หินเชิร์ตเรดิโอลาเรียนยุคไทรแอสซิกจากภาคเหนือของประเทศไทย: การตีความทางด้านสภาพแวดล้อมดึกดำบรรพ์และธรณีแปรสัณฐาน

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THE TRIASSIC RADIOLARIAN CHERTS FROM NORTHERN THAILAND: IMPLICATIONS FOR PALAEOENVIRONMENT AND TECTONIC SETTING

Hathaithip Thassanapak

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THE TRIASSIC RADIOLARIAN CHERTS FROM NORTHERN THAILAND: IMPLICATIONS FOR PALAEOENVIRONMENT AND TECTONIC SETTING

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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หินเชิร์ตเรดิโอลาเรียนและหินเนื้อซิลิกาอายุไทรแอสซิกจากบริเวณภาคเหนือของประเทศไทย จำนวน 8 แห่งถูกนำมาสำรวจและศึกษาเพื่อการตีความทางธรณีแปรสัณฐาน การศึกษาครั้งนี้ประกอบด้วย เรื่องบรรพชีวานุกรมวิธานของเรดิโอลาเรียน การลำดับชั้นหินตามชีวภาพ และธรณีเคมี พื้นที่ศึกษาทั้ง 8 แห่งกระจายตัวอยู่ในบริเวณของแนวทะเลด้านตะวันออกในพื้นที่เชียงดาว, ลำพูน และเด่นชัย ส่วนแนวทะเลด้านตะวันตกอยู่ในพื้นที่ของขุนยวม, แม่ลาน้อย และแม่สะเรียง การลำดับชั้นหินตามชีวภาพ เริ่มจากการสกัดเรดิโอลาเรียนและศึกษาลำดับชั้นของอนุกรมวิธาน พบว่าเรดิโอลาเรียนประกอบด้วย 28 วงศ์ จัดอยู่ใน 60 สกุล และ147 ชนิด จากข้อมูลกลุ่มชีวินเรดิโอลาเรียน อายุการลำดับชั้นหินทั้งหมดอยู่ในช่วงแอนิเซียนตอนกลางถึงคาร์เนียนตอนกลาง? แบ่งเป็น 6 ส่วนชั้นกลุ่มชีวินดังนี้คือ ส่วนชั้นกลุ่มชีวิน *Eptingium manfredi* (อายุแอนิเซียนตอนกลาง) ส่วนชั้นกลุ่มชีวิน *Triassocampe deweveri* (อายุแอนิเซียนตอนปลาย) ส่วนชั้นกลุ่มชีวิน *Oertlispongus inaequispinosus* (อายุแลดิเนียนตอนต้นถึงตอนกลาง) ส่วนชั้นกลุ่มชีวิน *Muelleritortis cochleata* (อายุแลดิเนียนตอนกลางถึงช่วงต้นตอนปลาย) ส่วนชั้นกลุ่มชีวิน *Tritortis kretaensis* (อายุแลดิเนียนช่วงต้นตอนปลายถึงคาร์เนียนตอนต้น) และส่วนชั้นกลุ่มชีวิน *Tetraporobrachia haeckelli* (อายุคาร์เนียนตอนต้นถึงตอนกลาง?) ตามลำดับอายุกาล ซึ่งอายุเหล่านี้ได้จากการเทียบสัมพันธ์กับกลุ่มชีวินเรดิโอลาเรียนบริเวณพื้นที่อื่นๆที่มีการศึกษามาแล้ว สำหรับการศึกษาด้านธรณีเคมี หินเชิร์ตเรดิโอลาเรียนและหินเนื้อซิลิกาจาก 6 พื้นที่ศึกษาได้นำมาวิเคราะห์ปริมาณธาตุหลักและธาตุส่วนน้อย โดยวิธี X-Ray Fluorescence (XRF) และวิเคราะห์ปริมาณธาตุหายาก โดยวิธี Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) ผลที่ได้บ่งชี้ว่าหินเชิร์ตและหินเนื้อซิลิกาในพื้นที่ศึกษาทั้งหมด มีการสะสมตัวบริเวณขอบทวีป

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HATHAITHIP THASSANAPAK: THE TRIASSIC RADIOLARIAN CHERTS FROM NORTHERN THAILAND: IMPLICATIONS FOR PALAEOENVIRONMENT AND TECTONIC SETTING. THESIS ADVISOR: CHONGPAN CHONGLAKMANI, Ph.D. 280 PP.

TRIASSIC/NORTHERN THAIALND/GEOCHEMISTRY/RADIOLARIAN/
/CHERT/TECTONIC/BIOSTRATIGRAPHY/SYSTEMATIC PALEONTOLOGY

Triassic radiolarian cherts and associated siliceous rocks from eight localities in northern Thailand have been investigated for tectonic setting interpretation. The study includes radiolarian systematic paleontology, biostratigraphy and geochemistry. The eight localities are distributed within the areas of the eastern oceanic belt in Chiang Dao, Lamphun, and Den Chai and the western oceanic belt in Khun Yuam, Mae La Noi, and Mae Sariang. In order to establish biostratigraphy, radiolarians were extracted and systematically studied. It consists of 28 families comprising 60 genera and 147 species. According to radiolarian data, the sequence of chert spans the Middle Anisian to Middle Carnian? They are discriminated and biostratigraphically subdivided into six assemblage zones namely; *Eptingium manfredi* Assemblage Zone (Middle Anisian), *Triassocampe deweveri* Assemblage Zone (Late Anisian), *Oertlispongus inaequispinosus* Assemblage Zone (Early to Middle Ladinian), *Muelleritortis cochleata* Assemblage Zone (Middle to early Late Ladinian), *Tritortis kretaensis* Assemblage Zone (Early Late Ladinian to Early Carnian), and *Tetraporobrachia haeckelli* Assemblage Zone (Early to Middle Carnian?) in chronological order. Their age assignment is based mainly on comparison with the well established radiolarian zonations and recent publications. For geochemical study, radiolarian chert and associated siliceous rock samples from six localities were analyzed by using X-Ray Fluorescence (XRF) methodology for major and trace elements analysis and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) methodology for rare earth elements analysis. The result indicates that chert and associated siliceous rocks of all localities were deposited in the continental margin.

School of Biology

Academic Year 2008

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CHAPTER I

INTRODUCTION

1.1 General concepts

Radiolarians are a group of siliceous open-ocean microzooplankton that live throughout the water column. They belong to Kingdom Protista, Phylum Sarcomastigophora, and Subphylum Sarcodina. They are palaeontologically significant because they are preserved in the fossil record that makes them one of the most important marine microfossil groups. They have the longest geologic range (Cambrian to present), the widest biogeography (pole to pole) and the most diverse taxonomy of the well-preserved microzooplankton.

Radiolarians absorb silicon compounds from their aquatic environment and secrete opaline silica exoskeletons, called tests. Because of their solid opaline skeletal structures, radiolarians play an important role in the silica cycle in the oceans. Generally, after death their skeletons sink to the bottom of the oceans and become buried in the sea-floor sediments called radiolarian oozes and which under lithification processes become radiolarian cherts or radiolarites (radiolarian-bearing rocks). In addition, the silica test is less soluble than the carbonates of the other main micro fossil groups, foraminifera and coccolithophorides, so radiolarians tend to be longer- lasting under diagenetic conditions (Knauth, 1994).

The main significance of radiolarians in micropaleontological research is to use them as a tool for biostratigraphic study. This study, in particular, is useful for geological mapping programs of government agencies and mining/oil companies. The other applications of radiolarians are extensively for reconstructing palaeogeography, palaeoceanography and palaeoenvironment of the oceanic basins.

In Thailand, based on previous works, radiolarian-bearing rocks are widely distributed in many areas such as in the north (e.g. Chiang Mai, Mae Hong Son), the east (e.g. Sra Kaeo, Chanthaburi), the central (e.g. Sukhothai, Saraburi) and the south (e.g. Songkhla and Phatthalung). Most of them were deposited as bedded cherts and siliceous shales. The previous works were concentrated mainly on classification of radiolarians for biostratigraphic indicators. However, palaeoenvironment and palaeogeographic investigations have been less focused in Thailand. This thesis study will concentrate on using radiolarians for palaeoenvironmental investigations of the Triassic oceanic basins in Thailand. Systematic of radiolarians from several localities from northern Thailand will be studied. In addition, some geochemical analyses of radiolarian-bearing rocks will be carried out in order to discriminate the tectonic setting.

1.2 Thesis objectives

The thesis study has four main objectives as shown below,

1. to identify the Triassic radiolaria by using morphological analysis,
2. to establish the Triassic radiolarian biostratigraphy,
3. to determine the geochemical features of radiolarites by analyses of major, trace and rare earth elements.
4. to summarize the characteristic and palaeoenvironment of radiolarites for interpreting the tectonic setting of the study areas.

1.3 Research hypotheses

Tectonostratigraphically, during Paleozoic to Early Mesozoic times, Thailand comprised two linear oceanic belts; the eastern belt and the western belt (Fig. 1). These two belts are divided by Chiang Mai-Malacca terrane. The eastern boundary of the eastern belt is marked by Sukhothai terrane whereas the western margin of the western belt is bounded by Shan-Mergui terrane (Chonglakmani, 1999). The western belt has recently been inferred as the main Paleotethyan remnant (Chonglakmani, 2002; Ueno, 1997; Wang et al., 2001). However, the definition of these stratigraphic belts remain controversial; Sukhothai terrane has been termed Sukhothai fold belt (Bunopas, 1981) and Sukhothai zone (Ueno, 1999); Chaing Mai terrane could be referred to as Inthanon zone (Ueno, 1999); Shan-Mergui terrane could be part of Shan-Thai (Bunopas, 1981), Thai-Malay Peninsular (Sengör, 1984), Sinoburmalaya (Gatinsky and Hutchinson, 1986) and Sibumasu (Metcalfe, 1988; Sashida, 1999).

Radiolarian biostratigraphy of the western belt indicates that the opening and the closing times of the ocean were before Early Carboniferous and during Middle to Late Norian, respectively (Feng et al., 2002; Chonglakmani, 1999).

As mentioned above, these two arms of oceanic basins closed during the Late Triassic. However, there are few documents of detailed radiolarian biostratigraphy of these belts in Thailand. Moreover, geochemical analysis of radiolarian-bearing rocks in Thailand is unknown so far. Recently, Wonganan (2004) studied radiolarian biostratigraphy of Devonian to Late Triassic strata in northern Thailand. However, the study was not focused in enough detail on the radiolarian succession. In addition, other previous works on the Triassic radiolarians in Thailand had never been studied in detail.

According to this thesis study, there are three main hypotheses have been proposed as bellows:

1. Detailed composition of Triassic radiolarian systematics between two oceanic belts should reveal some differences since these belts are believed to have had different paleogeographic locations at that time.

2. According to the Late Triassic closure time of the Paleotethys, radiolarian diversity and abundance should gradually decrease upward at the Late Triassic. Detailed study on the succession of radiolarians could be used to test this assumption.

3. If the environmental setting of radiolarites had changed during the Triassic, geochemical analysis should indicate this change. Tectonic setting could be inferred from environmental setting.

1.4 Scopes and limitations

The study areas are mainly located in northern Thailand. There are eight studied localities covered in the areas of Mae Sariang, Mae La Noi and Khun Yuam Districts of Mae Hong Son Province in the northwest, Chiang Dao District of Chiang Mai Province and Lamphun Province at the central north, and Den Chai District of Phrae Province in the northeast (Fig. 1.1). This research is focused mainly on using radiolarians as a major tool for interpreting palaeoenvironment of the oceanic basin in the Triassic period. Additionally, geochemical analyses will be used to clarify the tectonic setting of these areas.

1.5 Research methodology

Field investigation is proposed mainly for lithostratigraphy and sampling. The Triassic radiolarian-bearing sequences from eight localities in northern Thailand will be collected, described, and measured. Lithology of radiolarites, especially the clastic components, is significant in revealing the environment of deposition of the rocks. For example, large quantity of clastics in a radiolarite, such as in siliceous shale can be inferred to indicate proximity to a continent and conditions shallower than ribbon-chert. The study areas cover the localities of two oceanic belts in the north (Chonglakmani, 1999). Each sample is separated into two parts. The first part is for radiolarian systematic paleontology and the second part is for geochemistry. For the first part, samples will be prepared for radiolarian extraction after the technique of Green (2001). According to this technique, dilute hydrofluoric acid solution (5-10 % HF) was used for extracting siliceous radiolarians from cherts and associated siliceous rocks. These rock samples have been crushed into several centimeters and soaked with diluted hydrofluoric acid solution for at least twenty-four hours. The samples are washed and sieved for collecting the residue by nylon mesh of 50 µm. This process is repeated five to seven times until enough specimens are obtained. The sieved specimens are dried and picked for radiolarian tests under a stereomicroscope. Extracted radiolarian tests are then photographed by Scanning Electron Microscope (SEM). Extraction and SEM methods were done at Suranaree University of Technology (SUT) and China University of Geosciences (CUG) at Wuhan, China. Systematic paleontology of radiolarians is based mainly on Moore (1964) and other recent publications. Geochemically, the other part of the samples is prepared for major, trace element and rare earth (REEs) analyses. Obvious Fe-Mn coatings, calcite veins and other contaminations are removed from the crushed samples. Cleaned samples are then ground into powder using agate mortar. For major and trace element analyses, powdered samples are examined using X-ray Fluorescence (XRF) at SUT. REEs as well as some trace elements, which were unable to be determined under XRF analysis, were investigated using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) at CUG. Finally, geochemical data are integrated and interpreted for depositional environment based mainly on discrimination diagrams of radiolarian-bearing rocks of Murray (1994). Summarization of thesis methodology is shown in Figure 1.2. SEM stubs and acid residues are preserved in the collections at School of Biology of SUT.

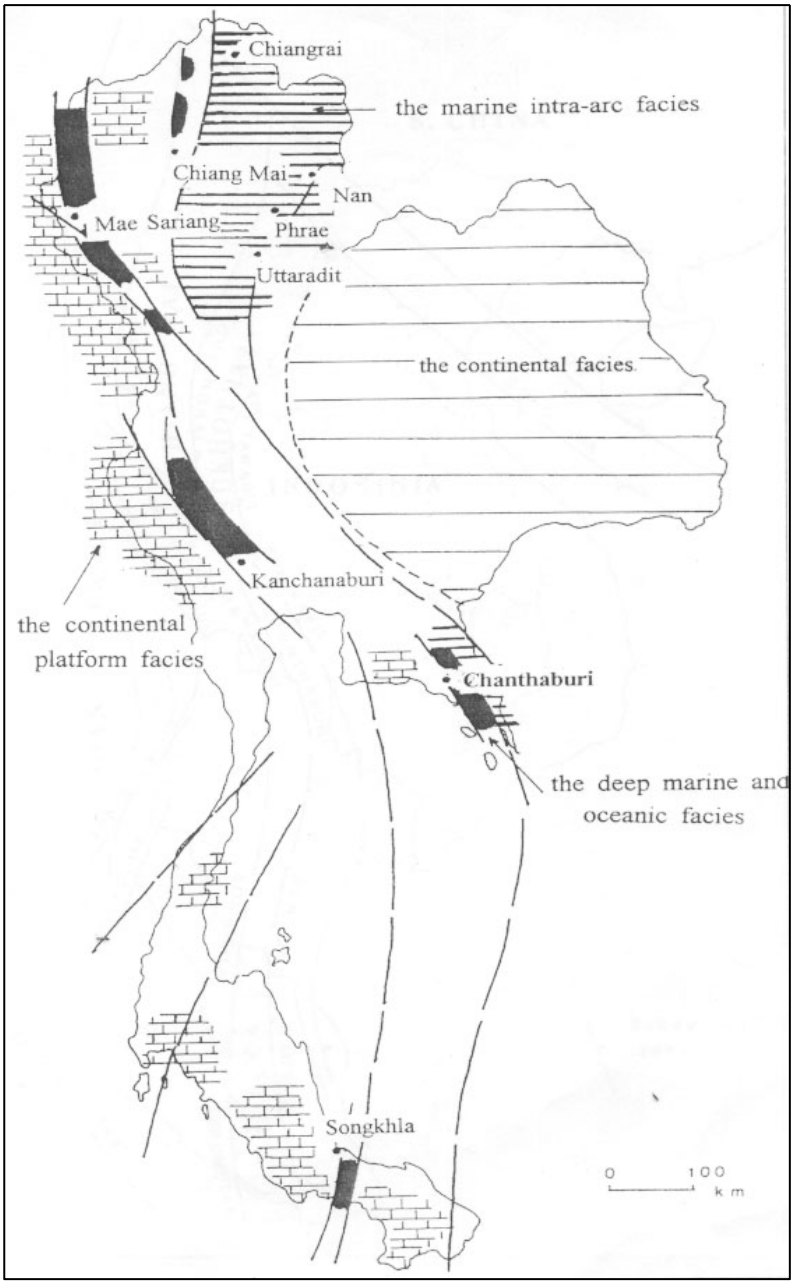


Figure 1.1 Triassic paleogeographic map of Thailand indicates two oceanic belts (dark areas)**.** The eastern belt is clearly delineated in northern part of Chiang Mai and Chanthaburi. The western belt is located mainly in Mae Sariang, Kanchanaburi and Songkhla. The thesis study covers within the areas of Khun Yuam, Mae La Noi, Mae Sariang, Chiang Mai, Lamphun and Den Chai in northern Thailand (after Chonglakmani, 1999).

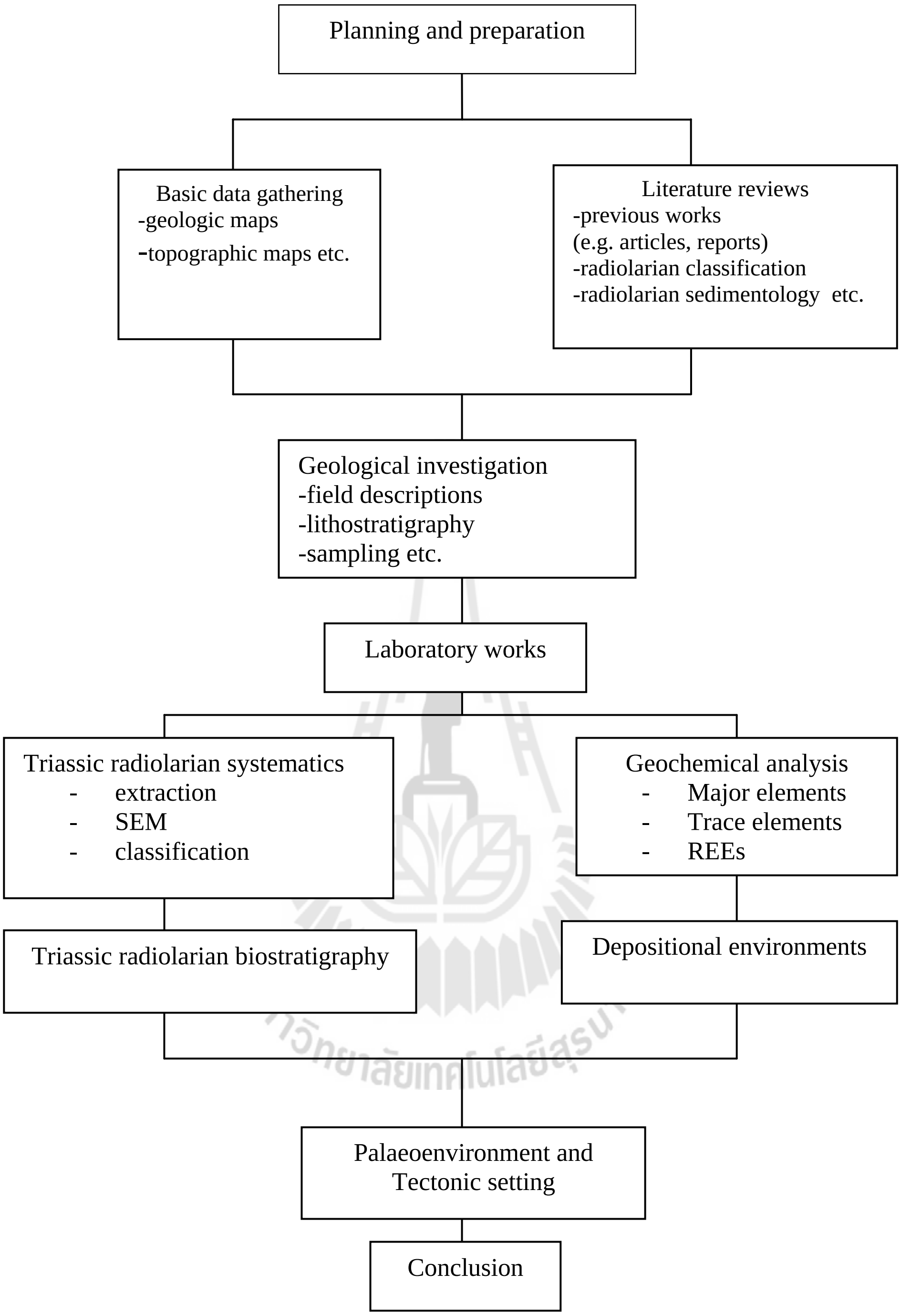


Figure 1.2 Flow-chart of thesis methodology

CHAPTER II

STRATIGRAPHY AND STUDY SECTIONS

2.1 Triassic stratigraphy of Thailand

Four main sedimentary facies of the Triassic have been recognized in Thailand. They consist of the continental facies, continental platform facies, marine associated with volcanic facies, and deep marine and oceanic facies (Chonglakmani, 2002). The continental facies is found mainly in the Indochina Block and the rest are observed in the Shan-Thai Block. A brief description of these facies is mentioned as follows.

The continental facies is overlain by Jurassic-Cretaceous strata of the Khorat Group in the Khorat Plateau, northeastern Thailand. This formation is observed as a minor intercalation within shallow marine strata in other parts of Thailand. It is known as the Huai Hin Lat Formation and could be equivalent to the Kuchinarai Formation of subsurface data. It consists of siliciclastic rocks accumulated in an alluvial fan, fluvial and lacustrine environments. The formation is Norian in age as shown by the occurrence of the *Dictyophylum-Clathropteris* flora (Kon' no and Assama, 1973).

The continental platform facies is characterized by the occurrence of shallow marine clastic and carbonate strata without volcanic rocks. This faceis was observed in two main parts of the Shan-Thai Block, the western and central parts. In the western part, it was deposited in the Mae Sariang and Kanchanaburi Basins (Fig. 2.2)

(Chonglakmani and Grant-Mackie, 1993) as the Lower Mae Moei and Si Sawat Groups. In the eastern part, it was observed in the central Shan-Thai Block as the Phrao limestone, Klaeng limestone, and Sabayoi and Klong Kon Formations in the north, the east and the south, respectively. The age of this facies ranges from Scytian to Early Norian.

The marine associated with volcanic facies occurs in the eastern part of the Shan-Thai Block. It is composed of shallow marine siliciclastic and carbonate rocks, turbidites, rhyolitic and andesitic rocks. These rocks were deposited in the Lampang-Phrae Basin as the Scytian-early Carnian Lampang Group and the Early Norian Phrae Group. In Uttaradit, it is observed as the Early Norian Nam Pat Group. In the east, it is found as the Early Carnian Pong Nam Ron Formation.

The deep marine and oceanic facies is found in two linear belts, the so-called eastern and western belts (see Fig. 1.1). The eastern belt covers the area of Chiang Rai to the north and can be traced southward through radiolarian Fang Chert, radiolarites in Chiang Dao, radiolarian siliceous rocks in Lamphun, Khanu Chert Formation in Sukhothai and Chanthaburi chert-clastic sequence (Caridroit, 1991; 1993; Caridroit et al., 1990; Feng et al., 2002; Hada et al., 1997; Sashida et al., 1993; 1998; 2000; Sashida and Nakornsri, 1997; Salyapongse, 1992;). According to radiolarian biostratigraphy, the age of this belt ranges from Devonian to Late Triassic (Early Carnian). It can be interpreted that this oceanic basin opened in the Silurian and closed during Middle to Late Carnian (Chonglakmani, 1999). The other belt contains radiolarian ribbon-chert and bedded chert in the northwestern of Mae Hong Son Province. This belt can be traced southward into Mae Sot, Bo Ploi in Kanchanaburi, and Nathawi Formation in

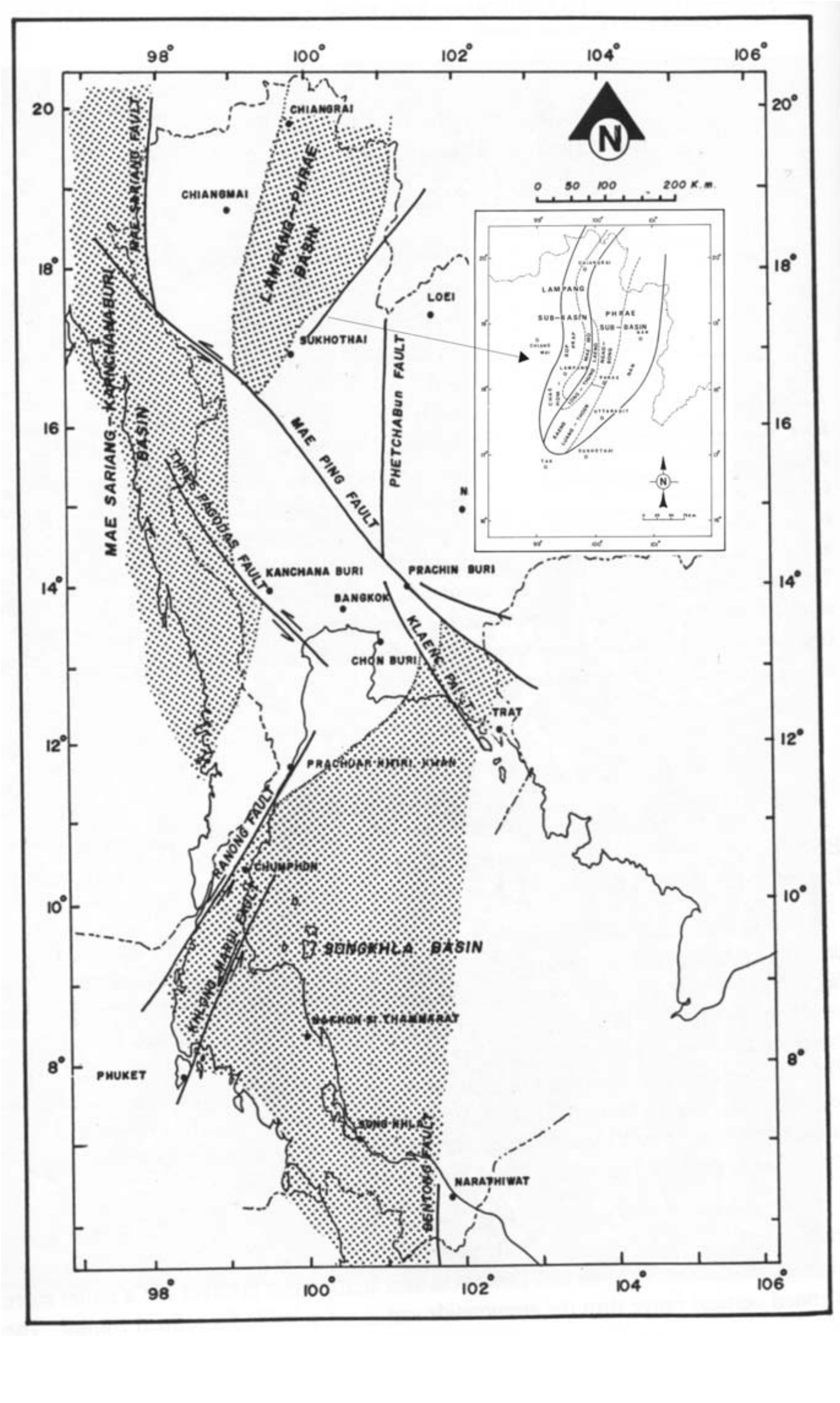


Figure 2.1 Marine Triassic Basin in Thailand. Small box showing Lampang and Phrae sub-basin in northern Thailand (after Chonglakmani and Grant-Mackie, 1993).

Songkhla (Tofke et al., 1993; Kamataet al., 2002; Feng et al., 2004; Sashida et al., 1998; 2002; Sashida and Igo, 1992; Chonglakmani and Grant-Mackie, 1993).

2.2 Triassic tectonic scenario of northern Thailand

During the last few decades, one of the most controversial topics on the geodynamic evolution of Southeast Asia has been the location and the closing time of the main Paleotethys. There have been several concepts proposed in order to explain this situation (e.g. Helmcke, 1985; 1994; Metcalfe, 1999; Bunopas, 1981; 1994; Hutchison, 1993; Mitchell, 1992). Various geological disciplines have been used for the solution on this topic, such as sedimentology, petrology, stratigraphy, geochemistry and paleontology. Radiolarian paleontology is an important tool for fulfilling geodynamic interpretation. Lithology of radiolarian-bearing rocks and radiolarian assemblages provide good indicators for tectonic settings and time constraint.

On the basis of tectonostratigraphy, Thailand consists of two main continental blocks, Indochina and Shan-Thai, which are separated by the Nan-Uttaradit Suture (Bunopas, 1992) (Fig. 2.1). The Indochina Block is located to the east of the suture and covers mainly the Khorat Plateau. The Shan-Thai Block is found to the west of that suture and consists mainly of northern, central and southern Thailand. In addition, the Shan-Thai Block can be further subdivided into several tectonostratigraphic terranes.

Recently, it has become accepted that the main Paleotethys of this region is situated along Thai-Myanmar border (Chonglakmani, 2002; Wang et al., 1999). By

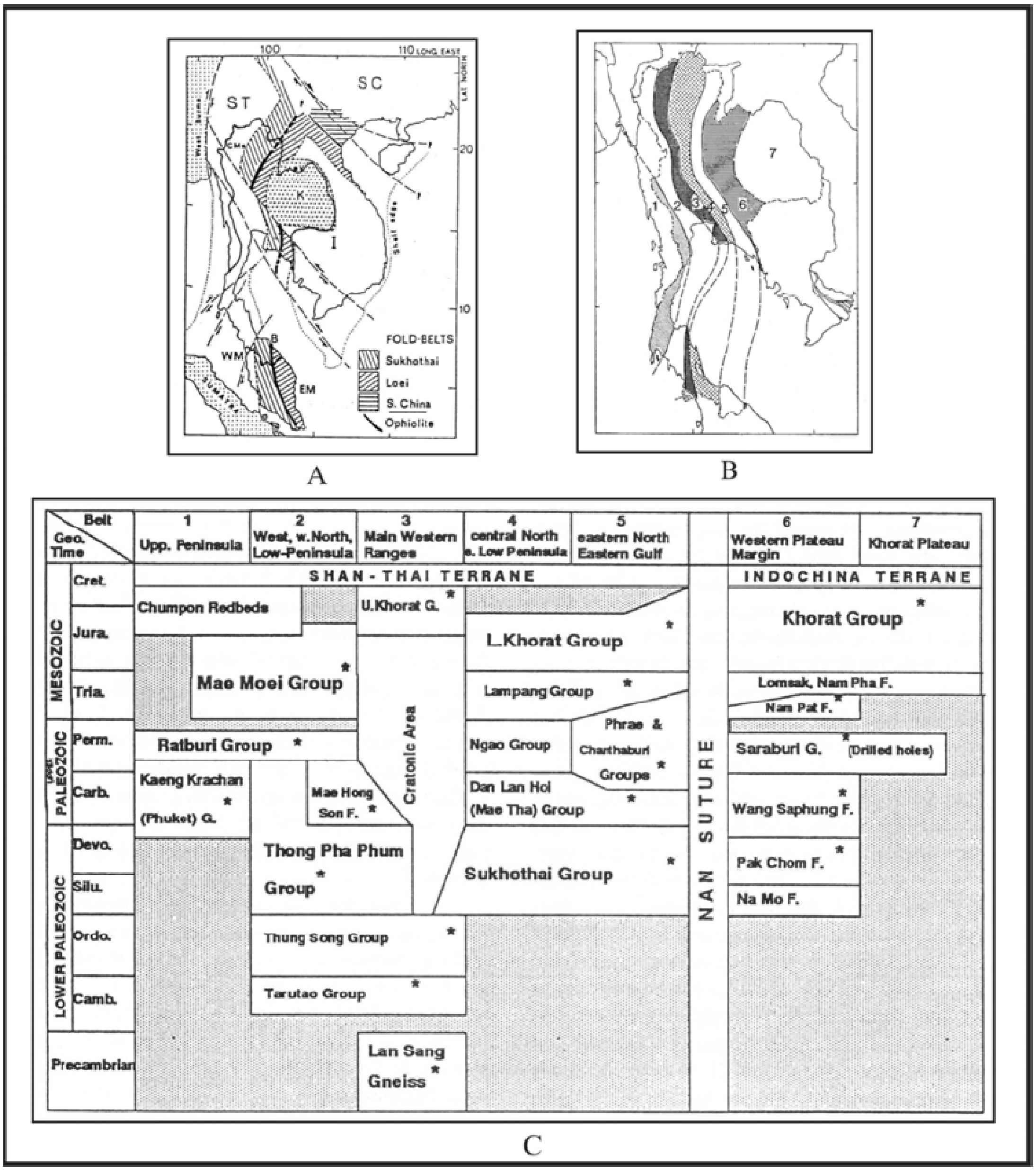


Figure 2.2 Tectonic subdivision of Thailand. A: Tectonic map of Thailand. I=Indochina Block, SC=South China Block, K=Khorat Plateau, ST=Shan-Thai, B-C: Stratigraphic belts of Thailand (after Bunopas, 1992).

contrast, the Nan-Uttaradit Suture should be ruled out as marking the main Paleothetys since it was closed not latter than Middle Permian (Helmcke, 1994).

In northern Thailand, there was another deep marine basin located to the east of the main Paleotethys within the Shan-Thai Block. It contains deep marine strata such as pelagic cherts and black shales which have been found to the north of Chiang Mai. The age of these strata ranges from Devonian to Middle Triassic (Jaeger et al., 1969; Sashida et al., 1993; Caridriot, 1993; Thassanapak et al., 2006). Moreover, this basin can be traced southward to Lamphun by the occurrence of Middle Triassic radiolarians (Feng et al., 2002). This basin can be compared with the eastern belt of Triassic deep marine and oceanic facies (see Fig. 1.1) (Chonglakmani, 1999). In addition, Carboniferous to Triassic sequences in this region can be correlated with the eastern zone of the Changning-Menglian belt, western Yunnan. They are similar not only in petrological characteristics but also sedimentology and fossil assemblages (Feng et al., 2002). The western limit of these sequences is located along deep marine and oceanic facies and the eastern limit is located along the eastern portion of the Nan-Uttaradit Suture (Chonglakmani, 2001).

2.3 Description of the study sections

2.3.1 Chiang Dao

2.3.1.1 General geology of Chiang Dao locality

The locality is occupied mainly by Carboniferous rocks (Fig. 2.3) (Hess and Koch, 1979). Middle Triassic granite and granodiorite are found in Doi Kam Phra and Doi Mae Tae. Relatively small areas of Upper Carboniferous basic volcanic rocks and Middle Permian rocks are exposed to the north of the area.

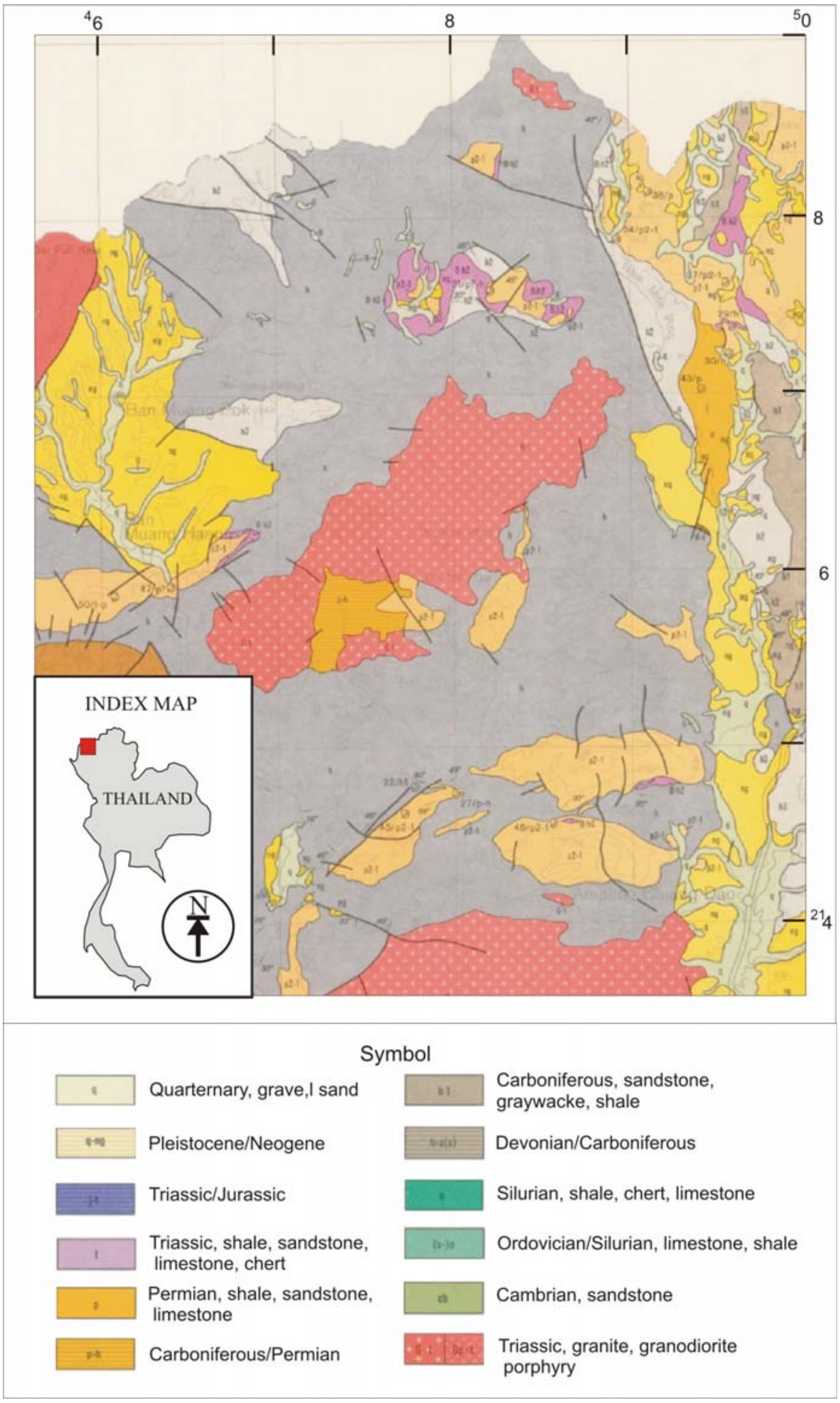


Figure 2.3 Geologic map of Chiang Dao area (after Hess and Koch, 1979).

There is a deep sea deposit located in the northeastern part of this area. It is known as the Fang Chert which ranges in age from Devonian to Middle Triassic (Jaeger et al., 1969; Sashida et al., 1993; Caridroit, 1993).

2.3.1.2 Outcrop description of Chiang Dao locality

CD section

The CD section is located in the area north of Chiang Dao District, Chiang Mai Province. It is found on topographic map of Thailand, scale 1:50,000, sheet 4747 I Amphoe Chiang Dao (Fig. 2.4). A small hill road cut outcrop is exposed on the left side of road no. 1322 between km 1 and km 2. It covers mainly clastic sedimentary rocks including sandstones at the north and gray mudstones at the south. Folded cherts are found in the central part between these rocks. The thickness of chert is about 10 meters. It consists of light brown and gray cherts with intercalated siliceous shale and claystone partings (Fig. 2.5). More than 300 samples (CD 1- CD 339) in a continuous succession were collected for this study. Thin-sections of chert under the microscope contain abundant radiolarian tests (Fig. 2.6). Stratigraphic column and ages of this section are shown in Figure 2.7.

2.3.2 Lamphun

2.3.2.1 General geology of Lamphun locality

Based on the geologic map of Thailand, scale 1:250,000, sheet Lampang (NE47-7), this locality lies in the southeastern portion of the Cenozoic Chiang Mai Basin (Fig. 2.8). It consists mainly of Carboniferous and Permian strata located to the west of the northeast trending Mae Tha fault, with Silurian-Devonian rocks and Triassic granite to the east of this fault. Quaternary sediment is deposited in valley, along the fault and in the basin. The Carboniferous strata consist of

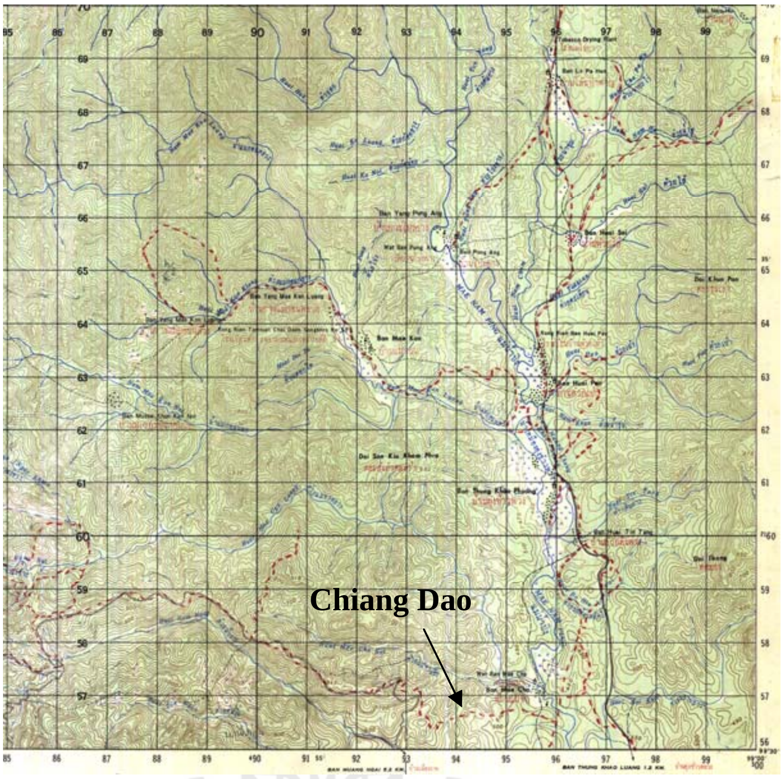


Figure 2.4 Topographic map showing location of Chiang Dao locality, which is located at southern part of sheet Ban Na Wai (4545 II).

graywackes, arkosic protoquartzites and orthoquartzites, quartzites and shales. The Lower Permian is composed of phyllites, sandstones, schists, siltstones, quartzites, quartzitic schists, agglomerates and tuffs. The Middle Permian consists of massive limestones, calcareous shales and sandstones (Charoenprawat et al., 1994).

2.3.2.2 Outcrop description of Lamphun locality

LP section

This outcrop is exposed as a road cut along Lamphun-Lampang route (Highway 11).

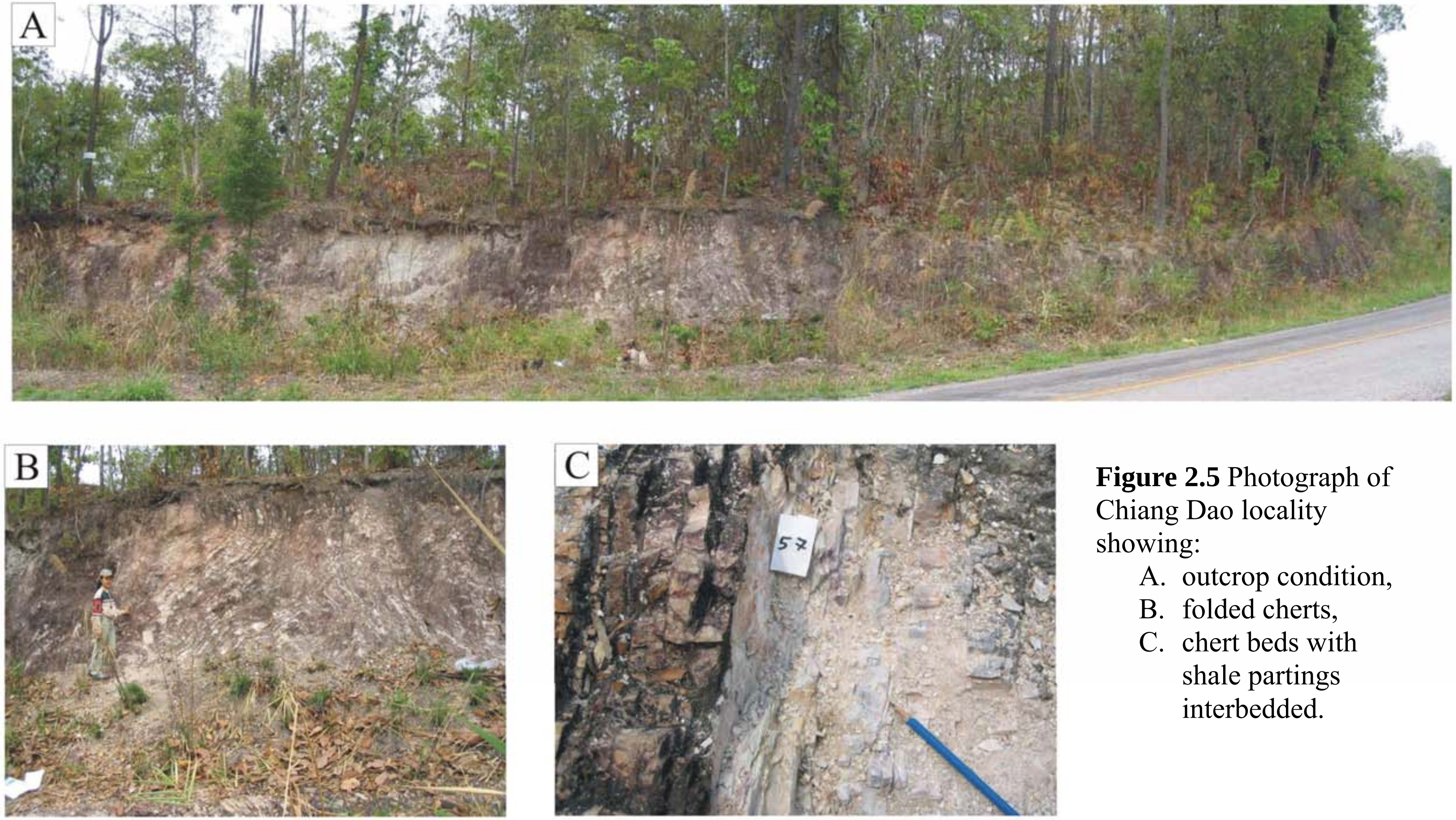


Figure 2.5 Photograph of Chiang Dao locality showing:

A. outcrop condition,
B. folded cherts,
C. chert beds with shale partings interbedded.

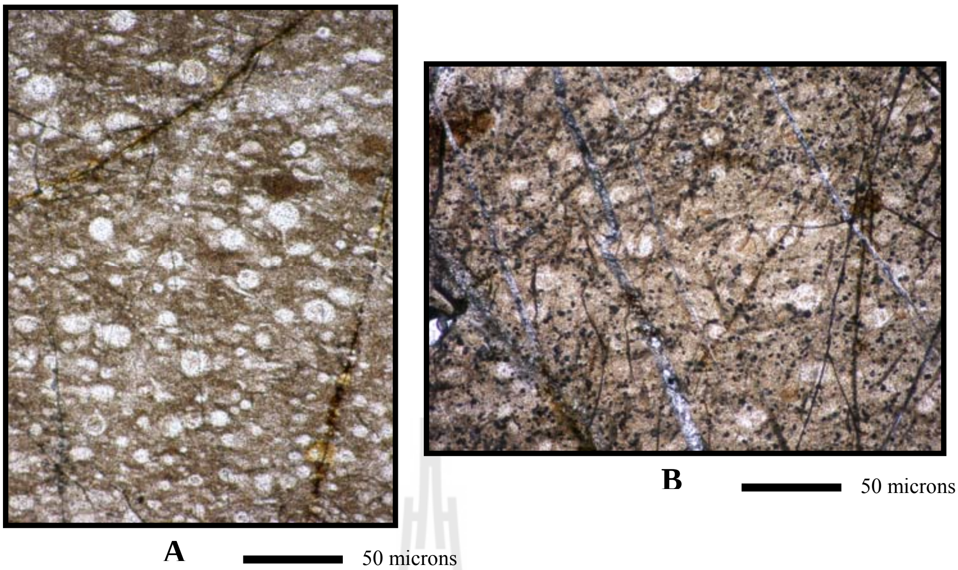


Figure 2.6 Photomicrographs of cherts from Chiang Dao locality. Radiolarian tests can be observed as light spots. A: sample no. CD 285, B: sample no. CD 315.

It is located at km 59.2 within the area of Ban Cham Bon village Muang District, Lamphun Province (Fig. 2.9). Grid co-ordination of the outcrop is 18 º 30′ 16″ N, 99º 5′ 43″ E. The outcrop is characterized by strongly folded chert strata embedded in brown clastic sediments (Fig. 2.10). The chert is mostly brown and light gray in color. The beds are variable in thickness but most are 5 to 10 cm thick. Brown shale partings are interbedded with the cherts. Four chert sections have been studied. Thirty-six samples were collected from these sections (LP 1 to LP 36). However, radiolarians from this locality are very poorly preserved due to being highly recrystallized and that makes them difficult to identify. Thin-sections of the rock sample show high abundances of radiolarian tests (Fig. 2.11). Stratigraphic column and ages for this section are shown in Figure 2.12.

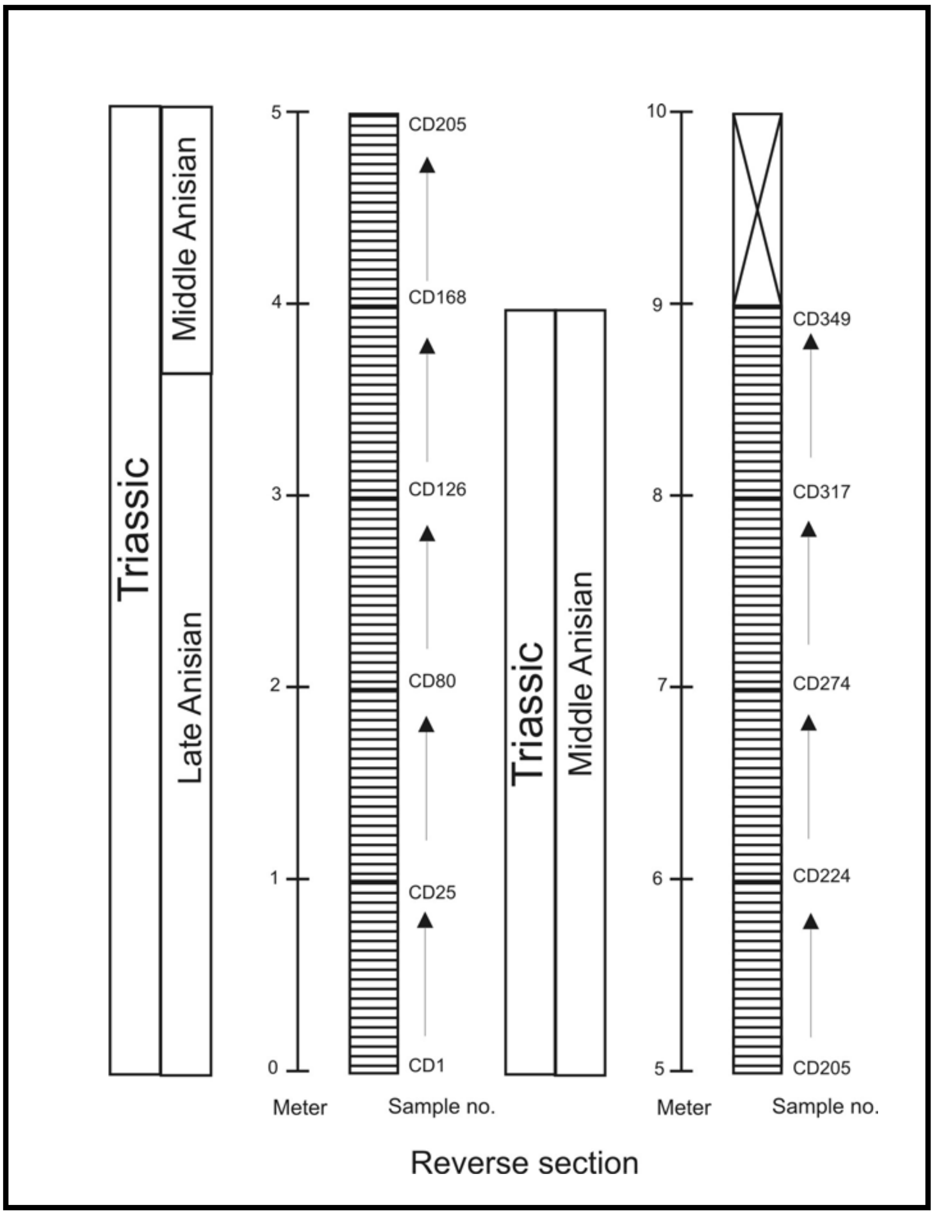


Figure 2.7 Stratigraphic column and sampling points with radiolarian ages from the Chiang Dao locality.

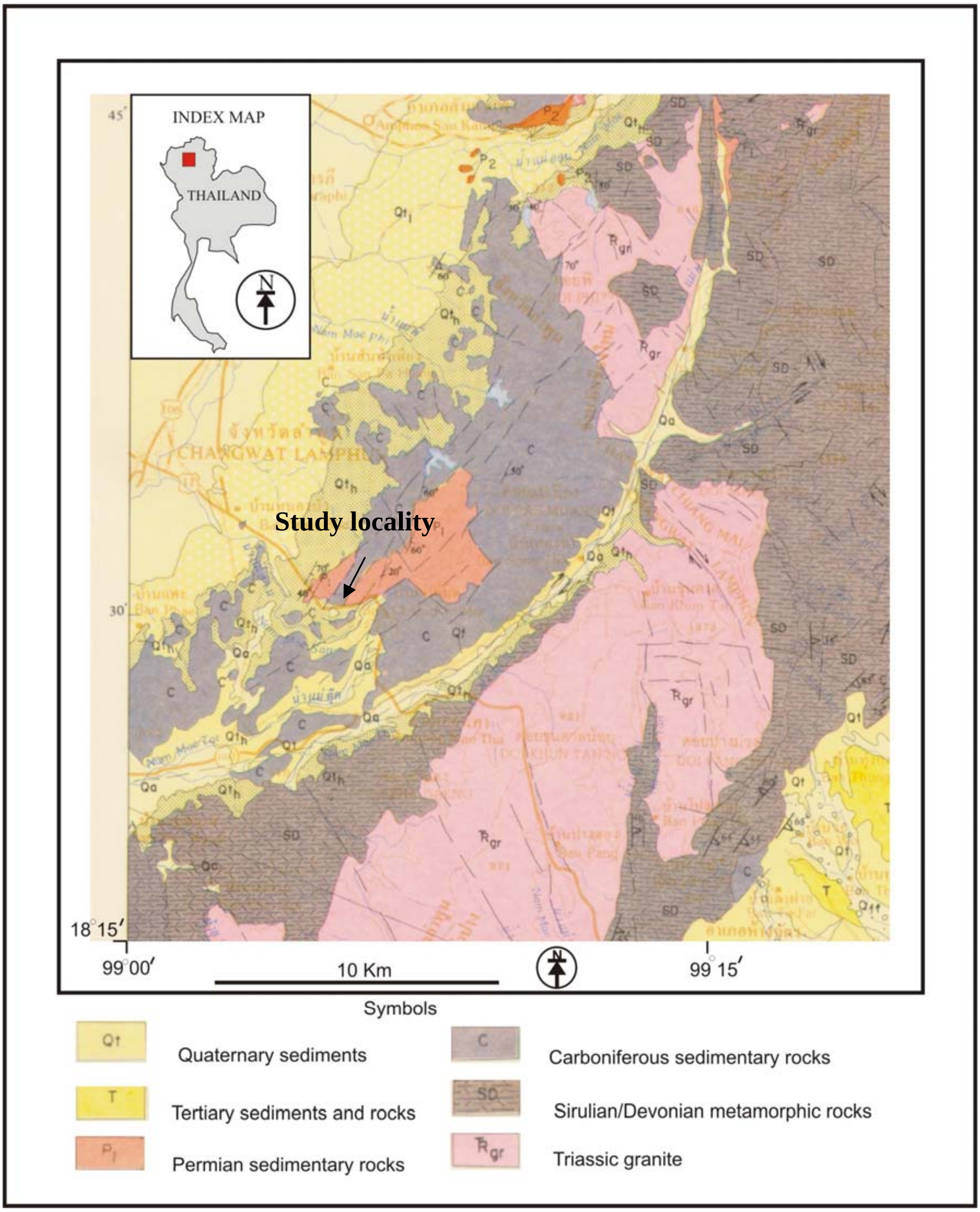


Figure 2.8 Geologic map of Lamphun locality. The study locality is at southeastern end of Lamphun town along HW 11. It was preciously mapped as Carboniferous, re-dated as Triassic by Feng et al., 2002 (after Chareonprawat et al., 1994).

Figure 2.9 Topographic map showing the Lamphun locality in the southern part of the Changwat Lamphun sheet (4846 III).

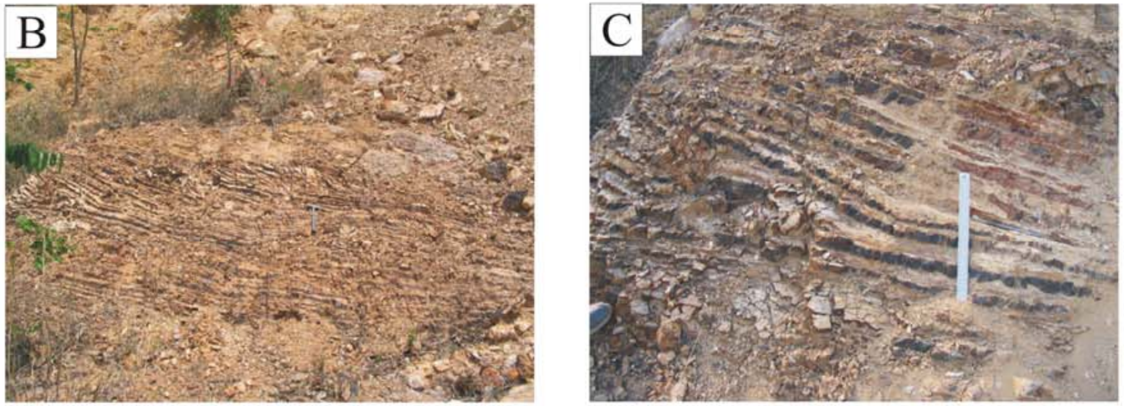


Figure 2.10 Photographs of Lamphun locality showing:

A. outcrop condition,

B. part of folded cherts,

C. chert beds.

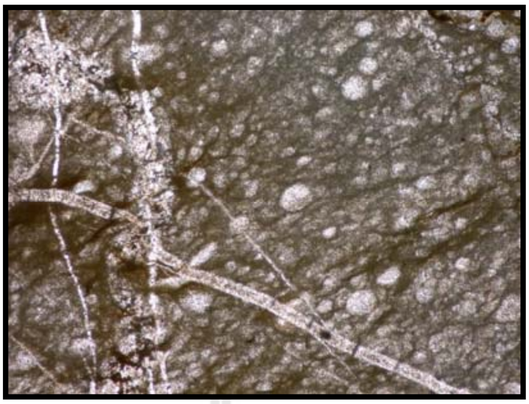


Figure 2.11 Photomicrograph of cherts from the Lamphun locality.

2.3.3 Den Chai

2.3.3.1 General geology of Den Chai locality

The study locality is in a mountainous area close to the southern edge of the Cenozoic Phrae Basin (Fig. 2.13). This area is covered mainly by Triassic rocks and Pleistocene Basalts (Geological Survey Division, 1999). The Triassic rocks are composed mainly of Wang Chin and Pha Daeng Formations of the Lampang Group. These rocks were deposited in Triassic Lampang-Phrae Basin (including Lampang Sub-basin and Phrae Sub-basin) which contains both shallow marine and deep marine facies. An off-shore environment (deep marine) is indicated by the common occurrence of pelagic ammonoids and bivalves (Posidoniidae) (Chonglakmani and Mackie, 1993). The Wang Chin Formation is composed mainly of a mud-rich sequence of submarine fan sediments with detached sand bodies (Chaodumrong, 1994). Fossils include *Halobia* sp., *Palaeocardita* sp., and *Posidonia* sp. (Meesook et al., 2002). An outcrop of siliceous rocks was exposed in the area.

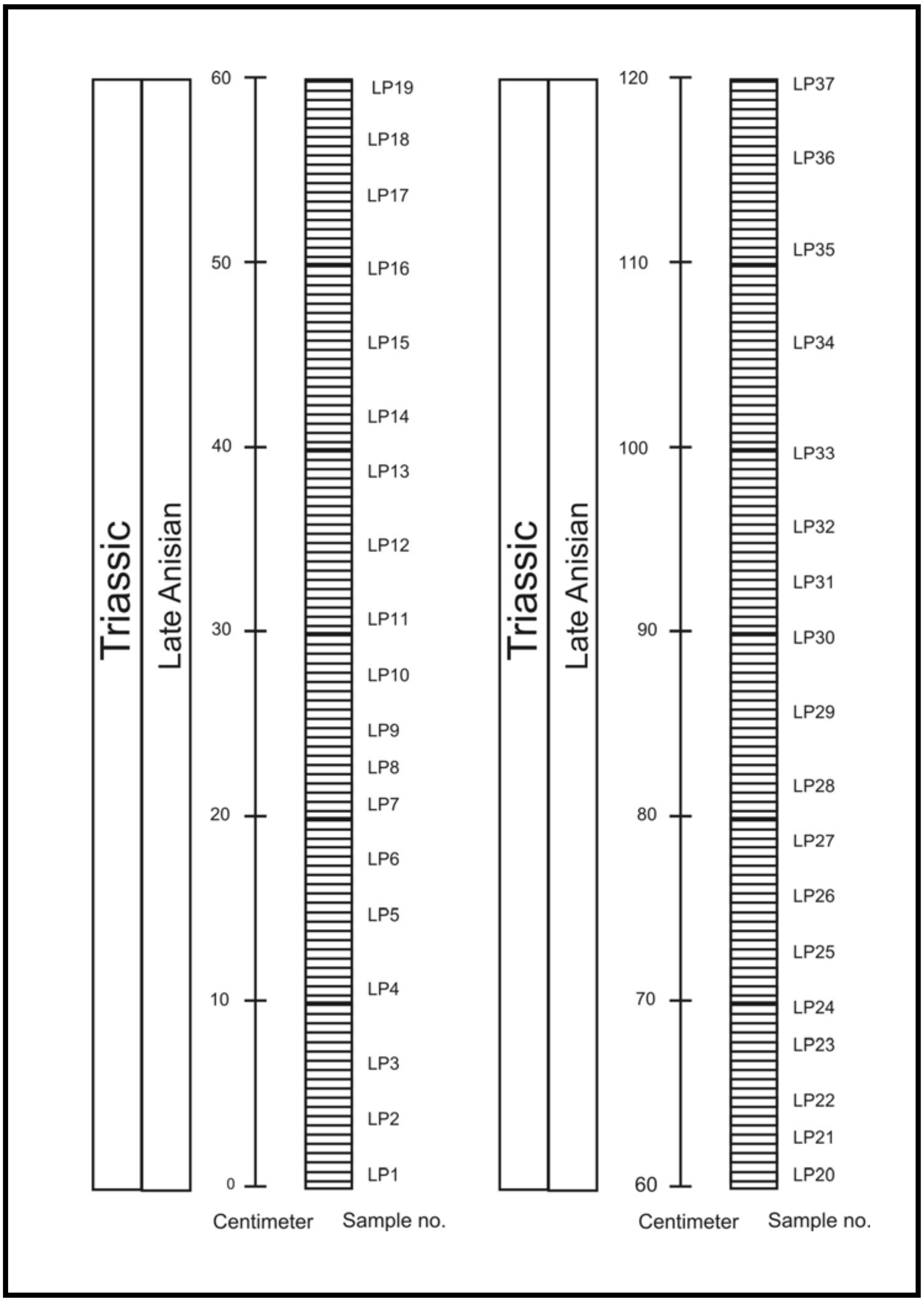


Figure 2.12 Stratigraphic column and sampling points with radiolarian ages for the Lamphun locality.

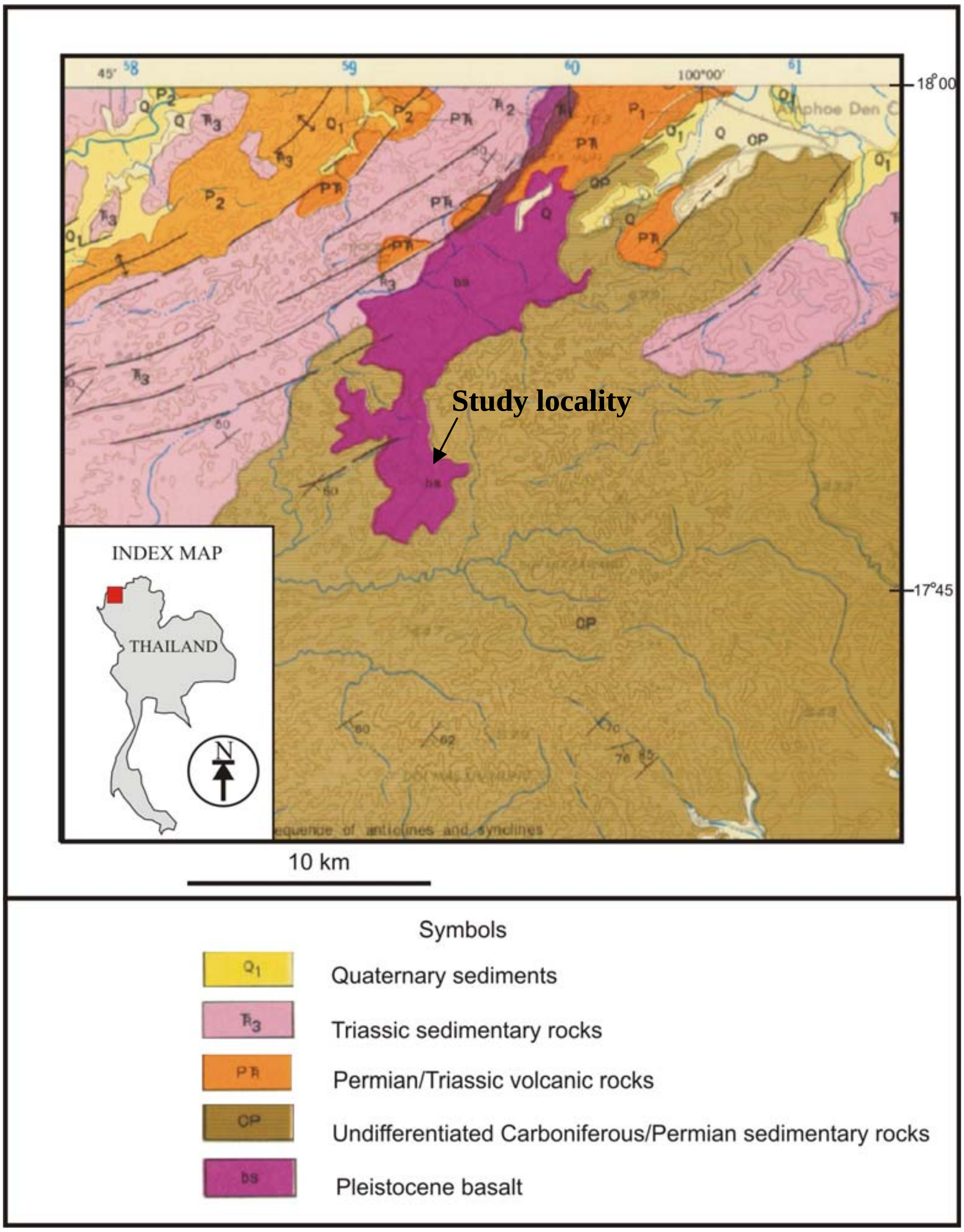


Figure 2.13 Geologic map of Den Chai. The study locality is located to the southeast of the Phrae Cenozoic Basin along HW 101 (after Piyasin et al., 1977).

They are Middle Triassic age as previously proved by radiolarian dating (Chonglakmani et al., 1991).

In addition, the Pha Daeng Formation is sporadically exposed in the north of the study area. It is characterised mainly by fine-grained red beds with Bouma sequences which are interpreted as shallow marine and fan-delta facies deposited on the extentional forearc basin (Chaodumrong and Burret, 1997). However, these flysch-like strata were interpreted as sediment deposited on a rapidly subsiding area of epicontinental setting (intramontane basins) (Helmcke, 1994).

Permo-Triassic volcanic rocks including rhyolite, andesite, tuff and agglomerate are found mainly between the Lampang Sub-basin and Phrae Sub-basin and locally at the north of study area (Piyasin, 1974). Major lineaments of this area have a northeast-southwest trend, slightly parallel to the major trend of the so-called Northern Basin and Range Province of this region.

2.3.3.2 Outcrop description of Den Chai locality

DC section

Cherts and siliceous shales were found cropped out at km 88, along Den Chai-Si Satchanalai route (Highway 101), south of Den Chai district, Phrae Province (Fig. 2.14). They were exposed by road-cut and found unconformably with basalts. Cherts and siliceous shales are maroon in color, very thinly to thinly bedded (1.5-8 cm thick) and intensely folded in various directions. Clay partings are observed (0.2-4 cm thick) intercalated with these siliceous rocks (Fig. 2.15). There are three sections and twenty- three samples of the outcrop have been studied. The first section consists of 62.2 cm thick. Ten samples of cherts were collected from this section (DC 1 to DC 10). The second section is 55.4 cm thick with eleven collected samples (DC

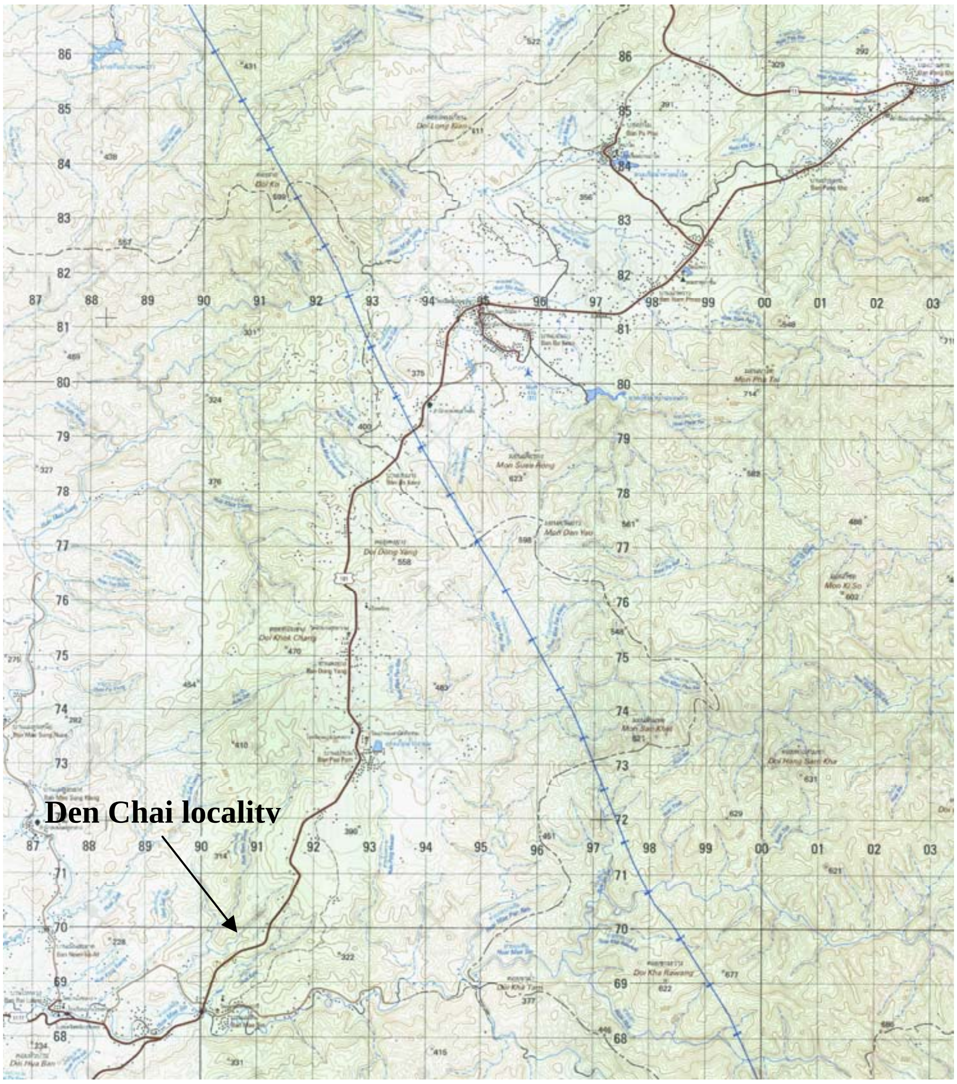


Figure 2.14 Topographic map showing the Den Chai locality in the southern part of the Ban Bo Kaew sheet (4944 I).

Figure 2.15 Photographs of Den-Chai locality showing:

A. outcrop condition,

B. folded chert and siliceous rocks,

C. chert and siliceous rocks.

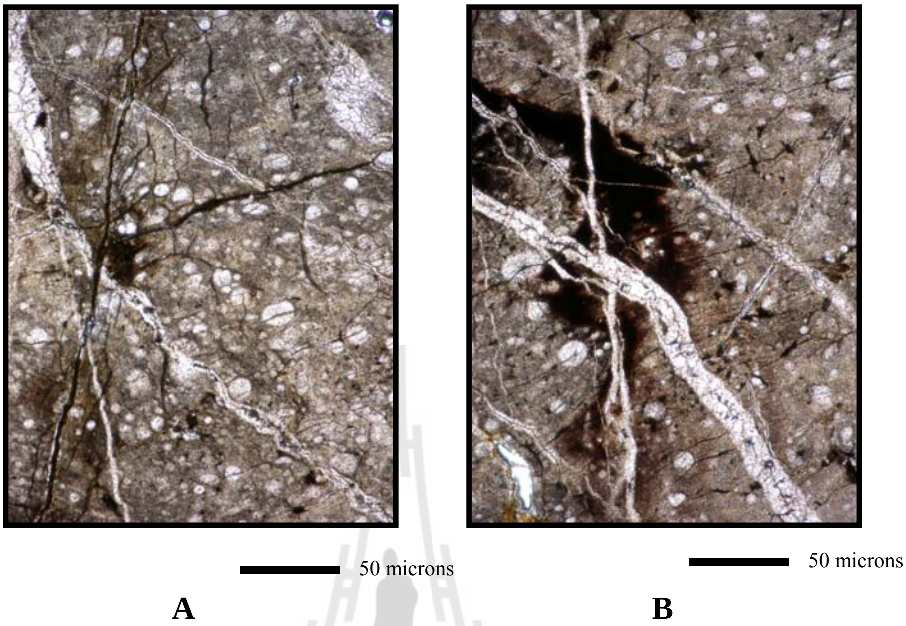


Figure 2.16 Photomicrographs of maroon cherts from the Den Chai locality. A: sample no. DC 18 showing radiolarian tests, B: same samples showing radiolarian tests, veinlets and maroon colour.

11 to DC 21). The last section is 63.7 thick with five collected samples (DC 22 to DC 26). The rock thin-section is shown in Figure 2.16. It is characterized by abundant radiolarian tests. Stratigraphic column and age for this section are shown in Figure 2.17.

2.3.4 Khun Yuam - Mae La Noi - Mae Sariang locality

2.3.4.1 General geology of Khun Yuam - Mae La Noi - Mae Sariang locality

According to the geological map of northern Thailand, sheet 5 (Chiang

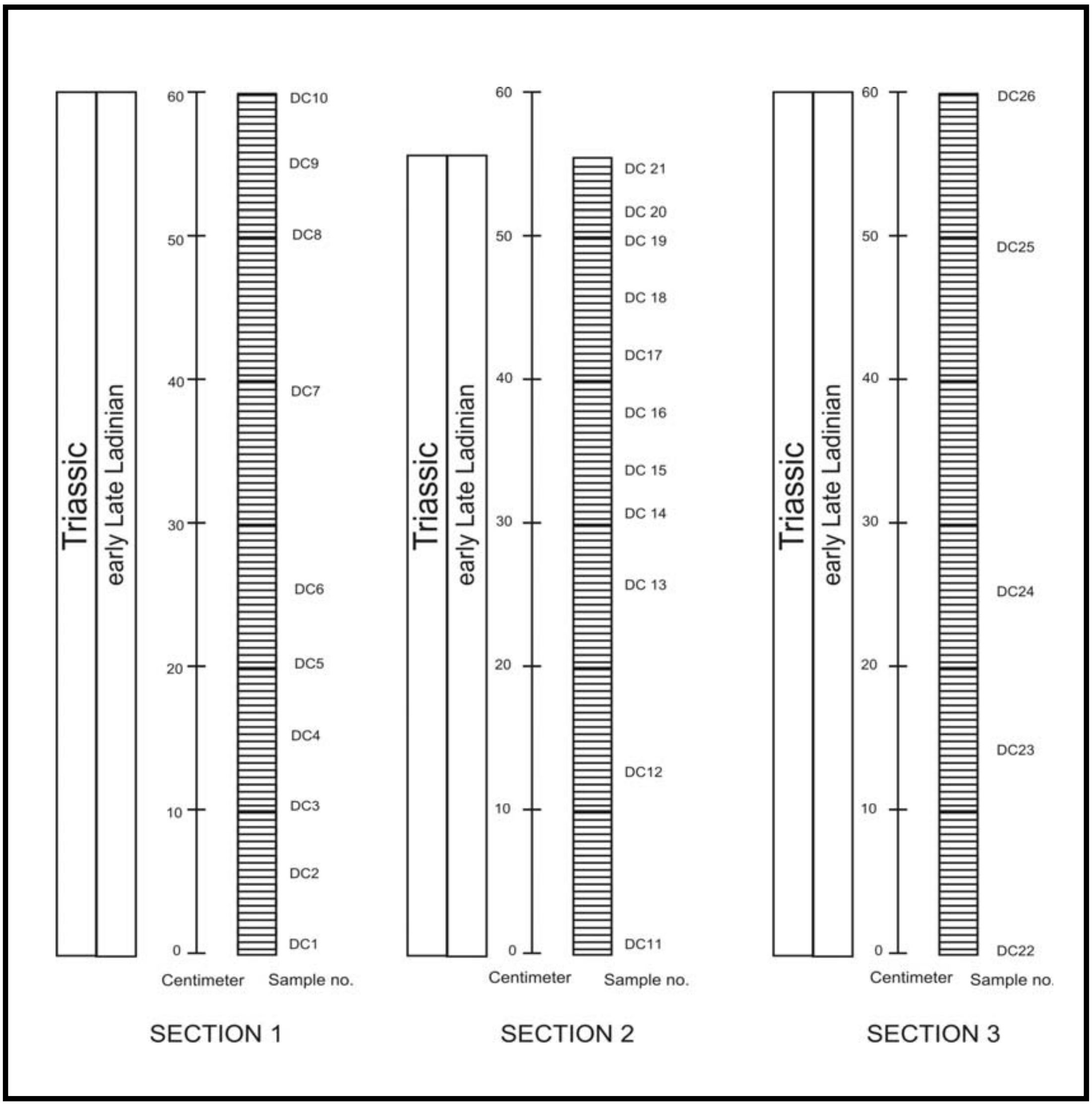


Figure 2.17 Stratigraphic column and sampling points with radiolarian ages from the Den Chai locality.

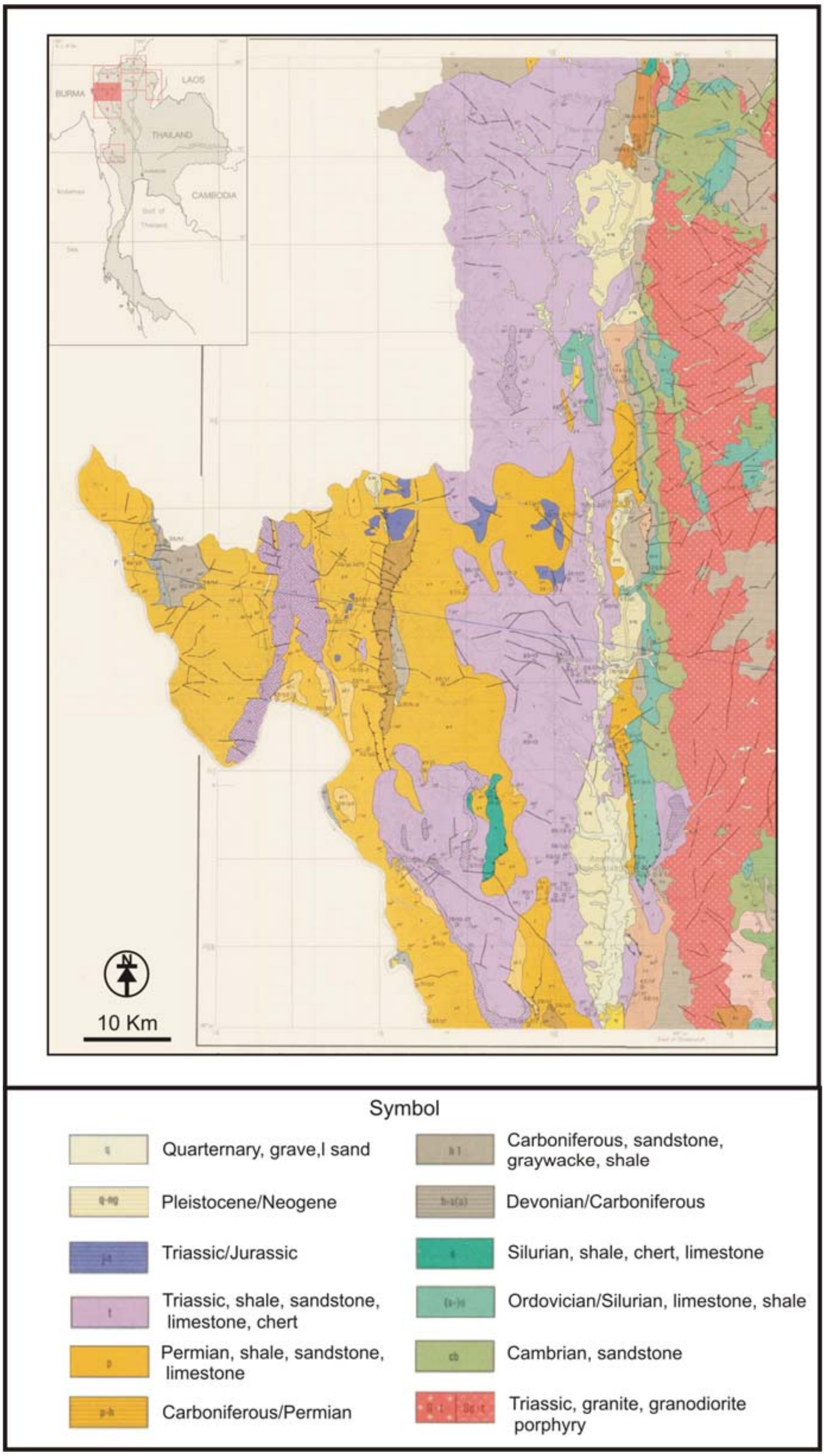


Figure 2.18 Geologic map of Mae Sariang-Mae Hong Son area (after Baum et al., 1981).

sporadically overlie these sequences. Carboniferous is found mostly in the northern part of this area while two main localities of Silurian-Devonian strata are located to the south and middle part. Quaternary and Tertiary sediments were accumulated in small basins along Mae Nam Yuam river in a north-south trend. The flower structure on the eastern side of HW 108 indicates compressional tectonism at the east of Mae Sariang town. It is characterized by the thrusting of Ordovician strata westwards on Permian-Carboniferous and eastwards on Triassic strata. These strata are observed to the north along the road together with Carboniferous-Silurian and Cambrian strata. Granite and granodiorite are exposed further to the east of these sequences. These plutonic rocks are of Triassic age.

2.3.4.2 Outcrop description of Khun Yuam - Mae La Noi - Mae Sariang locality

KYY section

It is located at km 179 along the Mae Sariang-Mae Hong Son road (Highway 108) on the hill between Ban Tha Hin Som and Ban Hang Pon Villages (18º 40′ 87″ N, 97º 55′ 23″ E) at position 864658 within topographic map of Thailand, scale 1: 50,000, sheet 4546 II Ban Mae La Luang (Fig. 2.19). It is exposed as road-cut outcrop. Three rock sections located on the western side of the road yielded thirteen samples (Fig. 2.20). The rocks from each section are of similar lithology, composed of folded strata of black cherts with shale partings intercalations. Chert beds are mostly 3 to 5 cm thick. Five samples of cherts from section one were collected (KYY 1-1 to KYY 1-5). Three chert samples were collected from section two (KYY 2-1 to KYY 2-3) and five samples from

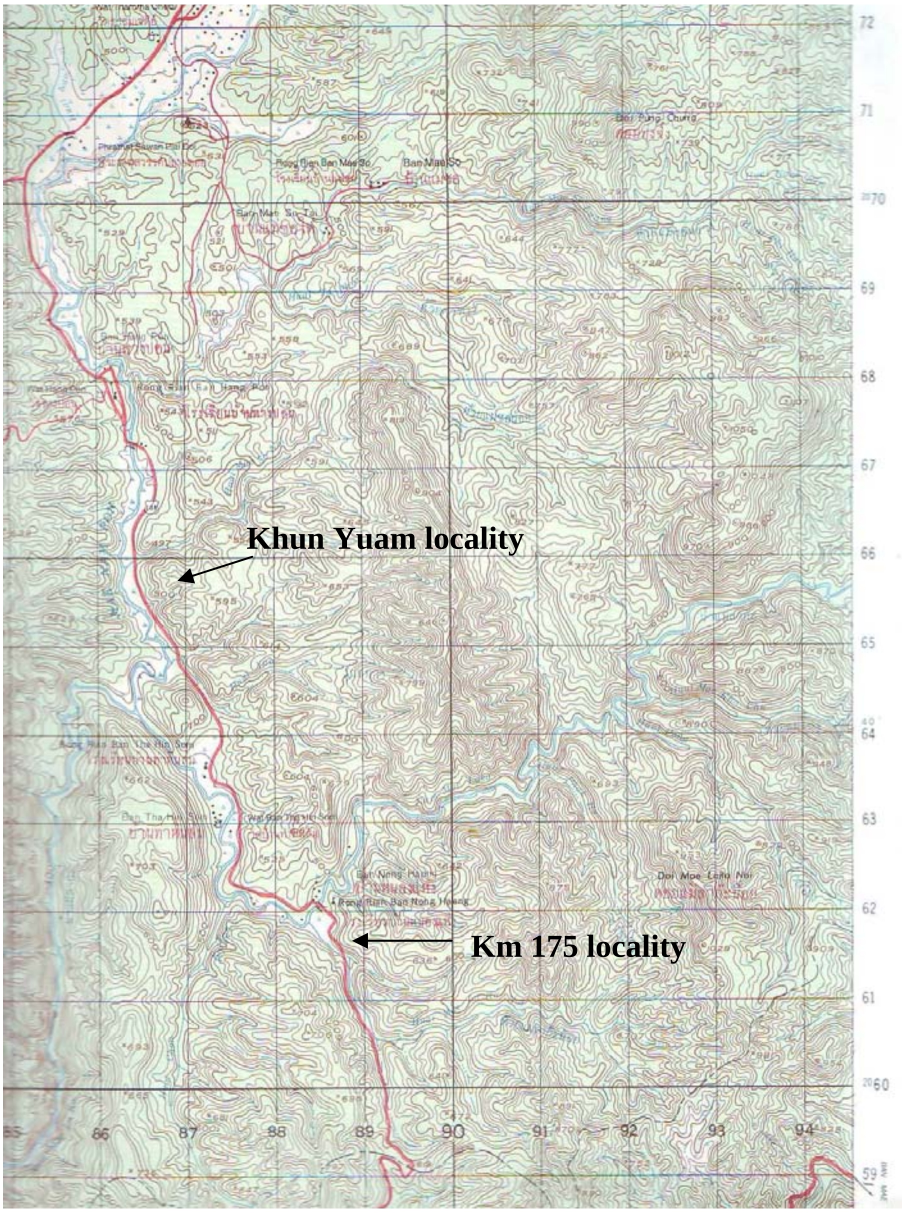


Figure 2.19 Topographic map showing location of Khun Yuam and Km 175 localities, which are located in map sheet Amphoe Khun Yuam (4546 I).

Figure 2.20 Photographs of Khun Yuam locality showing:

A. Outcrop along HW 108,

B. Bedded cherts,

C. Folded chert beds.

section three (KYY 3-1 to KYY 3-5). Thin sections of chert show a high abundance of radiolarian tests (Fig. 2.21). Stratigraphic column and ages of this section are shown in Figure 2.22.

Km 175 section

This section is situated at km 175 along Mae Sariang-Mae Hong Son road, Highway 108 within topographic map of Thailand, scale 1:50,000, sheet 4546 I Amphoe Khun Yuam at coordination 876626 (Fig. 2.19). It is not far from the last section. This section is 3 meters high and 25 meters wide and overelained by Quaternary sediments. The well bedded and slightly folded cherts exposed here are light greenish to dark gray color (Fig. 2.23). Beds are 3 to 5 cm in average. Siliceous shales are intercalated, 0.5 to 1 cm thick in average. Both sides of this section are contacted by dark gray siliceous shales. Six samples (Km 175-1 to Km 175-6) were collected from this section. Chert samples from this outcrop show a high abundance of radiolarians (Fig. 2.24). Stratigraphic column and ages of this section are shown in Figure 2.25.

Km 119 section

This section is located at km 119.600 in Mae La Noi District, Mae Hong Son Province along the right side of Mae Hong Son-Mae Sariang road (Highway 108) at position 868226 of topographic map of Thailand, scale 1:50,000, sheet 4545 I Amphoe Mae La Noi (Fig. 2.26). This outcrop mainly consists of gray bedded siliceous limestone intercalated by fine-grained siliciclastic rocks and overlain by the siliciclastic sequence (Fig. 2.27). Two individual samples were collected for this study (KM 119A and KM 119B). Some radiolarian tests and high number of

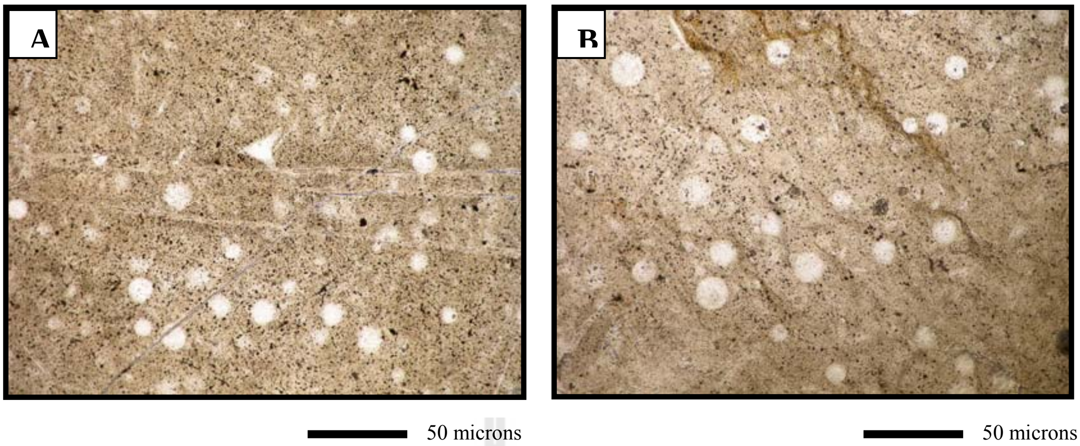


Figure 2.21 Photomicrographs of cherts. Radiolarian tests can be seen as light spots. A: sample no. KYY 1-5, B: sample no. KYY 1-6.

bivalve slivers prevail in thin section (Fig. 2.28). Stratigraphic column and ages of this section are shown in Figure 2.29.

MLN section

This outcrop is located at km 116.6 along the Mae Sariang-Mae Hong Son route (Highway 108) between the boundary of Mae La Noi and Mae Sariang Districts at position 882206 on topographic map of Thailand, scale 1:50,000, sheet 4545 I Amphoe Mae La Noi (Fig. 2.26). Well bedded gray black cherts are exposed at eastern side of the road-cut on the hill. The bed thickness ranges from 2 to 7 cm (mostly 4 cm) (Fig. 2.30). Three sections from this outcrop have been studied. Section one is 153.5 cm thick and 15 chert samples are collected (MLN 1-1 to MLN 1-15). Section two overlies section one and is 115 cm thick. Fifteen chert samples have been collected from this section (MLN2-1 to MLN 2-15). The last section is 90 cm thick and three chert samples have been collected (MSR3-1 to MLN 3-3).

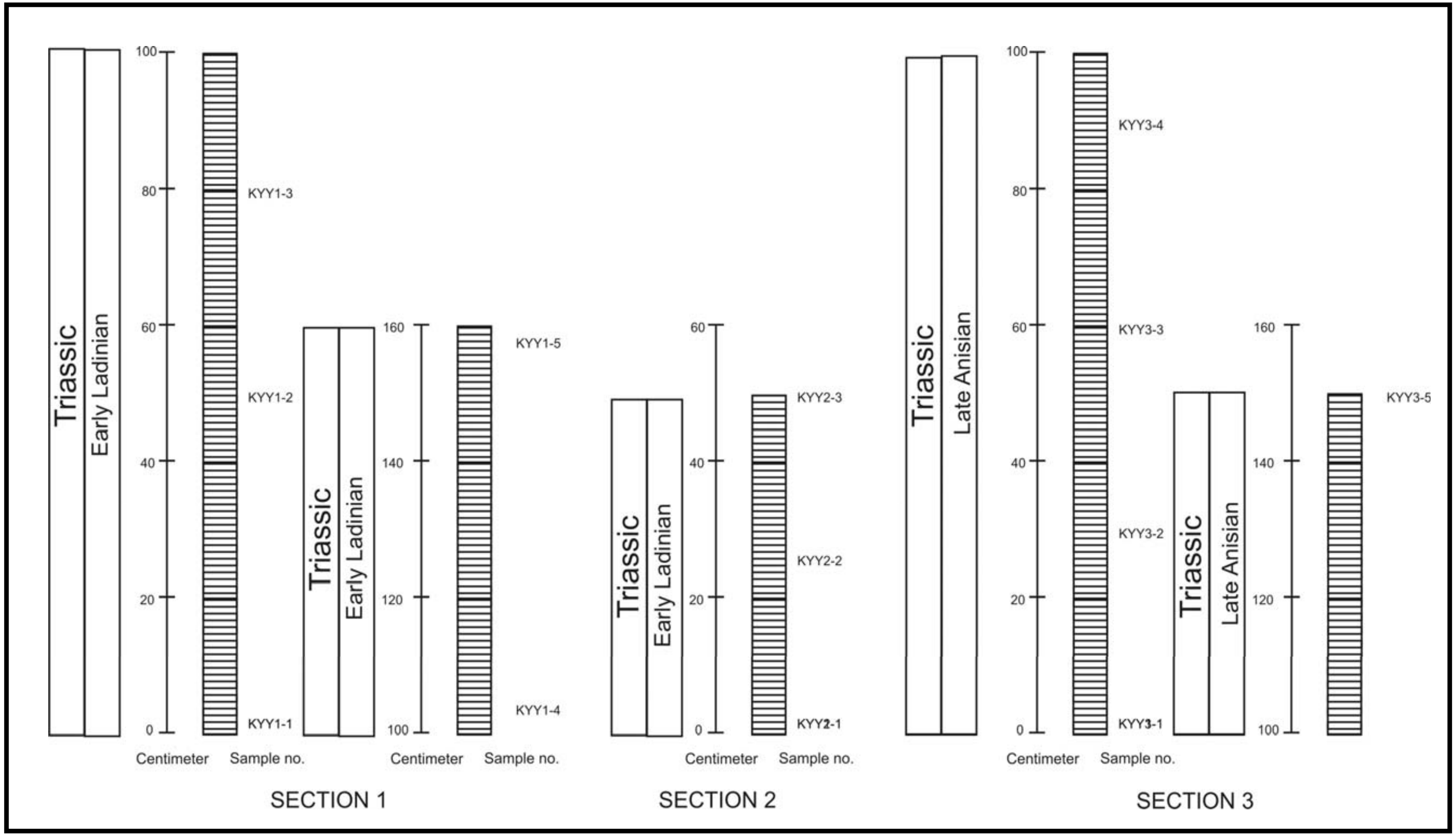


Figure 2.22 Stratigraphic column and sampling points with radiolarian ages of Khun Yuam locality

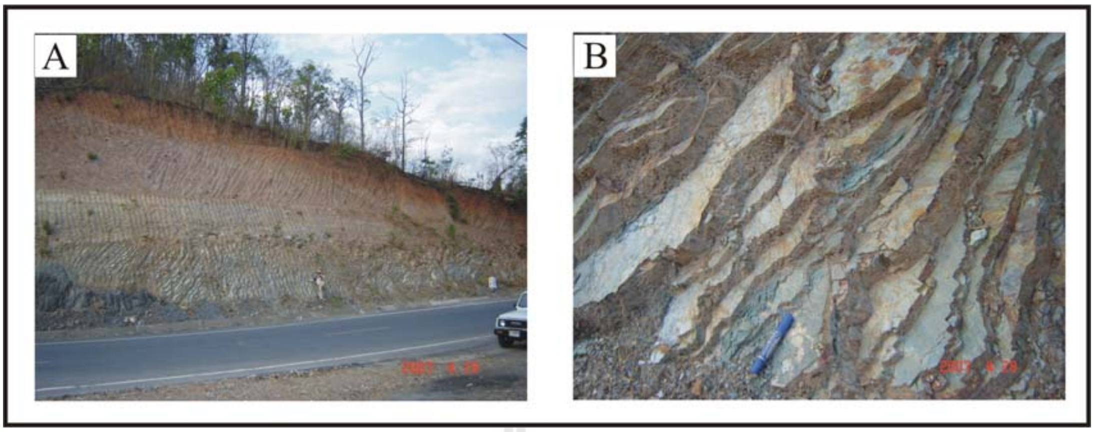


Figure 2.23 Photographs of cherts from Km 175 locality. A: Outcrop condition, B: Chert beds.

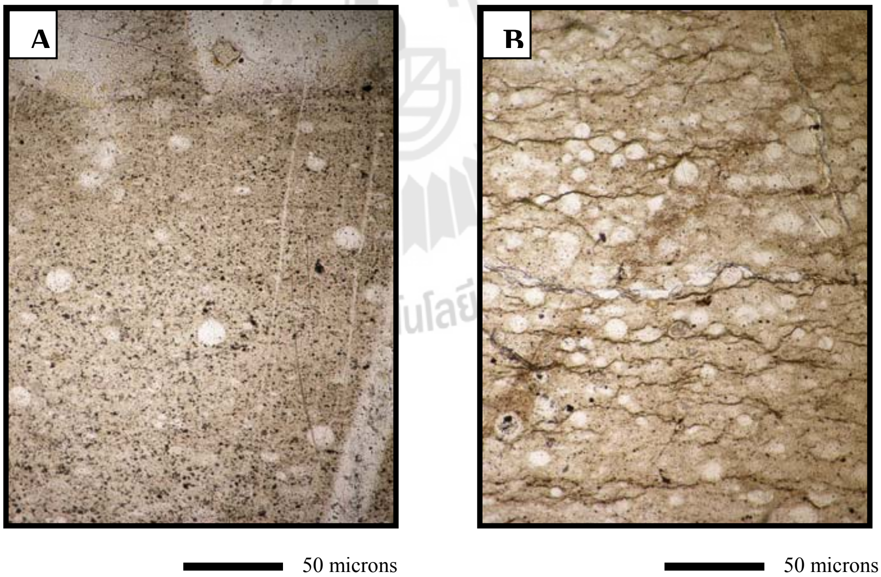


Figure 2.24 Photomicrographs of cherts from Km 175 locality. A: sample no. Km 175-1, B: sample no. Km 175-2.

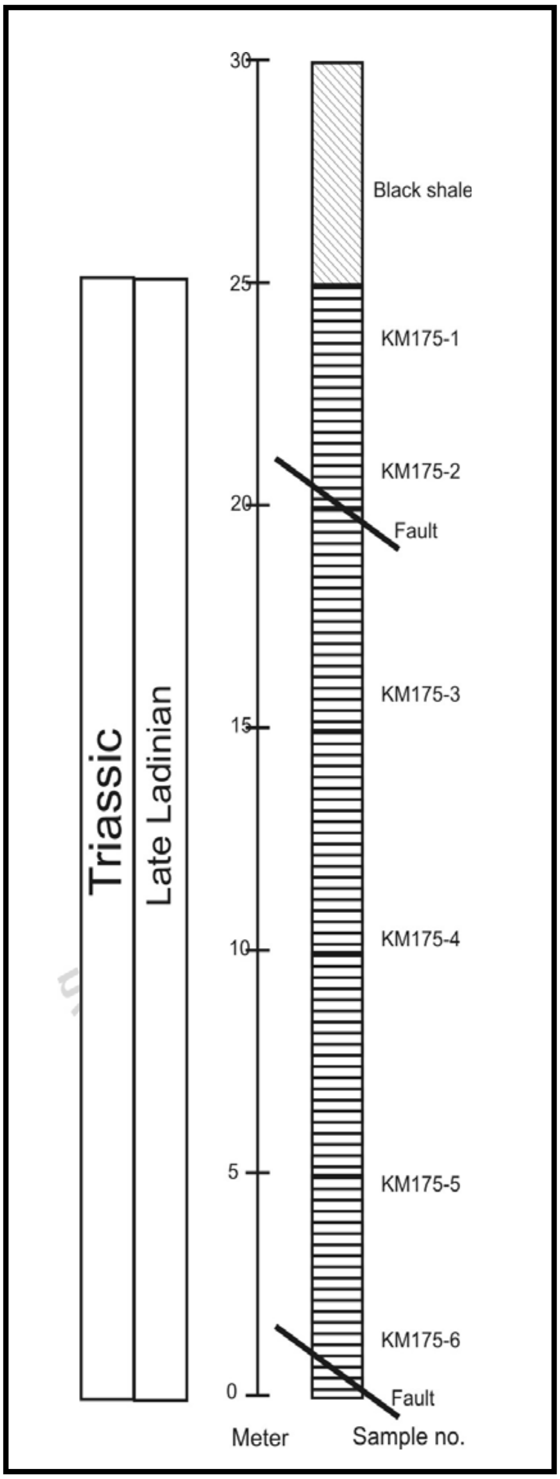


Figure 2.25 Stratigraphic column and sampling points with radiolarian ages of Km 175 locality.

Radiolarian tests can be observed in thin section (Fig. 2.31). In addition, red clastic rocks (major) and blocks of calcareous rocks (minor) have been found on the northern part of this outcrop. The red clastic rock contains predominantly well bedded shale and strongly folding. More than ten samples of siliceous shale and calcareous rocks were collected for preliminary tests. The result is negative for microfossils. Stratigraphic column and ages of this section are shown in Figure 2.32.

MSR section

This locality is located to the east of Mae Sariang town at km 99.575 (Highway 108) along Mae Sariang-Chom Thong route (Fig. 2.33) within topographic map of Thailand, scale 1:50,000, sheet 4545 II Amphoe Mae Sariang at position 911076. The outcrop is found as the road-cut on the hill. Strata are mainly dark gray cherts with shale parting intercalations. The cherts are 5-10 cm thick and shale partings are 1-5 cm thick in average. There are five sections with twenty-seven samples of this outcrop have been studied (Fig. 2.34). Section one consists of 100 cm thick and five samples were collected (MSR 1-1 to MSR 1-5). Section two is overlain section one and is 400 cm thick. Eight samples were collected (MSR 2-1 to MSR 2-8). Section three is one meter thick and four samples were collected (MSR 3-1 to MSR 3-4). Sections four and five are located on the northern side of section one. Section four is 80 cm thick and five samples were collected (MSR 4-1 to MSR 4-5). Section five is 220 cm thick and five samples were collected (MSR 5-1 to MSR 5-5). Thin sections of cherts from this locality show a high abundance of radiolarian test but in some cases test are less frequent (Fig. 2.35). Stratigraphic column and ages of this section are shown in Figure 2.36.

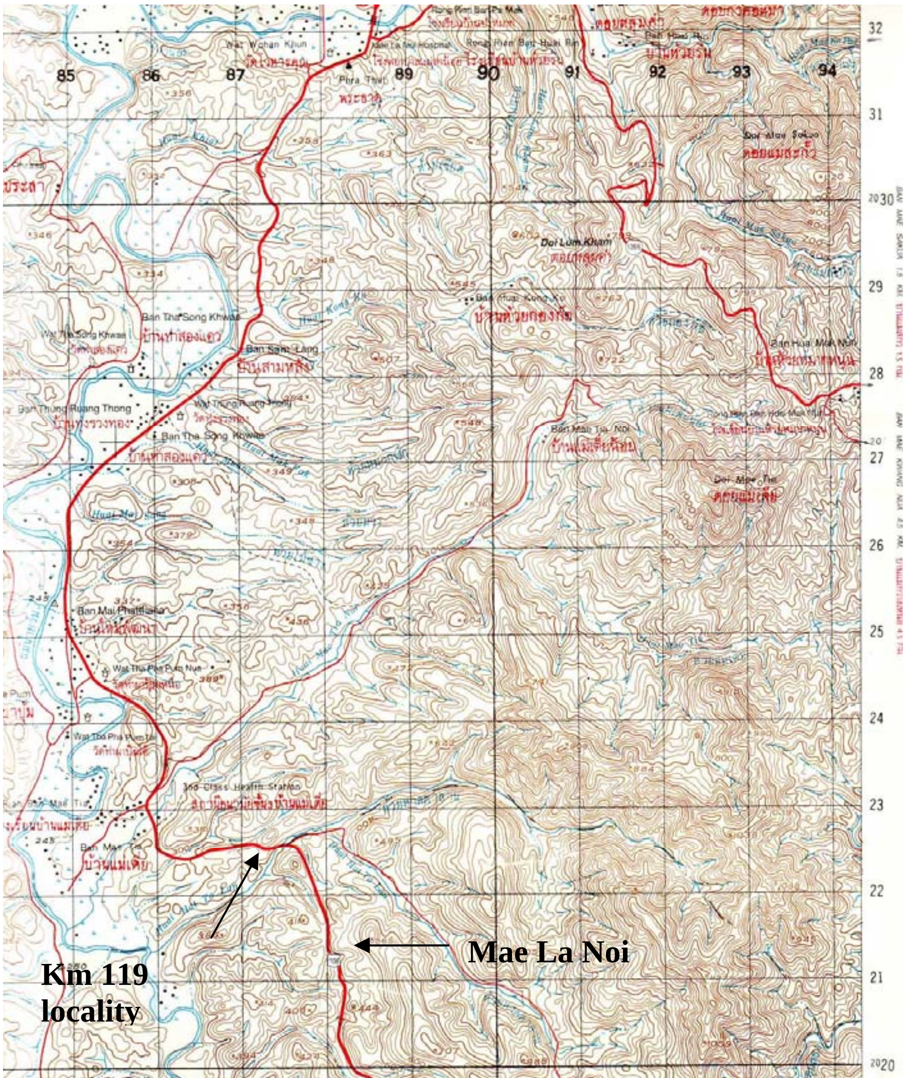


Figure 2.26 Topographic map showing location of Mae La Noi and Km 119 localities, which is located in the southern part of sheet Amphoe Mae La Noi (4545 I).

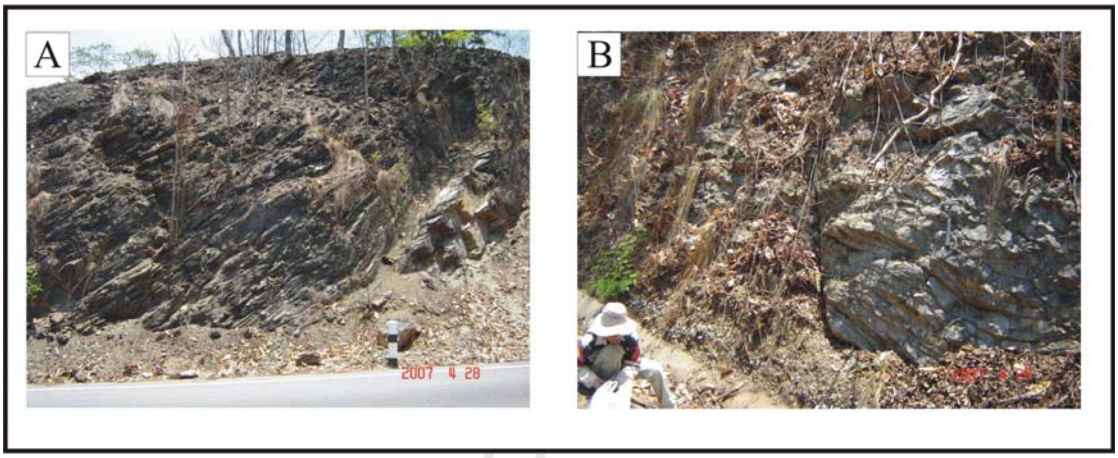


Figure 2.27 Photographs of Km 119 locality. A: Outcrop condition in north-eastern view, B: Siliceous limestone beds at southwestern view.

Figure 2.28 Photomicrograph of siliceous limestone from Km 119 locality.

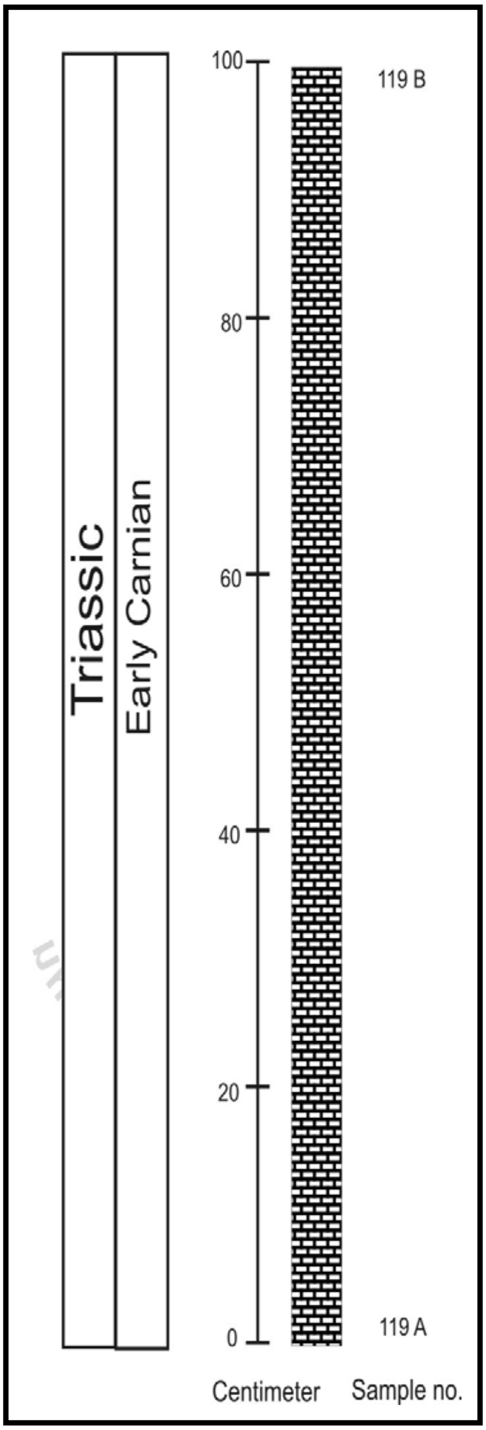


Figure 2.29 Stratigraphic column and sampling points with radiolarian ages of siliceous limestone from Km 119 locality.

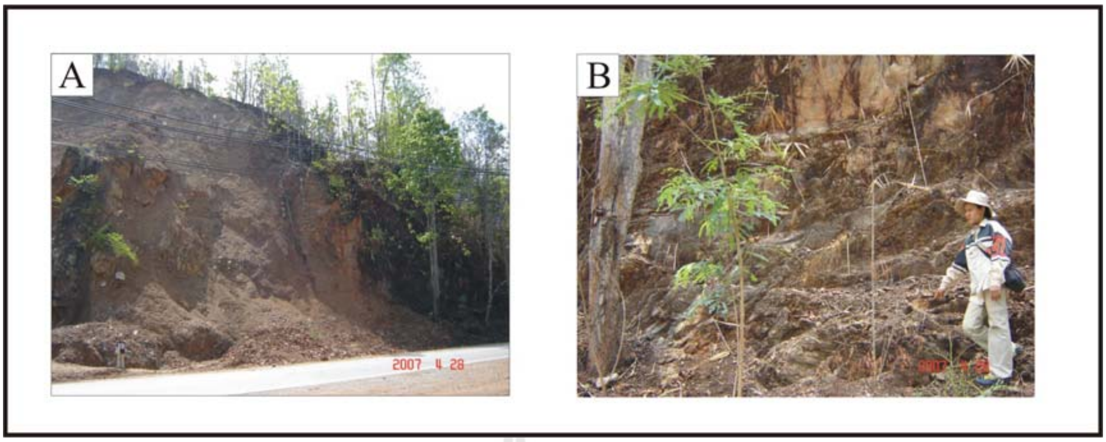


Figure 2.30 Photographs of Mae La Noi locality. A: Outcrop condition, B: Chert beds.

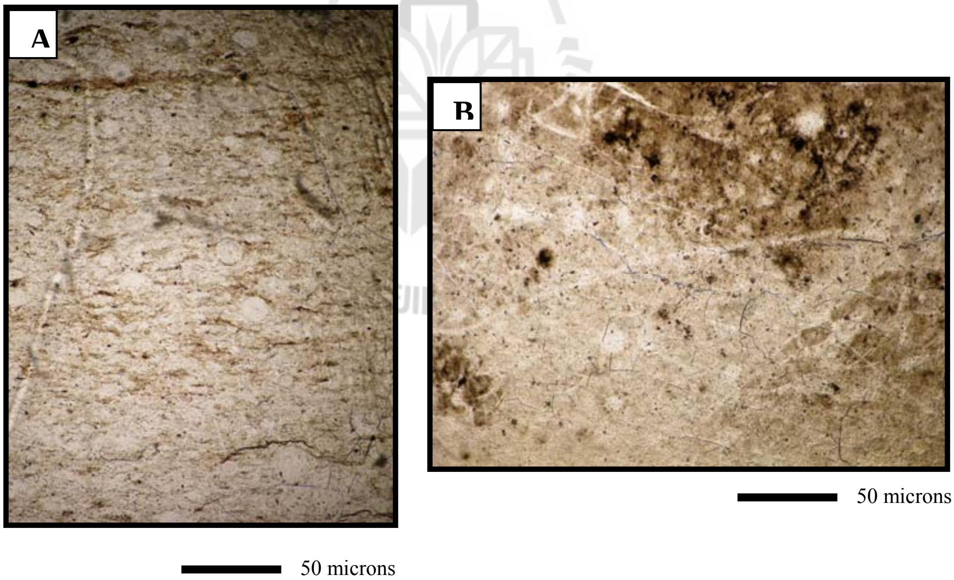


Figure 2.31 Photomicrographs of cherts from Mae La Noi locality. A: sample no. MLN 1-9, B: sample no. MLN 2-6.

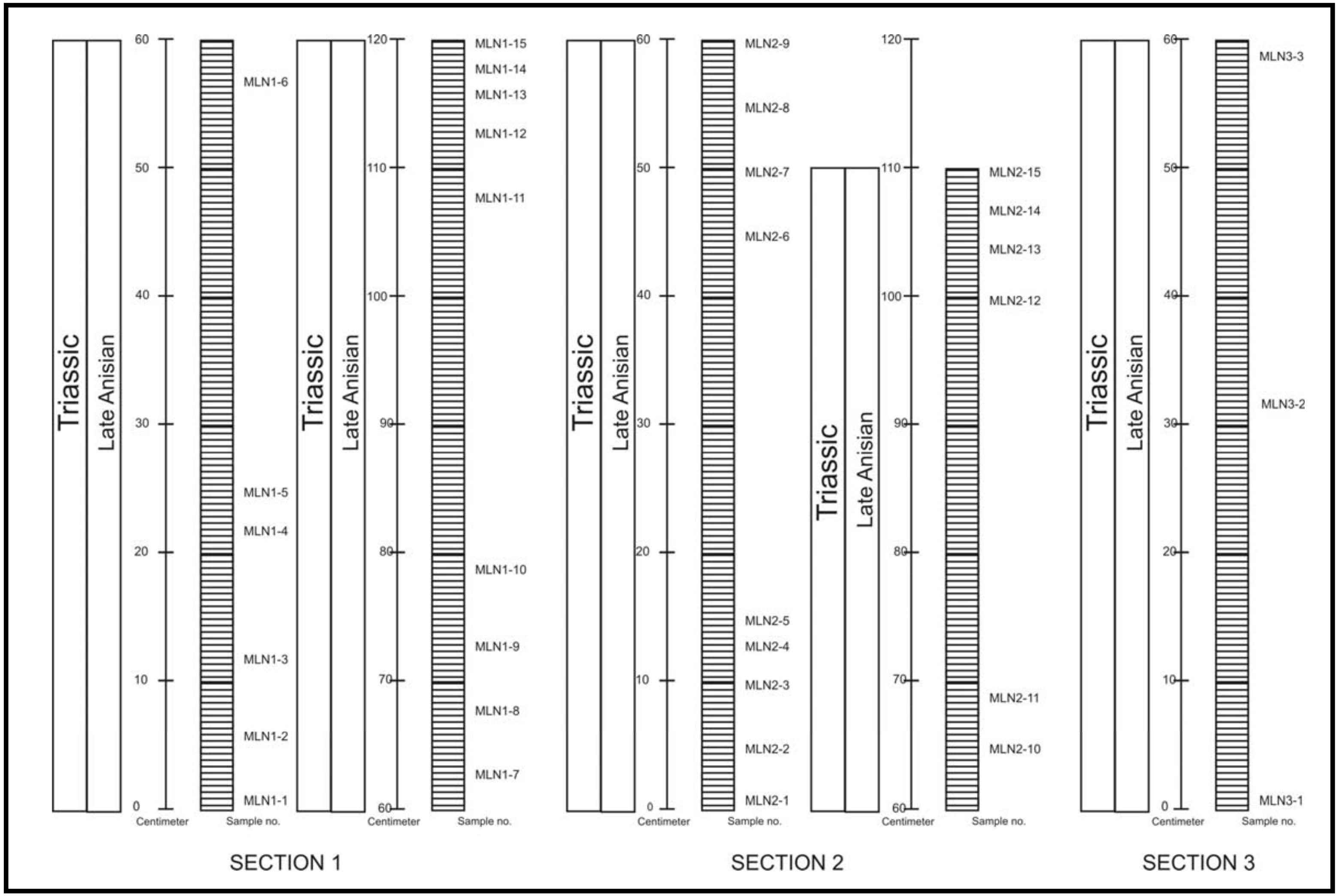


Figure 2.32 Stratigraphic column and sampling points with radiolarian ages of Mae La Noi locality

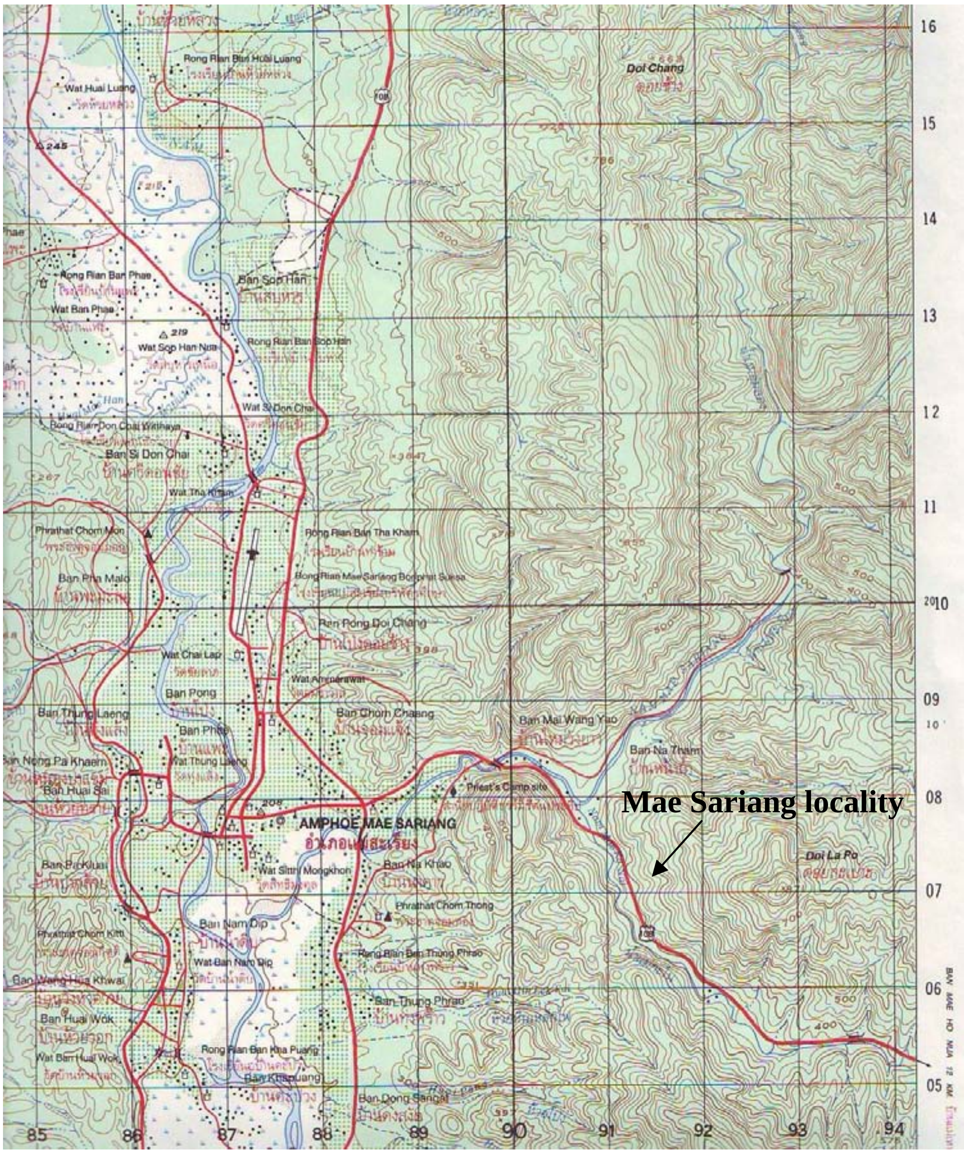


Figure 2.33 Topographic map showing location of Mae Sariang locality, which is located in map sheet Amphoe Mae Sariang (4545 II).

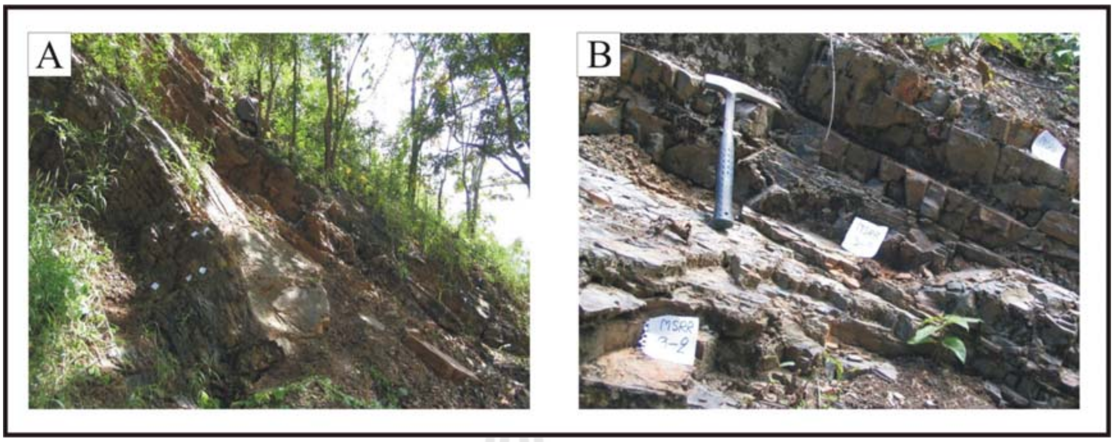


Figure 2.34 Photographs of Mae Sariang locality. A: Outcrop condition, B: Bedded cherts.

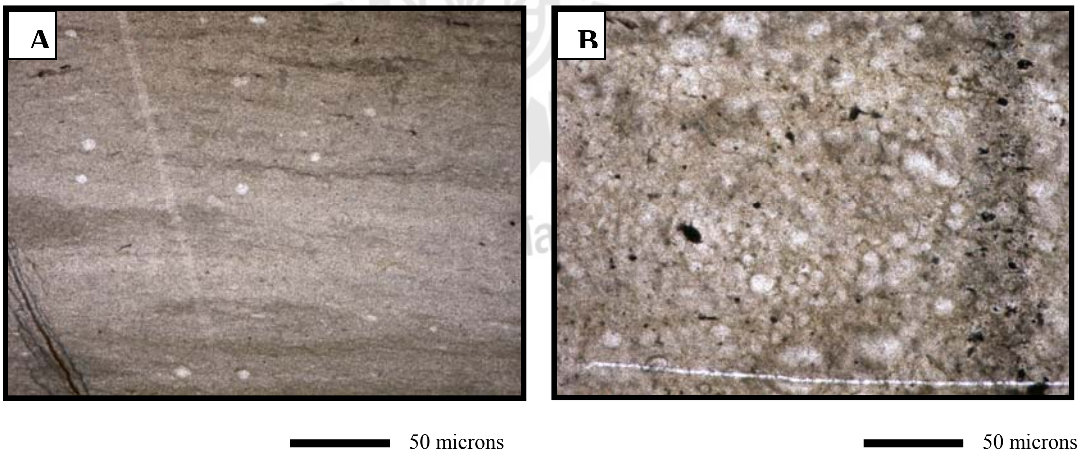


Figure 2.35 Photomicrographs of cherts from Mae Sariang locality, A: sample no. MSR 1-5, B: sample no. MSR 2-6.

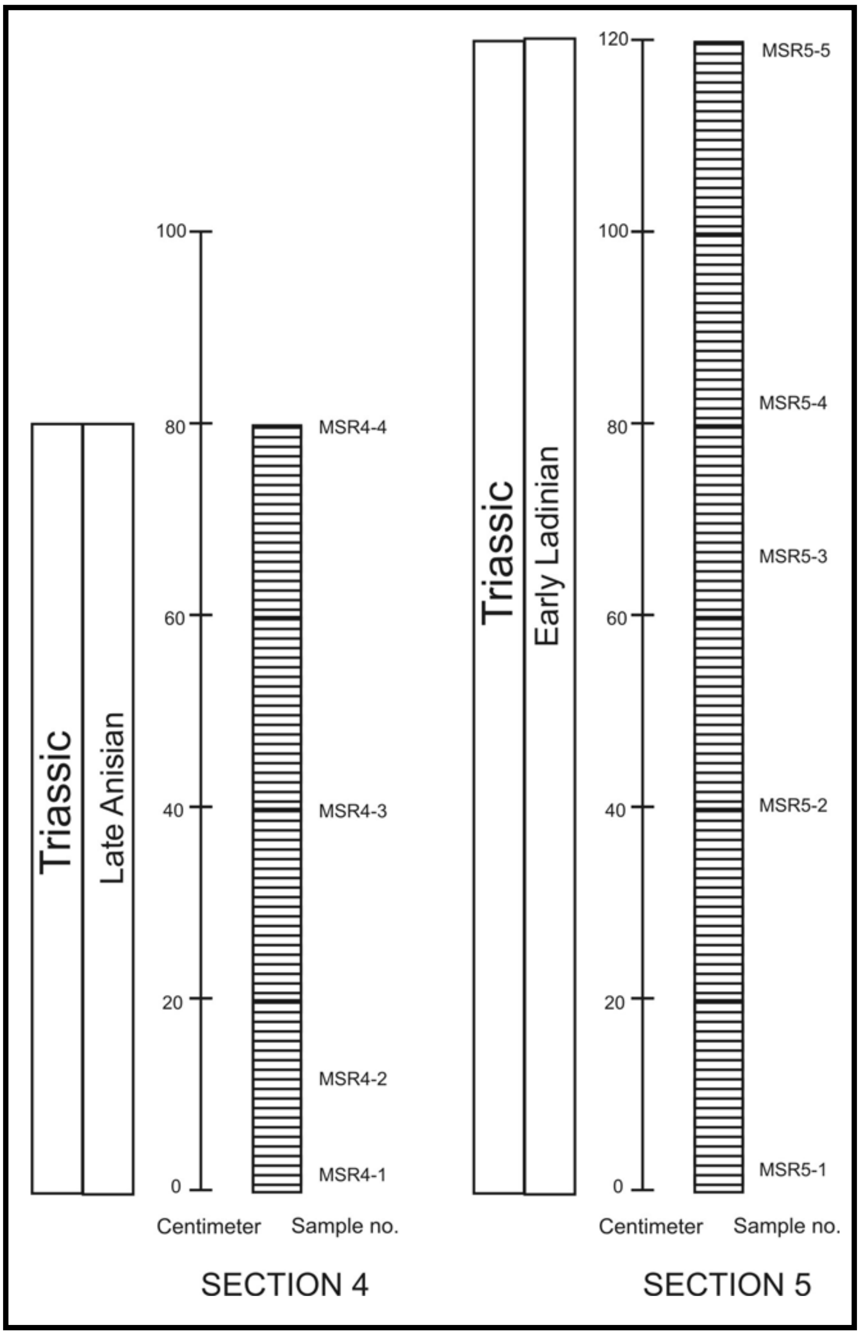


Figure 2.36 Stratigraphic column and sampling points with radiolarian ages of Mae Sariang locality.

CHAPTER III

SYSTEMATIC PALAEONTOLOGY

Radiolarians were extracted from chert and associated siliceous rock samples from northern Thailand. All of them are illustrated by means of Scaning Electronic Microscope and discussed in this chapter. Under the family level, taxa are listed in alphabetical order.

Phylum PROTOZOA

Subphylum SARCODINA

Class ACTINOPODA

Subclass RADIOLARIA Müller, 1858

Order POLYCYSTINA Ehrenberg, 1838 emend Riedel, 1967

Suborder SPUMELLARIA Ehrenberg, 1875

Superfamily ACTINOMMACEA Haeckel, 1862 emend. Kozur and Mostler, 1979

Family **XIPHOSTYLIDAE** Haeckel, 1862

Genus ***Archaeocenosphaera*** Pessagno and Yang, 1989

Type species: ***Archaeocenosphaera ruesti*** Pessagno and Yang, 1989

Archaeocenosphaera* sp. cf. *A. laseekensis Pessagno and Yang, 1989

Plate 1, Figure 6

cf. 1989 *Archaeocenosphaera laseekensis* n. sp. - Pessagno, Six and Yang, p.203, pl.2, figs. 18, 21, 22, 25

cf. 1993 *Archaeocenosphaera* sp. aff. *A. laseekensis* Pessagno and Yang- Carter, p.67, pl.1, figs. 14, 19, 20

cf. 1999 *Archaeocenosphaera* sp. - Bragin and Krylov, p.545, fig. 2F

Remarks: This form is similar to *A. laseekensis* Pessagno and Yang. It differs only in possessing smaller pores.

Range: Late Anisian to Late Ladinian

Occurrence: Denchai (DC) section

***Archaeocenosphaera* sp.**

Plate 1, Figure 7 and 8

Remarks: The most common specimens in this study have spherical cortical shells without spines. Pore frame is large polygonal, mostly pentagonal and hexagonal, or sometime roundish with small nodes at the vertices. They present two layered shell, but inner shell can not observed due to its preservation.

Range: Anisian to Carnian

Occurrence: Chiang Dao (CD), Denchai(DC), KYY, MLN, MSR, Km 119 and Km 175 section.

Family **ACTINOMMIDAE** Haeckel, 1862 emend. Kozur and Mostler, 1979

Genus ***Acanthosphaera*** Ehrenberg, 1858

Type species: ***Acanthosphaera haliphormis*** Ehrenberg, 1861

Acanthosphaera carterae Kozur and Mostler, 1996

Plate 1, Figure 1 and 2

1996 *Acanthosphaera carterae* n. sp.- Kozur and Mostler, p.221, pl.9, figs. 15-18

Remarks: Shell is sphaerical with large pentagonal or hexagonal pores. The vertices of pore frames bear tiny spines. Seven or eight small spines of different sizes lie around the shell. One of the largest spines is needle- like at distal end.

Range: Late Anisian

Occurrence: KYY section

Acanthosphaera nicorae Kozur and Mostler, 1996

Plate 1, Figure 3 and 5

1996 *Acanthosphaera nicorae* n. sp.- Kozur and Mostler, p.221, pl.8, fig. 9

Remarks: This species has a single sphaerical shell with large polygonal pores as other known of Triassic *Acanthosphaera* species. There are seven to eight tricarinate main spines, not longer than their shell diameter, around the shell. The base of these main spines is very broad and then tapering to the distal ends.

Range: Late Anisian

Occurrence: MLN and Km 175 section

Acanthosphaera sp.

Plate 1, Figure 4

Remarks: The specimens are very common in the studied materials. Cortical shell is spherical with large polygonal or even circular pore frames of different sizes and shapes. They also possess about ten small spines of different size and shape. There are three broad blades and wide grooves at proximal part then gradually needle- like distal ends.

Range: Late Anisian

Occurrence: CD, DC, KYY, MLN, and Km 175 section

Genus ***Astrocentrus*** Kozur and Mostler, 1979

Type species: ***Astrocentrus pulcher*** Kozur and Mostler, 1979

Astrocentrus sp.

Plate 3, Figure 10-12

Remarks: Specimens have small, spherical cortical shell with spongy pore frames. The spines are numerous with broad, long when compared with its shell, three bladed and with needle- like tips. The present specimens are quite similar to *A. pulcher* Kozur and Mostler, 1979, but differ by having broader spines and smaller poreframes. Moreover, they are similar to the type specimen of *Welirella mesotriassica* of Kozur, Krainer and Mostler, 1996 by having the same typical spines but differ by having smaller pore frames.

Range: Carnian

Occurrence: CD, MLN, and Km 119 section

Genus ***Triassospongosphaera*** Kozur and Mostler, 1981

Type species: ***Spongechinus triassicus*** Kozur and Mostler, 1979

Triassospongosphaera multispinosa (Kozur and Mostler, 1979)

Plate 17, Figure 9 and 10

1996 *Triassospongosphaera multispinosa* (Kozur and Mostler)- Kozur, Krainer and Mostler, p.222, pl.8, figs. 8, 12

Remarks: Cortical shell is small spherical form with small circular pore frames. There are numerous thin spines, three bladed proximally and rod- like distally. Their length is variable, but not shorter than their shell axes.

Range: Late Anisian to Middle Carnian

Occurrence: CD, KYY, Km 119, and Km 175 section

Family **PATULIBRACHIIDAE** Pessagno, 1971 emend. Baumgartner, 1980

Genus ***Paronaella*** Pessagno, 1971 emend. Baumgartner, 1980

Type species: ***Paronaella solanoensis*** Pessagno, 1971

***Paronaella* sp.**

Plate 18, Figure 18 and 19

Remarks: The specimens placed here are well correlated with genus *Paronaella* based on the general outline of arms and shell. The specimens, however, are poorly preserved. It is difficult to assign a specific name. It is similar to *P. elegans* Pessagno, 1977 by having a single spine on each arm tip, but differs by possessing finer pore frames. It isalso similar to *P.claviformis* (Kozur and Mostler, 1978) in character of pore frames, but the latter have no spine on the ray tips.

Range: Ladinian to Carnian

Occurrence: DC section

Family **PANTANELLIIDAE** Pessagno, 1977

Genus ***Pantanellium*** Pessagno, 1977

Type species: ***Pantanellium riedeli*** Pessagno, 1977

***Pantanellium* sp.**

Plate 14, Figure 10 and 11

Remarks: Shell is subspherical to spherical. Pore frames are large polygonal, mostly pentagonal or hexagonal pore frames, and having nodes at the vertices. There are two triradiate polar spines with three wide grooves between three ridges. One polar spine is slightly longer than the other.The polar spines are tapered from the lateral side of cortical shell with convex constriction below the base before gradually widening and tapering to needle- like ends. From these basic characteristics, it can be correlated to this genus. However, the specimens are quite similar to *Pantanellium riedeli* (Pessagno, 1977, only plate 6, figure 11) and *Pantanellium* sp. reported from Northern

Thailand by Sashida et al., 2000 by having the same characteristics of both cortical shell and polar spines.

Range: Anisian

Occurrence: CD section

Family **STYLOSPHAERIDAE** Haeckel, 1882

Genus ***Spongostylus*** Haeckel, 1882

Type species: ***Spongostylus hastatus*** Haeckel, 1882

Spongostylus tricostatus Kozur, Krainer and Mostler, 1996

Plate 14, Figure 12 and 13

1990 *Spongopallium* cf. *koppi* (Lahm)- Goričan and Buser, p.157, pl.4, figs. 2-4

1995 *Spongopallium* sp.- Ramovš and Goričan, pl.1, figs. 6-7

1996 *Spongostylus tricostatus* n.sp.- Kozur,Krainer and Mostler, p. 227, pl.6, fig. 16

1999 *Spongostylus tricostatus* Kozur,Krainer and Mostler- Sashida, Kamata, Adachi and Munasri, p.771, fig. 8.9

Remarks: This species is characterized by having relatively small cortical shell with big polar spines. Its cortical shell is rather globular with densely spongy pore frames. Its size is small by comparison with its polar spines. The polar spines are very big and long. They are three sharp blades with deep, wide V- shaped furrows between the blades. The polar spines are parallel sided from the proximal part to before the distal ends and they abruptly narrow to the needle- like ends. However, a specimen with one slightly twisted spine also occurs in the materials.

Range: Late Anisian to Early ladinian

Occurrence: CD, KYY, and MLN section

Spongostylus tetrapterus (Ramovš and Goričan, 1995)

Plate 14, Figure 15

1995 *Spongopallium*? *tetrapterum* n.sp.- Ramovš and Goričan, p.190, pl.1, figs. 1-5

1996 *Spongostylus*? *tetrapterus* (Ramovš and Goričan) - Kozur, Krainer and Mostler, p. 228

Remarks: There is only one specimen obtained from the materials. The cortical shell of the test is small with a spherical spongy shell as in other species of the genus *Spongostylus.* The important characteristic of this species is four-bladed of polar spines. Two polar spines have wide furrows between the blades. They display parallel sided proximally. Distally, they rapidly taper to the ends with short thickened spine tips. *S. tricostatus* is very similar to this species, however, it differs by displaying three-bladed of polar spines with needle-like spine tips.

Range: Anisian to Ladinian

Occurrence: CD section

Spongostylus tortilis Kozur and Mostler, 1979

Plate 14, Figure 14

1999 *Spongostylus tortilis* Kozur and Mostler- Tekin, p.67, pl.2, figs. 7, 8

Remarks: It is characterized by spongy shell with two twisted polar spines which are long and strong with dextral torsion.

Range: Late Ladinian

Occurrences: Km 119 section

***Spongostylus* sp. A**

Plate 14, Figure 18 and 19

Remarks: The present specimens have a sub- globular to globular cortical shell. They are spongy meshwork surface with four to six needle- like rays around the outer shell. Polar spines are thin and equal in size, but specimens with unequal polar spines also occur in the materials. The polar spines display three narrowed blades at the base. After one third of their total length, they have three rod- like or very thin blades tapering toward the distal ends to needle-like points. The polar spines are the same length as shell diameter or a little bit longer. This species is tentatively assigned to this genus by its spongy shell but differ from other species in the same genus by having the rays pointing around the outer shell.

Range: Anisian

Occurrence: CD section

***Spongostylus* sp. B**

Plate 14, Figure 16

Remarks: The spongy shell is sub- globular to globular shape. Two polar spines are unequal in length, with one is twice long as the other. The longer one is long as the shell diameter. The polar spines are thin and have three blades proximally before gradually tapering with needle-like at the distal ends. They differ from *Spongostylus* sp.A by having unequal polar spines and have no rays around the shell.

Range: Anisian

Occurrence: CD section

Genus ***Staurolonche*** Haeckel, 1882

Typec species: ***Staurolonche robusta*** Rüst, 1885

Staurolonche trispinosum trilobum (Nakaseko and Nishimura, 1979)

Plate 14, Figure 17

1979 *Staurosphaera triloba* n. sp.- Nakaseko and Nishimura, p.72, pl.5, figs. 1, 2

1980 *Stauracontium*? *trispinosum ladinicum* n. sp.- Dumitrică, Kozur & Mostler, p.17, pl.1, fig. 5(?); pl.2, fig. 4; pl.3, figs. 6, 7; pl.5, fig. 4; pl.14, figs. 4, 5

1990 *Stauracontium*? *trispinosum* (Kozur and Mostler)- Goričan and Buser, p.158, pl.1, fig. 2

1996 *Staurolonche trispinosum trilobum* (Nakaseko and Nishimura)- Kozur,Krainer and Mostler, p. 228, pl.10, fig. 16

Remarks: Shell is globular with four three- bladed main spines at right angle to each other. Each main spine has three short distal spinules directed obliquely centrifugally. A needle- like prolongation is present in all main spines.

Range: Late Anisian to Early Ladinian

Occurrence: KYY section

Genus ***Vinassaspongus*** Kozur and Mostler, 1979

Type species: ***Vinassaspongus subsphaericus*** Kozur and Mostler, 1979

Vinassaspongus erendili Tekin, 1999

Plate 14, Figure 21 and 22

1999 *Vinassaspongus erendili* n. sp.- Tekin, p.68, pl.2, figs. 9, 10

2005 *Vinassaspongus erendili* Tekin- Feng et al., p.243, pl.1, fig. 11

Remarks: Cortical shell is globular with three strong spines twisted in a dextral direction.

Range: Late Ladinian to Early Carnian

Occurrence: Km 119 and Km 175 section

Family **STAUROLONCHIDAE** Haeckel, 1881 emend. Pessagno, 1977

Genus ***Plafkerium*** Pessagno, 1979

Type species: ***Plafkerium abbotti*** Pessagno, 1979

Plafkerium contortum Dumitrică, Kozur and Mostler, 1980

Plate 17, Figure 15 and 16

1979 *Plafkerium*? *contortum* n. sp.- Dumitrică , Kozur and Mostler, p.13, pl.1, fig. 4

2003 *Tetraspongodiscus nazarovi* (Kozur and Mostler)- Feng and Liang, p.225, pl.2, fig. 13

Remarks: Cortical shell is circular and covered with very fine pores on shell surface. It is composed of four strongly twisted three bladed spines. They are situated in two axes at right angle to each other. The twisted position starts at midlength of the spine and displays sinistral torsion. The distal part ends in needle- like tips. Specimens herein are well correlated to the type specimen of *Plafkerium*? *contortum* (Dumitrică , Kozur and Mostler). It differs from *Tetraspogodiscus nazarovi* (Kozur and Mostler) in having shorter spines.

Range: Anisian to Ladinian

Occurrenes: CD section

Plafkerium antiquum Sugiyama, 1992

Plate 17, Figure 13 and 14

1980 *Staurosphaera*(?) sp. A- Yao, Matsuda and Isozaki, pl.1, fig. 5

1980 *Staurosphaera*(?) sp. B- Yao, Matsuda and Isozaki, pl.1, fig. 6

1992 *Plafkerium*(?) *antiquum* n. sp.- Sugiyama, p.1218-1219, figs. 18-4, 5 and 6

Remarks: Specimens placed here are poorly preserved. Cortical shell is subspherical to spherical with spongy meshwork. They have four non- twisted spines at right angles. All four spines are thin and needle- like distally and rod- like or three bladed tapering from the proximal part to the middle part.

Range: Anisian

Occurrence: CD section

Superfamily **SPONGURACEA** Haeckel, 1862 emend. Kozur and Mostler, 1981

Family **ARCHAEOSPONGOPRUNIDAE** Pessagno, 1973

Genus ***Archaeospongoprunum*** Pessagno, 1973 emend. Kozur and Mostler, 1981

Type species: ***Archaeospongoprunum venadoense*** Pessagno, 1973

Archaeospongoprunum bispinosum Kozur and Mostler, 1981

Plate 6, Figure 11

1994 *Archaeospongoprunum bispinosum* Kozur and Mostler- Kozur and Mostler, p.53, pl.7, figs. 1-2

Remarks: Shell is spindle- shaped with two opposite sides of axial spines. One side have two polar spines enclose together. The other spine is longer than the opposite axial spine.

Range: Late Anisian

Occurrence: MLN section

Archaeospongoprunum mesotriassicum mesotriassicum Kozur and Mostler, 1981

Plate 6, Figure 15-18

1994 *Archaeospongoprunum mesotriassicum mesotriassicum* Kozur and Mostler-
Kozur and Mostler, p.53, pl.7, fig. 3

2005 *Archaeospongoprunum* sp. cf. *A. mesotriassicum*- Wonganan, p.260, pl.50, fig. 13

Remarks: This species characterized by having two polar spines with one generally shorter than the other in the opposite side. All spines are tricarinate and point straight in distal ends. Shell is symmetrically spindle- shaped and consists of fine-spongy meshwork structure. However, some of the present specimens have thinner shell and two polar spines larger than the type specimens of *A.m.mesotriassicum* by Kozur&Mostler, 1981.

Range: Late Anisian

Occurrence: CD, and MLN section

Archaeospongoprunum* sp. cf. *A. m. mesotriassicum Kozur and Mostler, 1981

Plate 6, Figure 19-21

Remarks: The present specimens are similar to *A.m.mesotriassicum* but differ slightly by having a thinner spindle- shaped shell. Two spines are large. One polar spine is nearly twice as long as the opposite spine. All spines are tricarinate but some specimens show torsion.

Range: Late Anisian

Ocurrence: CD section

Archaeospongoprunum mesotriassicum asymmetricum Kozur and Mostler, 1981

Plate 6, Figure 12-14

1994 *Archaeospongoprunum mesotriassicum asymmetricum* Kozur and Mostler-Kozur and Mostler, p.53, pl.7, fig. 4

Remarks: This species differs from *A.m. mesotriassicum* by having one side of the shell convex and the other side straight resulting in an asymmetrically spindle- shaped shell.

Range: Anisian

Occurrence: CD, and MLN section

Family **GOMBERELLIDAE** Kozur and Mostler, 1981

Genus ***Karnospongella*** Kozur and Mostler, 1981

Type species: ***Karnospongella bispinosa*** Kozur and Mostler, 1981

Karnospongella bispinosa Kozur and Mostler, 1981

Plate 17, Figure 12

1990 *Gomberellus bispinosus* (Kozur and Mostler)- Goričan and Buser, p.146, pl.1, fig. 10

1994 *Karnospongella bispinosa* (Kozur and Mostler)- Kozur and Mostler, p.57

1999 *Karnospongella bispinosa* (Kozur and Mostler)- Tekin, p.103, pl.14, figs. 6, 7

Remarks: Based on the description of Kozur and Mostler (1994) under genus *Karnospongella*, this species display two twisted spines. It differs from two twisted main spines of typical Fassanian *Gomberellus* by having stronger twisted spines than the latter.

Range: Late Ladinian to Early Norian

Occurrence: Km 119 section

Family **INTERMEDIELLIDAE** Lahm, 1984

Genus ***Paurinella*** Kozur and Mostler, 1981

Type species: ***Paurinella curvata*** Kozur and Mostler, 1981

Paurinella aequispinosa Kozur and Mostler, 1981

Plate 16, Figure 11 and 12

1994 *Paurinella aequispinosa* Kozur and Mostler- Kozur and Mostler, p. 72, pl.15, figs. 9 and 11

2001 *Paurinella aequispinosa* Kozur and Mostler- Feng, Zhang and Ye, p.196, pl.7, fig. 14

Remarks: Test is subspherical to spherical or discoidal with spongy shell. It has no by- spines. There are three main spines displaying equal, straight and round in cross section. They are situated in the lateral plane. The spines are robust with needle- like ends.

Range: Early Ladinian

Occurrence: CD section

***Paurinella* sp. cf. *P. curvata* Kozur and Mostler, 1981**

Plate 16, Figure 13

cf. 1994 *Paurinella curvata* Kozur and Mostler- Kozur and Mostler, p.71, pl.15, figs. 1-3, 8

cf. 2001 *Paurinella* sp. cf. *P. curvata*- Kozur and Mostler- Feng, Zhang and Ye, p.196, pl.7, figs. 5-7

Remarks: This present specimens are not well preserved. It differs from *P. aequispinosa* by showing curved of the three main spines but not in the same direction.

Range: Early Ladinian

Occurrence: CD section

Paurinella* sp. cf. *P. trettoensis Kozur and Mostler, 1994

Plate 16, Figure 16

cf. 1994 *Paurinella trettoensis* n. sp.- Kozur and Mostler, p.74, pl.15, fig. 15

Remarks: Only one specimen is obtained. It is rather poorly preserved. However, it can be related to *P. trettoensis* by the characteristic of main spines. The three main spines are thin with one spine is longer than other two. Unfortunately, shell is not well enough preserved to observe more fully.

Range: Early Ladinian

Occurrence: CD section

***Paurinella* sp.**

Plate 16, Figure 14, 15, 17 and 18

Remarks: The specimens are broken and poorly preserved. Although they have limit of preservation, we can tentatively assign them to this generic from its outer characteristic.

Range: Early Ladinian

Occurrence: CD, KYY, MLN, MSR, and Km 175 section

Genus ***Tetrapaurinella*** Kozur and Mostler, 1994

Type species: ***Tetrapaurinella discoidalis*** Kozur and Mostler, 1994

***Tetrapaurinella* sp.**

Plate 17, Figure 8

Remarks: The specimens are very rare in the materials. Moreover, they are imperfect. They do, however, show the four main spines with no direction.

Range: Early Ladinian

Occurrence: CD section

Family **OERTLISPONGIDAE** Kozur and Mostler, 1981

Genus ***Baumgartneria*** Dumitrică, 1982

Type species: ***Baumgartneria retrospina*** Dumitrică, 1982

Baumgartneria ambigua Dumitrică, 1999

Plate 3, Figure 1

1999 *Baumgartneria ambigua* n. sp.- Dumitrică, p.37, pl.1, figs. 4-8, 10, 12

Remarks: The specimens are rare. Main spine is circular in cross section with a moderately long stem and two distal asymmetrical branches. One branch is recurved making an angle about 60˚ - 75˚ with the stem. The other branch, is recurved and resembles the spine of *O. inaequispinosus*, arising a little over the bending level of the first branch.

Range: Early Ladinian

Occurrence: KYY section

Baumgartneria curvispina Dumitrică, 1982

Plate 3, Figure 3

1996 *Baumgartneria curvispina* Dumitrică- Kozur and Mostler, p.109-110, pl.14, figs. 8, 9, 12

Remarks: It differs from *B. ambigua* by having a stem with downward curved symmetrical branches. It displays a straight portion opposite to the stem.

Range: Late Ladinian

Occurrence: KYY, Km 119, and Km 175 section

Baumgartneria* sp. cf. *B. curvispina Dumitrică, 1982

Plate 3, Figure 2

cf. 1996 *Baumgartneria curvispina* Dumitrică- Kozur and Mostler, p.109-110, pl.14, fig. 12

Remarks: This specimen is similar to *B. curvispina* morphotype 1 in Kozur and Mostler (1996). It presents a round subtriangular small blade above the long straighted stem.

Range: Late Ladinian

Occurrence: Km 119 section

Baumgartneria retrospina Dumitrică, 1982

Plate 3, Figure 4-6

1994 *Baumgartneria retrospina* Dumitrică- Kozur and Mosler, p.63, pl.12, figs. 1, 4, 6, 8, 9

2003 *Baumgartneria retrospina* Dumitrică- Feng and Liang, p.224, pl.1, figs. 14, 15, 16, 19

Remarks: This species has a stem with two slightly down curved symmetrical branches. The opposite portion to the stem displays broad and triangular axial spine.

Range: Early Ladinian

Occurrence: KYY section

Baumgartneria yehae Kozur and Mostler, 1994

Plate 3, Figure 7

1994 *Baumgartneria yehae* n. sp.- Kozur and Mostler, p.65, pl.12, figs. 2, 11

1994 *Baumgartneria retrospina* Dumitrică- Kozur and Mosler, p.63, pl.12, fig. 5

1999 *Baumgartneria yehae* Kozur and Mostler- Dumitrică, p.37, pl.2, figs. 3, 4, 6, 7, and 9

Remarks: The stem is moderately long with asymmetrical branches. The form is similar to *B. ambigua* but differs by having the triangular axial spine opposite the stem.

Range: Early Ladinian

Occurrence: KYY section

Genus ***Bogdanella*** Kolar- Jurkovšek, 1989

Type species: ***Bogdanella trentana*** Kolar- Jurkovšek, 1989

***Bogdanella* sp.**

Plate 3, Figure 8 and 9

Remarks: The specimen is incomplete but presents the characteristic of this genus with its corkscrew- like twisted polar spine.

Range: Late Ladinian

Occurrence: Km 119 section

Genus ***Falcispongus*** Dumitrică, 1982

Type species: ***Falcispongus falciformis*** Dumitrică, 1982

Falcispongus calcaneum Dumitrică, 1982

Plate 10, Figure 4 and 5

1990 *Falcispongus calcaneum* Dumitrică- Goričan and Buser, p.144, pl.3, figs. 4, 5, 6

1999 *Falcispongus calcaneum* Dumitrică- Dumitrică, p.38, pl.2, fig. 1

Remarks: The slender stem with recurved distal part is typical for this species. Moreover, it displays a narrow inner flattened wing on the main spine.

Range: Early Ladinian

Occurrence: KYY section

Genus ***Oertlispongus*** Dumitrică, Kozur and Mostler, 1980

Type species: ***Oertlispongus inaequispinosus*** Dumitrică, Kozur and Mostler, 1980

Oertlispongus inaequispinosus Dumitrică, Kozur and Mostler, 1980

Plate 11, Figure 10 and 11

1980 *Oertlispongus inaequispinosus* n. gen. n. sp.- Dumitrică, Kozur and Mostler, p.5, pl.10, fig. 7

1990 *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler- Goričan and Buser, p.148, pl.3, figs. 10, 11

1994 *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler- Kozur and Mostler, p.59, pl.10, figs. 1, 4, 7, 13; pl.47, fig. 6

1996 *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler- Kozur and Mostler, p.108-109, pl.14, figs. 10, 11

1999 *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler- Dumitrică, p.35, pl.1, figs. 1, 3

Remarks: This species has single long spines strongly curved in the middle region. The distal end is mostly below the shell level.However, the shell of these specimens is not preserved here. It represented only the isolated curved spine.

Range: Early Ladinian

Occurrence: KYY, MSR, and Km 119 section

Oertlispongus* sp. cf. *O. diacanthus Sugiyama, 1992

Plate 11, Figure 1 and 2

cf. 1992 *Oertlispongus diacanthus* n.sp.- Sugiyama, p.1217, figs. 17-10, 11 and 12

Remarks: The specimens placed here have a subspherical to spherical shell with spongy surface that is sometimes relatively fragile. Two equal polar spines are long, straight or sometimes slightly curved at the distal ends. They differ from the type specimens of *O.diacantus* of Sugiyama (1992) by having stronger polar spines.

Range: Anisian

Occurrence: CD section

Genus ***Paroertlispongus*** Kozur and Mostler, 1981

Type species: ***Paroertlispongus multispinosus*** Kozur and Mostler, 1981

Paroertlispongus chinensis (Feng, 1992)

Plate 10, Figure 16

1996 *Paroertlispongus chinensis* (Feng)- Kozur, p.291, pl.1, fig. 3

Remark: This species presents a cylindrical form with two unequaul polar spines. Cortical shell is spongy. It is characterised by several small and low ribs at the base of each polar spine.

Range: Late Anisian to Early Ladinian

Occurrence: KYY section

Paroertlispongus multispinosus Kozur and Mostler, 1981

Plate 10, Figure 10-12

1994 *Paroertlispongus multispinosus* Kozur and Mostler- Kozur and Mostler, p.69, pl.12, fig. 10; pl.13, figs. 4, 11

1996 *Paroertlispongus multispinosus* Kozur and Mostler- Kozur, p.291, pl.1, fig. 1

1996 *Paroertlispongus multispinosus* Kozur and Mostler- Kozur and Mostler, p.230, pl.11, fig. 12

2001 *Paroertlispongus multispinosus* Kozur and Mostler- Feng, Zhang and Ye, p.192, pl.6, figs. 12, 14-18

Remarks: This species has a long main spine that widens from its proximal part, and, becomes widest behind its midlength and decreases in width distally. Typically, this species are obtained as isolated main spines.

Range: Late Anisian to Early Ladinian

Occurrence: CD, KYY, MLN, MSR, and Km 175 section

Paroertlispongus rarispinosus Kozur and Mostler, 1981

Plate 10, Figure 13-15

1994 *Paroertlispongus rarispinosus* Kozur and Mostler- Kozur and Mostler, p.69, pl.12, fig. 7

1996 *Paroertlispongus rarispinosus* Kozur and Mostler- Kozur, p.291, pl.1, fig. 2

2001 *Paroertlispongus rarispinosus* Kozur and Mostler- Feng, Zhang and Ye, p.192, pl.7, fig. 8

Remarks: This species is distinguished from other species of *Paroertlispongus* by being cylindrical in its proximal half, and then becomes needle-like towards its distal end. Specimens are preserved as isolated main polar spines, which is typical preservation for Oertlispongidae as described by Kozur, Krainer and Mostler (1996).

Range: Late Anisian to Early Ladinian

Occurrence: CD, KYY, MLN, and Km 175 section

Paroertlispongus daofuensis Feng, 2003

Plate 10, Figure 6-9

2001 Oertlispongid, gen. and sp. indt.- Hauser et al., pl.3, fig. 9

2003 *Paroertlispongus daofuensis* n. sp.- Feng, p.221, pl.1, figs. 4-6

Remarks: This is preserved only as isolated main spines. The spine is short, straight and circular in cross section. It increases in width from the lower part and reaches a maximum width at the middle part before gradually decreasing in width to the distal end with a needle tip. The central and distal parts before the tip are covered by many short and node- like spines.

Range: Ladinian

Occurrence: KYY section

Paroertlispongus* sp. aff. *P. daofuensis Feng, 2003

Plate 10, Figure 1 and 2

Remaks: The present specimens can be related to *P. daofuensis* Feng, 2003, but differ in having a morefinnely nodose surface.

Range: Ladinian

Occurrence: KYY section

Genus ***Pseudoertlispongus*** Lahm, 1984

Type species: ***Pseudoertlispongus weddigei*** Lahm, 1984

Pseudoertlispongus* sp. cf. *P. angulatus Kozur, 1996

Plate 11, Figure 3 and 4

cf. 1996 *Pseudoertlispongus angulatus* n. sp.- Kozur, p.291, pl.1, figs. 4, 5

Remarks: This species is characterised by distal end of the main polar spine being sharply inward curved. The angle with the straight axis is not more than 45˚. The straight proximal part is longer than the bent distal part. It differs from the type specimens *P. angulatus* Kozur (1996) by having the width of main spine before the angular bent narrower than the latter. Moreover, the length of distal part after the bend is longer than in *P. angulatus*.

Range: Upper most part of Late Anisian to Early Ladinian

Occurrence: CD, MSR section

Pseudoertlispongus mostleri mostleri Kozur, 1996

Plate 11, Figure 5 and 6

1996 *Pseudoertlispongus mostleri* n. sp.- Kozur, p.292, pl.1, figs. 6, 7

Remarks: Like others in genus *Pseudoertlispongus*, it is always preserved only by the isolated polar main spine. This subspecies has gently curved at the bend. The main polar spine is broadest before the bend. The distal part after the bend is short and the angle with the straight axis is not more than 45˚. The form of this species includes both forms *P. mostleri mostleri* and *P. mostleri siciliensis* (Kozur, 1996).

Range: Upper most part of Late Anisian to Early Ladinian

Occurrence: CD, KYY, and MSR section

Genus ***Scutispongus*** Kozur and Mostler, 1996

Type species: ***Scutispongus tortilisspinus*** Kozur and Mostler, 1996

***Scutispongus* sp.**

Plate 10, Figure 3

Remarks: The specimens represent only the stem with bilateral blades. Blade is large and flattened. It is terminated with needle- like tip.Unfortunately; one of the wings is missing, so the material is too poor to ascribe to a described species. They are tentalively assigned to this genus based on its typical characters.

Range: Late Ladinian (Longobadian)

Occurrence: Km 175 section

Genus ***Spongoserrula*** Dumitrică, 1982

Type Species: ***Spongoserrula rarauana*** Dumitrică, 1982

Spongoserrula rarauana Dumitrica, 1982

Plate 1, Figure 9-12

1995 *Spongoserrula rarauana* Dumitrică- Halamić and Goričan, p.136, pl.1, fig. 2

1996 *Spongoserrula rarauana* Dumitrică- Kozur and Mostler, p.115, pl.5, figs. 8, 10, 11, 13-15; pl.6, figs. 1-3, 6, 9; pl.8, fig. 9

1999 *Spongoserrula rarauana* Dumitrică- Tekin, p.106, pl.15, figs. 7-8

2002 *Spongoserrula rarauana* Dumitrică- Kamata et al., p.503, figs. 6N and O

Remarks: The illustrated poorly preserved specimen has wide flattened spine, strongly curved teeth. The ends of its teeth are rounded. Based on these features, we can tentatively assign it to this species.

Range: Late Ladinian

Occurrence: DC and Km 175 section

***Spongoserrula* sp.**

Plate 1, Figure 13 and 14

Remarks: Although the specimen is incomplete, it can be assigned to this genus by the presence of a big blade- like polar spine with needle- like subsidiary spines.

Range: Late Ladinian

Occurrence: Km 175 section

Genus ***Steigerispongus*** Kozur and Mostler, 1996

Type species: ***Steigerispongus subsymmetricus*** Kozur and Mostler, 1996

***Steigerispongus* sp.**

Plate 1, Figure 15 and 16

Remarks: The specimen is not completed. It shows only flated blade with needle-like spines at the rim as typical for this genus.

Range: Late Ladinian

Occurrence: Km 119 section

Family **PARASATURNALIDAE** Kozur and Mostler, 1972 emend. Kozur and Mostler, 1983

Genus ***Palaeosaturnalis*** Donofrio and Mostler, 1978 emend. Kozur and Mostler, 1981

Type species: ***Spongosaturnalis triassicus*** Kozur and Mostler, 1972

Palaeosaturnalis karnicus (Kozur and Mostler, 1972)

Plate 19, Figure 8

1999 *Palaeosaturnalis karnicus* (Kozur and Mostler) - Tekin, p.110, pl.16, fig. 10

Remarks: The present species is characterised by narrow circular ring with short small spines around the rim.

Range: Middle Carnian to Lower Norian

Occurrence: Km 119 section

Palaeosaturnalis triassicus (Kozur and Mostler, 1972)

Plate 19, Figure 6 and 7

1999 *Palaeosaturnalis triassicus* (Kozur and Mostler)- Tekin, p.111, pl.17, figs. 6, 7

Remarks: It differs from *P. karnicus* by having a wider ring than the latter. Spines are also longer, bigger and much more numerous.

Range: Middle Carnian to Lower Norian

Occurrence: Km 119 section

Family **ORBICULIFORMIDAE** Pessagno, 1973

Genus ***Orbiculiforma*** Pessagno, 1973

Type species: ***Orbiculiforma quadrata*** Pessagno, 1973

Orbiculiforma* sp. cf. *O. gazipasaensis Tekin, 1999

Plate 19, Figure 1

1999 *Orbiculiforma gazipasaensis* n. sp. - Tekin, p.118, p.20, figs. 5-7

Remarks: Test large and roughly circular in outline, without equatorial spines and with a moderately developed raised boss within the central cavity. The boss in our specimen is lower than that in the type specimens of *O. gazipasaensis*, Tekin.

Range: Late Ladinian to Early Carnian

Occurrence: DC section

Orbiculiforma goestlingensis (Kozur and Mostler, 1978)

Plate 19, Figure 2 and 3

1999 *Orbiculiforma goestlingensis* (Kozur and Mostler)-Tekin, p.118, pl.20, figs. 8, 9

Remarks: Test is circular with long three- bladed spines at periphery. Central cavity is missing. Large polygonal pore frames present at the shell.It differs from *O. karnica* by having broader and longer spines at periphery.

Range: Early to Middle Carnian

Occurrence: Km 119 section

Orbiculiforma karnica (Kozur and Mostler, 1978)

Plate 19, figure 4

1999 *Orbiculiforma karnica* (Kozur and Mostler) – Tekin, p.119, pl.20, fig. 10

2005 *Praeorbiculiformella karnica* (Kozur and Mostler) – Feng et al., p.247, pl.2, figs. 19, 20

Remarks: This species shows a circular test in outline with short spines at periphery. The central cavity is commonly missing. Our specimens are not well preserved but have similar features to the type specimens of *O.karnica* (Kozur and Mostler) in test, spines and shape of pore frames.

Range: Late Ladinian to Middle Carnian

Occurrence: DC, Km 119, and Km 175 section

Genus ***Pseudogodia*** Tekin, 1999

Type species: ***Pseudogodia sonmezi*** Tekin, 1999

***Pseudogodia*? sp.**

Plate 11, Figure 12-14

Remarks: The specimens have polygonal in outline. There are many strong nodes on shell surface. Pore frame is circular. It can compare to *P. sonmezi* Tekin, 1999 based on this outline but differs from the latter by have no byspines.

Range: Ladinian to Carnian

Occurrence: DC section

Superfamily **TREMATODISCACEA** Haeckel, 1862 emend. Kozur and Mostler, 1979

Family **RELINDELLIDAE** Kozur and Mostler, 1980 (in: Dumitrică, Kozur and Mostler, 1980)

Genus ***Pentaspongodiscus*** Kozur and Mostler, 1979

Type species: ***Pentaspongodiscus tortilis*** Kozur and Mostler, 1979

Pentaspongodiscus mesotriassicus Dumitrică, Kozur and Mostler, 1980

Plate 17, Figure 1 and 2

1981 *Pentaspongodiscus mesotriassicus* n. sp.- Dumitrică , Kozur and Mostler, p.10, pl.8, fig. 7

1990 *Pentaspongodiscus mesotriassicus* Dumitrică , Kozur and Mostler- Goričan and Buser, p.151, pl.2, figs. 1, 2

1996 *Pentaspongodiscus mesotriassicus* Dumitrică , Kozur and Mostler- Kozur, Krainer and Mostler, p.231, pl.4, fig. 14

Remarks: Although, the specimens are very poorly preserved. They can be assigned to this species by its spine forming structure. Based on the description by Dumitrică, Kozur and Mostler (1980), this species has six spines with small to medium sized central spongy disc. All six spines are quite slender, long, three bladed and slightly twisted. Moreover, they always end with needle-like tips. This species is easily to distinguish from *P. tortilis ladinicus* (Dumitrică, Kozur and Mostler.1980) because the latter has five slender spines.

Range: Late Anisian to Early Ladinian

Occurrence: CD section

Pentaspongodiscus steigeri Lahm, 1984

Plate 17, Figure 3 and 4

1996 *Pentaspongodiscus steigeri* Lahm- Kozur and mostler, p.231, pl.4, fig. 15

1999 *Pentaspongodiscus steigeri* Lahm- Tekin, p.122, pl.22, figs. 8, 9

Remarks: It is a spongy shell with six strongly dextrally twisted spines. Each is straight before torsion and end with needle tips.

Range: Late Anisian to Early Ladinian

Occurrence: Km 119 section

Pentaspongodiscus symmetricus Dumitrică, Kozur and Mostler, 1980

Plate 17, Figure 5

1980 *Pentaspongodiscus symmetricus* n.sp.- Dumitrică , Kozur and Mostler, p.10, pl.8, fig. 4

1990 *Pentaspongodiscus symmetricus* Dumitrică , Kozur and Mostler- Goričan and Buser, p.151, pl.2, fig. 5

Remarks: As discussed by Dumitrică, Kozur and Mostler (1980), this species has a symmetrical arrangement of the six long three bladed spines in the equatorial plane. The characteristic that differ from other species in the same genus is all six spines are straight without any torsion. Only one specimen was obtained from the materials.

Based on the above description, the specimen shown here can correlate to this species by its form.

Range: Late Anisian to Early Ladinian

Occurrence: CD section

Genus ***Tetraspongodiscus*** Kozur and Mostler, 1979

Type species: ***Tetraspongodiscus tortilis*** Kozur and Mostler, 1979

Tetraspongodiscus nazarovi (Kozur and Mostler, 1981)

Plate 17, Figure 6 and 7

1999 *Tetraspongodiscus nazarovi* (Kozur and Mostler)- Tekin, p.122, pl.22, fig. 10

Remarks: This species has spongy shell with four spines with strong dextral torsion at right angle to each other.

Range: Early Ladinian to Middle Carnian

Occurrence: Km 119 section

Suborder **ENTACTINARIA** Kozur and Moster, 1982

Family **AUSTRISATURNALIDAE** Kozur and Mostler, 1983

Genus ***Praeheliostaurus*** Kozur and Mostler, 1972

Type species: ***Praeheliostaurus goestlingensis*** Kozur and Mostler, 1972

Praeheliostaurus levis Kozur and Mostler, 1972

Plate 19, Figure 5

2005 *Praeheliostaurus levis* Kozur and Mostler- Feng et al., p.249, pl.2, fig. 17

Remarks: The species is represened by central circular cortical shell surrounded by ring of curved plate with short spines at margin. Cortical shell is elevated. Pore frames are subcircular to polygonal pores. Number of spines is uncertain because of incomplete nature of the specimen.

Range: Late Ladinian to Early Carnian

Occurrence: Km 119 section

Praeheliostaurus quadrispinosus Mostler and Krainer, 1994

Plate 19, Figure 9

1997 *Praeheliostaurus levis* Kozur and Mostler- Sugiyama, p.185, fig. 48-25

1999 *Ornatisaturnalis quadrispinosus* Mostler and Krainer- Tekin, p.125, pl.24, fig. 5

Remarks: This species differs from *P. levis* in having straight instead of curved maginal plate.

Range: Late Ladinian to Early Carnian

Occurrence: Km 119 section

***Praeheliostaurus* sp.**

Plate 19, Figure 10

Remarks: There is only one specimen obtained from materials. Due to poor preservation, it can not assign to the right species. However, it can be placed into this genus based on the characteristics of the test.

Range: Anisian to Ladinian

Occurrence: DC section

Family **EPTINGIIDAE** Dumitrică, 1978

Genus ***Cryptostephanidium*** Dumitrică, 1978

Type species: ***Cryptostephanidium cornigerum*** Dumitrică, 1978

Cryptostephanidium cornigerum Dumitrică, 1978

Plate 9, Figure 1-4

1978 *Cryptostephanidium cornigerum* n. sp.- Dumitrică, p. 31, pl. 1, figs. 1-4; pl. 4, fig. 4

1982 *Cryptostephanidium* cf. *cornigerum* Dumitrică- Yao, pl. 1, fig. 16

1990 *Cryptostephanidium cornigerum* Dumitrică- Goričan and Buser, p. 142, pl. 8, figs. 1-3

1995 *Cryptostephanidium cornigerum* Dumitrică- Ramovš and Goričan, p. 184, pl. 5, fig. 3

1996 *Cryptostephanidium cornigerum* Dumitrică- Kozur, Krainer and Mostler, p. 207, pl. 10, fig. 12

Remarks: This species is characterized by a globular cephalic and meshwork surface with triangular, quadrangular or irregular meshes dividing into different sizes. All three spines are three- bladed and gradually taper toward the distal end. Their length is usually unequal, with one longer than other two. Angles between the spines are also unequal. *C. verrucosum* Dumitrică, 1978 is distinguished from this species by its much longer horns with needle- shaped ends and its verrucose surface.

Range: Late Anisian to Early Ladinian

Occurrence: CD, KYY, and Km 175 section

Genus ***Eptingium*** Dumitrică, 1978

Type species: ***Eptingium manfredi*** Dumitrică, 1978

Eptingium manfredi manfredi Dumitrică, 1978

Plate 8, Figure 8-11

1978 *Eptingium manfredi* n. sp.- Dumitrică, p. 33-34, pl. 3, figs. 3, 4; pl.4, figs. 1-3, 5-7

1979 *Eptingium manfredi* Dumitrică - Pessagno, Finch and Abbott, 1979, pl. 6, figs. 9-11

1980 *Eptingium manfredi manfredi* Dumitrică - Dumitrică, Kozur and Mostler, p.19-20, pl. 3, figs. 1-3; pl. 6, figs. 5-7

1982 *Eptingium* sp. cf. *E. manfredi* Dumitrică- Matsuda and Isozaki, pl. 3, fig. 25

1982 *Eptingium* sp. cf. *E. manfredi* Dumitrică- Yao, p. 55, pl. 1, fig. 17

1990 *Eptingium manfredi* Dumitrică- Goričan and Buser, p. 144, pl. 8, figs. 7, 8

1994 *Eptingium manfredi manfredi* Dumitrică- Kozur and Mostler, p. 42, pl. 1, fig. 3

1996 *Eptingium manfredi manfredi* Dumitrică- Kozur and Mostler, p. 204-205, pl.10, figs. 1-4, 6, 10

1999 *Eptingium manfredi* Dumitrică- Sashida et al., p. 773, figs. 6.16-6.17

2000 *Eptingium manfredi* Dumitrică- Sashida et al., p. 806, figs. 9.13-9.16

2002 *Eptingium manfredi* Dumitrică- Feng et al., p. 110-111, pl. 1, figs. 7-10; pl.2, fig. 8

Remarks: The present specimens have three-bladed spines of variable shape, size and twisting degree as discussed by Dumitrică (1978). However, the illustrated specimens have unequal angles between the spines in the same plane, deep secondary furrows and some transverse bridges between the ridges in each spine. The distal ends of the spines are pointed or slightly rounded.

Range: Anisian to Ladinian

Occurrence: CD, KYY, MLN, and MSR section

Eptingium manfredi japonicum Nakaseko and Nishimura, 1979

Plate 8, Figure 5-7

1979 *Tripocyclia japonica* n. sp.- Nakaseko and Nishimura, p.73, pl.4, figs. 4-5

1993 *Eptingium manfredi* Dumitrică- Sashida et al., p.82, 84, figs. 6-1, 2

1993 *Eptingium*? sp., pars- Sashida et al., p. 84, fig. 6-5

1995 *Eptingium nakasekoi* Kozur and Mostler- Ramovš and Goričan, p. 185, pl.5, fig. 10

1996 *Eptingium manfredi japonicum* Nakaseko and Nishimura- Kozur, Krainer and Mostler, p.205, pl.10, fig. 7

Remarks: This subspecies has the same unequal angle between three spines as *E. manfredi manfredi* but it is easily distinguished from the latter by having no secondary furrow and transverse bridge on spines. Moreover, there is slightly twisted in distal end of one spine and one angle between the spines is larger than the other two angles. The undivided blades of spines are narrow to moderately wide.

Range: Anisian to Ladinian

Occurrence: CD and KYY section

Eptingium nakasekoi Kozur and Mostler, 1994

Plate 8, Figure 1-4

1979 *Tripocyclia* cf. *acythus* De Wever- Nakaseko and Nishimura, p.72-73, pl.4, figs. 1-3

1993 *Eptingium*? sp., pars- Sashida et al., p. 84, figs. 3, 4

1994 *Eptingium nakasekoi* n. sp.- Kozur and Mostler, p.43, pl. 1, fig. 5

1996 *Eptingium nakasekoi* Kozur and Mostler- Kozur, Krainer and Mostler, p. 205, pl. 11, fig. 11

Remarks: It is easily distinguished from other *Eptingium* because angles between three spines are equal. The distal part of all spines is straight and the undivided blades are narrow. *E.ramovsi* Kozur, Krainer and Mostler, 1996 is quite similar to *E.nakasekoi* but the former differ from the latter by all main spines being twisted.

Range: Anisian

Occurrence: CD and KYY section

Eptingium ramovsi Kozur and Mostler, 1996

Plate 8, Figure 12-14

1979 *Tripocyclia japonica* n. sp.- Nakaseko and Nishimura, p.73, pl.4, fig. 6

1994 *Eptingium manfredi japonicum* Nakaseko and Nishimura- Kozur and Mostler, p. 42-43, pl.1, fig. 4

1995 *Eptingium* sp. A- Ramovš and Goričan, p. 185, pl.5, figs. 4, 5

Remarks: This species is distinguished from others species of genus *Eptingium* by having twisted spines with narrow and undivided blades.

Range: Anisian

Occurrence: KYY section

***Eptingium* sp.**

Plate 8, Figure 15

Remarks: Only one specimen was obtained. It has spherical cortical shell with a spongy surface and circular pores of unequal size. Two spines of undivided blade are wide in the proximal part and then abruptly taper to the distal end. Another one spine is not show of the same size as the others but looks similar in shape. Specimen is questionably assigned to *E.nakasekoi* by its form and the degree of angle between spines or it might be the transitional form between *E.nakasekoi* and *E.japonicum*.

Range: Anisian

Occurrence: CD section.

Genus ***Perispyridium*** Dumitrică, 1978

Type species: ***Trilonche*(?) *ordinaria*** Pessagno, 1977

***Perispyridium* sp.**

Plate 9, Figure 5 and 6

Remarks: The present specimens have flat cortical shell triangular in outline. The cephalis is small, subglobular or ellipsoidal. The three spines are equal, slightly short, triradiate and point straight in distal ends. It is similar to *P. ordinarium* Dumitrică, 1978 but differs from the type specimen by the angles between three spines being not equal and the pores at surface structure of cortical shell are smaller than the latter.

Range: Ladinian

Occurrence: CD and KYY section

Genus ***Pylostephanidium*** Dumitrică, 1978

Type species: ***Pylostephanidium clavator*** Dumitrică, 1978

Pylostephanidium clavator Dumitrică, 1978

Plate 9, Figure 7

1978 *Pylostephanidium clavator* n. sp.- Dumitrică, p.34-35, pl.2, figs. 6, 7

1994 *Pylostephanidium clavator* Dumitrică- Kozur and Mostler, p.43, pl.1, fig. 6

Remarks: The specimen is very poorly preserved.It has globular cephalis with irregular surface. The spines have nodes around its rim and needle- like distal ends. It can tentatively assign to this species by this character.

Range: Ladinian

Occurrence: KYY section

Genus ***Spongostephanidium*** Dumitrică, 1978

Type species: ***Spongostephanidium spongiosum*** Dumitrică, 1978

Spongostephanidium* sp. cf. *S. longispinosum Dumitrică, 1978

Plate 9, Figure 8 and 9

Remarks: The specimens present here have a subspherical to spherical spongy shell. They have three rod- like spines producing from the cortical shell. Sometimes they are tricarinate at the very base of the spines. One spine is always longer than other two, nearly twice the length. The arrangement of each spine is not equal in angle. Specimens are similar to the type specimens of *S. longispinosum* Sashida, 1991, however, the former differ from the latter by possessing finer spongy pore frames and have no short spinules from the vertices of pore frames.

Range: Anisian

Occurrence: CD and MSR section

Spongostephanidium spongiosum Dumitrică, 1978

Plate 9, Figure 11 and 12

1978 *Spongostephanidium spongiosum* n. sp.- Dumitrică, p.32, pl.2, figs. 2-5

Remarks: This species has spherical cephalis with spongy shell. Its three spines are rod- like with pointed ends. They are unequal spines which are sometimes shorter than the diameter of the shell. The angles between these three spines are also unequal.

Range: Early Ladinian

Occurrence: KYY section

Genus ***Triassistephanidium*** Dumitrică, 1978

Type species: ***Triassistephanidium laticorne*** Dumitrică, 1978

Triassistephanidium laticorne Dumitrică, 1978

Plate 9, Figure 10

1978 *Triassistephanidium laticorne* n. sp.- Dumitrică, p.32, pl.1, figs. 5, 6; pl.2, fig. 1; pl.4, fig. 3

1980 *Triassistephanidium laticorne* Dumitrică- Dumitrică, Kozur and Mostler, p.20, pl.6, fig. 9

1990 *Triassistephanidium laticorne* Dumitrică- Goričan and Buser, p. 159, pl. 8, fig. 6

1999 *Triassistephanidium laticorne* Dumitrică- Sashida, Kamata, Adachi and Munasri, p.773, figs. 6.14, 6.15

Remarks: Cephalis of this species is subtriangular with large pores, mostly placed with microgranular silica. The three spines are very broad, three- bladed, with wide grooves and blunt ends. They are situated in frontal plane with equiangle. They are often widened behind the midlength.

Range: Early Ladinian

Occurrence: KYY section

Family **HEXAPOROBRACHIIDAE** Kozur and Mostler, 1979

Genus ***Tetraporobrachia*** Kozur and Mostler, 1979

Type species: ***Tetraporobrachia haeckelli*** Kozur and Mostler, 1979

Tetraporobrachia haeckelli Kozur and Mostler, 1979

Plate 16, Figure 9 and 10

1999 *Tetraporobrachia haeckelli* Kozur and Mostler- Tekin, p.127, pl.25, fig. 2

Remarks: Cortical shell is tetrahedral shaped with four lonh symmetrical or asymmetrical arms. All four arms composed of irregularly arranged pore frames and terminate in long triradiate spines.

Range: Middle Carnian

Occurrence: Km 119 section

Family **HINDEOSPHAERIDAE** Kozur and Mostler, 1981

Genus ***Hindeosphaera*** Kozur and Mostler, 1979

Type species: ***Hindeosphaera foremanae*** Kozur and Mostler, 1979

Hindeosphaera spinulosa (Nakaseko and Nishimura, 1979)

Plate 14, Figure 7-9

1982 *Archaeospongoprunum spinulosum* n.sp.- Nakaseko and Nishimura, p.69, pl.2, figs. 3, 4, 6

1982 "*Archaeospongoprunum*" *spinulosum* Nakaseko and Nishimura - Matsuda and Isozaki, pl.3, figs. 27, 28

1993 *Psuedostylosphaera spinulosa* (Nakaseko and Nishimura)- Sashida, Nishimura, Igo, Kazama and Kamata, p.92, figs. 7-15, 17, 20(?)

1995 *Hindeosphaera*? *Spinulosa* (Nakaseko and Nishimura) - Ramovš and Goričan, p.185, pl.3, figs. 6-8

1996 *Hindeosphaera spinulosa* (Nakaseko and Nishimura) - Kozur, Krainer and Mostler, p.210-211, pl.4, figs. 4, 8

2001 *Hindeosphaera spinulosa* (Nakaseko and Nishimura) - Feng, Zhang and Ye, p.190, pl.5, figs. 15, 21

Remarks: This species has variable form of spines but they are usually very broad and three bladed polar spines of different sizes. Length is variable but mostly one is shorter than the opposite spine. Both polar spines gradually taper toward the distal ends, or simetime the polar spine is twisted. The pore frame of surface structure is spongy meshwork of irregular form.

Range: Late Anisian

Occurrence: CD and MLN section

Genus ***Pseudostylosphaera*** Kozur and Mostler, 1981

Type species: ***Pseudostylosphaera gracilis*** Kozur and Mostler, 1981

Pseudostylosphaera coccostyla acrior (Bragin, 1986)

Plate 12, Figure 1-3

1979 *Archaeospongoprunum compactum* n. sp.,pars- Nakaseko and Nishimura, p.68, pl.1, fig. 3 non! fig. 7

1993 *Pseudostylosphaera japonica* (Nakaseko and Nishimura) - Sashida, Nishimura, Igo, Kazama and Kamata, p.89, figs. 7-9, 7-15

1994 *Pseudostylosphaera coccostyla compacta* (Nakaseko and Nishimura) - Kozur and Mostler, p.44, pl.1, fig. 8

1996 *Pseudostylosphaera coccostyla acrior* (Bragin) - Kozur, Krainer and Mostler, p.211, pl.6, figs. 12-14

Remarks: This species does not have a secondary furrow in the ridges of three-bladed polar spines. The spines are gradually tapering toward distal ends. The length of polar spines is not much greater than the diameter of the cortical shell. Its cortical shell is ellipsoidal in outline and bearing spongy meshwork of irregular pores.

Range: Late Anisian to Early Ladinian

Occurrence: CD section

Pseudostylosphaera coccostyla coccostyla (Rüst, 1982)

Plate 12, Figure 4-6

1994 *Pseudostylosphaera coccostyla coccostyla* (Rüst)- Kozur and Mostler, p.44

1999 *Pseudostylosphaera coccostyla coccostyla* (Rüst)- Tekin, p.128, pl.25, fig. 8

Remarks: This species is quite similar to *P.c.acrior* but differs from the latter by displaying a secondary furrow in the ridges of three-bladed polar spines.

Range: Ladinian

Occurrence: CD, KYY, MLN, MSR, and Km 175 section

Pseudostylosphaera compacta (Nakaseko and Nishimura, 1979)

Plate 12, Figure 7-9

1979 *Archaeospogoprunum compactum* n. sp.,pars- Nakaseko and Nishimura, p.68, pl.1, fig. 7 non! fig. 3

1994 *Pseudostylosphaera coccostyla compacta* (Nakaseko and Nishimura)- Kozur and Mostler, p.44

1996 *Pseudostylosphaera compacta* (Nakaseko and Nishimura)- Kozur, Krainer and Mostler, p.212, pl.6, fig. 17

Remarks: According to Nakaseko and Nishimura (1979), this species displays broad ridges on the big polar spines. It differs from *P. c. coccostyla* by lacking secondary furrows in the ridges and has a more globular cortical shell than the latter. However, the length of polar spines is greater than *P. c. acrior*.

Range: Late Anisian

Occurrence: CD section

Pseudostylosphaera goestlingensis (Kozur and Mostler, 1979)

Plate 12, Figure 10-12

1997 *Pseudostylosphaera goestlingensis* (Kozur and Mostler)- Sugiyama, p.186, fig. 48-19

1999 *Pseudostylosphaera goestlingensis* (Kozur and Mostler)- Tekin, p.128, pl.25, fig. 9

Remarks: The present specimens show a globular cortical shell in outline with spongy meshwork of pores. The polar spines are tricarinate displaying dextral torsion.

It differs from *P. hellenica* (De Wever, 1979) by gradual taper spines toward distal ends more than in the latter.

Range: Late Ladinian to Early Carnian

Occurrence: CD, Km 119, and Km 175 section

Pseudostylosphaera goricanae Kozur and Mostler, 1996

Plate 12, Figure 13-15

1995 *Pseudosepsagon*? aff. *Illyricus* Kozur and Mostler- Ramovš and Goričan, p.189, pl.2, figs. 1-5

1996 *Pseudostylosphaera goricanae* n.sp.- Kozur and Mostler, p.213

Remarks: Shell is globular with three- bladed polar spines twisted in dextral direction. It looks similar to *P. goestlingensis*, but differs by having shorter spines of the same diameter as the shell.

Range: Late Anisian

Occurrences: Km 119 and Km 175 section

Pseudostylosphaera gracilis Kozur and Mock, 1981

Plate 13, Figure 1-3

1997 *Pseudostylosphaera gracilis* Kozur and Mock- Sugiyama, p.186, fig. 48-18

1999 *Pseudostylosphaera gracilis* Kozur and Mock- Tekin, p.128-129, pl.25, figs. 10, 11

Remarks: This species is characterized by having gentle sinistral torsion at the distal ends of the two polar spines.

Range: Ladinian

Occuurences: Km 119 and Km 175 section

Pseudostylosphaera imperspicua (Bragin, 1986)

Plate 13, Figure 4 and 5

1999 *Pseudostylosphaera imperspicua* (Bragin)- Tekin, p.129, pl.25, fig. 13

Remarks: General shape of shell is as in other species in this genus. One or two of three- bladed polar spines display slight sinistral torsion.

Range: Ladinian

Occurrence: DC and Km 175 section

Pseudostylosphaera japonica (Nakaseko and Nishimura, 1979)

Plate 13, Figure 6-8

1979 *Archaeospogoprunum japonicum* n. sp.- Nakaseko and Nishimura, p.67-68, pl.1, figs. 2, 4, 9

1982 *Archaeospogoprunum japonicum* Nakaseko and Nishimura- Yao, p.55, pl.1, fig. 21

1996 *Pseudostylosphaera japonica* (Nakaseko and Nishimura)- Kozur, Krainer and Mostler, p.212, pl.6, fig. 15

Remarks: This species has globular shell with spongy meshwork of irregular pores. Two polar spines are equal in length and divided into three blades with three very broad ridges. Mostly the polar spines are longer than the long axis of the cortical shell. It is very easy to distinguish from others *Psuedostylosphaera* by having the shape of polar spines broadest at or behind the midlenght.

Range: Late Anisian

Occurrence: CD and KYY section

Pseudostylosphaera longispinosa Kozur and Mostler, 1981

Plate 13, Figure 9-11

1990 *Pseudostylosphaera longispinosa* Kozur and Mostler- Goričan and Buser, p.155, pl.5, figs. 3-5

1997 *Pseudostylosphaera longispinosa* Kozur and Mostler- Sugiyama, p.186, fig. 48-16

1999 *Pseudostylosphaera longispinosa* Kozur and Mostler- Tekin, p.129, pl.25, fig. 14

Remarks: The cortical shell is spherical to subspherical with spongy meshwork of pore frames. According to Goričan and Buser (1990), two straight polar spines are more or less equal in their length and at least 1.5 times longer than the main axis of cortical shell.The present specimens have three ridges on spines but differ slightly from the type specimens of Kozur and Mostler (1981) in having more slender polar spine. Moreover, the specimens are similar to *Pseudostylosphaera* sp. A of Sugiyama (1997), but the latter is differs slightly by having obliquely directed polar spines.

Range: Early Ladinian

Occurrence: CD, KYY, MLN, and Km 119 section

Pseudostylosphaera magnispinosa Yeh, 1989

Plate 13, Figure 12 and 13

1987 ?*Pseudostylosphaera* sp. A- Kojima and Mizutani, p.265, fig. 2-2

1993 *Pseudostylosphaera magnispinosa* Yeh- Sashida, Nishimura, Igo, Kazama and Kamata, p.90, fig. 7-18

1997 *Pseudostylosphaera magnispinosa* Yeh- Sugiyama, p.186, fig. 48-23

Remarks: Test of the present species is quite sub-spherical to elliptical shell with spongy meshwork and two opposite polar spines. Polar spines are very stout, more so than others in the genus *Pseudostylosphera*. They are triradiate in cross section and composed of three blades or alternating with narrow secondary furrows on them. The proximal part of polar spines is as wide as main axis of cortical shell and then gradually decreases toward the distal ends. Based on these described characteristics, they can tentatively assign to this species.

Range: Anisian

Occurrence: CD and KYY section

Pseudostylosphaera nazarovi (Kozur and Mostler, 1979)

Plate 13, Figure 14-16

1997 *Pseudostylosphaera nazarovi* (Kozur and Mostler)- Sugiyama, p.186, fig. 48-17

1999 *Pseudostylosphaera nazarovi* (Kozur and Mostler)- Tekin, p.130, pl.25, fig. 15

Remarks: This species is characterized by having gentle sinistral torsion of polar spines. *P. goestlingensis* is quite similar to this species, but is distinguished from the latter by possessing torsion of polar spines in different direction.

Range: Ladinian

Occurrence: CD, MLN, Km 119, and Km 175 section

Pseudostylosphaera tenuis (Nakaseko and Nishimura, 1979)

Plate 14, Figure 1-3

1979 *Archaeospongoprunum tenue* n. sp.- Nakaseko and Nishimura, p.68, pl.1, figs. 8, 10

1987 *Pseudostylosphaera* sp. cf. *P. tenue* (Nakaseko and Nishimura)- Kojima and Mizutani, p.262, fig. 2-5

1989 *Pseudostylosphaera tenuis* (Nakaseko and Nishimura)- Goričan and Buser, p.155, pl.5, fig. 6

1997 *Pseudostylosphaera tenuis* (Nakaseko and Nishimura)- Sugiyama, p.186

Remarks: Originally described by Nakaseko and Nishimura (1979), this species displays sub-spherical to spherical cortical shell with spongy frameworks of irregular structure and two polar spines. Polar spines are slender and unequal in length; one being nearly twice as long as the other. The shorter one is as long as the shell diameter. Both have three blades. All of the present specimens are showing as those characteristics.

Range: Anisian

Occurrence: CD, KYY, and Km175 section

Pseudostylosphaera timorensis Sashida and Kamata, 1999

Plate 14, Figure 4-6

1999 *Pseudostylosphaera timorensis* n.sp.- Sashida, Kamata, Adachi and Munasri, p.770, figs. 8.3-8.6

Remarks: The main characteristics of this species are the large globular shell with circular pore frames on its surface and unequal polar spines with needle-like distal ends. One polar spine is as long as the shell diameter, whereas the other is shorter than as half as long. It is easy to distinguish from *P. tenuis* (Nakaseko and Nishimura, 1979) by having thicker and shorter polar spines. The present specimens are quite similar to the type specimens of *P. timorensis* of Sashida and Kamata (1999). However, some specimens have the longest spine shorter than the shell diameter.

Range: Ladinian

Occurrence: CD, KYY, Km 119, and Km 175 section

***Pseudostylosphaera* sp. A**

Plate 13, Figure 17

Remarks: Only four specimens are obtained from rock samples of them one is well preserved, whereas others are poorly preserved. The cortical shell is globular and consists of meshwork pore frames polygonal at the shell surface. The three bladed polar spines are unequal in length. The longer one is twice the length of the shorter and nearly equal to the shell diameter. The widest part is at the base of polar spines which then gradually taper toward their termination. This species are similar to *P. timorensis* (Sashida et al., 1999), but can be distinguished from the latter by its polar spines that are sharper than the former. It also differs from *Pseudostylosphaera*(?) sp. of Kojima and Mizutani (1987) by having smaller pore frames than the latter.

Range: Anisian

Occurrence: CD section

Family **MUELLERITORTIDAE** Kozur, 1988

Genus ***Muelleritortis*** Kozur, 1988

Type species: ***Emiluvia*? *cochleata*** Nakaseko and Nishimura, 1979

Muelleritortis cive Sugiyama, 1997

Plate 15, Figure 5

1997 *Muelleritortis cive* n. sp.- Sugiyama, p.161, figs. 41-19, 20

1999 *Muelleritortis cive* Sugiyama- Tekin, p.130, pl.26, figs. 2, 3

Remarks: Cortical shell of this species is subspherical to spherical in outline with four spines crossing at right angles. The spines are three- bladed, long, and widest in the middle before tapering to distal point. This species is well distinguished from other species in the same genus by having small nodes on the ridges of all spines.

Range: Late Ladinian

Occurrence: Km 175 section

Muelleritortis cochleata cochleata (Nakaseko and Nishimura, 1979)

Plate 15, Figure 9-11

1979 *Emiluvia*? *cochleata* n. sp. - Nakaseko and Nishimura, p.70, pl.3, figs. 2-4, 6

1988 *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura) - Kozur, p.53, pl.1, figs. 1-8; pl.2, figs. 1, 2; pl.3, fig. 1

1996 *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura) – Kozur and Mostler, p.86, pl.1, fig. 9

1999 *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura) - Tekin, p.130, pl. 26, figs. 4-5

2002 *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura)- Kamata et al., p.501, fig. 6D

Remarks: The specimens are characterized by having four main spines. Three main spines are twisted tightly. An untwisted spine is either the same length as or a little longer than other spines. The cortical shell is spherical to subspherical and rarely round in polar view. These characteristics are similar tothose of the type specimens of *M. c. cochleata* (Nakaseko and Nishimura) by Kozur, 1988.

Range: Late Ladinian

Occurrence: DC and Km 175 section

Muelleritortis cochleata koeveskalensis Kozur, 1988

Plate 15, Figure 1 and 2

1988 *Muelleritortis cochleata koeveskalensis* n. subsp.- Kozur, p.53-54, pl.3, fig. 3

1996 *Muelleritortis cochleata koeveskalensis* Kozur- Kozur and Mostler, pl.2, figs. 1, 8

1996 *Muelleritortis* cf. *cochleata koeveskalensis* Kozur- Kozur and Mostler, p.87, pl.2, fig. 4

1999 *Muelleritortis cochleata koeveskalensis* Kozur- Tekin, p.131, pl.26, fig. 6

Remarks: The general outline of this subspecies, one untwisted main spine longer than the three twisted spines with spherical cortical shell, is similar to *M. c. cochleata*, but it is distinguished from the latter by the spines being expanded in width at the end of each spine.

Range: Late Ladinian

Occurrence: Km 175 section

Muelleritortis cochleata tumidospina Kozur, 1988

Plate 15, Figure 3, 4 and 6

1988 *Muelleritortis cochleata tumidospina* n. subsp. - Kozur, p.54, pl.3, fig. 2

1999 *Muelleritortis cochleata tumidospina* Kozur - Tekin, p.131, pl.26, fig. 7

2002 *Muelleritortis cochleata tumidospina* Kozur - Kamata et al., p.502, fig. 6C and E

Remarks: The main spines of this species are broader than in *M. c. cochleata* (Nakaseko and Nishimura). All main spines are rather the same width.

Range: Late Ladinian

Occurrence: DC and Km 175 section

Muelleritortis expansa Kozur and Mostler, 1996

Plate 15, Figure 13-15

1996 *Muelleritortis expansa* n. sp. - Kozur and Mostler, p.88, pl.1, figs. 1-5, 8?

1999 *Muelleritortis expansa* Kozur and Mostler - Tekin, p.131, pl.26, fig. 8

Remarks: The special characteristics of this species are very broad and deep median groove on all four main spines, arranged in cross-like and having the same length. The three twisted spines are distally expanded, round and blunt at distal ends without terminal spine. An untwisted main spine is slightly expanded and rounded pointed at distal ends with a long terminal spine.

Range: Late Ladinian

Occurrence: DC and Km 175 section

Muelleritortis firma (Goričan and Buser, 1990)

Plate 15, Figure 12 and 16

1990 *Plafkerium*? *firmum* n. sp.- Goričan and Buser, p.152, pl.6, figs. 3-6

1996 *Muelleritortis*? *firma* (Goričan and Buser)- Kozur and Mostler, p.86,89

Remarks: This species has all four untwisted spines, or sometimes three spines are very slightly twisted with one untwisted spine.

Range: Late Ladinian

Occurrence: Km 175 section

Muelleritortis longispinosa Kozur, 1988

Plate 15, Figure 17 and 18

1988 *Muelleritortis longispinosa* n. sp.- Kozur**,** p.54, pl.3, fig. 4

1999 *Muelleritortis longispinosa* Kozur- Tekin, p.131, pl.26, figs. 9, 10

Remarks: This species has distinctly longer main spines than other species in this genus. Moreover, the cortical shell is subspherical and rather small.

Range: Late Ladinian

Occurrence: Km 175 section

Muelleritortis* cf. *M. quadrata Kozur and Mostler, 1996

Plate 15, Figure 7 and 8

cf. 1996 *Muelleritortis* cf. *quadrata* n. sp.- Kozur and Mostler, p.88-89, pl.2, fig. 3

Remarks: The specimens show the typical form of *M. quadrata* in having three broad twisted main spines with one untwisted spine. All four main spines are the same length. However, they differ from the type specimens of *M. quadrata* Kozur and Mostler (1996) by possessing a subspherical to spherical cortical shell in polar view.

Range: Late Ladinian

Occurrence: Km 175 section

Genus ***Tritortis*** Kozur, 1988

Type species: ***Sarla*? *Kretaensis*** Kozur and Krahl, 1984

Tritortis kretaensis dispiralis (Bragin, 1986)

Plate 16, Figure 5-7

1988 *Tritortis kretaensis subcylindrica* n. subsp.- Kozur, p.98-99, pl.4, figs. 6, 8

1996 *Tritortis kretaensis dispiralis* (Bragin)- Kozur and Mostler, p.91-92, pl.3, fig. 11

1999 *Tritortis kretaensis dispiralis* (Bragin)- Tekin, p.132-133, p.27, fig. 3

Remarks: Cortical shell of this species is subglobular in outline. Pores on the shell are subcircular or polygonal with nodes on the vertices of poreframes. The three main spines, one untwisted and two twisted with deep and wide ridge of median groove, are of the same length or sometimes the untwisted one is slightly longer than the twisted ones. They are arranged in triangular outline. The sides of the main spines are pararell until the distal part before ending with round, blunt and with or without short terminal spine.

Range: Late Ladinian to Early Carnian

Occurrence: Km 175 section

Tritortis kretaensis kretaensis (Kozur and Khahl, 1984)

Plate 16, Figure 1-3

1988 *Tritortis kretaensis kretaensis* (Kozur and Khahl)- Kozur, p.61, pl.4, figs. 3-5

1997 *Tritortis kretaensis* (Kozur and Khahl)- Sugiyama, p.188, fig. 48-21

1999 *Tritortis kretaensis kretaensis* (Kozur and Khahl)- Tekin, p.133, pl.27, figs. 4, 5

Remarks: This species is distinguished from *T. k. dispiralis* by displaying more slender main spines than the latter. All of main spines gradually taper toward the pointed distal end.

Range: Late Ladinian to Early Carnian

Occurrence: Km 175 section

***Tritortis* sp. A**

Plate 16, Figure 4 and 8

Remarks: This species is distinguished from other species of the genus by having nodes on all three spines. It is similar to *Tritortis* sp. A of Sugiyama (1997) reported from Japan.

Range: Late Ladinian to Early Carnian

Occurrence: Km 119 section

Family **SEPSAGONIDAE** Kozur and Mostler, 1981

Genus ***Sepsagon*** Dumitrică, Kozur and Mostler, 1980

Type species: ***Triactonia longispinosum*** Kozur and Mostler, 1979

Sepsagon* sp. cf. *S. robustus Lahm, 1984

Plate 17, Figure 11

cf. 1994 *Sepsagon robustus* Lahm- Kozur and Mostler, p.49, pl.4, fig. 10; pl.5, figs. 1, 6

Remarks: Shell is spherical with large pore frames. There are nodes on the vertices of shell surface. Some specimens show the inner structure but it is not clear enough to observe due to poor preservation. The three main spines display three blades straight in one plane.

Range: Early Ladinian

Occurrence: CD section

Genus ***Parasepsagon*** Dumitrică, Kozur and Mostler, 1980

Type species: ***Parasepsagon tetracanthus*** Dumitrică, Kozur and Mostler, 1980

Parasepsagon variabilis (Nakaseko and Nishimura, 1979)

Plate 17, Figure 20 and 21

1979 *Staurodoras variabilis* n. sp.- Nakaseko and Nishimura, p.71-72, pl.3, figs. 5, 8

1995 *Parasepsagon variabilis* (Nakaseko and Nishimura)- Ramovš and Goričan, p.187, pl.3, fig. 5

1996 *Parasepsagon variabilis* (Nakaseko and Nishimura)- Kozur,Krainer and Mostler, p.217, pl.4, figs. 2, 3, 7 and 9

Remarks: This species is characterised by having four of three- bladed, untwisted spines. One spine is often longer than others. The outer pore frames have nodes at the vertices and enclose larger pores.

Range: Late Anisian

Occurrence: MLN section

Parasepsagon* sp. cf. *P. variabilis (Nakaseko and Nishimura, 1979)

Plate 17, Figure 17

cf. 1979 *Staurodoras variabilis* n. sp.- Nakaseko and Nishimura, p.71-72, pl.3, figs. 5, 8

cf. 1995 *Parasepsagon variabilis* (Nakaseko and Nishimura)- Ramovš and Goričan, p.187, pl.3, fig. 5

cf. 1996 *Parasepsagon variabilis* (Nakaseko and Nishimura)- Kozur, Krainer and Mostler, p.217, pl.4, figs. 2, 3, 7 and 9

Remarks: Only one specimen was obtained from the materials. There are four spines but the present specimen is missing one spine. However, it can be correlated to this species because of the characteristics of test and spines. It has the three blades and untwisted spines are robust and short. The spherical shell has slightly small pore frames with nodes at the vertices.

Range: Late Anisian

Occurrence: CD section

***Parasepsagon* sp.**

Plate 17, Figure 18 and 19

Remarks: They are poorly preserved specimens. The shell is subspherical to spherical with medium sized pore frames. The four main spines are three blades and untwisted. It is similar to *P. tetracanthus* with one of the spine axes shorter than the other. However, the length of each spine and more details can not be observed due to inadequate preservation.

Range: Late Anisian to Early Ladinian

Occurrence: CD, KYY, Km 119 and Km 175 section

Family **TIBORELLIDAE** Kozur and Mostler, 1994

Genus ***Tiborella*** Dumitrică, Kozur and Mostler, 1980

Type species: ***Tiborella magnidentata*** Dumitrică, Kozur and Mostler, 1980

Tiborella florida florida (Nakaseko and Nishimura, 1979)

Plate 16, Figure 19 and 20

1979 *Cecrops floridus* n. sp.- Nakaseko and Nishimura, p.69-70, pl.2, figs. 5, 8

1994 *Tiborella florida* (Nakaseko and Nishimura)-Kozur and Mostler, p. 52

1995 *Tiborella florida* (Nakaseko and Nishimura)- Ramovš and Goričan, p.191-192, pl.4, figs. 1-4, non! Fig. 5

Remarks: The main characteristic of this subspecies is knob- like ending of all four tricarinate main spines. The spines are nearly the same length and untwisted or very slightly twisted if present. Sometimes one slightly twisted spine is longer than other three spines occurred. Cortical shell is subspherical and has a subquadratic equatorial outline in upper view. The pore frames of cortical shell are very large and polygonal with nodes at the vertices of pores. This species differs from *T. agria* Sugiyama (1992) by the latter having thin rod-like spines whereas the former has thicker spines with knob-like tips. They also differ from *T. anisica* Kozur and Mostler (1994) in possessing blunt knob- like tips of four spines and having slight torsion.

Range: Late Anisian to Early Ladinian

Occurrence: CD section

Suborder **NASSELLARIA** Ehrenberg, 1875

Family **CANOPTIDAE** Pessagno, 1979

Genus ***Canoptum*** Pessagno, 1979

Type species: ***Canoptum poissoni*** Pessagno, 1979

Canoptum inornatus Tekin, 1999

Plate 4, Figure 6 and 7

1999 *Canoptum inornatus* n. sp.- Tekin, p.136-137, pl.28, figs. 10-12

Remarks: Test is long and slender. It is generally covered by microgranular silica. Cephalis is small and dome- shaped. The width of test is the same until the first postabdominal segment, then abruptly widening before decreasing in width at the last two or three postabdominal segments. Many very small scattered circular pores occur on surface of test.

Range: Ladinian to Carnian

Occurrence: DC and Km 119 section

Canoptum levis Tekin, 1999

Plate 4, Figure 3-5

1999 *Canoptum levis* n. sp.- Tekin, p.137-138, pl.28, figs. 13-15

Remarks: This species is distinguished from *Canoptum inornatus* by its gradually increasing width until a maximum at about second or third postabdominal segment.

Range: Ladinian to Carnian

Occurrence: DC, Km 119, and Km 175 section

***Canoptum* sp. A**

Plate 4, Figure 10-12

Remarks: Only the upper part of this specimen is preserved. However, based on the outline, it can compare to *C. browni* Blome (1984) by having the small apical spine.

Range: Ladinian to Carnian

Occurrence: Km 119 section

***Canoptum* sp.**

Plate 4, Figure 8 and 9

Remarks: The present specimens are poorly preserved, with the test covered by microgranular silica. It is difficult to describe in detail or to get a precise identification. However, the specimens compare with the genus *Canoptum* by their external characteristics.

Range: Ladinian to Carnian

Occurrence: DC section

Genus ***Japonocampe*** Kozur, 1984

Type species: ***Triassocampe nova*** Yao, 1982

Japonocampe nova (Yao, 1982)

Plate 7, Figure 11 and 12

1980 *Dictyomitrella* sp. B- Yao, Matsuda and Isozaki, pl.3, figs. 1-3

1982 *Triassocampe nova* n. sp.- Yao, p.59-60, pl.2, figs. 1-4

1986 *Triassocampe nova* Yao- Yoshida, pl.4, figs. 7, 8

1997 *Japonocampe nova* (Yao)- Sugiyama, p.181, fig. 50-1

Remarks: Test is conical. Cephalis is dome- shaped without horn. Each postabdominal segment has well- developed ridge and smooth surface at lower part. There is one row of circular pores beneath ridge.

Range: Carnian to Norian

Occurrence: DC, Km 119, and Km 175 section

Genus ***Pachus*** Blome, 1984

Type species: ***Pachus firmus*** Blome, 1984

Pachus firmus Blome, 1984

Plate 7, Figure 13

1983 *Pachus firmus* n. sp.- Blome, p.49, pl.12, figs. 3, 4, 8, 9, 15, 17; pl.17, fig. 8

1999 *Pachus firmus* Blome- Tekin, p.139, pl.29, fig. 7

Remarks: Test is conical. Post-abdominal segment is rectangular in outline with high nodes on well- developed circumferential ridge. Each segment is separated from the next by wide stricture with scattered small pores, sometimes covered by microgranular silica.

Range: Late Carnian to Early Norian

Occurrence: Km 119 section

Pachus multinodosus Tekin, 1999

Plate 7, Figure 14

1999 *Pachus multinodosus* n. sp.- Tekin, p.139, pl.29, figs. 9-12

Remarks: This species differs from other known species of the genus by having many rows of nodes on the wider circumferential ridges.

Range: Late Carnian to Early Norian

Occurrence: Km 119 section

Family **PSEUDODICTYOMITRIDAE** Pessagno, 1977

Genus ***Corum*** Blome, 1984

Type species: ***Corum speciocum*** Blome, 1984

Corum kraineri Tekin, 1999

Plate 7, Figure 6-8

1999 *Corum Kraineri* n. sp. - Tekin, p.152-153, pl.35, figs. 7-9

Remarks: Test of this species is conical with six or seven postabdominal segments. Cephalis is dome- shaped, smooth and poreless. The width slightly increases from thorax to the last segments, sometimes the last one is slightly decreased in width. The stricture between segments is indistinct. Irregular thin and discontinuous costae are visible at all postabdominal segment .Scattered pores situated between the costae are rare and mainly covered by microgranular silica.

Range: Ladinian to Carnian

Occurrence: DC, Km 119, and Km 175 section

Corum* sp. cf. *C. regium Blome, 1984

Plate 7, Figure 4 and 5

cf. 1984 *Corum regium* n. sp.- Blome, p.51, pl.13, figs. 3, 8, 15

cf. 1986 *Corum regium* Blome- Yoshida, pl.5, fig. 4

cf. 1999 *Corum regium* Blome- Tekin, p.153, pl.35, figs. 10, 11

Remarks: The specimens differ from the type specimens of *C. regium* Blome, 1984 by having more smaller pores at the stricture under costae and having sometimes two rows of pores.

Range: Late Carnian to Early Norian

Occurrence: Km 119 section

***Corum* sp. A**

Plate 7, Figure 9 and 10

Remarks: The specimens show the test characteristics of the genus *Corum*. It differs from other known species in the genus by having the broad apical horn and weaker circumferential ridges.

Range: Ladinian to Carnian

Occurrence: Km 119 and Km 175 section

Family **RUESTICYRTIIDAE** Kozur and Mostler, 1979

Genus ***Pararuesticyrtium*** Kozur and Mock, 1981

Type species: ***Pararuesticyrtium densiporatum*** Kozur and Mock, 1981

***Pararuesticyrtium* sp. A**

Plate 18, Figure 11 and 12

Remarks: It is long spindle- shaped in general outline. It consists of cephalis, thorax, abdomen and eight to ten postabdominal segments. Cephalis probably possesses a very small vertical apical horn. The postabdominal segments are hoop- like and have about three rings of circular pores. The stricture between segments is narrow and deep. The specimens reach the maximum width at the fourth or fifth postabdominal segment, then width gradually decreases to equal the width in the proximal part.

Range: Ladinian to Carnian

Occurrence: DC section

Pararuesticyrtium* sp. cf. *P. illyricum Kozur and Mostler, 1981

Plate 18, Figure 7-9

cf. 1994 *Pararuesticyrtium*? *illyricum* (Kozur and Mostler)- Kozur and Mostler, p.109, pl.43, figs. 11, 12, 15, 16

Remarks: The present specimens differ from *P. illyricum* Kozur and Mostler (1981) in displaying three rings of pores in the first two or three postabdominal segments, then two rings of pores on remaining segments. Moreover, the width increases gradually from cephalis to abdomen, then remains the same to the distal part.

Range: Anisian to Ladinian

Occurrence: DC and KYY section

***Pararuesticyrtium* sp.**

Plate 18, Figure 10

Remarks: Two specimens. Test is elongate-conical, gradually widening from abdomen. Cephalothorax is smooth, poreless and dome- shaped. It possesses two rings of pores on five to six postabdominal segments. Pores are small and circular form. The constriction between all segments is rather deep, smooth and poreless. It resembles to *P. eofasanicum* reported by Kozur and Mostler (1994) however, it differs by having no small apical horn.

Range: Ladinian

Occurrence: CD, KYY, and MSR section

Family **SANFILIPPOELLIDAE** Kozur and Mostler, 1979

(Synonym: **POULPINAE** De Wever, 1981)

Genus ***Hozmadia*** Dumitrică, Kozur and Mostler, 1980

Type species: ***Hozmadia reticulata*** Dumitrică, Kozur and Mostler, 1980

Hozmadia rotunda (Nakaseko and Nishimura, 1979)

Plate 18, Figure 3

1979 *Tripilidium rotundum* n. sp.- Nakaseko and Nishimura, p.81-82, pl.8, figs. 1-3

1982 *Hozmadia*(?) sp. A- Yao, pl.1, fig. 15

1993 *Hozmadia rotunda* (Nakaseko and Nishimura)- Sashida, Nishimura, Igo, Kazama and Kamata, p.84, fig. 6-10

1994 *Hozmadia rotunda* (Nakaseko and Nishimura)- Kozur and Mostler, p.116, pl.29, figs. 3, 4, 7

1995 *Hozmadia rotunda* (Nakaseko and Nishimura)- Ramovš and Goričan, p.186, pl.7, figs. 5-6

1996 *Hozmadia rotunda* (Nakaseko and Nishimura)- Kozur and Mostler, p.231, pl.3, figs. 3, 4, 6, 7 and 11

1996 *Hozmadia* cf. *rotunda* (Nakaseko and Nishimura)- Kozur and Mostler, p.231, pl.3, fig. 8

1996 *Hozmadia* aff. *rotunda* (Nakaseko and Nishimura)- Kozur and Mostler, p.231, pl.3, fig. 10

Remarks: The specimens are well correlated to the type specimens of *H. rotunda* reported by Nakaseko and Nishimura (1979) by having stout apical horn.

Range: Late Anisian

Occurrence: MLN section

Hozmadia* sp. cf. *H. rotunda (Nakaseko and Nishimura, 1979)

Plate 18, Figure 2

Remarks: The cephalis of the specimen is subspherical with large pentagonal pores. Its three feet are curved and pointed to needle- like ends. Its apical horn is stout and pointed distally; however, the form of apical horn is variable. The specimens are similar to *H. rotunda* Nakaseko and Nishimura, but the latter differs by having the stout apical horn and bigger feet than the former. Although the specimen is poorly preserved, it can correlate to this species based on the characteristics above.

Range: Late Anisian

Occurrence: CD section

Hozmadia* sp. cf. *H. gifuensis Sugiyama, 1992

Plate 18, Figure 1

cf. 1980 *Saitoum*(?) sp.- Yao, Matsuda and Isozaki, pl.1, fig. 7

cf. 1982 (?)*Hozmadia*(?) sp. - Matsuda and Isozaki, pl.3, figs. 29 and 30

cf. 1992 *Hozmadia gifuensis* n. sp.- Sugiyama, p.1194-1196, figs. 9-6, 7 and 8

cf. 1997 *Hozmadia gifuensis* Sugiyama- Sugiyama, fig. 48-8

Remarks: Only one specimen was obtained from the materials. This specimen is similar to the type specimens of *H. gifuensis* (Sugiyama, 1992) by its shape. The cephalis is hemisphere with constricted at the base. Its surface has circular, oval or irregular shaped pore frames. Its three feet are divergent. All of them are small three bladed a short distance at the proximal part. From the middle part to distal part, they are rod- like pointed and less curved outward. The apical horn is three bladed proximally then straight and rod- like till its distal end. However, this specimen is slightly different from the type specimen of *H. gifuensis* (Sugiyama, 1992) by having thinner apical horn and feet.

Range: Late Anisian

Occurrence: CD section

Hozmadia sp. A

Plate 18, Figure 4

Remarks: This unidentified species is represented by only one specimen. The apical horn is missing. It shows only a very short proximal part with three blades. Cephalis is much longer than in other known species in the same genus. Its surface can not be observed due to a covering of microgranular silica. There is the constriction at the base of cephalis before extended to feet. The three feet are straight divergent and weak bladed proximally for a short distance and then rod- like toward the ends. This species is similar to *H. longicephalis* Kozur and Mostler (1994) in having an elongate cephalis. The latter, however, has stout three bladed feet.

Range: Late Anisian

Occurrence: CD section

***Hozmadia* sp. B**

Plate 18, Figure 5

Remarks: A couple of poorly preserved specimens were obtained. This unidentified species is characterized by a globular cephalis. The cephalis wall seems to have reticulate network of ridges. The apical horn has three sharp blades and deep ridges between them; however it is not well preserved because the middle to distal part is broken. The position of apical horn is not set in symmetry but slightly inclined. Feet are three bladed and slightly curved outward. This specimen resembles *H. costata* Kozur and Mosler, 1994.

Range: Late Anisian

Occurrence: CD section

***Hozmadia* sp. C**

Plate 18, Figure 6

Remarks: This unidentified species is poorly preserved, showing only cephalis and feet. The cephalis is subspherical and having polygonal pore frames on cephalis wall. Its feet have three blades but become distally trifurcate.

These specimens resemble *H. spinosa* Kozur and Mostler (1994) in the form of its feet. Due to poor preservation, it can not be identified any more closely.

Range: Late Anisian

Occurrence: CD section

Family **SILICARMIGERIDAE** Kozur and Mostler, 1980

Genus ***Spongosilicarmiger*** Kozur, 1984

Type species: ***Spongosilicarmiger italicus*** Kozur, 1984

***Spongosilicarmiger* sp.**

Plate 18, Figure 13

Remarks: Specimens in the studied material are rare and poorly preserved. This unidentified species is characterized by having a slender cylindrical apical horn. The details of post cephalic part of test can not be known due to the lack of preservation. It is similar to *S. gabiolaensis* reported by Kozur and Mostler (1994) by the outline of apical horn but differs by being slightly curved at the tip.

Range: Ladinian

Occurrence: DC section

Spongosilicarmiger nakasekoi Yeh, 1990

Plate 18, Figure 14

1979 *Stichopterium*(?) sp. B- Nakaseko and Nishimura, p.80-81, pl.11, figs. 2, 5

1996 *Spongosilicarmiger nakasekoi* Yeh- Kozur,Krainer and Mostler, p. 233, pl.1, figs. 1-2, 6-10; pl.2, figs. 1-3 (cf.)

Remarks: This species has a smooth cephalis sometimes with open pores on the smooth surface. The apical horn is short, conical proximally and needle-like at the tip.

Range: Late Anisian

Occurrence: KYY section

Family **TRIASSOCAMPIDAE** Kozur and Mostler, 1981

Genus ***Annulotriassocampe*** Kozur, 1994

Type species: ***Annulotriassocampe baldii*** Kozur, 1994

Annulotriassocampe baldii Kozur, 1994

Plate 2, Figure 1 and 2

1994 *Annulotriassocampe baldii* Kozur- Kozur and Mostler, p.249-250, pl.1, figs. 1a and b

1997 *Triassocampe baldii* Kozur- Sugiyama, p.188, fig. 49-6

1999 *Annulotriassocampe baldii* Kozur- Tekin, p.168-169, pl.41, figs. 1-2

Remarks: Test is subconical to subcylindrical consisting of five to seven post-abdominal segments. Cephalothorax is dome-shaped and poreless. Apical part has both wider and slender forms. Post-abdominal segments slightly increase in width until fourth or fifth segment then decrease into cylindrical outline. All post-abdominal segments have one ring of pores beneath the lower part of each ridge. Pores are large and circular.

Range: Late Ladinian

Occurrence: Km 119 and Km 175 section

Annulotriassocampe companilis Kozur, 1994

Plate 2, Figure 3 and 4

1994 *Annulotriassocampe companilis* n. sp.- Kozur and Mostler, p.132-133, pl.41, figs. 1-4, 7, 9-11, 13-18

2001 *Annulotriassocampe companilis* Kozur- Feng, Zhang and Ye, p.178-179, pl.1, figs. 8-12

Remarks: The specimens have a long test, slender and cylindrical. On each postabdominal segment present one row of circular pores. All segments are hoop- like and elevated against the constriction. The constrictions therefore, are rather wide, deep and poreless.

Range: Anisian

Occurrence: DC, MLN, and Km 119 section

Annulotriassocampe multisegmantus Tekin, 1999

Plate 2, Figure 6 and 7

1999 *Annulotriassocampe multisegmantus* n. sp.- Tekin, p.169, pl.41, figs. 3-6

Remarks: Some specimens differ slightly from the type specimens reported by Tekin (1999) in having weaker circumferential ridges than the latter.

Range: Late Ladinian to Early Carnian

Occurrence: DC, Km 119, and Km 175 section

Annulotriassocampe sulovensis (Kozur and Mock, 1981)

Plate 2, Figure 8 and 9

1994 *Annulotriassocampe sulovensis* (Kozur and Mock)- Kozur and Mostler, p.249

1999 *Annulotriassocampe sulovensis* (Kozur and Mock)- Tekin, p.170, pl.41, fig. 8

2002 *Triassocampe* cf. *sulovensis* Kozur and Mock- Kamata et al., fig. 7D

Remarks: The specimens figured here have a cylindrical test. Its circumferencial ridge is strong. There is one row of large pores on the ridge. The constriction at each segment margin is wide and deep.

Range: Ladinian to Early Carnian

Occurrence: CD, DC, Km 119, and Km 175 section

***Annulotriasocampe* sp.**

Plate 2, Figure 5

Remarks: Test of this specimen is similar to *A. spinosa* Kozur and Mostler (1994) but differs from the latter by the presence of only one oblique apical spine.

Range: Anisian

Occurrence: DC section

Genus ***Paratriassocampe*** Kozur and Mostler, 1994

Type species: ***Paratriassocampe gaetanii*** Kozur and Mostler, 1994

Paratriassocampe* sp. cf. *P. gaetanii Kozur and Mostler, 1994

Plate 2, Figure 10

cf. 1994 *Paratriassocampe gaetanii* n. sp.- Kozur and Mostler, p.134, pl.42, figs. 7, 8, 10, 11

Remarks: The dominant characteristic of this species is triangular outline of postabdominal segments. Each segment has two rings of pores. It is small and circular with nodules at the vertices between pores. Test is cone- shaped with dome- shaped cephalis. It has eight to ten postabdominal segments which gradually widen. The stricture between segments is deep, narrow and poreless.

Range: Early Ladinian

Occurrence: CD and KYY section

Genus ***Pseudotriassocampe*** Kozur and Mostler, 1994

Type species: ***Pseudotriassocampe hungarica*** Kozur and Mostler, 1994

Pseudotriassocampe **sp.**

Plate 2, Figure 11 and 12

Remarks: Test displays a conical shape proximally and cylindrical in the distal part. The apical horn on the short conical cephalis is obliquely directed. There are two or three rows of small pores scattered on circumferential ridge of each postabdominal segment. Constriction between segments is rather wide and deep. It resembles *P. angustiannulata* reported by Kozur and Mostler (1994), but slightly differs by the latter having a strong node of pores on the circumferential ridge.

Range: Anisian

Occurrence: CD section

Genus ***Striatotriassocampe*** Kozur and Mostler, 1994

Type species: ***Striatotriassocampe nodosoannulata*** Kozur and Mostler, 1994

Striatotriassocampe nodosoannulata Kozur and Mostler, 1994

Plate 2, Figure 13 and 14

1994 *Striatotriassocampe nodosoannulata* n. sp.- Kozur and Mostler, p.138, pl.43, figs. 4, 10

2001 *Striatotriassocampe nodosoannulata* Kozur and Mostler- Feng, Zhang and Ye, p.178, pl.1, figs. 6, 7

Remarks: Test of this species is long, slender, and cylindrical. Cephalis is conical, smooth and poreless. Thorax, abdomen and the first five to six post abdominal segments display low circumferential ridges; the constriction between segments is very gentle. The following segments display stronger ridges and deeper constrictions. Every segment has one ring of elongate pores aligned along the long axis of the test.

Range: Early Ladinian

Occurrence: CD and KYY section

Genus ***Triassocampe*** Dumitrică, Kozur and Mostler, 1980

Type species: ***Triassocampe scalaris*** Dumitrică, Kozur and Mostler, 1980

Triassocampe coronata Bragin 1991

Plate 5, Figure 6-9

1979 *Dictyomitrella* sp. A - De Wever et al., p.90, pl.5, figs. 12, 16

1992 *Triassocampe coronata* Bragin- Sugiyama, p.1198-1199, figs. 11-5, 6

1997 *Triassocampe coronata* Bragin- Sugiyama, p.110, figs. 27-6 and 7

2001 *Triassocampe coronata coronata* Bragin- Feng, Zhang and Ye, p.180, pl.2, figs. 11-15

Remarks: This species is elongate-conical. Cephalis is dome- shaped, smooth and poreless. It has a strong circumferential ridge each postabdominal segment. Single ring of large subcircular pores is beneath this ridge at the upper part of the segment.

Range: Anisian

Occurrence: CD, DC, MLN, and Km 119 section

Triassocampe deweveri (Nakaseko and Nishimura), 1979

Plate 5, Figure 11-14

1979 *Dictyomitrella deweveri* n. sp. - Nakaseko and Nishimura, p.77, pl.10, figs. 8, 9

1982 *Triassocampe deweveri* (Nakaseko and Nishimura)-Yao, pl.1, figs. 1-3

2001 *Triassocampe deweveri* (Nakaseko and Nishimura) - Feng, Zhang and Ye, p.182, pl.3, figs. 1-6

Remarks: This species has two to three rings of circular pores beneath each circumferential ridge. The circumferential ridge is weaker than in *T. coronata*. Cephalis is dome-shaped without a horn.The specimens figured here are identical to the type specimens reported by Nakaseko and Nishimura (1979).

Range: Ladinian

Occurrence: CD, DC, KYY, MLN, MSR, and Km 175 section

Triassocampe myterocorys Sugiyama, 1992

Plate 6, Figure 1-3

1992 *Triassocampe myterocorys* n. sp.- Sugiyama, p.1198, figs. 11-1-3b

2000 *Triassocampe myterocorys* Sugiyama- Sashida et al., p.807, figs. 9.2-9.5

2001 *Triassocampe myterocorys* Sugiyama - Feng, Zhang and Ye, p.180, pl.2, figs. 16, 17

Remarks: As mentioned by Sugiyama (1992), this species shows a wide variety of morphology. However, the main characteristic is a conical apical spine that is usually oblique. Moreover, it has one or, sometimes, two rows of large pores beneath strong circumferential ridge on each postabdominal segment.

Remark: Anisian

Occurrence: CD and MLN section

Triassocampe scalaris Dumitrica, Kozur and Mostler 1980

Plate 6, Figure 6-9

1980 *Triassocampe scalaris* n.gen.n.sp.-Dumitrica, Kozur and Mostler - p.26, pl.9, figs. 5, 6, 11, pl. 14, fig. 2

1990 *Triassocampe scalaris* Dumitrica, Kozur and Mostler- Gorican and Buser, p.159, pl.12, figs. 2, 3

1999 *Triassocampe scalaris* Dumitrica, Kozur and Mostler- Tekin, p.170, pl.41, fig. 10

2001 *Triassocampe scalaris* Dumitrica, Kozur and Mostler- Feng, Zhang and Ye, p.182, pl.3, figs. 14-16

Remarks: The specimens figured here has cone- shaped in the first four to five segments and become cylindrical in outline at distally. Each postabdominal segment has two rings of nodose pores. Node of pores is very strong, especially in the upper row. Constriction in each segment is moderately deep.

Range: Ladinian

Occurrence: CD, DC, KYY, and Km 175 section

Triassocampe* sp. cf. *T. diordinis Bragin, 1991

Plate 5, Figure 1-3

cf. 1992 *Triassocampe* sp. aff. *T. diordinis* Bragin- Sugiyama, p. 1199, figs.11- 7, 8

Remarks: Test is slender and cylindrical. Cephalis is conical. It has one ring of large circular pores beneath moderately circumferential ridge. It has many segments ten to twelve. The constrictions between segments are moderately deep. However, as mentioned by Sugiyama (1992), this species is variable in form and possibly conspecific with *T.diordinis.* The specimens placed here are similar to the general form of *Striatotriassocampe nodosoannulata* in this study, but differ by having the row of large and circular pores on the upper part of each segment.

Range: Anisian

Occurrence: CD, KYY, and Km 119 section

Triassocampe* sp. cf. *T. eruca Sugiyama, 1997

Plate 5, Figure 4 and 5

cf. 1992 *Triassocampe*(?) sp. A- Sugiyama, p. 1199, figs. 11-4, 9

cf. 1997 *Triassocampe eruca* n. sp. - Sugiyama, p.172, figs. 47-7, 8

Remarks: Test is short, conical. Cephalis is very short and poreless. Circumferential ridge and constriction between segments are shallow. There are many small pores scattered in the middle surface of each segment. In *T. eruca* as mentioned by Sugiyama (1997), an apical spine is either present or absent.

Range: Anisian

Occurrence: CD section

***Triassocampe* sp.**

Plate 5, Figure 10 and 15; Plate 6, Figure 4

Remarks: The specimens are common in the studied materials. The test is slender, long and cylindrical. Cephalis is dome shaped with a round apical horn. One row of pores is present on each postabdominal segment. Circumferential ridge has both weak and strong forms. Constriction is rather shallow. The specimens resemble *Triassocampe* sp.A and *Triassocampe* sp. B reported from the Mino Terrane, Japan, by Sugiyama (1997) in general form. It also similar to *Triassocampe* sp. cf. *T. diordinis* reported in this study, but differs by having an apical horn.

Remark: Anisian

Occurrence: CD and MSR section

Genus ***Yeharaia*** Nakaseko and Nishimura, 1979

Type species: ***Yeharaia elegans*** Nakaseko and Nishimura, 1979

Yeharaia annulata Nakaseko and Nishimura, 1979

Plate 6, Figure 10

1979 *Yeharaia annulata* n. sp.- Nakaseko and Nishimura, p.82-83, pl.10, fig. 1; pl.12, fig. 5

1994 *Yeharaia annulata* Nakaseko and Nishimura- Kozur and Mostler, p.147-148, pl.46, figs. 6-11 and 13; pl.47, figs. 4 and 5

Remarks: The specimens present the typical form of *Yeharaia.* The specimens are similar to *Y. annulata* from Japan as reported by Nakaseko and Nishimura (1979) in having well developed circumferential ridge with one ring of circular pores beneath the ridge. There is no distinct separation between cephalis and thorax.

Range: Early Ladinian

Occurrence: CD, KYY, and Km 119 section

Family **XIPHOTHECIDAE** Kozur and Mostler, 1981

Genus ***Xiphotheca*** De Wever, 1979

Type species**: *Xiphotheca karpenissionensis*** De Wever, 1979

***Xiphotheca* sp.**

Plate 18, Figure 15-17

Remarks: Test of this genus typically is long and cylindrical with nine to ten postabdominal segments. Cephalis is hemispherical to dome- shaped and poreless. Thorax and abdomen are subtrapesoidal in outline, poreless or with small pores with many small nodes.Stricture between abdominal segment and first postabdominal segment is deep depression.In the first postabdominal the test is at maximum width and then reduces its width in the next segment. Species in this genus are long, but these specimens are preserved only as the broken parts. That makes it difficult to find a complete form for identification species.

Range: Middle Carnian to Early Norian

Occurrence: Km 119 section

NASSELLARIA INCERTAE SEDIS

Genus ***Canesium*** Blome, 1984

Type species: ***Canesium Lentum*** Blome, 1984

Canesium lentum Blome, 1984

Plate 4, Figure 1 and 2

1979 *Eucyritidium*(?) sp. A- Nakaseko and Nishimura, p.78, pl.9, figs. 5, 9

1982 *Eucyritidium*(?) sp. A- Yao, pl.2, figs. 9, 10

1984 *Canesium Lentum* n. sp.- Blome, p.53-54, pl.14, figs. 3, 8, 11; pl.17, fig. 13

1986 *Canesium Lentum* Blome- Yoshida, pl.6, figs. 1, 2

1999 *Canesium Lentum* Blome- Tekin, p.177, pl.43, fig. 12

Remarks: Test is conical with one post abdominal segment. The width increases to the last chamber, with constriction at each chamber. Cephalis dome-shaped without horn. Thorax and abdoment are imperforate. The post abdominal segment possesses many large subcircular pore frames with nodes on the vertices of pores.

Range: Late Carnian to Early Norian

Occurrence: Km 119 section

Genus ***Castrum*** Blome, 1984

Type species: ***Castrum perornatum*** Blome, 1984

Castrum perornatum Blome, 1984

Plate 4, Figure 13-15

1979 *Dictyomitrella* sp. B- De Wever, San Filippo, Riedel and Gruber, p.90, pl.5, fig. 17

1984 *Castrum perornatum* n. sp.- Blome, p.54, pl.14, figs. 4, 9, 12, 14, 18; pl.17, fig. 9

1999 *Castrum perornatum* Blome-Tekin, p.177, pl.43, figs. 13, 14

Remarks: Test is conical with seven to eight post abdominal segments. Post abdominal segments have two different sized sets of polygonal pore frames separated by nodose circumferential ridges. Larger pore set is of large triangular to rectangular pores while the smaller set has subcircular to circular pores.

Range: Late Ladinian to Early Carnian

Occurrence: Km 119 and Km 175 section

Genus ***Celluronta*** Sugiyama, 1997

Type species: ***Celluronta donax*** Sugiyama, 1997

Celluronta donax Sugiyama, 1997

Plate 7, Figure 1 and 2

1997 *Celluronta donax* n. gen. n. sp. - Sugiyama, p.150, figs. 37-14, 15

Remarks: Test is long and slender, cylindrical in outline. Cephalis is subspherical to spherical, with rugged surface and imperforate. Apical spine is present or absent. Collar stricture marked by change in contour, but strictures between post- abdominal segments are not prominent. Pores of test are large and set in circular pore frames.

Remarks: Anisian

Occurrence: CD section

***Celluronta* sp.**

Plate 7, Figure 3

Remarks: The specimens are similar to *C. donax* (Sugiyama, 1997) by having the same cylindrical test and circular pores of test. Cephalis is sometimes subspherical or dome shaped. Apical spine is straight, long, needle- like and circular in cross section.

It is also similar to *C.conica* (Sugiyama, 1997), but differs by having a slender test and smaller pores than the latter.

Range: Anisian

Occurrence: CD and KYY section

CHAPTER IV

RADIOLARIAN BIOSTRATIGRAPHY

Triassic radiolarian faunas in this thesis were obtained from eight localities in northern Thailand including Chiang Dao (CD), Lamphun (LP), Den Chai (DC), Mae Sariang (MSR), Mae La Noi (MLN), KM 119, KM 175 and Khun Yuam (KYY). These are located within Inthanon Zone and Sukhothai Zone according to tectonic subdivision scheme (e.g., Ueno, 2003) (Fig. 4.1). Radiolarian occurrences and radiolarian biostratigraphy of this thesis study have been described as following.

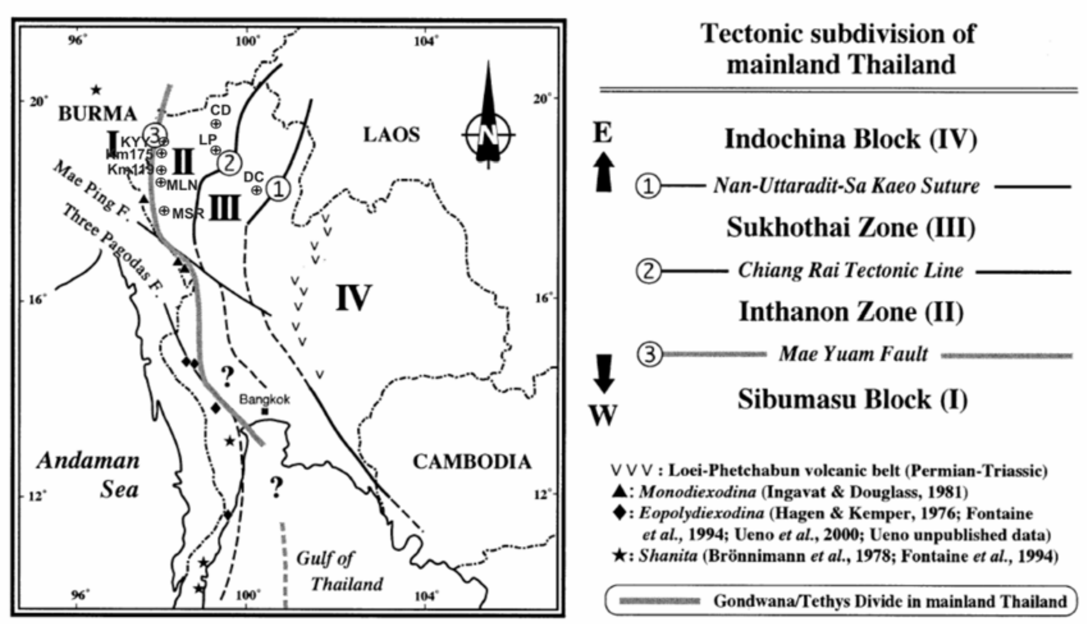


Figure. 4.1 Triassic Radiolarian localities in northern Thailand from this thesis in comparison with tectonic subdivision from Ueno (2003). Abbreviations of locality name see above.

4.1 Radiolarian occurrences in the study sections

4.1.1 CD section

Radiolarians from this chert section are moderately preserved and diverse in taxa but small in number. The common species of radiolarians in this study section are *Eptingium manfredi manfredi* Dumitrică, *E. m. japonicum* Nakaseko and Nishimura, *E. nakasekoi* Kozur and Mostler, *Triassocampe deweveri* (Nakaseko and Nishimura), *T. coronata* Bragin, *T. myterocorys* Sugiyama, *Archaeospongoprunum mesotriassicum mesotriassicum* Kozur and Mostler, *A. m. asymmetricum* Kozur and Mostler, *Hindeostylosphaera spinulosa* (Nakaseko and Nishimura), *Pseudostylosphaera coccostyla coccostyla* (Rüst), *P. longispinosa* Kozur and Mostler, *P. nazarovi* (Kozur and Mostler), *Spongostylus tricostatus* Kozur, Krainer and Mostler, *Paroertlispongus multispinosus* Kozur and Mostler, *P. rarispinosus* Kozur and Mostler, *Archaeocenosphaera* sp., *Acanthosphaera* sp., and *Astrocentrus* sp.

The other co-occurrence species consist mainly of *Triassocampe scalaris* Dumitrica, Kozur and Mostler, *Triassocampe* sp. cf. *T. diordinis* Bragin, *Triassocampe* sp. cf. *T. eruca* Sugiyama, *Striatotriassocampe nodosoannulata* Kozur and Mostler, *Celluronta donax* Sugiyama, *Tiborella florida florida* (Nakaseko and Nishimura), *Archaeospongoprunum bispinosum* Kozur and Mostler, *Pseudostylosphaera compacta* (Nakaseko and Nishimura), *Spongostylus tetrapterus* Ramovš and Goričan, *Oertlispongus* sp. cf. *O. diacanthus* Sugiyama, *Hozmadia rotunda* (Nakaseko and Nishimura), *Paurinella aequispinosa* Kozur and Mostler, *Paurinella* sp. cf. *P. curvata* Kozur and Mostler, *Paurinella* sp. cf. *P. trettoensis* Kozur and Mostler, *Paurinella* sp., *Tetrapaurinella* sp., *Plafkerium antiquum*

Sugiyama, *Hozmadia rotunda* (Nakaseko and Nishimura), *Hozmadia* sp. cf. *H. gifuensis* Sugiyama, *Hozmadia* sp. and others.

Among these fauna *Eptingium manfredi manfredi* Dumitrică are frequent at the base while the genus *Archaeospongoprunum* and *Triassocampe* are common at the upper part. *Archaeospongoprunum mesotriassicum mesotriassicum* Kozur and Mostler, *Tiborella florida florida* (Nakaseko and Nishimura) are typical Illyrian species (Kozur and Mostler, 1994). They are first occurred in the upper part of this section.

Advanced forms of the family Oertlispongiidae with recurved main polar spine which is common in Ladinian were not found in this section. The appropriated range of this assemblage is Middle to Late Anisian (Table 4.1).

4.1.2 LP section

The radiolarian fauna of this locality is very poorly preserved. All of them are recrystallized and can hardly be determinated. However, some characteristics of these fauna are represented and have been assigned to *Triassocampe* sp., *Eptingium* sp. and *Archaeocenosphaera* sp. These species are common in Middle Triassic.

This locality was previously investigated by Feng et al., 2002. From their study, the radiolarian assemblage is composed of *Triassocampe deweveri* (Nakaseko and Nishimura), *Eptingium manfredi* Dumitrică, *Cryptostephanidium* sp. cf. *C. cornigerum* Dumitrică, *Parasepsagon asymmetricus praetetracanthus* Kozur and Mostler, *Pseudostylosphaera coccostylus* (Rüst), *Pseudostylosphaera longispinosa* Kozur and Mostler, *Parasepsagon* variabilis (Nakaseko and Nishimura), *Paroertlispongus multispinosus* Kozur and Mostler, *Astrocentrus* sp. and others.

Based on their assemblage, they are correlated to Late Anisian in age. Therefore, this chert section is considered as Late Anisian followed the previous study.

4.1.3 Den Chai section

At the base of Den Chai Section, *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura) is abundant together with *Muelleritortis cochleata tumidospina* Kozur and *Muelleritortis expansa* Kozur and Mostler. Other co-occurrence species are composed of *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera imperspicua* (Bragin), *Pseudostylosphaera* sp., *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe scalaris* Dumitrica, *Annulotriassocampe companilis* Kozur, *Annulotriassocampe multisegmantus* Tekin, *Annulotriassocampe sulovensis* (Kozur and Mock), *Annulotriasocampe* sp., *Pararuesticyrtium* sp.cf. *P. illyricum* Kozur and Mostler, *Pararuesticyrtium* sp. A, *Pararuesticyrtium* sp., *Striatotriassocampe nodosoannulata* Kozur and Mostler, *Japonocampe nova* (Yao), *Canoptum inornatus* Tekin, *Canoptum levis* Tekin, *Canoptum* sp.A, *Canoptum* sp.**,** *Corum kraineri* Tekin, *Archaeocenosphaera* sp. cf. *A. laseekensis* Pessagno and Yang, *Archaeocenosphaera* sp., *Acanthosphaera* sp., *Pseudogodia* ? sp. and some occurrences of *Orbiculiforma karnica* (Kozur and Mostler), *Orbiculiforma* sp. cf. *O. gazipasaensis* Tekin, *Praeheliostaurus* sp.**,** *Spongoserrula rarauana* Dumitrică**,** and *Paronaella* sp.

According to the occurrence of *Spongoserrula rarauana* which is first occurred in the middle of Longobardian (Late Ladinian) with abundant species of *Muelleritortis cochleata* group and the absent of genus *Tritortis*, it indicates that the age of this section is Late Ladinian (Longobardian) (Table 4.4).

4.1.4 KYY section

At the base of this section, the fauna is very rare. It is represent by small number of following species: *Paroertlispongus chiensis* (Feng), *Cryptostephanidium cornigerum* Dumitrică, *Perispyridium* sp., *Spongostephanidium spongiosum* Dumitrică, *Parasepsagon* sp., *Triassospongosphaera multispinosa* (Kozur and Mostler), *Archaeocenosphaera* sp. and *Acanthosphaera* sp.

About one meter above the base of this section, the first appearance of advanced species of genus Oertlispongidae is occurred. These fauna are diverse and abundant. They are *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler, *Baumgartneria ambigua* Dumitrică, *Baumgartneria curvispina* Dumitrică, *Baumgartneria retrospina* Dumitrică, *Baumgartneria yehae* Kozur and Mostler and *Falcispongus calcaneum* Dumitrică. They occurred together with the forerunner form of the genus, they are *Paroertlispongus chinensis* (Feng), *Paroertlispongus multispinosus* Kozur and Mostler, *Paroertlispongus rarispinosus* Kozur and Mostler, *Pseudoertlispongus mostleri mostleri* Kozur, *Paroertlispongus daofuensis* Feng and *Paroertlispongus* sp. aff. *P. daofuensis* Feng.

Other co-occurrence species of this assemblage comprise mainly of *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe scalaris* Dumitrica, *Triassocampe* sp. cf. *T. diordinis* Bragin, *Pararuesticyrtium* sp.cf. *P. illyricum* Kozur and Mostler, *Pararuesticyrtium* sp., *Striatotriassocampe nodosoannulata* Kozur and Mostler, *Eptingium manfredi manfredi* Dumitrică, *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera japonica* (Nakaseko and Nishimura), *Pseudostylosphaera longispinosa* Kozur and Mostler, *Pseudostylosphaera magnispinosa* Yeh, *Pseudostylosphaera tenuis* (Nakaseko and Nishimura), *Pseudostylosphaera timorensis* Sashida and Kamata, *Parasepsagon* sp., *Archaeocenosphaera* sp. and *Acanthosphaera* sp. Some associated species are *Eptingium nakasekoi* Kozur and Mostler, *Eptingium ramovsi* Kozur and Mostler, *Cryptostephanidium cornigerum* Dumitrică, *Spongostephanidium spongiosum* Dumitrică, *Pylostephanidium clavator* Dumitrică, *Triassistephanidium laticorne* Dumitrică, *Spongostylus tricostatus* Kozur,Krainer and Mostler, *Staurolonche trispinosum trilobum* (Nakaseko and Nishimura), *Triassospongosphaera multispinosa* (Kozur and Mostler), *Acanthosphaera carterae* Kozur and Mostler, *Spongosilicarmiger nakasekoi* Yeh, *Paratriassocampe* sp. cf. *P. gaetanii* Kozur and Mostler and *Yeharaia annulata* Nakaseko and Nishimura.

Based on the the occurrence of advanced Oertlispongidae with different spines, especially the occurrence of the long recurved spine as *Oertlispongus inaequispinosus* which is the typical guideform in Fassanian age. The typical Late Ladinian species were not found. Therfore, the base of this section should be Late Anisian (Illyrian) and the upper part is Early Ladinian (Fassanian). The total range of this locality is Late Anisian (Illyrian) to Early Ladinian (Fassanian) (Table 4.7).

4.1.5 Km 175 section

The radiolarian assemblage of this locality is characterized by the diverse occurrence of *Muelleritortis* together and *Tritortis*. They are *Muelleritortis cive* Sugiyama, *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura), *Muelleritortis cochleata koeveskalensis* Kozur, *Muelleritortis cochleata tumidospina* Kozur, *Muelleritortis expansa* Kozur and Mostler, *Muelleritortis firma* (Goričan and Buser), *Muelleritortis longispinosa* Kozur, *Muelleritortis* cf. *M. quadrata* Kozur and

Mostler, *Tritortis kretaensis dispiralis* (Bragin), and *Tritortis kretaensis kretaensis* (Kozur and Khahl).

Other common co-occurrence species are advanced form of genus *Pseudostylosphaera*; *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera goestlingensis* (Kozur and Mostler), *Pseudothstylosphaera goricanae* Kozur and Mostler, *Pseudostylosphaera gracilis* Kozur and Mock, *Pseudostylosphaera imperspicua* (Bragin), *Pseudostylosphaera nazarovi* (Kozur and Mostler), *Pseudostylosphaera tenuis* (Nakaseko and Nishimura) and *Pseudostylosphaera timorensis* Sashida and Kamata together with advanced form of genus *Oertlispongidae*; *Spongoserrula rarauana* Dumitrică, *Spongoserrula* sp.**,** *Scutispongus* sp., and primitive form of *Paroertlispongus multispinosus* Kozur and Mostler and *Paroertlispongus rarispinosus* Kozur and Mostler.

Additional fauna are *Annulotriassocampe baldii* Kozur, *Annulotriassocampe multisegmantus* Tekin, *Annulotriassocampe sulovensis* (Kozur and Mock), *Japonocampe nova* (Yao)**,** *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe scalaris* Dumitrica, *Yeharaia annulata* Nakaseko and Nishimura, *Cryptostephanidium cornigerum* Dumitrică, *Orbiculiforma karnica* (Kozur and Mostler), *Castrum perornatum* Blome, *Canoptum levis* Tekin, *Corum kraineri* Tekin, *Corum* sp. A, *Vinassaspongus erendili* Tekin, *Karnospongella bispinosa* (Kozur and Mostler), *Parasepsagon* sp., *Paurinella* sp., *Triassospongosphaera multispinosa* (Kozur and Mostler), *Archaeocenosphaera* sp. and *Astrocentrus* sp.

Based on the abundance of co-ocurrence species of *Spongoserrula rarauana*, it indicates that the base of this section is not older than Middle Longobardian of Late Ladinian. The abundance of genus *Muelleritortis* and genus *Tritortis* also reveals that the upper part of this section is not younger than Ladinian / Carnian boundary. Therefore, the suitable age of this section is Late Ladinian (Middle Longobardian to Uppermost Longobardian) (Table 4.6).

4.1.6 Km 119 section

The radiolarian assemblage of this locality is based on two rock samples of siliceous limestone. The radiolarian fauna are very diverse and well preserved. They are composed of the following species: *Pseudostylosphaera goestlingensis* (Kozur and Mostler), *Pseudostylosphaera goricanae* Kozur and Mostler, *Pseudostylosphaera gracilis* Kozur and Mock, *Pseudostylosphaera longispinosa* Kozur and Mostler, *Pseudostylosphaera nazarovi* (Kozur and Mostler), *Pseudostylosphaera timorensis* Sashida and Kamata, *Spongostylus tortilis* Kozur and Mostler, *Vinassaspongus erendili* Tekin, *Tritortis* sp. A, *Tetraporobrachia haeckelli* Kozur and Mostler, *Parasepsagon* sp., *Pentaspongodiscus steigeri* Lahm, *Tetraspongodiscus nazarovi* (Kozur and Mostler), *Praeheliostaurus levis* Kozur and Mostler, *Praeheliostaurus quadrispinosus* Mostler and Krainer, *Orbiculiforma goestlingensis* (Kozur and Mostler), *Orbiculiforma karnica* (Kozur and Mostler), *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler, *Baumgartneria* sp. cf. *B. curvispina* Dumitrică, *Bogdanella* sp., *Steigerispongus* sp., *Palaeosaturnalis karnicus* (Kozur and Mostler), *Palaeosaturnalis triassicus* (Kozur and Mostler), *Annulotriassocampe baldii* Kozur, *Annulotriassocampe companilis* Kozur, *Annulotriassocampe multisegmantus* Tekin, *Annulotriassocampe sulovensis* (Kozur and Mock), *Triassocampe coronata* Bragin, *Triassocampe* sp. cf. *T. diordinis* Bragin, *Yeharaia annulata* Nakaseko and Nishimura, *Canoptum inornatus* Tekin, *Canoptum levis* Tekin, *Canoptum* sp. A**,** *Japonocampe nova* (Yao)**,** *Pachus firmus* Blome, *Pachus multinodosus* Tekin, *Corum* *kraineri* Tekin, *Corum* sp. cf. *C. regium* Blome, *Corum* sp. A, *Castrum perornatum* Blome, *Canesium Lentum* Blome, *Xiphotheca* sp.**,** *Triassospongosphaera multispinosa* (Kozur and Mostler), *Archaeocenosphaera* sp. and *Astrocentrus* sp. In addition, some poorly preserved conodonts are also obtained (Table 4.5).

The age of this assemblge is based on the occurrence of *Tetraporobrachia haeckelli* Kozur and Mostler together with species of genus *Palaeosaturnalis* and *Xiphotheca*, which indicate Early to Middle Carnian age (Kozur, 1994).

4.1.7 MLN section

The section is moderately well preserved. The species are rare and small in number. It contains the following radiolarian species: *Eptingium manfredi manfredi* Dumitrică, *Archaeospongoprunum bispinosum* Kozur and Mostler, *A. mesotriassicum mesotriassicum* Kozur and Mostler, *A. mesotriassicum asymmetricum* Kozur and Mostler, *Hindeosphaera spinulosa* (Nakaseko and Nishimura), *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera longispinosa* Kozur and Mostler, *Pseudostylosphaera nazarovi* (Kozur and Mostler), *Spongostylus tricostatus* Kozur, Krainer and Mostler, *Paroertlispongus multispinosus* Kozur and Mostler, *Paroertlispongus rarispinosus* Kozur and Mostler, *Paroertlispongus* sp., *Paurinella* sp., *Hozmadia rotunda* (Nakaseko and Nishimura), *Parasepsagon variabilis* (Nakaseko and Nishimura), *Archaeocenosphaera* sp., *Acanthosphaera nicorae* Kozur and Mostler, *Acanthosphaera* sp., *Astrocentrus* sp.**,** *Annulotriassocampe companilis* Kozur**,** *Triassocampe coronata* Bragin**,** *Triassocampe deweveri* (Nakaseko and Nishimura) and *Triassocampe myterocorys* Sugiyama (Table 4.2).

Among these fauna, *Archaeospongoprunum bispinosum* and *A. mesotriassicum mesotriassicum* are Illyrian species, the typical of Late Anisian guideform. *Hindeosphaera spinulosa* is also frequently occured in the Late Anisian. Some species such as *Acanthosphaera nicorae* and *Hozmadia rotunda* are the taxon that restricted to *Tiborella florida* Subzone of *Spongosilicarmiger transitus* Zone (Kozur and Mostler, 1994; Kozur, Krainer and Mostler, 1996).

No taxa first appearing in the Ladinian age have been found.The age of this assemblage is therefore a Late Anisian (Illyrian).

4.1.8 MSR section

The fauna of this section are rarely and very poorly preserved. The characteristic species are *Eptingium manfredi manfredi* Dumitrică, *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Spongostephanidium* sp. cf. *S. longispinosum* Dumitrică, *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe* sp., *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler, *Paroertlispongus multispinosus* Kozur and Mostler, *Pseudoertlispongus mostleri* Kozur, *Paurinella* sp., and *Pararuesticyrtium* sp. (Table 4.3).

Based on the occurrence of the typical guideform of Fassanian as recurved spine of *Oertlispongus inaequispinosus*, the age of this section is confirmed as Early Ladinian (Fassanian).

4.2 Triassic Radiolarian Biostratigraphy

Radiolarian faunas from this study can be catagorised into six assemblage zones including *Eptingium manfredi* Assemblage Zone, *Triassocampe deweveri* Assemblage Zone, *Oertlispongus inaequispinosus* Assemblage Zone, *Muelleritortis cochleata* Assemblage Zone, *Tritortis kretaensis* Assemblage Zone, and

Tetraporobrachia haeckelli Assemblage Zone. Their boundaries, characteristics, and age are provided as follows.

4.2.1 *Eptingium manfredi* Assemblage Zone

Lower boundary: Not defined

Upper boundary: First appearance of *Triassocampe deweveri*

Definition: This assemblage zone is characterized by the abundant occurrence of diverse species of *Eptingium*, particularly *Eptingium manfredi manfredi* Dumitrică, *E. m. japonicum* Nakaseko and Nishimura, *E. nakasekoi* Kozur and Mostler.

Other co-occurrence species are *Cryptostephanidium cornigeum* Dumitrică, *Spongostephanidium* sp. cf. *S. longispinosum* Dumitrică, *Plafkerium antiquum* Sugiyama, *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera compacta* (Nakaseko and Nishimura), *P. longispinosa* Kozur and Mostler, *Pseudostylosphaera japonica* (Nakaseko and Nishimura), *Pseudostylosphaera coccostyla acrior* (Bragin), *Pseudostylosphaera magnispinosa* Yeh, *Pseudostylosphaera tenuis* (Nakaseko and Nishimura), *Pseudostylosphaera* sp. A**,** *Spongostylus* sp. A, *Spongostylus* sp. B, *Perispyridium* sp**.,** *Parasepsagon* sp., *Sepsagon* sp. cf. *S. robustus* Lahm, *Pantanellium* sp., *Hozmadia* sp. cf. *H. gifuensis* Sugiyama, *Hozmadia* sp. A, *Archaeocenosphaera* sp**.,** *Acanthosphaera* sp., *Triassospongosphaera multispinosa* (Kozur and Mostler), *Celluronta donax* Sugiyama, *Celluronta* sp., *Oertlispongus* sp. cf. *O. diacanthus* Sugiyama, and *Paroertlispongus multispinosus* Kozur and Mostler**.**

In the uppermost part of this assemblage zone is the first appearance of *Archaeospongoprunum mesotriassicum mesotriassicum* Kozur and Mostler, *A.m.asymmetricum* Kozur and Mostler, *Striatotriassocampe nodosoannulata* Kozur and Mostler, *Triassocampe* sp. cf. *T. eruca* Sugiyama, *Triassocampe* sp. and *Pseudoertlispongus* sp. cf. *P. angulatus* Kozur.

Remarks: This assemblage that lacks *Triassocampe deweveri* has some species in common with Triassic rocks from Mino Terrane, Central Japan, which are dated as Middle Anisian in age (Sugiyama, 1992; 1997).

Occurrence: This assemblage zone occurs in bedded chert of Chiang Dao (CD 135 to 339) and Mae La Noi (MLN 1-10 to 1-12, 2-6, and 3-1 to 3-2).

Age: Middle to early Late Anisian

4.2.2 *Triassocampe deweveri* Assemblage Zone

Lower boundary: First appearance of *Triassocampe deweveri*

Upper boundary: First appearance of *Oertlispongus inaequispinosus*

Definition: This assemblage zone is marked at the base by the first appearance of *Triassocampe deweveri* and other species that belonging to this genus; *T. coronata* Bragin, *T. myterocorys* Sugiyama, *Triassocampe* sp. cf. *T. diordinis* Bragin. The first appearance of *Yeharaia annulata* Nakaseko and Nishimura, *Hindeostylosphaera spinulosa* (Nakaseko and Nishimura), *Plafkerium contortum* Dumitrică, Kozur and Mostler, *Pseudostylosphaera nazarovi* (Kozur and Mostler), *Pseudostylosphaera timorensis* Sashida and Kamata, *Paroertlispongus rarispinosus* Kozur and Mostler, and *Pseudoertlispongus mostleri mostleri* Kozur seem to coincide with or occur slightly above or below the base of this assemblage zone.

Hozmadia sp. cf. *H. rotunda* (Nakaseko and Nishimura), *Hozmadia* sp. B, *Hozmadia* sp. C, *Astrocentrus* sp., *Pararuesticyrtium* sp., *Paratriassocampe* sp. cf. *P. gaetanii* Kozur and Mostler, and *Pseudotriassocampe* sp. also make their first appearance in this assemblage zone. Other characteristic constituents are *Paurinella* sp., *Tetrapaurinella* sp. *Eptingium manfredi* Dumitrică group, *Pseudostylosphaera* group, *Celluronta donax* Sugiyama, *Celluronta* sp., *Parasepsagon* sp., *Sepsagon* sp. cf. *S. robustus* Lahm, *Pantanellium* sp., *Plafkerium antiquum* Sugiyama, *Triassospongosphaera multispinosa* (Kozur and Mostler), *Archaeocenosphaera* sp. and *Acanthosphaera* sp.

The upper part of this zone is distinguished from the lower part by the presence of *Triassocampe scalaris* Dumitrica, *Annulotriassocampe sulovensis* (Kozur and Mock), *Paurinella aequispinosa* Kozur and Mostler, *Spongostylus tricostatus* Kozur,Krainer and Mostler, *Spongostylus tetrapterus* Ramovš and Goričan, *Tiborella florida florida* (Nakaseko and Nishimura), *Pentaspongodiscus mesotriassicus* Dumitrică , Kozur and Mostler, *P. symmetricus* Dumitrică , Kozur and Mostler, and *Pseudostylosphaera goestlingensis* (Kozur and Mostler) .

Species that belonging to genus *Archaeospongoprunum*, namely: *Archaeospongoprunum mesotriassicum mesotriassicum* Kozur and Mostler, *A. m. mesotriassicum* Kozur and Mostler, and *A. m. asymmetricum* Kozur and Mostler are abundant throughout the upper part of this zone .

Remarks: Similar faunas have been reported from Japan by Nakaseko and Nishimura (1979), Far East Russia by Bragin (1991), Europe by Kozur and Mostler (1994) and Slovenia by Ramovs and Gorican (1995), which are dated as Late Anisian in age.

Occurrence: This assemblage zone occurs in the section of Chiang Dao (CD 1-135), Lamphun, Mae La Noi (MLN 1-1 to 1-9), Mae Sariang (MSR 4-1 to 4-5), and Khun Yuam (KYY 3-1 to 3-5).

Age: Late Anisian

4.2.3 *Oertlispongus inaequispinosus* Assemblage Zone

Lower Boundary: First appearance of *Oertlispongus inaequispinosus*

Upper Boundary: First appearance of *Muelleritortis cochleata*

Definition: The base of this assemblage zone is characterised by the first occurrence of *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler and other species of advanced form in this genus. Co-occurring radiolarians are *Baumgartneria ambigua* Dumitrică, *Baumgartneria curvispina* Dumitrică, *Baumgartneria retrospina* Dumitrică, *Baumgartneria yehae* Kozur and Mostler and *Falcispongus calcaneum* Dumitrică. They occur together with precursors of the genus: *Paroertlispongus chinensis* (Feng), *Paroertlispongus multispinosus* Kozur and Mostler, *Paroertlispongus rarispinosus* Kozur and Mostler, *Pseudoertlispongus mostleri mostleri* Kozur, *Paroertlispongus daofuensis* Feng and *Paroertlispongus* sp. aff. *P. daofuensis* Feng.

Other species in this assemblage consist mainly of *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe scalaris* Dumitrica, *Triassocampe* sp. cf. *T. diordinis* Bragin, *Pararuesticyrtium* sp.cf. *P. illyricum* Kozur and Mostler, *Pararuesticyrtium* sp., *Striatotriassocampe nodosoannulata* Kozur and Mostler, *Eptingium manfredi manfredi* Dumitrică, *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera japonica* (Nakaseko and Nishimura), *Pseudostylosphaera longispinosa* Kozur and Mostler, *Pseudostylosphaera magnispinosa* Yeh, *Pseudostylosphaera tenuis* (Nakaseko and Nishimura), *Pseudostylosphaera timorensis* Sashida and Kamata, *Parasepsagon* sp., *Archaeocenosphaera* sp. and *Acanthosphaera* sp.

With some specimens of the following species: *Eptingium nakasekoi* Kozur and Mostler, *Eptingium ramovsi* Kozur and Mostler, *Cryptostephanidium cornigerum* Dumitrică, *Spongostephanidium spongiosum* Dumitrică, *Pylostephanidium clavator* Dumitrică, *Triassistephanidium laticorne* Dumitrică, *Spongostylus tricostatus* Kozur,Krainer and Mostler, *Staurolonche trispinosum trilobum* (Nakaseko and Nishimura), *Triassospongosphaera multispinosa* (Kozur and Mostler), *Acanthosphaera carterae* Kozur and Mostler, *Spongosilicarmiger nakasekoi* Yeh, *Paratriassocampe* sp. cf. *P. gaetanii* Kozur and Mostler and *Yeharaia annulata* Nakaseko and Nishimura.

Remarks: This radiolarian assemblage can be correlated to *Oertlispongus inaequispinosus* Subzone, upper subzone of *Spongosilicarmiger italicus* Zone (Kozur and Mostler, 1994) due to the occurrence of species. Moreover, study of the Mesozoic radiolarian biostratigraphy of Oman reveals the age of this assemblage as Fassanian, Early Ladinian (Dumitrica, 1999).

Occurrence: Mae Sariang (only MSR 5-3) and Khun Yuam (KYY 1-1 to 1-5 and 2-1 to 2-3).

Age: Early Ladinian (Fassanian)

4.2.4 *Muelleritortis cochleata* Assemblage Zone

Lower Boundary: First appearance of *Muelleritortis cochleata* group

Upper Boundary: First appearance of *Tritortis kretaensis* group

Definition: This assemblage zone is defined by the first occurrence of the *Muelleritortis cochleata* group. *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura) is abundant together with *Muelleritortis cochleata tumidospina* Kozur and *Muelleritortis expansa* Kozur and Mostler.

Other co-occurring species include *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera imperspicua* (Bragin), *Pseudostylosphaera* sp., *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe scalaris* Dumitrica, *Annulotriassocampe companilis* Kozur, *Annulotriassocampe multisegmantus* Tekin, *Annulotriassocampe sulovensis* (Kozur and Mock), *Annulotriasocampe* sp., *Pararuesticyrtium* sp. cf. *P. illyricum* Kozur and Mostler, *Pararuesticyrtium* sp. A, *Pararuesticyrtium* sp., *Striatotriassocampe nodosoannulata* Kozur and Mostler, *Japonocampe nova* (Yao), *Canoptum inornatus* Tekin, *Canoptum levis* Tekin, *Canoptum* sp.A, *Canoptum* sp.**,** *Corum kraineri* Tekin, *Archaeocenosphaera* sp. cf. *A. laseekensis* Pessagno and Yang, *Archaeocenosphaera* sp., *Acanthosphaera* sp., *Pseudogodia* ? sp., and some occurrence species of *Orbiculiforma karnica* (Kozur and Mostler), *Orbiculiforma* sp. cf. *O. gazipasaensis* Tekin, *Praeheliostaurus* sp.**,** *Spongoserrula rarauana* Dumitrică**,** and *Paronaella* sp.

Remarks: This assemblage can be correlated with the European *Muelleritortis cochleata* Zone of Kozur and Mostler (1994; 1996) and TR 4A (*Muelleritortis cochleatum* Lowest-occurrence Zone) from the Mino Terrane, Central Japan (Sugiyama, 1997), which are dated as Late Ladinian in age (base of Middle Longobardian to uppermost Longobardian).

Occurrence: Denchai Section and Km 175-6

Age: early to late Late Ladinian (Early to early Late Longobardian)

4.2.5 *Tritortis kretaensis* Assemblage Zone

Lower Boundary: First appearance of *Tritortis kretaensis* group

Upper Boundary: First appearance of *Tetraporobrachia haeckelli*

Definition: This assemblage zone is characterised by the first occurrence of *Tritortis kretaensis dispiralis* (Bragin) and *Tritortis kretaensis kretaensis* (Kozur and Khahl) together with *Muelleritortis cochleata* group. They are *Muelleritortis cive* Sugiyama, *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura), *Muelleritortis cochleata koeveskalensis* Kozur, *Muelleritortis cochleata tumidospina* Kozur, *Muelleritortis expansa* Kozur and Mostler, *Muelleritortis firma* (Goričan and Buser), *Muelleritortis longispinosa* Kozur, *Muelleritortis* sp. cf. *M. quadrata* Kozur and Mostler, *Tritortis kretaensis dispiralis* (Bragin), *Tritortis kretaensis kretaensis* (Kozur and Khahl). Other common co-occuring species are advanced forms of genus *Pseudostylosphaera*; *Pseudostylosphaera coccostyla coccostyla* (Rüst), *Pseudostylosphaera goestlingensis* (Kozur and Mostler), *Pseudothstylosphaera goricanae* Kozur and Mostler, *Pseudostylosphaera gracilis* Kozur and Mock, *Pseudostylosphaera imperspicua* (Bragin), *Pseudostylosphaera nazarovi* (Kozur and Mostler), *Pseudostylosphaera tenuis* (Nakaseko and Nishimura) and *Pseudostylosphaera timorensis* Sashida and Kamata together with abundant of advanced forms of genus *Oertlispongus*; *Spongoserrula rarauana* Dumitrică, *Spongoserrula* sp.**,** *Scutispongus* sp., and primitive forms of *Paroertlispongus multispinosus* Kozur and Mostler and *Paroertlispongus rarispinosus* Kozur and Mostler. Additional members are *Annulotriassocampe baldii* Kozur, *Annulotriassocampe multisegmantus* Tekin, *Annulotriassocampe sulovensis* (Kozur and Mock), *Japonocampe nova* (Yao)**,** *Triassocampe deweveri* (Nakaseko and Nishimura), *Triassocampe scalaris* Dumitrica, *Yeharaia annulata* Nakaseko and Nishimura, *Cryptostephanidium cornigerum* Dumitrică, *Orbiculiforma karnica* (Kozur and Mostler), *Castrum perornatum* Blome, *Canoptum levis* Tekin, *Corum* *kraineri* Tekin, *Corum* sp. A, *Vinassaspongus erendili* Tekin, *Karnospongella bispinosa* (Kozur and Mostler), *Parasepsagon* sp., *Paurinella* sp., *Triassospongosphaera multispinosa* (Kozur and Mostler), *Archaeocenosphaera* sp. and *Astrocentrus* sp.

Remarks: An identical fauna occurs in the upper part of the *Muelleritortis cochleata* Zone of Kozur and Mostler (1994; 1996) and reported from Turkey by Tekin (1999), which are dated as Cordevorlian in age, but the lower boundary of this zone can be either in the uppermost Longobardian or in the lowermost Cordevolian.

Occurrence: Km 175 (Km 175-1 to 175-5)

Age: late Late Ladinian (Late Longobardian) to Early Carnian

4.2.6 *Tetraporobrachia haeckelli* Assemblage Zone

Lower Boundary: First appearance of *Tetraporobrachia haeckelli*, *Palaeosaturnalis karnicus* , *Palaeosaturnalis triassicus* and *Xiphotheca* sp.

Upper Boundary: Not yet defined

Definition: This assemblage zone is characterised by the first occurrence of *Tetraporobrachia haeckelli* Kozur and Mostler together with the first occurrence of species in genus *Palaeosaturnalis* and *Xiphotheca*, including the following species: *Pseudostylosphaera goestlingensis* (Kozur and Mostler), *Pseudostylosphaera goricanae* Kozur and Mostler, *Pseudostylosphaera gracilis* Kozur and Mock, *Pseudostylosphaera longispinosa* Kozur and Mostler, *Pseudostylosphaera nazarovi* (Kozur and Mostler), *Pseudostylosphaera timorensis* Sashida and Kamata, *Spongostylus tortilis* Kozur and Mostler, *Vinassaspongus erendili* Tekin, *Tritortis* sp. A, *Parasepsagon* sp., *Pentaspongodiscus steigeri* Lahm, *Tetraspongodiscus nazarovi* (Kozur and Mostler), *Praeheliostaurus levis* Kozur and Mostler, *Praeheliostaurus* *quadrispinosus* Mostler and Krainer, *Orbiculiforma goestlingensis* (Kozur and Mostler), *Orbiculiforma karnica* (Kozur and Mostler), *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler, *Baumgartneria* sp. cf. *B. curvispina* Dumitrică, *Bogdanella* sp., *Steigerispongus* sp., *Palaeosaturnalis karnicus* (Kozur and Mostler), *Palaeosaturnalis triassicus* (Kozur and Mostler), *Annulotriassocampe baldii* Kozur, *Annulotriassocampe companilis* Kozur, *Annulotriassocampe multisegmantus* Tekin, *Annulotriassocampe sulovensis* (Kozur and Mock), *Triassocampe coronata* Bragin, *Triassocampe* sp. cf. *T. diordinis* Bragin, *Yeharaia annulata* Nakaseko and Nishimura, *Canoptum inornatus* Tekin, *Canoptum levis* Tekin, *Canoptum* sp. A, *Japonocampe nova* (Yao), *Pachus firmus* Blome, *Pachus multinodosus* Tekin, *Corum kraineri* Tekin, *Corum* sp. cf. *C. regium* Blome, *Corum* sp. A, *Castrum perornatum* Blome, *Canesium Lentum* Blome, *Xiphotheca* sp., *Triassospongosphaera multispinosa* (Kozur and Mostler), *Archaeocenosphaera* sp. and *Astrocentrus* sp.

Remarks: A similar fauna has been reported from Turkey by Tekin(1999) , North – Central Nevada, America by Blome and Reed (1995), and in Hungary it is known as *Tetraporobrachia haeckelli* Zone (Kozur and Mostler, 1994), which are dated as Middle Carnian in age.

Occurrence: Km 119 Section

Age: Early to Middle Carnian?

4.3 Biostratigraphic Correlation with Other Assemblages

4.3.1. Correlation with Yao (1982)

Yao (1982) established four assemblages of Middle Triassic to Early Jurassic age from the Inuyama area, Central Japan, namely *Triassocampe deweveri*, *Triassocampe nova*, *Canoptum triassicum*, and *Parahsuum simplum* Assemblages in chronological order. Only the first two assemblages can be lelated to the sections analyses here. The *Triassocampe deweveri* Assemblage of Yao (1982) is well correlated with *Triassocampe deweveri* Assemblage Zone of this study based on the co-occurrence of identical species such as *Triassocampe deweveri*, *T. coronata*, *T. myterocorys*, *Yeharaia annulata*, *Hozmadia* sp., *Cryptostephanidium cornigerum*, *Eptingium manfredi*, and *Pseudosylosphaera japonica*.

The next overlying assemblage of *Triassocampe nova* is difficult to make a presice correlation. It is probably correlated with *Tetraporobrachia haeckeli* Assemblage Zone based on the occurrence of *Triassocampe nova* (*Japonocampe nova* herein), *Triassocampe* sp. cf. *T. coronata* and *Canesium lentum*, but this is uncertain due to the lack of a greater number of identical species.

4.3.2. Correlation with Bragin (1991)

Bragin (1991) studied Triassic radiolarians from siliceous claystone and bedded chert units in Sikhote-Alyn, Sakhalin and the Koryak Upland. Seven zones of Triassic age were established. They are the *"Stylosphaera" fragilis* Zone, *Hozmadia*, *Triassocampe diordinis*, *Triassocampe deweveri*, *Sarla dispiralis*, *Triassocampe nova*, and *Canoptum triassicum* Zones in ascending order.

The characteristic species of *"Stylosphaera" fragilis* Zone are not presented in this study. The *Hozmadia* Zone and *Triassocampe diordinis* possibly lie within the *Eptingium manfredi* Assemblage Zone due to the first appearance of species *Hozmadia*, *"Stylosphaera" compacta* (*Pseudostylospheara japonica* group herein) and the absence of *Triassocampe deweveri* of the overlying zone. Bragin's *Triassocampe deweveri* Zone is correlative with *Triassocampe deweveri* Assemblage

Zone and *Oertlispongus inaequispinosus* Assemblage Zone of this study owning to the occurrence and stratigraphic range of the nominal species.

The nominal species of the *Sarla dispiralis* Zone is refered to here as *Tritortis kretaensis*. Bragin subdivided it into two subzones; a lower *Yeharaia elegans* subzone and an upper *Plafkerium cochleatum* subzone, refered to here as *Muelleritortis cochleata*. *Yeharaia elegans* is absent in this study, and this subzone is tentatively placed in the lowermost part of *Muelleritortis cochleata* Assemblage Zone based on its stratigraphic relation with the overlying zone. *Plafkerium cochleatum* subzone is correlated with the lower part of *Muelleritortis cochleata* Assemblage Zone and the *Tritrortis kretaensis* Assemblage Zone based on the ranges of the nominal species.

Triassocampe nova is possibly correlative with a part of the *Tetraporobrachia haeckeli* Assemblage Zone based on the appearance of *Japonocampe nova*, but the details are uncertain owning to poorly preserved characteristic species.

4.3.3 Correlation with Sashida et al. (1993)

Sashida et al. (1993) recognised five Triassic radiolarian assemblages in bedded cherts in the Kiso Mountains, eastern part of the Mino Terrane, Japan. They are *Pseudostyloshaera japonica*, *Pseudostyloshaera helicata*, *Cryptostephanidium sp.*, *Capnuchosphaera sp.*, and *Betraccium sp.* Assemblages, in ascending order.

The *Pseudostyloshaera japonica* is tentatively correlated with *Triassocampe deweveri* Assemblage Zone to *Muelleritortis cochleata* Assemblage Zone based on the ranges of co-occurring species such as *Eptingium manfredi*, *Triassocampe deweveri, Emiluvia* ? *cochleata* (*Muelleritortis cochleata* herein) and species of the genus *Pseudostyloshaera.*

The *Pseudostyloshaera helicata* Assemblage is probably correlative with the lower part of *Muelleritortis cochleata* Assemblage Zone based on species in common such as *Emiluvia* ? *cochleata* (*Muelleritortis cochleata* herein), species of *Pseudostyloshaera*, and *Triassocampe deweveri*.

The *Cryptostephanidium sp*. Assemblage is uncertain because of the lack of identical species. However, it is tentatively equated with the upper part of *Muelleritortis cochleata* Assemblage Zone based on the occurrence of *Emiluvia* ? *cochleata* (*Muelleritortis cochleata* herein). No equivalent of the *Capnuchosphaera sp.* Assemblage was identified in this study.

The *Betraccium sp.* Assemblage possibly correlates with a part of the *Tetraporobrachia haeckelli* Assemblage Zone based on the characteristic species of *Palaeosaturnalis* sp., but the details are also uncertain owing to the lack of characteristic species.

4.3.4 Correlation with Kozur and Mostler (1994, 1995)

Kozur and Mostler (1994, 1995) recovered Triassic radiolarian faunas from several sections in Hungary, Italy, Austria, and several single samples from other European countries. An Anisian to Middle Carnian radiolarian zonations was established with the following zones; *Parasepsagon robustum*, *Tetraspinocyrtis laevis*, *Spongosilicarmiger transitus, Spongosilicarmiger italicus*, *Ladinocampe multiperforata*, *Muelleritortis cochleata*, *Tritrortis kretaensis*, *Tetraporobrachia haeckeli*, *Nakasekoellus inkensis*, *Capnodoce ruesti*, and *Livarella densiporata* in ascending order.

The boundary between *Parasepsagon robustum* Zone and *Tetraspinocyrtis laevis* Zone is characterized by last occurrence of *Parasepsagon asymetricus*

asymetricus, Plafkerium robustus, and *Plafkerium*? *anisicum*. These faunas are absent in this study. However, the top of *Tetraspinocyrtis laevis* Zone heralds the first appearance of genera *Oertlispongus*, *Yeharaia*, and diverse *Triassocampe* species, including *Triassocampe deweveri* and *T. scalaris*. According to this study, *Parasepsagon* sp. and *Plafkerium* sp. are present in *Eptingium manfredi* Assemblage Zone without *Triassocampe deweveri*. Thus, *Parasepsagon robustum* and *Tetraspinocyrtis laevis* Zones are assumed to lie below the boundary of *Eptingium manfredi / Triassocampe deweveri* Assemblage Zones of this study based on the diagnostic species and stratigraphic position of the overlying zone.

The lower part of *Spongosilicarmiger transitus Zone* is defined by the first occurrence of *Triassocampe deweveri* and the upper part is recognized by the occurrence of *Triassocampe scalaris*, *Yeharaia annulata* and a few Ladinian species. .Therefore, this zone of Kozur and Mostler (1994, 1995) is well correlated with the *Triassocampe deweveri* Assemblage Zone of this study.

Spongosilicarmiger italicus Zone is further divided into two subzones; *Oertlispongus primitivus* Subzone, for the lower part and *Oertlispongus inaequispinosus* Subzone, for the upper part. The upper subzone, *Oertlispongus inaequispinosus* is roughly correlative with *Oertlispongus inaequispinosus* Assemblage Zone of this study based on the first appearance of the nominal species of the zone and other common species with curved spines. However, the lower part of *Oertlispongus primitivus* subzone is not recognised in this study due to absent of *O. primitivus* and the common co-occurrence species of the zone. Therefore, this subzone is tentatively placed at the base of the *Oertlispongus inaequispinosus* Assemblage Zone due to its stratigraphic position.

The lower boundary of *Ladinocampe multiperforata* Zone immediately overlies *Spongosilicarmiger italicus* Zone and is defined by the first appearance of *Ladinocampe multiperforata*, *Planispinocyrtis multiporata* and evolved species of *Anicyrtis*, but the upper boundary is not yet defined. These species are absent in this thesis study area. Thus it is impossible to correlate this zone with this study in detail.

The base of *Muelleritortis cochleata* Zone is defined by the first appearance of *Muelleritortis cochleata* and and the top by the dominant occurrence of *Tritrortis kretaensis*. This zone is correlative with *Muelleritortis cochleata* Assemblage Zone to the lower part of *Tritrortis kretaensis* Assemblage Zone of this study.

The base and the top of *Tritrortis kretaensis* Zone of Kozur and Mostler, 1994 are marked by dominant occurrence of *Tritrortis kretaensis* above *Muelleritortis cochleata* and the disappearance of *Tritrortis kretaensis*, respectively. However, the occurrence of *Tritrortis kretaensis* above *Muelleritortis cochleata* and the disappearance of *Tritrortis kretaensis* were not investigated in this study. Thus, it is tentatively placed the *Tritrortis kretaensis* Zone of Kozur and Mostler, 1994 at the upper part of the *Tritrortis kretaensis* Assemblage Zone in this study.

Tetraporobrachia haeckeli Zone is estimated to correlate with the *Tetraporobrachia haeckeli* Assemblage Zone of this study based on the occurrence in both of the nominal species *Tetraporobrachia haeckeli* and other species such as species of *Palaeosaturnalis* and *Xiphotheca.*

4.3.5 Correlation with Sugiyama (1997)

Sugiyama (1997) established eigthteen Triassic and two lower Jurassic radiolarian zones of Triassic and Lower Jurassic age in the Mino Terrane, Central Japan. Among the eigthteen Triassic Zones, the first ten Zones range from Early

Spathian to Early Carnian.The definitions of them are as follows in chronological order: TR 0, *Follicucullus* Assemblage Zone; TR 1, *Parentactinia nakatsugawaensis* Assemblage Zone; TR 2A, *Eptingium nakasekoi* Lowest-occurrence Zone; TR 2B, *Trissaocampe coronata* group Lowest-occurrence Zone; TR 2C, *Triassocampe deweveri* Lowest-occurrence Zone; TR 3A, Spine A2 (possibly derived from *Oertlispongus inaequispinosus*) Lowest-occurrence Zone; TR 3B, *Yeharaia elegans* group Lowest-occurrence Zone; TR 4A, *Muelleritortis cochleatum* Lowest-occurrence Zone; TR 4B, *Spongoserrula dehli* Lowest-occurrence Zone; and TR 5A, *Capnuchosphaera* Lowest-occurrence Zone.

The diagnostic species in TR 0, *Follicucullus* Assemblage Zone and TR 1, *Parentactinia nakatsugawaensis* Assemblage Zone, are absent in this study.

The TR 2A, *Eptingium nakasekoi* Lowest-occurrence Zone, is correlated with the *Eptingium manfredi* Assemblage Zone in this stuy based on the occurrence of *Eptingium nakasekoi* and *Celluronta donax*.

TR 2B, *Trissaocampe coronata* group Lowest-occurrence Zone, is difficult to make a precise correlation with this study because the base and the top of this zone are marked by the first occurrence of *Triassocampe coronata* and *T. deweveri*, respectively, which appear at nearly the same level in the lower part of *Triassocampe deweveri* Assemblage Zone of this study. Thus, TR 2B is questionably correlatated with the boundary of *Eptingium manfredi* and *Triassocampe deweveri* Assemblage Zones.

TR 2C, *Triassocampe deweveri* Lowest-occurrence Zone, is correlated with *Triassocampe deweveri* Assemblage Zone based on the occurrence of the nominal species.

The base of TR 3A, Spine A2 Lowest-occurrence Zone, is defined by the first occurrence of Spine A2 (possibly derived from *Oertlispongus inaequispinosus*) and the top is defined by *Yeharaia elegans* group, whereas *Yeharaia elegans* group and *Muelleritortis cochleatum* are the base and the top of TR 3B, *Yeharaia elegans* group Lowest-occurrence Zone, respectively. According to this present study, it is difficult to make a precise correlation because *Yeharaia elegans* is absent in this study. However, they can be roughly estimated and these two zones are placed in the *Oertlispongus inaequispinosus* Assemblage Zone, with TR 3A in the lower part and TR 3B in the upper part of *Oertlispongus inaequispinosus* Assemblage Zone.

TR 4A, *Muelleritortis cochleatum* Lowest- occurrence Zone, is correlated with the *Muelleritortis cochleata* Assemblage Zone by the first occurrence of *Muelleritortis cochleata* at the base of the zone, but the top is different. Therefore, the top of TR 4A is defined by the first occurrence of *Spongoserrula dehli* and abundant of *Tritrortis kretaensis* against *Muelleritortis cochleata*, whereas at the top of *Muelleritortis cochleata* Assemblage Zone is the first occurrence *Tritrortis kretaensis*. Thus, the probably position of TR 4A is as a correlative of the *Muelleritortis cochleata* Assemblage Zone and the lower part of *Tritrortis kretaensis* Assemblage Zone.

The base and the top of TR 4B, *Spongoserrula dehli* Lowest-occurrence Zone are the first occurrence of *Spongoserrula dehli* and the genus *Capnuchosphaera*, respectively. Both of these are absent in this study. However, TR 4B can be tentatively correlated with the upper part of the *Tritrortis kretaensis* Assemblage Zone based on the appearance of *Muelleritortis cive*, *Pseudostylosphaera gracilis*, *Corum* sp., *Canoptum* sp., and *Praeheliostaurus* sp.

TR 5A, *Capnuchosphaera* Lowest-occurrence Zone is represented by the first occurrence of the the genus *Capnuchosphaera* and *Poulpus carcharus* at the base and the top of the zone, respectively. These fauna are absent in this study. However, this TR 5A is probably correlated with the base of *Tetraporobrachia haeckeli* Assemblage Zone based on the first occurrence of *Canesium lentum* and species of *Palaeosaturnalis* and *Xiphotheca.*

4.3.6 Correlation with Sashida and Igo (1999)

Sashida and Igo (1999) proposed thirteen radiolarian assemblages of Upper Devonian to Middle Triassic in Thailand and Peninsular Malaysia, namely; *Helenifore laticlavium*, *Entactinia variospina*, *Pseudoalbaillella bulbosa*, *Pseudoalbaillella elegans*, *Pseudoalbaillella lomentaria*, *Pseudoalbaillella scalprata*, *Follicucullus monacanthus*, *Follicucullus scholasticus*, *Neoalbaillella optima*, *Neoalbaillella ormithoformis*, *Entactinia nikorni*, *Parentactinia nakatsugawaensis*, and *Eptingium manfredi* Assemblages, in chronological order. Among them, only the last two assemblages are Early to Middle Triassic assemblages.

The diagnostic species in *Parentactinia nakatsugawaensis* Assemblage are absent in this study. The *Eptingium manfredi* and *Triassocampe deweveri* Assemblage Zone of this study are correlated with *Eptingium manfredi* Assemblage based on the occurrence of *Eptingium manfredi*, *Triassocampe deweveri*, *Pseudostylospheara coccostyla coccostyla, Pseudostylospheara spinulosa* (*Hindeostylosphaera spinulosa* herein), *Plafkerium* sp. and *Cryptostephanidium* sp.

Table 4.1 Radiolarian species from Chiang Dao locality (CD)

no.	species	sample no. CD_																																		
		1	2	3	4	6	7	9	10	11	12	13	16	17	20	21	22	23	24	25	27	30	31	32	33	34	37	39	43	44	45	46	47	48	49	50
1	*Crysptostephanidium cornigeum*																																			
2	*Eptingium manfredi manfredi*	■	■										■							■		■					■		■	■				■	■	■
3	*E. manfredi japonicum*		■	■																																
4	*E. nakasekoi*	■	■	■																							■									
5	*Eptingium sp.*			■																																
6	*Perispyridium cf. P. ordinarium*																																			
7	*Spongostephanidium sp. cf. S.longispinosum*																																			
8	*Archaeospongoprunum mesotri mesotriassicum*	■	■	■			■															■								■		■	■	■	■	
9	*A. cf. A. m. mesotriassicum*																																			
10	*A. m. asymmetricum*																																			
11	*Hindeostylosphaera spinulosa*			■	■											■	■			■				■					■	■					■	
12	*Pseudostylospheara coccostyla acrior*	■	■	■						■											■	■														
13	*P. coccostyla coccostyla*																					■										■				
14	*P. compacta*		■	■																		■											■			
15	*P. goestliangensis*	■	■																																	
16	*P.japonica*	■	■	■					■											■		■					■				■					■
17	*P. longispinosa*																																			
18	*P. magnispinosa*																																			
19	*P. nazarovi*			■																					■						■					■
20	*P. tenuis*																																			
21	*P. timorensis*		■																										■							
22	*Pseudostylosphaera sp.A*																																			
23	*Spongostylus tricostatus*		■	■																																
24	*S.tetrapterus*		■																																	
25	*S. sp. A*																																			
26	*S. sp. B*																																			
27	*Triborella florida florida*		■	■																																
28	*Oertlispongus sp. cf. O. diacanthus*																					■									■					
29	*Paroertlispongus multispinosus*	■	■		■		■		■			■			■	■		■	■	■		■	■	■	■	■			■	■	■	■	■			■
30	*P. rarispinosus*	■	■	■				■	■	■	■	■	■	■	■		■	■		■		■	■	■	■			■		■	■	■	■			■
31	*Pseudoertlispongus sp.cf. P. angulatus*																																			
32	*P. mostleri*																														■					
33	*Paurinella aequispinosa*	■	■	■																																
34	*P. cf. P. curvata*		■	■																		■			■											

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	52	53	54	56	63	68	75	78	80	81	82	84
		sample no. CD_											
1	*Crysptostephanidium cornigeum*												
2	*Eptingium manfredi manfredi*		x	x		x	x					x	x
3	*E. manfredi japonicum*												
4	*E. nakasekoi*											x	
5	*Eptingium sp.*												
6	*Perispyridium cf. P. ordinarium*												
7	*Spongostephanidium sp. cf. S.longispinosum*												
8	*Archaeospongoprunum mesotri mesotriassicum*		x	x	x	x		x					x
9	*A. cf. A. m. mesotriassicum*			x									
10	*A. m. asymmetricum*			x		x							
11	*Hindeostylosphaera spinulosa*					x					x		
12	*Pseudostylospheara coccostyla acrior*					x							
13	*P. coccostyla coccostyla*								x				
14	*P. compacta*												
15	*P. goestliangensis*												
16	*P.japonica*		x			x							
17	*P. longispinosa*												
18	*P. magnispinosa*					x							
19	*P. nazarovi*								x				
20	*P. tenuis*												
21	*P. timorensis*			x		x							
22	*Pseudostylosphaera sp.A*												
23	*Spongostylus tricostatus*												
24	*S.tetrapterus*												
25	*S. sp. A*												
26	*S. sp. B*												
27	*Triborella florida florida*												
28	*Oertlispongus sp. cf. O. diacanthus*												
29	*Paroertlispongus multispinosus*	x	x	x	x	x							
30	*P. rarispinosus*	x	x	x	x	x		x		x			x
31	*Pseudoertlispongus sp.cf. P. angulatus*												
32	*P. mostleri*												
33	*Paurinella aequispinosa*												
34	*P. cf. P. curvata*												

no.	species	89	91	92	94	95	97	100	101	104	105	109	111
1	*Crysptostephanidium cornigeum*											x	
2	*Eptingium manfredi manfredi*		x	x				x				x	x
3	*E. manfredi japonicum*												
4	*E. nakasekoi*												
5	*Eptingium sp.*												
6	*Perispyridium cf. P. ordinarium*												
7	*Spongostephanidium sp. cf. S.longispinosum*												
8	*Archaeospongoprunum mesotri mesotriassicum*					x				x	x	x	x
9	*A. cf. A. m. mesotriassicum*												
10	*A. m. asymmetricum*												
11	*Hindeostylosphaera spinulosa*											x	x
12	*Pseudostylospheara coccostyla acrior*												
13	*P. coccostyla coccostyla*		x										
14	*P. compacta*					x						x	
15	*P. goestliangensis*												
16	*P.japonica*										x		
17	*P. longispinosa*		x	x							x	x	
18	*P. magnispinosa*											x	
19	*P. nazarovi*										x		
20	*P. tenuis*												
21	*P. timorensis*					x							x
22	*Pseudostylosphaera sp.A*												
23	*Spongostylus tricostatus*												
24	*S.tetrapterus*												
25	*S. sp. A*							x					
26	*S. sp. B*		x								x		
27	*Triborella florida florida*												
28	*Oertlispongus sp. cf. O. diacanthus*							x					
29	*Paroertlispongus multispinosus*					x							
30	*P. rarispinosus*								x		x		x
31	*Pseudoertlispongus sp.cf. P. angulatus*							x					
32	*P. mostleri*										x		
33	*Paurinella aequispinosa*												
34	*P. cf. P. curvata*												

no.	species	112	113	115	118	120	121	122	131	132	135	138	140
1	*Crysptostephanidium cornigeum*												
2	*Eptingium manfredi manfredi*		x				x	x	x	x		x	x
3	*E. manfredi japonicum*										x		
4	*E. nakasekoi*												
5	*Eptingium sp.*												
6	*Perispyridium cf. P. ordinarium*												
7	*Spongostephanidium sp. cf. S.longispinosum*												
8	*Archaeospongoprunum mesotri mesotriassicum*		x		x		x						
9	*A. cf. A. m. mesotriassicum*												
10	*A. m. asymmetricum*						x						
11	*Hindeostylosphaera spinulosa*												
12	*Pseudostylospheara coccostyla acrior*												
13	*P. coccostyla coccostyla*		x						x				
14	*P. compacta*						x						
15	*P. goestliangensis*												
16	*P.japonica*												
17	*P. longispinosa*												
18	*P. magnispinosa*												
19	*P. nazarovi*												
20	*P. tenuis*												
21	*P. timorensis*												
22	*Pseudostylosphaera sp.A*												
23	*Spongostylus tricostatus*												
24	*S.tetrapterus*												
25	*S. sp. A*						x						
26	*S. sp. B*												
27	*Triborella florida florida*												
28	*Oertlispongus sp. cf. O. diacanthus*												
29	*Paroertlispongus multispinosus*												
30	*P. rarispinosus*				x	x							
31	*Pseudoertlispongus sp.cf. P. angulatus*												
32	*P. mostleri*												
33	*Paurinella aequispinosa*												
34	*P. cf. P. curvata*												

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	sample no. CD_																																		
		144	145	146	148	149	151	153	154	155	156	158	159	163	167	169	170	178	180	185	186	188	190	191	195	196	202	204	205	210	227	232	236	238	241	242	243
1	*Crysptostephanidium cornigeum*																						■									■		■			
2	*Eptingium manfredi manfredi*							■	■			■	■		■		■		■	■					■				■		■			■			
3	*E. manfredi japonicum*																				■			■						■							
4	*E. nakasekoi*															■				■						■											
5	*Eptingium sp.*																																				
6	*Perispyridium cf. P. ordinarium*																																				
7	*Spongostephanidium sp. cf. S.longispinosum*						■						■							■									■					■		■	
8	*Archaeospongoprunum mesotri mesotriassicum*	■																																			
9	*A. cf. A. m. mesotriassicum*																																				
10	*A. m. asymmetricum*				■								■																								
11	*Hindeostylosphaera spinulosa*																																				
12	*Pseudostylospheara coccostyla acrior*				■																															■	
13	*P. coccostyla coccostyla*																	■	■						■												
14	*P. compacta*												■												■												
15	*P. goestliangensis*																																				
16	*P.japonica*									■																■											
17	*P. longispinosa*						■							■																							■
18	*P. magnispinosa*							■					■			■	■																				
19	*P. nazarovi*																																				
20	*P. tenuis*															■		■												■							
21	*P. timorensis*																																				
22	*Pseudostylosphaera sp.A*																															■					■
23	*Spongostylus tricostatus*																																				
24	*S.tetrapterus*																																				
25	*S. sp. A*						■									■											■										
26	*S. sp. B*																							■												■	
27	*Triborella florida florida*																																				
28	*Oertlispongus sp. cf. O. diacanthus*				■								■							■												■				■	
29	*Paroertlispongus multispinosus*																			■																	
30	*P. rarispinosus*																																				
31	*Pseudoertlispongus sp.cf. P. angulatus*		■																																		
32	*P. mostleri*																																				
33	*Paurinella aequispinosa*																																				
34	*P. cf. P. curvata*																																				

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	sample no. CD_																								
		244	257	258	260	261	276	284	295	299	300	301	307	310	313	320	322	323	324	325	326	327	328	329	334	339
1	*Crysptostephanidium cornigeum*		■			■																				
2	*Eptingium manfredi manfredi*	■	■		■	■		■												■		■				
3	*E. manfredi japonicum*																									
4	*E. nakasekoi*																									
5	*Eptingium sp.*																									
6	*Perispyridium cf. P. ordinarium*							■									■	■								
7	*Spongostephanidium sp. cf. S.longispinosum*			■		■				■		■	■	■		■				■						
8	*Archaeospongoprunum mesotri mesotriassicum*																									
9	*A. cf. A. m. mesotriassicum*																									
10	*A. m. asymmetricum*																									
11	*Hindeostylosphaera spinulosa*																									
12	*Pseudostylospheara coccostyla acrior*																									
13	*P. coccostyla coccostyla*																									
14	*P. compacta*																									
15	*P. goestliangensis*																									
16	*P.japonica*																									
17	*P. longispinosa*																									
18	*P. magnispinosa*																									
19	*P. nazarovi*																									
20	*P. tenuis*			■		■		■						■				■	■			■				
21	*P. timorensis*																									
22	*Pseudostylosphaera sp.A*														■					■						
23	*Spongostylus tricostatus*																									
24	*S.tetrapterus*																									
25	*S. sp. A*										■									■	■					
26	*S. sp. B*												■													
27	*Triborella florida florida*																									
28	*Oertlispongus sp. cf. O. diacanthus*				■																					■
29	*Paroertlispongus multispinosus*																									
30	*P. rarispinosus*																									
31	*Pseudoertlispongus sp.cf. P. angulatus*																									
32	*P. mostleri*																									
33	*Paurinella aequispinosa*																									
34	*P. cf. P. curvata*																									

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	sample no. CD_																																
		1	2	3	4	6	7	9	10	11	12	13	16	17	20	21	22	23	24	25	27	30	31	32	33	34	37	39	43	44	45	46	47	48	49	50
35	*P. cf. P. trettoensis*																																			
36	*Paurinella sp.*	x	x	x																x		x				x										
37	*Tetrapaurinella sp.*		x																																	
38	*Pentaspongodiscus mesotriassica*		x	x					x																											
39	*P. symmetricus*		x																																	
40	*Platkerium contortum*																																			
41	*P. antiquum*																										x						x			
42	*Hozmadia sp.cf. H.rotunda*																			x		x			x						x					
43	*H. cf. H. gifuensis*																																			
44	*H. sp. A*																																			
45	*H. sp. B*																																			
46	*H. sp. C*			x														x				x														
47	*Sepsagon robustus*																																			
48	*Parasepsagon sp.cf. P.variabilis*		x																																	
49	*Parasepsagon sp.*			x																				x									x			
50	*Pantanellium sp.*																																			
51	*Archaeocenosphaera sp.*	x	x	x		x	x	x	x	x	x		x	x				x		x	x	x			x	x		x	x	x	x	x				
52	*Acanthosphaera sp.*					x	x		x											x		x							x	x	x		x	x		
53	*Astrocentrus sp.*		x																	x																
54	*Triassospongosphaera multispinosa*	x	x	x					x		x			x				x		x	x	x		x								x	x	x	x	
55	*Annulotriassocampe sulovensis*					x																							x		x					
56	*Celluronta donax*																					x		x												
57	*C. sp.*																																	x		
58	*Parauesticyrtium sp.*		x																							x										
59	*Paratriassocampe sp.cf. P. gaetanii*																			x																
60	*Pseudotriassocampe sp.*																																			
61	*Striatotriassocampe nodosoannulata*			x																		x			x				x		x		x			
62	*Triassocampe coronata*	x	x	x					x								x			x		x			x	x		x	x	x	x	x	x			
63	*T. deweveri*	x	x	x		x					x						x			x		x			x						x	x	x	x	x	x
64	*T. myterocorys*		x	x		x																x	x	x			x				x	x	x	x		
65	*T. scalaris*	x	x	x													x					x									x					
66	*T. cf. diodinis*									x															x		x		x	x	x		x	x		
67	*T. cf. eruca*						x																	x							x					
68	*T. sp.*																																			
69	*Yeharaia annulata*																																			

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	sample no. CD_																																			
		52	53	54	56	63	68	75	78	80	81	82	84	89	91	92	94	95	97	100	101	104	105	109	111	112	113	115	118	120	121	122	131	132	135	138	140
35	*P. cf. P. trettoensis*																																				
36	*Paurinella sp.*			■																																	
37	*Tetrapaurinella sp.*																																				
38	*Pentaspongodiscus mesotriassica*																																				
39	*P. symmetricus*																																				
40	*Platkerium contortum*																								■								■				
41	*P. antiquum*													■	■									■	■		■										
42	*Hozmadia sp.cf. H.rotunda*			■														■																			
43	*H. cf. H. gifuensis*																																				
44	*H. sp. A*																																				
45	*H. sp. B*																						■		■												
46	*H. sp. C*																																				
47	*Sepsagon robustus*			■		■																	■	■				■				■	■				
48	*Parasepsagon sp.cf. P.variabilis*																																				
49	*Parasepsagon sp.*					■																															
50	*Pantanellium sp.*		■																						■												
51	*Archaeocenosphaera sp.*	■		■		■									■			■						■				■									
52	*Acanthosphaera sp.*				■	■	■			■				■	■			■						■	■												
53	*Astrocentrus sp.*																																				
54	*Triassospongosphaera multispinosa*		■	■		■									■	■		■					■				■			■							
55	*Annulotriassocampe sulovensis*																																				
56	*Celluronta donax*																							■	■											■	
57	*C. sp.*																																				
58	*Parauesticyrtium sp.*																																				
59	*Paratriassocampe sp.cf. P. gaetanii*																																				
60	*Pseudotriassocampe sp.*			■		■																															
61	*Striatotriassocampe nodosoannulata*		■		■									■				■			■		■		■												
62	*Triassocampe coronata*		■	■	■	■						■	■									■															
63	*T. deweveri*			■	■	■				■		■		■	■		■						■	■	■	■	■						■	■			
64	*T. myterocorys*	■		■														■				■		■		■						■					
65	*T. scalaris*																																				
66	*T. cf. diodinis*			■			■	■	■			■	■		■			■		■			■				■										
67	*T. cf. eruca*																						■	■													
68	*T. sp.*																		■	■			■		■		■							■			
69	*Yeharaia annulata*																										■										

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	sample no. CD_																																			
		144	145	146	148	149	151	153	154	155	156	158	159	163	167	169	170	178	180	185	186	188	190	191	195	196	202	204	205	210	227	232	236	238	241	242	243
35	*P. cf. P. trettoensis*																															■					
36	*Paurinella sp.*																																				
37	*Tetrapaurinella sp.*																																				
38	*Pentaspongodiscus mesotriassica*																																				
39	*P. symmetricus*																																				
40	*Platkerium contortum*																																				
41	*P. antiquum*												■		■			■					■	■										■		■	
42	*Hozmadia sp.cf. H.rotunda*																																				
43	*H. cf. H. gifuensis*																																			■	
44	*H. sp. A*																																				
45	*H. sp. B*																																				
46	*H. sp. C*																																				
47	*Sepsagon robustus*																																				
48	*Parasepsagon sp.cf. P.variabilis*																																				
49	*Parasepsagon sp.*									■							■		■		■		■		■												
50	*Pantanellium sp.*																		■								■			■							
51	*Archaeocenosphaera sp.*					■		■																	■				■	■							
52	*Acanthosphaera sp.*					■									■			■	■				■	■	■				■			■			■		
53	*Astrocentrus sp.*																																				
54	*Triassospongosphaera multispinosa*						■											■				■		■			■				■						■
55	*Annulotriassocampe sulovensis*																																				
56	*Celluronta donax*	■			■		■	■		■		■				■			■		■																
57	*C. sp.*				■				■		■		■									■															
58	*Parauesticyrtium sp.*																																				
59	*Paratriassocampe sp.cf. P. gaetanii*																																				
60	*Pseudotriassocampe sp.*																																				
61	*Striatotriassocampe nodosoannulata*										■																										
62	*Triassocampe coronata*																																				
63	*T. deweveri*																																				
64	*T. myterocorys*																																				
65	*T. scalaris*																																				
66	*T. cf. diodinis*																																				
67	*T. cf. eruca*												■																	■							
68	*T. sp.*	■			■																																
69	*Yeharaia annulata*																																				

Table 4.1 Radiolarian species from Chiang Dao locality (CD) (cont.)

no.	species	sample no. CD_																								
		244	257	258	260	261	276	284	295	299	300	301	307	310	313	320	322	323	324	325	326	327	328	329	334	339
35	*P. cf. P. trettoensis*																									
36	*Paurinella sp.*																									
37	*Tetrapaurinella sp.*																									
38	*Pentaspongodiscus mesotriassica*																									
39	*P. symmetricus*																									
40	*Platkerium contortum*																									
41	*P. antiquum*					■	■	■																		
42	*Hozmadia sp.cf. H.rotunda*																									
43	*H. cf. H. gifuensis*																									
44	*H. sp. A*							■																		
45	*H. sp. B*																									
46	*H. sp. C*																									
47	*Sepsagon robustus*							■																		
48	*Parasepsagon sp.cf. P.variabilis*																									
49	*Parasepsagon sp.*																									
50	*Pantanellium sp.*																									
51	*Archaeocenosphaera sp.*						■	■	■	■						■										
52	*Acanthosphaera sp.*						■	■		■						■										
53	*Astrocentrus sp.*																									
54	*Triassospongosphaera multispinosa*		■		■																					
55	*Annulotriassocampe sulovensis*																									
56	*Celluronta donax*																									
57	*C. sp.*					■																				
58	*Parauesticyrtium sp.*																									
59	*Paratriassocampe sp.cf. P. gaetanii*																									
60	*Pseudotriassocampe sp.*																									
61	*Striatotriassocampe nodosoannulata*																									
62	*Triassocampe coronata*																									
63	*T. deweveri*																									
64	*T. myterocorys*																									
65	*T. scalaris*																									
66	*T. cf. diodinis*																									
67	*T. cf. eruca*																									
68	*T. sp.*																									
69	*Yeharaia annulata*																									

CHAPTER V

GEOCHEMISTRY

5.1 Introduction

The main propose of geochemical discrimination in this study is to evaluate depositional environment of cherts or other siliceous rocks. Geochemical methods, results and interpretation of the origin and depositional environment of the sediments are provided in the following sections. Rock samples for geochemical analysis are collected from six areas in northern Thailand. They were came from Chiang Dao, Lamphun and Den Chai which are located in the eastern belt. The rest are located in the western belt, which include Mae La Noi, Mae Sariang, and Khun Yuam. The outcrop and rock descriptions of these localities are mentioned in chapter II. Several cherts or siliceous rocks were collected for radiolarian study. Five selected samples from each locality are used for geochemical analyses.

In the laboratory works, three groups of elements have been analysed. They are major, trace and rare earth elements. Geochemical methods used for this study include X-Ray Fluorescence spectrometry (XRF) for major and trace element analysis and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) for rare earth element discrimination. XRF analysis is conducted at Suranaree University of Technology. Instrument for XRF analysis is EU2000. American phosphate rocks are used for analytical calibration. ICP-MS analysis was performed at State Key Laboratory in China University of Geosciences (Wuhan).

5.2 Geochemical method

The general concepts of XRF and ICP-MS are given as follows. Further information on these methods are described in various literatures (e.g., Jarvis and Jarvis, 1992; Gäbler, 2002; Rollinson, 1993)

5.2.1 X-Ray Fluorescence (XRF)

The main concept of this method is based on x-ray excitation technique. The primary x-ray beam from the instrument is used for exciting the secondary x-rays (elements in sample). Each element has unique wavelength characteristic which can be converted into elemental concentration. The concentration of elements is performed by reference to calibration standards. Correction has been made for instrumental error and other effects on x-ray emission intensities. Limitation of this method is that elements with atomic number less than 11 (Na) cannot be analysed.

5.2.2 Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)

The objective of ICP is to serve as an ion source for a mass spectrometer. The sample is introduced into a nebuliser which converts it into an aerosol and disperses in argon gas. Droplet of aerosol is transmitted into a plasma torch by spray chamber. The aerosol is separated into a mixture of atoms, ions, undissociated molecular fragments and unvolatilized particles in the mount of the torch. Ions are extracted from the axial zone of the torch and are transmitted into the mass spectrometer. In general, a mass spectrometry is used for measuring isotopic ratios. There are various methods which relate to chemical separation of elements (ICP in this case). Charged ions are separated from the element in form of ion beam. Atoms are split up when the ion beam is fired along a curved tube through an electromagnet. This process produces mass spectrum in which lighter ions are deflected with a smaller radius of curvature than heavy ions.

5.3 Results

5.3.1 Major Elements

5.3.1.1 Chiang Dao, Lamphun and Den Chai localities

The silica content of chert from Chiang Dao and Lamphun areas is higher than chert form Den Chai area (Table 5.2). In Chiang Dao area, it contains between 81.41 and 90.69 w%. For the Lamphun area, it ranges between 79.30 and 93.50 w%. The lowest content which is between 68.48 and 77.50 w% was found in Den Chai area. The decreasing of silica content in three samples from Den Chai area is compatible with the increasing of phosphate content (between 3.63 and 5.68 w%).

Correlation coefficients (r) of silica in Chiang Dao, Lamphun and Den Chai localities are very low and most of them are highly negative to other elements.

The aluminium content from Den Chai area is highest in comparison with the others. It ranges 2.35-4.58 w%. It is between 1.11 and 3.63 w% in Chiang Dao and between 0.69 and 2.40 w% in Lamphun localities, respectively. In Chiang Dao locality, aluminium has a high positive correlation coefficient to titanium, iron, manganese, magnesium, calcium and potassium (0.91 to 1).In Den Chai area, it shows a relative high positive correlation coefficient to titanium, iron, magnesium and phosphate (0.86 to 0.97). In Lamphun locality, aluminium shows a high positive correlation coefficient to only titanium, magnesium, manganese and potassium (0.91 to 1). It shows moderate value to iron (0.78).

The titanium content in the Den Chai area is highest and lies between 0.076 and 0.168 w%. The titanium content in the Chiang Dao and Lamphun localities is between 0.086 and 0.0738 w% and 0.0213 and 0.0762 w%, respectively. The highest titanium content in the Den Chai area is corresponded with a high phosphate content. The correlation coefficient of titanium in Chiang Dao locality is high positive to aluminium, iron, calcium, manganese, potassium (from 0.97 to 1), and magnesium (0.89).

The potassium content is between 0.197 w% and 2.2 w% in the Chiang Dao locality. It is between 0.00 and 1.717 w% at Lamphun and between 1.071 and 2.151 w% at Den Chai. With the exception of silica and sodium, the correlation coefficient of potassium to titanium, aluminium and iron is very high positive in the Chiang Dao locality (0.92 to 1). In Lamphun area, this element has a high positive correlation coefficient to titanium, aluminium, magnesium, and calcium (0.93 to 1).While only sodium has a relative positive high correlation coefficient to aluminium in the Den Chai locality.

The iron content is highest in Den Chai, between 3.096 and 5.784 w%. It ranges between 0.159 and 1.424 w% in Chiang Dao. For Lamphun, it contains between 0.223 and 0.51 w%. Iron shows a high positive correlation coefficient to titanium, aluminium, magnesium, manganese, calcium, and potassium (0.93 to 1) in Chiang Dao locality. In Den Chai locality, it has a high positive correlation coefficient to titanium (0.98) and aluminium (0.95). It has moderate to high positive correlation coefficient to magnesium (0.87) and potassium (0.86).

The phosphorous content in Den Chai locality is found to lie between 3.63 and 5.68 w%. The increasing phosphorous content is corresponding with the decreasing silica content. Only the Den Chai locality shows the phosphate signal with moderate to high positive correlation coefficient to aluminium, iron, and manganese (0.86 to 0.88).

5.3.1.2 Mae Sariang, Mae La Noi and Khun Yuam localities

The silica content of the Mae La Noi locality is found to lie between 83.20 and 87.98 w%, except for two samples of phosphatic rock which contain 2.69 and 37.96 w% silica content with 88.38 and 46.33 w% phosphorous (Table 5.2). In the Mae Sariang locality, silica content ranges between 81.77 and 87.57 w%, except for one sample which shows 28.33 w% of phosphorous and 55.22 w% of silica content. In the Khun Yuam locality, SiO_2 concentration ranges between 82.27 and 85.48 %. The increasing silica content of the rocks in these localities is correspoded with the decreasing phosphorous content and *vice versa*. This relationship is the same as what has been observed at the Den Chai locality. Correlation coefficients of silica and other elements in these localities are mostly high negative (Table 5.3).

For aluminium concentration, it lies between 0.847 and 2.26 w% in the Mae Sariang locality. In Mae La Noi, it is between 0.137 and 1.199 w%. It is between 1.438 and 2.008 w% in the Khun Yuam locality. At Mae La Noi, the correlation coefficient of aluminium with titanium and potassium is high positive (0.93 and 0.99 respectively). From the same locality, this element shows moderate positive correlation coefficient to iron oxide (0.86). In the Mae Sariang locality, aluminium has a high positive correlation coefficient to iron (0.96) and manganese (0.99). It shows moderate positive to titanium (0.88) and potassium (0.85). In the Khun Yuam locality, aluminium has a moderate positive correlation coefficient only to titanium (0.83) and potassium (0.80).

Among these three localities, the highest titanium content is 942 ppm. It was observed in the Mae Sariang locality. One sample with a non-detectable value is found at Mae La Noi. It ranges between 0 and 364 ppm in this locality. While the Khun Yuam locality contains between 33 and 667 ppm. The correlation coefficient of titanium in Mae La Noi is high positive to aluminium and potassium (0.96). This element has a moderate to high positive correlation coefficient to aluminium, iron, manganese and potassium (0.85 to 0.99) in Mae Sariang locality. In Khun Yuam locality, this element shows moderate to high positive correlation coefficient to aluminium, iron, calcium, and potassium (0.82 to 0.98).

From chert samples, potassium content in Khun Yuam locality is the highest with mean value of 1.11 w% (n=5). This mean value in Mae La Noi and Mae Sariang is 0.48 w% (n=3) and 0.29 w% (n=4), respectively. Normally, five samples from each outcrop were selected for geochemical discrimination. However, some samples showing high phosphate content with low silica content (phosphate rock) were separated from cherts for interpretation. On the other hand, sample with low silica concentration is also discarded. In the Khun Yuam locality, correlative coefficient of potassium with titanium, aluminium and calcium is high positive (between 0.90 and 0.98) and moderately positive with iron (0.80). In the Mae La Noi locality, correlative coefficient of this element is high positive to titanium (0.96) and aluminium (0.99) and moderately positive with iron (0.81).

The iron concentration in Mae Sariang is relatively high in comparison with the others. It shows 1.30 w% (n=4) of the mean value. The correlation coefficient of this element to titanium, aluminium, magnesium, and potassium is high positive (between 0.93 and 0.98). The mean value of iron content in Khun Yuam and

Mae La Noi localities is 0.46 w% (n=5) and 0.38 w% (n=3), respectively. The correlation coefficient of this element to titanium, calcium and potassium is moderate to high positive (0.87 to 0.93) in the Khun Yuam locality. It shows moderate positive to aluminium, calcium, sodium, and potassium (0.81 to 0.86) at Mae La Noi.

Normally, phosphate content for all samples is under detection limit, except for two samples of phosphate rock from Mae La Noi and a sample of phosphatic chert from Mae Sariang. Phosphate rock samples show 46.33 and 88.38 w% phosphate content, while the phosphatic chert contains 28.33 w% of phosphate content.

5.3.2 Trace Elements

5.3.2.1 Chiang Dao, Lamphun and Den Chai localities

The concentration of trace elements is presented in Table 5.4. Their contents are very low and most of them are less than 100 ppm except W and Ba content in Chiang Dao (mean 124 and 123 ppm, respectively). In Lamphun, Co and W are relative high compared to the other (mean153.46 and 65.75 ppm, respectively), while the others are low and less than 100 ppm. Ba is the highest in Den Chai (167.30 ppm) and the others are less than 100 ppm. Some trace elements are selected for correlation with some major elements to determine their relationship (Table 5.6). As a result, correlation coefficients of Cr, Rb, Zr, Hf, and Th with some major elements (TiO_2, Al_2O, MgO, and K_2O) are relatively low (0.58 to 0.79) in Chiang Dao. Except correlation of these major elements with Th and Cu, their correlation coefficient is relatively high positive (0.89 to 0.98 and 0.78 to 0.87, respectively). The correlation coefficient of Mo, Ni, and Zn with these major elements are mostly low positive (0.12 to 0.71) except for one correlation between Mo and MgO which shows low negative

(-0.06). In Lamphun, these elements show negative correlation (-0.53 to -0.10). In Den Chai, Zr, Hf, Ni, Cu, and Zn all show high positive correlation (0.79 to 0.99) to these major elements, while the others show a low positive correlation.

5.3.2.2 Mae Sariang, Mae La Noi and Khun Yuam localities

In most cases, Co, Ba, and W have high significant concentrations among other trace elements in these localities. In Khun Yuam, there are 80.16 and 128.04 ppm average content of Co and Ba, respectively. In Mae La Noi, the average concentration of Co and Ba is 103.19 and 79.51 ppm, respectively. The average content of these elements in Mae Sariang is 80.56 and 374.92 ppm, respectively. Other high significant content is observed in W (average 378.02 ppm) in Mae Sariang. Concentrations of other trace elements in these localities are low and variable. They are less than one ppm in some elements and up to a few tens ppm in others.

In Khun Yuam, titanium and potassium show a good correlation to most of trace elements (Cr, Rb, Th, Cu, and Zn) with 0.91 to 0.99 and 0.83 to 0.99, respectively (Table 5.6). Aluminium shows a variable positive correlation to trace elements (0.35 to 0.82). However, MgO is mostly a low negative correlation to these elements.

In Mae La Noi, titanium has a high positive correlation only to Cr but shows high negative to most selected trace elements. In Mae Sariang, most correlation coefficients between given major and trace elements show a negative or poor relationship. However, most of these trace elements show moderate to good positive correlation to silica (0.69 to 0.83) except Mo and Cu.

5.3.3 Rare Earth Elements

5.3.3.1 Chiang Dao, Lamphun and Den Chai localities

Most of REE content in these localities is relatively low (less than 1 ppm) (Table 5.5). A relative high REE value was obtained from LREE. The Den Chai locality shows a relatively higher REE content. It also contains high total REE content (∑REE) in comparison with the others (44.45 to 84.59 ppm) (Table 5.1).Total REE content in Chiang Dao and Lamphun ranges from 15.52 to 73.12 ppm and 5.11 to 25.58 ppm, respectively.

The REE distribution pattern for all samples is normalized to NASC (North American shale composite normalization value from Gromet et al., 1984). The REE distribution patterns from Chiang Dao and Den Chai locality are relatively flat. However, they show slightly HREE enrichment compared to LREE (average of ratio La_n/Yb_n 0.73 and 0.65 respectively). Lamphun shows a concave REE distribution pattern (average of ratio La_n/Yb_n 0.98). The REE concentration from Chiang Dao is lower than NASC. In addition, most of the REE content from Den Chai is lower than NASC. However, the REE data from Lamphun is higher than NASC.

The lanthanum concentration in the Den Chai is the highest. It ranges from 7.87 to 15.9 ppm (mean 10.73). This element from Lamphun and Chiang Dao ranges from 0.89 to 5.47 ppm (mean 2.55) and 2.65 to 12.5 ppm (mean 5.29), respectively. For the Ce anomaly (Ce/Ce*), Chiang Dao shows both slightly positive and negative (mean 1). Most samples from Lamphun and Den Chai show slightly negative Ce anomaly (mean 0.92 and 0.91 respectively).

The Eu anomaly (Eu/Eu*) from all localities is slightly negative. It averages 0.95, 0.96 and 0.98 from Chiang Dao, Lamphun and Den Chai, respectively.

La_n/Ce_n values from all localities are positive and close to one. The average value is 1.05, 1.07 and 1.07 from Chiang Dao, Lamphun and Den Chai, respectively.

5.3.3.2 Mae Sariang, Mae La Noi and Khun Yuam localities

The ∑REE in Mae Sariang is relative high compared to the others (from 20.05 to 99.93) (Table 5.1). This value ranges from 20.50 to 57.05 and 16.87 to 62.20 in Khun Yuam and Mae La Noi, respectively. However, most REE content is relative low (less than 1). Most of the positive and high values are observed in LREE.

The REE pattern in relation to NASC in all localities is flat. It shows a slightly low HREE in Mae La Noi and Mae Sariang (average of ratio La_n/Yb_n 1.16 and 1.21, respectively). The REE pattern in Khun Yuam is smoothest with La_n/Yb_n 1.04. Most REE are close to NASC except for that from Mae La Noi which is slightly lower than NASC.

La abundance in Mae Sariang is highest compared to other localities. It ranges from 4.12 to 20.0 ppm (mean 9.2). In Mae La Noi and Khun Yuam, it ranges from 2.96 to 11.50 ppm (mean 6.0) and 4.85 to 10.40 ppm (mean 7.6), respectively.

The Ce anomaly in Khun Yuam and Mae La Noi is slightly negative and close to 1. In Mae Sariang, all values are positive.

Most Eu anomalies in all localities are positive and slightly more than 1. A few samples show a slightly negative Eu anomaly very close to 1. It lies from 0.98 to 1.05 in Khun Yuam. In Mae La Noi and Mae Sariang, it ranges from 0.92 to 1.04 and 0.91 to 1.15, respectively.

La_n/Ce_n values in all localities are low with both slightly negative and slightly positive values. It ranges from 0.97 to 1.08, 0.88 to 1.03 and 0.96 to 1.0 in Khun Yuam, Mae La Noi and Mae Sariang, respectively.

Table 5.1 Summarization of La, ∑REE, Ce/Ce*, Eu/Eu*, La_n/Yb_n and La_n/Ce_n

Locality	La(ppm)	∑REE (ppm)	Ce/Ce*	Eu/Eu*	La_n/Yb_n	La_n/Ce_n
Chiang Dao	**2.65-12.5**	**15.52-73.12**	**0.94-1.12**	**0.86-1.0**	**0.61-0.81**	**0.86-1.07**
(n=5)	(avg=5.29)	(avg=30.09)	(avg=1.00)	(avg=0.95)	(avg=0.73)	(avg=1.05)
Lamphun	**0.89-5.47**	**5.11-25.58**	**0.79-1.05**	**0.90-1.04**	**0.53-1.92**	**0.85-1.26**
(n=5)	(avg=2.55)	(avg=13.25)	(avg=0.92)	(avg=0.96)	(avg=0.98)	(avg=1.07)
Den Chai	**7.87-15.9**	**44.45-84.59**	**0.87-0.97**	**0.79-1.06**	**00.52-0.77**	**1.03-1.10**
(n=5)	(avg=10.73)	(avg=57.97)	(avg=0.91)	(avg=0.98)	(avg=0.65)	(avg=1.07)
Mae La Noi	**2.96-11.5**	**16.87-62.20**	**0.92-1.11**	**0.92-1.04**	**0.91-1.69**	**0.88-1.01**
(n=5)	(avg=6.0)	(avg=32.80)	(avg=1.00)	(avg=1.00)	(avg=1.16)	(avg=0.96)
Mae Sariang	**4.12-20.0**	**20.77-99.93**	**1.03-1.09**	**0.91-1.15**	**1.18-1.27**	**0.96-1.00**
(n=5)	(avg=9.2)	(avg=47.06)	(avg=1.05)	(avg=1.03)	(avg=1.21)	(avg=0.98)
Khun Yuam	**4.85-10.4**	**28.50-57.05**	**0.87-0.98**	**0.98-1.05**	**0.79-1.19**	**0.97-1.10**
(n=5)	(avg=7.6)	(avg=40.08)	(avg=0.91)	(avg=1.00)	(avg=1.01)	(avg=1.04)

5.4 Interpretation of the origin of chert and siliceous rocks

Based on an Al-Fe-Mn diagram, cherts and siliceous rocks from all localities are mostly related to non-hydrothermal origins except those from Den Chai (Fig. 5.1). Most data are compatible with a non-hydrothermal field and show low Mn content (several hundreds ppm). However, samples from Den Chai plot between the hydrothermal and non-hydrothermal field, with relatively high Mn content (ten thousand ppm). The Al-Fe-Mn diagram was developed by Adachi (1986) and Yamamoto (1987) to discriminate the origin of cherts (either hydrothermal or non-hydrothermal). For their study, hydrothermal chert is related to mafic volcanic rocks which contain high Mn concentrations (several thousands ppm).

The Al/(Al+Fe+Mn) ratio in marine chert is a good marker for determining its origin (Bostrom and Peterson, 1969).This ratio varies from 0.01 (pure hydrothermal chert) to 0.60 (pure biogenic chert) (Adachi, 1986; Yamamoto, 1987). In this thesis, most samples from all localities show a high ratio (mean 0.57 to 0.78) except for Den

Chai (mean 0.39). This result indicates the rocks from these localities are biogenic in origin. However, the rocks from Den Chai show a relatively low ratio.

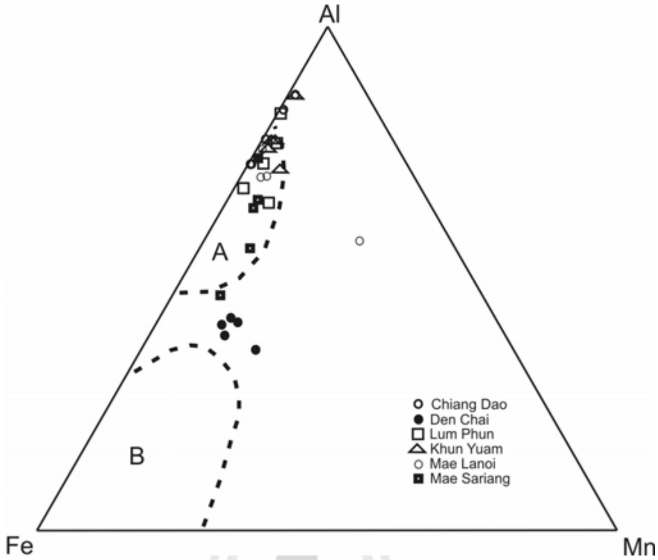


Figure 5.1 Al-Fe-Mn diagram of chert and siliceous rocks from six localities in northern Thailand. A= non-hydrothermal or biogenic field, B= hydrothermal field. (Hydrothermal and non-hydrothermal field from Adachi et al., 1986).

A high Fe content in Den Chai causes a low Al/(Al+Fe+Mn) ratio. Normally this result suggests mixed conditions between a majority of biogenic and minority of hydrothermal origin during sedimentation, but the Eu anomalies are not consistent with the interpretation of hydrothermal influences.

The Eu anomalies among Chiang Dao, Lamphun and Den Chai are slightly negative (Fig. 5.2). The Eu element shows no significant signal in NASC normalized REE distribution patterns. These Eu anomalies and NASC normalized patterns suggest non-hydrothermal related sedimentation. By contrast, there are slightly positive average Eu anomalies among Mae La Noi, Mae Sariang and Khun Yuam.

However, NASC normalized REE distribution diagrams show a relatively smooth pattern without pronounced Eu concentrations. This information suggests a lower hydrothermal input in comparison to a typical hydrothermal chert as mentioned in previous works (e.g., Chen et al., 2006). The Eu element from Chiang Dao, Lam phun, Den Chai, Mae Sariang, Mae La Noi and Khun Yuam is of non-hydrothermal origin. This interpretation (Eu anomalies) is compatible with results from the Al-Fe-Mn diagram.

In general, Eu occurs in a strongly reduced environment and is related to magmatic processess within the lower crust. In addition, detrital feldspar minerals can play a significant rule in contributing to the Eu concentration in sediments (Taylor and McClennan, 1985). It does not seem to be deposited in oceanic basins except in hydrothermal systems by a chemical exchange process related to feldspar. Sediments deposited in a hydrothermal regime contain an REE pattern with relative LREE enrichment (compared with typical LREE-depleted pattern of seawater) and a positive Eu anomaly (Michard, 1989; German et al., 1990; 1999; Douville et al., 1999). However, rare positive Eu anomalies and REE-enriched patterns are well documented in the geological record although large amount of hydrothermal fluid was recharged to the ocean (Murray et al., 1990).

A negative average value of La_n/Yb_n ratio in Lamphun, Chiang Dao and Den Chai results indicates a reduction of LREE content in comparison to HREE. The decreasing trend of this value among these localities suggests decreasing hydrothermal influences or increasing influences of seawaters. By contrast, positive

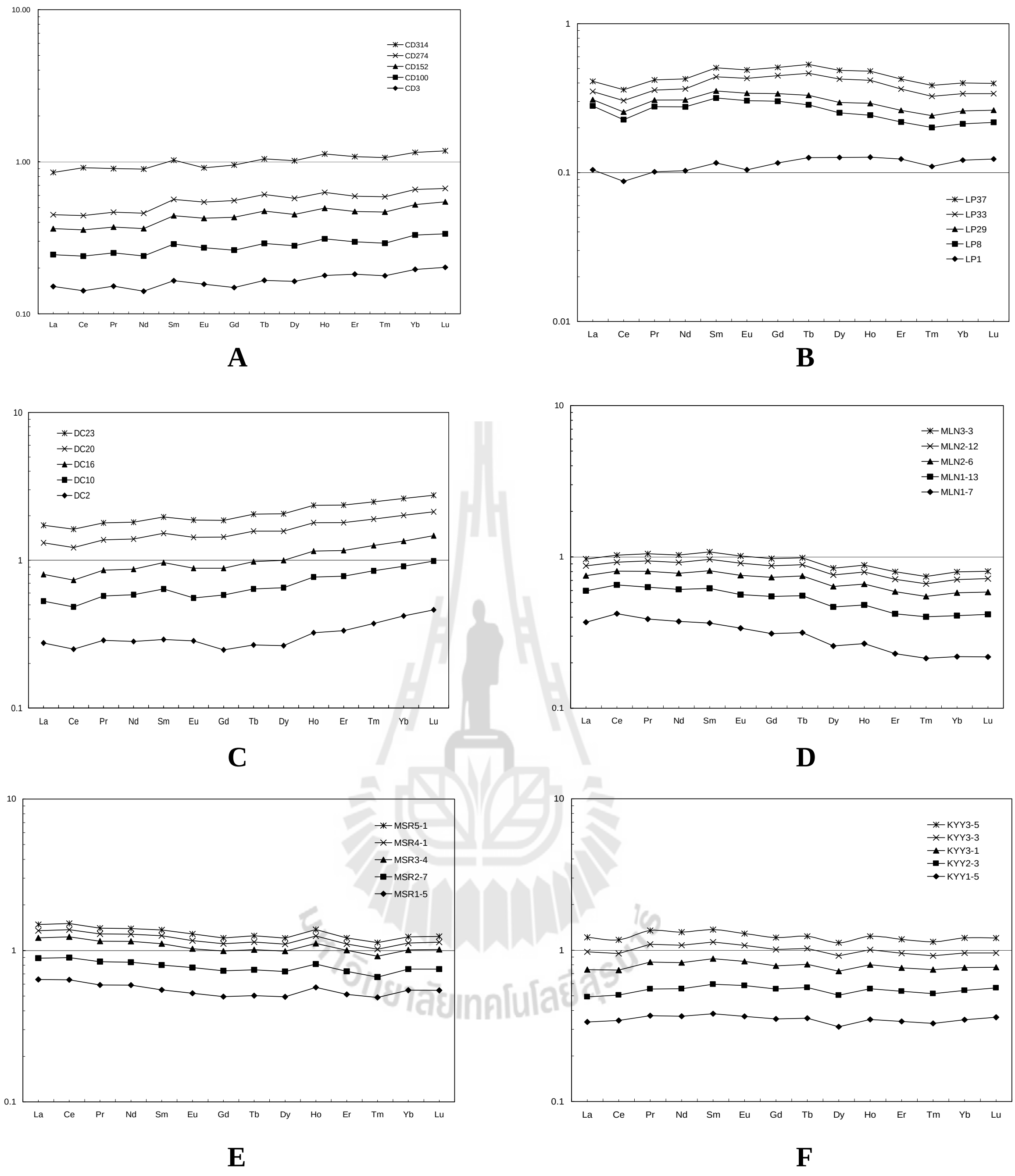


Figure 5.2 REE with NASC (North American Shale Composite) Normalized pattern from northern Thailand. A=Chiang Dao, B=Lamphun, C=Den Chai, D=Mae La Noi, E=Mae Sariang , F=KhunYuam.

average values of La_n/Yb_n abundances in Mae Sariang and gradually decreasing through Mae La Noi and Khun Yuam indicate a relatively high LREE content compared with HREE. The decreasing ratio indicates decreasing hydrothermal influences or increasing influences of seawaters along this trend. However, as mentioned above, Al-Fe-Mn diagram and Eu anomalies identified in this thesis indicate non-hydrothermal origin. The La_n/Yb_n ratio can only be used for correlating the relative influences of seawater among these localities.

5.5 Interpretation of depositional environment

On the basis of La_n/Ce_n vs. $Al_2O_3/ (Al_2O_3+Fe_2O_3)$ diagram (La and Ce NASC normalized) (Fig. 5.3), most samples from all localities are grouped in the field of continental margin except all samples from Den Chai. The majority of samples from Chiang Dao belong to the continental margin except one located between continental margin and pelagic. In Lamphun, it shows similar results to Chiang Dao. Most samples belong to continental margin but two are located between continental margin and pelagic. However, as mentioned above, all samples from Den Chai are located outside all fields. Samples in this locality contain similar of La_n/Ce_n vs. $Al_2O_3/ (Al_2O_3+Fe_2O_3)$ ratios to each other. These ratios are closely related to the continental margin or the area between continental margin and pelagic. This distribution is caused mainly by a low ratio of $Al_2O_3/ (Al_2O_3+Fe_2O_3)$ which is due to increasing Fe concentration. Distribution diagrams of all samples from Mae La Noi are compatible and located in the continental margin environment. Samples from Mae Sariang are separated into three groups because of different $Al_2O_3/ (Al_2O_3+Fe_2O_3)$ ratios. The majority is located in the continental margin and between continental margin and pelagic. Only one sample is located outside these fields because of lowering the Al_2O_3/ (Al_2O_3+Fe_2O_3) ratio by increasing the Fe content. However, it is more closely related to the continental margin than any other as indicated by the low La_n/Ce_n ratio. In Khun Yuam, the distribution diagram presents a good distribution pattern of the data and indicates the continental margin field. This result is caused mainly by a relatively high Al_2O_3/ (Al_2O_3+Fe_2O_3) ratio.

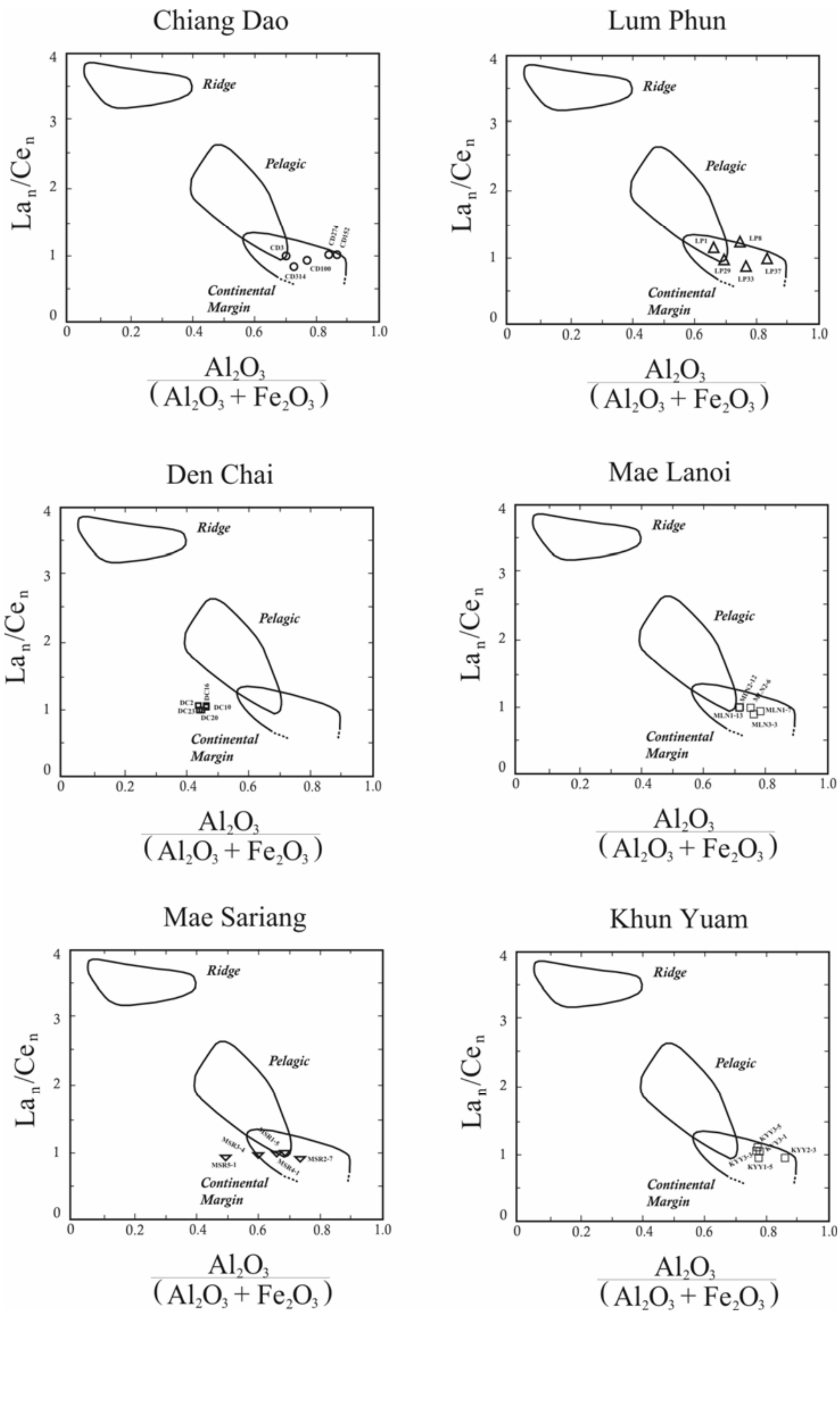


Figure 5.3 La_n/Ce_n vs. Al_2O_3/ (Al_2O_3+Fe_2O_3) diagrams of chert and siliceous rocks from northern Thailand

Table 5.2 Major element content (w%) of chert and siliceous rocks from northern Thailand

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
CD3	81.41	0.08	3.63	1.42	0.04	0.06	8.24	0.12	2.23	0.00
CD100	89.34	0.02	1.41	0.40	0.01	0.04	4.76	0.04	0.47	0.00
CD152	90.69	0.02	1.11	0.16	0.02	0.01	5.00	0.18	0.30	0.00
CD274	90.37	0.02	1.23	0.23	0.01	0.00	4.06	0.09	0.20	0.00
CD314	81.45	0.07	3.61	1.40	0.03	0.07	8.16	0.00	2.20	0.00
MEAN	**86.65**	**0.04**	**2.20**	**0.72**	**0.02**	**0.03**	**6.04**	**0.09**	**1.08**	**0.00**
STDEV	**4.79**	**0.03**	**1.30**	**0.64**	**0.01**	**0.03**	**2.00**	**0.07**	**1.04**	**0.00**
LP1	92.16	0.02	0.95	0.45	0.03	0.00	2.75	0.05	0.08	0.00
LP8	93.51	0.01	0.69	0.24	0.03	0.02	2.65	0.07	0.00	0.00
LP29	91.32	0.01	0.70	0.31	0.08	0.01	3.14	0.41	0.00	0.00
LP33	92.52	0.01	0.78	0.22	0.03	0.02	2.89	0.01	0.04	0.00
LP37	79.30	0.07	2.40	0.51	0.04	0.08	8.96	0.00	1.52	0.00
MEAN	**89.76**	**0.03**	**1.11**	**0.35**	**0.04**	**0.03**	**4.08**	**0.11**	**0.33**	**0.00**
STDEV	**5.90**	**0.03**	**0.73**	**0.13**	**0.02**	**0.03**	**2.73**	**0.17**	**0.67**	**0.00**
DC2	77.50	0.08	2.35	3.10	1.37	0.22	10.66	0.07	1.07	0.00
DC10	76.76	0.09	3.50	3.92	1.13	0.29	8.65	0.52	2.11	0.00
DC16	71.34	0.11	4.24	4.70	1.22	0.33	8.84	0.52	2.15	3.95
DC20	68.48	0.15	4.58	5.44	1.25	0.35	8.60	0.65	2.10	5.68
DC23	71.93	0.17	4.48	5.78	1.47	0.32	7.51	0.36	1.51	3.63
MEAN	**73.21**	**0.12**	**3.83**	**4.59**	**1.29**	**0.30**	**8.85**	**0.42**	**1.79**	**2.65**
STDEV	**3.82**	**0.04**	**0.93**	**1.10**	**0.13**	**0.05**	**1.14**	**0.23**	**0.48**	**2.54**
KYY1-5	84.09	0.05	1.82	0.50	0.03	0.03	7.79	0.00	1.14	0.00
KYY2-3	85.48	0.03	1.64	0.25	0.02	0.05	6.98	0.30	0.85	0.00
KYY3-1	84.51	0.04	1.61	0.45	0.05	0.00	8.82	0.00	1.13	0.00
KYY3-3	84.93	0.04	1.44	0.47	0.10	0.01	8.21	0.00	0.99	0.00
KYY3-5	82.27	0.07	2.01	0.63	0.05	0.04	9.69	0.00	1.46	0.00
MEAN	**84.26**	**0.05**	**1.70**	**0.46**	**0.05**	**0.03**	**8.30**	**0.06**	**1.12**	**0.00**
STDEV	**1.22**	**0.01**	**0.22**	**0.14**	**0.03**	**0.02**	**1.03**	**0.14**	**0.23**	**0.00**
MLN1-7	37.96	0.02	0.75	0.21	0.02	0.01	12.79	0.00	0.41	46.33
MLN1-13	87.87	0.02	0.75	0.30	0.04	0.03	7.03	0.07	0.24	0.00
MLN2-6	87.98	0.04	1.14	0.38	0.02	0.00	6.21	0.00	0.60	0.00
MLN2-12	83.21	0.03	1.20	0.49	0.06	0.02	9.53	0.33	0.62	0.00
MLN3-3	2.70	0.00	0.14	0.04	0.07	0.00	4.64	2.73	0.00	88.38
MEAN	**86.35**	**0.03**	**1.03**	**0.39**	**0.04**	**0.02**	**7.59**	**0.13**	**0.49**	**0.00**
STDEV	**2.72**	**0.01**	**0.24**	**0.09**	**0.02**	**0.01**	**1.73**	**0.18**	**0.21**	**0.00**
MSR1-5	87.57	0.02	0.98	0.45	0.07	0.13	6.28	0.00	0.45	0.00
MSR2-7	55.22	0.03	0.85	0.31	0.02	78.00	12.14	0.25	0.43	28.33
MSR3-4	85.74	0.04	2.22	1.49	0.36	0.51	5.56	0.21	0.57	0.00
MSR4-1	85.86	0.02	1.04	0.53	0.06	605.00	5.57	0.00	0.46	0.00
MSR5-1	81.77	0.09	2.62	2.74	0.41	0.64	6.47	0.00	1.06	0.00
MEAN	**85.23**	**0.04**	**1.72**	**1.30**	**0.23**	**151.57**	**5.97**	**0.05**	**0.64**	**0.00**
STDEV	**2.46**	**0.04**	**0.83**	**1.07**	**0.19**	**302.29**	**0.47**	**0.11**	**0.29**	**0.00**

Remark elemental concentration in MLN1-7, MLN3-3 and MSR 2-7 is not used for mean and standard deviation calculation

Table 5.3 Correlation coefficient (r) of major elements of chert and siliceous rocks from northern Thailand

Chiang Dao (N=5)

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O
SiO2	1.00								
TiO2	-1.00	1.00							
Al2O3	-1.00	1.00	1.00						
Fe2O3	-1.00	0.99	1.00	1.00					
MnO	-0.94	0.97	0.95	0.93	1.00				
MgO	-0.92	0.89	0.91	0.93	0.77	1.00			
CaO	-0.98	0.99	0.98	0.98	0.97	0.89	1.00		
Na2O	0.42	-0.36	-0.42	-0.44	-0.16	-0.62	-0.29	1.00	
K2O	-1.00	1.00	1.00	1.00	0.96	0.92	0.99	-0.38	1.00

Den Chai (N=5)

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5
SiO2	1.00									
TiO2	-0.78	1.00								
Al2O3	-0.89	0.86	1.00							
Fe2O3	-0.86	0.98	0.95	1.00						
MnO	-0.05	0.43	-0.03	0.26	1.00					
MgO	-0.91	0.75	0.97	0.87	-0.22	1.00				
CaO	0.57	-0.85	-0.87	-0.88	-0.08	-0.77	1.00			
Na2O	-0.69	0.44	0.79	0.60	-0.61	0.90	-0.62	1.00		
K2O	-0.51	0.20	0.65	0.39	-0.78	0.77	-0.49	0.95	1.00	
P2O5	-1.00	0.78	0.87	0.86	0.12	0.88	-0.55	0.63	0.45	1.00

Lamphun (N=5)

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O
SiO2	1.00								
TiO2	-0.97	1.00							
Al2O3	-0.98	1.00	1.00						
Fe2O3	-0.74	0.82	0.78	1.00					
MnO	-0.06	-0.16	-0.11	0.02	1.00				
MgO	-0.90	0.88	0.91	0.45	-0.19	1.00			
CaO	-1.00	0.97	0.98	0.71	0.01	0.94	1.00		
Na2O	0.26	-0.46	-0.42	-0.22	0.94	-0.45	-0.30	1.00	
K2O	-0.99	0.98	1.00	0.73	-0.08	0.93	1.00	-0.38	1.00

Khun Yuam (N=5)

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O
SiO2	1.00								
TiO2	-0.99	1.00							
Al2O3	-0.85	0.83	1.00						
Fe2O3	-0.90	0.93	0.59	1.00					
MnO	0.10	-0.05	-0.60	0.26	1.00				
MgO	-0.20	0.19	0.54	-0.16	-0.61	1.00			
CaO	-0.84	0.82	0.48	0.87	0.29	-0.23	1.00		
Na2O	0.56	-0.60	-0.17	-0.85	-0.51	0.64	-0.72	1.00	
K2O	-0.99	0.98	0.80	0.92	-0.05	0.06	0.90	-0.65	1.00

Table 5.3 Correlation coefficient (r) of major elements of chert and siliceous rocks from northern Thailand. (cont.)

Mae La Noi (N=3)

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O
SiO2	**1.00**								
TiO2	**-0.26**	**1.00**							
Al2O3	**-0.59**	**0.93**	**1.00**						
Fe2O3	**-0.92**	**0.62**	**0.86**	**1.00**					
MnO	**-0.93**	**-0.10**	**0.27**	**0.72**	**1.00**				
MgO	**-0.39**	**-0.79**	**-0.51**	**-0.01**	**0.69**	**1.00**			
CaO	**-0.98**	**0.04**	**0.41**	**0.81**	**0.99**	**0.58**	**1.00**		
Na2O	**-0.99**	**0.10**	**0.45**	**0.84**	**0.98**	**0.54**	**1.00**	**1.00**	
K2O	**-0.51**	**0.96**	**0.99**	**0.81**	**0.17**	**-0.59**	**0.31**	**0.36**	**1.00**

Mae Sariang (N=4)

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O
SiO2	**1.00**								
TiO2	**-0.92**	**1.00**							
Al2O3	**-0.82**	**0.88**	**1.00**						
Fe2O3	**-0.93**	**0.98**	**0.96**	**1.00**					
MnO	**-0.76**	**0.85**	**0.99**	**0.93**	**1.00**				
MgO	**0.17**	**-0.53**	**-0.54**	**-0.48**	**-0.60**	**1.00**			
CaO	**-0.43**	**0.64**	**0.25**	**0.46**	**0.23**	**-0.56**	**1.00**		
Na2O	**0.14**	**-0.06**	**0.40**	**0.12**	**0.47**	**-0.33**	**-0.57**	**1.00**	
K2O	**-0.96**	**0.99**	**0.85**	**0.96**	**0.80**	**-0.41**	**0.62**	**-0.15**	**1.00**

Table 5.4 Trace element concentration (ppm) of chert and siliceous rocks from northern Thailand

	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Cs	Ba	Hf	Ta	W	Tl	Pb	Th	U
CD3	4.02	7.18	7.35	62.55	1.24	1.42	1.64	1.98	11.42	13.46	5.68	14.77	2.70	1.56	0.58	120.39	0.29	0.56	153.63	0.09	1.67	2.67	0.94
CD100	3.43	10.63	10.08	99.18	2.05	0.92	1.83	2.68	13.54	13.79	3.66	10.63	1.20	0.60	0.48	96.08	0.28	0.34	180.01	0.06	1.19	0.94	0.40
CD152	2.98	5.65	5.00	55.00	0.87	0.65	1.69	2.14	10.53	29.46	5.55	10.53	1.21	0.30	0.49	90.23	0.28	0.34	180.01	0.06	1.19	0.94	0.40
CD274	3.46	6.12	5.92	103.76	1.22	0.82	1.39	1.94	9.28	14.87	3.69	17.50	1.16	2.04	0.48	81.81	0.30	0.52	87.95	0.07	1.37	0.91	0.53
CD314	7.51	21.43	15.60	17.57	3.58	2.38	5.10	9.16	48.40	37.40	14.40	67.83	3.23	0.87	1.32	227.29	1.70	0.35	19.09	0.28	3.01	3.18	0.63
Mean	**4.28**	**10.20**	**8.79**	**67.61**	**1.79**	**1.24**	**2.33**	**3.58**	**18.63**	**21.80**	**6.60**	**24.25**	**1.90**	**1.07**	**0.67**	**123.16**	**0.57**	**0.42**	**124.14**	**0.11**	**1.69**	**1.73**	**0.58**
STDEV	**1.85**	**6.57**	**4.26**	**35.33**	**1.09**	**0.70**	**1.56**	**3.13**	**16.71**	**11.00**	**4.47**	**24.53**	**0.99**	**0.71**	**0.37**	**59.96**	**0.63**	**0.11**	**69.75**	**0.09**	**0.77**	**1.11**	**0.22**
LP1	0.96	3.80	4.36	157.45	5.45	5.60	6.81	1.20	3.95	5.27	4.11	7.88	0.40	0.50	0.24	18.54	0.17	0.43	86.52	0.02	3.85	0.47	0.27
LP8	1.64	5.79	5.42	167.16	5.22	4.35	6.30	1.78	8.08	12.17	2.96	9.32	0.65	0.39	0.46	38.23	0.25	0.47	103.45	0.03	5.26	0.74	0.28
LP29	0.89	2.79	12.67	106.69	3.63	2.69	2.87	1.01	5.80	2.08	1.42	5.72	0.36	0.96	0.33	19.97	0.13	0.37	59.37	0.05	1.50	0.27	0.19
LP33	0.74	1.70	7.36	186.47	3.24	6.27	3.11	0.91	3.59	3.39	4.15	5.89	0.15	0.31	0.23	13.46	0.13	0.22	34.81	0.03	2.14	0.30	0.20
LP37	1.01	2.67	5.14	149.52	2.89	1.58	2.55	1.08	6.45	3.21	2.03	5.12	0.32	0.25	0.37	22.30	0.13	0.41	44.62	0.05	1.88	0.36	0.18
Mean	**1.05**	**3.35**	**6.99**	**153.46**	**4.09**	**4.10**	**4.33**	**1.20**	**5.58**	**5.22**	**2.93**	**6.79**	**0.38**	**0.48**	**0.32**	**22.50**	**0.16**	**0.38**	**65.75**	**0.04**	**2.93**	**0.43**	**0.22**
STDEV	**0.35**	**1.55**	**3.36**	**29.57**	**1.17**	**1.96**	**2.05**	**0.35**	**1.85**	**4.05**	**1.22**	**1.76**	**0.18**	**0.28**	**0.10**	**9.37**	**0.05**	**0.10**	**28.71**	**0.01**	**1.58**	**0.19**	**0.05**
DC2	4.30	18.56	9.44	73.73	5.20	8.65	45.46	5.95	26.65	30.66	8.15	38.26	2.70	0.19	2.06	115.39	1.09	0.64	39.19	0.18	6.54	2.30	1.02
DC10	5.41	22.03	9.88	54.70	6.50	10.26	61.71	8.67	49.17	37.88	12.38	57.07	3.60	0.21	4.40	190.80	1.55	0.58	24.78	0.29	7.23	2.99	1.24
DC16	6.59	26.74	10.86	26.68	9.61	18.88	69.49	8.53	47.70	57.25	10.85	51.49	2.75	0.20	4.26	190.12	1.41	0.35	10.59	0.28	8.08	2.57	1.24
DC20	8.29	32.37	15.19	21.40	10.79	23.38	75.20	9.56	47.99	69.85	19.37	92.82	4.93	2.64	4.27	191.63	2.58	0.53	5.61	0.27	11.20	6.70	1.53
DC23	8.03	38.91	16.52	37.57	10.60	19.99	71.03	8.68	34.45	100.91	16.46	79.43	4.09	0.55	4.35	148.58	2.18	0.53	9.99	0.21	15.14	4.23	0.81
Mean	**6.52**	**27.72**	**12.38**	**42.82**	**8.54**	**16.23**	**64.58**	**8.28**	**41.19**	**59.31**	**13.44**	**63.81**	**3.61**	**0.76**	**3.87**	**167.30**	**1.76**	**0.53**	**18.03**	**0.25**	**9.64**	**3.76**	**1.17**
STDEV	**1.70**	**8.12**	**3.25**	**21.47**	**2.54**	**6.43**	**11.75**	**1.37**	**10.12**	**27.95**	**4.47**	**22.00**	**0.94**	**1.06**	**1.01**	**34.31**	**0.60**	**0.11**	**13.85**	**0.05**	**3.56**	**1.80**	**0.27**
KYY1-5	3.19	9.50	9.85	90.90	2.45	5.11	5.31	4.16	31.04	11.20	10.40	32.60	2.33	0.63	6.31	128.02	0.75	0.89	10.90	0.20	11.30	2.15	0.69
KYY2-3	2.76	6.46	4.15	98.38	1.93	3.15	2.70	3.09	23.10	7.84	6.77	18.81	0.88	0.36	3.05	135.87	0.48	0.47	8.59	0.15	6.76	1.22	0.72
KYY3-1	2.99	11.32	8.36	57.49	3.68	5.69	4.07	3.65	29.14	8.69	7.06	30.44	1.59	0.30	4.65	119.11	0.67	0.62	6.83	0.18	1.73	1.86	0.72
KYY3-3	2.76	10.63	8.25	81.99	3.42	5.49	4.44	3.28	27.22	9.02	6.11	20.42	1.42	0.21	4.35	130.59	0.51	0.79	9.03	0.17	1.73	1.82	0.62
KYY3-5	3.38	14.70	11.89	72.04	4.71	7.88	6.64	4.60	41.00	10.50	7.77	24.43	2.34	0.19	5.77	126.59	0.72	0.73	8.09	0.23	2.19	2.40	0.52
Mean	**3.01**	**10.52**	**8.50**	**80.16**	**3.24**	**5.46**	**4.63**	**3.76**	**30.30**	**9.45**	**7.62**	**25.34**	**1.71**	**0.34**	**4.82**	**128.04**	**0.63**	**0.70**	**8.69**	**0.19**	**4.74**	**1.89**	**0.65**
STDEV	**0.27**	**2.99**	**2.84**	**16.05**	**1.09**	**1.69**	**1.46**	**0.62**	**6.67**	**1.37**	**1.67**	**6.05**	**0.62**	**0.18**	**1.27**	**6.12**	**0.12**	**0.16**	**1.48**	**0.03**	**4.23**	**0.44**	**0.09**

Table 5.4 Trace element concentration (ppm) of chert and siliceous rocks from northern Thailand (cont.)

	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Cs	Ba	Hf	Ta	W	Tl	Pb	Th	U
MLN1-7	2.80	8.59	8.79	58.32	5.92	9.15	6.59	2.76	18.51	17.03	8.11	19.19	1.27	0.19	2.60	76.49	0.48	0.78	7.28	0.17	5.20	1.97	1.29
MLN1-7	3.10	12.75	9.12	52.31	5.54	11.56	9.20	3.46	22.71	15.36	6.60	20.52	1.56	0.20	2.91	76.39	0.49	0.70	5.73	0.17	5.96	1.78	0.78
MLN2-6	2.21	12.11	16.27	128.05	3.91	9.67	4.83	2.73	16.44	13.34	5.22	13.88	1.23	0.22	2.16	92.47	0.38	0.74	9.78	0.11	4.53	1.42	0.86
MLN2-12	2.45	9.38	11.66	210.24	4.90	6.38	6.63	2.75	18.93	12.17	4.01	13.19	1.33	0.35	2.06	92.09	0.39	1.45	15.50	0.15	8.64	1.32	1.34
MLN3-3	1.40	7.50	9.86	67.05	5.39	12.28	11.17	1.46	8.67	11.58	2.64	8.81	0.60	0.73	1.52	60.12	0.27	0.58	6.11	0.09	5.15	1.03	0.51
Mean	**2.39**	**10.07**	**11.14**	**103.19**	**5.13**	**9.81**	**7.68**	**2.63**	**17.05**	**13.90**	**5.32**	**15.12**	**1.20**	**0.34**	**2.25**	**79.51**	**0.40**	**0.85**	**8.88**	**0.14**	**5.90**	**1.51**	**0.95**
STDEV	**0.65**	**2.27**	**3.08**	**67.05**	**0.77**	**2.31**	**2.49**	**0.72**	**5.20**	**2.27**	**2.14**	**4.76**	**0.36**	**0.23**	**0.54**	**13.43**	**0.09**	**0.34**	**4.03**	**0.04**	**1.62**	**0.38**	**0.35**
MSR1-5	8.10	52.41	29.65	17.62	9.46	22.20	290.16	10.76	75.14	9.79	15.74	75.82	7.63	0.76	5.26	674.86	2.19	0.71	161.90	0.31	245.42	6.96	1.16
MSR2-7	2.95	18.08	11.05	32.20	6.18	10.32	119.28	4.03	27.84	8.07	7.30	27.22	2.39	0.18	2.50	445.37	0.73	0.54	295.20	0.16	19.79	2.36	0.51
MSR3-4	4.32	22.79	15.80	28.01	7.11	16.54	207.99	5.52	29.60	6.93	8.63	42.25	3.92	0.32	4.23	295.70	1.12	0.55	251.00	0.13	30.67	3.48	0.91
MSR4-1	1.46	3.47	3.52	257.15	2.90	6.54	81.56	2.01	13.60	5.97	3.55	9.43	0.26	0.64	0.82	327.78	0.30	0.31	746.40	0.06	32.64	1.26	1.09
MSR5-1	1.62	6.03	5.14	67.82	2.11	18.09	31.47	2.31	14.91	6.75	3.58	12.81	0.61	1.41	0.89	130.92	0.36	0.50	435.60	0.13	31.33	1.48	0.80
Mean	**3.69**	**20.56**	**13.03**	**80.56**	**5.55**	**14.74**	**146.09**	**4.93**	**32.22**	**7.50**	**7.76**	**33.51**	**2.96**	**0.66**	**2.74**	**374.92**	**0.94**	**0.52**	**378.02**	**0.16**	**71.97**	**3.11**	**0.89**
STDEV	**2.72**	**19.55**	**10.49**	**100.51**	**3.04**	**6.26**	**103.21**	**3.56**	**25.07**	**1.48**	**4.99**	**26.99**	**3.00**	**0.48**	**1.98**	**201.84**	**0.77**	**0.14**	**228.43**	**0.09**	**97.10**	**2.33**	**0.26**

Table 5.5 REE element concentration (ppm) of chert and siliceous rocks from northern Thailand

	CD3	CD100	CD152	CD274	CD314	LP1	LP8	LP29	LP33	LP37	DC2	DC10	DC16	DC20	DC23
La	4.71	2.91	3.67	2.65	12.52	3.25	5.47	0.89	1.30	1.86	8.56	7.87	8.53	15.85	12.84
Ce	9.51	6.55	7.84	5.80	31.54	5.86	9.33	1.92	3.29	3.75	16.77	15.63	16.75	32.61	26.98
Pr	1.20	0.79	0.95	0.74	3.44	0.80	1.39	0.23	0.41	0.48	2.27	2.26	2.24	4.09	3.27
Nd	4.28	3.02	3.77	2.87	13.29	3.13	5.28	0.95	1.75	1.84	8.57	9.20	8.70	15.84	12.70
Sm	0.99	0.73	0.92	0.74	2.74	0.70	1.20	0.22	0.52	0.39	1.74	2.08	1.95	3.34	2.62
Eu	0.20	0.14	0.19	0.15	0.46	0.13	0.25	0.05	0.11	0.08	0.36	0.34	0.41	0.68	0.56
Gd	0.82	0.62	0.93	0.69	2.18	0.64	1.02	0.21	0.60	0.33	1.36	1.84	1.65	3.04	2.33
Tb	0.14	0.11	0.16	0.12	0.37	0.11	0.14	0.04	0.11	0.06	0.23	0.32	0.29	0.50	0.41
Dy	0.91	0.65	0.94	0.69	2.45	0.70	0.70	0.24	0.72	0.34	1.46	2.15	1.92	3.19	2.71
Ho	0.19	0.14	0.19	0.14	0.52	0.13	0.12	0.05	0.13	0.07	0.34	0.46	0.40	0.67	0.58
Er	0.60	0.38	0.57	0.40	1.59	0.40	0.31	0.14	0.34	0.20	1.09	1.46	1.26	2.07	1.84
Tm	0.09	0.06	0.09	0.06	0.24	0.05	0.05	0.02	0.04	0.03	0.19	0.24	0.21	0.32	0.29
Yb	0.61	0.42	0.60	0.42	1.54	0.38	0.28	0.15	0.25	0.19	1.31	1.53	1.36	2.07	1.89
Lu	0.09	0.06	0.10	0.06	0.23	0.06	0.04	0.02	0.04	0.03	0.21	0.24	0.22	0.30	0.29
REE(SUM)	**24.32**	**16.57**	**20.91**	**15.52**	**73.12**	**16.33**	**25.58**	**5.11**	**9.59**	**9.64**	**44.45**	**45.62**	**45.89**	**84.59**	**69.29**
Ce/Ce	**0.94**	**1.01**	**0.98**	**0.97**	**1.12**	**0.85**	**0.79**	**0.99**	**1.05**	**0.93**	**0.89**	**0.87**	**0.90**	**0.95**	**0.97**
Eu/Eu	**1.00**	**0.98**	**0.95**	**0.96**	**0.86**	**0.90**	**1.04**	**1.00**	**0.91**	**0.95**	**1.06**	**0.79**	**1.05**	**0.98**	**1.03**
La/Yb	**0.77**	**0.70**	**0.61**	**0.63**	**0.81**	**0.86**	**1.92**	**0.60**	**0.53**	**0.99**	**0.66**	**0.52**	**0.63**	**0.77**	**0.68**
La/Ce	**1.07**	**0.96**	**1.01**	**0.99**	**0.86**	**1.20**	**1.26**	**1.00**	**0.85**	**1.07**	**1.10**	**1.08**	**1.10**	**1.05**	**1.03**

	KYY1-5	KYY2-3	KYY3-1	KYY3-3	KYY3-5	MLN1-7	MLN1-13	MLN2-6	MLN2-12	MLN3-3	MSR1-5	MSR2-7	MSR3-4	MSR4-1	MSR5-1
La	10.43	4.85	7.87	7.13	7.48	11.52	7.08	4.79	3.77	2.96	20.04	7.63	10.04	4.33	4.12
Ce	23.00	10.83	15.66	14.17	14.64	28.27	15.52	10.17	7.93	7.06	42.98	17.20	22.29	9.41	9.22
Pr	2.91	1.47	2.21	2.05	2.01	3.07	1.92	1.36	1.08	0.86	4.68	1.99	2.42	1.06	0.95
Nd	11.13	5.77	8.27	7.60	7.18	11.40	7.14	5.20	4.18	3.38	17.94	7.47	9.56	3.94	3.48
Sm	2.28	1.29	1.70	1.52	1.39	2.18	1.52	1.15	0.92	0.67	3.28	1.51	1.84	0.85	0.69
Eu	0.46	0.27	0.32	0.29	0.27	0.42	0.28	0.24	0.19	0.13	0.65	0.31	0.32	0.17	0.16
Gd	1.93	1.11	1.28	1.23	1.11	1.72	1.30	1.01	0.78	0.55	2.72	1.32	1.42	0.64	0.56
Tb	0.30	0.18	0.20	0.19	0.18	0.27	0.20	0.16	0.12	0.08	0.43	0.21	0.23	0.11	0.10
Dy	1.73	1.07	1.23	1.07	1.12	1.43	1.16	0.95	0.68	0.46	2.74	1.28	1.46	0.63	0.57
Ho	0.36	0.22	0.26	0.21	0.24	0.28	0.22	0.19	0.14	0.09	0.59	0.25	0.31	0.14	0.13
Er	1.11	0.64	0.75	0.62	0.73	0.75	0.63	0.55	0.40	0.28	1.68	0.70	0.91	0.33	0.34
Tm	0.16	0.09	0.11	0.09	0.11	0.11	0.09	0.07	0.06	0.04	0.24	0.09	0.12	0.05	0.05
Yb	1.08	0.61	0.70	0.60	0.76	0.68	0.59	0.53	0.40	0.27	1.70	0.64	0.79	0.35	0.35
Lu	0.16	0.09	0.10	0.09	0.11	0.10	0.09	0.08	0.06	0.04	0.25	0.09	0.12	0.06	0.05
REE(SUM)	**57.05**	**28.50**	**40.65**	**36.86**	**37.33**	**62.20**	**37.77**	**26.45**	**20.71**	**16.87**	**99.93**	**40.70**	**51.83**	**22.05**	**20.77**
Ce/Ce	**0.98**	**0.95**	**0.88**	**0.87**	**0.88**	**1.11**	**0.98**	**0.93**	**0.92**	**1.03**	**1.04**	**1.03**	**1.06**	**1.03**	**1.09**
Eu/Eu	**1.00**	**1.05**	**1.01**	**0.98**	**0.98**	**1.00**	**0.92**	**1.02**	**1.04**	**1.00**	**1.00**	**1.01**	**0.91**	**1.06**	**1.15**
La/Yb	**0.97**	**0.79**	**1.13**	**1.19**	**0.98**	**1.69**	**1.19**	**0.91**	**0.94**	**1.09**	**1.18**	**1.18**	**1.27**	**1.24**	**1.19**
La/Ce	**0.98**	**0.97**	**1.08**	**1.08**	**1.10**	**0.88**	**0.98**	**1.01**	**1.03**	**0.90**	**1.00**	**0.96**	**0.97**	**0.99**	**0.96**

Table 5.6 Correlation coefficient (r) of major and trace elements from chert and siliceous rocks from northern Thailand

Chiang Dao

	SiO2	TiO2	Al2O3	MgO	K2O	Fe2O3	MnO	Cr	Rb	Zr	Hf	Th	Mo	Ni	Cu	Zn
SiO2	1.00															
TiO2	-1.00	1.00														
Al2O3	-1.00	1.00	1.00													
MgO	-0.92	0.89	0.91	1.00												
K2O	-1.00	1.00	1.00	0.92	1.00											
Fe2O3	-1.00	0.99	1.00	0.93	1.00	1.00										
MnO	-0.94	0.97	0.95	0.77	0.96	0.93	1.00									
Cr	-0.62	0.58	0.61	0.79	0.60	0.62	0.43	1.00								
Rb	-0.62	0.61	0.62	0.68	0.61	0.61	0.54	0.93	1.00							
Zr	-0.63	0.62	0.63	0.62	0.62	0.62	0.57	0.87	0.98	1.00						
Hf	-0.61	0.60	0.61	0.63	0.60	0.60	0.56	0.89	0.99	0.99	1.00					
Th	-0.98	0.98	0.98	0.89	0.98	0.98	0.95	0.68	0.74	0.75	0.74	1.00				
Mo	-0.16	0.16	0.18	-0.06	0.12	0.17	0.14	-0.21	-0.21	-0.04	-0.15	0.11	1.00			
Ni	-0.55	0.51	0.54	0.71	0.54	0.56	0.38	0.99	0.94	0.90	0.92	0.63	-0.19	1.00		
Cu	-0.87	0.86	0.87	0.86	0.86	0.87	0.78	0.88	0.92	0.92	0.91	0.93	0.03	0.87	1.00	
Zn	-0.61	0.60	0.61	0.67	0.61	0.60	0.55	0.92	1.00	0.98	0.99	0.73	-0.24	0.93	0.91	1.00

Lamphun

	SiO2	TiO2	Al2O3	MgO	K2O	Fe2O3	MnO	Cr	Rb	Zr	Hf	Th	Mo	Ni	Cu	Zn
SiO2	1.00															
TiO2	-0.97	1.00														
Al2O3	-0.98	1.00	1.00													
MgO	-0.90	0.88	0.91	1.00												
K2O	-0.99	0.98	1.00	0.93	1.00											
Fe2O3	-0.74	0.82	0.78	0.45	0.73	1.00										
MnO	-0.06	-0.16	-0.11	-0.19	-0.08	0.02	1.00									
Cr	0.21	-0.45	-0.38	-0.32	-0.33	-0.39	0.90	1.00								
Rb	-0.20	0.15	0.17	0.37	0.23	-0.06	0.07	-0.03	1.00							
Zr	0.61	-0.46	-0.51	-0.46	-0.53	-0.30	-0.47	-0.43	0.36	1.00						
Hf	0.41	-0.30	-0.34	-0.20	-0.33	-0.28	-0.45	-0.42	0.63	0.94	1.00					
Th	0.31	-0.17	-0.21	-0.10	-0.21	-0.18	-0.54	-0.54	0.62	0.92	0.99	1.00				
Mo	0.36	-0.51	-0.49	-0.59	-0.47	-0.16	0.89	0.84	-0.01	-0.10	-0.18	-0.30	1.00			
Ni	0.61	-0.44	-0.52	-0.62	-0.56	-0.08	-0.33	-0.38	0.13	0.92	0.78	0.76	0.09	1.00		
Cu	0.75	-0.61	-0.65	-0.63	-0.69	-0.49	-0.54	-0.26	-0.60	0.44	0.19	0.17	-0.21	0.45	1.00	
Zn	0.54	-0.34	-0.42	-0.52	-0.47	-0.03	-0.49	-0.55	0.09	0.92	0.78	0.79	-0.10	0.98	0.50	1.00

Den Chai

	SiO2	TiO2	Al2O3	MgO	K2O	Fe2O3	MnO	Cr	Rb	Zr	Hf	Th	Mo	Ni	Cu	Zn
SiO2	1.00															
TiO2	-0.78	1.00														
Al2O3	-0.89	0.86	1.00													
MgO	-0.91	0.75	0.97	1.00												
K2O	-0.51	0.20	0.65	0.77	1.00											
Fe2O3	-0.86	0.98	0.95	0.87	0.39	1.00										
MnO	-0.05	0.43	-0.03	-0.22	-0.78	0.26	1.00									
Cr	-0.75	0.98	0.77	0.66	0.08	0.93	0.51	1.00								
Rb	-0.45	0.15	0.59	0.73	1.00	0.33	-0.82	0.03	1.00							
Zr	-0.80	0.87	0.82	0.80	0.39	0.87	0.12	0.90	0.37	1.00						
Hf	-0.80	0.87	0.80	0.79	0.36	0.86	0.14	0.90	0.35	1.00	1.00					
Th	-0.77	0.70	0.66	0.70	0.33	0.71	0.05	0.78	0.33	0.94	0.95	1.00				
Mo	-0.74	0.51	0.52	0.62	0.33	0.54	-0.07	0.60	0.34	0.82	0.84	0.96	1.00			
Ni	-0.95	0.91	0.96	0.91	0.46	0.97	0.18	0.85	0.40	0.82	0.81	0.70	0.58	1.00		
Cu	-0.99	0.86	0.92	0.91	0.46	0.92	0.15	0.82	0.40	0.83	0.83	0.76	0.69	0.98	1.00	
Zn	-0.89	0.82	0.99	0.99	0.71	0.92	-0.12	0.74	0.66	0.83	0.81	0.69	0.57	0.94	0.91	1.00

Table 5.6 Correlation coefficient (r) of major and trace elements from chert and siliceous rocks from northern Thailand. (cont.)

Khun Yuam

	SiO2	TiO2	Al2O3	MgO	K2O	Fe2O3	MnO	Cr	Rb	Zr	Hf	Th	Mo	Ni	Cu	Zn
SiO2	1.00															
TiO2	-0.99	1.00														
Al2O3	-0.85	0.83	1.00													
MgO	-0.20	0.19	0.54	1.00												
K2O	-0.99	0.98	0.80	0.06	1.00											
Fe2O3	-0.90	0.93	0.59	-0.16	0.92	1.00										
MnO	0.10	-0.05	-0.60	-0.61	-0.05	0.26	1.00									
Cr	-0.90	0.93	0.63	-0.17	0.93	0.99	0.18	1.00								
Rb	-1.00	0.99	0.82	0.15	0.99	0.92	-0.04	0.92	1.00							
Zr	-0.32	0.32	0.35	-0.48	0.41	0.42	-0.25	0.52	0.32	1.00						
Hf	-0.74	0.74	0.73	-0.15	0.79	0.74	-0.30	0.81	0.74	0.87	1.00					
Th	-0.90	0.92	0.66	-0.15	0.92	0.98	0.12	1.00	0.91	0.56	0.85	1.00				
Mo	0.21	-0.17	0.16	0.04	-0.21	-0.21	-0.57	-0.09	-0.23	0.60	0.38	-0.02	1.00			
Ni	-0.78	0.76	0.38	-0.21	0.83	0.82	0.41	0.77	0.81	0.11	0.42	0.73	-0.67	1.00		
Cu	-0.91	0.91	0.56	-0.14	0.94	0.96	0.29	0.93	0.93	0.28	0.63	0.90	-0.44	0.95	1.00	
Zn	-0.94	0.97	0.72	0.04	0.93	0.97	0.10	0.98	0.95	0.39	0.76	0.98	-0.10	0.73	0.91	1.00

Mae La Noi

	SiO2	TiO2	Al2O3	MgO	K2O	Fe2O3	MnO	Cr	Rb	Zr	Hf	Th	Mo	Ni	Cu	Zn
SiO2	1.00															
TiO2	-0.26	1.00														
Al2O3	-0.59	0.93	1.00													
MgO	-0.39	-0.79	-0.51	1.00												
K2O	-0.51	0.96	0.99	-0.59	1.00											
Fe2O3	-0.92	0.62	0.86	-0.01	0.81	1.00										
MnO	-0.93	-0.10	0.27	0.69	0.17	0.72	1.00									
Cr	0.18	0.90	0.68	-0.98	0.75	0.22	-0.52	1.00								
Rb	0.10	-0.99	-0.86	0.88	-0.91	-0.49	0.26	-0.96	1.00							
Zr	0.56	-0.95	-1.00	0.55	-1.00	-0.84	-0.22	-0.71	0.88	1.00						
Hf	0.38	-0.99	-0.97	0.70	-0.99	-0.71	-0.02	-0.84	0.96	0.98	1.00					
Th	0.66	-0.90	-1.00	0.44	-0.98	-0.90	-0.34	-0.62	0.82	0.99	0.95	1.00				
Mo	-0.99	0.40	0.70	0.25	0.63	0.97	0.87	-0.04	-0.24	-0.67	-0.51	-0.76	1.00			
Ni	-0.14	-0.92	-0.71	0.97	-0.78	-0.26	0.49	-1.00	0.97	0.74	0.86	0.65	0.00	1.00		
Cu	0.93	-0.61	-0.86	-0.01	-0.80	-1.00	-0.73	-0.20	0.47	0.83	0.70	0.89	-0.97	0.25	1.00	
Zn	0.08	-0.98	-0.85	0.89	-0.90	-0.47	0.28	-0.96	1.00	0.87	0.95	0.80	-0.22	0.98	0.45	1.00

Mae Sariang

	SiO2	TiO2	Al2O3	MgO	K2O	Fe2O3	MnO	Cr	Rb	Zr	Hf	Th	Mo	Ni	Cu	Zn
SiO2	1.00															
TiO2	-0.92	1.00														
Al2O3	-0.82	0.88	1.00													
MgO	0.17	-0.53	-0.54	1.00												
K2O	-0.96	0.99	0.85	-0.41	1.00											
Fe2O3	-0.93	0.98	0.96	-0.48	0.96	1.00										
MnO	-0.76	0.85	0.99	-0.60	0.80	0.93	1.00									
Cr	0.69	-0.36	-0.39	-0.55	-0.47	-0.46	-0.31	1.00								
Rb	0.69	-0.39	-0.50	-0.46	-0.48	-0.51	-0.44	0.98	1.00							
Zr	0.70	-0.37	-0.38	-0.55	-0.48	-0.46	-0.30	1.00	0.97	1.00						
Hf	0.71	-0.39	-0.42	-0.53	-0.49	-0.48	-0.34	1.00	0.98	1.00	1.00					
Th	0.70	-0.38	-0.44	-0.51	-0.48	-0.49	-0.36	1.00	0.99	0.99	1.00	1.00				
Mo	-0.75	0.78	0.39	-0.21	0.82	0.64	0.32	-0.32	-0.20	-0.34	-0.32	-0.28	1.00			
Ni	0.79	-0.49	-0.40	-0.48	-0.60	-0.53	-0.31	0.97	0.91	0.97	0.96	0.95	-0.54	1.00		
Cu	0.03	0.35	0.24	-0.93	0.24	0.24	0.29	0.74	0.71	0.73	0.72	0.73	0.25	0.62	1.00	
Zn	0.83	-0.56	-0.46	-0.40	-0.67	-0.60	-0.37	0.95	0.90	0.96	0.95	0.94	-0.58	1.00	0.55	1.00

CHAPTER VI

DISCUSSION

According to La and Ce NASC normalized diagrams, the depositional environments of radiolarites from almost all localities are compatible with a continental margin setting (see details in Chapter V). Based on radiolarian chronology as mentioned earlier, these radiolarites range in age from Middle Triassic to early Late Triassic. These data reveal that during Middle to early Late Triassic time, these radiolarites were deposited at a continental margin rather than in the deep ocean realm or a pelagic environment as previously assumed. However, the long-aged range of oceanic realm concept in this region could not be completely ruled out, for at least some sequences show evidence of a deep marine environment. On the other hand, some Devonian strata (probably also Carboniferous-Permian) could have been deposited under deep marine conditions including pelagic shale (with graptolites) and radiolarian chert (typical of Fang Chert). The other consists of carbonate and clastic deposits an indication of shallow marine environments. Detailed discussions on the Triassic tectonic scenario and related topics are listed below.

Tectonostratigraphically, deep marine and oceanic facies of the Triassic in Thailand can be separated into two discontinues linear belts (Chonglakmani, 1999; 2002). Both of them are arranged in approximately a north-south trend. One belt is located in Fang-Chiang Dao area to the north, Sukhothai to the central and Chantaburi to the south. This belt ranges in age from Devonian to Triassic by the occurrence of radiolarian chert (Jaeger et al., 1969; Sashida et al., 1993; Caridroit, 1993; Hada, 1997; Salyapongse, 1992; Thassanapak et al., 2006a; 2006b). The other belt lies to the west and is located along Thai-Myanmar border. It is delineated in N-S trend along the Tertiary-covered Mae Yuam Fault zone to the north of Mae Sariang. It can be traced along Tak-Mae Sot-Kanchanaburi in the central region and Songkhla to the south. The unit is composed of chert, pelagic limestone and turbidite sequence (Caridroit et al., 1993; Chonglakmani and Grant- Mackie, 1993; Tofke et al., 1993). The eastern limit of this belt is bounded by the "Doi Inthanon Metamorphic Core Complex" in Chiang Mai province. Tectonic scenario of the belt containing Chiang Dao and Lamphun localities of this thesis is discuss separately from Den Chai since they are located in different tectonostratigraphic belts. Tectonic scenario of the western belt along the Mae Yuam Fault zone is given later.

6.1 Chiang Dao and Lamphun localities

These localities in this thesis are part of the Doi Inthanon-Lincang tectonostratigraphic unit (Chonglakmani et al., 2001). Geographically, these localities are located within Chiang Mai-Malacca terrane (Chonglakmani, 1999), or Inthanon zone (Ueno, 1999; 2003) as part of Shan-Thai (Bunopas, 1989). Chiang Mai-Malacca terrane or Inthanon zone is bounded to the west by the Mae Yaum Fault zone and to the east by the Chiang Rai Line ("Cryptic suture"). A summary of marine depositional environments during the Paleozoic along this belt based on previous works is given below. Discussion on the Triassic tectonic scenario on the basis of this thesis and some other literature is as follows.

The existence of deep marine or oceanic realm along this belt occurred during at least Early Devonian (or Silurian) by the occurrence of Devonian pelagic shale and radiolarian cherts in northern Chiang Mai (Kobayashi and Igo, 1968; Jaeger et al., 1968). In addition, Carboniferous and Permian radiolarian cherts in Chiang Dao area indicate a long-lived deep marine environment. Thick sequence of Carboniferous siliciclastics, quartz-rich and mature sandstone, is found between Mae Hong Son and Pai area and supports this interpretation (Fujikawa and Ishibashi, 2000). By contrast, a Carboniferous-Permian and Triassic shallow carbonate platform was observed in Chiang Dao area (Caridroit, 1993; Ueno and Igo, 1997). This sequence indicates the existence of a tropical-subtropical realm. It is similar to carbonate strata observed between Mae Hong Son and Pai area (e.g., Fontaine, 1993; Chonglakmani et al., 2001). In some case such as in Mae Lana north of Mae Hong Son and Chiang Dao, limestone was observed with basalts which lead to the interpretation of an ancient seamount environment (e.g., Metcalfe, 2002). This case is unlikely since this limestone was developed in a carbonate platform (Barr, 1990). However, Ueno and Hisada (2001) and Ueno (2003), interpreted this pile of sediments as tectonic nappes migrating from the east. In their reports, a cryptic suture was inferred as the main Paleotethys.

According to this thesis, geochemical analyses and the radiolarian chronology indicate the occurrence of a continental margin environment during the Middle Triassic along this belt. Tectonically, continental extension with subsidence is the main cause for step faults with haft-graben structures (Fig. 6.1). The process provides a relatively deep depositional environment as accommodation for the radiolarite or radiolarian chert accumulation. This scenario is compatible with “a disrupted passive continental margin' concept. As mentioned earlier, continental margin existed during Late Paleozoic and lasted till at least the upper Middle Permian (Chonglakmani et al., 2001) Moreover, Barr et al. (1990) noted that Permo-Carboniferous basalts which scattered between Chiang Mai and Mae Hong Son are associated with a continental intraplate origin. It means that accommodation space for radiolarites on the disruptive continental margin was prolonged till Middle Triassic. This thesis favors this interpretation. The discovery of radiolarian cherts along this belt with ages ranging from Devonian to Middle Triassic supports this thesis interpretation.

6.2 Den Chai locality

It is located to the west of and close to the Nan-Uttaradit suture in the Lampang-Yunxian unit of Chonglakmani et al. (2001). It is located within the Sukhothai-Indosinia terrane (Chonglakmani, 1999), or Sukhothai zone of Ueno (2003), which is the easternmost part of Shan-Thai (Bunopas, 1989). Triassic radiolarites were found along the Nan-Uttaradit suture in both northern and eastern Thailand by some authers (e.g., Hada et al., 1997; Sashida et al., 1997; Saesaengseerung, 2006). However, they interpreted these discoveries as a remnant of the main Paleotethys existed along this suture. This scenario differs to this thesis's tectonic point of view.

In this locality, Late Ladinian radiolarian-bearing siliceous rocks are exposed in a complex zone which contains mainly Triassic Lampang Group and Permian units (Charoenprawat et al., 1994). Lithologically, the texture of siliceous rocks exhibits a dull surface but not vitreous as common in cherts. The colour is maroon probably due

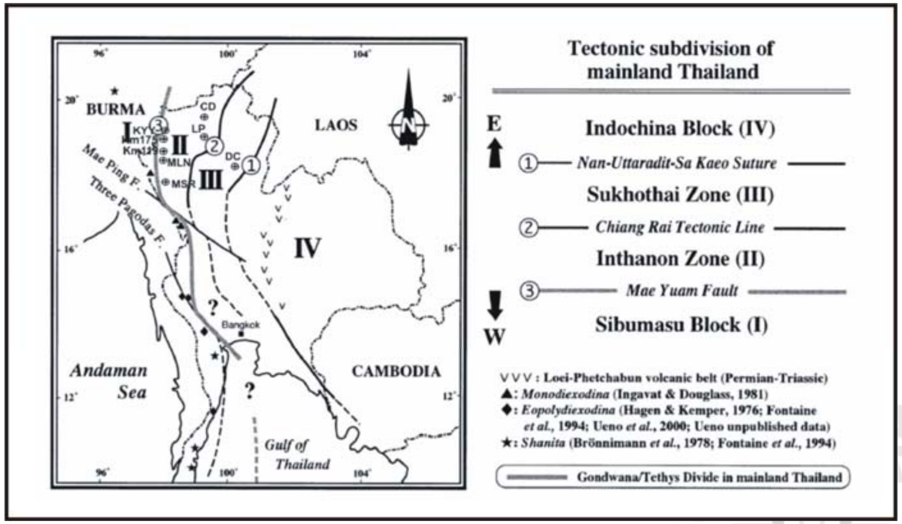
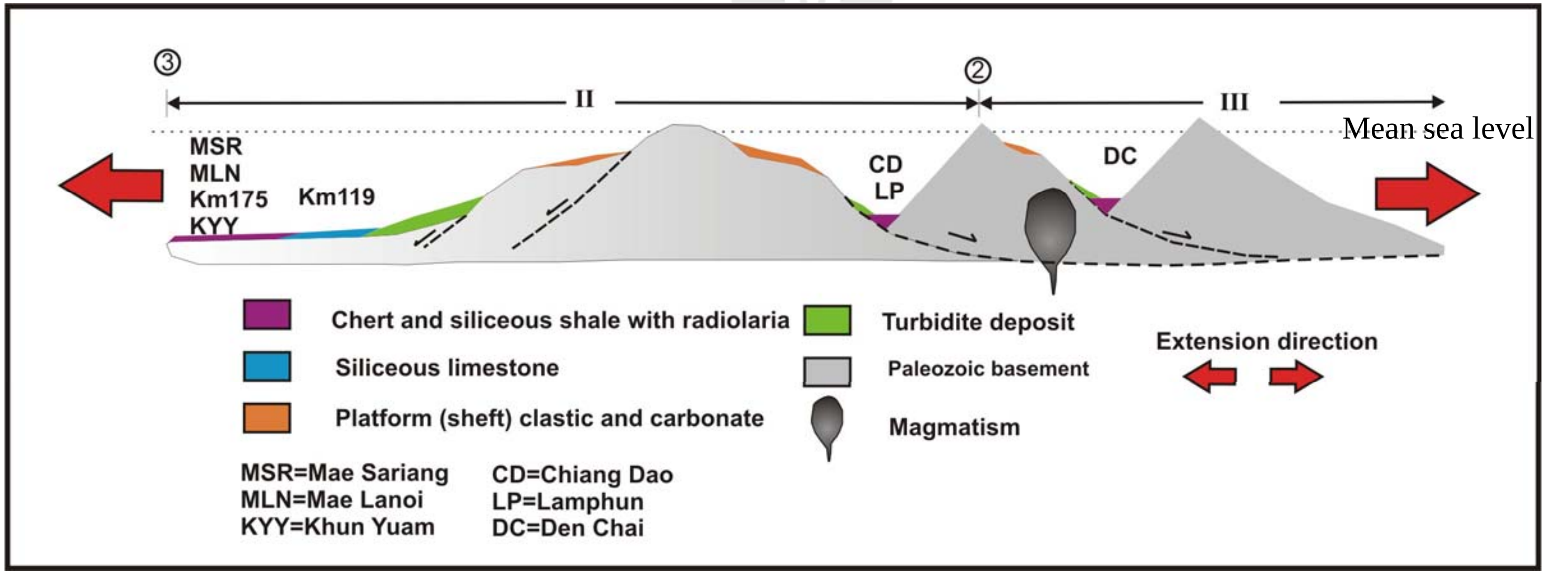


Figure 6.1 Tectonic model. A= Tectonic subdivision of Thailand showing tectonic component and radiolarian rock localities of this thesis study. B= Tectoinic model of Triassic period in northern Thailand based mainly on radiolarian and geochemical data from this study



to the effect of iron hydroxides. The rocks differ from the cherts of Chiang Dao and Lamphun in containing a relatively higher amount of clastics. These siliceous rocks should the regarded as radiolarite or siliceous mudstone rather than chert.

The La_n/Ce_n vs. $Al_2O_3/(Al_2O_3+Fe_2O_3)$ discrimination diagrams reveal that depositional environment of radiolarites exhibit close relations with a continental margin setting. Consequently, the studied section is interpreted as a remnant of strata deposited in a shallower environment than those in Chiang Dao and Lamphun areas. The sediment in this section accumulated under an extensional regime of epicontinental setting subsequent to a Late Variscan (Permian) orogeny. This interpretation is compatible with continental extensional intraplate magmatism of the Lampang Volcanic Belt (Barr et al., 1990). The volcanic rocks were deposited in an intramontane basin (Helmcke, 1982; Chonglakmani and Helmcke, 1989). These volcanics are Anisian in age based on U/Pb dating (Barr et al., 2000).

6.3 Mae Sariang, Mae La Noi, Khun Yuam, Km 175, and Km 119 localities

Based on this thesis, Triassic radiolarian cherts and radiolarites between Mae Sariang and Mae Hong Son along HW 108 are investigated. Their age ranges between Ladinian and Middle Carnian. On the basis of geochemical analysis and La_n/Ce_n vs. $Al_2O_3/(Al_2O_3+Fe_2O_3)$ discrimination diagrams, these rocks were deposited at a continental margin. It can be inferred that extensional phase of tectonism in this belt occurred during this time interval. The result is half grabens with relatively deep marine accommodation space available for accumulation of radiolarian cherts and radiolarites. This means that radiolarian cherts and radiolarites are not necessarily deposited only in the oceanic realm. In addition, they can be deposited under any deep marine structure including a rifted-continental margin. Sections along HW 108 between Mae Sariang and Mae Hong Son are characterized by bedded cherts, limestone blocks, turbiditic sandstone, arkosic sandstone and conglomerate. Arkosic sandstone and conglomerate are obviously accumulated under continental-epicontinental environment (Ferrari, 2007). The Triassic shallow marine shelf carbonate and clastic facies of the Lower Mae Moei Group in the Mae Sariang area deposited continuously since the Late Permian (Chonglakmani and Grant-Mackie, 1993). Tofke et al. (1993) mentioned that typical pre-orogenic deposition which had been followed by syn-orogenic strata is exposed in the area of Mae Sariang. These strata are Middle to Late Triassic. They include true ribbon-chert, pelagic limestones, and a turbidite sequence of siliciclastics. Cherts, shale, and filament limestone were deposited in a deep marine basin possibly on the ocean floor (Chonglakmani and Grant-Mackie, 1993). Radiolarian assemblages indicate Early Carboniferous, Late Permian, Late Ladinian and Middle Carnian for these cherts and pelagic limestones (Feng et al., 2004; 2005). However, this thesis study favors an environment of tectonic extension of the continental-margin based on geochemical discrimination results.

According to recent published literatures, it is widely accepted that the main Paleotethys in Thailand is situated west of Mae Sariang near the Thai-Myanmar boarder from Tak, Kanchanaburi and to the South. The Mae Yuam Fault zone is regarded as Paleotethyan divide. In the past decades, the idea related to this concept was proposed by several authors including Helmcke (1985). He suggested that the

Paleotethys was located west of the Shan-Thai craton including the Tenassarim region and south of Thailand. The occurrence of Carbonifeous-Permian (Triassic) overlying an olistrostome which in turn overrides Upper Paleozoic and Triassic indicates a nappe and thrust sheet tectonic feature (Caridroite, 1993). This feature could be the result of collision tectonism along this belt. Tofke et al. (1993) stated that terrane along the Mae Sariang Zone might be of Gondwana origin since it contains fossils of Gondwana affinities. *Monodiexodina sutchanica* (Dutkevich) was observed in Dan Tha Ta Fang west of Mae Sariang and *M. shiptoni* (Dunbar) was found in Huai Um Yom in Lan Sang and Mae Ka Sa Fall in Mae Ramat of Tak (Ingavat and Douglass, 1981). *Monodiexodina* was distributed within mesothermal climatic belts between high latitudinal cool/cold-water climatic realms and a paleo-tropical warm-water realm in two hemispheres during Permian time (Ueno, 2006). *Eupolydiexodina*, *Shanita*, *Thomasiphyllum*, *Wentzellophyllum persicum* indication of Cimmerian age have found in the west and south of Thailand (Wang et al., 2001).

Diamictites ("pebbly mudstone"), indication of low-latitude, glacio-marine conditions, have been observed in the southern and western part of Thailand including the Phuket Group and Kaeng Krachan Group (Stauffer and Lee, 1986). They have not been observed in the Chiang Mai zone, Sukhothai zone or Indochina block so far. In addition they are found further north in the Shan State and South China along the Changning-Menglian belt (Wang et al., 1999; 2001). In conclusion, both Gondwana fossil affinities and glacio-marine rocks are evidence of the Eastern Cimmerian block/terrane which was located along the Thai-Myanmar boarder and to the west of the Shan-Thai terrane (Inthanon zone). The Paleotethys was located between these terranes and the closure time was during Late Triassic-Early Jurassic (e.g., Hirsch et al., 2006; Ferrari et al., 2008).

CHAPTER VII

CONCLUSION

7.1 Triassic radiolarians of northern Thailand

7.1.1 Triassic radiolarians recovered from eight localities of chert and associated siliceous rocks in northern Thailand have been identified. These localities are situated in the areas of Chiang Dao, Lamphun, Den Chai, Khun Yuam, Mae La Noi, and Mae Sariang.

7.1.2 Radiolarians are composed of 28 families, 60 genera and 147 species. Their age ranges from Middle Anisian to Early or Middle Carnian?.

7.1.3 They are discriminated and proposed into six assemblage zones namely; *Eptingium manfredi* Assemblage Zone (Middle Anisian), *Triassocampe deweveri* Assemblage Zone (Late Anisian), *Oertlispongus inaequispinosus* Assemblage Zone (Early to Middle Ladinian), *Muelleritortis cochleata* Assemblage Zone (Middle to early Late Ladinian), *Tritortis kretaensis* Assemblage Zone (Early Late Ladinian to Early Carnian), and *Tetraporobrachia haeckelli* Assemblage Zone (Early to Middle Carnian?), chronologically. Their age assignment is based mainly on correlation with other established zones and recent publications.

7.2 Geochemistry of radiolarian-bearing siliceous rocks

7.2.1 For geochemical study, the radiolarian chert and associated siliceous rock samples from six localities including Chiang Dao, Lamphun, Den Chai, Khum Yuam, Km 175, Mae La Noi, and Mae Sariang were analysed. Geochemical methods used for this study include X-Ray Fluorescene (XRF) for major and trace elements analysis and Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) for rare earth elements analysis.

7.2.2 All of the analysed samples are high silica content rocks (SiO_2). The maximum content is in the Lamphun locality (89.76% in average), while the minimum is in the Den Chai locality (73.21% in average).

7.2.3 The Al-Fe-Mn diagram and Eu anomalies indicate that samples from all localities, except Den Chai, are related to non-hydrothermal origin. Den Chai is located between the area of the hydrothermal and non-hydrothermal origin.

7.2.4 The La/Ce vs Al/(Al+Fe) ratios suggest that samples from all localities were accumulated within the continental margin or at least close to the continental margin.

7.3 Triassic tectonics in northern Thailand

Radiolarian chronology and geochemical discrimination indicate that the tectonic setting for radiolarian chert and associated rocks in this study was accumulated in a continental margin under extensional regime. The half-graben structure formed by step faults provided depositional space for accumulation of radiolarian chert and associated rocks accommodation.

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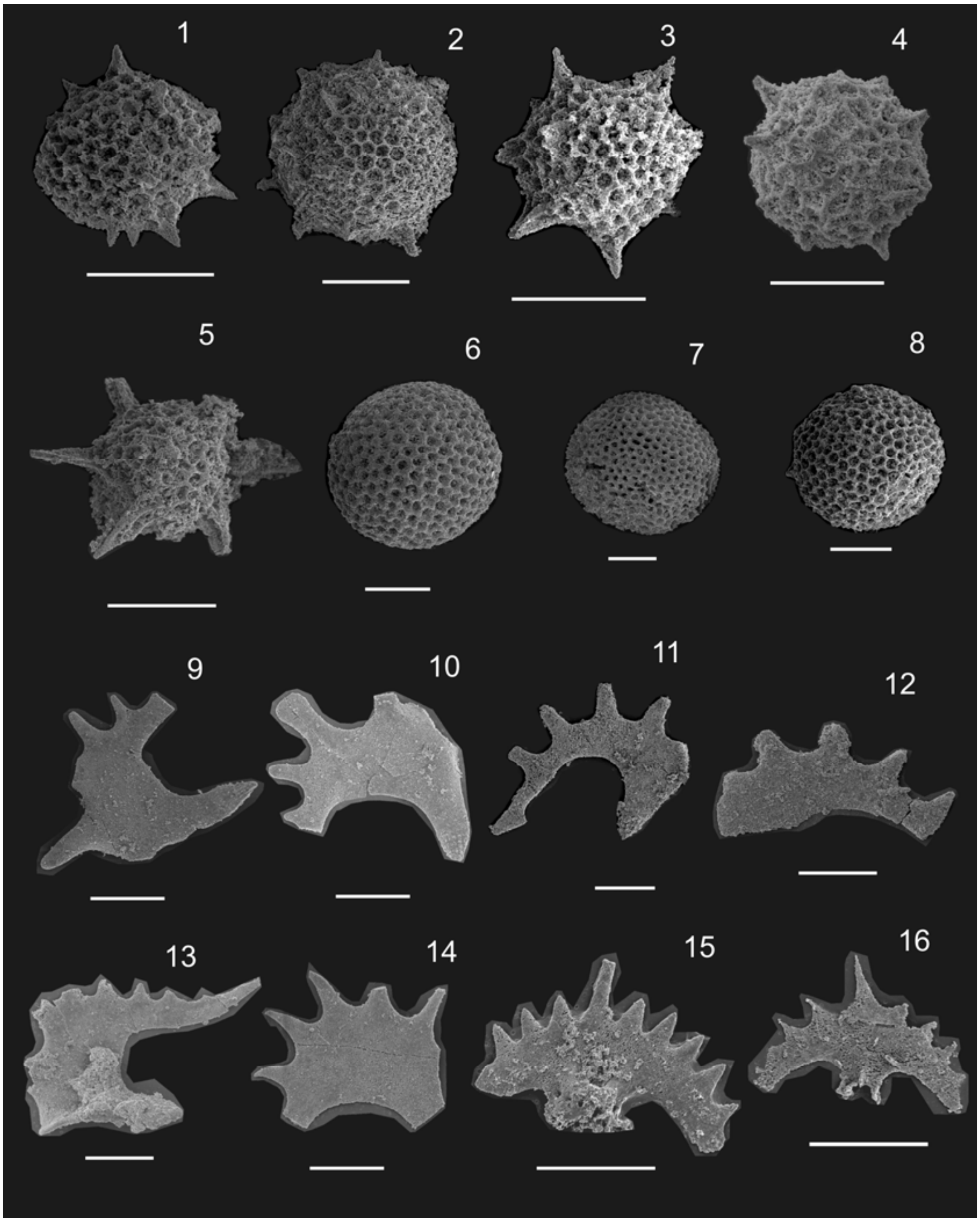
APPENDIX

PLATE OF TRIASSIC RADIOLARIANS

PLATE 1



Explanation of Plate 1

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1, 2: *Acanthosphaera carterae* Kozur and Mostler

(1= KYY 1-1; 2= KYY 1-4)

Figure 3, 5: *Acanthosphaera nicorae* Kozur and Mostler

(3= 175-6; 5= MLN 2-6)

Figure 4: *Acanthosphaera* sp.

(4= CD 95)

Figure 6: *Archaeocenosphaera* sp. cf. *A. laseekensis* Pessagno and Yang

(6= DC 4)

Figure 7, 8: *Archaeocenosphaera* sp

(7= 175-2; 8= KYY 1-5)

Figure 9-12: *Spongoserrula rarauana* Dumitrică

(9, 10= 175-1; 11= 175-4; 12= DC 5)

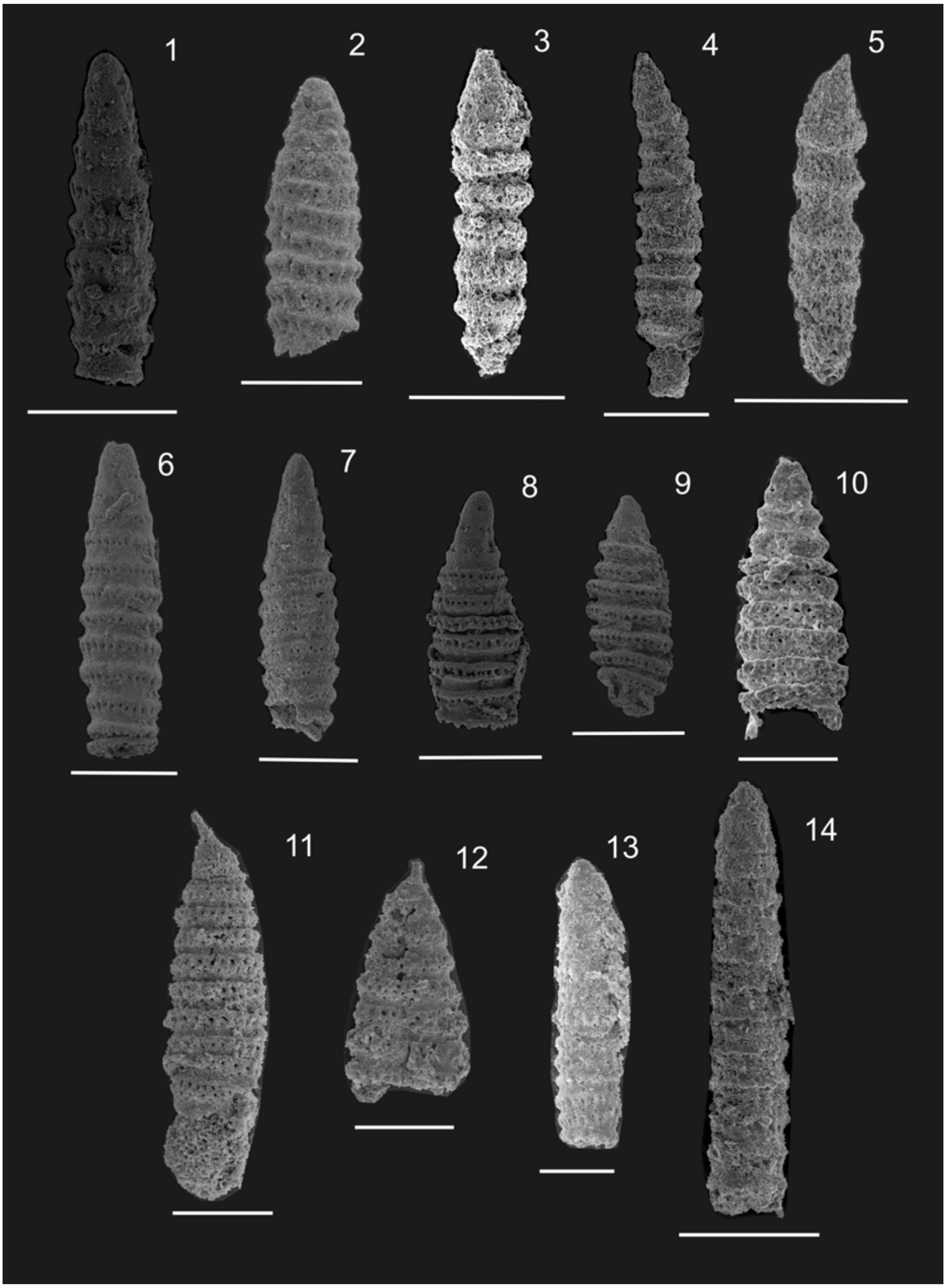
Figure13, 14: *Spongoserrula* sp.

(13= 175-2; 14= 175-1)

Figure15, 16: *Steigerispongus* sp.

(15, 16= 119 B)

PLATE 2



Explanation of Plate 2

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1, 2: *Annulotriassocampe baldii* Kozur

(1= 119 B; 2= CD 63)

Figure 3, 4: *Annulotriassocampe companilis* Kozur

(3= 119 A; 4= DC 18)

Figure 5: *Annulotriassocampe* sp.

(5= DC 4)

Figure 6, 7: *Annulotriassocampe multisegmantis* Tekin

(6= 119 A; 7= 175-1)

Figure 8, 9: *Annulotriassocampe sulovensis* (Kozur and Mock)

(8= 119B; 9= 119A)

Figure 10: *Paratriassocampe* sp. cf. *P. gaetanii* Kozur and Mostler

(10= CD 25)

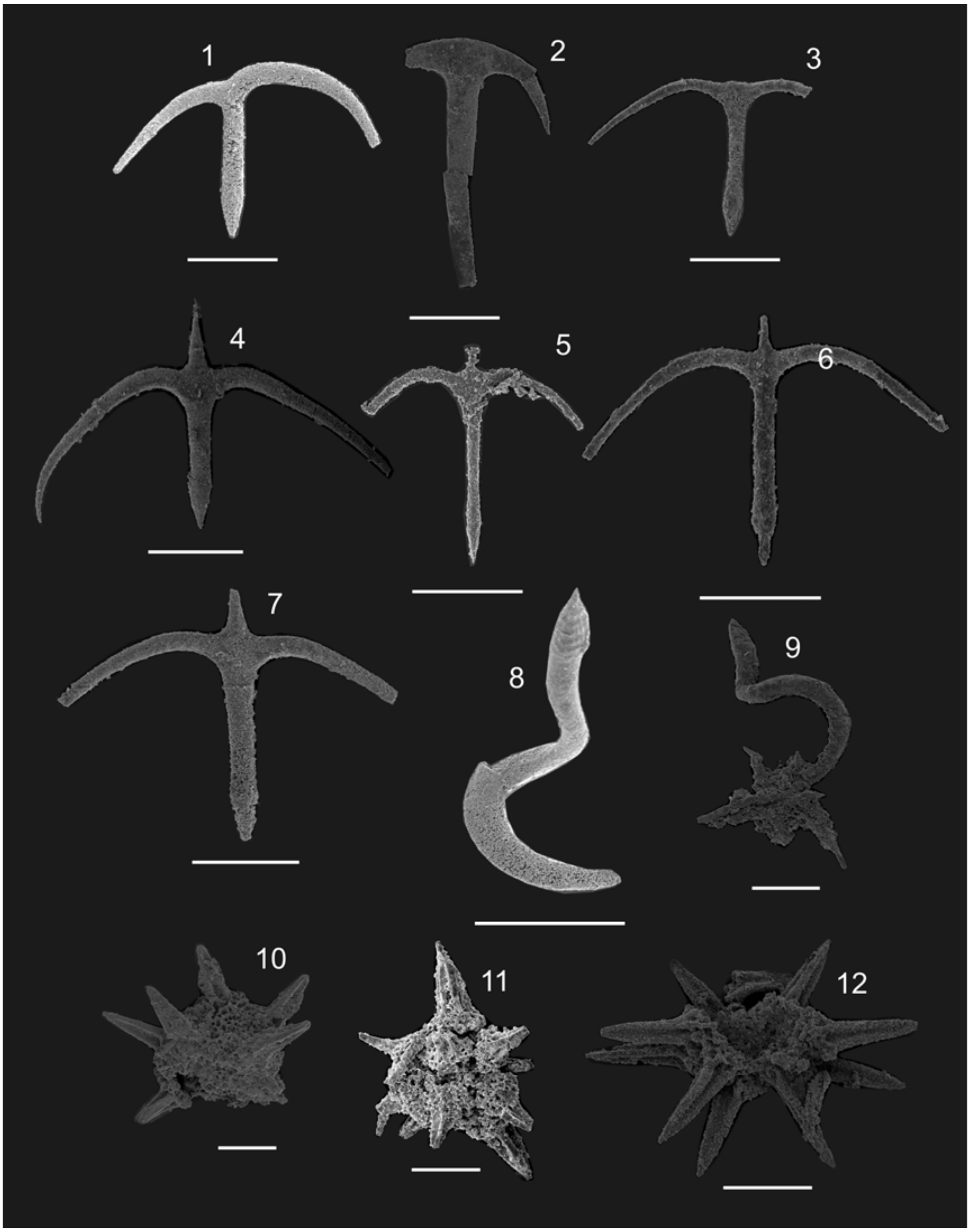
Figure 11, 12: *Pseudotriassocampe* sp.

(11=CD 63; 12= CD 54)

Figure 13, 14: *Striatotriassocampe nodosoannulata* Kozur and Mostler

(13= CD 43; 14= KYY1-5)

PLATE 3



Explanation of Plate 3

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1: *Baumgartneria ambigua* Dumitrică

(1= KYY 1-1)

Figure 2, 3: *Baumgartneria* sp. cf. *B. curvispina* Dumitrică

(2= 119 A; 3= KYY 1-5)

Figure 4-6 *Baumgartneria retrospina* Dumitrică

(4= KYY 1-5; 5= KYY 1-1; 6= KYY 2-3)

Figure 7: *Baumgartneria yehae* Kozur and Mostler

(7= KYY 1-5)

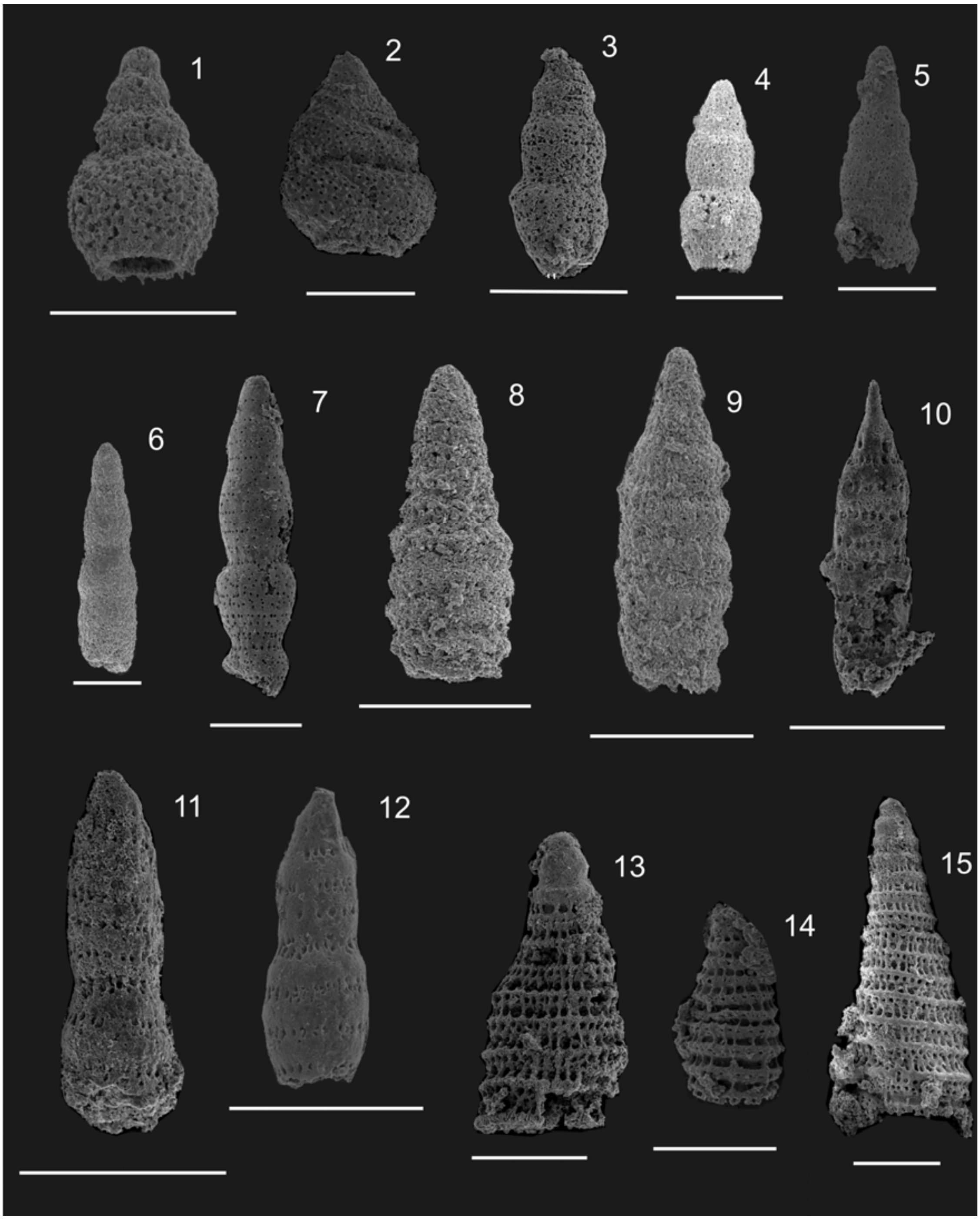
Figure 8, 9: *Bogdanella* sp.

(8, 9= 119 A)

Figure 10-12: *Astrocentrus* sp.

(10= 119 A; 11= CD 25; 12= 175-2)

PLATE 4



Explanation of Plate 4

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1, 2: *Canesium lentum* Blome

(1= 119 A; 2= 119 B)

Figure 3-5: *Canoptum levis* Tekin

(3= 119 A; 4= 175-1; 5= 119A)

Figure 6, 7: *Canoptum inormatus* Tekin

(6= DC 5; 7= 119 B)

Figure 8, 9 *Canoptum* sp.

(8= DC 13; 9= DC 7)

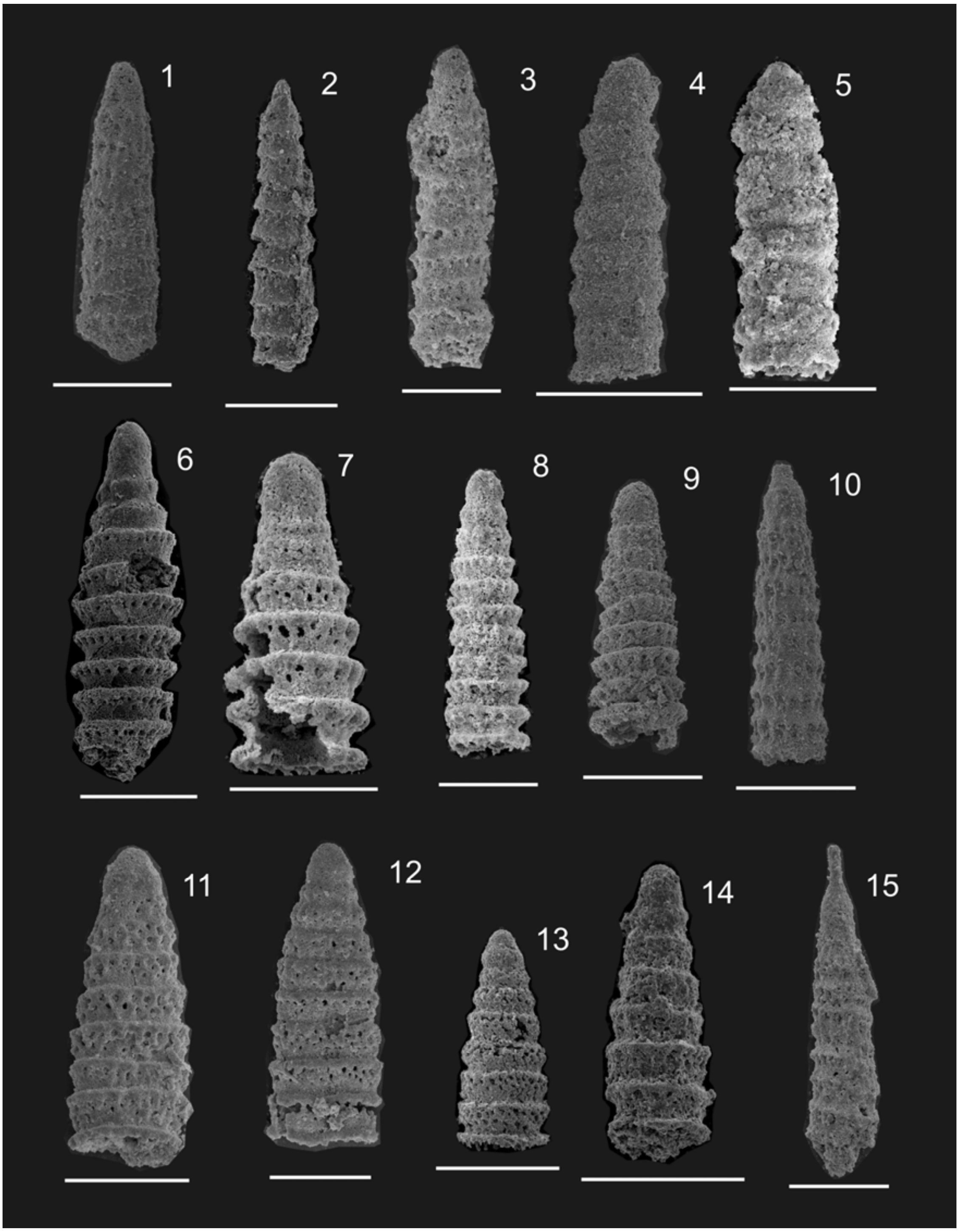
Figure 10-12: *Canoptum* sp. A

(10-12= 119 A)

Figure 13-15: *Castrum pernatum* Blome

(13-15= 119 B)

PLATE 5



Explanation of Plate 5

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1-3: *Triassocampe* sp. cf. *T. diordinis* Bragin

(1= CD 113; 2= KYY 1-5; 3= CD 44)

Figure 4, 5: *Triassocampe* sp. cf. *T. eruca* Sugiyama

(4= CD 44; 5= CD 7)

Figure 6-9: *Triassocampe coronata* Bragin

(6= 119 A; 7= CD2; 8= CD 10; 9= MSR1-8)

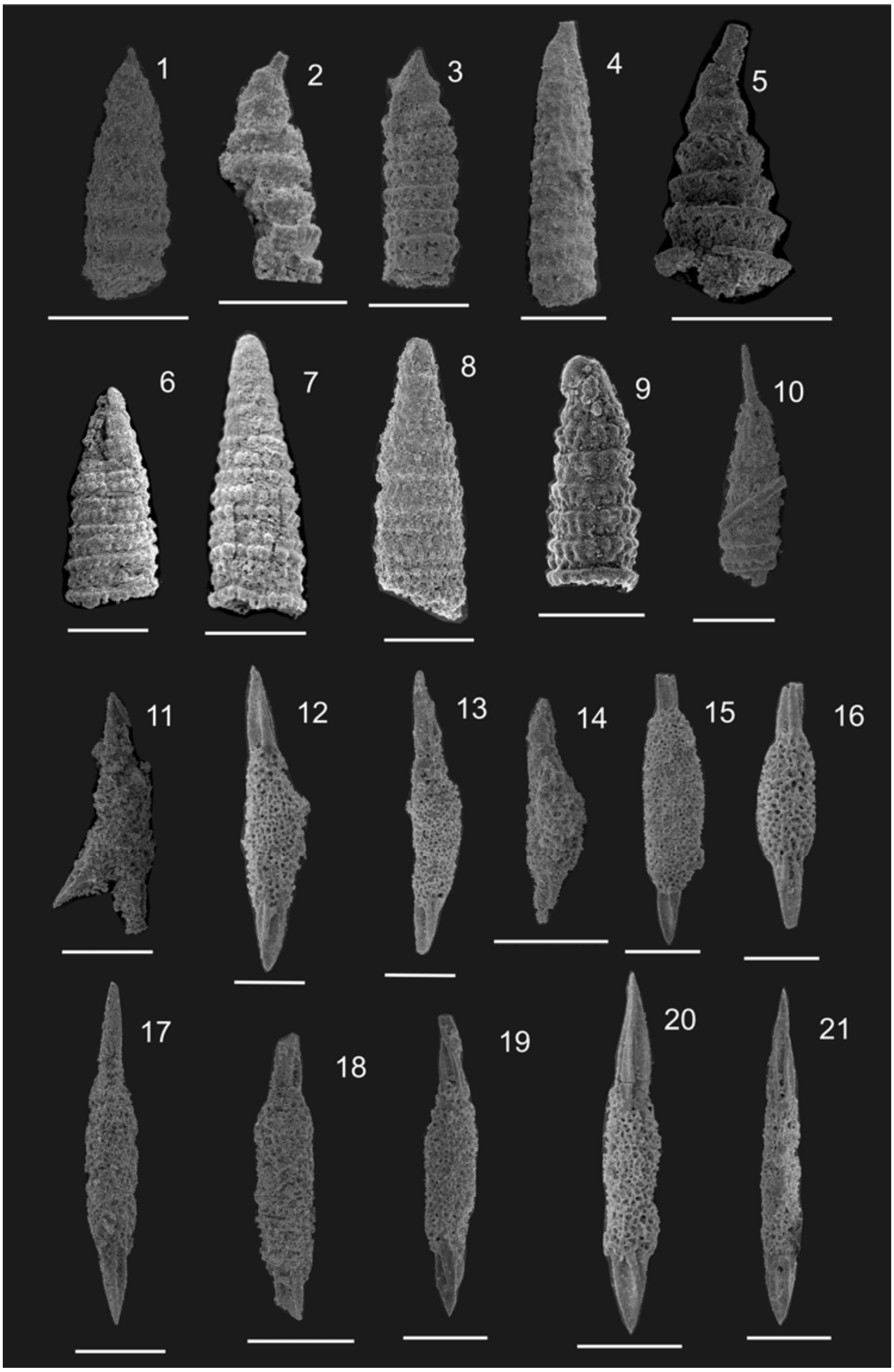
Figure10, 15: *Triassocampe* sp.

(10= CD 113; 15= CD 105)

Figure 11-14: *Triassocampe deweveri* (Nakaseko and Nishimura)

(11, 12= CD 54; 13= KYY 2-2; 14= KYY 2-2)

PLATE 6



Explanation of Plate 6

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1-3: *Triassocampe myterocorys* Sugiyama

(1= CD 122; 2= CD 3; 3= MLN 1-8)

Figure 4: *Triassocampe* sp.

(4= CD 111)

Figure 5, 10: *Yeharaia annulata* Nakaseko and Nishimura

(5= KYY 1-4; 10= CD 113)

Figure 6-9: *Triassocampe scalaris* Dumitrică, Kozur and Mostler

(6, 7= 175-5; 8= DC 5; 9= CD 1)

Figure 11-13: *Archaeospongoprunum bispinosum* Kozur and Mostler

(11= MLN3-2; 12= CD 63; 13= CD 54)

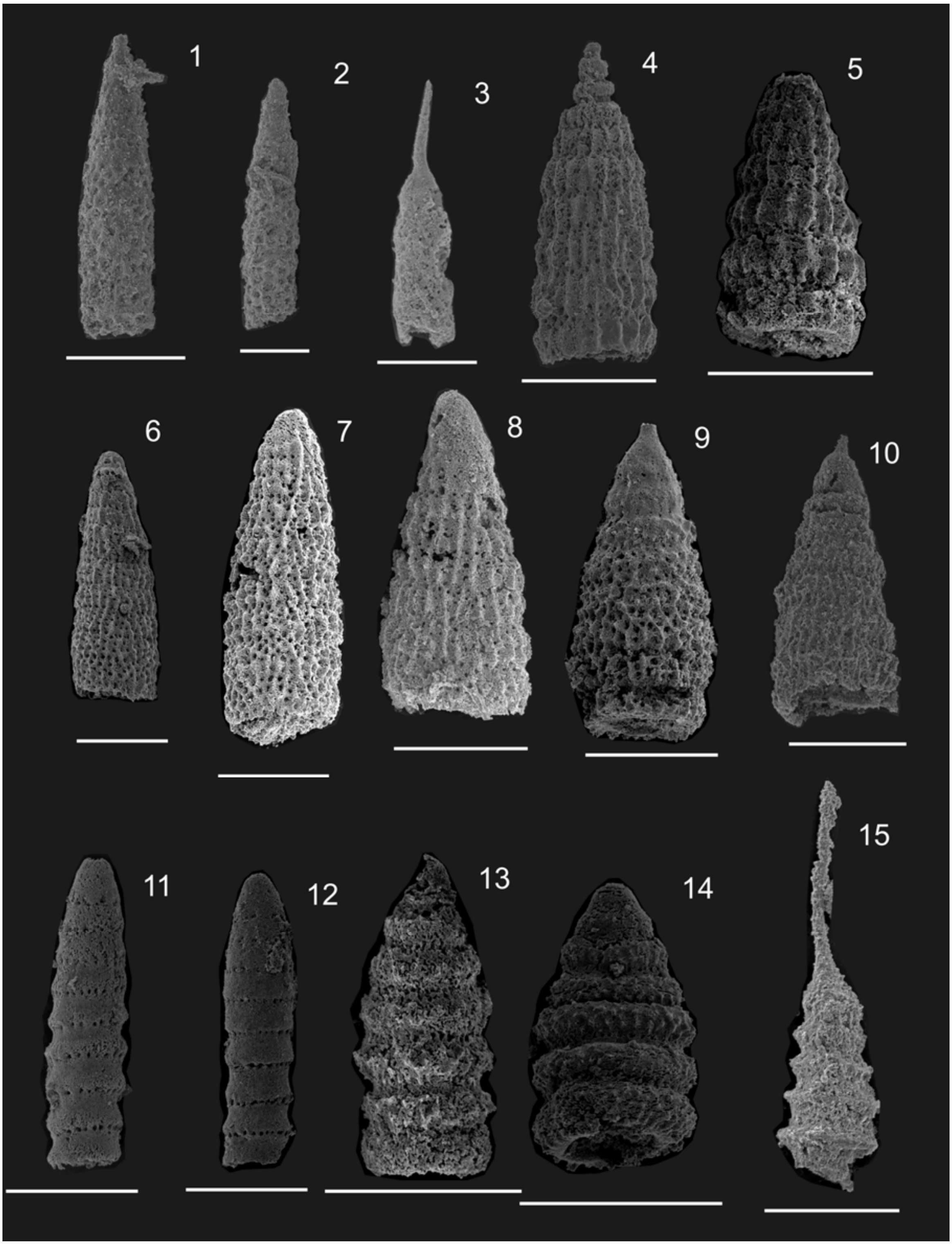
Figure 14-18: *Archaeospongoprunum mesotriassicum mesotriassicum* Kozur and Mostler,

(14= MLN 2-6; 15, 16= CD 54; 17, 18= MLN 3-1)

Figure 19-21: *Archaeospongoprunum* sp. cf. *A. mesotriassicum* Kozur and Mostler

(19-21= CD 54)

PLATE 7



Explanation of Plate 7

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 μm.

Figure 1, 2: *Celluronta donax* Sugiyama

(1, 2= CD 153)

Figure 3: *Celluronta* sp.

(3= CD 261)

Figure 4, 5: *Corum* sp. cf. *C. regium* Blome

(4, 5= 119 A)

Figure 6-8: *Corum kraineri* Tekin

(6, 7= 119 A; 8= 175-1)

Figure 9, 10: *Corum* sp. A

(9= 119 B; 10= 175-1)

Figure 11, 12: *Japonocampe nova* (Yao)

(11, 12= 119 B)

Figure 13: *Pachus firmus* Blome

(13= 119 B)

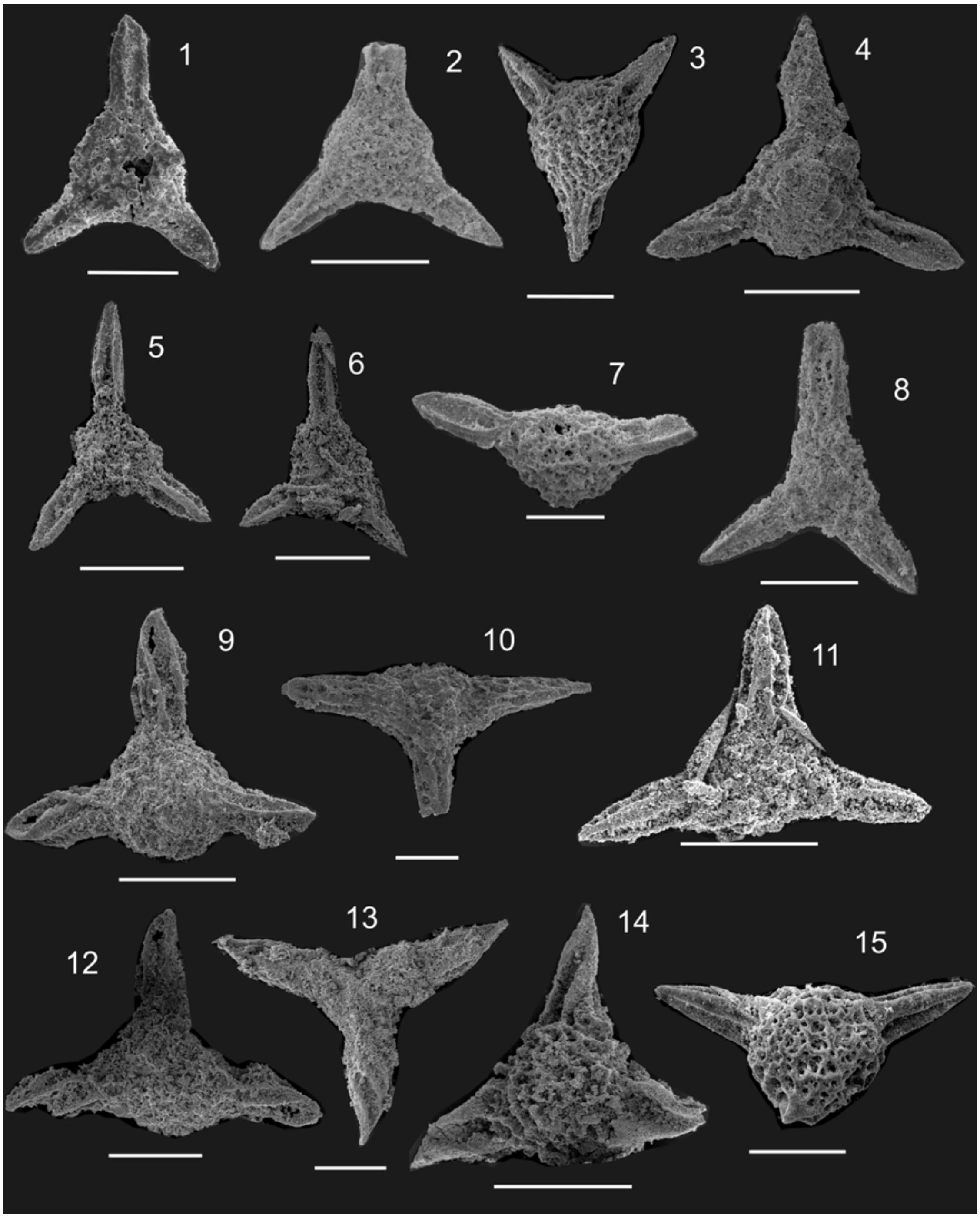
Figure 14: *Pachus multinodosus* Tekin

(14= 119 B)

Figure 15: *Yeharaia annulata* Nakaseko and Nishimura

(15= KYY 1-4)

PLATE 8



Explanation of Plate 8

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1-4: *Eptingium nahkasekoi* Kozur and Mostler

(1= CD 1; 2= CD 185; 3= CD 196; 4= KYY 1-5)

Figure 5-7: *Eptingium japonicum* Nakaseko and Nishimura

(5, 6= KYY 1-5; 7= CD 3)

Figure 8-11: *Eptingium manfredi manfredi* Dumitrică

(8= CD 91; 9= KYY 1-3; 10= KYY 1-5; 11= KYY 2-2)

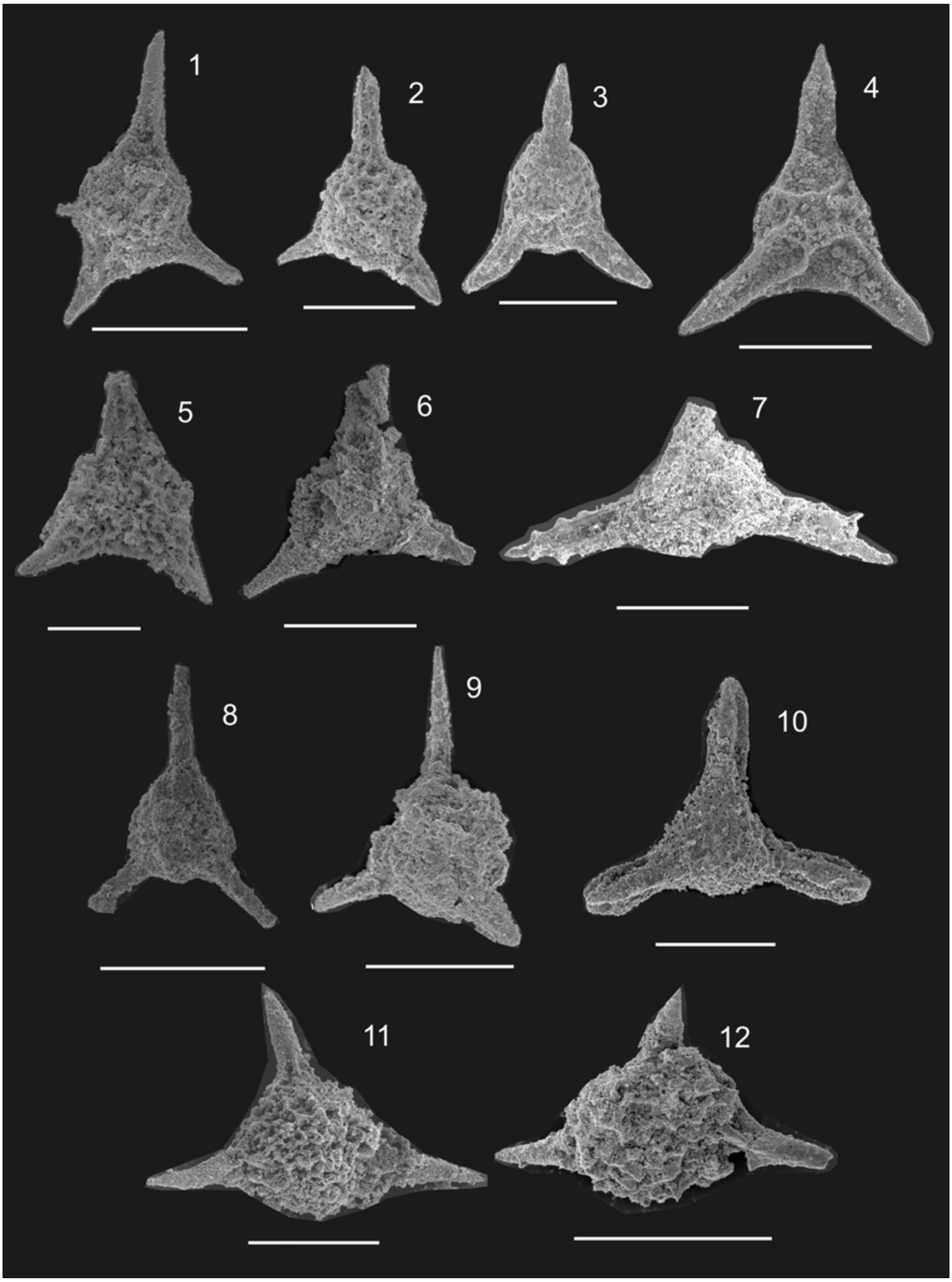
Figure 12-14: *Eptingium ramovsi* Kozur and Mostler

(12= KYY 1-5; 13, 14= KYY 1-4)

Figure 15: *Eptingium* sp.

(15= CD 3)

PLATE 9



Explanation of Plate 9

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1-4: *Cryptostephanidium cornigerum* Dumitrică

(1= CD 261; 2= CD 190; 3= 175-2; 4= KYY 2-2)

Figure 5, 6: *Perispyridium* sp.

(5= CD 284; 6= CD 322)

Figure 7: *Pylostephanidium clavator* Dumitrică

(7= KYY 1-4)

Figure 8, 9: *Spongostephanidium* sp. cf. *S. longispinosum* Dumitrică

(8= CD 159; 9= CD 238)

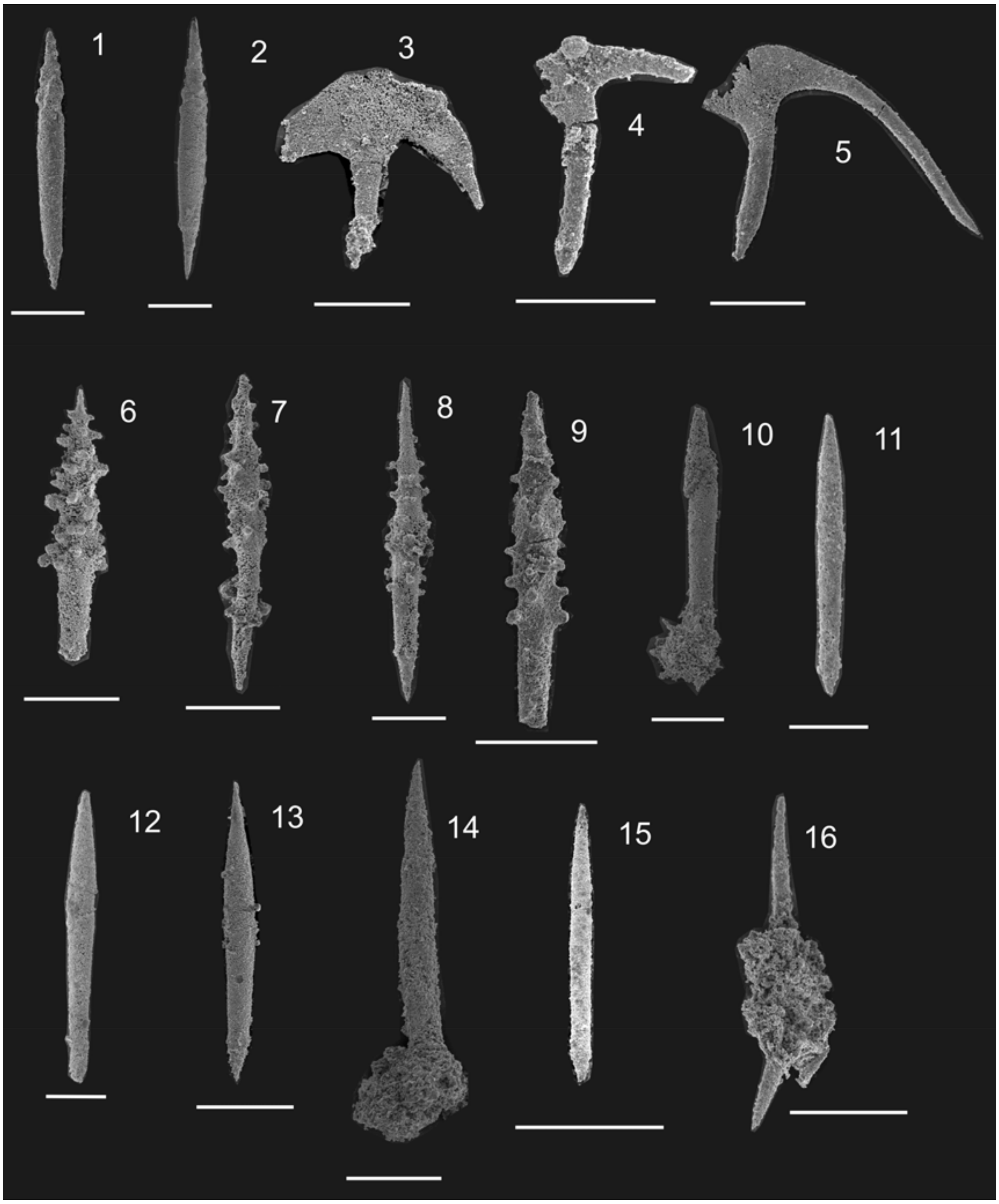
Figure 10: *Triassistephanidium laticorne* Dumitrică

(10= KYY 1-1)

Figure 11, 12: *Spongostephanidium spongiosum* Dumitrică

(11= KYY 3-5; 12= KYY 1-4)

PLATE 10



Explanation of Plate 10

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 μm.

Figure 1, 2: *Paroertlispongus* sp. aff. *P. daofuensis* Feng

(1= KYY 1-1; 2= KYY 1-4)

Figure 3: *Scutispongus* sp.

(3= 175-3)

Figure 4, 5: *Falcispongus calcaneum* Dumitrică

(4= KYY 2-2; 5= KYY 1-1)

Figure 6-9: *Paroertlispongus daofuensis* Feng

(6-9= KYY 2-1)

Figure 10-12: *Paroertlispongus multispinosus* Kozur and Mostler

(10=MLN 1-2; 11= CD 185; 12= CD 2)

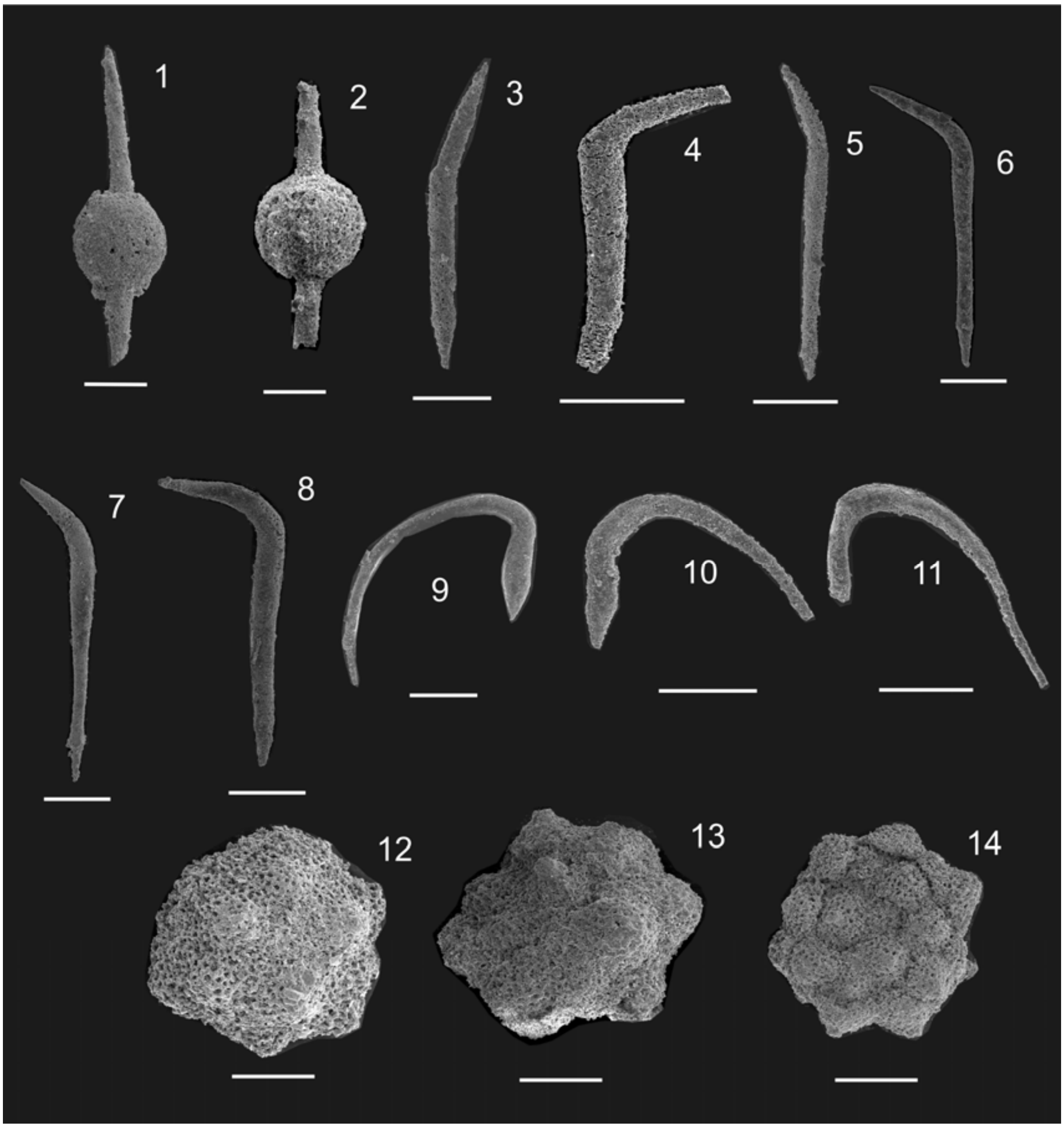
Figure 13-15: *Paroertlispongus rarispinosus* Kozur and Mostler

(13= KYY 1-1; 14= MLN 1-2; 15= CD 10)

Figure 16: *Paroertlispongus* sp.

(16= KYY 1-1)

PLATE 11



Explanation of Plate 11

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1, 2: *Oertlispongus* sp. cf. *O. diacanthus* Sugiyama

(1= CD 100; 2= CD 30)

Figure 3, 4: *Pseudoertlispongus* sp. cf. *P. angulatus* Kozur

(3= CD 100; 4= MSR 4-3)

Figure 5-8: *Pseudoertlispongus mostleri mosteri* Kozur

(5= CD 105; 6= KYY 1-4; 7= KYY 1-5; 8= KYY 1-4)

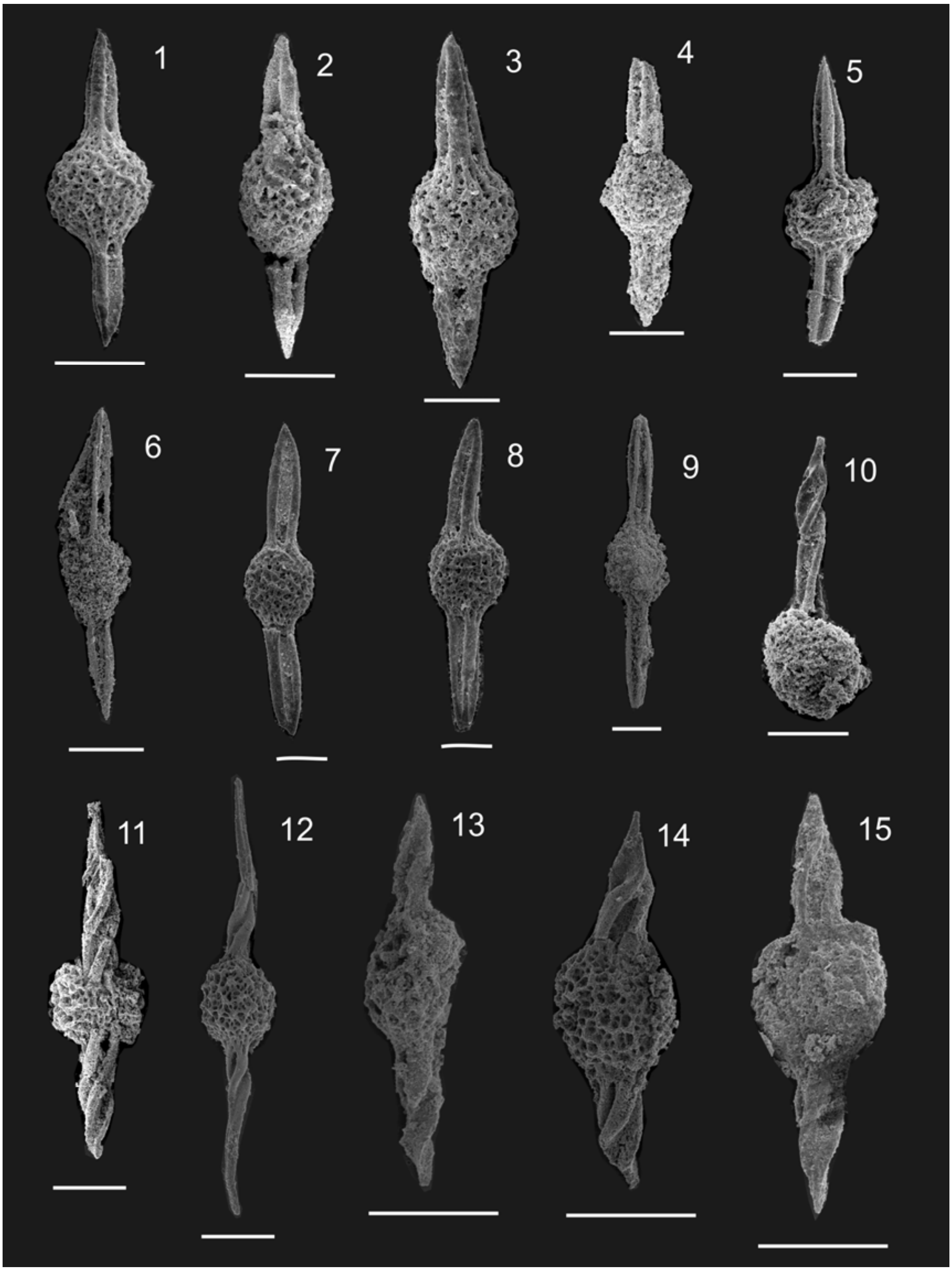
Figure 9-11: *Oertlispongus inaequispinosus* Dumitrică, Kozur and Mostler

(9= KYY 1-5; 10= KYY 2-1; 11=119 A)

Figure 12-14: *Pseudogodia*? sp.

(12= DC 5; 13= DC 16; 14= DC 5)

PLATE 12



Explanation of Plate 12

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1-3: *Pseudostylosphaera acrior* (Bragin)

(1= CD 2; 2=CD 3; 3= CD 1)

Figure 4-6: *Pseudostylosphaera coccostyla coccostyla* (Rüst)

(4= CD 30; 5= 175-6; 6= KYY 1-1)

Figure 7-9: *Pseudostylosphaera compacta* (Nakaseko and Nishimura)

(7, 8= CD 2; 9= KYY 1-1)

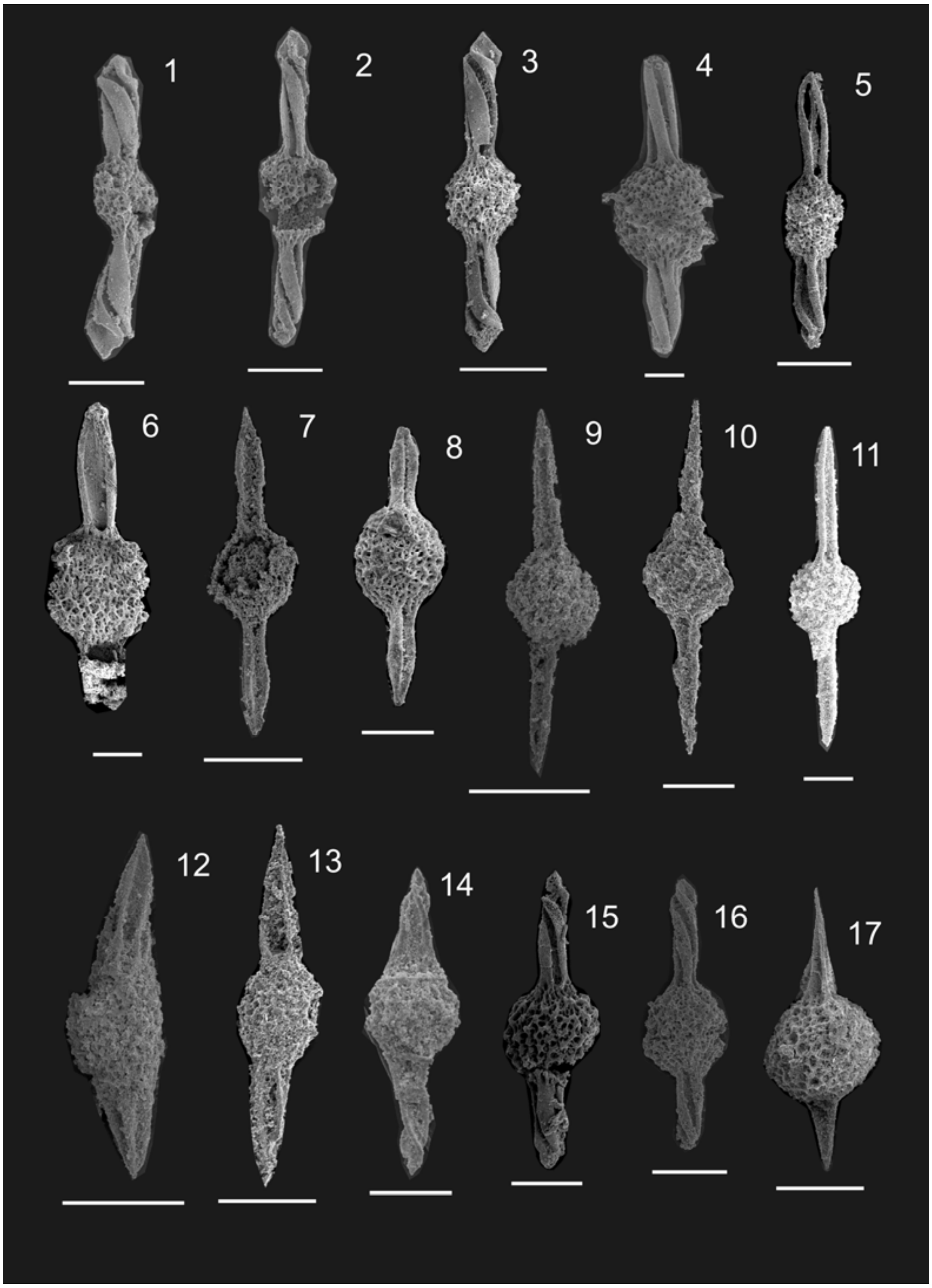
Figure 10-12: *Pseudostylosphaera goestlingensis* (Kozur and Mostler)

(10= CD 2; 11=175-5; 12= 119 A)

Figure 13-15: *Pseudostylosphaera goricanae* Kozur and Mostler

(13, 15= 175-1; 14= 119 A)

PLATE 13



Explanation of Plate 13

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 μm.

Figure 1-3: *Pseudostylosphaera gracilis* Kozur and Mock

(1= 175-1; 2= 119 A; 3= 119 B)

Figure 4, 5:*Pseudostylosphaera imperpicua* (Bragin)

(4= 175-2; 5= 175-6)

Figure 6-8: *Pseudostylosphaera japonica* (Nakaseko and Nishimura)

(6= 175-3; 7= KYY 1-3; 8= CD 2)

Figure 9-11: *Pseudostylosphaera longispinosa* Kozur and Mostler

(9= CD 191; 10= MLN 3-1; 11= KYY 1-4)

Figure 12, 13: *Pseudostylosphaera magnispinosa* Yeh

(12= CD 159; 13= CD 167)

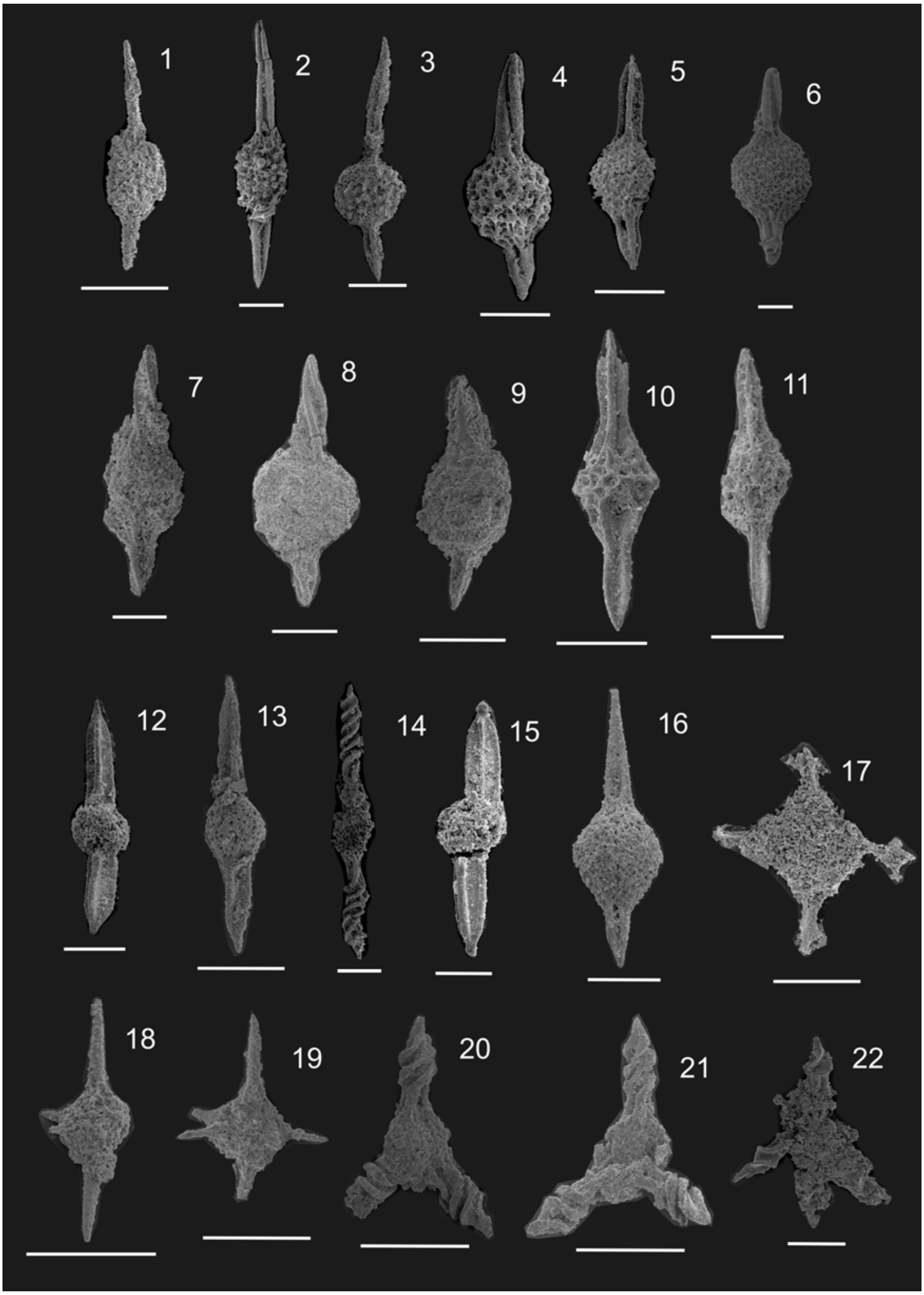
Figure 14-16: *Pseudostylosphaera nazarovi* (Kozur and Mostler)

(14= CD 50; 15= 119B; 16= 175-1)

Figure 17: *Pseudostylosphaera* sp.

(17= CD 232)

PLATE 14



Explanation of Plate 14

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang. Scale bars= 100 μm.

Figure 1-3: *Pseudostylosphaera tenuis* (Nakaseko and Nishimura)

(1= CD 169; 2= 175-6; 3= KYY 1-1)

Fig. 4-6: *Pseudostylosphaera timorensis* Sashida and Kamata

(4= 119 B; 5= KYY 1-5; 6= 175-2)

Figure 7-9: *Hindeosphaera spinulosa* (Nakaseko and Nishimura)

(7= CD 111; 8= CD 49; 9= MLN 3-1)

Figure 10, 11: *Pantanellium* sp.

(10= CD 111; 11= CD 180)

Figure 12, 13: *Spongostylus tricostatus* Kozur, Krainer and Mostler

(12= CD 2; 13= MLN 1-5)

Figure 14: *Spongostylus tortilis* Kozur and Mostler

(14= 119 B)

Figure 15: *Spongostylus tetrapterus* (Ramovš and Goričan)

(15= CD 2)

Figure 16: *Spongostylus* sp. B; 18, 19: *Spongostylus* sp. A

(16= CD 105; 18= CD 325; 19= CD 326)

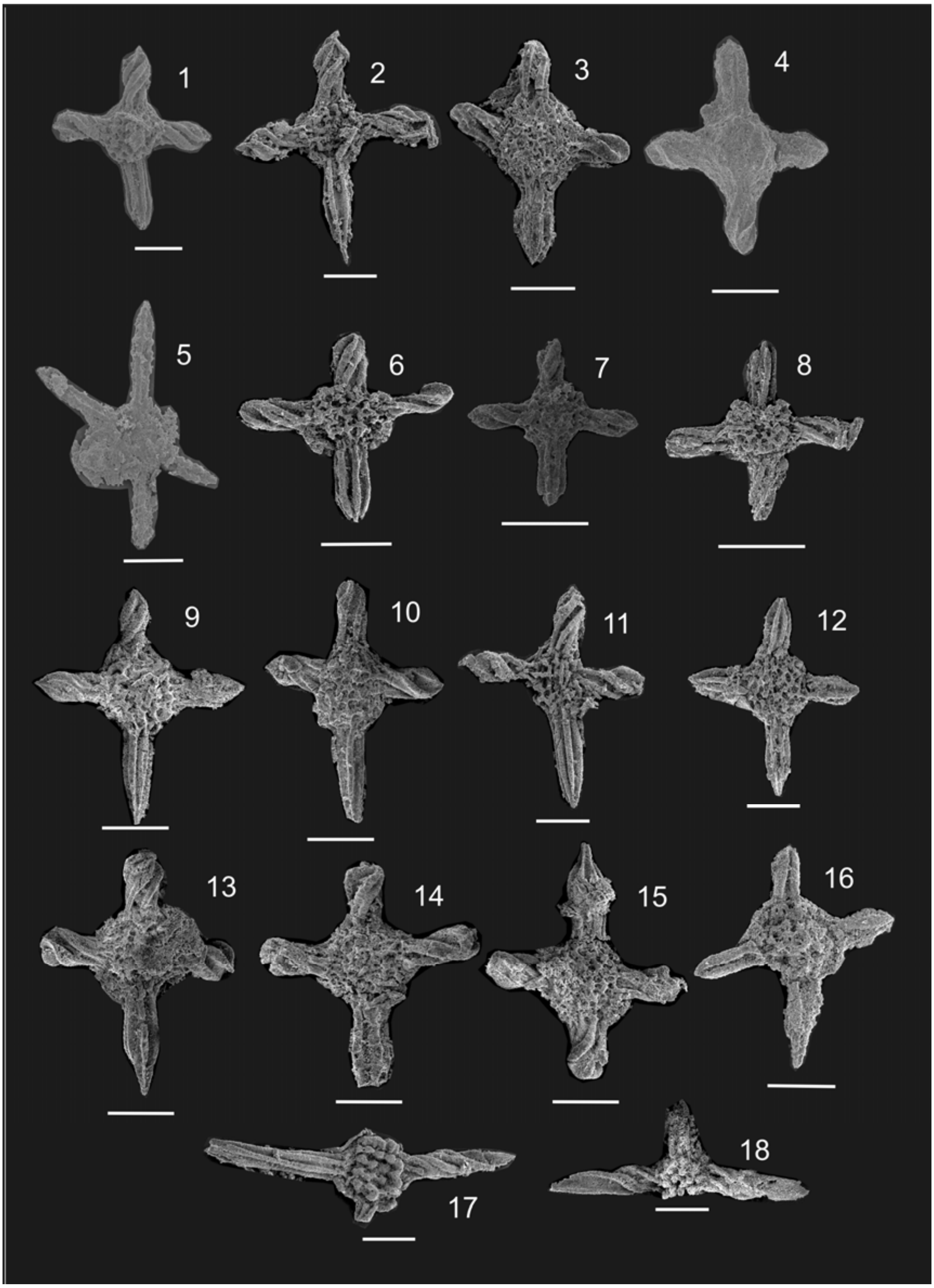
Figure 17: *Staurolonche trispinosum trilobum* (Nakaseko and Nishimura)

(17= KYY 1-1)

Figure 20-22: *Vinassaspongus erendili* Tekin

(20, 21= 175-2; 22= 119 A)

PLATE 15



Explanation of Plate 15

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1, 2: *Muelleritortis cochleata koeveskalensis* Kozur

(1= 175-2; 2= 175-3)

Figure 3, 4, 6: *Muelleritortis cochleata tumidospina* Kozur

(3= 175-4, 4= DC 2, 6= 175-3)

Figure 5: *Muelleritortis cive* Sugiyama

(5= 175-2)

Figure 7, 8: *Muelleritortis* sp. cf. *M. quadrata* Kozur and Mostler

(7= 175-2; 8= 175-3)

Figure 9-11: *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura)

(9, 10= 175-4; 11= 175-3)

Figure 12, 16: *Muelleritortis firma* (Goričan and Buser)

(12= 175-5; 16= 175-5)

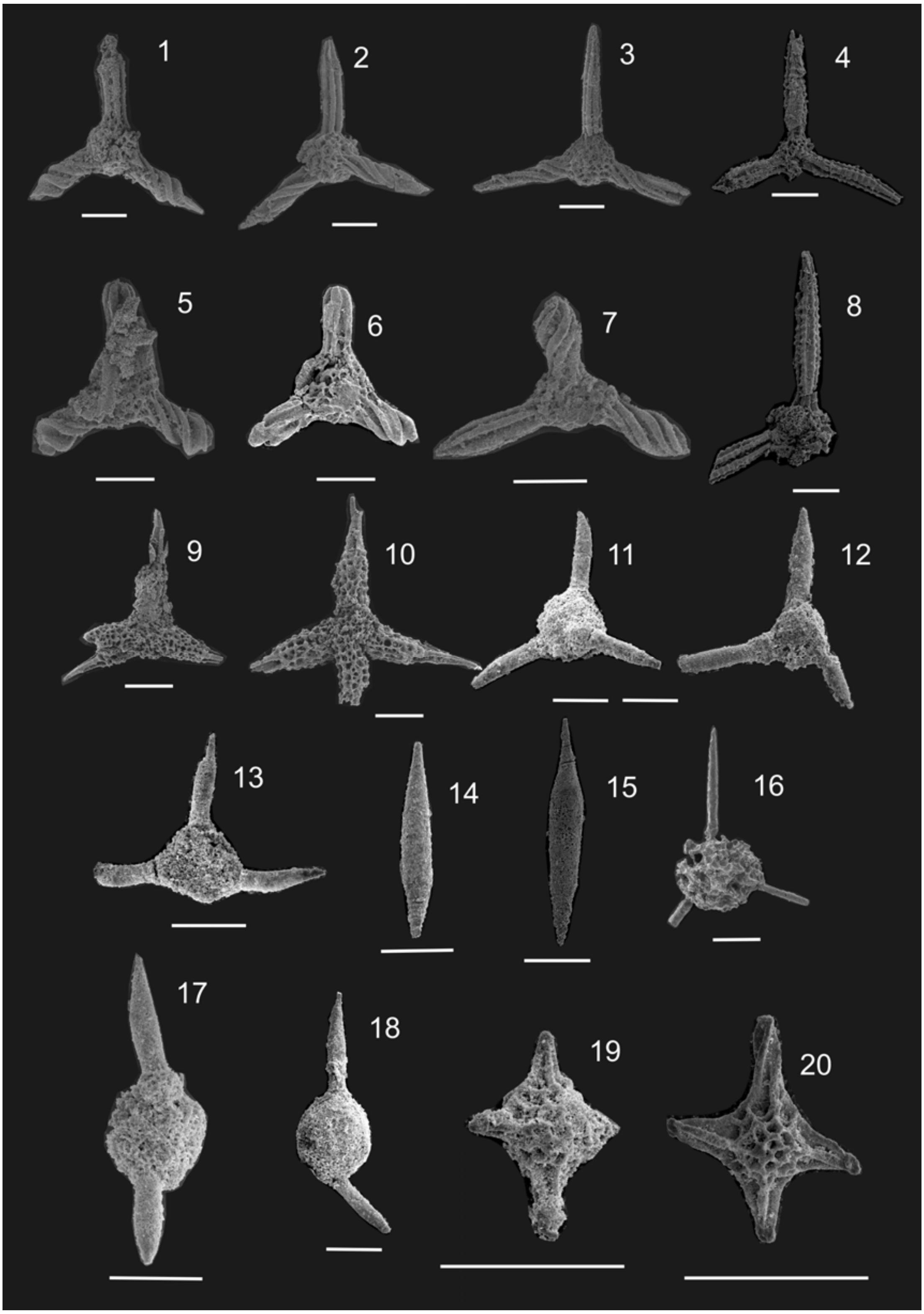
Figure 13-15: *Muelleritortis expansa* Kozur and Mostler

(13-15= 175-4)

Figure 17, 18: *Muelleritortis longispinosa* Kozur

(17, 18= 175-3)

PLATE 16



Explanation of Plate 16

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1-3: *Tritortis kretaensis kretaensis* (Kozur and Khahl)

(1, 3= 175-1; 2= 175-2)

Figure 4, 8: *Tritortis* sp. A

(4, 8= 119 B)

Figure 5-7: *Tritortis kretaensis dispiralis* (Bragin)

(5= 175-1; 6= 175-2, 7= 175-3)

Figure 9, 10: *Tetraporobrachia haeckelli* Kozur and Mostler

(9, 10= 119 B)

Figure 11, 12: *Paurinella aequispinosa* Kozur and Mostler

(11, 12= CD 2)

Figure13: *Paurinella* sp. cf. *P. curvata* Kozur and Mostler

(13= CD 2)

Figure 14, 15, 17, 18: *Paurinella* sp.

(14= 175-6; 15= KYY 2-1; 17, 18= CD 2)

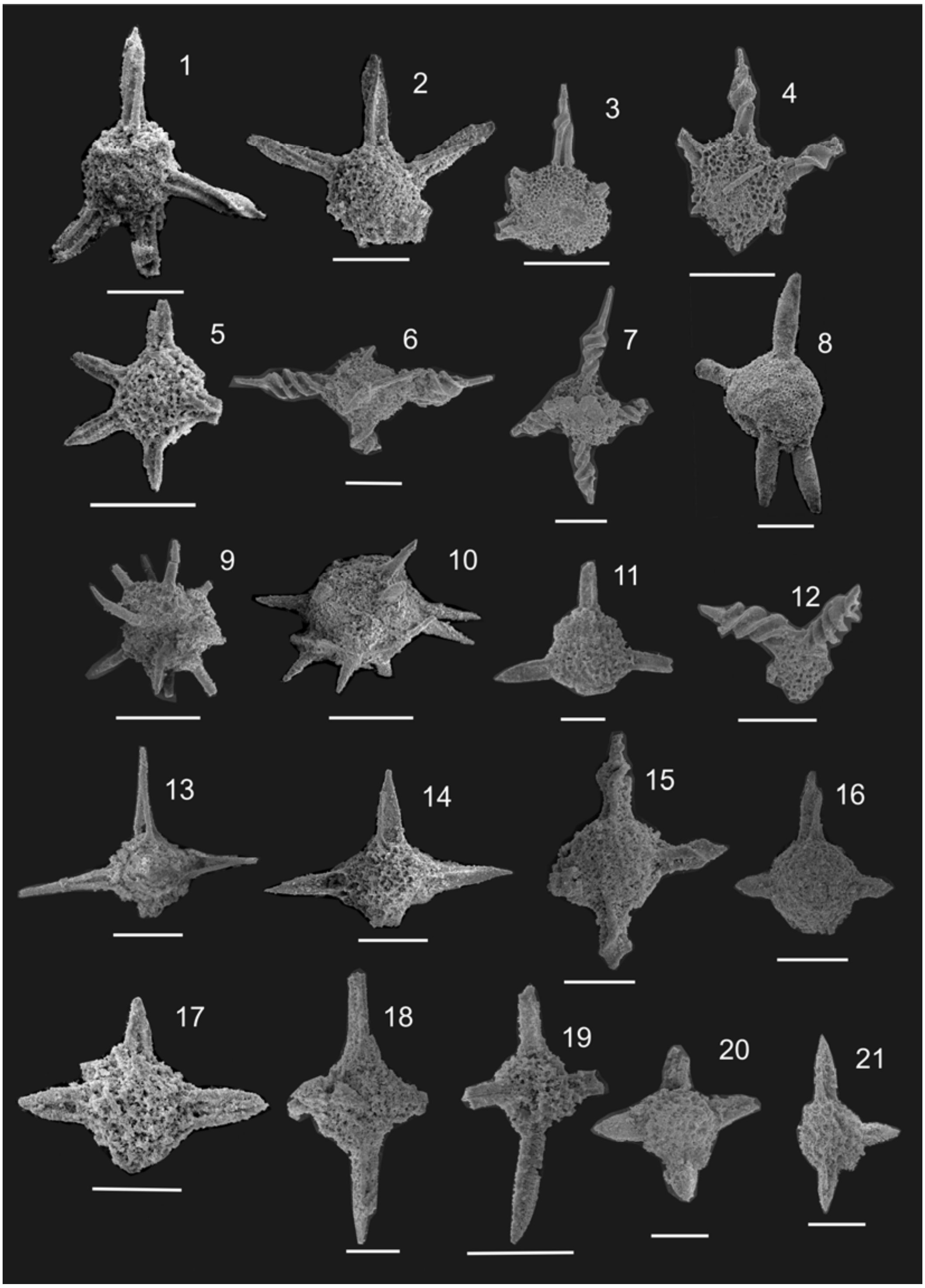
Figure 16: *Paurinella* sp. cf. *P. trettoensis*, Kozur and Mostler

(16= CD 232)

Figure 19, 20: *Tiborella florida florida* (Nakaseko and Nishimura)

(19, 20= CD 2)

PLATE 17



Explanation of Plate 17

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 μm.

Figure 1, 2: *Pentaspongodiscus mesotriassicus* Dumitrică, Kozur and Mostler

(1, 2= CD 2)

Figure 3, 4: *Pentaspongodiscus steigeri* Lahm

(3, 4= 119 A)

Figure 5: *Pentaspongodiscus symmetricus* Dumitrică, Kozur and Mostler

(5= CD 2)

Figure 6, 7: *Tetraspongodiscus nazarovi* (Kozur and Mostler)

(7= 119 A)

Figure 8: *Tetrapaurinella* sp.

(8= CD 2)

Figure 9, 10: *Triassospongosphaera multispinosa* (Kozur and Mostler)

(9= 119 A; 10= CD 202)

Figure 11: *Sepsagon* sp. cf. *S. robustus* Lahm

(11= CD 54)

Figure 12: *Karnospongella bispinosa* Kozur and Mostler

(12= 175_1)

Figure13, 14: *Plafkerium antiquum* Sugiyama

(13= CD 261; 14= CD 191)

Figure 15, 16: *Plafkerium contortum* Dumitrică, Kozur and Mostler

(15= CD 111; 16= CD 131)

Figure 17: *Parasepsagon* sp. cf. *P. variabilis* (Nakaseko and Nishimura)

(17= CD 2)

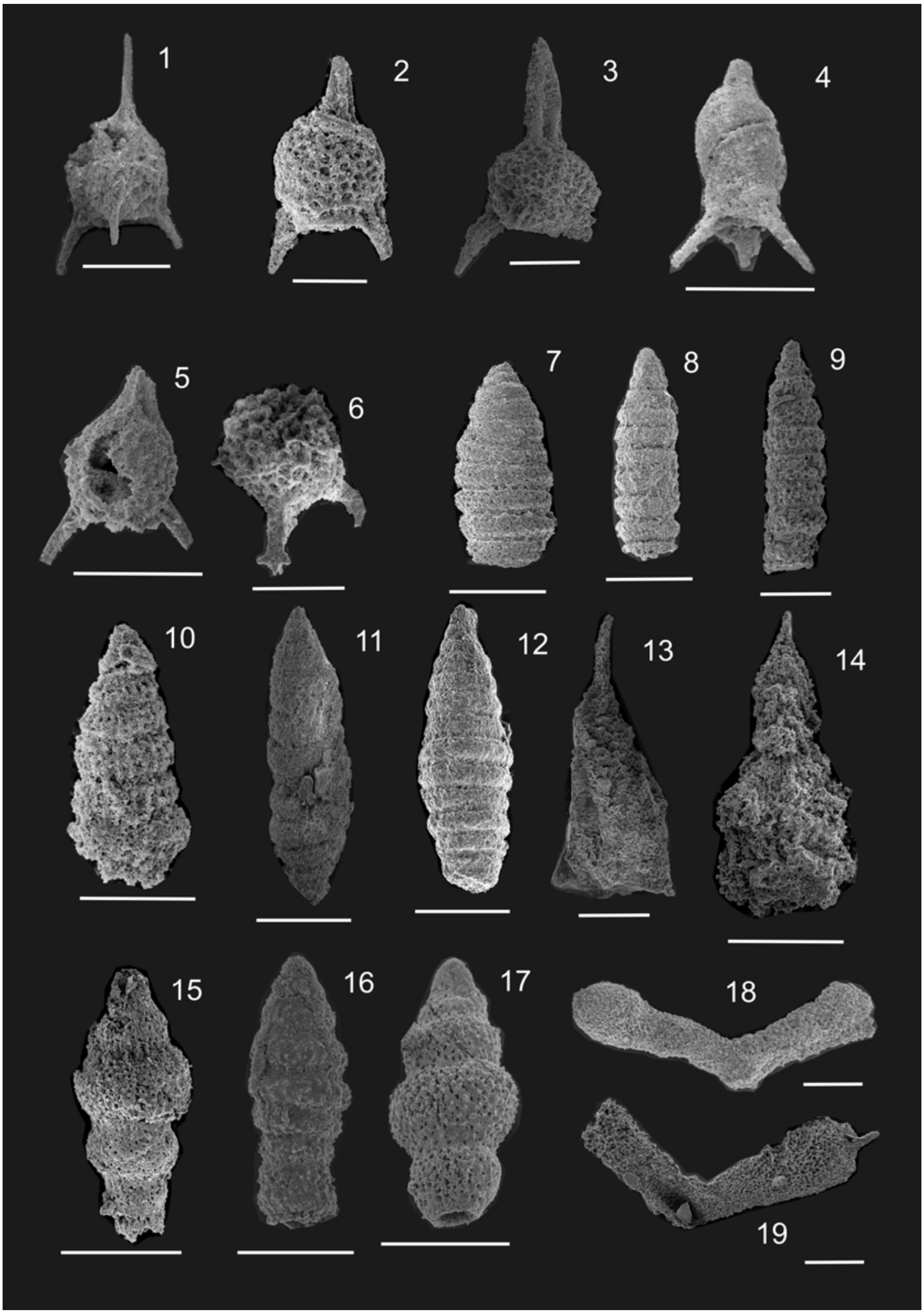
Figure 18, 19: *Parasepsagon* sp.

(8= CD 195; 19= CD 63)

Figure 20, 21: *Parasepsagon variabilis* (Nakaseko and Nishimura)

(20= MLN 2-6; 21= MLN 3-1)

PLATE 18



Explanation of Plate 18

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 μm.

Figure 1: *Hozmadia* sp. cf. *H. gifuensis* Sugiyama

(1= CD 242)

Figure 2: *Hozmadia* sp. cf. *H. rotunda* (Nakaseko and Nishimura)

(2= CD 30)

Figure 3: *Hozmadia rotunda* (Nakaseko and Nishimura)

(3= MLN 1-10)

Figure 4: *Hozmadia* sp. A

(4= CD 284)

Figure 5: *Hozmadia* sp. B

(5= CD 105)

Figure 6: *Hozmadia* sp. C

(6= CD 3)

Figure 7-9: *Pararuesticyrtium* sp. cf. *P. illyricum* Kozur and Mostler

(7= DC 11; 8= DC 5; 9= KYY 1-4)

Figure 10: *Pararuesticyrtium* sp.

(10= CD 2)

Figure 11, 12: *Pararuesticyrtium* sp. A

(11= DC 3; 12= DC 17)

Figure 13: *Spongosilicarmiger* sp.

(13= DC 12)

Figure 14: *Spongosilicarmiger nakasekoi* Yeh

(14= KYY 1-1)

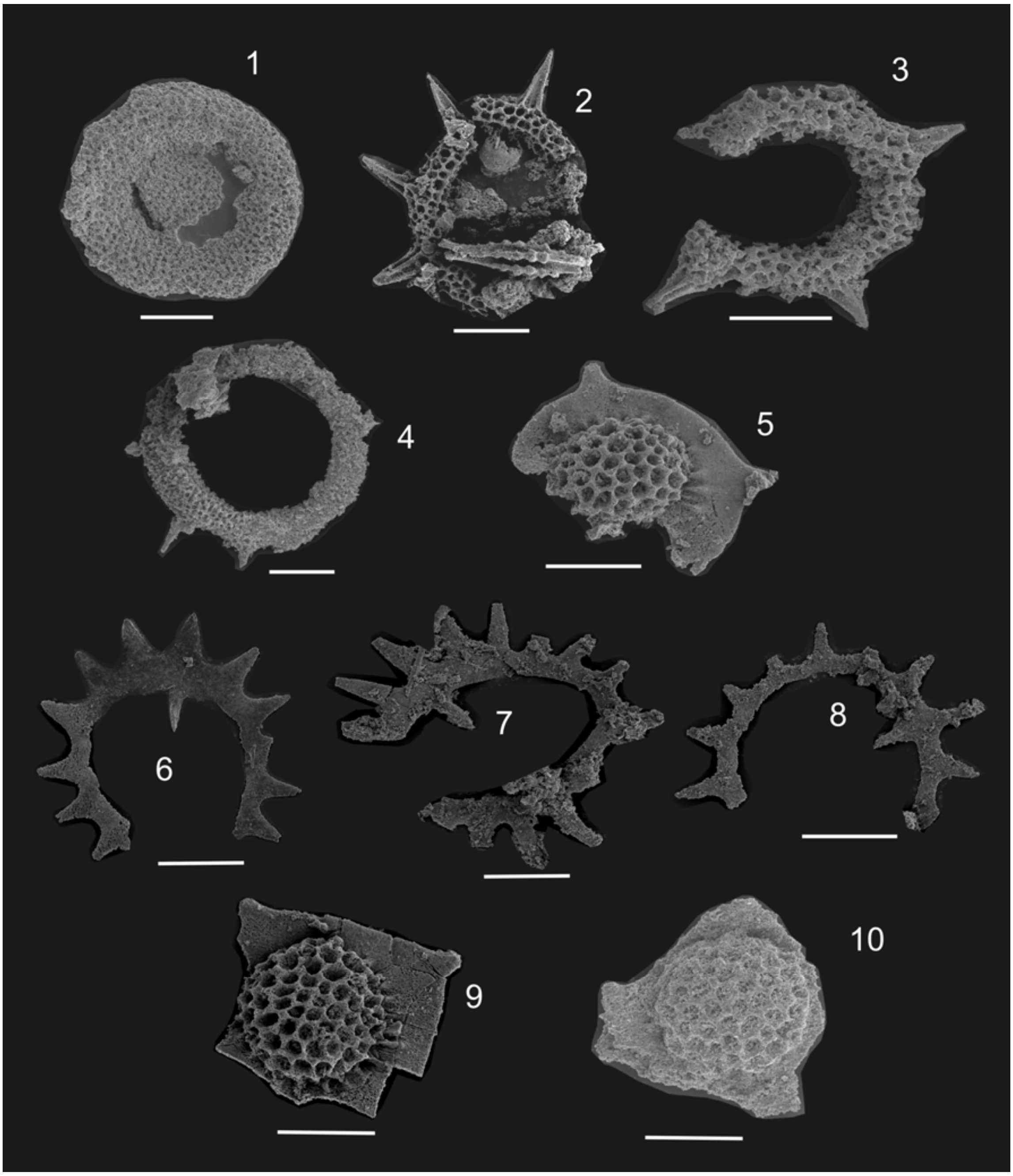
Figure 15-17: *Xiphotheca* sp.

(15, 16= 119 A; 17= 119 B)

Figure 18, 19: *Paronaella* sp.

(18= DC 5; 19= DC 25)

PLATE 19



Explanation of Plate 19

Scanning electron micrographs of Triassic radiolarians from Chiang Dao, Lamphun, Denchai, Khun Yuam, Mae La Noi, and Mae Sariang localities; northern Thailand. All scale bar= 100 µm.

Figure 1: *Orbiculiforma* sp. cf. *O. gazipazaensis* Tekin

(1= DC 22)

Figure 2, 3: *Orbiculiforma goestlingensis* (Kozur and Mostler)

(2= 119 B; 3= 119 A)

Figure 4: *Orbiculiforma karnica* (Kozur and Mostler)

(4= 175_2)

Figure 5: *Praeheliostaurus levis* Kozur and Mostler

(5= 119 B)

Figure 6, 7: *Palaeosaturnalis triassicus* (Kozur and Mostler)

(6=, 7= 119 B)

Figure 8: *Palaeosaturnalis karnicus* (Kozur and Mostler

(8= 119 B)

Figure 9: *Praeheliostaurus quadrispinosus* Mostler and Krainer

(9= 119 A)

Figure 10: *Praeheliostaurus* sp.

(10= DC 1)

CURRICULUM VITAE

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