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Stratigraphy of the Mae Sariang Group of Northwestern Thailand: Implication for Paleoenvironments and Tectonic Setting

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ABSTRACT.– Marine Triassic rocks of the Mae Sariang Group in the Mae Hong Son-Mae Sariang area of north-western Thailand have been investigated in detail for lithostratigraphic subdivision on the bases of field mapping, petrographic, and remote-sensing information. The Mae Sariang Group occurs in a long and narrow north-south facing belt with somewhat folded and faulted structures. The Group conformably overlies the deformed Permian marine clastic rocks and unconformably underlies the subhorizontal, much less deformed, Jurassic clastic rocks of the Huai Pong Group. The Triassic rocks with an overall thickness of 900 meters can be grouped into the following three units: (i) the Kong Sum, (ii) the Pratru Muang and (iii) Mae Laeb units, in ascending order. The Kong Sum unit, with a thickness of 150 to 250 meters, consists mainly of 2 lithofacies; conglomerate and overlying lithic sandstone. *Halobia* and *Daonella* bivalves are found in the lithic sandstone and we assign the age of the Kong Som unit as Middle (to Early?) Triassic. The Pratru Muang unit, with a total thickness varying from 200 to 770 meters, comprises of four lithofacies which are from bottom to top; mudstone and sandstone, chert with interbedded mudstone, conglomerate with interbedded sandstone, and sandstone and shale. Abundant radiolarian faunas are reported from the chert and a few *Daonella* bivalves occur in the sandstone and we consider the age of the Pratru Muang unit to be Triassic. The 80-120 m-thick Mae Laeb unit consists predominantly of three lithofacies; calcareous mudstone and sandstone, siliceous shale with interbedded mudstone, and sandstone with shale in ascending order. Radiolarian faunas in the siliceous shale and abundant *Halobia* and *Posidonia* bivalves in the calcareous mudstone suggest the age as being Late Triassic. Thus, based upon stratigraphic and paleontological points of view, the age of the Mae Sariang Group is considered as Middle to Late Triassic. The overall lithology, stratigraphy, sedimentary structure, geometry and fossil assemblages reflect a deep-water submarine fan environment in a subduction-related tectonic setting. Such Triassic deep-water marine facies can be found in several places in northern and southern Thailand.

KEY WORDS: Mae Sariang Group, Mae Hong Son, Triassic, paleoenvironments, tectonics, northwestern Thailand.

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INTRODUCTION

Paleontological Background: Triassic sedimentary rocks are widespread in Thailand (Fig. 1A, B). Before the 1960's most of the research involving Triassic sedimentary sequences was focused on paleontological studies. Special emphasis was placed on the Triassic fossils in northern Thailand (Högbom, 1914; Lee, 1923; Heim and Hirschi, 1939) and the Kamawkale Limestone on the Thailand-Myanmar border between Tak and Kanchanaburi Provinces (Gregory, 1930; Pia, 1930). Assemblages of marine fossils, i.e., algae, corals, brachiopods, bivalves and ammonoids, pointed to a Late Triassic (Norian) age, supported by reports of Triassic (Anisian to Carnian) ammonoids in the Mae Moh District, Lampang Province (Pitakpaiwan, 1955; Kummel, 1960).

Triassic rocks, which are extensively distributed in northern Thailand, have been carefully investigated for marine macrofossils (Piyasin, 1972, 1975; Braun and Jordan, 1976; Bunopas, 1976) and microfossils (Baum et al., 1970; Piyasin, 1971a, b; von Braun and Jordan, 1976; Hagen and Kemper, 1976; Kemper et al., 1976).

Marine Triassic sediments are widely distributed in the Mae Hong Son Province and contain abundant marine fossils, which have been studied paleontologically by Hahn and Siebenhüner (1982). Baum et al. (1970) first described sediments with Triassic fossils in the Mae Sariang-Mae Hong Son area, including thick sequences of sandstone, shale and limestone. Bunopas (1976) proposed the term “Mae Sariang Group” (see Fig. 2A, B) for the rock strata composed chiefly of basal red conglomerate, followed by interbeds of gray shale, interbedded gray siltstone and fine-grained sandstone, sandy shale with gray and red sandstone, and a few beds of limestone.

Purpose and Location: The purpose of this study was to provide a detailed lithostratigraphy of Triassic clastic rocks in the Mae Hong Son Province in northwestern Thailand and additionally to reconstruct the depositional environments and related tectonic setting based upon the sedimentary facies in this study area.

The study area is a narrow north-south lying belt 120 km long by 20 km wide situated near the Thailand-Myanmar border (Fig. 1A), lying at a latitude of 18º 00’ 16’’ to 19º 09’ 41’’N and a longitude of 97º 48’ 33’’ to 97º 58’ 48’’E, located between Mae Hong Son City and Mae Sariang District, about 150 km west of Chiang Mai (Fig. 1B). The physiography of the area is marked by a long, narrow, flat, north-south lying river valley in the middle region from which the major districts are situated with high mountainous areas bordering the eastern, and western flanks.

Geological Setting: Regionally, rocks ranging in age from Paleozoic to Recent mainly occupy the Mae Hong Son area (Fig. 1B). The Lower Paleozoic strata are much more common in the eastern area and commence with a 700 -m thick siliciclastic Tarutao Group (Cambrian), overlain conformably, by 100 -m thick, conodont-bearing carbonate rocks of the Thung Song Group (Bunopas, 1981). These have been strongly deformed and largely metamorphosed to low-grade quartzite, calc-silicate, and schistose rocks. The Middle Paleozoic rocks of the Mae Hong Son area, called the Mae Hong Son Group by Bunopas (1981), are composed largely

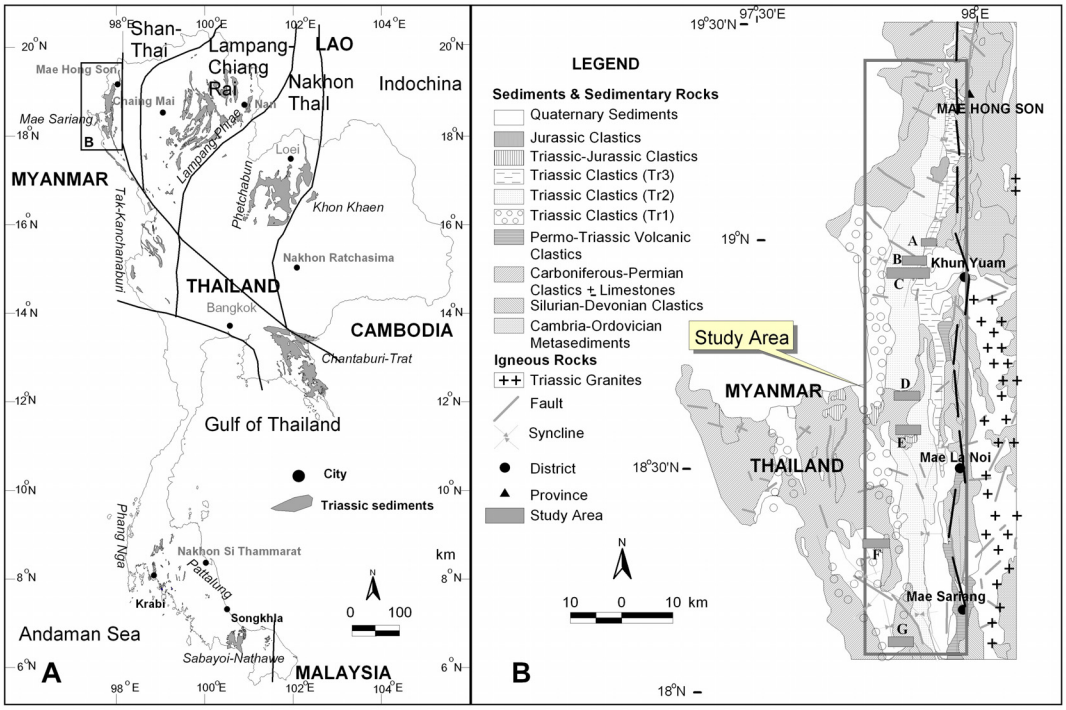

FIGURE 1. Index map of Thailand showing (A) the distribution of Triassic sedimentary rocks in major tectonic (modified after Department of Mineral Resources, 1999 and Charusiri et al. 2002) (B) Regional geologic map of Mae Hong Son area showing the main study sites (indicated as a solid triangular box), dominated by Triassic clastic rocks (modified from Charusiri et al., 2002; Department of Mineral Resources, 1999; and Srinak, 2002) northwestern Thailand. Note that A = Ban Huai Pong, B = Ban Sape, C = Ban Pratru Muang, D = Ban Huai Na, E = Huai Hin Lak Fai, F = Ban Mae Laeb, and G = Huai Pho.

of weakly metamorphosed shale and sandstone with interbedded chert beds and late Silurian-Early Devonian conodont-bearing limestone lenses (Stoppel, 1969). The group is more or less equivalent to the Thong Pha Phum Group (Bunopas, 1981), which is widely distributed in the Kanchanaburi and Tak provinces of western Thailand and perhaps extends northwest to this study region. In the Mae Hong Son area, the Upper Paleozoic strata are characterized by 400 m-thick dark gray to greenish gray shale, siltstone and sandstone with occasional limestone beds in the lower part, and chert beds in the upper part. These were collectively designated as the Mae Hong Son Formation by Bunopas (1981). A less than 50 m - thick Permian sequence in the western part of the Mae Sariang-Mae Hong Son area consists of 2 unmappable and undifferentiated units (Jindasuth et al., 1990), which are comprised of dark gray argillaceous limestone with shale and chert interbeds in the lower part, and clastic rocks with chert beds and limestone lenses in the upper part.

Srinak (2002) reported that Permian to Triassic sediments of about 100-200 m in thickness in the Mae Hong Son area, particularly at Huai Lan and the Mae La Luang villages, on the eastern side of the Nam Yuam River between the Mae Sariang and Sob Moei Districts. They are mainly comprised of medium-grained and tuffaceous sandstones, argillaceous and oncolitic limestone, (meta-)rhyolitic to andesitic

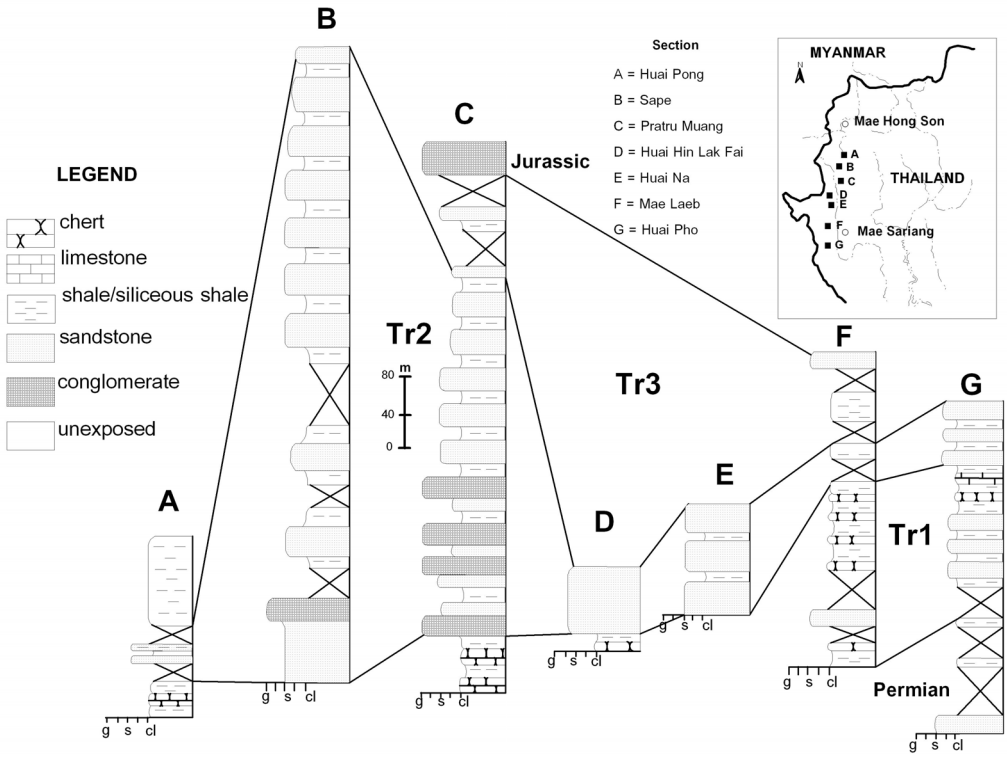

FIGURE 2A. Correlation diagram for the Triassic rocks of the Mae Sariang Group in the southern part of Muang Mae Hong Son district,

tuffs, and chert beds. Subsequently, 900 m-thick clastic sediments of the Mae Sariang Group were deposited over the Mae Hong Son study area during Triassic time. These deep-marine sequences are unconformably overlain by 200 m-thick, subhorizontal strata of Jurassic marine clastics belonging to the Huai Pong Group (Meesook, 1994). The Jurassic strata include regular alternating sequences of predominantly gray mudstone with subordinate thinly bedded sandstone with well-bedded sandy limestone (the Pa Lan Formation) at the base, fossilifereous siltstone (the Mai Hun Formation) in the middle and sandy limestone grading to arkosic sandstone (the Kong Mu Formation) in the top portion.

On the eastern side of the Mae Hong Son area, the Early Paleozoic strata were intruded by Triassic porphyritic biotite ± muscovite granites (Charusiri, 1989, Charusiri et al., 1992). By Cretaceous-Early Tertiary times, the mainly Paleozoic rocks in the western part of the Mae Hong Son study area was intruded by S-type two-mica granites (Charusiri et al., 1992). During the Cenozoic, deposition in the Mae Hong Son study area was dominated by semi-consolidated gravel beds of high to low river terraces as well as basaltic rocks, both occurring predominately in a north-trending narrow belt and mainly along the Mae Hong Son fault zone.

MATERIALS AND METHODS

Geological data of the study area were collected, compiled and reviewed. Aerial photography and satellite image (Fig. 3A)

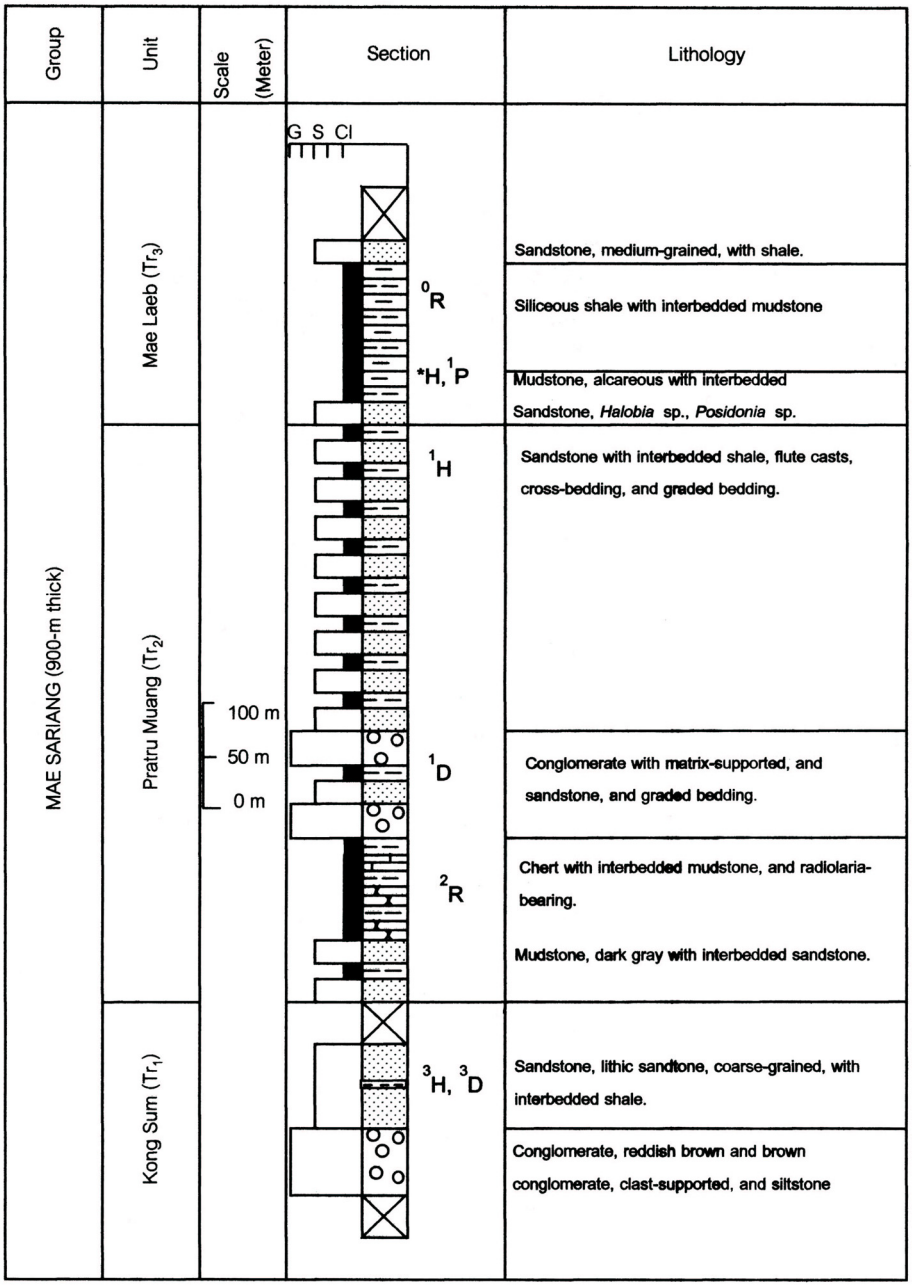

FIGURE 2B:Composite section of the Mae Sariang Group.

interpretation as well as field checking of reliable data were undertaken. Aerial photographic and satellite image investigations were undertaken at 1:50,000 and 1:250,000 scales respectively. The second step involved systematic field transects, stratigraphic mapping and, particularly, measuring rock sections at Huai Pong-Khun Yuam-Mae La Noi-Mae Sariang villages. Representative sampling of fresh Triassic clastic rocks was carried out for more detailed laboratory investigations. Sedimentary rocks were described using the classification of Pettijohn (1975), and interpretations of lithofacies were done based on the work of Selley (1996). Sedimentary structures, textures, and compositions were studied using petrographic techniques. Mesoscopic and microscopic petrographic analyses were performed mainly on 50 selected rock-slaps and 70 thin-sections, respectively. Finally, interpretation was made of the composite stratigraphic designation and depositional environments as well as the tectonic setting of the Triassic clastic and related rock units.

RESULTS

Composite Section

During the 3 field seasons, about 160 rock samples were collected from 7 measured sections within the southern part of the Mae Hong Son District area (Fig. 2A). A detailed description of these measured sections can be found in Srinak (2002) and will not be repeated here.

In the present study, an attempt was made to combine and correlate the mapped sedimentary sequences of all 7 measured sections of the Mae Sariang Group. The combined section of the Mae Sariang Group was divided into 3 units, in ascending order, named the Kong Sum (Tr_1), Pratru Muang (Tr_2), and Mae Laeb (Tr_3) units, based on lithological and sedimentological characteristics. Due to the limited exposures and their distribution, we cannot formalize the sedimentary units found in the study area as "formations". Therefore the units are herein divided into lithofacies instead of "members". The synthesis of combined sections is illustrated in Figure 2B and Table 1. The total thickness of the Mae Sariang Group based on the 7 measured sections is about 900 meters. A more detailed description of individual units is given below.

Stratigraphy

The so-called Mae Sariang Group (Bunopas, 1976) was proposed for the Triassic thick marine sequences of sandstone, shale and limestone, mapped earlier by Baum et al. (1970) and widely exposed in the Mae Sariang-Mae Hong Son area. These Triassic sediments show major north-trending fractures and faults and unconformably overlie Upper Paleozoic rocks. The basal red conglomerates are located mainly to the west of the Mae Hong Son Fault (Charusiri, 1989) and are widely exposed, with an aerial extent of 150 km in length and 40 km in width.

The western and eastern parts of the Mae Hong Son Fault are mainly Upper Paleozoic clastic/carbonate rocks. A detailed study by Srinak (2002) indicated that most Permian rocks crop out in the western part. Intrusive rocks are mainly exposed along the eastern margin of the Mae Hong Son-Mae Sariang Fault Zone. Small exposures of Cenozoic basalts occur at Tha Ria Village about 30 km south of the Mae Sariang District.

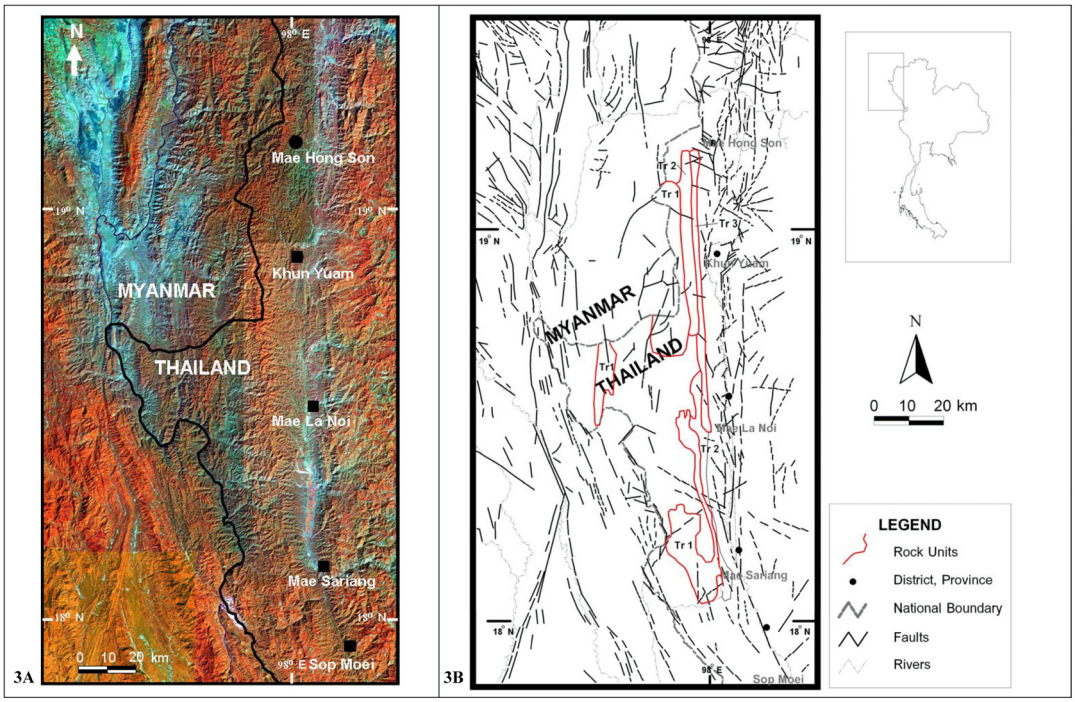

FIGURE 3. A. Enhanced TM5 image Landsat showing the distribution of the Kong Sum formation (Tr_1 unit), Pratru Muang formation (Tr_2 unit), and Mae Laeb formation (Tr_3 unit). **B.** Major geological structures and lineaments interpreted from the enhanced Landsat TM7 magery (from Charusiri et al., 2002).

Based on the results of Landsat image interpretation (Fig 3A, B), these 3 rock units are orientated roughly in a north-south direction and align as a composite, long (>150 km) and narrow (20-25 km) belt. The type sections are composite based on investigations along several road cuttings and stream exposures, west of Muang Mae Hong Son, Khun Yuam, Mae La Noi and Mae Sariang Districts. The best exposure is along Highway 108 from km 30 to km 150 in the Mae Hong Son and Mae Sariang Districts.

The Kong Sum (or Tr_1) unit

Based on the studies of Jindasuth et al. (1990) and our reconnaissance survey, the Kong Sum unit (or the Tr_1 unit) is considered as the oldest unit. An enhanced Landsat TM5 analysis reveals that in the west the unit displays high topography with steep slopes, high denudation, and east-west spaced fractures. Field investigation shows the major strike to be in a north-south direction, with mainly moderately steep, west-dipping angles. The Kong Sum unit occupies about 40 % of the regional study area and can be further subdivided into two lithofacies, a lower conglomerate lithofacies and a lithic sandstone lithofacies.

Lower conglomerate lithofacies is observed clearly in and around Kong Sum Village. This lithofacies unconformably overlies the Paleozoic rocks and consists largely of thick-bedded (10 to 20 cm), reddish brown, spotted siltstone interbedded with pebbly sandstone and conglomerate. Clasts are mostly chert, limestone, and sandstone and vary in size

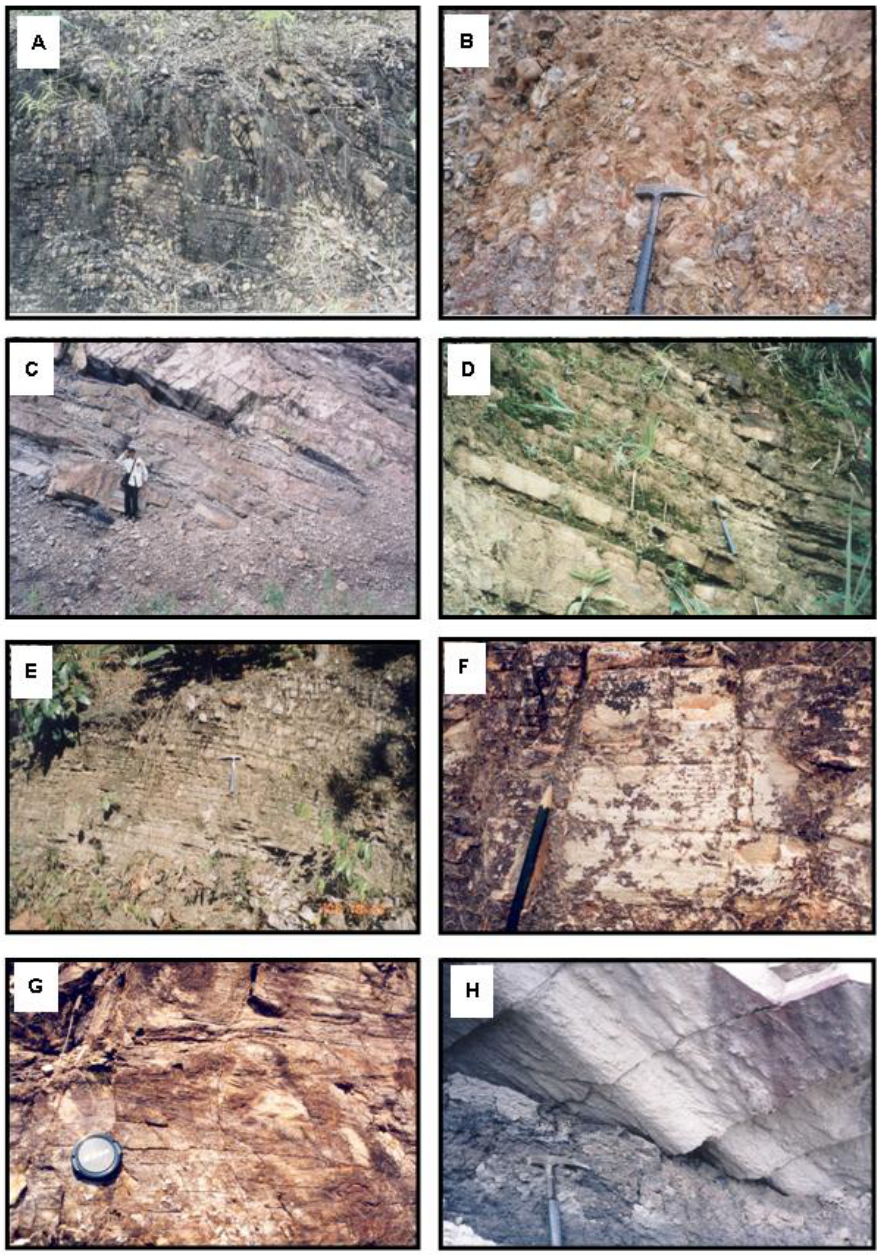

FIGURE 4. Natural exposures of **A**: Radiolaria-bearing chert interbedded with mudstone, the lower part of the Pratru Muang formation at 18° 48' 39''N/98° 51' 15''E; **B**: Matrix-supported conglomerate, the middle part of the Pratru Muang formation at 18° 48' 36''N/98° 51'42''E; **C** and **D**: Sandstone with interbedded shale facies, the upper part of the Pratru Muang formation, at 18° 48' 52''N/98° 52' 21''E. Road-cut of exposures of **E** well-bedded siliceous shale with intercalated mudstone, the Mae Laeb formation, at Ban Huai Pong; **F**: Well-laminated siltstone beds of the Pratru Muang formation at Ban Sape; **G**: Cross-beds of fine-grained greywacke at Pratru Muang; and **H**: A flute cast in sandstone at Pratru Muang.

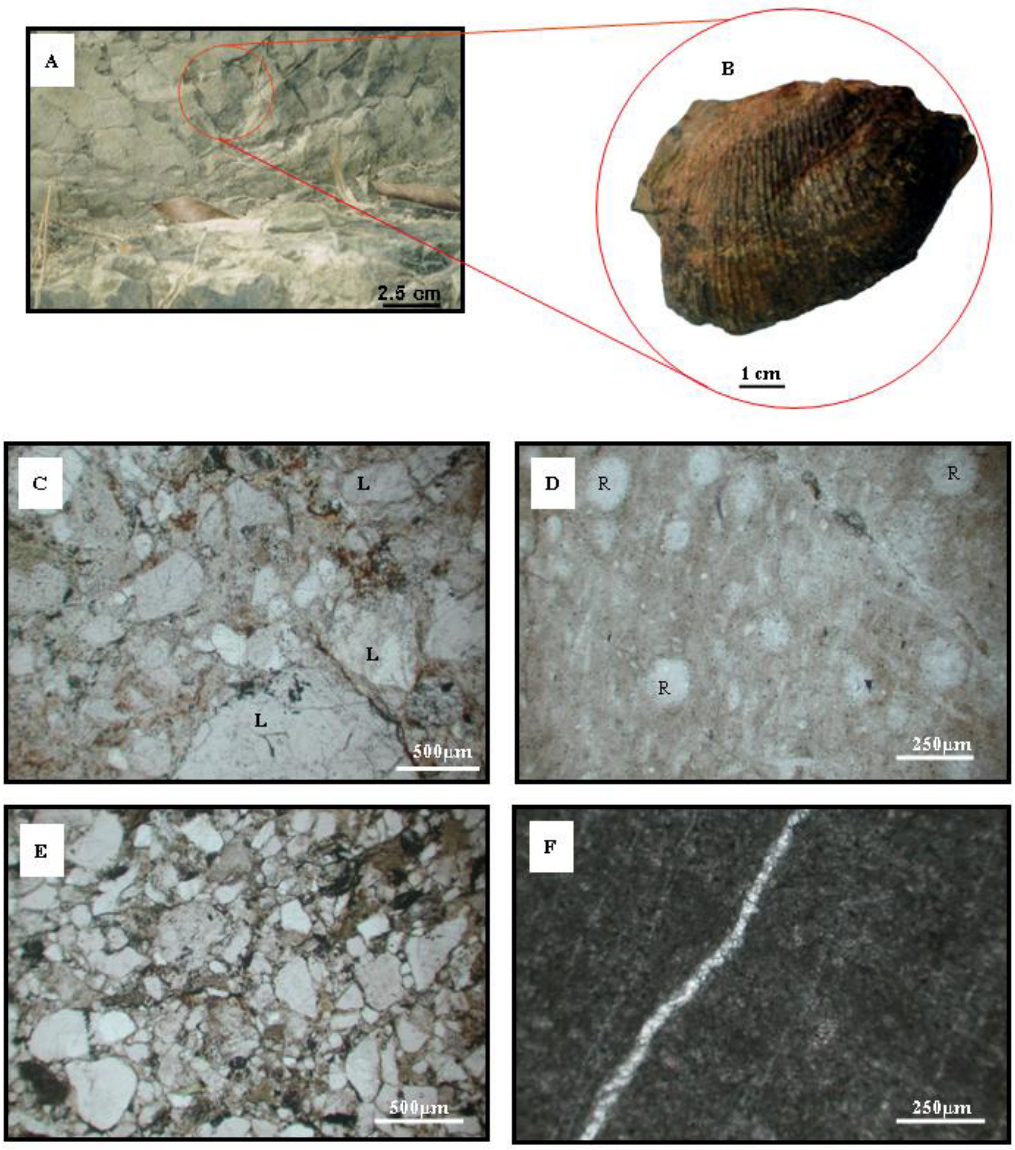

FIGURE 5. **A**: An outcrop of calcareous mudstone containing fossil (red circle), the lower part of the Mae Laeb formation, at Ban Huai Pong; **B**: Close-up view of *Halobia* sp.; **C** to **F**: Photomicrographs of sedimentary rocks of the Mae Sariang Group showing **C**-poorly-sorted greywacke with lithic fragment (*L*), Pratru Muang formation; **D**-radiolaria (*R*) in well laminated chert, Pratru Muang formation; **E**-moderately well-sorted, arkose with siliceous cement, Pratru Muang formation; **F**-laminated siliceous shale with a quartz veinlet, Mae Laeb formation. Transmitted light (**C**-**F**).

from 1 to 10 cm. Sorting is moderate, and subangular to subround clasts are quite common, particularly at the Mae Lamong stream. The conglomerate is mostly clast-supported. Petrographically, both the sandstone and siltstone invariably contain few feldspar clasts and more abundant quartz. At present, it is difficult to assign an age to this lithofacies, as fossils have not been found. However, a Triassic age is assumed.

Lithic sandstone lithofacies, a north-south trending outcrop, particularly between Kong Sum Village and Mae La

TABLE 1. Summary of characteristics of the Mae Sariang Group.

Triassic age	Formation (unit) (m)	Lithofacies	Lithology	
			Color	Lithological characteristics
Late	Mae Leab (Tr_3) (80-120)	IX	White	Medium-grained sandstone
		VIII	Dark gray	Siliceous shale interbedded with mudstone
		VII	Dark gray	Calcareous mudstone interbedded with fine-grained sandstone
Middle to Late	Pratru Muang (Tr_2) (200-770)	VI	White to light gray	Sandstone interbedded with shale
		V	Brown, reddish brown	Conglomerate and sandstone
		IV	Dark gray to almost black	Chert interbedded with mudstone
		III	Dark gray	Mudstone interbedded with sandstone
Middle (to Early?)	Kong Sum (Tr_1) (150-150)	II	Gray	Lithic sandstone
		I	Brown, reddish brown	Conglomerate (clast-supported) and siltstone

Noi District. The rock sequence overlies conformably the lower conglomerate lithofacies and consists chiefly of thick-bedded (4 to 40 cm), gray-colored, poorly-sorted, fine- to coarse-grained lithic sandstone with size grading and cross bedding. This sandstone is always interbedded with thinly bedded blackish gray siltstone/shale near Kong Sum Village. Under thin section, the clasts are seen to be mainly sandstone and siltstone with a minority of volcanic rocks. The other interesting feature is the presence of well-bedded calcareous sandstone and massive, gray-colored and lens-shaped limestone beds showing slump structures in some parts. The limestone beds grade into thickly bedded gray sandstone showing graded bedding. The sandstone always shows cross lamination and load casts. Structurally, the whole sequence is folded but its bedding attitudes strikes mostly to the east. Important fossils such as *Halobia* sp. and Daonella cf. sumatrensis have been found (Jindasuth et al., 1990; this study).

The Pratru Muang (or the Tr_2) unit

Outcrops collectively called the Pratru Muang unit (or the Tr_2 unit) are widely exposed only in the western part of the Mae Hong Son Fault in a north-south trend. Detailed study on enhanced Landsat TM5 imagery indicates that the Tr_2 unit is characterized by moderate topography, gentle slopes and north-northwest - trending spaced fractures. These features contrast with those of the Tr_1 unit. In general, the strike of the rocks varies from north-northeast to north-northwest. The strata of the Tr_2 unit overlie those of the Tr_1 unit, and are therefore apparently younger unit. As shown in Figures 1B and

TABLE 1. Continue

Geometry		Sedimentary structure	Fossils
Thickness (meters)	**Distribution**		
20-30	Local	Fining upward sequence	-
80-90	Extensive	Laminar and well-bedded sequence	*Halobia** Radiolaria[o] *Posidonia*[1]
20-30	Local	Well-bedded sequence	-
480-510	Extensive	Flute cast, graded bedding, cross bedded	*Halobia*[1]
90-100	Local	Graded-beds	*Daonella*[1]
16-148	Extensive	Limestone lens, laminar beds	Radiolaria[2]
60-70	Local	Well-bedded sequence	-
50-100	Extensive	Graded-bedding, cross-lamination, load casts	*Halobia** *Daonella* cf. *sumatrensis*.[3]
20-50	Extensive	Well-bedded sequence	-

*= this study; o = Caridroit et al. (1993); 1 = Hahn and Siebenhüner (1982); 2 = Kamata et al., 2002; 3 = Jindasuth et al. (1990).

3B, strata belonging to the Tr_2 unit occupy about 50 % of the total study area.

In some parts of the middle succession a few index fossils such as bivalves were observed in the shale. The ages of these bivalves, which are considered on few spot-locations, are mostly Early Triassic (Baum et al., 1970). Based upon the lithological and structural relations, the following four lithofacies can be recognized from bottom to top:

(**i**) Mudstone interbedded with sandstone lithofacies is about 60 m thick. The lithofacies is characterized by thinly bedded, dark gray mudstone intercalated with thinly bedded, dark gray, sparsely spotted, lithic greywacke. Modal analysis shows that the sandstone is composed of 30% quartz, 35% feldspar and 35% rock fragments. Common rock fragments are sandstone, chert and volcanics. Most of the quartz grains are fine and polycrystalline, some are rounded. The sandstone is poorly sorted and contains 15% silt to clay matrix.

(**ii**) Chert interbedded mudstone lithofacies is characterized by a dark gray radiolarian-bearing chert (Fig. 4A) which is always intercalated with thinly bedded mudstone and, in some parts with gray limestone. The thickness varies considerably from 16 to 148 meters. The measured sections were located at Pratru Muang Village, Mae Laeb Village, and Huai Pho Village (sections C, F and G, respectively in Figure 2A insert). However, petrographic investigations by us, and by Kamata et al. (2002), revealed that some parts of this dark gray chert are siliceous shale (Fig. 4A) containing abundant Triassic radiolarian (Fig. 5D).

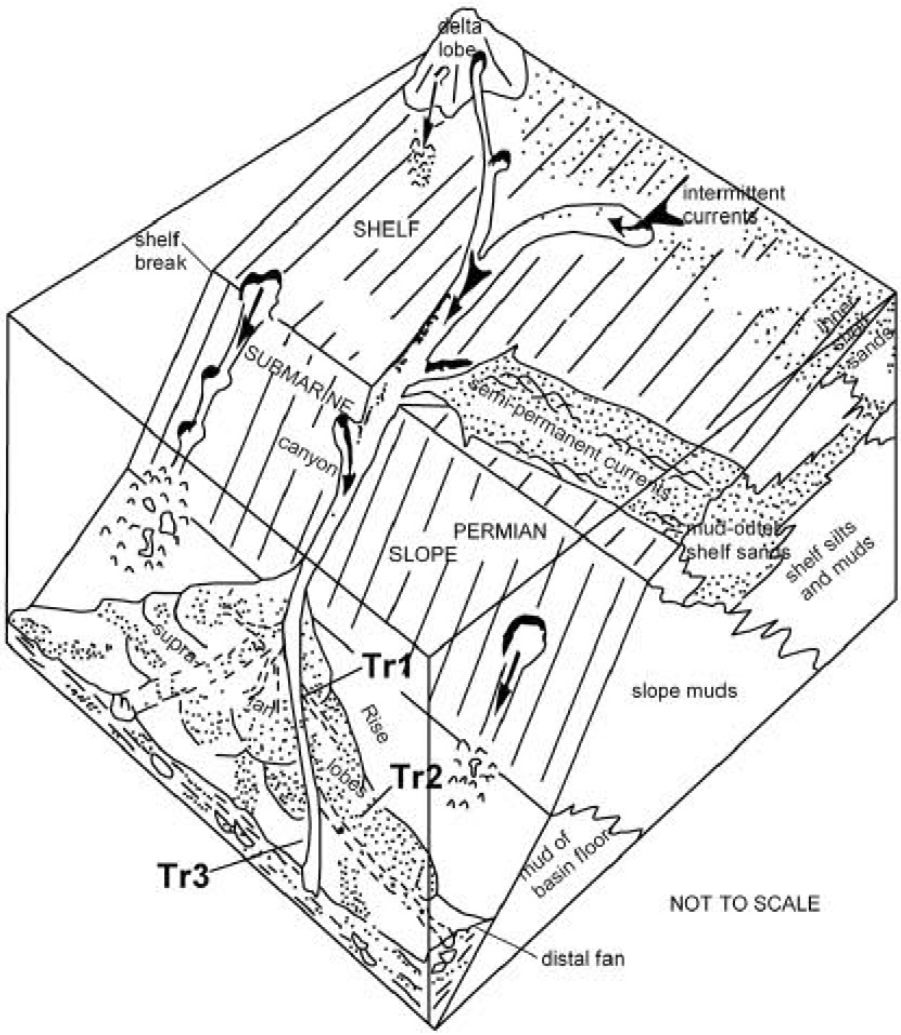

FIGURE 6. Schematic block diagram of a deep-water submarine fan setting and sediment supply system (based on Lewis, 1982). In this diagram the Permian, Triassic, and Jurassic strata of the Mae Hong Son-Mae Sariang area are also assigned. Tr_1: Kong Sum; Tr_2: Pratru Muang; and Tr_3: Mae Laeb formation.

(**iii**) Conglomerate interbedded sandstone lithofacies (Fig. 4B) is regarded herein as the youngest lithofacies and is predominantly comprised of conglomerate with interbed-ded sandstone and shale and thinly- to medium-bedded sandstone. The maximum measured thickness is about 97 m. This lithofacies unconformably overlies the chert interbedded mudstone lithofacies and is unconformably overlain by the sandstone and shale lithofacies. Conglomerates are largely matrix-supported and invariably poorly sorted. Most of the clasts are chert (60%), with some quartz (30%) and sandstone (10%) and vary in size from 0.2 to 5.0 cm. The sandstone (Fig. 5C) is always light gray to yellowish brown, thinly- to medium-bedded, medium-grained and consists mainly of quartz (60%), feldspar (25%)

and Fe-Mg oxide dark minerals (15%). Common structures are well-defined, alternated lager and graded-beds. The sandstone usually shows sharp contacts with overlying reddish brown mudstone. The lowermost part of this unit is marked by conglomerate with interbedded sandstone and siltstone (Fig. 4F). Pratru Muang and Sape villages are considered as the type localities for this remarked unit.

(**iv**) Sandstone and shale lithofacies (Fig. 4C, D) is the youngest lithofacies of this unit and unconformably overlies the conglomerate interbedded sandstone lithofacies. The sandstone and shale lithofacies is characterized by a medium- to very thick-bedded sandstone with interbedded thinly-bedded shale with graded bedding, cross bedding (Fig. 4G), and flute casts (Fig. 4H). The sandstone is white to light gray, medium to very thick-bedded arkose (Figs 4D and 5E) and lithoarenite. Modal analysis reveals an average of 35% quartz, 30% feldspar, and 25% rock fragments. The shale is gray to brown, and thinly bedded. The lowermost part of this unit is white fine-grained sandstone interbedded with brown shale. Good exposures are observed at Pratru Muang Village in the Khun Yuam District. The overall thickness of this lithofacies is estimated at about 500 meters.

The Mae Laeb (or Tr_3) unit

The Mae Laeb unit refers to the sequence between the Tr_2 unit and the overlying Jurassic clastic rocks. This unit has a limited outcrop, totalling about 10% of the exposed Triassic rocks. It is well exposed locally at Huai Pong Village, Huai Hin Lak Fai Village, and Mae Laeb Village (measured sections A, E and F in Figure 2A insert) (see Fig. 4A).

Detailed study of enhanced Landsat TM5 imagery reveals that the Tr_2 unit displays a low topography and gentle slopes. Field study shows that rock strata have a north-south strike with a high-angle dip ($\sim 70^{o}$ to the east). Several fractures follow rock attitudes. The Tr_3 unit has the thickness of about 118 m. Important fossils are cephalopods, conodonts, *Posidonia*, and *Halobia*, (Hahn and Siebenhüner, 1982) indicating an age of Middle to Late Triassic. The Tr_3 unit can be divided into the following three lithofacies:

(**i**) Calcareous mudstone and sandstone lithofacies forms the lower part of the Mae Laeb unit and is characterized by a medium-bedded mudstone intercalated with thinly-bedded graywacke sandstone. Apart from quartz, clay and micaceous minerals, calcite is also present as calcareous cement in the mudstone. Modal analysis reveals that the sandstone is composed of an average of 35% quartz, 30% feldspar and 35% rock fragments, with siliceous cement. Most of the clasts are very fine-grained and well sorted.

(**ii**) Siliceous shale interbedded mudstone lithofacies (Figs 4E nad 5F) is usually characterized by black, thinly bedded, siliceous shale interbedded with black thinly-bedded, spotted mudstone with fossils of *Halobia* (Fig. 5A, B). The lithofacies has a thickness of about 80 meters.

(**iii**) Medium-grained sandstone lithofacies is characterized in the lower part by a well-bedded medium-grained white arkosic to micaceous sandstone, and in the upper part by a brown, medium- to fine-grained, sub-rounded, poorly-sorted, medium- to thinly-bedded, gray wacke sandstone. Both sandstones have broadly similar compositions of quartz (30-40%), feldspar (25-40%) and rock fragments (20-

30%). This lithofacies, about 20 m in thickness, is a composite of mainly medium- to thick-beds of the parallel-bed type with a few interbeds of siltstone.

DISCUSSION

Depositional environments

The lower conglomerate facies (**I**), the oldest unit of the Kong Sum unit (Tr_1 unit), is characterised by clast-supported clasts of mostly pebble size and made up mainly of chert, limestone, and sandstone, presumably derived from the older sedimentary units. The lithic sandstone (**II**) is dominated by thickly bedded lithic sandstone with well-defined graded beds, cross-beds and slump structures. It is quite likely that sediments of the Tr_1 unit were deposited in a deep marine high-energy environment with steep slopes, not close to the shelf. This environment is equivalent to the deep-water submarine fan setting proposed by Mutti and Ricchi-Luchi (1978).

The Pratru Muang (Tr_2) unit consist of 6 lithofacies including thinly-bedded mudstone intercalated with thinly-bedded fine-grained sandstone (III), thinly-bedded radiolarian chert intercalated with thinly-bedded mudstone (IV), conglomerate interbedded graded sandstone (V), and shale interbedded with sandstone with cross-bedding, graded bedding, and flute casts (VI). These lithofacies indicate that sediments of the Tr_2 unit were deposited as turbidite sequences in a deep-water submarine fan environment.

Results from Landsat and aerial photographic analysis reveal that lithofacies of the Tr_1 unit are remarkably different from those of Tr_2 unit based on topography and drainage patterns. Field evidence also supports that cherty rocks are only present in the Tr_2 unit and are absent in the Tr_1 unit.

Three lithofacies of the Mae Laeb (Tr_3) unit; dark gray calcareous mudstone and sandstone (VII), siliceous shale interbedded mudstone (VIII), and medium-grained sandstone (IX) with a fining-upward sequence, show diagnostic sedimentary assemblages which points to deposition in a rather deep marine environment but on a gentle slope and low energy setting.

Tofke et al. (1993) mapped the Mae Sariang and surrounding area and reported that sedimentary rocks in the area are deep marine facies as characterized by the "true" ribbon-chert, "true" pelagic limestone and a thick turbiditic sequence of siliciclastics. Chonglakmani (1999) proposed the Triassic sedimentary belt exposed in the Mae Sariang area, which extends southward to Tak, Mae Sot, Kanchanaburi, and to Songkhla in peninsular Thailand. He considered that this belt comprises a deep marine and oceanic facies.

It is considered in this study that the sedimentary sequences of the Mae Sariang Group were deposited from an outer shelf to the slope of a relatively deep marine environment. The appearance of lateral graded beds of conglomerate, the nature of the cross beds and the orientation of flute casts lead us to believe that the provenance of the Mae Sariang Group rocks is from east to west, approximately, based on cross bedding. A comparison is made with the deep-water submarine fan model proposed by Lewis (1982) (see Fig. 6). The Kong Sum (Tr_1) unit can be compared with the inner fan facies (Facies A), as indicated by the thick-bedded siltstone interbedded with pebbly sandstone, and with the middle fan

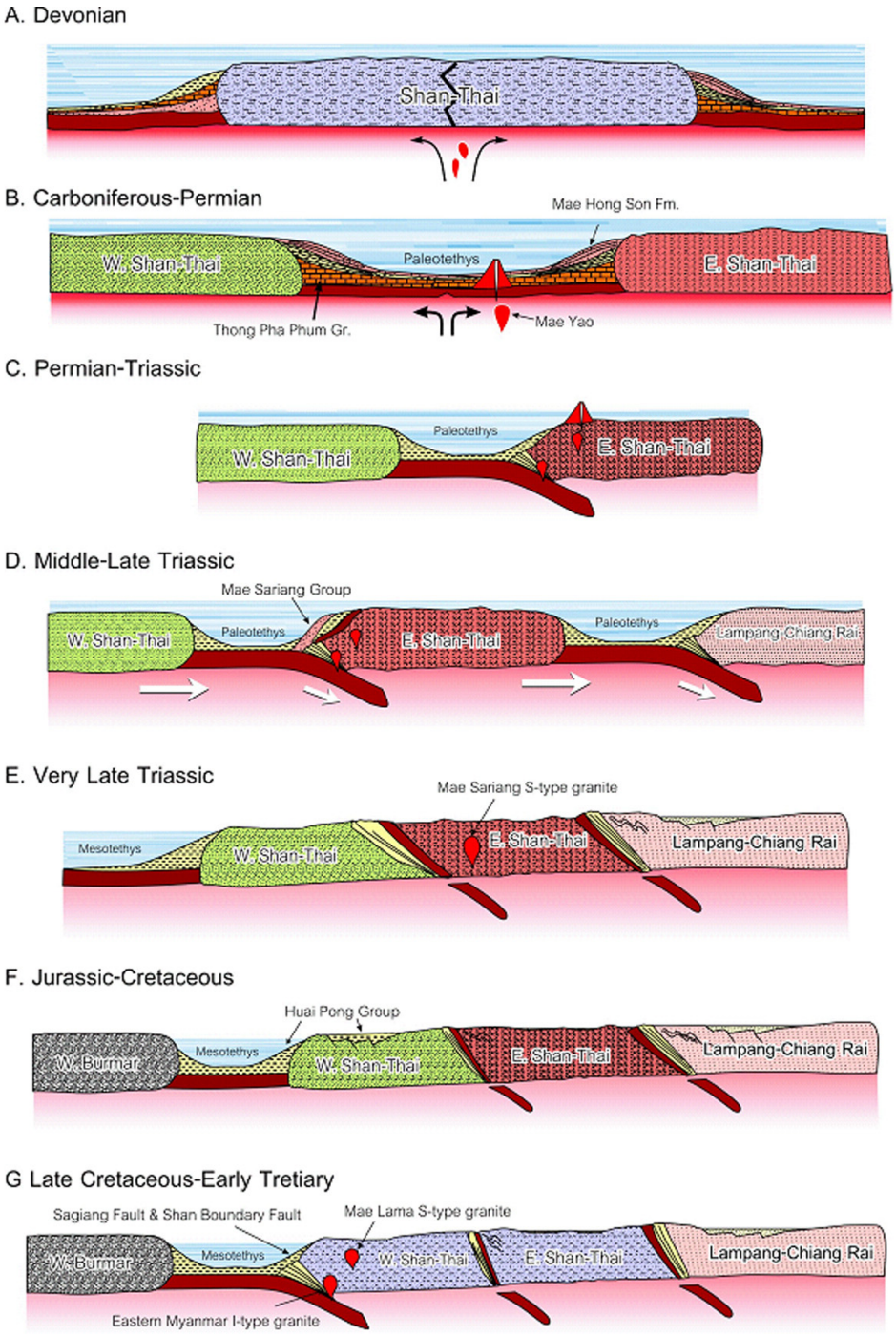

FIGURE 7. Tectonic reconstruction during the Late Paleozoic to Late Mesozoic of the Shan-Thai microcontinent in the Mae Hong Son area, northwest Thailand.

facies (Facies C), as indicated by the thick-bedded, lithic sandstone. The Pratru Muang (Tr_2) unit is comparable with the middle fan facies (Facies C, D, and E), as indicated by the thinly-bedded mudstone intercalated with thinly-bedded sandstone, thinly-bedded chert intercalated with thinly-bedded mudstone, conglomerate interbedded sandstone, and sandstone interbedded shale with common cross-bedding, graded bedding and flute cast. The Mae Laeb (Tr_3) unit is similar to the basin plain facies (Facies D and G), as indicated by the medium-bedded mudstone intercalated with thinly-bedded fine- to medium-grained sandstone and black, thinly-bedded, siliceous shale interbedded with black thinly-bedded mudstone. However, since no "true" oceanic facies are evident we infer that the Triassic sedimentary facies can be correlated with the Semanggol Formation of the Kulim-Taiping zone in northwest Malaysia (Grant-Mackie et al., 1980). In this light it is of note that an equivalent facies consisting of chert, meta-argillite, red shale, limestone, and deep-water rhythmite occurs in central Sumatra (Eubank and Makki, 1981).

Based on the above-mentioned lines of evidence, the Mae Sariang Group was deposited as a deep-water submarine fan. The Permian sequence in the Mae Hong Son-Mae Sariang area consists of 2 major units: (i) dark gray argillaceous limestone with shale and chert interbeds in the lower part; and (ii) clastics with chert beds and limestone lens in the upper part. This suggests that these Permian sediments were deposited in a rather deep environment of the outer shelf facies, but possibly not as deep as that of the succeeding Triassic. Deep marine environments persisted into the Triassic period where the sedimentary facies is characterized by a deep-water submarine fan in response to shallow marine conditions (inner to middle shelf) existing over most of western and southern Thailand in the Jurassic period (Toarcian-Bajocian) (see Meesook, 1994). These conditions are indicated by the abundance of fauna and the presence of oncolitic and oolitic limestones and plant remains in sandstones (see Meesook, 1994).

Ages

The age of the Mae Sariang Group was first proposed as Middle Triassic by Baum et al. (1970) and subsequently an Anisian-Norian (Middle-Late Triassic) age was suggested after examination of fossils of *Halobia* and *Posidonia* (Hahn and Siebenhüner, 1982; Tofke et al., 1993). At the same time, Caridroit et al. (1993) mapped a clastic sequence in the area to the west of the Mae Sariang district, corresponding to the clast-supported conglomerate of the Kong Sum unit in this study. The paleontological data proves that this sequence is not of Middle Triassic age, but seems to be younger (Late Triassic or younger) as supported by the presence of two types of radiolarians in the pebbles with one aged to the Middle to Late Permian age and the other of Triassic age.

Recently Kamata et al. (2002) found (Early?) to Late Triassic (Spathian? to Carnian) radiolarians, which were obtained from the bedded chert sequence of the Mae Sariang Group and belong to the Pratru Muang unit of this study. Additionally, our study indicated that fossils of *Halobia*, found in the shale of the Mae Laeb unit at Ban Huai Pong support Middle to Upper Triassic age (Hahn and Siebenhüner, 1982). So from the paleontological point of view, it is considered that the age of the

Mae Sariang Group is mainly restricted to Middle to Late Triassic period. More details on Triassic ages of individual units are explained in Table 1.

Tectonic History

Based on the results presented here we consider that during the Late Paleozoic period mostly intracratonic silici-clastic sediments of outer shelf facies were deposited in the north-trending Mae Hong Son-Mae Sariang basin of the Paleotethys (Fig. 7). The basin was situated almost in the middle portion of the Gondwana-derived Shan-Thai terrane (Bunopas, 1981). Therefore, the Shan-Thai may have been split into two parts herein called the western and the eastern Shan-Thai (Fig 7A, B) with a marked boundary along the Mae Hong Son Fault (or weak zone) probably during the Middle to Late Paleozoic times. Such continental rifting initiated a new, but short-lived, oceanic (basaltic) crust/plate between the eastern and the western Shan-Thai together with a transgression of Paleotethys (Fig. 7B). The notion of rifting tectonics is supported by the alkaline intrusion in Mae Yao area, north of Mae Hong Son (Petfeld et al., 1997). Deposition of shelf sediments containing a paleotethyan biota (Ueno, 1999) took place mainly in the western Shan-Thai.

During Late Permian to Early Triassic times, the eastward subduction of a new oceanic crust/plate may have occurred beneath the eastern Shan-Thai. This eventually led to the appearance of rhyolitic to andesitic volcaniclastics (Fig. 7C) and epiclastic affinity. In the Middle to Late Triassic times, the eastern and western Shan-Thai moved closer and the Paleotethys became narrower and deeper. Subsequently, deep-water submarine fan deposits of the Mae Sariang Group may have been deposited along continental slopes of the western Shan-Thai during the Middle to Late Triassic age (Fig. 7D). Almost simultaneously, compression developed due to the eastward subduction of the western Shan-Thai beneath the eastern Shan-Thai and the eastern Shan-Thai beneath the Lampang-Chiang Rai plate. This triggered a partial melting of metasediments of Shan-Thai, and eventually the S-type, tin-bearing granites (Fig. 7E) were emplaced by Late Triassic times. The Paleotethys was almost entirely closed during the Early Jurassic period along the Mae Hong Son Fault as the eastern and western Shan-Thai blocks were nearly attached. This was probably due to the Western Burma (Myanmar) plate progressively drifting nearby the Shan-Thai block. Open shelf to onshore deposits of the Huai Pong Group (Fig. 7F) may have been deposited in response to the westward tilting of Shan-Thai. Interaction by basaltic-plate subduction of the Western Burma block caused I-type granite intrusions in eastern Myanmar. Compression of the western Shan-Thai block may have caused S-type granite intrusions (Fig. 7G) and associated spotted rocks. The north-south trending major synclines in the study region may have formed due to such compressional tectonics.

Based upon the paleogeography, marine transgression seems to have been more dominant to the west than to the east. In other words, the Indochina plate may have been uplifted more rapidly than the Shan-Thai and related plates. Judging only from Thailand, continuing sudduction of the Lampang-Chiang Rai and Nakhon Thai oceanic plates may have occurred from the west to the east in response to the

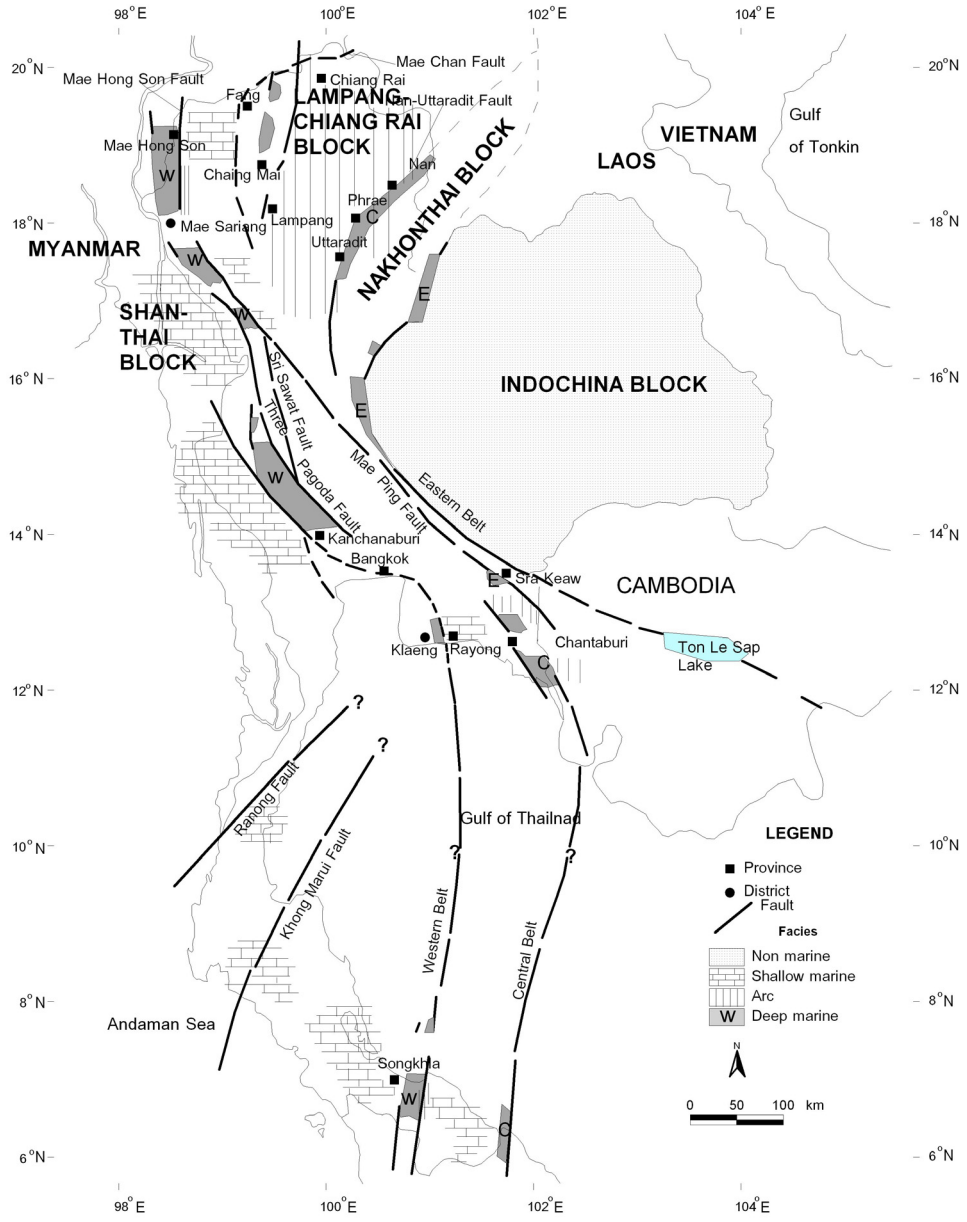

FIGURE 8. Triassic paleogeography of Thailand showing major tectono-sedimentary facies (modified from Chonglakmani, 1999, Charusiri et al. 2002).

progressively uplifted Indochina plate, and have become an exposed megalandmass during the Jurassic and Cretaceous Periods (Fig. 7G).

Comparison with other Triassic Sequences in Thailand

Based on our current investigation of the Mae Sariang Group in conjunction with those of the other Triassic sedimentary sequences in Thailand, the Triassic clastic

sequences of the Mae Sariang Group are regarded as deep marine, possibly partly, oceanic facies. The Group may have occurred immediately to the west of the Mae Hong Son Fault and extended southward along the Mae Ping Fault zone. Similar Triassic sedimentary facies have been encountered in several places in Thailand. Good examples are the radiolarian-bearing chert beds with basalts of the Laem Mae Pim, Chantaburi (Sashida et al., 1993; Hada, 1990) and the chert/pelagic sediments of the Sra Kaew Formation (Bunopas, 1981) in the Sra Kaew-Chantaburi area of eastern Thailand. The slightly older, deep-water marine facies of the Nam Duk Formation (Chutakositkanon et al., 2002), and those along the NE-trending Nan-Uttaradit (Bunopas, 1981), and the W-trending Pattani suture zones, are regarded as equivalent to this deep-marine facies. The ribbon radiolarian-bearing chert beds at Fang (the so-called Fang Chert, Buonpas, 1981) and in the Bo Phloi district of Kanchanaburi (the Bo Phloi Formation, Shashida et al., 1993) are also included in this marine facies. It is also interesting that the Triassic chert/hemipelagic beds of the Klaeng Formation and those of the Ko Yoe Formation can be correlated and probably extends northward to the Kanchanaburi-Tak areas along the Three-Pagoda and Sri Sawat fault zones.

In contrast to the deep-marine facies, Triassic shallow-marine facies can also be recognized. Mostly, they are observed in the Shan-Thai terrane. Good examples are the shelf carbonate strata of the Chaiburi formation (Ampornmaha, 1995) and the shelf clastic sequences of the Nathawi formation (Grant-Mackie et al., 1980), which are widespread in southern peninsular Thailand (Chonglakmani, 1999). Poorly studied shelf facies of the Kamokala Limestone are quite extensive in western Thailand. We, therefore, propose that these limestone beds as well as those clastic shelf sequences to the west of Chiang Mai are limited to the Shan-Thai terrane.

As shown in Figure 8, the region between Chiang Mai and Loei-Phetchabun is characterized by sedimentary sequences, which are more related temporally and spatially to the volcanic arcs. These sediments are herein called “arc facies”, including clastic-carbonate sequences of the Lampang and Phare groups. These two groups are present only in the Lampang-Chiang Rai and Nakhon Thai tectonic blocks (Charusiri et al., 2002). Submarine-fan sediments of the Pong Nam Ron Formation (Chonglakmani, 1999) are more or less equivalent to arc facies. It is obvious that northeastern Thailand is mainly occupied by thick Triassic sequences of continental and terrigenous sediments referred to here as “non-marine” facies (Fig. 8). Most of the sediments are either fluvio-lacustrine gray-colored fine-grained clastics or brackish-water fine- to medium-grained clastics as reported by Maneechai (1994). These continental sediments are mainly confined to the Indochina terrane.

CONCLUSION

The Mae Sariang Group of Triassic age in the Mae Hong Son-Mae Sariang area, northwestern Thailand, can be subdivided into three units in descending order, namely; the Mae Laeb, Pratru Muang, and Kong Sum units. The total thickness is about 900 meters. These three units are distributed as a narrow north-south belt.

The 200 m-thick Kong Sum unit, with *Halobia* and *Daonella* bivalves of Middle (or Early?) Triassic age was deposited in the high-energy environment of a deep-marine setting with steep slopes.

The Pratru Muang unit, with a thickness ranging from 200 to 770 meters, is characterized by thinly bedded chert intercalated with thinly bedded mudstone with abundant radiolarian fossils. Cross beds, graded beds and flute casts are common in intercalated sandstones. The unit is inferred to have been deposited as turbidite sequences in a deep-water submarine fan environment.

The 120 m thick Mae Laeb unit contains *Posidonia*, *Halobia* and radiolarian fossils of Late Triassic age. The sedimentary sequences point to deposition in the basin-plain environment but with a gentle slope and low energy.

Stratigraphical and paleontological lines of evidence suggest the age of the Mae Sariang Group as Middle to Upper Triassic period.

The marine Triassic sequences of the Mae Hong Son-Mae Sariang area were deposited in a deep-water submarine fan environment in a subduction-related tectonic setting, similar to those of Tak, Kanchaburi and Songkhla regions. Both the oldest and younger sequences are suggestive of depositional environments not as deep as those of the Triassic period.

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