozoic system (Table 1). The same stratigraphic subdivisions were generally accepted by most geological workers for almost two decades.

Lithostratigraphic subdivisions were first introduced much later, and were recognised on the 1:1,000,000 geological map of Thailand (Javanaphet, 1969), which drew information from sources such as Sresthaput (1956), Buravas (1961), Baum et al., (1970), Piyasin (1972) and many unpublished geological maps (on a scale of 1:50,000 for the compilation of the 1:250,000 map) produced in northern Thailand since 1965. In his short unpublished

manuscript to follow the published 1:1,000,000 map Javanaphet subdivided Paleozoic sequences in Thailand into four groups (Table 1). Javanaphet's subdivision formed the basis for the regional mapping for many years.

The Phuket Series (Brown et al., 1951) is now known to be late Paleozoic in age. Upper Cambrian strata included in it by Brown et al., (1951) are now classed as the Tarutao Formation (Bunopas et al., 1980) which equals the Tarutao Group of Javanaphet (1969). The sequence previously known as the Phuket Series at Phuket Island is now known as the Phuket Group (Mitchell et al., 1970), and probably is equivalent to the Kaeng Krachan Formation of the upper part of the Tanaosri Group of Javanaphet (1969) in the upper peninsula.

Baum et al., (1970) used an informal time-stratigraphic subdivision, e.g. Carboniferous rocks (C), Permo-Carboniferous rocks (CP), Mesozoic rocks ( $Ms_1$ ,  $Ms_2$ ,  $Ms_3$ ) etc. in mapping the northern part of Thailand. They noticed the facies changes in the Upper Paleozoic and Triassic across North Thailand. Similar large scale facies changes are also possible. More local facies changes in the Middle Paleozoic to Triassic strata were summarised by Bunopas (1975, 1976a). The current views of the late Paleozoic and Mesozoic structural evolution of northern Thailand (Ziegler et al., 1977; Gatinsky et al., 1978; Bunopas and Vella, 1978) lead to a revision of stratigraphic nomenclature in the major sedimentary basins (Bunopas, 1981, see Table 1 to 7).

### PRESENT STRATIGRAPHIC CLASSIFICATION


The stratigraphic units in the western regions of Thailand which were proposed by Bunopas (1981) were described according to the International Stratigraphic Guide (Hedberg et al., 1976). This classification was based on regional studies and local semi-detailed mapping by him and others from the Department of Mineral Resources before 1980 and on specific fieldwork on stratigraphy and paleomagnetism throughout the country. New stratigraphic names were proposed, and many published stratigraphic names were redefined. The stratigraphic terminology presented is partly by his interpretation of the paleogeography of Thailand, especially the interpretation of the late Paleozoic and Mesozoic structural evolution of northern Thailand, largely as the result of the interaction of two microcontinents, Shan-Thai and Indochina. Different groups or formations of rocks of correlative age could be expected across the country—from west to east or from north to south, if they were confined to certain sedimentary basins.

Simplified stratigraphic correlations are shown in Table 1 to 7 in this paper.

### THE BASEMENT ROCKS

The Precambrian basement rocks exposed in Thailand are metasediments of amphibolite facies. The Precambrian rocks (Natalaya, 1974 MS; Baum et al., 1970; Campbell, 1973; Bunopas, 1981) are thought to be mostly metamorphosed marine (flysch) sediments of a continental margin, and were

Table 1 Stratigraphic subdivisions of Thailand from 1951 to 1976 and new stratigraphic subdivision proposed by Bunopas (1981). See also figs. 2-7.

Age	Brown et al. (1951)	Javanaphet (1969) Mitchell et al. (1970)	Baum et al. (1970) Bunopas (1976a)	Bunopas (1981) Detail see figs. 2-7
CENOZOIC	alluvium Krabi & Mae Sot Series	alluvium Mae Moh & Li Groups	gravel, sand, clay sand, silt with lignite	terrace deposits Mae Sot, Mae Moh, Li group, etc.
CRETACEOUS	Khorat Series with Kamawkala Limestone and marine Triassic	Khorat Group	red sandstone, shale conglomerate	W  E Khorat Group
JURASSIC		Lampang Group	greywacke, cgl., ss.	Mae Moei Group Lampang Group Tak Group Nam Pat Group
TRIASSIC				
PERMIAN	Ratburi Limestone	Ratburi Group	limestone with clastic sediments toward top	Ratburi Group Ngao Gr. Mae Tho Gr. Phrae Gr. Sai Yok Group
CARBONIFEROUS	Kanchanaburi Series (include gneiss)	Tanaosi Group Kaeng Krachan Formation (Phuket Group) Kanchanaburi Formation	greywacke, limestone (thin)	Kaeng Krachan Mae Tha Gr. Dan Lan Hoi Gr.
DEVONIAN -			black shale, chert, limestone	Thung Saium Group Bo Phloi Formation Donchai Group
SILURIAN			Sandstone, shale, chert	
ORDOVICIAN	Thung Song Limestone	Thung Song Group	limestone and shale	Chao Nen Group (and equivalent)
CAMBRIAN	Phuket Series	Tarutao Group	quartzite, slate, phyllite	
PRECAMBRIAN	?granite pebbles in Phuket Series	? granite pebbles in Tanaosi Group	paragneiss with marble intercalations	Orb Luang Gneiss Yan He Complex Lansang Gneisses Thabsila Gneiss

Metamorphic rocks


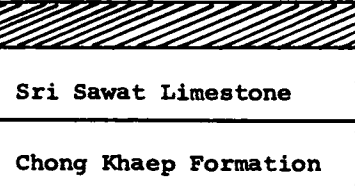
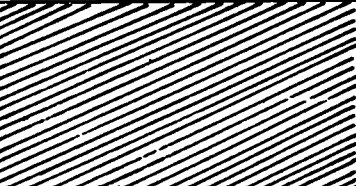
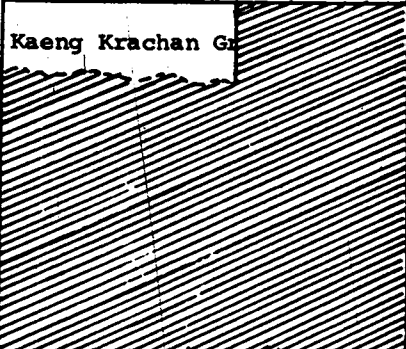
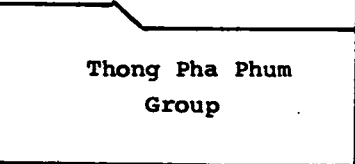
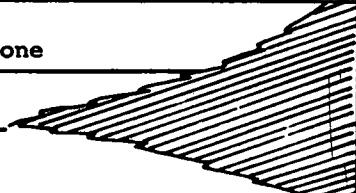
Saraburi Gr.  
Pha Som Gr.

Table 2 Stratigraphic subdivision of North Thailand

Age	Western Mountains		Sukhothai Fold Belt		Loei F.B. east Uttaradit
	Mae Hong Son	Fang	Chiangmai-Lampang-Phrae	Phrae-Uttaradit	
Cenozoic	Gravels and alluvium in most basins Sandstone, shale, lignite and oil shale				Gravels (not Known)
Cretaceous					
Jurassic		red-beds W.Hod		Khorat Group (Nan-Phayao Basin)	Khorat Group (Nakhon Thai Syncl.)
Triassic	Mae Sariang Group			Lampang Group	Nam Pat Group
Permian	Pai, Doi Chiang Dao limestones		Ngao Group	Phrae Group	limestone at Tron
Carboniferous	Doi Kong Mu	Fang red-beds Thoen red-beds	Mae Tha Group		See Tables 4,6.
Devonian-Silurian	Mae Hong Son Group	Fang Chert	Donchai Group	Mae Ko Comp. Thung Saliam Group Pha Som Group	
Ordovician-Cambrian	Hod Limestone Pha Bong Quartzite				
Precambrian	Orb Luang Gneiss				

Age	← Western Mountains →		← Sukhothai Fold Belt →		← Loei Fold Belt →	
	Mae Sot	Tak	Tak	- Sukhothai-Nakhon Sawan	NW Khorat Plateau - Khorat Plat.	
Cenozoic	Alluvium Mae Sot Gr. Lansang Gr.		Alluvium Chao Phraya plain deposits		Alluvium Phetchabun shale	Alluvium Loess?
Cretaceous						Maha Sarakham Fm.
Jurassic			Khao Daeng Fm.		Khorat Group	Khok Kruat Fm. Phu Phan Formation Sao Khua Formation Phra Wihan Fm. Phu Kradung & Nam Phong Fms.
Triassic	Mae Moei Group		Tak Group	Lampang Group	Nam Pat Group	Lom Sak tuff Nam Pha Fm.
Permian	Phr Woh Limestone		Mae Tho Formation	(Ngao Group) Phrae	limestone at Tron	Saraburi Group
Carboniferous	Doi Musur			Dan Lan Hoi Group Mai Ngam Haeng Group		(Wang Saphung shale)
Devonian-Silurian	Group		Bo Phloi Fm. Den Matum	Thung Saliam Group Pha Som Gr.		Chert, limestone at Loei
Ordovician		Klong Wang Chao Gr.				
Cambrian						
Precambrian		Lansang Gneiss Van He Complex				

Table 4 Stratigraphic subdivision in West Thailand

Age	West of Western Mountains (west Khwae Noi)	Central Western Mountains (Khwae Noi and Khwae Yai)	East of Western Mountains and Highlands
CENOZOIC	Gravel	Gravel	Gravel
CRETACEOUS			
JURASSIC			
TRIASSIC			
PERMIAN	Ratburi Limestone	Sai Yok Group	Khao Plukmu Limestone
CARBONIFEROUS			Mae Plung Shale
DEVONIAN - SILURIAN			Bo Phloi Formation
ORDOVICIAN			
CAMBRIAN		<div>Chao Nen Group</div> <div>Tha Manao Limestone</div> <div>Chao Nen Quartzite Formation</div>	
PRECAMBRIAN		Thabsila Gneiss	

Age	WEST (Phetchabun-Lamnarai)	NORTH-WEST (Loei-Phitsanulok)	KHORAT PLATEAU (Northeast Thailand)
CENOZOIC	alluvium Phetchabun shale	alluvium -	alluvium & Loess -
Cretaceous	-	(Nakhon Thai Syncli.) Maha Sarakham Form. Khok Kruat Form.	Maha Sarakham Form. Khok Kruat Form.
Jurassic	Phu Phan Form. Sao Khua Form. Phra Wihan Form. Phu Kradung Form.	Phu Phan Form. Sao Khua Form. Phra Wihan Form. Phu Kradung & Nam Pong Form.	Phu Phan Form. Sao Khua Form. Phra Wihan Form. Phu Kradung & Nam Phong Form.
Triassic	rh. Lom Sak Tuff -	Nam Pha & Huai Hin Lat Form. -	-
Permian	Saraburi Group	Saraburi Group	-
Carboniferous	-	-	-
Devonian-Silurian?	-	1 — ? — ? — ? — ? — ? — ? — Pak Chom chert	-

**Table 3 Stratigraphic subdivision in Central and Lower North Thailand**  
(Gr., Group; Fm., Formation, v., volcanic rocks)

Table 6 Stratigraphic units in the Eastern Gulf  
(Gwk.= Graywacke, rh.= Rhyolite, Gr. Group, Ls. Limestone)

Age	S h a n - T h a i			Indochina
	Chonburi	Chonburi-Rayong-Klaeng	Chanthaburi-Trat-Sra Kaeo	east Sra Kaeo
CENOZOIC	gravel and alluv.	gravel and alluvium	gravel and alluvium	?
Cretaceous				Khorat Group
Jurassic		Khao Hin Tang Red-beds	Ban Ta Muan conglomerate	
Triassic			Pong Nam Ron Gwk.	Gwk.
Permian			volc.	volc.
	Bang Phra lst.	limestone at Klaeng	Khao Cha Kan limestone	limestone
Carboniferous		Khao Talai sandstone and red-beds and shale	(Sra Kaeo pillow lavas) Sra Kaeo Group	(volcanics) chert
Devonian-Silurian	Sattahip shale	Klaeng phyllite	?	?
Ordovician-Cambrian	Sri Chang Ls. Ko Lan Quartzite			
PRECAMBRIAN		Chonburi gneiss		

Table 7 Stratigraphic units in the Peninsula

Age		South Peninsula		
		west	Middle	East
CENOZOIC	Coastal and alluvium Krabi lignite	Coastal and alluvium Sadao lignite	Coastal and alluvium not known	Coastal and alluvium not known
Cretaceous	-	-	-	-
Jurassic	Chumphon Red-beds	White quartz sandstone and red shale near Thung Song	Chian Yai red-beds	-
Triassic	-	-	Na Thawi shale	-
Permian	Ratburi Limestone	Ratburi Limestone?	Ratburi Limestone?	-
Carboni- ferous	Phuket Group ? ? ? ? ? ? ? ? ? ? ? ? ?	Sandstone & shale at Trang	Ko Yo shale and chert	Mayo red-beds
Devonian- Silurian		Khuan Din So and Thung Wa shale, chert and limestone	Satun shale	Yala, Narathiwat phyllite, metatuff
Ordovician- Cambrian		Thung Song Limestone Tarutao Formation	-	-
PRECAMBRIAN		Khanom gneiss	-	-

deeply burried, uplifted and eroded before deposition of the Cambrian.

### **LOWER PALEOZOIC ROCKS**

Lower Paleozoic rocks are siliclastic and carbonate rocks of Upper Cambrian to Ordovician formerly known from Tarutao Island, off the west coast of south peninsular Thailand (Brown et al., 1951, Kobayashi, 1975) and subsequently known also from the eastern Gulf and along the Western Mountains from Kanchanaburi in the south to Mae Hong Son in the north (Javanaphet, 1969; Baum et.al., 1970; Bunopas, 1976 abcd, Bunopas 1981).

#### **Tarutao Formation (Late Cambrian-Early Ordovician)**

The Tarutao Formation is proposed by Bunopas (1981) and Bunopas et al. (in press) to replace the name Tarutao Group (Javanaphet, 1969) elsewhere quoted as Tarutao quartzite (Burton, 1974) and the Phuket Series at Tarutao Island (Brown et al., 1951). The formation consists of a sequence exceeding 1,000 m thick, and mainly comprises quartzose and variegated sandstone which are thinly to thickly bedded and some of which contain poorly developed tabular cross-beds which indicate west to east transport (Bunopas, 1981; Taraoka and Sawata, 1982). The fossils which occur in the higher part of the formation were dated as Upper Cambrian (Kobayashi, 1957). The Cambrian-Ordovician boundary is somewhat in the top most part of the Tarutao Formation at the Malaka Bay, north-west end of Tarutao Island (Wongwanich et al., 1983).

The Tarutao Formation extends north from Tarutao Island into the peninsula, the northernmost outcrop being in west Nakhon Si Thammarat.

#### **Ko Lan Quartzite (Cambrian?)**

Ko Lan Quartzite (Bunopas, 1981) forms the small Ko Lan Island 10 km west of the Pattaya coast in south Chonburi on the eastern Gulf. The rocks estimated to be 500 m thick consist of well to poorly bedded brown quartzite, brownish grey shaly slate and black to brown slate which is reddish when weathered, all showing mesoscopic folds. A Cambrian age is inferred on stratigraphic grounds since similar rocks underlie Ordovician limestone of Ko Si Chang.

#### **Chao Nen Quartzite Formation (Bunopas, 1976d Cambrian to Early Ordovician)**

The Chao Nen Quartzite Formation is proposed (Bunopas, 1981) for the lower part of the Lower Paleozoic sequence in West Thailand. At the type locality at the Chao Nen Dam, the formation, exceeding 600 m thick, consists predominantly of well bedded whitish brown, whitish grey, and greenish grey fine to medium grained sandstone and quartzite, graded to interbedded shale and phyllite and rare limestone beds, and then finally to grade bedded sandstone and impure limestone containing shell fragments, with sharply defined base. The Cambrian to Early Ordovician age was given on evidence of trilobites, cephalopods and a gastropod. The rocks of the formation form resistant ridges along the Western Mountains from Kanchanaburi to Uthai Thani and beyond where they are known as Pong Nam Ron Quartzite Formation of Khlong

Wang Chao Group, in west Kamphaengphet and Tak.

**Pong Nam Ron Quartzite Formation (Bunopas, 1981, equals Pong Nam Ron Sandstone (Bunopas, 1976 b): Cambrian to Early Ordovician)**

The Pong Nam Ron Quartzite Formation is applied to a 1,000 m thick sandstone, locally metamorphosed to quartzite, quartz-schist and phyllite. The base was not seen and the top is marked by the overlying Suan Mark Limestone. Similar monotonous bedded quartzite and quartz-schist underlying limestone are distributed along the Western Mountains between Tak and Kamphaengphet on the east and between Mae Sot and Umphang to the west. No fossil was found in the Pong Nam Ron Formation. The age is controlled solely by poorly preserved supposedly Ordovician fossils in the overlying formation, suggesting that the rocks are possibly earliest Ordovician or Cambrian.

**Pha Bong Quartzite (Bunopas, 1981: Cambrian?)**

The Pha Bong Quartzite is found north and west of Chiang Mai and east of Mae Hong Son. It consists entirely of pinkish brown to whitish brown, thick-bedded, medium grained orthoquartzite with scattered well rounded pebbles of quartz and black chert up to 1 cm in diameter. Fine laminations showing thin colour bands in the quartzite are occasionally seen. The uppermost part contains interbeds of grey slaty shale increasing in frequency and thickness towards the top. The top few metres contain thin limestone bands. No fossil was found in the Pha Bong Quartzite. From its lithology and its stratigraphic position (conformably underlying Lower Ordovician), the Pha Bong Quartzite is correlated with the Chao Nen Quartzite Formation in Kanchanaburi, the Pong Nam Ron Quartzite Formation in Kamphaengphet, the Ko Lam Quartzite in the eastern Gulf, and the Tarutao Formation in the south Peninsula.

**Thung Song Formation (Ordovician)**

The Thung Song Formation is introduced by Bunopas (1981, Bunopas et al., in press). It was originally referred to as the Thung Song Limestone (Brown et al., 1951), but was renamed as the Thung Song Group by Javanaphet (1969). The lower part of the sequence near Nakhon Sri Thammarat was named the Nai Tak Formation (Burton, 1974). The Thung Song Limestone at the type section near Thung Song was described as a separate formation by Burton (1974). The Nai Tak Formation and the Thung Song Limestone formed the Satun Group of Burton (1974).

The name Thung Song Formation is preferred by Bunopas (1981), Bunopas et al., (in press) for the limestone at Tarutao Island. Stratigraphic and age correlation between the Thung Song Formation from Tarutao Island and Lower Satun Limestone from the Langkawi Islands are carried out by Wongwanich et al. (1983, this volume).

**Si Chang Limestone (Ordovician)**

Si Chang Limestone, 400 m in thickness, forms the island of Ko Si Chang, 11 km west of Sriracha, between Chonburi and Pattaya in the eastern Gulf. The

lower part of Si Chang limestone which is represented by outcrops along the coast from Sriracha to Bang Lamung (both in south Chonburi), consists of interbedded quartzite, quartz-schist and limestone. On the island the rocks which represent the main part of the formation consist of dark grey well bedded to massive argillaceous limestone with rare Ordovician nautiloid.

#### **Tha Manao Limestone Formation (Bunopas, 1981: Ordovician)**

The name Tha Manao Limestone Formation which is found north of Kanchanaburi is proposed by Bunopas (1981) for a formation consisting chiefly of carbonate, conformably overlying the Chao Nen Quartzite formation, and forming the upper part of the Chao Nen Group. The limestone was formerly mapped as Thung Song Group by Bunopas (1976 d). The lower part of the formation consists of about 100 m of calcareous mudstone, impure limestone conformably overlying quartzite and quartz-schist of the Chao Nen Quartzite Formation. The basal beds grade up to thick cliff-forming limestone, 200 m thick. The lower 100 m of limestone which is thickly bedded, contains abundant chert nodules and occasional fossil nautiloids of Ordovician age. The upper 100 m is thinly bedded, grey recrystallized limestone with interbedded thin sandstone, grading up from the thick-bedded limestone. The limestone subsequently grades up to interbedded quartzite and phyllite 50 m thick. The highest part of the formation consists of dark grey, light grey and brownish grey thinly bedded limestone conformably underlying white shales of the Silurian-Devonian Bo Phloi Formation. The total thickness of The Tha Manao Limestone is exceeding 450 m.

#### **Suan Mark Limestone (Bunopas, 1981: Ordovician)**

The Suan Mark Limestone was previously mapped as Thung Song Group by Bunopas, 1976 bc; Piyasin, 1975) for the Ordovician outcrops in Lower Northern Thailand. The type section of the formation chosen is in west Kamphaengphet where the rocks are mainly well banded, argillaceous limestone with alternating horizons of gray slate and quartzite making up to over 800 m in thickness.

#### **Hod Limestone (Bunopas, 1981: Ordovician)**

The Hod Limestone was mapped as Ordovician rocks by Baum et al. (1970). It is locally fossiliferous. At the type section west of Hod, south of Chiangmai the rocks, 800 m thick, were thrust over the Mesozoic red-beds, which unconformably overly Precambrian gneisses. The lower 300 m of the formation consists of thinly bedded argillaceous limestone; the middle 100 m consists of slaty shale and sandstone with bands of limestone; the upper 400 m consists of massive to thickly bedded grey to dark grey limestone with stylolites, and a few argillaceous bands. Fossils found are mainly conodonts and rare megafossils.

## MIDDLE PALEOZOIC ROCKS

### 1) WEST OF THE WESTERN PROVINCE

#### **Mae Hong Son Formation (Bunopas, 1981: Silurian - Carboniferous)**

The name Mae Hong Son Formation was given by Bunopas (1981) for a shale chert-limestone-sandstone sequence outcropping south of Mae Hong Son and Mae Sarieng mapped by Baum et al. (1971) as Silurian to Early Carboniferous. At a quarry on the road 8 km south of Mae Hong Son the strata include well bedded brown and black cherts with some interbedded sandstone and grey shale. They evidently overlie Ordovician Hod Limestone forming a steep ridge to the east. Seven kilometres upstream from Pha Bong Dam in Nam Mae Samat, east of the above locality, a sequence of sandstone, shale, subgreywacke and chert with occasional limestone bands, totalling 500 m in thickness, graded up from the Hod Limestone is found. The upper part of the formation which is exposed along the Highway from Mae Sariang to Mae Hong Son may be more than 400 m thick, and includes sandstone, shale, chert and limestone. Fossils from the limestone beds in the lower part of the formation, between Mae Sariang and Mae Hong Son, close to the Burmese border, are mainly conodonts. They indicate an age range from Late Silurian to Late Devonian (Bastin et al., 1970). The upper part of the formation contains conodonts of Early Carboniferous age in east Mae Hong Son and east Mae La Noi in south Mae Hong Son. The fossils enable correlation of Mae Hong Son Formation with the Doi Musur Group and the Thong Pha Phum Group (see below).

#### **Doi Musur Group (Bunopas, 1981: Silurian-Devonian and Early Permian)**

The name Doi Musur Group is given for a sedimentary sequence of quartzite, phyllite, shale, siltstone, sandstone and banded limestone with chert nodules toward the top. It outcrops on the western side of the Western Mountains, especially between Tak and Mae Sot (from east to west). The lower part of the group, the Doi Musur Phyllite consists of 600 m thick white to light brown quartzitic phyllite. The upper part, the Mae Ya U Siltstone consists of 1600 m thick green-grey siltstone, and massive dark grey shale and 1200 m alternations of brown-grey shale, siltstone, sandstone, limestone with chert nodules containing Lower Permian bryozoa and fusulinids near top. The estimated 3.4 km thickness of the sequence is only tentative because the rocks were repeated by open folds and a few northwest trending faults.

#### **Thong Pha Phum Group (Bunopas, 1981: Latest Ordovician to Carboniferous)**

The Thong Pha Phum Group is erected to include a number of unnamed formations, representing most of the Paleozoic rocks in the Thong Pha Phum-Sangkhlaburi, 140 km northwest of Kanchanaburi (Bunopas, 1981). The rocks of the group can be divided into three or four formations, where there are sufficient geologic field work (Koch, 1971, 1973), but up until now there has been adequate fieldwork over only small areas, and the formations were not mapped continuously for any great distance.

The type section is exposed along the banks of Huai Thong Pha Phum, north of Amphoe Thong Pha Phum (Sheets CG 19 and 23). The Huai Thong Pha Phum section

was described in some detail by Hagen and Kemper (1976) and their map was reproduced by Bunopas (1981). The strata included in the Thong Pha Phum Group contain age diagnostic fossils at frequent intervals, indicating a complete sequence from Late Ordovician to Late Carboniferous. The sequence commences with sandy marl, 20 m thick, overlying thinly-bedded Tha Manao Limestone of Ordovician age. The base of the Thong Pha Phum Group is defined as the contact between the sandy marl and the Tha Manao Limestone. It is exposed on the track between Kwa Noi and Huai Thong Pha Phum. The sandy marl passes up to well-cleaved black shale 120-125 m thick, with Lower Silurian graptolites about 30 m above the base. The black shale grades up to a distinct unit of 20 m thick and consisting of dark grey calcareous siltstone. Above this unit is a great thickness of thinly-bedded, nodular limestone, varying in composition from pure to argillaceous, silty, or sandy, and in colour from grey to red, with fossils ranging from Late Silurian near the base, through Devonian to Early Carboniferous. The total thickness of this limestone unit is uncertain, but is between 650 m and 800 m. The nearly continuous sequence of limestone is broken only by a light-grey sandy shale 100 m thick, within the Devonian part of the section. The highest unit of the Thong Pha Phum Group is olive-grey shale containing Late Carboniferous cephalopods, conformably overlying the Early Carboniferous limestone.

Permian Sai Yok Limestone conformably overlies the olive-grey shale. Near the contact the shale is strongly folded. The total thickness of the Thong Pha Phum Group at the type section is between 1000 m and 1275 m (Hagen and Kemper, 1976).

## **2) EAST OF THE WESTERN PROVINCE AND THE SUKHOThai FOLD BELT**

### **Northern Thailand and Western Thailand**

#### **Fang Chert**

The name Fang Chert is here used informally for siliceous black argillites and associated cherts 42 km south of Fang on the Chiangmai-Fang Road which were described by Kobayashi (1964), Kobayashi and Igo (1965) and Jaeger et al. (1968).

The rocks, exceeding 570 m in thickness, are exposed between km 100 and km 110 and consist of, from bottom to top: over 200 m interbedded grey shale and sandstone often crushed along faults; 100 m well bedded cherts (0.5-5 cm), green, grey and brown in colour, with very thin feldspathic shale bands; 70 m black argillite, black carbonaceous shale, and rare siltstone bands with graptolites (between km 105 and km 106); and 200 m medium-grained, well bedded sandstone, mudstone and silicified shale, green-grey-red and brown in colour. Fang Chert lies at the western edge of the Sukhothai Fold Belt close to the Western Mountains. The rocks form a narrow belt extending north of the reference section for about 200 km then disappear under Upper Paleozoic cover. They are not known south of the reference section.

Jaeger et al. (1968) and Baum et al. (1970) collected fossils from the black shale at three localities, probably at the same place as the

Kobayashi and Igo (1965) collection, and listed Early Devonian (Gedinnian-Emsian) graptolites and conodonts. Dr. R.A. Cooper of the New Zealand Geological Survey kindly identified fossils collected by Bunopas (1981) and commented that the assemblage is similar to those collected by Jaeger et al. (1968) and suggested a late Pragian (late Early Devonian) age. In terms of the paleogeographic model presented by Bunopas (1981) the basin was a small structural depression on the continental side of the back-arc area, in a situation likely to cause restricted bottom circulation. It is regarded as a small fore-land basin.

#### **Donchai Group (Piyasin, 1972)**

The name Donchai Group was introduced by Piyasin (1972) for a set of low grade metamorphic rocks outcropping from Doi Kuntan northward to Doi Angka between Chiangmai and Lampang.

The type section of the Donchai Group was located at Nam Mae Bon Stream near Ban Donchai, Amphoe Mae Tha, east Lamphun, Sheet DC 14. The rocks consist of repeated beds of quartzite, quartzo feldspathic schist, phyllite, chloritic phyllite, calcsilicate phyllite and chert. Piyasin (1972) was unable to determine the stratigraphic sequence because the beds are mesoscopically folded. The thickness of the sequence was not given, but is estimated by Bunopas (1981) to be more than 1500 m. On the east side of the Khuntan Range at Ban Thung Luang, 20 km west of Lampang, similar rocks include up to 300 m thick bedded quartzite passing up to interbedded phyllite and schist for some 400 m, above which the same lithological sequence is repeated, how many repetitions occur is not known.

The Donchai Group forms a belt from east of the Bhumiphol Dam, northward into the area west of Thoen, through Doi Khuntan and Doi Angka between Chiangmai and Chiangrai. Piyasin (1972) included also rocks along the road from Thoen to Lampang, which were treated by Bunopas (1981) as the Khao Khieo Tuff and rocks between Phrae and Nan which were treated by Bunopas (1981) as the Pha Som Group. In Bunopas paper (1982) the name Donchai Group is restricted to the rocks forming a north-south belt from the type section south to the Bhumiphol Dam and north to Doi Angka. The rocks in this belt include no volcanogenic component.

The Donchai Group outcrops along the eastern edge of the Western Mountains and the western edge of the Sukhothai Fold Belt. It possibly represents foreland basin deposits of quartzo-feldspathic and orthoquartzitic composition, the detrital components having been derived from the craton to the west. The inferred Silurian-Devonian volcanic arc lay at some distance to the east.

#### **Mae Ko Complex (Silurian-Devonian)**

The name Mae Ko Complex is used informally for metavolcanic rocks at Wiang Pa Pao, between Chiangmai and Chiangrai. Previously the complex had been mapped as Silurian-Devonian metasediments intruded at their eastern side by a body of stressed granite supposed to be Carboniferous in age (Baum et al., 1970). The rocks include sillimanite schist, andalusite

schist and amphibolite schist, usually grey or greenish grey to black in colour. Quartz epidote schist and occasional thin layers of calcsilicate and marble, grey or green-grey to white in colour are also observed. Some layers exhibit fine layering which were thought to be the relict flow-layering. The amphibolite schist often contains radiating aggregates of amphibole crystals up to 15 cm long. Aplite dykes cut across the layers at places. Mesoscopic and microscopic folds are common.

The petrography of most of the rocks indicates an igneous origin, and the well defined layering indicates extrusive volcanics. The thin marble and calcsilicate layers represent non-volcanogenic and partly volcanogenic sediments that confirm the extrusive nature of the volcanics, and suggest a marine environment. Probable relict flow-layering in some of the metavolcanic layers implies that they were originally lavas, but the regularity of the layering throughout most of the complex is thought to indicate that most of the metavolcanics were originally subaqueous tuffs.

#### **Thung Saliam Group (Bunopas 1981; Silurian-Devonian)**

The name Thung Saliam Group is proposed by Bunopas 1981 for a sequence of tuff, limestone, marble and chert outcropping at Thung Saliam, northwest Sukhothai, in the Sukhothai Fold Belt. The group consists of three formations, from bottom to top, namely 1, Khao Khieo Tuff Formation 2; Thung Saliam Limestone; and 3, Khanu Chert Formation.

##### **a) Khao Khieo Tuff Formation (Bunopas, 1976 b)**

The type section of the Khao Khieo Tuff Formation extends across the mountain from west to east near Phran Kratai, from grid ref. 553-1855 (NE 47-7). The rocks at the type section are a monotonous sequence of poorly differentiated interbedded greywackes, argillites, sandy slate, tuffaceous phyllite, quartzo-feldspathic tuff, andesitic tuff, lithic and crystal tuffs, and some well cleaved agglomerates. The rocks are green to grey when fresh and brown to yellowish when weathered. The tuff content, mainly quartzo-feldspathic, increases toward the top of the sequence which underlies the limestone of the younger unit. The thickness of the sequence from the western slope of the hill to the middle of the hill is estimated to be more than 1800 m.

##### **b) Thung Saliam Limestone (Bunopas, 1981)**

Thung Saliam Limestone consists of grey recrystallised limestone, tuffaceous shale and sandstone and white marble outcropping along hills in west Thung Saliam, north Sukhothai. The formation, altogether around 900 m thick, extends in discontinuous exposures through Kamphaengphet to west Nakhon Sawan about 200 km south of Thung Saliam. The marble is known as Khao Sawang Marbles at Phran Kratai in Kamphaengphet (Bunopas, 1976 b), and as Khao Mano Marbles at west Nakhon Sawan (Bunopas, 1976 c, 1980 a). The Thung Saliam Limestone Formation is here considered a more appropriate name because the Thung Saliam area contains a more complete limestone sequence, and its stratigraphic relationship to other formations of the group is much more clearly exposed.

### **c) Khanu Chert Formation (Bunopas, 1976 b)**

Khanu Chert Formation consists mainly of thin-bedded white, black, grey, brown, blue and green cherts with laminae of feldspathic and tuffaceous material between the chert beds. The rocks are best exposed in a number of small hills between Sawankalok and Thung Saliam, in north Sukhothai. Rare radiolarian fossils were identified in the brown and black varieties of the chert. The thickness of the cherts estimated from a number of different exposures is about 800 m (not including 70 m at the basal part containing phyllite). The rocks were folded into a series of anticlines and synclines and in places the folds were overturned to the east. Some mesoscopic folds are also common. The cherts were originally named Khanu Cherts for their distribution at Khanu Woralakburi in south Kamphaengphet (Phitsanulok Quadrangle: Bunopas, 1976 b), and were also known as the Khao Gob Cherts at Khao Gob, Nakhon Sawan (Nakhon Sawan Quadrangle: Bunopas, 1976, 1980 a).

Radiolarian cherts typically are deposited on relatively deep ocean floors below the calcium carbonate compensation depth, but possibly can accumulate in shallow marine environments where associated with volcanic activity. Thick chert deposits are commonly associated with volcanic arcs, in parts of both back-arc and fore-arc basins that are starved of clastic detritus (Dickinson, 1974). The Khanu Cherts include a small proportion of fine-grained volcanoclastic material, and are considered to be an equivalent lateral facies of the Khao Khieo Tuff and Thung Saliam Limestone. The conformable contact of Khanu Cherts with the Thung Saliam Limestone Formation at the type locality is the only contact known. The true relationship is likely to be interdigitating. The cherts outcrop over a broad belt 70 km wide, to the east of the Thung Saliam Limestones. They are considered to have been deposited in the deepest and most distal part of the fore-arc basin, which may have been separated from the trench by a ridge at the top of the inner trench slope (Dickinson, 1974). In central and lower North Thailand much of the cherts are now low-lying and covered by Cenozoic sediments of the Chao Phraya central plain, but it appears never to have been covered by younger Paleozoic rocks.

### **Pha Som Group (Bunopas, 1969 MS: Silurian-Devonian)**

The Pha Som Group is proposed (without any named formations) for a sequence of sedimentary rocks which are usually metamorphosed to greenschist facies, found mainly in a northeast trending belt especially at the Pha Som Dam (Sirikit Dam) in Sheet EB 23 mainly on the west side of the Nan River, but also in small inliers east of Nan River. It is typically exposed at the Pha Som Dam.

The type section is designated at the excavations for the dam abutments, the upper parts of which were not covered by the dam structure and at access roads to the dam abutments. The rocks generally dip from 20 to 90 degrees west. Mesoscopic folds are common. A detailed stratigraphy of the section cannot be determined owing to the folding, lack of key beds, and discontinuity of exposure.

The rocks at the dam and north of the dam on the reservoir side are

banded quartzite, quartzitic phyllite, phyllite, phyllitic schist, muscovite-quartz schist, epidote-quartz schist, actinolite-quartz schist, chlorite schist, and hornblende schist. The rocks are usually well cleaved, the cleavage plane dipping steeply (60-80 degrees) to the west. Bunopas, (1969 MS) and Thanasuthipitak (1978) recognised six main rock types near Uttaradit, 20 km south of the dam.

The Pha Som Group contains no fossil. Stratigraphically it is pre-Permo-Carboniferous and a Silurian-Devonian age seems likely. It is thought to be an equivalent lateral facies of the Silurian-Devonian tuff, marble and chert of the Thung Saliam Group to the west.

Most of the rock types of the Pha Som Group are thought to have been altered from pelites and flyschoid sandstone and siltstone. The metamorphism, and the severe deformation and probably chaotic stratigraphy are consistent with their having formed the inner trench slope in the Silurian-Devonian paleotectonic model presented by Bunopas (1981). Their geographic position also is consistent with the model, being immediately east of the Khanu Chert, the most distal facies of the presumed fore-arc basin represented by the Thung Saliam Group. The origin of the quartz - rich rocks is uncertain. Possibly they were derived from the craton to the west, but it is difficult to imagine how they could be transported across the volcanic arc and its associated fore-arc and back-arc basins. Alternatively the quartz-rich rocks might have been derived by recycling of the Pha Som Group itself as a result of erosion of islands formed at the top of the inner trench slopes. Narrow dykes of diabase, pyroxenite and serpentinite were intruded into the Pha Som Group but not into overlying Triassic or adjacent Permo-Triassic rocks.

Large bodies of Pha Som Ultramafics are faulted against the group, providing further evidence of an origin within the trench of an arc-trench system.

#### **Bo Phloi Formation (Bunopas and Bunjitradulya, 1975: Silurian-Devonian)**

The type section of the Bo Phloi Formation is at Khao Ka and Khao Yai, two isolated hills 10 km southeast of Bo Phloi, north Kanchanaburi. At the type section the Bo Phloi Formation consists of quartzite, shale, chert, tuff, phyllite and thin crystalline limestone, totalling about 350 m in thickness. The formation in the Bo Phloi area is not known to overlie any older strata, but to the northwest it is conformably overlying the Ordovician limestone.

The fossil *Tentaculites* cf, *alegans* was reported from Khao Ka (Bunopas and Bunjitradulya, 1975).

Quartzites at the base of the formation, containing recognisable quartz grains, represent a mature shallow water sediment derived from a plutonic source, presumably the Precambrian basement now exposed in the Western Mountains. The interbedded argillites, at places metamorphosed to phyllites, are consistent with that interpretation.

Volcanic detritus in the tuffaceous rocks in the middle part of the

Bo Phloi Formation is thought to be predominantly andesitic in composition, and to have been derived from a volcanic arc with its axis probably a short distance to the east (Bunopas and Vella, 1978).

The Bo Phloi Formation thus consists of continental margin deposits. The vertical changes in it reflect a change from a passive (Atlantic-type) margin to an active (Pacific-type) margin. The volcanic rocks are considered to have resulted from westward dipping subduction beneath the Shan-Thai Craton, part of which is represented by Precambrian rocks now outcropping in the Western Mountains of Thailand (Bunopas and Vella, 1978). The Bo Phloi Formation represents the back-arc facies.

### 3) THE LOEI FOLD BELT

#### Pak Chom chert (Silurian-Devonian)

Possible Silurian-Devonian shale and chert occur only north of Loei. The Paleozoic formation outcrops only northwest of the Plateau, and is a part of the Loei Fold Belt. Coralloid Devonian limestone is known on the Laotian side of the Mekong valley (Ban Vang) and in Thailand (Ban Muang) (Fontaine, 1980).

### 4) EASTERN GULF

#### Sattahip shale (Silurian-Devonian ?)

Sattahip shale includes a sequence of interbedded slaty shale, fine grained argillaceous sandstone and a few thin limestone bands. The shale is best exposed at the Sattahip Naval Base, south of Pattaya. The rocks are well cleaved and mesoscopically folded. The shale and sandstone are reddish brown and white when weathered, but are green-grey to brown-grey at one quarry near the Sattahip-Rayong road.

#### Klaeng schist and phyllite (Silurian-Devonian)

Klaeng schist and phyllite form a low terrain adjacent to the side of and subparallel to the Precambrian gneiss hills east of Klaeng. The lower part of the sequence consists of interbedded quartz-mica schist, tuffaceous quartzite and brown tuffaceous phyllite. In thin section the quartz-mica schist consists mainly of quartz, feldspar, biotite and muscovite. The rocks often are weathered. Overlying the schist are interbeds of white to brown-grey quartzite, quartzose sandstone, and in some areas near Klaeng also some intercalations of grey slate, slaty shale, chert, phyllite and rare thin limestone bands (each less than 10 m thick). The rocks were well cleaved and were mesoscopically folded. The strata dip mainly about 55 degrees to the northeast. The only fossil found in the chert at Laem Thong Lang near Klaeng (47P/FE5, 790975) is a small nautiloid species *Michelinoceras micheline*, probably of Silurian age. The Klaeng schist and phyllite are probably comparable with the Bo Phloi Formation, while the Sattahip shale is comparable with the Thong Pha Phum Group both in West Thailand.

## 5) THE PENINSULA

Silurian-Devonian strata form two north-south trending facies belts in southern Peninsula. A western belt which consists of shale, siltstone, sandstone, and thin limestone is found at Khuan Din So and Thung Wa. An eastern belt of fine grained tuffs interbedded with cherts very like the Bo Phloi Formation of West Thailand is formed in Surat Thani, Nakhon Si Thammarat, Songkhla, Pattani, Yala and Narathiwat.

### **Khuan Din So and Thung Wa shale, chert and limestone (Silurian-Devonian) and Satun shale**

The western facies belt, very much like the Thong Pha Phum Group in West Thailand outcrops adjacent to the Ordovician and Cambrian formations in the north-south trending belt ranges between Nakhon Si Thammarat and Satun. *Tentaculites*, trilobites and the graptolites *Diplograptus* and *Climocograptus* (Middle to Late Ordovician) have been reported from black shale interbedded with the limestone at Trang (Kobayashi and Hamada, 1968).

### **Narathiwat phyllite (Silurian-Devonian)**

Narathiwat phyllite contains fine grained tuffs, interbedded with cherts. The Narathiwat phyllite is the eastern facies belt found east of Khuan Din So. The Thung Wa shale, chert and limestone comprise the western facies belt. These two belts are restricted to Yala and Narathiwat, immediately north of the Malaysian border, and are poorly exposed in jungle-covered ground with low relief. The best exposures are at the excavation for the Banglang Dam, Narathiwat. The rocks are overlain by Carboniferous red-beds and their base is unknown.

The strong resemblance of the Yala-Narathiwat rocks to the Bo Phloi Formation, and their similar position east of Lower Paleozoic and Precambrian terrain, lead to the conclusion that the Yala-Narathiwat rocks are the southern continuation of the Bo Phloi facies, though now separated from it by the Gulf of Thailand. They indicate the southern continuation of the inferred Silurian-Devonian volcanic arc in West and North Thailand.

## UPPER PALEOZOIC ROCKS

### 1. WESTERN PROVINCE AND SUKHOTHAI FOLD BELT

#### **Doi Kong Mu Formation (Bunopas, 1981: Carboniferous)**

The name Doi Kong Mu Formation is introduced for a sequence of red sandstone, red shale and red conglomerate typically exposed at Doi Kong Mu, a small hill 200 m high on the west side of the town of Mae Hong Son. The rocks were not previously described. They are well exposed in a road cut extending from the base to the top of Doi Kong Mu where a celebrated

Buddhist temple is situated.

The beds, 300 m thick, consist of well bedded (5-100 cm) conglomerate, red and purplish red sandstone, and shale dipping steeply to the east (about 60-70 degrees). Judging from graded bedding in conglomeratic sandstone beds, load casts, and infrequent small ripple marks, the strata are overturned toward the west.

The conglomerates are poorly to moderately sorted and consist of sub-rounded to angular pebbles of quartz, chert, quartzite and brown sandstone probably derived from the Cambrian Pha Bong Quartzite and Silurian-Carboniferous Mae Hong Son Formation. The sandstones are mostly arkosic, and quartzose, in composition. The sandstone and shale are moderately cleaved.

No fossil was found in the Doi Kong Mu Formation. Judging from its stratigraphic position underlying the limestone containing Lower or Middle Permian fusulinids, small foraminiferas and conodonts in northwest Mae Sariang (Baum et al., 1970), the Doi Kong Mu Formation is probably Carboniferous, possibly Upper Carboniferous (Baum et al., 1970). Doi Kong Mu Formation is comparable with the Fang Red beds and Mae Tha Group to the east. It is also possible that the Doi Kong Mu Formation is a lateral facies equivalent of the upper part of the Mae Hong Son Formation.

#### **Fang Red Beds (Carboniferous)**

The name Fang Red Beds is here used informally for red conglomerate, sandstone and shale about 200 m thick, exposed on the Chiangmai-Fang road, 40 km south of Fang. The beds are thick conglomerates and interbedded conglomeratic sandstones grading to sandstone and shale, which dip about 45 degrees to the northwest, to the base of the Permian limestone of Doi Hoato Hill (Lower Permian, Sakamarian or Wolfcampian: Kobayashi, 1964).

The conglomerate is well sorted and consists of round to subrounded pebbles of chert, quartzite, slate and some limestone, probably derived from the Silurian-Devonian Fang Chert and the Ordovician Hod Limestone.

The Fang Red Beds are probably equivalent in age to the more widespread Mae Tha Group and are probably a near source facies. The age of the Fang Red Beds is considered to be Carboniferous, probably Upper Carboniferous. Locally the beds are intruded by small diabase dykes probably of Late Permian to Early Triassic age.

#### **Mae Tha Group (Piyasin, 1972: Carboniferous-Early Permian)**

Piyasin (1972) proposed the name Mae Tha Group for mixed reddish brown, white, grey and green-grey sandstones and shales exposed on the Lampang-Chiangmai road at Amphoe Mae Tha west of the Mae Tha River. The type section designated by Piyasin is on the western flank of the Khuntan Range on the northern side of the road. Besides the lithologies exposed there, Piyasin included some greywacke and agglomerate outcropping to the east between Lampang and Phrae and between Phrae and Uttaradit within this Mae Tha Group also, but Bunopas (1981) excluded them from this Group.

The type section contains interbedded white quartzose sandstones, red-brown arkosic sandstones and red-brown, brown-grey and green-grey shales. The beds were folded and faulted, dipping at angles up to 70 degrees both to the east and to the west, and as there is no distinct marker bed the sequence cannot be determined. Piyasin (1972) gave no thickness for the section, but the writer has estimated it to be possibly as great as 2,000 m.

No identifiable fossil was found in the Mae Tha Group. From its stratigraphic position unconformably overlying the presumed Silurian-Devonian and conformably underlying the well dated Middle Permian, the Mae Tha Group is considered to be Carboniferous to Early Permian in age.

Lithologically the Mae Tha Group is similar to the Fang Red Beds north of Chiangmai, to some red beds of the Dan Lan Hoi Group in the lower North Thailand and to the red-beds presumably Carboniferous at Ban Tao Mo, near Chantaburi in the Eastern Gulf area. All of these formations lie in the western part of the Sukhothai Fold Belt.

The conglomerates at the base of the Mae Tha Group indicate that the underlying Donchai Group was uplifted and partly emerged from the sea. The fineness of the conglomerate, and dominant proportion of sandstone suggest that the land area formed by the uplift was of slight relief. It is uncertain whether or not the Mae Tha Group contains true continental red-beds. A few underterminable plant fragments were found, but they could have been transported into a marine environment. Small-scale cross bedding and ripple marks indicate subaqueous deposition at some horizons. Most likely the Mae Tha Group is a paralic facies, partly continental and partly marine.

#### **Phrae Group (Bunopas, 1981: Carboniferous-Permian)**

The name Phrae Group, derived from the city of Phrae (180 km north of Sukhothai), was proposed by Bunopas (1981) for a sedimentary sequence up to 4000 m thick, consisting of two formations, the Mae Sai Formation below and the Rong Kwang Formation above. A large proportion of the Mae Sai Formation consists of agglomerates and conglomerates, while the Rong Kwang Formation is mainly greywacke, argillite and limestone. The Phrae Group forms the greater part of the mountain range (1000 to 1727 m elevation) extending from Sukhothai in the south to Nan in the north. The range is about 250 km long and 30 km wide. The cities of Phrae and Uttaradit lie midway along the range, on its western and eastern margins respectively. The Mae Sai Formation is best developed northeast of Phrae, and thins rapidly southward from Phrae. The Rong Kwang Formation extends throughout the whole length of the mountain range, and becomes progressively more calcareous from south to north.

The strata were previously mapped in part as the Mae Tha Group (Carboniferous), Kui Lom Formation (Permian) and Hong Hoi Formation (Triassic) (Piyasin, 1972) and in part (south of Phrae) as undifferentiated Permo-Carboniferous (Piyasin, 1975); and in part as Mae Pung Formation and Mae Raem Formation (Bunopas, unpublished Geological Survey Report).

The name Phrae Group is here also applied to rocks immediately west of Phrae and areas between Phrae and Lampang (in Mae Tha valley), which have

been mapped previously as the Permian Kui Lom and Huai Tak Formations (Piyasin, 1972).

On the evidence of fossils (in Rong Kwang Formation) and stratigraphic superposition the Phrae Group probably ranges from Carboniferous to Permian in age.

The volcanic chert at the base of the Mae Sai Formation and its equivalent suggests a depositional environment within the arc-trench gap, probably not far from the arc. This is supported by the existence of volcanic rocks about 20 km west of the chert and also volcanic rocks and shallow intrusive bodies west of Phrae which were thought to be of the same age. According to the Bunopas's interpretation the Carboniferous arc-trench gap would be east of the volcanic arc, consistent with the position of Huai Mae Sai, and the Mae Sai Formation.

The fragmented part of the chert, contrasting with the little disturbed lower part, is thought to reflect the beginning of a slumping regime on the ocean floor, and the overlying agglomerate, conglomerate, sandstone and shale are regarded as submarine fan deposits originating by erosion of emergent anticlinal ridge along the line of the volcanic arc. Volcanic clasts are in a majority, and a minority of the clasts represent the basement formed by the former (Silurian-Devonian) arc-trench gap facies. The increase of relatively well sorted clasts and progressive thinning towards the northeast may suggest increasing distance from the arc in that direction. The progressive decrease in clast sizes, increase in sandy beds, and rapid thinning to the northeast and east indicates rapid facies change. The mapped boundary with the overlying formation is oblique to the strike of the beds.

Rare fossils were found at scattered horizons in the Rong Kwang Formation. Only a few of them were identified. The most important are the fusulinid *Paraschwagerina* sp. (Middle Permian) and *Orthoceras* sp. from high in the formation at Huai Pui west of Phrae (locality EC 9, 217275). These fossils were identified by Mrs. Rucha Ingavat. Small bivalves from Huai Thang Laeng (EC 10, 367428), and Huai Mae Kon (EC 2, 328950) are thought to be Carboniferous in age. Other fossils include an unidentified colonial coral, relatively common broken crinoid stems, and some worm trails.

The seemingly conformable superposition on the Pha Som Group at Huai Mae Sai suggests that the Rong Kwang Formation ranges in age from Lower Carboniferous to Permian. The contact with the underlying Mae Sai Formation (Carboniferous) is considered to be time-transgressive, and youngest at the point where the Mae Sai Formation reaches its maximum thickness.

#### **Mae Plung Shale (Bunopas, 1981: Carboniferous)**

The type section of the Mae Plung Shale Formation is in Huai Mae Plung stream between two small hills, Khao Kan Hok, and Khao Hin Tang, 30 km north-northwest of Bo Phloi. The thickness of the type section is 300 m and the strata are greenish-grey shale beds up to 1 m thick interbedded with green-grey tuffaceous sandstones up to 0.5 m thick, with infrequent well sorted

subrounded pebble conglomerates up to 1.5 m thick, and rare argillaceous limestone bands up to 0.3 m thick. Clasts in the conglomerates include shale, quartz, limestone and chert, possibly all derived from Bo Phloi Formation.

The shales contain infrequent well-preserved bivalves, and the limestone bands contain indeterminate fossils. The beds overlie Bo Phloi Formation at Khao Chang Noi, apparently conformably, though the contact is not exposed.

**Kaeng Krachan Group (Javanaphet, 1969; Piyasin, 1975: Carboniferous-Early Permian)**

The Kaeng Krachan Formation (Javanaphet, 1969) was proposed as the upper part of the Tanaosri Group, the lower part being the Kanchanaburi Formation (Javanaphet, 1969). Piyasin (1975) raised the Kaeng Krachan Formation to group status. Both formations of the Tanaosri Group were introduced without designation of type sections, and were applied to all Silurian to Carboniferous rocks shown on the 1:1,000,000 Geological Map of Thailand (Javanaphet, 1969). Various names have since been used in place of the Kanchanaburi Formation in different areas (e.g. Piyasin, 1972, 1975; Bunopas, 1975, 1976 a, 1976 b, 1976 c), and also in place of the Kaeng Krachan Formation in areas north of Kanchanaburi (e.g. Piyasin, 1972, 1975; Bunopas, 1976 b, 1976 c, 1976 d).

The Kaeng Krachan Group as described by Piyasin (1975) includes three formations, totalling more than 1,950 m in thickness. From youngest to oldest the formations are:

a) **Khao Chao Formation** consists mainly of greenish grey shale, inter-bedded sandstone and shale, brown to greyish brown feldspathic sandstone and quartzose sandstone. The thickness of the formation at the type locality, Khao Chao at the Kaeng Krachan Dam, south Petchaburi, is about 270 m. The total estimated thickness at Khao Phrik is over 850 m.

b) **Khao Phra Formation** consists mainly of green-grey pebbly mudstone, massive and well-bedded shale with intercalations of fine-grained sandstone, and pebbly shale. Well-bedded shale and pebbly shale contain Carboniferous bivalves, brachiopods and bryozoans. The thickness of the formation at the type section at Khao Phra, 8 km west of km 140 of the Phet Kasem Highway near Phetchaburi, is over 344 m, and the total thickness is estimated at over 600 m.

c) **Huai Phu Noi Formation** consists mainly of grey, carbonaceous shale with a few intercalations of pebbly shale and pebbly mudstone beds locally fossiliferous with Carboniferous brachiopods. The thickness estimated from the type section, Huai Phu Noi near Khao Phra, Ratchaburi Province, is over 480 m. The lowest part of the group is not known. The uppermost part that underlies the limestones of the Ratburi Group is exposed at an isolated hill Khao Kling, about 3 km west of km 31.8 of the Phet Kasem Highway. The total thickness suggested is thus only an estimate.

Exotic clasts are rather common in the Khao Phra Formation, and much less common in the overlying Khao Chao Formation. The size of the clasts varies from 0.5 to 4 cm, but the most common size is around 1 to 2.5 cm.

The megaclasts consist mainly of quartz, orthoquartzite, green metaquartzite, brown sandstone, slate, limestone and granite. Small clasts are predominantly quartz and feldspar. The megaclasts vary from rounded to angular, the clasts are distributed irregularly through massive beds of highly lithified medium to dark grey mudstone. The rock is diamictite, but is usually called pebbly mudstone. Of the megaclasts only the granites can be regarded as definitely exotic. All the other lithologies represented could possibly be derived from local older Paleozoic or Precambrian formations, although the green metaquartzite and brown sandstone have no obvious possible sources. No pre-Carboniferous granites are known in Thailand or Burma or the Malay Peninsula, and the only Carboniferous granites in Thailand are small bodies far away from the area of the Kaeng Krachan Group.

## **2) THE EASTERN GULF**

**Khao Thalai Red Beds** in east Klaeng and Thamai consist of brownish white quartzose sandstone, red conglomeratic sandstone, feldspathic sandstone, and purplish red feldspathic shale. The sandstones are fine to medium grained and consist of subangular to subrounded quartz in a siliceous cement. The rocks dip 40 to 70 degrees to the east and form elongated hills probably bounded by faults (e.g. at Khao Thalai). The rocks probably represent late Carboniferous red beds are thought to be overlain by Permian limestone.

**Khao Kaeo Kamprang Shale and Sandstone** constitute a group of small low hills east of Khao Thalai. The rocks consist of alternations of micaceous siltstone, shale, sandstone, chert, limestone and intraformational conglomerate dipping toward the northeast at 30 to 70 degrees. Local dipping in the opposite direction because of local folding are also observed. The limestone can be up to 25 m thick and contains Visian (Lower Carboniferous) bryozoans, brachiopods and crinoid stems (identified by Mrs. Rucha Ingavat). Nakinbodee and colleagues (pers. comm.) reported some intercalations of basic volcanic tuff near Klaeng.

**Sra Kaeo Group** is here used informally for a mainly chert and feldspathic shale sequence found between Chanthaburi and Trat in the east and between Chanthaburi and Sra Kaeo in the north. The rocks can possibly be divided into two formations, a lower formation comprises mainly chert and shale between Chanthaburi and Trat, and an upper Formation which occurs between north Pong Nam Ron and Sra Kaeo on the Chanthaburi Sra Kaeo road is mainly chert with some basic lavas (Sra Kaeo pillow lavas). The age of the group could range from Carboniferous to early Late Permian. Chert beds in the Khao Kaeo Kamprang Shale and Sandstone increase eastward towards Chanthaburi suggesting a progressive lateral facies change into the basal part of Sra Kaeo group, and deep ocean further east during Carboniferous time.

## **3) THE PENINSULA**

The Carboniferous rocks in the southern peninsula has not been clearly defined. Some rocks which are now fairly certainly known to be Carboniferous were mapped previously as of different ages. For example a belt between Songkhla and Haad Yai formerly mapped as Triassic (Javanaphet, 1969) was

considered on good grounds to be Carboniferous by Grant-Mackie et al. (1978). Clarification of the Carboniferous part of the sequence in the southern peninsula is essential to the understanding of the facies relations to the Phuket Group, which in turn should lead to a better understanding of the mode of origin of the Phuket Group.

At Songkhla a definite Carboniferous age (late Tournaisian or early Osagian) is known from conodonts from alternating black to grey siliceous shale and chert at the northern end of Ko Yo (Igo, 1973). Strata included in the Carboniferous rocks between Songkhla and Haad Yai are 2,800 m of sandstone, chert and shale that were considered to have been deposited in quite anoxic offshore waters (Grant-Mackie et al., 1978). To the west of Songkhla (between Songkhla and Satun), strata of probable Carboniferous age are siltstone, shale, sandstone and chert, possibly overlain by the Permian Ratburi Limestone (Muanlek, pers. comm.), and containing Visean brachiopods, *Marginirugus* sp. and *Kitakamithyris* sp. (Hamada, 1961). Northwards on the same trend, at Pattalung, Reed (1920) described a Visean fauna, including *Chonetipustula* sp., *Plicatifera* sp., and *Pronorites* sp. The belt of Carboniferous rocks extends south into the Northwest Malay Peninsula (Kobayashi and Hamada, 1966; Hamada, 1969; Gobbett, 1973). These rocks represent a different facies from the Phuket Group in the middle peninsula.

The rocks which are found to the east at Yala, overly the presumed Silurian-Devonian tuffaceous strata. They were mapped previously as Triassic or Jurassic Khorat Group, but possibly represent Carboniferous red beds. They consist of unfossiliferous purplish red shale, sandstone and feldspathic sandstone and were thought to be overlain by the adjacent Permian Ratburi Limestone west of Yala (Muanlek, pers. comm.).

#### **Phuket Group (Mitchell, 1970: Carboniferous-Early Permian)**

Permo-Carboniferous pebbly mudstone bearing facies, known as the Phuket Group does not differ much in lithology and structure from the Kaeng Krachan Group to the north or the Mergui Formation in adjacent Burma. The dominant lithologies in the Phuket Group are grey laminated mudstone and alternating graded sandstones and mudstones interpreted as turbidites. Locally at Phuket and Krabi, sections up to 3 km thick, without top or bottom, were measured. The base of the group has never been found; locally the top which is found overlain, apparently conformably by Ratburi Limestone (Middle Permian) is preserved in narrow synclinal axes or in the down thrown sides of the faults.

Siliceous shales and fine grained sandstone which are found near the top of the group, 50 m below Ratburi Limestone at Ko Yao Noi, Ko Muk, and Ko Phi Phi, between Phuket and Trang, contain cold-water bivalves and abundant brachiopods, of Early Permian age (Waterhouse, 1982).

In the grey fine sandstone near the top of the group, 15 m below the base of Ratburi Limestone, at Pak Meng (Khao Meng) 30 km west of Trang, fossil plants including *Walchia* cf. *piniformis* Schlotheim, *Taeniopteris* ? sp. and *Samoropsis* sp. were discovered (Holden et al., in press). *Walchia* is not known in the Cathaysian/Permian flora and is typically Euramerican,

and those low diversity floral assemblages appear to be rather common in the Lower Permian.

## **PERMIAN ROCKS**

### **1) WESTERN PROVINCE**

#### **Ngao Group (Bunopas, 1981: Permian)**

The Ngao Group is proposed by Bunopas (1981) for a sequence consisting mainly of shale, sandstone and limestone of Permian age in the Lampang-Ngao area previously mapped as Ratburi Group by Piyasin (1972). Here the name Ratburi Group is confined to the peninsular area.

The Ngao Group consists of the following three formations (oldest at the bottom):

a) **Huai Tak Formation** (Piyasin, 1972) consists mainly of fossiliferous shale and thin intercalations of sandstone, limestone and intraformational conglomerate, at least 760 m and possibly up to 1,500 m thick. Twenty five late Permian lyttonid fauna from the formation are correlated with the lower Changning fauna of south China (Waterhouse, 1983).

b) **Pha Huat Formation** (Piyasin, 1972) consists mainly of massive to well bedded, recrystallised limestone, locally fossiliferous, at least 600 m thick.

c) **Kiu Lom Formation** (Piyasin, 1972) comprises mainly sandstone, shale, calcareous shale and thin limestone with fusulinids, 500 to 600 m thick at the type section, but much thinner in other places.

These rocks are best exposed between Ngao and Lampang, and are well developed throughout the Permo-Triassic Lampang basin which lies between east Lampang and west Phrae.

The calcareous shale with interbedded fusulinid limestone represents an open marine environment indicating transgression of the sea after the deposition of the paralic Mae Tha Group. Deepening of the sea was consistent with the general paleogeographic model presented by Bunopas (1981).

#### **Phra Woh Limestone**

Phra Woh Limestone is intended to be an informal name for rocks previously known as the limestone at Mount Pawa (equals Phra Woh) by Heim and Hirschi (1939) and referred to as Permian limestone (at point 919) by von Braun and Jordan (1976).

The best known section of Phra Woh Limestone is at Phra Woh, a dolomitic limestone tower karst at km 62.3 to km 66 on the Tak-Mae Sot Highway near Mae Sot. The section is 650 m thick and the lower 500 m consists of coarse grained to massive dolomitic limestone with rare intercalations of quartzose sandstone, while the upper 150 m consists of dolomitic limestone and chert. The chert is weathered to a light colour and shows boxwork weathering in some exposures. The Phra Woh Limestone is

limited in its distribution to isolated outcrops 40 km north of Phra Woh and about 70 km south of Phra Woh.

The limestone contains no identifiable fossils but it contains rounded structures that may be algae. To the north of Phra Woh, calcareous feldspathic sandstone near the top of the underlying Doi Musur Group contains well preserved fusulinids, *Monodioxodina shiptoni* (Dunbar) of Early Permian age. The Phra Woh Limestone is thus probably Middle to Late Permian.

The limestone with some intercalations of quartzitic sandstone and chert was probably a carbonate shelf facies deposited on a continental margin or continent fragment when supply of terrigenous detritus become exhausted or nearly exhausted because of low relief of the adjacent land.

#### **Mae Tho Formation (Bunopas, 1976 c)**

The Mae Tho Formation is here proposed for a sedimentary sequence confined to the Lansang Fault Zone (Bunopas, 1976 c). The rocks cannot be directly correlated with any other formations either in Lampang to the north or in the area to the south.

The type section of the Mae Tho Formation is in a small dry creek off the right branch of Um Yom near Huai Mae Tho, about 3 km due west of Ban Tha Chang Tai. A large part of the Huai Mae Tho drainage area is composed of rocks of this formation.

The unnamed small creek containing the type section originates at a small hill in the Lansang Fault Zone near the Tak-Mae Sot Highway close to the Lansang Park. The creek runs eastwards and the rocks are exposed along the whole short length of the creek. The section measured downstream (from west to east) consists of shale, limestone and tuffaceous shale and sandstone over 300 m in thickness.

Fusulinacean fossils were kindly identified by Mrs. Rucha Ingavat. Originally she identified them as *Monodioxodina* sp. aff. *kattaensis*, but later altered the identification to *Monodioxodina shiptoni* (Dunbar), the same species that was identified in the calcareous sandstone of east Mae Sot (see Phra Woh Limestone), and in Permian limestone at northwest Mae Sariang (Baum et al., 1970; Bunopas, 1981), indicating an Early Permian age (late Artinskian or Leonardian), above the *kattaensis* horizon of the Salt Range. Unidentified ammonite specimens (about 5 cm in diameter), a bryozoan, *Dyscritella* sp., and crinoid stems probably also indicate a Permian age. A hiatus representing the Upper Permian and probably the Middle Permian exists between the Mae Tho Formation and the overlying Lower to Middle Triassic Tak Group. The Ngao Group near Lampang which includes the Kiu Lom Formation contains different Lower Permian fusulinids, and has slightly different lithology, but probably is comparable in age to the Mae Tho Formation.

#### **Sai Yok Group (Bunopas, 1981)**

The Sai Yok Group is defined as containing the Kho Muang Khrut Formation,

Sai Yok Limestone, and Tha Madua Formation (in order of decreasing age). It was previously referred to as the Ratburi Group (Bunopas, 1967 d).

The rocks of the Sai Yok Group are most extensively preserved in the Three Pagodas Fault Zone between Kwa Noi and Kwa Yai. Some remnants were mapped in the Western Mountains east of the fault zone.

The most useful correlation fossils are fusulinids and brachiopods. Fusulinids from the lower part of Sai Yok Limestone at Khao Muang Khrut and its vicinity include *Parafusulina nosoensis*, *Yangchienia* cf. *eniqua* and *Polydierodina* sp. (with some small foraminifera). These fossils were identified by Mrs. Rucha Ingavat and were considered to be Middle Permian in age. Brachiopods from the lower part of the limestone which were also identified by Mrs. Rucha, include *Fletcherithyris amyyadala*. They were thought to indicate a Lower Permian age.

Fusulinids from the uppermost part of the limestone identified by Mrs. Rucha include *Ozawainella* sp. and *Parafusulina* sp. Their ages were consistent with Late Middle or Late Permian ages of the rocks. The limestone at Khao Plukmu, north of Bo Phloi, contains possibly Late Permian fusulinids.

From Thong Pha Phum, near the Burma border, Hagen and Kemper (1976) reported the fusulinids *Polydierodina afghanensis*, *Yangchienia tobleri*, *Y. iniqua* and *Nankinella* spp. and considered them to indicate a middle Permian or early Late Permian age.

#### **Khao Plukmu Limestone (Bunopas, 1976 d)**

Bunopas (1976 d) used the informal name Khao Plukmu Limestone for the Permian strata exposed in a hill beside Huai Taphoen stream, (west of Dan Chang) 40 km north of Bo Phloi. The name has not been applied to any other place, and the limestone was regarded as a correlative of the Sai Yok Limestone by Bunopas (1976 d). The only reason for using the different (informal) name was to stress the importance of the outcrop, which is the only known remnant of Sai Yok Limestone in a very large area, and which contains a potentially important fusulinid assemblage.

The rocks are medium-grey thin-bedded argillaceous limestone with chert nodules and with interbedded red and green-grey shales, dipping east at 40 degrees. The base has a gradational contact with the underlying well-bedded non-calcareous grey shale (mae Plung Shale, Carboniferous). The top is faulted against the same grey shale.

#### **2) THE EASTERN GULF**

Permian rocks cover widely separated areas from Chonburi to Chantaburi and Sra Kaeo near the Kampuchean border (except Trat). The rocks are mainly limestone but may include shale and chert. From west to east the main occurrences of the Permian rocks are:

**Bang Phra Limestone** constitutes a small remnant forming a small limestone hill (Khao Revadi) near Chonburi (47P/EF 8, 131604). It is in fault contact

with the Lower Paleozoic rocks and contains the fusulinid *Pseudofusulina* cf. *regularis* (identified by Mrs. Rucha Ingavat) and unidentified bryozoans probably of Lower Permian age.

**Limestone at Klaeng** forms two limestone ridges subparallel to the Silurian-Devonian rocks. The limestone is mainly recrystallised, bedded to massive, white, grey or pink in colour, and dipping mainly between 20 and 65 degrees to the northeast. Thin argillaceous bands contain fossil bryozoans, crinoids and corals at grid reference 188136 (47P/EF 20). The bryozoans indicate a Lower Permian age. North of Klaeng the mainly Late Permian brachiopod was found (Muanlek, pers. comm.).

**Khao Chakan Limestone** is found in east and south Sra Kaeo. It forms the easternmost belt of Permian, and consists of well bedded to massive limestone containing Late Permian fusulinids (Pitakpaiwan and Ingavat, 1980). Similar limestone occurs in west Kampuchea (Ishii et al., 1969). The Permian limestone overlies rocks of varying lithologies including chert, tuffaceous sandstone and spilitic lavas. During the Permian, limestone was deposited widely over all of the Eastern Gulf area. It is thickest around Klaeng (the middle belt). The limestone appears to be entirely Upper Permian near Sra Kaeo (eastern belt) and in west Kampuchea, but is mainly of Middle Permian age to the west.

### 3) EASTERN PROVINCE AND LOEI FOLD BELT

#### **Saraburi Group (Bunopas, 1981)**

The name Saraburi Group is here proposed for a mixed limestone and inorganic clastic sequence outcropping on the eastern side of the lower Chao Phraya central plain from Nakhon Sawan southward to Saraburi, and also on the western edge of the Khorat Plateau from Loei southward to Saraburi. The Saraburi Group was previously mapped as part of the Ratburi Group (Brown et al., 1951; Javanaphet, 1969; Bunopas, 1976 c; Nakhonsri, 1976), but the Ratburi Group is here restricted to the peninsula only. The limestone part of the group around Saraburi has been well studied by many workers and its karstic limestone ridges dominate other rocks of the group. Rocks of this group are peripheral to the western edge of the Indochina craton. The Saraburi Group consists of three rock units listed in descending order as follows:

**Dan Sai Shale** (Bunopas, 1981) consists of shale and thinly interbedded sandstone. It contains a few fossil leaves.

**Saraburi Limestone** (Bunopas, 1981) consists mainly of massive to well-bedded limestone, often fossiliferous and reefal.

**Khao Luak Formation** (Nakhonsri, 1976) consists mainly of interbedded shale, sandstone and thin-bedded limestone. The sandstone is slightly tuffaceous in the lower part.

Fossils from the Khao Luak Formation indicate a Carboniferous to Lower Permian age. Fossils from the Saraburi Limestone are mainly late Lower

Permian to Middle Permian in age. Khao Luak Formation is found mainly east of the Saraburi Limestone, which occurs mainly along the west edge of the Khorat Plateau, suggesting a facies change from east of west during the formation of the upper part of the Khao Luak Formation and the lower part of the Saraburi Limestone. This probably applies also to the upper formation of the group (Dan Sai Shale) also. The Dan Sai Shale is restricted in its distribution.

#### **4) THE PENINSULA**

##### **Ratburi Group (Javanaphet, 1969)**

The names Ratburi Limestone (Brown and Buravas, 1951) and Ratburi Group (Javanaphet, 1969) have been used loosely (Hagen and Kemper, 1976) throughout Thailand for limestone and associated clastic sediments of Permian age. Usually the rocks were mapped as Ratburi Group without any constituent formations. No type section has yet been designated. Exposures in Ratchaburi (formerly Ratburi) Province are isolated outliers protruding through Quaternary alluvial cover, and at no place provides a complete section of the Ratburi Group. Elsewhere in Thailand rocks attributed to the group are overlain conformably by late Permian shale or volcanics, or unconformably by Triassic rocks, but no late Permian or Mesozoic rocks are found in Ratchaburi Province.

The name Ratburi Group is here limited to the Permian limestone and interbedded shale in the Peninsula. Fossil fusulinids and brachiopods from the lower part of the limestone at Khao Phrik, west Ratchaburi, indicate an Artinskian age (Sakagami, 1969; Yanagida, 1970). Higher parts of the limestone yielded Kungurian fusulinids.

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