PALAEOENVIRONMENTAL INTERPRETATION OF PHA KAN FORMATION, LAMPANG PROVINCE : IMPLICATION FROM MIDDLE TRIASSIC OSTRACODS

Patteera Ketmuangmoon

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Geotechnology

Suranaree University of Technology

Academic Year 2017

การแปลความหมายสภาพแวดล้อมบรรพกาลของหมวดหินผาก้าน จังหวัดลำปาง: การตีความจากออสตราคอตยุคไทรแอสซิกตอนกลาง

นางสาวพัทธ์ธีรา เขตเมืองมูล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

สาขาวิชาเทคโนโลยีธรณี

มหาวิทยาลัยเทคโนโลยีสุรนารี

ปีการศึกษา 2560

PALAEOENVIRONMENTAL INTERPRETATION OF PHA KAN FORMATION, LAMPANG PROVINCE: IMPLICATION FROM MIDDLE TRIASSIC OSTRACODS

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

Thesis Examining Committee

(Asst. Prof. Dr. Akkhapun Wannakomol)

Chairperson

(Asst. Prof. Dr. Anisong Chitnarin)

Member (Thesis Advisor)

(Dr. Pol Chaodumrong)

Member

(Prof. Dr. Santi Maensiri)

Vice Rector for Academic Affairs and Internationalization

(Assoc. Prof. Flt. Lt. Dr. Kontorn Chamniprasart)

Dean of Institute of Engineering

พัทธ์ธีรา เขตเมืองมูล : การแปลความหมายสภาพแวดล้อมบรรพกาลของหมวดหินผาก้าน จังหวัดลำปาง: การตีความจากออสตราคอตยุคไทรแอสซิกตอนกลาง (PALAEOENVIRONMENTAL INTERPRETATION OF PHA KAN FORMATION, LAMPANG PROVINCE : IMPLICATION FROM MIDDLE TRIASSIC OSTRACODS) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.อานิสงส์ จิตนารินทร์, 78 หน้า.

การศึกษาครั้งนี้มีจุดประสงค์เพื่อจัดทำอนุกรมวิธานออสตราคอตยุคไทรแอสซิกตอนกลาง (Anisian age) และเพื่อแปลความหมายสภาพแวดล้อมของการสะสมตะกอนของหมวดหินผาก้าน กลุ่มลำปางที่วัดพระธาตุม่วงคำ จังหวัดลำปาง ตัวอย่างหินปูนจำนวน 17 ตัวอย่างถูกนำมาสกัดด้วยวิธีฮอทอะซิโตไลซิส หินปูนจำนวน 2 ตัวอย่างจากส่วนล่างและส่วนบนของพื้นที่ศึกษาถูกเตรียมไว้สำหรับทำแผ่นหินบางเพื่อแสดงชุดลักษณะทางจุลภาค ออสตราคอตมีจำนวน 24 ชนิด 13 สกุล 7 วงศ์ และ 6 กลุ่มวงศ์ ประกอบด้วย Bairdioidea, Healdioidea, Cavellinoidea, Cytherelloidea, Cypridoidea และ Polycopidae ลักษณะเฉพาะของกลุ่มออสตราคอตบ่งชี้ว่าสภาพแวดล้อมบรรพกาลของบริเวณพื้นที่ศึกษาสามารถแบ่งออกได้เป็น 2 ส่วน ส่วนล่างตั้งแต่ตัวอย่าง 15MK01 ถึง 15MK04 สอดคล้องกับสภาพแวดล้อมที่มีความหลากหลายของการเปลี่ยนแปลงความเข้มข้นของเกลือที่สิ่งมีชีวิตสามารถอาศัยอยู่ในธรรมชาติได้ในบริเวณที่เป็นน้ำตื้นถึงตื้นมา และส่วนบนตั้งแต่ตัวอย่าง 15MK05 ถึง 15MK17 สอดคล้องกับสภาพแวดล้อมในเขตทะเลเปิด การตีความเทียบเคียงได้กับชุดลักษณะทางจุลภาคของตัวอย่างหินปูนที่ศึกษา กลุ่มออสตราคอตมีลักษณะคล้ายคลึงกับออสตราคอตยุคไทรแอสซิกตอนกลางที่ถูกพบในพื้นที่อื่น ดังนั้นอายุของพื้นที่ศึกษาจึงถูกกำหนดให้เป็นยุคไทรแอสซิกตอนกลางแทนที่จะเป็นยุคไทรแอสซิกตอนต้น

สาขาวิชา เทคโนโลยีธรณี

ปีการศึกษา 2560

ลายมือชื่อนักศึกษา พัทธ์ธีรา เขตเมืองมูล

ลายมือชื่ออาจารย์ที่ปรึกษา Anisong C.

PATTEERA KETMUANGMOON : PALAEOENVIRONMENTAL INTERPRETATION OF PHA KAN FORMATION, LAMPANG PROVINCE : IMPLICATION FROM MIDDLE TRIASSIC OSTRACODS. THESIS ADVISOR : ASST. PROF. ANISONG CHITNARIN, Ph.D., 78 PP.

HOT ACETOLYSIS/TAXONOMY/PALAEOENVIRONMENT

The objective of this study is to establish systematic of Middle Triassic (Anisian age) ostracods and to interpret depositional environment of the Pha Kan Formation, Lampang Group at the Wat Phra That Muang Kham section, Lampang province. Seventeen limestone samples are collected for processed by the hot acetolysis technique. Two samples at the lower and the upper parts of the studied section were prepared for rock thin-sections to represent microfacies. Twenty four species of ostracods were identified which belonged to 13 genera 7 Families and 6 Superfamilies including Bairdioidea, Healdioidea, Cavellinoidea, Cytherelloidea, Cypridoidea, and Polycopidae. The characteristics of the ostracod assemblage suggests that palaeoenvironment at the studied section can be divided into two parts. The lower part extends from samples 15MK01 to 15MK04 and corresponds to the euryhaline environments in shallow/very shallow waters. The upper part extends from samples 15MK05 to 15MK17 and corresponds to the open marine carbonate environment. The interpretation is comparable with microfacies of the limestone samples. The ostracod assemblages resemble Middle Triassic ostracods found elsewhere. Thus, age of the studied section is assigned to Middle Triassic rather than Early Triassic.

School of Geotechnology　　　　Student's Signature ____________

Academic Year 2017　　　　Advisor's Signature Anisong C.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the funding support from Suranaree University of Technology (SUT).

I would like to express my sincere thanks to my thesis advisor, Asst. Prof. Dr.Anisong Chitnarin for her consistent supervision and thoughfully advice towards the completion of this study.

In addition, I am grateful to Dr.Marie-Béatrice Forel, Asst. Prof. Dr.Prachya Tepnarong, Dr.Pol Chaodumrong, Asst. Prof. Dr.Akkapun Wannakomol and Professor Dr.Kittitep Fuenkajorn for their valuable suggestions. I would also like to thank Ms.Supharapon Sakulpakdee in Geotechnology Laboratory for her help throughout of this work.

Finally, I most gratefully acknowledge my parents, my brother and my friends for all their support and encouragement me throughout of this study.

Patteera Ketmuangmoon

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER I

INTRODUCTION

1.1 Background and rationale

The marine Triassic sedimentary rocks of Thailand are distributed in the northern, western, eastern, and southern parts of the country. In northern Thailand, the Lampang Group (Piyasin, 1971) covers most areas of Lampang province and consists predominantly of carbonate rocks. The Lampang Group consists of seven formations including the Phra That, Pha Kan, Hong Hoi, Doi Long, Pha Daeng, Kang Pla and Wang Chin Formations in ascending order and ranging in age from Early Triassic to Late Triassic (Chaodumrong and Berrett, 1997). For the geological age of Pha Kan Formation, Chonglakmani and Grant-Mackie (1993) proposed that the age of Pha Kan Formation is assigned to Late Anisian by ammonoid fauna. Later on, Carey et al. (1995) reported that the conodonts suggested the age of Pha Kan Formation down to the Early Triassic. As mentioned above, the ammonoid and conodont faunas can be indicated for the age of the Pha Kan Formation, but they cannot be interpreted in term of palaeoenvironment. The depositional environments of Pha Kan Formation studied by Chaodumrong and Rao (1992) based on characteristics of carbonate microfacies. They considered that Pha Kan Formation formed on a ramp platform.

The fossil ostracods are also well known for the palaeoenvironmental studies based on the characteristics of shell morphology and the composition of ostracod assemblages (Melnyk and Maddocks, 1988a,b; Crasquin et al., 2006; Forel, 2012). The information of Triassic ostracods is rare especially in Southeast Asia. In Thailand, the preliminar report of Triassic ostracods have been reported from Pha Kan Formation of Lampang Group by Chitnarin et al. (2006). They consist of 15 species belonged to four genera (e.g. *Bairdia*, *Acratia*, and *Bairdiacypris*) and suggest as shallow marine conditions with normal salinity environment of deposition.

Although both of carbonate microfacies and ostracod assemblages can be used to interpret the depositional environments, and the ostracod assemblages are more useful for palaeoenvironment interpretation due to abundant, taxonomically diverse and characteristic of shell morphology. Therefore, this study of ostracods from Pha Kan Formation is to provide the systematic of Early Triassic ostracods, applied them as a tool for the palaeoenvironmental interpretation, as evidences to interpret palaeogeography and as a tool to correlate palaeogeography with the relavant area.

1.2 Research objectives

1.2.1 To establish the systematic of Triassic ostracods recovered from limestones apart of Pha Kan Formations at Wat Phra That Muang Kham.

1.2.2 To interpret the environment of deposition of the study section based on ostracod assemblage.

1.2.3 To use ostracods as the palaeontological evidences for palaeogeographic interpretation.

1.3 Scope and limitation

1.3.1 The study section is located at Wat Phra That Muang Kham, (18°11′49″N, 99°32′31″E), Muang district, Lampang Province.

1.3.2 The study is focused on the systematic of the Triassic ostracods based on the taxonomic study and comparisons to previous works of Triassic records.

1.3.3 The paleoenvironment and palaeogeography are interpreted based on the ostracod assemblages and comparison with the previous studies.

CHAPTER II

LITERATURE REVIEW

2.1 Triassic stratigraphy and palaeogeography

2.1.1 Triassic stratigraphy of the Lampang Group in Northern Thailand

The marine Triassic Lampang group is distributed in Northern Thailand and was named originally by Piyasin (1972). The rocks were formed in two adjacent sub-basins, namely Lampang and Phrae sub-basins (Figure 2.1). The Lampang group is divided into seven formations including the Phra That, Pha Kan, Hong Hoi, Doi Long, Pha Daeng, Kang Pla and Wang Chin Formations, in ascending order. The first five formations were deposited in the Lampang sub-basin during Early Triassic to early Late Triassic whereas the last three formations were deposited in Phrae sub-basin during early Late Triassic to Late Triassic (Norian). The Pha Daeng Formation is common to both sub-basins. The Lampang sub-basin is estimated at more than 3000 m thick and explicated by Chaodumrong and Burrett (1997) as follows:

The Phra That Formation (90-650 m thick) includes the basal clastic rocks which overlies the Permo-Triassic volcanic rocks or Permian sedimentary rocks. It consists of sandstones, siltstones, conglomerates and limestones. The bivalves indicate the age range from Early Scythian to Early Anisian (Lower-Middle Triassic).

The Pha Kan Formation (400-640 m thick) overlies the Phra That Formation and consists of grey limestones with minor grey to green shale and sandstone beds. The limestones are thinly bedded to massive with packed oncolite beds.

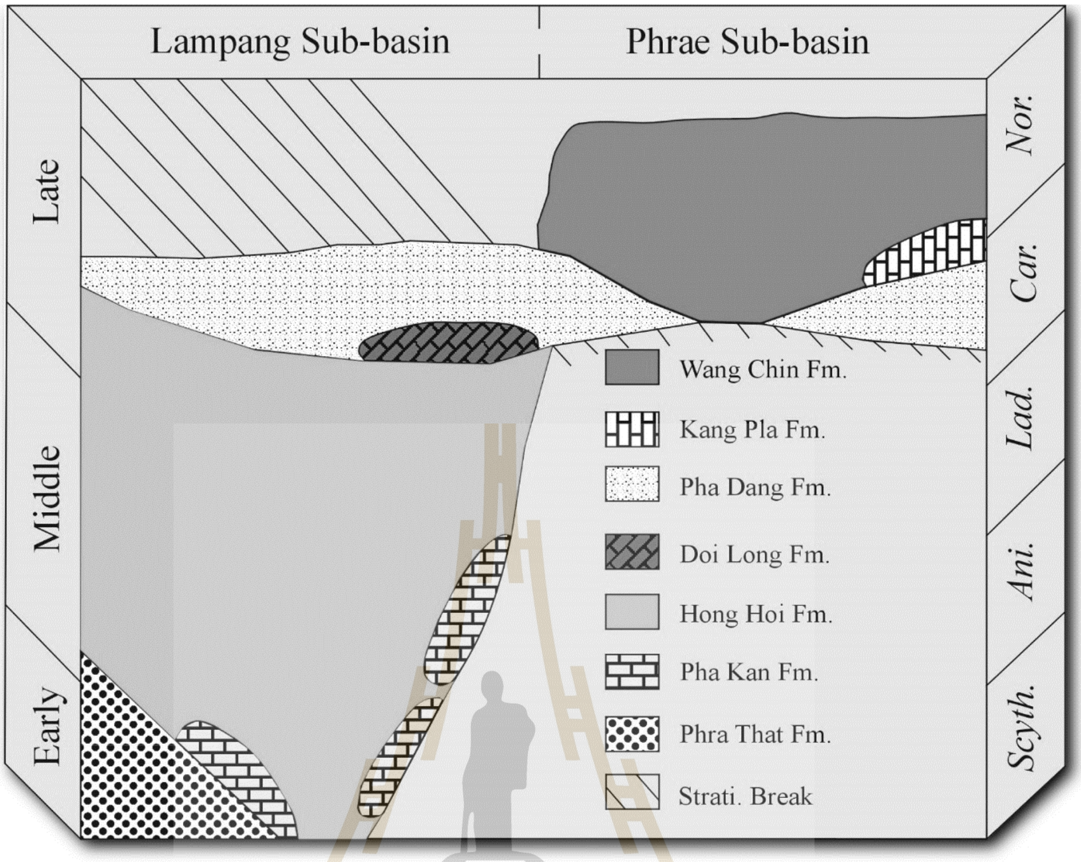


Figure 2.1 Diagram illustrates stratigraphy of the Lampang Group (DMR, 2014).

The formation contains ammonoid fauna of Middle Triassic (late Anisian age) (Chonglakmani and Grant-Mackie, 1993). However, the conodonts suggest the age down to the Early Triassic (Carey et al., 1995).

The Hong Hoi Formation (more than 700 m thick) is characterized by a sequence of greenish-grey shales and sandstones. The bivalves and ammonoids indicate the age range from Middle to Late Triassic (Ladinian to early Carnian age) (Chonglakmani and Grant-Mackie, 1993).

The Doi Long Formation (230 m thick) consists of massively bedded, grey to light grey crystalline limestone. Macrofossils are scarce but may be abundant locally. The formation contains poor and undetermined fossils, it is considered to be middle Carnian age (Late Triassic).

The Pha Daeng Formation (200-700 m thick) is characterized by red to maroon sandstones, siltstones and mudstones with subordinate conglomerates. This formation occurs in both the Lampang and the Phrae sub-basins. The middle Carnian (Late Triassic) bivalves have been reported from both sub-basins (Chonglakmani, 1981).

The biostratigraphic study of the Lampang and Phrae sub-basins is completed from Early Triassic (Scythian) to Late Triassic (Norian). The diverse fossils are consisted of ammonoids, bivalves, conodonts, corals and small foraminifera (Pitakpaiwan, 1955; Kummel, 1960; Buravas, 1961; Chonglakmani and Grant-Mackie, 1993; Carey et al., 1995; Kobayashi et al., 2006; Chonglakmani, 2011). These assemblages are summarized in Table 2.1.

2.1.2 Regional stratigraphy of the Pha Kan Formation

According to Chaodumrong (1992) and Chaodumrong and Burrett (1997), the Pha Kan Formation is distributed extensively in the Lampand subbasin and consisted of three limestone members including the Wiang Sawan, Chang Garb, Cave Temple and one intervening clastic member, the Muang Kham Members (Figure 2.2) as summarized below:

Wiang Sawan Member is characterized by dark grey to grey, thinly to thickly bed of wavy and nonparallel bed type of oncolitic packstone to wackestone and wackestone with minor interbeded shale. Lateral facies changes are common. The upper boundary is the thick oolite unit that exposed at Wat Phra That Muang Kham or the thick oncolite unit that exposed at Doi Chang (Figure 2.2).

Table 2.1 Biostratigraphy of the Lampang Group.

Ma		Series	Stages	Substages	Ammonoids (Chonglakmani, 2011)	Bivalves (Chonlakmani, 2011)	Conodonts (Carey et al., 1995)	Foraminifera (Kobayashi et al., 2006)
210 (Ma)	Triassic	Late	Norian	Sevatian				
				Alaunian				
220				Lacian		*Indopecten* *Halobia distincta*	*Epigondolella triangularis*	
			Carnian	Tuvalian	*Anatomites*	*Halobia parallela* *Halobia styriaca - Halobia charlyana*		*Aulotortus sinuosus*
230				Julian	*Paratrachyceras*			
		Middle	Ladinian	Longobardia		*Daonella indica*		*Endothyroid foraminifers - Diplotremina astrofimbriata*
240				Fassanian				
			Anisian	Illyrian	*Hollandites-Balatonites*			*Pilammina densa*
				Pelsonian				
				Bithynian				
				Aegean		*Costatoria*		
		Early	Olenekian	Spathian				*Glomospirella lampangensis*
250				Smithian			*Neospathodus pakistanensis*	
			Induan	Dienerian	*Ophiceras*	*Claraia*		
				Griesbachian				

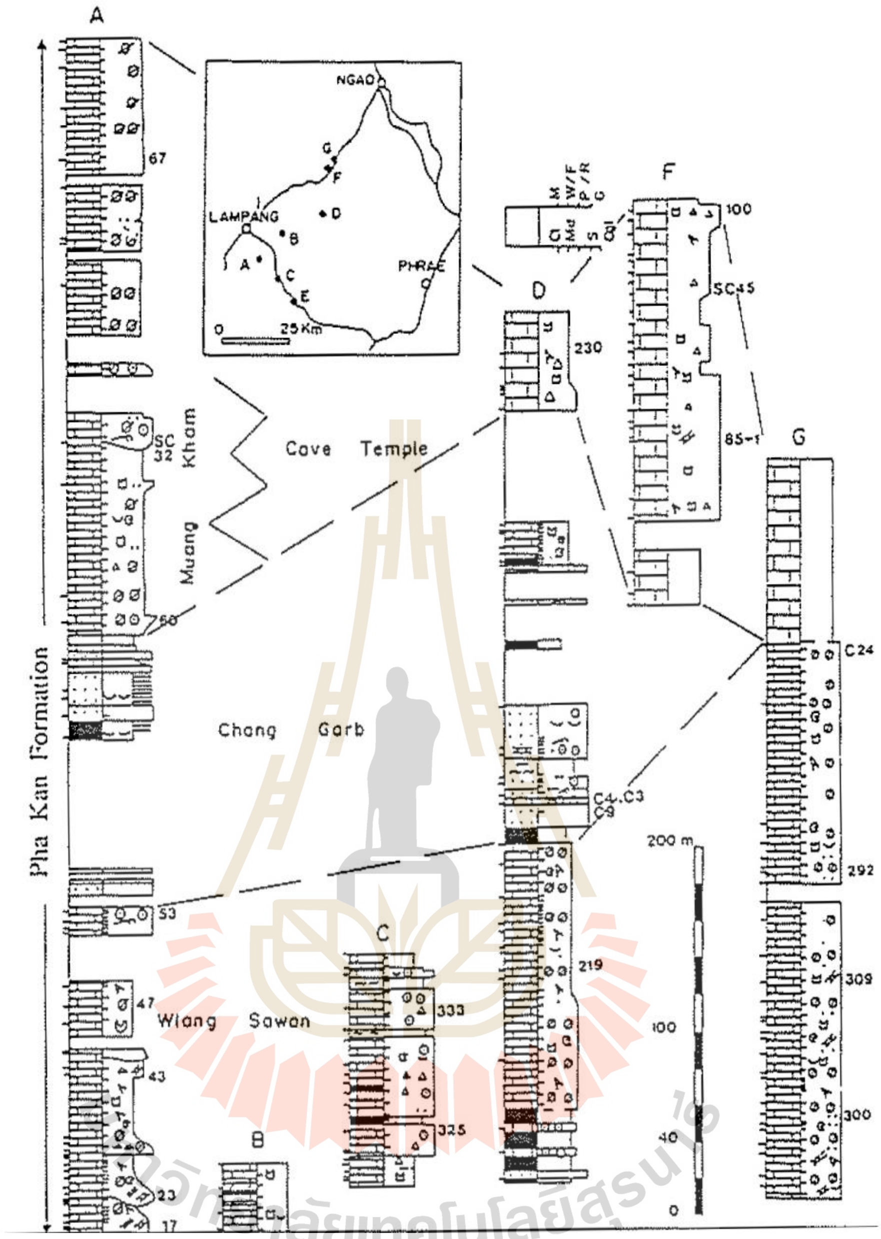


Figure 2.2 Lithostratigraphic correlations of Pha Kan Formation; A) Wat Phra That Muang Kham section, B) Nopawong quarry, C) km 22.8 on Lampang - Denchai highway, D) Doi Chang sections, F) Doi Pha Kan quarry, and G) Pha Thu Pha quarry and sacred place (Chaodumrong and Burrett, 1997).

Chang Garb Member is characterized by sandstones, siltstones and mudstones with minor limestones beds containing ooids, oncoids and peloids. Cross-stratification is common and in some instances is represented by oriented fossils. Bivalves are common and aggregated as lenticular beds within some sandstone successions, commonly occur convex-side up. The base of the first massive limestone unit is on the upper boundary of this member that may be distributed between Wat Phra That Muang Kham and Doi Chang, and shows exposure in Ban Tha Si and Phra Thu Pha areas (Figure 2.2).

Cave Temple Member is characterized by massive and light grey limestones. It consists of packstone, grainstone, wackstone and boundstone. This member is widely distributed in Doi Chang, Neramit Cave Temple, Doi Wiang Ho, southward to km post 19 on the Lampang-Denchai highway, and at Ban Tha Si northward Pha Thai Cave (Figure 2.2).

The last, Muang Kham Member is characterized by grey to dark grey, thin to thick beds, oncolitic packstone to wackestone, peloidal-skeletal packstone to grainstone, wackestone and lime mudstone. Shallowing-upward sequences are common. This member is distinguished from the Wiang Sawan Member by the stratigraphic position overlying the Chang Garb Member (Figure 2.2).

Chaodumrong (1992) and Chaodumrong and Rao (1992) interpreted that the carbonate microfacies of the Pha Kan Formation are dominated by oncolitic wackestone to mudstone and oncolitic peloidal packstone. They indicated depositions on the ramp platform of shallow marine environment.

According to Carey et al. (1995), the conodont materials identified as *Neospathodus pakistanensis* which recovered from limestone of the Wiang Sawan

Member at km 9.6 on Lampang-Denchai highway indicates the Early Triassic (latest Dinerian-earliest Smithian age). Later, Kobayashi et al. (2006) confirmed the age of Anisian by foraminifera *Pilammina densa-Meanidrospira dinarica* (Table 2.1).

2.1.3 Palaeogeography of the Lampang Group

The evolution of northern Thailand is associated with the collision between the Shan-Thai (also called Sibumasu) and Indochina Terranes. The Shan-Thai terranen rifted from Gondwana in Early Permian. As it drifted north a subduction complex developed along northern margin. The Late Permian to Late Triassic fore-arc basin sediments are preserved in Sukhothai Terrane. The Lampang Group was deposited within the intra-arc and fore-arc basins on Sukhothai Terrane. It consists of the shallow marine siliciclastics and carbonates, the basinal turbidites and rhyolitic and andesitic volcanic (Chonglakmani, 1999; Singharajwarapan and Berry, 2000).

2.2 Triassic ostracods

Ostracods are micro-crustaceans with bivalved carapaces. They appeared from Ordovician to the Recent. They are the most abundant of fossil arthropods and are represented 33,000 living and fossil species. Most of the ostracods are living in marine environment and probably benthic inhabitants, so they are valuable indicators of ecology and environment. The fossil ostracods are found abundantly in limestones, shales, and marls. The carapace length is measured around 0.15 – 3 mm. The characteristics of shell morphology are essential for taxonomic study (Moore, 1961; Pokorný, 1978; Armstrong and Brasier, 2005).

In addition, the end-Permian mass extinction eliminated the marine diversity more than 52% at the family level. This mass extinction followed by the flood basalt volcanism and the ocean anoxia (Payne and Clapham, 2012). Through the Permian-Triassic events, the ostracods survive from mass extinction and the main turnover of ostracod group occurs at the Permian-Triassic boundary (Table 2.2). This turnover is characterized by the Paleozoic affinities faunas were replaced by the Meso-Cenozoic affinities faunas as proposed by Crasquin et al. (2007) and Crasquin and Forel (2013). According to the previous works, Triassic ostracods can be divided into two groups: 1) Early Triassic (Griesbachian-Spathian age) ostracods and 2) Middle Triassic (Anisian age) to Late Triassic ostracods (Figure 2.3).

2.2.1 Early Triassic (Griesbachian-Spathian age) ostracods

Ostracod assemblages are diversified in the Griesbachian and the Spathian age. The Gresbachian ostacods are present in the different environment setting between with or without microbialites. In Dajiang section is associated with microbial formation (Forel, 2012), there are 32 species belonging to 9 genera with 4 Palaeozoic forms (Acratiidae indet, *Bairdiacypris*, *Orthobairdia*, Paraparchitiidae indet). The section of ostracod occurrence without microbiolites is Meishan GSSP (Crasquin et al., 2010; Forel and Crasquin, 2011b), 23 species belonging to 9 genera with 5 typical Palaeozoic forms (*Acratia*, *Hollinella*, *Bairdiacypris*, *Revyia* and *Microcheilinella*) are recognized.

During the Dienerian and the Smithian age, the ostracod data are scarce. In Jinya/Waili section in Guangxi (Craquin et al., 2006), 4 species are recognized: *Bairdia fengshanensis* Craquin-Soleau, 2006; *Paracypris jinyensis* Craquin-Soleau, 2006; *?Acratia nostorica* Monostori, 1994 and *Bythocypris*? sp.3.

In the Spathian age, ostracods are diversified and still present the Palaeozoic forms (35 species in Tulong section; Forel and Crasquin, 2011a), while the

Table 2.2 Selected previous studies on Late Permian – Triassic ostracods.

Period			Permian	Triassic										
			Upper Lopingian	Lower						Middle			Upper		
	References	Locations	Upper Changshingian	Lower Griesbachian	Upper Griesbachian	Dienerian	Smithian	Spathian	Lower Anisian	Upper Anisian	Ladinian	Carnian	Norian	Rhaetian
1	Shi and Chen, 1987	Meishan GSSP												
2	Hao, 1996	Guizhou												
3	Crasquin et al., 2005	Saudi Arabia												
4	Forel et al., 2009; Forel, 2012	Dajiang, Guizhou												
5	Forel et al., 2013	Bálvány, Hungary												
6	Crasquin et al., 2004	Çürük dag, Turkey												
7	Crasquin et al., 2008	Bulla, Italy												
8	Crasquin et al., 2010; Forel and Crasquin, 2011a	Meishan GSSP												
9	Crasquin-Soleau and Kershaw, 2005	Laolongdong, Sichuan												
10	Sohn, 1970	Pakistan												
11	Agarwal et al., 1980	Kashmir												
12	Crasquin et al, 2006	Jinya/Waili, Guangxi												
13	Forel and Crasquin, 2011b; Forel et al., 2011	Tulong, Tibet												
14	Sebe et al., 2013	Dobrogea, Romania												
15	Honigstein and Crasquin, 2011	Israel												
16	Monostori, 1995	Felsoors hill, Hungary												
17	Crasquin-Soleau and Gradinaru, 1996	Dobrogea, Romania												
18	Mette et al., 2014	Austria												
19	Kozur, 1971a,b	Hungary, Slovakia, Austria												
20	Kristan-Tollmann, 1991	NE, Iran												
21	Kollmann, 1960, 1963	Austria												
22	Monostori and Tóth, 2013	Balaton highland, Hungary												
23	Sohn, 1987	Northeastern Alaska												
24	Reuss, 1868; Gümbel, 1869; Ulrichs, 1971; Kristan-Tollmann, 1978	Italy												
25	Dépêche and Crasquin-Soleau, 1992	Australia												

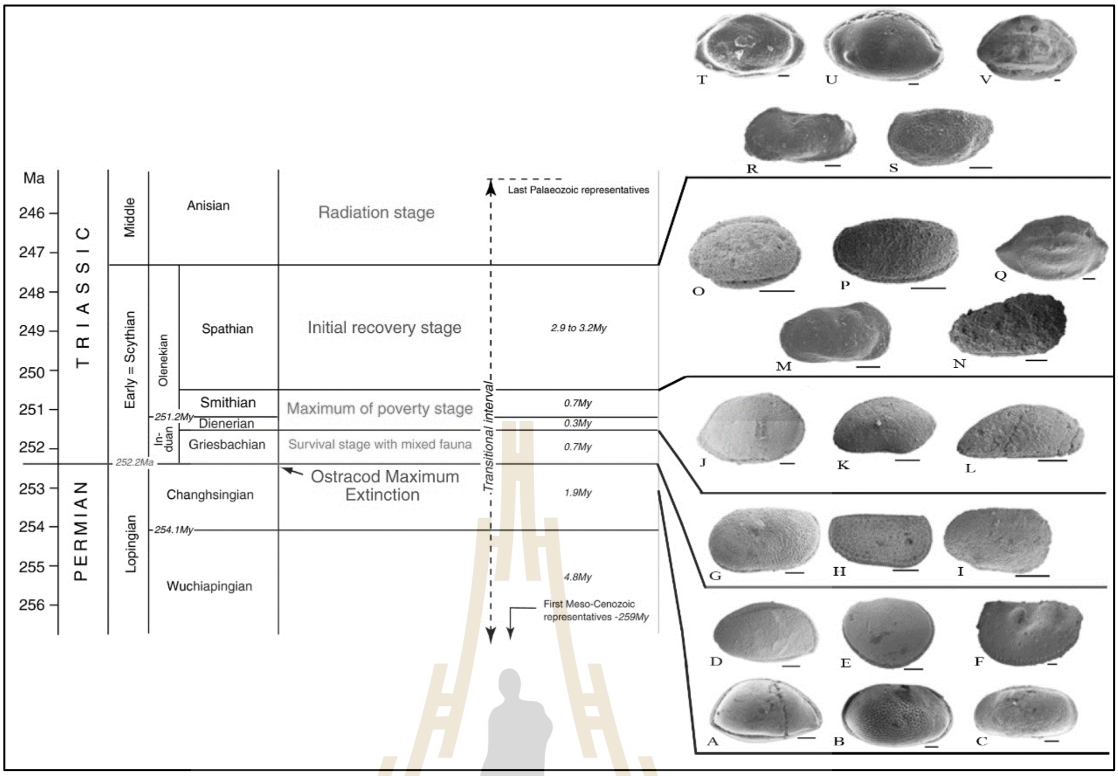


Figure 2.3 The recovery of ostracod forms through Permian-Triassic boundary events (Crasquin and Forel, 2013).

Spathian ostracods of Israel section (Honigstein and Crasquin, 2011) do not present the Palaeozoic forms. The genera *Acratia*, *Carinaknightina* and *Langdaia* are disappeared at the end of the Spathian age.

2.2.2 Middle Triassic (Anisian age) to Late Triassic ostracods

During the Early Anisian age (Middle Triassic), also found the Paleozoic forms from Tulong, Tibet sections including *Triassicindivisia*, *Bairdiacypris* and *Microcheilinella* (Forel and Crasquin, 2011a). Other works on the Middle Triassic ostracods by many authors are known from several places worldwide such as Hungary

(Bunza and Kozur, 1971; Kozur 1971a,b; Monostori and Toth, 2013), Romania (Crasquin-Soleau and Gradinaru, 1996), Tibet (Forel and Crasquin, 2011a), India (Goel et al., 1984), Poland (Styk, 1972; 1990) and Israel (Sohn, 1968). From the Late Anisian age to Late Triassic, all ostracods species are typical Meso-Cenozoic forms.

2.3 Characteristics of ostracod for palaeoenvironmental interpretation

The main palaeoecological characteristics of Late Palaeozoic and Early Triassic ostracods are considered on genera, families and/or superfamilies (Melnyk and Maddocks, 1988a,b; Crasquin-Soleau et al., 1999; 2005; 2006; Forel et al., 2011) as summarized below (Figure 2.4):

Superfamily Bairdioidea presents in shallow to deep water, open marine carbonate environments with normal salinity and well oxygenation. In Genus *Microcheilinella* (Family Pachydomellidae) are inhabitants of offshore environment. Members of Family Bairdiocyprididae prefer nearshore and muddy environment. Family Hollinoidea can characterize environments such as interdistributary bays, prodelta and interdeltaic embayments and lagoons. Family Kloedenelloidea live in very shallow, euryhaline environment. Family Cytherideidae, species of genus *Basslerella* is an offshore inhabitants. In Family Cavellinidae, some species of Family Cavellinidae appear to have been adapted to nearshore environment which present in shallow to very shallow or euryhaline environment. In Family Paraparchitidae, most species increase in offshore, but some species live in euryhaline environment, shallow to very shallow water. Family Kirkbyidae, the common species spread out in subtidal, normal-marine environment. Superfamily Healdioidea is a good indicator of relatively nearshore, muddy environment. Member of Cladocopina live in nearshore conditions. Member of

Family Youngiellidae, members of this family live in shallow water, normal-marine environment.

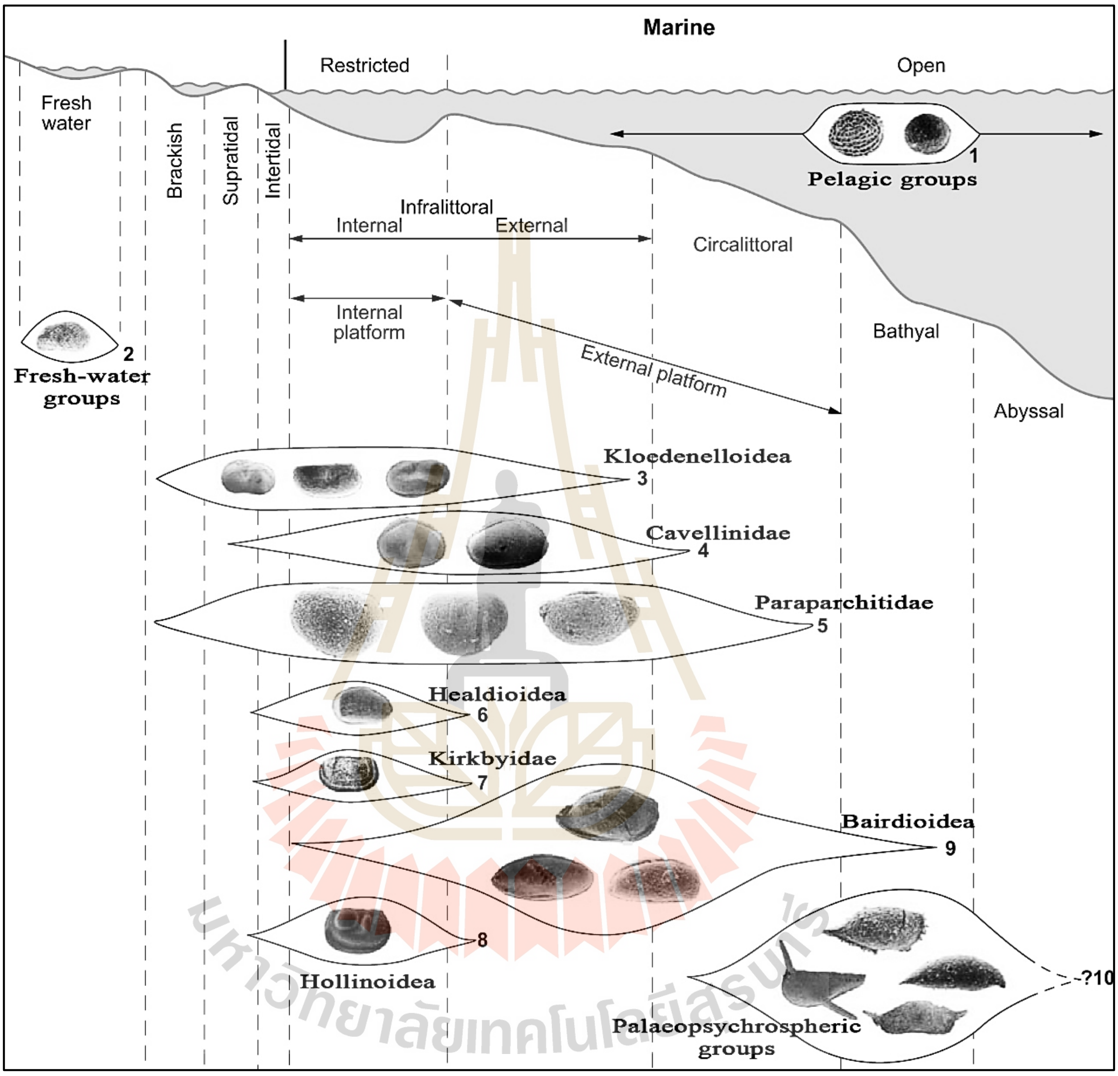


Figure 2.4 Distribution of main ostracod groups during the Late Palaeozoic along a platform (after Craquin-Soleau et al., 2006).

CHAPTER III

METHODOLOGY

The methodology of this study consists of Literature review and study, field investigation, laboratory works, data analysis and interpretation, and thesis writing.

3.1 Literature review and study

Reviews of previous works including Triassic geology, stratigraphy and paleontology relevant to the study section were carried out. Literatures of the ostracods such as techniques in laboratory, systematics and geological applications were also achieved. Thesis plan was set up and started as a consequence.

3.2 Field investigation and sampling

Field investigation was carried out in December, 2015. Limestone samples were collected from the section at Phra That Muang Kham temple, Lampang Province. Location of the studied section is located at about 10 km SE of Lampang city, approximately at 18°11´49´´N, 99°32´31´´E as show on topographic map sheet Amphoe Mae Thaa (4945 III) (Figures 3.1) and geological map sheet Changwat Lampang (NE47-7) on scale 1:250,000 (Figures 3.2). The studied section was measured with a total thickness of 58.4 m (Figures 3.3). The section is predominantly made of bedded limestone with minor mudstone and sandstone (Figures 3.4). Limestone is gray to dark gray, showing medium to thick bedded and can be classified as wackestone to packstone (Dunham, 1962). There are several beds of packed oncolite in the lower part of the section (Figure 3.4B).

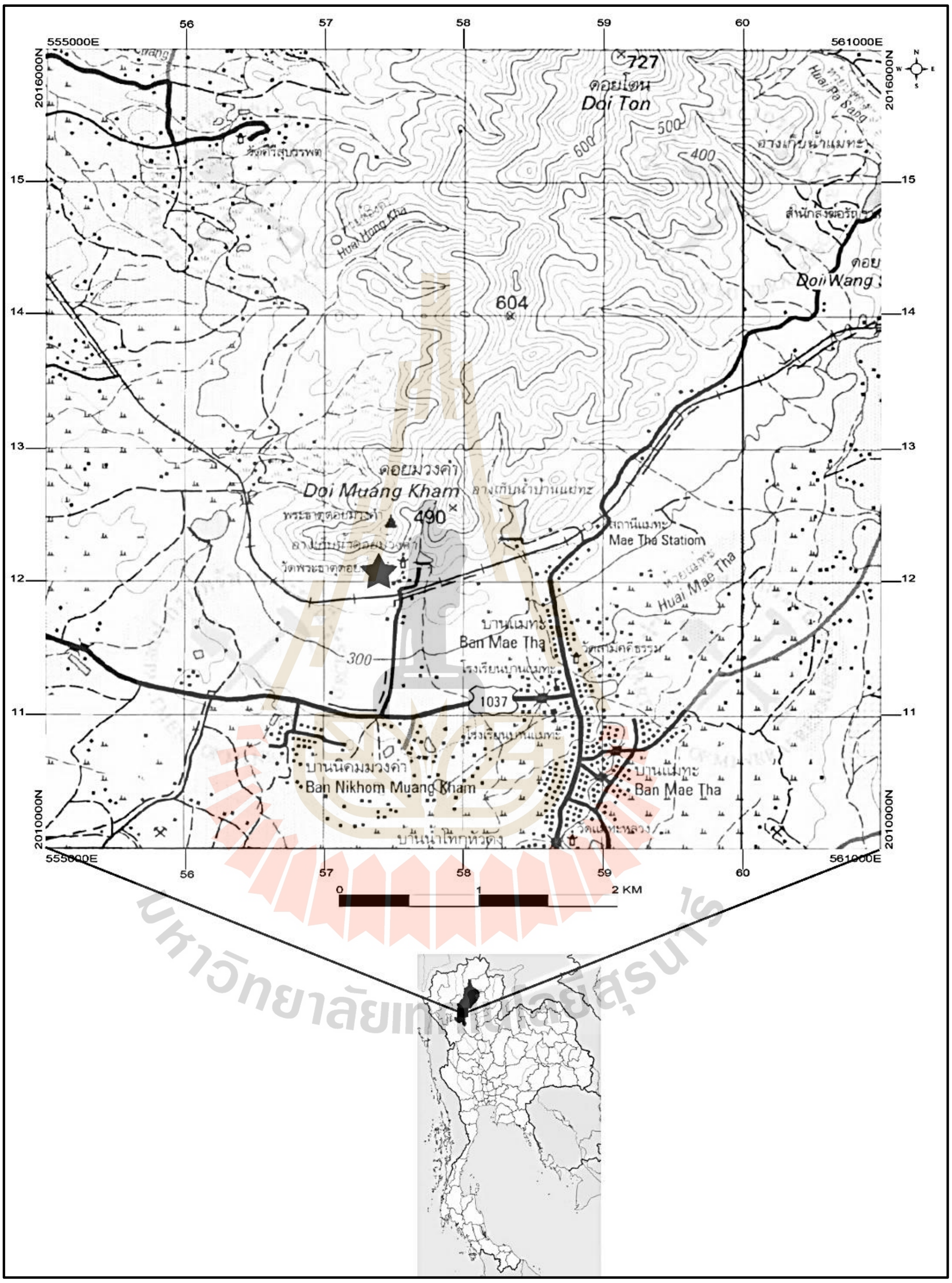


Figure 3.1 Map showing location of the stuied section (modified from Royal Thai Survey Department, 1999).

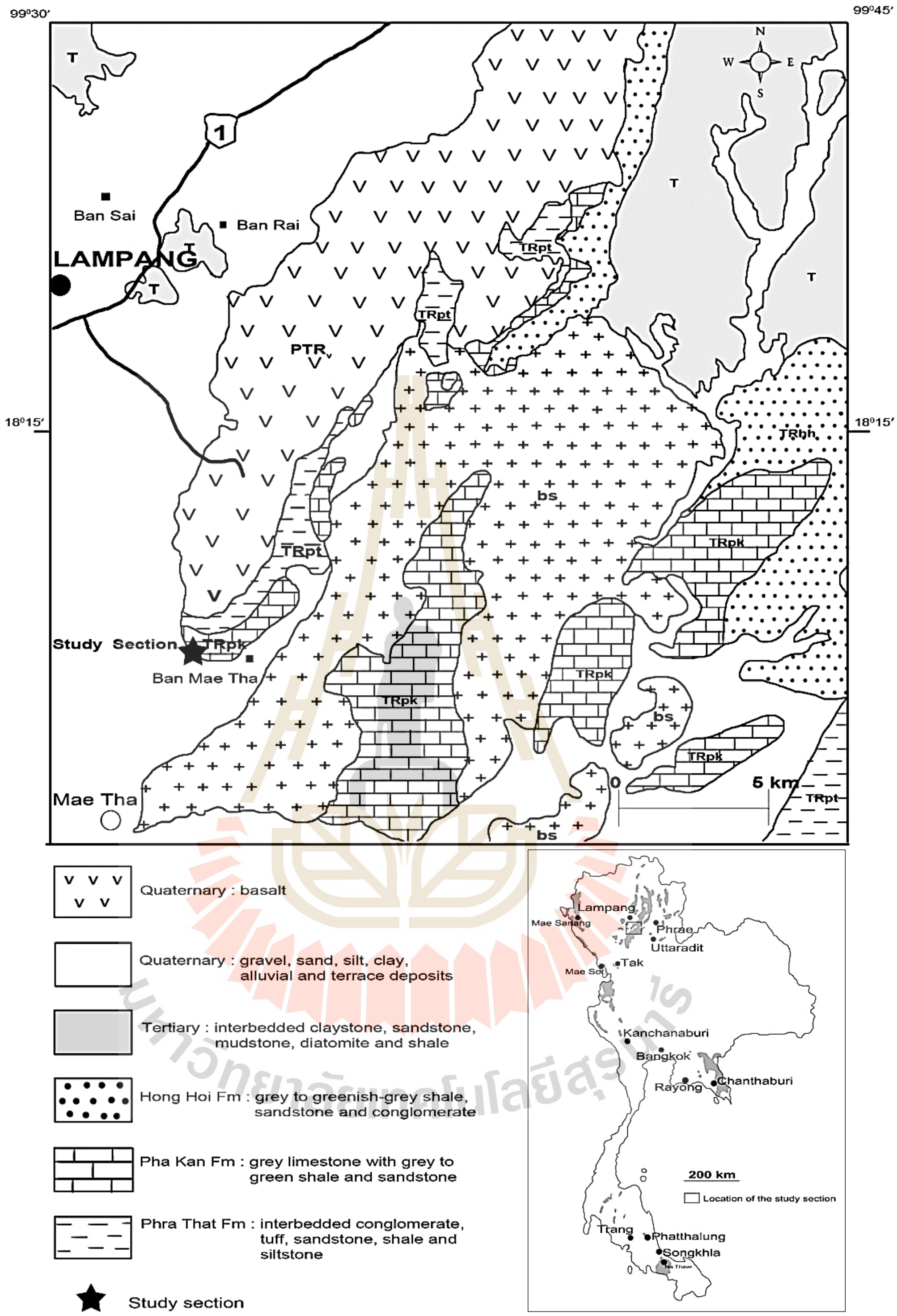


Figure 3.2 Geological map and location of the studied section (after Charoenprawat et al., 1994 and Chonglakmani, 2011).

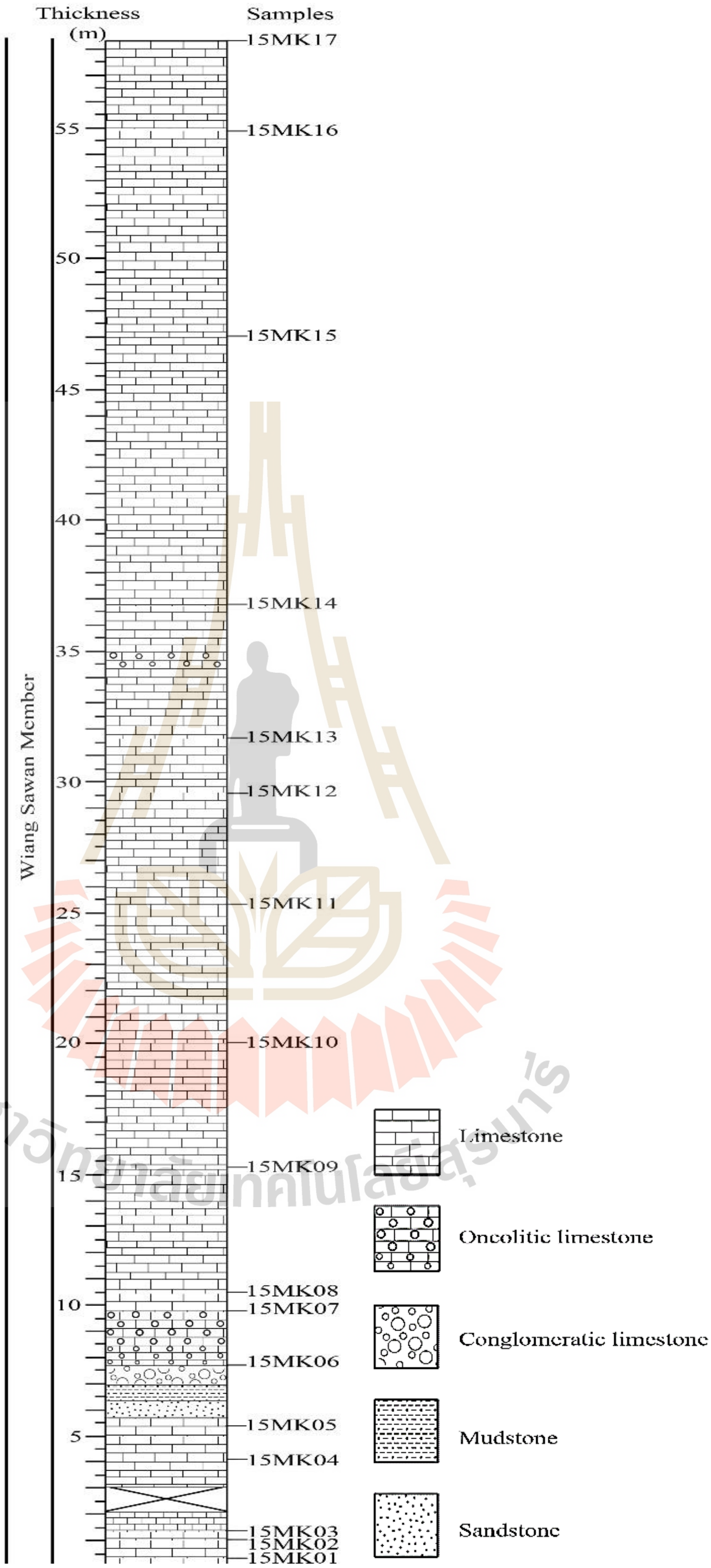


Figure 3.3 Lithologic log of Wat Phra That Muang Kham section.

Figure 3.4 Photographs of the outcrop: A, at the lower part of the section (15MK03); B, packed oncolite (15MK06); C, at the sample 15MK10 level; D, at sample 15MK11 level; E, at sample 15MK17 level.

3.3 Laboratory works

The laboratory works are subdivided into 2 parts as follows.

Part 1: The rock samples were identified and the lithologic log was constructed. Rock thin-sections were prepared from samples 15MK02 and 15MK17 to represent the lower and the upper parts of the studied section. Petrography of the thin-sections was carried out.

Part 2: The limestone samples were processed by hot acetolysis technique (Lethiers and Crasquin-Soleau, 1988; Crasquin et al., 2005) at Geotechnology Laboratory, Facility Building 7 (F7), Suranaree University of Technology. The hot acetolysis technique is suitable to extract the fossil ostracods from calcareous rocks by using concentrated acetic acid (CH_3COOH) because the ostracod carapaces can be released without corrosion. The technique is as follows (Figure 3.5).

Step I. Sample crushing and dehydration

To increase the reaction surfaces, 500 g of each limestone samples are crushed into small pieces (approximately 1-2 cubic centimetres) by hammer (Figure 3.5A). Then, the sample was placed in a glass bottle labeled with sample number. To avoid an acid reaction due to water content, the sample should be dried overnight in a hot air oven where temperature should be controlled at 100°C (Figure 3.5B).

Step II. Acetolysis

After waiting until the samples cooled down, pour the pure acetic acid into the glass bottle. Then cover the bottle with aluminium foil and close with a cap. Next put the bottle on a heating sand-bath at 60ºC (Figure 3.5C). To avoid the acid vapours, this process should be proceeded in an extractor hood. The reaction will occur from one week to several weeks, then a muddy deposit should form at the bottom of the bottle.

Step III. Settling-filtering and washing

Before washing, the excess acid is filtered off by a funnel and a filter paper, the acid can be reused (Figure 3.5D). After that, washing and sieving the residues over 2 mm, 0.5 mm and 0.1 mm sieve mesh (Figure 3.5E). Then, dry the residues and the residues with larger size than 2 mm are collected for the second acid attack (repeat from step I). Dried residues repeating the second acetolysis of the smaller size are sorted and picked under a stereomicroscope. The well-preserved samples specimens are prepared for the Scanning Electron Microscope (SEM) photography (Figure 3.5F-G).

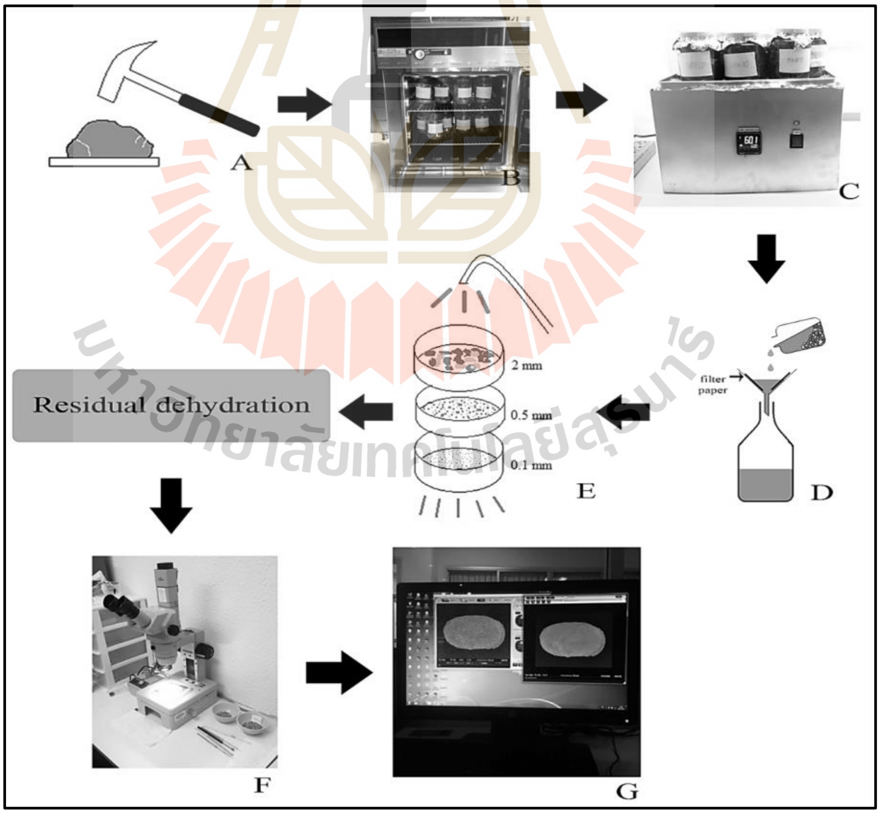


Figure 3.5 Processes of hot acetoysis technique (modified from Crasquin et al., 2005).

3.4 Data analysis and interpretation and thesis writing

The palaeoenvironmental analysis and interpretation are based on carapace characteristic and the composition of the ostracod assemblages as studied by these authors: Melnyk and Maddocks, 1988a,b; Crasquin-Soleau et al., 1999; 2005; 2006; Forel et al., 2011. Moreover, the microfacies analysis and geological information were used for interpreted the studied section. Then thesis writing has been done.

CHAPTER IV

RESULTS

4.1 Ostracod shell morphology

For fossil ostracods, the most useful character to classify is shell morphology. Ostracod carapace is formed by two valves namely right valve (RV) and left valve (LV). The area adjacent to the hinge is dorsal border (DB) and dorsum. Free margins are divided into anterior border (AB), posterior border (PB) and ventral border (VB) (Figure 4.1). Each valve is similar but not a mirror image of each other. They are sub-equal or unequal in size so the smaller valve is overlapped by the larger one along part or all of the free margin.

The shape/outline of ostracod is important criteria in classification. In lateral view, the carapace may be described as ovate, elliptical, rectangular, rhombic, bean-shaped or kidney-shaped, etc. The specific shape of Genus *Bairdia* is termed as "bairdian shape" (Figure 4.2). The maximum convexities of AB and PB may located at/above or below mid-height. In dorsal or ventral view, the carapace has symmetrically or asymmetrically biconvex lensoid shape. DB may be straight, convex or arched. The juncture between dorsal border and AB/PB are called cardinal anger (CA) that can be useful in classification. VB is straight, convex or concave. AB and PB are usually rounded (broadly or acutely) or pointed.

The valve surface can be smooth or highly ornamented. Lobes represent elevations of the carapace which are directly opposite internal depressions or internal anatomy. Lobes have been designed numerically from anterior to posterior part as L_1, L_2, L_3 and L_4. Sulci are elongate depressions of the domicilium labeled as S_1, S_2 and S_3 from anterior to posterior.

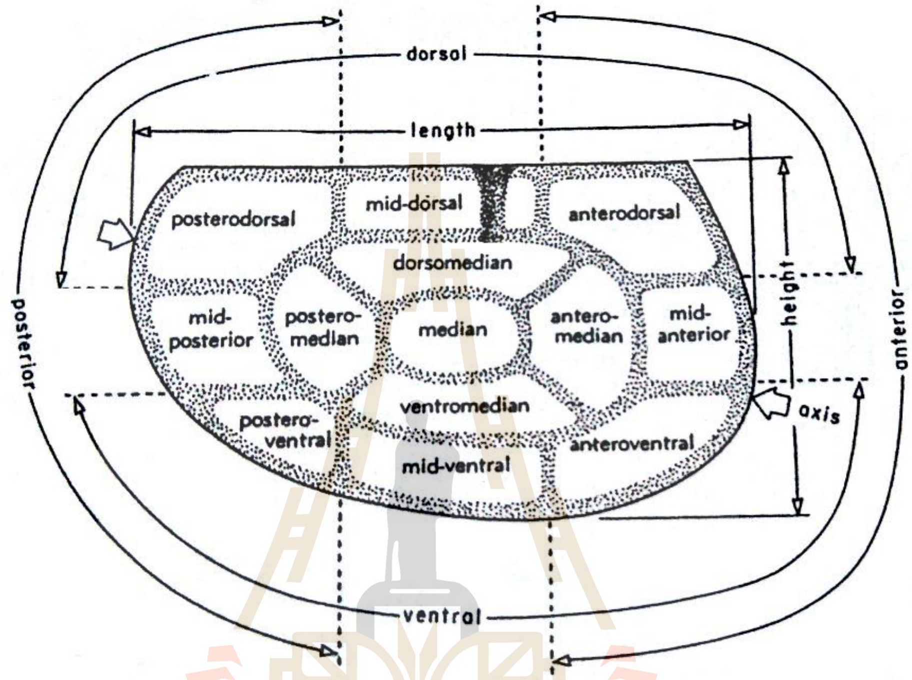


Figure 4.1 Feature and nomenclature of the lateral surface of right valve (Moore, 1961).

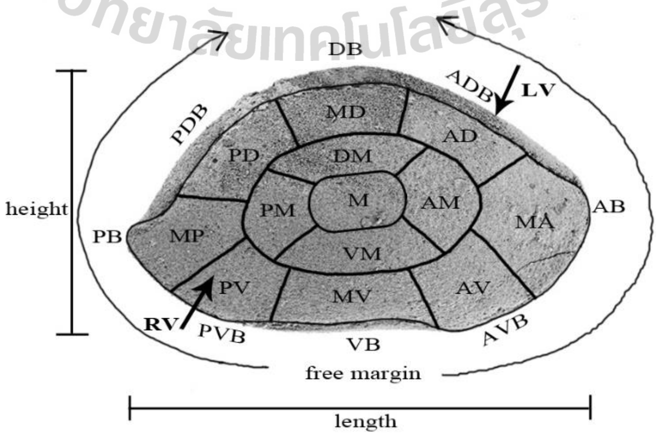


Figure 4.2 Right lateral view of *Bairdia* carapace from this thesis.

4.2 Systematic palaeontology

In this thesis, the classification of ostracod is Moore (1961) modified after Lethiers (1981) and Horne et al. (2002). In this part, the SEM photographs were used to identify fossil ostracods and to compare with previous works of Triassic ostracods. Twenty four species belonging to 13 genera and 7 families are recognized.

Abbreviations: DB: dorsal border; AB: anterior border; ADB: anterior dorsal border; 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, 1806

Order **PODOCOPIDA** Sars, 1866

Superfamily **CYPRIDOIDEA** Baird, 1845

Family **PARACYPRIDIDAE** Sars, 1923

Genus *Paracypris* Sars, 1866

Type-species *Paracypris polita* Sars, 1866

Paracypris? sp.

Plate 1, Figure 1-5

Material: 25 complete carapaces, 10 broken carapaces

Dimensions: L = 0.36 - 0.39 mm, H = 0.20 – 0.26 mm, H/L = 0.56-0.70

Occurrence: sample 15MK09, 15MK11 and 15MK13, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by AB semicircular rounded with maximum of convexity located at mid-H; DB straight and rapidly sloping to posterior-end; PB blunted; VB straight; surface smooth.

Remarks: This present species is similar to *Paracypris tabulasaxensis* Kristan-Tollmann, 1991 and *Paracypris loferensis* Kristan-Tollmann, 1991 identified from Kammerköhralm-Steinplatte area (Tirol), Rhaetian age, Late Triassic (Kristan-Tollmann et al., 1991). However, the carapace of *Paracypris loferensis* Kristan-Tollmann, 1991 is more elongated than *Paracypris tabulasaxensis* Kristan-Tollmann, 1991 and *Paracypris?* sp. (this study).

?Family **PARACYPRIDIDAE** Sars, 1923

Genus *Triassocypris* Kozur, 1970

Type-species *Macrocypris? pusilla* Kozur, 1968

Triassocypris sp.

Plate 1, Figure 6-10

Material: 32 complete carapaces, 22 broken carapaces

Dimensions: L = 0.48 – 0.95 mm, H = 0.21 – 0.38 mm, H/L = 0.39 – 0.43

Occurrence: sample 15MK07, 15MK08, 15MK09, 15MK11, 15MK13, 15MK14, 15MK15, 15MK16 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace elongated in lateral view; RV larger than LV and overlaps all around the carapace except at AB; DB convex in both valves; PB acuminate; VB long and straight in RV and almost straight in LV; AVB slightly concave, ADB slightly convex creating a beak at AB with the maximum convexity located at mid-H; surface smooth.

Remarks: The genus *Triassocypris* Kozur, 1970 originally assigned to the Paracyprididae (Kozur, 1970). However, Sohn (1987) was reported that *Triassocypris* Kozur, 1970 probably should not be classified in the Paracyprididae. Because in his work *Triassocypris* has a wide anterior and a narrow posterior, otherwise the Paracyprididae in Moore (1961). The present specimen is also close to genus *Acratia* Delo, 1930 in lateral outline, but the present species exclude from genus *Acratia* Delo, 1930, which has LV overlapping RV.

Suborder **PODOCOPINA** Sars, 1866

Superfamily **BAIRDIOIDEA** Sars, 1865

Family **BAIRDIIDAE** Sars, 1865

Genus *Bairdia* McCoy, 1844

Type-species *Bairdia curta* McCoy, 1844

Bairdia sp.1

Plate 2, Figure 2-6; Plate 3, Figure 8

Material: 11 complete carapaces, 38 broken carapaces

Dimensions: L = 0.49 - 0.62 mm, H = 0.33 – 0.41 mm, H/L = 0.66 - 0.69

Occurrence: sample 15MK07, 15MK08, 15MK10, 15MK11, 15MK13, 15MK14, 15MK15 and 15MK16 Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace subtriangular and plump in lateral view; LV overlaps RV; DB regularly arched on LV; PDB and ADB straight at RV; AB rounded with large radius of convexity and maximum located at mid-H; AVB straight and steep; VB slightly concave at RV and slightly convex at LV; PB with small radius of convexity and maximum located low; surface smooth and extremities flattened ventrally.

Remarks: This present materials are similar to *Silenites limatus* Guan, 1978 and

Bairdia limatusformis Forel, 2010 described from the Changhsingian, Late Permian of Meishan section, South China (Shi and Chen, 1987; Crasquin et al., 2010) by their lateral outline.

Bairdia sp.2

Plate 2, Figure 7-8

Material: 2 complete carapaces, 1 broken carapace

Dimensions: L = 0.92 - 0.98 mm, H = 0.56 – 0.57 mm, H/L = 0.58 - 0.60

Occurrence: sample 15MK07, 15MK16 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace elongate, slightly upward-directed posterior end; DB broadly convex; PDB and ADB slightly straight; AB rounded with maximum of convexity below mid-H, AVB broadly convex; VB slightly concave; LV overlaps RV on the whole dorsal margin and in the central part of the ventral margin; surface smooth.

Remarks: The *Bairdia* sp.2 is close to *Bairdia cassiana* (Reuss, 1868) by having slightly upward-directed posterior end and the asymmetrical AB. The *B. cassiana* has been recorded from Middle to early Late Triassic: Anisian of Felsöörs hill, Hungary (Monostori, 1995); Middle Anisian of the Northern Calcareous Alps, Austria (Mette et al., 2014); Ladinian, Middle Triassic of the Balaton highland, Hungary (Monostori and Tóth, 2013); Early Carnian of Cassian beds, Italy (Reuss, 1868; Gümbel, 1869; Ulrichs, 1971; Kristan-Tollmann, 1978).

Bairdia sp.3

Plate 2, Figure 9

Material: 1 broken carapaces

Dimensions: L = 1.11 mm, H = 0.70 mm, H/L = 0.63

Occurrence: sample 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Remarks: The *Bairdia* sp.3 is close to *Bairdia letangae* Forel, 2011 from Early Anisian of Tulong section, Southern Tibet (Forel and Crasquin, 2011a). However, the present species differs from *Bairdia letangae* by having smaller reticulations on the carapace surface. The posterior part is poorly preserved, therefore, it is difficult to be certain about the identification of species.

Bairdia sp.4

Plate 2, Figure 10-14

Material: 37 complete carapaces, 27 broken carapaces

Dimensions: L = 0.49 – 1.07 mm, H = 0.28 – 0.64 mm, H/L = 0.57 - 0.63

Occurrence: sample 15MK10, 15MK11, 15MK13, 15MK14, 15MK15 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by subfusiform carapace in lateral view; a pointed posterior end with small radius of convexity; DB of some specimens convex on both valves, and others straight in RV and convex in LV; AB rounded with large radius of curvature and maximum convexity located slightly above mid-H, AVB compressed laterally; VB straight; LV overlaps RV with maximum at DB; surface smooth.

Remarks: The *Bairdia* sp.4 is similar to figure of *Bairdia (Urobairdia) angustus recta*

Monostori, 1995 from Spathian, Early Triassic of South China (Crasquin-Soleau et al., 2006), and from Anisian, Middle Triassic of Dobrogea, Romania (Crasquin-Soleau and Gradinaru, 1996). However, this present species has shorter posterior part and less laterally compressed at PVB than *Bairdia (Urobairdia) angustus recta*.

Bairdia sp.5

Plate 2, Figure 15

Material: 2 complete carapaces

Dimensions: L = 0.70 mm, H = 0.45 mm, H/L = 0.64

Occurrence: sample 15MK14, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace plump, elongated and pointed-posterior end in lateral view; DB broadly convex in LV; AB broadly rounded with large radius of curvature, AVB convex; VB slightly concave; PVB slightly convex, PDB straight in RV; surface smooth.

Remarks: The *Bairdia* sp.5 is differ from *Bairdia* sp.4 (this work) by their carapace shorter and less pointed-posterior end than *Bairdia* sp.4.

Bairdia sp.6

Plate 3, Figure 1-4

Material: 26 complete carapaces, 28 broken carapaces

Dimensions: L = 0.56 – 0.93 mm, H = 0.32 – 0.55 mm, H/L = 0.57 - 0.62

Occurrence: sample 15MK05, 15MK07, 15MK09, 15MK10, 15MK11, 15MK13, 15MK14, 15MK15, 15MK16 and 15MK17, Middle Triassic, Pha Kan Formation, Wat

Phra That Muang Kham section, Northern Thailand.

Description: The *Bairdia* sp.6 is characterized by a long carapace in lateral view with a long straight DB and almost parallel with VB; ADB straight, AB rounded with large radius of curvature and maximum convexity located at mid-H, AVB straight; VB straight; PVB convex, PB rounded with small radius of curvature and maximum convexity located near mid-H, PDB straight; LV overlaps RV; surface smooth.

Remarks: The *Bairdia* sp.6 differs from another *Bairdia* species in this work by having a long straight DB.

Bairdia sp.7

Plate 3, Figure 5-7

Material: 23 complete carapaces, 14 broken carapaces

Dimensions: L = 0.41 – 0.88 mm, H = 0.24 – 0.52 mm, H/L = 0.59 - 0.63

Occurrence: sample 15MK05, 15MK09, 15MK11, 15MK13, 15MK14 and 15MK15, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by a broadly convex DB; ADB and AVB straight to slightly convex, AB rounded with small radius of curvature and maximum convexity located at mid-H; VB straight to slightly concave; PB rounded with small radius of curvature and maximum of convexity located below mid-H, PVB convex, PDB slightly straight to convex; LV slightly overlaps RV; surface smooth.

Bairdia sp.8

Plate 3, Figure 9

Material: 1 complete carapace, 1 broken carapace

Dimensions: L = 0.52 – 0.65 mm, H = 0.34 – 0.41 mm, H/L = 0.63 - 0.65

Occurrence: sample 15MK05 and 15MK15, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by a broadly convex DB; ADB slightly convex, AB rounded with small radius of curvature and maximum of convexity located below mid-H, AVB straight and steep; VB slightly straight; PVB straight, PB rounded with maximum of convexity located below mid-H, PDB convex; LV overlaps RV; surface smooth.

Bairdia sp.9

Plate 3, Figure 10

Material: 2 broken carapaces

Occurrence: sample 15MK05, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by a pointed posterior end and DB broadly convex; AB rounded with large radius of curvature and maximum of convexity located at mid-H, AVB convex; VB slightly straight; LV overlaps RV; surface smooth.

Bairdia sp.10

Plate 3, Figure 11

Material: 7 complete carapaces, 4 broken carapaces

Dimensions: L = 0.60 mm, H = 0.29 mm, H/L = 0.48

Occurrence: sample 15MK09, 15MK10, 15MK11, 15MK14 and 15MK17 Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace elongated; AB rounded and inclined to ventral border, ADB and AVB convex; VB straight; PB blunted; surface smooth.

Genus *Bairdiacypris* Bradfield, 1935

Type-species *Bairdiacypris deloi* Bradfield, 1935

Bairdiacypris sp.

Plate 1, Figure 13-15

Material: 18 complete carapaces, 7 broken carapaces

Dimensions: L = 0.47 – 0.86 mm, H = 0.22 – 0.41 mm, H/L = 0.45 – 0.49

Occurrence: sample 15MK11, 15MK13, 15MK14 and 15MK16, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by bean-shaped and elongated carapace in lateral view; LV overlaps RV strongly at dorsal border; DB convex; ADB convex, AB rounded with small radius of curvature and maximum convexity located at mid-H, AVB truncated; VB straight or slightly concave; PVB convex, PB rounded with large radius of curvature and maximum of convexity located at mid-H, PDB slightly convex; surface smooth.

Remarks: This species is similar with both *Bairdiacypris anisica* Kozur, 1971 and *Bairdiacypris galbruni* Crasquin-Soleau and Gradinaru, 1996. The *B. anisica* and *B. galbruni* were reported from several areas including Felsöörs, Hungary: Late Anisian (Kozur, 1971b; Monostori, 1995); Romania: ?Middle Triassic (Salaj and Jendrejáková, 1984); Dobrogea (Romania): Early to Middle Anisian (Crasquin-Soleau and Gradinaru, 1996; Sebe et al., 2013); Meishan, South China: Late Permian to Early Triassic (Griesbachian) (Crasquin et al., 2010; Forel and Crasquin, 2011b); South Tibet: Early to Middle Triassic, Olenekian-Anisian (Forel and Crasquin, 2011a; Forel et al., 2011); Balaton Highland, Hungary: Middle Triassic, Ladinian (Monostori and Tóth, 2013); Schneeberg, Austria: Middle Anisian (Mette et al., 2014).

Genus *Nodobairdia* Kolloman, 1963

Type-species *Nodobairdia mammilata* Kolloman, 1963

Nodobairdia sp.1

Plate 3, Figure 12-15

Material: 2 complete carapaces, 6 broken carapaces

Dimensions: L = 0.70 – 0.85 mm, H = 0.38 – 0.46 mm, H/L = 0.50 – 0.54

Occurrence: sample 15MK10, 15MK13, 15MK14 and 15MK15, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: This species is characterized by DB pretty extending horizontally; ADB flat and sloping to the anterior end, AB pointed and located above mid-H, AVB sloping downwards; VB horizontal to slightly curve; surface smooth with nodes at antero-dorsal, postero-dorsal and antero-median of lateral surface of carapace.

Remarks: *Nodobairdia* sp.1 is poorly preserved and differ from *Nodobairdia mammilata* Kollmann, 1963 from Late Norian to Rhaetian of Australia (Dépêche and Crasquin-Soleau, 1992) by the weaker nodes on the lateral surface of carapace.

Nodobairdia sp.2

Plate 4, Figure 8

Material: 1 broken carapace

Dimensions: L = 0.55 mm, H = 0.31 mm, H/L = 0.56

Occurrence: sample 15MK07, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: This species is characterized by DB straight; ADB straight, AB pointed, AVB straight and parallel with PDB; ventral border straight; a pointed posterior end; surface smooth with some nodes at mid-dorsal, antero-dorsal and antero-median of lateral surface.

Remarks: This species is differ from *Nodobairdia* sp.1 by the position of nodes on the lateral surface of carapace.

Nodobairdia sp.3

Plate 4, Figure 9

Material: 1 broken carapace

Occurrence: sample 15MK13, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Remarks: The specimens of this species is differ from *Nodobairdia* sp.1 and *Nodobairdia* sp.2 by the position of nodes on the lateral surface of carapace and also poorly preserved, so it cannot be identified at specific level.

Genus *Petasobairdia* Chen, 1982

Type-species *Petasobairdia bicornuta* Chen, 1982

Petasobairdia sp.

Plate 4, Figure 10

Material: 1 complete carapace

Dimensions: L = 0.88 mm, H = 0.52 mm, H/L = 0.59

Occurrence: sample 15MK11, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by the presence of dorsal blade at LV; ADB and AVB straight; VB slightly straight to slightly concave on RV; PVB slightly convex, PB pointed with small radius of curvature and maximum convexity located below mid-H, PDB straight; LV overlaps RV and strongly at dorsal border; surface smooth.

Remarks: The *Petasobairdia* sp. differs from *Petasobairdia collini* Forel, 2011 from Early Anisian, Middle Triassic of Tulong section, Southern Tibet (Forel and Crasquin, 2011a). In *Petasobairdia* sp. (this work) the maximum of convexity of PB located below mid-H and also lack the detail at AB, then it cannot be identified at species level.

Genus *Lobobairdia* Kolloman, 1963

Type-species *Lobobairdia salinaria* Kolloman, 1963

Lobobairdia sp.

Plate 4, Figure 11-13

Material: 3 complete carapaces, 17 broken carapaces

Dimensions: L = 0.72 – 0.78 mm, H = 0.45 – 0.54 mm, H/L = 0.63 – 0.74

Occurrence: sample 15MK07, 15MK09, 15MK11, 15MK13, 15MK14, 15MK15, 15MK16 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: These material are characterized by carapace bloated in the central area and flattened at AVB and PVB; DB strongly convex at both valves; ADB straight at both valves, AB rounded with medium radius of curvature and maximum convexity located at mid-H; VB gently concave at RV and straight at LV; PB rounded with small radius of convexity and maximum located below mid-H, PDB straight at both valves; LV overlaps RV; surface smooth.

Remarks: This species is close to *Lobobairdia levis* Kozur, 1971 from Middle Triassic of Slowakia (Kozur, 1971a). However, the present specimens show indistinctly the furrows and the size between the present species and *Lobobairdia levis* are also different (*L. levis*: H = 0.67-0.72 mm; L= 1.00-1.08 mm).

Genus *Fabalicypris* Cooper, 1946

Type-species *Fabalicypris wileyensis* Cooper, 1946

Fabalicypris sp.

Plate 1, Figure 11

Material: 15 complete carapaces, 2 broken carapaces

Dimensions: L = 0.47 mm, H = 0.22 mm, H/L = 0.47

Occurrence: sample 15MK07, 15MK09, 15MK11, 15MK13, 15MK14 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: The present species is characterized by tumid carapace, elongate-elliptical in lateral view; DB gently arched; PB rounded; PDB gently convex, PVB straight and inclined toward VB; AVB convex, AB rounded with maximum of convexity located at mid-H, ADB convex; surface smooth.

Remarks: This species is very close to *Fabalicypris* cf. *parva* Wang, 1978 sensu Forel et al., 2013 from Bükk Mountains, Hungary (Forel et al., 2013) in outline and carapace size.

Family **ACRATIIDAE** Gründel, 1962

Genus *Acratia* Delo, 1930

Type-species *Acratia typica* Delo, 1930

Acratia sp.

Plate 1, Figure 12

Material: 9 complete carapaces, 8 broken carapaces

Dimensions: L = 0.43 – 0.51 mm, H = 0.21 – 0.24 mm, H/L = 0.47 – 0.49

Occurrence: sample 15MK09 and 15MK11, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace sub-elliptical in lateral view; DB short and gently convex; PDB convex and inclined toward posterior border, PB rounded with small radius of convexity, maximum of convexity located below mid-H, PVB convex; ventral border slightly convex; AVB and ADB convex, AB rounded with small radius of convexity, maximum of convexity located below mid-H; surface smooth.

Remarks: *Acratia* sp. is close to the *Acratia* cf. *symmetrica* Hao, 1992 *sensu* Forel and Crasquin, 2011 from Early to Middle Triassic, Olenekian-Anisian of South Tibet (Forel and Crasquin, 2011a) in outline.

Suborder **METACOPINA** Sylvester-Bradley, 1961

Superfamily **HEALDIOIDEA** Harlton, 1933

Family **HEALDIIDAE** Harlton, 1933

Genus *Hungarella* Méhes, 1911

Type-species *Bairdia? problematica* Méhes, 1911

Hungarella sp.

Plate 4, Figure 1-7

Material: 59 complete carapaces, 77 broken carapaces

Dimensions: L = 0.32 – 0.61 mm, H = 0.22 – 0.36 mm, H/L = 0.57 – 0.75

Occurrence: sample 15MK01, 15MK02, 15MK03 and 15MK04, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace sub-ovate in lateral view; LV overlaps RV especially at dorsal and ventral border; DB broadly convex in both valves; AB rounded with large radius of convexity and maximum of convexity located at mid-H, ADB and AVB convex; VB broadly convex and parallel with dorsal border in both valves; PB rounded with large radius of convexity, PVB convex and steep, PDB convex; surface smooth.

Order **PLATYCOPIDA** Sars, 1866

Suborder **PLATYCOPINA** Sars, 1866

Superfamily **CYTHERELLOIDEA** Sars, 1866

Family **CYTHERELLIDAE** Sars, 1866

Genus *Leviella* Sohn, 1968

Type-species *Leviella bentori* Sohn, 1968

Leviella sp.

Plate 2, Figure 1 and Plate 5, Figure 1-5

Material: 11 complete carapaces, 9 broken carapaces

Dimensions: L = 0.42 – 0.62 mm, H = 0.27 – 0.38 mm, H/L = 0.51 – 0.71

Occurrence: sample 15MK04, 15MK07, 15MK09, 15MK11, 15MK13, 15MK14 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace suboval to subrectangular in lateral view; DB straight to slightly convex; ADB and AVB convex, AB broadly rounded with maximum of convexity below or at mid-H; VB straight to slightly convex and parallel with DB; PVB and PDB convex, PB rounded with maximum of convexity at mid-H; RV overlaps LV all around the carapace; inflated medio-lateral area by two long and parallel ridges, inter-ridges area depressed; surface smooth.

Remarks: The present species is differ from all discovered species of the genus *Leviella* shon, 1968. However, this genus has been reported from several areas: Julian/Tuvalian of Italy (Lieberman, 1979), Carnian of Israel (Sohn, 1968) and Rhaetian of Austria (Mette et al., 2012).

Superfamily **CAVELLINOIDEA** Egorov, 1950

Family **CAVELLINIDAE** Egorov, 1950

Genus *Bektasia* Sohn, 1968

Type-species *Reubenella avnimelechi* Sohn, 1968

Bektasia sp.

Plate 5, Figure 6-9

Material: 10 complete carapaces, 3 broken carapaces

Dimensions: L = 0.52 – 0.65 mm, H = 0.27 – 0.31 mm, H/L = 0.48 – 0.52

Occurrence: sample 15MK09, 15MK11, 15MK13, 15MK14, 115MK16 and 15MK17, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Description: Carapace elongate, rectangular to sub-rectangular in lateral view, slightly tapered posterior end; dorsal border long, straight to slightly convex; AB rounded with maximum of convexity located at mid-H, ADB convex, AVB convex and inclined to ventral border; VB straight and shorter than DB; PVB and PDB convex, PB rounded to almost vertical with smaller radius of convexity than AB; short and deep median sulcus; surface smooth.

Remarks: The present species is close to *Bektasia Khanehkatensis* Crasquin-Soleau and Teherani, 1995 from the Early Carnian, Late Triassic of West Iran (Crasquin-Soleau and Teherani, 1995) but the material of this work is more elongated.

Order **MYODOCOPIDA** Sars, 1866

Suborder **CLADOCOPINA** Sars, 1866

Family **POLYCOPIDAE** Sars, 1866

Genus *Polycope* Sars, 1866

Type-species *Polycope orbicularis* Sars, 1866

Polycope sp.

Plate 4, Figure 14-15

Material: 7 complete carapaces, 1 broken carapace

Dimensions: L = 0.26 – 0.34 mm, H = 0.26 – 0.35 mm, H/L = 0.87 – 1.04

Occurrence: sample 15MK11 and 15MK13, Middle Triassic, Pha Kan Formation, Wat Phra That Muang Kham section, Northern Thailand.

Remarks: These present specimens are assigned to the genus *Polycope* by sub-circular outline and dorsal border straight or almost straight.

CHAPTER V

CONCLUSION AND DISCUSSION

5.1 Palaeoenvironmental interpretation and palaeogeography

5.1.1 Distribution of ostracods along the studied section

Twenty four species of the ostracods of the Wat Phra That Muang Kham section are recovered from 15 samples of 15 levels (Figure 5.1) and are belonged to 6 Superfamilies including Bairdioidea, Healdioidea, Cavellinoidea, Cytherelloidea, Cypridoidea, and Polycopidae (Figure 5.2). The most abundant Superfamily is Bairdioidea which consisted of genus *Bairdia*, *Bairdiacypris*, *Nodobairdia, Lobobaidia*, *Fabalicypris, Petasobairdia, and Acratia.* They appear from the upper part (samples 15MK05-15MK17) of the studied section. The proportions of species number in the Bairdioidea are varied from 44.23% to 100%. The second abundant Superfamily is Healdioidea which consisted of a single genus *Hungarella.* It appears only at the lower part of the studied section (samples 15MK01-15MK04). The proportions of species number in the Healdioidea are varied from 98.11% to 100%. The Cavellinoidea (genus *Bektasia*) is found in samples 15MK09, 15MK11, 15MK13, 15MK14, 15MK16, and 15MK17. The proportions of Cavellinoidea are varied from 0.84% to 8.33%. The Cytherelloidea (genus *Leviella*) is found in samples 15MK04, 15MK07, 15MK09, 15MK11, 15MK13, and 15MK17. The proportions of Cytherelloidea are varied from 1.89% to 23.68%. The Cypridoidea (genus *Paracypris*) and *Triassocypris*) is found in samples 15MK07-15MK09 and 15MK11-15MK17. The proportions of

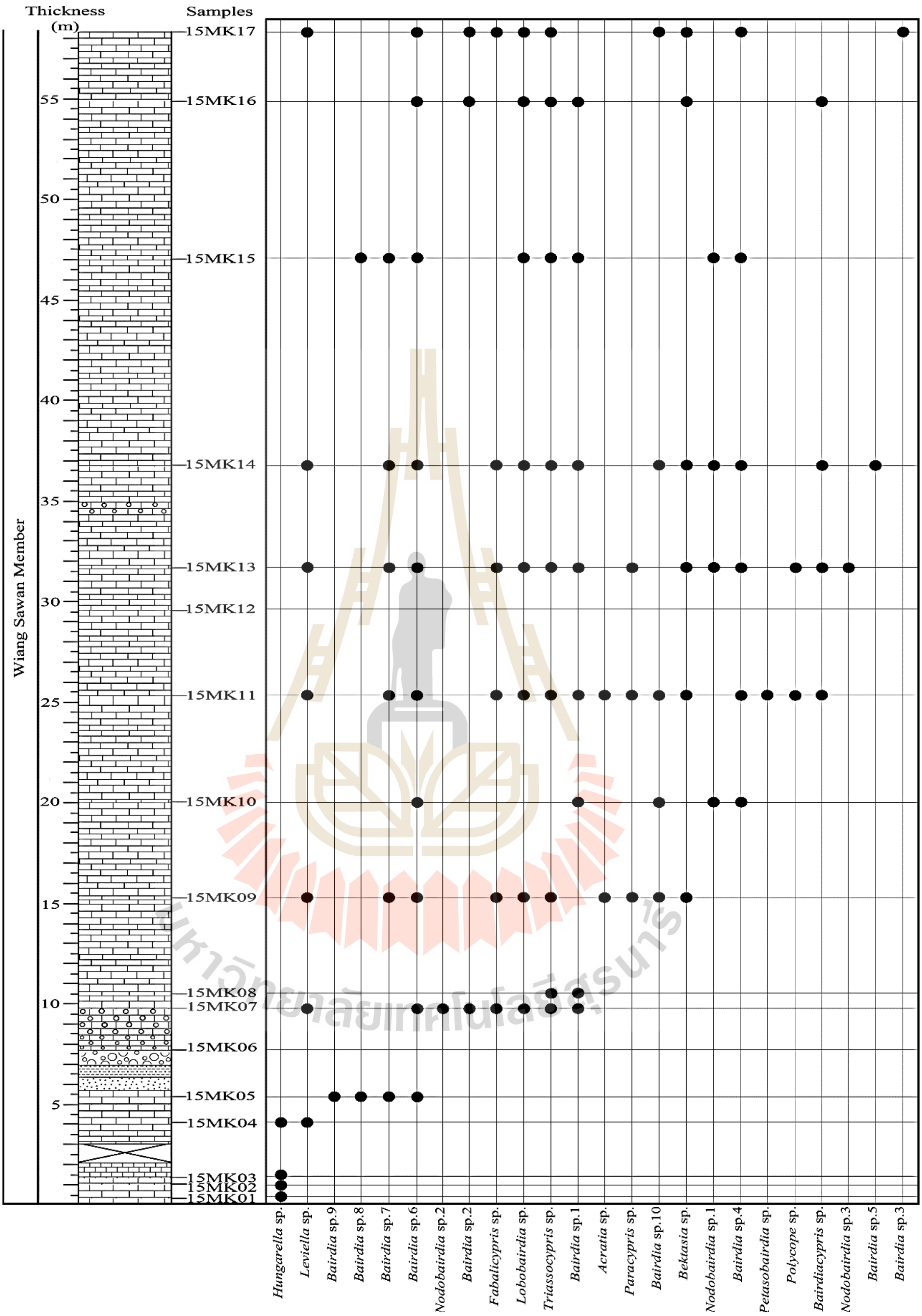


Figure 5.1 Distribution of ostracod species at the Wat Phra That Muang Kham section.

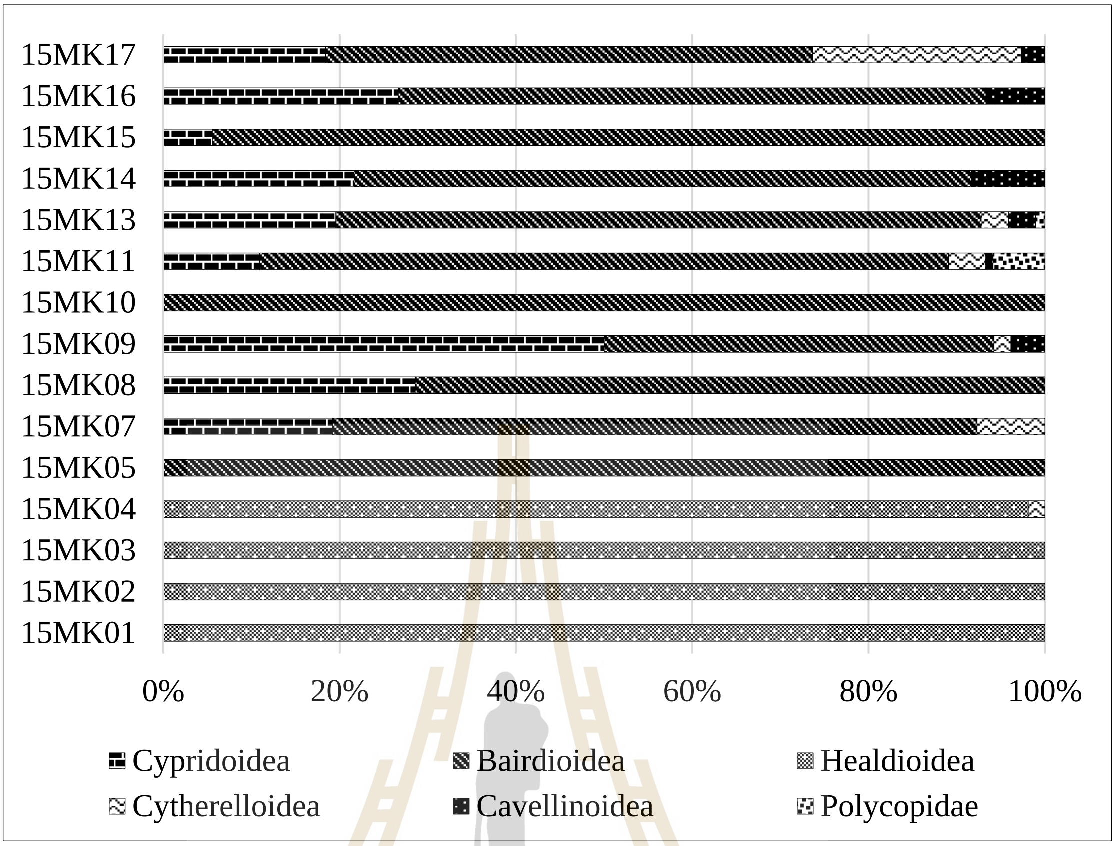


Figure 5.2 Distribution of ostracods at Superfamily/Family along the studied section.

Cypridoidea are varied from 5.56% to 50%. The Polycopidae (genus *Polycope*) is found in only two samples: 15MK11 (5.88%) and 15MK13 (1.03%).

5.1.2 Palaeoenvironmental interpretation by ostracod assemblage

The ostracods are important indicator of palaeoenvironmental interpretation based on their carapace characteristic and the composition of the ostracod assemblages, the palaeoenvironment of Wat Phra That Muang Kham section can be summarized as follows. The palaeoenvironment of the studied section can be interpreted by the ostracod assemblages (Melnyk and Maddocks, 1988a,b; Crasquin-Soleau et al., 1999; 2005;

2006; Forel et al., 2011). According to Figure 5.2, the assemblages along the section are varied and can be classified into two groups, the lower and the upper parts.

The lower part is dominated by the Healdioidea with minor Cytherelloidea (samples 15MK01-15MK04). *Hungarella* the only genus representing the Healdioidea and indicating nearshore, muddy environment is found in sample 15MK01-15MK04. In sample 15MK04, *Leviella* sp. (Cytherelloidea) is suggested for euryhaline environments in shallow waters.

The upper part is assigned for sample 15MK05 and above according to presence of Bairdioidea, Cytherelloidea, Cypridoidea, Cavellinoidea and Polycopidae. Sample 15MK05 and 15MK10 consist of 100% of the Bairdioidea. Member of these Bairdioidea ostracods have elongate-ovate, thick carapaces which suggest preference of living on soft, muddy carbonate substrate, in subtidal environment. The diversity increases between samples 15MK07-15MK13 and the highest diversity is at level 15MK11. The diversified assemblage represents more stable environment and slightly offshore. The uppermost part (from 15MK14-15MK17) is occupied by Bairdioidea, Cypridoidea and Cavellinoidea which suggest the shallower environment than the earlier stage.

On the other hand, if we consider the ostracod assemblages as a whole, the percentage of ostracod species at Superfamily and Family level of the studied section consists of Bairdioidea 54.56%, Healdioidea 23.14%, Cytherelloidea 3.55%, Cypridoidea 15.20%, Cavellinoidea 2.20% and Polycopidae 1.35% (Figure 5.3).

The overall composition points out the palaeoenvironment of Wat Phra That Muang Kham section is dominated by two Superfamilies. The Healdioidea recovered at the lower part of the studied section can indicate the nearshore muddy environment.

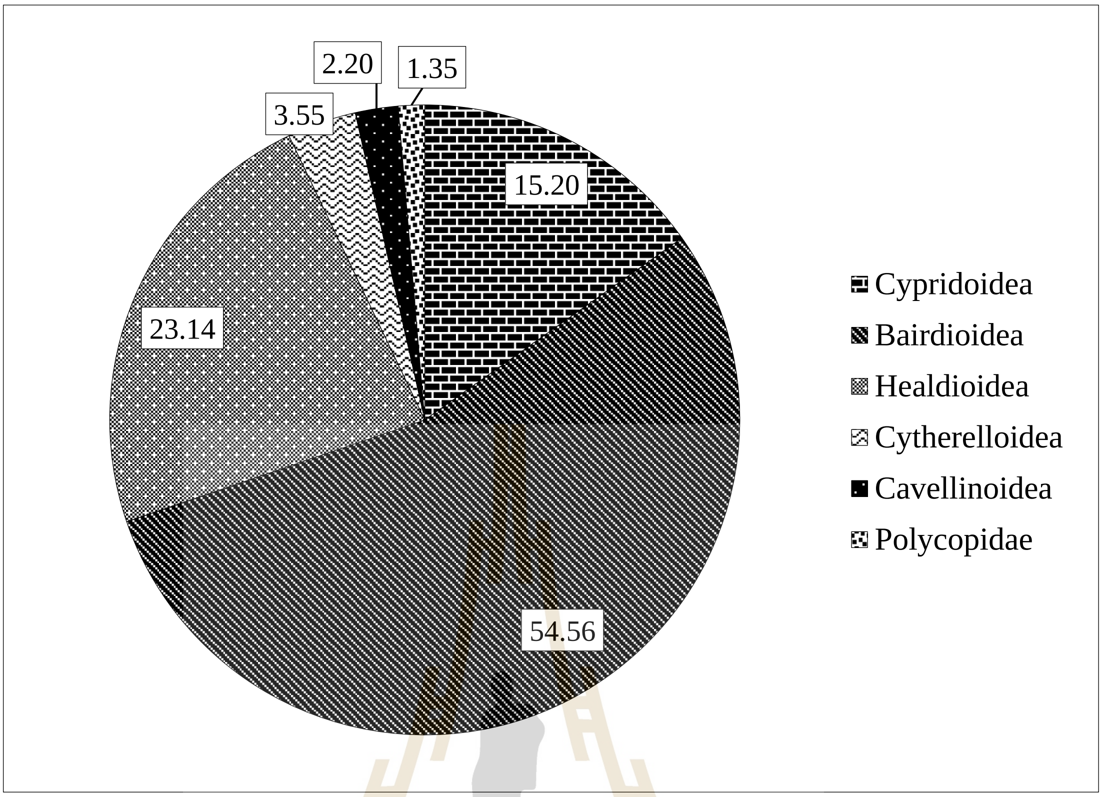


Figure 5.3 Percentage of ostracod at Superfamily/Family level in the studied section.

The highest diversities tend to occur at the upper part of the section (sample 15MK05, 15MK07 to 15MK11, 15MK13 to 15MK17) which the Bairdioidea (genus *Bairdia, Bairdiacypris, Nodobairdia, Lobobaidia, Fabalicypris, Petasobairdia, Triassocypris, and Acratia*) is the most abundant, which indicates shallow shelf, open carbonate environment with normal salinity and deeper than the lower part. Cytherelloidea suggests euryhaline environments in shallow waters, and Paracyprididae indicates shallow to very shallow waters, euryhaline environment. The Cavellinidae represents shallow to very shallow, nearshore environment where as the Polycopidae are ubiquitous (Forel, 2012). The depositional environment seemed to be shallow at the lower part of the section and then changed to deeper in the upper part. However, in the uppermost of the section, the condition slightly changed where sea level decreased again but not as shallow as in the lower part.

Almost the specimens of this study are represented by closed carapaces which indicate limited transportation, soft substratum and relatively high rate of sedimentation (Oertli, 1971). This assemblage consists a mixture of adult and juvenile stages which indicates a low-energy thanatocoenosis (Boomer et al., 2003).

5.1.3 Palaeoenvironmental interpretation by carbonate microfacies

The carbonate microfacies and depositional model of the Lampang Group were described in Chaodumrong (1992) and Chaodumrong and Rao (1992) based on the microlithology, type of allochems, bedding type, palaeontology and facies associations. The petrographic classification of carbonate rocks according to Dunham (1962) and Flügel (2004) as summarized below.

For the present work, lithology of the Wat Phra That Muang Kham section with the oncolitic limestone beds corresponds to the Wiang Sawan Member of the Pha Kan Formation. The rock thin sections of the rock samples 15MK02 and 15MK17 were prepared to represent microfacies of the lower and the upper parts of the studied section. The petrographic classification of carbonate rocks according to Dunham (1962) and Flügel (2004) and the characteristics of microfacies of the studied section are summarized as follows.

The sample 15MK02 (Figure 5.4) is characterized by thin- to medium-bedded, gray wackestone to packstone, consists of spongiostromate oncoinds with some bioclast (e.g. ostracods) and cemented by mainly sparry calcite. This sample is closely related to Microfacies C2 (Onclitic peloidal packstone) that interpreted as accumulated in shaol to back ramp environment and the abundance of algae, oncoinds and fauna assemblages suggest as in a shallow marine environment within a photic zone and this microfacies occurs mainly in the Wiang Sawan Member at the Phra That Muang Kham temple (Chaodumrong, 1992 and Chaodumrong and Rao, 1992).

The sample 15MK17 (Figure 5.5) is characterized by medium-to thick bedded, gray mudstone to wackestone, consists mainly of dasyclad fragments in fine- grained matrix. As Wilson and Jordan (1983) and Flügel (2004) described that dasycladacean algae are relatively to salinity variation and common found in shallow environment of less than 5 m depth. Then, this rock sample closely related to Microfacies C10 (Dasycladacean grainstone) that interpreted as deposited in a marine shoal (landward) environment and restricted to the Wiang Sawan Member of the Pha Kan Formation (Chaodumrong, 1992 and Chaodumrong and Rao, 1992).

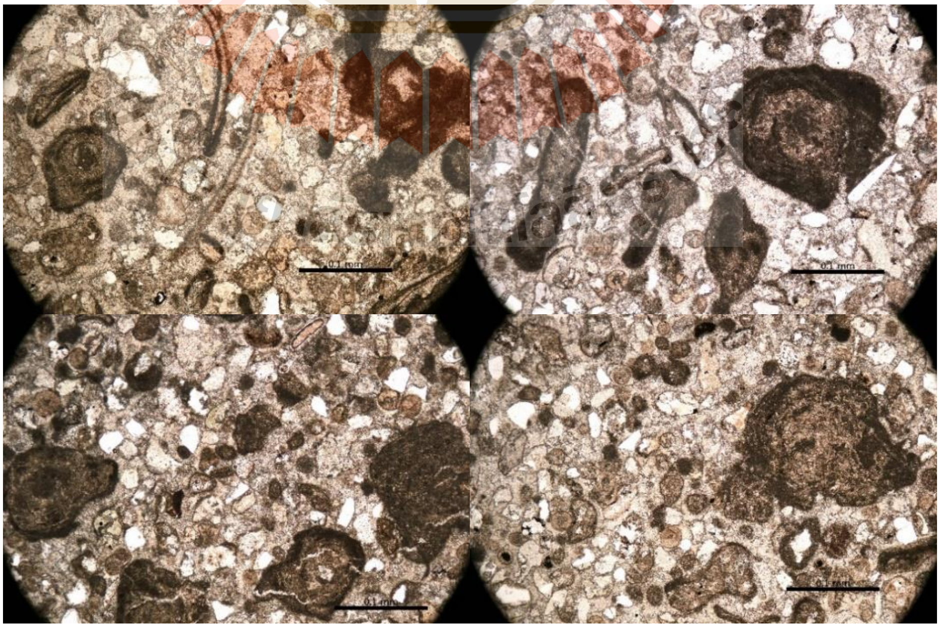


Figure 5.4 Photomicrographs of sample 15MK02.

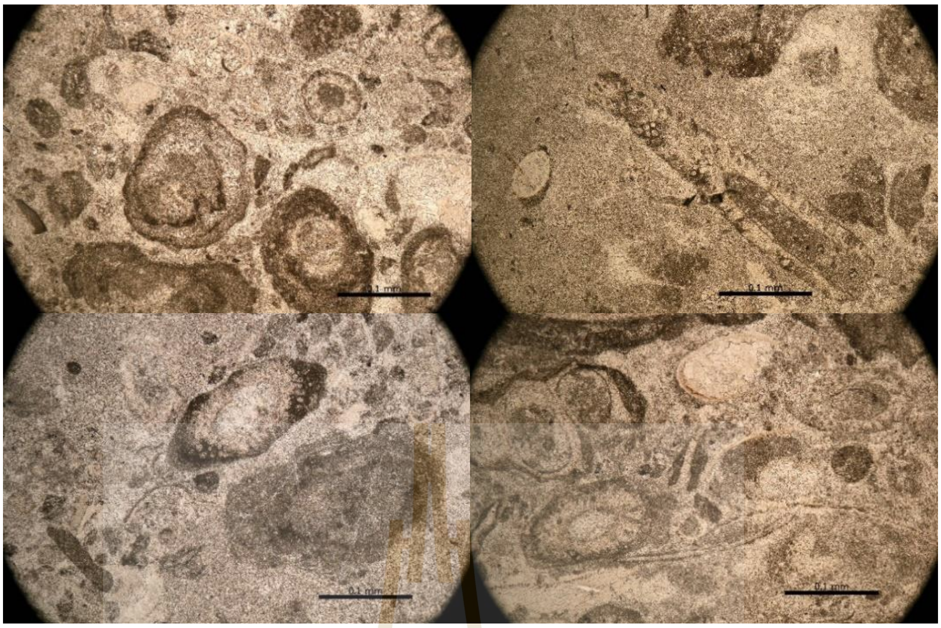


Figure 5.5 Photomicrographs of sample 15MK17.

5.2 Conclusion on palaeoenvironment of the studied section

Based on the ostracod assemblages found in the studied section are typical of intertropical warm waters (Crasquin-Soleau et al., 1999; 2004) and the microfacies of the Wat Phra That Muang Kham section, the palaeoenvironment can be summarized as follows.

The environment at the Wat Phra That Muang Kham section are divided into two part. The first part extends from samples 15MK01 to 15MK04 and corresponds to the euryhaline environments in shallow/very shallow waters. The second part extends from samples 15MK05 to 15MK17 and corresponds to the open marine carbonate environment. However, the depositional environment seemed to be shallow at the lower part of the section and then changed to deeper in the upper part where sea level decreased again but not as shallow as in the lower part. Therefore, this study found that the ostracod assemblages correspond to the microfacies analysis that suggested the studied section deposited in a shallow ramp and shaol (landward) environment of shallow marine environment.

5.3 Discussion on palaeogeography and age of the studied section

Based on the palaeontological evidences consist of ammonoids, bivalves, conodonts and small foraminifera (Chonglakmani and Grant-Mackie, 1993; Carey et al., 1995; Kobayashi et al., 2006) indicate the age of the lower and the upper boundary of Pha Kan Formation range from the Upper Induan up to the Anisian. In addition to the ostracod assemblages of the Wat Phra That Muang Kham section indicates that the depositional time span of the Wiang Sawan Member to Middle Triassic.

Several ostracod species recovered from the Wat Phra That Muang Kham section, Pha Kan Formation, Lampang Group are known from other areas during the Permian and Triassic time interval (Crasquin-Soleau et al., 2007; Crasquin and Forel, 2014). According to ostracod fauna from studied section have relationships with other Triassic sites in Paleo-Tethys region especially with South China (Ketmuangmoon et al., 2018) can be suggested the importance of the migration of ostracods during the Triassic of Sukhothai terrane.

REFERENCES

Agarwal, P. N., Singh, S. N., and Ashok, S. (1980). Scythian ostracodes from Kashmir Himalayas. **Journal of the Palaeontological Society of India**. 23 (24): 110-114.

Armstrong, H. A. and Brasier, M. D. (2005). **Microfossils** (2nd ed.). United Kingdom: Blackwell Publishing. 296 pp.

Baird, W. (1845). Arrangement of the British Entomostraca, with a list of species, particularly noticing those which have as yet been discovered within the bounds of the Club. **History of the Berwickshire Naturalists' Club 2**. 145-158.

Boomer, I., Horne, D. J., and Slipper, I. J. (2003). The use of Ostracodes in Paleoenvironmental Studies, or What can you do with an ostracod shell?. **Paleontological Society Papers**. 9: 153-180.

Bradfield, H. H. (1935). Pennsyvanian Ostracoda of Ardmore Basin, Oklahoma. **Bulletin of American Paleontology**. 22: 1-145.

Bunza, G. and Kozur, H. (1971). Beiträge zur Ostracodenfauna der tethyalen Trias. **Geologisch-Paläontologische Mitteilungen Innsbruck**. 1 (2): 1-76.

Buravas, S. (1961). Stratigraphy of Thailand. **Proceedings of the 9th Pacific Science Congress, 1957**. 12: 301-305. Bangkok: Geology and Geophysics.

Carey, S. P., Burrett, C., Chaodumrong, P., Wongwanich, T., and Chonglakmani, C. (1995). Triassic and Permian conodonts from the Lampang and Ngao Groups, Northern Thailand. **Sonderdruck aus CFS-Courier Frankurt am Main**. 142: 497-513.

Chaodumrong, P. (1992). Stratigraphy, sedimentology and tectonic setting of the Lampang Group, central north Thailand. **Unpublished Ph.D. Thesis.** University of Tasmania.

Chaodumrong, P. and Burrett, C. (1997). Stratigraphy of the Lampang Group in Central North Thailand: New Version. **CCOP Technical Bulletin**. 26: 65-80.

Chaodumrong, P. and Rao, P. (1992). Depositional Environments of Triassic Carbonates, Lampang Group, Central North Thailand. In Pianchareon, C. (ed.). **Proceedings of a National Conference on Geologic Resources of Thailand: Potential for Future Development** (pp. 355-367). Bangkok, Thailand: Department of Mineral Resources.

Charoenprawat, A., Chuaviroj, S., Hinthong, C., and Chonglakmani, C. (1994). **Geological map of Thailand on 1: 250,000 scale: sheet Changwat Lampang (NE 47-7).** Bangkok: Department of Mineral Resources.

Chitnarin, A., Thanee, N., Crasquin-Soleau, S., and Chonglakmani, C. (2006). First Discovery of Middle Triassic (Anisian) Ostracodes from the Pha Kan Formation, Northern Thailand. In Lüer, V., Hollis, C., Campbell, H., and Simes, J. (eds.). **InterRad 11 & Triassic Stratigraphy Symposium** (p. 15 in Abstract). Wellington, New Zealand: Institute of Geological and Nuclear Science.

Chen, D. Q. and Shi, C. G. (1982). Latest Permian ostracoda from Nantong, Jiangsu and from Miannyang, Hubei. **Bulletin of Nanjing Institut of Geology and Palaeontology, Academia Sinica**. 4: 105– 152.

Chonglakmani, C. (1981). The systematics and biostratigraphy of Triassic bivalves and ammonoids of Thailand. **Unpublished Ph.D. Thesis.** Geology Department, University of Auckland.

Chonglakmani, C. (1999). The Triassic system of Thailand: implications for the paleogeography of Southeast Asia. In Ratanasthien, B. and Rieb, S. L. (eds.). **Proceedings of the international symposium on Shallow Tethys (ST) 5** (pp. 486–496). Department of Geological Science, Chiang Mai University: Chiang Mai.

Chonglakmani, C. (2011). Triassic. In Ridd, M. F., Barber, A. J., and Crow M. J. (eds.). **The Geology of Thailand** (pp. 137-150). The Geological Society of London.

Chonglakmani, C. and Grant-Mackie, J. A. (1993). Biostratigraphy and facies variation of the marine Triassic sequences in Thailand. In Thanasuthipitak, T. (ed.). **Proceedings of International Symposium on Biostratigraphy of Mainland Southeast Asia: Facies and Paleontology (BIOSEA)** (vol.1, pp. 97-123). Chiang Mai, Thailand.

Cooper C. L. 1946. Pennsylvanian ostracodes of Illinois. **Illinois State Geological Survey Bulletin**. 70: 1-177.

Crasquin, S. and Forel, M.-B. (2013). Ostracods (Crustacea) through Permian–Triassic events. **Earth-Science Reviews**. 137: 52-64.

Crasquin-Soleau, S. and Gradinaru, E. (1996). Early Anisian ostracode fauna from the Tulca Unit (Cimmerian) North Dobrogean Orogen, Romania. **Ann. Paleont. (Vertebrate-Invertebrate)**. 82 (2): 59-116.

Crasquin-Soleau, S. and Kershaw, S. (2005). Ostracod fauna from the Permian–Triassic boundary interval of South China (Huaying Mountains, eastern Sichuan Province): Palaeoenvironmental significance. **Palaeogeography, Palaeoclimatology, Palaeoecology**. 217 (1-2): 131-141.

Crasquin-Soleau, S. and Teherani, K. (1995). Première découverte d'ostracodes triasiques dans la formation de Khaneh Kat, Montagne Michparvar (Ouest Iran). **Revue de Micropaléontologie**. 38: 27-36.

Crasquin-Soleau, S., Broutin, J., Roger, J., Platel, J.-P., Hashmi, H. A., Angiolini, L., Baud, A., Bucher, H., and Marcoux, J. (1999). First Permian Ostracode Fauna from the Arabian Plate (Khuff Formation, Sultanate of Oman). **Micropaleontology**. 45 (2): 163-182.

Crasquin-Soleau, S., Marcoux, J., Angiolini, L., Richoz, S., Nicora, A., Baud, A., and Bertho, Y. (2004). New ostracod fauna from Permian-Triassic boundary in Turkey (Taurus, Antalya Nappes). **Micropaleontology**. 50: 281-295. Flushing, NY.

Crasquin-Soleau, S., Vaslet D., and Le Nindre Y. M. (2005). Ostracods from Permian-Triassic boundary in Saudi Arabia (Khuff Formation). **Palaeontology**. 48: 853-868.

Crasquin-Soleau S., Galfetti T., Brayard, A., and Bucher H. (2006). Paleoeclogical change after the end Permian mass extinction: Early Triassic ostracods from South China. **Rivista Italiana di Paleontologia e Stratigrafia**. 112 (1): 55-75.

Crasquin-Soleau, S., Galfetti, T., Bucher, H., Kershaw, S., and Feng, Q. (2007). Ostracod fauna recovery in the aftermath of Permian–Triassic crisis: dating of the Palaeozoic–Mesozoic turnover**. Hydrobiologia**. 585: 13–27.

Crasquin, S., Perri, M. C., Nicora, A., and De Wever, P. (2008). Ostracods across the Permian–Triassic boundary in Western Tethys: the Bulla parastratotype (Southern Alps, Italy). **Rivista Italiana di paleontologia e Stratigrafia**. 114 (2): 235–264.

Crasquin, S., Forel, M.-B., Qinglai, F., Aihua, Y., Baudin, F., and Collin, P.-Y. (2010). Ostracods (Crustacea) through the Permian-Triassic boundary in South China: the Meishan stratotype (Zhejiang Province). **Journal of Systematic Palaeontology**. 8 (3): 331-370.

Delo, D. M. (1930). Some Upper Carboniferous Ostracoda from the shale basin of Western Texas. **Journal of Paleontology**. 4: 152-178.

Department of Mineral Resources. (2014). Mesozoic. **Geology of Thailand**. Department of Mineral Resources, Ministry of Natural Resources and Environment. Bangkok, Thailand. 113-157.

Dépêche, F. and Crasquin-Soleau, S. (1992). Triassic marine ostracodes of the Australian margin (holes 795B, 760B, 761C, 764A, and 764B). In von Rad, U., Haq, B. U., Kidd, R. B., and O′Connell, S. (eds.). **Proceedings of the Ocean Drilling Program, Scientific Result** (vol. 122, pp. 453-462). College Station, TX (Ocean Drilling Program).

Dunham, R. J. (1962). Classification of carbonate rocks according to depositional texture. In Ham, W. E. (ed.). **Classification of carbonate rocks** (pp. 108-121). American Association of Petroleum Geologists Memoir.

Egorov, V. G. (1950). Frasnian ostracods from Russian platform. I. Kloedenellitidae. **VNIGRI** (All Russia Petroleum Research Exploration Institut). 175 p.

Flügel, E. (2004). **Microfacies of Carbonate Rocks**. Germany: Springer. 976 p.

Forel, M.-B. (2012). Ostracods (Crustacea) associated with microbialites across the Permian-Triassic boundary in Dajiang (Guizhou Province, South China). **European Journal of Taxonomy**. 18: 1-34.

Forel, M.-B. and Crasquin, S. (2011a). In the aftermath of Permian-Triassic boundary mass-extinction: new ostracod (Crustacea) genus and species from South Tibet. **Geodiversitas**. 33 (2): 247-263.

Forel, M.-B. and Crasquin, S. (2011b). Lower Triassic ostracods (Crustacea) from the Meishan section, Permian–Triassic boundary GSSP (Zhejiang Province, South China). **Journal of Systematic Palaeontology**. 9 (3): 455-466.

Forel, M.-B., Crasquin, S., Kershaw, S., Feng, Q., and Collin, P. Y. (2009). Ostracods (Crustacea) and water oxygenation in earliest Triassic of South China: implications for oceanic events of the end-Permian mass extinction. **Australian Journal of Earth Sciences**. 56 (6): 815–823.

Forel, M.-B., Crasquin, S., Brühwiler, T., Goudemand, N., Bucher, H., Baud, A., and Randon, C. (2011). Ostracod recovery after Permian–Triassic boundary mass-extinction: The south Tibet record. **Palaeogeography, Palaeoclimatology, Palaeoecology**. 308: 160-170.

Forel, M.-B., Crasquin, S., Hips, K., Kershaw, S., Collin, P.-Y., and Haas, J. (2013). Biodiversity evolution through the Permian-Triassic boundary event: Ostracods from the Bükk Mountains, Hungary. **Acta Palaeontol. Pol**. 58 (1): 195-219.

Goel, R., Kozur, H., and Srirvastava, S. S. (1984). Middle Anisian (Pelsonian) Ostracoda from Spiti (Himachal Pradesch), India. **Geoscience Journal**. 5: 53–62.

Gründel, J. (1962). Zur Taxionomie der Ostracoden der Gattendorfia-Stufe Thüringens. **Freiberger Forschungshefte C**. 151: 51–105.

Gümbel, C. W. (1869). Über Foraminiferen, Ostracoden und mikroskopische Thier Überreste in den St. Cassianer and Raibler Schichten. **Jb. KK geol. Reichsans. Wien.** 19: 175-186.

Hao, W. (1996). Ostracods from the Upper Permian and Lower Triassic of the Zhenfeng Section, South China. **Journal of Geoscience, Osaka City University**. 39 (2): 19-27.

Harlton, B. H. (1933). Micropaleontology of the Pennsylvanian Johns Valley Shale of Ouachita Mountains, Oklahoma and its relationships to the Mississippian Caney Shale. **Journal of Paleontology**. 7: 3-29.

Honigstein, A. and Crasquin, S. (2011). Late Scythian-Anisian ostracods (Crustacea) from the Meged-2 borehole, central Israel. **Journal of Micropalaeontology**. 30 (1): 17-31.

Horne, D. J., Cohen, A., and Martens, K. (2002). Taxonomy, Morphology and Biology of Quaternary and Living Ostracoda. In Holmes, J. A. and Chivas, A. (eds.). **The Ostracoda: applications in Quaternary Research** (vol. 131, pp. 5-36). Washington, DC: American Geophysical Union.

Ketmuangmoon, P., Chitnarin, A., Forel, M.-B., and Tepnarong, P. (2018). Diversity and paleoenvironmental significance of Middle Triassic ostracods (Crustacea) from northern Thailand: Pha Kan Formation (Anisian, Lampang Group). **Revue de Micropaléontologie**. 61: 3-22.

Kobayashi, F., Martini, R., Rettori, R., Zaninetti, L., Ratanasthien, B., Saegusa, H., and Nakaya, H. (2006). Triassic foraminifers of the Lampang Group (Northern Thailand). **Journal of Asian Earth Sciences**. 27: 312-325.

Kollmann, K. (1960). Ostracoden aus der alpinen Trias Österreichs. I. Parabairdia n. g. und Ptychobairdia n. g. (Bairdiidae). **Jahrbuch der Geologischen Bundesanstalt**. 5: 79–105.

Kollmann, K. (1963). Ostracoden aus der Trias. II. Weitere Bairdiidae. **Jahrbuch der**

Geologischen Bundesanstalt. 106: 121–203.

Kozur, H. (1968). Neue Ostracoden aus dem Rot und Muschelkalk des germanschen Binnenbeckens. **Monatsber Deutsche Akademie Wissenschaften**. Berlin. 10 (7). 498-519.

Kozur, H. (1970). Neue Ostracoden-Arten der germanischen Mittel-und Obertrias. **Geologie.** 19 (4): 434-455.

Kozur, H. (1971a). Die Bairdiacea der Trias. Teil I: Skulpturierte Bairdiidae aus Mitteltriassischen Flachwasser. **Geologisch Paläontologische Mitteilungen Innsbruck**. 1 (3): 1–27.

Kozur, H. (1971b). Die Bairdiacea der Trias. Teil III: Einige neue Arten triassischer Bairdiacea und Bemerkungen zur Herkunft der Macrocyprididae (Cypridacea). **Geologisch-Paläontologische Mitteilungen Innsbruck**. 1 (6): 1-18.

Kristan-Tollmann, E. (1978). Bairdiidae (Ostracoda) aus den obertriadischen Cassianer Schichten der Ruones-Wiesen bei Corvara in Süd Tirol. **Erdwissenschaftliche Kommission Österreichische Akademie der Wissenschaften.** 4: 77-104.

Kristan-Tollmann, E. (1991). Ostracods from the Middle Triassic Sina Formation (Aghdarband Group) in NE Iran. **Abh. Geol. Bundes**. 38: 195-200.

Kristan-Tollmann, E., Lobitzer, H., and Solti, G. (1991). Mikropaläontologie und Geochemie der Kössener Schichten des Karbonatplattform-Becken-Komplexes Kammerköhralm–Steinplatte (Tirol/Salzburg). In Lobitzer, H. and Császár, G. (eds.). **Jubiläumsschrift 20 Jahre Geologische Zusammenarbeit Österreich – Ungarn** (pp. 155-191). Wien, Austria: Geologische Bundesanstalt.

Kummel, B. (1960). Triassic ammonoids from Thailand. **Journal of Paleontology**. 39: 682-694.

Latreille, P. A. (1806). **Genera crustaceorum et insectorum: secundum ordinem naturalem in familias disposita, iconibus exemplisque plurimis explicate**. Koenig, Paris. 302 p.

Lethiers, F. (1981). Ostracodes du Dévonien terminal de l'Ouest du Canada: Systématique, biostratigraphie et paléoécologie. **Géobios**. 5: 234 p.

Lethiers, F. and Crasquin-Soleau, S. (1988). Comment extraire des microfossiles à tests calcitiques de roches calcaires dures. **Revue de Micropaléontologie**. 31 (1): 56–61.

Lieberman, H. M. (1979). Die Bivalven- und Ostracodenfauna von Raibl und ihr stratigraphischer Wert. **Verh. Geol. B.-A**. 2: 85-131.

McCoy, F. (1844). **A synopsis of the characters of the Carboniferous Limestone fossils of Ireland**. Dublin University Press, Dublin. 207 p.

Méhes, G. (1911). Über Trias-Ostrakoden aus dem Bakony. In Resultate der Wissenschaftlichen. Erforschung des Balatonsees. **Palaeontologie der Umgebung des Balatonsees**. 3 (6): 1-38.

Melnyk, D. H. and Maddocks, R. F. (1988a). Ostracode biostratigraphy of the Permo-Carboniferous of central and north-central Texas, Part I: paleoenvironmental framework. **Micropaleontology**. 34: 1-20.

Melnyk, D. H. and Maddocks, R. F. (1988b). Ostracode biostratigraphy of the Permo-Carboniferous of central and north-central Texas, Part II: ostracode zonation. **Micropaleontology**. 34: 21-40.

Mette, W., Elsler, A., and Korte, C. (2012). Palaeoenvironmental changes in the Late Triassic (Rhaetian) of the Northern Calcareous Alps: Clues from stable isotopes and microfossils. **Palaeogeography, Palaeoclimatology, Palaeoecology**. 350-

352: 62-72.

Mette, W., Honigstein, A., and Crasquin, S. (2014). Deep-water ostracods from the Middle Anisian (Reifling Formation) of the Northern Calcareous Alps (Austria). **Journal of Micropalaeontology**. 34: 71-91.

Monostori, M. (1995). Environmental Significance of the Anisian Ostracoda fauna from the Forras Hill near Felsoors (Balaton Highland, Transdamubia, Hungary). **Acta Geologica Hungarica**. 39 (1): 37-56.

Monostori, M. and Tóth, E. (2013). Ladinian (Middle Triassic) silicified ostracod faunas from the Balaton Highland (Hungary). **Rivista Italiana di Paleontologia e Stratigrafia**. 119: 303-323.

Moore, R. C. (1961). Ostracoda. In Moore, R. C. (ed.). **Treatise on Invertebrate Paleontoloy, Part Q, Arthropoda 3: Crustacea**. Lawrence, Kansas: Geological Society of America and University of Kensas Press. 442p.

Oertil, H. J. (1971). The aspect of Ostracode fauna-a possible new tool on petroleum sedimentology. In Oertli, H. J. (ed.). **Paléoécologie des Ostracodes** (pp. 137-151). Bull. Cent. Rech. Pau, SNPA.

Payne, J. L. and Clapham, M. E. (2012). End-Permian Mass Extinction in the Oceans: An Ancient Analog for the Twenty-First Century?. **Annual Review of Earth and Planetary Sciences**. 40 (1): 89-111.

Pitakpaiwan, K. (1955). Occurrences of Triassic formation at Mae Moh. Department of Mineral Resources. **Report of Investigation**. 1: 47-57.

Piyasin, S. (1971). Marine Triassic sediments of Northern Thailand. **Geological Society of Thailand Newsletter**. 4: 4-6.

Piyasin, S. (1972). Geology of the Lampang quadrangle sheet NE 47-7, scale 1:

250,000. **Report of Investigation No. 14**. Bangkok: Department of Mineral Resources. 98p.

Pokorný, V. (1978). Ostracodes. In Haq, B. U. and Boersma, A. (eds.). **Introducton to marine micropaleontology** (pp. 109-149). New York: Elsevier.

Reuss, A. E. (1868). Palaeontologische Beiträge (Zweite Folge). Foraminiferen und Ostracoden aus den schichten von St. Cassian. **Sitzungsber. König.-kaiserl. Akad. Wissen. Wien**. 1: 101-108.

Royal Thai Survey Department. (1999). **Topographic map sheet Amphoe Mae Thaa** (4945 III), scale 1: 50000, series L7018, edition 1-RTSD. Bangkok.

Sars, G. O. (1865). Norges Ferskvandskrebsdyr. Ferste Afsnit Branchiopoda. I. Cladocera Ctenopoda (Sididae and Holopedidae). **Christiania**. 1-79.

Sars, G. O. (1866). Oversigt af marine Ostracoder. **Forhandlinger Videnskabs-Selskabet Christiania 1865**. 1-130.

Sars, G. O. (1922-1928). Ostracoda. **An account of the Crustacea of Norway.** Bergen, Norway: Bergen Museum. 9. 277 p.

Salaj, J. and Jendrejáková, O. (1984). Ecology and facial relation of some groups of Triassic foraminfers and ostracods of stratigraphic importance. **Geologica Carpathica**. 35 (2): 231-240.

Sebe, O-G, Crasquin, S., and Grădinaru, E. (2013). Early and Middle Anisian (Triassic) deep-water ostracods (Crustacea) from North Dobrogea (Romania). **Revue de Paléontologie**. 32 (2): 509-529.

Shi, C. and Chen, D. (1987). The Changhsingian ostracodes from Meishan Changxing, Zhejiang. **Stratigraphy and Palaeontology of Systmic Boundaries in China; Permian and Triassic Boundary**. 5: 23-80.

Singharajwarapan, S. and Berry, R. (2000). Tectonic implications of the Nan Suture Zone and its relationship to the Sukhothai Folded Belt, northernThailand. **Journal of Asian Earth Sciences**. 18: 663–673.

Sylvester-Bradley, P. C. (1961). Suborder Metacopina Sylvester-Bradley, n. suborder. (pp. 358-359). In Moore, R. C. (ed.). **Treatise on Invertebrate Paleontoloy, Part Q, Arthropoda 3: Crustacea**. Lawrence, Kansas: Geological Society of America and University of Kensas Press.

Sohn, I. G. (1968). Triassic Ostracodes from Makhtesh Ramon, Israel. **Geological Survey of Israel Bulletin**. 44: 1–71.

Sohn, I. G. (1970). Early Triassic Marine Ostracodes from the Salt Range and Surghar Range, West Pakistan. In Kummel, B. and Teichert, C. (eds.). **Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan** (pp. 149–206). Lawrence: Department of Geology, University of Kansas.

Sohn, I. G. (1987). Middle and Upper Triassic Marine Ostracoda from the Shublik Formation, Northeastern Alaska. **United States Geological Survey Bulletin 1664**. C1-C21.

Styk, O. (1972). Kilka ważniejszych nowych gatunków otwornic małżoraczków z osadów triasu Polski. **Kwartalnik Geologiczny**. 16 (4): 866-885.

Styk, O. (1990). Stratygrafia mikropaleontologiczna osadów retu i dolnego wapienia muszlowego w SW Polsce. **Kwartalnik Geologiczny**. 34 (4): 697-724.

Urlichs, M. (1971). Variability of some ostracods from the Cassian Beds (Alpine Triassic) depending on the ecology. In Oertli, H. J. (ed.). **Paléoécologie Ostracodes** (pp. 695-715). Bull. Centre Rech. Pau-S.N.P.A.

Wilson, J. L. and Jordan, C. (1983). Middle Shelf. In Scholle, P. A., Bebout, D. G., and

Moore, C. H. (eds.). **Carbonate Depositional Environments**. American Association of Petroleum Geologists, Memoir 33. 297-343.

Plate 1

Ostracods from the Wat Phra That Muang Kham section, Northern Thailand. All specimens are stored in the collections of Suranaree University of Technology (All scale bar is 100 µm).

Figure 1 – 5 *Paracypris*? sp.; **1** left lateral view of complete carapace, sample 15MK09, collection number SUT-17-0002; **2** left lateral view of complete carapace, sample 15MK09, collection number SUT-17-0001; **3** left lateral view of complete carapace, sample 15MK09, collection number SUT-17-0003; **4** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0009; **5** left lateral view of complete carapace, sample 15MK09, collection number SUT-17-0006.

Figure 6 – 10 *Triassocypris* sp.; **6** left lateral view of complete carapace, sample 15MK17, collection number SUT-17-0015; **7** left lateral view of complete carapace, sample 15MK17, collection number SUT-17-0011; **8** left lateral view of complete carapace, sample 15MK07, collection number SUT-17-0012; **9** left lateral view of complete carapace, sample 15MK09, collection number SUT-17-0010; **10** left lateral view of complete carapace, sample 15MK08, collection number SUT-17-0016.

Figure 11 *Fabalicypris* sp.; left lateral view of complete carapace, sample 15MK09, collection number SUT-17-0088.

Figure 12 *Acratia* sp.; right lateral view of complete carapace, sample 15MK09, collection number SUT-17-0089.

Figure 13 – 15 *Bairdiacypris* sp.; **13** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0069; **14** right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0070; **15** right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0071.

Plate 1

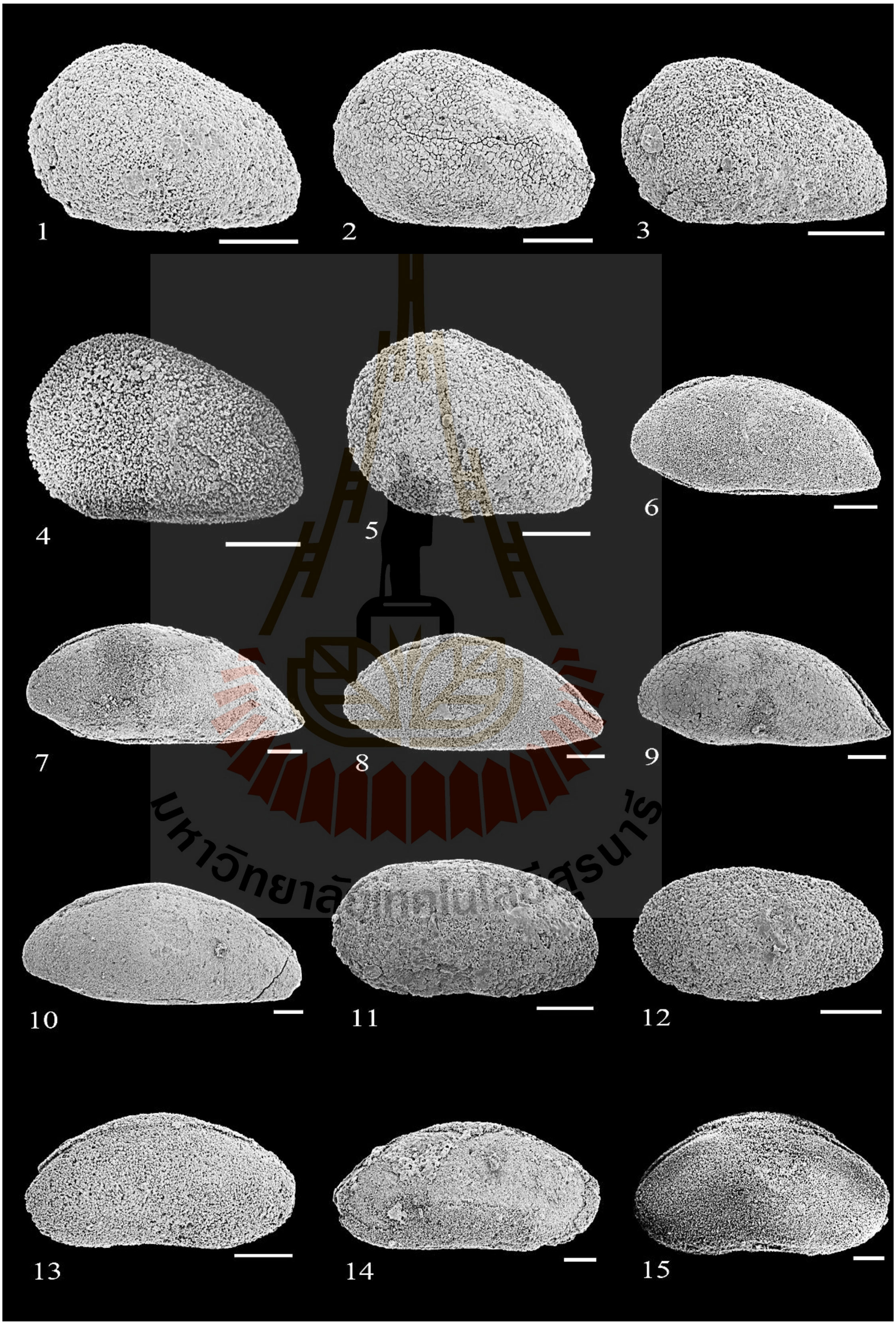


Plate 2

Ostracods from the Wat Phra That Muang Kham section, Northern Thailand. All specimens are stored in the collections of Suranaree University of Technology (All scale bar is 100 µm).

Figure 1 *Bektasia* sp.; right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0017.

Figure 2 – 6 *Bairdia* sp.1; **2** right lateral view of complete carapace, sample 15MK08, collection number SUT-17-0033; **3** right lateral view of complete carapace, sample 15MK08, collection number SUT-17-0036; **4** right lateral view of complete carapace, sample 15MK10, collection number SUT-17-0035; **5** right lateral view of complete carapace, sample 15MK10, collection number SUT-17-0037; **6** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0034.

Figure 7 – 8 *Bairdia* sp.2; **7** right lateral view of complete carapace, sample 15MK16, collection number SUT-17-0039; **8** right lateral view of complete carapace, sample 15MK07, collection number SUT-17-0040.

Figure 9 *Bairdia* sp.3; right lateral view of complete carapace, sample 15MK17, collection number SUT-17-0041.

Figure 10 – 14 *Bairdia* sp.4; **10** right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0044; **11** right lateral view of complete carapace, sample 15MK10, collection number SUT-17-0045; **12** right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0047; **13** right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0046; **14** right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0048.

Figure 15 *Bairdia* sp.5; right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0049.

Plate 2

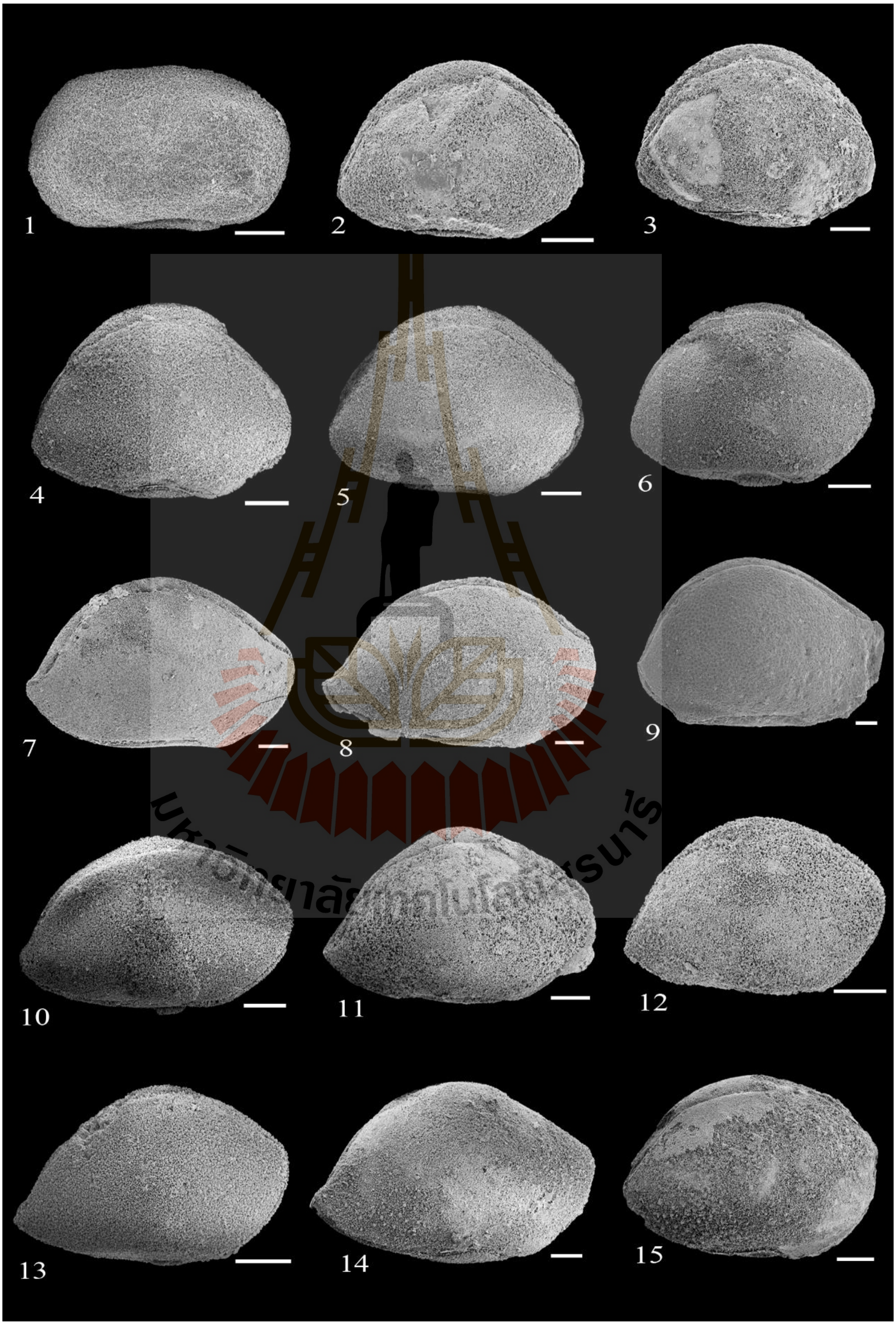


Plate 3

Ostracods from the Wat Phra That Muang Kham section, Northern Thailand. All specimens are stored in the collections of Suranaree University of Technology (All scale bar is 100 µm).

Figure 1 – 4 *Bairdia* sp.6; **1** right lateral view of complete carapace, sample 15MK15, collection number SUT-17-0053; **2** right lateral view of complete carapace, sample 15MK16, collection number SUT-17-0050; **3** right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0051; **4** right lateral view of complete carapace, sample 15MK05, collection number SUT-17-0052.

Figure 5-7 *Bairdia* sp.7; **5** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0054; **6** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0055; **7** right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0056.

Figure 8 *Bairdia* sp.1; right lateral view of complete carapace, sample 15MK15, collection number SUT-17-0060.

Figure 9 *Bairdia* sp.8**;** right lateral view of complete carapace, sample 15MK05, collection number SUT-17-0061.

Figure 10 *Bairdia* sp.9; right lateral view of complete carapace, sample 15MK05, collection number SUT-17-0062.

Figure 11 *Bairdia* sp.10; left lateral view of complete carapace, sample 15MK11, collection number SUT-17-0064.

Figure 12 – 15 *Nodobairdia* sp.1; **12** right lateral view of complete carapace, sample 15MK15, collection number SUT-17-0072; **13** right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0076; **14** right lateral view of complete

carapace, sample 15MK10, collection number SUT-17-0073; **15** right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0074.

Plate 3

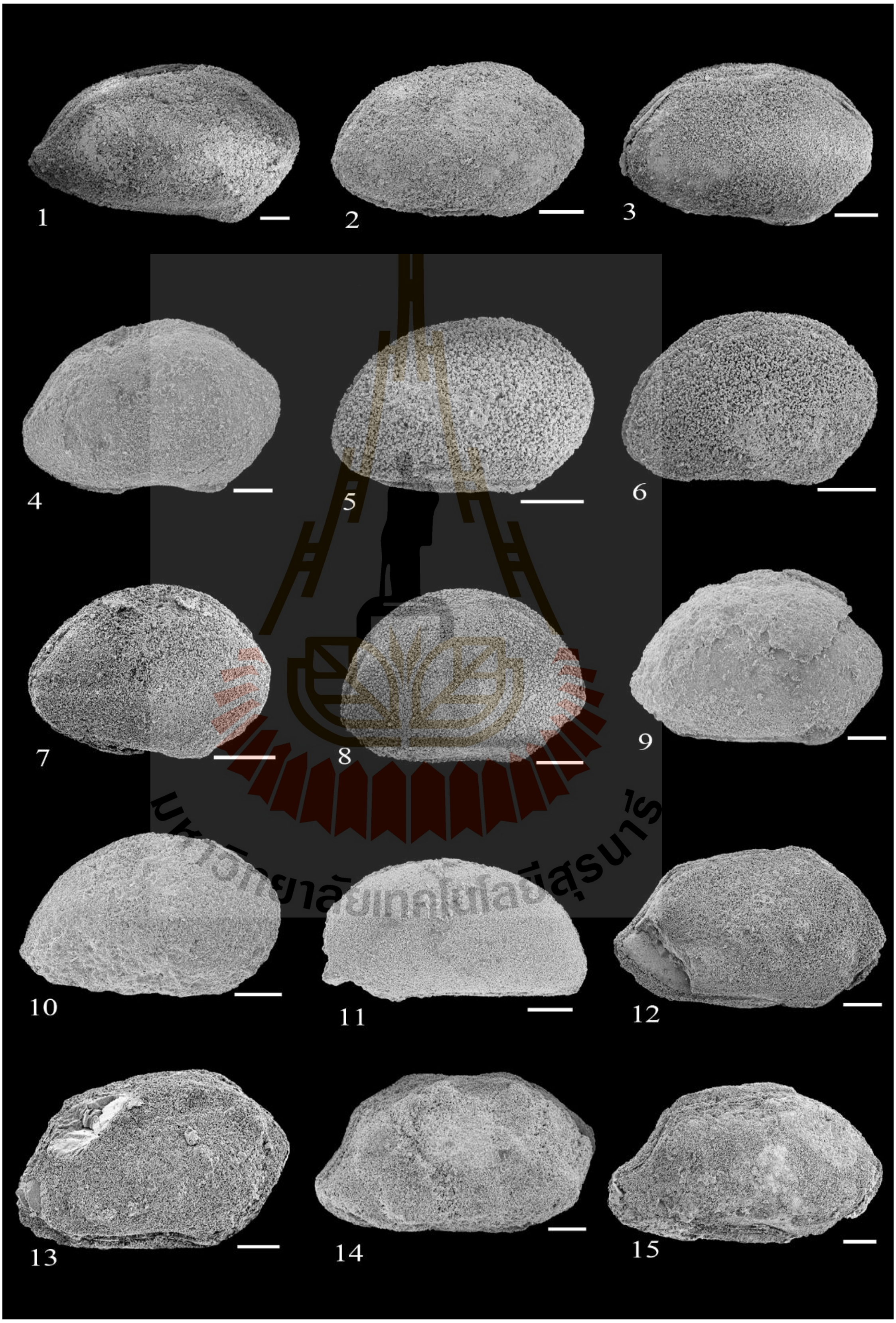


Plate 4

Ostracods from the Wat Phra That Muang Kham section, Northern Thailand. All specimens are stored in the collections of Suranaree University of Technology (All scale bar is 100 µm).

Figure 1 - 7 *Hungarella* sp.; **1** right lateral view of complete carapace, sample 15MK03, collection number SUT-17-0110; **2** right lateral view of complete carapace, sample 15MK04, collection number SUT-17-0113; **3** right lateral view of complete carapace, sample 15MK03, collection number SUT-17-0104; **4** right lateral view of complete carapace, sample 15MK03, collection number SUT-17-0093; **5** right lateral view of complete carapace, sample 15MK03, collection number SUT-17-0092; **6** right lateral view of complete carapace, sample 15MK03, collection number SUT-17-0099; **7** right lateral view of complete carapace, sample 15MK03, collection number SUT-17-0100.

Figure 8 *Nodobairdia* sp.2; left lateral view of complete carapace, sample 15MK07, collection number SUT-17-0077.

Figure 9 *Nodobairdia* sp.3; right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0080.

Figure 10 *Petasobairdia* sp.; right lateral view of broken carapace, sample 15MK11, collection number SUT-17-0086.

Figure 11 - 13 *Lobobairdia* sp.; **11** right lateral view of complete carapace, sample 15MK07, collection number SUT-17-0085; **12** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0081; **13** right lateral view of complete carapace, sample 15MK17, collection number SUT-17-0082.

Figure 14 – 15 *Polycope* sp.; **14** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0118; **15** left lateral view of complete carapace,

sample 15MK13, collection number SUT-17-0119.

Plate 4

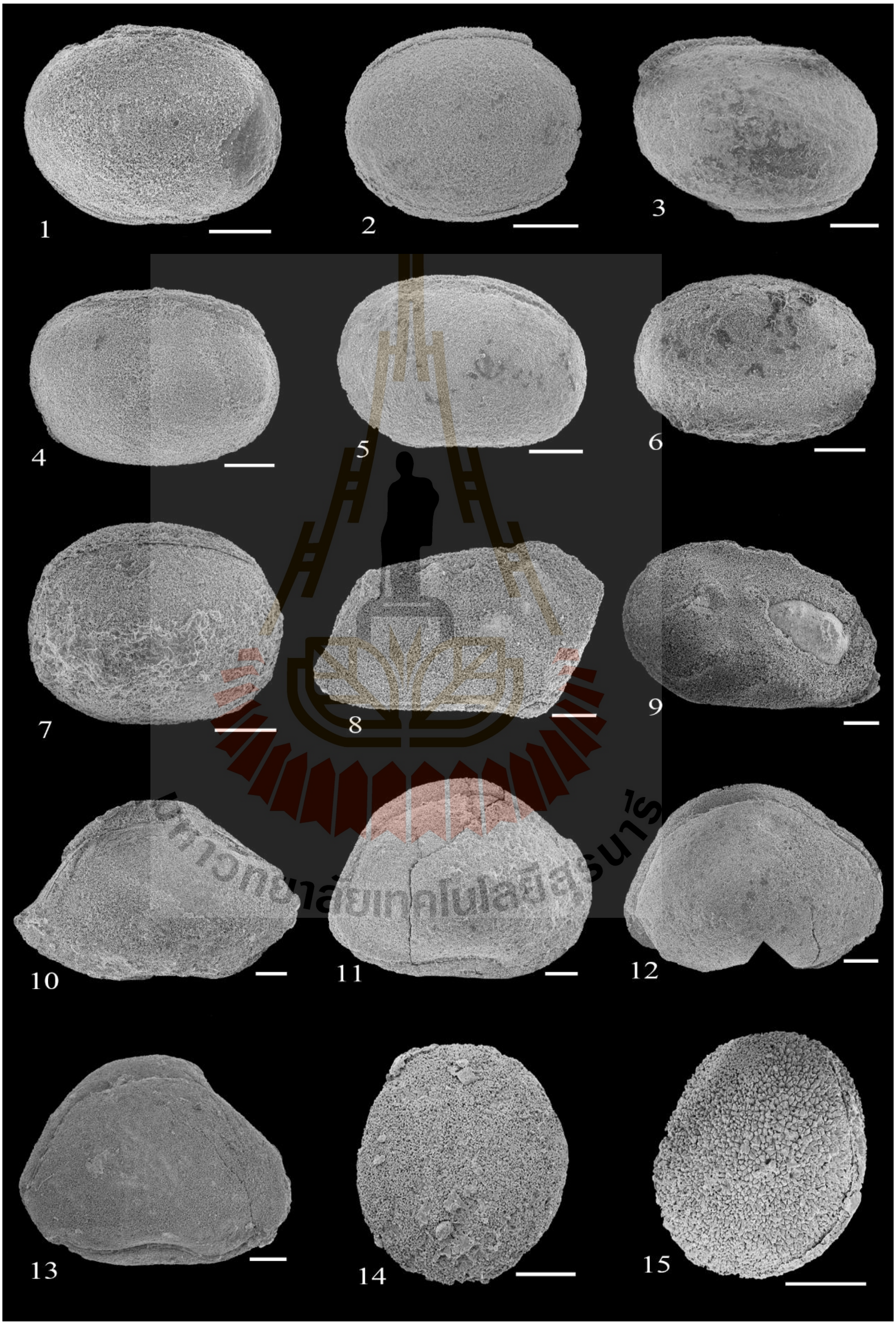


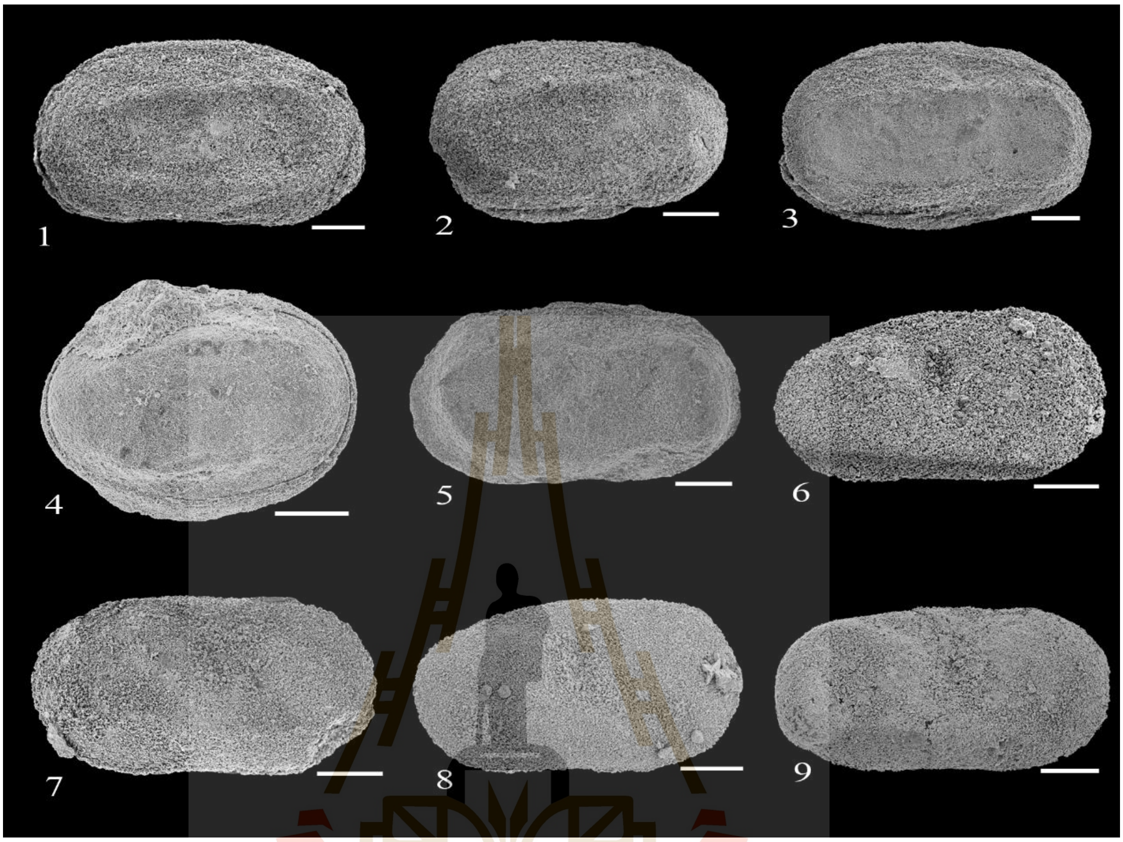
Plate 5

Ostracods from the Wat Phra That Muang Kham section, Northern Thailand. All specimens are stored in the collections of Suranaree University of Technology (All scale bar is 100 µm).

Figure 1-5 *Leviella* sp.; **1** right lateral view of complete carapace, sample 15MK17, collection number SUT-17-0027; **2** right lateral view of complete carapace, sample 15MK17, collection number SUT-17-0026; **3** right lateral view of complete carapace, sample 15MK17, collection number SUT-17-0025; **4** right lateral view of complete carapace, sample 15MK04, collection number SUT-17-0030; **5** right lateral view of complete carapace, sample 15MK09, collection number SUT-17-0032.

Figure 6-9 *Bektasia* sp.; **6** right lateral view of complete carapace, sample 15MK14, collection number SUT-17-0020; **7** right lateral view of broken carapace, sample 15MK09, collection number SUT-17-0021; **8** right lateral view of complete carapace, sample 15MK11, collection number SUT-17-0018; **9** right lateral view of complete carapace, sample 15MK13, collection number SUT-17-0019.

Plate 5



BIOGRAPHY

Miss Patteera Ketmuangmoon was born on October 14, 1991 in Phrae Province, northern Thailand. She was educated at Nareerat School Phrae before attending Chiang Mai University where she completed a Bachelor of Science degree in Geology in 2014. Then, she was a teacher assistant for School of Geotechnology and attended Master degree in Civil, Transportation and Geo-Resources Engineering, Institute of Engineering, Suranaree University of Technology in 2015.