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Geology and stratigraphy of the Sri Racha area, Chonburi Province, Eastern Thailand.

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Abstract: The Sri Racha area in southwestern Chonburi province is underlain by late Palaeozoic sedimentary or metasedimentary rocks, Triassic granites, and Quaternary sediments. The late Palaeozoic rocks occupy 30 percent of the western portion of the area while granites dominate the eastern portion and underlie approximately 20 percent of the area.

The late Palaeozoic rocks are believed to be of Permian and Carboniferous age and possibly as old as Devonian. The Carboniferous rocks are lowgrade metamorphics consisting of both foliated and non-foliated varieties. They are divided into 3 distinctive units, in order of descending age, namely inter-bedded schist and quartzite, quartzite, and metacarbonate. After correction for possible thickening due to folding, the overall thickness of these rocks does not exceed 1,000 m. The Permian rocks are rather limited in distribution, comprising less than 50 m of clastic and non-clastic rocks. Foraminifera found in the limestone indicate a Permian age.

The late Palaeozoic sedimentary rocks have been folded. The fold is interpreted to be a westerly-dipping overturned anticline. It is located principally in the western and central portions of the area. In the northeastern portion, the area is intruded by fine to coarse-grained granites.

INTRODUCTION

Location

The area studied is located in the eastern Gulf coast of Thailand (fig. 1). It is bounded by longitudes 100°51' 40" and 101° 3' 21" E, and latitudes 13° 3' 58" and 13° 20' 42" N and covered by the topographic maps (scale 1 : 50,000) of Amphoe Sri Racha, Ban Chom Pho, Changwat Chonburi, and Amphoe Phanat Nikhom. The area is approximately 570 km^2.

Physiography

The general topography of the studied area is undulating, rolling, and hilly to mountainous terrain with flat lowlands between the mountainous ranges. Physiographically, the land surface slopes gently towards the sea. In the eastern and particularly the central parts of the area, the relief is relatively higher, comprising steeply broad-slope granitic mountain ranges. In the west, the land is lower in relief with small and isolated hills of various types of metamorphic rocks. There are also several islands along the western part of the mapped area, but only a major one, called "Ko Si Chang" (Si Chang Island).

Regional Geology

The regional geology of the Chonburi-Rayong Area (fig. 2), is compiled from the results of systematic mapping by Nakinbodee *et al.*, (1976) and Salyaponse and Jungyusuk (1982), and the detailed works by the geology students from Chulalongkorn University in 1965, 1978, 1979 and 1981. The rocks in the area can be divided into 5 major stratigraphic units, namely, Pre-Cambrian, Devonian-Silurian, Carboniferous, Permian and Triassic. Inferred Pre-Cambrian rocks are reported to occur in many parts of the area (Workman, 1972;

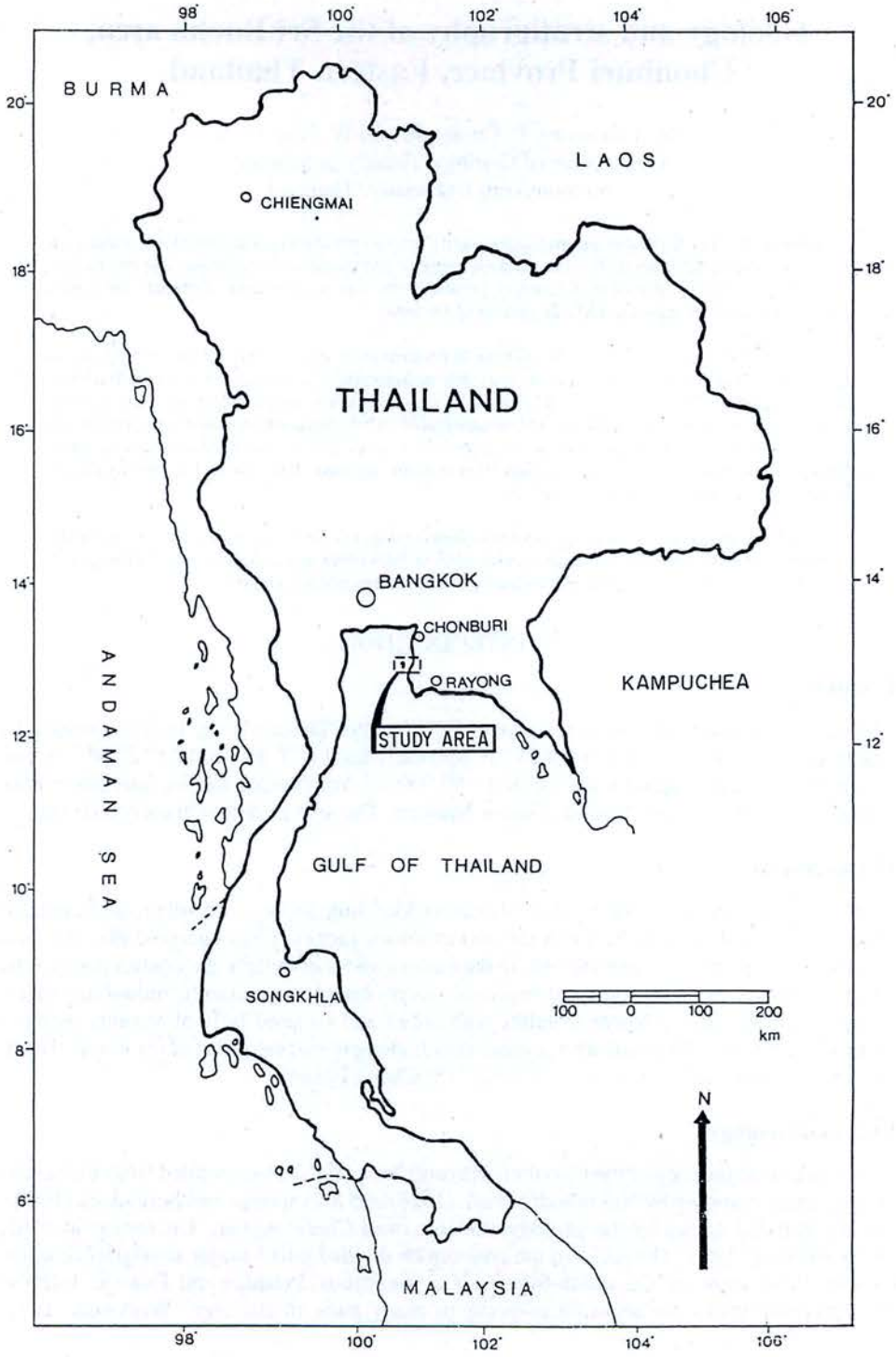

Fig. 1. Map showing the location of the studied area.

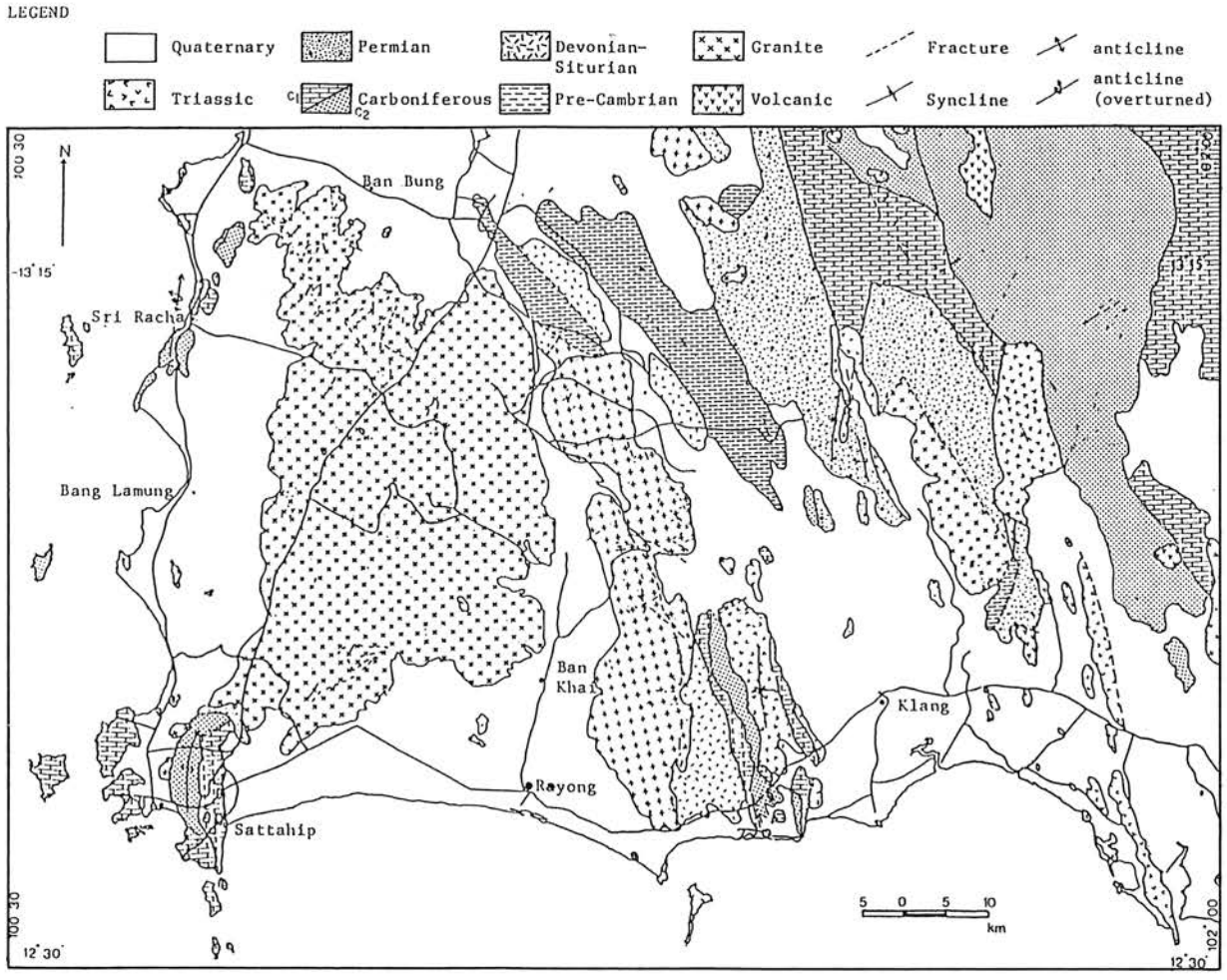

Fig. 2. Regional Geology of Chonburi-Rayong Area (modified after S. Salvapongse and Jungyusuk, 1982)

Campbell, 1975; Bunopas, 1976; Nakinbodee *et al.*, 1976; Dheerakilok and Lamjuan, 1983; and Pongsapich *et al.*, 1983; on the basis of the high-grade metamorphism. These inferred oldest rocks include gneiss and schist with interbedded quartzite and calcsilicate (Nakinbodee *et al.*, 1976). Areas where these rocks outcrop are located at the north-central part of the region (Salyapongse and Jungyusuk, 1982). Overlying unconformably the Pre-Cambrian rocks are Devonian-Silurian rocks, consisting mostly of quartz-mica schist, quartzite, and phyllite (Nakinbodee *et al.*, 1976). Next is the Carboniferous (to possibly Devonian) rocks which range from metamorphosed to non-metamorphosed sedimentary rocks (Suwanvas, 1978; Toprasert, 1981). Large exposures of these rocks are found in the northeastern part of the region. The other outcrops are mostly in Sri Racha and the western part of Sattahip. Younger than the Carboniferous rocks are the mainly non-clastic Permian rocks. Generally most of the Permian rocks concentrate at the northeastern part of Rayong and the northern part of Sattahip area. Small exposures of the Permian rocks are also found in the Sri-Racha area. Several types of fossils such as gastropods, crinoids, corals, bryozoas and gastropods, have been reported in the region (Nakinbodee *et al.*, 1976) and determined as Permo-Carboniferous. The rocks of Mesozoic are can also be found particularly in the central and eastern parts of the region. They are mostly sandstone and area believed to be the youngest rock unit (Salyaponse and Jungyusuk, 1982).

Plutonic rocks outcrop dominantly in the centre of the region (fig. 2). They are mainly granites with aplite, pegmatite, and quartz dykes from different phases of intrusions (Nakinbodee *et al.*, 1976). The more mafic rocks (diorite and granodiorite) and volcanic rocks (basalt, dacite, rhyolite and tuff) are subordinate phases (Salyaponse and Jungyusuk, 1982).

GEOLOGY AND STRATIGRAPHY

Generally, the geology of the area under investigation is not quite intricate. Two principle rock types, namely (meta)-sedimentary rocks and igneous rocks, are found in the area (fig. 3). The sedimentary rocks can be grouped into 2 distinct stratigraphic units, namely Carboniferous rocks and Permian rocks (Workman, 1972), Ordovician (Nakinbodee *et al.*, 1976), and pre-Permian (Bunopas *et al.*, 1983). The Carboniferous rocks may be further subdivided into 3 subunits: interbedded schist/quartzite; quartzite; and carbonates. These dynamothermal metamorphic rocks are found mainly in the western part of the area including the islands just off the mainland. The rocks strike NNE and dip to the west. They form relatively low mountains and hills, nearly parallel to the coast line. The Permian rocks are restricted to the area adjacent to the Bang Phra reservoir, and include both clastic and non-clastic sedimentary rocks. More than 30% of the total area is underlain by the Carboniferous and Permian rocks. Granitic rocks mainly Triassic in age underline approximately 20% of the area, forming high mountain ranges in the eastern part of the map. The rest of the area is covered by Cenozoic sediments. The overall stratigraphic successions of the major rock units are shown in Table 1.

In general the regional structure trends NE-SW and dips to the west. The main geological structure is a large overturned anticlinal fold with a NNE-axis plunging towards the N. The anticline can be traced for more than 35 km from the south to the north of the area, with an exposed width of as much as 10 km. From the south to the middle portions, it is distinctively characterized by the homoclinal structure with interbedded schists/quartzites acting as the

TABLE 1
STRATIGRAPHIC COLUMN OF SRI RACHA AREA

Period		Symbol in map	Estimated Thickness (m)		Description
Quaternary		Q	?		Alluvium, colluvium, beach and old beach deposits, calcareous tufa, and residium.
Permian		P	30-50		*Fine-grained clastic rocks* : mudstone, red shale chert lens, 10m. *Limestone* : dark-gray micrite to biomicrite, and argillaceous limestone, 10-15 m. *Sandstone* : whitish to pale brown protoquartzite, reddish brown arkose, with shale & siltstone interbedded, 15-20 m.
Carboniferous	Upper	C_0	1000	50	Spotted shale, spotted slate, metasandstone and quartzite : mostly yellowish brown to brown.
		C_1		250	*Carbonate* : greenish-gray fine-grained limesilicate rock, greenish white recrytrallized limestone, and whitish-cream dolomitic marble.
	Lower	C_2		200	*Quartzite* : yellowish brown massive to well-bedded quartzite, brown micaceous quartzite with minor amount of quartzitic schist.
		C_3D		500	*Schist & phyllite* : yellowish brown mica schist, sericite schist and phyllite *Quartzite interbedded* : yellowish white to brownish yellow quartzite and micaceous quartzite.
Triassic		Gr Gn			Granite (Gr), Sheared granite (Gn)

structural core. Here, the normal limb of the west flanks the well-exposed rock units whereas the rocks on the other hand, are nearly absent on the overturned limb. At the central part, the structure becomes a small overturned syncline (?) whose axis is located at the valley between Khao Chalak and KhaoYai Li. To the northen part of the area, where the overturned anticline commences, the exposed rocks are Carbonates and Quartzites of the normal limb of the west. The inverted limb of the east flank is entirely eroded. It should be noted here that since the rocks in the area are complexly deformed it is very necessary that major structural units be clearly reidentified and available structural information analysed so that a better geological sequence can be established. The simplified geological structure is shown in Figure 4.

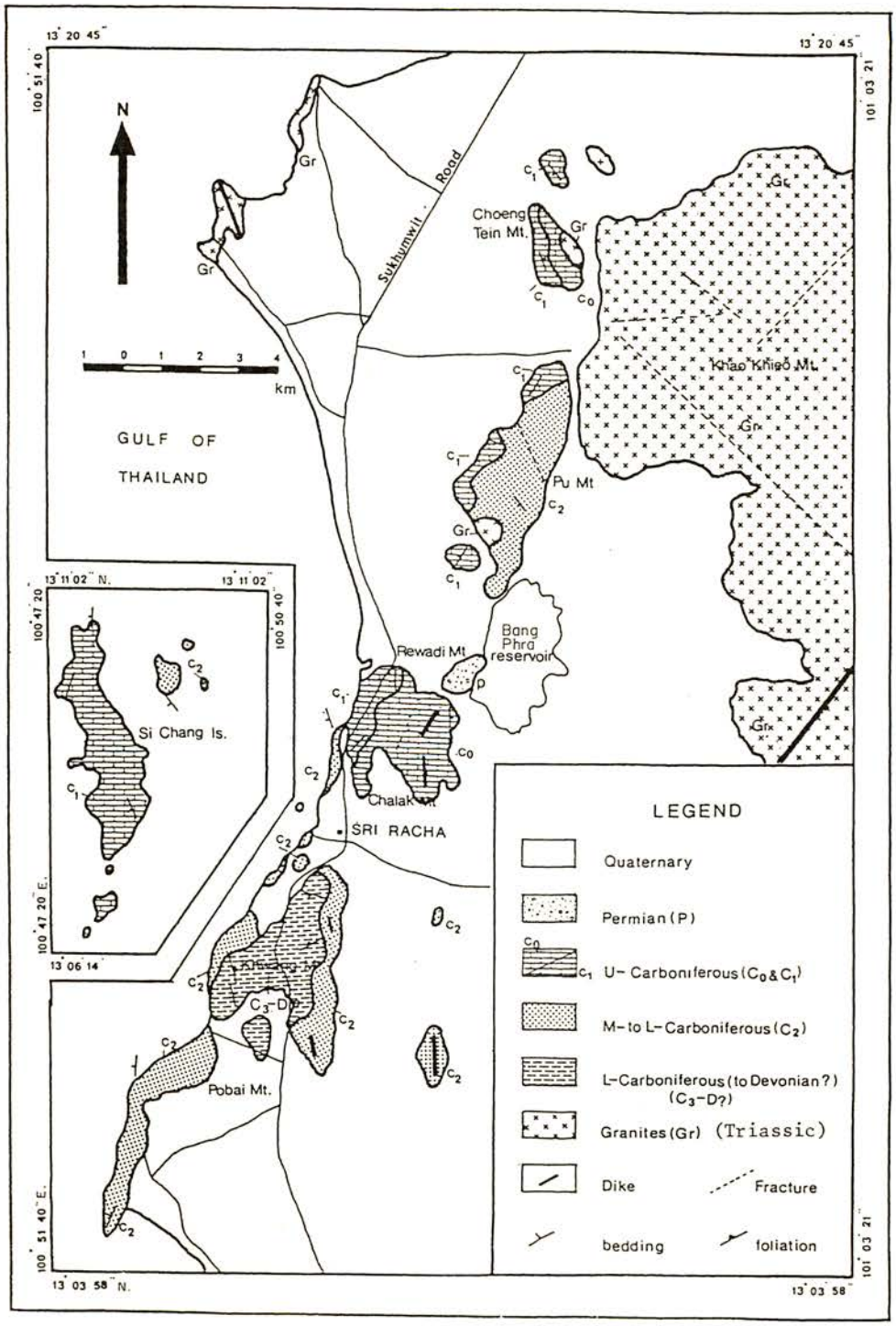

Fig. 3. Geology of Sri Racha Area

Carboniferous Rocks

The supposed oldest rocks in the studied area are a sequence of clastic sedimentary rocks with intercalation of non-clastic rocks. The rocks are believed to be Carboniferous age (Salyapongse and Jungyusuk, 1981) on the basis of their relative stratigraphic position below the Permian rocks. Moreover, the degree of metamorphism is rather low, never beyond greenschist facies. The Carboniferous rocks are equivalent to the Kaengkrachan Formation which is the upper part of the Tanao Sri Group. (Thai DMR Geological Map, 1969). The upper part of the sequence is composed mainly of slightly metamorphosed fine-grained clastic rocks with minor carbonate. These rocks in the area can be traced for 15 km along strike in the north-south and 3 km across strike in the east-west direction. The total thickness was estimated to be not more than 1,000 m. These rocks are confined mostly in the southern and western parts of the mainland and small islands lying between Ko Si Chang and the mainland.

The Carboniferous rocks in this area can be subdivided into 3 distinct units on the basis of their lithologic characteristics, namely interbedded schist and quartzite (Lower Carboniferous to possibly Devonian), quartzite (Middle Carboniferous), and metacarbonates (Upper Carboniferous).

Interbedded Schist and Quartzite.

The interbedded Schist and Quartzite is supposed to be the oldest stratigraphic succession in the mapped area, and is found in the southwestern part of the mainland, namely at Khao Khwang, Khao Pho, and western parts of Khao Phra Khru, Khao Yai, Khao Nam Sap and Khao Tung Wia. The areal extent of this rock sequence is continuous for at least 4 km^2. Most of the rocks are quartzite, phyllite, and schist of various types. The quartzites include grayish-white to brownish-yellow quartzite, brownish-gray micaceous quartzite, and dark-brown fine-grained quartzite. These quarzites are interbedded, in many parts, with slender yellow coloured mica schist, yellowish-brown sericite schist, quartz-sericite schist, quartz schist, and phyllite. This sequence changes slightly from thick-bedded quartzite (up to 2 m thick) alternating with thin-layered schist and phyllite (max. 5 cm thick), in the western part of Khao Khwang, Khao Phu, Khao Phra Kru and northwestern flank of Khao Yai, to thick-layered schist-phyllite (up to 1.5 m thick) interbedded with thin-bedded quartzite (up to 4 cm thick) in the central part of Khao Khwang and Khao Phu.

Petrographic studies reveal that the rocks of this sequence are of sedimentary origin and have undergone regional metamorphism to low-grade greenschist facies. In some places near the granite intrusion, the rocks were subsequently subjected to contact metamorphism forming spotted schist/phyllite. Microscopically, the quartzite is composed almost entirely of quartz with minor amounts of fine-grained mica and opaques. The quartz (0.1-0.3 mm across) is slightly strectched and shows moderately well preferred orientation. The schistose texture of the schists indicated by relatively finer-grained (0.05-0.2 mm), well-defined foliated mineral constituents. Mineralogically these rocks consist mainly of quartz, muscovite, sericite, and chlorite as major minerals whereas tourmaline, opaques and sphene are the accessory minerals.

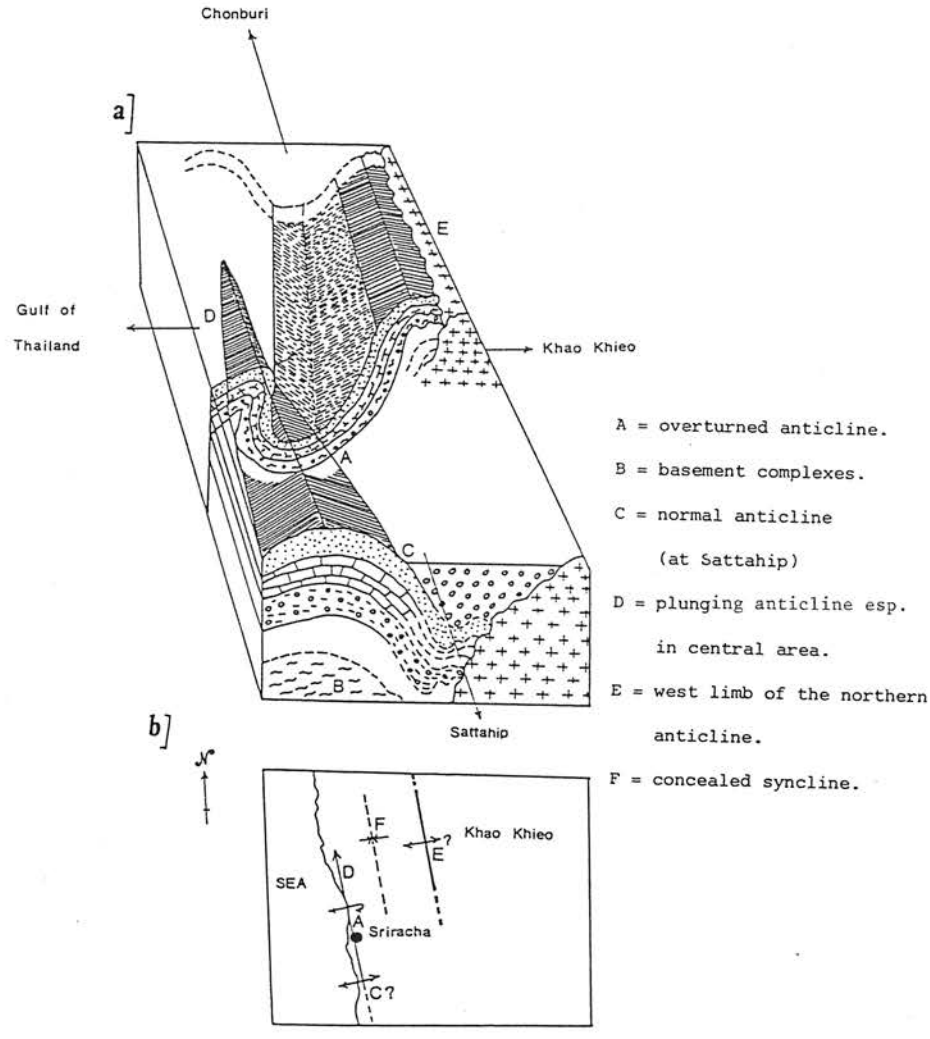

Fig. 4. Idealized block diagram showing Sri Racha Anticlinorium (a) and symplified structural symbols (b).

The overall thickness of this rock sequence is estimated to be as much as 500 m. Structurally, the attitudes of foliation, deviate somewhat from the NE-SW regional trend. However, the foliation is somewhat in the same direction of bedding attitude. The rocks are highly deformed and fractured as expressed by many micro-folds and-faults. Due to the fact that the rocks are more strongly deformed compared to the other rock sequences and appear to be overlain by the younger sequences, this rock-unit is believed to form the core of the anticlinal structure.

Quartzite

The quartzite appears to be the longest exposure among the Devonian?-Carboniferous rocks and can be traced for as long as 15 km from the centralmost part of the mapped area to the southernmost end. The general trend of this sequence is in the NE-SW direction, with a total thickness of 200 m. Good exposures of this unit can be found at Laem Chabang, Khao Bo Ya, Khao Nong Ang and Khao Po Bai to the southwest, at Khao Khwang, Khao Ta Sua and Ko Loi to the west and central portions and finally at the shoreline west of Khao Krok Ta baek. The rocks are found again at Khao Plai, Khao Pu Chao and west of Khao Phu and Khao Bo Yang as well as at Ko Kam Noi and Ke Kam Noi and Ke Kam Yai.

This rock unit consists of quartzite predominantly and schists. The quartzite grades into quartzitic schist and quartz-sericite schist. In general, the foliation is more or less paralled to the general trend of bedding, i.e. strike NNW-SSE and dip at a moderate angle to WSW. The schists are texturally fine-grained (0.2 mm) and display shiny luster on their foliation surfaces. The massive quartzite beds generally form steep cliffs and large broken blocks. These quartzitic rocks include massive quartzite, well-bedded quartzite, and micaceous quartzite. Petrographically, almost all the grains range in size from 1 mm to cryptocrystalline. The rocks contain up to 85-90 % quartz and recrystallized chert with minor amounts of muscovite, chlorite, sericite and opaques. The quartzite, in some places, shows relict texture, mainly cross-lamination and lamination. Well-defined beddings are present at the western and southern ends of Khao Laem Chabang and along the shoreline of Ao Udom. Quite commonly the quartzite occurs in thick beds, with individual beds up to 2 m thick. The metamorphosed non-clastic sedimentary rocks also occur but in very small amounts. They are yellowish to greyish-green calc-silicate rocks and believed to occur as lenses with a maximum thickness of about 8 m. Carbonate lenses are exposed sporadically along the shorelines at Laem Hin Khao, Ao Udom and north of Khao Ta Sai.

Metacarbonates

These carbonate rocks with an estimated total thickness of about 250 m, form a rather continuous cover over the western and central portions of the mapped area. The rock crops out at the northern part of Figure 3, i.e. Khao Phong Sua and western flank of Khao Choeng Tein, then extends southwards through the northern end of Khao Bo Yang, western foot of Khao Phu to Khao Laeng, Khao Yai Li and Khao Krok Tabaek. The other large exposure is located at Ko Si Chang. This carbonate unit structurally overlies the quartzite unit in many places. Therefore, it is believed to be younger stratigraphically than the quartzite. In hand specimen, the rock is pale to grayish green or bluish green, finer-grained and relatively harder than the calc-silicate rocks of the older unit. Petrographically, the rock is mostly composed of calcite and other constituents include quartz, dolomite, diopside, epidote, zoisite, clinozoisite, chlorite, tremolite, actinolite and sphene. Calcite is absent in some rocks where wollastonite is abundant as layers in the calcsilicate.

The limesilicate rock grades to greyish-white recrystallized limestone to marble of similar color. The rocks are usually interbedded with greenish-gray limesilicate to grayish white rather massive, recrystallized limestone and cream-colored dolomitic marble. Typical exposures are found near the western flank of Khao Yai Li. At the northern part of the map (Khao Bo Yang), the rocks are subject to contact metamorphism by granite intrusion. Since

the overall thickness of the rock never exceed 200 m and the rock can be traced over long distances, it can be used as a key bed for structural interpretation. The bedding attitude, in general, ranges in strikes from south to west and in dips from gentle to steep angles. It is quite important to note here that the thickness of the carbonate is considerably varied and becomes gradually thinner and thinner until it is rarely found in the southern part of the map.

The carbonate rocks also occur at Ko Si Chang, about 12 km west of the Sri Racha area. The age of the rocks was previously assigned to lower Ordovician as indicated by the nautiloid, *Nulticameroceras* (?) sp., in crystalline dolomitic limestone (Nakinbodee and others, 1976). Furthermore, Workman (1975) also strongly recommended a similar age for the impure limestone of the Thai-Malay Peninsula. Recently, Bunopas and others (1983) reported that a few poorly-preserved ammonoids, collected from the island, indicated an age ranging from Ordovician to probably Triassic. This means that the age of the carbonates has not been definitely ascertained. The carbonate rocks exposed at the mainland show distinct lamination and bedding through alternating layers of carbonate-rich areas and quartz-feldspar-rich materials. Such distinctive features are also found at the eastern part of Ko Si Chang. It could be concluded here that because of the controversy of the wide-range fossil age and because of the petrographical and lithological similarities of rocks at these two places, the carbonates at Ko Si Chang can be correlated to have the same Carboniferous age as the carbonates on the mainland. Other exposures of the carbonate rocks are also found at several small islands located at the north and the south of the Ko Si Chang and they include Ko Sam Pan Yu, Ko Yai Thao, Ko Thai Khang Khao and Ko Thai Ta Mun. In general the carbonate rocks include dark-gray to bluish-gray marble or recrystallized limestone and greenish-gray limesilicate marble. In the eastern part of the island, the carbonate rocks are predominantly limesilicate marble intercalated with marble whereas in the western part limesilicates are rare but alternating layers of light to mediumgray marble are more common. The carbonates are well jointed and vary from mostly well-defined beds to uncommon poorly-defined beds.

Petrographically, the rocks consist principally of calcite with dolomite, quartz, tremolite and possibly diopside and minor amounts of sphene, pyrite, and wollastonite. In some certain rocks, they are lighter in color and can be called tremolite marble owing to their bimineralic composition of tremolite and calsite. Sometimes micaceous minerals are so abundant in certain beds that the metamorphic banding is clearly distinctive. The rocks at Ko Si Chang are also characterized by the presence of chert nodules. Dolomite marble has been reported to be previously mined and rhodochrosite as well as manganese oxides have also been found. Structurally, attitudes of rocks strike more or less in the north-south direction and dip principally to the west.

However, carbonate at Ko Si Chang is strongly deformed as indicated by complex folding that exist in several parts of the island. The carbonate rock of island is believed to be the western normal flank of large overturned anticline whereas those of the mainland represent the eastern inverted flank.

Overlying the carbonate rocks is the fine-grained clastic sedimentary rock. This clastic rock is grouped in the carbonate unit because of its relative position and limited spatial extent. The rock includes shale, slate and very fine-grained sandstone. Most of these rocks have deep

reddish brown to yellowish brown color. They crop out in the mainland at Khao Choeng Thien, Khao Pong Sua and Khao Pong Pan in the northern part of the area. The rocks are also subject to contact metamorphism. Thus spotted rocks and hornfels are recognized throughout. The spots vary in sizes from 0.4 mm of microscopic scale up to as large as 1 cm. They are clusters of sericite, muscovite, iron oxides, quartz or andalusite minerals. These fined-grained rocks have the overall estimated thickness of about 10 m.

The other rock is sandstone which is also subjected to metamorphism to become very hard, dense, resistant and pale brown to brownish-gray quartzite. Such rock outcrops at Khao Chalak and is subsequently cross-cut quartz veins and dykes at the summit of the mountain. The rock is composed almost entirely of quartz. The grain sizes vary from 1 mm to microscopic size. This quartzite can be distinguished from the others by its massive beds and ill-defined bedding attitudes.

Permian Rocks

Other than the Quaternary deposits, one of the youngest stratigraphic unit in the area studied is the Permian rocks of the Ratburi Group. It was first described by Nakinbodee *et al.*, (1976). The Permian rocks are distinguished from the others on the basis of the lack of dynamothermal metamorphism effects, and the absence of quartz veinlets and igneous injections. They are derived fron both clastic and non-clastic materials. However, the latter occurs only in minor proportions. Though the prominent outcrops are confined only to Khao Rewadi and Khao Chak Khanim, they are well-exposed and hence serve as the best sections. The overall thickness of the rocks is not more than 50 m. The beds strike approximately N-S and dip on the average 30° to the east. The rocks are deformed as indicated by minor foldings, brecciation and sheer zones developed in a NNW-SSE direction. The Permian age was based on foraminifera found in a limestone bed (Bunopas *et al.*, 1983). The microfossils at Khao Rewadi as identified by R. Ingavat (1983, per. com.) include Foraminifera (*Globivalvulina* sp., *Endothyra* sp.), algae (*Tubiphytes* sp.), fusulinid (*Pseudofusulina, Schubertella* sp.), bryozoa (*Tuberitina* sp.), and bryozoa fragments. These fossils are also commonly found in the limestone of the Ratburi Group and suggest an Early to Middle Permian age (Ingavat, 1983, per. com.).

The sandstone, mudstone, red shale and chert-like layers crop out on the eastern part of Khao Rewadi and Khao Chak Khanim. The estimated thickness of these rocks is not more than 10 m.

The limestone is located on the northeastern part of Khao Rewadi and Khao Chak Khanim. The rock grades from dark-gray to greenish-gray micrite to gray biomicrite and intraclastic limestone. The total thickness of the limestone is about 10-15 m.

Evidence from both field and petrographic studies indicate that limestone as well as sandstone are subjected to the tectonic stress, to a certain degree, in many parts. The limestone is so sheared and brecciated that it becomes lens-shaped bodies bounded by the argillaceous layers. The differentiation of argillaceous layer and black limestone with platy minerals is presumably caused by shear forces.

Granitic Rocks

Granitic rocks underlie about 20% of the area under investigation. Most of the granitic rocks are naturally exposed in the eastern part of the area (fig. 3). These rocks include coarse-grained mica granites, fine-to medium-grained mica granites, pegmatites, and quartz veins and dykes.

The absolute ages of the different intrusions are not quite certain. However, from many studies, such as those carried out by Workman (1972), Burton and Bignell (1969), and Bignell and Snelling (1972), the different granites from the mapped and neighbouring areas have been dated. They indicate many phases of plutonic activities ranging in age from Triassic to as young as Tertiary.

Cenozoic Deposits

At least 50 % of the area is covered by unconsolidated to semi-consolidated deposits with ages ranging from Tertiary to Quaternary. There are 5 types of deposits present in the area. They include alluvial deposits, colluvial deposits, terrace deposits and residual deposits (saprolite, calcareous tufa and laterite). All these deposits are of economic interest for use as construction materials.

In the central part of the area, these deposits consists of poorly-sorted sediments and saprolites. The saprolites are red to reddish-brown, soft, earthy, clay-rich, thoroughly decomposed rocks formed in place by chemical weathering of granitic rocks. It is, therefore, believed and concluded that the rocks underlying the sediments in the central part of the area are granites.

Economic Mineral Resources

Economic minerals in the area are not abundant except for construction materials such as crushed stone and rubble, sand and gravel, and laterite/lateritic soils. The carbonate rocks are the most suitable rocks for use as crushed stones and rubble (Hinthong and Sarapirome, 1983). The other rocks which were quarried in the past are the quartzites at Khao Chalak, Khao Khwang and Khao Din. Sand and gravel from unconsolidated deposits are extracted and used mainly as aggregates in portland cement concrete (Sarapirome, 1982).

Economic minerals found in the area include iron, tin and heavy minerals; most of them, however, occur in limited amount and are sporadically distributed. The geochemical exploration for tin using stream sediments from the granite terrane, namely Khao Khieo, reveals anomalously high values (Sarapirome, 1982). It is believed that some of the granitic bodies in the study area could be the possible primary sources of tin and other heavy minerals.

CONCLUSIONS AND REMARKS

The stratigraphic sequences of rock units present in the area may gain from more detailed information, particularly that of paleontological evidences and a revision is needed later on if some more detailed structural analysis and interpretations are carried out. In this investigation the stratigraphy was established based on limited fossils found in the limestone occuring in a very small part of the area. Where fossils are not found, the ages of the various

rock units are assigned based on structural relationships. In some cases, the rock units were correlated with similar lithologic successions found in other parts of Thailand. Though rock exposures are good in many places, the structural interpretation is very difficult, due to intense deformation, folding and faulting in several parts of the area.

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