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New micropalaeontological evidence for a Late Triassic Shan-Thai orogeny

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ABSTRACT: The Shan-Thai block is viewed as a remnant of Paleotethys in South East Asia. The general consensus about its origin is that it happened through the rifting from Gondwanaland and final amalgamation to Eurasia, sealed by fluvial–shallow marine Jurassic deposits. As the main Paleotethyan closure, the Nan–Uttaradit/Nan–Chantaburi and Bentong–Raub sutures were proposed by other workers. However, a suture further west, flanked by the Gondwana–Tethys divide (GTD), is advocated here as the main Paleotethyan closure. The Middle and Late Triassic radiolarian faunas were extracted from a chert-sequence in the Mae-Sot and Umphang areas of NW Thailand. The radiolarian faunas indicate early Ladinian, early–middle Norian, and Norian–Rhaetian, individually. The Triassic chert-sequence is overlain by the 'Jurassic base-conglomerate'. The limestone and chert clasts in the conglomerate yield Early–Late Triassic conodonts and Middle–Late Triassic radiolarians, respectively. Chert clasts in the conglomerate yield among others Norian–Rhaetian radiolarians that are correlative with those from TM3, while Early–Late Triassic conodonts are found in limestone clasts. The silici-pelagic origin of the clasts suggests the presence of an ocean before the end-Triassic orogeny along the Mae Sariang Zone that amalgamated the parts of the Shan-Thai block. This first finding of Late Triassic radiolarians from chert-sequence, next to the Middle Triassic and older radiolarian faunas, adds another element to the reconstruction of the sequence now comprised in the Mae Sariang Zone, west of the Nan–Uttaradit Suture. The occurrence of Triassic limestone, as that of the Chaiburi Formation in the Mae Sariang Zone, or the Kodiang Limestone in the "Western Zone", may elucidate the question about the provenance of the Triassic conodont-bearing limestone clasts in the Jurassic base-conglomerate that seals the Mae–Sariang Zone. The newly dated Triassic sequence is further sealed by the continental-shelf deposits of the Toarcian-early Bajocian Hua Fai Group.

Key words: radiolarian chert, conodont limestone, provenance, Shan-Thai Terrane, end-Triassic orogeny

1. INTRODUCTION

The Mae Sot–Umphang area (NW Thailand) is structurally a part of the Shan-Thai Terrane. For the Triassic development, the details on the formal nomenclature that have been established in Thailand are derived from Chonglakmani and Grant-Mackie (1993) and Carey et al. (1995), complemented by several authors. Hirsch et al. (2005) delineated the tectonostratigraphic terranes of SE Asia (Fig. 1), mainly based on Hada et al. (1999), Ueno (1999), Chonglakmani et al. (2001), Myo Min et al. (2001), Bunopas et al. (2002) and Charusiri et al. (2002). After a Late Paleozoic history of detachment from Gondwana, it transited into the lower latitudes of the Sibumasu Province in the Middle Permian and became a part of the low latitude Cathaysian Province during the Late Permian (Shi and Archbold, 1998). The Jurassic so called 'base-conglomerate' is significant for the understanding of the tectonic evolution of the Shan-Thai Terrane to the Asian Continent (Hada et al., 1999). The section along the Tak–Mae Sot highway, NW Thailand, exposes well this significant Shan-Thai Terrane event. According to Hirsch et al. (2005), the studied section belongs to the Mae Sariang Zone. The Permian–Triassic sequence is topped by the pre-Jurassic TM3 bedded-chert that yields Middle and Late Triassic radiolarians. The 'Jurassic base-conglomerate' TM4 is composed of varicoloured clasts of limestones and cherts in a reddish silt matrix. The limestone clasts yield Early–Late Triassic conodonts and the chert clasts contain Middle and Late Triassic radiolarians, similar to those from TM3. The research was carried out in the frame of the Japan–Thai 'Shan-Thai' IGCP 434 working group. For two consecutive years, 2001–2002, our team conducted a week-long field work in the Mae Sot and Umphang areas, Tak Province, northwestern Thailand.

2. GEOLOGICAL OUTLINE

Southeast Asia consists of four major tectonic terranes, the names of which sometimes vary: South China, Indochina, Shan-Thai and West Burma. The main difficulty consists in unraveling end-Middle Permian from Late Triassic Palaeo-Tethyan scars.

The Shan-Thai consists primarily of a metamorphic craton and Late Paleozoic–Early Mesozoic sediments. Its eastern boundary in the Nan-Uttaradit suture zone, originally a Lower Permian basin containing radiolarian cherts and serpentinite, ending in siliciclastic turbidites and occluded in late Middle Permian (Helmcke, 1984), marks the main suture

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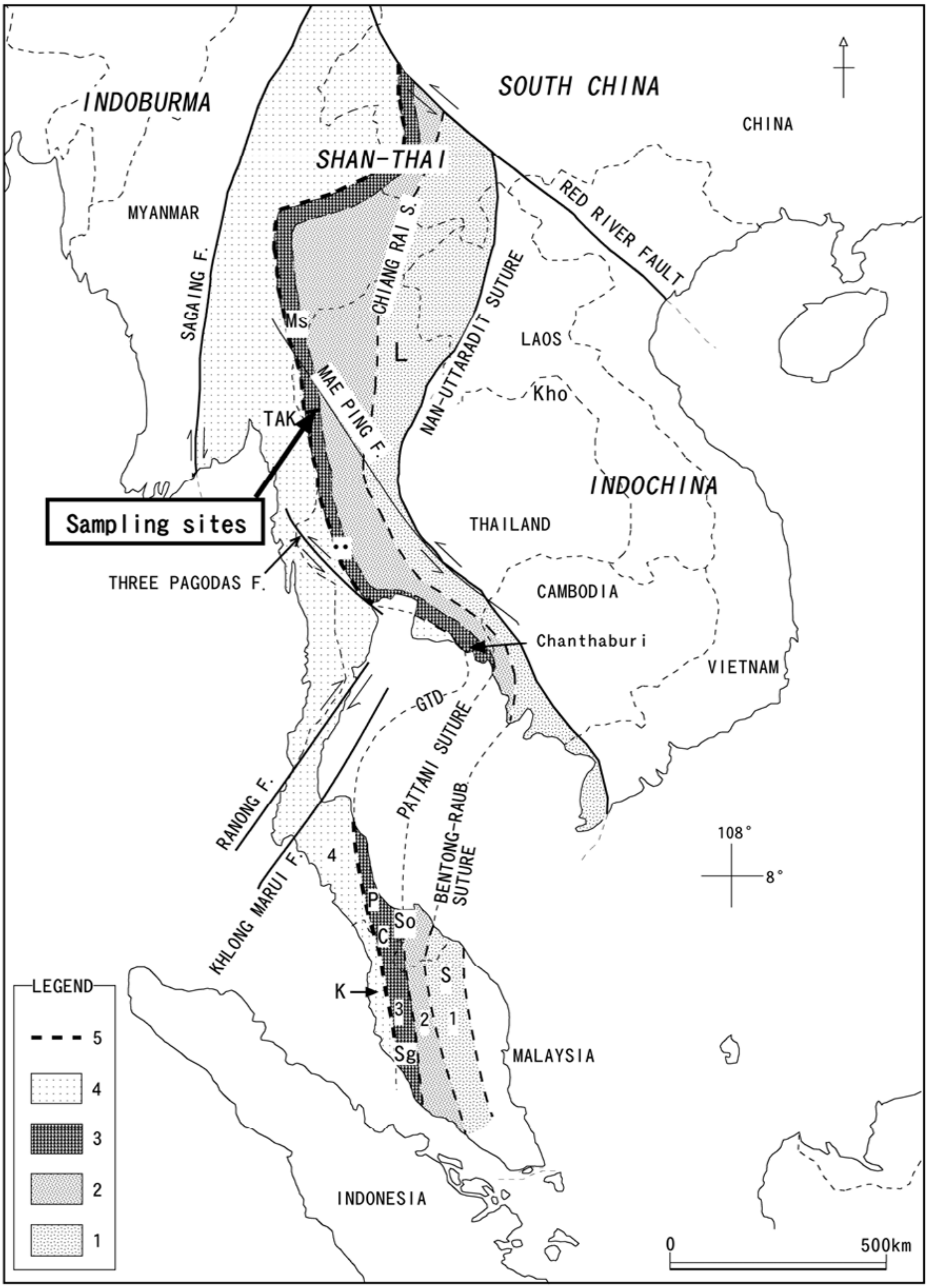

Fig. 1. Tectonostratigraphic terranes of SE Asia. After Hirsch et al. (2005); modified after Hada et al. (1999); Ueno (1999); Bunopas et al. (2002); Chonglakmani et al. (2001); Charusiri et al. (2002); Gondwana-Tethys Divide after Myo Min et al. (2001). Triassic basins after Chonglakmani and Grant-Mackie (1993) and Meesook et al. (2002). Legend. 1: Sukhothai Zone; 2: Inthanon Zone; 3: Mae Sariang Zone; 4: "Western Zone" (Tengchon-Tenasserim and Phuket); 5: Gondwana-Tethys Divide (GTD): Triassic basins of K: Kodiang Limestone; Kho: Khorat Group; L: Lampang-Phrae Basin; Cc: Chaiburi Formation; So: Songkhla Basin; Ms: Mae Sariang Basin; P: Phatthalung Basin; S: Semantan Formation; Sg: Semanggol Formation; TAK: study section.

ZONE	N Thailand	Chanthaburi	Peninsular Thailand – Malaysia
SUKHOTHAI	Thick Triassic carbonates & turbidites, rhyolitic & andesitic volcanism **Lampang - Phrae basins (L)**		East Malaysia: Triassic **Semantan Formation**
CHIANG RAI	(Permian – Triassic)	cryptic	**Bentong – Raub Suture**
INTHANON	Paleozoic & Triassic		**Songkhla (So)** Basin
MAE SARIANG	Permian & Triassic oceanic bedded-cherts & orogenic deep marine shale **Mae Hon – Mae Sariang (Ms) – Mae Sot (TAK) – Kantchanaburi**	Permian – Triassic oceanic/orogenic chert – clastic sequence	Triassic orogenic sequence **Phatthalung (P)** **Chaiburi Limestone (C)** **Semanggol Fm. (Sg)**
Gondwana – Tethys Divide			
"WESTERN"	**Tengchon – Tenasserim Zone** Early Permian tillites Triassic epicontinental platform, devoid of volcanics		**Phuket Zone** Early Permian tillites & Triassic **Kodiang Limestone (K)**

Fig. 2. Realms composing Shan-Thai (after Hirsch et al., 2005).

between Shan-Thai and Indochina terranes (Barr and MacDonalds, 1987: Carey et al., 1995). East of it, the Phetchabun fold and thrust belt (Helmcke, 1984) also includes ophiolites from a Permian oceanic seaway that closed in the Late Middle Permian. Its Mesozoic cover consists of continental Carnian–Norian deposits of the Khorat Group (Chonglakmani et al., 2001).

The Shan-Thai is subdivided into several zones from the east to west (Figs. 1 and 2; Hirsch et al., 2005). Among them, **The Mae Sariang Zone** extends along the NS-trending Tertiary strike-slip valley of Mae Nam Yuam in NW Thailand. It consists of Permian and Triassic ribbon-cherts and pelagic limestone that Hahn and Siebenhuner (1982) and Fontaine and Suteethorn (1988) attribute to the Shan-Thai Terrane. The pelagic and synorogenic siliclastics in the Mae Sariang–Kanchanaburi Basin suggest an end-Triassic orogeny. Above the pelagic sequence, follow synorogenic siliciclastic turbidites, which for Chonglakmani et al. (1991) witness a strong Triassic orogenic event that dissected the Shan Thai Terrane. The latter would thus consist of metamorphic complexes situated during Early Permian in a warm climate, alongside which Gondwana derived terranes docked during a Triassic orogenic event. A conglomerate with radiolarite pebbles yielding radiolarians determines the age of the Mae Sariang orogeny. The region east of Mae Sariang might be regarded as the Paleo-Eurasian margin of Paleotethys while the region west of Mae Sariang has a Gondwanian origin (Caridroit et al., 1993). Sediments that are similar to the Mae Sariang are found in the Semanggol Formation (Sashida et al., 1995), east of the Langkawi Island, Malaysia. Fontaine and Suteethorn (1988) first mentioned pelagic limestone along the highway Tak–Mae Sot. Only a narrow belt in the west is built up of Gondwana derived terranes, which docked during the Middle to Late Triassic (e.g., Hirsch et al., 2006).

The "Western Zone" of Gondwanian origin yields glacio-marine sediments. They consist to the north of the Baoshan craton, which is topped by Asselian oolitic limestone with *Pseudoshwagerina.* Separated from the latter by the Nujiang fault, the Tengchong–Tenasserim Zone encompasses crystalline pebbles of glacial-marine origin, as young as Stephano-Asselian, covered by late Early Permian limestone. The Phuket Zone represents the Western units further south.

3. TRIASSIC TECTONO-STRATIGRAPHY OF THE MAE SARIAG ZONE

Recently, microfossil dating has clarified the detailed distribution and stratigraphy of Triassic formations in Thailand and Malaysia (e.g., Sashida and Igo, 1999; Metcalfe et al., 1999; Hada et al., 1999). The Mae Sariang Zone contains rocks of Triassic chert-, carbonate-, and turbiditic facies that originate from the pelagic ocean which are believed to be of synorogenic nature.

3.1. Turbiditic Facies

From the Mae Sariang and Kanchanaburi Basins, a sequence of presumably Lower to Upper Triassic is found. In the Mae Sariang area, the Mae Sariang Formation consists of a sequence of shale, sandstone and conglomerate, intercalated with chert and limestone. *Daonella* and *Halobia*, allow its correlation with similar rocks in the Lampang Group. The turbiditic facies of the Mae Sariang Zone is characterized by *Daonella sumatrensis.* At 34 km of the Tak–Mae Sot road, mudstone with *Halobia*, wood fragments and poorly preserved radiolarians occur (Meesook personal communication). In the Mae Sot Basin, along the Thai-Myanmar border, the over 900 m of shale and sandstone of the Mae Sariang Formation contain limestones that yield *Jovites*, *Juvavites* and *Choristoceras*, brachiopods, bivalves and algae (Tamura et al., 1975; Chonglakmani and Grant-Mackie, 1993).

3.2. Chert Facies

In NW Thailand, intensely folded chert and siliceous black shale formations north of Chiang Mai were informally named as "Fang Chert" (Bunopas, 1981). Caridroit et al. (1990), Caridroit (1991, 1993), and Sashida et al. (1993) reported the occurrence of Paleozoic and Early Mesozoic radiolarians from the siliceous clastic rock sequences in North Thailand. Late Permian to Middle Triassic radiolarians were reported from the chert beds at Ban Huai Tin Tang, near the Thai–Myanmar border, north of Chiang Mai. Among them, Triassic radiolarians belong to the *Parentactinia nakatsugawaensis* and *Eptingium manfredi* assemblages of Anisian age (Sashida and Igo, 1999). At km 34 of the Tak–Mae Sot road, bedded-chert yielded well-preserved radiolarians (Ishida et al., 2004). In the Sra Kaeo-Chanthanaburi area, east Thailand, red bedded-chert of the Chanthaburi chert-clastic sequence (Hada et al., 1999) yielded *Eptingium manfredi* assemblage at Trat, near the Gulf of Thailand (Sashida and Igo, 1999). In Peninsular Thailand, the turbidites of the Na Thawi Formation are imbricated with the Chaiburi limestone (see below) and chert. These correlate with the deep marine and oceanic Mae Sariang facies (Chonglakmani, 2002). The thin-bedded chert at Khao Chiak yielded the *Entactinia nikorni* assemblage together with late Spathian to early Anisian conodonts *Neospathodus homeri* and *N. timorensis* near Phatthalung (Sashida and Igo, 1999).

In the Semanggol area in Kedah (Malaysia), Teoh (1991) subdivided Paleozoic and Mesozoic of the Sungai Tiang area of central Kedah into the Mahang (Lower Silurian), Kubang Pasu (Carboniferous), and Semanggol (Middle to Upper Triassic) formations. Burton (1973) subdivided the formation into the Lower Chert, Middle Rhythmite, and the Upper Conglomerate members. Sashida and Igo (1999) extracted late Middle and Late Permian radiolarians from the lower Chert Member. As illustrated in the review paper of Sashida and Igo (1999), the Triassic in the Alor Setar (Alor Star) region consists of a sequence of chert followed by turbidites and covered by conglomerates, depicted alongside the Kodiang limestone. Koike (1973) described conodonts.

3.3. Carbonate Facies

Most limestones in the Phatthalung area were viewed as Permian (Ratburi Limestone). Igo et al. (1988) and Sashida and Igo (1992) have reported early Middle Triassic conodonts and late Early Triassic radiolarians from the limestone at Khao Chiak, now described as the Chaiburi Formation (Ampornmaha, 1995). The Chaiburi Formation is subdivided into the following three members in ascending order.

3.3.1. Phukhaothong member

66 m of bedded to massive, light gray dolomites with some chert nodules, yielding the conodonts *Neospathodus kummeri* Sweet and *Neospathodus waageni* Sweet (Dienerian to Smithian);

3.3.2. Chiak limestone member

300 m of gray to dark gray bedded-limestone, with many chert layers, nodules and lenses intercalated in laminated-limestone beds. Laminated lime-mudstone yield radiolarians, ostracods, gastropods and echinoids. The lower part can be dated by the conodonts *Neospathodus timorensis* (Nogami), *Neospathodus kockeli* (Tatge), *Neogondolella burgarica* (Budurov and Stefanov) as Spathian to middle Anisian, gradually changing into bioclastic wackestone.

3.3.3. Phanomwang limestone member

A 90 m thick mostly massive limestone, including coral reef-limestone, yielding calcisponges, scleractinian corals, mollusks, echinoids, crinoids and foraminifers, the age of which is Carnian. Sardsud (2002) confirmed three Late Triassic conodont zones: *Epigondolella abneptis* subsp. A, *E. a.* subsp. B, and *E. postera* zones that represent lower–middle Norian.

4. TRIASSIC–JURASSIC ROCKS IN THE MAE SOT AND UMPHANG AREAS

In both the Tak–Mae Sot and Umphang areas, the nature of the Permian and Triassic contacts as well as the relation between chert beds and *Halobia*-bearing turbidites of Carnian age remains unclear (Meesook et al., 2002). In the Mae Sot Basin, marine Jurassic rocks are well exposed.

The marine Lower Jurassic **Hua Fai Group** (Meesook and Grant-Mackie, 1996), 900 m in thickenss, is exposed along the unsealed road to the Huai Mae Sot power station 7 km east of Mae Sot and along Huai Mae Sot (Fig. 3). The group consists of limestone-marl-mudstone-dominated sequences which have yielded bivalve and ammonite macrofaunas. The base is estimated to unconformably overlie on the Triassic strata, and the top of the group is interrupted at the fault-bounded margin of the Tertiary basin. The group is subdivided into the following three formations in descending order.

4.1. Pha De Formation

390 m, consisits mainly of limestone-marl dominated thinnning-upward sequences. Late Aalenian – early Bajocian

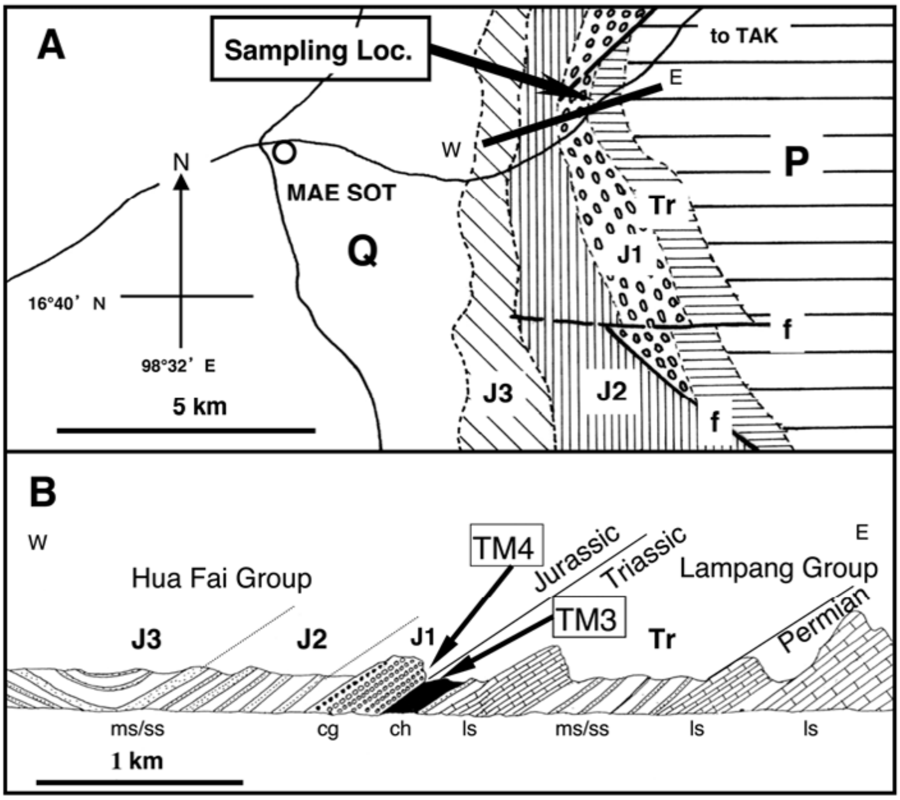

Fig. 3. (A) Geological outline map of Jurassic Hua Fai Group and Triassic Pha de Formation in the east of Mae Sot, with section line and sample locality (after Tantiwanit et al., 1985). Permian (P) and Triassic (Tr) formations of the Lampang Group; Khun Huai (J1), Doi Yot (J2) and Pha De (J3) formations of the Hua Fai Group (Jurassic). Q: Quaternary; WE: section line; f: fault. (B) Stratigraphic position of the TM3 chert and TM4 base-conglomerate in the Section along the Tak -Mae Sot highway, NW Thailand. TM4 and TM3: sampling localities; ch: chert; ls limestone; cg: conglomerate; ms/ss: alternation of sandstone and mudstone.

age is suggested by the occurrence of ammonites *Graphoceras* sp., *Eutmetoceras* sp., and *Docidoceras* sp.

4.2. Doi Yot Formation

370 m thick is composed of mudstone with interbedded limestones. Occurrence of *Onychoceras* sp., *Pseudolioceras* sp. and *Leioceras* sp. indicates late early Toarcian – early Aalenian.

4.3. Khun Huai Formation

140 m thick from the basal conglomerate, consists of limestone-marl dominated sequences interbedded with mudstone. In the type section, the lower part of the formation is assumed to be unconformable on marine Triassic strata because of the presence of a limestone-chert conglomerate (TM4) between the two. This contact is located about halfway between the Weir and Ban Kun Huai. Early Toarcian ammonite *Dactylioceras* sp. dates the formation. The upper part is conformably overlain by the Doi Yot Formation.

4.4. Relation Between Pre-Jurassic Chert And Hua Fai Group

The section along the Tak - Mae Sot highway, NW Thailand, is topped by the pre-Jurassic chert (TM3) containing very fine vitritic-tuff, and yielded radiolarians of Middle to Late Triassic age (cf. Ladinian to Norian). It is overlain by the base-conglomerate (TM4) and continental-shelf deposits of the Jurassic Khun Huai Formation of the Hua Fai Group (Fig. 4). Along the Mae Sot–Umphang road, at km 138–139, a cherty acid tuff (MU-1) is similar to TM3 and yielded Middle Triassic radiolarians. Lithology and microfossil content provide clues as to the age of the TM3 chert and both the origin and age of the clasts within the TM4 conglomerate.

4.4.1. TM3

The chert unit is composed of 5 to 10 cm thick, dark-gray to black well-laminated bedded sequences. The TM3 chert commonly contains a large amount of fine vitric tuff as well as radiolarian shells (Fig. 5). From the top of the sequence, four horizons, TM3-1 (topmost), TM3-2 (2 m below), TM3-3 (4 m below), and TM3-4 (7m below) were sampled for microfossils (Fig. 4).

4.4.2. TM4

The unit is a poorly-sorted conglomeratic breccia formed by a kind of gravity flow. The conglomerate is mainly composed of varicolored clasts of limestones and cherts (Fig. 6). The clasts are subangular to subrounded, and the matrix contains reddish silt. The maximum size of gravels exceeds 20 cm. The chert fragments are well-laminated, dark gray to black and reddish-brown in color, commonly less than 3 cm in diameter, and contain vitric tuff materials and radiolarians. The difference of the color probably depends on the

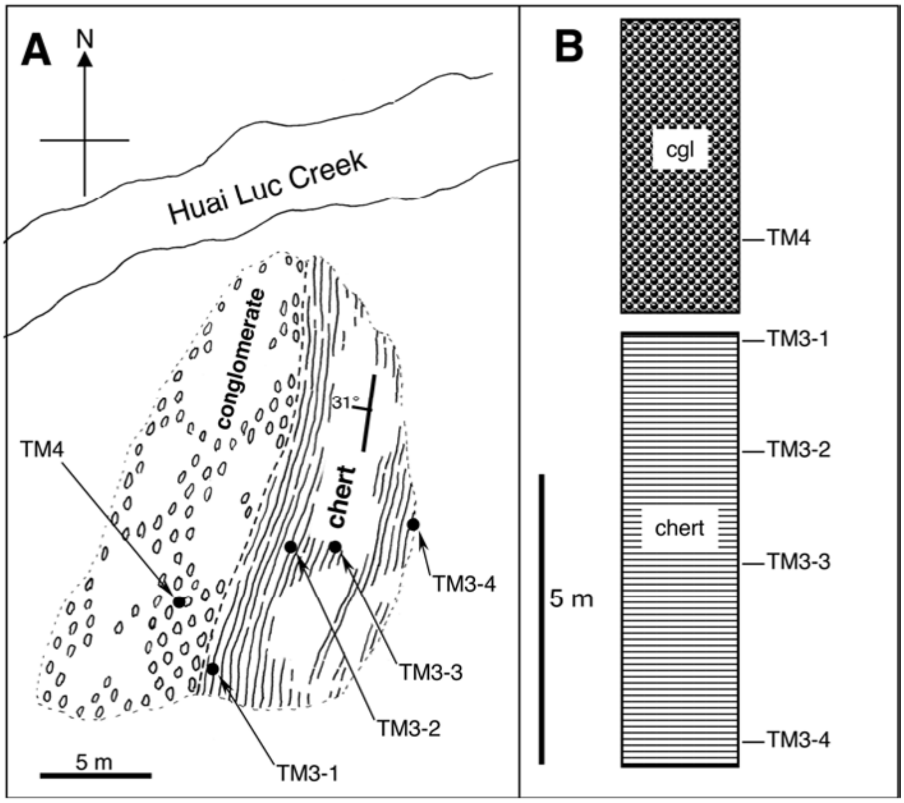

Fig. 4. Sketch (A) and column (B) showing the locality of the TM3 chert and TM4 conglomerate and the stratigraphic positions of the sampled horizons.

Fig. 5. Cross section of the TM3 bedded-chert, dark-gray to black, well-laminated, containing a large amount of fine vitric tuff materials (whitish bands and dotted grains).

effect of weathering because they are basically the same texture and the reddish-brown colored fragments are stained. The limestone fragments, usually less than 5 cm in diameter, vary from yellowish, reddish and grayish in color. The yellowish fragments, dominantly included in the conglomerate, are wackestone with a significant amount of thin small bivalve shells. The grayish clasts are packstone and grainstone dominated by crinoid stems. The reddish fragments are packstone with bioclasts of echinoids and corals and some ooids. The other limestone fragments are gray lime-mudstones. Among them, limestone fragments contain Early and Late Triassic conodonts, whereas the chert fragments contain Middle and Late Triassic radiolarians.

5. MICROFOSSIL AGE

5.1. Radiolarians from the TM3 Chert

The upper part of the TM3 chert ranges from upper Middle to Upper Triassic (Figs. 7 and 8).

5.1.1. TM3-1

The uppermost horizon of the chert sequence yielded *Canoptum rhaeticum* Kozur and Mostler, 1981, *Canoptum* sp., *Livarella densiporata* Kozur and Mostler, 1981. From the range of the species (e.g., Carter, 1993; Sugiyama, 1997) found in the TM3-1, the horizon is Upper Norian to Rhaetian.

Fig. 6. Cross section of the TM4 base conglomerate. The poorly-sorted breccia is mainly composed of varicolored clasts of limestones and cherts (subangular to subrounded), and the matrix contains reddish clay. The maximum length of the specimen is 18.5 cm.

5.1.2. TM3-2

2 m below the top of the sequence yielded *Sarla natividadensis* Pessagno in Pessagno et al. (1979), *Castrum perornatum* Blome, 1984, and *Japonocampe* aff. *nova* (Yao, 1982). Co-occurrence of these two species indicates middle Norian horizon.

5.1.3. TM3-3

4 m below the top of the sequence, the chert yielded *Castrum perornatum* Blome, 1984, *Pararuesticyrtium* cf. *mediobulbosum* Tekin, 1999, *Corum* sp., *Pachus multinodosus* Tekin, 1999, and Spine D2 of *Spongostylus carnicus* Kozur and Mostler, 1979. Based on the co-occurrence of the species, the horizon TM3-3 belongs to Lower Norian.

5.1.4. TM3-4

7 m below the top of the sequence yielded *Triassocampe deweveri* (Nakaseko and Nishimura, 1979), *Triassocampe postdeweveri* Kozur and Mostler, 1994. Co-occurrence of the two species indicates that TM3-4 belongs to lower Ladinian.

5.2. Radiolarians from the TM4 Gravels

Latest Middle to Late Triassic radiolarians were extracted from the chert clasts of the TM4 unit (Figs. 7 and 9).

5.2.1. Latest Ladinian–early Carnian

An additional species, *Annulotriassocampe sulovensis* (Kozur and Mock) in Kozur and Mostler (1981) is older. This species ranges from late Ladinian (*M. cochleata* /? *P. priscus* Subz.) to early Carnian in the Sugozu Measured Section of the Antalya Nappes, Turkey, East-Central Oregon, USA, and Busuanga Island, Philippines (Tekin, 1999).

5.2.2. Latest Carnian–early Norian

Latium mundum Blome, 1984, *Capnodoce antiqua* Blome, 1983, *Corum regium* Blome, 1984, *Pararuesticyrtium* (?) *anatoliaensis* Tekin, 1999, *Dicapnuchosphaera elegans* Tekin, 1999, *Pachus multinodosus* Tekin, 1999, *Capnuchosphaera tricornis* De Wever, 1982, *Castrum perornatum* Blome, 1984, *Capnuchosphaera lea* De Wever in De Wever et al. (1979), Spine D3 of *Spongostylus* sp. aff.

S. carnicus Kozur and Mostler, 1979, *Spongostylus carnicus* Kozur and Mostler, 1979 in Tekin (1999), Spine D2 of *Spongostylus carnicus* Kozur and Mostler, 1979, Spine D1 of *Spongostylus tortilis* Kozur and Mostler, 1979. They are regarded as cosmopolitan in low latitude Late Triassic (Bragin and Krylov, 1996; Tekin, 1999).

5.2.3. Early Norian-Rhaetian

Canoptum rhaeticum Kozur and Mostler, 1981 is known from the Lower Norian (*Navicula* Subzone of *Spatulatus* A.Z.) to Rhaetian of the Zlambachgraben, Austria (Kozur and Mostler, 1981). Sugiyama (1997) extended the range of this specific group from late Norian (TR8C) to Early Jurassic (Hettangian/Sinemurian).

5.3. Conodonts from the TM4 Gravels

Olenekian, late Anisian, late Carnian, and early Norian conodonts were extracted from the limestone gravels in the TM4 conglomerate (Figs. 7, 10–12).

5.3.1. Olenekian

Platyvillosus costatus (Staesche, 1964) sensu Koike (1988), *Platyvillosus hamadai* Koike, 1982a, and *Platyvillosus* sp. 1 (Fig. 10). *Platyvillosus costatus* occurs in the middle part of the Campil beds (Upper Scythian) of St. Vigil, South Tyrol, Italy (Staesche, 1964). *Platyvillosus hamadai* is firstly reported from the lower part of the Gunong Keriang Limestone in the Peninsular Malaysia with co-occurrence of Dienerian to late Smithian conodonts of *Neospathodus dieneri* Sweet, and *N. pakistanensis* Sweet as well as *Platyvillosus costatus* (Koike, 1982b). The co-occurrence of *P. hamadai* and *P. costatus* was also reported from the *Neospathodus dieneri–N. conservatives* Zone (Smithian) of the lower part of the Taho Limestone (Koike, 1982b).

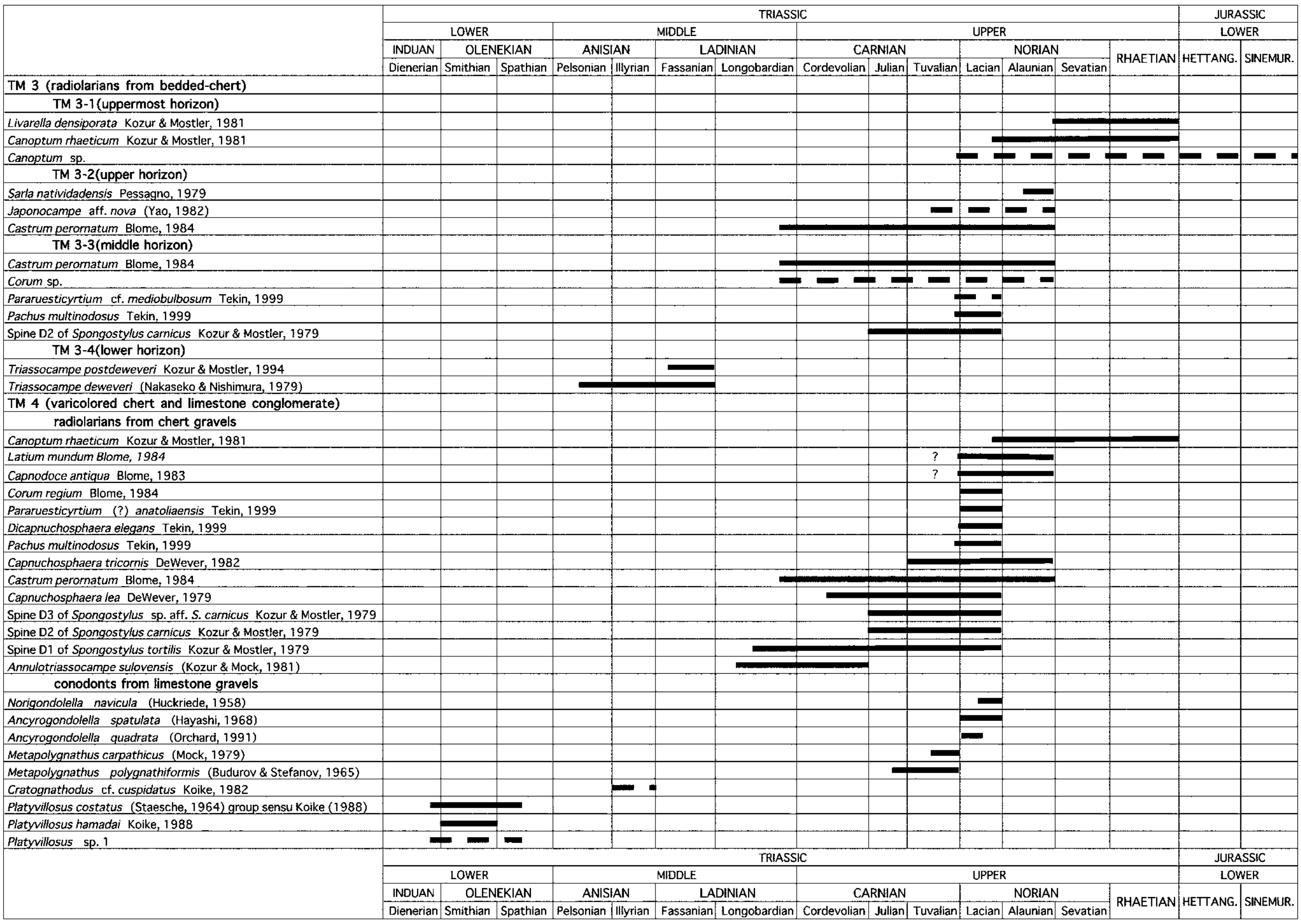

Fig. 7. List and range of microfossils from the TM3 chert and gravels in TM4 conglomerate.

5.3.2. Late Anisian

A specimen was identical to *Cratognathodus* cf. *cuspidatus* Koike, 1982b (Fig. 11: 4a, b). *Cratognathodus cuspidatus* has originary descrived by Koike (1982b) from the dark gray thin-bedded biomicritic limestone member of the Bukit Kalong Limestone, in Kedah, West Malaysia. Based on the co-occurrence of *Gladigondolella tethydis*, *Neogondolella bulgarica*, *Neospathodus kockeli*, the fauna indicates a late Anisian age.

5.3.3. Late Carnian

Metapolygnathus carpathicus (Mock, 1979), and *Metapolygnathus polygnathiformis* (Budurov and Stefanov, 1965) were recognized (Fig. 12). *M. carpathicus* belongs to the *Tropites subbulatus* Zone and the lower *Klamathites macrolobatus* Zone (uppermost Carnian: mid-upper Tuvalian) of Silicka brezova, Slovakian Karst (Mock, 1979). The range of *M. polygnathiformis* is late Carnian (late Julian to latest Tuvalian).

5.3.4. Early Norian

Norigondolella navicula (Huckriede, 1958), *Ancyrogondolella spatulata* (Hayashi, 1968), *Ancyrogondolella quadrata* (Orchard, 1991) were identified (Figs. 11 and 12). The fauna in the TM4 conglomerate has a similarity to the early Norian Hisaidani fauna of Tethyan affinity, characterized by the specific predominance *of Ancyrogondolella spatulata, A. quadrata* and *A. triangularis* (Ishida and Hirsch, 2001; Hirsch and Ishida, 2002).

6. DISCUSSION: PROVENANCE OF THE TM4 GRAVELS

While the age of the TM4 gravels may vary, all of them are Triassic. Chert and limestone lithologies correspond to age groups, suggesting a stratigraphical sequence at their origin. Chert gravels are uppermost Ladinian–lower Carnian, lower Norian, and mid-upper Norian–Rhaetian. Limestone gravels are Olenekian, lower Anisian, upper Carnian–lower Norian, and middle–upper Norian. Among them, lower Norian gravels are probably dominant, encompassing both chert and limestones (Fig. 7).

6.1. Chert Gravels

The radiolarian assemblage from the chert gravels in the

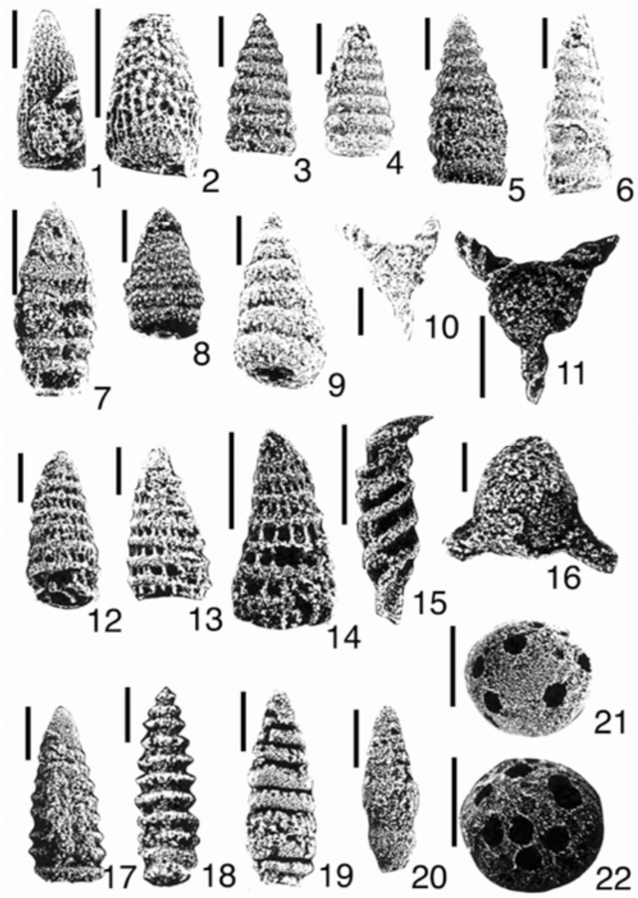

Fig. 8. Middle and Late Triassic (Ladinian–Norian) radiolarians from the TM3 chert. Scale bars indicate 0.1 mm. TM3-1: 3 -8, 16, 21, 22; TM3-2: 7–13; TM3-3: 1, 2, 9, 14, 15, 20; 17, 18, 19; 1, 2: *Corum* sp.; 3, 4, 5, 6: *Canoptum rhaeticum* Kozur and Mostler, 1981; 7: *Japonocampe* aff. *nova* (Yao, 1982); 8: *Canoptum* sp.; 9: *Pachus multinodosus* Tekin, 1999; 10, 11: *Sarla natividadensis* Pessagno in Pessagno et al. (1979); 12, 13, 14: *Castrum perornatum* Blome, 1984; 15: Spine D2 of *Spongostylus carnicus* Kozur and Mostler, 1979; 16, 21, 22: *Livarella densiporata* Kozur and Mostler, 1981; 21, 22: inner molds; 17: *Triassocampe deweveri* (Nakaseko and Nishimura, 1979); 18: *Triassocampe postdeweveri* Kozur and Mostler, 1994; 19: Nassellaria gen. and sp. indet., inner mold; 20: *Pararuesticyrtium* cf. *mediobulbosum* Tekin, 1999.

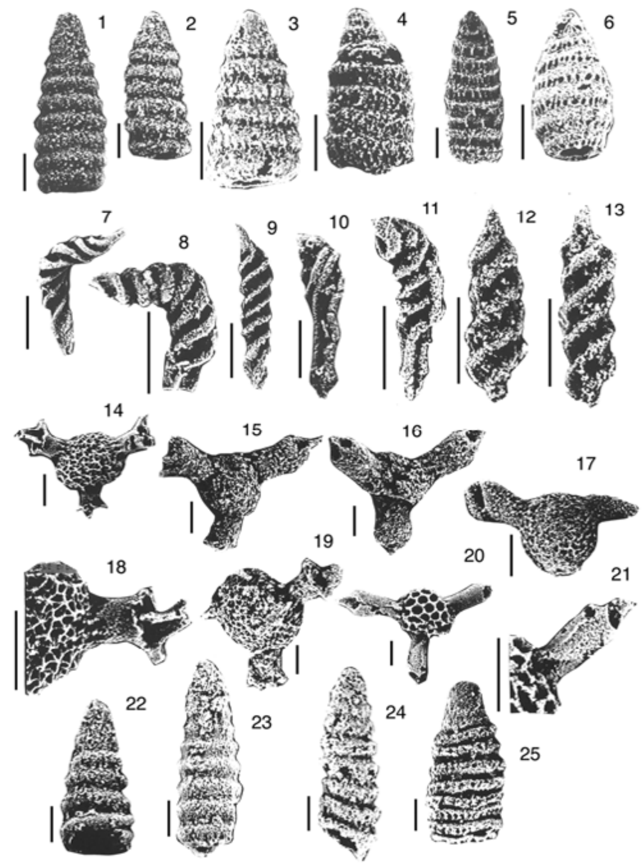

Fig. 9. Middle -Late Triassic (late Ladinian–Norian) radiolarians from the chert gravels in the TM4 conglomerate. Scale bars indicate 0.1 mm. 1, 2: *Canoptum rhaeticum* Kozur and Mostler, 1981; 3: *Corum regium* Blome, 1984; 4: *Pachus multinodosus* Tekin, 1999; 5: *Castrum perornatum* Blome, 1984; 6: *Latium mundum* Blome, 1984; 7, 8: Spine D3 of *Spongostylus* sp. aff. *S. carnicus* Kozur and Mostler, 1979; 9, 10, 11: Spine D2 of *Spongostylus carnicus* Kozur and Mostler, 1979; 12, 13: Spine D1 of *Spongostylus tortilis* Kozur and Mostler, 1979; 14, 18: *Capnuchosphaera tricornis* De Wever, 1982; 15, 16, 17: *Capnuchosphaera lea* De Wever in De Wever et al. (1979); 19: *Dicapnuchosphaera elegans* Tekin, 1999; 20, 21: *Capnodoce antiqua* Blome, 1983; 22, 23: *Pararuesticyrtium* (?) *anatoliaensis* Tekin, 1999; 24, 25: *Annulotriassocampe sulovensis* (Kozur and Mock) in Kozur and Mostler (1981).

TM4 conglomerate can be compared with that of the TM3 chert-sequence. Both latest Ladinian–early Carnian and latest Carnian–Rhaetian species are found. Among them, *Canoptum rhaeticum* (Norian–Rhaetian), *Castrum perornatum* (latest Ladinian–middle Norian), *Pachus multinodosus* (latest Carnian–early Norian), and Spine D2 of *Spongostylus carnicus* (late Ladinian–early Norian) are common in both TM3 and TM4. Based on the dominant occurrence of specimens and specific numbers, Lower Norian chert gravels are contained abundantly in the chert gravels of TM4 conglomerate. The reddish brown-colored stained chert fragments as well as the dark-gray to black-colored ones in the TM4 conglomerate contain vitric-tuff material of the same lithology as the TM3 chert beds. Therefore, the chert gravels in the TM4 conglomerate were probably derived from a bedded-chert, equivalent to that of TM3.

At the end of Triassic time, pre-Jurassic siliceous pelagic facies has docked, and widery eroded to form the Lower Jurassic shallow-marine cover formations, like the continental-shelf deposits of the Toarcian–early Bajocian Hua Fai Group in the Shan-Thai Terrane. The first discovery of Late Triassic (Norian–Rhaetian) radiolarian faunas from bedded-cherts, next to the Middle Triassic and older ones, adds another element to the reconstruction of the sequence of the Mae Sariang Zone. The pelagic origin of the siliceous clasts suggests that an ocean was still present shortly before

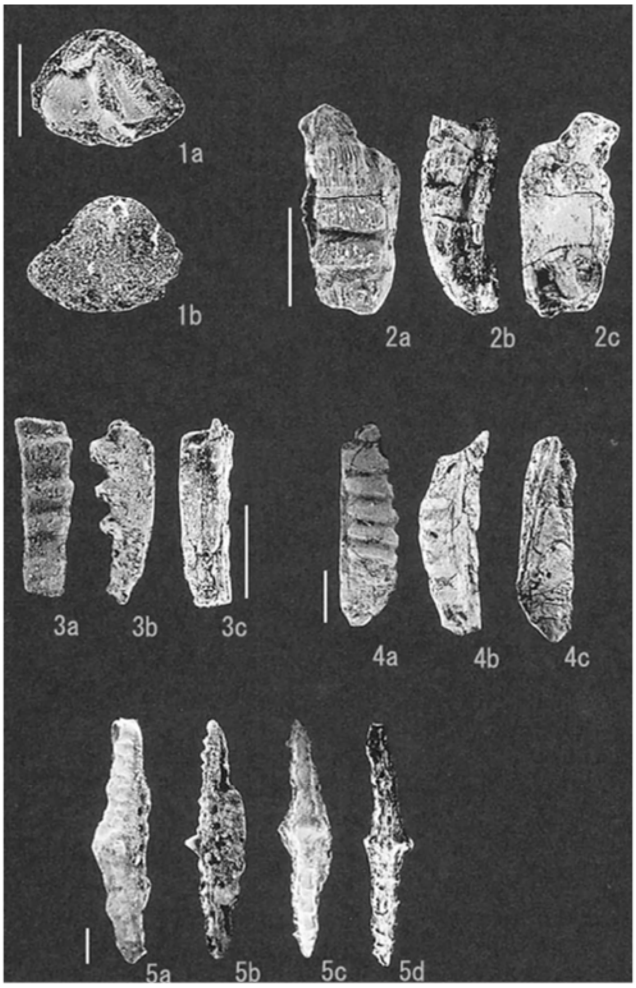

Fig. 10. Early Triassic (Olenekian) conodonts from the limestone gravels in TM4 conglomerate. Scale bars indicate 0.1 mm. 1a, b: *Platyvillosus hamadai* (Koike, 1982b), 1a: basal (with some organic attachments of spongy textured polygonal fragments), and 1b: oral views of Pa element; 2a, b, c: *Platyvillosus costatus* (Staesche, 1964) sensu Koike (1988), 2a: oral, 2b: lateral, and 2c: basal views of Pa element; 3a, b, c: *Platyvillosus costatus* (Staesche, 1964) sensu Koike (1988), 3a: oral, 3b: lateral, and 3c: basal views of Pa element; 4a, b, c: *Platyvillosus costatus* (Staesche, 1964) sensu Koike (1988), 4a: oral, 4b: lateral, and 4c: basal views of Pa element; 5a, b, c, d: *Platyvillosus* sp. 1, 5a: lateral, 5b: basal, 5c: oblique oral, and 5d: oral views of Pa element.

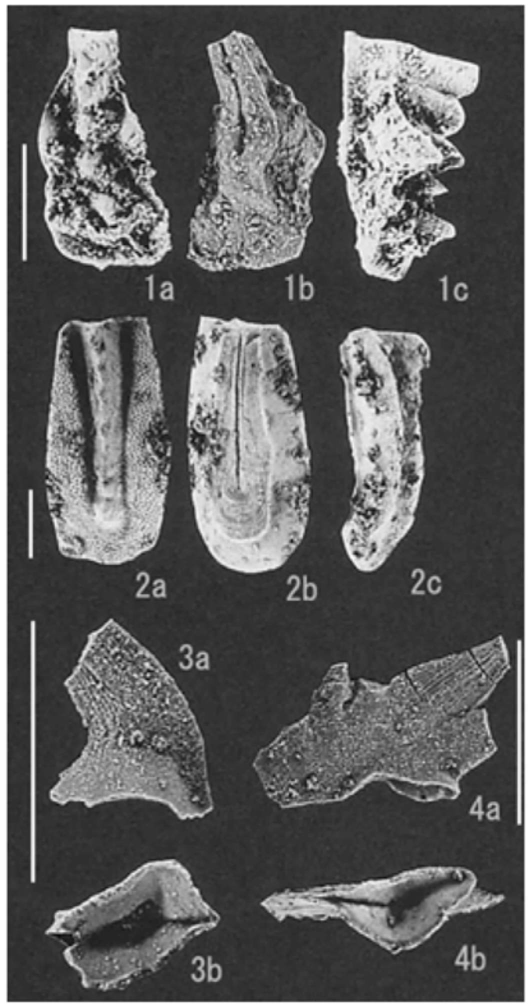

Fig. 11. Middle and Late Triassic (late Anisian and early Norian) conodonts from the limestone gravels in TM4 conglomerate. Scale bars indicate 0.1 mm. 1a, b, c: *Ancyrogondolella quadrata* (Orchard, 1991), 1a: oral, 1b: basal, and 1c: lateral views of Pa element (intermediate stage); 2a, b, c: *Norigondolella navicula* (Huckriede, 1958), 2a: oral, 2b: basal, and 2c: lateral views of Pa element; 3a, b: Gen. et sp. indet., 3a: lateral, and 3b: basal views of coniform element; 4a, b: *Cratognathodus* cf. *cuspidatus* Koike, 1982b, 4a: lateral, and 4b: basal views of Pa element.

the end of the Triassic, to which the Mae Sariang orogeny brought an end. This final closure of the Paleo-Tethys took place due West of the Nan–Uttaradit Suture of the Indochina Block and the Sukhothai Terrane, amalgamating the eastern and western parts of the Shan-Thai Block. It may be noteworthy that the Triassic radiolarian faunas of the Shan-Thai Block are characteristically Tethyan low latitude faunas.

6.2. Limestone Gravels

The provenance of the limestone clasts in the TM4 conglomerate from a nearby source still remains problematic. Three time intervals, Olenekian, late Anisian, and late Carnian–early Norian are indicated by conodonts (Figs. 7, 10, 11, and 12).

One of the possible match of the ages of TM4 limestone pebbles in the Mae Sariang Zone are the Chaiburi Formation in Peninsular Thailand, yielding Early, Middle and Late Triassic conodonts and late Early Triassic radiolarians from a limestone of Khao Chiak near Phatthalung (Igo et al., 1988; Sashida and Igo, 1992; Sardsud, 2002). Ladinian and Carnian ages have not yet been confirmed.

In northwest Peninsular Malaysia, the Kodiang/Chuping limestones yield Olenekian, Anisian, Ladinian, Carnian and Norian conodont faunas (Ishii and Nogami, 1966; Nogami,

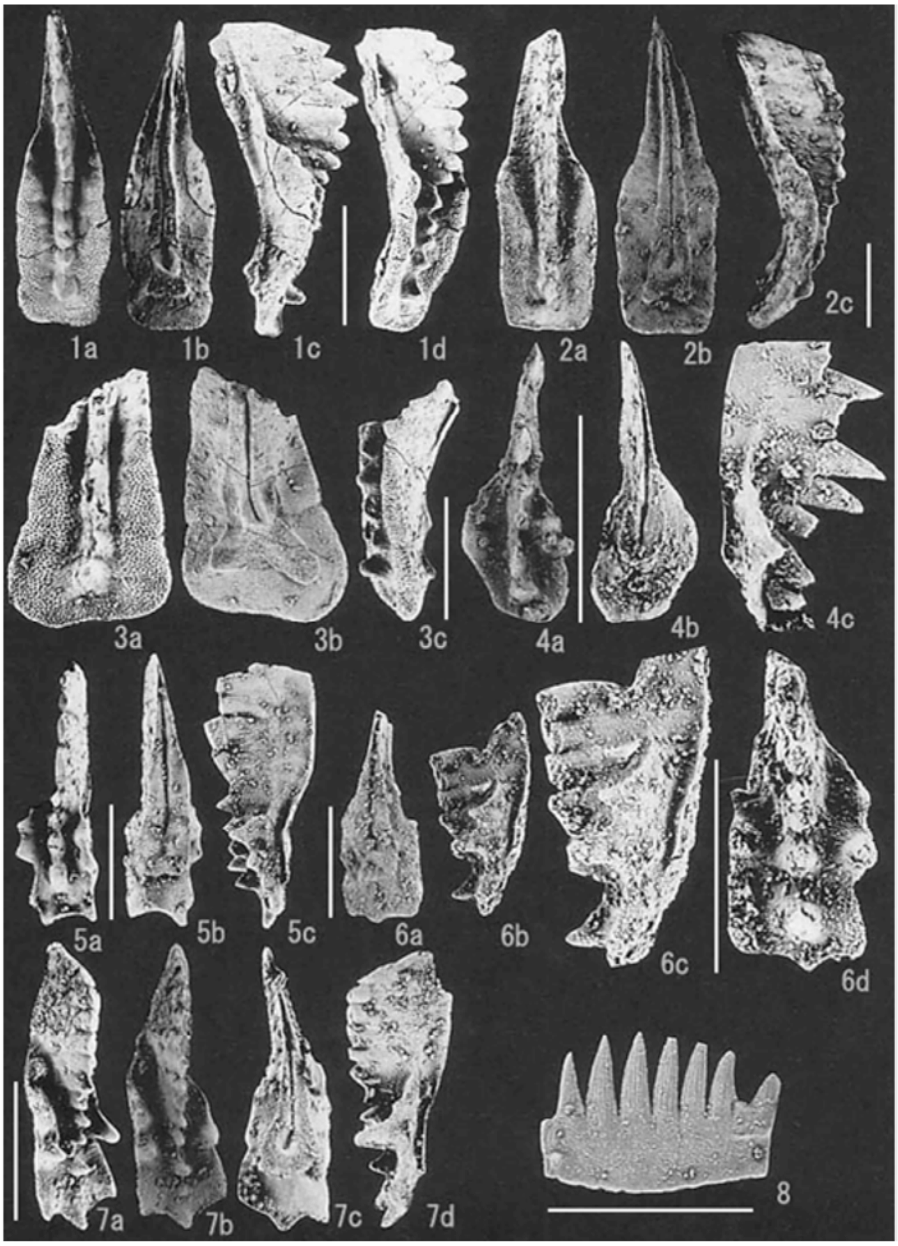

Fig. 12. Late Triassic (late Carnian–early Norian) conodonts from the limestone gravels in TM4 conglomerate. Scale bars indicate 0.1 mm. 1a, b, c, d: *Metapolygnathus polygnathiformis* (Budurov and Stefanov, 1965), 1a: oral, 1b: basal, 1c: lateral, and 1d: oblique oral views of Pa element; 2a, b, c: *Metapolygnathus polygnathiformis* (Budurov and Stefanov, 1965), 2a: oral, 2b: basal, and 2c: lateral views of Pa element; 3a, b, c: *Metapolygnathus carpathicus* (Mock, 1979), 3a: oral, 3b: basal, and 3c: lateral views of Pa element (free blade and anterior end of platform were broken); 4a, b, c: *Ancyrogondolella spatulata* (Hayashi, 1968), 4a: oral, 4b: basal, and 4c: lateral views of Pa element (Juvenile stage); 5a, b, c: *Ancyrogondolella spatulata* (Hayashi, 1968), 5a: oral, 5b: basal, and 5c: lateral views of Pa element (intermediate stage); 6a, b, c, d: *Ancyrogondolella spatulata* (Hayashi, 1968), 6a: basal, 6b, 6c: lateral, and 6d: oral views of Pa element (intermediate stage); 7a, b, c, d: *Ancyrogondolella spatulata* (Hayashi, 1968), 7a: oblique oral, 7b: oral, 7c: basal, and 7d: lateral views of Pa element (intermediate - mature stage); 8: *Ancyrogondolella* or *Norigondolella* sp., lateral view of Pa element (Juvenile stage).

1968; Koike, 1973, 1982b; Metcalfe, 1990). Therefore, depending on their distance, it is also possible to postulate that the rocks were transported across the Gondwanian–Tethyan Divide (GTD) at the closure of the Mae Sariang Terrane by the docking of the "Western Zone". It might be a part of the erosive event that is also characterized by the formation of the TM4 breccia.

The possible derivation of limestone clasts in the TM4 conglomerate from limestone of the type of the Chaiburi Formation or Si Sawat Limestone in the Mae Sariang Zone, and further from the Kodian Limestone in the "Western Zone" should be retained. It may as well elucidate the question about the provenance of the Triassic conodont-bearing limestone clasts, found in the base-conglomerate of the Toarcian–Aalenian continental-shelf deposits of the Hua Fai Group that seals the Mae-Sariang Zone.

7. CONCLUSIONS

(1) Microfossil ages of siliceous pelagic sediments in the Mae Sariang Zone and in the overlying conglomerate elucidate the timing of the Palaeo-Tethyan closure that is sealed by the continental-shelf deposits of the Toarcian-Aalenian Hua Fai Group.

(2) The section along the Tak–Mae Sot highway, NW Thailand, topped by the pre-Jurassic chert (TM3) containing significant fine vitritic-tuff, suggests the presence of an ocean shortly before the end-Triassic Mae Sariang orogeny.

(3) Lithology and microfossil content provide clues as to the age of the TM3 chert and both the origin and age of the clasts within the TM4 base-conglomerate. This first finding of the -youngest age-Late Triassic (Norian–Rhaetian) radiolarian faunas from the bedded-cherts (TM3) in the Mae Sariang Zone, next to the Middle Triassic and older radiolarian faunas, adds another element to the reconstruction of the sequence now comprised in the Mae Sariang Zone, west of the Nan–Uttaradit Suture.

(4) The examination of the limestone clasts within the TM4 base-conglomerate suggests their provenance from the limestone biostratigraphic intervals. The possible sources of the clasts are the limestones correlative with the Chaiburi Formation or Si Sawat Limestone in the Mae Sariang Zone, and further from the Kodian Limestone in the "Western Zone".

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