PALEOENVIRONMENTAL INTERPRETATION OF MIDDLE PERMIAN LIMESTONE AT BAN PHU TOEI, WICHIAN BURI DISTRICT, PHETCHABUN PROVINCE, CENTRAL THAILAND, FROM MICROFACIES ANALYSIS AND OSTRACOD ASSEMBLAGE

Phattraporn Kulnok

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Civil, Transportation and Geo-resources Engineering

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สภาพแวดล้อมบรรพกาลของหินปูนยุคเพอร์เมียนตอนกลาง บริเวณบ้านพุเตย อำเภอวิเชียรบุรี จังหวัดเพชรบูรณ์ ภาคกลางของประเทศไทย จากการวิเคราะห์ชุดลักษณ์ระดับจุลภาคและกลุ่มบรรพชีวินออสตราคอด

นางสาวพัสตราภรณ์ กุลนอก

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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พัสตราภรณ์ กุลนอก : สภาพแวดล้อมบรรพกาลของหินปูนยุคเพอร์เมียนตอนกลาง บริเวณบ้านพุเตย อำเภอวิเชียรบุรี จังหวัดเพชรบูรณ์ ภาคกลางของประเทศไทย จากการวิเคราะห์ชุดลักษณ์ระดับจุลภาคและกลุ่มบรรพชีวินออสตราคอด (PALEOENVIRONMENTAL INTERPRETATION OF MIDDLE PERMIAN LIMESTONE AT BAN PHU TOEI, WICHIAN BURI DISTRICT, PHETCHABUN PROVINCE, CENTRAL THAILAND, FROM MICROFACIES ANALYSIS AND OSTRACOD ASSEMBLAGE) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.อานิสงส์ จิตนารินทร์,158 หน้า.

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อแปลความหมายสภาพแวดล้อมบรรพกาลและสภาพแวดล้อมการตกทับถมของหินปูนยุคเพอร์เมียนตอนกลาง ในบริเวณบ้านพุเตย อำเภอวิเชียรบุรี จังหวัดเพชรบูรณ์ หน้าตัดศึกษาตั้งอยู่บนหมวดหินตากฟ้าซึ่งแสดงเป็นชั้นหินปูนแทรกสลับกับชั้นหินดินดาน ตัวอย่างหินปูน 5 ตัวอย่าง ถูกนำมาสกัดด้วยวิธีฮอทอะซิโตไลซิส และทำแผ่นหินขัดบาง โดยชนิดของชุดลักษณ์ระดับจุลภาคสามารถแบ่งออกได้เป็น 2 ชนิด ได้แก่ bioclast wackestone และ bioclast grainstone ซึ่งชนิดของชุดลักษณ์ระดับจุลภาคสามารถเปรียบเทียบได้กับ RMF13, RMF14, RMF17, RMF18 และ RMF27 บนแบบจำลอง Ramp Carbonate Platform มีการตกทับบนสภาพแวดล้อมแบบด้านในของ Ramp ได้แก่ ทะเลสาบน้ำเค็ม สันทรายในบริเวณที่ถูกจำกัด ได้รับอิทธิพลจากคลื่นทะเลน้อย ไปจนถึงบริเวณนอกชายฝั่งหรือทะเลเปิด ฟูซูลินิดที่พบในแผ่นหินขัดบาง ได้แก่ *Rugososchwagerina*? sp., *Kahlerina* sp., *Parafusulina* sp., *Nankinella* sp. *Sphaerulina* sp. and *Chusenella* sp. โดยสิ่งมีชีวิตนี้บ่งชี้ว่าชั้นหินปูนมีอายุตั้งแต่ช่วงต้นของเพอร์เมียนตอนกลาง (Rodian) ไปจนถึงช่วงปลายของเพอร์เมียนตอนกลาง (Capitanian) ออสตราคอดถูกจำแนกออกเป็น 36 ชนิด 14 สกุลและ 8 วงศ์ ประกอบด้วย Bairdioidea, Kirkbyidae, Coelonellidae, Paraparchitidea, Cytheroidae, Kloedenelloidea, Polycopidae, และ Cavellinoidea ลักษณะเฉพาะของกลุ่มออสตราคอดบ่งชี้ว่าสภาพแวดล้อมบรรพกาลของบริเวณพื้นที่ศึกษาอยู่ในบริเวณที่เป็นน้ำตื้นถึงตื้นมาก กับสภาพแวดล้อมในเขตทะเลเปิด และอยู่ในบริเวณต่ำกว่าระดับน้ำขึ้นน้ำลง

สาขาวิชา เทคโนโลยีธรณี	ลายมือชื่อนักศึกษา พัสตราภรณ์
ปีการศึกษา 2562	ลายมือชื่ออาจารย์ที่ปรึกษา [signature]

PHATTRAPORN KULNOK : PALEOENVIRONMENTAL INTERPRETATION OF MIDDLE PERMIAN LIMESTONE AT BAN PHU TOEI, WICHIAN BURI DISTRICT, PHETCHABUN PROVINCE, CENTRAL THAILAND, FROM MICROFACIES ANALYSIS AND OSTRACOD ASSEMBLAGE. THESIS ADVISOR : ASST. PROF. ANISONG CHITNARIN, Ph.D., 160 PP.

PALEOENVIRONMENT/ TAK FA FORMATION/ INDOCHINA BLOCK/ KHOA KHWANG PLATFORM

The objective of this research is to interpret paleoenvironment and depositional environment of Middle Permian limestone at Ban Phu Toei section, in Wichian Buri District, Phetchabun Province. The studied section is a part of Tak Fa Formation and consisted of bedded limestone intercalated with shale. Five limestone samples are collected for dissolving by the hot acetolysis technique and rocks thin section. The microfacies types can be subdivide into two types included bioclastic wackestone and bioclastic grainstone which these microfacies types can be compared with RMF13, RMF14, RMF17, RMF18 and RMF27 on the ramp carbonate platform model. These RMFs suggest the deposition on the inner ramp including lagoon, sand shoals restricted to open-marine environments. The fusulinids found in thin section including *Rugososchwagerina*? sp., *Kahlerina* sp., *Parafusulina* sp., *Nankinella* sp. *Sphaerulina* sp. and *Chusenella* sp. This faunal indicates are early Middle Permian (Roadian) to upper Middle Permian (Capitanian) of the limestone sequence. The ostracods are recovered and classified into 36 species belonging to 14 genera and 8 families including Bairdioidea, Kirkbyidae, Coelonellidae, Paraparchitidea, Cytheroidae, Kloedenelloidea, Polycopidae, and Cavellinoidea. The characteristics of the recovered ostracod assemblage suggest the paleoenvironment on subtidal in external zone and shallow to open marine environment with normal salinity.

School of Geotechnology

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Student's Signature พัสตาภรณ์

Advisor's Signature

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CHAPTER I

INTRODUCTION

Permian rocks, predominantly limestones, are widely exposed in Central Thailand. These rocks have been interested and studied by many researchers in the scopes of lithostratigraphy and paleontology. Microfacies analysis is one of tools developed to interpret depositional environment of carbonate rocks. And another is ostracods, which they are known to be one of crustacean and the excellent group of microfossils for paleoecology. Thus, this study has used both tools for interpretation.

1.1 Background and rationale

The mainland of Thailand consists of four geotectonic units including the Sibumasu Terrane in the West, the Inthanon Zone and the Sukhothai Zone in the Central and the Indochina Terrane in the East, which are separated by the Mae Yuam Fault, the 'Cryptic' Suture (Chiang Mai Line) and the Nan–Sakaeo Suture, respectively (Ueno and Hisada, 1999; Ueno, 2002; Ridd et al., 2011) (Figure 1.1). These terranes merged and the Paleotethys was closed during closure of the Permian to early Jurassic. Thus, there are many different marine sediments on these terranes. This research will focus on a part of Permian limestones of the Indochina Terrane.

The Permian rocks are distributed extensively in every part of Thailand. In the Central and Northeastern Thailand, the Saraburi Group (Bunopas, 1981) covers most areas from Nakhon Sawan to Saraburi Provinces and western rim of the Korat Plateau.

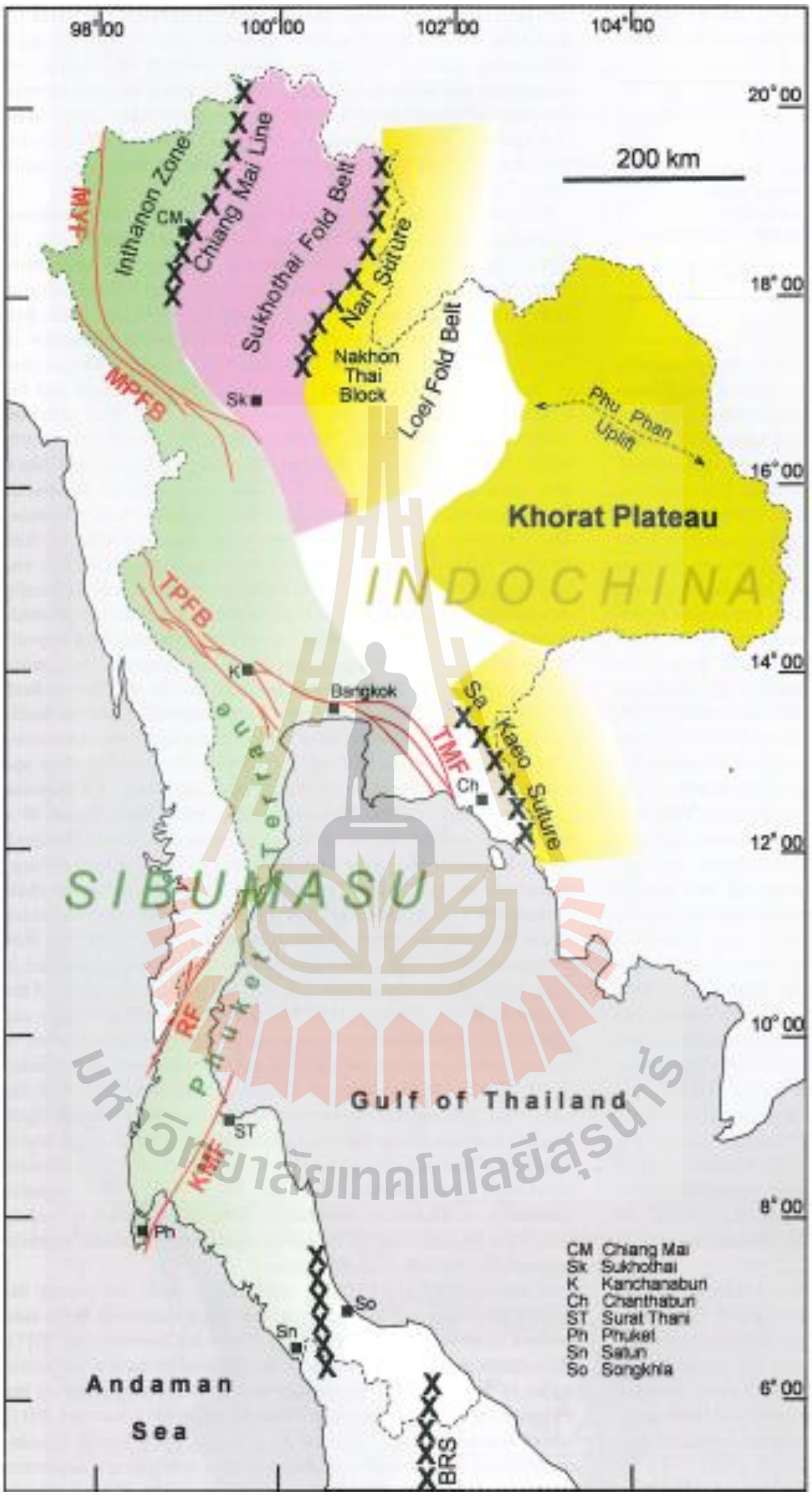


Figure 1.1 Principal structural element of Thailand (Ridd et al., 2011).

The Permian rocks exposed in Phetchabun Province can be divided into three formations including the Num Duk, Hua Na Kham, and Pha Nok Khao Formations (Chonglakmani and Sattayarak, 1984). The Permain marine sedimentary rocks in this area consist predominantly of limestones with minor sandstones and shales (Pha Nok Khao and Hau Na Kham Formations). Num Duk Formation consists of well-bedded alternations of sandstones, shales and turbidites.

In Nakhon Sawan-Phetchabun-Lopburi area, the Saraburi Group consist of Tak Fa and Khao Luak Formations. The Khao Luak Formation is the southward extension of the Nam Duk Formation. The Tak Fa Formation is mainly massive- to well-bedded grey to bluish grey limestones with minor sandstones and shales, and ranged from Early–Middle Permian (Antinskian–Kungurian age) according to Nakornsri (1977; 1981) and Ueno and Charoentitirat (2011). In Saraburi-Nakhon Ratchasima area, the Saraburi Group is divided to six Formations in ascending order Phu Phe, Khao Kwang, Nong Pong, Pang Asok, Khoa Khad and Sub Bon Formations. A diverse fossil including fusulinids, algae, conodonts, bivalves, gastropods, carals, brachiopods, smaller foraminifers and crinoids has been reported from the Permian rocks of the Saraburi Group. Fusulinids and conodonts indicate Early-Middle Permian age.

There are several studies concerning paleoenvironmental interpretation. The regional interpretation is generally based on an intensive work of Wielchosky & Young (1985) who conducted microfacies analysis and outlined the Permian rocks in the West of Nam Duk Basin to locate on the Khao Kwang Carbonate Platform. Dawson (1993) accomplished field investigation and microfacies analysis in an area North of Saraburi City and reported that there were complicated geological structures and different environments during Early - Late Permian. Udchachon et al. (2014) conducted microfacies analysis of Alatochonchid-bearing limestone was deposited on carbonate ramp during the Middle Permian. Several researchers (Chutakositkanon et al., 2000; Thambunya et al., 2007; Singhasuriya, 2017; Uttarawiset, 2017) also carried out microfacies analysis in Saraburi-Nakhon Ratchasima area and found out that the depositional environment varied from shallow marine to slope and deep basin.

Few researchers interpreted paleoenvironment from paleontological data. Chitnarin et al. (2008) discovered fossil ostracods from Middle Permian limestone of the Tak Fa Formation in Bung Sam Phan area, south of Phetchabun, therefore, an ostracod assemblage (Chitnarin, 2015) evidenced shallow marine, nearshore environment.

Although both techniques, the microfacies analysis and ostracod assemblage analysis, can be used to interpret depositional environment. The ostracod assemblage analysis is less well-known. But it is considered more powerful as it provided information of paleogeography and geological history of the studied sections in South China, Southeastern margin of the Arabian Plate in central Oman and Greece (Hydra Island) (Crasquin-Soleau et al., 1998; 1999; 2005). In this study, both techniques were conducted in order to testify and to confirm the paleoenvironmental interpretation of a new outcrop exposed in Wichain Buri District, Phetchabun Province.

1.2 Research objectives

1.2.1 To interpret depositional environment of Tak Fa limestones exposed in the Ban Phu Teoi, Wichian Buri District, Phetchabun Province by microfacies analysis and ostracod assemblage.

1.2.2 To establish taxonomy of Permian ostracods.

1.2.3 To compare results of microfacies analysis and ostracod assemblages analysis.

1.3 The study sections

The study section is located at Ban Phu Toei, in Wichian Buri District, Phetchabun province (Figure1.2) and situated on the Khao Khwang Platform. The study section belongs to the Tak Fa Formation (Nakornsri, 1977).

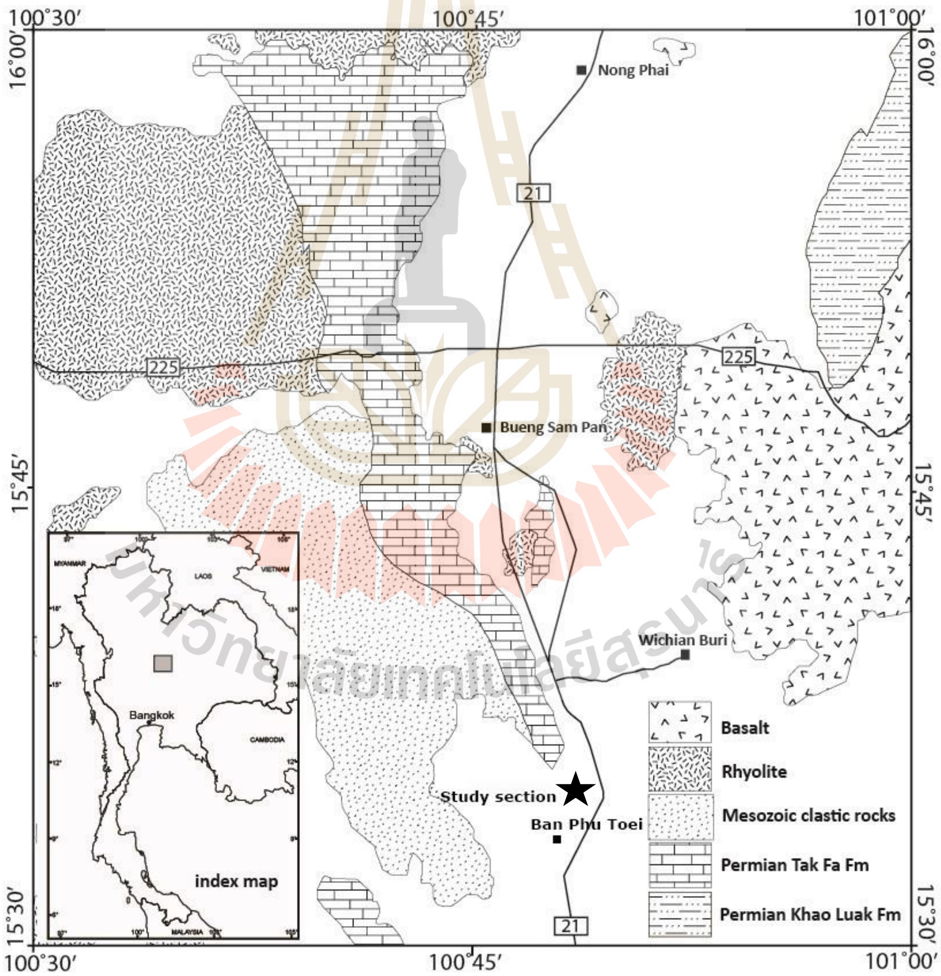


Figure 1.2 Map showing the location of the study section in southern part of Phetchabun Province (modified after Nakornsri, 1997).

1.4.1 Scope and limitation

1.4.1 The study will conduct on limestones collected from the study section located in Ban Phu Toei in Wichian Buri District, Phetchabun province.

1.4.2 Depositional environment will be interpreted using microfacies analysis. Principles of microfacies analysis applied in this study followed Flügel (2010).

1.4.3 Ostracod preparation was processed following Crasquin-Soleau et al., 2005

1.4.4 Paleoenvironment were interpreted from recovered ostracod assemblages.

1.5 Thesis contents

This thesis is presented as follows; Chapter I describes the background and rationale, the research objectives, and scope and limitations of the research, Chapter II summarizes results of the literature review, Chapter III describes the sample preparation and laboratory, Chapter IV analyzes the microfacies and ostracod assemblage of the studied section and interprets the depositional environment of the studied section, and Chapter V discusses and reports concludes the research results and provides recommendations for future research studies.

CHAPTER II

LITERATURE REVIEW

This chapter provides the result of literature review carried out to improve an understanding about stratigraphy of the Permian rocks in central Thailand; general information about Permian ostracods; paleoenvironmental interpretation tools including microfacies analysis and ostracod assemblage analysis. The updated knowledges are summarized and presented as follows.

2.1 Stratigraphy of the Permian rocks in central Thailand

The Permian rocks, predominantly limestones, are exposed throughout Thailand (Figure 2.1) and they were primarily named as "Ratburi limestone" (Brown et al., 1951) After more investigations had been carried out, it was found that the rocks were composed of limestones, clastic rocks and volcaniclastic rocks. Then "Ratburi Group" was established by Javanaphet (1969) for these rocks and usually used for all Permian rocks in Thailand. The Permian rocks have diverse fossils such as fusulinids, brachiopods, corals, radiolarians and they have been used as index fossils. According to different paleobiogeographic affinity among fusuline assemblages (e.g. Ingavat et al., 1978), the idea of plate tectonic had been modified, and the Permian limestones had been focused. In 1981, Bunopas recognized differences between limestones in western and central Thailand, therefore; he limited the Ratburi Group for those in the West and established "Saraburi Group" for the rocks exposed in central region. The Saraburi Group is composed of carbonate rocks and silisiclastic rocks and characterized by

Cathysian affinity invertebrate fossils which are constituents of the Indochina Terrane (Hutchison, 1993; Shi and Archbold, 1998). Figure 2.1 shows distribution of the Permian rocks in Thailand, the Permian rocks in central Thailand include all rocks exposed on the western edge of the Indochina Terrane, also called the Loei Fold Belt (Udchachon et al., 2014; Thassanapak and Udchachon, 2019).

2.1.1 Lithology and stratigraphy of the Permian rocks in central Thailand

DMR geologists carried out field investigations and mapping the 250,000 scale geologic maps in 80s including the map sheets Loei (NE47-12), Phetchabun (NE47-16), Chaiyaphum (ND48-1), Amphoe Ban Mi (ND47-4), and Phranakhon Sriayuthaya (ND47-8) as shown in Figure 2.2 (Nakornsri, 1976; Charoenpravat and Wongwanich, 1976; Chonglakmani and Sattayarak, 1984; Hinthong ,1981). Hence, different rock Formations were established almost at the same time. Lithology of these Formations is summarized as follows.

1) The Permian rocks in Loei-Nong Bua Lumphu area

The Permian rocks exposed in Loei-Nong Bua Lumphu area were mapped by Charoenprawat and Wongwanich (1976) and consist of Nam Mahoran, E-Lert and Pha Dua Formations. The Nam Mahoran Formation consists mainly of thick-bedded limestone with interbedded shale, sandstone, chert and/ or dolomitic limestone. The E-Lert Formation is predominated by intercalation of shale and chert with tuffaceous rocks and limestone lenses.

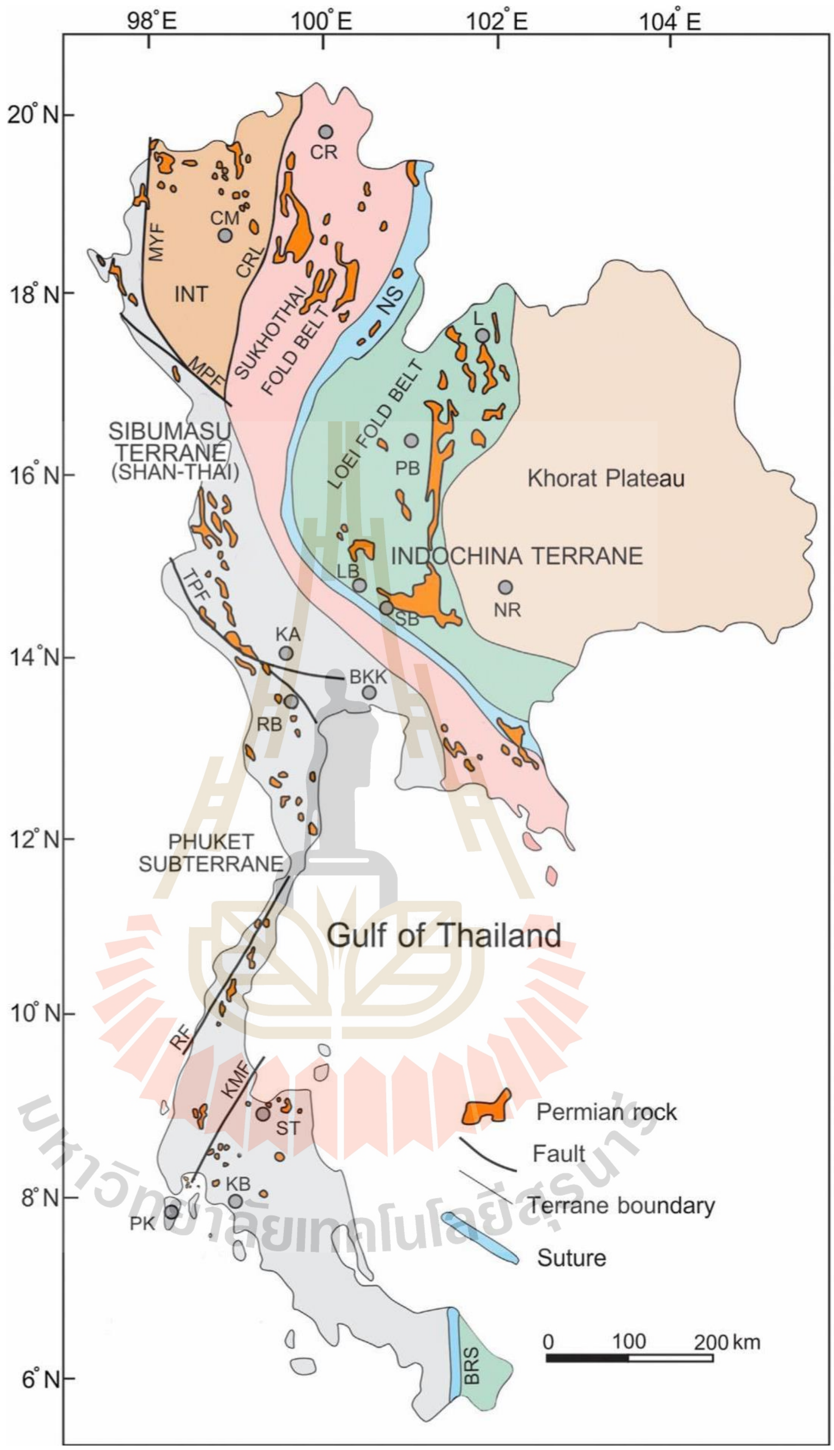


Figure 2.1 Map of Thailand showing distribution of Permian rocks in the tectonostratigraphic belt of Thailand (edited after Thassanapak and Udchachon, 2019).

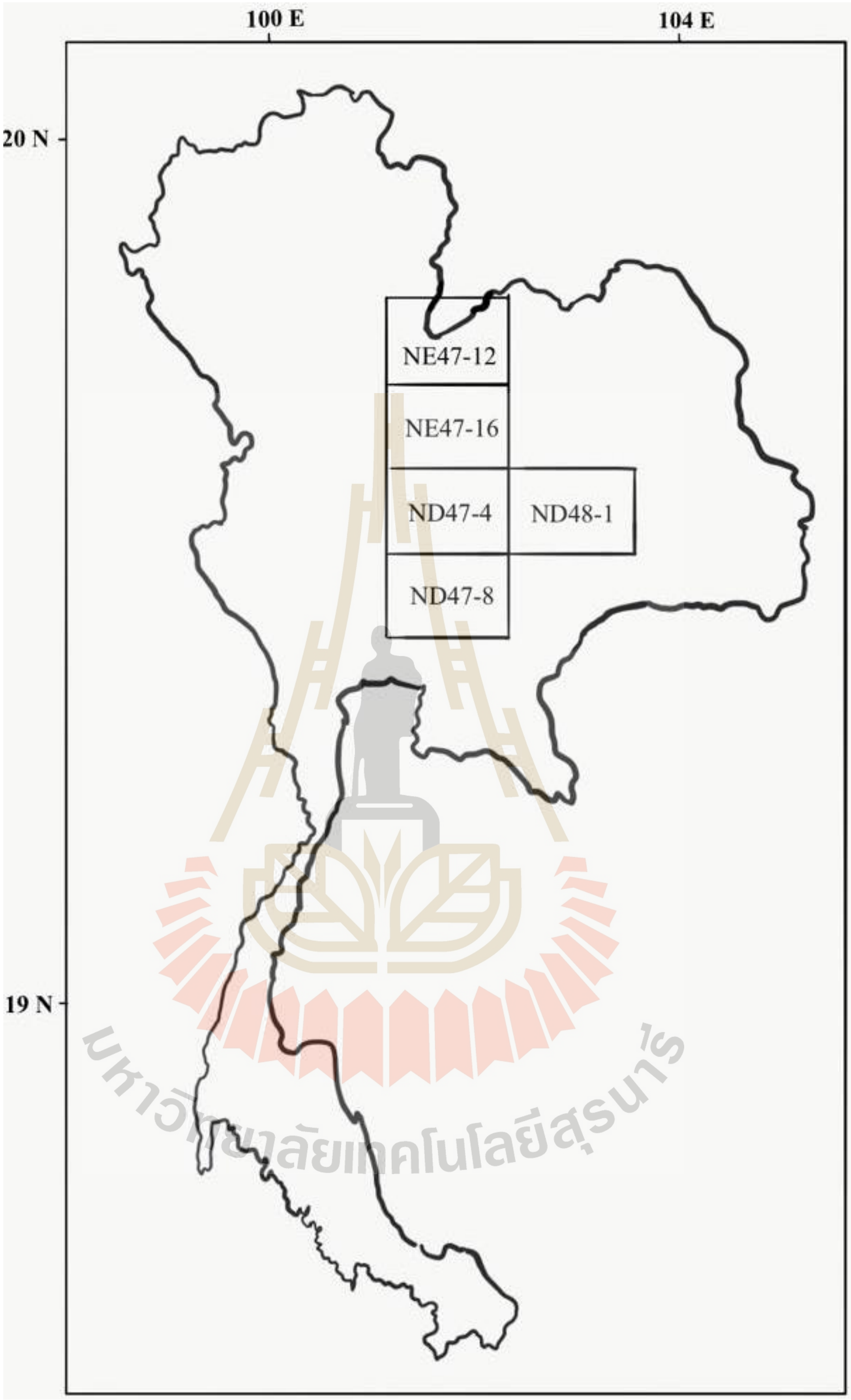


Figure 2.2 Index map of geologic map sheets on scale 1: 250,000

The Pha Dua Formation is probably the upper most Permian succession in this area and is characterized by thin-bedded greenish to brown shale, sandy shale, micaceous sandstone and also interbedded siltstone. The Nam Mahoran Formation contains many fossils including fusulinids, brachiopods, algae, corals and crinoid which indicate Upper Carboniferous to Middle Permian (Gzhelian-Wordian age). The E-Lert Formation contains ammonoids (*Agathiceras* sp.), fusulinids (*Parafusulina* sp., *Schwagerina* sp.), smaller foraminifers and bryozoans which indicate Lower-Middle Permian. The Pha Dua Formaion was assigned to the Middle-Upper Permian by *Agathiceras* sp.

2) The Permian rocks in Phetchabun-Chaiyaphum area

Chonglakmani and Sattayarak (1979; 1984) classified the Permian strata in Phetchabun and Chaiyaphum area and divided them to three formations in ascending order Pha Nok Khao, Hua Na Kham, and Num Duk Formations. The Pha Nok Khao Formation consists of thick-bedded, gray limestone with nodular and thin-bedded chert, and also thin-bedded shale. The Hua Na Kham Formation is characterized by gray shale and yellowish-brown sandstone with interbedded gray limestone lenses. The Nam Duk Formation comprises gray to back shale sandstone, dark gray thin-bedded limestone and chert. The Pha Nok Khao Formation contains fusulinids and corals which indicate Lower-Middle Permian. The Hua Na Kham Formation was designated to be Middle Permian. The Nam Duk Formation has yielded a prolific fusulinids and smaller foraminifers of Middle Permian age.

3) The Permian rocks in Nakhon Sawan-Lopburi area

The Permian rocks in Nakhon Sawan-Lopburi area are characterized by two different formations, Tak Fa in the West and Khao Luak in the East (Nakornsri, 1977;1981). The Tak Fa Formation consists mainly of well bedded and locally massive, fossiliferous limestones. In Amphoe Ban Mi map sheet (Figure 2.3), the Tak Fa Formation is exposed at three regions of karst mountains in Tak Fa District, West of Wichian Buri District, and East of Lam Narai District (Khao Somphot) (See A, B , C in Figure 2.3).The Khao Luak Formation exposed in a long narrow trend of more or less N-S direction at San Khao Luak in the central part of Amphoe Ban Mi map sheet. The Khao Luak Formation (Nakornsri, 1981) consists of tuffaceous sandstone in the lower part, and shale and sandstone with intercalations of thin-bedded limestone in the upper part. The beds of rocks generally strike N-S and dip the East and West. In the Khao Luak Formation, fossil corals (*Pseudohuangia* sp.) are found and they indicate Lower Permian. In the Tak Fa Formation, fusulinids (*Verbeekina verbeeki* and *Parafusulina* sp.) are found and indicate Middle Permian.

4) The Saraburi Group in Saraburi area

Hinthong et al. (1981; 1985) divided the Permian rocks in Saraburi area into six formations in ascending order Phu Phe, Khao Khwang, Nong Pong, Pang Asok, Khao Khad, Sap Bon Formations. The Phu Phe Formation consists of thick-bedded limestone with nodular chert and intercalated slaty shale in some part. The Khao Kwang Formation consists of dark to light gray, thick-bedded limestone with thin-bedded and nodular cherts. The Nong Pong Formation consists of laminated to thin-bedded shale and limestone with argillite and chert intercalation locally. The Pang Asok Formation consists of interbedded gray shale and slaty shale with limestone lenses locally. The Khao Khad Formation consists mainly of thin-bedded to very thick-bedded limestone with chert nodules. Marbles and calc-siticate rocks associated with some argillites and dolomites are also present.

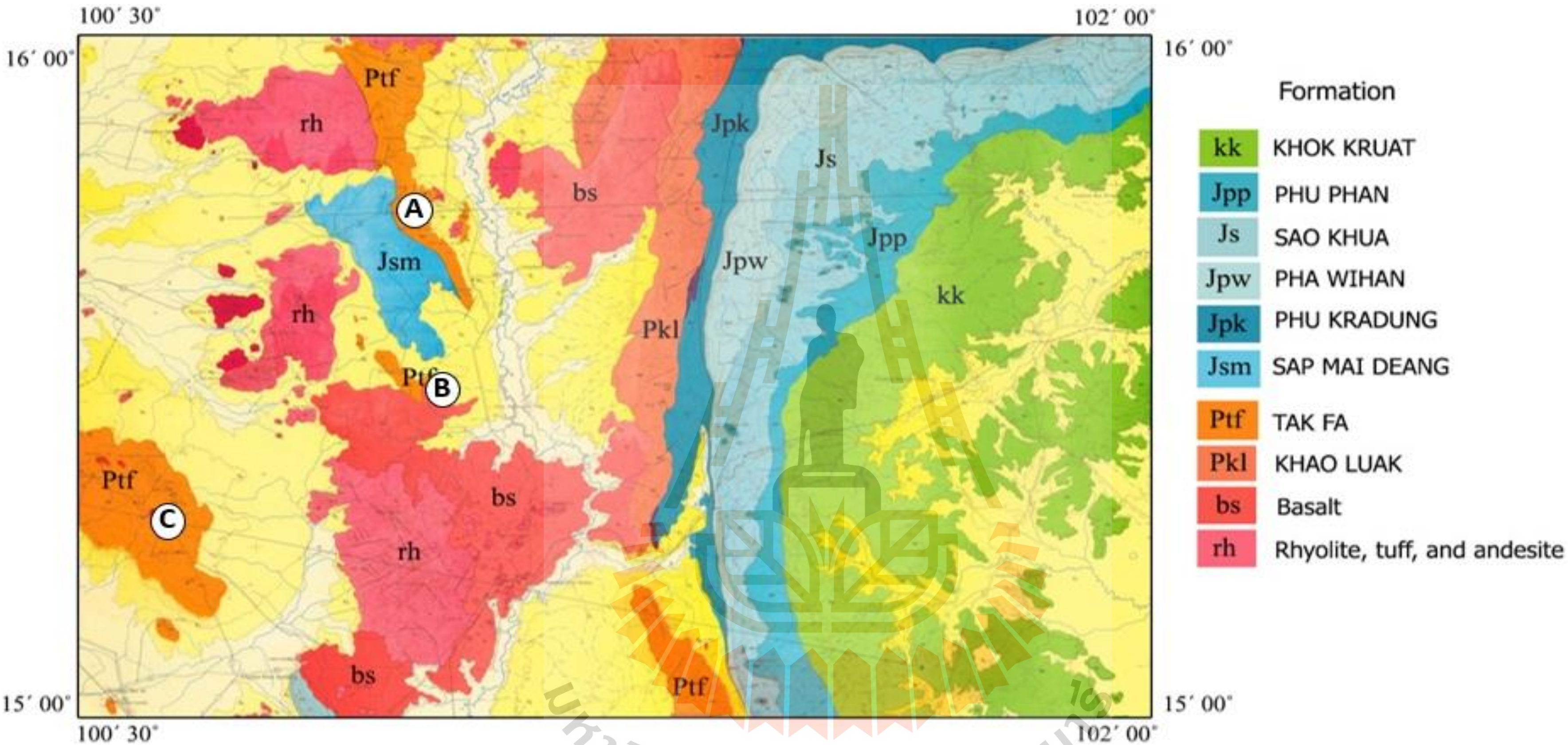


Figure 2.3 Geologic map of Amphoe Ban Mi (ND47-4) showing distribution of Tak Fa Formation in Nakhon Sawan, Lopburi and Phetchabun area (modified from Nakornsri, 1977): (A), (B), (C), The Tak Fa Formation is exposed at three regions of karst mountains in Tak Fa District

The Sap Bon Formation represents pale brown to pale green of interbedded shale and sandstone with local dark gray limestone. In the Phu Phe Formation, fusulinids such as *Pseudoschwagerina* sp. and *Triticites* sp. were discovered and indicated Early Permian (Sakmarian age). The Khao Khwang Formation has diverse fossils including fusulinids, brachiopods, bivalves, bryozoans and crinoid stems which indicate Early Permian (Sakmarian age). Fossil ammonoids (*Agathiceras* sp.) and several unidentified fusulinids were recovered in the Nong Pong Formation and indicated middle-late Early Permian (Artinskian to Kungurian). Fossils found in the Pang Asok Formation include bivalves and leaves which indicate middle-late Early Permian (Artinskian to Kungurian age). The Khao Khad Formation contains fusulinids, brachiopods, gastropods and ammonoids which indicate middle-late Early Permian (Artinskian to Kungurian age). The Sap Bon Formation contains fusulinids (*Pseudofusulina* sp., *Neoschwagerina* sp.) and ammonoid (*Agathiceras* sp.) which indicate late Early Permian-middle Middle Permian (Kungurian to Kazanian age).

5) The Permian rocks in Saraburi-Loei area

Bunopas (1981) established the Saraburi Group for the Permian strata exposed in central Thailand, distributed from Saraburi, Nakhon Sawan, Lopburi to Phetchabun, Chiyaphum and Loei Provinces, and divided them to three formations, namely, Khao Luak Formation, Saraburi Limestone and Dan Sai Shale. The Khao Luak Formation consists of shale, sandstone and thin-bedded limestone in the upper part and the tuffaceous sandstone in the lower part. The Saraburi Limestone consists mainly of well-bedded limestone with beds of bioclastic limestone. The Dan Sai Shale is predominantly of shale and sandstone and consisted of few fossil leaves. Fusulinids such as *Pseudofusulina* sp. and *Triticites* sp. found in the Khao Luak Formation indicate

Carboniferous-Middle Permian. The Saraburi Limestone contains diverse fossils including fusulinids, bryozoans, brachiopods, and corals which indicate Early-Middle Permian (Sakmarian-Wordian age) (Toriyama et al., 1974). The Dan Sai Shale contains fossil leaves e.g., *Gingantopteris* sp. which indicates late Early Permian (Kungurian age) (Asama, 1976).

According to the 250,000-scale geologic maps, the rock formations mentioned above are ranged from Lower to Middle Permian, and the lithostratigraphy can be correlated as shown in Figure 2.4.

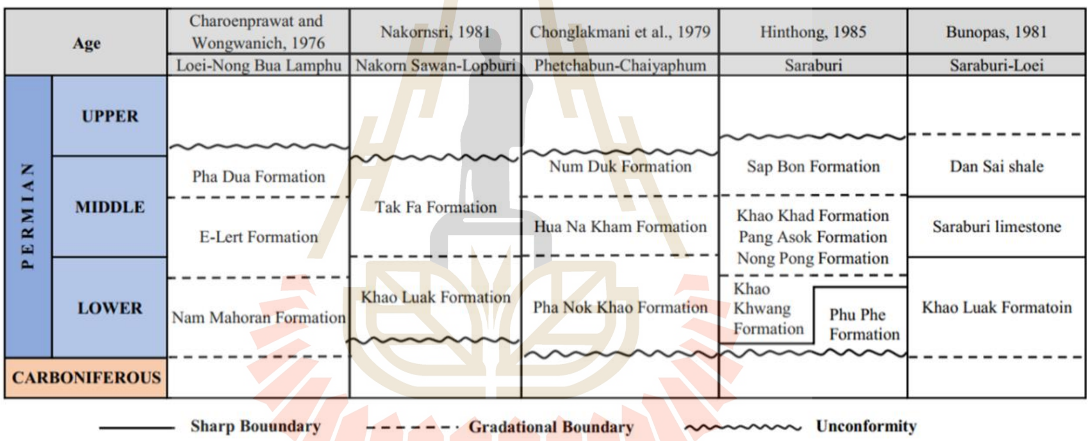


Figure 2.4 Stratigraphic correlation of the Permian Saraburi Group in Central Thailand (modified from Assavapatchara, 1998).

In 1985, Wielchowsky and Young carried out microfacies analysis of the Permian carbonate and silisiclastic rocks from Loei to Saraburi Provinces. They recognized 17 carbonate facies which could be assigned to five depositional environments; three terrigenous clastic facies assigned to three siliciclastic depositional environments. They indicated a north-south oriented carbonate platform and basin including Pha Nok Khao Platform to the East, Khao Kwang Platform to the West, with mixed siliciclastic-carbonate Nam Duk Basin located between the two platforms (Figure 2.5). The rocks from the platforms and the basin yielded Early Permian-late Middle Permian fusulinids (Asselian-Late Guadalupian age).

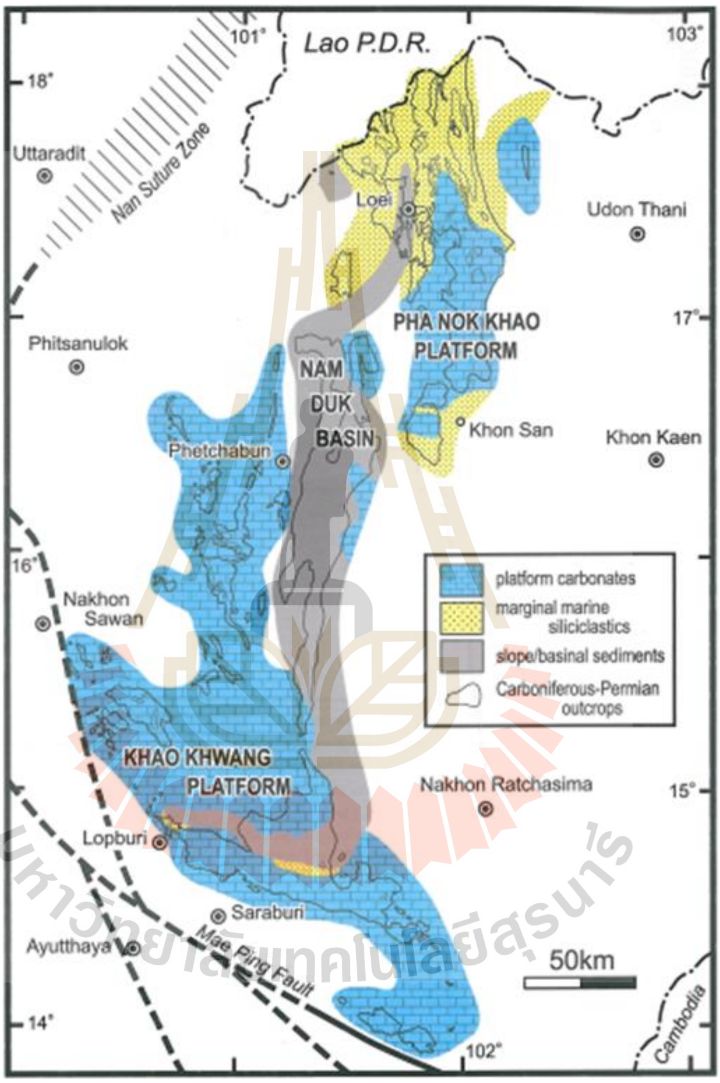


Figure 2.5 Late Paleozoic major facies subdivisions in central Thainad (Ueno and Charoentitirat, 2011-modified after Wielchowsky and Young, 1985).

Dawson (1993) and Dawson and Racey (1993) achieved the microfacies analysis and fusuline foraminiferal biostratigraphy in the Saraburi area, southwestern part of the Khao Khwang Platform. They proposed eight fusuline assemblage zones which ranged from Early to Late Permian (Sakmarian-Early Midian age), and revealed that the studied outcrops were highly deformed and faulted.

Ueno and Chareontitirat (2011) revised and updated the Permian rocks in Thailand, particularly, those in Northeastern region based on paleogeographic reconstruction of Wielchowsky and Young (1985). Ueno and Chareontitirat (2011) listed evidences to confirm that lithology and paleontological components of the rock formations on the Khao Khwang Platform were similar, therefore; the Khao Khwang, the Khao Khad, the Sub Bon, and the Tak Fa Formations were comparable. They recognized differences in lithofacies and paleoenvironments between the two platforms, and proposed a new name "Loei Group" for the rocks on the Pha Nok Khao Platform. They also justified that the Khao Luak and the Nam Duk Formations were identical and can be correlated with the E-Lert Formation on the Pha Nok Khao Platform (Figures 2.6 and 2.7).

2.1.2 Age of the Saraburi Group

The Saraburi Group limited to the rocks on the Khao Khwang Platform (Ueno and Chareontitirat, 2011), is adopted in this study. Invertebrate fossils recovered from the Saraburi Group are diversified and have been studied intensively. They include fusulinaceans (Foraminifera/Fusulinida), corals (Anthozoa/Cnidaria), ammonoids (Mollusca/Cephalopoda), brachiopods (Brachiopoda/Linoproductus), calcareous algae (Dasycladaceae/Dasycladales), smaller foraminifers (Retaria/Foraminifera), bryozoans (Lophophorata/Bryozoa), ostracods (Arthropoda/Ostracoda), gastropods (Mollusca/

Gastropoda), giant bivalve (Mollusca/Bivalvia). The list of paleontological researches of the Saraburi Group is shown in Figures 2.8, 2.9, 2.10.

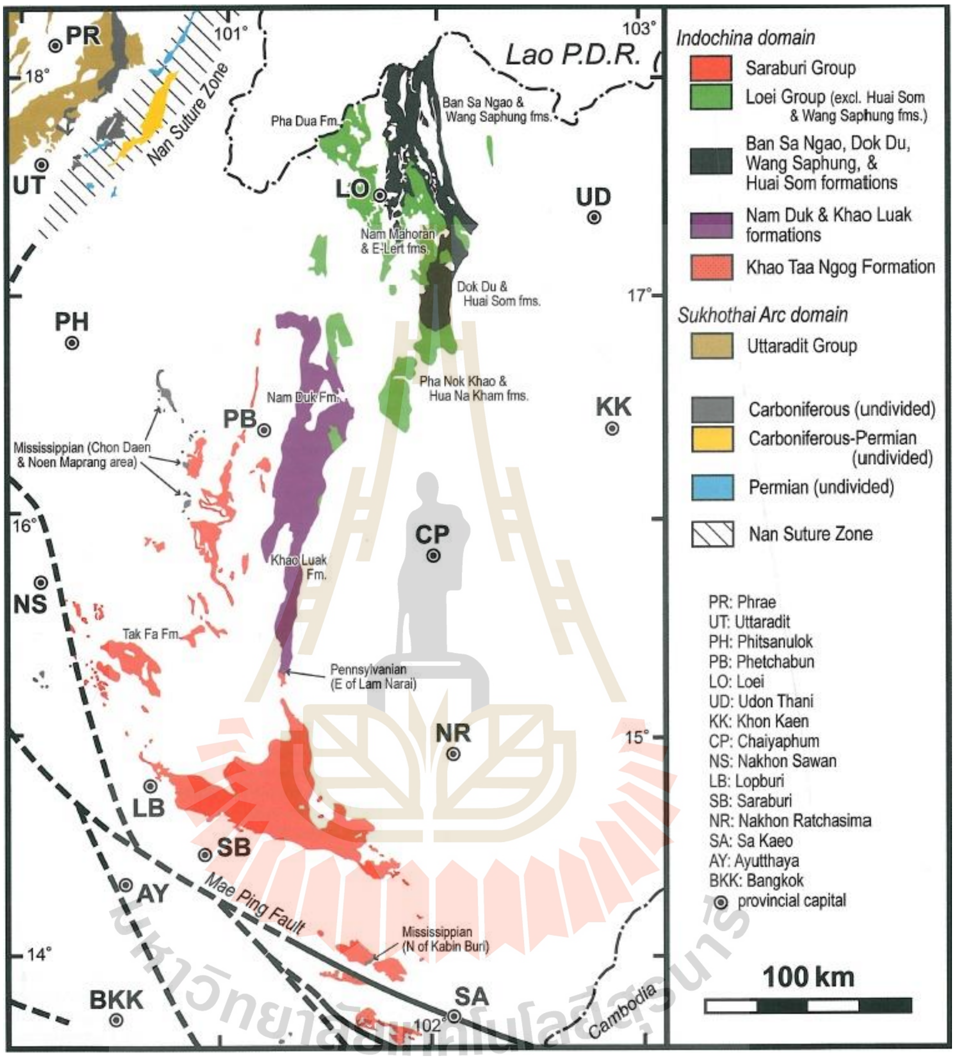


Figure 2.6 Distribution of Carboniferous and Permian rocks in Northeastern of Thailand. (Ueno and Charoentitirat, 2011).

Generally, age of the Permian limestones in central Thailand can be designated by index fossils such as fusulinids, corals, conodonts and ammonoids (e.g., Wieldchowsky and Young, 1985; Chonglakmani and Fontaine, 1990; Dawson, 1993;

Dawson and Racey, 1993; Fontaine et al., 2009; Zhou and Liengchareon, 2004; Metcalfe and Sone, 2008; Burrett et al., 2014). Other fossils, for example brachiopods, calcareous algae, smaller foraminifers, bryozoans which are commonly found in more argillaceous rocks are also important (e.g., Sakagami, 1975; 1999; Yanagida, 1988; Yanagida and Nakornsri, 1999; Pérez-Huerta et al., 2007; Fontaine et al., 2009). Bizarre bivalves (Alatochochidae) is also index of the Middle Permian (Udchachon et al., 2014). The most reliable range of the Permian rocks in central Thailand is established by Ueno and Charoentitirat (2011) as shown in Figure 2.7.

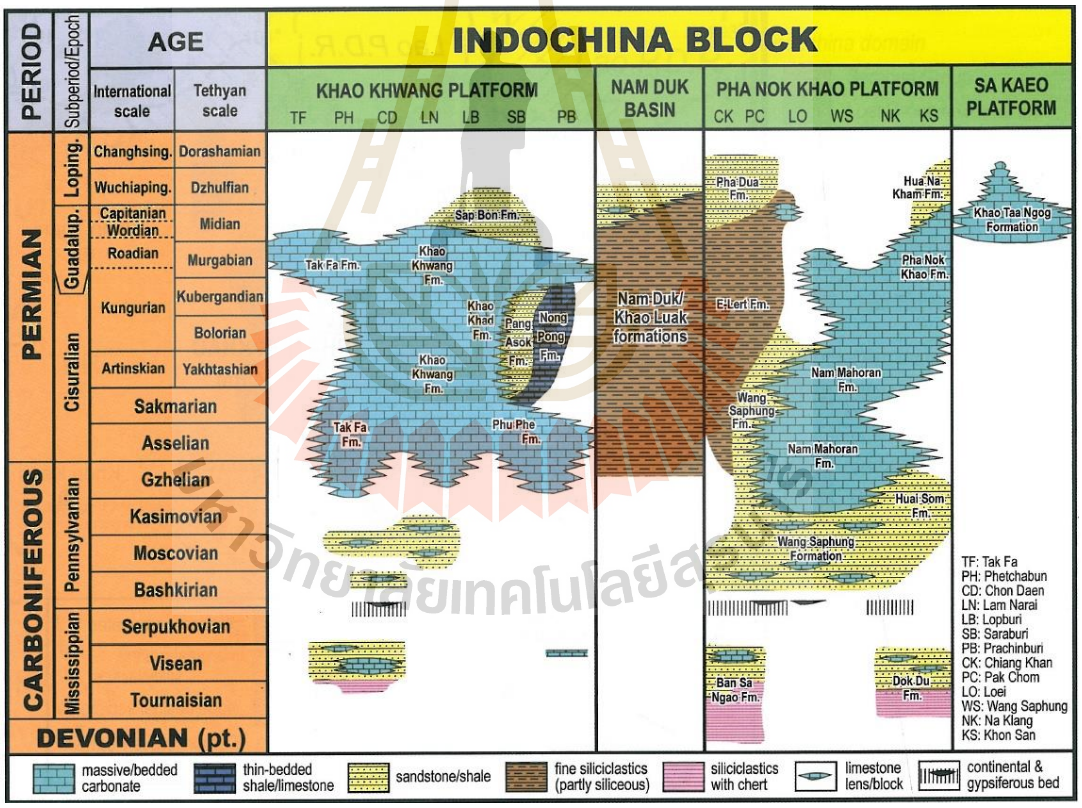


Figure 2.7 Carboniferous and Permian facies distribution and resultant stratigraphic subdivision on the western margin of the Indochina Block (Ueno and Charoentitirat, 2011)

Index fossils of limestones in the Saraburi Group are fusulinids, smaller foraminifers and corals. Fusulinids are ranged from Early Permian (Asslian age) to Middle Permian (Capitanian or Midain age). The smaller foraminifers in Phetchabun area are ranged from Upper Carboniferous – late Upper Permian (Gazhelian-Wuchiapingian age) then they are found in Saraburi area are range from early Middle Permian – late Middle Permian (Rodian-Capitanian age). And also, the corals can be indicated Upper Carbomiferous – late Upper Permian (Gazhelian-Wuchiapingian age) According to the classification of Saraburi Group by many researchers divided unit of rocks as follows (Shown as in Figure 2.8, 2.9, 2.10).

	Period	Epoch	Age	Pitakpivan (1965)	Toriyama (1974)	Nakornsri (1981)	Fusulinid Generic Zones (After Ingavat, 1988)	Chonglakmani and Fontaine (1990)	Yanagida and Nakornsri (1999)	Dowson (1993)	Fontaine et al. (2009)	Uttarawiset et al. (2017) and Singhasuriya et al. (2017)	Udchachon et al. (2014)
254.14	Permian	Lopingian	Chagxingian				*Paleofusulina*						
259.1			Wuchiapingian				*Codonofusiella*						
265.1		Guadalupian	Capitanian			*Verbeekina verbeeki*	*Lepidolina Yabeina*	*Colania douvillei, Verbeekina verbeeki*		*Verbeekina verbeeki, Metadoliolina lepida,*	*Verbeekina verbeeki*	*Verbeekina* sp.	*Sumatrina annae, Sumatrina longisima Chusenella , Yabeina, Conodofusiella, Lepidolina cf. multiseptata Lepidolina cf. kumaensis, Nankinella, Dunbarula, Rauserella.*
			Wordian		*Neoschwagerina simplex*		*Neoschwagerina*	*Sumatrina annae* Neoschwagerina, Hemigordiopsis	*schubertella* sp. Schwagerinids	*Neoschwagerina haydeni, Neoschwagerina*	*Neoschwagerina* cf. *occidentalis*	*Neoshwagerina* sp.	
										Afghanella schencki	*Sumatrina* cf. *annae*	*Pseudodolina* sp.	
										Afghanella pesuliensis, Pseudodoliolina pseudolepida		*Dunbarula* sp.	
268.8						*Neoshwagerina simplex*				*Afghanella megaspherica, Neoschwagerina simplex, Chusenella sp.*		*Afghanella* sp.	*Neoschwagerina margaritae, Verbeekina verbeeki, Neoschwagerina, Nankinella*
272.95			Roadian		*Maklaya sethaputi, Maklaya pamirica, Maklaya saraburiensis*	*Maklaya* sp.	*Cancellina*		*Nankinella* sp.			*Nankinella* sp., *Staffella* sp.	
283.5		Cis-Uralian	Kungurian		*Misellina confragaspira , Misellina otai*	*Misellina ovalis, Misellina confragaspira, Schubertella* sp.	*Parafusulina* / *Misellina*	*Misellina claudidae*		*Armenina* sp., *Miselina contragaspira, Misellina otai, Parafusulina* sp.	*Misellina claudiae, Misellina termieri*	*Parafusulina* sp.	
290.1			Artinskian	*Schwagerina crassa padangensis, Schwagerina cf.techengkiangensis*		*Parafusulina* cf. *granuma vena, Parafusulina gigantea*	*Parafusulina* / *Pseudofusulina* / *Chalaroschwagerina*	*Pseudofusulina globosa , Pseudofusulin a* sp.		*Pseudofusulina vulgaris, Chalaroschwagerina* sp.			
293.52			Sakmarian				*Robustoschwagerina*; *Paraschwagerina*			*Robustoschwagerina* sp., *Nagatoella* sp.			
298.9			Asselian				*Psudoschwagerina*	*Pseudoschwagerina muongthensis, Rugosofusulina* sp.					

Figure 2.8 Fusuline assemblage zones in Central Thailand compared with the International Permian Scale.

Boundary (Ma)	Period	Epoch	Age	Chonglakmani & Fontaine (1990)	Fontaine et al. (2009)	Uttarawiset et al. (2017)
254.14	Permian	Lopingian	Chagxingian			
259.1	Permian	Lopingian	Wuchiapingian		*Dagmarita, Hemigordiopsis, Globivalvulina bulloides*	
265.1	Permian	Guadalupian	Capitanian			*Climacammina* sp., *Globivalvulina* sp., *Eotuberitina* sp., *Tuberitina* sp., *Glomospira* sp., *Umbellina* sp., *Vicinespheara* sp., *Stipulina* sp., *Earlandia* sp., *Nodosinelloides* sp., *Pachyphloia* sp., *Ichtyolaria* sp., *Tetrataxis* sp., *Protonodosaria* sp., *Frondina* sp., *Calcitornella* sp., *Neodiscus* ? sp., *Schubertella* ? sp.
268.8	Permian	Guadalupian	Wordian	*Agathammina, Globivalvulina, Dagmarita chanakchensis, Nodosariidae, Hemigordiopsis, Climacammina, Pachyphlopis, Pseudovermiporella nipponica.*		
272.95	Permian	Guadalupian	Roadian	*Tuberitina collosa Reitlinger, Globivalvulina, Climacammina*		
283.5	Permian	Cis-Uralian	Kungurian	*Pachyphloia, Codonofusiella, Globivalvulina*	*Climacammina*	
290.1	Permian	Cis-Uralian	Artinskian			
293.52	Permian	Cis-Uralian	Sakmarian		*Nodosariidae*	
298.9	Permian	Cis-Uralian	Asselian		*Bradyina, Deckerella*	
	Carboniferous	Upper	Gzhelian		*Globivalvulina bulloides*	

Figure 2.9 Smaller foraminifera assemblages in Central Thailand.

Boundary (Ma)	Period	Epoch	Age	cited in Nakornsri (1981)	Chonglakmani & Fontaine (1990)	Fontaine et al. (2009)
254.14	Permian	Lopingian	Chagxingian			
259.1	Permian	Lopingian	Wuchiapingian			*Ipciphyllum laosense Multimurinus Crassiparietiphyllum Ipcipphyllum phadaengense Ipciphyllum subelegans Ptotomichelinia Khemeria problematica*
265.1	Permian	Guadalupian	Capitanian		*Ipciphyllum subelegans, Protomichelinia, Wentzelloides* **Tabulata:** *Sinopora, Bothrophyllidae?, Pseudohuangia*	
268.8	Permian	Guadalupian	Wordian		*Pseudohungia chiuyaoshanensis* **Tabulata:** *Sinopora, Micheliniidae*	
272.95	Permian	Guadalupian	Roadian			
283.5	Permian	Cis-Uralian	Kungurian	*Pseudohungia* cf. *pesica*		*Pseudohuangia Ipciphyllum laosense*
290.1	Permian	Cis-Uralian	Artinskian			
293.52	Permian	Cis-Uralian	Sakmarian			*Pavastehphyllum*
298.9	Permian	Cis-Uralian	Asselian			
	Carboniferous	Upper	Gzhelian			*Sestrophyllum*

Figure 2.10 Coral assemblage in Central Thailand.

2.1.3 Paleogeography and paleoenvironment of the Saraburi Group

The Permian Saraburi Group consisted of the carbonate and siliciclastic rocks; the limestones were deposited not only in shallow marine environment but the deeper environment was also recognized in the Phetchabun area (Chonglakmani and Sattayarak, 1984). Paleogeography and paleoenvironment have been interested and studied by many researchers in the scopes of lithostratigraphy and paleontology as follows.

1) The Paleoenvironment of Loei – Saraburi provinces

Wielchowsky and Young (1985) studied the rocks samples collected from the Loei to Saraburi areas including preparing rock thin sections, identifying microfacies, considering faunal characteristics and distributions. Then they assigned corresponding depositional environments within the Loei – Saraburi area (see Figure 2.5). They recognized 17 carbonate facies and assigned these facies to five depositional environments including basin plain, basin margin, outer platform, platform interior and restricted platform. They also recognized three terrigenous clastic facies and assigned them to three siliciclastic depositional environments (Figure 2.11).

The carbonate depositional environments consist of 1) basin including basin plain and basin margin environments; 2) platform including outer platform, platform interior and restricted platform environments. The facies assigned to these depositional settings are discussed below.

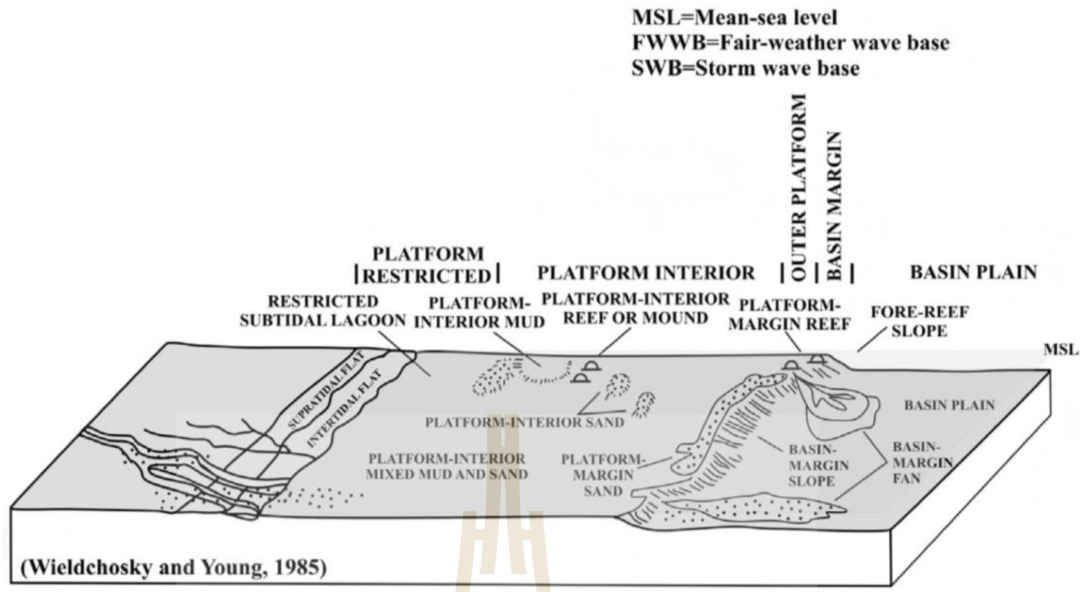


Figure 2.11 Permian deposition environments northeastern Thailand (Wielchowsky and Young, 1985).

The basin plain consists of thin-bedded, interbedded black to gray shales, cherts, gray graded limestones.

The basin margin can be subdivided into three sub-environments including basin margin fan, basin margin slope and forereef slope margin. In the basin margin fan, thin- to thick-bedded, argillaceous carbonate mudstone through grainstone and matrix-supported conglomerates were characterized. Thin- to thick bedded limestone and shale, massive limestone conglomerate facies were found in the basin-margin slope. The fore-reef slope composed of thin- to thick-bedded limestones, shales, and conglomerates.

The outer platform can be divided into platform margin sand shoal and platform margin reef. In the platform margin sand shoal, medium- to thick -bedded, skeleton and/or oolitic grainstons, packestones were dominated. The platform margin reef was characterized by massive coral-algae-sponge boundstones and dolomites.

The platform interior can be divided to four sub-environments including sand shoal, lagoon, mixed mud and sand complex, and reef or mound. The platform interior sand shoal consisted of skeletal and oolitic grainstones and packstones. The platform interior lagoon consisted of burrowed carbonate mudstones and skeletal and peloidal wackestones. The platform interior mixed mud and sand complex consisted of skeletal and peloidal wackestones and packstones. The platform interior reef or mound consisted of massive coral-algae-sponge boundstones and dolomites.

The restricted platform environment was subdivided into restricted subtidal lagoon, intertidal flat and supratidal flat subenvironments. The restricted subtidal lagoon can be characterized by burrowed carbonate mudstones and dolomites with few fossils and low diversity. The intertidal flat was dominated by burrowed to laminated carbonate mudstones and dolomites with few fossils and intercalated red siltstones and fine-grained sandstone, or carbonate breccia. The supratidal flat composed of laminated and/or stromatolitic limestones and dolomites, birdeye carbonate mudstones and dolomites, breccias with laminated limestone and dolomite clasts, and pisolitic limestone and dolomites.

Three siliciclastic facies were recognized including 1) thin-and thick-bedded greywackes and shales with complete Bouma sequences and convoluted bedding represented deep marine environment; 2) interbedded shales, siltstones, cross-laminated sandstones and minor limestones represented shallow marine environment; 3) medium- to thick-bedded sandstones, conglomerates, shales, and limestones with channel burrows, clay rip-up clasts and plant materials represented marginal marine environment.

In addition, Wielchowsky and Young (1985) established the presence of three Permian paleogeographic provinces, namely, Khao Khawang carbonate platform to the west, the central Nam Duk mixed siliciclatic-carbornate basin and Pha Nok Khao mixed carbonate-siliciclastic platform to the east (see Figure 2.5).

2) The Paleoenvironment in area North of Saraburi province

Dawson and Racey (1993) carried out microfacies analysis of the sections located North of the Saraburi city which is in the southern part of the Khao Khwang Platform (C in Figure 2.12). They recognized and subdivided the microfacies on the basis of a particularly abundant and diverse fusuline and calcareous algal biota. The sequence yielded a diverse fusiline-algal assemblage from Early Permian to early Late Permian (Sakmarian-Midain age). Six main biofacies were recognized and they represented paleoenvironments such as slope and turbidite deposits, algal reef complex and marginal platform, back reef/ middle platform, inner platform with path reefs, protected lagoon/ inner platform and peritidal flat. The presence of diversified dasycladacean algae suggested the deposition in a warm, tropical open marine, shelf/platform environment.

They concluded that the presence of fusulinids *Robustoschwagerina-Nagatoella-Pseudofusulina* assemblage showed that the Paleotethys was still linked with the Arctic until at least the late Early Permian (Yahtashain age). On the contrary, during the late Early to early Middle Permian (Yahtashian-Bolorian age), these paleo oceans were disconnected and different in facies due to eustatic sea level variation and regional tectonic event. The *Verbeekina-Pseudodoliolina-Chusenella* assemblage represented a rather calm, inner platform lagoon in Middle Permian. During the late Murgabian-early Midian, a poor of *Verbeekina*-rich horizon was overlain by dolomitized algal mats and red shales suggesting a sea level fall.

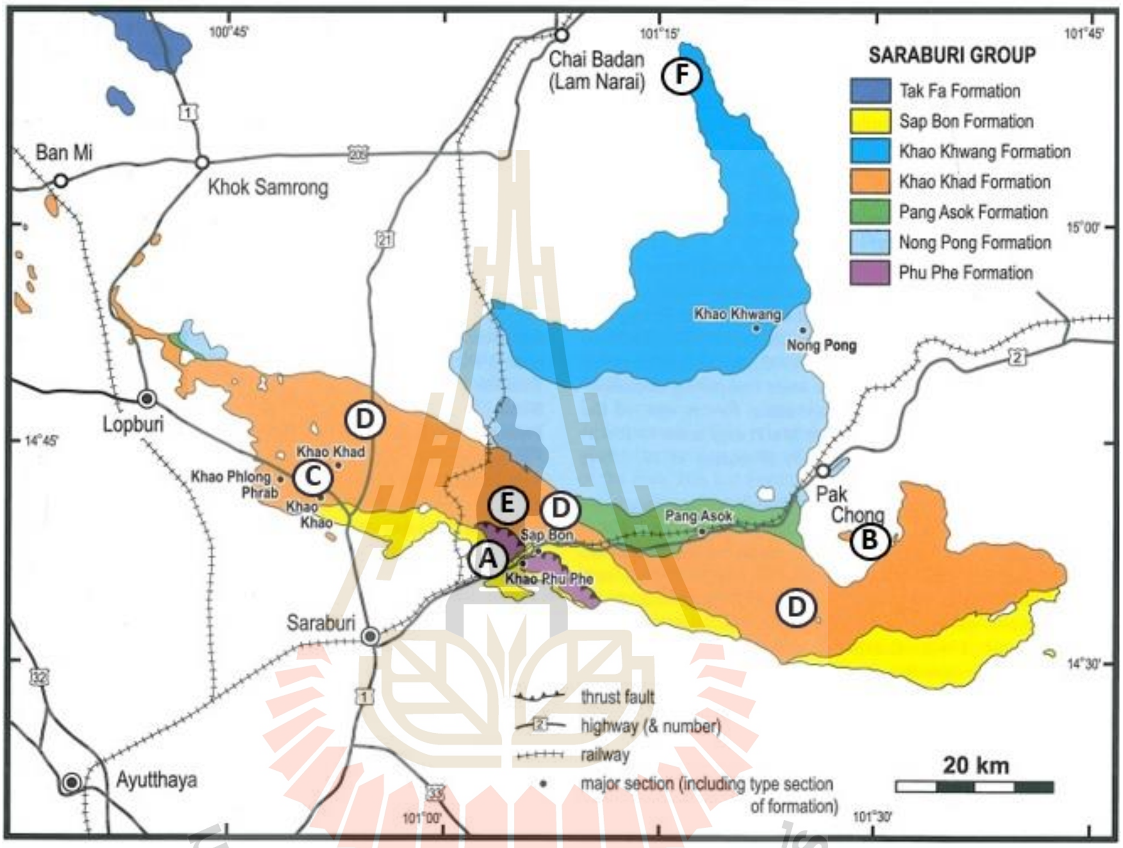


Figure 2.12 Geological map of the Saraburi Group in Saraburi area showing localities of previous studies: A) Singhasuriya et al., 2017; B) Uttarawiset et al., 2017; C) Dawson and Racey, 1993; D) Thambunya et al., 2007; E) Chutakositkanon et al., 2000; F) Udchachon et al., 2014 (modified after Ueno and Charoentitirat, 2011).

3) The Paleoenvironments in the southern part of Saraburi - Nakhon Ratchasima area

Singhasuriya et al. (2017) studied limestone samples collected from two different sections including 1) ML section from the Khao Kad Formation and 2) TPI section from the Sup Bon Formation, both were located in Muak Lek district of the Saraburi province (A in figure 2.12). The ML section was dominated by medium- to thick-bedded, gray limestones and dark brown shales. The TPI section comprised medium-bedded, light gray to gray limestones and brown shales. Fossils such as fusulinids, conodonts, smaller foraminifers, corals and crinoid stems were found in both sections. Fusulinids and conodonts indicate Middle Permian (Roadian to Capitanian age) as shown in Figures 2.8 and 2.9. The microfacies facies data of the sequences indicate warm-tropical marine environment, from slope basin to deep basin.

Also, in 2017, Uttarawiset and others made an investigation in Pak Chong District, Nakhon Ratchasima province. They collected limestones from the outcrop in a part of the Khao Khad Formation (B in figure 2.12) in order to determine the age and depositional environment of the section. The limestone samples were gray to black, partly dolomitic, with some cherts and volcaniclastic rocks. The limestones consisted of diverse fossils such as alatoconchids, bivalves, gastropods, corals, brachiopods and crinoids. Fusulinids and smaller foraminifers indicate Middle Permian (see Figures 2.8-2.9). The depositional environment was interpreted based on microfacies analysis which included three microfacies, namely, Fusuline wackestone, Fusuline packstone and Bioclastic wakestone, represented a shallow-marine tropical depositional environment.

According to both studies, the studied sections exposed in the Khao Khad and the Sup Bon Formations range in age from Early to Middle Permian. The depositional environments of these Formations include shallow marine, slope basin and deep margin basin. These environments indicate that the boundary between Saraburi - Nakhon Ratchasima provinces is an area connecting the Khao Kwang Platform and the Num Duk Basin.

Thambunya et al. (2007) made detailed investigation of several sections in a part of the Khao Khad Formation which were composed of limestones, dolomitic limestones, argillaceous limestones and silty shales with nodular and bedded cherts. The sections were located at Khao Khad, Khao Chan and the area along Pak Chong-Khao Yai route (D in Figure 2.12). They subdivided the composite-studied sections into 15 rock units, namely, from Units A to O, consecutively in ascending order. They interpreted that the Khao Khad Formation was likely deposited during a major transgressive and regressive cycle of seawater during the Lower to Middle Permian time on the marine shelf condition, under sub-environments of intertidal to subtidal zones near shore, subtidal zone of lagoon, shallow platform, barrier bar or shoal and foreslope of barrier bar.

The transgressive sequence (Figure 2.13A) probably occurred during the deposition of the Units A to H. The sequence started with the unit A which was the subtidal zone of lagoon at the Khao Khad and the Khao Chan areas. The Unit B presented in the Khao Khad area, was algal stromatolites in the intertidal zone. The Units C to E were barrier bars or shoals at the Khao Khad and the Khao Chan areas and containing crinoid fragments, intraclasts, some fusulinids, and bryzoans fragments. The Unit F was the foreslope of barrier bar exposed in the Khao Chan area. The Unit G was deposited in the intertidal to subtidal zones of lagoon. The Unit H was deposited in the shallow platform.

The regressive sequence (Figure 2.13B) probably occurred during the deposition of the Units I to O. The Units I and J were deposited in the intertidal to subtidal zone of lagoon. After that sea level fell down, then the Unit K was deposited in the intertidal zone of lagoon with abundant bioturbation and fenestral features. The Unit L was deposited in the subtidal zone of lagoon. The Units M and N were the increasing influx of terrigeneous sediments into the intertidal and subtidal zones near shore. The Unit O was deposited in the intertidal to subtidal zones of inner shelf with slightly high-energy condition.

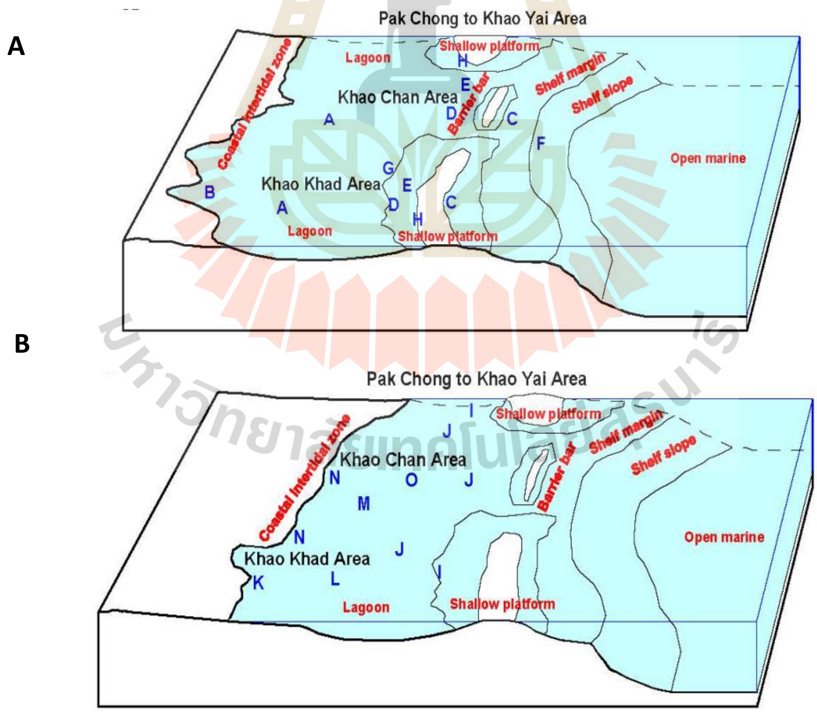


Figure 2.13 Depositional environment of the studied sections: A) Depositional environment of the transgressive sequence Units I to O (Thambunya et al., 2007).

Chutakositkanon et al. (2000) interpreted paleoenvironments and tectonic setting of the Permian marine sedimentary sequence in Keang Khoi District, to the East of the Saraburi Province (E in Figure 2.12). The sequence was subdivided three lithostratigraphic units, namely, the Phu Phe, Khao Sung and Khao Pun Formations. The Phu Phe Formation was designated to Lower Permian (Sakmarian age) according to fusulinids (Hinthong et al., 1981) whereas the Khao Sung and Khao Pun Formations were dated as Middle Permian by the fusulinids (Chutakositkanon et al., 2000). They combined lithology and geochemical analysis to interpret the rock samples and showed that the Lower to lower Upper Permian sedimentary facies indicated the transgressive and regressive of shelf sea/platform environment to pelagic or abyssal environment below the carbonate compensation depth (CCD). The Lower Permian strata represented shallow or lagoon environment (stage 1). The depositional environment changed to pelagic environment, as indicated by laminated radiolarian cherts (stage 3). This cryptic evidence might indicate the abyssal environment during middle Middle to early Late Permian. The evolution of the study area and areas nearby was divided into six stages as follows (Figure 2.14).

In the first stage, the Phu Phe Formation of the study area indicated the sheltered shallow or lagoon environment, which it was supported by finely grained clastic sediments and organic matter during Middle Permian. However, this was different from the general of the Phu Phe Formation exposed elsewhere which was dominated by gray-fossiliferous wakcestone or biomicrite-biomicrosparite with fusulinids and bivalve shells which indicated Early Permian.

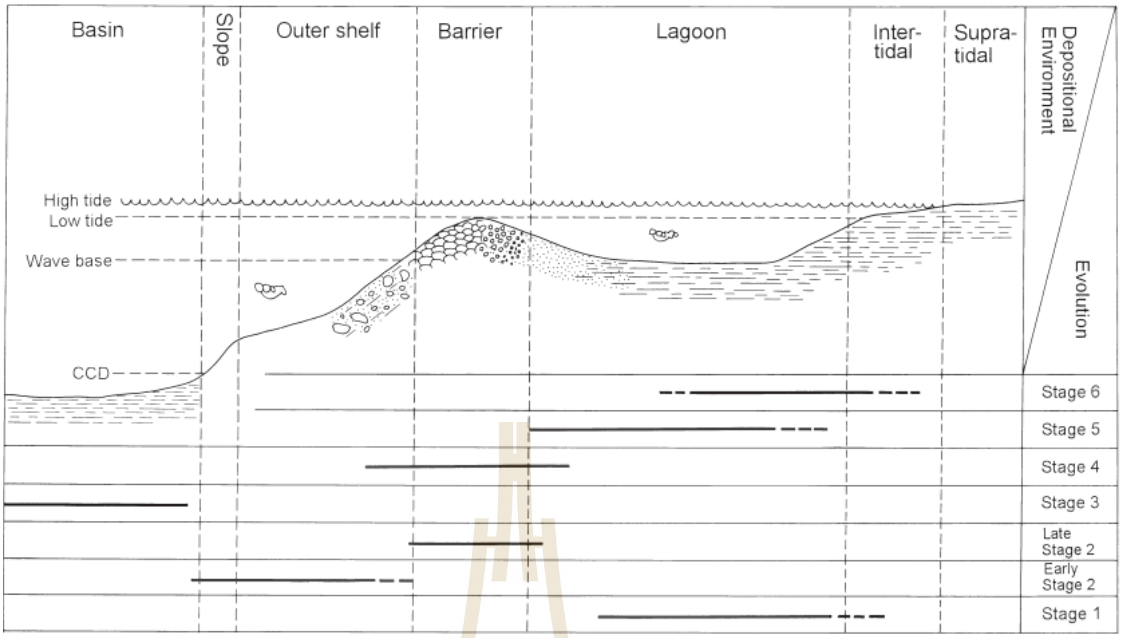


Figure 2.14 Depositional environment model of the Khao Pun Area during Permian Period (Chutakositkanon et al., 2000).

Second stage, the sedimentary basin was shallower and locally filled by the carbonate. The observed fossils including crinoids, calcareous algae, bryozoans and rare corals indicated of ecologically zoned with respect to the barrier or reef mounds.

The third stage was distinguished by deep marine deposits of laminated radiolarian chert with some porcellanite and ironstone. Radiolarians have been thought traditionally to accumulate in sediments on the deep ocean floor.

In the fourth stage, the depositional environment was thought to be a barrier during late Middle Permian. The rocks included skeletal floatstone, rudstone, grainstone and wackestone interpreted non-reef bioherm or mound-like accumulation. The rocks of this stage were characterized by the transition or intercalation of reddishbrown calcareous shales and argillaceous limestone/ black shale indicating transgression/ regression.

The fifth stage was marked by the sequence of the late Middle Permian mudstones. These rocks were devoid of fossils with the disseminated pyrite grains and framboids which may indicate an oxygen deficiency.

The deposition in sixth stage occurred during late Middle to early Late Permian. The last stage was distinguished by homogeneous and light-colored limestone and shale-dominated. These rocks composed entirely of fine-grained microsparry calcite with sparry calcite in fenestral indicate tidal flat to the sheltered lagoon.

4) The Paleoenvironment of Khao Somphot in Lop Buri province

Udchachon et al. (2014) interpreted depositional environments of the Saraburi Group at Khao Somphot in Lop Buri Province (F in Figure 2.12) by microfacies analysis. Nine major microfacies types were determined consisting of algal-foram facies (MF1), fusuline facies (MF2), alatoconchid facies (MF3), lime mudstone/ wackestone facies (MF4), laminated bindstone facies (MF5), fine-grained cortoid grainstone facies (MF6), coral biostrome facies (MF7), crinoidal packstone facies (MF8) and carbonate breccia/ conglomerate facies (MF9). The microfacies were interpreted to be deposited on the carbonate ramp, that is; the laminated bindstone deposited in shallow subtidal or intertidal environments, the fenestral fabric developed in the intertidal or supratidal, fusuline grainstone and cortoid grainstone facies deposited as sand shoals located around fair-weather wave base of the inner ramp, the fusuline wackestone/packestone deposited in sub-tidal environments, below fair-weather wave base, located mainly in the middle ramp (Figure 2.15). They also suggested that the carbonate ramp probably evolved from a rimmed platform that existed during the Early Permian which indicated by occurrence of slope, basin and platform facies.

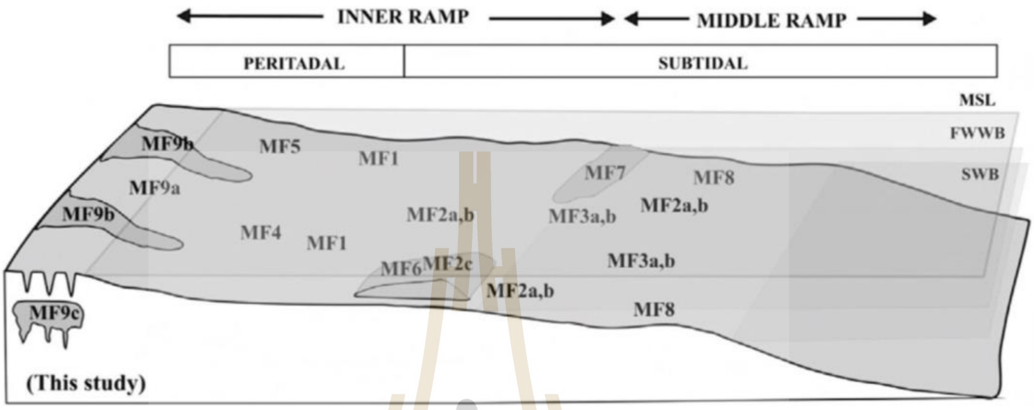


Figure 2.15 A depositional model and major microfacies types of the carbonate platform during Wordian – Capitanian age (Udchachon et al., 2014).

5) The Palaeoenvironment in southern part of Phetchabun province

The depositional environment of the Permian limestones, a part of the Tak Fa Formation exposed in Phetchabun province, was interpreted by a different technique from the researches mentioned above. Chitnarin et al. (2008) investigated and collected samples from the Bung Sam Phan section which is located in the South of the Phetchabun city, and situated on the Khao Khwang Platform (Figure 2.16). The sequence consisted mainly of intercalations of medium- to thick-bedded limestones and shales. The rocks contained brachiopods, fusulinids, gastropods, crinoid stems, shells and ostracods. They disaggregated the ostracods (micro-size crustaceans) from the limestones, identified the taxon, and interpreted the paleoenvironment based on the ostracod assemblage. The results showed that the ostracods belonged to four Superfamilies (Kloedenellacea, Bairdiacea, Krikbyacea and Sansabellacea), eight genera, and 15 species. Of which, four species were newly described including *Sargentina phetchabunensis*, *Geffenina bungsamphanensis*, *Bairdia takfarnsis*, and *Reviya Subsompongensis.* The percentage of ostracod species in Superfamily/Family level was used to resolve the depositional environments. The ostracod assemblages were varied from the lower part to the upper part of the section. thus, they indicated a shallow marine, euryhaline, nearshore environment, and the shallowing upward sequence.

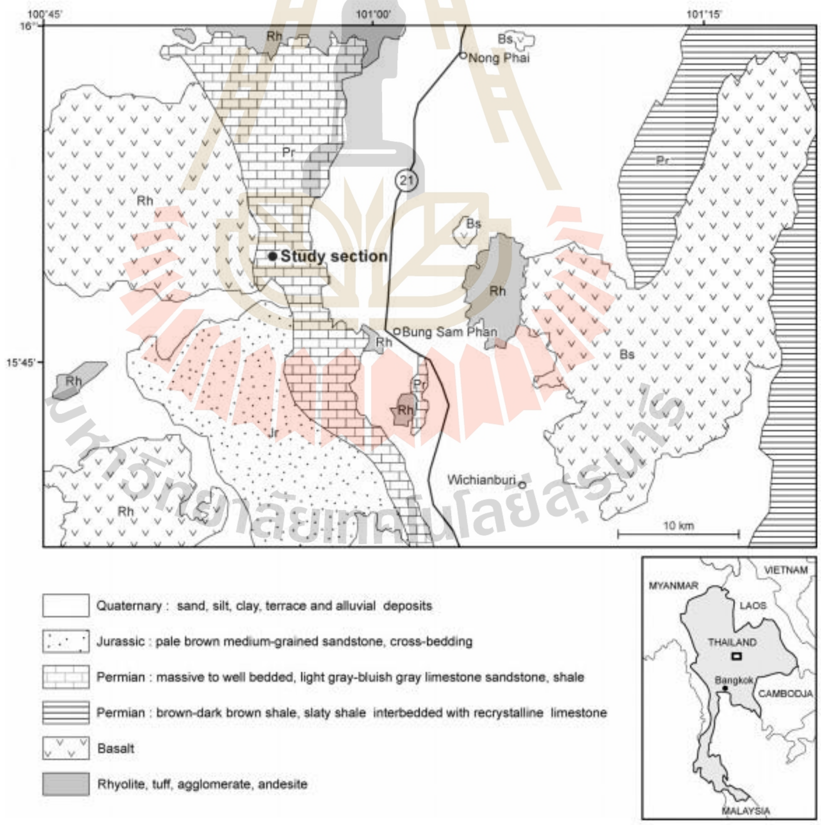


Figure 2.16 Geological map and location of the Bung Sam Phan section (Chitnarin et al., 2008)

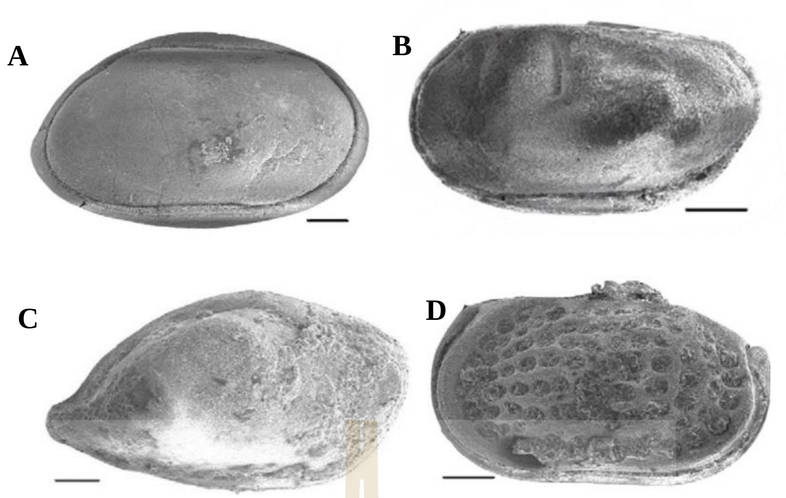


Figure 2.17 Four new species form the Bung Sam Phan section. Scale bar is 100 μm (Chitnarin et al., 2008).

6) The Palaeoenvironment in Nakhon Sawan province

Chitnarin (2015) studied the Middle Permian limestone and black shale collected from Khao Luk Klon section, Nakhon Sawan province based on ostracod assemblage analysis. The result showed that the ostracods contains one Superfamilies and two Families (Bairdioidea, achydomellidae and Cytherideidae respectively), thus, they suggested subtidal, open marine environment, on the continental shelf, slightly offshore, and on the soft carbonate substrate.

2.2 Permian Ostracod

Ostracods are small invertebrates in Phylum Arthropoda and Subclass Ostracoda. They are the most abundant of fossil arthropods and are represented by some 30,000 living and fossil species (Cohen et al., 1998). The scientific study of ostracods began in 1776 when O.F. Müller named the first living species. However, the ostracods lived on the earth since Early Ordovician (Salas, 2002). Biological information of the ostracods are summarized from several articles (i.e., Moore, 1961; Pokorný, 1978; Henderson, 1990; Cohen et al., 1998; Horne et al., 2002) and presented here to provide essential elements of the organisms.

2.2.1 General biology of the ostracods

The ostracods are small, bivalved crustaceans belonged to Subphylum Crustacea and Class Ostracoda. The body of an ostracod is short, laterally compressed and enclosed within a bivalved calcareous carapace. The hinge of the two valves is in the upper region of the body. They are typically around 0.4-1.5 mm in microscopic size, though some freshwater forms are rather larger (5-30 mm). They have lived in marine, brackish and freshwater environments.

1) The soft body structure of the ostracod

The ostracods are characterized by a segmented body covered by a jointed external skeleton of chitin with a different number of paired appendages. The head is large and bears a centrally placed mouth and a dorsal, usually single eye. The anus is at the posterior end of the body. The head (cephalic) and the thorax (post-cephalic) are fused to form a "cephalothorax" and it is difficult to homologize the segments and appendages with other crustaceans (A and B in Figure 2.18). Covering the body is a cuticle, the two folds of which hang down on each side of the body and secrete a bivalved shell called "carapace".

The ostracods commonly have seven pairs of appendages, but up to eight pairs of appendages in the adult stage, borne on the ventral side of the body (C in Figure 2.18), Also, they have a "furca" near the posterior end of the body. As in other crustaceas, the limbs are essentially biramous include and outer exopodite and an inner endopodite. These ostracod appendages bear fine chitinous bristles called "setae" and terminate in claws. The first and second known as the “antennules” and the “antenna” are consisting of long and tapering appendages, mainly used for feeding, walking and swimming. The upper lip forms the front and the hypostome the back of the mouth. A pair of biramous “mandibles” and “maxillae” are attached to the hypostome and aid mastication of the food. The fifth to seventh limbs are basically similar and mostly take the form of walking legs in which the endopodite has a well-developed claw and the exopodite is reduced. An eighth limb is present only in the rare Puncioidea in Superfamily Palaeocopida.

The respiratory and circulatory system are greatly reduced. Large blood vessels and heart are also lacking in all except the relatively large and planktonic Myodocopida. Muscles that operate the appendages are connect to the chitinous endoskeleton or the central or dorsal part of the carapace where they form the dorsal muscle-scar pattern. The adductor muscles close the valves and form the central muscles-scar pattern on the valves (D in Figure 2.18), their bearing is distinguished on the external of the valve by a subcentral tubercle or an in fold of the valve known as the “sulcus”.

The sexual behavior of the ostracods is diverse, and seven different types of brood care have been recognized in various lineages from Paleozoic to Recent (Horne et al., 1998; Jaanusson, 1985). These various types have arisen independently in several marine and non-marine lineages of ostracod, so diverse carapace shapes acting as brood pouches are found. The ability of the ostracod female to brood egg or juveniles within the carapace might protect the young from severe environmental fluctuation and predation (see A in Figure 2.18).

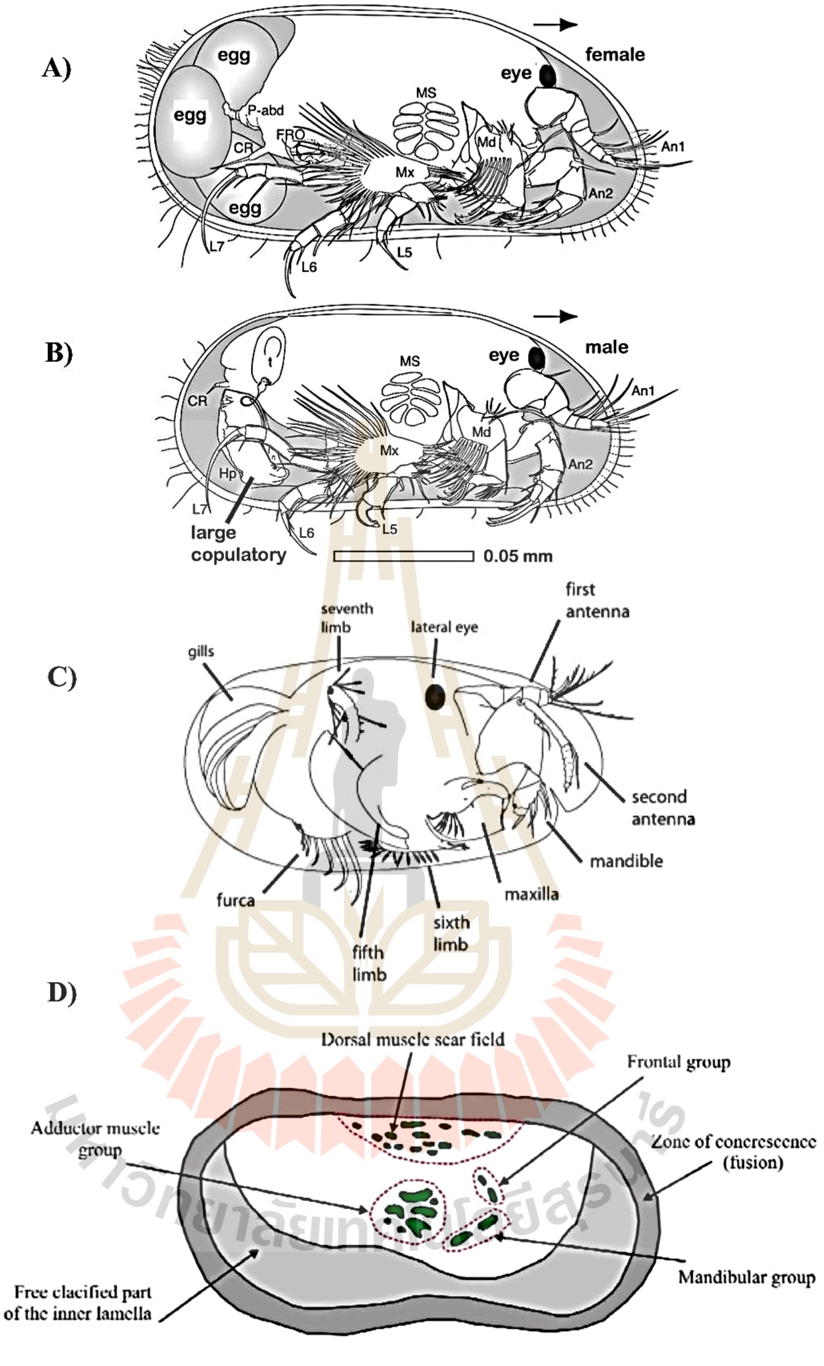


Figure 2.18 Morphology of the ostracod: A, B) morphology of female and male with right valve removed of *Vestalenula cornelia*; C) appendages of the ostracod, D) Types of muscles in Ostracoda (A-C, Ozawa, 2013; D, Youssef and El-Sorogy, 2015).

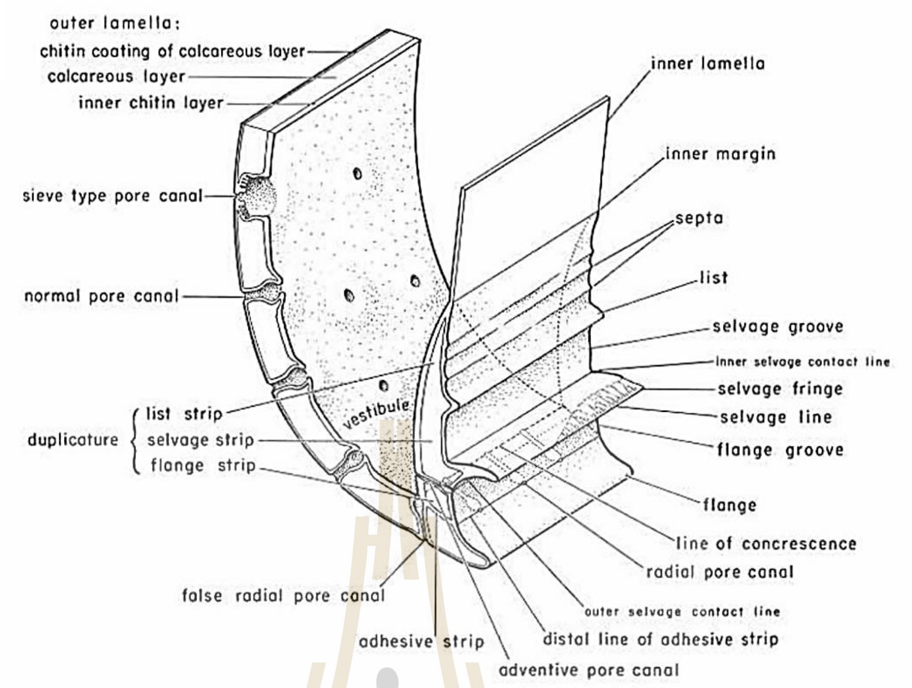
2) The general feature of ostracod carapace

The ostracod carapace is bivalved, either valve being identical but not consistently a mirror sight of other. The two valves may be subequal or inequitable in size. Diversity in size results in overlap of part of the larger or in enclosure of the smaller valve by the larger all around the margin. The free margin may be tilted in such a manner that the two valves fit without marked overlap, giving the shape of impartiality. Nonetheless, the free margin edge on one valve slightly overlaps the thin edge of the opposite valve. The carapace comprises two parts including a hard layer of calcium carbonate, and a soft layer, or the epidermis.

The hard-shell layer is usually composed of two parts, the outer lamella and duplicature (Figure A in 2.19). Both parts are composed of crystalline calcium carbonate. The amount of calcium in the diet may control some shell features. Unusually thin or thick shells, ornamentation, or aberrant feature may be environmentally controlled. The carapaces of most ostracods may show different types and degrees of ornamentation, varied from sulci and ridges which divide the valve into lobes to fine markings on the surface. The principle types of these distinctive features are shown in B in Figure 2.19.

Spines are distinctive features of many ostracod carapaces. They are highly variable in number and size. Some are solid and apparently held some portion of the soft parts. Lobes and sulci are among the most distinctive feature of many ostracod carapaces. Nodes are common on valves, particularly in the various Paleozoic genera, including *Holinella*, *Mauryella*, *Keisowia*.

A)



B)

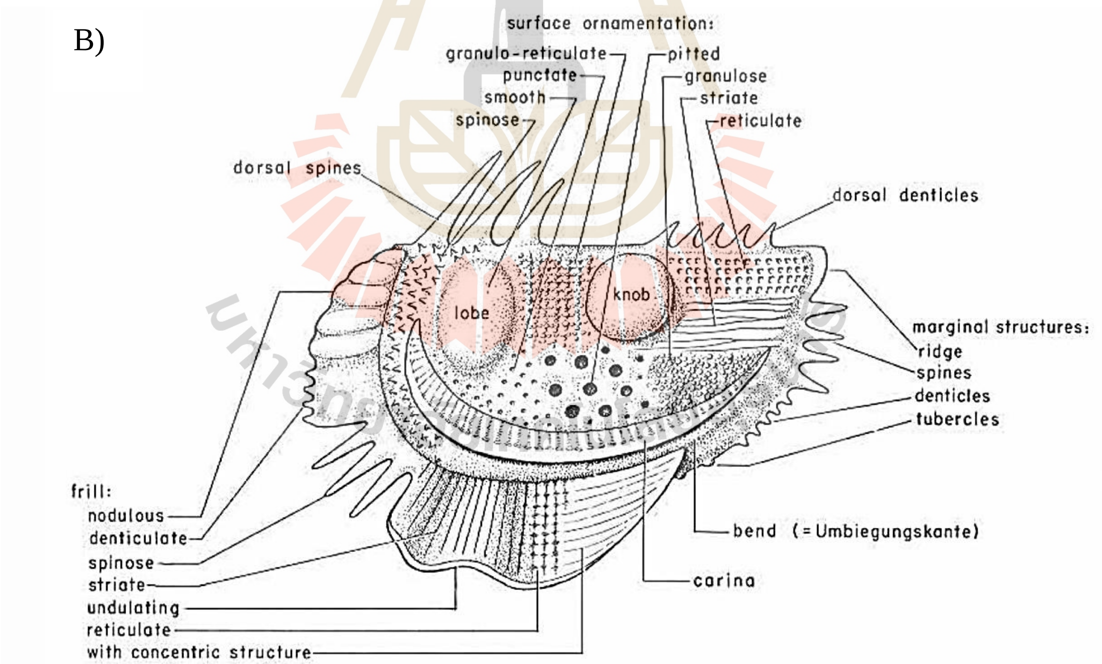


Figure 2.19 A) Nomenclature of the duplicature and wall structure of typical podocopid ostracod; B) Nomenclature of the lateral and marginal palaeocopid feature of ostracods (Moore, 1961).

3) The shell morphology of the ostracods

One of the most significant characteristics of the ostracods is that so much paleoenvironmental data can be carried out from a carapace. The shape and ornament or lack of ornament of the carapace also reflects the environment. The carapace of swimmers generally is smooth, high in proportion to length, with thin light-weight valves and simple hinges. Variation in shell size within a community may be appropriate to normal generic controls, while it is known that it is seasonal diversity in shell size which reflect calcification at different water temperature. They commonly measure 0.70 or 0.80 mm. in length, but some species may greatly exceed the average.

The framework or shape of ostracod probably described as ovate, elliptical, and quadrate. Infrequently ostracod carapaces are sub-rectangular, trapezoidal, or rounded in outline. Examples of Permian ostracod carapaces shown in Figure 2.20. The dorsal edge of the carapace may be convex or straight, and the ventral margin may be convex, straight, or concave. The area adjacent to the hinge in dorsal view is dorsum. The juncture between the dorsal border and ends of the carapace is cardinal corners which are very important in categorize shape of the carapace (see in Figure 2.21). The position of greatest height controls the shape. If the greatest height is in front of the mid-length, the carapace is called preplete, if posterior to the mid-length is postplete, and at or near the mid-length as amplete. The valve/carapace shape and size vary within and between populations and sometimes this variability can be attributed to environmental. The shape as well as the size of ostracod valves changes throughout ontogeny.

The area of valve indifferent with hinge is the free margin including anterior and posterior ends and into ventral and dorsal positions. For description of specific positions on the lateral surface, smaller subdivisions can be defined as anteroventral, posteroventral, etc. (Figure 2.22). The length and height are measured from anterior to posterior ends and from dorsal to ventral edges of the carapace. The valve surface may be smooth or ornamented; therefore; the ornamentation is one of the useful criteria for identification. The lobes represent elevations of the shell which are directly opposite internal depressions or the internal anatomy.

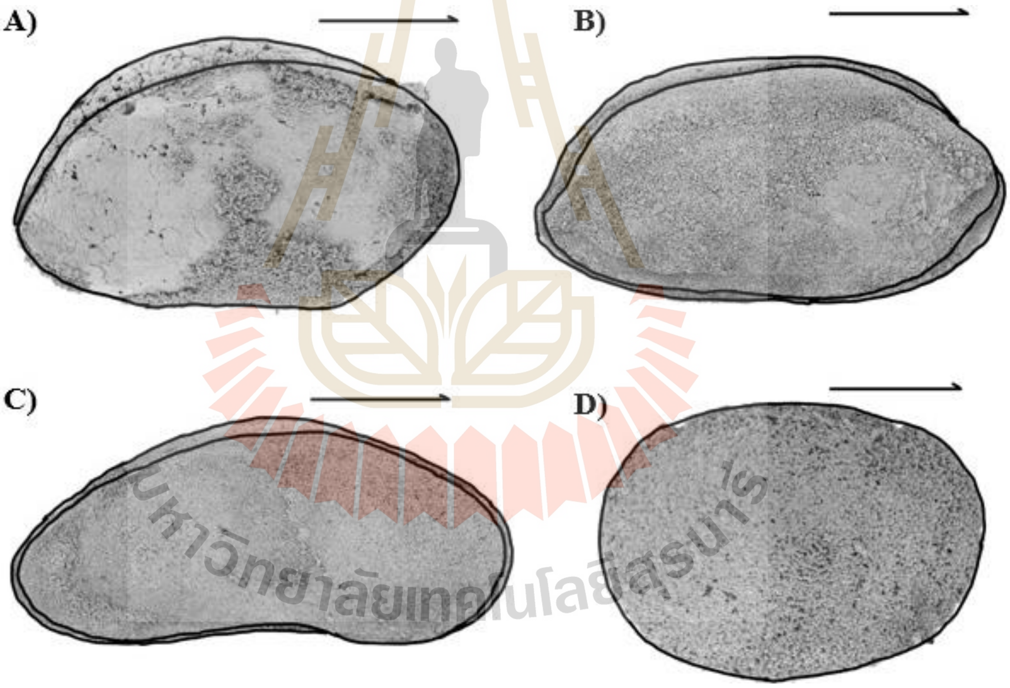


Figure 2.20 Examples of some selected ostracods from this research A), B) *Baridia* sp., right lateral view of the complete carapace; C) *Bairdiacypris* sp., right lateral view of the complete carapace; D) *Microcoelonella* sp. right lateral view of the complete carapace.

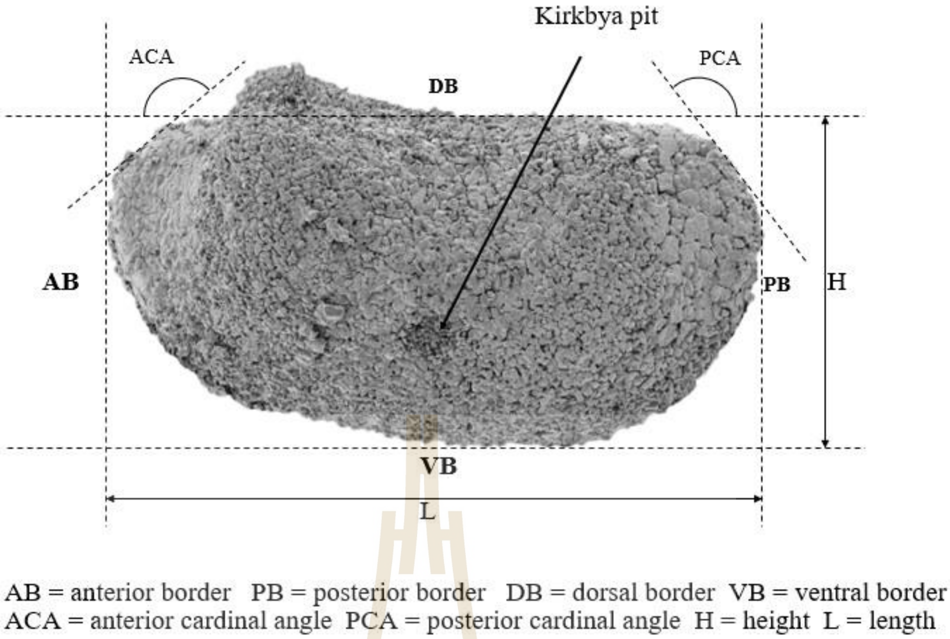


Figure 2.21 Schematic representation of *Knightina* sp. on right lateral view.

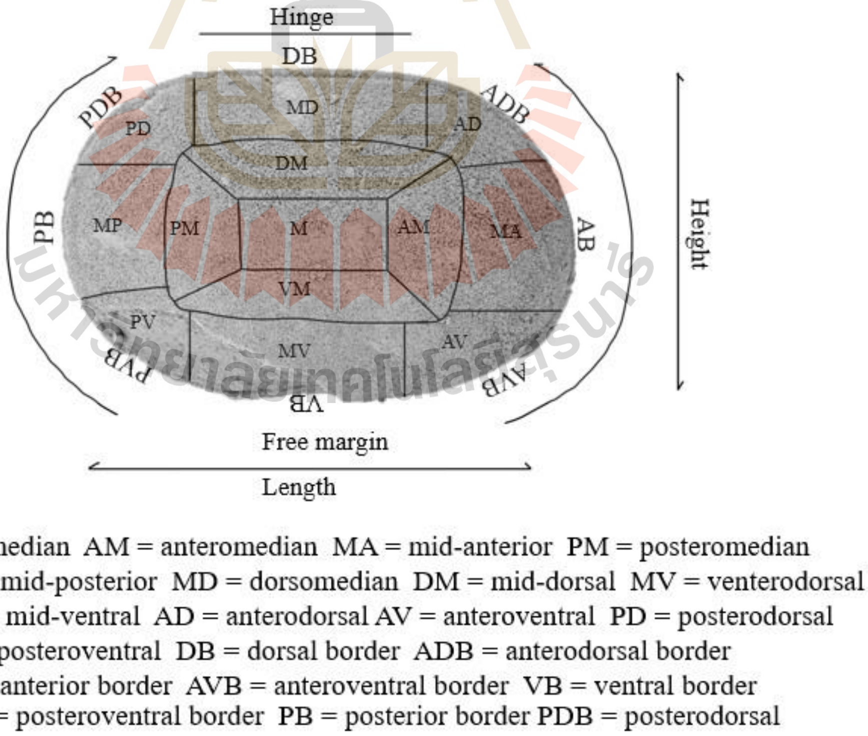


Figure 2.22 Features and nomenclature of the lateral surface.

2.2.2 Characteristic of the Permian ostracods

The Permian ostracods have been discovered from Lower to Upper Permian rocks and distributed in almost all continents. Figure 2.23 shows selected examples of previous works on ostracods throughout the Permian time. Identification of the Permian ostracods, like those from the Paleozoic Era, is based mainly on morphological characteristics of their valves, verified with regional ,and standard identification keys and taxonomic reports (i.e., Kellett, 1933, 1934, 1935; Hou, 1954; Ishizaki, 1964, 1967; Khivintseva, 1969; Bless, 1987; Melnyk and Maddocks, 1988; Lethiers et al., 1989; Kozur, 1991; Crasquin et al., 1999, 2005, 2008, 2010; Zazzali et al., 2015; Chitnarin et al., 2008, 2012, 2017; Burrett et al., 2014)

In general, the Permian ostracods can be classified into three subclasses particularly: 1) Subclass Podocopa including Orders Palaeocopida, Podocopida and Platycopida; 2) Subclass Myodocopa including Order Myodocopida; 3) Subclass Metacopa including Order Healdiodea. Characteristics of common Permian ostracods and the paleoenvironmental trends at Superfamily and Family level have been recognized and summarized as follows (Moore, 1961; Melnyk and Maddocks, 1988; Craquin-Soleau et al., 2006).

Author	Permian									Triassic
	Cisuralian				Guadalupian			Lopingian		
	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordain	Carpitanain	Wuchiapingian	Changhsingian	
Chen, 1958	**Podocopida:** *Bairdia, Bythocypris, Bairdaianella, Bairdiacypris, Fabalicypris, Acratia, Microchelinella* **Palaecopida:** *Paraparchites, Kirkbya, Amphissites, Microcoelonella,*									
Chen, 1986	**Podocopida:** *Bairdia, Cryptobairdia, Othobairdia, Lobobairdia, Abrobairdia, Bairdaianella, Fabalicypris, Macrocypris, Acratia, Silenites, Microchelinella, Basslerella, Cyathus* **Platycopida:** *Cavellina, Cytherella* **Metacopina:** *Healdianella* **Palaecopida:** *Paraparchites, Kirkbya, Shleesha, Roundyella, Coelonella*									
Kozur, 1991								**Podocopida:** *Praezabythocypris, Paraberounella, Pseudospinella, Microchelinella, Spinomicrocheilinella, Baschkirina, Pseudospinella, Parabythocythere, Triassocythere, Paraberounella, Ovornina, Haworthina* **Platycopida:** *Spinososioella* **Palaecopida:** *Parvicyathus, Nodoparaparchitites, Roundyella, Kirkbya, Knightina, Nodokirkbya, Kellettina, Amphissites, Tubulikirkbya, Solleikope*		
Weicheng, 1996								**Podocopida:** *Petasobairdia, Ceratobairdia, Mirabairdia, Bairdia, Rectobairdia, Bairdiacypris, Acanthoscapha, Acratia, Basslerella* **Palaecopida:** *Knoxiella, Coronakirkbya, Roundyella, Kellettina, Amphissites, Hollinella*		
Olempska and Blaszyk, 1996	**Podocopida:** *Bairdia* **Metacopina:** *Healdia* **Palaecopida:** *Shemonaella, Kirkbya, Roundyella, Kindlella, Amphissites, Mitonella*									

Figure 2.23 Selected previous studies and common ostracod genera during Permian–Lower Triassic.

Author	Permian									Triassic
	Cisuralian				Guadalupian			Lopingian		
	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordain	Carpitanain	Wuchiapingian	Changhsingian	
Sohn and Kornicker, 1998								**Myodocopida:** *Polycope, Thaumatomma*		
Benzarti and crasquin, 1998								**Podocopida:** *Bairdiacypris, Praelobobairdia, Fabalicypris, Microchelinella, Basslerella* **Platycopida:** *Cavellina, Sulcella,* **Palaecopida:** *Sargentina, Nuterella, Shemonaella, Paraparchites, Kirkbya, Carinaknightina, Roundyella, Hollinella*		
Crasquin and Baud, 1998								**Podocopida:** *Bairdia, Petasobairdia, Bairdiacypris, Fabalicypris, Praezabythocypris, Microchelinella, Acratia, Paramacrocypris, Parabythocythere, Basslerella, Cyathus* **Platycopida:** *Cavellina, Sulcella* **Myodocopida:** *Polycope, Cypridina* **Palaecopida:** *Cyathus, Knoxiella, Indivisia, Shishaella, Chamishaella, Paraparchites, Shemonaella, Kirkbyella, Knightina, Parvikirbya, Amphissites, Hollinella*		
Crasquin et al., 1999					**Podocopida:** *Bairdia, Fabalicypris, Acratia,* **Metacopina:** *Healdianella* **Platycopida:** *Cavellina, Sulcella* **Myodocopida:** *Birdsallella?* **Palaecopida:** *Langdaia, Perprimitia, Sargentina, Carinaknightina, Roundyella, Moorites, Jordanite, Hollinella*					
Craquin-Soleau, 2003					**Podocopida:** *Bairdia, Fabalicypris* **Platycopida:** *Cavellina, Sulcella* **Palaecopida:** *Geffenina, Perprimitia, Sargentina, Knightina, Roundyella, Hollinella*					

Figure 2.23 Selected previous studies and common ostracod genera during Permian–Lower Triassic (continued).

<table>
<tr><th rowspan="3">Author</th><th colspan="9">Permian</th><th>Triassic</th></tr>
<tr><th colspan="4">Cisuralian</th><th colspan="3">Guadalupian</th><th colspan="2">Lopingian</th><th></th></tr>
<tr><th>Asselian</th><th>Sakmarian</th><th>Artinskian</th><th>Kungurian</th><th>Roadian</th><th>Wordain</th><th>Carpitanain</th><th>Wuchiapingian</th><th>Changhsingian</th><th></th></tr>
<tr><td>Crasquin et al., 2005</td><td colspan="10">Podocopida: Bairdia, Bairdiacypris, Spinocypris, Acratia, Arqoviella, Haworthina Platycopida: Cavellina, Sulcella Palaecopida: Knoxiella, Kloedenellitina, Langdaia, Sargentina, Paraparchites, Shemonaella, Hollinella</td></tr>
<tr><td>Honigstein et al., 2006</td><td colspan="4"></td><td colspan="3"></td><td colspan="2">Podocopida: Praelobobairdia, Rectobairdia, Cryptobairdia, spinobairdia, Bairdiacypris, Triassocyprid, Acratia, Pseudobythocypris, Arqoviella Platycopida: Cavellina, Sulcella Myodocopida: Polycope Palaecopida: Sargentina, Chamishaella, Knightina, Carinaknightina, Roundyella, Amphissites, Moorites</td><td></td></tr>
<tr><td>Yuan et al., 2007</td><td colspan="4"></td><td colspan="3"></td><td colspan="2">Podocopida: Bairdia, Petasobairdia, spinobairdia, Bairdiacypris, Fabalicypris, Cooperuna, Microchelinella, Spinomicrocheilinella, Pseudobythocypris, Rectonaria, Paraberounella, Bohemina, Monoceratina Platycopida: Cavellina</td><td></td></tr>
<tr><td>Mette, 2008</td><td colspan="4"></td><td colspan="3"></td><td colspan="2">Podocopida: Bairdiacypris, Bairdia, Othobairdia, Praezabythocypris, Liuzhinia, Fabalicypris, Microchelinella, Basslerella Platycopida: Cavellina, Sulcella Palaecopida: Italogeisina, Kirkbya, Nodokirkbya, Iranokirkgya, Parahollinella, Permoyoungiella, Hollinella Metacopina: Absina, Healdia, Healdiopsis Myodocopida: Polycope, Waldeckella Palaecopida: Paraparchites, Kirkbya, Aurikirkbya, Nodokirkbya, Kellettina, Permoyoungiella, Macronotella, Libumella</td><td></td></tr>
</table>

Figure 2.23 Selected previous studies and common ostracod genera during Permian – Lower Triassic (continued).

Author	Permian									Triassic
	Cisuralian				Guadalupian			Lopingian		
	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordain	Carpitanain	Wuchiapingian	Changhsingian	
Crasquin et al., 2008								**Podocopida:** *Fabalicypris, Bairdiacratia, Acratia, Arqoviella, Callicythere* **Platycopida:** *Cavellina, Sulcella* **Palaecopida:** *Knoxiella, Sargenitna, Neoulrichia*		
Chitnarin et al., 2008					**Podocopida:** *Bairdia, Rectobairdia, Praelobobairdia, Bairdiacypris, Praebythocypris,* **Palaecopida:** *Geffenina, Sargentina, Reviya*					
Crasquin et al., 2010								**Podocopida:** *Acratia, Basslerella* **Palaecopida:** *Knoxiella,*		
Crasquin et al., 2010	**Podocopida:** *Bairdia, Abrobairdia, Petasobairdia, Ceratobairdia, Mirabairdia, Othobairdia, Bairdiacypris, Fabalicypris, Liuzhinia, Kempfina, Praezabythocypris, Microchelinella, Acratia, Paramacrocypris, Silenites, Baschkirina, Parabythocythere, Triassocythere, Basslerella, Pseudorayella, Cyathus* **Platycopida:** *Cavellina, Birdsallela* **Metacopina:** *Reversocypris* **Myodocopida:** *Polycope, Eumiraculum, Cetollina,* **Palaecopida:** *Knoxiella, Langdaia, Indivisia, Paraparchites, Shemonaella, Samarella, Knightina, Shleesha, Aurikirkbya, Permoyoungiella, Hollinella*									
Chitnarin et al., 2012	**Palaecopida:** *Cyathus, Knoxiella, Langdaia, Sargentina, Eukloendenella, Geisina, Geffenina, Kloedcytherella, Paraparchites, Shemonaella, Samarella, Shishella, Kirkbya, Knightina, Reviya, Shleesha, Polytylites, Permoyoungiella, Hollinella, Microcoelonella*									
Tanaka et al., 2012	**Podocopida:** *Bairdia, Microchelinella,*									
Zazzali and Crasquin, 2015					**Podocopida:** *Bairdia, Ceratobairdia, Acratia, Microchelinella* **Platycopida:** *Sulcella* **Palaecopida:** *Cyathus, Geffenina, Samarella, Reviya, Hollinella*					
Burrett et al., 2015	**Podocopida:** *Bairdia, Cryptobairdia, Bairdiacypris, spinocypris, Paraberounella, Pseudobythocypris, Baschkirina, Microchelinella, Basslerella, Cyathus* **Myodocopida:** *Polycope* **Palaecopida:** *Paraparchites, Shemonaella, Shivaella, Carinaknightina,*									
Chitnarin et al.,2017	**Podocopida:** *Bairdia, Bairdiacypris, Fabalicypris, Silenites, Liuzhiania, Baschkirina, Lobobairdia, Petasobairdia, Cryptobairdia, Acratia, Basslerella,* **Platycopida:** *Cavellina, Sulcella* **Myodocopida:** *Polycope*									

Figure 2.23 Selected previous studies and common ostracod genera during Permian–Lower Triassic (continued).

1) Superfamily Bairdioidea. Generally, carapaces of Superfamily Bairdioidea are covex-backed podocopids with wide duplicature, wide vestibule at anterior end, narrow or wide vestibule at posterior end (A in Figure 2.24). This superfamily greatly developed during Late Paleozoic time (Carboniferous-Permian periods). The common genera are, for example; *Bairdia*, *Bairdiacypris, Fabalicypris, Silenites, Acratia, Liuzhiania, Lobobairdia, Petasobairdia, Cryptobairdia*. Genus *Bairdia* diversity was very high in offshore environments with low terrigenous Sedimentation. However, some species have tolerated muddier and shallower condition. Genus *Bairdiacypris* is most abundant in nearshore environments. Member of *Cryptobairdia* and *Orthobairdia* appear to have been more eurytopic than member of *Bairdia*, but the highest diversity occurs offshore in calcareous mudstones.

2) Family Cavellinidae. Member of Family Cavellinidae has subovate to subelliptical carapace in lateral view, subelliptical in dorsal view with noticeable posterior swelling in female (B in Figure 2.24). Dorsal border is convex, commonly with slight anterodorsal slope; ventral border is almost straight, varying to slightly convex or concave; ends are round or subround; valves are unequal, right valve over left valve; surface is smooth, genera distinguished by slight muscle scar pit or development of posterior rim and possibly anterior rim. The superfamily developed during Devonian to Late Permian. The common genera are *Cavellina* and *Sulcella*.

3) Superfamily Kirkbyoidea. Distinctive characteristics of Family Kirkbyoidea include reticulate carapace, straight-backed, with or without lobes, nodes and carinae. Hinge is ridge-and-groove type, with or without terminal dentition; valve is rabbeted to receive opposing valve; marginal rim can be one or more (see C in Figure 2.24). The common genera are, for example; *Kirkbya*, *Knightina*, *Reviya*, *Shleesha,* *Polytylites, Kellettina, Amphissites, Roundyella, Aurkirkbya, Carinaknghtina.* The well-ornamented species of Families Amphissitidae and Scrobiculinidae appear to have been largely restricted to offshore environment. The heavily ornamented Kirkbyidae are usually offshore dwellers.

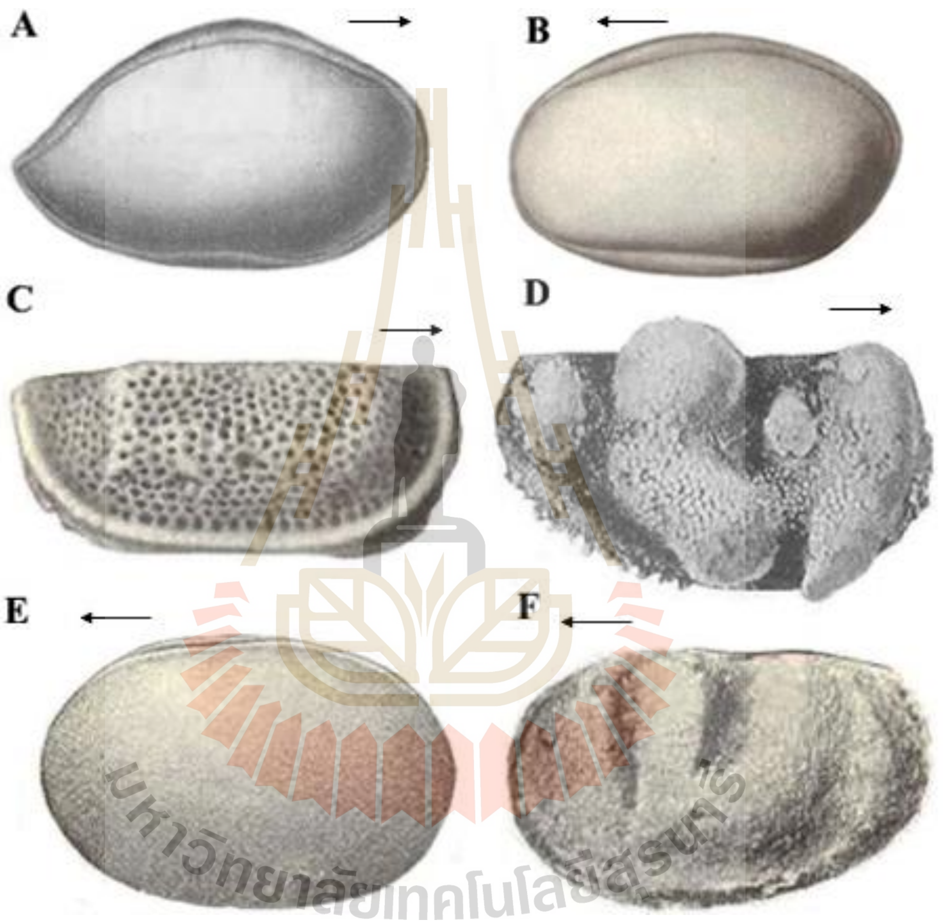


Figure 2.24 Examples of common Permian ostracods: A) *Bairdia* (Bairdiacea); B) *Cavellina* (Cavellinidae); C) *Kirkbya* (Kirkbyacea), D) *Hollinella* (Hollinacea), E) *Paraparchites* (Paraparchitacea), F) Kloedennellacea (Moore, 1961)

4) Superfamily Hollinoididae. Member of Family Hollinellidae is a large assemblage of dimorphic straight-hinged palaeocopids (D in Figure 2.24) that was dominated in Lower Palaeozoic strata, especially in Ordovician age. A few forms occur in post-Devonian rocks, among which the long-ranging genus *Hollinella* extends into the Permian formations. The larger forms appear to have tolerated higher terrigenous sedimentation rates and closer proximity to the shoreline, whereas the smaller forms usually indicate deep water.

5) Superfamily Paraparchitoidea. This group is characterized by nonsulcate, nonlobate, nonvelate carapace with unequal valves, the lager overlapping the smaller around all or most of the free margin (E in Figure 2.24). The common genera are, for example; *Paraparchites*, *Shemonaella*, *Samarella*, *Shishaella*. Species of this superfamily were quite widely distributed, but more diversified offshore. Smooth and larger forms appear to have occupied very shallow areas with low sedimentation rates.

6) Superfamily Kloedenelloidea. Member of Superfamily Kloedenelloidea has distinctive carapace with strongly unequal valves and the larger valve overlaps the smaller one around all or part of free margin (F in Figure 2.24). The carapace has a straight tongue-and-groove hinge type, a hinge line is impressed, cardinal angles are rounded, Surface of the carapace can be smooth or reticulated, with pit, sulci and with or without costae. The common genera are, for example; *Knoxiella, Langdaia, Sargentna, Geisina, Geffenina*, *Perprimitia*. The Kloedenellids are usually inhabited in nearshore environments, and some rare glyptopleurids (e.g., genus *Glyptopleura*) appear to have lived in slightly deeper water.

2.2.3 Permian ostracods in Southeast Asia

Unlike those in China and Russia, only few Permian ostracod researches have been done in Southeast Asia (see Figure 2.23). The first article was published by Bless in 1987, describing materials collected from Timor in Indonesia. He showed that the samples from Lower Permian strata (Sakmarian-Artinskian age) yielded rich and diversified ostracods which could be classified into three Superfamilies such as Bairdiidiodea, Kirkbyoidea and Polycopidae. He proposed two new genera including *Marginotimorites* and *Timorhealdia* and described six new species, namely, *Tetrasacculus*? *timarensis*, *Spinella bitauniensis*, *Anahuacia mutisensis*, *Marginotimorites ofienensis*, *Timorhealdia vandenboogaardi*, and *Microcheilinella*? *elonggatisima*. He concluded that the ostracod assemblage indicated deep-marine, low-energy, low-temperature environments.

Twenty years later, Chitnarin et al. (2008) reported fifteen ostracod species from Middle Permian limestone of the Tak Fa Formation in Phetchabun Provinc, central Thailand. The ostracods belonged to Superfamilies Kloedenelloidea, Bairdioidea, Kirkbyoidea and Sansabelloidea. Eight genera including *Sargentina, Reviya, Geffenina, Bairdia, Rectobairdia, Praelobobairdia, Bairdiacypris, Praebythocypris* were identified. Four new species were described such as *Sargentina phetchabunensis*, *Geffenina bungsamphanensis*, *Reviya subsompongensis* and *Bairdia takfaensis*. The assemblage suggested the deposition in a shallow marine, euryhaline, nearshore environment.

Burrett et al. (2014) recovered Early Permian ostracods from the E-Lert Formation in Loei Province, on the Pha Nok Khao Platform, North-Central Thailand. However, In this study, the E-Lert Formation is included in the Loei Group according to Ueno and Chareontitirat (2011). The rock samples were turbiditic limestones and cherts hence, they yielded conodonts, ostracods and radiolarians. The age of the study section was assigned to late Kungurian-Roadian or until Wordian age by the conodonts and radiolarians. They identified 16 genera and 23 species composed of *Bairdia, Cryptobairdia, Bairdiacypris, Spinocypris, Paraberounella, Pseudobythocypris, Baschkirina, Microchelinella, Basslerella, Cyathus, Polycope, Paraparchites, Shemonaella, Shivaella, Carinaknightina*, and one new species was described. The ostracod assemblage composed of mixed external platform and deep-water forms that indicated the proximal part of the continental slope.

Chitnarin et al. (2012; 2017) identified 38 genera and 130 species including 22 new species from the Permian limestones of central Thailand which included the Nam Maholan and the Pha Nok Khao Formations (on the Pha Nok Khao Platform) and the Tak Fa Formation (on the Khao Khwang Platform). The rocks were assigned to Lower to Middle Permian (Asselian to Capitanian age) by other fossils such as fusulinids and brachiopods. The occurrence of ostracods at specific level was used to determine a provincialism index. It was found that the Early Permian fauna had close relationship with Eastern China whereas the Middle Permian fauna was closer to Tunisia, South China and Eastern China.

Chitnarin (2015) interpreted paleoenvironment of dark grey limestones and black shales, a part of the Tak Fa Formation, at Ta Kli section in Nakhon Sawan province, on basis of the ostracod assemblage. 99 species of ostracods were identified, they comprised *Cyathus, Kirkbya, Knightina, Reviya, Polytylites, Knoxiella, Sargentina, Eukloedenella, Geisina, Paraparchites, Shemonaella, Samarella, Hollinella, Microcoelonella, Bairdia, Bairdiacypris, Fabalicypris, Silenites, Acratia, Baschkirina, Acratinella,* *Microcheilinella, Basslerella, Cavellina, and Polycope.* The assemblage was dominated by members of Superfamily Bairdioidea (38 species) and Families Pachydomellidea and Cytherideidae in smaller number that suggested subtidal, open marine environment, on the continental shelf, slightly offshore, and on the soft carbonate substrate.

2.3 Paleoenvironmental interpretation tools

There are different techniques to study the rock samples in order to interpret the depositional environment, for example; microfacies analysis, bio-geological analysis by considering the fossil assemblage, and geochemical analysis. Previous studies on the microfacies analysis of the Permian rocks in Central Thailand are such as Wielchowsky and Young (1985), Dawson and Racey (1993), Thambunya et al. (2007), Udchachon et al. (2014), Singhasuriya et al. (2017) and Uttarawiset et al. (2017). The studies on the fossil assemblage analysis are, for example; Chitnarin et al. (2008), Burrett et al. (2014) and Chitnarin (2015). Chutakositkanon et al. (2000) is an example of the lithology and geochemical analysis. In this study, the microfacies analysis and the fossil assemblage analysis are emphasized, and concepts of these techniques are summarized as follows.

2.3.1 Microfacies analysis

According to Flugel (2004; 2010), the microfacies analysis is aimed for recognition of overall patterns that reflect the history of the carbonate rocks, by means of a thorough examination of their sedimentological and paleoenvironment characteristics. The microfacies based on thin section studies subdivides facies into units of similar compositional aspect that reflect specific depositional environments and controls. Generally, the limestones are classified using scheme of Dunham (1962). The criteria of microscopic texture, composition and fossils of the limestones are set and must be identified together with the help of Standard Microfacies Types following Flugel (2010). Then, when the diagnostic criteria of the Standard Microfacies Types are defined, they are able to indicate their distribution in the Facies Zones of the Wilson model. The microfacies types and facies associations are fundamental to the development of models for carbonate sedimentation. The following part lists elements of the microfacies analysis.

1) Limestone classification based on depositional texture

Dunham's classification, usually applied in the field and for hand specimens, is adopted in the microfacies analysis. Dunham's rock names are accepted because they are not too complex. There are still some problems that the classification strongly suggests a depositional character of the textures. However, the limestones exhibiting mudstone, wackestone, packstone and grainstone fabric could also products of diagenetic processes. The complete rock name requires combination of the name of the category with adjective referring to grain types. Texture, mineralogy and frequency criteria can be included in the rock name as follows (Figure 2.25).

- Mudstone is a muddy carbonate rock containing less than 10% grains measured as grain-bulk percent. Generally, it indicates calm water and apparent inhibition of grain-producing organisms (low-energy depositional setting).
- Wackestone is a mud-supported carbonate rock containing more than 10% grains. Generally, it indicates calm water and restriction of grain-producing organisms (low-energy depositional setting).
- Packstone is a grain-supported muddy carbonate rock exhibiting

features pointing to deposition in agitated water and criteria pointing to quiet water deposition. A grain-supported fabric containing 1% or more mud-grade fraction.

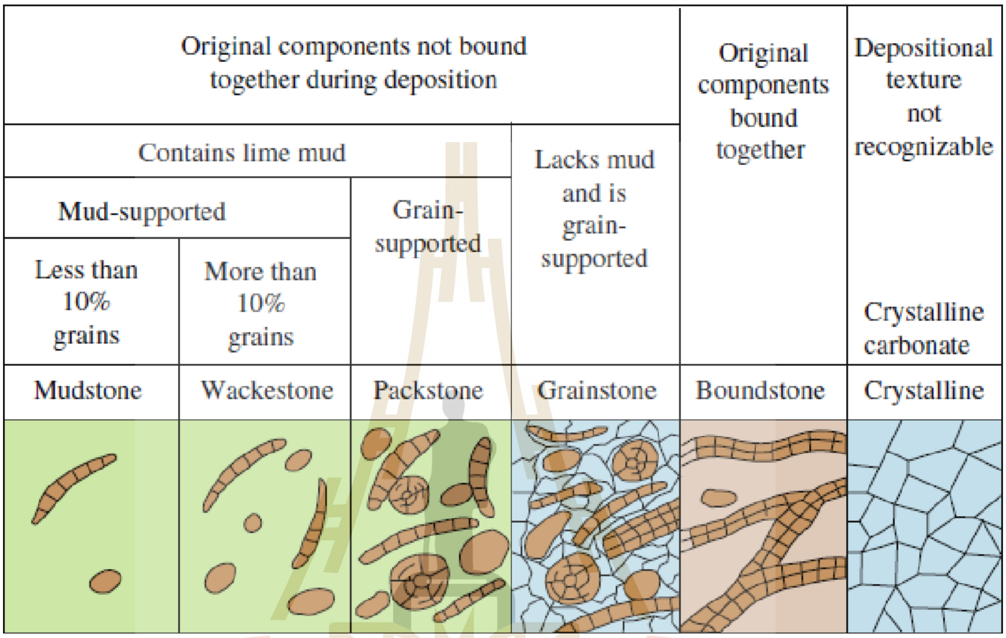


Figure 2. 25 Dunham's classification of carbonate rocks (Hanken et al., 2010)

- Grainstone is a grain-supported and mud-free carbonate rock and consisted of skeletal and non-skeletal carbonate grains (a grain-supported carbonate rock with <1% mud). It generally deposits in moderate- to high-energy environments, but a hydraulic significance can vary.

Boundstone is a special type of carbonate rock where there is any evidence that the carbonate sediments were bound at the time of deposition. Boundstone generally deposits in higher energy environments, where currents can provid enutrients for the organisms that form the boundstone, as well as carry away waste products.

- Crystalline carbonates are carbonate rocks that lack enough evidence of depositional texture to be classified. Extensive dolomitization commonly destroys the original depositional texture.

2) Depositional facies models

Flügel (2010) generalized these types of carbonate platform, namely rimmed carbonate platform, ramp carbonate platform and non-rimmed cool water shelf (Figure 2.26). Depositional facies models are ideal models which have been established after gathering, comparing and normalization from local case studies of modern and ancient examples. The facies models are norms for purposes of comparison, as a framework and guideline for future observations, as a predictor of new geological situations, and as an integrated basis for the system that it represents. Flügel (1972) established common microfacies types of Triassic carbonates, and introduced a set of Standard Microfacies Type (SMF) which aimed at categorizing common and widely distributed Phanerozoic microfacies types. Wilson (1975) observed successions of facies belts of Holocene and Phanerozoic carbonates and established the Standard Facies Model that describes Standard Facies Zones (FZ) of rimmed tropical carbonate platform along a strongly generalized shore to basin transect (A in Figure 2.27). He also extended the generalizations made by Flügel in 1972.

2.1) Rimmed carbonate platform

Rimmed carbonate platform can be divided into ten Facies Zones (FZ) including (see Figure 2.26A)

- FZ 1 Deep sea: Below wave base and below the euphotic zone in oceanic deep water. Which sediment include pelagic clay, siliceous and carbonate ooze, hemipelagic muds, turbidites. Periodically anhydrite. Sometime common cherts. Frequent lithofacies have Pelagic mudstone and wackestone, marls, allochthnous packstone, grainstone, breccia, lime mudstone, wackestone, packestone.

- FZ 2 Deep shelf: Below fair-weather wave base but within the reach of extreme storm waves. Forming plateaus between active platforms and deeper basins. Mostly carbonate interbedded with marl beds. Skeletal wackestone and fossil wackestone, some grainstone and coquinas. Matrix commonly pelmicrite and some silica.
- FZ 3 Toe of slope apron (deep shelf margin): Below wave base and barely at oxygen level. The sediments include predominantly pure fine-grained detritus moved off from adjacent shallow shelves. Grain size highly variable. Common lithofacies consist of lime mudstone, allochthonous packstones and grainstones.
- FZ 4 Slope: Distinctly inclined sea floor seaward of platform margins. The sediments have mostly reworked platform material and pelagic admixtures. And also have gentle muddy slopes with much slumping and sandy or rubbly slopes with steep foresets. Prevalent lithofacies have mudstone, allochthonous packstone and grainstone, rudstone and floatstone.

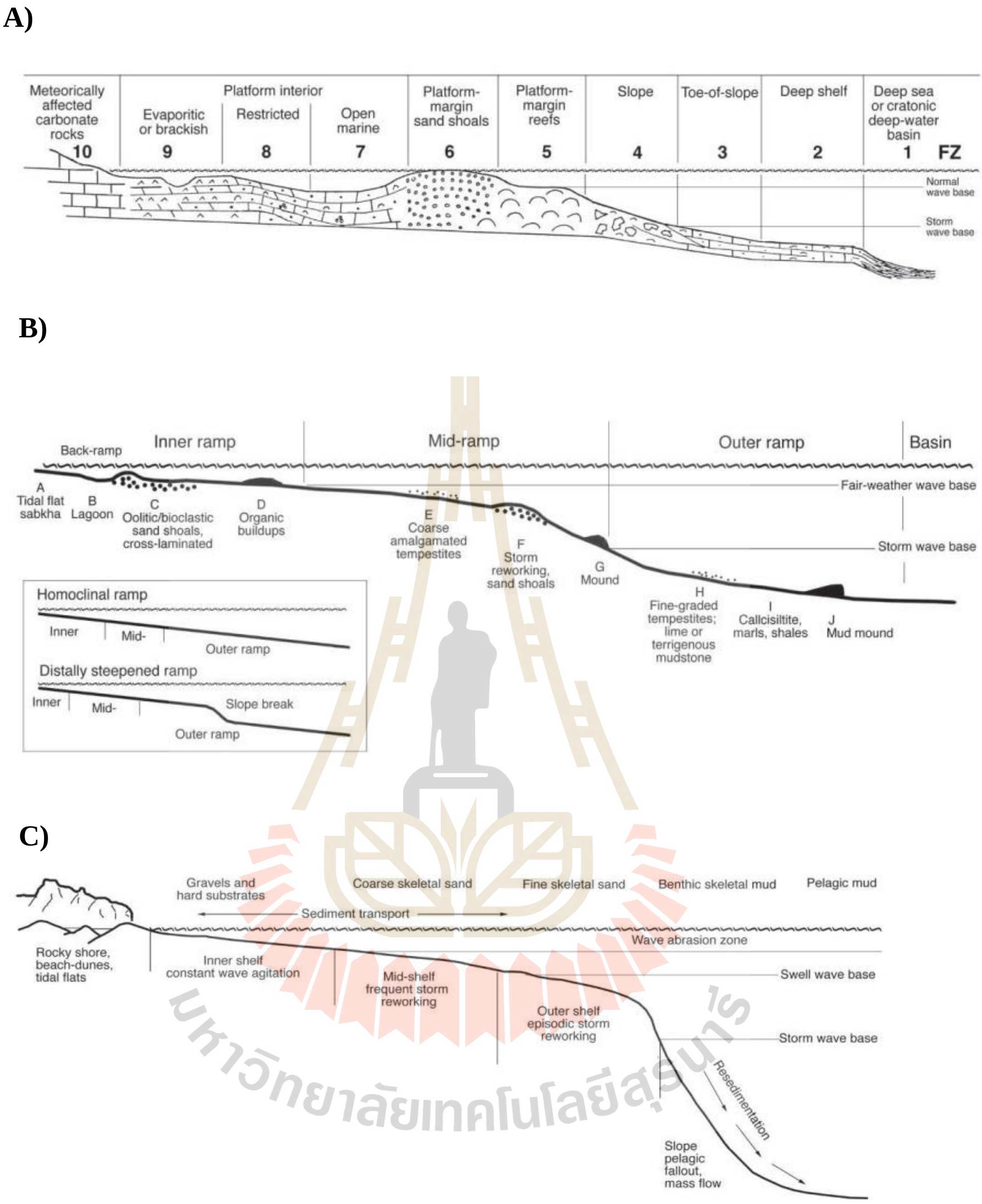


Figure 2.26 Facies Models of different carbonate platforms: A) Rimmed Carbonate Platform, the Standard Facies Zones of the modified Wilson model; B) Carbonate Ramp Model modified from Burchette and Wright, 1992; C) Hydrodynamic zones and subdivision of a non-rimmed cool-water shelf. Modified from James, 1997 (Flügel, 2010).

- FZ 5 Platform-margin reefs: The surroundings of platform include mud mound on the upper slope, ramps with knoll reefs and sand shoals, wave-resistant barrier reefs rimming the platform. Debris have almost pure carbonates of very variable grain size. Massive limestone and dolomites. Masses or patches of various types of boundstones. Common lithofacies have framestone, bindstone, wackestone, grainstone, rudstone and floatstone.
- FZ 6 Platform-margin sand shoals: Above fair-weather wave base and within the euphotic zone, strongly influenced by tidal currents. The sediments include clean calcareous, often rounded, coated and well-sorted sands, occasionally with quartz and sand grains are skeletal grain. Common lithofacies have grainstone and packstone.
- FZ 7 Platform interior-normal marine (open marine): Flat platform top within euphotic zone, normally above fair-weather wave base, lagoon, sand shoals, islands or reefs of the platform margin. The sediment comprises of lime mud, muddy sand amd clean sands, depending on the grain size of local sediment production and the efficiency of winnowing by waves and tidal currents. Common lithofacies include lime mudstone, wackestone and floatstone, packstone, and grainstone.
- FZ 8 Platform interior-restricted: Similar to Facies 7, but less well connected with the open ocean, causing large

variations in salinities and temperatures. Lagoons behind barrier reefs, within atolls or behind coastal splits. The sediments mainly lime mud and muddy sand, some clean sand, limestones and dolomites. Common lithofacies have lime mudstone and dolomite mudstone, wackstone, grainstone, and bindstone.

- FZ 9 Evaporitic or brackish: Normal marine waters and dry climate so that gypsum, anhydrite or halite may be deposited beside carbonates, supratidal, and salt pond. The fabric has calcareous or dolomitic mud or sands, with nodular, wavy or coarse-crystalline gypsum or anhydrite, and sand with occasional freshwater lime mud and peat layers. The common lithofacies comprises of laminated lime, dolomitic, mudstones and bindstone.
- FZ 10 Meteorically affected carbonate rocks: The surrounding have subaerial or subaerial, formed under meteoric-vadose and marine-dose conditions. Abundant in karst settings and pedogenic carbonates, supratidal, and intertidal environments. The biota in platform include indigenous biota lacking except cyanobacteria and microbes.

2.2) Standard Microfacies Types

Standard Microfacies Types are virtual categories that summarize microfacies with identical criteria. These criteria are simple, non-or semi-quantitative, and easy to recognize. Most SMF Types are based on only a few dominant characteristics comprising grain types, grain frequency, grain associations, matrix types, depositional fabrics, fossils, and depositional texture types.

The SMF concept occur from the understanding astounding compositional and textural correlation of limestones of different age formed corresponding environments. Basically, developed for categorizing common Late Triassic platform and reef carbonates, and based on the combination of texture and paleontological criteria, the classification was expanded and more strictly defined by Wilson (1975) for the past of carbonate facies over time. Wilson distinguished 24 SMF Types and used types as follows (Figure 2.27).

- SMF 1 Spiculitic wackestone or packstone, often with calcisiltite matrix. Subtype emphasizes burrowing.
- SMF 2 Microbioclastic peloidal calcisiltite with fine grainstone and packstone fabrics.
- SMF 3 Pelagic lime mudstone and wackestones with abundant pelagic microfossils. Subtypes differentiate the groups of planktonic organisms.
- SMF 4 Microbreccia, bio- and lithoclastic packstone or rudstone.
- SMF 5 Allochthonous bioclastic grainstone, rudstone, packstone, floatstone, breccia with reef-derived biota.
- SMF 6 Densely packed reef rudstone.
- SMF 7 Organic boundstone. Subtypes try to differentiate the kind of contribution by potential reef builders to the formation of reefs and other buildups.

- SMF 8 Wackestones and floatstones with whole fossils and well-preserved endo- and epibiota.
- SMF 9 Strongly burrowed bioclastic wackestone.
- SMF 10 Bioclastic packstone and wackestone with abraded and worn skeletal grains.
- SMF 11 Coated bioclastic grainstone.
- SMF 12 Limestone with shell concentrations. Subtypes characterize shell-providing fossils.
- SMF 13 Oncoid rudstone and grainstone.
- SMF 14 Lag deposit.
- SMF 15 Oolite, commonly grainstone but also wackestone. Subtypes highlight the structure of ooids.
- SMF 16 Peloid grainstone and packstone. Subtypes differentiate non-laminated and laminated rocks.
- SMF 17 Grainstone with aggregate grains (grapestones).
- SMF 18 Bioclastic grainstone and packstone with abundant and rock-building benthic foraminifera or calcareous green algae. Subtypes describe the systematic assignment of the various groups.
- SMF 19 Densely laminated bindstone.
- SMF 20 Laminated stromatolitic bindstone/boundstone.
- SMF 21 Fenestral packstone and bindstone. Subtypes characterize fenestral voids and the contribution of calcimicrobes.

- SMF 22 Oncoid floatstone and wackestone.
- SMF 23 Non-laminated homogenous micrite or microsparite without fossils.
- SMF 24 Lithoclastic floatstone, rudstone or breccia.
- SMF 25 Laminated evaporite-carbonate mudstone.
- SMF 26 Pisoid cementstone, rudstone or packstone.

All these SMF types and some RMF types also expand other texture and are, therefore, also included in Figure 2.28.

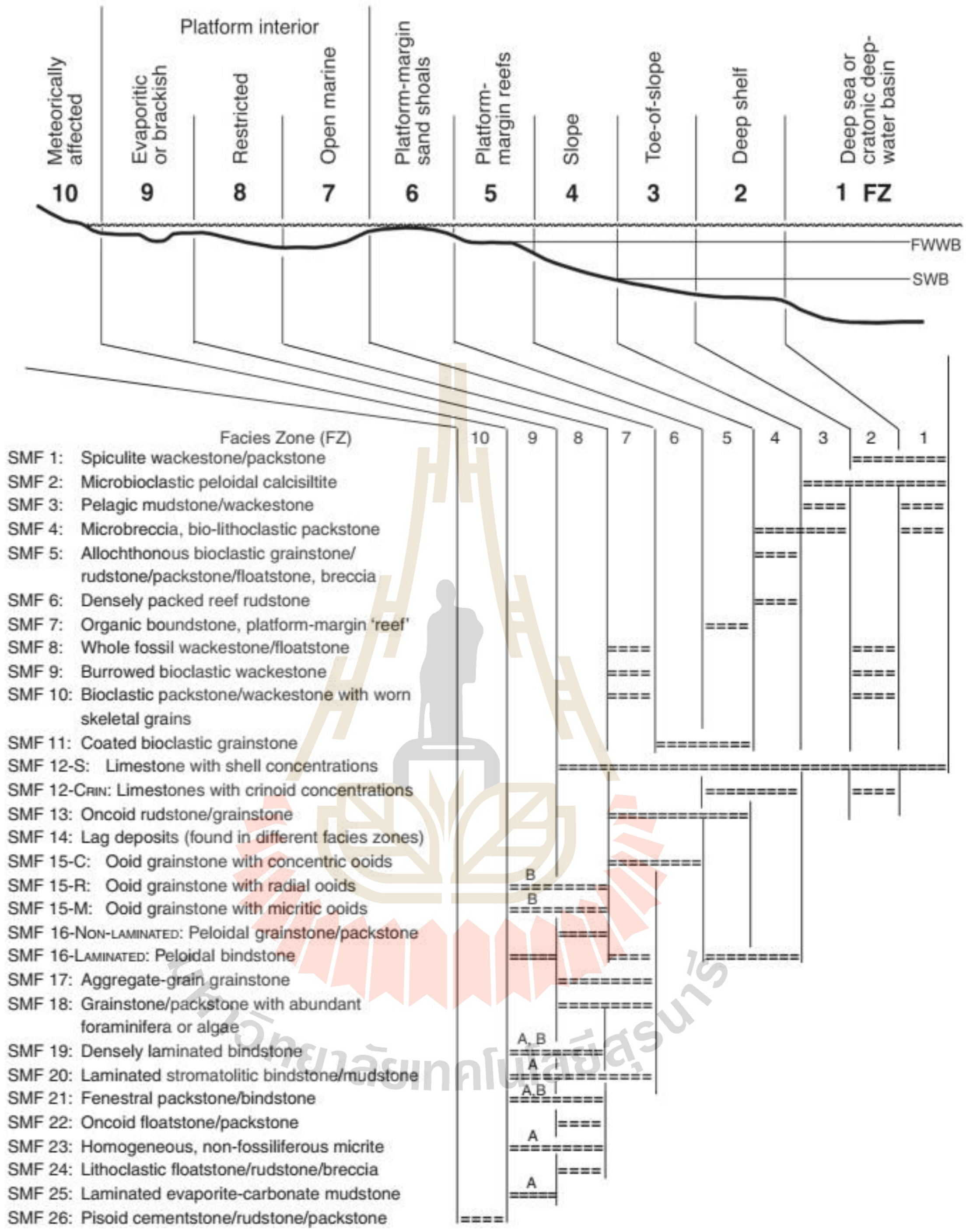


Figure 2.27 Rimmed carbonate platform: The Standard Facies Zones of the modified Wilson model (Flügel, 2010).

Mudstone	Wackestone	Floatstone	Packstone	Grainstone	Rudstone
SMF 3 Abundant planktonic microfossils (RMF 5)	**SMF 1** Sponge spicules, often calcisiltite matrix (RMF 1)	**SMF 5** Densely packed whole fossils and frangments of fossils, often reef-derived	**SMF 1** Sponge spicules, often calcisiltite matrix (RMF 1)	**SMF 5** Densely packed whole fossils and frangments of fossils, often reef-derived	**SMF 4** Microbreccia, small bioclasts and lithoclasts
SMF 23 Micrite or microsparite without fossils	**SMF 3** Abundant planktonic microfossils (RMF 5)	**SMF 8** Whole fossils, fine bioclastic micrite matrix (RMF 3)	**SMF 4** Microbreccia, small bioclasts and lithoclasts	**SMF 11** Abundant coated skeletal grains	**SMF 5** Densely packed whole fossils and frangments of fossils, often reef-derived
	SMF 8 Whole fossils, fine bioclastic micrite matrix (RMF 3)	**SMF 22** Millimeter-to centimeter-sized agglutinated oncoids (RMF 21)	**SMF 5** Densely packed whole fossils and frangments of fossils, often reef-derived	**SMF 13** Millimeter to centimeter sized oncoids with tube-like structure	**SMF 6** Millimeter to centimeter sized reef-derived bioclasts and fossils (RMF 15)
	SMF 9 Abundant fragments of fossils, bioturbation	**SMF 24** Millimeter to centimeter sized lithoclasts	**SMF 10** Abraded and worn skeletal grains (RMF 7)	**SMF 15-C** Ooids with concentric structures (RMF 29)	**SMF 13** Millimeter to centimeter sized oncoids with tube-like structure
	SMF 10 Abraded and worn skeletal grains (RMF 7)		**SMF 16** Non-Laminated very small equally sized peloids	**SMF 15-R** Ooids with radial or radial-concentric structures	**SMF 24** Millimeter to centimeter sized lithoclasts
	SMF 15-M Scattered micritic ooids		**SMF 18** Abundant rock-building benthic foraminifera or calcareous algae (RMF 13, 16, 17)	**SMF 16** Non-Laminated very small equally sized peloids	**SMF 26** Pisoids
	SMF 22 Millimeter-to centimeter-sized agglutinated oncoids (RMF 21)		**SMF 21** Spar-filled voids within a micritic or pelmicritic framework (RMF 23)	**SMF 17** Abundant aggregate grains	
			SMF 26 Pisoids	**SMF 18** Abundant rock-building benthic foraminifera or calcareous algae (RMF 13, 16, 17)	

Figure 2.28 Key to the determination of Standard Microfacies Types (Flügel, 2010).

2.3) Ramp carbonate platform

In 1973, Ahr recognized the difficulties related to the facies distribution of many Paleozoic and Mesozoic shelf carbonates and proposed the carbonate ramp model. This model represents the facies distribution on a gently slope from the shore to deeper part without a sudden change of geomorphic gradient. The ramps differ from rimmed shelves in the absence of continuous shelf-marginal reef trends, the location of high-energy deposits near the shoreline and not at the shelf edge, and the lack of shallow-water derived clasts in deep-water part of the ramp (B in Figure 2.26).

The carbonate ramp model is a sloping topographic surface on which carbonate facies are deposited while subject to open ocean conditions from the surf zone to depth of hundreds of feet. The grainy facies, therefore, will be deposited near the surf zone and the adjacent mainland. The ramp model displays facies patterns which are opposite to the shelf model in lateral relationships. That is, in the ramp model, grainstones and packstones are landward facies and the sediments become muddy as one move seaward. In the typical shelf model, the landward facies are muddy and they pass seaward into shelf-margin grainstones and boundstones. Combining the fair-weather wave base and the storm wave base, Burchette and Wright (1992) have suggested the subdivision in Figure and described as follows (Figure 2.29).

Outer ramp is the zone below normal storm wave base. Water depths vary between tens of meters and several hundreds of meters. The zone is characterized by lowenergy allochthonous and autochthonous carbonates, and hemipelagic sedimentation. Common lithofacies types are bedded, fine-grained limestones (argillaceous lime mudstone and wackestone) associated and interbedded with marl or shale beds.

- RMF 1 Calcisiltite and mudstone with peloids, very fine skeletal debris, sponge spicules, sometimes fine-laminated.
- RMF 2 Argillaceous burrowed mudstone and wackestone; rare agglutinated foraminifera, ostracods, echinoderms.
- RMF 3 Burrowed bioclastic wackestone and packstone with diverse, common to abundant fossils (bivalves, brachiopods, echinoderms) and peloids. Skeletal grains not worn; whole fossil preservation common.

- RMF 4 Peloidal wackestone and packstone.
- RMF 5 Pelagic mudstone with planktonic microfossils and open-marine nektonic fossils.
- RMF 6 Graded, laminated and finely cross-bedded bioclastic and peloidal grainstone.

Mid-ramp is the zone between fair-weather wave base and the storm wave base. Fair-weather phases are represented by burrowed sediments dominated by lime mud or terrigenous mud forming lime mudstones and marls. Storm-related features are graded packstone, grainstone beds, hummocky cross-stratification. Skeletal grains exhibit signs of transport.

- RMF 7 Bioclastic packstone with abundant echinoderms and common bivalves and foraminifera. Skeletal grains worn.
- RMF 8 Burrowed packstone and grainstone with various skeletal grains, intraclasts, oncoids and peloids.
- RMF 9 Wackestone, packstone, floatstone with micritic intraclasts and ramp-derived bioclasts; sometimes microbreccias.
- RMF 10 Limestone conglomerates.
- RMF 11 Marls with intraclasts and limestone pebbles.
- RMF 12 Boundstones comprising coral and coral-crust framestone, red algal framestone.

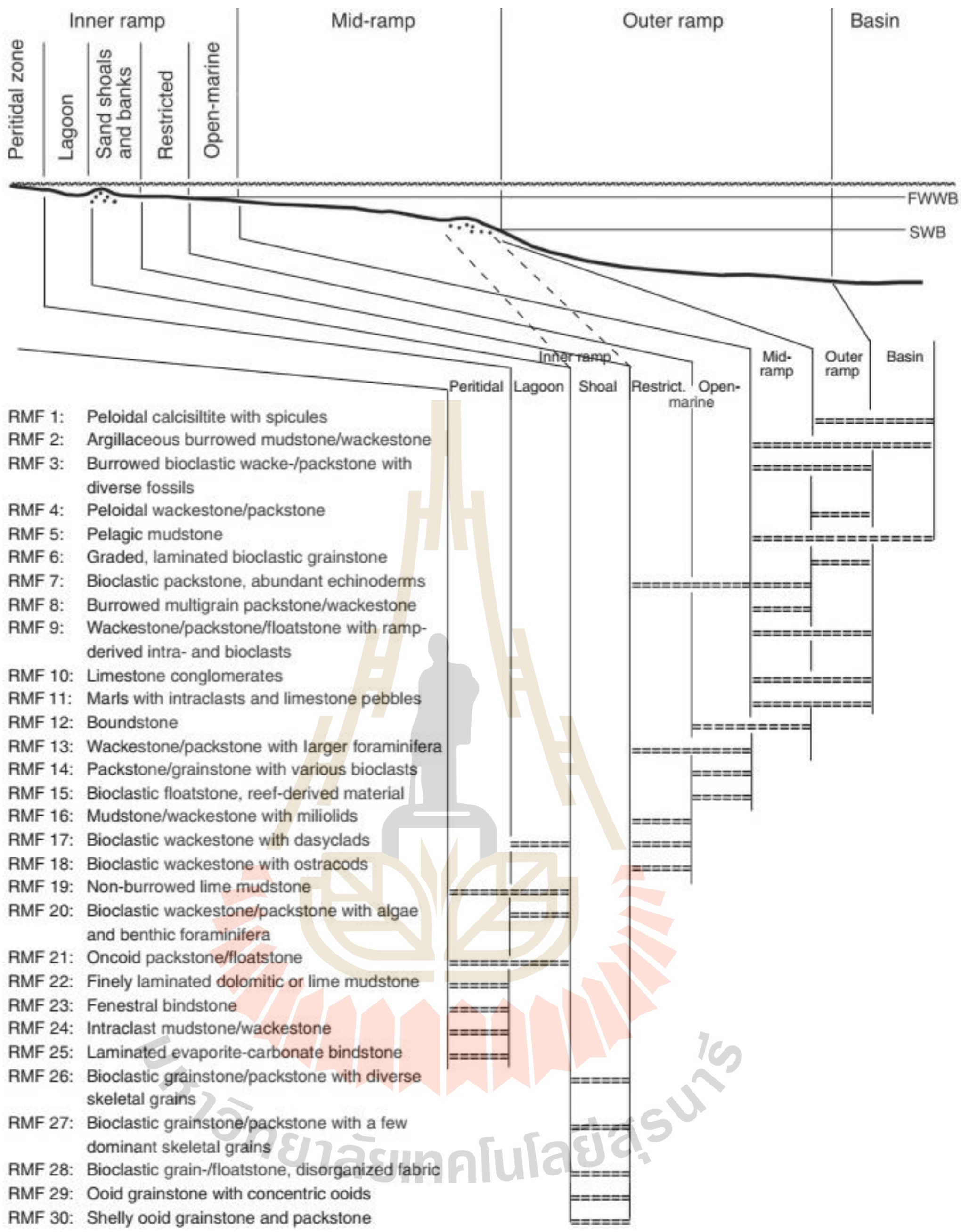


Figure 2.29 Distribution of microfacies types of carbonate ramp (Flügel, 2010).

Inner ramp: The sediments are bedded, microfacially differentiated limestone and dolomites forming relatively the inner ramp comprises the euphotic zone between the upper shoreface (beach or lagoon shoreline) and the fair-weather wave base. The sea floor is almost constantly affected by wave action. Common texture types of open and protected inner ramps are bioclastic packstones and wackestones.

- RMF 13 Bioclastic wackestone and packestone with abundant larger foraminifera.
- RMF 14 Bioclastic packstone and wackestone with skeletal grains, various amounts of intraclasts and some ooids.
- RMF 15 Bioclastic floatstone with various reef-derived material.
- RMF 16 Mudstone, wackestone or packstone with abundant miliolid foraminifera.
- RMF 17 Bioclastic wackestone with dasyclad green algae.
- RMF 18 Bioclastic wackestone with ostracods.
- RMF 19 Non-burrowed lime mudstone.
- RMF 20 Bioclastic wackestone and packstone with calcareous algae and benthic foraminifera.
- RMF 21 Oncoid packstone and floatstone.
- RMF 22 Fine-laminated dolomitic/lime mudstone
- RMF 23 Fenestral bindstone.
- RMF 24 Intraclast mudstone and packstone.

- RMF 25 Laminated evaporite-carbonate bindstone.
- RMF 26 Medium- and coarse-grained bioclastic grainstone and packstone with various benthic skeletal grains.
- RMF 27 Bioclastic grainstone and packstone composed of few dominant skeletal grains.
- RMF 28 Bioclastic floatstone and rudstone exhibiting a strongly disorganized fabric.
- RMF 29 Ooid grainstone with densely packed concentric ooids.
- RMF 30 Shelly ooid grainstone and packstone.

2.4) Non-rimmed Shelves and Platforms

A non-rimmed shelf or open platform is characterized by the lack of a barrier at the shelf break. Non-rimmed platforms and ramps are similar in the nonappearance of a rim at the shelf edge. In both systems sediment transport occurs onshore and downslope, and carbonate production takes place in all parts. The major difference, however, is the very gentle slope angle of the ramp, producing different distribution patterns and sizes of facies zones as compared with un-rimmed platforms. Non-rimmed shelves appear at the leeward side of large tropical banks and are abundant in all cool-water environments. C in Figure 2.26 showing the subdivision of a non-rimmed carbonate cool-water shelf.

- Inner shelf: The depositional processes are constant wave agitation.Particle abrasion and bioerosion. In area of sediment movement and active sediment production. Grain size of clastic are gravels, lithoclastic sands and hard substrates. Biota in region consist coralline red algae, benthic foraminifera, bryozoans, sponges, bivalves, gastropods, serpulids, and echinoids.

- Mid-shelf: The environment settings are frequent storm reworking. Particle abrasion. Sediment transport to outer and inner shelf areas results in sediment-free areas. Characteristics of sediment have active sediment production and thin bedrock. The fauna in environments include coralline red algae, mollusks, benthic and planktonic foraminifera, bryozoans, brachiopods, sponges, barnacles, and echinoids.
- Outer shelf: The depositional processes is sea bottom reworked by episodic storms and suspension deposits. The characteristics of sediments are fine bioclastic sands, calcitic plankton and skeletal fragments, siliceous sponge spicules, and clay. The biota consists of bryozoans, sponges, mollusks, brachiopods, benthic and planktonic foraminifera.

2.3.2 Fossil assemblage analysis

Ostracod assemblages have been used efficiently to interpret marine, marginal marine and non-marine depositional conditions. Environmental interpretation can be actualize based on the generic and suprageneric composition. The marine and non-marine ostracods are especially sensitive to salinity, substrate, or dissolved oxygen levels and generalists. Ostracods are able to live in sulphur springs, stagnant ponds, lakes, swamps, streams, brackish lagoons, estuaries, tidepools, salt marshes, epicontinental seas, and on the floor of ocean basins. As fossils they may occur in sediments deposited in all these environments, being particularly useful as paleoecological indicators of brackish water and fresh water sediment (Figure 2.30).

1) The ecology of ostracods

Ostracod are found in ponds, lakes, lagoon, brackish, etc. They may occur in sediments deposited in all these environments and useful as paleoenvironmental of sediments. The fauna is benthonic or pelagic which pelagic ostracod are rare as fossils. Most benthonic ostracods living and swimming in the bottom of the water.

- The freshwater ostracods: Freshwater ostracods assemblages have also been identified from Carboniferous strata. They are different from most marine ostracods in the relatively unornamented nature of their carapace. Some freshwater marls and limestones are almost entirely composed of the smooth valves of such ostracods. They are sensitive to environmental conditions in their habitat. Hence, freshwater ostracods are of great interest as biological indicators of climate and environmental changes in the Quaternary past and in modern studies (Holmes 1992; Holmes and Chivas 2002; Horne et al. 2012).

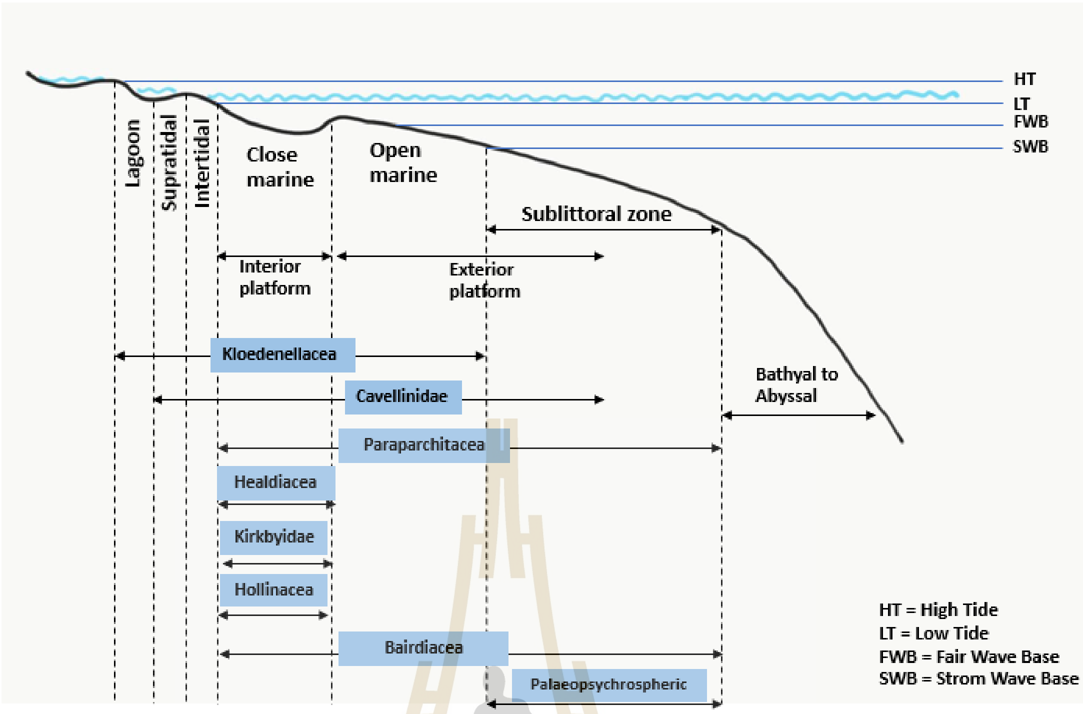


Figure 2.30 Distribution of main ostracod groups during the Late Paleozoic along a platform: (after Craquin-Soleau et al., 2006; Chitnarin, 2009).

- The brackish water ostracods: The ecologic flexibility of ostracods is well demonstrated by the presence of large populations belonging to endemic assemblage in brackish water estuaries and lagoons. Ostracods are the most abundant microfossils present in brackish water sediments, and they contribute significantly to the volume of sediments in some brackish lagoons. Brackish water ostracods are found sometimes in hypersaline lagoons. The tolerance of ostracods usually associated with estuaries and brackish lagoons for great change in salinity allows them to live in lagoons too saline for most normal marine ostracods. The Paraparchitidae were fundamentally marine inhabitants, though some species showed tolerance to brackish environments or even hyper salinity.

- The marine ostracods: Most marine ostracods process complicated exoskeletons that in some way reflect the surrounding marine, benthonic habitat. A few other fossil pelagic ostracods have been described, but most fossil marine ostracods were crawlers, burrowers, and near-bottom swimmers. Marine ostracods seldom survive to reproduce in waters with less than 17 % salinity.

2) Environmental factors

The environmental factors are important in determination of the ranges and locations of certain living marine ostracods species and assemblage as follows.

Depth: Bathymetric pressure seems to exert little or no effect on ostracods, but other factors such as fading light, diminishing plant life, stability and change in composition of the bottom sediment do affect the benthonic ostracods. The Bairdiodea represent shallow to deep, open-marine carbonate environments. These factors affect the fresh-water ostracod living in deeper lake, marine ostracods.

Bottom sediment or substrate: The texture and stability of the sediment composing the substrate exerts a strong influence on marine ostracods, just as it does on freshwater forms.

Lithologic and micropaleontologic association: Most workers on fossil ostracods collect their specimens from calcareous shales and sands, particularly the shale partings in limestone sequences.

Salinity: Except in lagoons and estuaries where the marine water becomes brackish because of continental run-off, and in confined shallow basins where evaporation is dominant, variations in salinity of open marine waters are not sufficiently large to influence marine ostracods appreciably.

Temperature: Change in the temperature of the sea northward and southward along the coasts of continents, along the edges of off-shore water masses, and during seasonal heating of shallow waters are reflected in the geographic distribution of vegetative stenothermal species and time of reproduction during the year of the year of the reproductively stenothermal species. In warm tropical waters more species are present than in colder waters. Cold-water faunas are distinct from warm-water faunas.

Association with other animals: Ostracods live in association with most invertebrates that are now found preserved as fossils. They are found in the brachiopod-trilobite-bryozoan assemblages of the lower Paleozoic and are found in most of the normal marine benthonic faunas through and including the mollusk-foraminifer faunas of today.

CHAPTER III

METHODOLOGY

The methodology can be categorized into six main aspects, namely, literature review, field work and sample collection, laboratory work, data analysis and interpretation, discussions and conclusions. Detail of methodology present as follows.

3.1 Literature review

Reviews of previous works including lithology and stratigraphy of the Permian rocks in central Thailand, age of rocks in central Thailand, paleogeography and paleoenvironment, general biology and morphology of the Permian ostracod, and paleoenvironmental interpretation are presented in chapter II.

3.2 Field work and sample collection

Field work was undertaken in August 2018. The samples were collected from the section in Wichianburi Distict, Phetchabun Province. The study section is located at 15˚ 35'13''N, 101˚ 03' 36'' E on the west side of highway No.21 (see in Figure 1.2). The rocks are exposed on the ground in an agricultural area where villagers have developed the land for plantation (Figure 3.1). The section shows intercalation of well bedded, medium-bedded limestone and shale with beds of bioclastic limestone (Figure 3.2). The limestone is pale gray in color, identified as mudstone to wackestone. Mudstone is brown to grayish brown. In beds of bioclastic limestone, the rocks are partly silicified and usually contain pieces of bioclasts such as corals, crinoid stems and chert nodules. The thickness of section in about 25 meters with bedding attitude of 168, 60W.

Figure 3.1 Photographs of the outcrops at the study section.

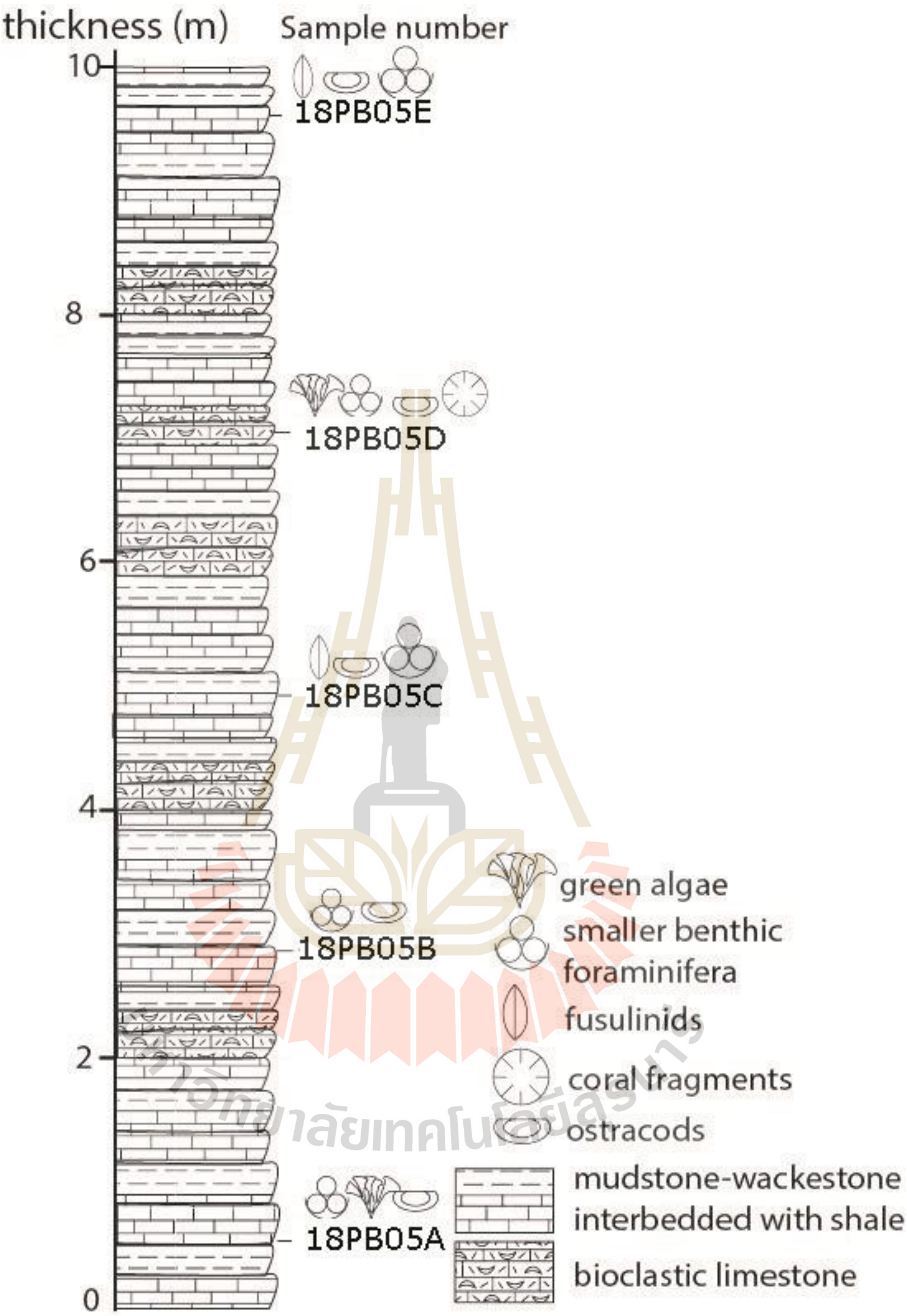


Figure 3.2 Lithologic log of the study section with sample levels.

3.3 Laboratory work

Laboratory work including rock slab and thin section preparation and ostracod disaggregation is described as follows.

3.3.1 Rock slab and thin section preparation

Thin section preparation was carried out following technique described by Vogelsang (1867) as much as possible. The thin sections are prepared in order to investigate the feature of carbonate rocks. This work is a part of microfacies analysis and helps to reveal the origin and evolution of the studied limestone samples. The steps to make the thin sections are as follows.

1. **Cutting the rock slap**
   - Decide hand specimen for cutting.
   - Mark lines on the rock sample with the pencil.
   - Then cut the specimens to a size approximately 20 x 30 x 8.0 mm (Figure 3.3).
2. **Preparing the chip and glass slide**
   - Grind or lap the specimen and glass to complete planeness.
   - The samples polish to eliminate the traces of cutting and to obtain a flat surface (Figure 3.4).

Figure 3.3 Cut and decide the rock sample.

Figure 3.4 Grind the hand specimen.

3. Cementing the chip

- Clean the chip and glass slides.
- Put the chip and glass slides on the hot plate smooth side up.
- Cement the specimen to a glass slide using Canada balsam. (Figure 3.5).

4. Trimming the chip

- Cut off specimen material to a thickness of 0.5-2.0 mm.
- Grind of thin sections to a thickness (Figure 3.6).

5. Hand grinding

- Grind or lap a thin section to a final thickness of 0.03 mm (Figure 3.7).

Figure 3.5 Cement the rock to slide by canada balsam

Figure 3.6 Trimming the chip to the thickness and grinding of thin section.

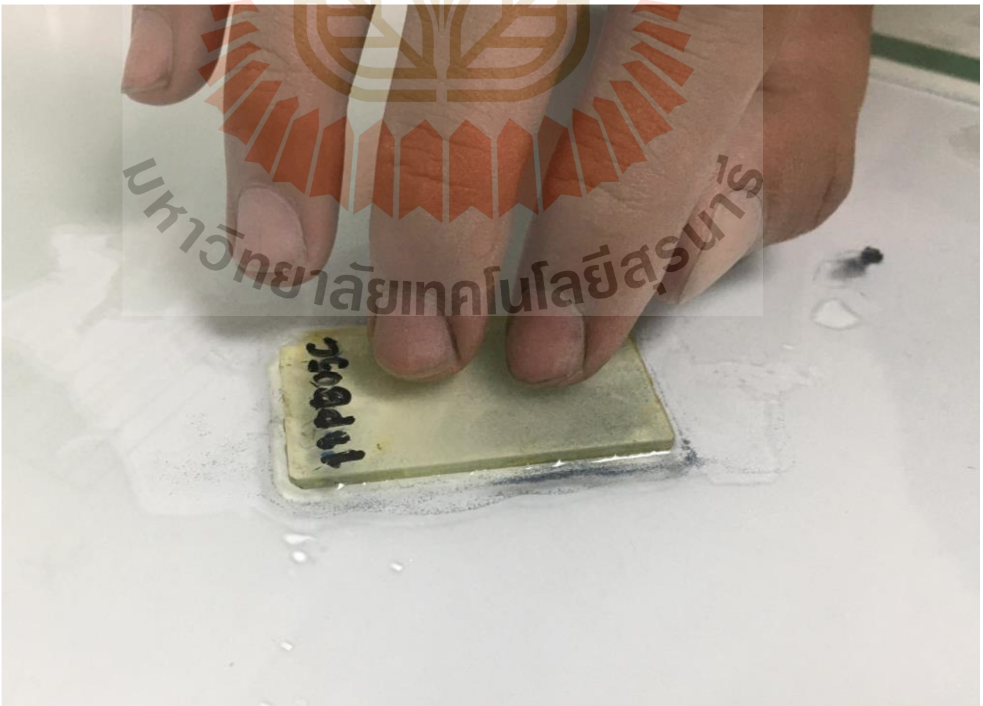


Figure 3.7 Hand grind a thin section thickness 0.03 mm.

3.3.2 Ostracod disaggregation

The limestone samples were processed by Hot Acetolysis Technique (Lethiers and Crasquin-Soleau, 1988; Crasquin et al., 2005) The Hot Acetolysis Technique is suitable to extract the fossils ostracods from calcareous rocks using concentrated acetic acid (CH_3COOH), because the ostracod shells can be released without corrosion. There are four steps in method including Crushing, Dehydration, Acetolysis and Settling and washing.

1. Crushing

To increase the reaction surface, 400-500 g of limestone where crush by hammer to crush them. A mechanical press should be avoided because the stress can lead to breakage of the carapaces, particularly large specimens (Figure 3.8).

Figure 3.8 Crush the rocks by hammer.

2. **Dehydration**

The sample must be dried in a hot-air oven at 120˚C for 24-48 hours, and all the water within the sample removed, to avoid a later acid attack. (Figure 3.9)

Figure 3.9 Dry the sample in the dryer at the temperature 100 C.

3. **Acetolysis**

Wait until the sample has cooled down to avoid the breakage of the glass. The sample is then totally covered with concentrated acetic acid. Cover the beaker with a household aluminium foil and cover one more time with a lid. The pot is placed on a heating sand-bath at a temperature of 60-80˚C. After some time, a muddy deposit should from at the bottom of the jar (Figure 3.10).

Figure 3.10 The sample dissolves in acetic acid on the heating sand-bath.

4. Settling and washing

The sample are then washed. For ostracods a battery of three sieves is used: the 2-mm mesh retains not separated sediment, the 0.5-mm mesh retains adults and large forms, and the 0.1-mm sieve retains small specimens and larvae. The residues, collected in porcelain or Teflon cups, are dried on a heating (Figure 3.11)

5. Hand-sorting

Drying the residue and repeating the second acetolysis. Finally, hand-sorting with stereomicroscope and choosing well-preserved samples for photography (Figure 3.12) with the Scanning Electron Microscope (SEM) at Facility Building 10 (F10), Suranaree University of Technology.

Figure 3.11 Wash the sample by three sieves.

Figure 3.12 Choose well-preserved samples for photography.

3.4 Data analysis and interpretation

3.4.1 Classification of limestone and microfacies analysis

The rock sample were collected and examined in the laboratory. Firstly, hand specimens were classified, and prepared as rock slabs and thin section (see Figure 3.1) The thin section were studied under a polarized light microscope. Detailed limestone classification and microfacies analysis were carried out following Flügel (2010). The depositional environment was interpreted based on grain type, matrix type, bioclasts and depositional texture. Then the standard microfacies (SMF) types were defined. The main criteria used in differentiating SMFs included grain types, grain frequency, grain associations, matrix types, depositional fabric, fossils and depositional texture types. The SMF types were in the compare with facies on the rimmed platform facies model (see Figure 2.27). The SMF types were also compared with the carbonate ramp model (see Figure 2.28).

3.4.2 Classification of ostracods

One of the defining characteristics of ostracods is their carapace or shell. The classification of the Permian ostracods depends on the appearance of the shells (carapace) such as shape, dimorphism, and ornamentation of shell in lateral and dorsal. In this study, the classification is based on the previous work and taxonomic reports (i.e., Kellett, 1933, 1934, 1935; Hou, 1954; Ishizaki, 1964, 1967; Khivintseva, 1969; Bless, 1987; Melnyk and Maddocks, 1988; Lethiers et al., 1989; Kozur, 1991; Crasquin et al., 1999, 2005, 2008, 2010, 2015; Chitnarin et al., 2008, 2012, 2017; Burrett et al., 2014).

The features which are valuable in classification of fossil taxa include

- Carapace shape of ostracod,

- Nature, location and degree of overlap carapace,
- Feature of dimorphism,
- Surface sculpture and nature of marginal zone,
- Position and arrangement of muscle scar, feature of normal and marginal pore canals, and form of selvages and flanges.

The ostracods are classified into four Orders: Palaeocopida, Platycopida Podocopida, and Myodocopida (Table 3.1) Members of the last three orders are concerned to this thesis.

3.4.3 Ostracod assemblage analysis

According to Table 3.1, the ostracod assemblage at the Superfamilies and Families levels are classified for interpretation. The ostracod assemblage analysis was done by making at the percentage of the population at the Superfamily or Family level found in the sample. But it is found that there is ostracod which is an index of the environment, it must be considered at the first.

3.5 Discussion and conclusion

The depositional environment interpretation of study area is use microfacies analysis and detailed limestone classification based on grain type, matrix type, bioclasts and depositional texture. Then compare and interpret of the depositional as studied by these authors: Wielchowsky and Young (1985), Singhasuriya et al. (2017), Uttarawiset et al. (2017), Dowson and Racey (1993), Thambunya et al. (2007), Chutakositkanon et al. (2000), Udchachon et al. (2014) and Chitnarin (2008) The taxonomic study of ostracod systematic is based on characteristic of shell morphology (Moore, 1961). The composition of ostracod assemblages as study in Table 3.1.

Table 3.1 Classification of ostracods in this study.

Subphylum Crustacea			
Class Ostracoda			
Subclass	**Order**	**Suborder**	**Superfamily**
Podocopa	Paleocopida (Ord.-Trias., Tert.)	Beyrichiocopina	Beyrichioidea
			Tetradelloidea
			Eurychilinoidea
			Aparchitoidea
			Primitiopsoidea
		Kirkbyocopina	Kirkbyoidea
			Puncioidea
		Kloedenellocopina	Kloedenelloidea
			Paraparchitoidea
			Youngielloidea
			Hollinoidea
	Platycopida (Jur.-Rec.)	Platycopina	Leperditelloidea
			Cytherelloidea
		Metacopina	Healdiodea
			Thlipsuroidea
	Podocopida(L.Ord.-Rec.)	Podocopina	Bairdioidea
		Cypridocopina	Macrocypridoidea
			Pontocypridoidea
			Cypridoidea
		Cytherocopina	Quasillitoidea
			Cytheroidea
			Terrestricytheroidea
		Darwinulocopina	Carbonitoidea
			Darwinuloidea
		Sigillocopina	Sigillioidea
			Bairdiocypridoidea
Myodocopa	Myocopida (Ord.-Rec.)	Myodocopina	Cypridinoidea
			Cylindroleberidoidea
			Sarsielloidea
			Cyprelloidea
			Bolbozooidea

CHAPTER IV

RESULTS

Microfacies analysis and ostracod assemblage analysis are major tools for reconstruction of the paleoenvironments in this study. The first part of this chapter presents results of the microfacies analysis including limestone classification and SMF type classification, bioclasts in the studied limestones, and paleoenvironmental interpretation. The second part presents results of using ostracods assemblage analysis including ostracod taxonomy, distribution of the ostracods at the study section, and the paleoenvironmental interpretation based on the ostracod assemblage. The results of both techniques are discussed in the last part of the chapter.

4.1 Microfacies analysis

In this study, Dunham (1962) classification is adopted. The limestones can be divided into two main groups: those have originated within sedimentary basins are called autochthonous limestone; those have been swept into deposits are called allochthonous limestone. The limestone components are classified into grain categories, matrix, and cement types. Grains have diameters of approximately 2 mm. and more. Matrix is generally fine grain carbonates also called “lime mud”. Cement is mineral precipitated within voids between the grains. The association of grains is identified as “grain-supported” when the grains are connected or “mud-supported” when the limestone is matrix supported and contains few grains (less than 10%), it is called mudstone. The limestone with matrix supported and more grains (10-50%) is called wackestone. When the limestone is grain supported: if it contains large proportion of lime mud (more than 1%), it is called packstone; if it contains small proportion of lime mud (less than 1%), it is grainstone.

4.1.1 Limestone classification and microfacies type classification

In this study, five limestone samples (18PB05A-18PB05D) were collected from the study section. More than 10 rock thin sections were prepared. The thin sections were studied under the polarized-light microscope. As a result, they can be classified to wackestone and grainstone, and identified into two microfacies types namely bioclastic wackestone and bioclastic grainstone. Distribution of the microfacies types along the study section presents in Table 4.1. The characters of the microfacies types are shown in Figure 4.1 and summarized as follows:

Table 4.1 Distribution microfacies types of study section.

Sample	Bioclastic wackestone	Bioclastic grainstone
18PB05E		✓
18PB05D	✓	
18PB05C		✓
18PB05B		✓
18PB05A	✓	

The bioclastic wackestone is mud-supported and consists of many grains (more than 10-50%). Most of grains are bioclastic skeletons such as smaller foraminifers, fusulinids and green algae. Fragments of algae and smaller foraminifers are abundant and usually recrystallized. Most bioclasts are less than 2 mm. Peloids and intraclasts are absent.

The bioclastic grainstone is grain-supported, and contains more grains (more than 50%) with few lime mud (less than 1%) lime mud. The bioclasts are fragments of algae, fusulinids and smaller foraminifers.

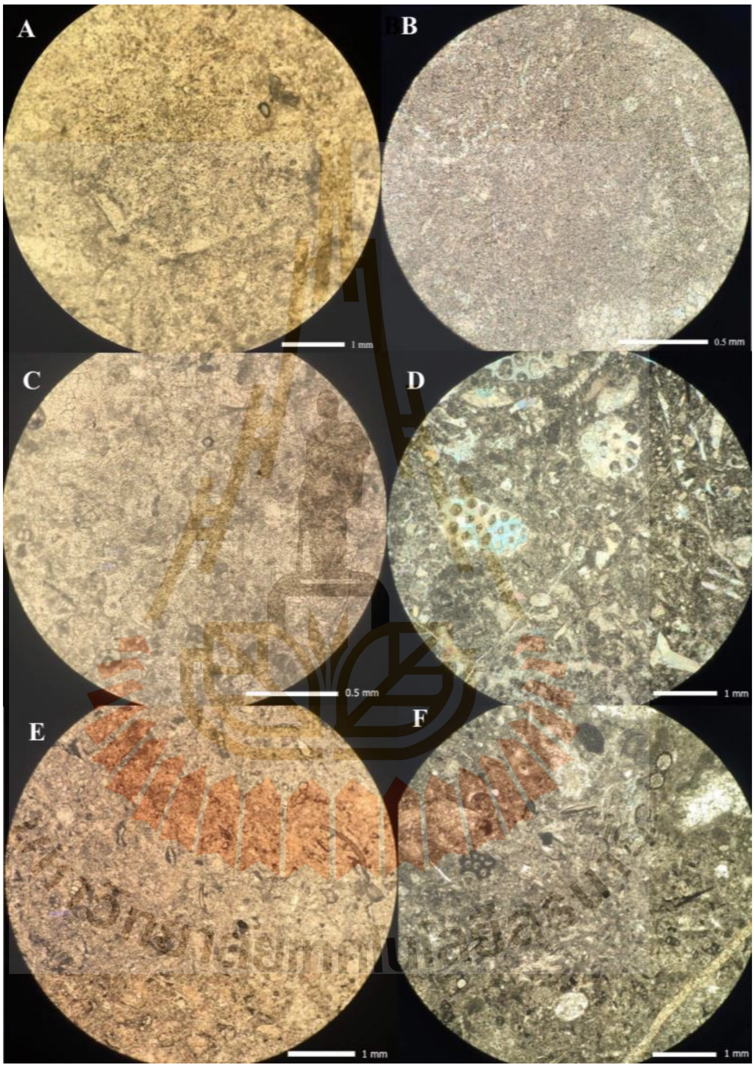


Figure 4.1 Texture of microfacies types: A, C, E, Bioclastic grainstone of Sample number 18PB05B, 18PB05C, 18PB05E; B, D, F, Bioclastic wackestone of Sample number 18PB05A and 18PB05D.

4.1.2 Bioclasts in the studied limestones

The studied limestones are characterized by prolific fossil contents including fusulinids, smaller foraminiferas, green algae and ostracods. Information of these bioclasts are summarized as follow.

1) The sample number 18PB05A

This sample comprises large bioclastic fragments varied from 0.25-3.5 mm. Most bioclasts are recrystallized. The large fragments of the algae can be identified to *Mizzia velebitana*. (Figure 4.2).

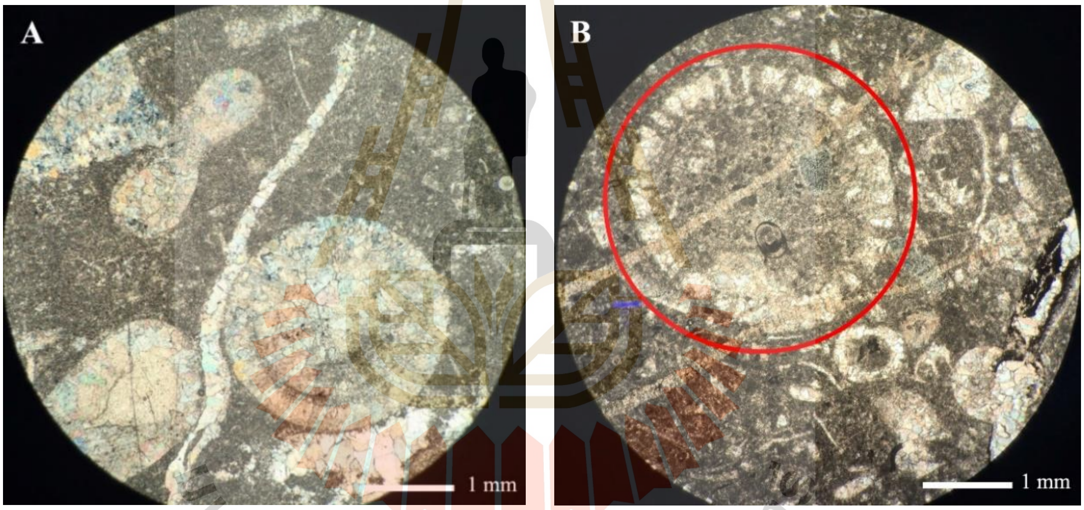


Figure 4.2 Photomicrographs of sample number 18PB05A showing bioclasts: (A), Bioclasts are recrytallized; (C) *Mizzia velebitana*

2) The sample number 18PB05B

This sample contains fragments of the smaller foraminiferas, algae and ostracods. Bioclasts range from 0.20-1.13 mm in size. The smaller foraminifers can be identified as *Labiodagmarita vasleti*, *Cribrogenerina sumatrana,* and *Nodosinelloides* sp. The algae is identified as *Pseudovermiporella* sp. The ostracods can be recognized by isolated single valves (Figure 4.3).

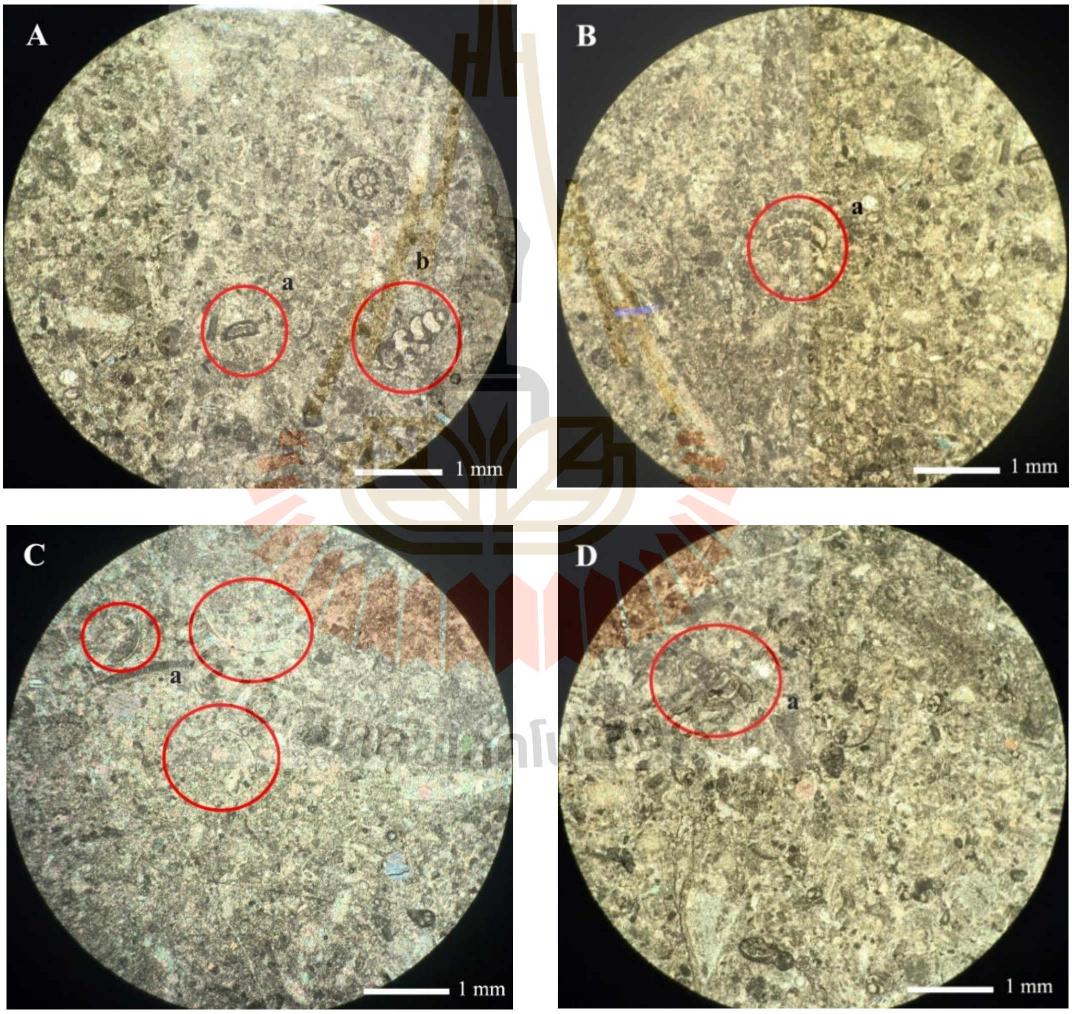


Figure 4.3 Photomicrograph of sample number 18PB05B showing bioclasts: (A) a, *Pseudovermiporella* sp., b, *Labiodagmarita vasleti*; (B) a, *Cribrogenerina sumatrana*; (C) a, Carapace of ostracods; (D) a, *Nodosinelloides* sp.

3) The sample number 18PB05C

This sample consists of 0.50-2.20 mm bioclastic fragments. The most abundant taxa is the smaller foraminifers including *Agathammina* sp., *Glomomidiellina* sp., *Labioglobivalvulina* sp., *Geinitzina* sp. *Climacammina* sp., *Globivalvulina vondershmitti*, *Dagmarita*? *sharezaensis*, *Pachyphloia schwageri* and *Glomospira?* sp. Few fusulinids are found and can be identified as *Nankinella* sp., *Chusenella* sp. (Figures 4.4-4.5) and *Sphaerulina* sp. (Figure 4.6). Fragments of the algae can be identified as *Pseudovermiporella nipponica* and *Mizzia velebitana*.

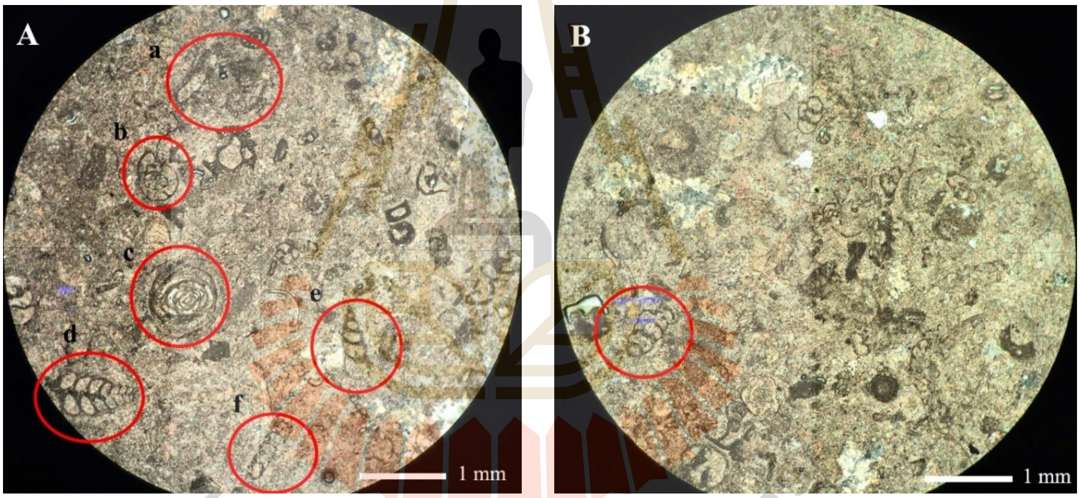


Figure 4.4 Photomicrograph of sample number 18PB05C showing bioclasts: (A) a, *Pseudovermiporella nipponica*, b, *Globivalvulina vondershmitti*, c, *Glomospira?* sp., d, *Dagmarita* ? *sharezaensis*, f, *Geinitzina* sp., e: *Phachyphloia schwageri*; (B), *Climacammina* sp.

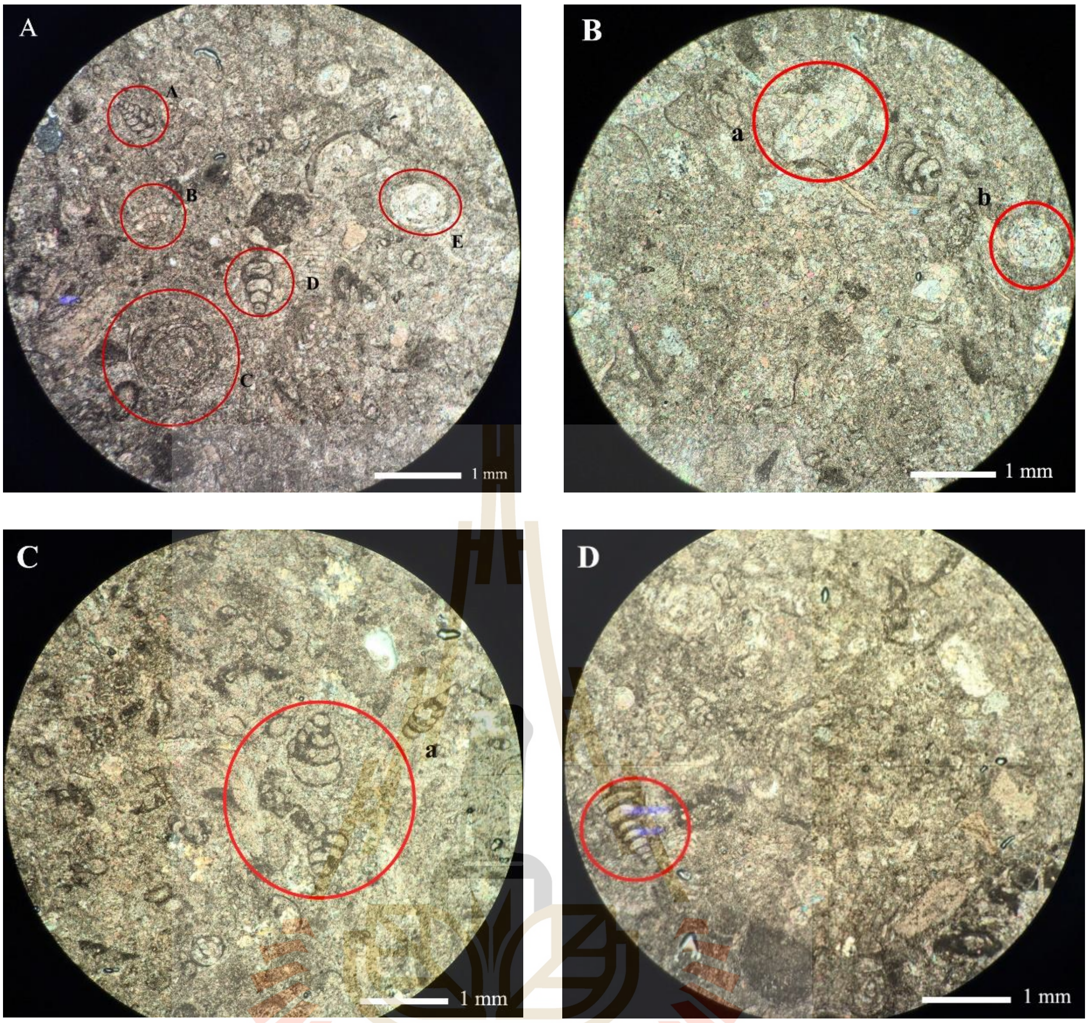


Figure 4.5 Photomicrograph of sample number 18PB05C showing bioclasts : (C) a, *Dagmarita ? Sharezaensis*, b, *Pseudovermiporella nipponica*, c, *Crassispirella hughesi*, d, *Langella* sp.; (D) a, *Agathammina* ? sp., b, *Glomomidiellopsis uenoi*; (E) a, *Labioglobivalvulina* sp.; (F) a, *Geinitzina* sp.

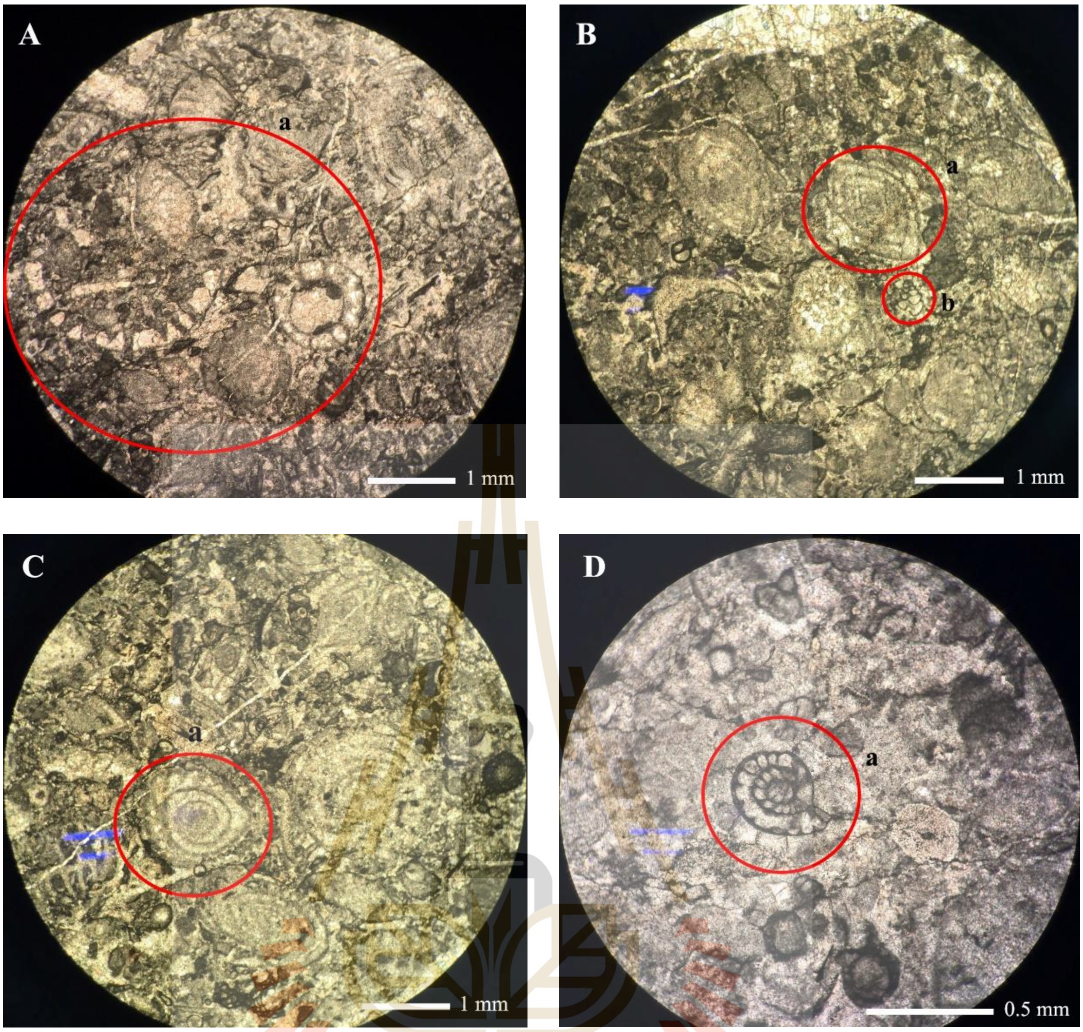


Figure 4.6 Photomicrograph of sample number 18PB05C showing bioclasts: (G) a, *Mizzia velebitana* ; (H) a, *Nankinella* sp., b, *Dagmarita* sp.; (I) a, *Sphaerulina* sp.; (J) a, *Chusenella* sp.

4) The sample number 18PB05D

This sample contains recrystallized bioclasts which are ranged from 0.45-2.7 mm in size. The smaller foraminifers can be identified as *Deckerella* sp. and *Dagmarita* sp. The algae can be identified as *Mizzia yabei* and *Mizzia velebitana* (Figure 4.7).

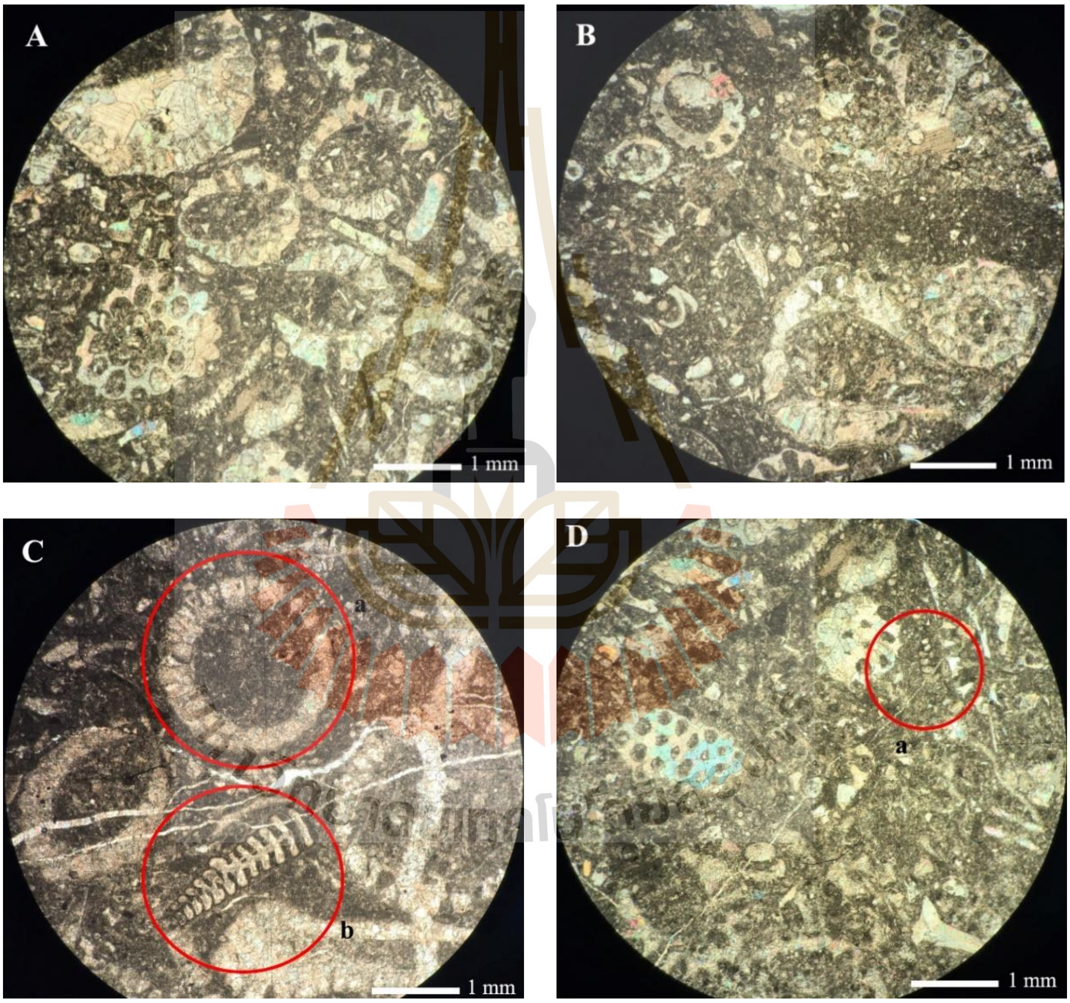


Figure 4.7 Photomicrograph of sample number 18PB05D showing bioclasts: (A), (B) *Mizzia yabei*; (C) a, *Mizzia velebitana* , b, *Deckerella* sp.; (D) a, *Dagmarita* sp.

5) The sample number 18PB05E

This sample contains abundant bioclasts such as smaller forminifers and fusulinids. Bioclasts range from 0.30-4.00 mm in size. Fragments of the smaller foraminifers can be identified as *Deckerella* sp., *Globivalvulina* sp., *Cribogenerina* sp. and *Dagmarita* sp. The fusulinids can be identified as *Nankinella* sp., *Parafusulina* sp., *Kahlerina* sp., and *Rugososchwagerina?* sp. (Figure 4.8)

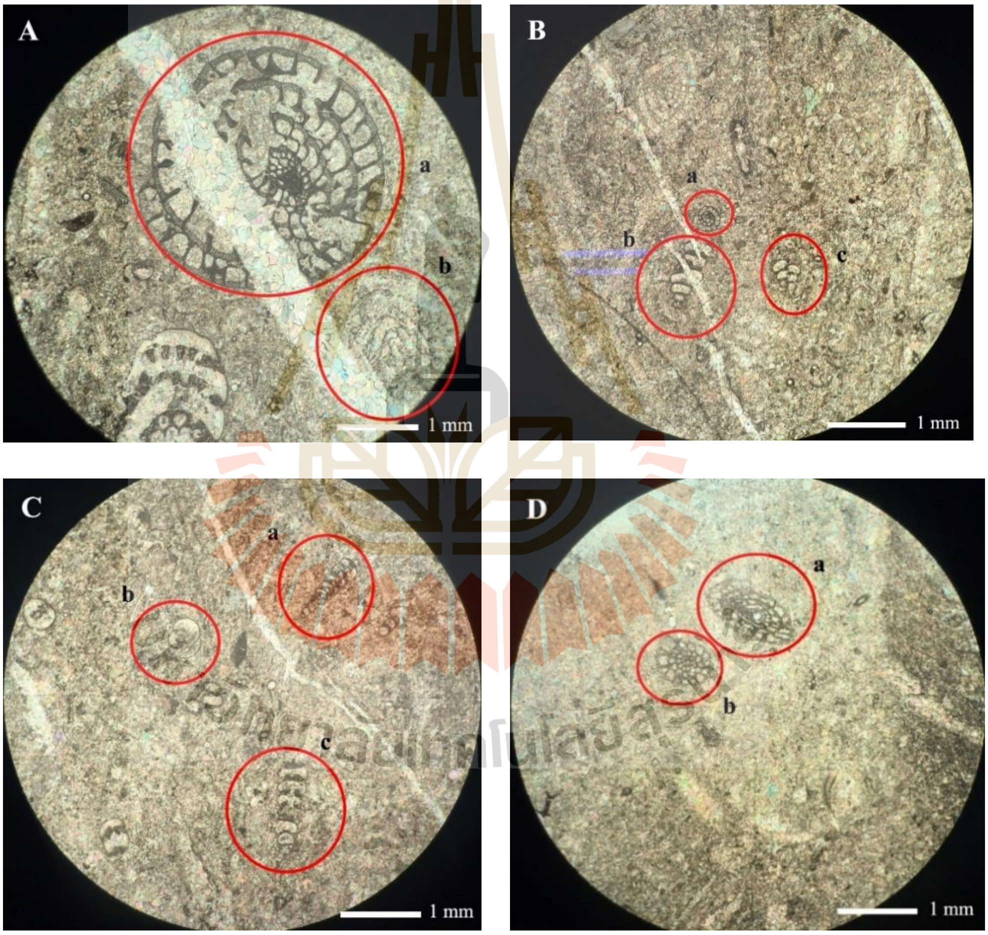


Figure 4.8 Photomicrographs of sample number 18PB05E showing bioclasts: (A) a, *Rugososchwagerina?* sp., b, *Nankinella* ? sp.; (B) a, *Kahlerina* sp., b, *Deckerella* sp., c, *Dagmarita* sp.; (C) a, *Cribogenerina* sp., b, *Globivalvulina* sp., *Deckerella* sp.; (D) a, *Parafusulina* sp., b, *Kahlerina* sp.

The bioclasts of the studied limestones are occupied by many smaller foraminifers, fusulinids, algae (Table 4.2) and coral in the hand specimen is *Ipciphylum subelegans* in Figure 4.9. The ostracod valves and bryozoan fragments are also found but less abundant. It should be noted that other Permian invertebrate fossils such as brachiopods, gartropods, crinoids are absent. The fusulinids including *Rugososchwagerina?* sp., *Kahlerina* sp., *Parafusulina* sp., *Nankinella* sp. *Sphaerulina* sp. and *Chusenella sp.*are Middle Permian (Roadian to Capitanian age) (Huang et al., 2015).

Figure 4.9 The rock samples showing the coral (*Ipciphylum subelegans*).

Table 4.2 Distribution of abundant bioclasts in the studied limestones.

Sample	Smaller foraminifera	Fusulinid	Algae
18PB05E	*Deckerella* sp., *Globivalvulina* sp., *Cribogenerina* sp. *Dagmarita* sp.	*Rugososchwagerina?* sp. *Kahlerina* sp., *Parafusulina* sp., *Nankinella* sp.	
18PB05D	*Deckerella* sp., *Dagmarita* sp.		*Mizzia yabei*, *Mizzia velebitana*
18PB05C	*Agathammina* sp., *Glomomidiellina* sp., *Climacammina* sp., *Globivalvulina vondershmitti*, *Dagmarita*? *Sharezaensis*, *Pachyphloia schwageri* and *Glomospira?* sp., *Labioglobivalvulina* sp., *Geinitzina* sp.	*Nankinella* sp. *Sphaerulina* sp., *Chusenella* sp.	*Pseudovermiporella nipponica*, *Mizzia velebitana*
18PB05B	*Labiodagmarita vasleti*., *Cribrogenerina sumatrana*, *Nodosinelloides* sp., *Nodosinelloides* sp.		*Pseudovermiporella* sp.
18PB05A			*Mizzia velebitana*

4.1.3 Paleoenvironmental interpretation

The studied limestones can be identified as the bioclastic wackestone and bioclastic grainstone microfacies types. The carbonate grains consist mainly of the smaller foraminifers, dasycladacean algae, fusulinids and other fragments. The bioclasts are commonly recrystallized. The lime mud is partly recrystallized to microspar matrix. The microfacies types can be compared to SMF 9 and SMF 18 of Wilson's Standard Microfacies (Flügel, 2010) on the rimmed carbonate platform model (see Figure 2.27, 4.10). The SMF 9 and SMF 18 suggest the depositional environments within FZ7 and FZ8 of Flügel's Facies Zones (Wilson, 1975) which can be situated between restricted and open marine platform interior.

According to the literature reviews and field investigation in Phetchabun area, the Early-Middle Permian reefs were grown by coral-algae-sponge community and known to occur as patches or mounds (i.e., Wielchowsky and Young, 1985; Dowson, 1993). Udchachon et al. (2014) gave an idea that the Early Permian environments might occur on the rimmed plaform, then evolved to the ramp platform in Middle Permian. Thus, the depositions on the carbonate ramp platform are also possible and cannot be neglected. The bioclastic wackestone and bioclastic grainstone microfacies types can be compared with RMF13, RMF14, RMF17, RMF18 and RMF27 (Flügel, 2010) on the ramp carbonate platform model (see Figure 2.28, 4.11). These RMFs suggest the deposition on the inner ramp including lagoon, sand shoals restricted to open-marine environments.

This interpretation is supported by the mud-supported and the low diversity of skeletal grains suggest deposition under low energy, very restricted lagoon. The skeletal fragments indicate the deposition environment occurred in a quiet water and lagoonal environment. The grain-supported and divers of fragments were deposited in a moderate energy environment, near shoal, subtidal setting, either foreshoal or backshoal. Smaller Foraminifers are used in divived the depositional environment of ramps and mud mounds as well as they are indicative of local shelf habitats (Flügel, 2010). Dasycladacean algae suggest deposition in an inner platform environment, semi-restricted lagoon, back barrier bar of mound or shaol and lived in normal salinity. Shape of fusulinid is spherical forms in low-energy environments (Ross, 1982) Abraded foraminifers and other fossils indicate transportation.

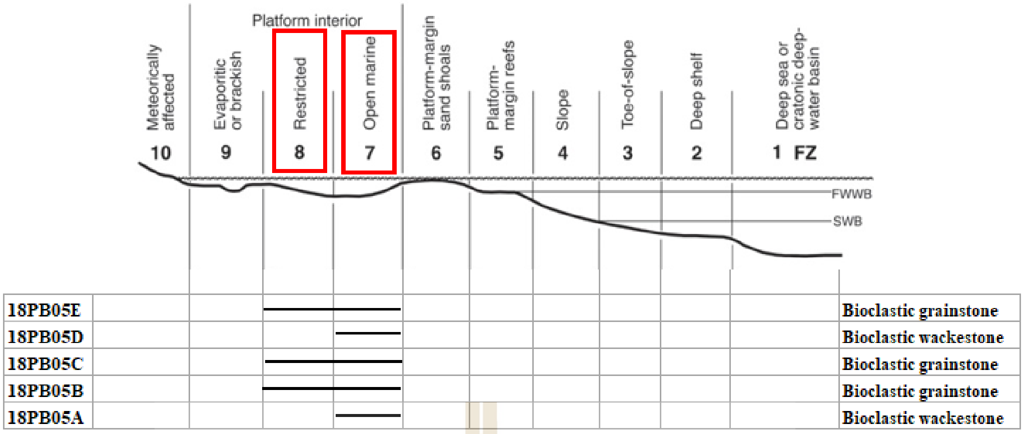


Figure 4.10 Comparision of study's carbonate microfacies with rimmed carbonate platform (Flügel, 2010).

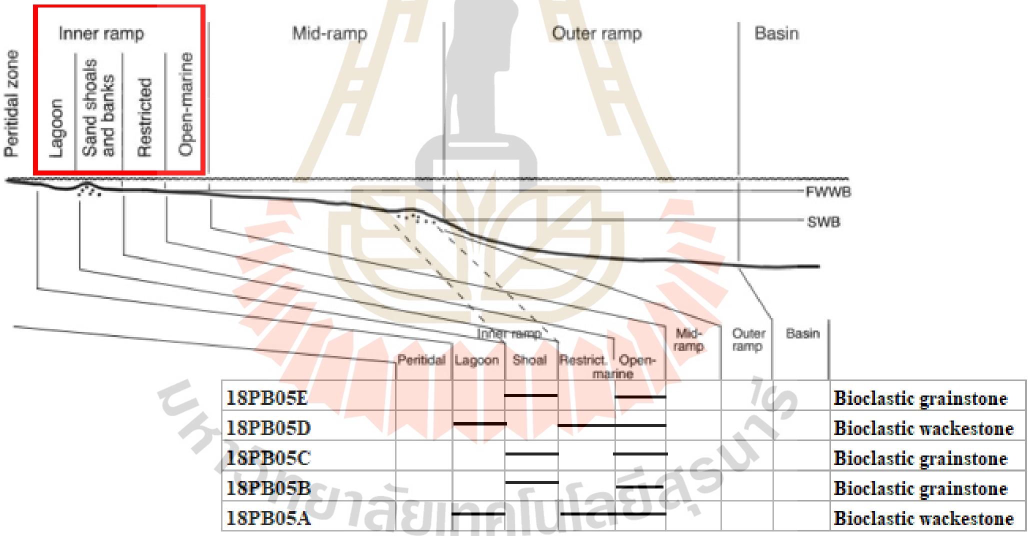


Figure 4.11 Comparision of study's carbonate microfacies with carbonate ramp model (Flügel, 2010).

4.2 Ostracod assemblage analysis

4.2.1 Ostracod Taxonomy

In this study, the classification of ostracods followed Moore (1961) modified after Lethiers (1981) and Horne et al. (2002). The SEM photographs were examined to identify the recovered ostracods and then compared with previous works of the Permian ostracods. Thirty six species belonging to 14 genera and 8 families are recognized. The ostracod taxonomy of the recovered ostracods of this study illustrated in Figure 4.13-4.16

Abbreviations: DB: dorsal border; AB: anterior border; ADB: anterior dorsalborder; AVB: anterior ventral border; VB: ventral border; PB: posterior border; PVB:posterior ventral border; PDB: posterior dorsal border; H: height; L: length.

Class OSTRACODA Latreille, 1802

Order PALAEOCOPIDA Latreille, 1802

Suborder KLOEDENELLOCOPINA Scott, 1961

Superfamily KLOEDENELLOIDEA Ulrich & Bassler, 1908

Family KNOXITIDAE Egorov, 1950

Genus Geffennina Coryell & Sohn, 193

Type species: Geffenina marmerae Coryell & Sohn, 1938

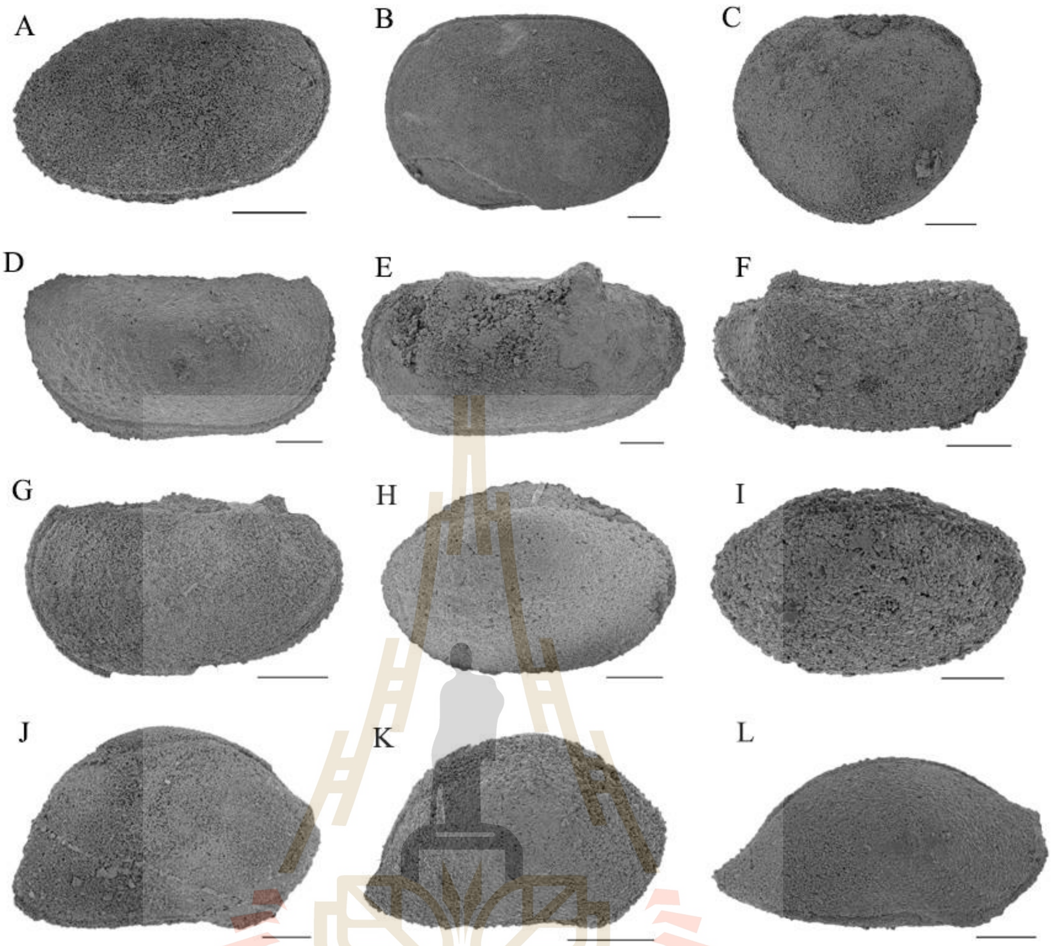


Figure 4.12 Ostracods from Wichian Buri area, Phetchabun Province: A, *Geffenina* cf. *posterodorsospina* Chitnarin, 2012; B, *Paraparchites chenshii* Crasquin, 2010; C, *Samarella victori* Crasquin, 2010; D, Kirkbya sp.1; E-G, *Knightina* cf. *ultima* Kozour, 1985; H-I, *Microcoelonella* cf. *takliensis* Chitnarin, 2012; J-K, *Bairdia bassoni* Crasquin, 2010; L, *Bairdia deweveri* Crasquin, 2010. See description of the specimen in text. Scale bar is 100 µm.

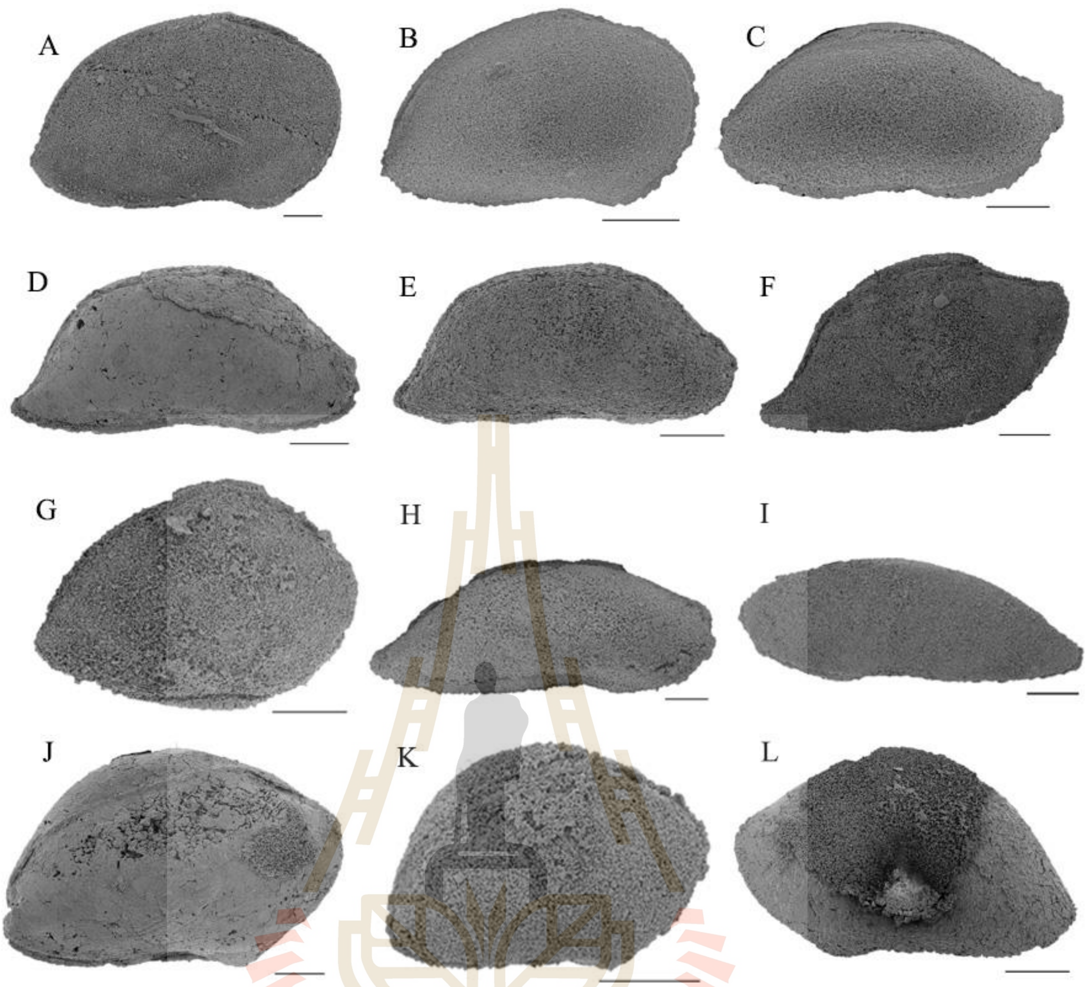


Figure 4.13 Ostracods from Wichian Buri area, Phetchabun Province: A-B, *Bairdia broutini* Crasquin, 2010; C, *Bairdia* cf. *episkopiensis* Crasquin-Soleau, 1998; D-E, *Bairdia* cf. *songthami Chitnarin*, 2017; F, *Bairdia* cf. *urodeloformis* Chen, 1987; G, *Bairdia* cf. *altiarcus* Chen, 1958; H-I, *Bairdia* cf. *fangnianqiaoi* Crasquin, 2010; J-L, *Bairdia* sp. 1. See description of the specimen in text. Scale bar is 100 µm.

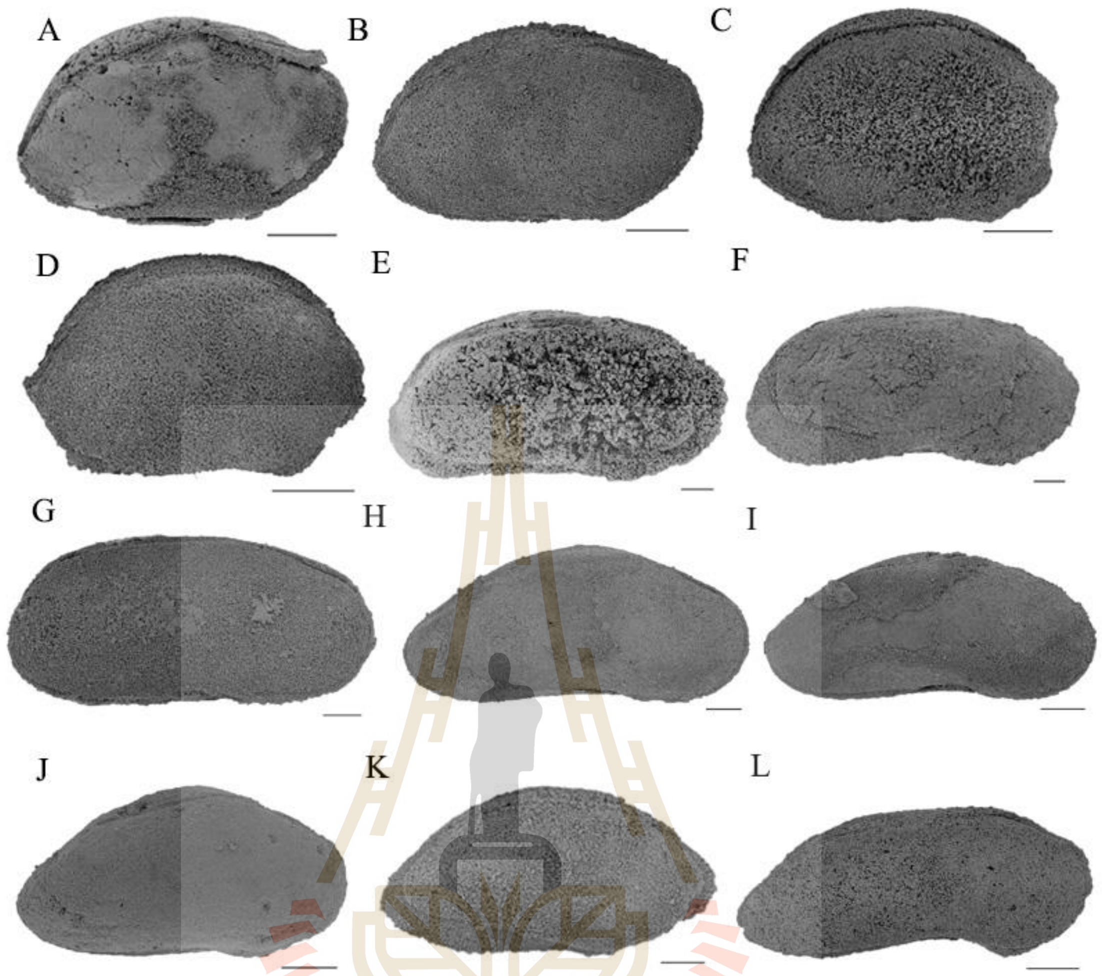


Figure 4.14 Ostracods from Wichian Buri area, Phetchabun Province: A-B, *Bairdia* sp. 2; C, *Bairdia* sp. 3; D, *Bairdia* sp. 4; E-F, *Bairdiacypris* cf. *longirobusta Chen,* 1958; G, *Bairdiacypris* cf. *reniformis* Chen, 1958; H-I, *Bairdiacypris* cf. *fornicata* Shi, 1982; J-K, *Bairdiacypris* sp.1; L, *Bairdiacypris* sp.2. See description of the specimen in text. Scale bar is 100 µm.

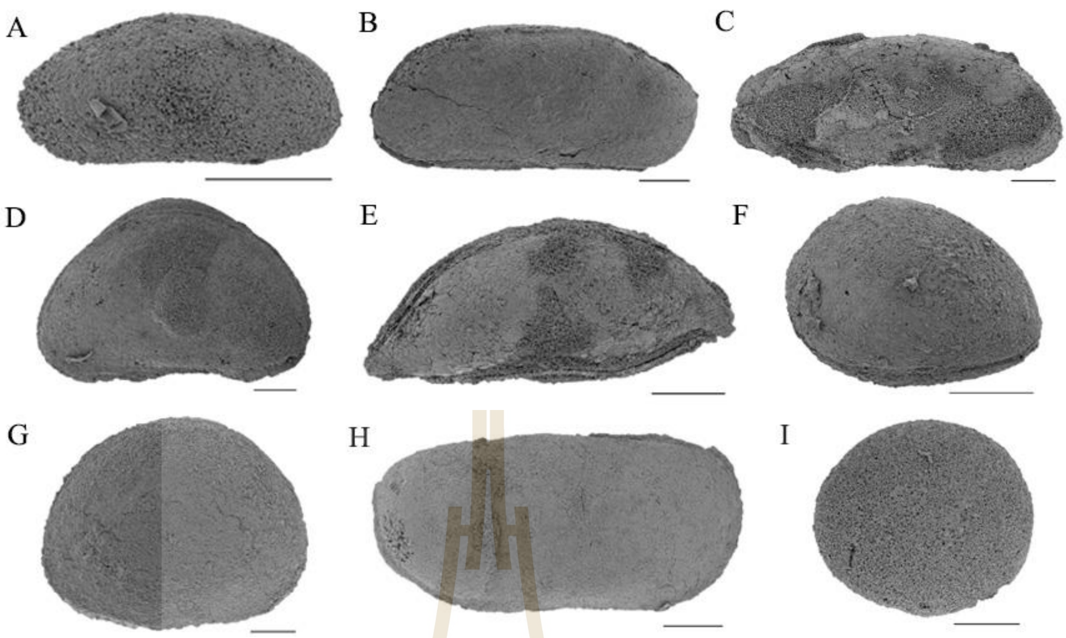


Figure 4.15 Ostracods from Wichian Buri area, Phetchabun Province: A, *Fabalicypris blumenstengeli* Crasquin, 2008; B, *Fabalicypris hathaithipae* Chitnarin, 2017; C, *Fabalicypris* sp.1; D, *Silenites sureeae* Chitnarin, 2012; E, *Acratia chongpani* Chitnarin, 2017; F, *Basslerella tota* (Chen & Bao, 1986) G, *Basslerella* cf. *wipanue* Chitnarin, 2017; H, *Sulcella* cf. *suprapermiana* Kozur, 1985; I, *Polycope* sp. See description of the specimen in text. Scale bar is 100 µm.

Geffenina cf. _posterodorsospina_ Chitnarin, 2012

Figure 4.13 A

Materials: three complete carapaces.

Figured materials: A, left lateral view of the complete carapace, sample number 18PB05D.

Measurement: H = 0.34 mm, L = 0.59 mm, H/L = 0.58.

Discussion: The specimen are closed to *Geffenina posterodorsospina* Chitnarin, 2012 in general outline, but differ by the smaller size of the carapace, and indistinct sulcus. AB broadly rounded with maximum curvature at mid height. VB straight to gently. PB with radius of curvature. DB straight. RV larger than LV.

Occurrence: Sample number 18PB05A and 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Superfamily PARAPARCHITOIDEA Scott, 1959

Family PARAPARCHITIDAE Scott, 1959

Genus *Paraparchites* Ulrich & Bassler, 1906

Type species: *Paraparchites humerosus* Ulrich & Bassler, 1906

***Paraparchites chenshii* Crasquin, 2010**

Figure 4.13 B

1982 *Paraparchites kansasensis* Harris & Lalicker, Chen & Shi: 116, Pl. 3, figs.1-3

1987 *Paraparchites kansasensis* Harris & Lalicker, Shi & Chen: 34, Pl. 11, figs.1-4

2002 *Paraparchites kansasensis* Harris & Lalicker, Shi & Chen: 62, Pl. 1, figs.26-30

2012 *Paraparchites chenshii* Crasquin sp. nov., Crasquin et al.: Figs. 4M-S

2017 *Paraparchites chenshii* Crasquin, Chitnarin et al.: Figs 8J-L

Materials: two complete carapaces.

Figured material: B, right lateral view of the complete carapace, sample number 18PB05A.

Measurement: H = 0.95 mm, L = 1.40 mm, H/L = 0.68.

Occurrence: Pingding section, Central Guangxi, Wuchiapingian (Shi & Chen,2002); Wantong section, Jiangsu, Mianyang, Hubei (Chen & Shi, 1982); Meishan section, Changxing Formation, Baoqing Member (Shi & Chen, 1987); Baoqing and Meishan Members, Changxing Formation, Changhsingian, Late Permian; Sample number 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Genus *Samarella* Polenova, 1952

Type species: *Samarella crassa* Polenova, 1952

***Samarella victori* Crasquin, 2010**

Figure 4.13 C

2010 *Samarella vi*ctori Crasquin sp.nov.,Crasquin et al.: Figs.4T-X

Materials: eight complete carapaces.

Figured material: C, left lateral view of the complete carapace, sample number 18PB05A.

Measurement: H = 0.44-0.66 mm, L = 0.52-0.80 mm, H/L = 0.83-0.84.

Occurrence: Meishan section, Baoqing and Meishan Members, Changxing Formation, Changhsingian, Late Permian; Sample number 18PB05A and 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun

Superfamily KIRKBYOIDEA Ulrich & Bassler, 1906

Family KIRKBYIDAE Ulrich & Bassler, 1906

Genus *Kirkbya* Jones, 1859

Type species: *Dithyrocaris permiana* Jones, 1850

***Kirkbya* sp.1**

Figure 4.13 D

Materials: two complete carapaces.

Figured material: D, left lateral view of the complete carapace, sample number 18PB05E.

Measurement: H = 0.74 mm, L = 0.39 mm, H/L = 0.52.

Discussion: *Kirkbya* sp.1 is characterised by slightly concave VB and around the kirkbyan pit in the median part of tha carapace. Radius of curvature of PB smaller than AB. DB long and straight. AB with large radius of curvature and maximum curvature located between mid and upper third of height. VB straight to curvature in PB and AB. Kirbkyan pit quite round and located at mid height and mid length. This sample is not well preserved and connot be compared to any known.

Occurrence: Sample number 18PB05D, Tak Fa Formation, Wichai Buri area, Phetchabun

Genus *Knightina* Kellett, 1933

Type species: *Amphissites allorismoides* Knight, 1928

***Knightina* cf. *ultima* Kozour, 1985**

Figure 4.13 E-G

Materials: 16 complete carapaces and six incomplete carapaces.

Figured materials: E, left lateral view of the complete carapace, sample number 18PB05C; F, right lateral view of the complete carapace, sample number 18PB05D; G, left lateral view of the complete carapace, sample number 18PB05C.

Measurement: H = 0.25-0.34 mm, L = 0.51-0.64 mm, H/L = 0.47-0.49.

Discussion: The specimens are closed to *Knightina ultima* (Kozur, 1985) in general outline, but differ by the smaller size of the carapace, and H/L ratio smaller than the types of Kozur (1985). AB with radius of curvature. Radius of curvature of PB smaller than AB. DB straight and VB convex. RV overlap LV.

Occurrence: Central Thailand, Nong Phai section, Pha Nok Khao Formation, Phetchabun Province, Early Permian; Ban Naen Sawan II section, Tak Fa Formation, Phetchabun Province, Middle Permian; Ta Kli section, Tak Fa Formation, Nakhon Sawan Province, Middle Permian (Chitnarin et al., 2012); Sample number 18PB05C, 18PB05A, 18PB05C and 18PB05D , Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Superfamily indet.

Family COELONELLIDAE Sohn, 1971

Genus *Microcoelonella* Coryell & Sohn, 1938

Type species: *Microcoelonella scanta* Coryell & Sohn, 1938

***Microcoelonella* cf. *takliensis* Chitnarin, 2012**

Figure 4.13 H-I

Materials: 17 complete carapaces.

Figured materials: H, left lateral view of the complete carapace, sample number 18PB05D; I, left lateral view of the complete carapace, sample number 18PB05D.

Measurement: H = 0.27-0.34 mm, L = 0.45-0.53 mm, H/L = 0.60-0.64.

Discussion: Carapace subelliptical in lateral view. AB and PB round with maximum comvexity at mid height. DB slightly convex at booth valve. VB gently bend. RV larger than LV. This species can be compared to *Microcoelonella takliensis* Chitnarin, 2012 but H/L ratio is higher than that of *M. takliensis* Chitnarin, 2012

Occurrence: Takli section, Nakhon Sawan Province, Central Thailand, Middle Permian (Chitnarin et al., 2012); Sample number 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Subclass PODOCOPA Sars, 1866

Order PODOCOPINA Müller, 1894

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIOIDEA Sars, 1888

Family BAIDIIDAE Sars, 1888

GENUS *Bairdia* McCoy, 184

Type species: *Bairdia curta* McCoy, 1844

***Bairdia bassoni* Crasquin, 2010**

Figure 4.13 J-K

1982 Bairdia radlerae Kellet. Chen & Shi: 121, pl. 4, figs. 9-10, Pl. 5, figs. 16

1987 Cryptobairdia cf. compacta (Geis). Shi & Chen: 44, Pl. 5, fig. 1

2010 Bairdia bassoni Crasquin (sp. nov.). Crasquin et al.: 24, Pl. 7, figs. 25-26, 29-32

Materials: 18 complete carapaces.

Figured materials: J, right lateral view of complete carapace, sample number 18PB05B; K, right lateral view of complete carapace, sample number 18PB05B.

Measurement: H = 0.28-0.49 mm, L = 0.62-0.76 mm, H/L = 0.62-0.65.

Occurrence: Mianyang section, Hubei Province, latest Permian (Chen & Shi, 1982); Meishan section, Meishan Member (Shi & Chen, 1987), beds of Baoqing? and Meishan members, Chagxing Formation, Changhsingian, Late Permian; Khao Kana section, Pha Nok Khao Formation, Phetchabun Province, Early Permian; Sample number 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia broutini* Crasquin, 2010**

Figure 4.14 A-B

1987 *Rectobairdia tantilla* (Kummerow); Shi & Chen: 41, Pl. 5, figs. 3, 4, 7, 8(?5, 6, 9,10)

2002 *Rectobairdia tantilla* (Kummerow); Shi & Chen: 71, Pl. 8, figs. 5-7, Pl. 9 figs. 6-9

2010a *Bairdia broutini* Crasquin sp. nov., Crasquin et al.: 340, 342, figs. 9O-T

2017 *Bairdia broutini* Crasquin, Chitnarin et al.: Figs. 11D-E

Materials: 12 complete carapace.

Figured materials: L, right lateral view of complete carapace, sample number 18PB05D; M, right lateral view of complete carapace, sample number 18PB05E.

Measurement: H = 0.4-0.58 mm, L = 0.6-0.96 mm, H/L = 0.60-0.67.

Occurrence: Matan and Pingding sections, Guangxi Province, Wuchaiapingian, Meishan section, Baoqing and Meishan members (Shi & Chen, 1987); beds 11, 15, 16, 19 and 22 of Changxing Formation, Changhsingian, Late Permian; Ta Kli section and

Phu Lam Yai section, Tak Fa Formation, Nakhon Sawan Province, central Thailand, Early Permian (Chitnarin et al, 2017); Sample number 18PB05B to18PB05D, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* cf. *episkopiensis* Crasquin-Soleau, 1998**

Figure 4.14 C

Materials: one complaete carapace**.**

Figured materials: N, right lateral view of incomplete carapace, sample number 18PB05E.

Measurement: H = 0.46-0.65 mm, L = 1.02-1.43 mm, H/L = 0.45.

Discussion: The specimen is compared to *Bairdia episkopiensis* Crasquin-Soleau, 1998 from Late Asselian to Early Artinskian of Episkopi section, southwest Hydra Island (Crasquin-Soleau et al., 1998) by having a larger radius of the curvature of the PB.

Occurrence: Sample number 18PB05E, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia deweveri* Crasquin, 2010**

Figure 4.14 D

1987 *Bairdia* cf. *trianguliformis* Chen, Shi & Chen: 37, Pl. 2, figs. 1-8.

1987 *Bairdia galei* Croneis & Thurman, Shi & Chen: 37, Pl. 1, figs. 19-22, Pl.19, fig.11

2008 *Bairdia galei* Croneis & Thurman, 1939 *sensu* Shi & Chen 1987, Crasquin et al.: Pl. 2, figs. 11, 12.

2010 *Bairdia deweveri* Crasquin sp. nov., Crasquin et al.: Figs. 7O-T

2017 *Bairdia deweveri* Crasquin, Chitnarin et al.: Figs. 12A-C

Materials: three complete carapaces**.**

Figured materials: O, right lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.31 mm, L = 0.60 mm, H/L = 0.51.

Occurrence: Bulla section, Dolomite, Italy, Bulla Member, Bellerophon Formation, Changhsingian (Crasquin et al., 2008); Meishan section, Changxing Formation, Baoqing and Meishan members, Late Permian (Shi & Chen, 1987); Sample number 18PB05D, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* cf. *songthami* Chitnarin, 2017**

Figure 4.14 D-E

Materials: six complete carapaces and two incomplete carapaces.

Figured materials: P, right lateral view of complete carapace, sample number 18PB05C; Q, right lateral view of incomplete carapace, sample number 18PB05A.

Measurement: H = 0.37-0.41 mm, L = 0.76-0.81 mm, H/L = 0.48-0.50.

Discussion: The specimen here are compared to *Bairdia songthami* Chitnarin, 2017 from Early-Middle Permian of Tak Ta Formation, Phetchabun Province and Nakhon Sawan Province, Central Thailand, but H/L ratio is ranged from 0.48-0.50. AB and PB at lower and DB is longer. They have wider overlap on DB and VB less than *Bairdia songthami* Chitnarin, 2017.

Occurrence: Sample number 18PB05C and 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Bairdia cf. _urodeloformis_ Chen, 1987

Figure 4.14 F

Materials: seven complete carapaces and one incomplete carapace.

Figured materials: R, right lateral view of complete carapace, sample number 18PB05B.

Measurement: H = 0.35-0.42 mm, L = 0.65-0.74 mm, H/L = 0.54-0.56.

Discussion: The specimen are compared to *Bairdia urodeloformis* from the lastest Permian of South China (Shi & Chen, 1987) by their small AB with maximum of convexity located very high and small PB with maximum of conveity located very low. The differences are the loger carapace, the more convex PVB, and the overlap along DB.

Occurrence: Sample number 18PB05A and 18PB05D, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Bairdia cf. _altiarcus_ Chen, 1958

Figure 4.14 G

Materials: one complete carapace.

Figured materials: , A, right lateral view of complete carapace, sample number 18PB05B.

Measurement: H = 0.38 mm, L = 0.52 mm, H/L = 0.73.

Discussion: The specimen very close to *Bairdia altiarcus* from the Early Permian of Eastern China (Chen, 1958) in lateral outline but H/L ratio is more than *B. altiarcus*. AB with larger than PB radius of curvature

Occurrence: Sample number 18PB05B, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* cf. *fangnianqiaoi* Crasquin, 2010**

Figure 4.14 H-I

Materials: four complete carapaces.

Figured materials: B, right lateral view of complete carapace, sample number 18PB05A; C, left lateral view of complete carapace, sample number 18PB05A.

Measurement: H = 0.30-0.40 mm, L = 0.85-1.02 mm, H/L = 0.36-0.39.

Discussion: The specimens are similar to *B.fangnianqiaoi* Crasquin, 2010 from latest Permian of Meishan section, South China (Crasquin et al. 2010a) in general outline, dosal parts regularly arched at RV and LV, VB concave in both valves. AB with meduim radius of curvature and maximum convexity located mid high. PB with small radius of curvature, maximum curvature located at the anterior part of DB, but H/L ratio range from 0.36-0.39.

Occurrence: Sample number 18PB05A and 18PB05E, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* sp. 1**

Figure 4.14 J-L

Materials: Five complete carapaces.

Figured materials: D, right lateral view of complete carapace, sample number 18PB05C; E, right lateral view of complete carapace, sample number 18PB05D; F, left lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.28-0.63 mm, L = 0.39-0.96 mm, H/L = 0.60-0.71.

Discussion: Bairdia sp. 1 has long and subfusiform carapace. AB is round with medium raduis of curvature, maximum convexity is located at three of height. PB is short and round with small raduis of curvature, maximum convexity is located at below mid height. AVB and PVB are short and convex. LV strongly overlaps on RV at DB. *B*. sp. 1 cannot be compared to any species known.

Occurrence: Sample number 18PB05C, 18PB05D, and 18PB05E, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* sp. 2**

Figure 4.15 A-B

Materials: Two complete carapaces.

Figured materials: G, right lateral view of complete carapace, sample number 18PB05C; H, right lateral view of complete carapace, sample number 18PB05A.

Measurement: H = 0.39-0.48 mm, L = 0.6-0.8 mm, H/L = 0.59-0.67.

Discussion: *Bairdia* sp. 2 is identified by subelliptical carapace, dorsal outline is arched, AB and PB are broadly rounded. LV strongly overlaps on RV at DB. *B*. sp. 2 can be compared to *Bairdia broutini* Crasquin, 2010 form Late Permian of Guangxi Provinces but VB of *B.* sp.2 is convex less than *B. broutini*. *B.* sp.2 can be compared *Bairdia folgeri* Kellett *sensu* (Chen & Shi, 1982) but PB of *B.* sp.1 is more obtuse than that of *B. folgeri*.

Occurrence: Sample number 18PB05C and 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* sp. 3**

Figure 4.15 C

Materials: Two complete carapaces.

Figured materials: I, right lateral view of incomplete carapace, sample number 18PB05A.

Measurement: H = 0.31-0.36 mm, L = 0.49-0.52 mm, H/L = 0.63-0.69.

Discussion: *Bairdia* sp. 3 has slightly convex DB. ABD and PDB are straight and slightly cureved upward at both ends. AB and PB are round with small raduis pf curvature, maximum convexities are located above and below mid height, respectively. *B*. sp. 3cannot be compared to any species known.

Occurrence: Sample number 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdia* sp. 4**

Figure 4.15 D

Materials: five complete carapaces.

Figured materials: J, right lateral view of incomplete carapace, sample number 18PB05A.

Measurement: H = 0.35-0.42 mm, L = 0.54-0.68 mm, H/L = 0.62-0.64.

Discussion: *Bairdia* sp. 4 is characterized by arched dorsal outline. AB is round with small redius and convexity located mid high, augular in part of PB and maximum curvature located mid high. AVB and PVB are ventrally flattened.

Occurrence: Sample number 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Genus *Bairdiacypris* Bradfield, 1935

Type species: *Bairdiacypris deloi* Bradfield, 1935

***Bairdiacypris* cf. *longirobusta* Chen, 1958**

Figure 4.15 E-F

Materials: 19 complete carapaces and five incomplete carapaces.

Figured materials: K, right lateral view of incomplete carapaces, sample number 18PB05C; L, left lateral view of complete carapaces, sample number 18PB05A.

Measurement: H = 0.38-0.72 mm, L = 0.78-1.44 mm, H/L = 0.48-0.50.

Discussion: The specimen are compared to *Bairdiacypris longirobusta* Chen, 1958 from Early Permian of Kwanshan and Lungtan sections, Chihsia Limestone, Nanking Province (Chen, 1958), but it differ by the more than H/L ratio of *B. longirobusta* Chen. AB with great radius of curvature and maximum of convexity located at mid height. RV larger and overlapping LV.

Occurrence: Sample number 18PB05C and 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdiacypris* cf. *reniformis* Chen, 1958**

Figure 4.15 G

Materials: four complete carapaces.

Figured materials: M, left lateral view of complete carapaces, sample number 18PB05B.

Measurement: H = 0.35-0.44 mm, L = 0.66-0.95 mm, H/L = 0.46-0.53.

Discussion: The specimen resemble *Bairdiacypris reniformis* Chen, 1958 from Permian of the upper part of the Chihsia limestone, Kwanshan, Lungtan, Southern China (Chen, 1958) in general outline but H/L ratio is varied from 0.46-0.53. PB and AB with larger radius of curvature and maximum of curvature at mid height. VB concave at mid length. DB straight to gently.

Occurrence: Chihsia limestone of Kwanshan, Lungtan, Southern China (Chen, 1958); Sample number 18PB05C and 18PB05B, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdiacypris* cf. *fornicata* Shi, 1982**

Figure 4.15 H-I

1982 *Bairdiacypris fornicata* Shi in Chen & Shi: 137, pl.10, figs 1-7, 19.

1987 *Bairdiacypris fornicata* Shi; Shi & Chen: 50, pl. 12, figs 7-13.

2002 *Bairdiacypris fornicata* Shi; Shi & Chen: 83, pl. 27, fig. 1.

2008 *Bairdia* sp. 3; Crasquin et al.: pl.3, figs 8,9.

Materials: five complete carapaces.

Figured materials: N, right lateral view of complete carapaces, sample number18PB05A; O, right lateral view of complete carapace, sample number 18PB05B.

Measurement: H = 0.46-0.65 mm, L = 1.02-1.43 mm, H/L = 0.45.

Discussion: The specimen are compared to *Bairdiacypris fornicata* Shi, 1982 from Late Permian of Nantong section, Jiangsu Province and Mianyang section, Hubei Province (Chen & Shi, 1982), but H/L ratio is 0.45. AB with radius of curvature and maximum of curvature located at mid height. PB with small radius and located between lower and mid height. VB concave at mid length. DB slightly arched.

Occurrence: Sample number 18PB5A, 18PB05B and 18PB05E, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdiacypris* sp.1**

Figure 4.15 J-K

Materials: eight complete carapaces and one incomplete carapace**.**

Figured materials: P, right lateral view of complete carapaces, sample number 18PB05E; Q, right lateral view of incomplete carapace, sample number 18PB05D.

Measurement: H = 0.36-0.46 mm, L = 0.69-0.90 mm, H/L = 0.50-0.52.

Discussion: Bairdiacypris sp.1 has broadly arched dorsal outline, convex DB, LV larger than RV and overlaps at DB. *B.* sp.1 has intermediate characters between *Bairdia* and *Bairdiacypris*, assignment to Bairdiacypris is due to presence of long DB. *B.* sp.1 can be compared *Bairdiacypris* sp. H (Chitnarin et al.,2017) by strong overlap of LV on RV only at DB.

Occurrence: Sample number 18PB05D and 18PB05E, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Bairdiacypris* sp.2**

Figure 4.15 L

Materials: one complete carapace.

Figured materials: K, right lateral view of complete carapace, sample number 18PB05A.

Measurement: H = 0.40 mm, L = 0.94 mm, H/L = 0.42.

Discussion: *Bairdiacypris* sp.2 is characterized by small and slender PB, maximum of curvature of PB is located below mid hight. Overlap of LV on RV is narrow DB. *B.* sp.2 can not be compared to any species know.

Occurrence: : Sample number 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Genus *Fabalicypris* Cooper, 1946

Type species: *Fabalicypris wileyensis* Cooper, 1946

***Fabalicypris blumenstengeli* Crasquin, 2008**

Figure 4.16 A

2008 *Fabalicypris blumenstengeli* sp. nov., Crasquin et al.: Pl. 3, figs. 6-8.

Materials: two complete carapaces.

Figured materials: A, left lateral view of complete carapace, sample number 18PB05D.

Measurement: H = 0.34 mm, L = 0.65 mm, H/L = 0.51.

Discussion: *Fabalicypris blumenstengeli* be different from *F. gruendeli* in having a lager radius of the curvature of the AB and a less slender PB. It is close to *Fabalicypris minuta* Cooper, 1946 (Shi & Chen, 1987).

Occurrence: Portella Rossa section, western Sicily, Italy (Crasquin et al., 2008); Sample number 18PB05D, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Fabalicypris hathaithipae* Chitnarin, 2017**

Figure 4.16 B

2017 *Fabalicypris hathaithipae* n. sp., Chitnarin: figs. 16C-F; 18.

Materials: four complete carapaces.

Figured materials: B, left lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.36-0.47 mm, L = 0.79-0.98 mm, H/L = 0.43-0.45.

Discussion: *Fabalicypris hathaithipae* Chitnarin, 2017 can be compared to *Fabalicypris elliptica* Chen, 1958 form Early Permian of Jiangsu Province, Eastern China (Chen, 1958) in lateral outline.

Occurrence: Nong Phai section, Pha Nok Khao Formation, Phetchabun Province, central Thailand, Asselian-Sakmarian, Early Permian; Sample number 18PB05C and 18PB05A, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

***Fabalicypris* sp.1**

Figure 4.16 C

Materials: four complete carapaces.

Figured materials: C, left lateral view of incomplete carapace, sample number 18PB05C.

Measurement: H = 0.46 mm, L = 1.09 mm, H/L = 0.42.

Discussion: *Fabalicypris* sp.1 is characterized by subelliptical carapace with broadly arched DB. AB is round and large raduis of curvature, maximum convexity is located on mid height. VB is concave located in mid length. *F.* sp.1 cannot compared to any know species.

Occurrence: Sample number 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Genus *Silenites* Coryell & Booth, 1933

Type species: *Silenites silenus* Coryell & Booth, 1933

***Silenites sureeae* Chitnarin, 2012**

Figure 4.16 D

2017 *Silenites sureeae* Chitnarin n. sp., Chitnarin: figs. 14J-L; 19.

Materials: one complete carapace.

Figured materials: D, right lateral view of complete carapace, sample number 18PB05A.

Measurement: H = 0.34-0.38 mm, L = 0.76-0.83 mm, H/L = 0.45.

Discussion: *Silenites sureeae* Chitnarin, 2017 is close to *Silenites testatus* Chen, 1958 from the Early Permian of Jiansu Province, Eastern China (Chen & Bao, 1986) but differ in having more rounded DB and maximum H located at mid L.

Occurrence: Nam Maholan section, Nam Maholan Formation, Loei Province, northeast Thailand, Early Permian; Nong Phai section, Pha Nok Khao Formation, Phetchabun Province, central Thailand, Early Permian; Ta Kli section, Tak Fa Formation, Nakhon Sawan Province, Early Permian; Ban Nean Sawan II section, Tak Fa Formation, Phetchabun Province, central Thailand, Middle Permian; Khao Som Phot section, Tak Fa Formation, Lopburi Province, Middle Permian; Sample number 18PB05A , Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Family ACRATIIDAE Gründel, 1962

Genus *Acratia* Delo, 1962

Type species: *Acratia typica* Delo, 1930

Acratia chongpani **Chitnarin, 2017**

Figure 4.16 E

1985 *Acratia gusevae* Kozur, Kozur: 104, Pl. 20, fig. 1.

1998 *Acratia gusevae* Crasquin-Soleau, Crasquin-Soleau & Baud: Pl. 3, fig. 1.

2017 *Acratia chongpani* Chitnarin n. sp., Chitnarin et al.: Figs. 21A-G; 22.

Materials: two complete carapaces**.**

Figured materials: E, right lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.34-0.38 mm, L = 0.76-0.83 mm, H/L = 0.45.

Discussion: *Acratia chongpani* Chitnarin, 2017 can be compared to *Acratia praetypica* Posner, 1951 from the Early Carboniferous of Moscow Basin, Russia (Posner, 1951) in lateral outline but different at VB. *A. chongpani* Chitnarin, 2017 due to the smaller AVB and the shorter PVB than those in *Acratina gusevae* Kozur, 1985.

Occurrence: Hydra Island, Greece, late Middle Permian (CrasquinSample number-Soleau & Baud, 1998); Sak Chai section, Pha Nok Khao Formation, Chiyaphum Province, northeast Thailand, Early Permian; Khao Kana section, Pha Nok Khao Formation, Phetchabun Province, central Thaialnd, Early Permian; Ta Kli section, Tak Fa Formation, Nakhon Sawan Province, central Thailand, Early Permian, Khao Som Phot section, Tak Fa Formation, Lopburi Province, central Thailand, Middle Permian; Sample number 18PB05C , Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Suborder CYTHEROCOPINA Baird, 1850

Superfamily CYHEROIDAE Baird, 1850

Family CYHERIDEIDAE Sars, 1925

Genus *Basslerella* Kellett, 193

Type species: *Basslerella crassa* Kellett, 1935

Basslerella tota Chen & Bao, 1986

Figure 4.16 F

1986 Basslerella tota Chen & Bao, Chen & Bao: 123, Pl. 1, figs. 31, 32, pl. 4, figs. 7, 8

2004 Basslerella tota Chen & Bao, Crasquin et al.: 288, Pl. 4, figs. 9, 10

2004 Basslerella tota Chen & Bao, Yi: Pl. 2, fig. 20

2008b Basslerella tota Chen & Bao, Crasquin et al.: Pl. 5, figs. 17, 18

2012 Basslerella tota Chen & Bao, Forel: 22, figs. 14O-Q

2017 Basslerella tota Chen & Bao, Chitnarin et al.: figs. 24E-H

Materials: one complete carapace.

Figured materials: F, right lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.26 mm, L = 0.36 mm, H/L = 0.72.

Occurrence: Jiangsu Province, Early Permian (Chen & Bao, 1986); Hydra Island, Greece, late Middle Permian (Crasquin-Soleau & Baud, 1998); Western Taurus, Turkey, Late Permian (Crasquin-Soleau et al., 2004); Meishan section, East China, latest Permian (Crasquin et al. 2010a); Fujian province, South china, Late Permian (Yi, 2004); Dajiang section, Guizhou Province, Soth China, Late Permian (Forel, 2012); Tham Nam Maholan section, Nam Maholan Formation, Loei Province, northeastern Thailand, Early Permian; Phu Lam Yai section, Tak Fa Formation, Nakhon Sawan Province, Pha Nok Khao Formation, Phetchabun Province, central Thailand, Early Permian; Khao Kana section, Pha Nok Khao Formation, Phetchabun Province, central Thailand, Early Permian; Nong Phai section, Pha Nok Khao Formation, Phetchabun Province, central Thailand, Early Permian (Chitnarin et al., 2017); Sample number 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Basslerella cf. _wipanue_ Chitnarin, 2017

Figure 4.16 G

Materials: one complete carapace.

Figured materials: G, left lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.90 mm, L = 1.04 mm, H/L = 0.86.

Discussion: The specimens are compared to *Basslerella wipanue* Chitnarin, 2017 from Early Permian of Kao Kana section, Pha Nok Khao Formation, Phetchabun Province, central Thiland (Chitnarin et al., 2017) by having triangular carapace. AB and PB round with nearly the same small radius of curvature but H/L ratio higher than *B. wipanue* Chitnarin, 2017.

Occurrence: Sample number 18PB05A , Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Order PLATYCOPIDA Sars, 1866

Suborder PLATYCOPINA Sars, 1866

Superfamily CAVELLINOIDEA Egorov, 1950

Family CAVELLINIDAE Egorov, 1950

Genus Sulcella Coryell & Sample, 193

Type species: Sulcella sulcata Coryell & Sample, 1932

Sulcella cf. _suprapermiana_ Kozur, 1985

Figure 4.16 H

Materials: one complete carapace.

Figured materials: H, left lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.4 mm, L = 0.83 mm, H/L = 0.48.

Discussion: The specimen are close to *Sulcella* cf. *suprapermiana* Kozur, 1985 in lateral outline, but differ by the smaller size of the carapace, and H/L ratio smaller than the types of Kozur (1985). AB with larger radius of curvature and maximum of convexity located at mid height. PB with small radius of curvature and maximum of convexity located between mid height and thrid of height. DB long and striaght. VB striaght to gently bend.

Occurrence: Sample number 18PB05C, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

Subclass MYODOCOPA Sars, 1866

Order HALOCYPRID Dana, 1853

Suborder CLADOCOPINA Sars, 1866

Family POLYCOPIDAE Sars, 1866

Genus *Polycope* Sars, 1866

Type species: *Polycope orbicularis* Sars, 1866

***Polycope* sp.**

Figure 4.16 I

Materials: three complete carapaces.

Figured materials: I, right lateral view of complete carapace, sample number 18PB05C.

Measurement: H = 0.33 mm, L = 0.37 mm, H/L = 0.89.

Discussion: *Polycope* sp. 1 is subcircular in lateral outline. DB is convex on both valves with and incised dorum.

Occurrence: Sample number 18PB05B and 18PB05D, Tak Fa Formation, Wichai Buri area, Phetchabun Province, Middle Permian.

4.2.2 Distribution of the ostracods at the study section

Thirty six ostracod species are discovered from the study section. Among these species, *Knightina* cf. *ultima*, *Bairdia bassoni*, and *B. broutini* are common species. Appearance of other species is limited and the changes can be observed (Figure 4.17). The sample 18PB05A comprises 15 species with more than 50 specimens. The ostracods are rare in 18PB05B which comprises 7 species with 8 specimens. The sample 18PB05C comprises 12 species with 47 specimens, 18PB05D comprises 13 species with 39 specimens, and 18PB05E comprises 10 species with 46 specimens. Diversity of each sample is compatible with number of the specimens.

The ostracod assemblage at the study section is dominated by Bairdioidea. Other Superfamilies/families are of Kirkbyidae, Coelonellidae, Paraparchitidae, Polycopidae, Cytherideidae, Kloedenelloidea and Cavellinoidea in descendent order (Figure 4.16) The Bairdioidea consists of genus *Bairdia*, *Bairdiacypris*, *Silienites*, *Fabalicypris*, and *Acratia*. They appear in samples 18PB05A, 18PB05B, and 18PB05C.

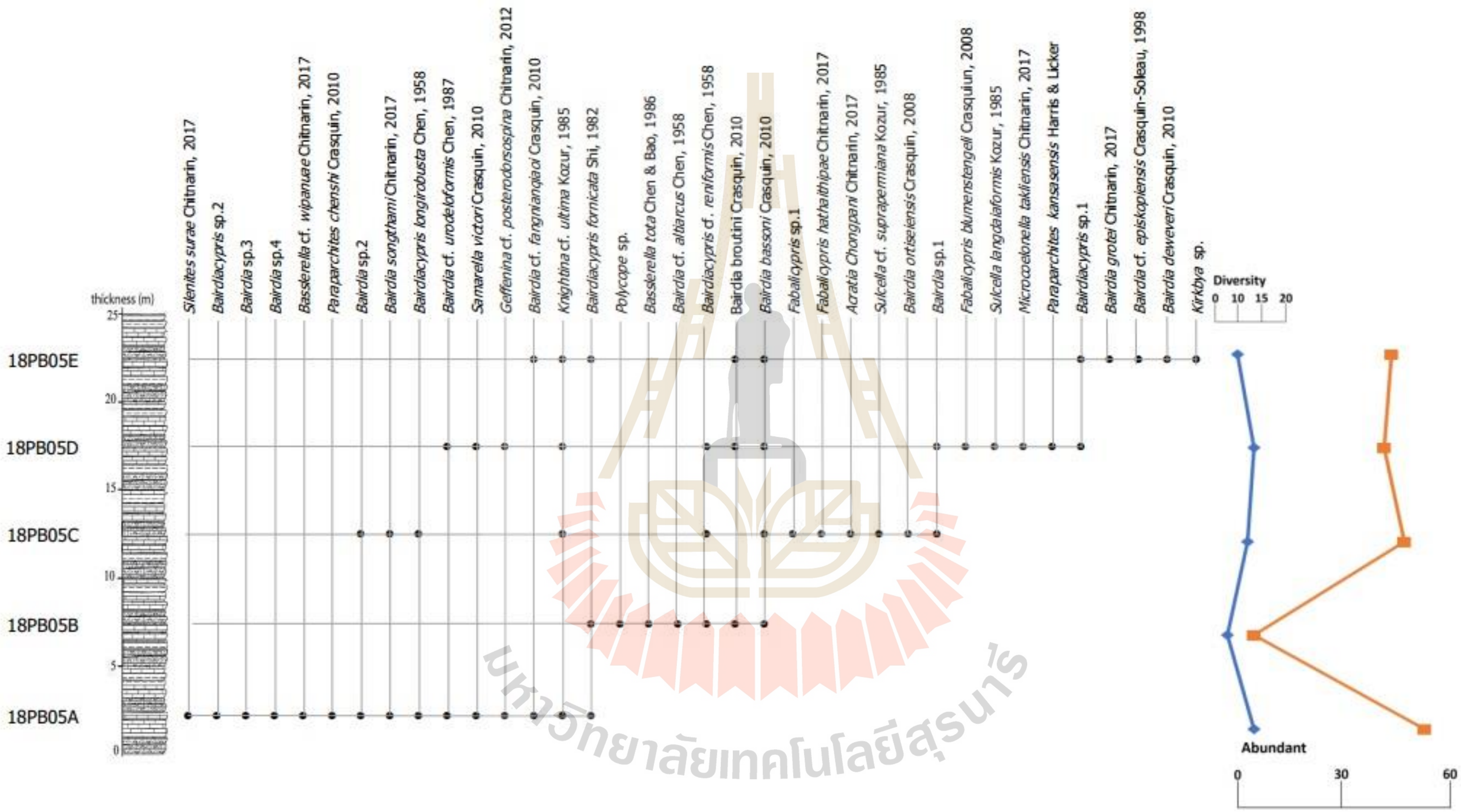


Figure 4.16 Distribution of ostracod along the study section.

The proportions of species number in the Bairdioidea are varied from 32.43% to 95.74%. The second abundant Family is Kirkbyidae which consisted of genera *Knightina* and *Kirkbya*. Kirkbyidae appears in 18PB05A, 18PB05C, 18PB05D, and 18PB05E. The proportions of species number in the Kirkbyidae are varied from 2.13% to 31.91%. The third abundant Family is Coelonellidae (genus *Microcoelonella)* but it appears only in 18PB05D which occupied 45.95% of the abundance. The Paraparchitidea (genera *Samarella* and *Paraparchites*) is found in 18PB05A and 18PB05D. The proportions of Paraparchitidea are varied from 2.7% to 20.45%. The Cytheroidae (genus *Basslerella*) is found in 18PB05A and 18PB05B, and the proportions of Cytheroidae are varied from 2.27% to 28.57%. The Kloedenelloidea (genus *Geffenina*) is found in 18PB05A and 18PB05E, the proportions of Kloedenelloidea are low and varied from 2.70% to 4.55%. The Cavellinoidea (genus *Sulcella*) is found in 18PB05C only, the proportion of Cytheroidae is 2.13%.

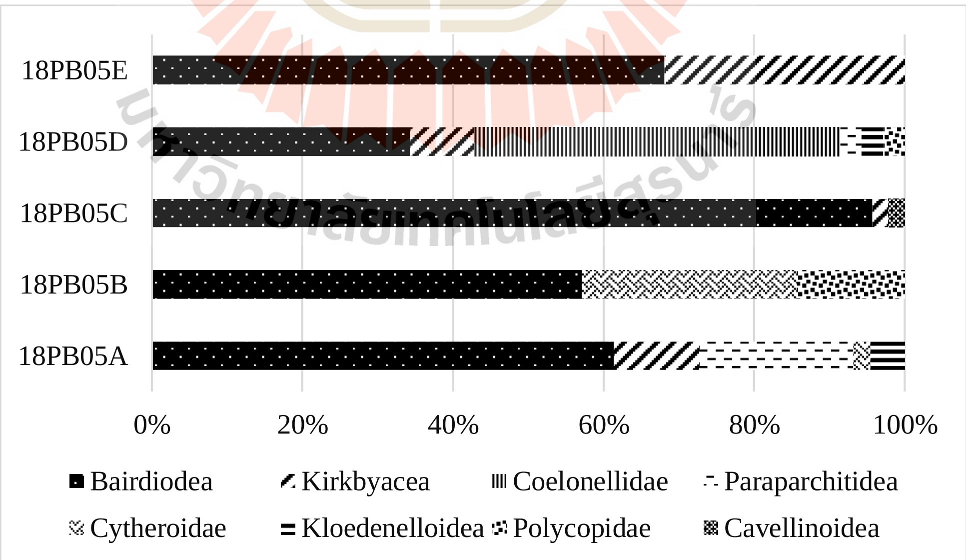


Figure 4.17 Distribution of the ostracods at Superfamily/Family level along the study section.

4.2.3 Paleoenvironmental interpretation based on ostracod assemblage

The ostracods are important indicators of palaeoenvironmental interpretation based on their carapace characteristic and the composition of the ostracod assemblages. The palaeoenvironment of the study section is interpreted using the ostracod assemblages following previous archives, for example, Melnyk and Maddocks, 1988a, b; Crasquin-Soleau et al., 1999; 2005; 2006; Crasquin et al., 2010b. Characteristics of the ostracods at Superfamily/Family level which help indicate the paleoenvironment are listed as follows.

Superfamily Bairdioidea: *Bairdia* diversity is very high in offshore environments with low terrigenous sedimentation, some species can be tolerated muddier and shallower condition; *Bairdiacypris* is most abundant in nearshore environments; *Cryptobairdia* and *Orthobairdia* are more eurytopic than member of *Bairdia*, but the highest diversity occurs offshore in calcareous mudstones.

Family Cavellinidae: *Cavellina* and *Sulcella* are usually represented offshore environment.

Superfamily Kirkbyidae: well-ornamented species of Families Amphissitidae and Scrobiculinidae appear to live in restricted to offshore environment. The heavily ornamented Kirkbyidae are usually offshore dwellers.

Superfamily Paraparchitoidea: members of this superfamily are widely distributed, but more diversified offshore. Smooth and larger forms appear to have occupied very shallow areas with low sedimentation rates.

Superfamily Kloedenelloidea: the Kloedenellids are usually inhabited in nearshore environments, and some rare genus appear to have lived in slightly deeper water.

As seen in Figure 4.16, the assemblages along the section are varied and can be classified into five groups by divers of Superfamilies /Families.

The 18PB05A is dominated by Bairdiodea (61.36%) with minor Paraparchitidea (20.45%), Kirkbyidae (11.36%), Kloedenelloidea (4.55%), and Cytheroidae (2.27%). The Bairdiodea is known to present in shallow to deep, open marine with normal salinity. The Paraparchitidae is known to represent the offshore zone. Members of Kirkbyidae are usually found associated with Kloedenelloidea in shallow environments. The Cytheroidae is usually represented offshore environment.

The 18PB05B contains members of Bairdiodea (57.14%), Cytheroidae (28.57%) and Polycopidae (14.29%) but in low diversity.

The 18PB05C consists of Bairdiodea (95.74%), Kirbyoidea (2.13%), and Cavellinoidea (2.13%). This sample is dominated by the Bairdiodae indicated shallow to deep environments.

The 18PB05D is dominated by Coelonellidae (49.95%) with Bairdiocea (32.43%), Kirkbyidae (8.11%), Polycopidae (8.11%), Paraparchitidae (2.70%), Kloedenelloidea (2.70%), and The genus *Microcoelonella* of family Coelonellidae that they lived in offshore, open marine environments. In this sample have high diversity of superfamilies/families.

The 18PB05C comprises Bairdiodae (68.09%) and Kirkbyidae (31.91%) are present in shallow marine, subtidal and normal-marine environments.

According to Crasquin et al. (2010b), the preference of Late Paleozoic-Early Triassic ostracode families can be defined to three environmental zone. The internal zone is occupied by Kloedenlloidea, Kirkbyoidea, Hollinoidea which teloranted to variations of paleoenvironmental conditions. The median zone is occupied by

Paraparchidoidea, Cytherideidae and Cavellinoidae which could live in euryhaline environments in shallow to very shallow water. The external zone, open carbonate environments with normal salinity is suitable for Bairdiodea (Figure 4.17, 4.19).

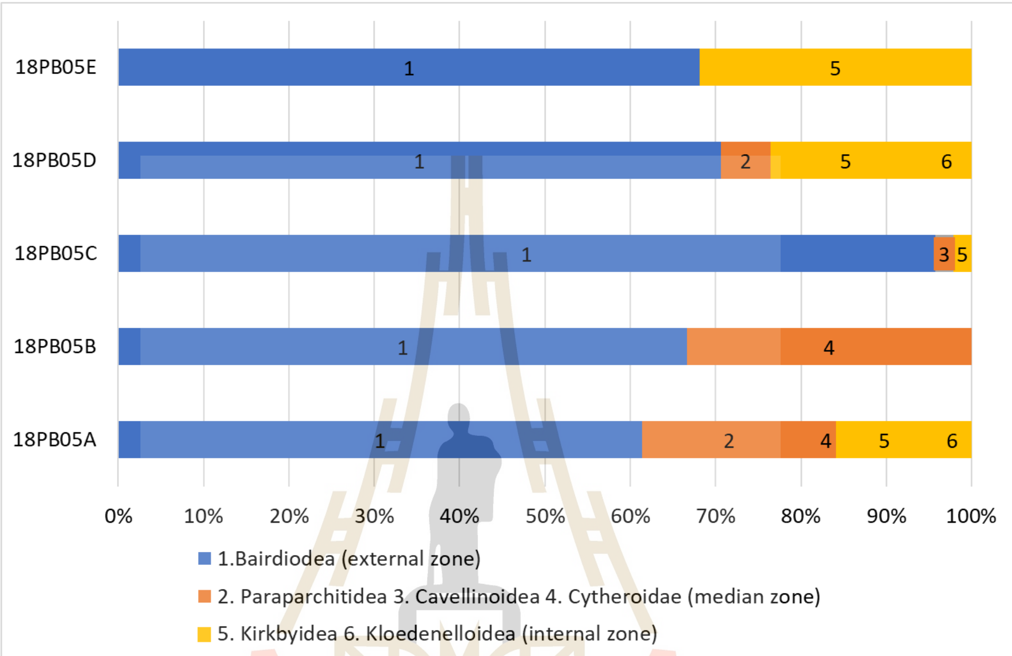


Figure 4.18 Repartition of families and/or superfamilies in the samples.

However, if we recognize the ostracod assemblages as a whole, the percentage of ostracod species at Superfamily and Family level of the studied section consists of Bairdioidea 67.55%, Kirkbyacea 12.23%, Cavellinoidea 9.04%, Paraparchitidea 5.32%, Polycopidae 2.13%, Cytheroidae 1.60%, Kloedenelloidea 1.60% and Cavellinoidea 0.53% (Figure 4.18).

The overall composition points out the palaeoenvironment of studied section is dominated by two Superfamilies are Bairdioidea and Kirkbyacea. The Bairdioidea recovered overall studied section can indicate the shallow to deep environment with normal salinity. The genus Bardiacypris of superfamily Bairdioidea inhabited nearshore environments. The Kirkbyacea indicated subtidal with normal marine. The families of Cavellinoidea, Paraparchitidea and Kloedenelloidea suggest very shallow marine. Cytheroidae suggests euryhaline environments in shallow waters where as the Polycopidae are ubiquitous.

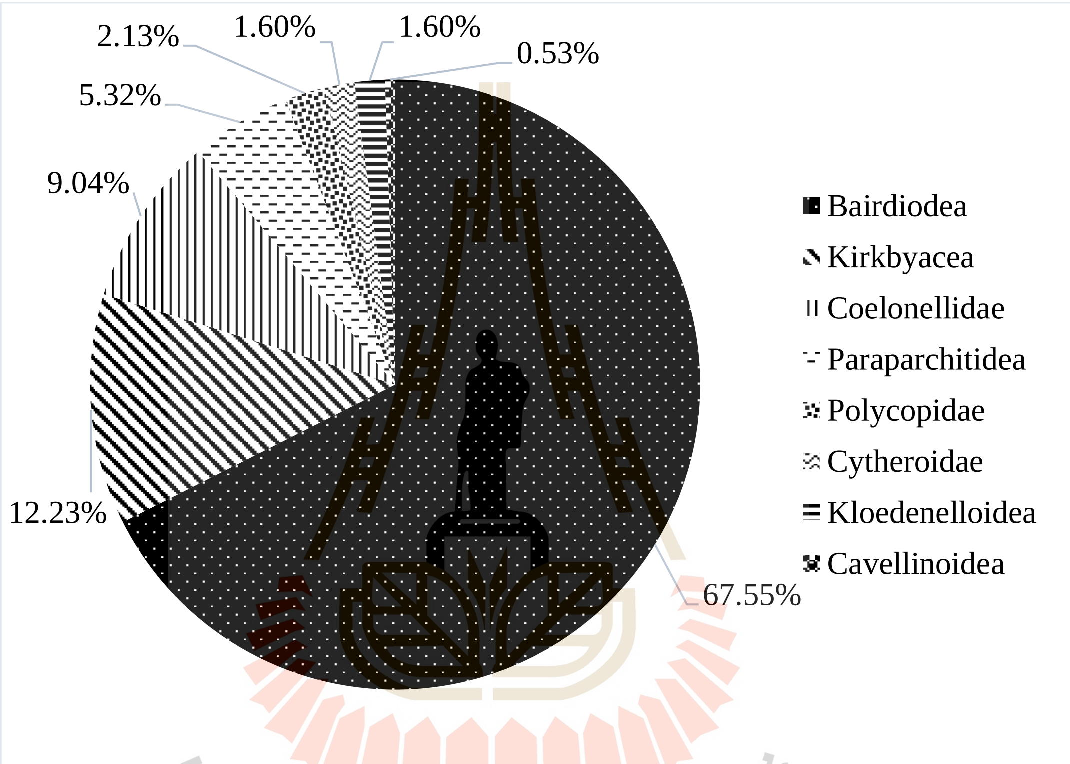


Figure 4.19 Percentage of ostracod at Superfamily/Family level in the studied section.

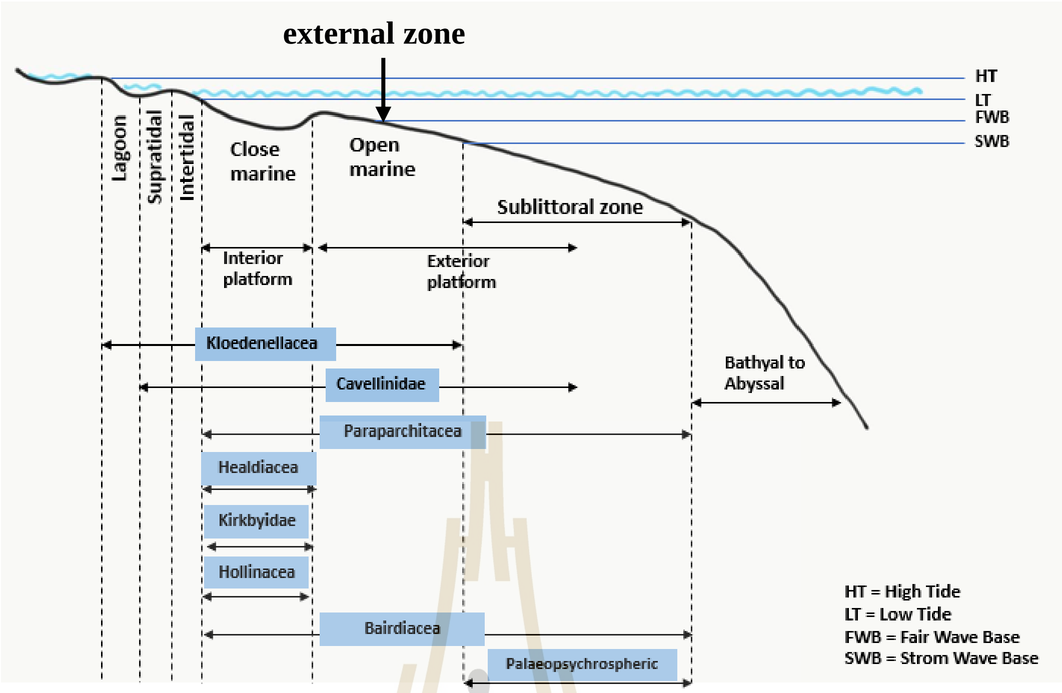


Figure 4.20 Showing the paleoevironmental of studied section

CHAPTER V

DISCUSSION AND CONCLUSION

In this thesis, the limestone samples were collected from Ban Phu Teoi locality, in Wichianburi District, Phetchabun Province. The microfacies analysis, the ostracod assemblage analysis, and the interpretations of depositional environment were carried out. Nevertheless, there are some points to be discussed and concluded as follows.

5.1 Discussion

5.1.1 Interpretation of the depositional environment based on the microfacies analysis

The study section is located in Wichianburi District, southern part of Phetchabun Province and it is on the well-known Permian Khao Khwang Platform. The age of the study section is designated by presence of Middle Permian fusulinid assemblage. The fusulinids including Rugososchwagerina? sp., Kahlerina sp., Parafusulina sp., Nankinella sp. Sphaerulina sp. and Chusenella sp. which range from early Middle Permian (Roadian) to upper Middle Permian (Capitanian). The fusulinids can be compared with those reported from the previous works in Phetchabun Province (Nakornsri, 1977; 1981; Chonglakmani and Fontaine, 1990; Yanagida and Nakornsri, 1999; Fontaine et al., 2009), in Saraburi Province (Dawson, 1993; Dawson and Racey, 1993; Uttrawiset, 2017; Singhasuriya, 2017), and Lopburi Province (Udchachon et al., 2014) As shown in Figure 5.1, the studied limestones contain prolific fossil contents including. fusulinids, smaller foraminifers, and green algae. The smaller foraminifers and green algae are also the late Early Permian-Middle Permian assemblages.

The limestone samples are classified to bioclastic wackestone and bioclastic grainstone microfacies types. According to previous studies, Middle Permian reef were identified are patches and mounds, thus the ramp carbonate platform model is preferred and interpreted here. The microfacies types can be compared with RMF13, RMF14, RMF17, RMF18 and RMF27 (Flügel, 2010). The depositions on the inner ramp include lagoon, sand shoals restricted to open-marine environments, however; it is not likely to be the lagoon because the limestones contain small amount of limemud. The interpreted deposition environments in this study can be compared with Algal-foram facies of the Middle Permian limestone exposed at Khao Somphot in Lopburi Province, on the southern part of the Khao Khwang Platform (Udchachon et al., 2014). They can also be compared with Facies 3 and 4 of the Murghabian limestone exposed in the north area of Saraburi Province which were interpreted to be deposited on the inner platform (Dawson, 1993).

5.1.2 Interpretation of the depositional environment based on the ostracod assemblage analysis

The recovered ostracods have relationships with other Permian sites in Paleotethys region especially with South China (Chen, 1958; 1986). The ostracod assemblage from the study section is similar to those reported from Middle Permian strata in central Thailand (Chitnarin et al, 2008; 2012; 2017), as shown in Figure 5.2 Interpretation of the depositional environment based on the ostracod assemblages was completed using the characteristic of the ostracod at Family and/or Superfamily level, and the percentage of species number at Family and/or Superfamily level (Melnyk and

Maddocks, 1988; Crasquin et al., 2010b). The variation of the ostracod assemblages can be recognized along the sequence, but the overall composition of the study section is dominated by two Superfamilies (Bairdioidea and Kirkbyacea) which suggest the normal marine, subtidal, slightly offshore environment. The paleoenvironment of the study section is different from the Middle Permian sequence exposed in Bung Sam Phan District which was interpreted to be deposited in shallow marine, euryhaline and nearshore environment (Chitnarin et al. 2008). The dominance of Bairdiodea and the presence of genus *Microcoellonella* is similar to the ostracod assemblage at the Ta Kli section in Ta Kli District, Nakhon Sawan Province (Chitnarin, 2015). But the absence of Families Pachydomellidea and Cytherideidea at the study section may point to the shallower environment than the Ta Kli section (Figure 5.2).

Author	18PB05A	18PB05B	18PB05C	18PB05D	18PB05E
Smaller foraminifers					
Chonglakmani & Fontaine (1990); Tak Fa Formation	*Nodosinelloides sp.*	*Nodosinelloides* sp.	*Agathammina* sp., *Glomomidiellina* sp., *Climacammina* sp., *Globivalvulina vondershmitti,*	*Dagmarita sp.*	*Deckerella sp., Globivalvulina sp.,*
Fontaine et al. (2009); Tak Fa Formation				*Deckerella* sp., *Dagmarita* sp.	*Deckerella* sp., *Globivalvulina* sp., *Dagmarita* sp.
Uttarawiset et al. (2017); Khao Khad Formation	*Nodosinelloides*	*Nodosinelloides* sp.,	*Climacammina sp.*		*Globivalvulina* sp.,
Fusulinids					
Yanagida and Nakornsri (1999); Tak Fa Formation			*Nankinella* sp.,		
Dowson (1993); Khao Khad Formation			*Nankinella* sp., *Chusenella* sp.		
Uttarawiset et al. (2017); Khao Khad Formation					*Nankinella* sp., *Parafusulina* sp.
Singhasuriya et al. (2017); Khao Khad Formation					*Nankinella* sp., *Parafusulina* sp.
Udchachon et al. (2014); Khao Khwang Formation					*Nankinella* sp.
Algea					
Chonglakmani & Fontaine (1990); Tak Fa Formation	*Mizzia* sp.	*Pseudovermiporella nipponica*	*Pseudovermiporella nipponica, Mizzia sp.*	*Mizzia* sp.	

Figure 5.1 Co-occurrence fossils on the Khao Khwang Platform.

Author	18PB05A	18PB05B	18PB05C	18PB05D	18PB05E
Ostracod					
Chitnarin et al. (2008); Tak Fa Formation		*Bairdia* cf. *altiarcus* Chen, 1958	*Bairdiacypris longirobusta* Chen, 1958		
Chitnarin et al. (2012); Tak Fa Formation, Pha Nok Khao Formation, Nam Maholan Formation	*Paraparchites chenshi* Crasquin, 2010			*Microcoelonella takliensis* Chitnarin, 2012;	
Chitnarin et al. (2015); Tak Fa Formation	*Paraparchites chenshi* Crasquin, 2010			*Microcoelonella takliensis* Chitnarin, 2012	
Chitnarin et al. (2017); Tak Fa Formation, Pha Nok Khao Formation, Nam Maholan Formation,	*Bairdia* cf. *urodeloformis* Chen, 1987; *Bairdia* cf. *fangnianqiaoi* Crasquin, 2010; *Knightina* cf. *ultima* Kozur, 1985; *Paraparchites chenshi* Crasquin, 2010; *Silenites surae* Chitnarin, 2017; *Bairdia songthami* Chitnarin, 2017	*Bairdia* cf. *altiarcus* Chen, 1958; *Bairdia broutini* Crasquin, 2010;	*Knightina* cf. *ultima* Kozur, 1985; *Fabalicypris hathaithipae* Chitnarin, 2017; *Acratia Chongpani* Chitnarin, 2017; *Bairdia songthami* Chitnarin, 2017	*Bairdia broutini* Crasquin, 2010; *Bairdia* cf. *urodeloformis* Chen, 1987; *Knightina* cf. *ultima* Kozur, 1985	*Bairdia broutini* Crasquin, 2010; *Bairdia deweveri* Crasquin, 2010; *Bairdia* cf. *fangnianqiaoi* Crasquin, 2010; *Knightina* cf. *ultima* Kozur, 1985

Figure 5.2 Co-occurrence species of ostracods on the Khao Khwang Platform.

5.1.3 Comparison between the microfacies analysis and the ostracod assemblage analysis

The methods and results of the microfacies analysis and the ostracod assemblage analysis are demonstrated in this research. Both techniques can be used to reconstruct the paleoenvironment of the Permian limestone at the study section. The microfacies analysis based mainly on texture and composition of carbonate grain provides information about wave energy (above or below fair wave base, above or below storm wave base) and the preferable locations for fossil and non-fossil grains. Whereas, the ostracod assemblage analysis based on community of the ostracods at Family and Superfamily level, provides ecological in formation such as salinity, depth and distance from shore. Several observations on applications of both techniques are presented in Figure 5.3.

Context	Microfacies analysis		Ostracod assemblage analysis	
	Advantage	Disadvantage	Advantage	Disadvantage
Sample preparation	Sample preparation process is simple.	-	-	Sample preparation process is complicated and time consuming (3-4 week to complete).
Number of sample	-	Many rock samples provide the better results. A single sample may not represent the right model.	Can be interpreted from a single sample but a sequence of samples provide the better result.	-
Microscopic study	-	Texture, grain composition and fossils must be identified	Ostracods are subjected to identification.	-
Equipment	Polarized light microscope	-	-	Scanning Electron Microscope
Paleoenvironmental interpretation	Results lead to either the rim-shelf carbonate platform model or the ramp carbonate model and their facies zone and subzones. The interpretation is the related to depth of the fair wave base and the storm wave base.		Results suggest the preferable ecological condition for ostracod community. The interpretation is related to salinity, substrate, volume of terrigenous sediments, depth of water and distance from shoreline.	

Figure 5.3 Comparison of the microfacies analysis and the ostracod assemblage analysis

5.2 Conclusion

The depositional environment at the study section was interpreted based on two techniques including the microfacies analysis and the ostracod assemblage analysis. The studied limestones are identified as the bioclastic wackestone and bioclastic grainstone microfacies types. They can be compared with the Carbonate Ramp Microfacies (RMF) and the ramp carbonate platform model is preferred. The study section is interpreted to be deposited on a part of the inner ramp including shoal, restricted and open marine environments.

The studied limestone samples yield 36 ostracod species belonging to 14 genera and 8 families. They are dominated by Bairdioidea (67.55%). The others are of Kirkbyidae (12.23%), Coelonellidae (9.04%), Paraparchitidae (5.32%), Polycopidae (2.13%), Cytherideidae (1.60%) Kloedenelloidea (1.60%) and Cavellinoidea (0.53%). The percentage of overall ostracod assemblage at Superfamily/Family level points to the shallow water, subtidal, open marine environments, with normal salinity. Nevertheless, the ostracod families and/or superfamilies can be grouped into three ecological assemblages according to their preferrences: the Bairdioidea living in the open marine environment or the external zone with normal salinity; the Paraparchidoidea, Cavellinoidea and Cytherideidae representing the midian zone were likely to spread from shallow to very shallow environments; the Kloedenelloidea and Krikbyidae representing the internal zone occupied very shallow, euryhaline and subtidal environments. In this study, members of the external zone inhabitants are the dominant, and followed by the midian zone inhabitants.

5.3 Recommendations for future studies

To confirm the conclusions drawn in this study, more interpretations are recommended as follows:

1. Fusulinids and smaller foraminifers in Ban Phu Toei should be studied intensively. To determine the exact age.
2. In this study, ostracods can interpret the depositional environment as well. Therefore, ostracod assemblage analysis can also be useful for the interpretation of the depositional environment in the future's other study.

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