TAXONOMY OF PERMIAN OSTRACODES FROM THE BUNG SAM PHAN AREA, PHETCHABUN PROVINCE, THAILAND

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อนุกรมวิธานออสตราคอดยุคเพอร์เมียนจากพื้นที่บึงสามพัน จังหวัดเพชรบูรณ์ ประเทศไทย

นางสาวอานิสงส์ จิตนารินทร์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master's Degree.

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การจัดหมวดหมู่ออสตราคอดยุคเพอร์เมียน จากพื้นที่บึงสามพัน จังหวัดเพชรบูรณ์ มีวัตถุประสงค์หลักเพื่อจำแนกชนิด และจัดแบ่งหมวดหมู่ฟอสซิลออสตราคอด รวมไปถึงการแปลความหมายสภาพแวดล้อมของการสะสมตะกอน โดยพิจารณาจากกลุ่มฟอสซิลออสตราคอด ตัวอย่างหินปูนอายุเพอร์เมียนตอนกลางจากหน้าตัดศึกษา จำนวน 17 ตัวอย่างถูกนำมาสกัดด้วยวิธีฮอทอะซิโตไลซิส พบว่ามีฟอสซิลออสตราคอดกว่า 600 ตัวอย่าง ทำการจำแนกชนิดโดยศึกษาสัณฐานของเปลือก ซึ่งจัดอยู่ใน 3 อันดับ 7 วงศ์ 8 สกุล และ 16 ชนิด ได้แก่ *Sargentina* sp. 1, *Sargentina* sp. 2, *Geffenina* sp., *Jonesina* sp., *Reviya* sp., *Hollinella* sp., *Bairdia* sp. 1, *Bairdia* sp. 2, *Bairdia* sp. 3, *Bairdia* sp. 4, *Bairdia* sp. 5, *Bairdia* sp. 6, *Bairdia* sp. 7, *Bairdiacypris* sp. 1, *Bairdiacypris* sp. 2, และ *Cavellina* sp. การแปลความหมายสภาพแวดล้อมโบราณบริเวณพื้นที่ศึกษาพิจารณาจากกลุ่มฟอสซิลออสตราคอด โดยการคำนวณร้อยละของออสตราคอดในระดับวงศ์ ซึ่งโดยภาพรวมของหน้าตัดศึกษา กลุ่มฟอสซิลออสตราคอดบ่งบอกการสะสมตัวในทะเลน้ำตื้นบริเวณชายฝั่งบนลาดทวีป การเปลี่ยนแปลงของกลุ่มฟอสซิลในแต่ละระดับชั้นแสดงให้เห็นการแปรผันของระดับน้ำทะเลในช่วงเวลาของการสะสมตัว

สาขาวิชาชีววิทยา

ปีการศึกษา 2547

ลายมือชื่อนักศึกษา ____________

ลายมือชื่ออาจารย์ที่ปรึกษา จงพันธ์ จงลักษมณี

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม Paul J. Grote

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PERMIAN/OSTRACODES/TAXONOMY/FOSSIL ASSEMBLAGE/ PALEOENVIRONMENT

The study of fossil ostracodes from the Bung Sam Phan area is aimed at the taxonomy of Permian ostracodes in Thailand and paleoenvironment interpretation based on the identified ostracodes. Limestone samples of Middle Permian age were collected and processed by hot acetolysis. More than 600 ostracodes were recovered. Taxonomic study was based on morphology of carapaces. They can be classified into 3 orders, 7 families, 8 genera, and 16 taxa as follows: *Sargentina* sp. 1, *Sargentina* sp. 2, *Geffenina* sp., *Jonesina* sp., *Reviya* sp., *Hollinella* sp., *Bairdia* sp. 1, *Bairdia* sp. 2, *Bairdia* sp. 3, *Bairdia* sp. 4, *Bairdia* sp. 5, *Bairdia* sp. 6, *Bairdia* sp. 7, *Bairdiacypris* sp. 1, *Bairdiacypris* sp. 2, and *Cavellina* sp. Based on the composition of the fossil ostracode assemblages at the superfamily level, interpretation of the paleoenvironment of the study area was concluded as representing the shallow marine, near shore environment. The variation of fossil ostracode assemblages from different layers suggested that the change of environments of deposition was caused by sea level fluctuation.

School of Biology

Academic Year 2004

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Besides knowledge of the classic science studying of past lives, paleontology convinces the close relationships between geology and biology. Fossils found in rocks, once were living on the earth, their lives behaved like the living organisms today. However, lives can not live without support of environment, both physical and biological. Similarly, this study can not be completed without help and encouragement of many people.

The author would like to express her sincere appreciation to her thesis advisor, Dr. Chongpan Chonglakmani, for his guidance, supports and kind encouragement throughout the study. The author also wishes to sincerely thank Dr. Sylvie Crasquin-Soleau and Prof. Dr. Jean Broutin, Universite Pierre et Marie Curie (Paris VI) in France, for the great experience in micropaleontology. Further appreciation is extended to Dr. Nathawut Thanee and Dr. Paul J. Grote for their constructive comments. The author has also benefited from the valuable help of Mr. Narames and Mrs. Suree Teerarungsigul for academic and technical supports.

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Anisong Chitnarin

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CHAPTER I

INTRODUCTION

Ostracodes, a group of microfossils, have been considered by many paleontogists to be the most useful group of crustaceans in geological science (Pokorny, 1978). They have been used as tools to understand the paleoenvironment and biostratigraphy. The greater advantage over other groups of microfossils is that fossil ostracodes have been widely distributed in many types of rocks and have ranged throughout the Phanerozoic Eon (540 million years ago to Recent). Fossil ostracodes are found mostly in calcareous rocks such as limestone, shale, mudstone and marl. The hard part of the ostracode body is mostly calcium carbonate that can easily be preserved. Moreover, the study of fossil ostracodes can be applied to various fields of sciences, for example, evolution, paleoecology, paleogeography and paleoclimatology.

1.1 Background of the Study

The study of Permian rocks in Thailand is interesting from several view points. Some areas of Permian paleontology remain unexplored, whereas Permian tectonic events are still controversial. The author considers that study of fossil ostracodes provides additional information in both subjects, and further application of the study may confirm the tectonic solution in the region of Southeast Asia. Permian rocks of Thailand are predominantly limestone that may contain many fossil ostracodes. The taxonomic study of Permian ostracodes is then essential, in order to gain some paleontological and paleoenvironmental information and for further study on these valuable microfossils.

1.2 Research Objectives

1. To document the Permian ostracodes from central Thailand.
2. To study the taxonomy of fossil ostracodes from the Bung Sam Phan section, Phetchabun Province.
3. To interpret the environment of deposition based on the identified fossil ostracode assemblages.
4. To understand and describe the change of paleoenvironment through time based on the fossil ostracode assemblages from different layers.

1.3 Scope and Limitation

1. The fossil ostracodes have been studied taxonomically.
2. The study is restricted to ostracode taxa that can be recovered from some layers of the study section.
3. The paleoenvironmental interpretation has been made by synthesis the available geological and paleontological information.

1.4 Location of the Study Section

The study section is located at km36+600 on highway No. 225, west of Bung Sam Phan District, 70 kilometers southwest of Muang District, Phetchabun Province

(Fig. 1-1). The roadcut outcrop is exposed on a small hill, at latitude 15° 50′ 03.3″ North and longitude 100° 55′35.9″ East (UTM Grid reference 062514). The section is appeared on the topographic map scale 1:50,000 of the Royal Thai Survey Department, sheet 5141 I, series L7017 edition 2-RTSD, Khao Phra (Fig. 1-2).

1.5 Expected Results

Initial data on taxonomy of Permian ostracodes in Thailand and paleoenvironment interpretation based on identified fossil ostracodes.

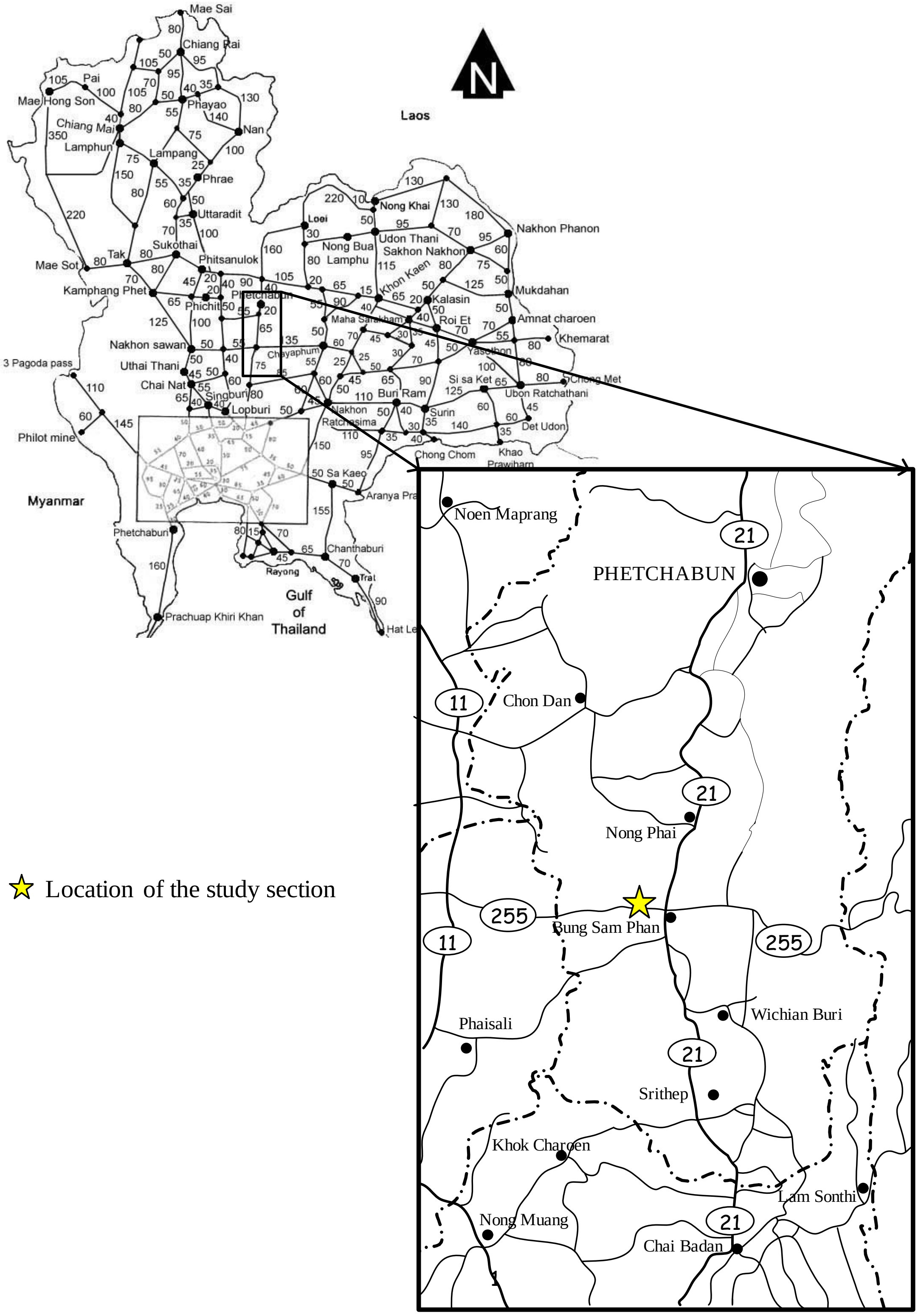
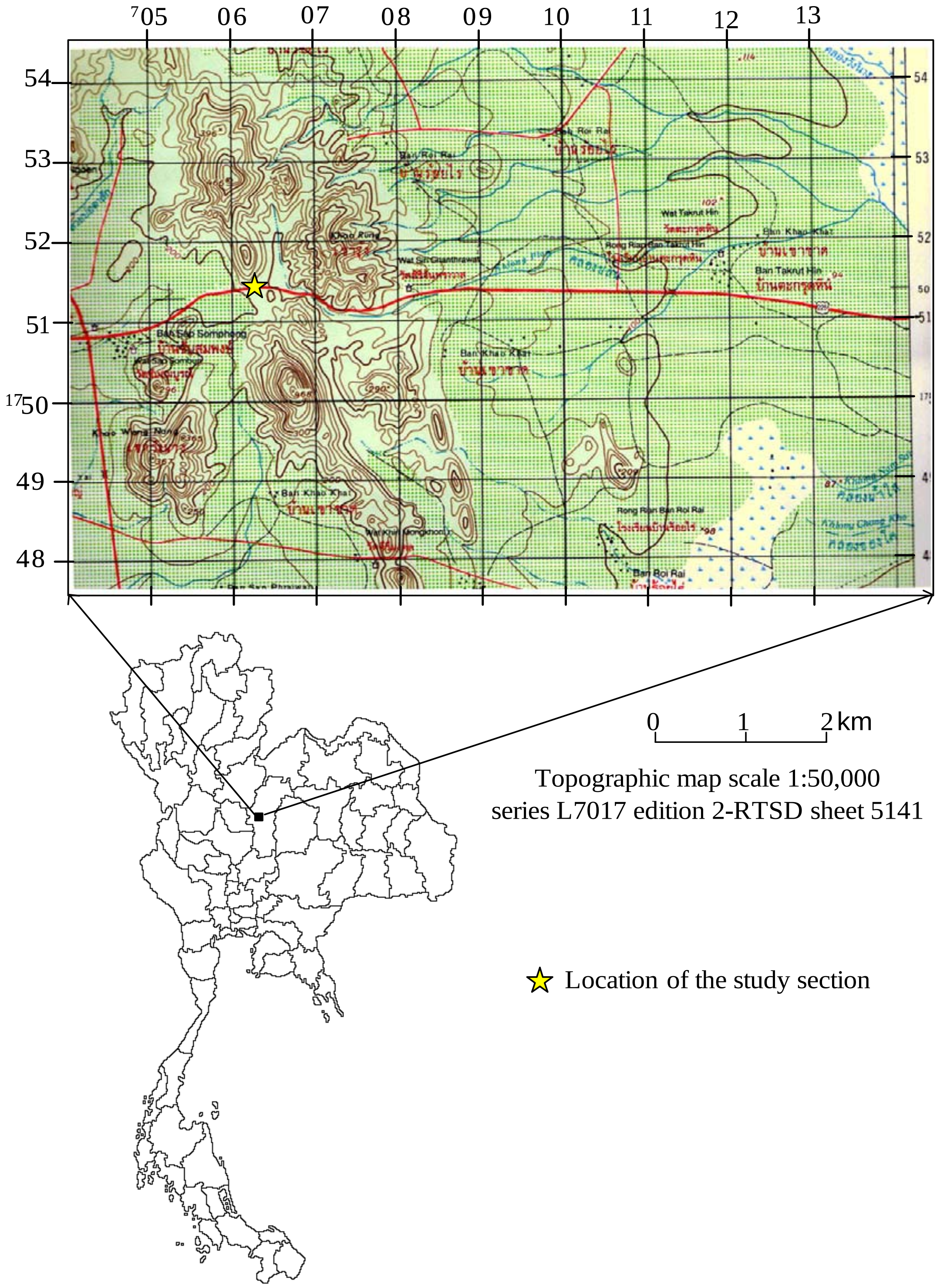


Figure 1-1 Locality of the study section



Topographic map scale 1:50,000
series L7017 edition 2-RTSD sheet 5141

☆ Location of the study section

Figure 1-2 Map showing location of the study section

CHAPTER II

LITERATURE REVIEW

2.1 Geology and Stratigraphy

2.1.1 Regional Permian Stratigraphy of Saraburi Group

Permian rocks are exposed extensively throughout the country. Formally, the limestones and associated clastic rocks of Permian age were named Ratburi Limestone (Brown *et al.,* 1951). Later on the nomenclature has been changed as the Permian sequences have been designated variously by many authors. The Permian sequence in particular was firstly named by Bunopas (1981) as Saraburi Group for a mixed carbonate and clastic sequence exposed in the Central Plain from Nakhon Sawan to Saraburi and at the western edge of the Khorat Plateau from Phetchabun to Loei. Generally, the Saraburi Group is found to be continuously overlaying on Upper Carboniferous strata and unconformably underlain the Upper Triassic conglomerate. Many authors, such as, Dawson (1978, 1993), Chonglakmani and Fontaine (1990), Charoentitirat (1995), have focused on the biostratigraphy of these strata and pointed the age of Early to Late Middle Permian (Asselian to Median) based on fusulinaceans, small foraminifers, corals and brachiopods (Table 2-1). The stratigraphic correlation of the Permian rocks in central Thailand and western edge of Khorat Plateau is shown in Table 2-2.

The Saraburi Group has been subdivided by many authors, namely, Nakornsri (1976; 1981), Charoenprawat and Wongwanich (1976), Charoenprawat *et* *al* (1976), Chonglakmani and Sattayalak (1979), Chonglakmani *et al.*, 1979, Bunopas (1981; 1983; 1992), and Hinthong (1985) based on the rock exposures in different areas. In the Saraburi area, six formations were proposed (DMR, 1992). They are Phu Phe Formation, Khao Khwang Formation, Nong Pong Formation, Pang Asok Formation, Khao Khad Formation, and Sub Bon Formation, respectively, in ascending order. The fusulinacean faunas are well observed in these formations. According to Hinthong (1985), fusulinids indicate Lower to Middle Middle Permian (Asselian to Kazanian age).

In the Central Plain, Nakornsri (1976; 1981) subdivided the Saraburi Group into two formations, the Tak Fa formation which is exposed in Nakhon Sawan Province, and the Khao Luak in Lopburi Province. These formations can be correlated to the Khao Khad and the Pang Asok Formations respectively in the Saraburi area with reference to the fusulinacean faunas (Early to Middle Permian).

Bunopas (1981) subdivided the Saraburi Group into three formations which is exposed in Phetchabun, Lopburi, Saraburi, and Loei areas. They are the Khao Luak Formation, Saraburi Limestone, and Dan Sai Shale, respectively, in ascending order. The Khao Luak Formation is identical to the formation described by Nakornsri but the overlaying sequence which is exposed in the Saraburi was named Saraburi Limestone. Fossils from the Saraburi Limestone indicate Sakmarian to Midian age that can be correlated with the Khao Khad Formation and the Tak Fa Formation. The Dan Sai Shale was proposed for the silisiclastic sequence with limestone lenses exposed in Loei area. Fossil fusulinids, brachiopods, and leaves indicate Middle to late Middle Permian. Dan Sai Shale can be correlated with the Sap

Bon Formation and the Pha Dua Formation in the Saraburi and in Loei areas, respectively.

In Loei area, Charoenprawat and Wongwanich (1976) and Charoenprawat *et al.* (1976) subdivided the Permian rocks into three formations in ascending order, the Nam Maholan, the E-Lert, and the Pha Dua, respectively. The Nam Maholan and the E-Lert formations are believed to be an interfingering relationship based on the fossil records. At present the Nam Maholan formation is known to range from Late Carboniferous to late Middle Permian as indicated by fusulinids and brachiopods. The E-Lert formation is predominated by shale and interbedded chert and sandstone with limestone lenses. Fossil ammonoids and fusulinids indicate Asselian to Kubergandian age. The uppermost Permian in the Loei area is designated as the Pha Dua formation representing clastic sequence. The age of the formation is indicated by fossil plants and ammonoid fragments as Kazanian (Middle Permian). The Pha Dua formation can be correlated with the Sap Bon Formation in the Saraburi area.

In the Phetchabun and Udonthani areas, Permian rocks were subdivided by Chonglakmani and Sattayalak (1979) and Chonglakmani *et al.,* (1979) into three formations in ascending order, the Pha Nok Khao, the Hua Na Kham, and the Num Duk formations. The Pha Nok Khao formation is mainly thick to very thick bedded limestone which can be correlated with the Nam Maholan formation in the Loei area. The Hau Na Kham formation consists of shale and sandstone with limestone lenses. Helmcke and Kraikhong (1982) considered the formation as a molasses facies without limestone. The Hua Na Kham formation can be correlated with the Pang Asok Formation in the Saraburi and the lower part of the E-Lert formation in the Loei area.

The Nam Duk formation is represented by shale, sandstone and thin bedded limestone. Limestone shows graded bedding indicating turbiditic sediments. The age of these formations was determined by fusulinids and ammonoids as Early to Middle Permian.

In 1985 Wielchowsky and Young studied the Lower to Middle Permian rocks of the Phetchabun fold and thrust belt and recognized six carbonate facies representing basin plain, basin margin, outer platform, platform interior, restricted platform, and marginal marine depositional environments. They also recognized three siliciclastic facies representing deep, shallow, and marginal marine depositional environments. According to their interpretation, three palaeogeographic provinces of the Saraburi Group in central and northeastern Thailand were established (Figs. 2-1a, b, c). The western carbonate platform is called Khao Khwang Platform, the central mixed siliciclastic-carbonate basin is called Num Duk basin, and the eastern mixed carbonate-siliciclastic platform is called Pha Nok Khao Platform.

2.1.2 Geology and Stratigraphy of Phetchabun Area and the Study Section

The study section is located between km. 36+600 to about 36+700 on Highway No 225, west of Bung Sam Phan District, Phetchabun Province. The location, as shown on Geological map sheet Ban Mi, is about latitude 15° 50′ 03.3″ North and longitude 100° 55′ 35.9″ East. In other word, the locality is at Grid Reference 062514 as presented on the topographic map sale 1:50,000 of the Royal Thai Survey Department, sheet 5141 I, series L7017 edition 2-RTSD, Khao Phra (see Fig. 1-2).

Paleozoic and post-Paleozoic sedimentary rocks are exposed in the Phetchabun area. According to Geological Map scale 1:1,000,000 (DMR, 1999) as shown in Fig. 2-2, the oldest strata exposed in this area is Carboniferous carbonate sequence which crops out west of Phetchabun city from Noen Maprang to Chon Dan Districts. The Permian sequence in western part is exposed further to the south, from north of Nong Phai to Chai Badan Districts. These Permian rocks are commonly intruded and covered by Permo-Triassic volcanic rocks, basalt and Triassic granite. The Jurassic sequence, namely Phra Wihan Formation, is exposed west of Bung Sam Phan Districts. The elongate central area is covered by Tertiary to Quaternary sediments. In eastern part Permian rocks are more extensively exposed with small exposures of the Jurassic Nam Phong Formation. The Mesozoic Khorat Group is exposed eastward in higher mountainous area, which is known as the Khorat Plateau.

Chonglakmani and Fontaine (1990) referred to fossil faunas described by previous authors (Yanagida, 1967; Sakagami, 1975) as Middle to late Middle Permian for marine facies in the Nong Phai area. They also mentioned middle to late Murgabian age for limestone exposed in area west of Wichian Buri District (Fig. 2-3).

Nearby the study section, Altermann (1989) made a detailed investigation on the southern continuity of the NW-SE trending hill, at the Ban Sapsamothot, about 10 km southeast of the study section. The rock sequence is identical to the study section. They consist of greenish volcanics, coarse clast-supported conglomerates and fossiliferous limestone. At the school of Ban Sub May Daeng, about 8 km southeast of the study section, coral reef of several to tens of meters in diameter are observed. The corals also indicate Murgabian age.

The stratigraphic column of the study section is presented in Fig. 2-4. Greenish volcanic rocks (?doleritic basalts according to Altermann, 1989) is exposed and formed as the basal part of the section. In the lower part, about 20 meters thick, there are intercalations of thin bedded limestone and reddish brown shale with ratio of 2:1. Limestones are mostly dark grey, micritic with few fossils. Shale is weathered and composed of fossil bryozoan. In the upper part, about 40 meters thick, there are sequences of thin to medium bedded limestone intercalated with reddish brown shale with ratio 5:1. Limestones are mostly grey to dark grey and contained many fossils (packstone to grainstone). These limestones are biomicrite, biocalciarenite and small biocalcirudite. The same bed of sample 02TH46, also contains trilobite pygidium and fusulinids (?*Verbeekina* sp.). Limestone in the uppermost part is silicified which can be observed by the less reaction with 10%HCL. From about 70 meters level, the section is covered by vegetation but at about 130 meters level, the coarse conglomerates are exposed. According to Altermann (1989), the section can be designated as late Middle Permian, a Murgabian age (see Table 2-1).

2.2 Ostracode Shell Morphology, Measurement and Abbreviations

2.2.1 Ostracode Shell Morphology

The bivalve carapace of ostracodes is composed of two parts, a hard layer of calcium carbonate, and a soft layer called the epidermis. The hard part could be preserved as fossil and usually studied by paleontologists. The hard layer is composed of two parts, the outer lamella and duplicature. Both parts are composed of crystalline calcium carbonate, which was induced to precipitate by the epidermal cells. The duplicature extends along the free margin of the valve and is welded onto the outer lamella (Fig. 2-5 a).

External features of ostracode carapace

Ostracode carapaces vary in size. The shape is one of the criteria in classification. The dorsal edge may be convex or straight, and the ventral edge can be straight, concave or convex. The ends are usually rounded but elongated in some genera.

The dorsum is an area adjacent to the hinge as seen in dorsal view (Fig. 2-5 b). It may be either broadly or narrowly arched, flat or concave. Cardinal corners are junctures between the dorsal border and ends of the carapace. The cardinal angles are measurable and important for classification. Position of the greatest height controls the shape of the carapace. If the greatest height is near one end of the carapace, it produces swing. The carapace with forward swing is called preplete, with backward swing is called postplete. If the greatest height is at or near midlength, it is called amplete (Fig. 2-5 c).

The ventral area is composed of free edge, venter and adventral. The two valves contact each other at the contact margin when the carapace is closed (see Fig. 2-5 b). The contact margin may be simple or complex as the presence of selvage, vestibule, list, flange, flange groove and line of concrescence. The ridges, frills and flanges may be restricted to the venter or extended to the cardinal corners. The velum can be a ventral ridge, flange, or frill. The velum related to dimorphism is called a pseudovelum. The carinal structure consists of nondimorphic ornamental ridges located lateroventrally. Ribs and ridges could be found on the lateral surface of ostracode valves.

The lateral surface of the carapace can be divided into posterior and anterior portions, and into dorsal and ventral portions (Fig. 2-6). The lateral surface may be smooth or ornamented by granules, pustules, striae, pits, spines, or reticula (Fig. 2-7). Lobation and sulcation are present in some ostracode species. Lobes represent elevations of the shell which are directly opposite internal depressions or troughs. The lobes have been designated for convenience from the anterior to the posterior part of the valve as $L_{1,}$ $L_{2,}$ $L_{3,}$ and L_4. Sulci are elongate depressions of the domicilium labeled as $S_{1,}$ $S_{2,}$ and S_3 from the anterior to the posterior. The S_2 is the most significance representing the position of the adductor muscle (Fig. 2-8).

In dorsal view, the outline, nature of the hinge contact, form of lobation and sulcation, and presence of dorsal carinae can be observed.

Internal Features

The internal features of the ostracode carapace such as muscle scars are very important for classification, but these features are commonly preserved in post Paleozoic ostracodes (Mesozoic and Cenozoic) but less commonly preserved in Paleozoic ostracodes.

Hingement

Hingement is one of the most important features for classification of the Mesozoic and Cenozoic ostracodes but not well known among the Paleozoic ostracodes. However, the hingement can be grouped into four groups: 1) smooth contact without interlocking devices, 2) straight or curved, smooth or denticulate hinge bar, 3) straight or curved hinge bar and groove supplemented by cardinal teeth and sockets, and 4) peripheral lock in genera in which one valve is larger than the other, the edge of the smaller valve is fitted into the larger valve.

Dimorphism

Dimorphic characteristics are well recognized in Paleozoic ostracodes. It is an important feature for classification. However, the sex can not be determined in all cases. The adult females of dimorphic species are referred to as heteromorphs and males and juveniles as tectomorphs.

There are five types of dimorphism. Kloedenellid dimorphism is present in the Kloedenellocopina and Recent ostracodes by inflation of the posterior portion of the domicilium of the heteromorphs. It can also be observed in dorsal view. The tectomorphs are usually elongate to ovate, with the greatest width medial, whereas the heteromorph carapace is wedge-shaped, with the greatest width in the posterior position. Lobate dimorphism is characterized by a distinct lobe in the anteroventral or ventral portion of some species. This ventral lobe may be part of the anterior and ventral lobes in some species. Beyrichiid dimorphism (also called cruminal dimorphism) is distinguished by the presence of a large pouchlike structure on the posterior part of the carapace. The pouch seems to be the expansion of the velum. Velate dimorphism is recognized in the development of velar adventral features. Histial dimorphism is recognized by character of a histium, a part of a ventral ridge connecting the lateral lobe and ridge that continues ventrally from the lateral lobes.

Orientation of the ostracode shells

The orientation of anterior and posterior portions of the shells can be recognized in order of importance as follows:

1) Fossils with living representatives may be oriented on the basis of observed internal morphology.

2) Adductor muscle scars are in anterior position.

3) S2 marks position of adductor muscle scars in anterior position.

4) Posterior ends are widest in dimorphic forms except in Beyrichiid dimorphism.

5) The anterior element of hinge structures usually is more complex than the posterior.

6) The posterior outline is usually more acuminate than the anterior part.

7) Ontogenetic development shows that the posterior half of the carapace is more acuminate than the anterior in instar stage.

8) Spines are directed backward.

9) The posterior portion of the hinge channel commonly is widest.

Orientation of the dorsal and ventral portions can be recognized by some criteria as follows:

1) Palaeocopids usually have straight backs with a concave ventral margin.

2) Cardinal angles denote the dorsal portion, and eye spots denote anterior and dorsal portion.

3) In some poorly developed hingement species, the dorsal margin is usually more convex than the ventral, or the ventral margin is straight to gently concave.

2.2.2 Measurement

To study the taxonomy of fossil ostracodes, some characters must be measured as follows:

1) The Palaeocopids; height, length, thickness, anterior cardinal angle, posterior cardinal angle, position of maximum of anterior and posterior curvature compared to height (Fig. 2-9).

2) The Podocopids; height, length, thickness, position of anterior end or maximum curvature compared to height, position of posterior end or maximum curvature compared to height, angle between dorsal and anterodorsal borders, angle between dorsal and posterodorsal border (Fig. 2-10).

2.2.3 Abbreviations

In the systematic descriptions the used abbreviations are

RV: right valve

LV: left valve

L: length

H: height

L1: anterior lobe

L2: median lobe

L3: posterior lobe

S1: anterior sulcus

S2: median sulcus

ACA: anterior cardinal angle

PCA: posterior cardinal angle

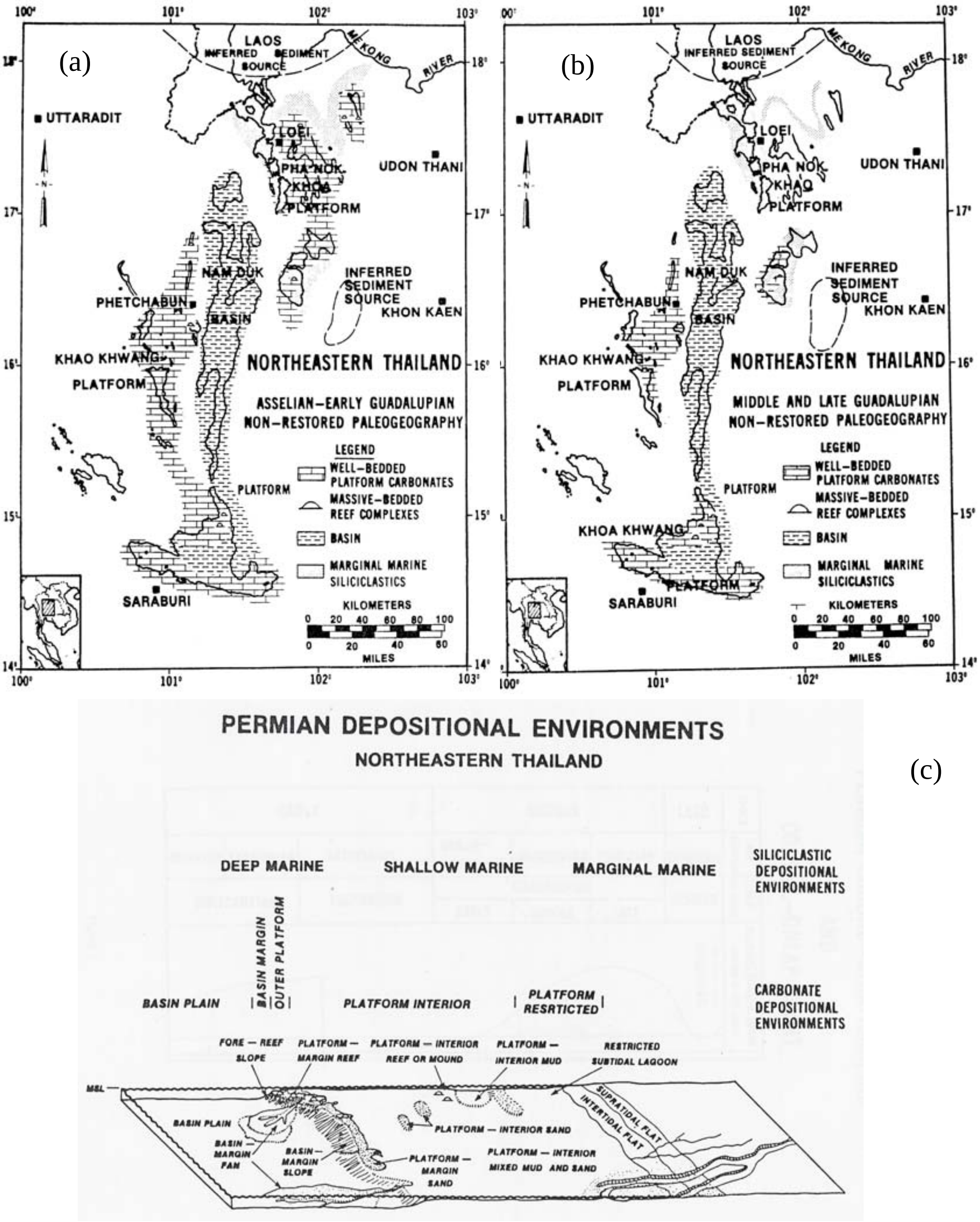


Figure 2-1 Permian Paleogeography of the Phetchabun Fold and Thrust Belt (Wielchowsky and Young, 1985), (a) non-restored paleogeographic map of Asselian to early Guadalupian, (b) non-restored palaeogeographic map of middle to late Guadalupian, (c) depositional environments and facies

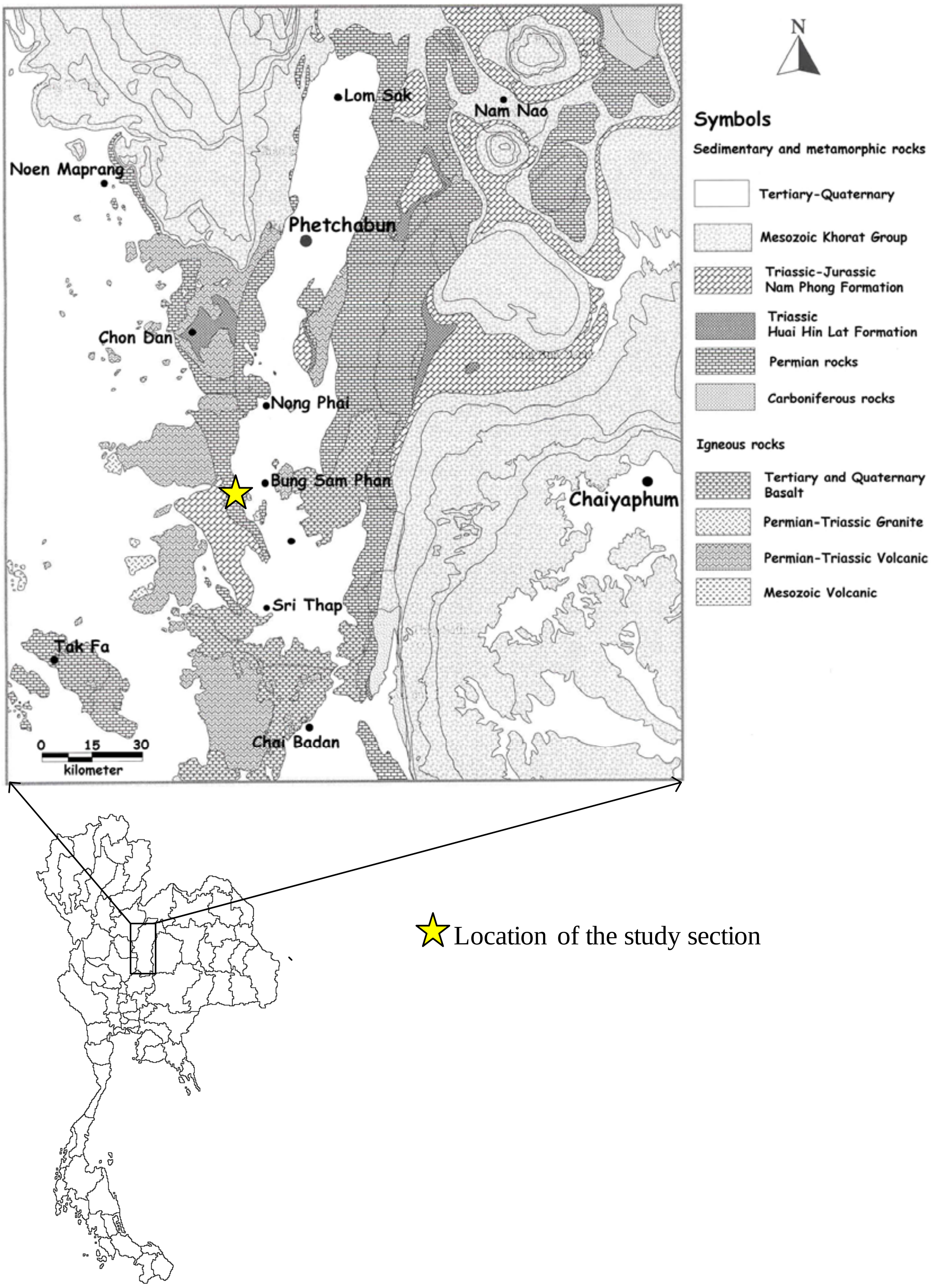
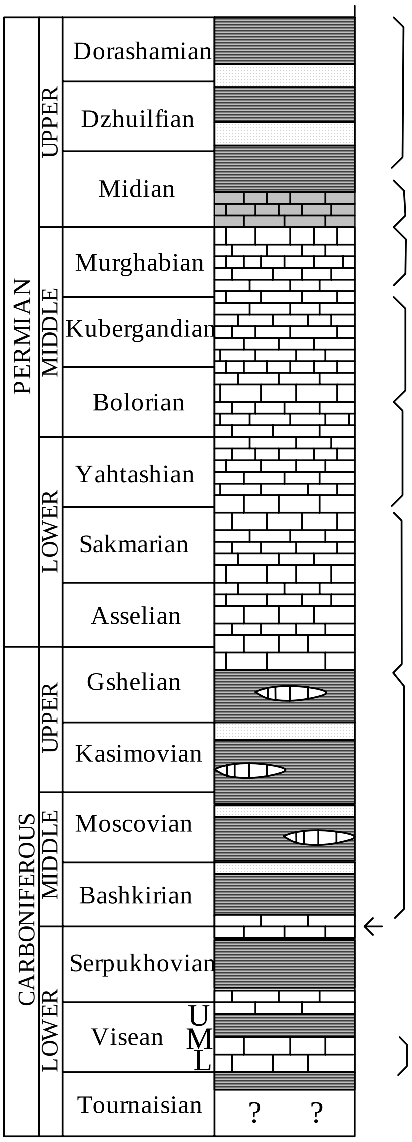


Figure 2-2 Geological map of Phetchabun area and the vicinity (modified from DMR, 1999)



Horizontal with plant imprints and fossil woods.
The woods do not display growth rings.

Argillaceous limestone with brachiopods.

Horizon rich in foraminifera (with *Misellina*
and fasciculate Rugosa (*Pseudohuangia*)).

This part of the stratigraphical column remains
poorly known; a few data have been gathered only
from the area east of Lam Narai

Confined environment with decreasing salinity (tidal
flat with gastropods) to subtidal facies rich in crinoids
and containing *Pseudoschwagerina*.

Clastic sequence containing a few limestone lenses. In shale
and sandstone, fossils are mainly brachiopods and bryozoa.
At the limestone outcrop, Moscovian foraminifera have been
mentioned.

Poorly fossiliferous limestone, containing some foraminifera.

Foraminifera (with Archaediscidae), solitary
Rugosa (*Palarosmilia*), Tabulata (*Syringopora*)

Figure 2-3 Stratigraphic column of the Carboniferous – Permian section exposed in the Phetchabun to Lam Narai region (Chonglakmani and Fontaine, 1990)

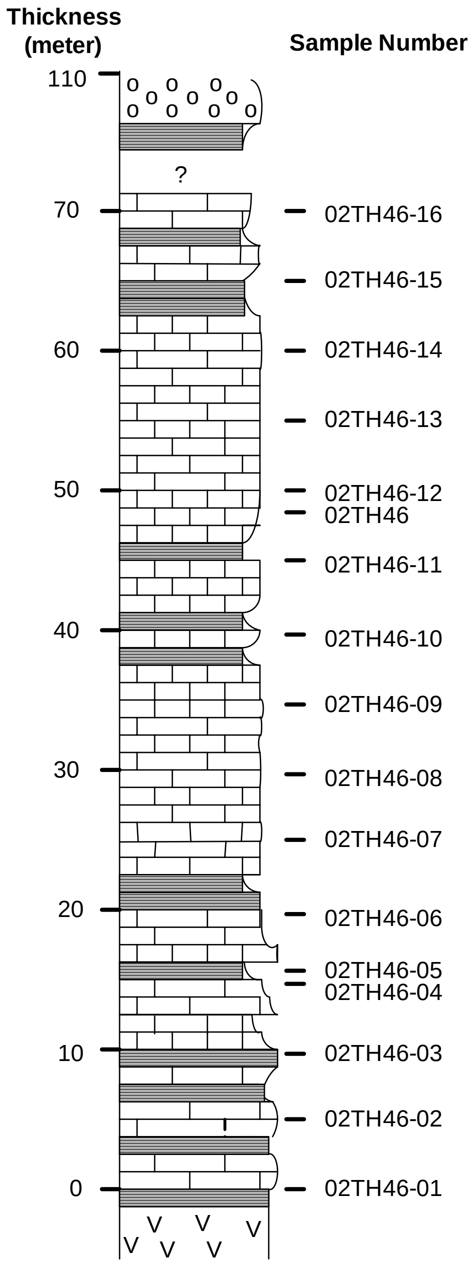


Figure 2-4 Stratigraphic column of the study section

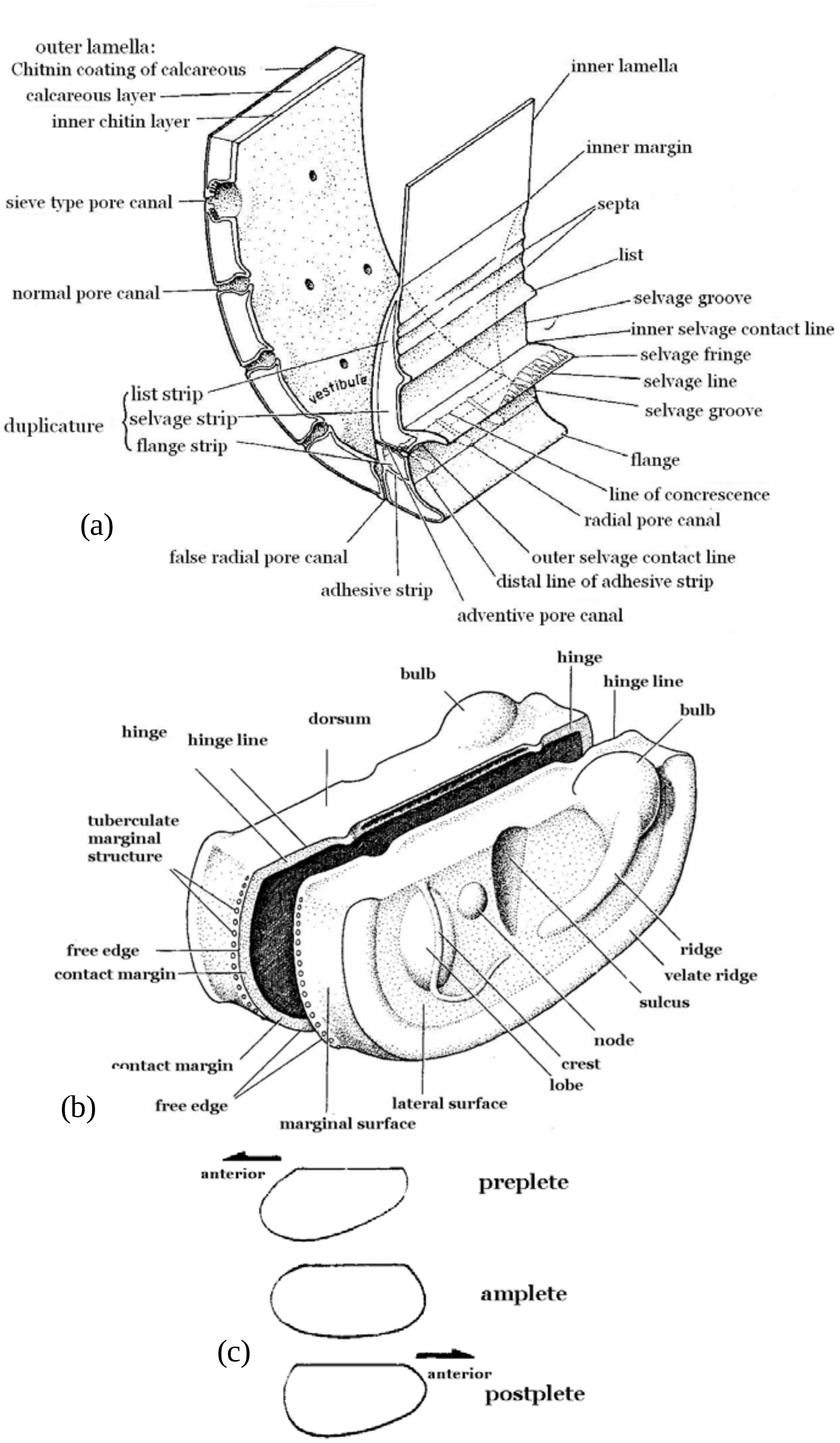


Figure 2-5 Ostracode shell morphology, (a) and (b) modified from Moore (1961), (c) from Lethiers (1981)

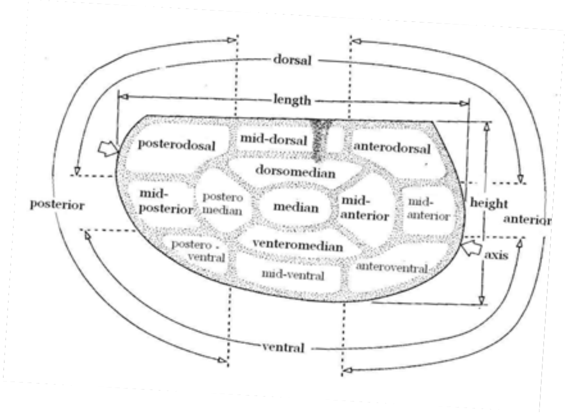


Figure 2-6 Lateral surface nomenclature (slightly modified from Moore, 1961)

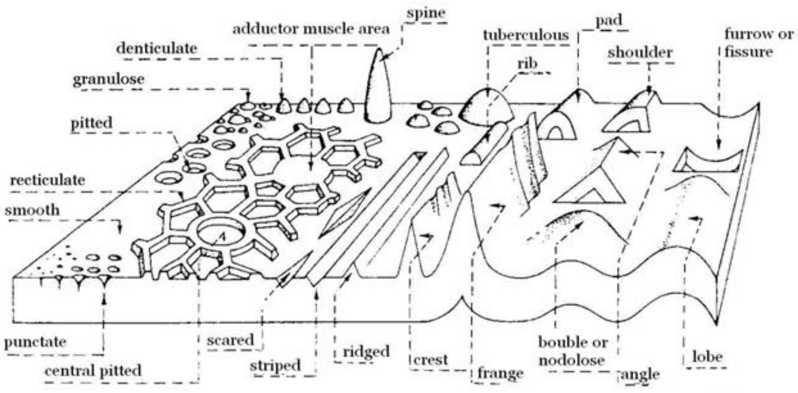


Figure 2-7 Ornamentation elements of carapace (modified from Crasquin, 1984)

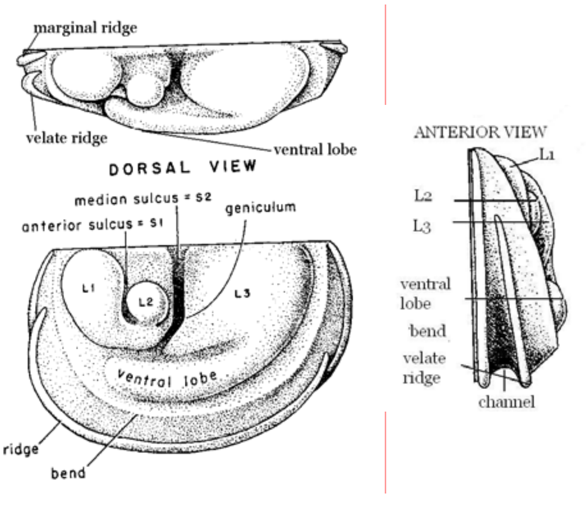
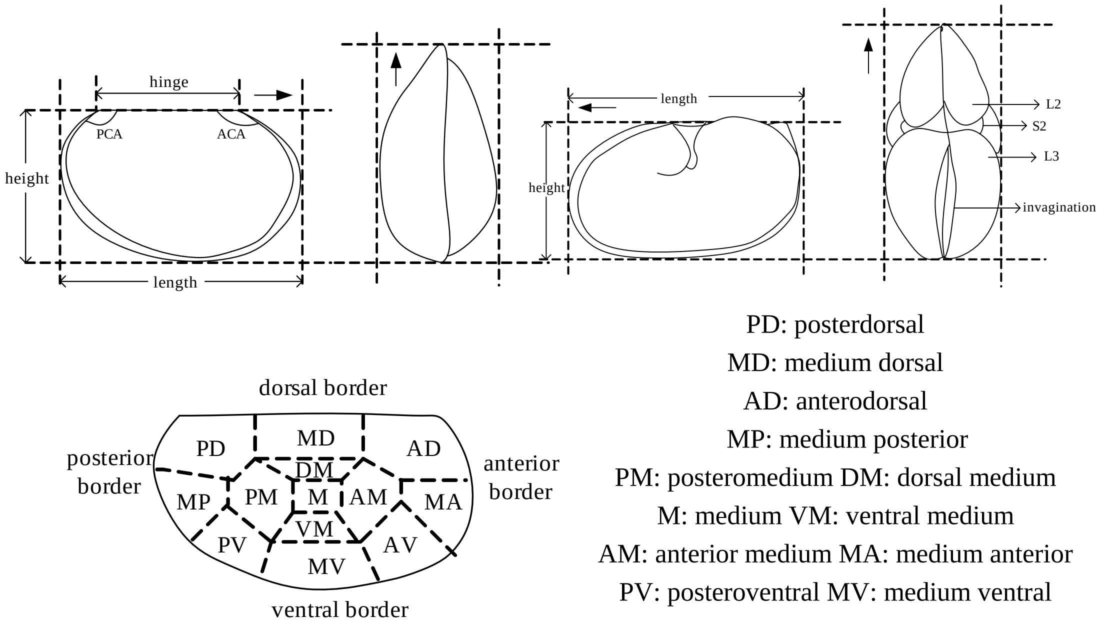


Figure 2-8 Lateral and dorsal elements of ostracode carapace (from Moore, 1961)



PD: posterdorsal
MD: medium dorsal
AD: anterodorsal
MP: medium posterior
PM: posteromedium DM: dorsal medium
M: medium VM: ventral medium
AM: anterior medium MA: medium anterior
PV: posteroventral MV: medium ventral
AV: anteroventral

Figure 2-9 Some characteristics for the ostracode carapace measurement for members of Order Palaeocopida, Suborder Beyrichicopina (left), Suborder Kloedenellocopina (right), and lateral surface nomenclature (lower) (slightly modified from Crasquin, 1984)

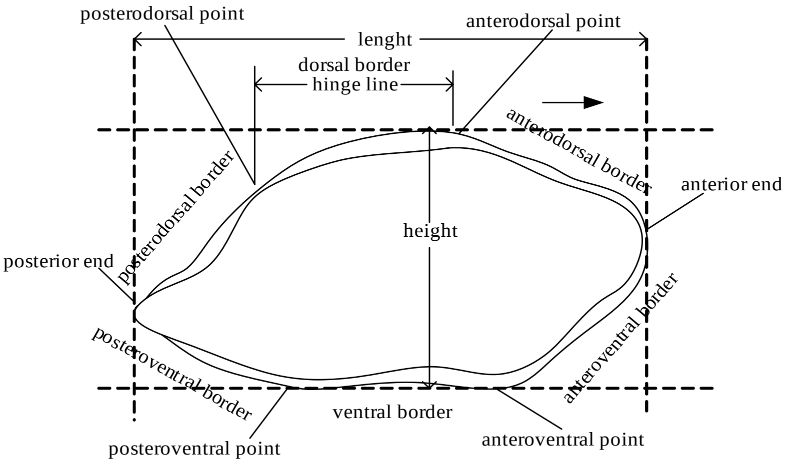
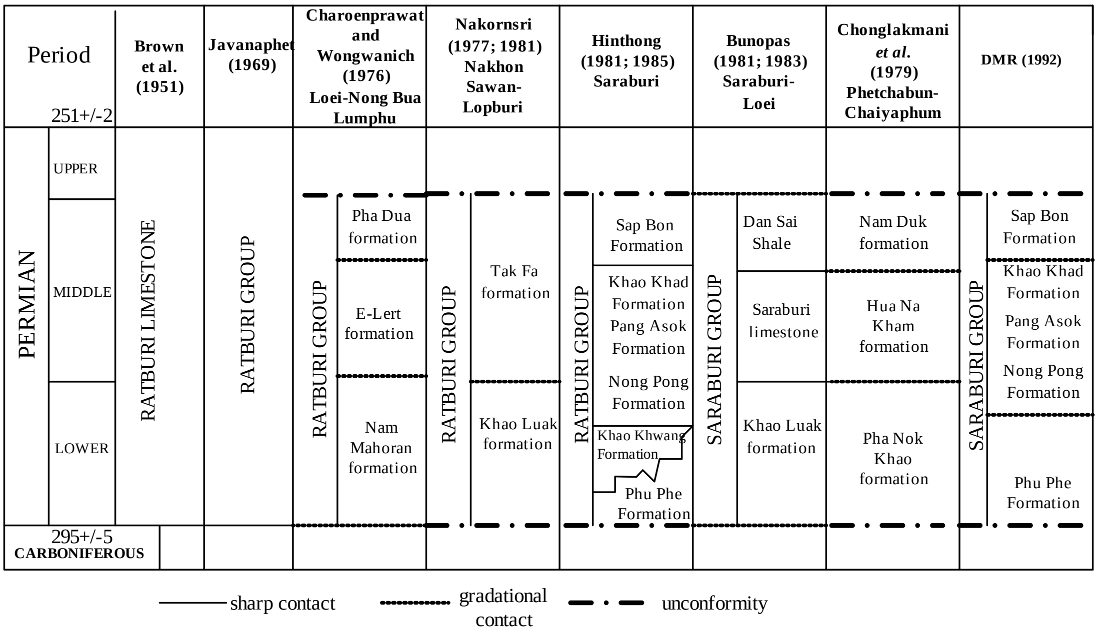
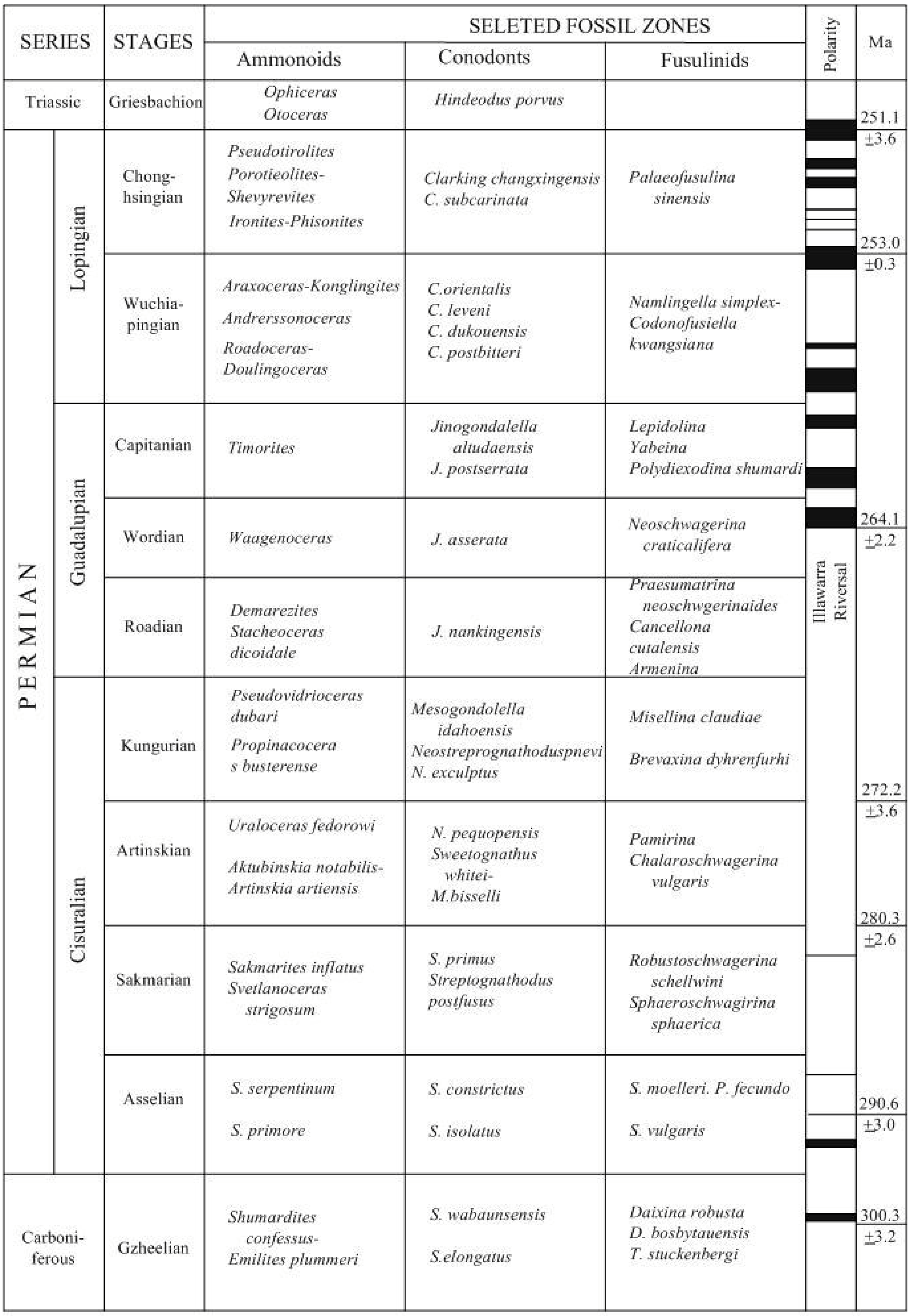


Figure 2-10 Some characteristics for the ostracode carapace measurement for members of Order Podocopida, *Bairdia* sp. is the example (slightly modified from Crasquin 1984)



Period 251+/-2		Brown et al. (1951)	Javanaphet (1969)	Charoenprawat and Wongwanich (1976) Loei-Nong Bua Lumphu	Nakornsri (1977; 1981) Nakhon Sawan-Lopburi	Hinthong (1981; 1985) Saraburi	Bunopas (1981; 1983) Saraburi-Loei	Chonglakmani *et al.* (1979) Phetchabun-Chaiyaphum	DMR (1992)
PERMIAN	UPPER	RATBURI LIMESTONE	RATBURI GROUP						
	MIDDLE			RATBURI GROUP Pha Dua formation E-Lert formation	RATBURI GROUP Tak Fa formation	RATBURI GROUP Sap Bon Formation Khao Khad Formation Pang Asok Formation Nong Pong Formation	SARABURI GROUP Dan Sai Shale Saraburi limestone	Nam Duk formation Hua Na Kham formation	SARABURI GROUP Sap Bon Formation Khao Khad Formation Pang Asok Formation Nong Pong Formation
	LOWER			Nam Mahoran formation	Khao Luak formation	Khao Khwang Formation Phu Phe Formation	Khao Luak formation	Pha Nok Khao formation	Phu Phe Formation
295+/-5 CARBONIFEROUS									

Table 2-2 Stratigraphic correlation of Permian rocks in central and northeastern Thailand (modified from Assavapatchara, 1998)



SERIES		STAGES	SELETED FOSSIL ZONES			Polarity	Ma
			Ammonoids	Conodonts	Fusulinids		
Triassic		Griesbachion	*Ophiceras* *Otoceras*	*Hindeodus porvus*			251.1
PERMIAN	Lopingian	Chong-hsingian	*Pseudotirolites* *Porotieolites-Shevyrevites* *Ironites-Phisonites*	*Clarking changxingensis* *C. subcarinata*	*Palaeofusulina sinensis*		±3.6 253.0
		Wuchia-pingian	*Araxoceras-Konglingites* *Andrerssonoceras* *Roadoceras-Doulingoceras*	*C.orientalis* *C. leveni* *C. dukouensis* *C. postbitteri*	*Namlingella simplex-Codonofusiella kwangsiana*		±0.3
	Guadalupian	Capitanian	*Timorites*	*Jinogondalella altudaensis* *J. postserrata*	*Lepidolina* *Yabeina* *Polydiexodina shumardi*		
		Wordian	*Waagenoceras*	*J. asserata*	*Neoschwagerina craticalifera*	Illawarra Riversal	264.1 ±2.2
		Roadian	*Demarezites* *Stacheoceras dicoidale*	*J. nankingensis*	*Praesumatrina neoschwgerinaides* *Cancellona cutalensis* *Armenina*		
	Cisuralian	Kungurian	*Pseudovidrioceras dubari* *Propinacoceras busterense*	*Mesogondolella idahoensis* *Neostreprognathoduspnevi* *N. exculptus*	*Misellina claudiae* *Brevaxina dyhrenfurhi*		272.2
		Artinskian	*Uraloceras fedorowi* *Aktubinskia notabilis-Artinskia artiensis*	*N. pequopensis* *Sweetognathus whitei-M.bisselli*	*Pamirina* *Chalaroschwagerina vulgaris*		±3.6 280.3
		Sakmarian	*Sakmarites inflatus* *Svetlanoceras strigosum*	*S. primus* *Streptognathodus postfusus*	*Robustoschwagerina schellwini* *Sphaeroschwagirina sphaerica*		±2.6
		Asselian	*S. serpentinum* *S. primore*	*S. constrictus* *S. isolatus*	*S. moelleri. P. fecundo* *S. vulgaris*		290.6 ±3.0
Carboni-ferous		Gzheelian	*Shumardites confessus-Emilites plummeri*	*S. wabaunsensis* *S.elongatus*	*Daixina robusta* *D. bosbytauensis* *T. stuckenbergi*		300.3 ±3.2

Table 2-1 Permian Chronostratigraphic Subdivision approved by the Permian Subcommission, ICS (Yugan *et al*., 1997)

CHAPTER III

METHODOLOGY

The methodology of this study can be categorized into four stages, the preparation, the field investigation, the laboratory work, and the taxonomic study, data interpretation and thesis writing.

3.1 Preparation

The preparation for the study started with the review of previous works of general geology and paleontology of the Permian in Thailand, emphasizing on the area near the study section, the review of fossil ostracodes and previously published taxa, the review of the uses of ostracodes for paleoenvironmental and paleobiogeographic interpretation; and the review of technique for fossil ostracode extraction.

3.2 Field Investigations

The preliminary field investigation was done in northeastern (Loei) and central (Phetchabun, Lopburi) Thailand where Permian rocks are widely exposed. Calcareous rock samples, mainly limestone, were collected randomly and carried back to the laboratory for processing. Limestone samples from the Bung San Phan locality, Phetchabun area, yielded many fossil ostracodes. Consequently, this locality has been chosen as the study section for systematic collection of samples.

The second field investigation was carried out in July, 2003, for measurement of the study section and systematic sampling of rock samples. From both field trips, 17 rock samples were collected.

3.3 Laboratory Work

Seventeen rock samples (mainly limestone) from the study section were prepared in the laboratory for fossil ostracode extraction. The laboratory work was carried out at the Center of Scientific and Technological Equipment, Suranaree University of Technology. The technique of hot acetolysis of Lethiers & Crasquin-Soleau (1988) was applied (Figs. 3-1 and 3-2). This technique is suitable for all calcareous rocks. Rocks are slowly digested by organic acid without strong chemical activity.

Technique of ostracode extraction

1) The rock samples are broken into small pieces and dried overnight at 100°C.

2) The rock samples are then soaked in acetic acid (conc.99.5%) and heated at 60ºC until chemical reaction occurs.

3) The rock samples are washed over 2, 0.5 and 0.1 mm. mesh and residuals are dried.

4) Fossil ostracode specimens are sorted using a stereomicroscope.

3.4 Taxonomic Study, Data Interpretation and Thesis Writing

3.4.1 Technique of Taxonomic Study

Taxonomic study was based on morphology of ostracode carapaces. SEM photographs were used for classification and description. After sorting the fossil ostracodes from the residues, the fossil ostracodes were photographed by scanning electron microscope (SEM). The systematic determination was based on carapace morphology. Measurement of the fossil ostracode carapaces was done on computer using Microsoft Visio software (Professional 2002 version). Subsequently, the identified taxa were compared to those described in the Permian ostracode literatures.

Data of fossil ostracode measurement which were studied and reported in this study have been computerized in a databank. The database is available through Microsoft Access software, containing information of sampling locality, locality information, rock sample number, lithology, SEM photograph number, SEM photograph, and taxonomic elements such as valve, height, length, cardinal angles, presence of sulcus, presence of lobe, ornamentation, diagnosis, specific name, genus, family or superfamily, and order. Described systematic specimens (dried samples) are stored in the collection at Suranaree University of Technology.

3.4.2 Data Interpretation and Thesis Writing

Percentage of fossil ostracode assemblages from different layers were calculated. Together with geological information, the local environments of deposition were interpreted for the study section. Then thesis writing has been done.

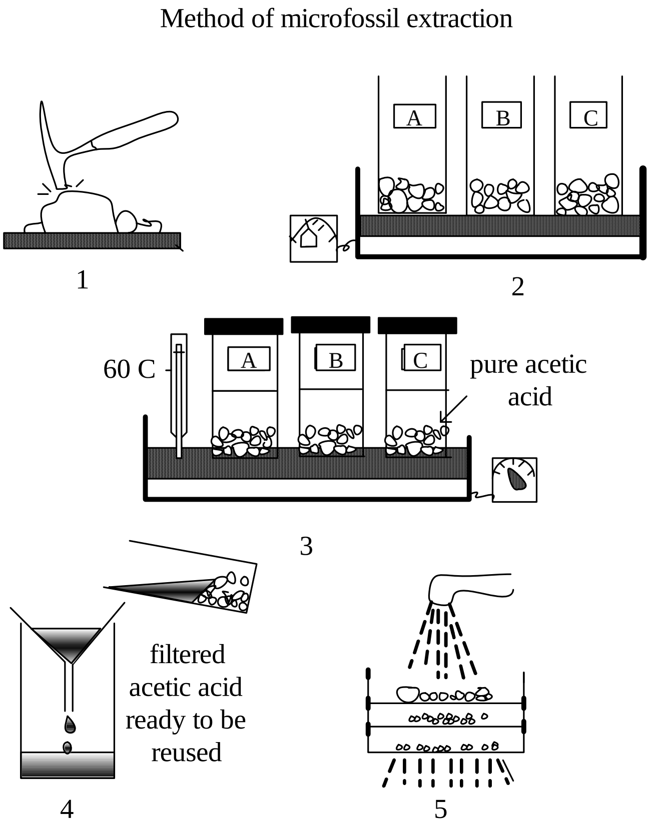


Figure 3-1 Technique of hot acetolysis (slightly modified from Lethiers and Crasquin-Soleau, 1988)

Figure 3-2 Process of hot acetolysis performed at the Center of Scientific and Technological Equipment, Suranaree University of Technology.

CHAPTER IV

RESULTS

4.1 Systematic Paleontology

The summary of described taxa is as follows;

- Subclass OSTRACODA Latreille 1802
  - Order PALAEOCOPIDA Henningmoen 1953
    - Suborder KLOEDENELLOCOPINA Scott 1961
      - Superfamily SANSABELLACEA Sohn 1961
        - Family SERENIDIDAE Rozhdesvenskaya 1972
          - Genus *Sargentina* Coryell and Johnson 1939
            - *Sargentina* sp.1 (Plate 1 Figs. 1-4)
            - *Sargentina* sp.2 (Plate 1 Fig. 5)
      - Superfamily KLOEDENELLACEA Ulrich and Bassler 1908
        - Family BEYRICHOPSIDAE Henningmoen 1953
          - Genus *Geffenina* Coryell and Sohn 1938
            - *Geffenina* sp. (Plate 1 Figs. 6-8)
        - Family KLOEDENELLIDAE Ulrich and Bassler 1923
          - Genus *Jonesina* Ulrich and Bassler, emend. Cooper 1941
            - *Jonesina* sp. (Plate 2 Figs. 1-4)
    - Suborder BERICHIOCOPINA Scott 1951

Superfamily KIRKBYACEA Ulrich and Bassler 1906

Family KIRKBYIDAE Ulrich and Bassler 1906

Genus *Reviya* Sohn 1961

Reviya sp. (Plate 2 Figs. 5-8)

Superfamily HOLLINACEA Swartz 1936

Family HOLLINELLIDAE Bless and Jordan 1971

Genus Hollinella Coryell 1928

Hollinella sp. (Plate 3 Figs. 1-3)

Order PODOCOPIDA Műller 1894

Suborder PODOCOPINA Sars 1866

Superfamily BAIRDIACEA Sars 1888

Family BAIRDIIDAE Sars 1888

Genus *Bairdia* McCoy 1844

Bairdia sp.1 (Plate 3 Figs. 4-8)

Bairdia sp.2 (Plate 4 Figs. 1-3)

Bairdia sp.3 (Plate 4 Figs. 4-8, Plate 5 Figs. 1-2)

Bairdia sp.4 (Plate 5 Figs. 3-4)

Bairdia sp.5 (Plate 5 Figs. 5-6)

Bairdia sp.6 (Plate 5 Figs. 7-8, Plate 6 Fig. 1)

Bairdia sp.7 (Plate 6 Fig. 2)

Genus *Bairdiacypris* Bradfield, 1935

Bairdiacypris sp.1 (Plate 6 Fig. 3)

Bairdiacypris sp.2 (Plate 7 Fig. 4)

Order PLATYCOPIDA Sars 1866

Suborder PLATYCOPINA Sars 1866

Family CAVELLINIDAE Egorov 1950

Genus *Cavellina* Coryell 1928

Cavellina sp. (Plate 7 Figs. 5-7)

4.1.1 Order PALAEOCOPIDA Henningmoen 1953

Suborder KLOEDENELLOCOPINA Scott 1961

Superfamily SANSABELLACEA Sohn 1961

Family SERENIDIDAE Rozhdesvenskaya 1972

Genus *Sargentina* Coryell and Johnson 1939

Suboval to subrhomboidal, inequivalve ostracoda with the right valve larger and overlapping the left all around; hinge straight; dorsum arcuate or slightly sinuate; valves with a single dimple drawn out into a distinct sulcus in the dorsal half.

Sargentina **sp.1**

Plate 1 Figures 1-4

Material: 21 carapaces and 11 fragments

Occurrence: sample No.02TH46,

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Sargentina* with shallow sulcus and anterior margin with maximum convexity located ventrally. Carapace suboval to subelliptical in lateral view, tumid; surface smooth; RV larger than LV and overlapping all around entire carapace; dorsal border straight on LV, convex on RV; PCA obtuse (140°); posterodorsal border bent making a sharp shoulder; posterior margin largely rounded with maximum convexity located at midheight, posteroventral portion oblique; ventral border straight to slightly concave on LV, slightly convex on RV, showing prominent overlap; maximum height located at midlength; anteroventral portion oblique, anterior margin convex but more acute than the posterior one; maximum convexity located at one-third of height (38%); anterodorsal border sloped and slightly convex; ACA obtuse (150°), dimorphism observed as a brood in ventral area.

Dimension:

SEM No.	12	95	133	190	195	204	206	207	216	218	222	225	227
H (mm.)	0.48	0.43	0.36	0.44	0.48	0.35	0.42	0.49	0.38	0.38	0.35	0.38	0.37
L (mm.)	0.8	0.82	0.6	0.77	0.79	0.66	0.72	0.86	0.74	0.74	0.69	0.74	0.71

Discussion: This species is closed to *Sargentina asulcata* Cooper 1941 but differs in having more elongate shape and the position of the anterior margin is lower. The outline of the species resembles that of *Sargentina woutersi* (in Crasquin-Soleau *et al.*, 1999) but is different in having a very straight dorsal border on LV.

Sargentina sp.2

Plate 1 Figure 5

Material: one carapace

Occurrence: sample No.02TH46

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Sargentina* with almost equal height of posterior and anterior margins. Carapace oval in lateral view, tumid; surface smooth; RV larger and overlapping all around entire LV; dorsal border straight to slightly concave on LV, slightly arched on RV; PCA obtuse (158°); posterior margin rounded with maximum convexity located just above midheight; ventral border subequal convex on both valves showing prominently overlap; maximum height located at midlength; anterior margin rounded with maximum convexity located at midheight; anterodorsal border sloped, ACA obtuse (165°); S2 slightly observed in dorsomedian region.

Dimension: Height = 0.41 mm., Length = 0.68 mm.

Discussion: The species resembles *Sargentina tumida* Cooper 1946 that the posterior and anterior margins are of about equal height. The difference is that *S.* sp.2 has a nearly straight to slightly concave dorsal border on whereas the other has a convex dorsal border.

Superfamily KLOEDENELLACEA Ulrich and Bassler 1908

Family BEYRICHOPSIDAE Henningmoen 1953

Genus *Geffenina* Coryell and Sohn 1938

Carapace subelliptical in lateral view; dorsal margin straight; ventral margin straight or boardly convex; end margins rounded; greatest thickness near anterior end; left valve larger overlap the right along free margin; surface of valve marked by a distinct node near the central portion of the posterior half, which is borded on the posterior and ventral sides by submarginal ridge that enlarges forward and merges into hook-like convexity of the anterior half of the valve; a distinct median sinus separates the anterior swelling from the posterior node; hingement sansabelloid; surface smooth or finely granulose.

Geffenina sp.

Plate 1 Figures 6-8

Material: 123 carapaces, 97 fragments

Occurrence: 02TH46 and 02TH46-11

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of elongate, trilobate *Geffenina* with posterior margin located very high. Carapace subelliptical to suboval in lateral view, tumid, surface smooth, RV larger and overlapping on the LV, moderately overlapping all around the carapace and strongly overlapping in ventral area; dorsal border straight to slightly convex on both valves; PCA obtuse (130-140°); posterodorsal border convex on the RV, concave on the LV; posterior margin rounded and laterally flattened with maximum convexity located above midheight (60%); posteroventral border convex on both valves; ventral border convex on RV, nearly straight on LV, maximum height located anteriorly, near L2; anterior margin largely rounded and laterally flattened with maximum convexity located below midheight; ACA obtuse(140-150°); S1 present; S2 elongate with the lower part located in dorsomedian region; L2 prominent;

dimorphism distinctive in posterior part; dorsal view trilobate, subfusiform, maximum thickness located in posterior part; hinge strongly invaginated.

Dimension:

SEM No. 131, Height = 0.33 mm., Length = 0.60 mm.

SEM No. 134, Height = 0.41 mm., Length = 0.75 mm.

SEM No. 208, Height = 0.37 mm., Length = 0.68 mm.

SEM No. 218, Height = 0.42 mm., Length = 0.85 mm.

Discussion: The species is classified into the genus *Geffenina* because of the presence of invagination and of a distinctive median sinus. The species is quite different from other members of the genus in having a more elongate shape, well defined cardinal angles and a trilobate form.

The specimens are different from *Geffennia wangi* described from the Middle Permian of central Oman (from Crasquin-Soleau, 2003) in the trilobate form and the deeper elongate S2.

Family KLOEDENELLIDAE Ulrich and Bassler 1923

Genus *Jonesina* Ulrich and Bassler, emend. Cooper 1941

Carapace ovate to elongate, thin to obese, greatest thickness posterior; lateral outline varied from subelliptical to parallelogram; valves unequal; overlap around entire free margin usually prominent; variously lobed; hinge straight, obscurely cardine, about two-third as long as total length of shell; median sulcus opening into cardinal area, usually deep and elongate, surface smooth or reticulate.

***Jonesina* sp.**

Plate 2 Figures 1-4

Material: 98 carapaces, 56 fragments

Occurrence: sample No.02TH46

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Jonesina* with anterior margin located very ventrally that lower than the position of the posterior one. Carapace suboval and elongate in lateral view, tumid, preplete, surface smooth to finely reticulate, RV larger and overlapping slightly around LV except in dorsal area; dorsal border straight; PCA obtuse (130-150°), posterodorsal border slightly convex; posterior margin rounded with small radius of curvature and flattened laterally, maximum convexity located very high (73% of height); posteroventral border slightly convex; ventral border convex on both valves; anterior margin largely rounded with maximum convexity located below mid height (31% of height); anterior part oblique; ACA obtuse (145-150°); S1 not observed; S2 distinctive with deep and elongate shape located in dorsomedian to median region; ventral lobe present as dimorphism; dorsal view bilobate with greatest thickness in median to posterior region; hinge with out invagination.

Dimension:

SEM No. 037, Height = 0.34 mm., Length = 0.66 mm.

SEM No. 126, Height = 0.47 mm., Length = 0.90 mm.

SEM No. 135, Height = 0.31 mm., Length = 0.56 mm.

SEM No. 166, Height = 0.30 mm., Length = 0.62 mm.

SEM No. 209, Height = 0.26 mm., Length = 0.57 mm.

SEM No. 214, Height = 0.30 mm., Length = 0.56 mm.

Discussion: The species is different from the type genus as described by Egorov (1950) in the ventral location of the anterior margin, which is lower than the posterior end. Dimorphism is present as a brood pouch in the posterior portion showing inflation and convexity toward the anterior margin.

Suborder BERICHIOCOPINA Scott 1951

Superfamily KIRKBYACEA Ulrich and Bassler 1906

Family KIRKBYIDAE Ulrich and Bassler 1906

Genus *Reviya* Sohn 1961

Straight-backed, subelliptical tumid reticulated marine ostracodes with out nodes or carinae and with elongate subcentral pit; differs from *Knightina* Kellett, 1933, by the absence of dorsoposterior shoulder, and from *Arcyzona* Kesling, 1952, in that the inner ridge in not thicken.

***Reviya* sp.**

Plate 2 Figures 5-8

Material: 27 carapaces, 19 fragments

Occurrence: 02TH46, 02TH46-07 and 02TH46-11

Pha Nok Khao Formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Reviya* with thick smooth edge extending from cardinal angle, subparallel to entire free margin and presence of posterodorsal shoulder. Carapace subquadrate in lateral view, tumid, surface coarse, thickly reticulated with thick smooth edge subparallel to entire free margin; subequal valves, RV slightly larger than the LV, overlap observable in anterodorsal area; anterior part and posterior part oblique; dorsal border straight and prolonged by posterior shoulder; PCA unclear; posterior margin rounded with maximum convexity located at mid height equal to the anterior margin; ventral border slightly concave, the greatest height located in anteroventral portion; anterior end rounded; ACA clear, obtuse (136°); elongate central pit observed.

Dimension:

SEM No. 020, Height = 0.37 mm., Length = 0.67 mm.

SEM No. 036, Height = 0.33 mm., Length = 0.61 mm.

SEM No. 067, Height = 0.40 mm., Length = 0.76 mm.

SEM No. 088, Height = 0.37 mm., Length = 0.65 mm.

SEM No. 090, Height = 0.37 mm., Length = 0.65 mm.

SEM No. 136, Height = 0.38 mm., Length = 0.71 mm.

SEM No. 171, Height = 0.31 mm., Length = 0.56 mm.

Discussion: *Reviya* sp. is different from *Reviya obesa,* the type species, is that *R. obesa* has a slightly convex ventral margin and the larger L/H ratio.

Superfamily HOLLINACEA Swartz 1936

Family HOLLINELLIDAE Bless and Jordan 1971

Genus *Hollinella* Coryell 1928

Lobes consisting of low gently arched L_1 confluent in most species with ventral lobe, L_2 distincly nodelike (in some forms partly confluent with L_1) and set below dorsal border, L_3 larger and bulbous, L_4 ill defined, ventral lobe (prominent in many species) connecting L_1 and L_4 and located between frill and ventral end of wide S_2; female with somewhat incurved long frill extending from anterior corner of valves to posteroventral part; male with outward-flaring frill that in most forms is narrower than frill of female. Dimorphism distinct to very distinct.

Hollinella **sp.**

Plate 3 Figures 1-3

Material: 4 carapaces

Occurrence: sample No.02TH46

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of preplete *Hollinella*. Carapace suboval in lateral view; two or three nodes protruded but not well preserved; dorsal margin straight; PCA 100-120°, ACA 115-130°; posterior margin rounded with maximum convexity located at mid height; anterior margin rounded with large radius of curvature, maximum convexity located ventrally, at about one-thirds of height; fringe obscured; S1 not distinct, S2 observerd in dorsomedian region.

Dimension:

SEM No. 035, Height = 0.32 mm., Length = 0.59 mm.

SEM No. 057, Height = 0.29 mm., Length = 0.52 mm.

SEM No. 067, Height = 0.25 mm., Length = 0.46 mm.

Discussion: Due to poor preservation, identification is difficult. The characters of the species are suited to the genus but comparison to other described taxa is not possible.

4.1.2 Order PODOCOPIDA Műller 1894

Suborder PODOCOPINA Sars 1866

Superfamily BAIRDIACEA Sars 1888

Family BAIRDIIDAE Sars 1888

Genus *Bairdia* McCOY 1844

Carapace mostly elongate, fusiform in lateral view, with broadly arched dorsal that becomes concave terminally, especially upward terminally so that extremities are nearly at mid-height, anterior end generally higher and better rounded than the posterior which generally acuminate; in dorsal view, lateral outlines symmetrically convex and extremities acuminate; surface of valves smooth, punctuate, or rarely with protuberances; LV larger than RV, mostly overreaching it around contact margin. Short ridge and groove hingement commonly marked by prominent cardinal angles, especially in RV; contact margins complex with wide duplicature, vestibule, and associated structures; adductor-muscle scar pattern of several discrete spots.

***Bairdia* sp.1**

Plate 3 Figures 4-8

Material: 34 carapaces, 4 fragments

Occurrence: sample No.02TH46-07

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Bairdia* with a very large and elongate carapace, anterior margin largely convex, posterior end tapering. Carapace subrectangular in lateral view, laterally flattened, surface smooth; LV larger and overlapping all around the RV especially for dorsal margin; dorsal outline slightly convex, dorsal border straight on both valves; hinge short; anterodorsal border long, slightly convex on LV, straight and concave terminally on RV; a tip of anterodorsal border turnning up; anterior margin rounded with small radius of curvature, maximum convexity located at midheight; anteroventral border slightly convex on both valves; posteroventral border slightly convex, posterior end tapering with maximum convexity located below midheight; posterodorsal border straight to slightly convex; angle between posterodorsal border and dorsal border 148°, between dorsal border and anterodorsal border 166°; maximum height located at midlength.

Dimension

SEM No. 071, Height = 0.72 mm., Length = 1.40 mm.

SEM No. 072, Height = 0.65 mm., Length = 1.50 mm.

SEM No. 073, Height = 0.71 mm., Length = 1.46 mm.

SEM No. 127, Height = 0.68 mm., Length = 1.51 mm.

SEM No. 270, Height = 0.67 mm., Length = 1.54 mm.

SEM No. 271, Height = 0.48 mm., Length = 1.00 mm.

SEM No. 274, Height = 0.67 mm., Length = 1.20 mm.

Discussion: The species is very large. Most specimens are compressed by the process of taphonomy. The species should be classified into the genus *Rectobairdia* by the shape of carapace. In lateral view, the species is similar to *R. fermata* (in Chen and Shi, 1982) which has been reported from the Upper Permian of China. However, *Rectobaridia* is included in *Bairdia* by many authors.

The species is also similar to *Arcibairdia bogdani* (in Gramm, 1997) which has been reported from the Upper Permian of Russia. The genus *Arcibairdia* was proposed for *Bairdia* sp. with a case-like appearance. However, they are different in dorsal view outline, *A. bogdani* is hexagonal whereas *Bairdia* sp.1 is oval.

***Bairdia* sp.2**

Plate 4 Figures 1-3

Material: 8 carapaces

Occurrence: 02TH46-07, 02TH46 and 02TH46-08

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Bairdia* with a short carapace, moderately overlapping with a short posterodorsal border. Carapace suboval in lateral view; surface smooth; LV moderately overlapping on RV all around the carapace, especially in dorsal border and ventral border; dorsal outline convex, hinge short; dorsal border straight; anterodorsal border nearly straight; anterior end rounded with small radius of curvature, maximum convexity located at midheight, anteroventral border nearly straight; ventral border concave on RV, nearly straight on LV; posteroventral border short and nearly straight; posterior margin tapering, maximum convexity located ventrally at 27% of height; posterodorsal border nearly straight on both valves; angle between dorsal border and posterodorsal border 160-175°, between dorsal border and anterodorsal border 150-160°; maximum height located at midlength.

Dimension:

SEM No. 092, Height = 0.36 mm., Length = 0.64 mm.

SEM No. 260, Height = 0.48 mm., Length = 0.76 mm.

SEM No. 264, Height = 0.36 mm., Length = 0.55 mm.

Discussion: The species resembles *Bairdia altiacus* (in Chen, 1958) in lateral view. The difference is that the arched dorsal border of *B. altiacus* is located nearly at midlength whereas it is located more anteriorly in *B*. sp.2. The anteroventral margin of *B. altiacus* is broadly rounded whereas it is narrower in *B*.sp.2. The posterodorsal point of *B*. sp.2 is located at a lower position.

***Bairdia* sp.3**

Plate 4 Figures 4-8, Plate 5 Figures 1-2

Material: 18 carapace

Occurrence: sample No.02TH46-07

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Bairdia* with elongate carapace with truncated antero-ventral and posteroventral borders. Carapace subfusiform to suboval in lateral view, surface smooth to finely granulose, LV overlapping on RV all around the carapace, moderately overlap observed in dorsal area; laterally flattened in anterior and posterior portions; dorsal border equally arched; hinge short, almost horizontally; anterodorsal border long and concave, anterior margin curve with small radius of curvature, maximum convexity located above midheight (61%); anteroventral border nearly straight; ventral border equally convex with truncation of anteroventral and postreoventral points; ventral border prolonged to tapering posterior margin located at 30% of height; posterodorsal border bent in the lower part but slightly convex in the upper part; angle between dorsal border and posterodorsal border 150-160°, between dorsal border and anterodorsal border 155-165°; maximum height located in front of midlength.

Dimension:

SEM No. 058, Height = 0.44 mm., Length = 0.86 mm.

SEM No. 060, Height = 0.60 mm., Length = 1.25 mm.

SEM No. 091, Height = 0.40 mm., Length = 0.81 mm.

Discussion: The species is similar to *Ceratobairdia?* sp. which has been reported from the Upper Permian of China (Chen and Shi, 1982). The description is in Chinese, so the comparison is not possible at the moment. However, the genus *Ceratobairdia* of Sohn (1954) resembles the genus *Bairdia* with the presence of ventral alae and one or more centerodorsal spines or knobs. Neither ventral alae nor spine is found in this species.

***Bairdia* sp.4**

Plate 5 Figures 3-4

Material: 6 carapaces, 5 fragments

Occurrence: sample No.02TH46 and 02TH46-07

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Bairdia* with equal height of anterior and posterior margins. Carapace subtriangular in lateral view, surface smooth; laterally flattened; LV overlapping around RV; dorsal outline convex; dorsal border slightly convex; anterodorsal border straight and steep; anterior margin rounded with small radius of curvature, maximum convexity located lower than midheight (39%); anteroventral border short and slightly convex; ventral border concave on RV, nearly straight on LV showing strongly overlapping; maximum height located at midlength; posteroventral border short and slightly convex; posterior margin rounded with small radius of curvature, maximum convexity located at 39% of height; posterodorsal border steep, bent in lower part, nearly straight in upper part; angles between dorsal and posterodorsal border, and between dorsal and anterodorsal border equally 150°.

Dimension:

SEM No. 014, Height = 0.43 mm., Length = 0.84 mm.

SEM No. 267, Height = 0.82 mm., Length = 1.39 mm.

Discussion: The specimens are compressed, possibly due to taphonomic process. The species is similar in lateral view to *Praelobobairdia silenitiformis* which has been reported from Hungary (Kozur 1985) and Israel (Gerry *et al.,* 1987). However, configuration is not enough to justify.

***Bairdia* sp.5**

Plate 5 Figure 5-6

Material: 2 carapaces

Occurrence: sample No.02TH46 and 02TH46-07

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Bairdia* with elongate carapace, posterior portion thicker than anterior portion. Carapace subelliptical and arched in lateral view; surface smooth; moderately overlapping all around the carapace; dorsal outline convex, hinge long; dorsal border nearly straight on RV, convex on LV; anterodorsal border long, nearly straight, slightly concave in lower part; anterior end rounded with small radius of curvature, maximum convexity located ventrally at one-third of height; anteroventral border slightly convex; ventral border concave on both valve; posteroventral border slightly convex; posterior end rounded with small radius of curvature, maximum convexity located ventrally at one-forth of height; posterodorsal border slightly concave in lower part but slight convex in upper part; angle between dorsal border and posterodorsal border 148-168°, between dorsal border and anterodorsal border 160-140°; maximum height located posteriorly.

Dimension

SEM No. 259, Height = 0.55 mm., Length = 1.30 mm.

SEM No. 269, Height = 0.71 mm., Length = 1.70 mm.

Discussion: The species is very distinctive but some characteristics still overlap between *Bairdia* and *Bairdiacypris*. Bairdian shape is still prominent but maximum height lacated posteriorly.

***Bairdia* sp.6**

Plate 5 Figures 7-8, Plate 6 Figure 1

Material: 3 carapaces

Occurrence: sample No.02TH46

Pha Nok Khao Formation, Bung Sam Phan District, Phetchabun
Middle Permian

Description: Species of *Bairdia* with elongate carapace and straight dorsal border. Carapace subfusiform in lateral view, surface smooth, slightly overlapping all around the carapace; hinge long, almost horizontally; dorsal border straight; anterodorsal border nearly straight, slightly concave on RV; anterior end rounded with small radius of curvature, maximum convexity located at midheight; anteroventral border long and slightly convex; anteroventral and posterior points prominent, maximum height located at this point; ventral border slightly concave; posteroventral border straight, shorter than anteroventral border; posterior end tapering with maximum convexity located at one-thirds of height; posterodorsal border steep, slightly concave at the lower part, nearly straight at the upper part; angle between dorsal border and posterodorsal border = 150°, between dorsal border and anterodorsal border = 168°.

Dimension

SEM No. 043, Height = 0.28 mm., Length = 0.69 mm.

SEM No. 045, Height = 0.34 mm., Length = 0.79 mm.

SEM No. 263, Height = 0.34 mm., Length = 0.84 mm.

Discussion: The species looks similar to *Bairdia piscariformis* (in Chen, 1958) in lateral view, especially in ventral part. However, *B. piscariformis* has the arched dorsal border whereas *B.* sp.6 has the straight one.

Bairdia sp.7

Plate 6 Figure 2

Material: one carapace

Occurrence: sample No.02TH46

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Bairdia* with elongate carapace, tapering anterior and posterior margins. Carapace subfusiform in lateral view; dorsal outline slightly arched; dorsal border slightly convex; anterodorsal and posterodorsal borders long and upward terminally; anterior margin tapering and sharply pointed with maximum convexity located at 62% of height; anteroventral border long and straight; anteroventral point prominent; ventral border concave on RV, nearly straight on LV; posteroventral border long and slightly convex; posterior end tapering and sharply pointed with maximum convexity located at 35% of height; angle between dorsal and posterodorsal borders 158°, between dorsal and anterodorsal borders 160°; maximum height located at midlength.

Dimension: Height = 0.54 mm., Length = 1.21 mm.

Discussion: This species looks similar to *Bairdia trianguliformis* (in Chen, 1958) in lateral view but different is the more blunt dorsal border and the more acute in anterior part.

Family BAIRDIIDAE Sars 1888

Genus *Bairdiacypris* Bradfield, 1935

Elongate, subreniform, resembling *Argilloecia* in lateral view but with slight angulaton and nearly straight dorsal slopes suggestive of *Bairdia*.

***Bairdiacypris* sp.1**

Plate 6 Figure 3

Material: one carapace

Occurrence: sample No.02TH46-07

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun
Middle Permian

Description: Species of *Bairdiacypris* with strongly overlap in dorsal and ventral part. Carapace elongate, subelliptical in lateral view; dorsal outline slightly convex; dorsal border broadly arched with truncation of anterior and posterior portions; anterodorsal border long, nearly straight; anterior margin rounded with maximum convexity located at midheight; anteroventral border short, nearly straight; ventral border slightly concave on LV, straight on RV; posteroventral border short, nearly straight; posterior end rounded with maximum convexity located at mid height; posterodorsal border short and slightly convex.

Dimension: Height = 0.27 mm., Length = 0.56 mm.

Discussion: The species is similar to *Bairdia longirobusta* Chen (1958) from the Lower Permian of North China. But the carapace of *B. longirobusta* is more arched and the overlapping is more prominent at dorsal border.

***Bairdiacypris* sp.2**

Plate 6 Figure 4

Material: one carapace

Occurrence: sample No.02TH46

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun
Middle Permian

Description: Species of *Bairdiacypris* with elongate carapace, strong overlapping in dorsal area, posterior margin located ventrally, anterior end located dorsally. Carapace long and slightly arched, surface smooth, slightly overlapping all around the carapace, weakly overlap in anterior and posterior portions; dorsal outline convex; dorsal border broadly arched; anterodorsal border long and slightly convex, anterior margin rounded with small radius of curvature, maximum convexity located below midheight (41%); anteroventral border slightly convex; anteroventral and posteroventral points developed; ventral border equally concave on both valves; posteroventral slightly convex; posterior margin rounded with small radius of curvature, located ventrally, at 29% of height; posterodorsal border short, slightly convex; maximum height located at midlength.

Dimension: Height = 0.34 mm., Length = 0.78 mm.

Discussion: The species is similar to *Bairdiacypris postrectiformis* (in Lethiers *et al*., 1989) in lateral view. The two species are different in position of maximum height, in *B. postrectiformis* it is located in posterior area, in *B.* sp.2 locate at mid length; the ventral border of *B. postrectiformis* is nearly straight with distinct ventral overlapping lip which is not present in *B.* sp.2.

4.1.3 Order PLATYCOPIDA Sars 1866

Suborder PLATYCOPINA Sars 1866

Family CAVELLINIDAE Egorov 1950

Genus *Cavellina* Coryell 1928

Carapace oblong to ovate in lateral view, dorsum moderately arched, venter slightly concave to convex, ends rounded, with posteroventral and posterodorsal extremities slightly to moderately truncated; subovate in dorsal view, posterior end thicker than anterior, especially pronounced in female; surface smooth; contact margin of right (larger) valve grooved along inner edge so as to receive edge of smaller valve which may be more subangular than right valve marginally; sexual dimorphism expressed by short, higher, and thicker carapace of females especially in posterior part, with inner body cavity is more fully developed than in male; some species show tendency to develop shallow muscle-scar pit and posterior rim or ridge

***Cavellina* sp.**

Plate 6 Figures 5-7

Material: 74 carapaces

Occurrence: sample No. 02TH46-07 and 02TH46

Pha Nok Khao formation, Bung Sam Phan District, Phetchabun

Middle Permian

Description: Species of *Cavellina* with elongate, tumid carapace. Carapace suboval in lateral view, the posterior part larger than the anterior one; surface smooth with moderately overlapping of RV on LV; dorsal outline arched; dorsal border arched; anterodorsal border long and nearly straight; anterior margin rounded with small radius of curvature, maximum convexity located ventrally, at one-third of height; anteroventral border and posteroventral border short and slightly convex; ventral border straight; posterior margin rounded with large radius of curvature; maximum convexity located at midheight; posterodorsal border truncated.

Dimension:

SEM No. 023, Height = 0.32 mm., Length = 0.53 mm.

SEM No. 040, Height = 0.26 mm., Length = 0.49 mm.

SEM No. 041, Height = 0.26 mm., Length = 0.46 mm.

SEM No. 194, Height = 0.38 mm., Length = 0.73 mm.

SEM No. 197, Height = 0.38 mm., Length = 0.72 mm.

SEM No. 205, Height = 0.25 mm., Length = 0.43 mm.

SEM No. 213, Height = 0.31 mm., Length = 0.58 mm.

Discussion: The species is similar to *Cavellina boomeri* (in Crasquin-Soleau *et al.*, 1999) but differs in size of radius of curvature in anterior margin whereas *C. boomeri* is larger. And the maximum convexity of anterior margin in *C.* sp. is located lower than *C. boomeri.*

4.2 Interpretation of Paleoenvironment

Ostracodes are known to be one of the most usefulness microfossils for paleoenvironmental reconstruction. The common interpretation can be done by considering fossil ostracode assemblages at superfamily/family level. Ostracode members of each superfamily/family are likely to prefer the same environmental condition. Melnyk and Maddocks (1988) were those researchers who figured out the paleoenvironmental models of ostracodes by analyzing data about Permo-Carboniferous ostracodes from North American literature. Their study demonstrates the distinctive nature of ostracode superfamilies in the very shallow shoreline to the continental shelf. Their model is shown in Fig. 4-1 and part of the contribution relevant to the study can be summarized as follows;

The Hollinacea are ubiquitous and overall species diversified increasingly off shore. The species with large size and heavy frill seem to have tolerated high terrigenous sedimentation rates and lived closer to the paleoshoreline. The species of small size and more delicate forms seem to prefer deeper conditions.

Within the Bairdiacea, several species of the *Acratia* are ubiquitous with large dispersions and were perhaps swimmers. The *Bairdia* diversity was very high in offshore environments with low terrigenous sedimentation, although several species appear to be tolerated muddier, shallower conditions. Most *Bairdiacypris* inhabited nearshore environments. Members of the genera *Cryptobairdia* and *Orthobairdia* appear to have been more eurytopic than species of *Bairdia* but the highest diversity still occurs offshore in calcareous mudstone. Of the two genera, Cryptobairdiids appear to have been slightly more tolerant offshore conditions than Orthobairdiids. Species of *Rectobairdia* and *Bairdiacypris* were propably the most eurytopic of the superfamily.

The sulcate and smooth Kloedenellacea were ubiquitous, some species show relatively large dispersion along the coenocline. Species of *Giesina* lived in nearshore environments. The species of the genus *Oliganisus*, along with the *Knoxina* and *glyptopleura*, prefered slightly deeper water condition.

For Cytherellacae, members of the *Cavellina* were eurytopic. The large, robust species adapted to relatively nearshore environments, while the smaller forms lived slightly farther offshore. *Sulcella sulcata* Coryell and Sample 1932, appear to be a ubiquitous species while *Cavellina pricei* Sohn 1983 is a good offshore indicator.

Within Kirkbyacea, the well ornamented species of Amphissitidae and Scrobiculinidae appear to be restricted to offshore environments. However *Kegelites dattanensis* Harlton 1927, *Amphissites carinodus* Cooper 1946 and *A. girty*i Knight 1928 can be indicator for nearshore habitats. The heavily ornamented kirkbyidae are offshore dwellers. Species of *Coronakirkbya* are consistently found in deep water. *Kellettina robusta* Kellett 1993 is offshore indicator. *Kellettina montosa* Knight 1928 and *Kindella* sp. *aff K. Fissoloba* Sohn 1954 were propably tolerant of terrigeneous substrates and may have lived at shallower depth.

Nevertheless, in this study the fossil ostracode assemblages can be established from some selected layers due to the abundant presence and well preservation of fossil ostracodes in some specific layers. Fossil ostracodes have been found from 7 rock samples; 02TH46-02, 02TH46-06, 02TH46-07, 02TH46-08, 02TH46-11, 02TH46 and 02TH46-13 in ascendent order (Figs. 4-2 and 4-3).

The sample No.02TH46-02 yielded 8 poorly preserved specimens which belong to superfamily Kloedenellacea.

The sample No.02TH46-04 yielded 20 specimens of which 17 specimens belong to superfamily Bairdiacea and 3 specimens to Kloedenellacea. *Bairdia* sp.3, *B*. sp.7 and *Bairdiacypris* sp.2 are recognized.

The sample No.02TH46-06 yielded 14 specimens which belong to Bairdiacea and Cavellinidae. *Bairdia* sp.2 and *B*.sp.6 are recognized.

The sample No.02TH46-07 yielded plenty of fossil ostracode, its assemblage was studied in detail (Fig. 4-4 a).

The sample No.02TH46-08 yielded 26 specimens, 15 of them belong to Bairdiacea (*Bairdia* sp.1 and *B*.sp.2 are recognized), 9 belong to Kloedenellacea, and 2 cavellinids.

The sample No.02TH46-11 yielded many fossil ostracodes but they are all poorly preserved and can only be assigned to superfamily Kloedenellacea. Its assemblage was analyzed (Fig. 4-4 b).

The sample No.02TH46 yielded plenty of fossil ostracodes, the assemblage was also studied (Fig. 4-4 c).

The sample No.02TH46-13 yielded 35 specimens and fragments which belong to Kloedenellacea, Kirkbyacea, and Bairdiacea. *Reviya* sp. is recognized.

The occurrence of all fossil ostracode of the section is illustrated in Fig. 4-3. The percentage of each superfamily/family is calculated by using numbers of the complete carapace only.

Paleoenvironmental analysis of the selected layers from the Bung Sam Phan area can be summarized as follows;

4.2.1 Sample No. 02TH46-07

Superfamilies/family found in the rock sample are Kloedenellacea (6.2%), Cavellinidae (2.5%), Kirkbyacea (22%), and Bairdiacea (69.1%). Because the Bairdiacea are the most abundant and diversified in this layer, it suggests that the condition should be somewhat further offshore. The members of this superfamily are then considered for more detail. The presence of mostly *Bairdia,* rarely *Bairdiacypis* and without other genera confirms the deeper water condition. *Bairdia* sp.1 occupied the largest number, and *B*. sp.3, *B*. sp.4, *B*. sp.4, and *B*. sp.2 and *Bairdiacypris* sp.2 are decreased respectively. Most specimens of *Bairdia* are large with thick carapace suggested that they might have lived as dwellers in a calm environment, far from shoreline. The specimens are highly compressed and destroyed and they may indicate the abrupt deposition of sedimentary load. These fossil ostracodes were recovered from limestone rock sample which is very dark grey, biopelmicritic with fossil gastropods and small fossil faunas.

4.2.2 Sample No. 02TH46-11

Most of fossil ostracodes (93.8%) found in this sample belong to superfamily Kloedenellacea. Unfortunately, they are preserved as molds of calcite which can not be identified to generic level. The presence of large amount of Kloedenellids represents the shallow water environment. The rock sample is dark grey, fossiliferous micritic limestone with presence of fossil brachiopods.

4.2.3 Sample No. 02TH46

Superfamilies/family found in this rock sample are Kloedenellacea (70.5%), Sansabellacea (5.1%), Cavellinidae (10%), Kirkbyacea (1.7%), Bairdiacea (9.3%), Hollinacea (0.6%), and other (2.1%). This level was occupied mostly by members of Kloedenellacea including genera *Geffenina*, *Jonesina*, and unidentified species. Generally, members of Kloedenellacea are ubiquitous. Many genera are known to prefer shallow water condition whereas several highly ornamented species are likely to prefer deep water condition. The sulcate and smooth forms appear to be dispersed along the shoreline where environmental gradients are changing. The presence of smooth, tri- and bi- lobate *Geffenina* and *Jonesina*, respectively, suggests the shallow water condition. Average size of Kloedenellids found in the rock sample is small with subrounded shape, representing high energy condition. Members of *Cavellina* are minor occupants. They are small in size but are of the large form of the genus. Large Cavellinids also confirm the nearshore environment. Members of Bairdiacea, occupied 9.3%, are of smaller size than in sample 02TH46-07. The giant *Bairdia* sp.1 is absent. This may point to higher energy condition of deposition of 02TH46 layer. These fossil ostracodes were recovered from limestone which is dark grey, fossiliferous, intramicritic limestone with many fossil faunas such as crinoids, fusulinids, and a trilobite.

4.2.4 The Total Rock Samples from the Study Section

The local paleoenvironment of this locality can be interpreted by using percentage of superfamilies/family of total fossil ostracodes recovered from the section. This interpretation seems to be more rough than the previous ones, but the overall local paleoenvironment can be deferred. Kloedenellacea occupied 62.97%, Bairdiacea 18.41%, Cavellinidae 7.96%, Kirkbyacea 5.16%, Sansabellacea 3.95%, Hollinacea 0.43%, and other 1.506% (Fig 4-4 d). So, it was likely to be shallow water condition in nearshore environment during the time of deposition.

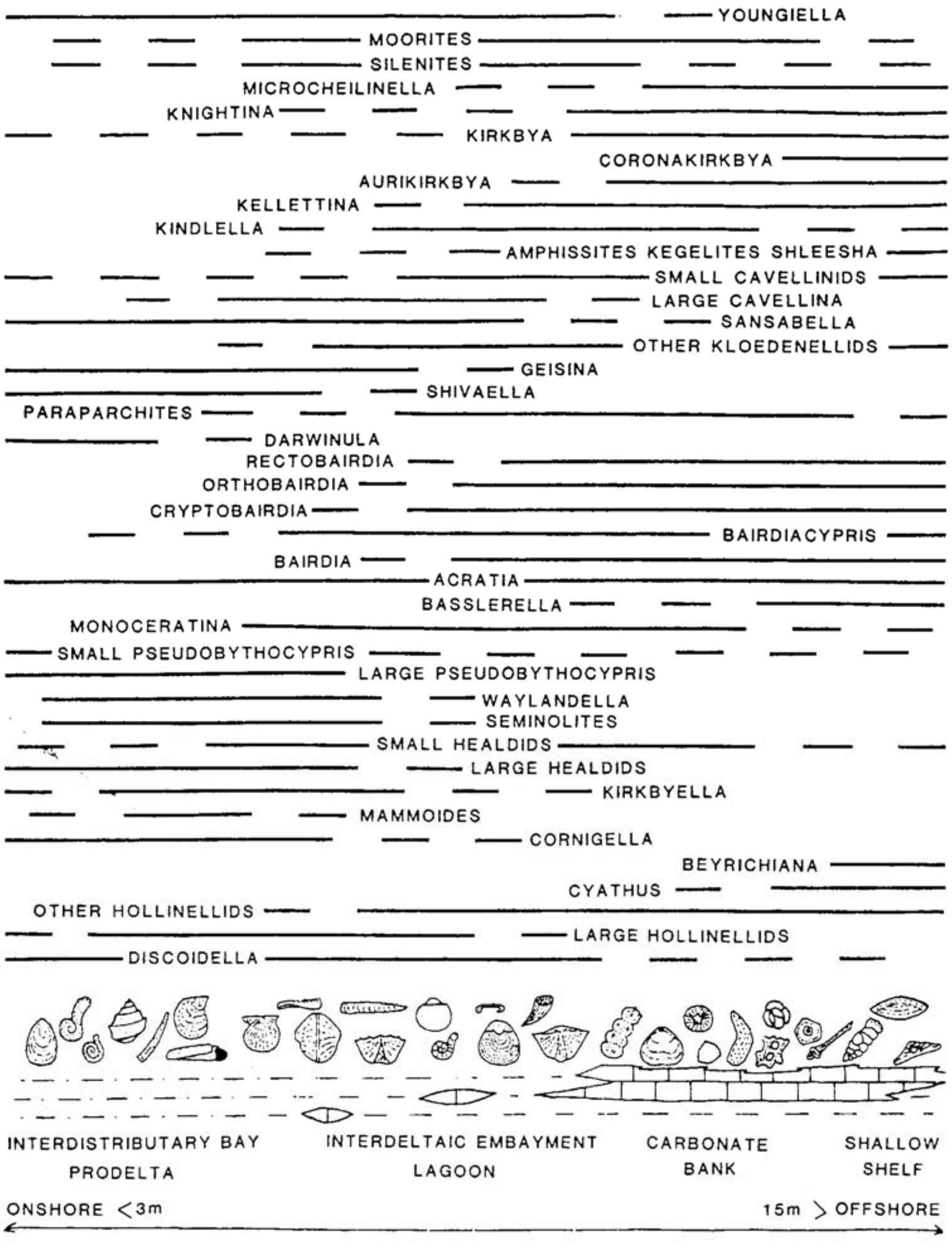


Figure 4-1 The generalized distributions of genera and larger groups along the inferred coenocline (Melnyk and Maddocks, 1998)

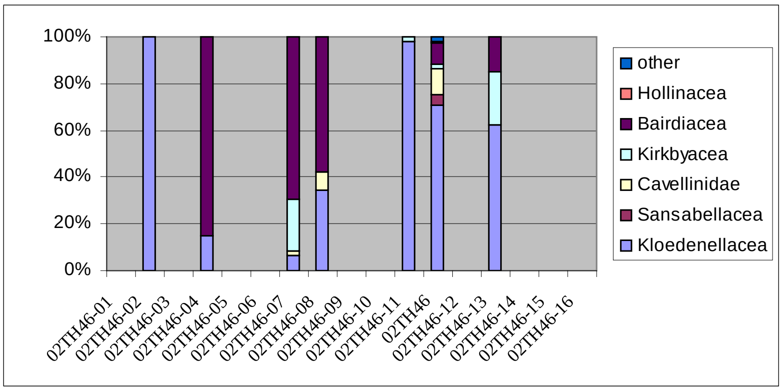


Figure 4-2 Percentage of ostracode superfamilies/family from rock samples

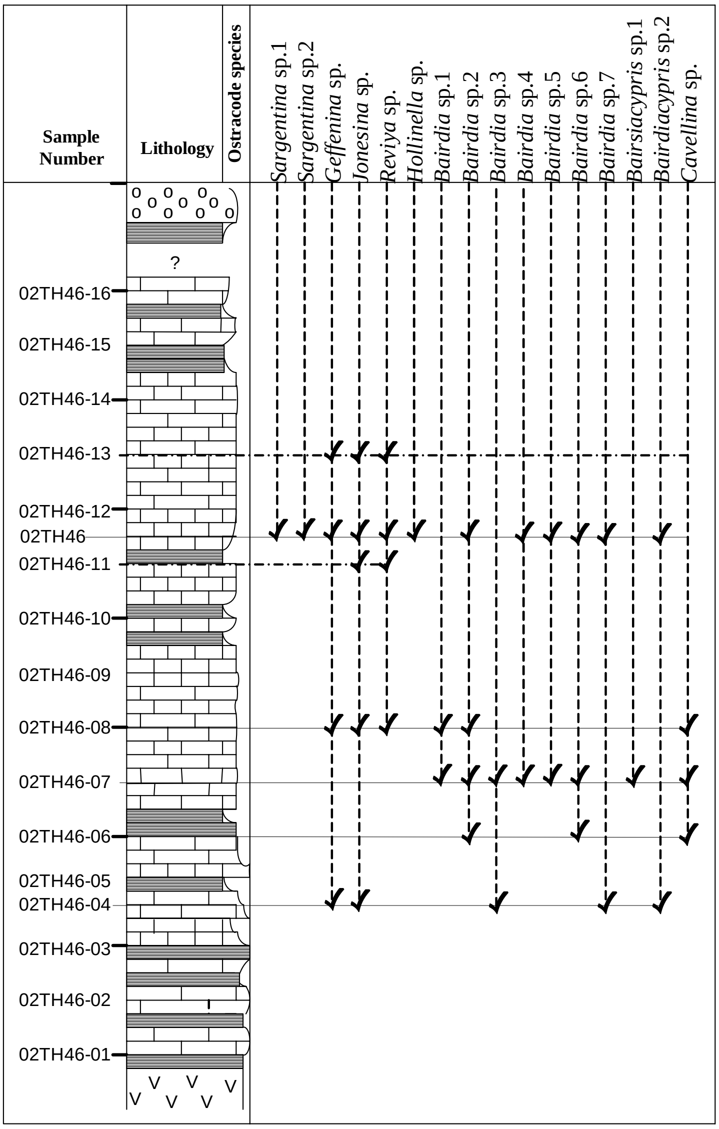


Figure 4-3 Occurrence of fossil ostracodes of the study section

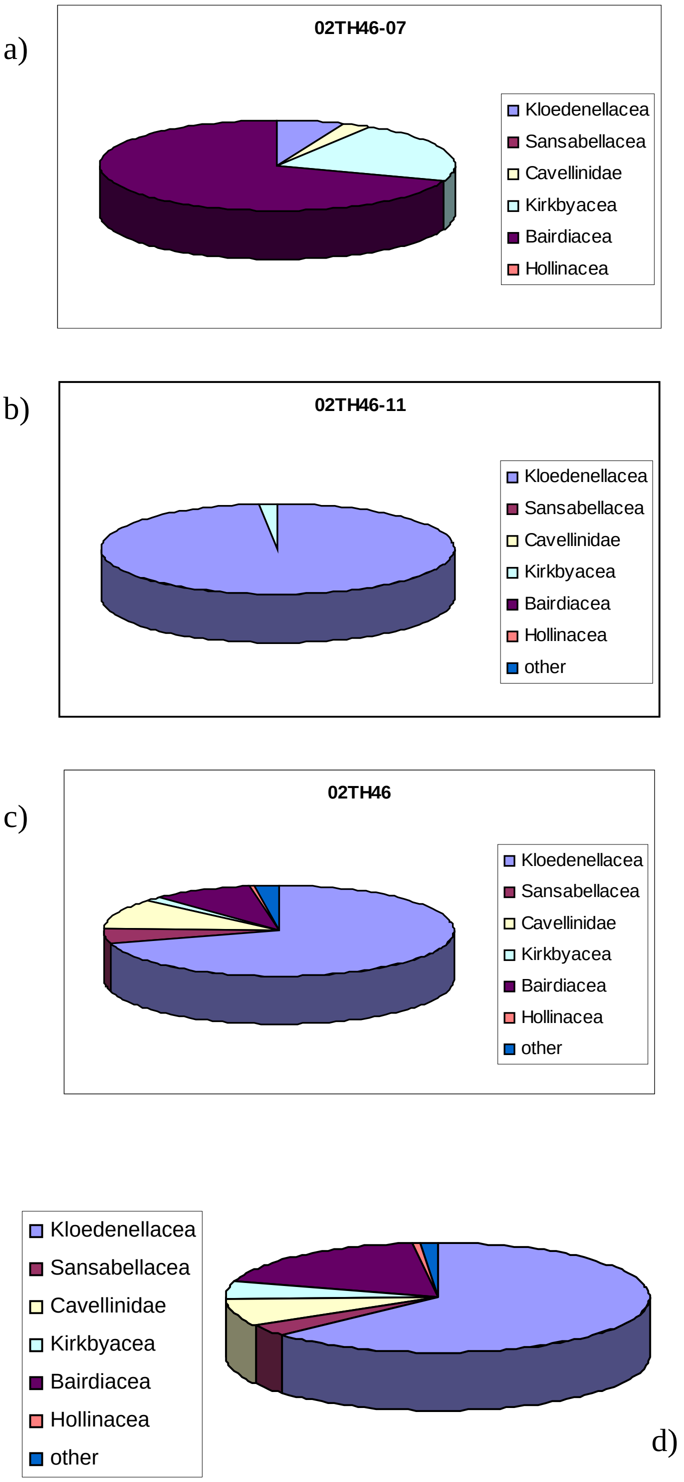


Figure 4-4 Percentage of superfamilies/family of Permian ostracodes from the Bung Sam Phan section; a) sample No.02TH46-07, b) sample No. 02TH46-11, c) sample No.02TH46, and d) all samples of the study section

CHAPTER V

DISCUSSION AND CONCLUSION

Results of taxonomic study and interpretation of local paleoenvironment, presented in previous chapters, are discussed in this chapter. Additional discussion on methodology, further study and conclusion are also included.

5.1 Discussion on Systematic Paleontology

The classification and identification are based on morphology of ostracode shells. The author considers that systematic classification in Moore (1961) is still valuable and creditable. Notwithstanding, many papers have been published and the systematics are quite different.

At generic level, the description of each genus is similar, commonly followed the first establishment or followed the emended version. This level is uncomplicated because each genus has its own characteristics. The fossil ostracodes were put into genera before looking for their specific characters of specific level. At family and higher levels, the author mainly follows Moore (1961), but agrees with the works of Crasquin-Soleau and Buad (1998) and Crasquin-Soleau *et al*. (1999) for some taxa, *Sargentina* and *Cavellina*, for instance. Some noticeable points are summarized as follows;

Sargentina was classified into Suborder uncertain by Moore (1961). Crasquin-Soleau *et al.* (1999) moved them to Suborder Kloedenellacea Scott 1961, Superfamily Sansabellacea Sohn 1961, and Family Serenididae Rozhdesvenskaya 1972. The family Sansabellidae was firstly established by Sohn (in Moore 1961) which contained genus *Sansabella*. *Sansabella* is very distinctive by the incised dorsum along entire length of hinge that was mentioned by Catalogue of Ostracoda (1994) as the V-shaped channel of sansabelliod hinge. According to unequivalve of *Sargentina* sp., this type of hinge is also present. The synthesis supports the classification of Crasquin-Soleau *et al.* (1999).

Geffenina sp. and *Jonesina* sp. are belonged to Superfamily Kloedenellacea Ulrich and Bassler 1908 without doubt. They are resembled in having prominent S2 and L2, smooth to finely recticulated surface, without marginal structure, spine or tubercle. However they can be distinguished by invagination of hinge, the lower hinge than the dorsum area, which strongly present in *Geffenina* sp. but absent or obscurely present in *Jonesina* sp. Though *Geffenina* sp. and *Jonesina* sp. reported here are not identical to any described taxa. They may be new species.

Reviya was established by Sohn (1961) to be a member of Family Kirkbiidae Ulrich and Bassler 1906. The genus is highly ornamented with reticulation but different from other members of the family in having thick area along carapace rim which makes it looked robust and dull. *Reviya* sp. recovered in this study can not be compared to any described taxa. It may be a new species.

Hollinaceans have some specific characters that can be identified in a short time. *Hollinella* was proposed by Coryell (1928) to be in Family Beyrichiidae. In this study, the author follows Crasquin-Soleau (in Crasquin-Soleau and Baud, 1998) who moved *Hollinella* to the Family Hollinellacae Swartz 1936, and Family

Hollinellidae Bless and Jordan 1971. Specimens of *Hollinella* sp. described in this study are poorly preserved. Nodes can be observed but without frill or ridge.

Classification of Superfamily Bairdiacea is certain. Members of *Bairdia* are found in large quantity, grading from minute to large size. They are very diversified. At least seven species are reported here and many are unidentifiable. The differences among the members of this superfamily are those small details such as position of anterodorsal and posterodorsal points, form of anterior and posterior ends, H/L ratio, etc. However, they are very distinctive by the bairdian shape. *Bairdiacypris* sp. has also been identified in this study.

Moore (1961) put *Cavellina* in Order Podocopida Mű̋ller 1894, Suborder Platycopina Sars 1866. In 1987, Pribyl and Pek established the new Order Platycopida Sars 1866, and Superfamily Cavellinacea Egorov 1950 for the genus. Crasquin-Soleau *et al.* (1999) put *Cavellina* into Order Platycopina Sars 1866, ignored the Superfamily, and retained only Family Cavellinidae Egorov 1950. In this study, the author follows the most up to date classification.

After the taxonomic study, the author recognizes similarity of many Middle Permian ostracodes from the Bung Sam Phan area to those taxa reported from Upper Carboniferous - Lower Permian of North America, and Middle Permian of China and Russia. In additional, this is the first occurrence of genera *Jonesina* and *Reviya* in Permian strata.

5.2 Discussion on Interpretation of Paleoenvironment

Fossil ostracodes in this study are of three broad groups, Palaeocopids, Podocopids, and Platycopids. They can be classified into at least 16 taxa belonging to

Sargentina, Geffenina, Jonesina, Reviya, Hollinella, Bairdia, Bairdiacypris, and *Cavellina*. Overall the described genera lived in a typical shallow marine environment from shoreline to the continental shelf (Melnyk and Maddocks, 1988). However, these genera prefer different physical condition such as salinity, substrate, depth, etc. The synthesis of local paleoenvironment is discussed below.

5.2.1 The Group Preferring Very Shallow Water, Euryhaline Condition

Geffenina sp. and *Jonesina* sp. appear for the first time in sample No.02TH46-04 where members of *Bairdia* occupied most territory. Few specimens are also found in 02TH46-08. They are more abundant in higher levels, 02TH46-11, 02TH46, and 02TH46-13. Especially in 02TH46-11, almost all fossils found are Kloedenellacean. Below these layers, their size ranged from 0.3-0.5 mm. in length. In 02TH46, both *Geffenina* sp. and *Jonesina* sp. are abundant and well preserved. In this layer, they reach the largest size of nearly 1 mm. in length. Both adult males and females are found. In 02TH46-13, poorly preserved specimens are again present in small number.

Many specimens of *Sargentina* sp.1 and *S.* sp.2 are present and restricted to sample No.02TH46. This may point to their favourite ecological condition. The size of *Sargentina* sp. is the same size as *Geffenina* sp. and *Jonesina* sp.. In the author's opinion, *Sargentina* sp.1 and *S.* sp.2 are closely related to *Geffenina* sp. and *Jonesina* sp..

Hollinella sp. are also found only in sample No.02TH46. Their carapaces are simple without velum or frill structure which indicate the preference for soft substrate. However, four specimens are too few to be considered for paleoenvironmental interpretation.

Cavellina sp. are ubiquitous but the higher percentage in sample 02TH46 may represent their preferred condition.

5.2.2 The Group Preferring Further Offshore, Normal Marine Condition

The genus *Bairdia* is diversified in sample No.02TH46-07. Many of them are larger than 1 mm. in length, some even reach 1.7 mm. Overall, they are large, thick having smooth to rough surface without spine or dent. Size and species diversification may point to condition of calm and deeper water. The thick shell ostracodes are dweller on sea bottom. It should be noticed that most of these large *Bairdia* carapaces are compressed and destroyed. An event was supposed to happen during the time of deposition, possibly load pressure of sediments. Members of Bairdiacea are present but they occupy low percentage in the higher levels.

Reviya sp. firstly appear in sample No.02TH46-07 and they are the second common in this layer. Very few specimens are present in 02TH46-11. They are also found in 02TH46 in low percentage. This observation suggests their favourite ecological condition is the same as in 02TH46-11. Thick, robust, and coarsely reticulated carapaces represent benthic or burrowing mode of live.

5.2.3 Integration of Paleontological and Geological Information

Looking at the lithology of the rocks sample from the study section, from the lower to the upper part, it is likely to be coarsening upward. In the lower part (from 02TH46-01 to 02TH46-11), intercalation of limestone and shale are present. Most limestones are dark, micritic with scattered macrofossils and some microfossils. This represents location of deposition far from inferred shoreline, in calm environment and small number of living organisms (fossils). In the upper part (from 02TH46-02TH46-16), limestones are composed of larger allochems. Macrofossils and intraclasts are abundant which can be identified as fossiliferous intramicrite. The observation indicates condition of a shallow water and a high energy environment. Ratio of limestone bed and clastic bed is reduced upward then changed into gravel bed at about m.130.

The information mentioned above refer to shallowing upward in palaeoenvironment. The gradual change of sedimentary accumulation can be observed in this section (less than 130 meters).

The fossil ostracode assemblages coincide with geological interpretation. In the lower part of the section, the depositional environment was further offshore, in deep and calm condition where few organisms inhabited. Fine-grained sediments were slowly deposited. The ostracodes can grow to the biggest size under the quiet and low energy condition. They are usually elongate. The Bairdiacean were very diversified. In the upper part of the section, it was closer to the paleoshoreline, in shallow, oxygenated and high energy condition where plenty of organisms inhabited. The coarser sediments were deposited. Ostracodes modified themselves to intermediate size, smooth, and rounded for resisting the high energy condition. The Kloedenellacean occupied mostly in this area.

5.3 Discussion on Methodology

The application of hot acetolysis technique (Lethiers and Crasquin-Soleau, 1988) for extracting fossil ostracodes is found to be suitable and successful. However, the main problem encountered in the extraction is time, some rock samples took very long time for the chemical reaction to occur. This trouble can be solved by using diluted acetic acid (95%, or 90%). Water allows hydrolysis to accelerate chemical activity. Another is to increase a little higher temperature when heating rock samples in acid. Higher temperature can also help accelerating the activity. Circumspection is concerned for this method.

Generally, the taxonomic study is based on fossil morphology which illustrated by SEM photographs. In this study, the author has learned that low accuracy of SEM photographs may lead to unclear images. After discussing with the advisor and co-advisors, it may be possible to solve the problem by 1) adjustment of the contrast level, 2) coating more times (with gold) before taking SEM photograph, or 3) using high resolution image to capture the photograph.

5.4 Recommendation for Further Study

Accomplishment and information of this study lead to further study of many disciplines, for example;

1) Taxonomic study of Permian ostracodes in adjacent area and other regions, for example central and northern Thailand.

2) Biostratigraphy of Permian strata based on fossil ostracodes.

3) Paleoenvironment reconstruction of the Permian with reference to fossil ostracodes.

4) Paleobiogeograpgy of Permian ostracodes from Thailand.

5) Geometric morphometric of Permian ostracodes from Thailand.

5.5 Conclusion

Sixteen species of fossil ostracodes were described from Middle Permian strata of Bung Sam Phan area, Phetchabun Province. They are belonged to genera

Sargentina, Geffenina, Jonesina, Reviya, Hollinella, Bairdia, Bairdiacypris, and Cavellina. These fossil ostracodes occupied the continental shelf from shoreline to open marine condition.

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Plate 1

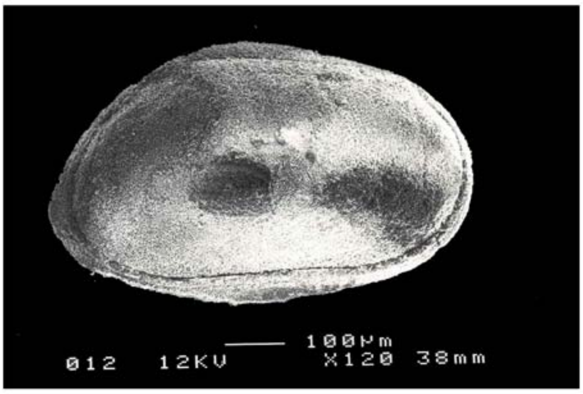
Figures 1-4 *Sargentina* sp.1 (left valve)

Figure 5 *Sargentina* sp.2 (left valve)

Figures 6-7 *Geffenina* sp. (left valve)

Figure 8 *Geffenina* sp. (dorsal view)

1	2
3	4
5	6
7	8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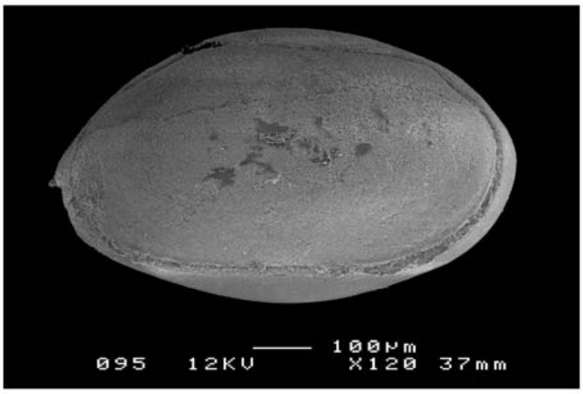
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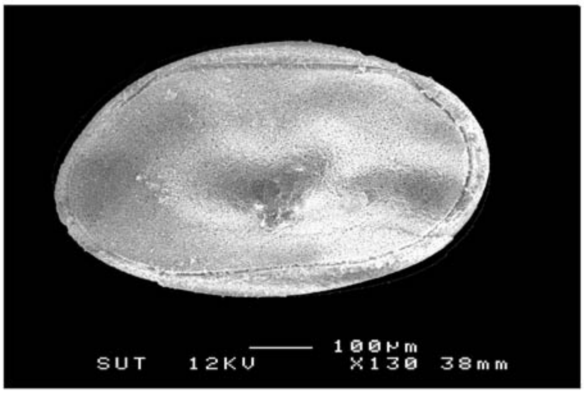
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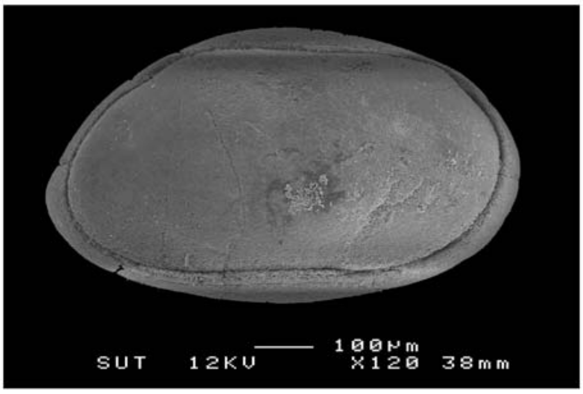
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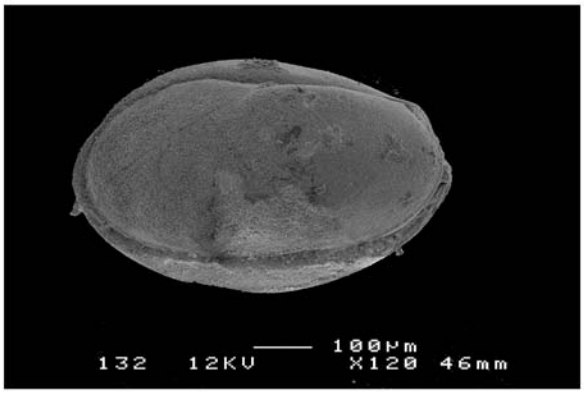
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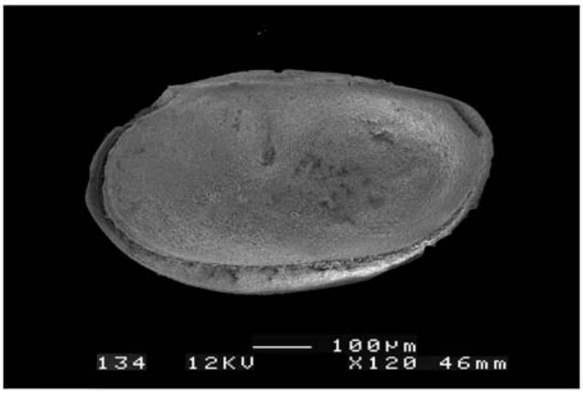
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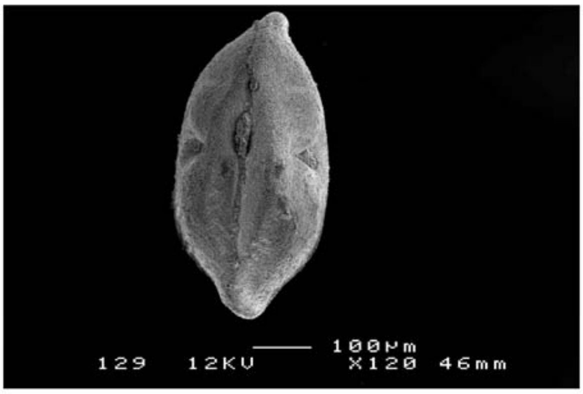
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Plate 2

Figures 1, 3 *Jonesina* sp. (left valve)

Figure 2 *Jonesina* sp. (right valve)

Figure 4 *Jonesina* sp. (dorsal view)

Figures 5-8 *Reviya* sp. (left valve)

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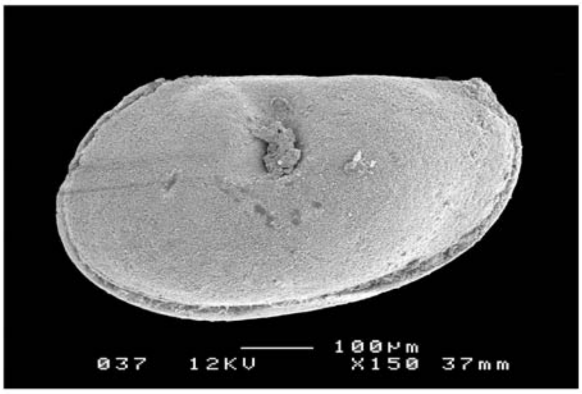
7	8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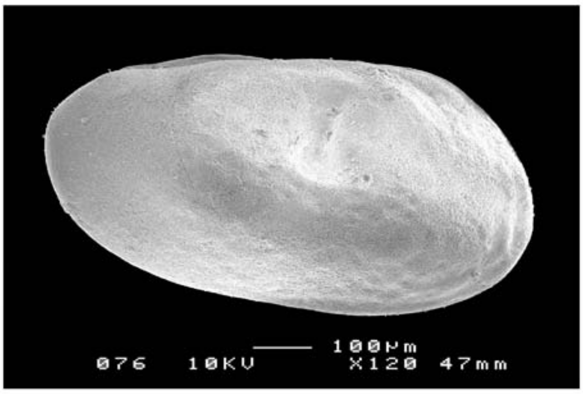
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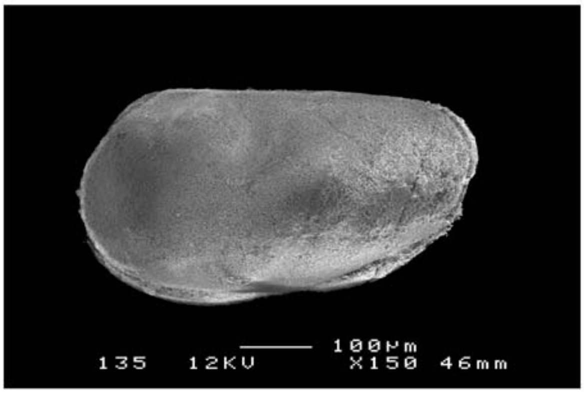
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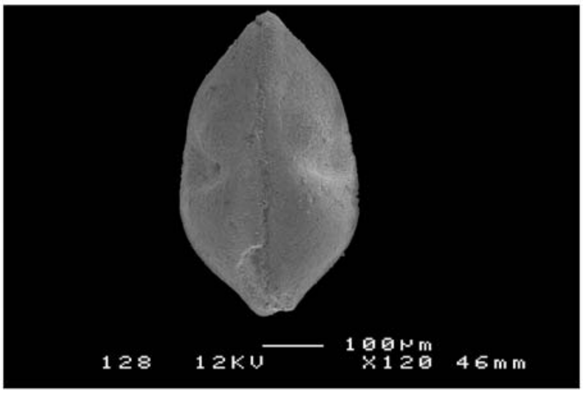
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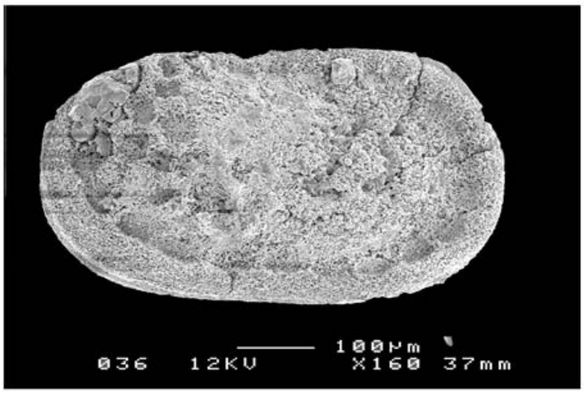
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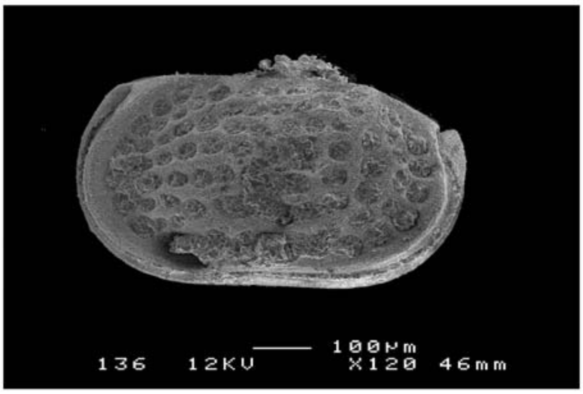
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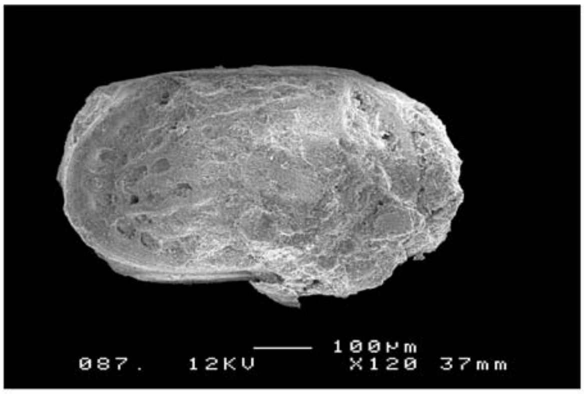
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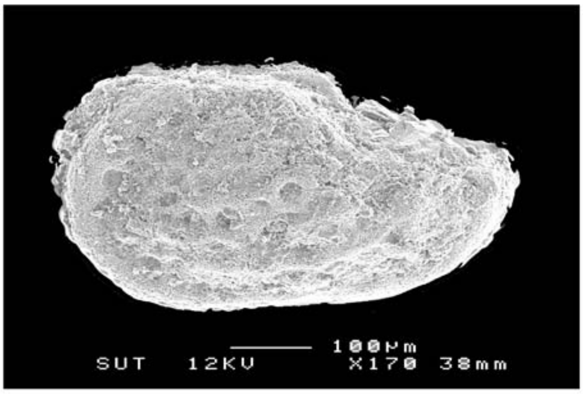
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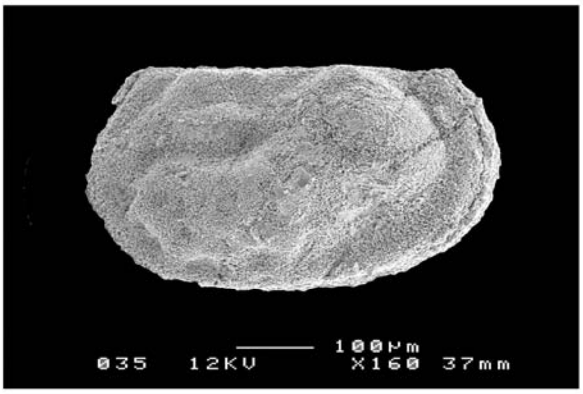
Plate 3

Figures 1-3 *Hollinella* sp. (left valve)

Figures 4, 6, 7 *Bairdia* sp.1 (left valve)

Figures 5, 8 *Bairdia* sp.1 (right valve)

1	2
3	4
5	6
7	8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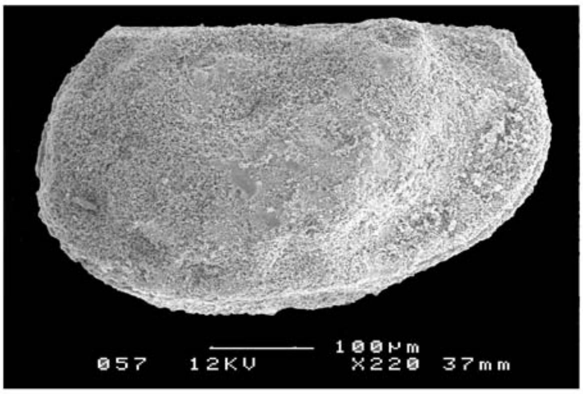
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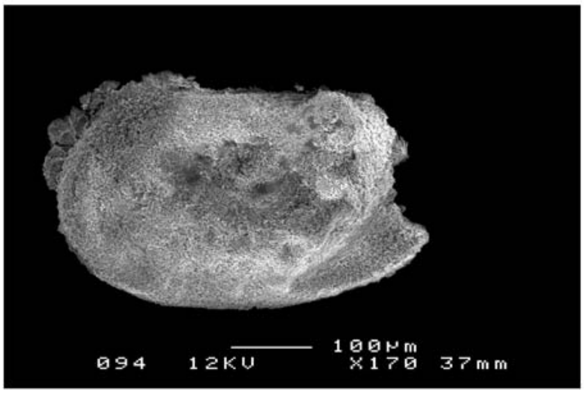
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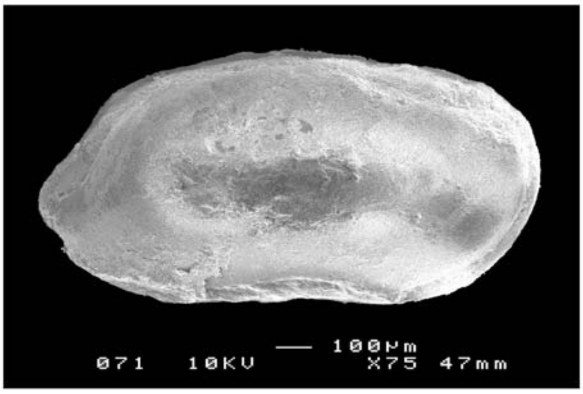
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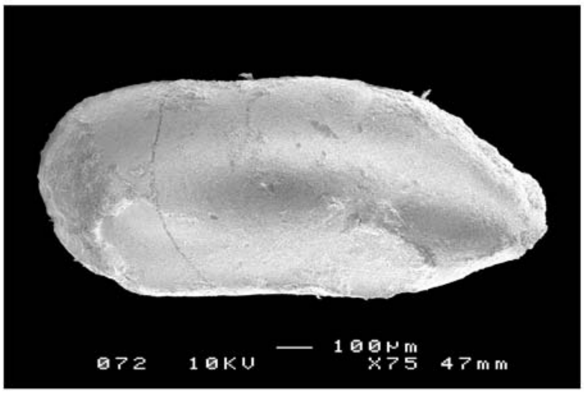
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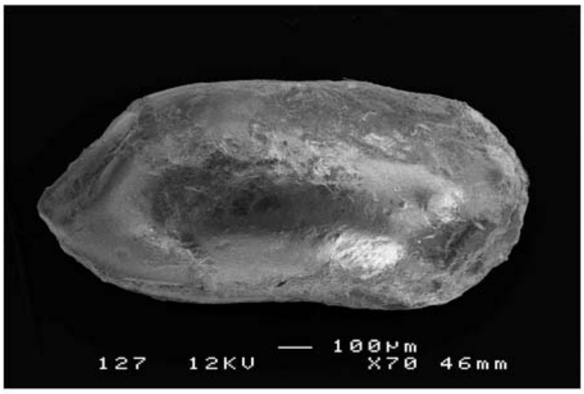
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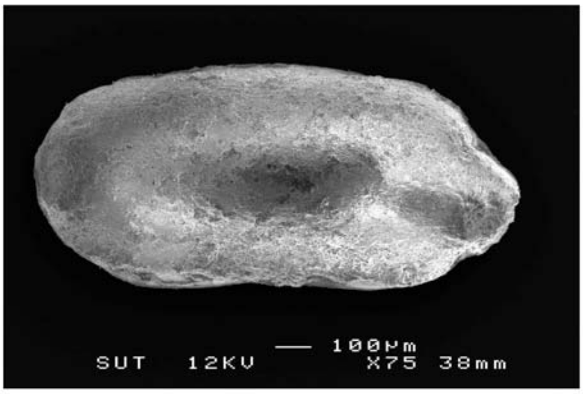
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Plate 4

Figures 1-3 *Bairdia* sp.2 (right valve)

Figures 4, 8 *Bairdia* sp.3 (right valve)

Figure 5 *Bairdia* sp.3 (dorsal view)

Figure 6 *Bairdia* sp.3 (left valve)

Figure 7 *Bairdia* sp.3 (ventral view)

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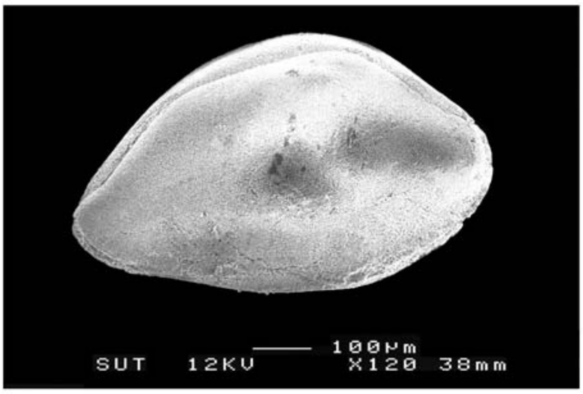
5	6
7	8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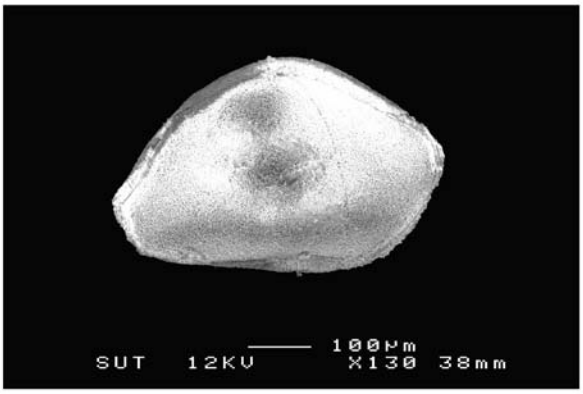
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SUT 12KV X130 38mm


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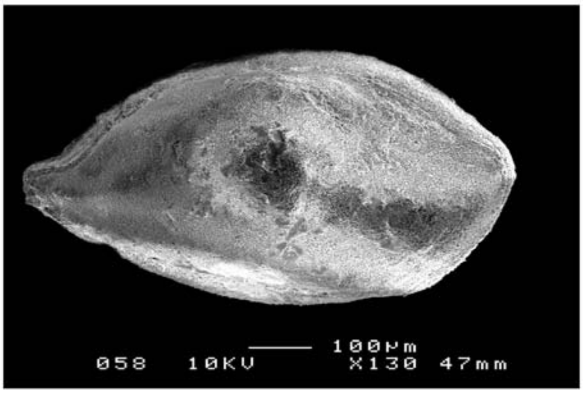
092 12KV X120 38mm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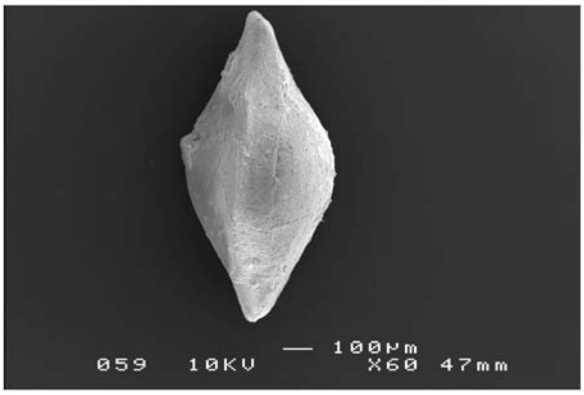
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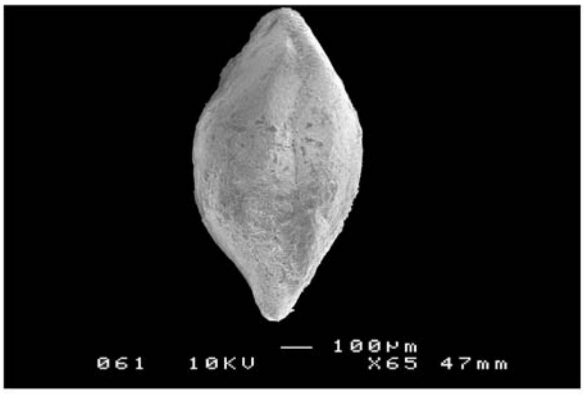
059 10KV X60 47mm


100µm
060 10KV X85 47mm


100µm
061 10KV X65 47mm

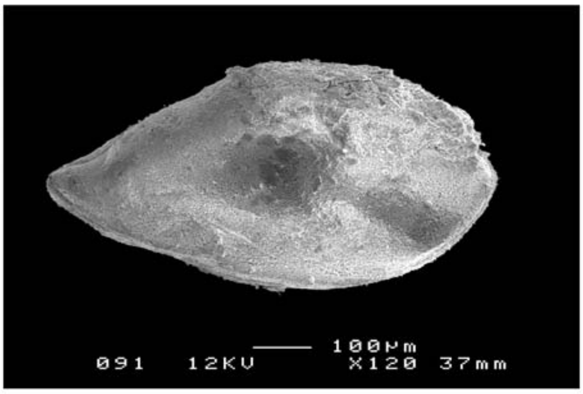

100µm
091 12KV X120 37mm

Plate 5

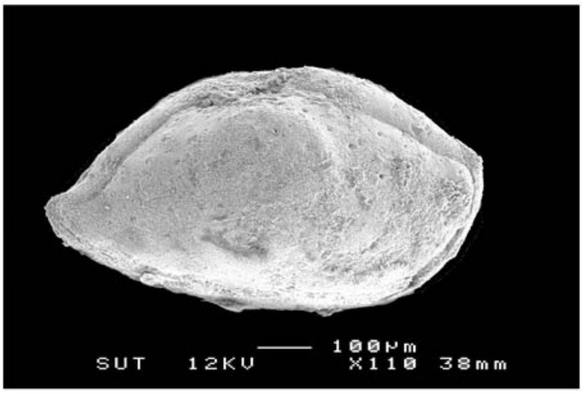
Figures 1-2 *Bairdia* sp.3 (right valve)

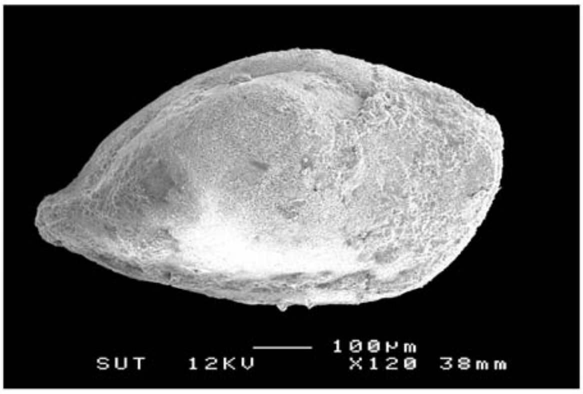
Figures 3-4 *Bairdia* sp.4 (right valve)

Figures 5-6 *Bairdia* sp.5 (right valve)

Figures 7-8 *Bairdia* sp.6 (right valve)

1	2
3	4
5	6
7	8


100µm
SUT 12KV X110 38mm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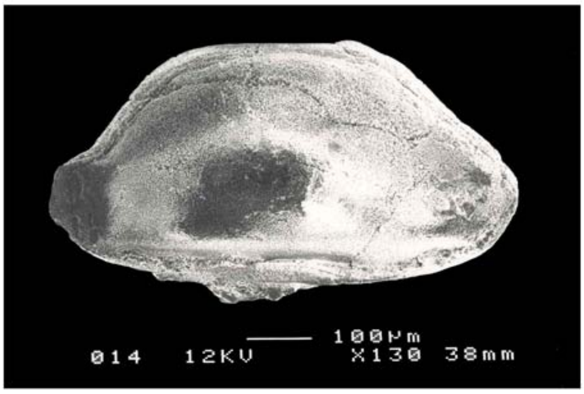
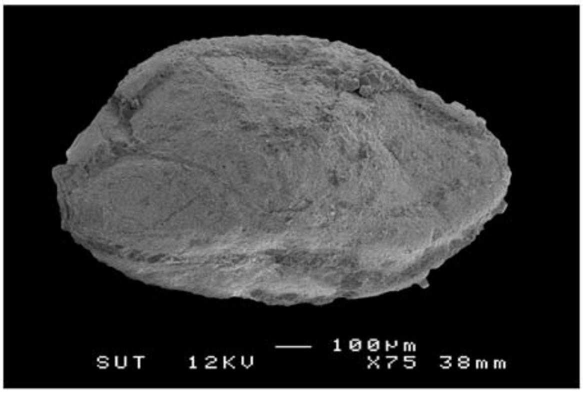
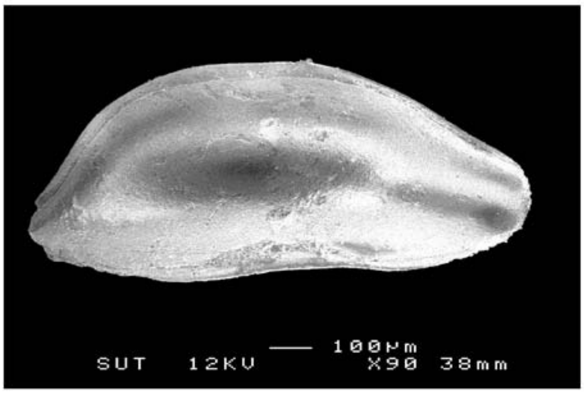
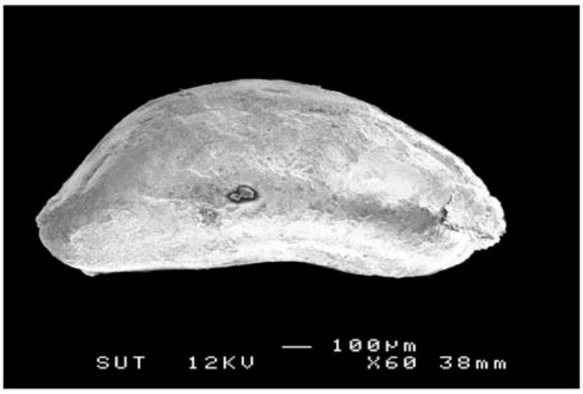
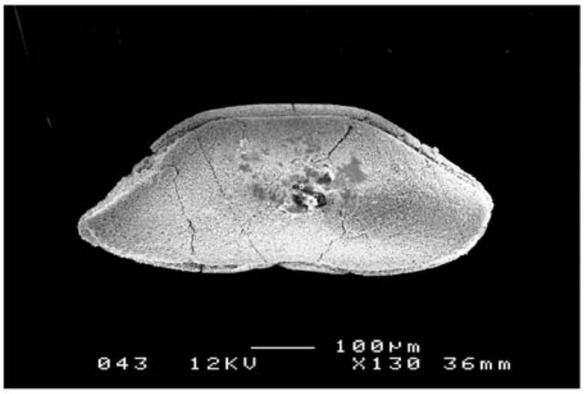
SUT 12KV X120 38mm


100µm
014 12KV X130 38mm


100µm
SUT 12KV X75 38mm


100µm
SUT 12KV X90 38mm


100µm
SUT 12KV X60 38mm


100µm
043 12KV X130 36mm

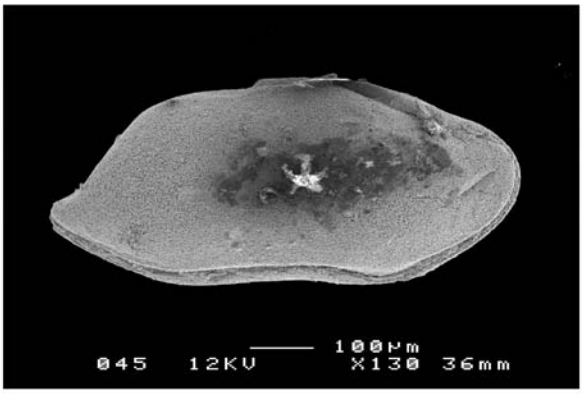

100µm
045 12KV X130 36mm

Plate 6

Figure 1 *Bairdia* sp.6 (right valve)

Figure 2 *Bairdia* sp.7 (right valve)

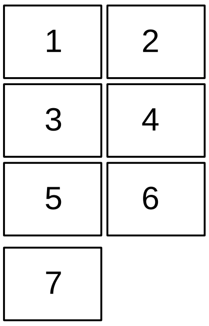
Figure 3 *Bairdiacypris* sp.1 (right valve)

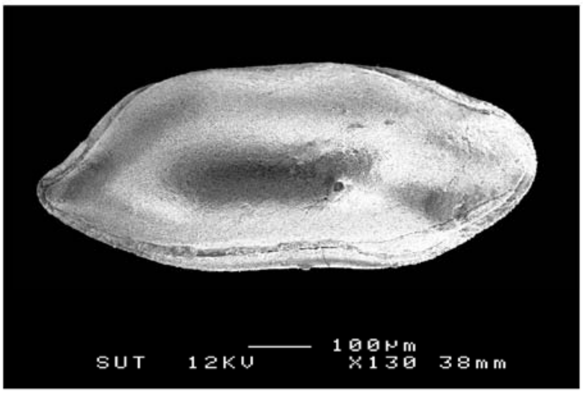
Figure 4 *Bairdiacypris* sp.2 (right valve)

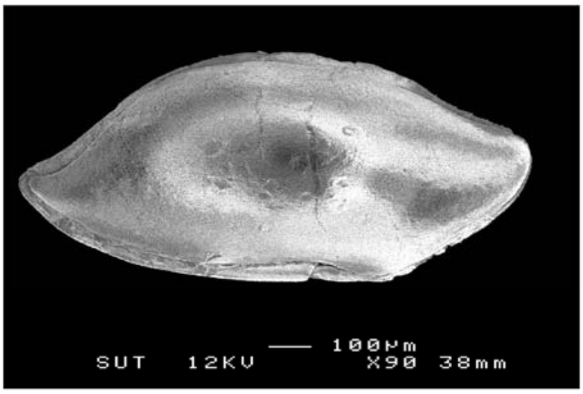
Figure 5 *Cavellina* sp. (left valve)

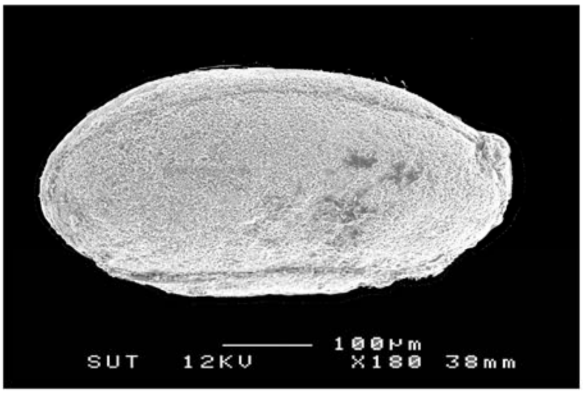
Figure 6 *Cavellina* sp. (ventral view)

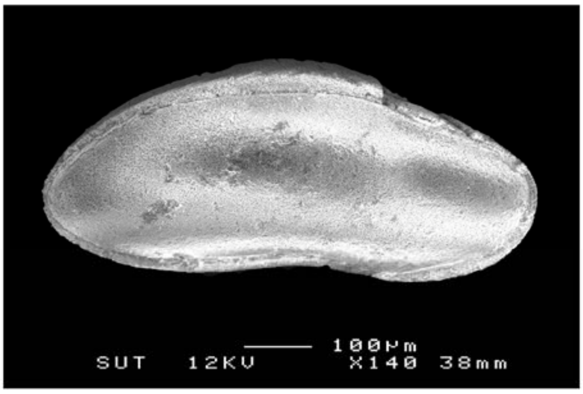
Figure 7 *Cavellina* sp. (right valve)

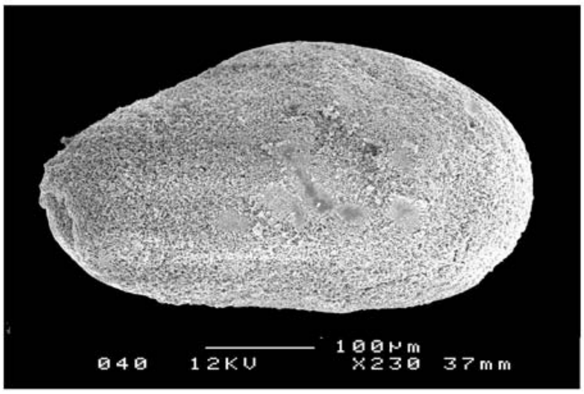



100µm
SUT 12KV X130 38mm

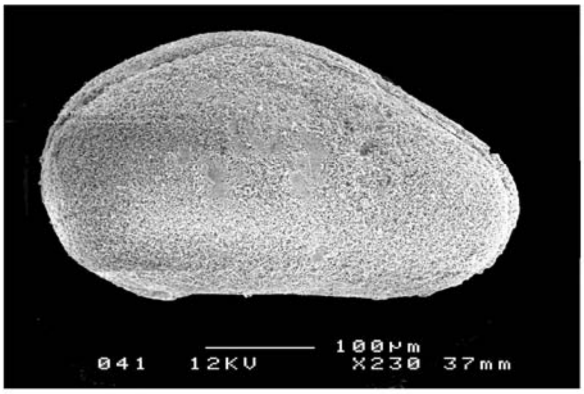

100µm
SUT 12KV X90 38mm


100µm
SUT 12KV X180 38mm


100µm
SUT 12KV X140 38mm


100µm
040 12KV X230 37mm


100µm
042 12KV X160 37mm


100µm
041 12KV X230 37mm

CURRICULUM VITAE

Originally from Chiang Mai, Miss Anisong Chitnarin was born on July 11, 1978. Her childhood was lifely and she had been educated at Dara Academy. She entered Faulty of Science, Chiang Mai University in 1995 and decided to be majored in geology. After having degree of B.Sc. she had worked in the field of environmental assessment, for the S.P.S consulting service company during 1999-2001. In 2002, she joined a project at the Chula Unisearch. Since 2003, she has been working as a research assistant for the Thai-French co-operation project (TRF/CNRS). Her interest is micropaleontology and biostratigraphy as she has attended Master degree at Suranaree University of Technology.