ชีวานุกรมวิธานของซากดึกดำบรรพ์หอยฝาเดียวจากหมวดหินตากฟ้ายุคเพอร์เมียน
อำเภอตากฟ้าและอำเภอตาคลี จังหวัดนครสวรรค์

นายฉัตรเฉลิม เกษเวชสุริยา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาธรณีวิทยา ภาควิชาธรณีวิทยา
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2558

BIOSYSTEMATICS OF GASTROPODA FOSSIL FROM PERMIAN TAK FA FORMATION, AMPHOE TAK FA AND AMPHOE TAKHLI, CHANGWAT NAKHON SAWAN

Mr. Chatchalerm Ketwetsuriya

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Geology
Department of Geology
Faculty of Science
Chulalongkorn University
Academic Year 2015

Thesis Title	BIOSYSTEMATICS OF GASTROPODA FOSSIL FROM PERMIAN TAK FA FORMATION, AMPHOE TAK FA AND AMPHOE TAKHLI, CHANGWAT NAKHON SAWAN
By	Mr. Chatchalerm Ketwetsuriya
Field of Study	Geology
Thesis Advisor	Assistant Professor Pitsanupong Kanjanapayont, Dr.rer.nat.
Thesis Co-Advisor	Professor Alexander Nützel, Dr.rer.nat.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.....Dean of the Faculty of Science
(Associate Professor Polkit Sangvanich, Ph.D.)

THESIS COMMITTEE

.....Chairman
(Professor Montri Choowong, Ph.D.)

.....Thesis Advisor
(Assistant Professor Pitsanupong Kanjanapayont, Dr.rer.nat.)

.....Thesis Co-Advisor
(Professor Alexander Nützel, Dr.rer.nat.)

.....Examiner
(Assistant Professor Chirasak Sutcharit, Ph.D.)

.....External Examiner
(Apsorn Saardsud, Ph.D.)

ฉัตรเฉลิม เกษเวชสุริยา : ชีวานุกรมวิธานของซากดึกดำบรรพ์หอยฝาเดียวจากหมวดหินตากฟ้า ยุคเพอร์เมียน อำเภอตากฟ้าและอำเภอตาคลี จังหวัดนครสวรรค์ (BIOSYSTEMATICS OF GASTROPODA FOSSIL FROM PERMIAN TAK FA FORMATION, AMPHOE TAK FA AND AMPHOE TAKHLI, CHANGWAT NAKHON SAWAN) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. พิษณุพงศ์ กาญจนพยนต์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ศ. ดร. อเล็กซานเดอร์ นีสเซิล, 156 หน้า.

หินคาร์บอเนตในพื้นที่ศึกษา อำเภอตากฟ้าและอำเภอตาคลี จังหวัดนครสวรรค์ ถูกจัดอยู่ในหมวดหินตากฟ้าของกลุ่มหินสระบุรี หินโผลในพื้นที่ศึกษาถูกจัดทำลำดับชั้นหินทางกายภาพ โดยมีความหนาทั้งหมด 50 เมตร พร้อมทั้งเก็บตัวอย่างหินเพื่อนำไปศึกษาศิลาวรรณนาและซากดึกดำบรรพ์ หินที่พบประกอบไปด้วยหินปูนชั้นปานกลางถึงชั้นหนามาก หินโคลน หินโดโลไมต์ ร่วมกับหินเชิร์ตก้อนทรงมนและหินดินดานสีดำเทาแทรกสลับ ซากดึกดำบรรพ์ของสัตว์ไม่มีกระดูกสันหลังทะเลพบร่วมกันหลากหลายชนิด ได้แก่ ฟิวซูลินิด หอยสองฝา ปะการัง ฟองน้ำ สาหร่าย และไบรโอซัว โดยเฉพาะซากดึกดำบรรพ์หอยฝาเดียวที่มีความหลากหลาย ซากดึกดำบรรพ์หอยฝาเดียว 40 ชนิดถูกรายงาน โดย 17 ชนิดที่ถูกกำหนดชื่อวิทยาศาสตร์ และ 23 ชนิดกำหนดชื่อแบบเปิด หอยฝาเดียวกลุ่มนี้ ได้รับการกลุ่มสิ่งมีชีวิตชนิดนี้ปรากฏเป็นกลุ่มหอยฝาเดียวยุคเพอร์เมียนที่พบมากที่สุดจากเอเชียตะวันออกเฉียงใต้ 17 ชนิด และ 1 สกุล ถูกระบุชื่อใหม่ สกุลใหม่คือ *Takfaia* ชนิดพันธุ์ใหม่คือ *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Baylea*? *umbilicata*, *Takfaia kuesi*, *Glabrocingulum magnum*, *Knightinella ornata*, *Anomphalus lateumbilicatus*, *Yunnania pulchra*, *Microdoma carinata*, *Trachydomia takhliensis*, *Goniasma tricarinata* และ *Cambodgia acuminate* หอยฝาเดียวที่พบคือกลุ่มหอยฝาเดียวพาลีโอโซอิกตอนปลาย ประกอบด้วย bellerophontoids และ pleurotomariines เป็นส่วนใหญ่ ซากดึกดำบรรพ์หอยฝาเดียวในพื้นที่ศึกษาสามารถแบ่งได้ 3 กลุ่ม ได้แก่ *Bellerophon* sp. – *Glabrocingulum* sp. zone, *Stegocoelia* sp. และ Gastropod barren zone จากการศึกษาลักษณะปรากฏทางกายภาพของหินตะกอนร่วมกับซากดึกดำบรรพ์ พบว่าบริเวณพื้นที่ศึกษามีการสะสมตัวในสภาพแวดล้อมแบบบริเวณไหล่ทะเลสาบภายในลานคาร์บอเนต จากบริเวณตื้นถึงลึก

ภาควิชา ธรณีวิทยา ลายมือชื่อนิสิต .....

สาขาวิชา ธรณีวิทยา ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ปีการศึกษา 2558 ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

5771948723 : MAJOR GEOLOGY
KEYWORDS: TAK FA FORMATION, GASTROPOD, PERMIAN

CHATCHALERM KETWETSURIYA: BIOSYSTEMATICS OF GASTROPODA FOSSIL FROM PERMIAN TAK FA FORMATION, AMPHOE TAK FA AND AMPHOE TAKHLI, CHANGWAT NAKHON SAWAN. ADVISOR: ASST. PROF. PITSANUPONG KANJANAPAYONT, Dr.rer.nat., CO-ADVISOR: PROF. ALEXANDER NüTZEL, Dr.rer.nat., 156 pp.

The Permian carbonate rocks of the study area from Amphoe Tak Fa and Amphoe Takhli, Changwat Nakhon Sawan belong to the Tak Fa Formation, Saraburi Group. The exposures have been measured that totally reach a thickness of 50 meters and samples were collected for both petrographic study and paleontological investigation. The rock consists of bedded limestones, mudstones and dolomites, together with nodular cherts and intercalation of dark-grey shale, which comprise many marine invertebrate fossils such as fusulinids, pelecypods, corals, spongs, calcareous algae and bryozoa, especially a diversity of gastropod. Forty gastropod species are reported, among them 17 nominate species and 23 species in open nomenclature. Thus, this fauna represents one of the richest Permian gastropod faunas known from Southeast Asia. Twelve species and one genus are new to science. The new genus is *Takfaia*. The new species are *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Baylea*? *umbilicata*, *Takfaia kuesi*, *Glabrocingulum magnum, Knightinella ornata*, *Anomphalus lateumbilicatus*, *Yunnania pulchra*, *Microdoma carinata*, *Trachydomia takhliensis*, *Goniasma tricarinata* and *Cambodgia acuminata*. The gastropod fauna is dominated by typical Late Palaeozoic cosmopolitan genera with bellerophontoids and pleurotomariines being most abundant. They were subdivided into 3 assemblages, including *Bellerophon* sp. – *Glabrocingulum* sp. zone, *Stegocoelia* sp. and Gastropod barren zone. The study of carbonate facies and fauna indicates that the depositional environment was on shelf lagoon within the carbonate platform varying from shallow to deep marine.

Department:	Geology	Student's Signature	.....
Field of Study:	Geology	Advisor's Signature	.....
Academic Year:	2015	Co-Advisor's Signature	.....

ACKNOWLEDGEMENTS

The author would like to express his deepest gratitude to his thesis advisor, Assistant Professor Dr. Pitsanupong Kanjanapayont, Department of Geology, Faculty of Science, Chulalongkorn University for invaluable advices, suggestion and encourangement. Much appreciation is co – advisor, Professor Dr. Alexander Nützel, Bayerische Staatssammlung für Paläontologie und Geologie, Department of Earth and Environmental Sciences, Palaeontology & Geobiology, Geobio-Center LMU, for his valuable contributions on Permian gastropods, critical reading of the manuscript and many ideas that make this thesis possible. I sincerely thank the committee, Professor Dr. Montri Choowong, Assistant Professor Dr. Chirasak Sutcharit, and Dr. Apsorn Saardsud for their valuable comments to improve my thesis. Grateful acknowledgements are extended Miss Chawisa Phucharoenchaiwan, Mr. Watcharapon Sreyangnok and Mr. Chidchon Chidpayak for their helps with field investigation.

Financial support for this study was provided by the Development and Promotion of Science and Technology (DPST) and Junior Science Talent Project (JSTP).

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CHAPTER I

INTRODUCTION

Gastropods have evolved from the Cambrian to the Recent. Gastropods have been found in stratigraphic layers in Thailand and other countries. Palaeozoic limestones from variuos localities of Thailand have yielded numerous invertebrate fossils such as fusulinids, corals, brachiopods, bivalves, crinoids, sponges, conodonts and gastropods. There are several palaeontological studies but the information of Permian gastropods of Thailand is scarce. Grant (1976) reported platyceratids and pleurotomarioids from limestones of southern Thailand. Waterhouse (1982) studied an early Permian fauna from the Kaeng Krachan Group and mentioned *Peruvispira* sp. Sone (2010) reported the species *Magnicapitatus huazhangae* from the Guadalupian (Middle Permian) of East Thailand. Ketwetsuriya et al. (2014) reported twenty gastropod species from the Tak Fa Limestone, Nakhonsawan, Northern Thailand. This report was preliminary and treated the species in open nomenlature. Palaeontological study facilitates information about diversity, palaeoecology and palaeoenvironment.

The Permian rocks of the study area at Khao Noi, Khao Chai Thong, Khao Kwang and Khao Tum Pha Sawan, Amphoe Tak Fa and Amphoe Takhli, Changwat Nakhon Sawan belong to the Tak Fa Formation, Saraburi Group. This formation crops out in the Khao Khwang Platform and consists of late Palaeozoic carbonate platform deposits that covered Changwat Phetchabun, Changwat Lop Buri and Changwat Nakhon Sawan. The study area consists of limestones, argillaceous limestones, mudstones and dolomites with many invertebrate fossils; especially gastropods are highly diverse and widely distributed. Gastropod assemblages of the study area vary in each stratigraphic layer. The study of these assemblages in combination with the study of carbonate facies can indicate paleoenvironment. In summary, the study focuses on systematics, diversity, palaleoecology and biostratigraphy of these Permian gastropods.

1.1 The study area

1.1.1 Location

The study area is located at Khao Noi, Khao Chai Thong, Khao Chon Due, Khao Kwang and Khao Tum Pha Sawan in Amphoe Tak Fa and Amphoe Takhli, southeastern part of Changwat Nakhon Sawan (Figure 1.1). This area covers approximately 60 square kilometers and lies between the latitude 15° 19' 38" to 15° 16' 23" and longitude 100° 22' 42" to 100° 28' 18". The thesis area is located within the topographic map scale 1:50,000 of the Royal Thai Survey Department, sheet 5039 I, Amphoe Takhli, series L 7018, edition 2-RTSD (Figure 1.2).

1.1.2 Accessibility

Accessibility to the study area can be undertaken via convenient Highway no.1 or Phahon Yothin Highway. By following the Highway no.1 to Ban Khok Sung, then turn left and follow the Highway no.3331 for approximately 1.5 kilometers to Khao Chon Due. Going straight along Highway no.3331 until meet Ban Nong Phikun School, there is junction, turn right and follow the concrete road for approximately 2 kilometers to north wing of Khao Noi, in the area of Amphoe TaKhli, Changwat Nakhon Sawan. South wing of Khao Kwang is located behind Wat Khiri Wong Wararam situated left-hand side of the Highway no.1. Going straight along Highway no.1 to Ban Khao Chai Thong until meet T intersection, then turn right and follow the concrete road for approximately 2 kilometers to Wat Tham Pha Sawan, Khao Tum Pha Sawan is located behind. The last location is Khao Chai Thong, there is situated beside Wat Khao Chai Thong Wararam that can be accessed by the Highway no.1 that far about 2 kilometers from Khao Kwang in the north-eastern direction, in the area of Amphoe Tak Fa, Changwat Nakhon Sawan.

1.1.3 Physiography and Climate

The study area is located on the southern part of Changwat Nakhon Sawan. The topography of the study area is characterized by the rolling terrain and limestone hills. The average elevation of the study area lies between 40 to 350 meters above

mean sea level. There is only a small stream called “Huai Heang” passing through the northeastern part of the study area.

The climate of the study area is tropical grassland or savanna type with the rainy season ranges from May to October while the rest of the year is relatively dry. The average annual mean temperature is 30 degree Celsius.

1.2 Purposes of study

1.2.1 To describe the gastropod fossils in the study area.

1.2.2 To do the biostratigraphy of gastropoda fossil and discuss paleoenvironment in the study area.

1.3 Methodology

1.3.1 Literature survey

The review includes previous reports about geology and palaeontology (espeacially about gastropods), palaeoecology of the study area, other Permian occurrences in Thailand and other regions countries and geographic information such as topographic maps of the study area and adjacent regions.

1.3.2 Field Investigation, Collecting the specimens and stratigraphic work

1.3.2.1 *Reconnaissance field investigation*

Geological study was conducted in Amphoe Tak Fa and Amphoe Takhli, Changwat Nakhon Sawan for field investigation planning.

1.3.2.2 *Detailed field investigation;*

Data collecting for biostratigraphic study including the sampling of rock and fossil samples from the measured sections of the study area.

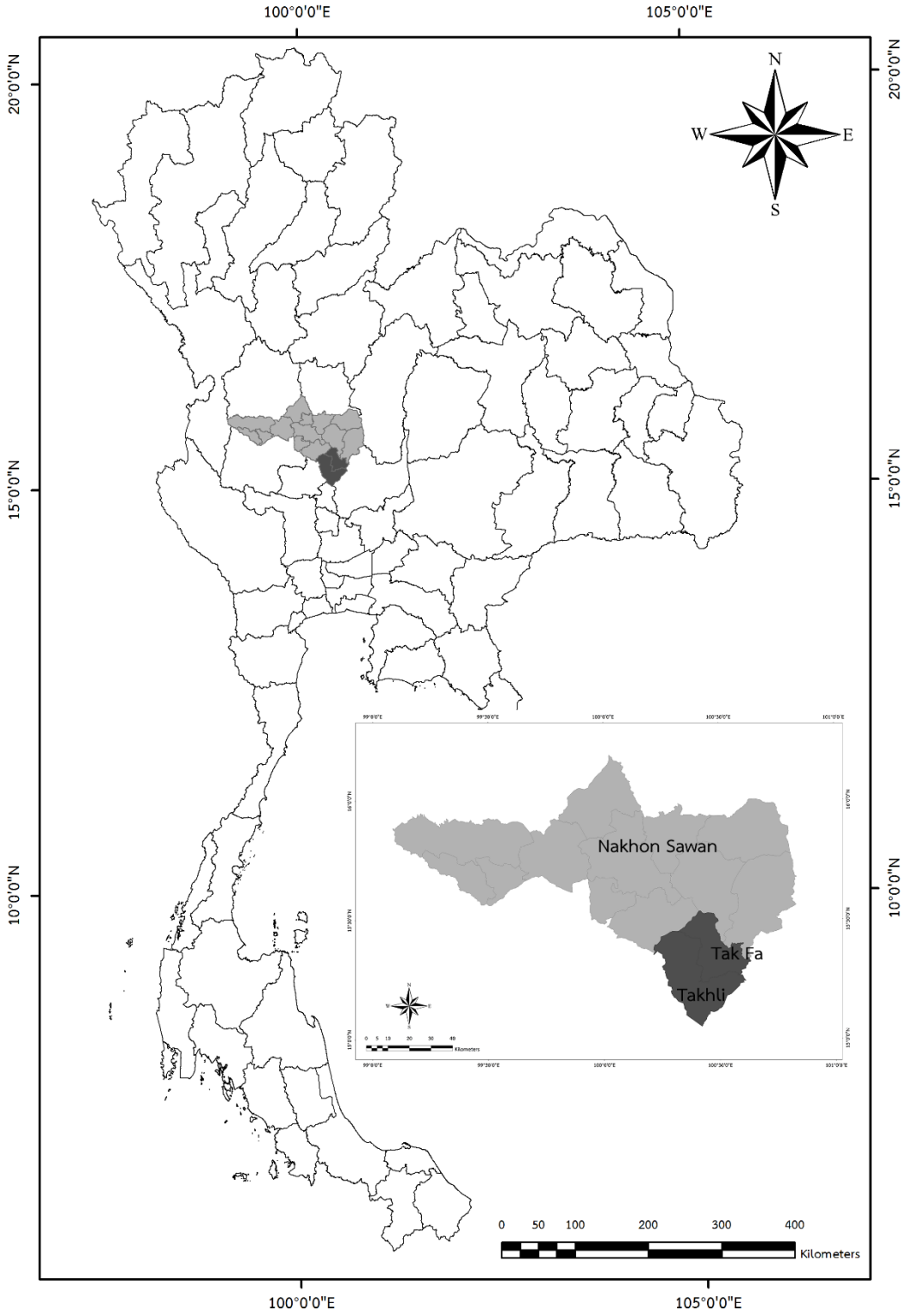


Figure 1.1 Index map of Thailand showing location of the study area at Amphoe Tak Fa and Amphoe Takhli in Changwat Nakhon Sawan.

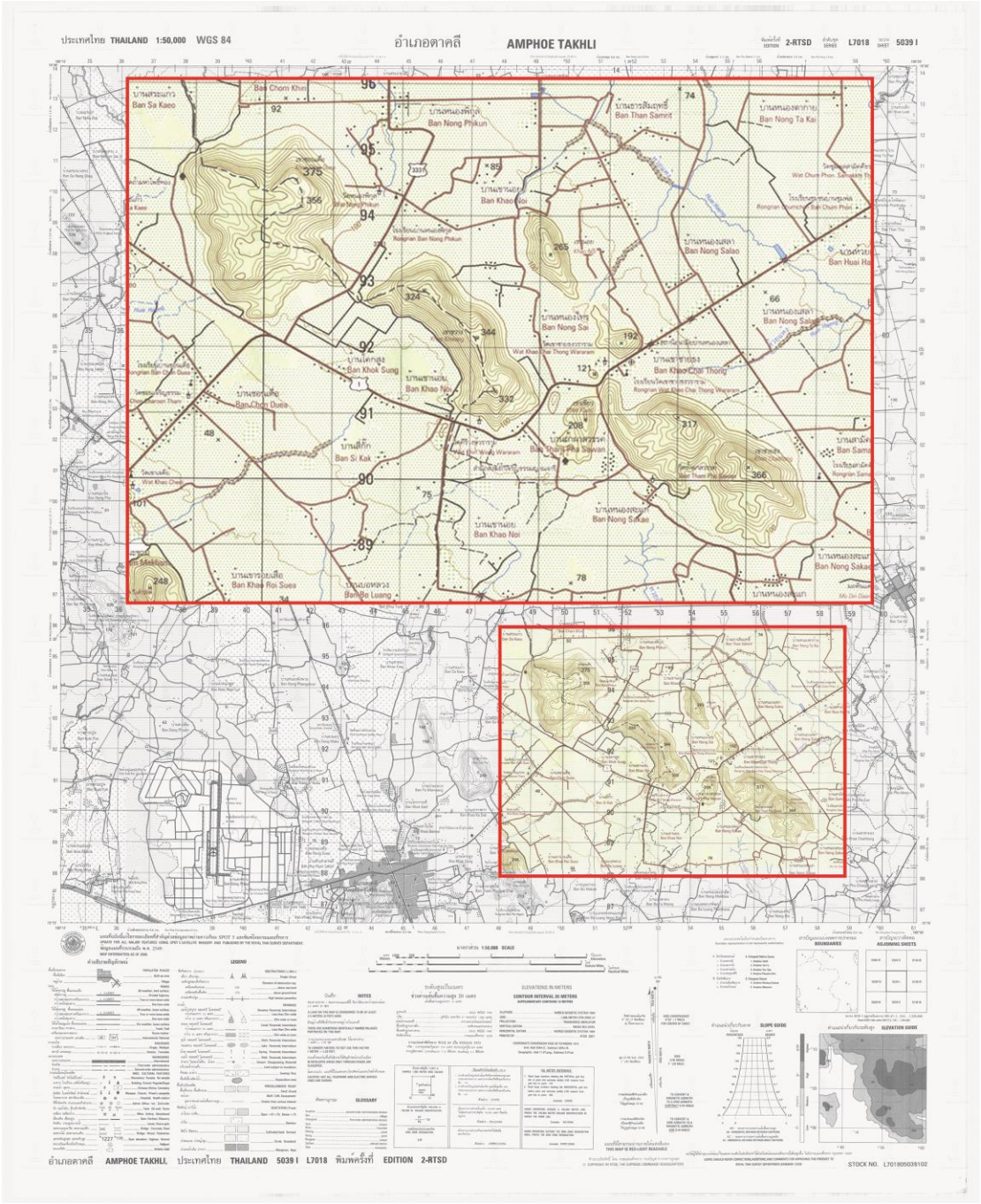


Figure 1.2 Topographic map of the study area, scale 1:50,000, sheet 5039 I, Amphoe Takhli, series L 7018, edition 2-RTSD. This map also shows the accessibility to the study area.

1.3.3 Sample preparation, documentation, classification and identification of gastropods

The gastropod fossil samples were prepared by etching with formic or acetic acid from the calcareous rocks at the Bayerische Staatssammlung für Paläontologie und Geologie in Munich, Germany. After etching, the material was sieved under rinsing water at a mesh size of 0.5 mm. All fossils including the gastropods were picked from the washed residues. Gastropods were sorted according to species and samples. Representatives of each gastropod species and some other species were whitened with ammonium-chloride and documented with microphotography.

1.3.4 Study on shell morphological characteristics for creating systematics

The specimens were measured for shell length, shell width and counted number of whorls. The specimens were sorted according to species. Based on a comparison with literature data, the specimens were determined.

1.3.5 Petrographic study for interpreting palaeoenvironment

Thin sections were made for micro-facies analyses. The main facies type yileding the gastropod fauna were determined according to the classification of Dunham (1962) and Flok (1962) see also Flügel (2004). It was attempted to give a biostratigraphic age based on fusulinids in thin-sections. Gastropods are not suitable for biostratigraphy.

1.3.6 Paleaoenvironmental analyses

Diversity of the invertebrate fauna, especially of the gastropod fauna and microfacies analysis was used to develop a paleoenvironment and depositional model. Palaeobiogeographical considerations were made by comparisons with other Permian gastropod faunas, especially with those from other regions in South East Asia.

1.3.7 Discussion, conclusion and report writing

The integration of all results, including lithostratigraphy, petrography paleontological study, and the previous works were conducted.

1.4 Literature reviews

A geological map at a scale of 1:250,000 of Amphoe Ban Mi (Nakornsri, 1976, 1981) shows the study area belonging to the Tak Fa Formation, Saraburi Group is exposed (Bunopas, 1981). The middle Permian Tak Fa formation composes limestones interbeded with argillaceous limestones, mudstones and dolomite which partially contain chert nodules and fossiliferous limestones. The invertebrate fossils in this formation have been studied in detail, e.g., fusulinids, corals, brachiopods, conodonts and bryozoans. Wielchowsky and Young (1985) studied facies variations in Permian rocks of the Phetchabun fold and thrust belt of Thailand based on measured sections and other field observations. The result revealed that there were two depositional environments in the lower to middle Permian. This area was divided into Khao Khwang platform, Pha Nok Khoa platform and Nam Duk basin. The study area is the part of Khao Khwang platform (Ueno and Charoentitirat, 2011). In this area, carbonate platform deposition took place in the late Palaeozoic. Metcalfe and Sone (2008) reported conodonts from the Tak Fa Formation (Saraburi Limestone). They found that this formation had been deposited on the western margin of the Indochina Terrane. Napradit (2005) studied Permian fusulinoidean limestones from east of Changwat Nakhon Sawan and established a biostratigrapic framework. The fusulinoideas indicate that the age of carbonate rock is Yakhtashian or Artinskian (late Early Permian) to Midian or Capitanian (late Middle Permian). From petrographic study of carbonate rock in combination with palaeontological analysis, they showed that the depositional environment was that of a shelf lagoon within a carbonate platform. This investigation suggests that carbonate platform deposition in this area originated in the same period as carbonate platform deposition in Saraburi and Lop Buri areas.

Permian gastropods from Thailand have not been studied in great detail. Sone (2010) reported the *Magnicapitatus huazhanga* (Figure 1.3) from fusulinoid-rich limestones. This naticiform species is known as an internal mold only. The study area belongs to Khao Ta Ngog Formation in the Guadalupian (Middle Permian) at Khao Makha, Changwat Sra Kaeo, Eastern Thailand. This limestone could be related to the Sisophon Limestone of western Cambodia along the Thai-Cambodia border according

to *Lepidolina multiseptata*. Ketwetsuriya et al. (2014) reported Permian gastropods from the Tak Fa Limestone, Nakhonsawan, Northern Thailand (Figure 1.4). This report is a preliminary description because the gastropods appeared on the surface of rock only. The fauna consists of typical late Palaeozoic taxa representing twenty species especially Bellerophontidae, Pleurotomarioidea, Meekospiridae and Goniasmatidae. In addition, there are some reports of Permian gastropods from Thailand but they lack descriptions, illustrations and detailed systematic assignments. Grant (1976) mentioned platyceratids and pleurotomarioids from limestones of southern Thailand. Waterhouse (1982) reported *Peruvispira* sp. in an early Permian fauna from Kaeng Krachan Group at the Tong Lang Bay and Ko Phi Phi Island.

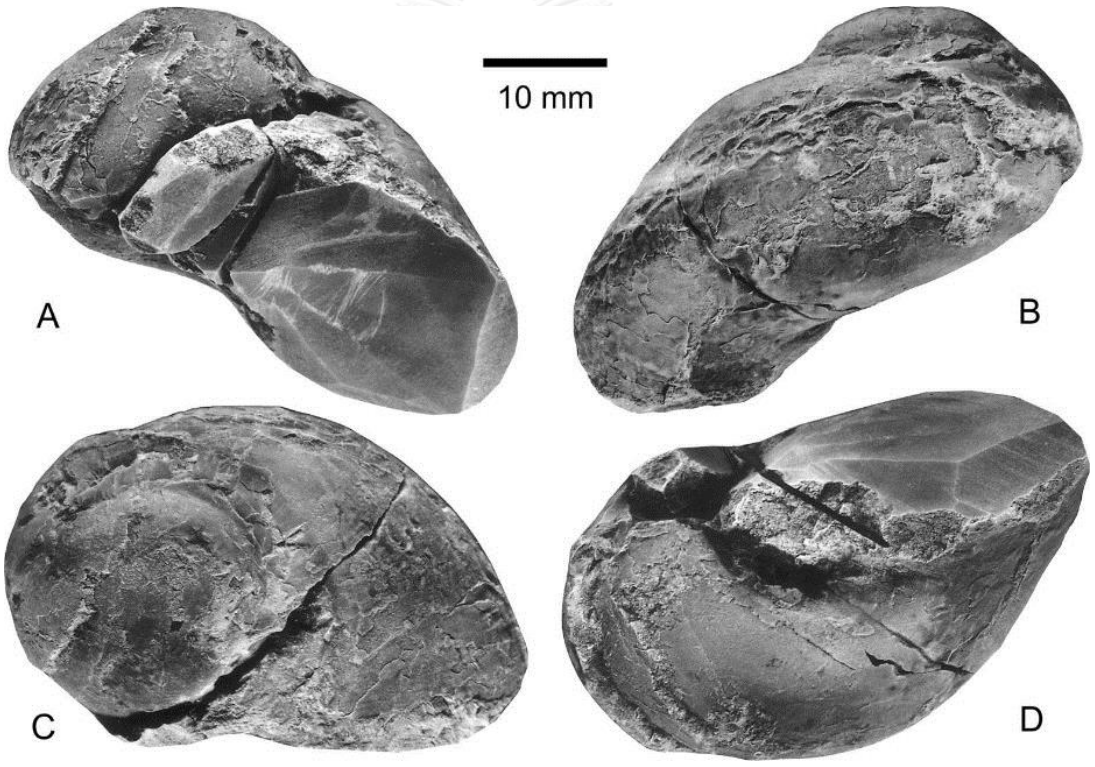


Figure 1.3 *Magnicapitatus huazhangae* from a limestone bed at Khao Makha (Capitanian, Middle Permian), East Thailand. A–D, apertural, ventral, apical and basal views respectively (Sone, 2010).

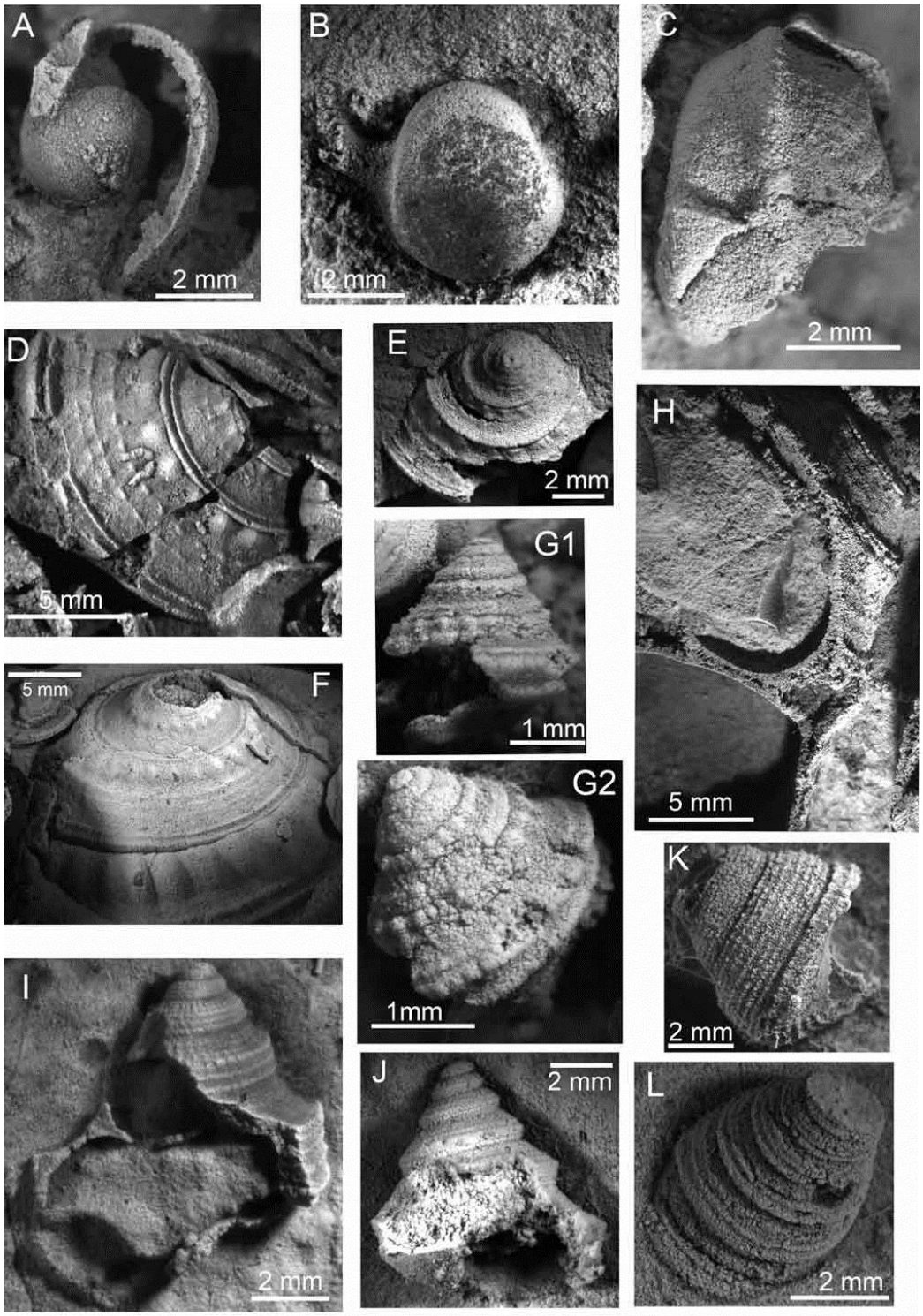


Figure 1.4 The gastropods from Khao Noi (Ketwetsuriya et al., 2014) (A) *Bellerophon* sp. 1 (B) *Bellerophon* sp. 1 (C) *Bellerophon*? sp. 2 (D-G) *Trepospira* sp. (H) *Glabrocingulum* sp. (I-J) *Worthenia*? sp., (K) *Tapinotomaria*? sp., (L) Pleurotomarioid indet.

Permian gastropods have been reported in many areas from other parts of South East Asia. Permian gastropods from limestones at Lee mine, Perak, Malaysia are reported (Batten, 1972, 1979, 1985). This gastropod fauna yielded bellerophontids, euomphalids, pleurotomarians, trochids, patellids, neritids, murchisoniids, cerithiids, loxonematids and subulitids. The age of this limestone could be determined from index fossil as middle Permian. These gastropod fauna is very divese and has major implications for the palaeobiogeography at the margin of the eastern Tethys.

Nützel and Nakazawa (2012) studied a very diverse Permian gastropod fauna from the Akasaka Limestone (Gifu Prefecture, Japan). This fauna comprises of 40 species. The Akasaka limestone is dominated by packstones with dark grey colour that were deposited in an open shallow marine environment (Ozawa and Nishiwaki, 1992). The invertebrate fauna is dominated by gastropods and bivalves (Nakasawa, 2007) Caenogastropoda are most abundanct and diverse. The Akasaka gastropod fauna shows relationships to faunas from China, Malaysia, and Vietnam.

CHAPTER II

GEOLOGY AND LITHOSTRATIGRAPHY

2.1 Regional Permian Stratigraphy of Thailand

Permian rocks have distributed throughout many areas in Thailand except in the Northeastern part (Figure 2.1), which are almost of shallow-marine environment. The dominant lithology is characterized predominately by carbonates-clastic sequence. Nevertheless, other Permian rocks have been found. According to their diverse lithology and fossil assemblages, they have been assigned into several different lithostratigraphic nomenclatures.

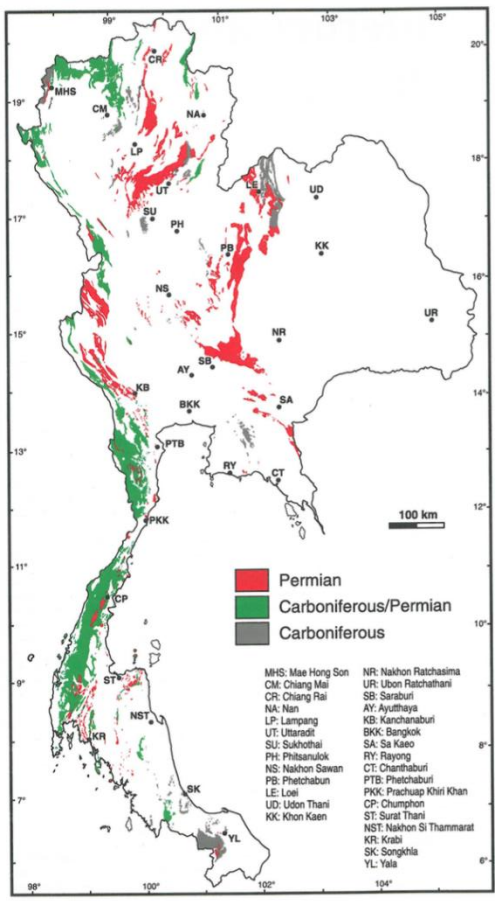


Figure 2.1 Map showing distribution of Carboniferous and Permian strata in Thailand (Ueno and Charoentitirat, 2011)

2.1.1 The Saraburi Group

Bunopas (1981) established the name of Saraburi Group for the limestone and clastic rock sequence exposing on the eastern side of the lower Chao Phraya central plain from south of Nakhon Sawan to Saraburi, and also on the western edge of the Khorat Plateau from Loei, northeastern part of Thailand to Saraburi. Previously, the Saraburi Group was as part of the Rat Buri Group (Brown et al., 1951; Javanaphet, 1969; Nakornsri, 1976). Bunopas (1992) finally performed the stratigraphic name for Thailand, which is subdivided into seven stratigraphic belts based on tectonic provinces and evolution concept of the Shan – Thai (western side) and the Indochina (eastern side) terranes. Paleogeographically, these limestones are the part of the Khao Khwang Platform Wielchowsky and Young (1985) during Middle Permian that covered Phetchabun, Lop Buri and Nakhon Sawan province at the western margin of the Indochina terrane (Figure 2.2).

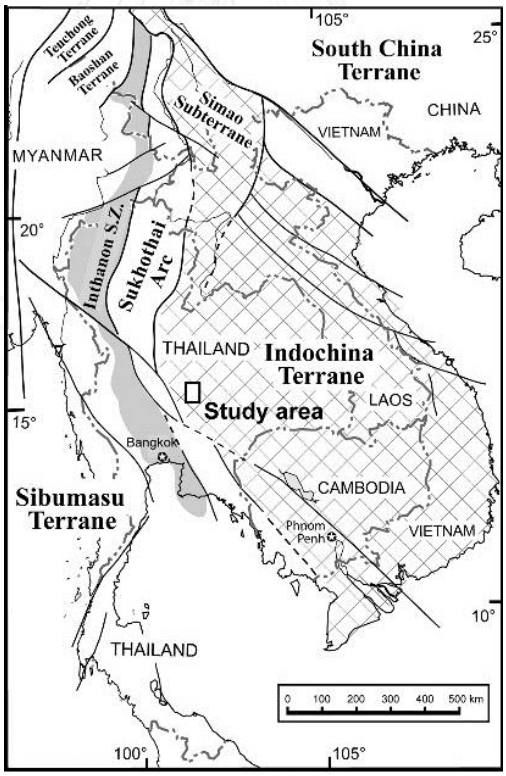


Figure 2.2 Tectonic subdivision map of mainland Southeast Asia (Metcalfe and Sone, 2008) showing Khao Khwang Platform (the study area is situated here) on the western margin of the Indochina terrane.

2.1.2 The Saraburi Group in Nakhon Sawan

The rocks in the study area and adjacent area are subdivided into Tak Fa formations based on the lithology and fossils content according to previously investigation (Nakornsri, 1976, 1981).

Tak Fa formation

This formation is named (Nakornsri, 1976, 1981) in the map of Ban Mi Sheet ND 47–4 after Amphoe Tak Fa, Changwat Nakorn Sawan. The rocks distribute throughout Phetchabun, Lop Buri and Nakhon Sawan province. The Tak Fa formation commonly consists of bedded fossiliferous limestones, massive limestone and siliciclastic rocks (Yanagida, 1988). Various marine invertebrate fossils are found in this formation such as fusilinids, brachiopods, conodonts, corals, calcareous algae and bryozoans. The fusulinids from carbonate rocks, *Verbeekina verbeeki* and *Parafusulina* sp. indicate Middle Permian age (Figure 2.3), and this assemblage is locally observed in the Tak Fa formation.

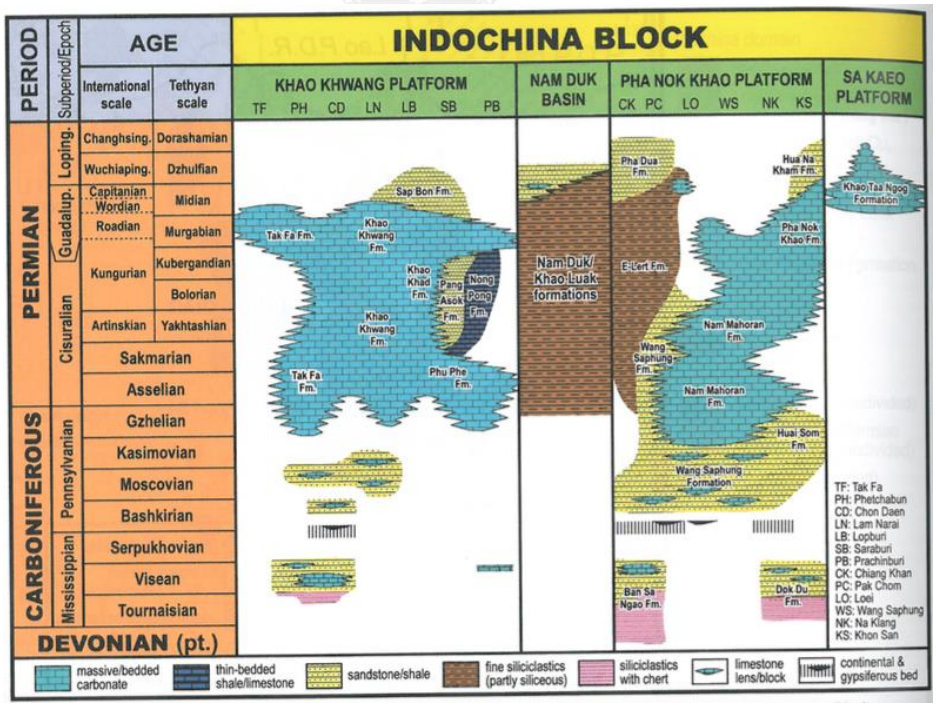


Figure 2.3 Stratigraphic subdivisions showing Tak Fa formation distribution on the western margin of the Indochina Block of Thailand (Ueno and Charoentitirat, 2011)

2.2 Regional Geology of the Study Area

According to previous investigation (Nakornsri, 1976, 1981), the age of the rocks found in the study area, Amphoe Tak Fa and Amphoe Takhli, is Permian Period.

The study area is situated in Amphoe Tak Fa and Amphoe Takhli, southeastern part of Changwat Nakhon Sawan. Geologic map of the study area is map sheet: Changwat Nakhon Sawan, scale 1:50,000 (DMR, 2007) illustrated in Figure 2.4. The rocks in the study area of Khao Noi, Khao Chai Thong, Khao Chon Due, Khao Kwang and Khao Tum Pha Sawan consist of Permian carbonate rock of the Tak Fa formation of Saraburi Group that ranges in Middle Permian. They are surrounded by Quaternary sediments with the average elevation of 300 meters above mean sea level.

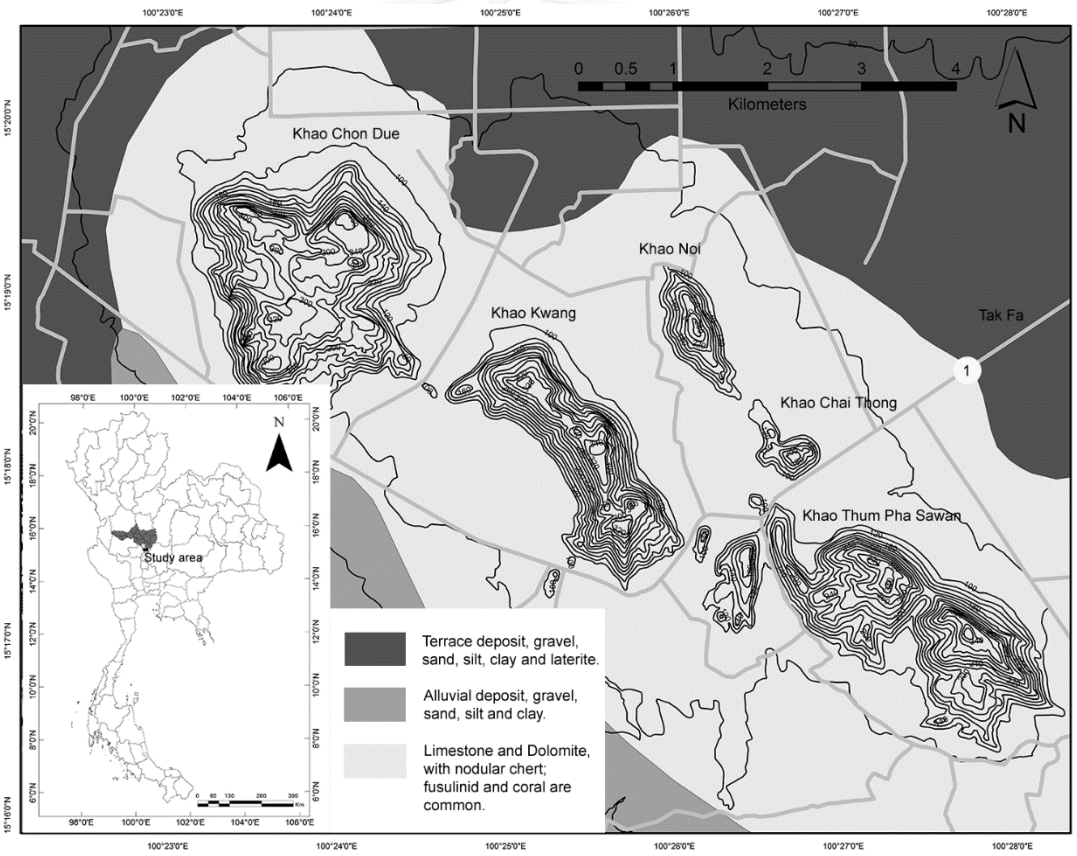


Figure 2.4 Geologic map of the study area (modified from DMR, 2007)

2.3 General Geology and stratigraphy of the Study Area

The limestones in this study are formed by 5 hills; Khao Noi, Khao Chai Thong, Khao Chon Due, Khao Kwang and Khao Tum Pha Sawan extending 8 km in the east-west direction and about 6 km in the north-south direction. They are surrounded by unconsolidated sediments with the average elevation of 300 meters above mean sea level. These limestones are called Tak Fa formation in Saraburi Group and are Middle Permian age. They have furnished a diverse fauna. The carbonate rocks are composed of thin-beded to massive limestones. The samples were collected and five lithostratigraphic sections were arranged from 4 localities; section N1 and N2 at Khao Noi, section C at Khao Chai Thong, section K at Khao Kwang, section T at Khao Tum Pha Sawan in Figure 2.5. These investigation sites were used for paleontological study of gastropods and for petrographic analysis of limestone to discuss the depositional environment.

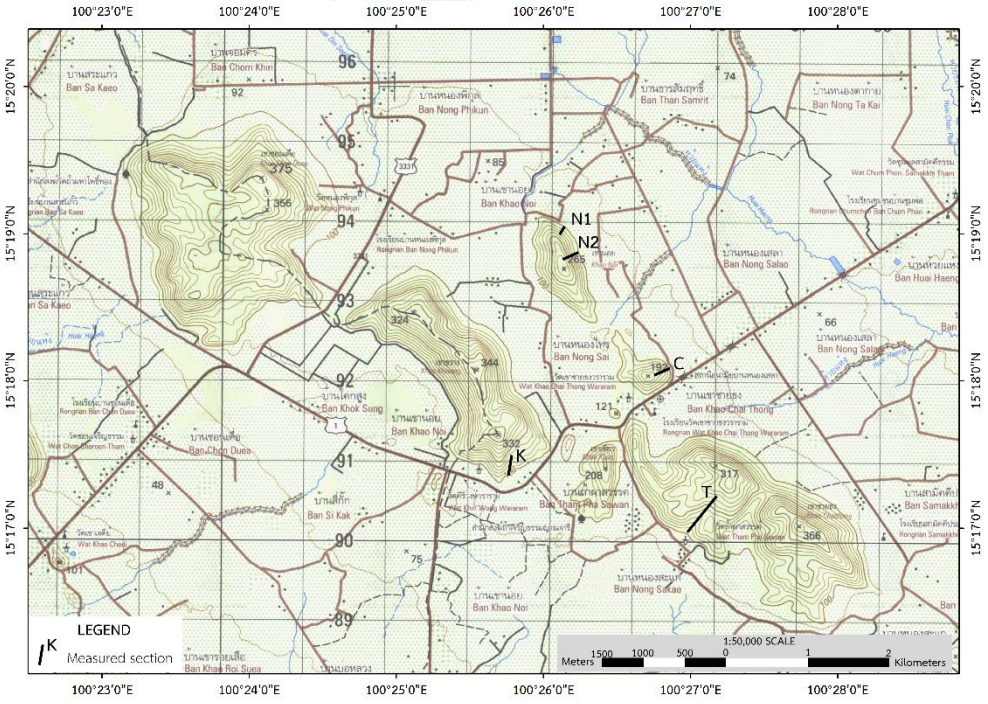


Figure 2.5 Topographic map showing location of five measured sections at Khao Noi section (N1 and N2), Khao Chai Thong section (C), Khao Kwang section (K), and Khao Tum Pha Sawan section (T) along highway no.1 (modified from topographic map scale 1:50,000 of the Royal Thai Survey Department, sheet 5039 I, Amphoe Takhli).

2.3.1 Lithostratigraphy of Khao Noi

Khao Noi is a small hill in the north of Amphoe Thakhli. Napradit (2005) identified fusulinids collected from this hill. They indicated Artinskian age. The exposures at southeastern part of Khao Noi have the continuous sequence of limestone layers with abundance fossils where the lithostratigraphic section was measured (15° 19' 08" N, 100° 25' 59" E) shown in Figure 2.8. The thickness of this section is 3.7 meters. It is composed of medium (20 - 30 cm) to thick-bedded (60 – 100 cm), light gray to dark gray limestone (Figure 2.10). The limestone were classified to bioclastic wakestone to packstone intercalated with thin black shale; black chert nodules are found at the upper part of sequence. The top of section is covered by dolomite. The section has a trend of strike 170° to 180 ° and dipping 20 ° to 30 ° to the west direction. They are flourished with invertebrate fossils such as fusulinids, corals, brachiopods?, bivalves, crinoid stems, sponges, ammonoids, and gastropods. The rocks and fossils samples were collected from each layer that differently changed lithology.

The other lithostratigraphic section was performed at the east side of this hill (15° 18' 50" N, 100° 26' 18" E) shown in Figure 2.9. The thickness of this section is approximately 50 meters. This lithostratigraphic section consists of thick (70 - 100 cm) to very thick-bedded (110 – 150 cm), mostly very thick bedded, light gray (lower part) to dark gray (upper part) limestone. Attitude of bedding are mainly 180 ° and dipping 30 ° to the west direction. The lower part of sequence (Unit N1) is dominated by thick-bedded micritic limestone with dark gray (Figure 2.11). Fusulinids, rugose corals, bryozoans, crinoid stems, and gastropods are commonly found. In the middle part (Unit N2), the limestone is identified as wackestone with very thick-bedded. Shell fragments and fusulinids are rarely investigated. The upper part (Unit N3) is composed of medium (Figure 2.12) to very-thick bedded, gray to dark gray limestones with black chert nodules in the base of this part (Figure 2.13) and locally interbeded with laminated dark gray shale (Figure 2.14) then covered with dolomitic limestone that are obvious (Figure 2.15). Gastropods and fusulinids are abundant (Figure 2.16). Other fossils are massive and solitary rugose corals, brachiopods?, crinoid stems and sponges that can be extensively observed.

The two lithostratigraphic sections of Khao Noi can be correlated according to bedding, lithology and fossil occurrences.

Unit N1

Description: This unit is dark gray, thick-bedded micritic limestone with bioclast. The weathered surface is usually grey to dark with grains of fusulinids, rugose corals, bryozoans, crinoid stems, and gastropods are commonly found. The thickness of this unit is approximately 9.6 meters, which represents the lowest unit of the lithostratigraphic section of the Khao Noi area.

Petrographic studies show that the unit N1 consists of fossiliferous micrite and poorly washed biosparite characterized by grains and some micrite remains, which sparry calcite cemented that are the major rock in this unit. The wackestone, contains less than 10% small grains in micrite matrix (Figure 2.6), is the most abundance.

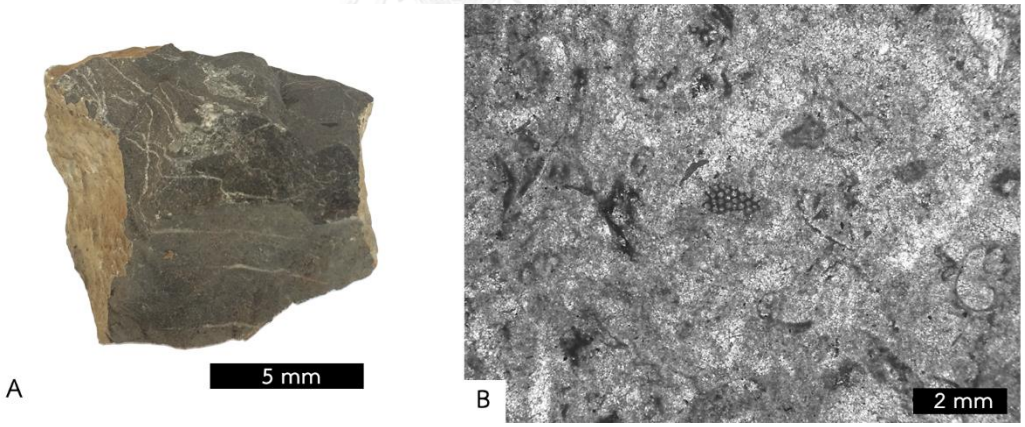


Figure 2.6 A sample representative of unit N1 **A:** A rock sample of the unit N1 showing dark grey limestone with calcite vein; **B:** Photomicrograph of wacked biomicrite of the unit N1 containing small bioclastic grains in micrite matrix.

Unit N2

Description: The unit N2 overlies on the unit N1. The very thick-bedded, light grey to grey on weathered surface limestone. The total thickness of this unit is about 7.2 meters. The fossils contain rarely shell fragments and fusulinids.

Petrographically, the rock in this unit is identified as mudstone to wackestone, which mainly supported by micrite. They yield only shell fragments and fusulinids.

Unit N3

Description: The unit N3 is characterized by medium to very-thick bedded, but mostly medium to thick-bedded, gray to dark gray fossiliferous micritic limestones, which are both gain-supported and matrix-supported. Black chert nodules are commonly found at the lower part of this unit and locally interbedded with laminated dark grey shale. The total thickness of this unit is approximately 16 meters. Bedding surfaces reveal parallel type. Gastropods and fusulinids are abundant in the middle part of this unit. The upper part consists of medium bedded limestones, which yield some fossils less than the middle part of this unit. Part of the rock is slightly silicified.

Microscopically the unit N3 consists of biosparite and packed biomicrite with some crystalline dolomite. The biosparite contains mainly shell fragments, fusulinid test and other grains, commonly cemented by sparry calcite (Figure 2.7). The packed biomicrite comprises bioclasts in micrite matrix. Grain is unidentified shells.

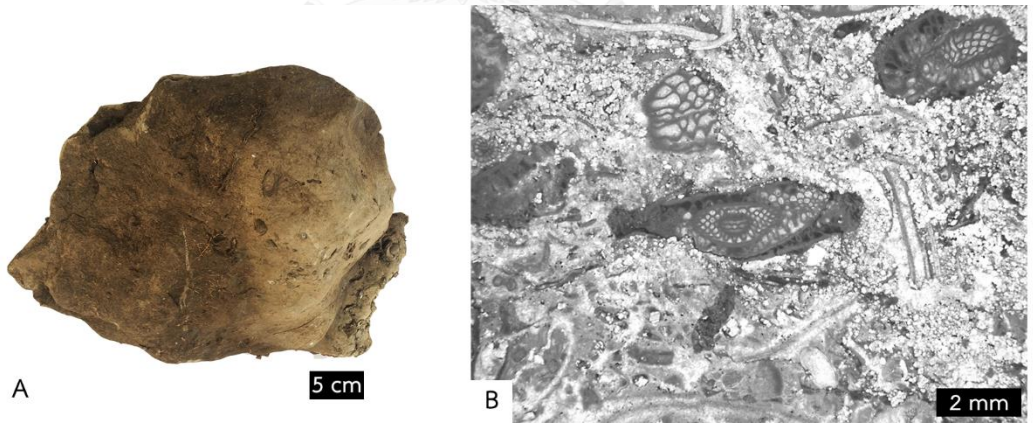


Figure 2.7 The samples represent unit N3 **A:** A rock sample of the unit N3 showing grey limestone with abundant invertebrate fossils; **B:** Photomicrograph of packstone of the unit N3 containing gain-supported of various bioclastic grains in sparite matrix.

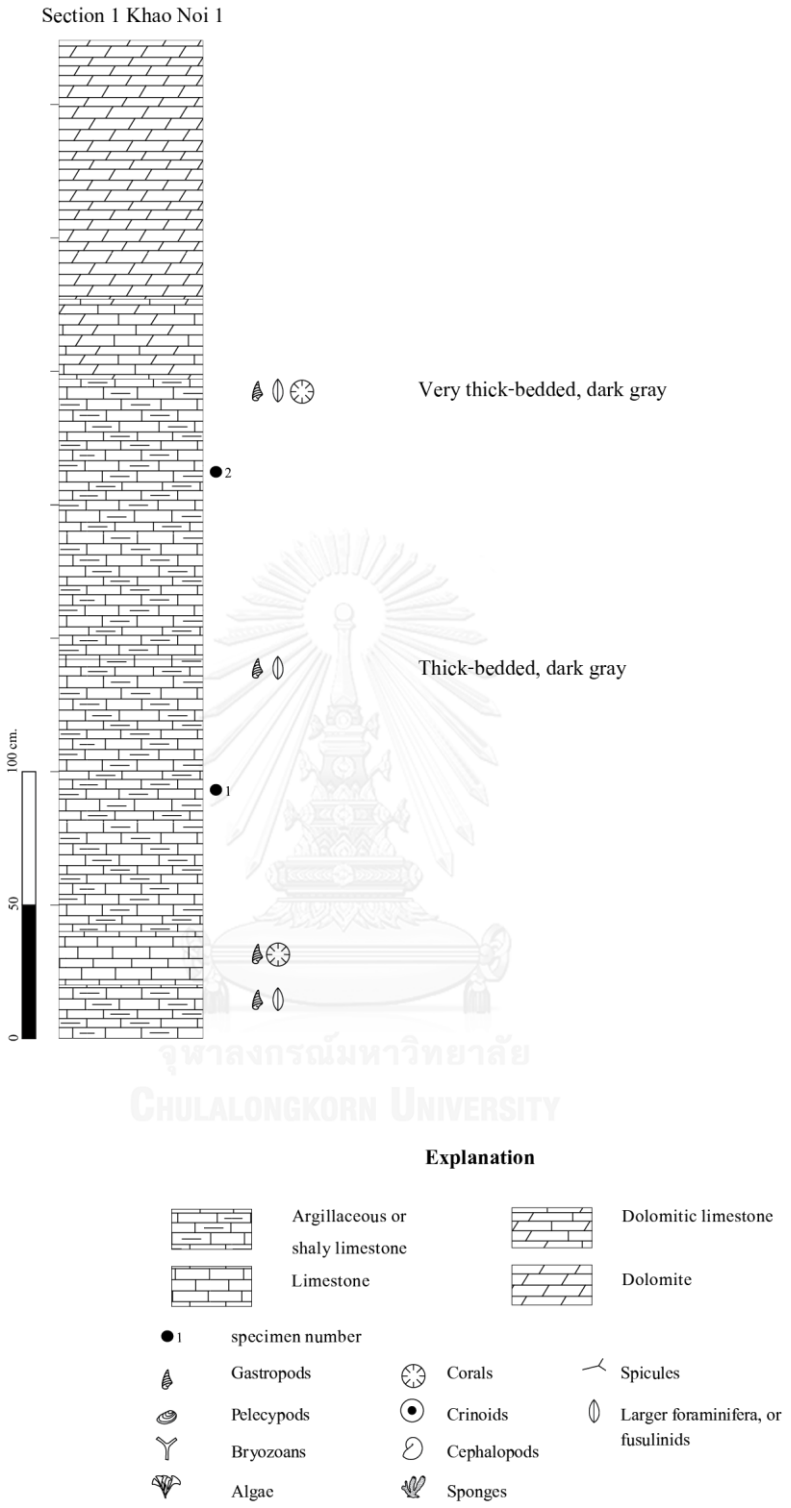


Figure 2.8 Stratigraphic column of section 1 at southeast of Khao Noi

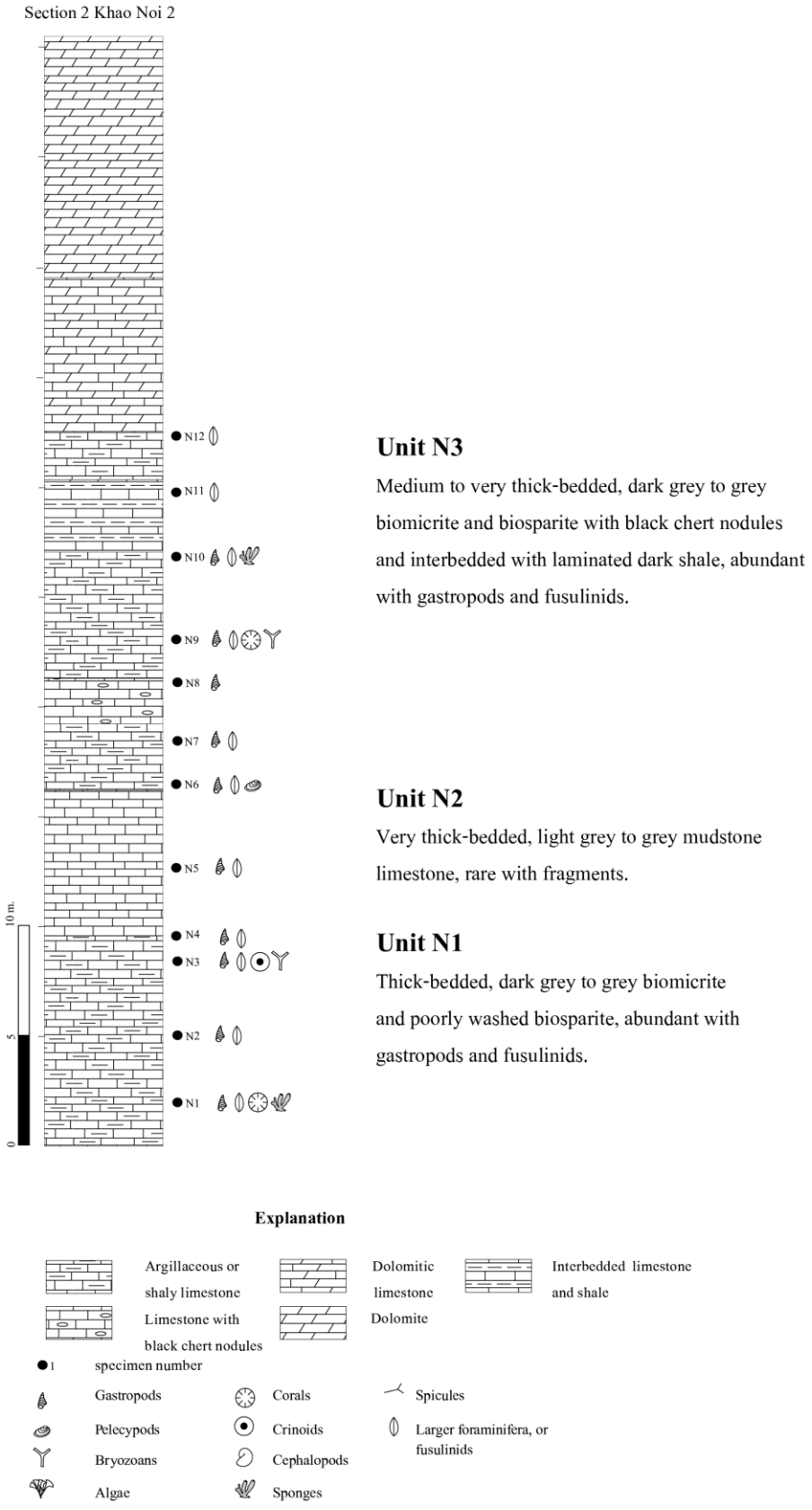


Figure 2.9 Stratigraphic column of section 2 at east of Khao Noi

Figure 2.10 Very thick-bedded argillaceous limestone at Khao Noi section 1 at northeast wing of Khao Noi

Figure 2.11 Thick to very thick-bedded gray micritic limestone (unit N1) shows discontinuous wavy parallel bedding surface at east of Khao Noi

Figure 2.12 Medium-bedded light-grey limestone and discontinuous wavy parallel bedding surfaces (unit N3) between each bed at east of Khao Noi

Figure 2.13 Thick-bedded fossiliferous argillaceous limestone with black chert nodule in unit N3 at east of Khao Noi

Figure 2.14 Medium to thick-bedded gray argillaceous limestone intercalated with dark gray shale lamina show distinctly parallel bedding surfaces at of Khao Noi (unit N3)

Figure 2.15 Dolomite extended widely above the section at east of Khao Noi

Figure 2.16 Shell fragments of gastropods and fusulinids are abundant including corals in thick-bedded fossiliferous limestone of unit N3 at Khao Noi

2.3.2 Lithostratigraphy of Khao Kwang

The strata were measured at the southern part of Khao Kwang (15° 17’ 30” N, 100° 25’ 38” E) that is totally 30 meters thick (Figure 2.24). The attitudes of bedding are 185 ° and dipping 40 ° to the west direction. They contained light grey to dark gray limestones. The lower part of this section is dolomitic limestone (Unit K1) with very thick-bedded (250 cm) (Figure 2.27). The middle part (Unit K2) is dominated by argillaceous limestone, thick-bedded, and interbedded with thin black shale in some layer (Figure 2.28). This part is covered with very thick-bedded (500 cm) fossiliferous micritic limestones with black chert nodules and dolomite nodules. It is prolific with fusulinids, corals, crinoid stems and gastropods. In the upper part, they are comprised of thin to thick-bedded (Figure 2.29), dark gray limestone and locally interbedded laminated dark gray shale (Unit K3). The dolomite widely extended above the Khao Kwang section.

Unit K1

Description: This lowest unit of Khao Kwang section is dominated by dolomitic limestone with thick to very thick-bedded. On the weathered surface show elephant skin texture with grey to light grey that make this unit different from the others. In the hand specimen, the dolomitic limestone reveals significant grain of shell fragment. The thickness of this unit is approximately 4 meters.

Petrographically, the unit K1 shows crystalline dolomite with micrite and some grains of bioclast? (Figure 2.17), is the most abundance.

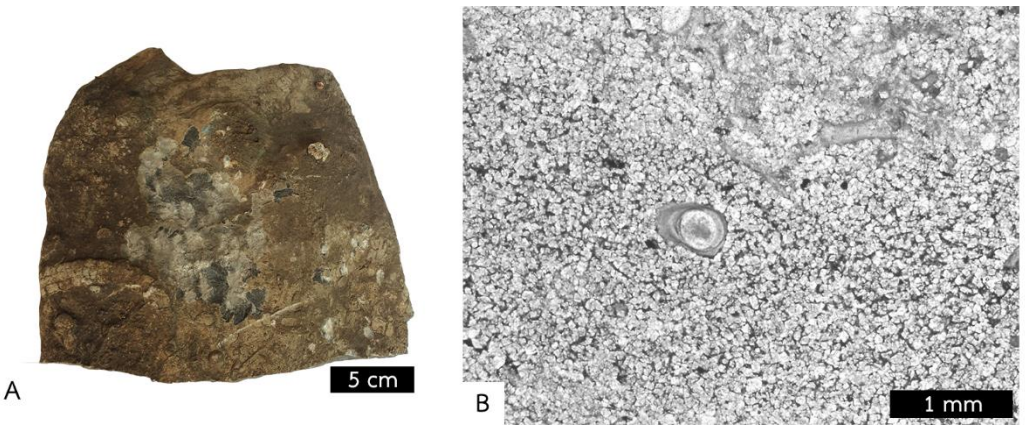


Figure 2.17 A sample representative of unit K1 **A:** A rock sample of the unit K1 showing dark grey limestone; **B:** Photomicrograph of crystalline dolomite with micrite and some grains of bioclast.

Unit K2

Description: The unit K2 is exposed conformably overlying on the unit K1, which consists of thick-bedded fossiliferous micritic limestone with commonly interbedded with thin-bedded black shale. In the upper part of this unit, there is black chert nodules and dolomite nodules in the limestones. The total thickness of this unit is approximately 9.5 meters. They are flourished with gastropods, fusulinids, brachiopods, crinoid stems, and sponges.

Under a microscope, the rock in unit K2 can be classified as packstone to wackestone, which mainly supported by fine-grained micrite (Figure 2.18). The pack biomicrite contains abundant shell fragments larger than 1 mm packed together with smaller unidentified fragment in micrite matrix. The large shell fragments are bivalves and gastropods.

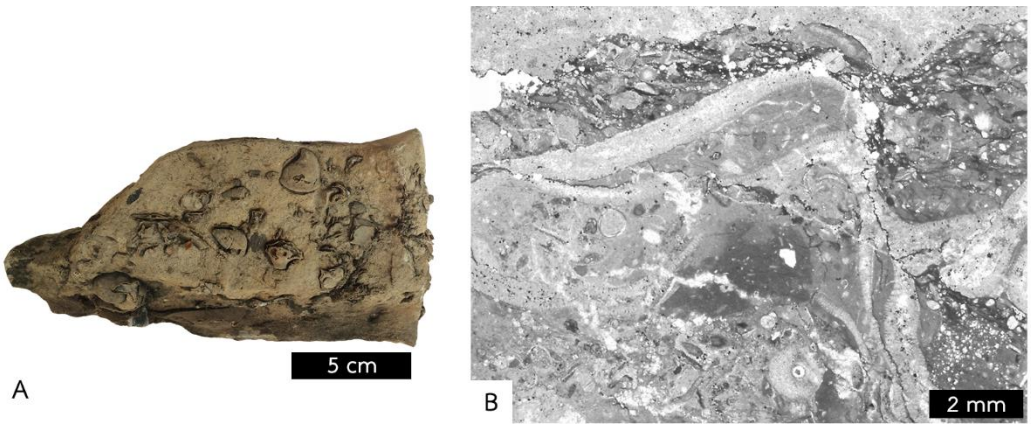


Figure 2.18 A sample representative of unit K2 **A:** A rock sample of the unit K2 showing limestone with several bioclasts; **B:** Photomicrograph of wackestone of the unit K2 containing small bioclastic grains and supported by fine-grained micrite.

Unit K3

Description: This unit is characterized by thin to thick-bedded, dark gray limestone and locally interbedded with laminated dark gray shale. The large grain consists exclusively of fusulinid tests. The total thickness of this unit is abuot 7.3 meters.

Microscopically, the unit K3 consists of packed biomicrit. The pack biomicrite contains abundant fusulinid tests in micrite matrix (Figure 2.19). The poorly washed biosparite characterized by grains and some micrite remains

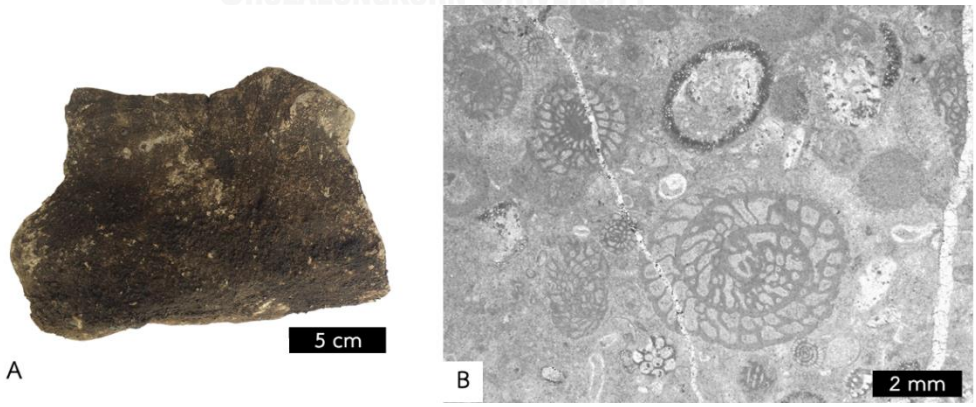


Figure 2.19 A sample representative of unit K3 **A:** A rock sample of the unit K3 showing dark limestone with slightly weathered surface; **B:** Photomicrograph of packstone of the unit K3 containing various fusulinid tests and supported by fine-grained micrite with calcite vein.

2.3.3 Lithostratigraphy of Khao Tum Pha Sawan

The outcrop is in the large isolate hill at Wat Tum Pha Sawan (15° 16' 58" N, 100° 26' 59" E), the rock strata are generally lay in direction of 185 ° and dipping 30 ° to the west. The thickness of Khao Tum Pha Sawan section approximately 52 meters (Figure 2.25). Two levels of this carbonate rock outcrops, lower and upper parts. There are almost very thick-bedded (100 - 800 cm). The lower part (Unit T1) contains limestone with dark gray and normally interbedded laminated dark gray shale. In the middle units of this part, there is chert nodules about 10 centimeters in diameter and black chert lenes (Figure 2.30) in diameter occurred in dolomitic limestone (Unit T2). There are plenty of fossils such as fusulinids, rugose corals, bivalves, crinoid stems, sponges, and gastropods. Dolomitic limestone and marble are nearly found in the upper part.

Unit T1

Description: The unit T1 is exposed the lowest part of Khao Tum Pha Sawan section, which comprises medium to thick-bedded dark grey limestone with normally interbedded laminated dark gray shale. The total thickness of this unit is approximately 17.5 meters. There are abundant of fossils such as fusulinids, rugose corals, bivalves, crinoid stems, sponges, and gastropod.

Petrographic studies show that the rock in the unit T2 is wackestone and poorly washed biosparite, which mainly supported by micrite (Figure 2.20). The biomicrite consists of broken skeletons together with abundant fusulinid tests in micrite matrix.

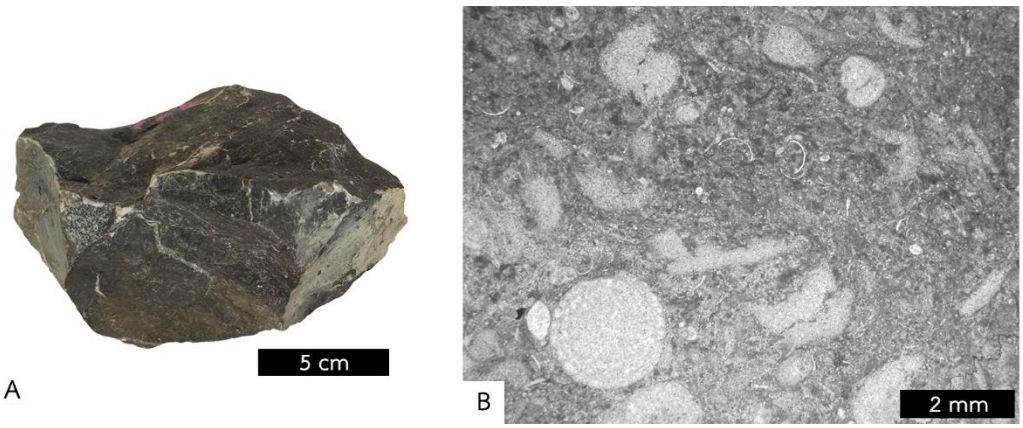


Figure 2.20 A sample representative of unit T1 **A:** A rock sample of the unit T1 showing dark limestone; **B:** Photomicrograph of wackestone of the unit T1 containing mostly fusulinid tests in micrite matrix.

Unit T2

Description: The unit T2 overlies on the unit T1. The very thick-bedded, light grey to grey on weathered surface limestone (Figure 2.31). There are chert nodules about 10 centimeters in diameter and black chert lenes in dolomitic limestone. The total thickness of this unit is about 15.2 meters. The fossils contain rarely shell fragments and fusulinids.

Petrographically, the rock in this unit is identified as mudstone, which mainly supported by micrite. They yield some fusulinid tests (Figure 2.21).

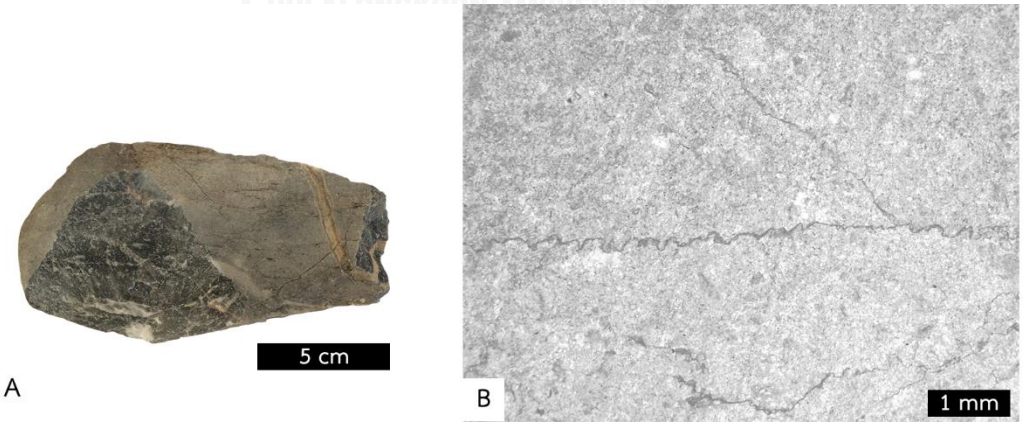


Figure 2.21 A sample representative of unit T2 **A:** A rock sample of the unit T2 showing limestone with light at weathered surface; **B:** Photomicrograph of mudstone of the unit T2 in micrite matrix and stylolite.

2.3.4 Lithostratigraphy of Khao Chai Thong

This limestone is exposed in a small hill at Wat Khao Chai Thong which attitude of bedding is from 135° to 150° and dipping 35 ° to the southwest direction. The lithostratigraphic section at the east of Khao Chai Thong (15° 17' 59" N, 100° 26' 51" E) was performed shown in Figure 2.26. The thickness of this section is approximately 30 meters. It is composed of thick to very thick-bedded, dark gray limestone (Figure 2.32). The fossils are not observed in the lower part (Unit C1). In the middle part (Unit C2), the rocks consist of medium-bedded argillaceous limestone (20 cm) intercalated with dark shale lamina. These limestone beds contain abundant invertebrate fossils such as fusulinids, rugose corals, crinoid stems, sponges, calcareous algae? especially gastropods commonly found in this part. Then, they are covered by thin to thick-bedded, dark gray limestone and locally interbedded laminated dark gray shale (Unit C3) (Figure 2.33). In the upper part are dominated by very thick-bedded limestone then covered by dolomitic limestone.

Unit C1

Description: This unit composes of thick to very thick-bedded, dark gray limestone. The weathered surface is usually grey with rarely fossils. The thickness of this unit is approximately 4.6 meters, which represents the lowest unit of the lithostratigraphic section of the Khao Chai Thong area.

Petrographic studies show that the unit C1 consists of mudstone with slightly fusulinid tests.

Unit C2

Description: The unit C2 overlies on the unit C1. The rocks consist of medium-bedded argillaceous limestone, light grey to grey on weathered surface. Black chert nodules are commonly found at the middle part of this unit and locally interbedded with laminated dark grey shale. These limestone beds contain abundant invertebrate

fossils such as fusulinids, rugose corals, crinoid stems, sponges, calcareous algae especially gastropods (Figure 2.34) commonly found in this unit. The total thickness of this unit is about 11.8 meters.

Petrographically, the rock in this unit is identified as mudstone (Figure 2.22A-B) to wackestone (Figure 2.22C-D), which mainly supported by micrite. They yield only shell fragments and fusulinids.

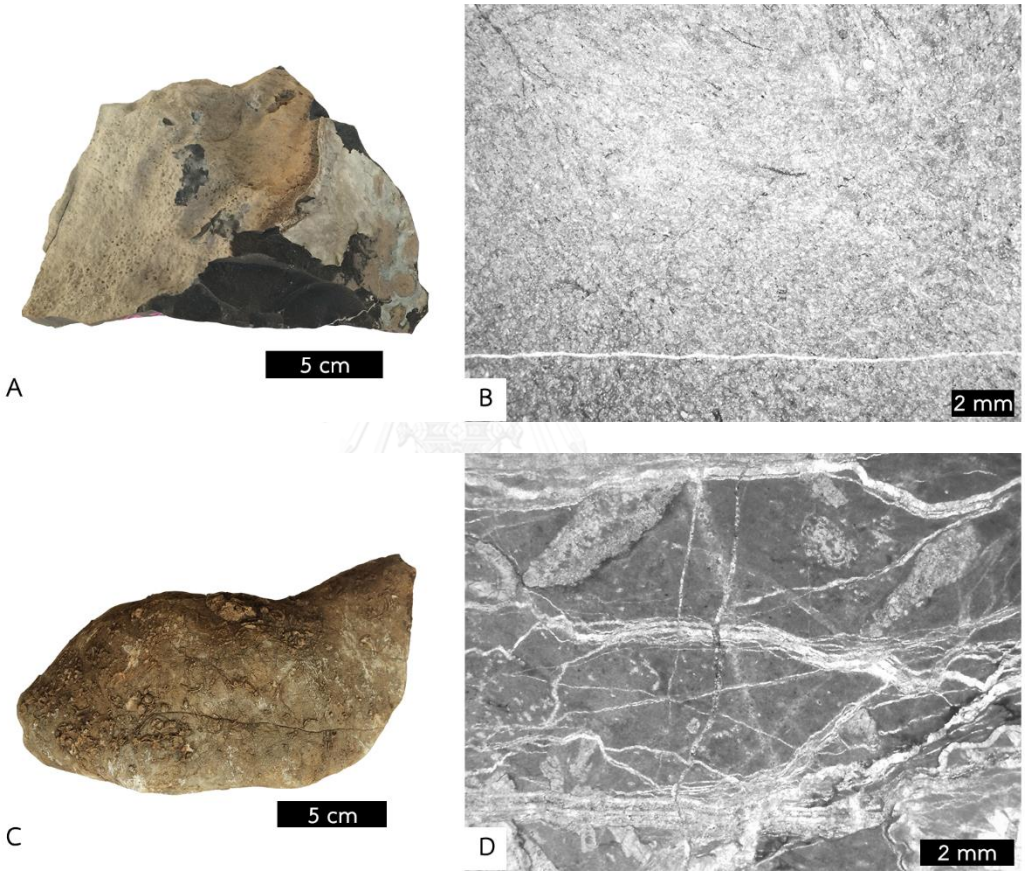


Figure 2.22 The samples represent unit C2 **A:** A rock sample of the unit C2 showing dark limestone with light weathered surface; **B:** Photomicrograph of mudstone of the unit C2 in micrite matrix; **C:** A rock sample of the unit C2 showing limestone with several bioclasts; **D:** Photomicrograph of wackestone of the unit C2 containing small bioclastic grains and supported by fine-grained micrite.

Unit C3

Description: The unit C3 is characterized by thin to thick-bedded, but mostly medium to thick-bedded, grey to dark grey fossiliferous micritic limestones. These units are both gain-supported and matrix-supported. Interbedded laminated dark gray shale locally found. The total thickness of this unit is approximately 7.2 meters. Bedding surfaces reveal parallel type.

Microscopically the unit C3 consists of mudstone to wackestone that comprises some bioclasts in micrite matrix. Grain is unidentified shells (Figure 2.23).

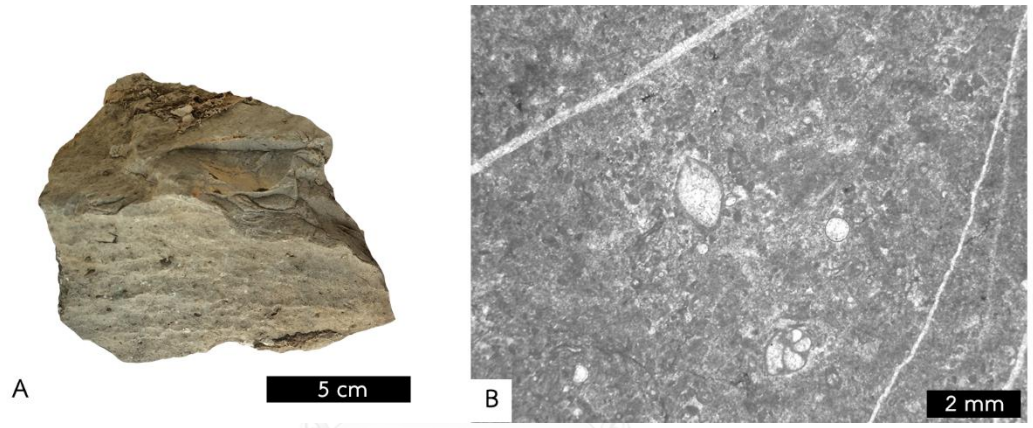


Figure 2.23 A sample representative of unit C3 **A:** A rock sample of the unit C3 showing limestone; **B:** Photomicrograph of mudstone of the unit C3 containing rarely bioclats in micrite matrix.

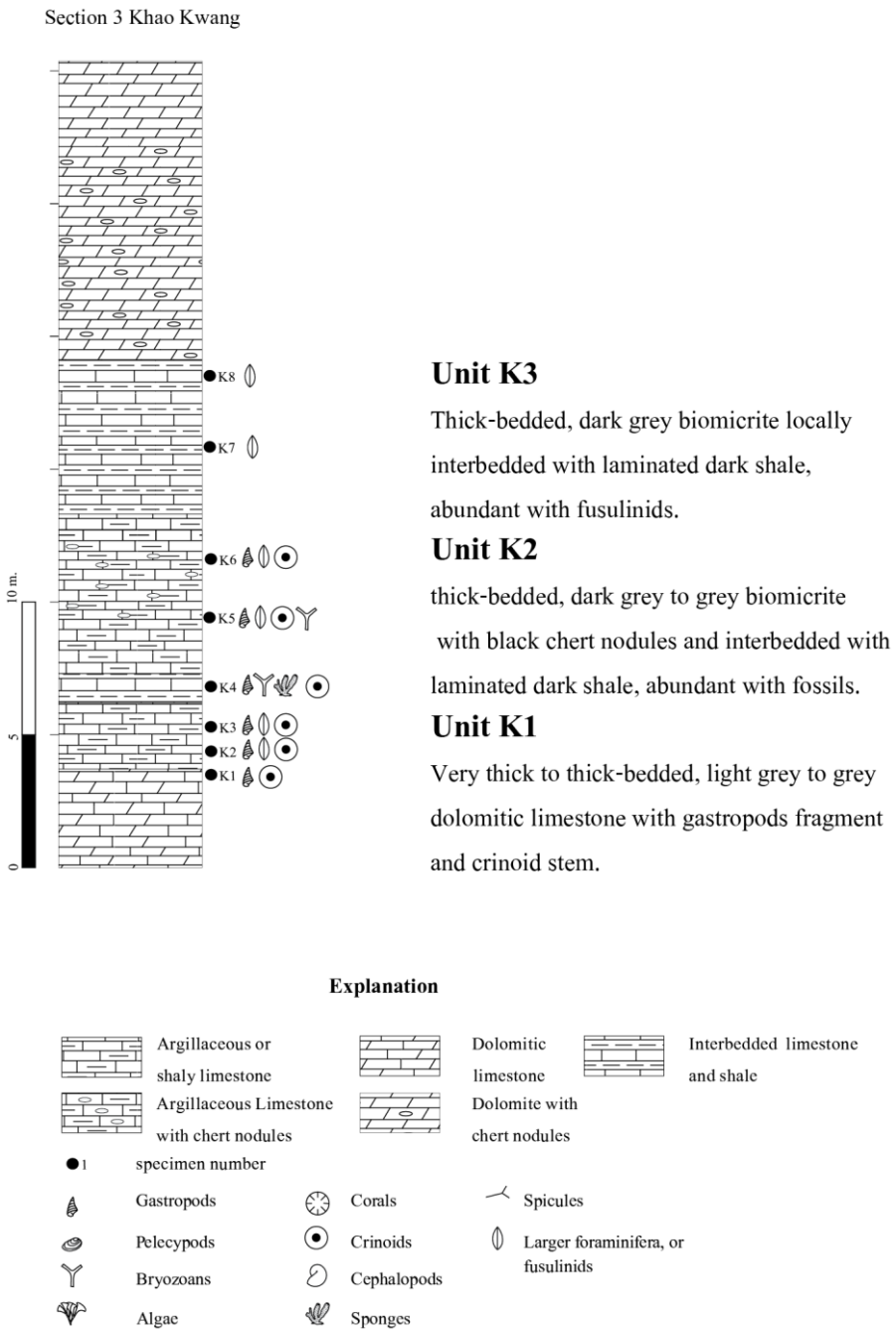


Figure 2.24 Stratigraphic column of section 3 at south of Khao Kwang

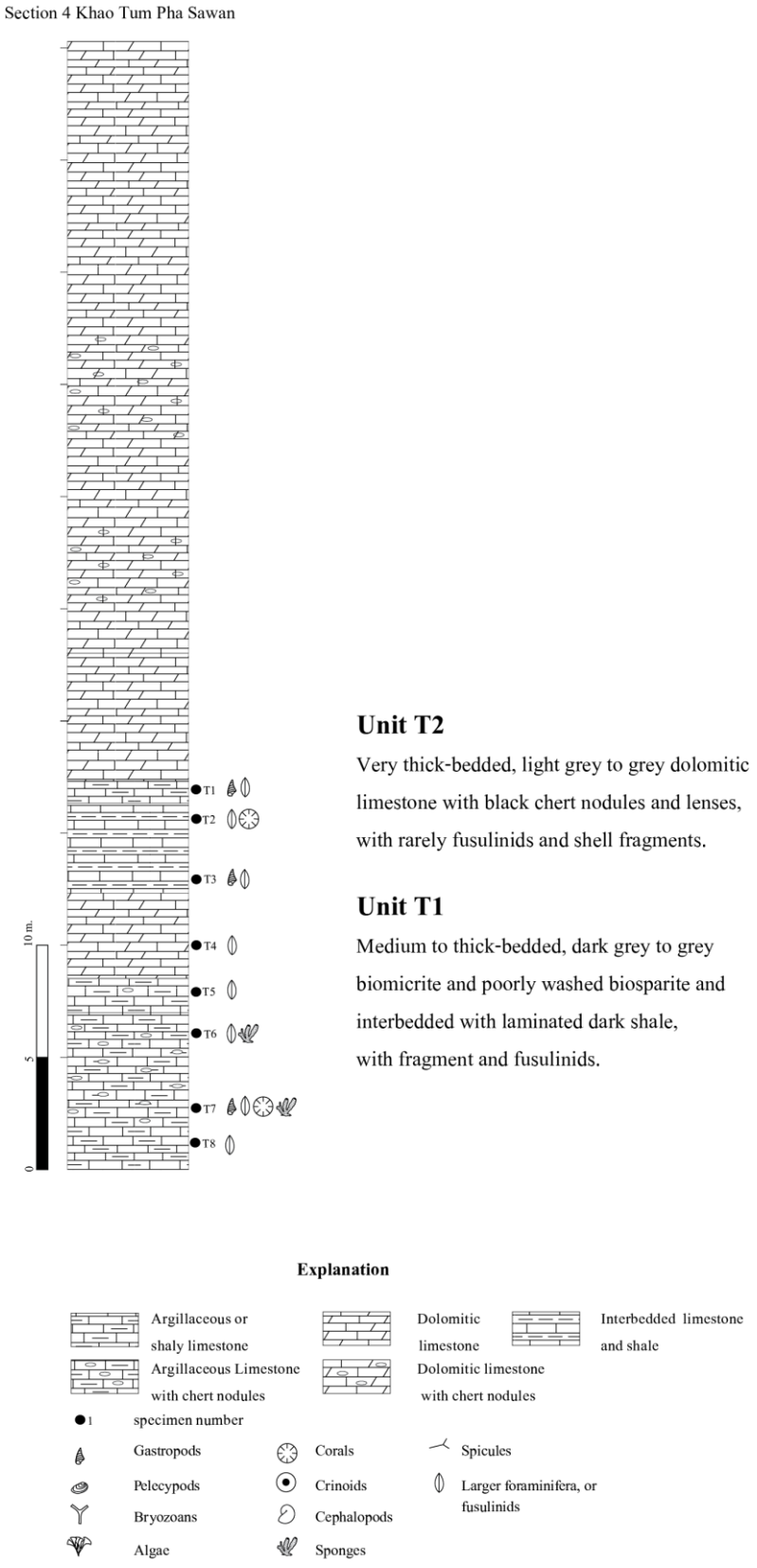


Figure 2.25 Stratigraphic column of section 4 at east of Khao Tum Pha Sawan

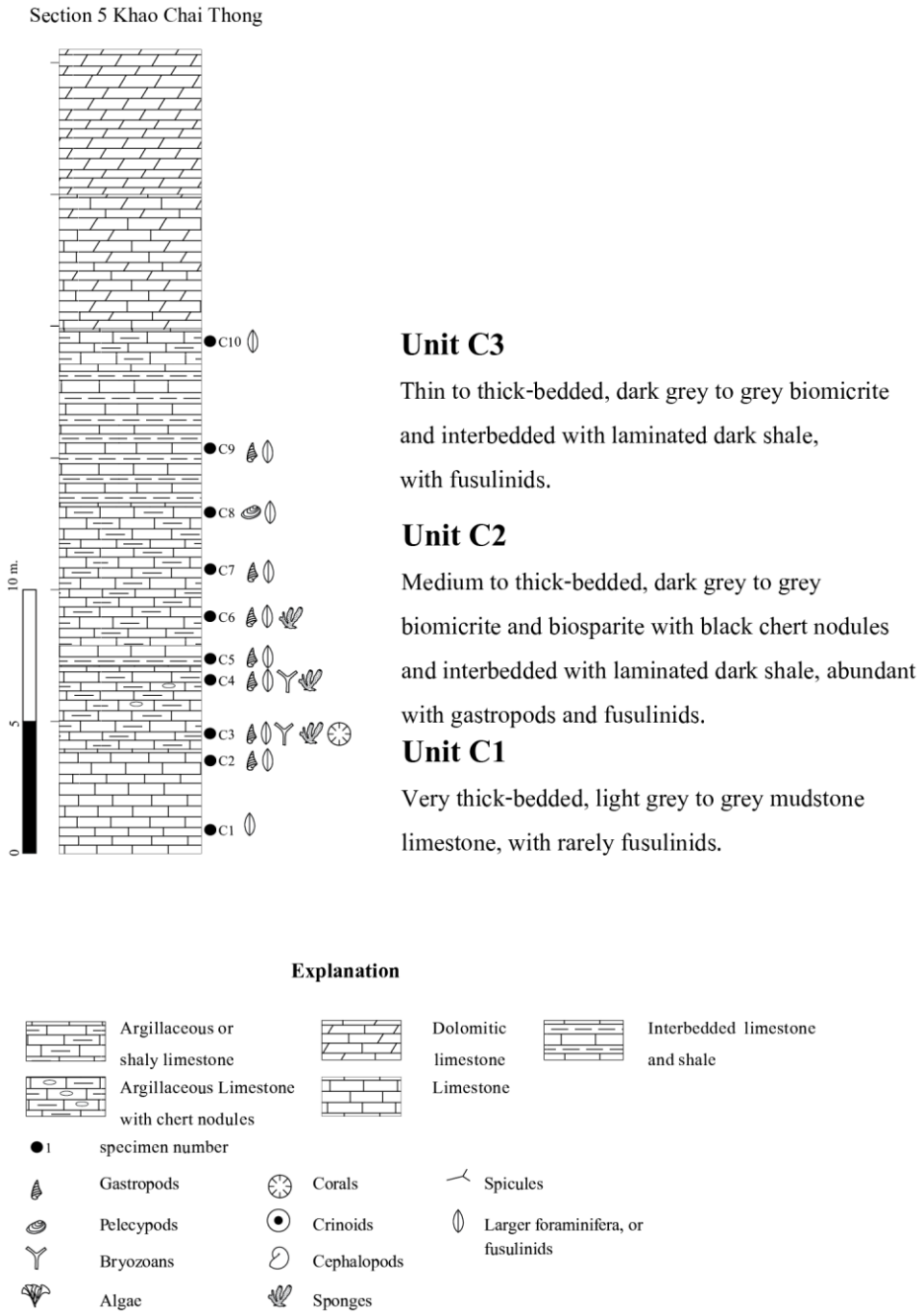


Figure 2.26 Stratigraphic column of section 5 at north of Khao Chai Thong

Figure 2.27 Dolomitic limestone is dominated at the lower part of unit K1 at Khao Kwang section showing elephant skin suface.

Figure 2.28 Medium to thick-bedded dark gray argillaceous limestone (unit K2) show obviously parallel bedding surfaces at Khao Kwang

Figure 2.29 Medium to very thick-bedded limestone show relatively discontinuous wavy parallel bedding surface (unit K3) at east of Khao Kwang

Figure 2.30 Thick-bedded argillaceous limestone intercalated with black chert lenses of unit T2 at Khao Tum Pha Sawan

Figure 2.31 Massive dolomitic limestone extend at the upper part of Khao Tum Pha Sawan section

Figure 2.32 Medium to thick-bedded dark gray micritic limestones show discontinuous wavy parallel bedding surface (unit C1) at east of Khao Chai Thong

Figure 2.33 Medium to very thick-bedded dark gray micritic limestone normally interbedded laminated black shale show clearly parallel bedding surfaces at Khao Chai Thong of unit C3

Figure 2.34 Thick-bedded fossiliferous limestone flourished with shell fragments of unit C2 at Khao Chai Thong

2.3.5 Lithostratigraphy of Khao Chon Due

The exposures of limestone at Khao Chon Due (Figure 2.35) is not continuous (15° 18’ 28” N, 100° 24’ 02” E). The sample could not be collected by the previous sampling method. It is random collected. The carbonate rock is characterized as mudstone to wackestone. Gastropods in this hill have a small to large size (Figure 2.36). Other fossils are massive and solitary rugose corals, tabulate corals, bryozoans, brachiopods, fusulinids, crinoid stems, and sponges.

Figure 2.35 The location of Khao Chon Due showing discontinuous exposures of limestone.

Figure 2.36 The one whorl of large size gastropod that preserved as a mold at Khao Chon Due.

CHAPTER III

SYSTEMATIC PALEONTOLOGY

3.1 Introduction to gastropoda

According to Holthuis (1995), gastropods can live in many habitat on Earth. There are two types of gastropods. First, gastropods in marine habitats ranging from the great deep ocean floor to intertidal zone. Most marine gastropods usually live in shallow water freshwater habitats, as well as other inland aquatic habitats salt lakes including estuaries. The other habitat is inland. Terrestrial mollusks, are found ranging from the tropics to high latitudes in mountains, deserts and rainforest.

The feeding habits of gastropod includes grazers, browsers, suspension feeders, scavengers, detritivores and carnivores. For example, some taxa of carnivore gastropods drill holes in their shelled prey, while some of them may involve grazing on colonial animals. Some species of gastropods feed suctorially and have lost the radula. Most taxa make use of a radula in some aspect of their feeding behavior. The majority of feeding habit is via mouth and radula.

Most marine gastropods are benthic and mainly Epifaunal. These type lives widely on sea bottoms, shielding below or creeping on stones. Some species burrowing into sediments. Some are planktonic. Few such as the violet snails (Janthinidae) and the sea lizards drift on the surface of the ocean where they feed on floating Siphonophore, while others (heteropods and Gymnosomata) are active predators swimming in planktons.

Some snails (such as the whelk *Syrinx aruanus*) reaches 600 mm in length. There are also large (and poorly known) fauna of microgastropods that live in marine, freshwater and terrestrial environments. It is amongst these tiny snails (0.5 - 4 mm) where many of the undescribed species lies.

Most gastropods have separate sexes. However, there are some groups (mainly the Heterobranchia) which are hermaphroditic. These type usually does not undergo

self-fertilization. Derived gastropods uses their penis to copulate or exchange spermatophores and produce eggs which are surrounded by capsules for protections.

Trochophore is the very first gastropod laval stage. It then transforms into a veliger. These veliger will then “settles and undergoes metamorphosis to form a juvenile snail”. Another development route for numerous marine taxa is the direct development. This route though occurs for the majority of freshwater and terrestrial taxa. “Brooding of developing embryos is widely distributed throughout the gastropods, as are sporadic occurrences of hermaphrodism in the non-heterobranch taxa”.

The basal groups have non-feeding larvae while veligers of many neritopsines, caenogastropods and heterobranchs are planktotrophic. Egg size is reflected in the initial size of the juvenile shell or protoconch. This feature has been useful in distinguishing feeding and non-feeding taxa in both Recent and fossil taxa.

3.1.1 Morphology of gastropod

3.1.1.1 *Morphology*

Gastropods can be categorized using their shell structure that having a single (usually coiled) shell. This character “is lost in some slug groups, and a body that has undergone torsion so that the pallial cavity faces forwards. They have a well-developed head that bears eyes and a pair of tentacles (cephalic tentacles)”. The also possess muscular foot used for creeping movement for most species. There are also some species which their foot are developed for swimming or burrowing. While the head-foot is retracted into the shell for their protection, an operculum of the foot seals the shells’ opening (aperture). This structure which existed in all gastropod veliger larvae, it is not present in embryos of some direct developing taxa and juveniles and adults of many heterobranchs. The nervous and circulatory systems are well developed with the concentration of nerve ganglia being a common evolutionary theme.

The shell is typically coiled, usually dextrally. A large retractor muscle is attached to the central columella where the axis of coiling centred. The aperture

which the gastropod can retract, is often sealed with a horny (sometimes calcareous) operculum. The top part of the shell is formed initially from larval shell (the protoconch). “The shell is partly or entirely lost in the juveniles or adults of some groups - with total loss occurring in several groups of land slugs and sea slugs.”

The exterior of gastropods appears to be bilaterally symmetrical. However, the gastropods are one of the most successful clades of asymmetric organisms known. Originally, these group used to have a bilateral symetry (e.g., chitons, cephalopods, bivalves), but gastropod molluscs twist their organ systems into an eight figure. This is possible by developing and/or loosing organs on either side of their midline. and generating shells that coils to the left or right. The best-documented source of gastropod asymmetry is the developmental process known as torsion.

Gastropod has a head with a pair of cephalic tentacles and eyes that are located near the outer bases of the tentacles. In some taxa the eyes are located on short to long eye stalkseyestalks. The mantle edge in some taxa is extended anteriorly to form a respiratory siphon .This is sometimes associated with an elongation of the aperture of the shell. The foot is usually rather large and is typically used for crawling. It can be modified for burrowing, leaping (as in conchs - Strombidae), swimming or clamping (as in limpets)

3.1.1.2 *Terminology*

Definitions of terms from Cox, 1960

Abapical - Away from shell apex toward base along axis or slightly oblique to it.

Adapical - Toward shell apex along axis or slightly oblique to it.

Aperture - Opening at last formed margin of shell, providing outlet for the head-fott mass.

Base - In conispiral shells (with spire projecting as cone), part of surface lying on abapical side of periphery of last whorl or of a carina or angulation that forms an obvious lower boundary on the side of whorl.

Cancellate - Having ornament of intersecting spiral and transverse threads or cords.

Carina - Prominent spiral ridge or keel.

Columella - Solid or hollow pillar surrounding axis of a coiled shell, formed by adaxial walls of whorls.

Cord - Round-topped moderately coarse spiral or transverse linear elevation on shell surface.

Dextral - Right handed; term originally applied to any shell with aperture on observer's right when shell apex is directed upward, or with apparent clockwise coiling when viewed from above apex, but in fact definition depends on features of soft anatomy. A dextral gastropod has genitalia on the right side of the head-foot mass or pallial cavity and the shell of such an animal commonly has the aperature on the right when viewed with the apex uppermost.

Disjunct - Condition of whorls when out of contact.

Dorsum - Dorsal side; side opposite the venter.

Growth lines - Collabrally disposed surface markings of shell, generally not prominent as to relief, that denote former positions of outer lip.

Hyperstrophic - Dextral anatomically, with genitalia on the right, but shell appears as if the anatomy would be on the left side.

Inductura - Smooth shelly layer secreted by general surface of mantle, commonly extending from inner side of aperture over parietal region, columellar lip, and (in some genera) part or all of shell exterior.

Inner lip - Adaxial margin of aperture extending from foot of columella to suture and consisting of columellar and parietal lips.

Involute - With the last whorl enveloping earlier ones so that height (or width in shells like bellerophonts) of aperture corresponds to that of shell; early whorls more or less visible in umbilici.

Lamellae - Thin plates.

Nucleus - Earliest-formed part of shell.

Orthostrophic - Coiled in normal manner, not hyperstrophic.

Outer lip - Abaxial margin of aperture extending from suture to foot of columella.

Parietal region - Basal surface of helicocone just within and just without aperture; the redundant expression parietal wall should not be used, for parietal signifies pertaining to wall.

Peristome - Margin of aperture.

Phaneromphalous - With completely open umbilicus; may be wide, narrow, or very minute.

Ramp - Abapically inclined flattened band on shell surface, which in some shells forms the adapical part of whorls, limited abaxially by ridge or angulation.

Selenizone - Spiral band of crescentic growth lines or threads (lunulae) generated by a narrow notch or slit and characteristic of dibranchiate gastropods.

Septum - Transverse plate secreted within early-formed whorls of some shells for closing them off.

Shoulder - Angulation of whorl forming abaxial edge of sutural ramp or shelf.

Sinus - Curved re-entrant of apertural margin or of growth lines.

Slit - Parallel-sided re-entrant of outer lip ranging from shallow incision to deep fissure as half a whorl in extent.

Spire - Adapical visible part of all whorls except last.

Sutural shelf - Horizontal flattened band, which in some shells adjoins adapical suture of whorls.

Suture - Continuous line on shell surface where whorls adjoin.

Thread - Fine linear surface elevation.

Trochiform - With flat-sided conical, not highly acute spire and rather flat base, like shell of Trochus.

Turbiniform - With broadly conical spire and convex base, as in shell of *Turbo.*

Umbilicus - Cavity or depression formed around shell axis between faces of adaxial walls of whorls where these do not coalesce to form a solid columella; in conispiral shells (except hyperstrophic ones) its opening is at base of shell but involute shells may have two umbilici.

Whorl - (1) Any complete coil of helicocone (a distally expanding coiled tube that forms most gastropod shells); (2) exposed surface of any complete coil of helicocone.

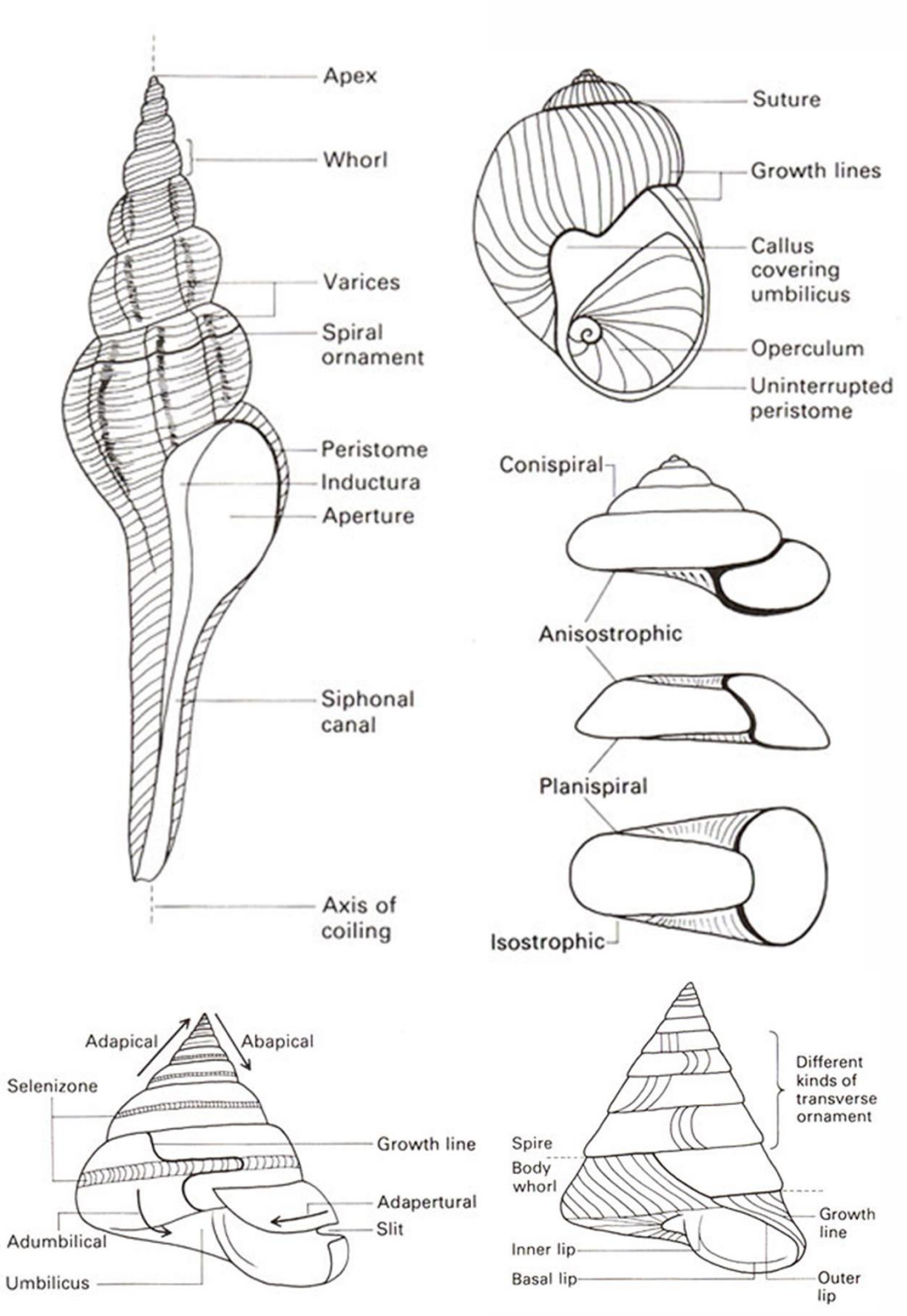


Figure 3.1 Morphology of Gastropod shell (Cheetham et al., 1987)

3.1.2 Measurement

There are sets of characters in which are measured to identify the gastropods in the study area (Moore, 1960).

The standard measurements which are used in various statistical studies are used to describe the specimens of gastropods. This standard measurements are conducted by measuring in the directions either parallel to or perpendicular to the axis of the shell.

The height of a shell or of its spire, last whorl, or aperture, is for most genera defined as the perpendicular distance between two planes perpendicular to the axis and touching both extremities of the shell or of part measured. It is important to note that the height of as of the spire and of the aperture are combined to be equal to that of the whole shell, and that the measurement usually given as the height of the last whorl is the sum of the height of the aperture (i.e., of the ultimate height of the helicocone) and of the distance (parallel with the axis) advanced by the adapical side of the helicocone when describing the last coil.

The main difficulty likely to arise when these measurements are made is that of determining the exact direction of the axis. Slight differences in the tilt of the shell do not greatly affect the measurements of height, but often appreciably affect those of diameter, for this reason, BOYCOTT preferred to define the diameter of the shell as “the greatest dimension that can be found starting with the edge of the lip to a point on the opposite side of the shell on the last whorl.” The direction of this measurement may be very oblique to the axis.

The angular measurements of a shell most frequently recorded relate to the spine and to the slope of the sutures. If the whorls increase in diameter at a regular rate, straight lines can be drawn from the apex or from just above it (since the apex is not a mathematical point) so as to touch all the whorls. The spire angle (or spiral angle) is the angle between two such lines passing down opposite sides of the shell. The angle between straight lines touching any two adjacent whorls on opposite sides of the shell may be termed the incremental angle of that part of the shell. When the

whorls in question are near the apex, the incremental angel is known as the apical angle. In a coeloconoid shell it decreases steadily. It is sometimes useful with shells of these types to cite the mean spire angle, measured by the angle between straight lines joining the apex to the periphery of the last whorl on opposite sides of the shell.

The steepness of coiling of any particular part of a shell is best measurement by the angle between the suture, viewed normally to the axis so as to appear as a straight line, and a plane perpendicular to the axis. This may be termed the sutural slope. This measurement is termed the “sutural angle” by many writers, but, as originally defined by D’Orbigny, the sutural angle is the angle between the suture, viewed as stated, and a line down the side of the shell touching the whorls.

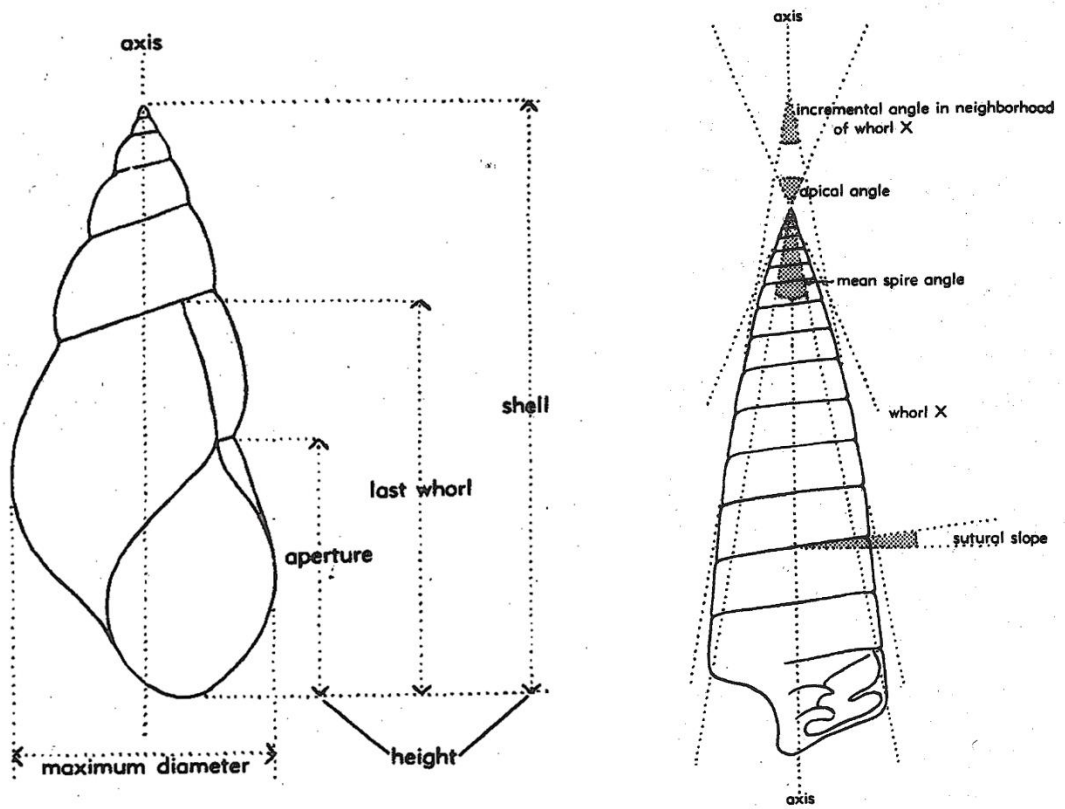


Figure 3.2 Standard measurements (left) and Angular measurement of gastropod shell (right) (Moore, 1960).

3.2 Preservation

The silicification is relatively coarse so that certain morphological features are obscured e.g., the growth line pattern is not visible in most of the specimens. This represents a major handicap for identification, especially in pleurotomariinas and muchisoniinas in which presence and position of the selenizone or sinus is of great diagnostic relevance. Protoconchs are not or not sufficiently preserved in the present collection. As a consequence open nomenclature was used for many species. On the other hand, preservation was sufficiently good to assign specimens to genera and to characterize several species including new taxa.

3.3 Repository

The studied material is housed in the Bayerische Staatssammlung für Paläontologie und Geologie (Bavarian State Collection for Palaeontology and Geology) in Munich, Germany under the general repository number SNSB-BSPG 2014 XI. Some of paratypes are housed in the Chulalongkorn University, Museum of Zoology, Bangkok, Thailand (CUMZ).

3.4 Systematic descriptions

Class **Gastropoda** Cuvier, 1795

Subclass **Amphigastropoda** Simroth, 1906

Order **Bellerophontida** Ulrich & Scofield, 1897

Superfamily **Bellerophontoidea** McCoy, 1852

Family **Euphemitidae** Knight, 1956

Genus ***Euphemites*** Warthin, 1930

Euphemites graffhami Moore, 1941.....Pl. 1 figs 1-7

Genus ***Warthia*** Waagen, 1880

Warthia* cf. *brevisinuata Waagen, 1880.....Pl. 2 figs 1-5

***Warthia* sp.** .....Pl. 2 figs 6-8

Family **Bellerophontidae** McCoy, 1852

Subfamily **Bellerophontinae** McCoy, 1852

Genus ***Bellerophon*** de Montfort, 1808

***Bellerophon* sp.** .....Pl. 2 figs 9-13

***Bellerophon*? sp.** .....Pl. 2 figs 14-15

Genus ***Pharkidonotus*** Girty, 1912

***Pharkidonotus khaonoiensis* n. sp.** .....Pl. 3 figs 1-10

Genus ***Khumerspira*** Murata, 1974

***Khumerspira thailandensis* n. sp.** .....Pl. 4 figs 1-3

Subfamily **Knightitinae** Knight, 1956

Genus ***Retispira*** Knight, 1945

Retispira lyelli Gemmellaro, 1890 .....Pl. 4 figs 4-6

Basal taxa that are certainly Gastropoda

Superfamily **Euomphaloidea** White, 1877

Family **Euomphalidae** White, 1877

Genus ***Discotropis*** Yochelson, 1956

***Discotropis*? sp.** .....Pl. 4 figs 7-9

Genus ***Euomphalus*** Sowerby, 1814

***Euomphalus* sp.** .....Pl. 4 fig. 10

Unassigned to superfamily

Family **Raphistomatidae** Koken, 1896

Subfamily **Omospirinae** Wenz, 1938

Genus ***Baylea*** de Koninck, 1883

***Baylea*? *umbilicata* n. sp.** .....Pl. 5 figs 1-7

Superfamily **Trochonematoidea** Zittel, 1895

Family **Trochonematidae** Zittel, 1895

Genus ***Knightinella*** Licharew, 1975

***Knightinella ornata* n. sp.** .....Pl. 5 figs 8-12

***Knightinella* sp.** .....Pl. 5 figs 13-15

Genus ***Amaurotoma*** Knight, 1945

Subclass **Neritimorpha** Koken, 1896

Order **Cycloneritimorpha** Fryda, 1998

Superfamily **Naticopsoidea** Waagen, 1880

Family **Naticopsidae** Waagen, 1880

Genus ***Naticopsis*** McCoy, 1844

***Naticopsis* spp.** .....Pl. 10 figs 1-9

Family **Trachyspiridae** Nützel, Frýda, Yancey & Anderson, 2007

Genus ***Trachydomia*** Meek & Worthen, 1866

***Trachydomia takhliensis* n. sp.** .....Pl. 9 figs 10-15

Subclass **Caenogastropoda** Cox, 1960

Superfamily **Orthonematoidea** Nützel and Bandel, 2000

Family **Goniasmatidae** Nützel and Bandel, 2000

Subfamily **Goniasmatinae** Nützel and Bandel, 2000

Genus ***Goniasma*** Tomlin, 1930

***Goniasma tricarinata* n. sp.** .....Pl. 11 figs 1-4

Genus ***Stegocoelia*** Donald, 1889

***Stegocoelia* sp. 1**.....Pl. 11 figs 5-6

***Stegocoelia* sp. 2**.....Pl. 11 fig. 7

Family **Orthonematidae** Nützel & Bandel, 2000

Genus ***Orthonema*** Meek & Worthen, 1862

***Orthonema* sp.** .....Pl. 11 figs 8-9

Genus ***Protostylus*** Mansuy, 1914a

***Protostylus* sp.** .....Pl. 12 figs 1-6

Superfamily **Soleniscoidea** Knight, 1931a

Family **Soleniscidae** Knight, 1931a

Subfamily **Soleniscinae** Knight, 1931a

Genus ***Soleniscus*** Meek & Worthen, 1861

***Soleniscus* sp.** .....Pl. 11 figs 10-11

The details descriptions of the forty species in the study area, are as follows:

Class Gastropoda Cuvier, 1795

Subclass Amphigastropoda Simroth, 1906

Order Bellerophontida Ulrich & Scofield, 1897

Superfamily Bellerophontoidea McCoy, 1852

Family Euphemitidae Knight, 1956

Genus ***Euphemites*** Warthin, 1930

Type species. – *Bellerophon urii* Fleming, 1828, Great Britain, Carboniferous.

Euphemites graffhami Moore, 1941

Pl. 1 figs 1-7

1941 *Euphemites graffhami* n. sp. - Moore, p. 142, pl. 2, figs 1–5.

Material. – Two specimens, SNSB-BSPG 2014 XI 58, 105.

Description. – Shell bellerophontiform, anomphalous, with geniculate curvature of body whorl in lateral view; holotype 30 mm long, 28 mm wide, 25 mm thick; first geniculation in aperture, second on opposite side; shell ventrally flattened between geniculations and rounded dorsally; body whorl smooth, probably covered with secondary shell deposits, neither growth lines, selenizone or slit observable; dorsal part of body whorl with broad shallow central furrow; inductura inside aperture with about 10 spiral lirae; aperture strongly bent kidney-shaped in transverse section with steep lateral lips, rounded anterior lip with central sinus (where shallow median furrow is situated) and a rounded triangular inner lip formed by the previous whorl; lateral lips joining body whorl with an U-shaped sinus in lateral view.

Remarks. – Despite the differences in age and region, we assign the present material to *Euphemites graffhami* Moore, 1941 from the late Pennsylvanian of Kansas, USA because there are no obvious morphological differences between our material and Moore (1941) type material as illustrated by this author. The geniculation was not mentioned in Moore's description but becomes obvious from his illustrations (Moore 1941, figs 4b, 5b). As pointed out by Yochelson (1960), there are not many distinctly geniculated species of the genus *Euphemites*. *Euphemites imperator* Yochelson, 1960 from the Permian of Texas is the most similar species. However, in this species, the spirally ornamented inductura extends much farer outside the aperture. Moreover, the shell *Euphemites graffhami* is much more flattened ventrally. *Euphemites graffhami* is similar to *E. nodosocarinatus* (Hall, 1858) from the Pennsylvanian of the USA as reported by Kues and Batten (2001). However, this species has many more inductural lirae and according to Yochelson (1960), it has nodes near the selenizone as is also the case in *E. callosus* (Weller, 1930).

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 58	29.7	27.0	-	-
2014 XI 105	30.0	28.0	25	10

Genus ***Warthia*** Waagen, 1880

Type species. – *Warthia brevisinuata* Waagen, 1880, Permian, India.

Warthia* cf. *brevisinuata Waagen, 1880

Pl. 2 figs 1-5

1880 *Warthia brevisinuata* n. sp. – Waagen, p. 161, pl. 15, fig. 6.

2014 *Bellerophon* sp. 1 – Ketwetsuriya *et al.*, p. 139, pl. 1, figs A, B.

Material. – SNSB-BSPG 2014 XI 2, 27 and several other specimens.

Description. – Shell globular bellerophontiform, anomphalous; larger illustrated specimen 4.9 mm long, 5.3 mm wide, 4.3 mm thick (SNSB-BSPG 2014 XI 27); whorl profile and anterior lip evenly rounded; whorls smooth, probably covered with secondary shell layers; whorls kidney-shaped, low in transverse section.

Remarks. – Several relatively small smooth bellerophontoids representing the genus *Warthia* are present in this collection. Of the numerous described Late Palaeozoic *Warthia* species, *Warthia brevisinuata* Waagen, 1880 from the Permian of the Salt Range, Pakistan seems to be most similar. But because of the preservation and the relatively uncharacteristic shell morphology, a safe identification is impossible.

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 2	3.2	3.1	2.7	0.8
2014 XI 27	4.9	5.3	4.3	1.7

***Warthia* sp.**

Pl. 2 figs 6-8

Material. – One specimen, SNSB-BSPG 2014 XI 106.

Remarks. – This shell representing the genus *Warthia* (31 mm long, 32 mm wide) resembles the much smaller specimens of *Warthia* cf. *brevisinuata* as described above but has callus (inductural) pads on the umbilical region and on the lateral lips. It is possible that these smaller specimens representing *Warthia* cf. *brevisinuata* are juveniles and are conspecific with the present mature shell.

Dimensions. (in mm.)

Specimen no.	H	W
2014 XI 106	31.0	32.0

Family Bellerophontidae McCoy, 1852

Subfamily Bellerophontinae McCoy, 1852

Genus ***Bellerophon*** de Montfort, 1808

Type species. – *Bellerophon vasulites* de Montfort, 1808, Devonian, Germany.

***Bellerophon* sp.**

Pl. 2 figs 9-13

Material. – Three specimens, SNSB-BSPG 2014 XI 49, 65 (fragment), 107 (fragment).

Description. – Bellerophontid with deeply umbilicated shell; whorls low, broad in transverse section ornamented with distinct collabral lirae separated by wider interspaces; selenizone narrow, bordered by undulating lirae, with distinct lunulae.

Remarks. – Although only fragments are present, the characteristic selenizone and ornament suggest the presence of an additional bellerophontid species in the Tak Fa fauna.

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 49	14.3+	18.1	12.6	5.7
2014 XI 65	11.2+			

***Bellerophon*? sp.**

Pl. 2 figs 14-15

Material. – One specimen, SNSB-BSPG 2014 XI 60.

Remarks. – This anomphalous bellerophontoid shows growth lines and a faint spiral striation. It is 24 mm long, 28 mm wide and 26 mm thick and seems to have a slight depression at the supposed position of the selenizone. The anterior lip is evenly rounded. Preservation is insufficient for a taxonomic assignment. It could represent the genera *Bellerophon*, *Retispira* or *Warthia* with outer shell layers peeled off.

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 60	24.0	28.0	26.3	15.0

Genus ***Pharkidonotus*** Girty, 1912

Type species. – *Bellerophon percarinatus* Conrad, 1842 ; Pennsylvanian, USA.

***Pharkidonotus khaonoiensis* n. sp.**

Pl. 3 figs 1-10

2014 *Bellerophon*? sp. 2 – Ketwetsuriya *et al.,* p. 139, pl. 1, fig. C.

Etymology. – After the Khao Noi Hill at which the studied gastropod material was found.

Material. – Holotype: SNSB-BSPG 2014 XI 88; paratypes: SNSB-BSPG 2014 XI 4, 46, 59, 61, CUMZ 7001.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell bellerophontiform, globose, longer than wide, anomphalous; holotype 30 mm long, 23 mm wide, 26 mm thick; whorl profile round in lateral view; whorls with pronounced, steeply sided median crest with selenizone; borders of selenizone undulating on last part of the body whorl; outer lip as reflected by growth lines sickle-shaped; aperture kidney-shaped in transverse section with rounded anterior lip, U-shaped at crest; inductura extending from umbilici over some area outside the aperture.

Remarks. – *Pharkidonotus khaonoiensis* n. sp. resembles *Khumerspira thailandensis* n. sp. but is more slender and lacks or has much weaker lateral angulations. *Pharkidonotus khaonoiensis* has a much more bent aperture in transverse section and the crest is much more pronounced. It also differs in these respects from *Bellerophon* (*Pharkidonotus*) *altitropis* Kulas & Batten, 1997 (Permian, USA) and moreover, that species is phaneromphalous. *Bellerophon deflectus* Chronic, 1952 from the Permian USA is much broader and its aperture is less bent in transverse section and has a much more pronounced callus. *Pharkidonotus khaonoiensis* n. sp. differs from the vast majority of species assigned to *Bellerophon* in having a strongly elevated crest with steep sides hosting the selenizone. However, some species of *Bellerophon* including its Devonian type species also have a distinctly elevated crest.

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 4	5.5+	4.5+	5.6+	
2014 XI 38	7.9	8.2	6.2	2.9
2014 XI 46	13.1	11.5	10.7	4.2
2014 XI 59	25.0	18.2+	24.2	13.2
2014 XI 61	16.3	15.2	14.6	9.6
2014 XI 88	24.1	22.2	28.4	13.6

Genus ***Khumerspira*** Murata, 1974

Type species. – *Khumerspira ishii* Murata, 1974 (in Ishii & Murata), Middle Permian, Cambodia.

Remarks. – The present species *Khumerspira thailandensis* n. sp. is assigned to the genus *Khumerspira* Murata, 1974 (in Ishii & Murata) because it has lateral edges, a wide low, subrectangular aperture in transverse section and a sharply projecting median crest. Accordingly, *Khumerspira* has also strongly reflexed lateral lips but judging from the illustration of the type species given in Ishii and Murata (1974), it is not quite clear what this means. *Khumerspira thailandensis* n. sp. also resembles species of the genus *Pharkidonotus* Girty, 1912. However, *Pharkidonotus* has usually rather strong collabral transverse undulations on the shell and some species also have nodules. Given the shape and gross morphology, *Khumerspira thailandensis* n. sp. is closer to the type species of *Pharkidonotus* as shown by Knight (1941) and Girty (1951) than to that of *Bellerophon* although this species (type of *Pharkidonotus*) has much stronger transverse rugae. The genus (subgenus) *Bellerophon* (*Sorobanobaca*) *matsumotoi* Nishida, 1969 from the Middle Permian of Japan is also similar but is umbilicated and has a spiral ornament.

Khumerspira and *Pharkidonotus* are so close to each other morphologically that they may represent synonyms (Mazaev 2016, written communication). *Sorobanobaca* is also quite similar and might also be synonymous to the other two genera. However, it is beyond the scope of the present contribution to present a formal synonymization. Preliminarily, we suggest to treat bellerophontoids with median crest, wide subrectangular aperture and lateral shoulders as follow:

Pharkidonotus: anomphalous, with transverse rugae and also with nodes in several species

Khumerspira: anomphalous, ornament with growth lines only

Sorobanobaca: phaneromphalous; spiral ornament present

In that sense, *Khumerspira* might be regarded as a *Pharkidonotus* lacking strong ornament of rugae and nodes.

***Khumerspira thailandensis* n. sp.**

Pl. 4 figs 1-3

Etymology. – After the country of Thailand.

Material. – Only the holotype, SNSB-BSPG 2014 XI 93.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell bellerophontiform, broad with sharp, distinctly elevated crest with selenizone and lateral rounded edges; holotype 22 mm long, 21 mm wide, 16 mm thick; shell concave between crest and lateral edges; shell slightly convex below edges; whorls approximately rectangular in transverse section; whorl surface largely smooth smooth, only weak traces of collabral rugae on dorsal side; growth lines very faint, not well-preserved; aperture broad, anterior lip thin, V-shaped at crest; posterior lip concave due to previous whorl, with parietal inductura and two lateral pads, smooth and thick; umbilici completely covered.

Remarks. – As mentioned above, *Khumerspira thailandensis* n. sp. resembles species of the genus *Pharkidonotus* in gross morphology but lacks strong rugae and nodes. It resembles *Bellerophon* (*Sorobanobaca*) *matsumotoi* Nishida, 1969 from the Middle Permian of Japan. However, this species and subgenus has a collabral and spiral ornament which is lacking in the present material. Moreover, Nishida (1969) mentioned that his species is phaneromphalous. *Khumerspira thailandensis* n. sp. is also similar to *Bellerophon khaonoiensis* n. sp. as described above but the shoulder of this species is rounded or only slightly angulated and the anterior lip has steeper sides. *Pharkidonotus thailandensis* n. sp. also resembles *Bellerophon deflectus* Chronic,

1952 (which may be transferred to *Khumerspira*) from the Early Permian of Arizona but the dorsal crest is less elevated in the latter and it is much larger. Yochelson (1960) reported a similar species from the Permian of Texas as "*Bellerophon* (?) species" but this shell is widely phaneromphalous. Yochelson (1960) stated that because of the crest, this species would not represent *Bellerophon* in a strict sense.

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 93	22.3	21.5	16.5	13.5

Subfamily Knightitinae Knight, 1956

Genus ***Retispira*** Knight, 1945

Type species. – *Retispira bellireticulata* Knight, 1945, Middle Permian, Texas.

Retispira lyelli Gemmellaro, 1890
Pl. 4 figs 4-6

1972 *Retispira lyelli* (Gemmellaro, 1890) – Batten, p. 13, figs 6, 7 (here more synonymy).

Material. – Two specimens, SNSB-BSPG 2014 XI 26, 32.

Remarks. – This rather characteristic species was originally described from the Sosio Limestone of Sicily, Italy. The larger present specimen is 6.3 mm long, 5.7 mm wide and 4.4 mm thick. Batten (1972) reported it from the Permian of Perak, Malaysia and considered several taxa described from Asia and North America to represent synonyms. It is distinctly phaneromphalous, has low whorls and an ornament of strengthened growth lines and densely spaced spiral threads.

Dimensions. (in mm.)

Specimen no.	H	W	Thickness	HPR
2014 XI 26	5.0	4.2+	4.3	1.1
2014 XI 32	6.3	5.7	4.4	1.9

Basal taxa that are certainly Gastropoda

Superfamily Euomphaloidea White, 1877

Family Euomphalidae White, 1877

Genus ***Discotropis*** Yochelson, 1956

Type species. – *Discotropis publicus* Yochelson, 1956, Permian, USA.

Remarks. – *Discotropis* was previously placed in Omphalotrochidae (Knight et al., 1960) but was placed in Euomphalidae by Linsley and Kier (1984) without explaining on what grounds.

***Discotropis*? sp.**

Pl. 4 figs 7-9

Material. – One specimen, SNSB-BSPG 2014 XI 91.

Description. – Discoidal, widely phaneromphalous dextral shell with upper umbilicus and somewhat deeper lower umbilicus; diameter 2.9 mm, height 1.2 mm; strong angulation above mid-whorl and a further angulation on the upper side of whorls; whorl profile asymmetrical with slope ca. 45° above angular periphery and much steeper below it; lower side of whorls distinctly convex; transition from whorl face to base distinctly angular; distinct spiral cords present on whorl face, four below periphery and at least one above; suture distinct; aperture subcircular, as wide as high.

Remarks. – The present specimen resembles *Discotropis klobukowskii* Mansuy, 1912 from the Carboniferous of Yunnan, a species also reported by Delpey (1941) from the Permian of Cambodia. However, that species has a slightly elevated spire, axial sculptural elements and an upper edge. The present species probably represents a new species that may represent the genus *Discotropis* but the single specimen to is too poorly preserved for a sufficient characterization. The generic and suprageneric assignment of this species is uncertain because tiny planispiral shells are present in various gastropod groups (e.g., Bandel 1988).

Dimensions. (in mm.)

Specimen no.	H	W	HPR	No.Whorls
2014 XI 91	1.2	2.9	0.7+	2.5+

Genus ***Euomphalus*** Sowerby, 1814

Type species. *Euomphalus pentangulatus* J. Sowerby, 1814, Carboniferous, Great Britain.

***Euomphalus* sp.**

Pl. 4 fig. 10

Material. – One specimen, SNSB-BSPG 2014 XI 69.

Description. – Discoidal, widely phaneromphalous shell with both umbilici equally deepened; diameter 4.8 mm; whorls round, almost circular in transverse section; whorl surface smooth; suture deep.

Remarks. – This small planispiral shell may represent early whorls of an unknown euomphalid.

Dimensions. (in mm.)

Specimen no.	H	W
2014 XI 69	4.5	4.8

Unassigned to superfamily

Family Raphistomatidae Koken, 1896

Subfamily Omospirinae Wenz, 1938

Genus ***Baylea*** de Koninck, 1883

Type species. – *Trochus yvanii* Léveillé, 1835, Carboniferous, Belgium.

Remarks. – Knight *et al.* (1960) and Batten (1995) placed *Baylea* in Raphistomatidae Koken, 1896 but Mazaev (2015) placed it in Phymatopleuridae.

***Baylea*? *umbilicata* n. sp.**

Pl. 5 figs 1-7

2014 *Worthenia*? sp. – Ketwetsuriya *et al.*, p. 140, pl. 1, fig. J.

Etymology. – For the distinctly umbilicated base.

Material. – Holotype: SNSB-BSPG 2014 XI 13, paratypes: SNSB-BSPG 2014 XI 22, 23, 29, 31, 97, 102, 103?, CUMZ 7002, 7003.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell turbinate, moderately high-spired, gradate; holotype comprises about 6 whorls, 8.2 mm high, 6.4 mm wide; largest specimen 9.8 mm high, 6.8 mm wide; whorls sharply angulated at about mid-whorl and somewhat below middle of spire whorls; whorls with distinctly inclined subsutural ramp above and vertical, concave below angulation; angulation forms crest-like periphery of whorls; transition to base angular; whorls ornamented with numerous, densely spaced spiral threads; up to eight spiral threads present on ramp and at least four below angulation; growth line pattern including selenizone obscured due to preservation; selenizone probably at peripheral angulation of whorls; base flatly convex, without visible ornament, distinctly phaneromphalous with umbilicus surmounted by a rounded edge.

Remarks. – Due to the coarse silicification, growth line pattern including selenizone are obscured in the present material and thus, the generic placement is uncertain. It is likely that the selenizone is situated at the peripheral angulation of the whorls. *Baylea*? *umbilicata* n. sp. is placed tentatively in the genus *Baylea* based on the gradate spire and the ornament of spiral lirae. The distinctly phaneromphalous base and the angular transition from whorl face to base are unusual for *Baylea* and differentiate the present species from other species of this genus. It is also possible that *Baylea*? *umbilicata* n. sp. belongs in the genus *Platyzona* Knight, 1945. The type species of *Platyzona* is only minutely phaneromphalous and the whorls are usually not strongly angulated but rounded.

A well-preserved specimen of *Baylea yvanii*, type species of *Baylea*, from the Mississippian of Belgium was illustrated by Lindström & Peel (2005, fig. 1A). It is more high-spired than *Baylea*? *umbilicata* n. sp., has a much shallower ramp and thus the spire is more gradate and the transition from whorl face to base is evenly rounded. Its base has only a pseudo-umbilicus. Several Middle Permian species from Russia have been assigned to *Baylea*. Most are much more high-spired than *Baylea*? *umbilicata* n. sp. and have stronger spiral lirae which are more distant from each other and non of them has such a wide umbilicus. *Baylea perthensis* Dickins, 1963 from the Permian of Australia is much more low-spired and less distinctly gradate and has a spiral ornament on the base. *Baylea*? *umbilicata* n. sp. resembles species of the genus *Biarmeaspira*

Mazaev, 2006 for instance the Middle Permian species *B. angulata* (Netchaev, 1894.) and *B. yakowlewi* (Licharew, 1967) but both have strong spiral cords on the base and they are not distinctly phaneromphalous.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	Apical angle(degrees)	No. Of whorls
2014 XI 13	8.2	6.4	5.1	61	6.0
2014 XI 22	9.8	6.8	-	53	5.5
2014 XI 23	7.7	7.0	3.1	54	5.5
2014 XI 29	7.2+	6.5	4.6	73	4.5+
2014 XI 31	8.1+	7.4	-	56	5.5+
2014 XI 97	6.6+	6.5	-	50	5.5+
2014 XI 102	6.1+	5.8	-	57	3+
2014 XI 103	3.6+	3.1	-	65	3+
2014 XI 104	6.4+	7.3	5.6	-	1+
2014 XI 113	6.9+	7.2	-	-	3+

Superfamily Trochonematoidea Zittel, 1895

Family Trochonematidae Zittel, 1895

Genus ***Knightinella*** Licharew, 1975

Type species. – *Pleurotomaria humerosa* Meek & Hayden, 1858, Carboniferous, USA.

Remarks. – *Knightinella* was proposed as a subgenus of *Amaurotoma* Knight, 1945.

***Knightinella ornata* n. sp.**

Pl. 5 figs 8-12

2014 *Worthenia*? sp. – Ketwetsuriya *et al.*, p. 140, pl. 1, fig. I

Etymology. – Latin ornamented.

Material. – Holotype: SNSB-BSPG 2014 XI 39; paratypes: SNSB-BSPG 2014 XI 9, CUMZ 7004.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell acutely turbiniform, moderately high-spired; holotype (largest specimen) consisting of ca. 5 whorls, earliest whorls missing, 13.5 mm high, 10.2 mm wide; early teleoconch whorls evenly convex; later, an angulation develops at middle of whorl face; angulation separates adapical slightly convex ramp and a subvertical, slightly convex abapical portion (outer whorl face); base evenly convex with rounded transition to whorl face, anomphalous; early teleoconch whorls with four to six spiral cords, abapical cords stronger; five to six spiral cords and weaker axial ribs or strengthened growth lines present on ramp in mature whorls; strengthened growth lines on ramp curving backward towards angulation; intersections of axial ribs and spiral cords slightly nodular; outer whorl face below angulation ornamented with three strong spiral cords and few weak spiral lirae; base with ca. 10 distinct spiral cords; aperture circular columellar lip reflexed.

Remarks. – We assign *Knightinella ornata* n. sp. to the genus *Knightinella* Licharew, 1975 based on the gross morphology and the dominant spiral ornamentation. Due to preservation, the growth line pattern is unclear i.e., whether a selenizone is present and if so, how it would look like. The juvenile specimen illustrated in Figure 11 F shows backward curving growth lines on the ramp and this could indicate that a selenizone is present at the angulation. If the present species had a selenizone at the angulation of the whorls, it could represent the genus *Biarmeaspira* Mazaev, 2006 (see also

Mazaev 2015). *Knightinella humerosa* (Meek and Hayden, 1858), the Carboniferous type species of *Knightinella* has a shallower ramp and the spiral cords are narrower (Knight, 1945; Kues and Batten, 2001). *Amaurotoma subsinuata* (Meek and Worthen, 1861), type species of the genus *Amaurotoma* Knight, 1945, lacks ramp and angulation of the whorls according to an illustration given by Knight *et al.* (1960, fig. 139/4). *Apachella* Winters, 1956 is more high-spired and the whorls are less angulated. The genus *Worthenia* yields similar species but is characterized by an elevated, nodular selenizone.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	No.Whorls	A angle(degrees)
2014 XI 9	5.5	5.3	-	5	60
2014 XI 39	13.5	10.2	10.0	5	83
2014 XI 86	6.9	6.3	4.7	5	75

***Knightinella* sp.**

Pl. 5 figs 13-15

2014 *Worthenia*? sp. – Ketwetsuriya *et al.*, p. 140, pl. 1, fig. J .

Material. – Two specimens, SNSB-BSPG 2014 XI 43, 110.

Description. – Turbinate shell with distinctly gradate spire; larger specimen ca. 6 whorls, 11.2 mm high, 11.5 mm wide; whorls with sharp angulation above mid-whorl; ramp between adapical suture and angulation rather shallow, concave with fine spiral threads which are slightly nodular when intersecting with strengthened growth lines; adapical spiral threads somewhat stronger and more nodular than those lower on ramp; outer whorl face below carination vertical, slightly concave; outer face with several sharp spiral threads of variable strength but generally stronger than threads on ramp; transition to base angular; base not preserved.

Remarks. – *Knightinella* sp. resembles *Knightinella ornata* n. sp. but has a lower spire, a weaker spiral ornament and the spire is more gradate because the ramp is shallower. As in *Knightinella ornata* n. sp., presence and nature of the selenizone are unclear due to preservation. The present shells resemble *Knightinella uralica* Licharew, 1975 from the Carboniferous of Russia but this species has fewer spiral lirae on whorl face.

Dimensions. (in mm.)

Specimen no.	H	W	No.Whorls	A angle(degrees)
2014 XI 43	11.2+	11.5	6.5	67
2014 XI 110	8.9+	7.1+	-	-

Genus ***Amaurotoma*** Knight, 1945

Type species. – *Pleurotomaria subsinuata* Meek & Worthen, 1861, Pennsylvanian, USA.

***Amaurotoma*? sp.**

Pl. 6 figs 1-6

Material. – Three specimens, SNSB-BSPG 2014 XI 16, 64, 89.

Description. – Shell small, turbinate; largest specimen (SNSB-BSPG 2014 XI 16) comprises ca. 3.5 whorls, 5.5 mm high, 3.6 mm wide (apex missing); whorls convex, ornamented with three strong spiral cords in abapical portion of whorls; second cord forms periphery at about mid-whorl; adapical portion of whorls form steep, straight or slightly convex ramp with three weaker spiral cords second of which somewhat more pronounced and angulating whorl face; adapical spiral cords slightly nodular; base convex, minutely phaneromphalous with up to seven distinct, narrowly spaced spiral cords; growth line pattern and aperture unknown.

Remarks. – *Amaurotoma*? sp. is distinct in this collection. Unfortunately neither growth line pattern nor aperture are known so that a further assignment is impossible. It is

also possible that the species belongs to pleurotomarioids. We assign it preliminarily to *Amaurotoma* because it resembles species such as *Amaurotoma subangulatum* (Hall, 1858) from the Mississippian of the USA (see Cumings 1906, pl. 25, fig. 32). An assignment to *Baylea* or *Apachella* Chronic, 1952 is also possible. *Rhabdotocochlis* Knight, 1933 from the Late Carboniferous of the USA has a lower spire and less convex whorls.

Dimensions. (in mm.)

Specimen no.	H	W	No.Whorls	A angle(degrees)
2014 XI 16	5.5	3.6	3.5+	61
2014 XI 64	6.9	4.8	4.5+	64

Subclass Vetigastropoda Salvini-Plawen, 1980

Order Pleurotomariida Cox & Knight, 1960 (in Knight *et al.*)

Superfamily Eotomarioidea Wenz, 1938

Family Eotomariidae Wenz, 1938

Takfaia new genus

Type species. – *Takfaia kuesi* n. sp.

Etymology. – After the Tak Fa Limestone

Diagnosis. – Shell low-spired, trochiform with flattened spire; mature shell broadly trochiform with almost straight to slightly convex whorl face; last portion of body whorl distinctly deflected abapically; selenizone immediately above suture, forming periphery, bordered by distinctly elevated, sharp crests; selenizone concave, vertical, parallel to shell axis; adapical border of selenizone forming angulation with sloping whorl face; whorls smooth, base convex, distinctly phaneromphalous with umbilicus vertical sided, surmounted by a distinct edge.

Remarks. – *Takfaia* resembles the genus *Ambozone* Batten, 1972 (type species *Ambozone rasmusseni* Batten, 1972 from the Middle Permian of Malaysia). However, *Ambozone* is more low-spired (almost planispiral). *Euconospira* Ulrich & Scofield, 1897 is more high-spired and is either anomphalous or only minutely phaneromphalous. The Devonian genus *Oehlertia*, Perner, 1907 is similar but the selenizone is well above the suture, it is more high-spired and the shell is ornamented with fine but distinct axial lirae. The eotomariid *Bradyospira* Batten, 1964 from the Permian of Arizona is similar but has a conical, non-depressed spire and the umbilicus is much narrower.

***Takfaia kuesi* n. sp.**

Pl. 6 figs 7-14

2014 *Discotropis*? sp. – Ketwetsuriya *et al.*, p. 142, pl. 2, fig. E.

Etymology. – After Barry Kues for his work on Late Palaeozoic gastropods.

Material. – Holotype: SNSB-BSPG 2014 XI 42; paratypes SNSB-BSPG 2014 XI 10, 17, CUMZ 7005, 7006.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell low-spired, trochiform with flattened apical whorls; holotype ca. 5 whorls, 7.7 mm high, 11.4 mm wide; largest specimen 9.8 mm high, 11.4 mm wide (SNSB-BSPG 2014 XI 10); earliest whorls convex, evenly rounded, very low-spired with spire only slightly elevated; after ca. three whorls the shell becomes broadly trochiform with almost straight to slightly convex whorl face; last portion of body whorl distinctly deflected abapically; selenizone immediately above suture, forming

periphery, bordered by distinctly elevated, sharp crests; selenizone vertical, parallel to shell axis; adapical border of selenizone forming angulation with sloping whorl face; abapical crest bordering selenizone emerges at suture; suture distinct; selenizone fully exposed when last portion of body whorl becomes deflected downward; whorls smooth, circular in transverse section; base convex, distinctly phaneromphalous with umbilicus opened throughout including initial whorls; umbilicus of last two whorls with vertical, slightly convex whorl sides; umbilicus surmounted by a distinct edge.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	A angle(degrees)
2014 XI 10	9.8	11.4	9.3	97
2014 XI 17	6.6	9.7	5.2	-
2014 XI 42	7.7	11.4	7.2	98
2014 XI 85	7.0	10.4	5.5	98

Genus ***Glabrocingulum*** Thomas, 1940

Type species. – *Glabrocingulum* (*Glabrocingulum*) *beggi* Thomas, 1940, Carboniferous, England.

***Glabrocingulum magnum* n. sp.**

Pl. 7 figs 1-13

2014 *Treposira* sp. – Ketwetsuriya *et al.*, p. 139, pl. 1, figs D–G.

2014 *Glabrocingulum* sp. – Ketwetsuriya *et al.*, p. 140, pl. 1, fig. H.

Etymology. – Latin magnum for large.

Material. – Holotype: SNSB-BSPG 2014 XI 92; paratypes: SNSB-BSPG 2014 XI 3, 12, 24, 25, 33, 44, 48, 50, CUMZ 7007, 7008.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell trochiform, low-spired, with slightly coeloconoid spire; body whorl height about 65% of total height; holotype (largest specimen) ca. 40 mm high and wide; apical angle of up to 90°; whorls angulated at about mid-whorl; second angulation at transition to base; outer face between angulations vertical (parallel to shell axis), concave; whorls above adapical angulation straight to slightly concave, forming evenly sloping ramp; narrow concave selenizone on adapical angulation bordered by distinct, sharp spiral lirae; whorls embrace just below selenizone so that selenizone is in suprasutural position in spire whorls; whorls ornamented with a row of subsutural axially elongated nodes which become stronger during ontogeny; in mature specimens this nodular row form a bulge that is adpressed to previous whorl; remainder ramp with several spiral lirae; abapical portion between carinations with several spiral cords which may be slightly nodular; growth lines prosocline on ramp and prosocyrt below adapical carination; base convex to conical, anomphalous with circumumbilical carination; base with variable number of spiral cords including one formed by carination; basal spiral cords may be nodular, especially in mature whorls; aperture oblique oval.

Remarks. – With up to 40 mm in height and width, *Glabrocingulum magnum* n. sp. is a rather large representative of the genus *Glabrocingulum*. The strong subsutural nodes and the angulations on the base and at the transition to the base are especially characteristic for this species. There are numerous Late Palaeozoic species of *Glabrocingulum* most of which are smaller and have a finer ornament. *Glabrocingulum coronatum* Chronic, 1952 from the Permian Kaibab Formation of Arizona, USA is much smaller, has a lower spire, a much finer ornament and it lacks a carinated and ornamented base (see also Batten 1989, pl. 1, fig. 1–23). *Glabrocingulum beedei* (Mark,

1912) from the Pennsylvanian of Ohio and the Pennsylvanian/Permian transition of New Mexico has a lower spire, is much smaller, subsutural nodes are not as pronounced and it has no pronounced carination at the transition to the base (Kues, 2004; Sturgeon, 1964). The Permian species *Glabrocingulum sarrauti* (Mansuy, 1912) and *Glabrocingulum stankovski* Mazaev, 2006 are similar but have a lower spire, differ in details of the ornament and have no pronounced basal angulation (see Batten 1972, figs 12, 13; Mazaev 2006, fig. 1).

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	Apical angle (degrees)	No. Of whorls
2014 XI 3	7.8	5.8	-	71	-
2014 XI 12	12.0	11.2	7.9	83	6.5
2014 XI 24	10.3	11.4	6.5	83	5.5
2014 XI 25	11.3+	11.2	-	75	5.5
2014 XI 33	7.7+	6.8+	4.6+	68	5
2014 XI 44	10.5	10.1	6.6	70	5.5
2014 XI 48	11.1	15.3	9.4	77	6.5
2014 XI 50	24.0+	23.1	16.4+	83	5+
2014 XI 63	24.4	25.6	16.1	84	5+
2014 XI 84	27.6	31.0	14.3	80	5.5
2014 XI 92	35.3+	35.3	31.8	85	3.5+

Order Trochida Cox & Knight, 1960 (in Knight *et al.*)

Superfamily Trochoidea Rafinesque, 1815

Family Anomphalidae Wenz, 1938

Genus ***Anomphalus*** Meek & Worthen, 1866

Type species. – *Anomphalus rotulus* Meek & Worthen, 1867, Carboniferous, USA.

***Anomphalus lateumbilicatus* n. sp.**

Pl. 8 figs 8-14

Etymology. – Latin widely umbilicated.

Material. – Two specimens, holotype: SNSB-BSPG 2014 XI 115; paratype: SNSB-BSPG 2014 XI 116.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell minute, discoidal with almost flat, only slightly elevated spire; holotype comprising ca. five whorls, diameter 2.7 mm, 1.5 mm high, whorls smooth, with distinctly convex periphery and flatly convex adapical side; whorls increasing slowly in diameter; suture distinct; base with wide umbilicus with circumumbilical rounded edge.

Remarks. – *Anomphalus lateumbilicatus* n. sp. differs from all its congeners by its minute size, its very wide umbilicus and the slow increase in whorl diameter. The most similar species is *Anomphalus straparoliformis* Mazaev, 1997 from the Middle Carboniferous of the Russian Platform. However, this species is much larger (at a comparable number of whorls), the whorls do increase faster in diameter and the umbilicus is smaller in relation to the total width of the shell.

Dimensions. (in mm.)

Specimen no.	H	W
2014 XI 115	1.5	2.7
2014 XI 116	1.3	2.6

***Anomphalus* sp.**

Pl. 8 figs 1-7

2014 *Anomphalus* cf. japonicus Nützel, 2012 – Ketwetsuriya *et al.*, p. 140, pl. 2, figs A, B.

Material. – Three specimens, SNSB-BSPG 2014 XI 6, 20, 28.

Description. – Shell small, low-spired, rotelliform; largest specimen with diameter of 5.2 mm, height 4.3 mm; whorls smooth, with convex periphery and flattened ab- and adapical sides, round, circular in transverse section; base distinctly umbilicated with circumumbilical edge; suture shallow, indistinct.

Remarks. – The present specimens are typical representatives of *Anomphalus* but the preservation is too poor to establish species identity. They resemble *Anomphalus japonicus* Nützel, 2012 (in Nützel & Nakazawa) from the Middle Permian of Japan. However, *A. japonicus* has a much deeper suture and the adapical portion of the whorl is much more convex. Moreover, this species is much smaller. The Late Carboniferous *Anomphalus rotulus* Meek & Worthen, 1867 as illustrated by Knight (1933) is similar but has an umbilical plug. *Anomphalus umbilicatus* Knight, 1933 from the Pennsylvanian of the USA is also very similar. *Anomphalus* sp. from the Permian of Perak, Malaysia is more high-spired and its umbilicus is filled with a plug (Batten 1979, figs 10, 11). *Anomphalus*? *sundaicus* Wanner, 1942 (according to Yochelson (1956) not a representative of *Anomphalus*) from the Permian of Timor has a flatter spire and more rapidly increasing whorls. The *Anomphalus* species that were illustrated by Yochelson (1956) from the Permian of the USA have a flatter spire.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	DPR	HPR	DOM	WWO
2014 XI 6	3.2	2.8	3.1	2.4	2.8	0.8	3.7
2014 XI 20	5.0	4.2	4.1	4.1	4.1	2.0	-
2014 XI 28	5.2	4.3	4.9	4.5	4.3	2.0	5.3

Family Araeonematidae Nützel, 2012 (in Nützel & Nakazawa)

Genus ***Yunnania*** Mansuy, 1912

Type species. – *Yunnania termieri* Mansuy, 1912, Late Carboniferous, China.

***Yunnania pulchra* n. sp.**

Pl. 7 figs 14-21

2014 *Tapinotomaria*? sp. – Ketwetsuriya *et al.,* p. 140, pl. 1, fig. K.

Etymology. – Latin beautiful.

Material. – Holotype: SNSB-BSPG 2014 XI 34; paratypes: SNSB-BSPG 2014 XI 21, 108, CUMZ 7009, 7010.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E.

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell turbiniform; holotype comprising ca. 4 whorls (apex missing), 9.3 mm high, 9.7 mm wide; suture impressed; whorls slightly convex and slightly shouldered; whorls embrace at periphery so that periphery is at suture; base convex with evenly rounded transition to whorl face; whorls ornamented with evenly spaced distinct spiral cords; distance between cords about twice as wide as cords; cords have approximately same strength; whorls also ornamented with numerous collabral, densely spaced, slightly prosocline axial threads; intersections of spiral cords and axial threads slightly nodular; base shallowly convex, anomphalous, ornamented with up to 10 strong spiral cords and a smooth circumumbilical area; aperture approximately

as high as wide; outer and inner lip convex, parietal lip concave; aperture acute adapically.

Remarks. – *Yunnania meridionalis* Mansuy, 1914b from the Permian Productus Limestone of Cambodia is similar to *Yunnania pulchra* n. sp. but *Y. meridionalis* has more convex whorls and the axial ribs are not sharp and thread-like but broad and low (Mansuy described them as 'ondulations transverses' i.e., transverse undulations). Moreover, the spiral cords are stronger in *Yunnania meridionalis.* The illustration of *Yunnania meridionalis* given by Delpey (1941) resembles the present specimens in shape but especially the nature of the axial ornament cannot be inferred from this illustration. The illustration of the specimen from the Permian of Malaysia determined as *Yunnania meridionalis* by Batten (1972) seems to be much more high-spired than *Y. meridionalis* and *Yunnania pulchra* n. sp. so that it is not clear whether this specimen really represents *Y. meridionalis*. Other gastropod species assigned to *Yunnania* generally lack axial ornament.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	No.Whorls	A angle(degrees)
2014 XI 21	5.0	3.7	2.7	5	80
2014 XI 34	9.3	9.7	6.0	4	65
2014 XI 108	6.1	5.6	3.4	4	-

Family Trochidae Rafinesque, 1815

Genus ***Anticonulus*** Cossmann, 1918

Type species. – *Trochus mariae* d'Orbigny, 1853, Early Jurassic, France.

***Anticonulus*? sp.**

Pl. 8 figs 15-16

2014 Pleurotomarioid indet. – Ketwetsuriya *et al.*, p. 140, pl. 1, fig. L.

Material. – One specimen, SNSB-BSPG 2014 XI 8.

Description. – Shell acutely conical, small, comprising ca. 9 whorls (apex missing), 5.8 mm high, 3.8 mm wide; flanks straight; whorl face straight with periphery at transition to base; suture shallow; transition to base markedly angular with a protruding edge; base flat, slightly conical, smooth; comprises nine whorls.

Remarks. – This small conical shell resembles the Mesozoic (Triassic/Jurassic) genus *Anticonulus*.

Dimensions. (in mm.)

Specimen no.	H	W	No.Whorls	A angle(degrees)
2014 XI 8	5.8	3.8	9	47

Genus ***Coeloconulus*** Nützel, 2012 (in Nützel & Nakazawa)

Type species. – *Coeloconulus panae* Nützel, 2012 (in Nützel & Nakazawa), Middle Permian, Japan.

Remarks. – When Nützel (in Nützel & Nakazawa 2012) introduced *Coeloconulus*, he did not differentiate it from the similar Triassic genus *Callotrochus* Kutassy in Wenz, 1938 (Szabó, 2011). In contrast to *Coeloconulus*, *Callotrochus* has a distinctly conical base and thus, the shell as a whole is biconical. Moreover, *Callotrochus* is much larger.

Coeloconulus panae Nützel, 2012

Pl. 8 figs 17-19

Material. – One specimen, SNSB-BSPG 2014 XI 109.

Remarks. – This tiny conical, coeloconoid and phaneromphalous shell is obviously identical with *Coeloconulus panae* as reported from the Middle Permian Akasaka Limestone from Japan (Nützel & Nakazawa 2012) although it is much larger and has a more convex base.

Dimensions. (in mm.)

Specimen no.	H	W	No.Whorls
2014 XI 109	6.9	4.3	6.5+

Genus ***Eocalliostoma*** Haas, 1953

Type species. – *Calliostoma interruptum* Cox, 1949, Late Triassic, Peru.

***Eocalliostoma* sp.**

Pl. 8 fig. 20

Material. – One specimen, SNSB-BSPG 2014 XI 81.

Remarks. – A single acutely trochiform shell (ca. 4.5 whorls, 2.7 mm high, 1.8 wide) with straight and slightly prosocline axial ribs that do not continue onto the base represents a distinct species in this collection. It resembles the Triassic genus *Eocalliostoma* Haas, 1953 (see also Knight *et al.* 1960; Nützel & Erwin 2004). The present specimen also resembles juvenile specimens of the caenogastropod *Palaeostylus lateapicatus* Nützel, 2012 (in Nützel and Nakazawa, 2012, p. 149, fig. 23O) from the Permian of the Akasaka Limestone, Japan but the latter species has lower whorls and orthocline axial ribs.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	No.Whorls	A angle(degrees)
2014 XI 81	2.7	1.8	1.8	4.5	56

Family Microdomatidae Wenz, 1938

Genus ***Microdoma*** Meek & Worthen, 1866

Type species. – *Microdoma conicum* Meek & Worthen, 1866; USA, Carboniferous.

***Microdoma carinata* n. sp.**

Pl. 9 figs 1-9

2014 *Babylonites*? sp. – Ketwetsuriya *et al.*, p. 142, pl. 2, figs F–H.

2014 *Euconodoma* sp. – Ketwetsuriya *et al.*, p. 142, pl. 2, fig. I.

Etymology. – For the angular transition from whorl face to base

Material. – Holotype SNSB-BSPG 2014 XI 47, paratypes 2014 XI 11, 18, 19, 35, 36, 62 CUMZ 7011, 7012.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell high-spired trochiform, conical with an apical angle of 50–60°; holotype consisting of about six whorls, 10.6 mm high, 7 mm wide; largest specimen (SNSB-BSPG 2014 XI 62) about 5 whorls (apex missing), 12.0 mm high, 8.3 mm wide; sutures distinct; flanks straight; whorl face straight to very slightly convex with narrow adapical shoulder in some specimens; whorls largely smooth except of weak reticulate ornament of collabral axial ribs and spiral cords with nodular intersection on early teleoconch whorls; growth lines straight, prosocline; pronounced carina with spiral cord present low on the whorls, emerging from abapical suture, fully exposed on last whorl

forming the periphery and angular transition to base of whorls; last part of last whorl somewhat deflected so that carina becomes fully exposed; base convex with pseudo-umbilicus formed by twisted inner lip of aperture; aperture subcircular, somewhat higher than wide; columellar lip slightly twisted forming a fold.

Remarks. – *Microdoma carinata* n. sp. resembles the Pennsylvanian type species of *Microdoma*, *Microdoma conicum* Meek & Worthen, 1866. However, *Microdoma conicum* has rather strong nodes as teleoconch ornament and lacks a twisted inner lip. Some of the Carboniferous Russian species assigned to *Microdoma* by Mazaev (1997) resemble *Microdoma carinata* n. sp. but these species have much stronger nodes or ribs at the suture. *Anematina permiana* (Yakowlew, 1899) as reported by Mazaev (1997) from the Late Carboniferous of the Russian Platform resembles *Microdoma carinata* n. sp. but lacks the strong basal carination. *Euconodoma gavinae* Kues, 1990, type species of the genus *Euconodoma* Kues, 1990, from the Pennsylvanian of New Mexico is similar but *Euconodoma* has strong nodes at the basal angulation and lacks the twisted inner lip of the aperture. *Euconodoma* was considered to represent a synonym of *Microdoma* by (Batten, 1995). However, it seems possible that *Euconodoma* represents a distinct genus.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	DPR	HPR	Apical angle	No. Of whorls
2014 XI 11	9.7	7.9	7.7	4.1	4.0	-	1+
2014 XI 18	11.2	7.5	6.5	4.7	2.8	60	6
2014 XI 19	9.3+	7.3	7.9	4.0	4.7	-	2+
2014 XI 35	9.0+	5.6+	-	-	-	63	6.5+
2014 XI 36	11.5	6.9	7.7	4.1	4.4	57	6
2014 XI 47	10.6	7.0	6.7	4.1	3.7	70	6
2014 XI 62	12.0	8.3	8.6	4.7	4.8	56	5+

Subclass Neritimorpha Koken, 1896

Order Cycloneritimorpha Fryda, 1998

Superfamily Naticopsoidea Waagen, 1880

Family Naticopsidae Waagen, 1880

Genus ***Naticopsis*** McCoy, 1844

Type species. – *Natica ampliata* Phillips, 1836, Carboniferous, Ireland.

***Naticopsis* spp.**

Pl. 10 figs 1-9

2014 *Naticopsis* sp. – Ketwetsuriya *et al.*, p. 144, pl. 2, fig. K.

Material. – Six specimens, SNSB-BSPG 2014 XI 57, 66, 68, 72, 79, 90, 95.

Remarks. – Several naticiform, low spired, smooth shells, all smaller 10 mm are present in this collection representing probably two to three species of the wide-spread and late Palaeozoic genus *Naticopsis*. The preservation of the specimens (especially the apertures) is not sufficient for identification.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	DPR	HPR	No.Whorls	A angle
2014 XI 57	6.1	5.7	5.7	3.3	4.4	3.5	112
2014 XI 66	8.4	8.0+	7.2	-	4.8	3	110
2014 XI 68	8.8	8.2+	7.9	3.5	-	3	111
2014 XI 72	4.3	5.2	3.5	-	-	2.5+	92
2014 XI 90	3.7	2.1	3.3	-	-	-	78
2014 XI 95	8.1	7.8	7.9	5.0	5.1	3.5	88

Family Trachyspiridae Nützel, Frýda, Yancey & Anderson, 2007

Genus ***Trachydomia*** Meek & Worthen, 1866

Type species. – *Naticopsis nodosa* Meek & Worthen, 1861, Carboniferous, USA.

Trachydomia takhliensis **n. sp.**

Pl. 9 figs 10-15

2014 *Trachydomia* sp. – Ketwetsuriya *et al.*, p. 144, pl. 2, fig. J.

Etymology. – After the district of Takhli where the species occurs.

Material. – Holotype: SNSB-BSPG 2014 XI 41; paratypes SNSB-BSPG 2014 XI 37, CUMZ 7013, 7014.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.
Description. – Shell naticiform to turbiniform; holotype 11.7 mm high, 9.8 mm wide; largest specimen (SNSB-BSPG 2014 XI 87) 30 mm high (apex missing), 31 mm wide; spire acute distinctly elevated; body whorl much higher than spire with height about 85% of total height; whorls round, convex with a narrow subsutural ramp; whorls embracing at periphery; whorls ornamented with distinct nodes which are strongest on the body whorl; suture distinct; base round, convex with evenly rounded transition to base; growth lines prosocline; aperture D-shape with thickened outer lip and parietal inductura; columellar lip straight, oblique to shell axis, widened with a crescent-shaped furrow; outer lip evenly convex; base anomphalous, convex.

Remarks. – *Trachydomia takhliensis* n. sp. is a typical representative of the genus *Trachydomia*. *Trachydomia dussaulti* Mansuy, 1913 from the Permian Productus Limestone of Laos is similar in shape but has finer and denser nodes. *Trachydomia dussaulti* has also been reported from the Permian of Perak, Malaysia by Batten (1979) and the specimen he illustrated has much finer nodes which are arranged in prosocline lines. Moreover, its ramp is less pronounced. *Trachydomia gobbeti* Batten, 1979 from the Permian of Perak, Malaysia has nodes which are strictly arranged in spiral lines and the adapical nodes are much stronger than the abapical ones. *Trachydomia imbricata* Batten, 1979 and *T. gemmulata* Batten, 1979, both from the Permian of Perak, Malaysia differ strongly from *Trachydomia takhliensis* n. sp. in shape and ornament. *Trachydomia* cf. *nodosa* (Meek & Worthen, 1866) from the Middle Permian of Japan as reported by Nützel & Nakazawa (2012) has nodes which are strictly arranged in spiral lines. *Trachydomia nodosa*, type species of the genus *Trachydomia*, is broader and has fewer but much coarser nodes. *Trachydomia minuta* Pan and Erwin, 2002 from the Late Permian of China is much more high-spired. *Trachydomia deprati* Mansuy, 1914b from the Permian Productus Limestone of Cambodia is broader and has less convex whorls.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	DPR	HPR	No.Whorls	A angle
2014 XI 37	17.3	14.1	15.1	8.6	9.7	3.5	94
2014 XI 41	11.7	9.8	9.7	6.6	8.3	4.5	72
2014 XI 82	24.0	23.3	22.6				
2014 XI 87	29.6+	31.3	26.7+	15.0	16.7+	3.5	96

Subclass Caenogastropoda Cox, 1960

Superfamily Orthonematoidea Nützel & Bandel, 2000

Family Goniasmatidae Nützel & Bandel, 2000

Subfamily Goniasmatinae Nützel & Bandel, 2000

Genus ***Goniasma*** Tomlin, 1930

Type species. *Murchisonia lasallensis* Worthen, 1890, Pennsylvanian, USA.

***Goniasma tricarinata* n. sp.**

Pl. 11 figs 1-4

Etymology. – Latin, with three carinae (spiral cords).

Material. – Holotype: SNSB-BSPG 2014 XI 45; paratypes: SNSB-BSPG 2014 XI 5, CUMZ 7015, 7016.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell high-spired; holotype comprises about 9 whorls, 9.5 mm high, 5.6 mm wide; suture distinct; whorls angulated at about mid-whorl with a broad, steep subsutural ramp; vertical, parallel to shell axis below angulation; ramp smooth; abapical portion of whorls with three equally spaced prominent spiral cords; strongest spiral cord located at mid-whorl at angulation forming periphery; ramp largely smooth, straight with very weak spiral cord near the suture; base slightly rounded.

Remarks: The present specimens resemble the Late Carboniferous type species of *Goniasma*, *Goniasma lasallensis* Worthen, 1890 (see also Mazaev 2011, p. 1564, pl. 1, figs 9–13) but in that species, the angulation is lower on the whorls and it lacks the three strong spiral cords low on the whorls. *Goniasma fortecarinata* Nützel, 2012 (in Nützel & Nakazawa) from the Middle Permian Akasaka Limestone, Japan is similar but the upper two spiral cords are much stronger than the abapical one.

Dimensions. (in mm.)

Specimen no.	H	W	Apical angle(degrees)	No. Of whorls
2014 XI 5	6.8	4.0	43	6
2014 XI 14	7.5+	4.0	43	6+
2014 XI 15	11.3+	5.2	47	5+
2014 XI 45	9.5	5.6	45	9+

Genus ***Stegocoelia*** Donald, 1889

Type species. – *Murchisonia* (*Stegocoelia*) *compacta* Donald, 1889, Early Carboniferous, Scotland.

Remarks. – The subgenus *Hypergonia* Donald, 1892 has been considered to represent a synonym of *Stegocoelia* by Mazaev (2001; 2011).

***Stegocoelia* sp. 1**

Pl. 11 figs 5-6

Material. – Two specimens, SNSB-BSPG 2014 XI 30, 80.

Remarks. – These small, high-spired slender murchisoniform gastropods have a prominent ornament of four spiral cords on whorl face. The whorls are distinctly convex and somewhat angulated. They resemble several Late Palaeozoic species, for instance some species from the Carboniferous of Russia as described by Mazaev (2001). *Murchisonia dussaulti* Mansuy, 1914b from the Productus Limestone of Cambodia could be similar but is too poorly known for a meaningful comparison (see also Delpey 1941, fig. 42). *Stegocoelia akasakiensis* Nützel, 2012 from the Middle Permian Akasaka Limestone of Japan but this species is much smaller and the spiral cords have a different position (Nützel and Nakazawa, 2012).

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	Apical angle(degrees)	No. Of whorls
2014 XI 30	9.5	3.7	-	55	8
2014 XI 80	8.9+	5.5	5.5	-	2+

***Stegocoelia* sp. 2**

Pl. 11 fig. 7

2014 *Stegocoelia*? sp. 2 – Ketwetsuriya *et al.*, p. 145, pl. 2, fig. P.

Material. One specimen, SNSB-BSPG 2014 XI 94.

Description. – Shell small, high-spired, slender, comprising about 9 whorls, 7.2 mm high, 2.3 mm wide; suture shallow; whorl face straight; whorls ornamented with four distinct spiral cords; adapical spiral cord in subsutural position; second spiral cord somewhat weaker, situated above mid-whorl; third spiral cord strongest, forming periphery, low on the whorl; fourth spiral cord weak, emerging from abapical suture; base flat with angular transition to whorl face.

Remarks. – This shell is poorly preserved but clearly represents a distinct species in the present collection. Similar shells, poorly preserved as well, were reported by Kulas and Batten (1997) as *Stegocoelia* (*Hypergonia*) *percostata* (Girty, 1939) and *Stegocoelia* (*Hypergonia*?) sp. from the Permian of Wyoming. *Stegocoelia turabievoensis* Mazaev, 2001 from the Carboniferous is also similar but much larger.

Dimensions. (in mm.)

Specimen no.	H	W	Apical angle(degrees)	No. Of whorls
2014 XI 94	7.2+	2.3	65	9+

Family Orthonematidae Nützel & Bandel, 2000

Genus ***Orthonema*** Meek & Worthen, 1862

***Orthonema* sp.**

Pl. 11 figs 8-9

Material. – One specimen, SNSB-BSPG 2014 XI 53.

Description. – Shell high-spired, slender, ca. 8 whorl with apex missing, 16 mm high, 7 mm wide; suture shallow but distinct; whorls largely smooth, ornamented with a distinct, sharp subsutural spiral cord bordering a narrow ramp; abapical spiral lira emerging just at suture; whorl face concave.

Remarks. – This specimen resembles species of the genus *Orthonema* as, for instance, reported from the Carboniferous of Russia (Mazaev, 2002) and the Permian of the Southwestern US (Erwin, 1988a).

Dimensions. (in mm.)

Specimen no.	H	W	No. Of whorls
2014 XI 53	16.0	6.9	6+

Genus ***Protostylus*** Mansuy, 1914a

Type species. *Protostylus lantenoisi* Mansuy, 1914a, Carboniferous, SE Asia.

Remarks. – Based on Middle Permian high-spired, smooth gastropods, Nützel & Nakazawa (2012) discussed the poorly known genus *Protostylus*. The type species as well as the other species assigned to this genus are poorly preserved and thus, identity and systematics of this genus remain uncertain. Batten (1995) placed *Protostylus* in Procerithiidae based on the presence of an anterior siphonal canal. Nützel in Nützel & Nakazawa (2012) placed *Protostylus* tentatively in the family Orthonematidae.

***Protostylus* sp.**

Pl. 12 figs 1-6

Material. – Five specimens, SNSB-BSPG 2014 XI 40, 56, 74, 99, 114.

Description. – Shell high-spired; largest specimen consists of about 10 whorls, 20 mm high, 6.8 mm wide; sutures distinct; whorls low, slightly convex with periphery somewhat below mid-whorl, embracing low on previous whorl; whorls smooth; base rounded, convex; aperture subovate, somewhat higher than wide.

Remarks. – The present specimens resemble *Protostylus* sp. from the Middle Permian Akasaka Limestone from Japan as reported by Nützel & Nakazawa (2012). However, the Japanese species is somewhat more slender. The studied specimens show a narrow spiral breakage high on the whorls. If this reflects the presence of a selenizone or sinus, this species could be related to genera like *Altadema* Kues, 2002 or *Kazanella* Mazaev, 2015. *Streptacis*? *complanata* Hoare, Sturgeon & Anderson, 1997 from the Pennsylvanian of the USA resembles *Protostylus* sp. and could be a representative of the genus *Protostylus* rather than *Streptacis* – the latter is usually more slender. The Chinese Carboniferous species *Protostylus lantenoisi* Mansuy, 1914a and *P. dussualti* Mansuy, 1914a closely resemble the present species as far as can be inferred from the original illustrations. *Protostylus lantenoisi* has also been reported from the Permian of Perak, Malaysia by Batten (1985).

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	No.Whorls	A angle(degrees)
2014 XI 40	19.6	6.3	-	8+	35
2014 XI 56	20.0	6.8	5.6	10+	35
2014 XI 74	12.6+	5.3	-	9+	33
2014 XI 99	19.0	6.4	5.0	9+	33

Superfamily Soleniscoidea Knight, 1931a

Family Soleniscidae Knight, 1931a

Subfamily Soleniscinae Knight, 1931a

Genus ***Soleniscus*** Meek & Worthen, 1861

Type species. – *Soleniscus typicus* Meek & Worthen, 1861, Carboniferous, USA.

***Soleniscus* sp.**

Pl. 11 figs 10-11

Material. One specimen, SNSB-BSPG 2014 XI 120

Remarks. – This relatively slender, fusiform, smooth soleniscid shell (13 mm high, 4 mm wide) shows a distinct columellar fold. Shells like this have been repeatedly reported from the Late Palaeozoic of the world for instance *Soleniscus variabilis* Erwin, 1988b from the Permian of the USA is quite similar (see also Nützel *et al.* 2000; Batten 1995).

Dimensions. (in mm.)

Specimen no.	H	W
2014 XI 120	13.0	4.0

Genus ***Strobeus*** de Koninck, 1881

Type species. – *Strobeus ventricosus* de Koninck, 1881, Mississippian, Belgium.

***Strobeus* sp.**

Pl. 11 figs 12-13

Material. – One specimen, SNSB-BSPG 2014 XI 119.

Remarks. – This broad, smooth incomplete soleniscid shell (7.3 mm high, 5.1 mm wide) shows a distinct columellar fold. Strobeus is wide-spread and diverse in Late Palaeozoic deposits for instance *Strobeus girtyi* Erwin, 1988b from the Permian of the USA and the Late Permian *Strobeus dongluoensis* (Pan and Yu, 1993) (see also Nützel & Nakazawa 2012) are similar. However, more and better preserved specimens are needed for identification.

Dimensions. (in mm.)

Specimen no.	H	W
2014 XI 119	7.3	5.1

Genus ***Cylindritopsis*** Gemmellaro, 1890

Type species. – *Cylindritopsis ovalis* Gemmellaro, 1890, Permian, Italy.

Cylindritopsis spheroides Erwin, 1988b

Pl. 11 figs 14-16

1988b *Cylindritopsis spheroides* n. sp. – Erwin, p. 65, fig. 4.1–4.4.

Material. – One specimen, SNSB-BSPG 2014 XI 52.

Description. – Shell spherical, oval, low-spired, 5.1 mm high, 5.2 mm wide; spire small; whorls smooth, convex, inflated; suture indistinct; aperture crescent shaped, acute adapically, rounded ababically; aperture with two strong columellar folds of equal strength with perpendicular orientation against inner lip; parietal callus present; base evenly rounded, anomphalous.

Remarks. – The present specimen closely resembles *Cylindritopsis spheroides* Erwin, 1988b from the Permian of the southwestern United States. *Cylindritopsis spheroides*

could also represent the neritid species genus *Oncochilus* Pethö, 1882 (in Zittel) which is based on a Jurassic type species. In fact, *Oncochilus* matches *Cylindritopsis spheroides* better than the usually more high-spired *Cylindritopsis*. Yochelson & Saunders (1967) listed two Permian species assigned to *Oncochilus* and stated that the genus was clearly present in the Late Palaeozoic.

Dimensions. (in mm.)

Specimen no.	H	W	DPR	HPR
2014 XI 52	5.1	5.2	2.4	4.5

Family Meekospiridae Knight, 1956

Genus ***Meekospira*** Ulrich, in Ulrich & Scofield, 1897

Type species. – *Eulima peracuta* Meek & Worthen, 1861, Carboniferous, USA.

***Meekospira* sp.**

Pl. 12 fig. 7

2014 *Meekospira* sp. – Ketwetsuriya *et al.*, p. 144, pl. 2, fig. M.

Material. – One specimen, SNSB-BSPG 2014 XI 7.

Remarks. – This single slender fusiform shell (7.8 mm high, 5.8 mm high) with straight flanks and slightly convex, smooth whorls is a typical representative of the genus *Meekospira* which is widespread and diverse in the Late Palaeozoic (e.g., Knight 1932; Erwin 1988b; Nützel *et al.* 2000). *Meekospira melanoides* and *M. ligonensis*, both described by Batten (1985) from the Permian of Perak, Malaysia, are more slender and have higher whorls.

Dimensions. (in mm.)

Specimen no.	H	W	Apical angle(degrees)	No. Of whorls
2014 XI 7	7.8	5.8	38	8

Genus ***Ceraunocochlis*** Knight, 1931a

Type species. *Ceraunocochlis fulminula* Knight, 1931a, Pennsylvanian, USA.

***Ceraunocochlis* sp.**

Pl. 12 fig. 8

Material. One specimen, SNSB-BSPG 2014 XI 78.

Description: Cigar-shaped shell, slender, high-spired, asymmetrical, with convex flank opposed to a to slightly concave flank; shell comprising ca. 7 whorls, 5.1 mm high, 1.4 mm wide; last whorl incomplete but seemingly slightly constricted; whorls high, smooth; suture obscure, very shallow; whorl face almost straight; aperture not preserved.

Remarks: The generic assignment of this specimen is beyond doubt. It resembles *Ceraunocochlis fulminula* Knight, 1931a from the Pennsylvanian of the USA and *Ceraunocochlis* sp. as reported by Nützel & Nakazawa (2012) from the Middle Permian Akasaka Limestone, Japan.

Dimensions. (in mm.)

Specimen no.	H	W	A angle(degrees)
2014 XI 78	5.1	1.4	37

Genus ***Cambodgia*** Mansuy, 1914b

Type species. *Cambodgia sinsistrorsa* Mansuy, 1914b, Permian, Cambodia.

***Cambodgia acuminata* n. sp.**

Pl. 12 figs 9-11

2014 *Cambodgia* cfr. *sinistrorsa* Mansuy, 1914b – Ketwetsuriya *et al.*, p. 144, pl. 2, fig. L.

Etymology. – Latin needle-shaped, acute.

Material. Four specimens, holotype: SNSB-BSPG 2014 XI 98, paratypes: SNSB-BSPG 2014 XI 54, 70, 117.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca. 80 km south of Nakon Sawan City, Northern Thailand, 15° 18' 51.801" N, 100° 26' 30.358" E (Fig.1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Description. – Shell sinistral, small, high-spired, very slender with an apical angel of less than 30 ° and numerous whorls; largest specimen comprising 9 whorls with apex missing 12.7 mm high, 3.3 mm wide; holotype comprising ca. 14 whorls, 7.4 mm high, 4.0 mm wide; early shell slightly coeloconoid; whorls smooth, weakly convex; sutures shallow but distinct; aperture unknown.

Remarks. – The sinistral species *Cambodgia acuminata* n. sp. is extremely needle-shaped. It resembles *Cambodgia sinistrorsa* Mansuy, 1914b from the Permian Productus Limestone of Cambodia. However, *Cambodgia acuminata* n. sp. is much more slender. The sinistral, needle-shaped species *Methorthonema sinistrale* Erwin, 1988a from the Early Permian of the Soutwestern USA is more pronouncedly coeloconoid in the early whorls and later whorls are straight-sided so that the teleoconch is almost cylindrical which is not the case in *Cambodgia acuminata* n. sp.

Dimensions. (in mm.)

Specimen no.	H	W	No.Whorls	A angle(degrees)
2014 XI 54	12.7	3.3	9+	26
2014 XI 98	7.4	4.0	14+	24
2014 XI 117	6.3	1.9	11	25

Family Palaeostylidae Wenz, 1938

Genus ***Trepsipleura*** Kues, 2002

Type species. – *Trepsipleura chordanodosa* Kues, 2002, Pennsylvanian, USA.

Remarks. – Kues (2002) discussed the assignment of *Trepsipleura* and placed it in Pseudozygopleuridae Knight, 1930 but also discussed a possible assignment to Palaeozygopleuridae. We think that an assignment to Palaeostylidae is the better choice because of the low whorls and the lack of the typical pseudozygopleurid larval shell as far as it is known (shown for *Palaeozygopleura*? *perversa* (Knight, 1930) by Nützel 1998). Synonymy of the three species *Palaeozygopleura*? *perversa* (Knight, 1930), *Palaeostylus*? (*Pseudozygopleura*) *bella* Carew, 1980 and *Trepsipleura chordanodosa* Kues, 2002 seems to be possible. The sinistral species *Palaeozygopleura retroflexa* Licharew, 1968 is distinct by having a denser ribbing.

Trepsipleura chordanodosa Kues, 2002

Pl. 12 fig. 12-13

2014 *Palaeostylus* sp. – Ketwetsuriya *et al.*, p. 144, pl. 2, fig. N.

Material. – Two specimens, SNSB-BSPG 2014 XI 1, 100.

Description. – Shell sinistral, high-spired, cyrtoconoid; larger specimen is 12.9 mm high, 3.7 mm wide; whorls low, rounded quadrangular in transverse section; whorls slightly

convex; sutures distinct; whorls ornamented with strong, straight to slightly opisthocyrt, broad, rounded axial ribs, numbering about 12-16 per whorl presumably reduced on the last whorls; aperture with indistinct siphonal notch.

Remarks. – The present specimens closely resemble the Middle Pennsylvanian *Trepsipleura chordanodosa* from West Texas so that the present material is identified with this species despite the considerable difference in age. Other similar sinistral species with zygopleuroid habitus are *Palaeozygopleura*? *perversa* (Knight, 1930) from the Pennsylvanian of the USA (see Nützel 1998) and *Palaeostylus*? (*Pseudozygopleura*) *bella* Carew, 1980 from the Pennsylvanian of Texas.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	No.Whorls	A angle(degrees)
2014 XI 1	12.9	3.7	2.9+	8+	27
2014 XI 100	3.6	7.6	-	7+	-

Superfamily Zygopleuroidea Wenz, 1938

Family Pseudozygopleuridae Knight, 1930

Genus ***Pseudozygopleura*** Knight, 1930

***Pseudozygopleura*? sp.**

Pl. 12 fig. 14

Material. – One specimen, SNSB-BSPG 2014 XI 55.

Description. – Shell high-spired to fusiform, comprising ca. 6 whorls, 12.6 mm high, 5.3 mm wide; whorls convex with strong axial ribs numbering about 14 to 16 per whorl; ribs round, as wide as interspaces, distinctly prosocline; ribs reduced on last preserved whorl; suture distinct; base rounded, anomphalous.

Remarks. – The present shell with zygopleuroid morphology could represent the diverse Late Palaeozoic gastropod family Pseudozygopleuridae but knowledge of the protoconch is needed for a meaningful taxonomic treatment.

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	No.Whorls	A angle(degrees)
2014 XI 55	12.6	5.3	4.1	6	41

Subclass Heterobranchia Burmeister, 1837

Superfamily Streptacidoidea Knight, 1931b

Family Streptacididae Knight, 1931b

Genus ***Streptacis*** Meek, 1871

Type species. – *Streptacis whitfieldi* Meek, 1871, Carboniferous, USA.

***Streptacis*? sp.**

Pl. 12 figs 15-16

Material. – Two specimens, SNSB-BSPG 2014 XI 51, 71

Description. – Shell high-spired, slender; larger specimen 11.3 mm high (apex missing), 3.5 mm wide; whorls smooth, strongly convex; suture impressed; base convex, rounded.

Remarks. – High-spired, small, smooth shells like the present ones have been commonly reported from Late Palaeozoic deposits of the world, for instance *Streptacis whitfieldi* Meek, 1871 from the Carboniferous of the USA and *Streptacis orientalis* Nützel, 2012 as well as *Streptacis*? sp. from the Middle Permian Akasaka Limestone of Japan (Nützel & Nakazawa 2012).

Dimensions. (in mm.)

Specimen no.	H	W	Hbw	DPR	HPR	No.Whorls	A angle
2014 XI 51	11.3+	3.5	4.5	1.6	2.3	5.5+	24
2014 XI 71	3.6+	1.1	1.4	0.8	0.8	6.5+	

CHAPTER IV

BIOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT

Interpretation of data from field works and laboratory establish the range of gastropod and biozone of the study area. This result shows gastropods from Khao Noi, Khao Chai Thong, Khao Kwang and Khao Tum Pha Sawan at Amphoe Tak Fa and Amphoe Takhli, Changwat Nakhon Sawan can be subdivided into 3 biozones.

4.1 Biostratigraphy of gastropod of study area

The study area covers four hills belong to Tak Fa formation: Khao Noi, Khao Chai Thong, Khao Kwang and Khao Tum Pha Sawan. The forty species of gastropods are described in this investigation. The following data are the gastropods of each hills of study area:

Khao Noi : *Euphemites graffhami*, *Warthia* cf. *brevisinuata*, *Warthia* sp., *Bellerophon* sp., *Bellerophon*? sp., *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Retispira lyelli*, *Discotropis*? sp., *Euomphalus* sp., *Baylea*? *umbilicata*, *Knightinella ornate*, *Knightinella* sp., *Amaurotoma*? sp., *Takfaia kuesi*, *Glabrocingulum magnum*, *Anomphalus lateumbilicatus*, *Anomphalus* sp., *Yunnania pulchra*, *Anticonulus*? sp., *Coeloconulus panae*, *Eocalliostoma* sp., *Microdoma carinata*, *Naticopsis* spp., *Trachydomia takhliensis*, *Goniasma tricarinata*, *Stegocoelia* sp. 1, *Stegocoelia* sp. 2, *Orthonema* sp., *Protostylus* sp., *Soleniscus* sp., *Strobeus* sp., *Cylindritopsis spheroids*, *Meekospira* sp., *Ceraunocochlis* sp., *Cambodgia acuminate*, *Trepsipleura chordanodosa*, *Pseudozygopleura*? sp. and *Streptacis*? sp.

Khao Chai Thong : *Warthia* cf. *brevisinuata*, *Bellerophon* sp., *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Discotropis*? sp., *Baylea*? *umbilicata*, *Knightinella* sp., *Amaurotoma*? sp., *Glabrocingulum magnum*, *Anomphalus* sp., *Naticopsis* spp., *Trachydomia takhliensis*, *Goniasma tricarinata*, *Stegocoelia* sp. 1, *Stegocoelia* sp. 2, *Orthonema* sp., *Protostylus* sp., *Soleniscus* sp., *Meekospira* sp., *Trepsipleura chordanodosa*, and *Streptacis*? sp.

Khao Kwang : *Warthia* cf. *brevisinuata*, *Bellerophon* sp., *Pharkidonotus khaonoiensis*, *Retispira lyelli*, *Baylea*? *umbilicata*, *Takfaia kuesi*, *Glabrocingulum magnum*, *Anomphalus* sp., *Yunnania pulchra*, *Naticopsis* spp., *Goniasma tricarinata*, *Stegocoelia* sp. 1, *Stegocoelia* sp. 2, *Protostylus* sp., *Trepsipleura chordanodosa*, and *Streptacis*? sp.

Khao Tum Pha Sawan : *Stegocoelia* sp.1 and *Streptacis*? sp.

The data of gastropods (Table 4.1) illustrates that the different fauna from each unit of each hill. Therefore, due to correlation of Khao Noi, Khao Chai Thong and Khao Kwang that that rock unit N2 of Khao Noi is equivalent to unit C2 of Khao Chai Thong and the unit K2 of Khao Kwang in gastropod assemblage together with lithostratigraphy and other fauna of the study area. So these units can be correlated into biostratigraphy of gastropod of the study area. Thus, the biozones of their area can be grouped together. However, Khao Tum Pha Sawan found only 1 species of gastropod with a few of specimen that can be established one biozone from this section.

However, the study area is situated within the Chainat duplex which is complex structure (Prasongtham and Kanjanapayont, 2014). According to this complex structure, the correlation of all unit of the measured sections is not able to be established properly. Some units metioned above can be correlated base on assemblage and lithostratigraphy

Table 4.1 Distribution of gastropods within the study area according to rock unit (Khao Noi, Khao Chai Thong, Khao Kwang and Khao Tum Pha Sawan)

Locality	Khao Noi			Khao Kwang			Khao Chai Thong			Khao Tum Pha Sawan	
Rock Unit / Species name	N1	N2	N3	K1	K2	K3	C1	C2	C3	T1	T2
Bellerophon sp.		✓				✓		✓			
Bellerophon? sp.		✓									
Pharkidonotus khaonoiensis n.sp.		✓				✓		✓			
Khumerspira thailandensis n.sp.		✓						✓			
Retispira lyelli		✓				✓					
Euphemites graffhami		✓									
Warthia cf. *brevisinuata*		✓						✓			
Warthia sp.		✓				✓					
Discotropis? sp.	✓						✓	✓			
Euomphalus sp.		✓									
Baylea? *Umbilicata* n. sp.		✓				✓		✓			
Takfaia kuesi n. sp.		✓				✓					
Glabrocingulum magnum n. sp.		✓				✓		✓			
Knightinella ornate n. sp.		✓									
Knightinella sp.		✓						✓			
Amaurotoma? sp.		✓						✓			
Yunnania pulchra n. sp.		✓				✓					
Anomphalus sp.		✓				✓		✓			

Table 4.1 (cointinue) Distribution of gastropods within the study area according to rock unit (Khao Noi, Khao Chai Thong, Khao Kwang and Khao Tum Pha Sawan)

Locality	Khao Noi			Khao Kwang			Khao Chai Thong			Khao Tum Pha	
Rock Unit / Species name	N1	N2	N3	K1	K2	K3	C1	C2	C3	T1	T2
Naticopsis spp.		✓				✓		✓			
Microdoma carinata n. sp.		✓									
Trachydomia takhliensis n. sp.		✓						✓			
Goniasma tricarinata n. sp.	✓	✓				✓		✓			
Stegocoelia sp.1	✓	✓			✓	✓		✓		✓	
Stegocoelia sp.2	✓	✓			✓	✓	✓				
Orthonema sp.		✓						✓			
Trepsipleura chordanodosa		✓				✓		✓			
Eocalliostoma sp.		✓						✓			
Pseudozygopleuro? sp.		✓									
Soleniscus sp.		✓						✓			
Strobeus sp.		✓									
Cylindritopsis spheroides		✓									
Ceraunocochlis sp.		✓									
Streptacis? sp.		✓				✓				✓	
Protostylus sp.	✓	✓				✓		✓			
Meekospira sp.	✓	✓				✓		✓			
Cambodgia acuminate n. sp.		✓									
Anomphalus lateumbilicatus n. sp.		✓									
Anticonulus? sp.		✓									
Coeloconulus panae		✓									

Gastropod fauna are abundant in the studied sections with several species are recovered, they are grouped as *Bellerophon* sp. – *Glabrocingulum* sp. zone, which is the most diverse biozone of the study areas at the middle part of stratigraphic section, while *Stegocoelia* sp. becomes the second diverse biozone in the lower part. The upper part of section contains rarely fragments and fusulinids. The range chart of gastropods at the study area (Table 4.2) shows that the distribution of gastropods of Tak Fa limestone in Nakhon Sawan city that is subdivided into three biozones. The followings are biozones of the study.

Upper Gastropod barren zone

.....

Middle *Bellerophon* sp. – *Glabrocingulum* sp. zone

.....

Lower? *Stegocoelia* sp. zone

4.1.1 *Stegocoelia* sp. zone

Lithofacies: Biomicrite (wackestone)

Locality: Unit N1 (Khao Noi), Unit C1 (Khao Chai Thong)

Characteristic species: *Stegocoelia* sp.

Associated species: *Discotropis*? sp., *Goniasma tricarinata*, *Stegocoelia* sp. 1, *Stegocoelia* sp. 2*, Protostylus* sp. and *Meekospira* sp.

Size distribution: small to moderate size

Associated fauna: fusulinid, pelecypod, coral and sponge

Bounded: This zone is bounded along the interval between the lowest and highest occurrence of the *Stegocoelia* sp.

Remark: *Protostylus* sp. and *Meekospira* sp. occur in the lower bed of this zone.

4.1.2 *Bellerophon* sp. – *Glabrocingulum* sp. zone

Lithofacies: Biomicrite (wackestone to packstone)

Locality: Unit N2 (Khao Noi), Unit C2 (Khao Chai Thong)

Characteristic species: *Bellerophon* sp. and *Glabrocingulum* sp.

Associated species: *Euphemites graffhami*, *Warthia* cf. *brevisinuata*, *Warthia* sp., *Bellerophon* sp., *Bellerophon*? sp., *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Retispira lyelli*, *Discotropis*? sp., *Euomphalus* sp., *Baylea*? *umbilicata*, *Knightinella ornate*, *Knightinella* sp., *Amaurotoma*? sp., *Takfaia kuesi*, *Glabrocingulum magnum*, *Anomphalus lateumbilicatus*, *Anomphalus* sp., *Yunnania pulchra*, *Anticonulus*? sp., *Coeloconulus panae*, *Eocalliostoma* sp., *Microdoma carinata*, *Naticopsis* spp., *Trachydomia takhliensis*, *Goniasma tricarinata*, *Stegocoelia* sp. 1, *Stegocoelia* sp. 2, *Orthonema* sp., *Protostylus* sp., *Soleniscus* sp., *Strobeus* sp., *Cylindritopsis spheroids*, *Meekospira* sp., *Ceraunocochlis* sp., *Cambodgia acuminate*, *Trepsipleura chordanodosa*, *Pseudozygopleura*? sp. and *Streptacis*? sp.

Size distribution: Various stages

Associated fauna: fusulinid, ammonoid, pelecypod, gastropod, coral, sponge, algae and bryozoan were discovered in this zone.

Bounded: This zone is bounded along the interval between the lowest and highest occurrence of the *Bellerophon* sp. and also *Glabrocingulum* sp.

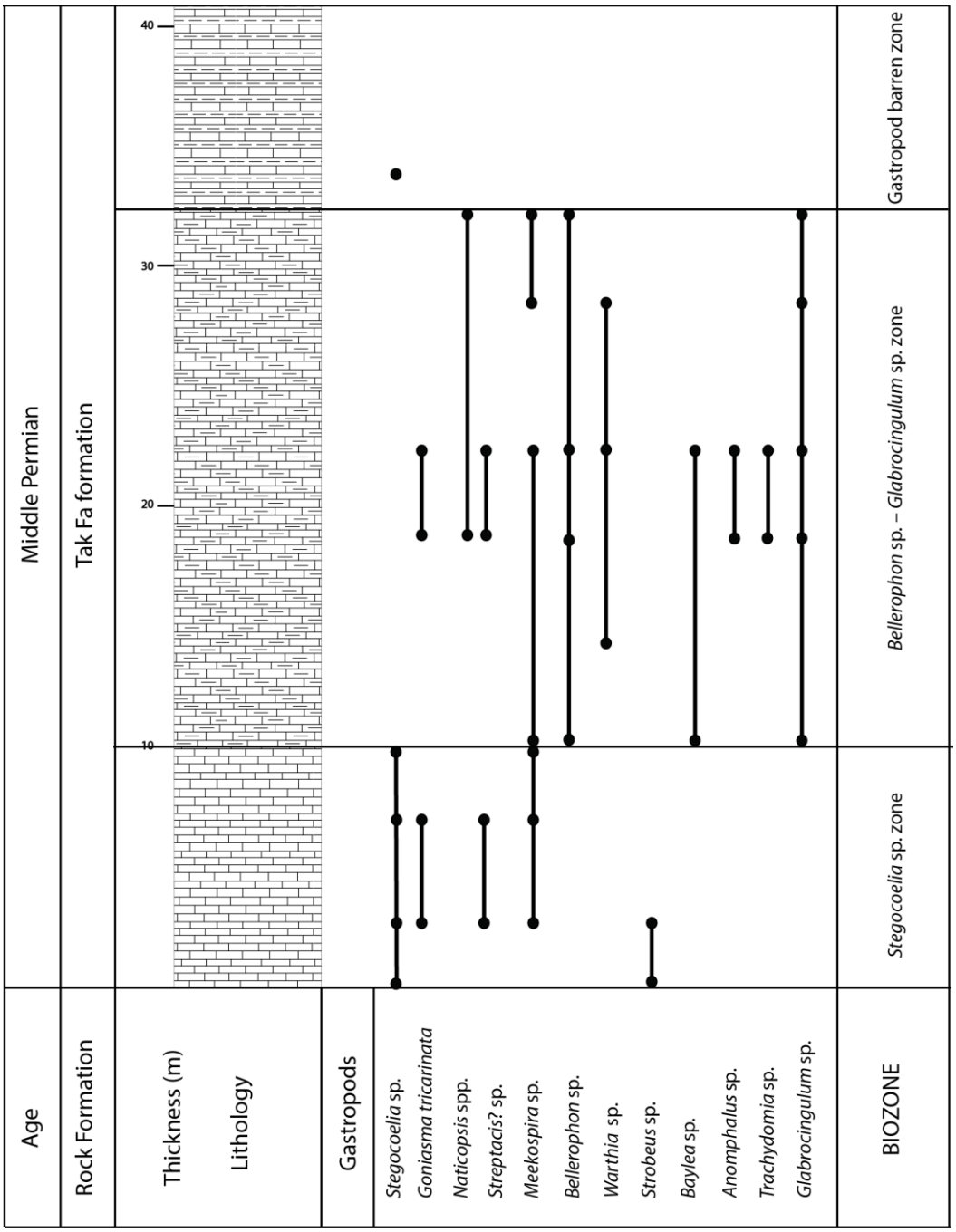
4.1.3 Gastropod barren zone

Lithofacies: mudstone to wackestone

Locality: this zone covered the upper part of these section; unit C3 (Khao Chai Thong) and including unit T1 and unit T2 of Khao Tum Pha Sawan this zone are rarely investigated. There is only fusulinid distributed throughout the zone.

Remark: This zone usually occurs at the upper part of the section that related with Lithofacies B.

Table 4.2 Stratigraphic distribution of Permian gastropods from the study area (Khao Noi, Khao Chai Thong, and Khao Tum Pha Sawan) showing range of three biozones in ascending order.



4.2 Depositional environment

According to the Permian paleogeographic map of the Phetchabun fold and thrust belt of Thailand (Wielchowsky and Young, 1985) shows major facies variations (Figure 4. 1) on the western margin of the Indochina Block (Metcalfe and Sone, 2008) that can be divided into Khao Khwang platform, Pha Nok Khoa platform and Nam Duk basin. The study area is the part of Khao Khwang platform (Ueno and Charoentitirat, 2011) that deposited on carbonate platform covered by shallow marine. Based on investigation of lithostratigraphy together with its petrography and fossils in the study area, they cloud be interpreted the depositional environment as follows.

Lithofacies A: Wackestone and packstone with whole fossils.

Description: The thick to very thick-bedded limestones are classified as wackestone and packstone with abundant marine invertebrate fossils in micrite, with black chert nodules are commonly found, parallel bed-type. The middle part of this lithifacies yields flourished gastropods and fusulinids containing massive and solitary rugose corals, brachiopods, crinoid stems and sponges. In contrast, the upper parts are represented medium bedded limestone, which yields rarely fossils. The weathered surface is usually grey to dark grey. This facie contains index fossils of lagoonal environment that located directly at the back reef such as *Acanthocladia anceps* (Bryozoa) (McKerrow, 1978), which are found in the study area.

Occurrence: Shelf lagoon at back reef (Figure 4.2) with circulation (open-marine platform interior), low-energy environment.

Locality: Unit N1 and Unit N3 of Khao Noi and Unit N2 is also situated in this facies, although this unit contain slightly fauna than others and thicker bedded, Unit K2 (Khao Kwang), Unit C1, Unit C2 (Khao Chai Thong) and Unit T1 (Khao Tum Pha Sawan).

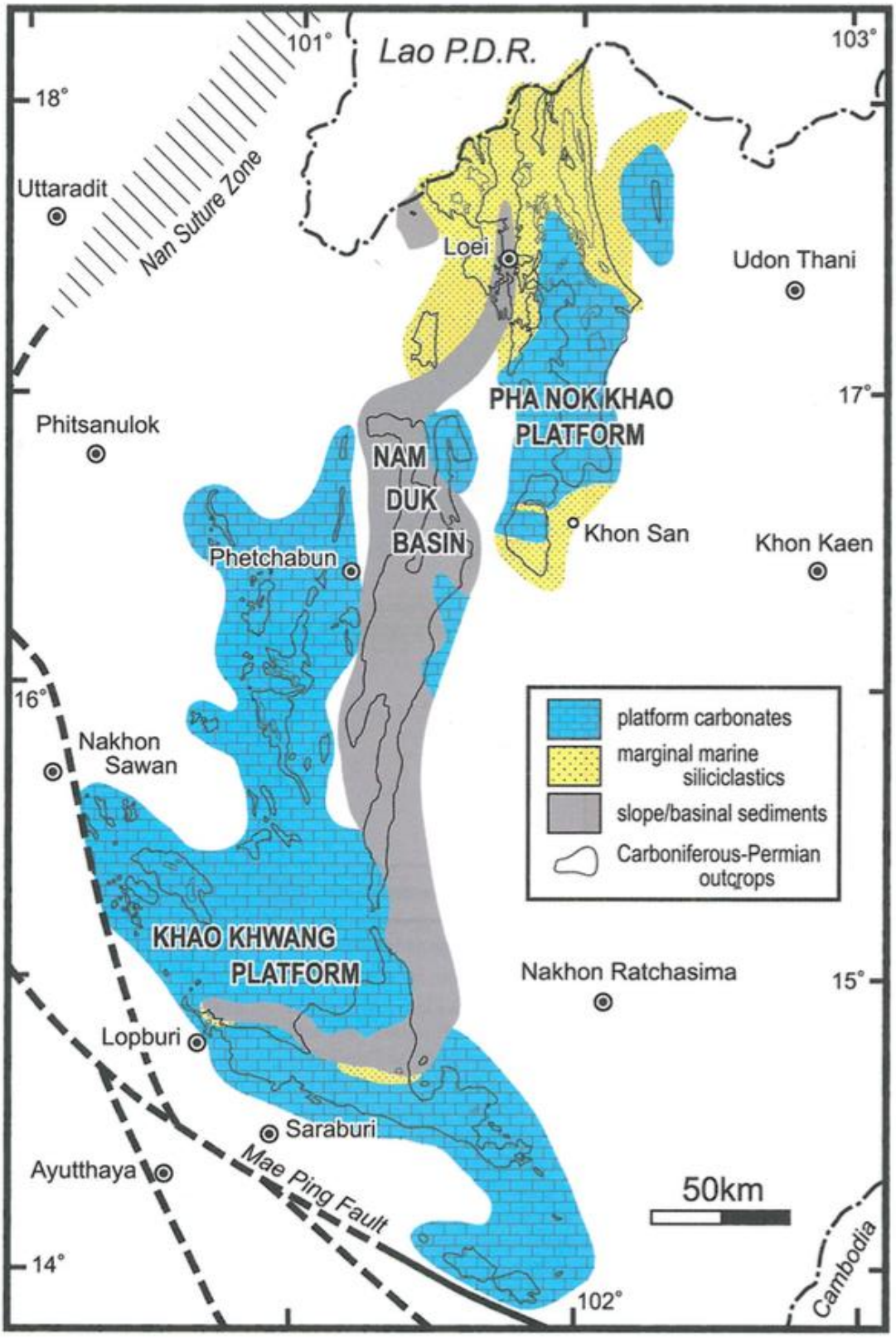


Figure 4. 1 Paleogeographic map of the western margin of the Indochina Block (Ueno and Charoentitirat, 2011)

Lithofacies B: Carbonate mudstone with little faunal diversity

Description: This lithofacies consists of thin to thick-bedded limestones that are classified as mudstone, and some wackestone may occur with a few marine invertebrate fossils such fusulinids and fragments. The rock is locally interbedded with laminated dark grey shale with parallel bed-type.

Occurrence: Lithofacies B is close to restricted marine-platform (Deep lagoonal environment) that deeper than Lithofacies A within lagoon (Figure 4.2), low-energy environment.

Locality: unit C3 (Khao Chai Thong), Unit K3 (Khao Kwang) and Unit T2 of Khao Tum Pha Sawan.

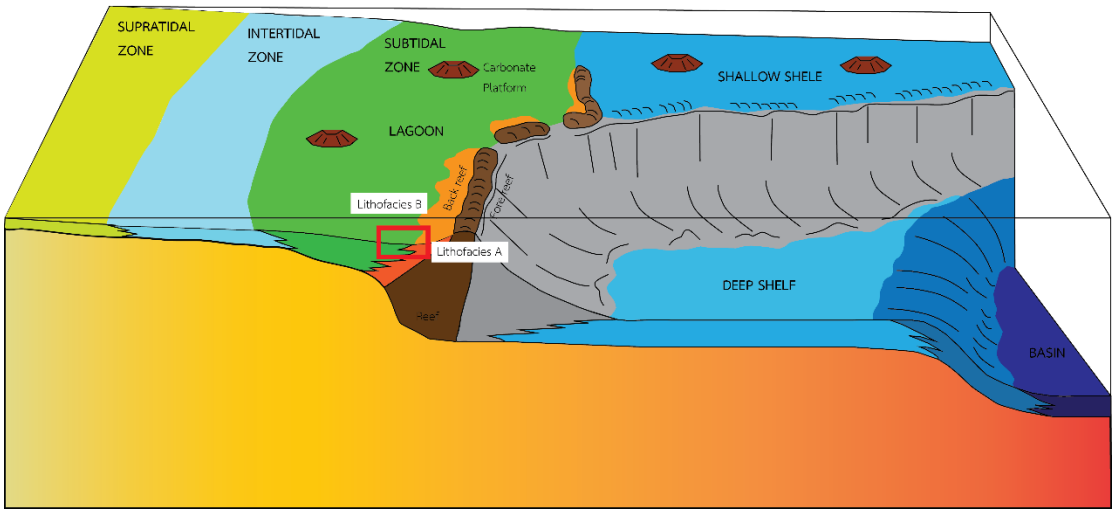


Figure 4.2 Depositional environment model of the rimmed carbonate platform at Nakhonsawan Province as shown in red square and indicating Lithofacies A and Lithofacies B.

4.3 Biota in the studied samples

Most of the samples that were dissolved were very fossiliferous and produced abundant silicified fossils. However, most of the fossil material consists of unidentifiable shell fragments. Remains of calcareous algae such as codiaceaens (Figure 4.3A) and the dasycladacean *Mitzia* sp. (Figure 4.3B) were abundant in some of the gastropod-rich samples. Silicified fusulinids are abundant in most of the samples (Figure 4.3C) and thin-sections showed that fusulinids are present in rock-forming quantities. The presence of these algae and foraminiferans suggest a tropical shallow water environment. The samples also yielded rather large sclerites probably deriving from sponges (Figure 4.3D, E). Among other invertebrates, gastropods are by far the most diverse and abundant group. They are commonly fragmented but more or less complete specimens are also present. The strong dominance of gastropods is remarkable but it must be taken into account that gastropod-rich rocks were sampled preferentially in the field. The samples also yielded few small articulate brachiopods (Figure 4.3F, left), scaphopods (Figure 4.3F, right), polyplacophoran (Figure 4.3G), small nuculoid bivalves (Figure 4.3H, I) and other bivalves (Figure 4.3J, K). The few present brachiopods and bivalves have commonly attached valves indicating that the fauna is basically autochthonous and not transported.

A quantitative census of the fossils in the studies samples is difficult because of the high degree of fragmentation and the problematic preservation of many of the fossils. However, it seems clear that the fauna is very diverse with a low dominance. A comprehensive study on the diversity of the Tak Fa fauna will be attempted at a later point.

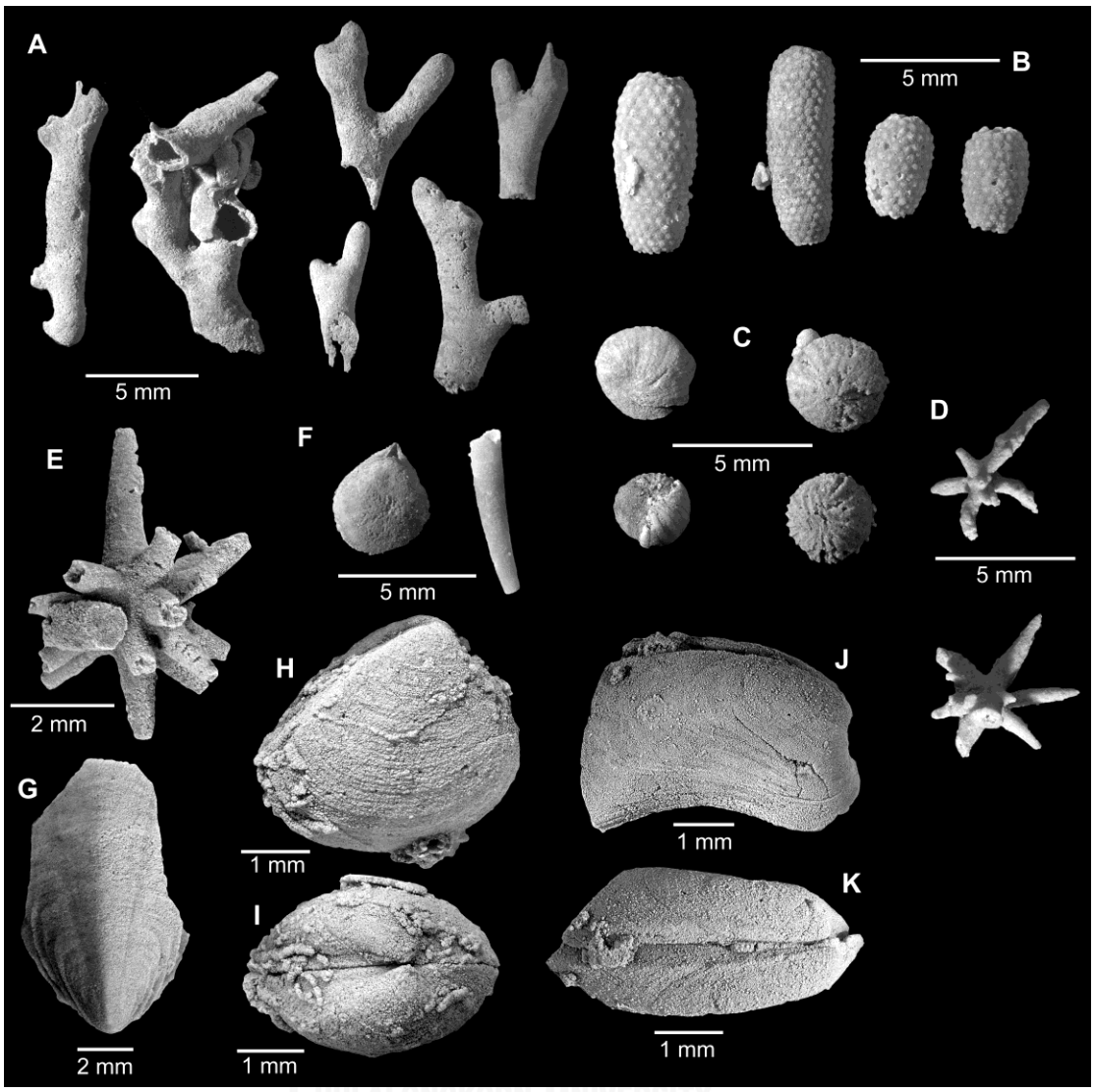


Figure 4.3 Examples for silicified fossils other than gastropods from the studied samples. A. – Codiacean algae. B. – Fragments of the dasycladacean algae Mitzia sp. C. – Poorly preserved foraminiferans (fusulinids). D, E. – Sclerites, probably deriving from sponges. F. – Small articulate brachiopod (left) and scaphopod (right). G. – Plate of polyplacophoran. H, I. – Small nuculoid bivalve. J, K. – Bivalve.

CHAPTER V

DISCUSSION AND CONCLUSIONS

5.1 Discussions

The present contribution reports and describes a Middle Permian (Wordian) gastropod fauna from the Tak Fa Formation of the Saraburi Group, Nakhonsawan, Northern Thailand. The Tak Fa Limestone is fossiliferous and yields a diverse Permian invertebrate fauna. The present gastropod fauna has previously been reported in a preliminarily note by Ketwetsuriya et al. (2014) based on silicified shells weathering out at the surface of calcareous rocks, which was described and treated the species in open nomenclature representing twenty species. Meanwhile, the carbonate samples have been dissolved and numerous silicified gastropod shells have been recovered with 39 species. There are several species are similarly found in this present study such as *Bellerophon* sp., *Glabrocingulum* sp., *Anomphalus* sp., *Trachydomia* sp., *Naticopsis* sp., *Cambodgia* sp. *Meekospira* sp., *Paleostylus* sp. and *Stegocoelia* sp. and there are also a number of others species that are new recorded in this study. The present fauna is one of the most diverse Permian gastropod faunas from Southeast Asia supplementing our knowledge of Middle Permian gastropod distribution in this region considerably.

Previously, there have been few reports or mentions on Permian gastropods from Thailand Grant (1976) studied Permian brachiopods from limestones of southern Thailand and mentioned the presence of platyceratids and pleurotomarioids. According to the study of the study area, they were found only *Takfaia kuesi* n. sp. and *Glabrocingulum magnum* n. sp. in Order Pleurotomariina. So, the gastropod fauna in the study area is certainly different from southern Thailand. Waterhouse (1982) studied an early Permian invertebrate fauna pebbly mudstones from the Kaeng Krachan Group at the Tong Lang Bay and Ko Phi Phi Island and mentioned presence of the gastropod genus *Peruvispira*. In comparison with the Tak Fa limestone of the study area, *Peruvispira* sp. or related characteristics of this genus have not been found.

This is one of the evidences that reveal the distinct fauna between two blocks. Sone (2010) reported the species *Magnicapitatus huazhangae* from the Middle Permian (Guadalupian) at Khao Makha, Changwat Sra Kaeo, East Thailand (the Indochina Terrain), this naticiform specimen was known as an internal mold only. The limestones could be related to the Sisophon Limestone of western Cambodia along the Thai-Cambodia border according to *Lepidolina. multiseptata*. and this is the only Permian gastropod species described from Thailand (type locality) to this point. In the study area, Subclass Neritimorpha comprises *Trachydomia takhliensis* n. sp. and *Naticopsis* spp. that were characterized by rounded, broad and low spires. Nevertheless, the specimens that found in study area are different in shape and also sculpture from *Magnicapitatus huazhangae*.

Gastropods are the most abundant and diverse group in the present collection (except for fusulinids) from the Tak Fa Limestone. According to the present genera, it is a typical Late Palaeozoic gastropod fauna encompassing cosmopolitan genera such as *Euphemites, Pharkidonotus, Glabrocingulum, Anomphalus, Yunnania, Microdoma, Trachydomia, Goniasma* and others. Other genera seem to be restricted to Southeast Asia according to the current state of knowledge. Although a complete census is difficult because of the poor preservation and fragmentation of many of the gastropods, it is obvious that bellerophontoids, pleurorotomariines and trochoids represent the most abundant groups with the genus *Warthia* and other bellerophontoids as well as *Glabrocingulum magnum* n. sp. being most abundant. This dominance of basal gastropod clades is certainly a Palaeozoic aspect of this fauna. This separates it from the diverse fauna of Perak, Malaysia and the Japanese Akasaka Limestone in which caenogastropods play a much larger role (Batten, 1972, 1979, 1985; Nützel and Nakazawa, 2012). As mentioned the strong gastropod dominance in the studied samples is a modern aspect of this fauna but the picture is biased because rocks with gastropods were preferentially sampled. Further studies are needed to test whether gastropod dominance is a real phenomenon in the Tak Fa Limestone.

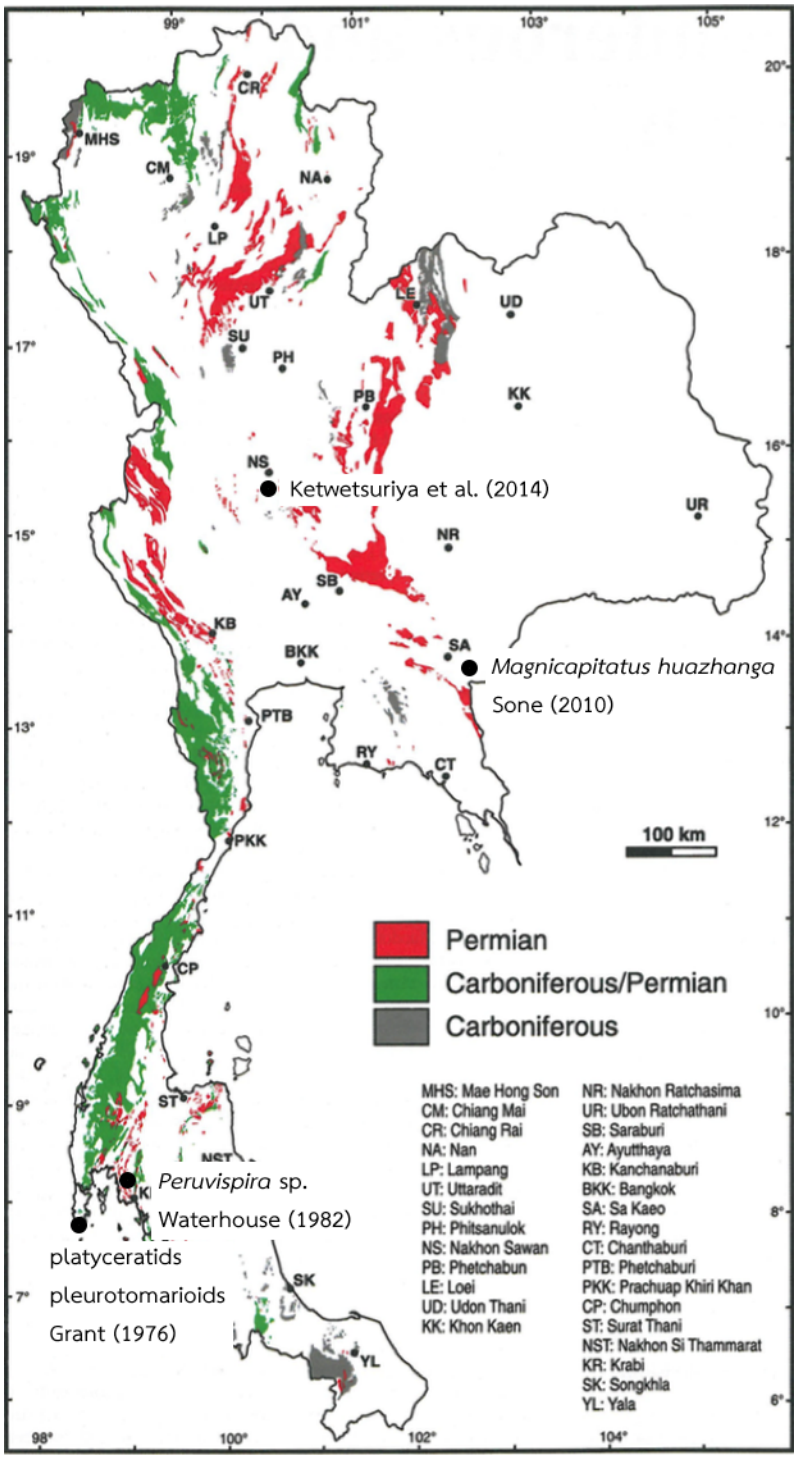


Figure 5.1 Map showing distribution of Carboniferous and Permian strata in Thailand with location of Permian gastropods in Thailand.

The age of the carbonate rock of the study area can be determined by fusulinids that commonly found. They compose of *Verbeekina verbeeki* and *Pseudofusulina* sp. In comparison, according to previous investigation, Napradit (2005) studied the fusulinoidean limestones of the Tak Fa Limestone in the East of the Nakhon Sawan province, there were several species found in Amphoe Takhli that indicated the Murgabian or Wordian.Jaiboon (2001) constructed biostratigraphy of Tak Fa formation at Changwat Lop Buri, approximately 40 km northeast of the study area with reference to fusulinids that was the Wordian. Therefore, in the studied section yielding the gastropods, the Tak Fa Limestone has a Wordian age.

5.2 Conclusions

The Tak Fa formation in the study area exposed along Khao Noi, Khao Chai Thong, Khao Chon Due, Khao Kwang and Khao Tum Pha Sawan in Amphoe Tak Fa and Amphoe Takhli, southeastern part of Changwat Nakhon Sawan. It consists mainly of bedded limestones including argillaceous limestones, mudstones and dolomites with nodular and banded cherts. Petrological study classifies rock sample as mudstone, wackestone and packstone. Parts of limestone succession are fossiliferous. There are abundant of marine invertebrate fossils such as fusulinids, corals, brachiopods, bivalves, crinoid stems, sponges, ammonoids, gastropods and algae. The attitudes of bedding are mainly 180 $^{\circ}$ and dipping 30 $^{\circ}$- 40 $^{\circ}$ to the west.

From the field investigation, the five lithostratigraphic sections had been done and they are subdivided into the rock units according to their own area, at Khao Noi: Unit N1, Unit N2 and Unit N3 is totally 50 meters thick. At Khao Kwang: Unit K1, Unit K2 and Unit K3 is totally 30 meters thick. At Khao Tum Pha Sawan: Unit T1 and Unit T2 is totally 50 meters-thick. At Khao Chai Thong: Unit C1, Unit C2 and Unit C3 is totally 30 meters-thick.

The gastropods identification shows that there are thirty-nine species: *Euphemites graffhami*, *Warthia* cf. *brevisinuata*, *Warthia* sp., *Bellerophon* sp., *Bellerophon*? sp., *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Retispira*

lyelli, *Discotropis*? sp., *Euomphalus* sp., *Baylea*? *umbilicata*, *Knightinella ornate*, *Knightinella* sp., *Amaurotoma*? sp., *Takfaia kuesi*, *Glabrocingulum magnum*, *Anomphalus lateumbilicatus*, *Anomphalus* sp., *Yunnania pulchra*, *Anticonulus*? sp., *Coeloconulus panae*, *Eocalliostoma* sp., *Microdoma carinata*, *Naticopsis* spp., *Trachydomia takhliensis*, *Goniasma tricarinata*, *Stegocoelia* sp. 1, *Stegocoelia* sp. 2, *Orthonema* sp., *Protostylus* sp., *Soleniscus* sp., *Strobeus* sp., *Cylindritopsis spheroids*, *Meekospira* sp., *Ceraunocochlis* sp., *Cambodgia acuminate*, *Trepsipleura chordanodosa*, *Pseudozygopleura*? sp. and *Streptacis*? sp. The new genus is *Takfaia.* The new species are *Pharkidonotus khaonoiensis*, *Khumerspira thailandensis*, *Baylea*? *umbilicata*, *Takfaia kuesi*, *Glabrocingulum magnum*, *Knightinella ornata*, *Anomphalus lateumbilicatus*, *Yunnania pulchra*, *Microdoma carinata*, *Trachydomia takhliensis*, *Goniasma tricarinata* and *Cambodgia acuminata*.

The data of gastropods lead that Tak Fa formation in this area is subdivided into 3 biozones. The followings are biozones of the study area in ascending order.

Stegocoelia sp. zone

Bellerophon sp. – *Glabrocingulum* sp. zone

Gastropod barren zone

The depositional environment of the study area is believed to be the shelf marine with sub-environment of back reef shallow restricted platform. This situation is low energy condition due to the evidences from variation of lithofacies and marine invertebrate fossils.

REFERENCES

Bandel, K. 1988. Repräsentieren die Euomphaloidea eine natürliche Einheit der Gastropoden? Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg 67: 1-33.

Batten, R.L. 1964. Some Permian Gastropoda From Eastern Arizona American Museum Novitates 2165: 1-16.

Batten, R.L. 1972. Permian gastropods and chitons from Perak, Malaysia. Part 1, Chitons, bellerophontids, euomphalids and pleurotomarians. Bulletin of the AMNH 147.

Batten, R.L. 1979. Permian gastropods from Perak, Malaysia. Part 2, The trochids, patellids and neritids. American Museum novitates 2685.

Batten, R.L. 1985. Permian gastropods from Perak, Malaysia. Part 3, The murchisoniids, cerithiids, loxonematids, and subulitids. American Museum novitates 2829.

Batten, R.L. 1989. Gastropoda Of The Southwestern United States. 7. Pleurotomariacea: Eotomariidae, Lophospiriidae, Gosseltinidae. American Museum Novitates 2958: 1-64.

Batten, R.L. 1995. Pennsylvanian (Morrowan) Gastropods From The Magdalena Formation Of The Hueco Mountains, Texas. American Museum Novitates 3122: 1–46.

Brown, G.F., et al. 1951. Geological reconnaissance of the mineral deposits of Thailand. United States Geological Survey, Bulletin 984: 1-183.

Bunopas, S. 1981. Paleogeographic history of Western Thailand and adjacent parts of Southeast Asia – A plate-tectonics interpretation. Doctoral, Victoria University of Wellington.

Bunopas, S. 1992. Regional stratigraphic correlation in Thailand. In: BIANCHAROEN, C. (ed.) in Proseedings of a National Conference on Geologic Resources of Thailand: Potential for Future Development. pp. 189-208. 17-24 November 1992. Bangkok.

Burmeister, H. 1837. Handbuch der Naturgeschichte. In Zoologie, pp. 369–858. Enslin, Berlin.

Carew, J.L. 1980. A new Pennsylvanian pseudozygopleurid gastropod from Texas. Journal of Paleontology 54: 1209–1212.

Cheetham, A., Rowell, A., and Boardman, R. 1987. Fossil Invertebrates. Blackwell Scientific Publications.

Chronic, H. 1952. Molluscan Fauna from the Permian Kaibab Formation, Walnut Canon, Arizona. Bulletin of the Geological Society of America 63: 95–166.

Conrad, T.A. 1842. Observations on the Silurian and Devonian systems of the United States, with description of new organic remains. Academy of Natural Sciences of Philadelphia, Journal 8 228–280.

Cossmann, M. 1918. Essais de paléoconchologie comparée Trans.). In (Ed.),^(Eds.), Livraison 11 (ed., Vol. pp. 388). Paris. (Reprinted from.

Cox, L.R. 1960. Thoughts on the classification of the Gastropoda. in Proceedings of the Malacological Society of London 33. pp. 239–261.

Cumings, E.R. 1906. Gasteropoda, Cephalopoda and Trilobita from the Salem limestone. Indiana Department of Geology and Natural Resources Annual Reports 30 1335–1375.

Delpey, G. 1941. Les Gastéropodes permiens du Cambodge. Journal de Conchyologie 84 255–278: 345–369.

Dickins, J.M. 1963. Permian pelecypods and gastropods from Western Australia. Bureau of Mineral Resources. Geology and Geophysics Bulletin 63 1–203.

Donald, J. 1889. Descriptions of new species of Carboniferous gastropods. Quarterly Journal of the Geological Society of London 45 619–625.

Donald, J. 1892. Notes on some new and little known species of Carboniferous Murchisonia. Quarterly Journal of the Geological Society of London 68 562–575.

Dunham, R.J. 1962. Classification of Carbonate Rocks According to Depositional Texture. In W.E.Ham(ed.), I. (ed.), Classification of Carbonate Rocks, pp. 108-121. Talsa-Oklahoma: The American Association Petroleum of Geologist.

Erwin, D.H. 1988a. Permian Gastropoda of the Southwestern United States: Cerithiacea, Acteonacea, and Pyramidellacea. Journal of Paleontology 62 566-575.

Erwin, D.H. 1988b. Permian Gastropoda of the Southwestern United States: Subulitacea. Journal of Paleontology 62 56–69.

Flok, R. 1962. Special Subdivision of Limestone Types. Classification of Carbonate Rocks. In Classification of Carbonate Rocks, pp. 62-84. Talsa-Oklahoma: The American Association Petroleum of Geologist.

Flügel, E. 2004. Microfacies of Carbonate Rocks. Springer-Verlag Berlin Heidelberg.

Gemmellaro, G.G. 1890. La Fauna dei calcari con Fusulina della valle del fiume Sosio nella Provincia di Palermo. Giornale di Science Naturali ed Economiche 20 97–182.

Girty, G.H. 1912. On some invertebrate fossils from the Lykins formation of eastern Colorado. Annals of the New York Acadademy of Sciences 12 1–8.

Girty, G.H. 1915. Fauna of the Wewoka Formation of Oklahoma. Bulletin of the United States Geological Survey 544 1–353.

Girty, G.H. 1939. Certain pleurotomariid gastropods from the Carboniferous of New Mexico and Texas. Journal of the Washington Academy of Sciences 29 21–36.

Grant, R.E. 1976. Permian brachiopods from southern Thailand. Paleontological Society Memoir 9: 1–269.

Haas, O. 1953. Mesozoic invertebrate faunas of Peru. Bulletin of the American Museum of Natural History 101 1–328.

Hall, J. 1858. Description of new species and fossils from the Carboniferous limestones of Indiana and Illinois. Transactions of the Albany Institute 4 1–36.

Hoare, R.D., Sturgeon, M.T., and Anderson, J.R.J. 1997. Pennsylvanian marine gastropods from the Appalachian Basin. Journal of Paleontology 71 1019–1039.

Holthuis, B.V. 1995. Evolution between marine and freshwater habitats: a case study of the gastropod suborder Neritopsina. Doctoral Degree, University of Washington.

Ishii, K., and Murata, M. 1974. Khumerspira, a new genus of Bellerophontidae, and some Middle Permian gastropods from Cambodia. ournal of Geosciences, Osaka City University 17 73–86.

Jaiboon, T. 2001. Biostratigraphy of Tak Fa Formation at Khao Wong and Khao Chakkachan, Amphoe Hong Muang, Changwat Lop Buri with reference to

Fusulinids. . Master Department of Geology, Faculty of Science Bangkok, Thailand, Chulalongkorn University.

Javanaphet, J.K. 1969. Geological Map of Thailand, Scale 1:1,000,000 Trans.). In (Ed.),^(Eds.), (ed., Vol. pp.). Bangkok: Department of Mineral Resources. (Reprinted from.

Ketwetsuriya, C., Nützel, A., and Kanjanapayont, P. 2014. A new Permian gastropod fauna from the Tak Fa Limestone, Nakhonsawan, Northern Thailand – a report of preliminary results. Zitteliana A 54: 137-146.

Knight, J.B. 1930. The Gastropods of the St. Louis, Missouri, Pennsylvanian outlier: The Pseudozygopleurinae. Journal of Paleontology 4 1–89.

Knight, J.B. 1931a. The Gastropods of the St. Louis, Missouri, Pennsylvanian outlier: The Subulitidae. Journal of Paleontology 5 177–229.

Knight, J.B. 1931b. The Gastropods of the St. Louis, Missouri, Pennsylvanian outlier: Aclisina and Streptacis. Journal of Paleontology 5 1–15.

Knight, J.B. 1933. The gastropods of the St. Louis, Missouri, Pennsylvanian outlier: V. The Trocho-Turbinidae. Journal of Paleontology 7 30–58.

Knight, J.B. 1941. Paleozoic gastropod genotypes. Geological Society of America Special Papers 32 1–510.

Knight, J.B. 1945. Some new genera of Paleozoic Gastropoda. Journal of Paleontology 19 573–587.

Knight, J.B. 1956. New families of Gastropoda. Journal of the Washington Academy of Sciences 46 41–42.

Knight, J.B., Cox, L.R., Keen, A.M., Batten, R.L., Yochelson, E.L., and Robertson, R. 1960. Systematic descriptions. In In MOORE, R.C.e. (ed.), Treatise on Invertebrate Paleontology, Part I, Mollusca 1, pp. I169–I310. Lawrence: Geological Society of America and University of Kansas Press.

Koken, E. 1896. Die Gastropoden der Trias um Hallstadt. Jahrbuch der kaiserlich-königlichen geologischen Reichsanstalt 46: 37–126.

Koninck, L.G.d. 1883. Faune du calcaire carbonifère de la Belgique. Quatrième partie, Gastéropodes (suite et fin). Annales du Musée Royal d´Histoire naturelle de Belgique 8 1–240.

Kues, B.S. 1990. New and little known Pennsylvanian gastropods from the Flechado Formation, Taos City, New Mexico. In New Mexico Geological Society Guidebook 41, pp. 251–258.

Kues, B.S. 2002. New genera and species of Middle Pennsylvanian gastropods from West Texas. Journal of Paleontology 76: 52–62.

Kues, B.S. 2004. Stratigraphy and brachiopod and molluscan paleontology of the Red Tanks Formation (Madera Group) near the Pennsylnanian-Permian boundary, Lucero uplift, west-central New Mexico. New Mexico Museum of Natural History and Science Bulletin 25 143–210.

Kues, B.S., and Batten, R.L. 2001. Middle Pennsylvanian gastropods from the Flechado Formation, north-central New Mexico. Journal of Paleontology 75 Supplement to No 1: 1–95.

Kulas, H.A., and Batten, R.L. 1997. Silicified gastropods from the Permian Phosphoria rock complex of Wyoming. Contributions to Geology, University of Wyoming 31 33–58.

Léveillé, C. 1835. Aperçu géologique de quelques localités très riches en coquilles sur les frontières de la France et de Belgique. Mémoires de la Société Géologique de la France 2 29-40.

Licharew, B.K. 1967. Scaphopods and gastropods—Archaeogastropoda (excluding the suborder Bellerophontina and suborder Neritopsina) from the Upper Paleozoic of southern Fergana. Trudy Vsesoyuzniei Navcho-Issledovatelbskii Geologicheskii Institut, Biostrat., Nov. Ser. 116: 1–115.

Licharew, B.K. 1975. Carboniferous gastropods from the region of the River Kavabolka. Trudy Vsesoyuzniei Navcho-Issledovatelbskii Geologicheskii Institut 206 5–183.

Lindström, A., and Peel, J.S. 2005. Repaired injuries and shell form in some Palaeozoic pleurotomarioid gastropods. Bulletin of Geosciences 85 541-550.

Linsley, R.M., and Kier, W.M. 1984. The Paragastropoda: A Proposal for a new class of Paleozoic Mollusca. Malacologia 25 241–254.

Mansuy, H. 1912. Paléontologie. In In Mansuy, H.D., J. (eds) Etude géologique du Yun-Nan oriental (ed.), Actes Societé Géologique de l' Indo-Chine 1(2), 1–146, pls. , pp. 1–25.

Mansuy, H. 1913. Faunes des Calcaires a Productus de L'Indochine. Mémoires du Service Géologique de L'Indochine 2 fascicule 4: 1–133.

Mansuy, H. 1914a. Nouvelle contribution à la paléontologie du Yunnan. Mémoires du Service Géologiques de l'Indochine 3 fascicule 2: 1–190.

Mansuy, H. 1914b. Faunes des Calcaires a Productus de L'Indochine, deuxième série. Mémoires du Service Géologique de L'Indochine 3 fascicule 3: 1–59.

Mark, C.G. 1912. The fossils of the Conemaugh Formation of Ohio. Ohio Geological Survey Bulletin 17 261–318.

Mazaev, A.V. 1997. Middle and Late Carboniferous gastropods from the Central part of the Russian Plate. Part 3. Microdomatidae and Anomphalidae. Ruthenica 7 91–110.

Mazaev, A.V. 2001. The gastropod genus Stegocoelia Donald, 1889, (Murchisoniidae) from Middle and Upper Carboniferous of the Central part of Russian Plate. Ruthenica 11 137–151.

Mazaev, A.V. 2002. Some murchisoniid gastropods from the Middle and Upper Carboniferous part of Russian Plate. Ruthenica 12 89–106.

Mazaev, A.V. 2006. Permian gastropods from Kulogory Formation of northern Moscow Syneclise. Paleontological Journal 40 42-53.

Mazaev, A.V. 2011. Pennsylvanian gastropods of the suborders Murchisoniina Cox et Knight, 1960 and Sinuspirina Mazaev subordo nov. from the central regions of the Russian Platform: Morphology, taxonomy, and phylogeny. Paleontological Journal 45 1533–1599.

Mazaev, A.V. 2015. Upper Kazanian (Middle Permian) Gastropods of the Volga–Urals Region. Paleontological Journal 49 869–986.

McCoy, F. 1844. A synopsis of the characters of Carboniferous Limestone Fossils of Ireland. Dublin: McGloshan and Gill.

McCoy, F. 1852. A synopsis of the classification of the British Palaeozoic rocks [by the Rev. Adam Sedgwick] with a systematic description of the British Palaeozoic fossils in the Geological Museum of the University of Cambridge [by Frederick McCoy] with figures of the new and imperfectly known species. Parker & Son, London. .

McKerrow, W.S. 1978. The Ecology of Fossils. London: Gerald Duckworth & Company Ltd.

Meek, F.B. 1871. Descriptions of new species of fossils from Ohio and other western states an territories. in Proceedings of the Academy of Natural Sciences of Philadelphia 23. pp. 159–184.

Meek, F.B., and Hayden, F.V. 1858. Remarks on the Lower Cretaceous beds of Kansas and Nebraska, together with descriptions of some new species of Carboniferous fossils from the valley of Kansas River. in Proceedings of the Academy of Natural SciencesProceedings of the Academy of Natural Sciences. pp. 256–264. Philadelphia.

Meek, F.B., and Worthen, A.H. 1861. Descriptions of new Carboniferous fossils from Illinois and other western states. in Proceedings of the Academy of Natural Sciences of Philadelphia 1860. pp. 447–472.

Meek, F.B., and Worthen, A.H. 1866. Descriptions of invertebrates from the Carboniferous system. Geological Survey of Illinois 2. Palaeontology 143–411.

Metcalfe, I., and Sone, M. 2008. Biostratigraphy and palaeobiogeography of Lower Permian (lower Kungurian) conodonts from the Tak Fa Formation (Saraburi Limestone), Thailand. Palaeogeography, Palaeoclimatology, Palaeoecology 257 139–151.

Moore, R.C. 1941. Upper Pennsylvanian gastropods from Kansas. State Geological Survey Kansas, Bulletin 38 121–164.

Moore, R.C. 1960. Treatise on Invertebrate Paleontology. the University of Kansas Press and the Geological society of America.

Nakasawa, K. 2007. Minute bivalve fossils from the Permian Akasaka Limestone, Central Japan: (Appendix) Description of a new species of Pernopecten. Earth Science (Chikyu Kagaku) 61 187–201.

Nakornsri, N. 1976. Geological Map of Ban Mi Sheet ND 47–4, Scale 1:250,000 Trans.). In (Ed.),^(Eds.), (ed., Vol. pp.). Bangkok, Thailand: Geological Survey Division. Department of Mineral Resources. (Reprinted from.

Nakornsri, N. 1981. Geology and Mineral Resources of Amphoe Ban Mi (ND 47–4) Trans.). In (Ed.),^(Eds.), Geological Survey Report Number 3 (ed., Vol. pp.). Bangkok, Thailand: Department of Mineral Resources. (Reprinted from.

Napradit, T. 2005. Permian Fusulinoidean Limestones from East of Changwat Nakhon Sawan. Master Thesis, Department of Geology, Faculty of Science Bangkok, Thailand, Chulalongkorn University.

Netchaev, A.V. 1894. Fauna of the Permian beds of the eastern part of European Russia. Tr. Ob-va Estestvoispyt. Kazan. Imp. Univ 1-503.

Nishida, T. 1969. Middle Permian gastropods from the Takaoka Formation of the Sakawa Basin, Kochi Prefecture, Shikoku, Japan. Saga Daigaku Kyoikugkuba Kenkyu-ronbunshu, Saga Daigaku Kyoikugkuba Kenkyu-ronbunshu 17 81–105.

Nützel, A. 1998. Über die Stammesgeschichte der Ptenoglossa (Gastropoda). Berliner Geowissenschaftliche Abhandlungen Reihe E 26: 1–229.

Nützel, A., and Bandel, K. 2000. Goniasmidae and Orthonemidae: two new families of the Palaeozoic Caenogastropoda (Mollusca, Gastropoda). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 9 557–569.

Nützel, A., and Erwin, D.H. 2004. Late Triassic (Late Norian) gastropods from the Wallowa Terrane (Idaho, USA). Paläontologische Zeitschrift 78 361–416.

Nützel, A., Erwin, D.H., and Mapes, R.H. 2000. Identity and phylogeny of the late Paleozoic Subulitoidea (Gastropoda). Journal of Paleontology 74 575–598.

Nützel, A., Frýda, J., Yancey, T.E., and Anderson, J.R.J. 2007. Larval shells of Late Palaeozoic naticopsid gastropods (Neritopsoidea: Neritimorpha) with a discussion of the early neritimorph evolution. Paläontologische Zeitschrift 81 213–228.

Nützel, A., and Nakazawa, K. 2012. Permian (Capitanian) gastropods from the Akasaka Limestone (Gifu Prefecture, Japan). Journal of Systematic Palaeontology 10 103–169.

Ozawa, T., and Nishiwaki, N. 1992. Permian tethyan biota and sedimentary facies of the Akasaka Limestone Group. In Field trip Guidebook of 29th International Geological Congress B, pp. 189-195.

Pan, H., and Erwin, D.H. 2002. Gastropods from the Permian of Guangxi and Yunnan provinces, South China. Journal of Paleontology 78 Supplement to No 1: 1–49.

Pan, Y., and Yu, W. 1993. Permian Gastropoda of China. Beijing: Ocean Press.

Perner, J. 1907. Système silurien du centre de la Bohême [par J. BARRANDE]. Partie 1: Recherches paléontologiques. . Gastéropodes (2) 4: 90-175.

Prasongtham, P., and Kanjanapayont, P. 2014. Deformation Styles of the Uthai Thani-Nakhon Sawan Ridge within the Chainat Duplex, Thailand. Journal of Earth Science 25: 854-860.

Rafinesque, C.S. 1815. Analyse de la nature, ou tableau de l´univers et des corps organisées. Palerme.

Salvini-Plawen, L.v. 1980. A reconsideration of systematics in the Mollusca (phylogeny and higher classification). Malacologia 19 249–278.

Simroth, H. 1906. Versuch einer neuen Deutung der Bellerophontidae. Versuch einer neuen Deutung der Bellerophontidae 32 1905: 3–8.

Sone, M. 2010. A new species of the rare neritopsid gastropod Magnicapitatus from the Guadalupian (Middle Permian) of East Thailand (the Indochina Terrane). Alcheringa 34: 1–6.

Sowerby, J. 1812–1822. The mineral conchology of Great Britain; or coloured figures and descriptions of those remains of testaceous animals or shells, which have been preserved at various times and depths in the Earth. London: Benjamin Meredith.

Sturgeon, M.T. 1964. New Descriptions of Hitherto Inadequality known Pennsylvanian Gastropods. Journal of Paleontology 38 739–748.

Szabó, J. 2011. Corrections To Three Gastropod Genera, Established By Kutassy On Late Triassic Type Species From Dachstein Limestone Localities Of Budapest (Hungary). Neues Jahrbuch Für Geologie Und Paläontologie, Abhandlungen 261: 37–47.

Thomas, E.G. 1940. Revision Of The Scottish Carboniferous Pleurotomariidae. Geological Society Of Glasgow Transactions 20: 30–72.

Tomlin, J.R.l.B. 1930. Some preoccupied generic names. in Proceedings of the Malacological Society of London 19. pp. 22–24.

Ueno, K., and Charoentitirat, T. 2011. Carboniferous and Permian. In RIDO, M.F., BARBER, A.J., and CROW, M.J. (eds.), The Geology of Thailand, pp. 71-135. London: Geological Society.

Ulrich, E.O., and Scofield, W.H. 1897. The Lower Silurian Gastropoda Of Minnesota. In Ulrich, E.O., et al. (eds.), The Geological And Natural History Survey Of Minnesota. Vol. 3, Part 2, The Geology Of Minnesota. Paleontology, pp.

Waagen, W. 1880. Salt-Range Fossils. I. Productus Limestone Fossils. 2. Pisces-Cephalopoda: Supplement Gasteropoda. Memoirs Of The Geological Survey Of India (Palaeontologia Indica) 13: 1–183.

Warthin, A.S. 1930. Micropaleontology Of The Wetumka. Wewoka And Holdenville Formations. Oklahoma Geological Survey Bulletin 53: 5–94.

Waterhouse, J.B. 1982. An Early Permian cool-water fauna from pebbly mudstones in south Thailand. Geological Magazine 119: 337–354.

Weller, J.M. 1930. A New Species Of Euphemus. . Journal Of Paleontology 4: 14–21.

Wenz, W. 1938–1944. Gastropoda. Teil 1: Allgemeiner Teil Und Prosobranchia. In: O. H. Schindewolf, Ed. Handbuch Der Paläozoologie, Band 6, Gastropoda 1639.

White, C.A. 1877. Report Upon The Invertebrate Fossils Collected In Portions Of Nevada, Utah, Colorado, New Mexico, And Arizona, By Parties Of The Expeditions Of 1871, 1872, 1873, And 1874. Report Upon United States Geographical Surveys West Of The One Hundredth Meridian. Vol. 4, Paleontology 1–219.

Wielchowsky, C.C., and Young, J.D. 1985. Regional facies variations in Permian rocks of the Phetchabun fold and thrust belt, Thailand. Conference on the Geology and Mineral Resource Development of NE Thailand, 41–55.

Winters, S.S. 1956. New Permian Gastropod Genera From Eastern Arizona. Journal Of The Washington Academy Of Sciences 42: 44–45.

Worthen, A.H. 1890. Descriptions Of Fossil Invertebrates. Illinois Geological Survey Bulletin 8: 69–154.

Yakowlew, N.N. 1899. Die Fauna Einiger Oberpaläozooischer Ablagerungen Russlands. 1. Die Cephalopoden Und Gasteropoden, Russia. . Trudy Geologicheskogo Komiteta, Saint Petersburg 15: 1–139.

Yanagida, J. 1988. Biostratigraphic Study Of Paleozoic And Mesozoic Group In Central And Northern Thailand – An Interim Report Trans.). In (Ed.),^(Eds.), (ed., Vol. pp.). Department Of Geology, Faculty Of Science, Kyushu University, Fukuoka. (Reprinted from.

Yochelson, E.L. 1956. Permian Gastropoda Of The Southwestern United States. 1. Euomphalacea, Trochonematacea, Anomphalacea, Craspedostomatacea, And Platyceratacea. Bulletin Of The American Museum Of Natural History 110: 179–275.

Yochelson, E.L. 1960. Permian Gastropoda Of The Southwestern United States. Bulletin Of The American Museum Of Natural History 119: 205–294.

Yochelson, E.L., and Saunders, B.W. 1967. . A Bibliographic Index Of North American Late Paleozoic Hyolitha, Amphineura, Scaphopda, And Gastropoda. Geological Survey Bulletin 1210: 1–271.

Zittel, K.A. 1895. Grundzüge Der Paläontologie (Paläozoologie), Abt. I, Invertebrata Trans.). In (Ed.),^(Eds.), (ed., Vol. pp. 971). Oldenburg, München & Leipzig. (Reprinted from.

APPENDIX

Explanation of Plate 1

Figs. 1-7 ***Euphemites graffhami*** .....page 56

1. apertural view, SNSB-BSPG 2014 XI 58.

2. SNSB-BSPG 2014 XI 58.

3. abapertural view, SNSB-BSPG 2014 XI 105.

4. apertural views at different angles to show spiral lirae within aperture, SNSB-BSPG 2014 XI 105.

5. lateral view

6. apertural view

7. apertural view

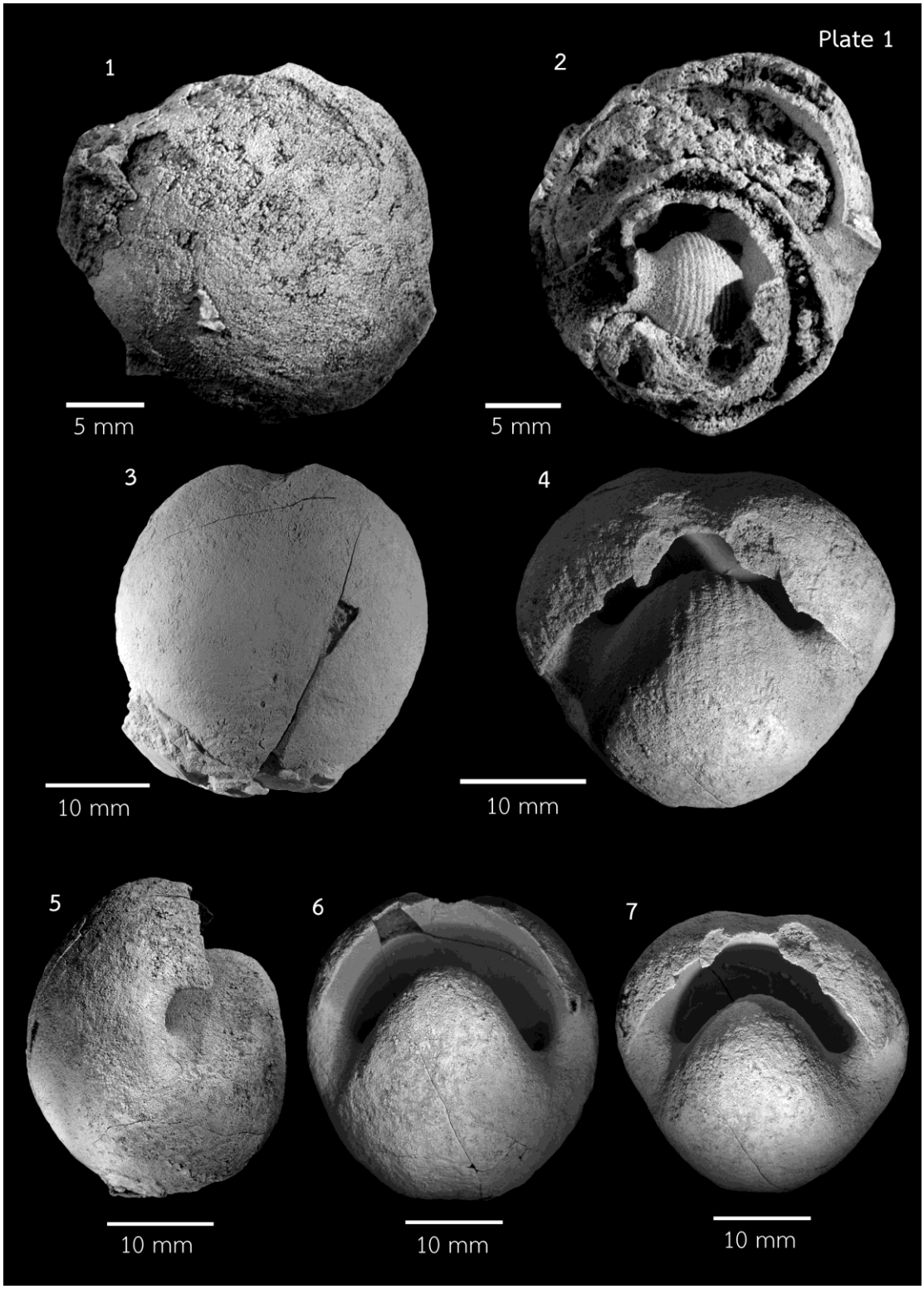


Plate 1
1
2
5 mm
5 mm
3
4
10 mm
10 mm
5
6
7
10 mm
10 mm
10 mm

Explanation of Plate 2

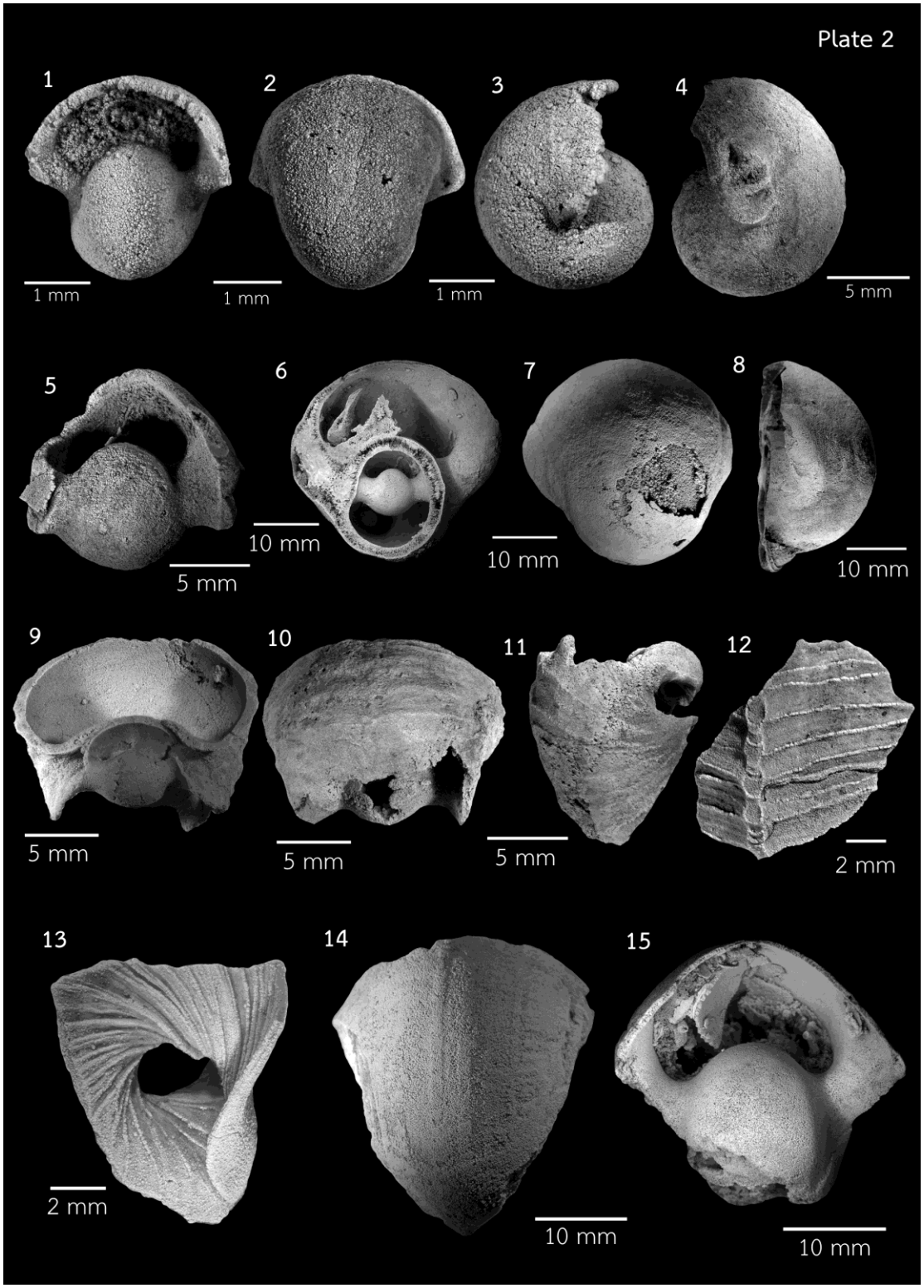


Plate 2
1
1 mm
2
1 mm
3
1 mm
4
5 mm
5
5 mm
6
10 mm
7
10 mm
8
10 mm
9
5 mm
10
5 mm
11
5 mm
12
2 mm
13
2 mm
14
10 mm
15
10 mm

Explanation of Plate 3

Figs. 1-10 ***Pharkidonotus khaonoiensis*** **n. sp.** .....page 60

1.paratype, apertural view, SNSB-BSPG 2014 XI 61.

2.paratype, abapertural view, SNSB-BSPG 2014 XI 61.

3.paratype, lateral view, SNSB-BSPG 2014 XI 61.

4.paratype, apertural view, SNSB-BSPG 2014 XI 59.

5.paratype, lateral view, SNSB-BSPG 2014 XI 59.

6.holotype, apertural view, SNSB-BSPG 2014 XI 88.

7.holotype, abapertural view, SNSB-BSPG 2014 XI 88.

8.holotype, lateral view, SNSB-BSPG 2014 XI 88.

9, 10. paratype, SNSB-BSPG 2014 XI 4.

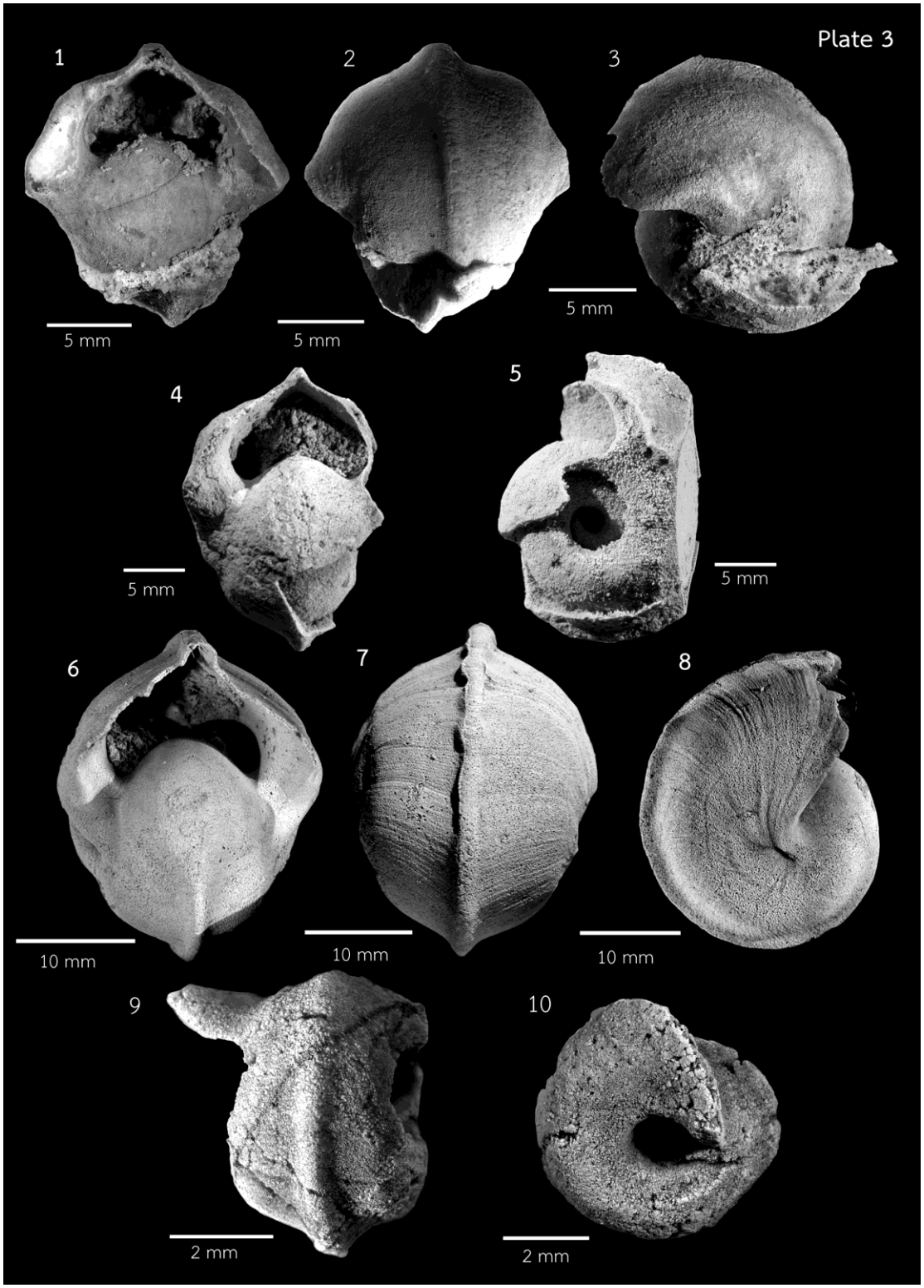


Plate 3
1
2
3
5 mm
5 mm
5 mm
4
5
5 mm
5 mm
6
7
8
10 mm
10 mm
10 mm
9
10
2 mm
2 mm

Explanation of Plate 4

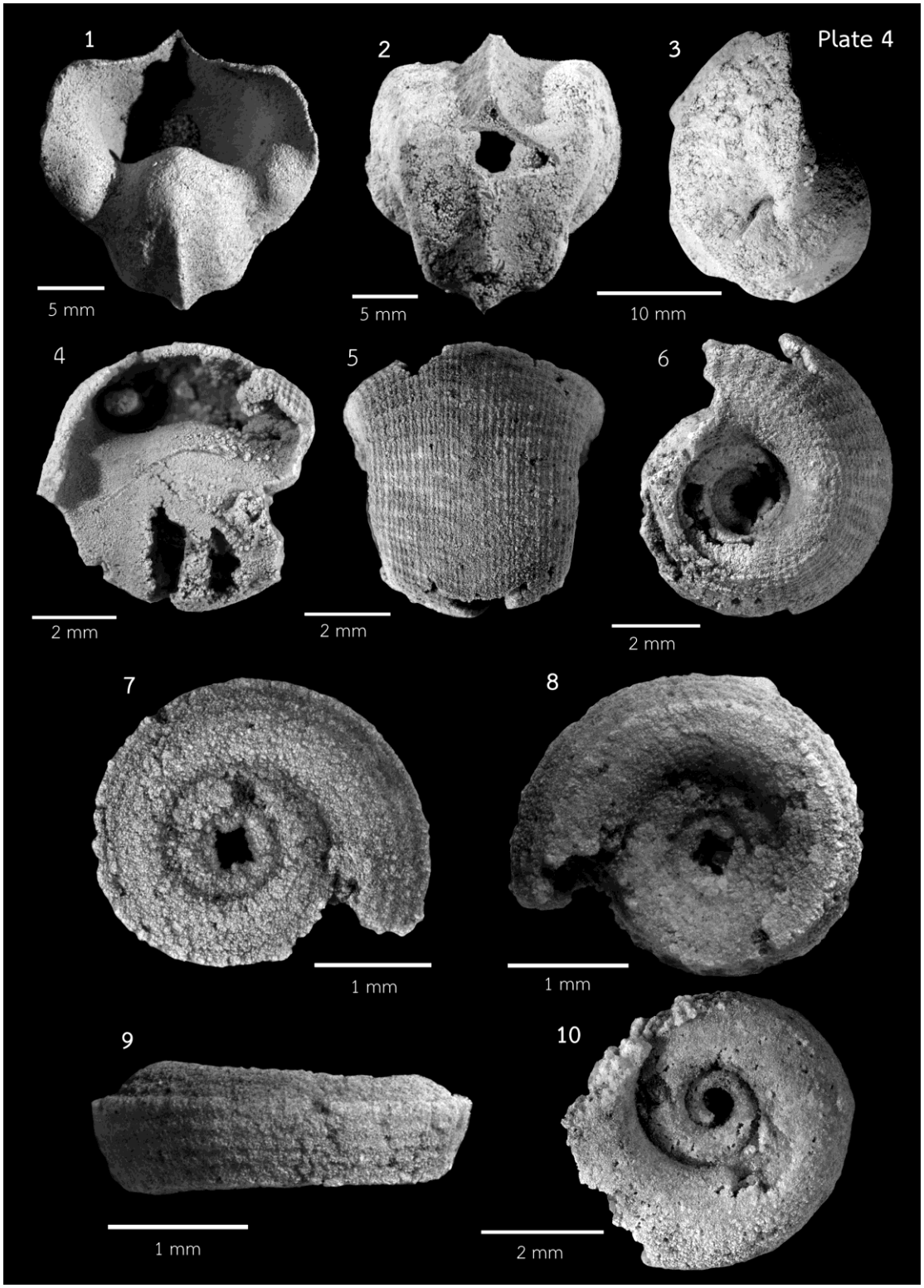


Plate 4
1
5 mm
2
5 mm
3
10 mm
4
2 mm
5
2 mm
6
2 mm
7
1 mm
8
1 mm
9
1 mm
10
2 mm

Explanation of Plate 5

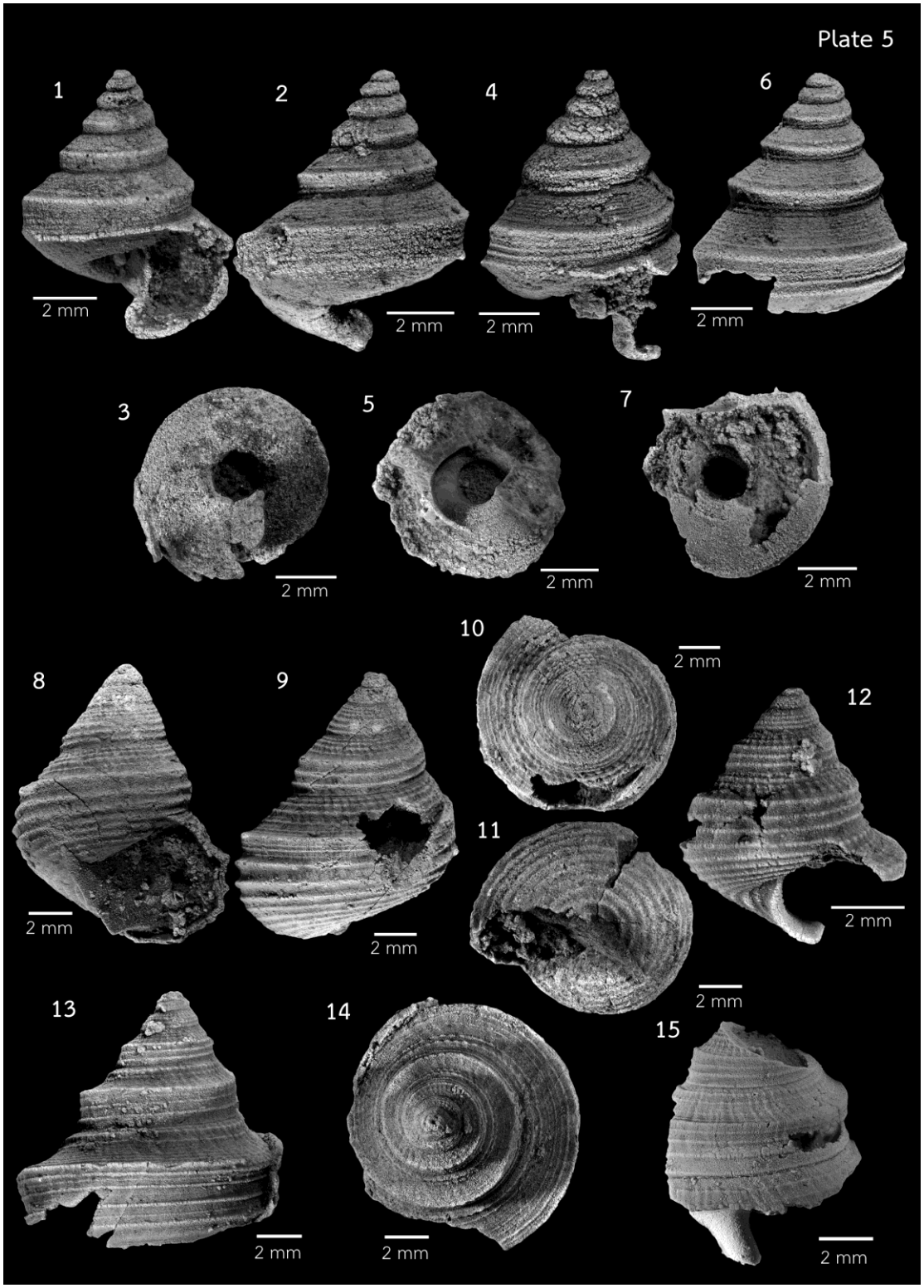


Plate 5
1
2
4
6
3
5
7
10
8
9
12
11
13
14
15
2 mm

Explanation of Plate 6

Figs. 1-6 ***Amaurotoma*? sp.** .....page 72

1.apertural view, SNSB-BSPG 2014 XI 16.

2.abapertural view, SNSB-BSPG 2014 XI 16.

3.basal view, SNSB-BSPG 2014 XI 16.

4.apertural view, SNSB-BSPG 2014 XI 64.

5.abapertural view, SNSB-BSPG 2014 XI 64.

6.basal view, SNSB-BSPG 2014 XI 64.

Figs. 7-14 ***Takfaia kuesi* n. sp.** .....page 74

7.holotype, apertural view, SNSB-BSPG 2014 XI 42.

8.holotype, abapertural view, SNSB-BSPG 2014 XI 42.

9.holotype, apical view, SNSB-BSPG 2014 XI 42.

10.holotype, basal view, SNSB-BSPG 2014 XI 42.

11.paratype, SNSB-BSPG 2014 XI 10 (specimen broken in two halves).

12.paratype, apertural view, SNSB-BSPG 2014 XI 10.

13.paratype, abapertural view, SNSB-BSPG 2014 XI 10.

14.paratype, apical view, SNSB-BSPG 2014 XI 10.

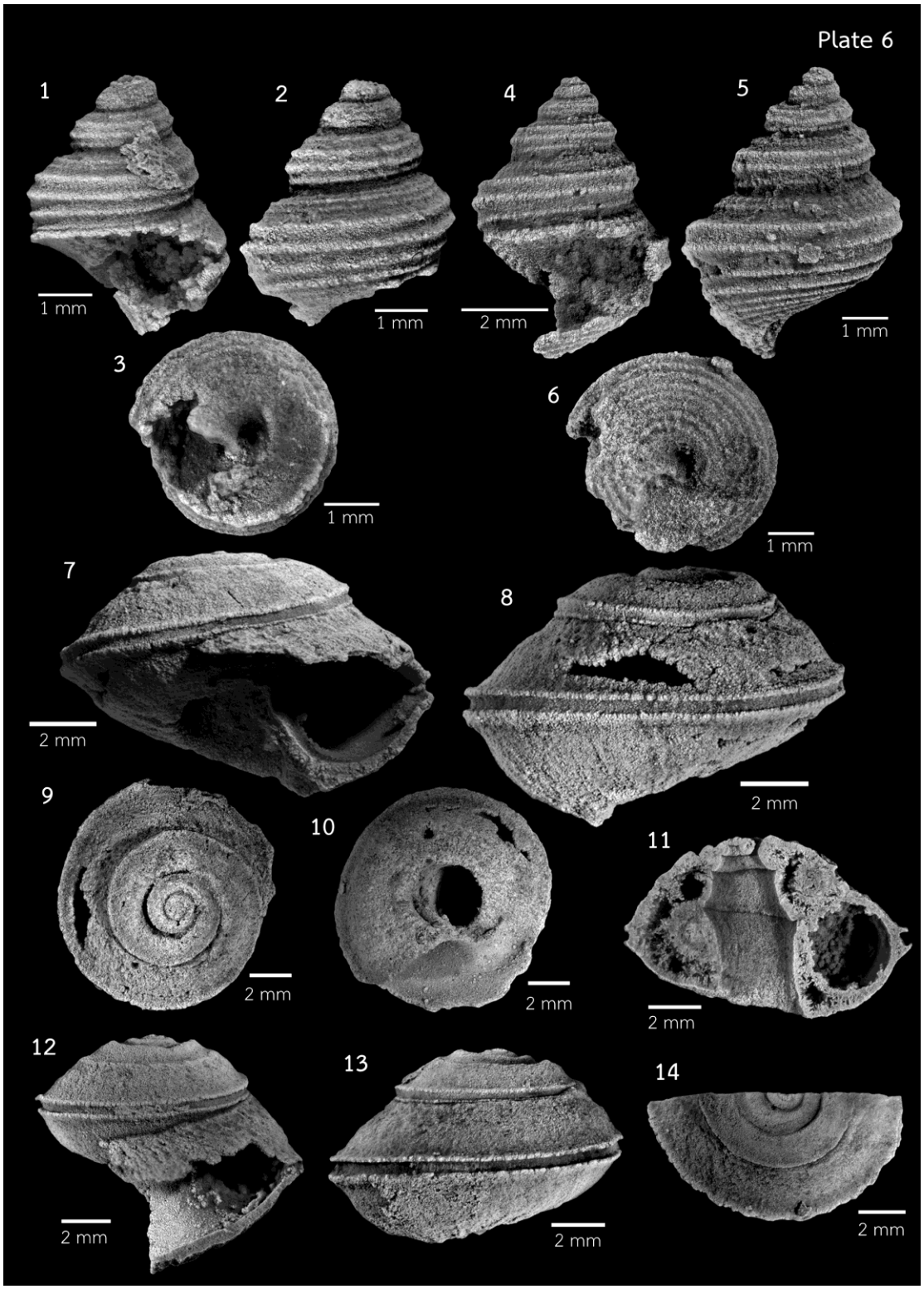


Plate 6
1
1 mm
2
1 mm
4
2 mm
5
1 mm
3
1 mm
6
1 mm
7
2 mm
8
2 mm
9
2 mm
10
2 mm
11
2 mm
12
2 mm
13
2 mm
14
2 mm

Explanation of Plate 7

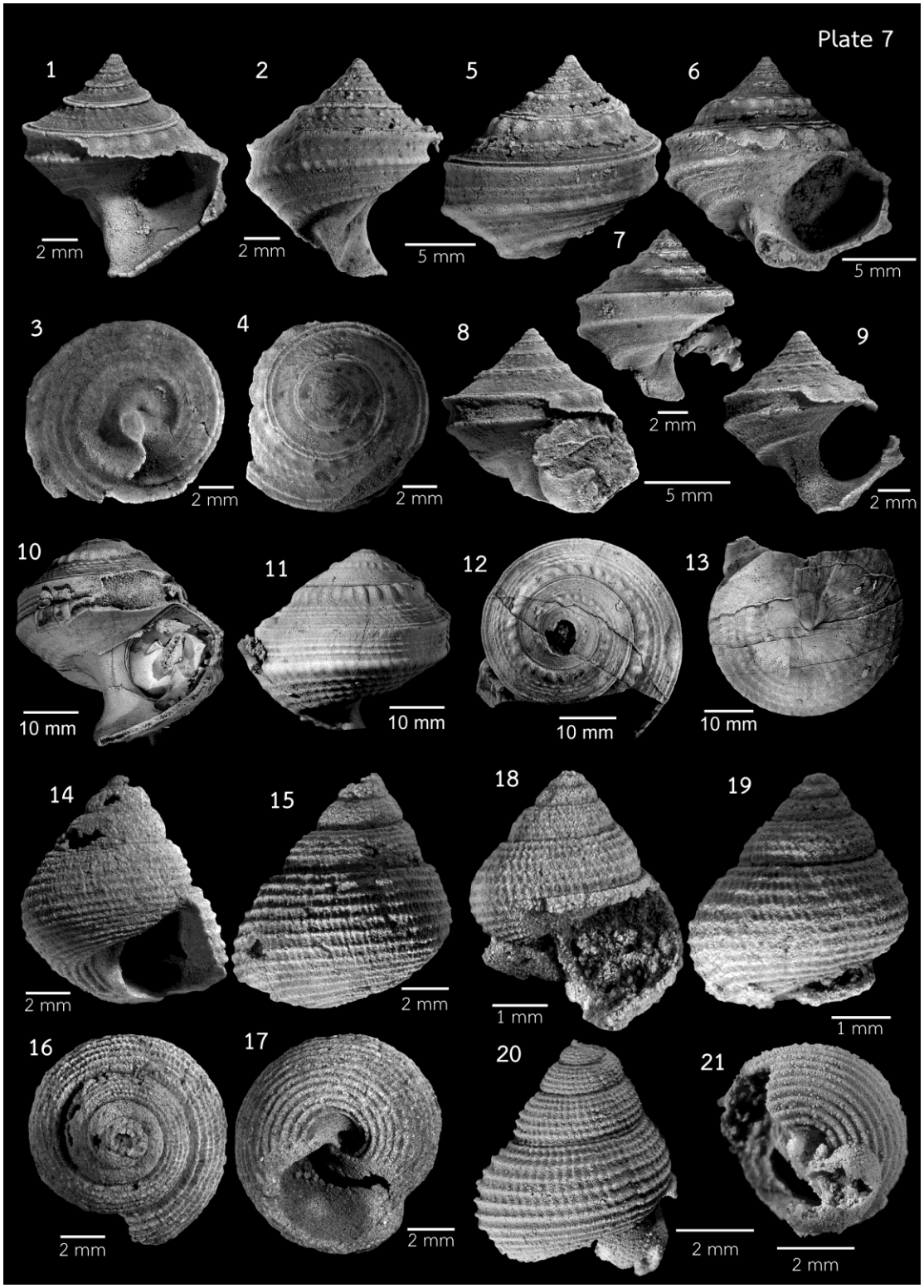


Plate 7
1
2 mm
2
2 mm
5
5 mm
6
5 mm
7
2 mm
3
2 mm
4
2 mm
8
5 mm
9
2 mm
10
10 mm
11
10 mm
12
10 mm
13
10 mm
14
2 mm
15
2 mm
18
1 mm
19
1 mm
16
2 mm
17
2 mm
20
2 mm
21
2 mm

Explanation of Plate 8

Figs. 1-7 ***Anomphalus* sp.** .....page 79

1.apical view, SNSB-BSPG 2014 XI 28.

2.basal view, SNSB-BSPG 2014 XI 28.

3.apertural view, SNSB-BSPG 2014 XI 28.

4.abapertural view, SNSB-BSPG 2014 XI 28.

5.apertural view, SNSB-BSPG 2014 XI 20.

6.abapertural view, SNSB-BSPG 2014 XI 20.

7.apical view, SNSB-BSPG 2014 XI 20.

Figs. 8-14 ***Anomphalus lateumbilicatus* n. sp.** .....page 78

8.holotype, apertural view, SNSB-BSPG 2014 XI 115.

9.holotype, apical view, SNSB-BSPG 2014 XI 115.

10.holotype, basal view, SNSB-BSPG 2014 XI 115.

11.holotype, basal view, SNSB-BSPG 2014 XI 115.

12.holotype, oblique side view, SNSB-BSPG 2014 XI 115.

13.paratype, apical view, SNSB-BSPG 2014 XI 116.

14.paratype, basal view, SNSB-BSPG 2014 XI 116.

Figs. 15-16 ***Anticonulus*? sp.** .....page 82

15.apertural view, SNSB-BSPG 2014 XI 8.

16.abapertural view, SNSB-BSPG 2014 XI 8.

Figs. 17-19 ***Coeloconulus panae*** Nützel, 2012.....page 83

17.apertural view, SNSB-BSPG 2014 XI 109.

18.apertural view, SNSB-BSPG 2014 XI 109.

19.basal view, SNSB-BSPG 2014 XI 109.

Fig. 20 ***Eocalliostoma* sp.** .....page 83

20.apertural view, SNSB-BSPG 2014 XI 81.

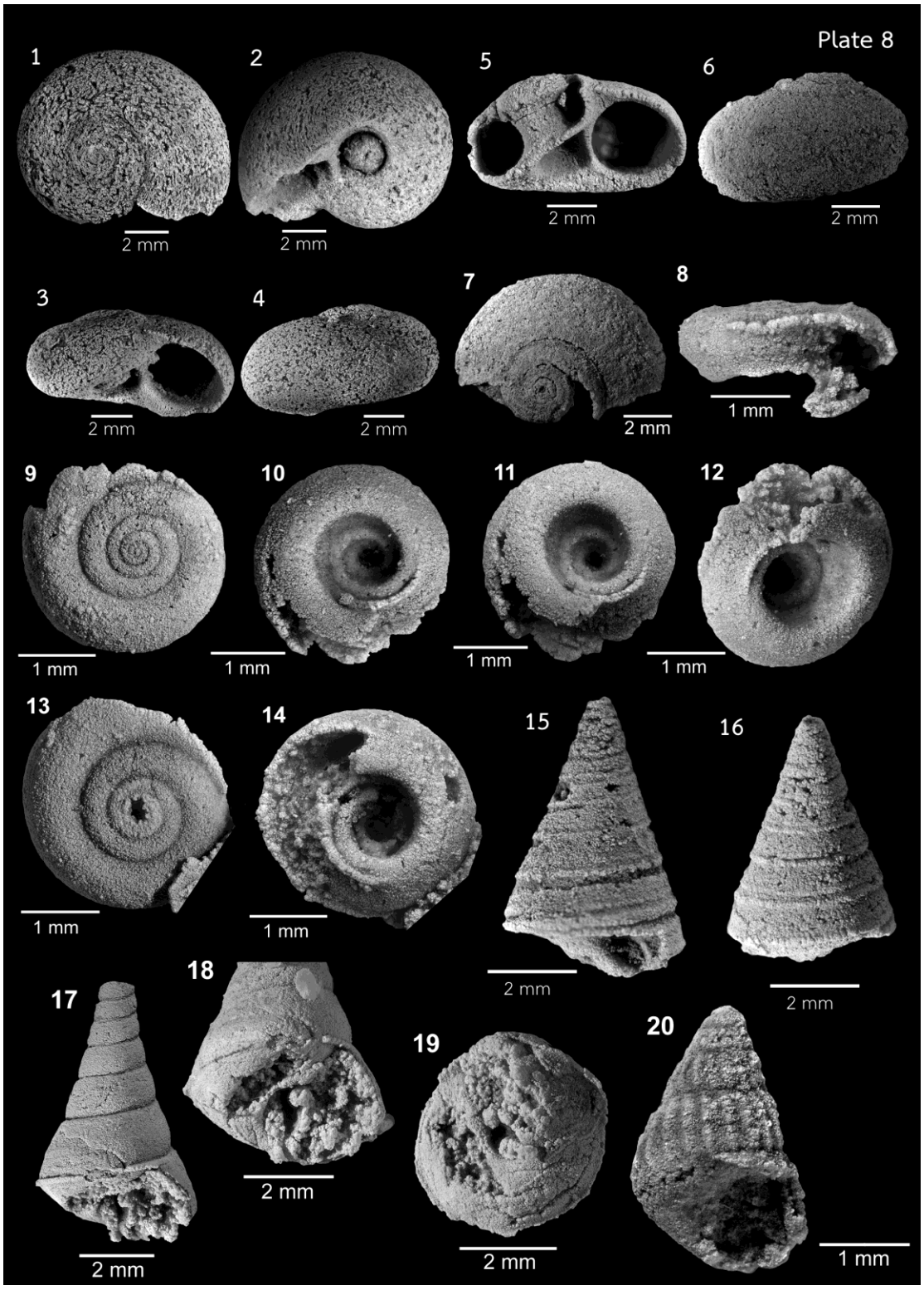


Plate 8
1
2 mm
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2 mm
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2 mm
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2 mm
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2 mm
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2 mm
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2 mm
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1 mm
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1 mm
10
1 mm
11
1 mm
12
1 mm
13
1 mm
14
1 mm
15
2 mm
16
2 mm
17
2 mm
18
2 mm
19
2 mm
20
1 mm

Explanation of Plate 9

Figs. 1-9 ***Microdoma carinata*** **n. sp.** .....page 84

1.paratype, apertural view, SNSB-BSPG 2014 XI 19.

2.paratype, basal view, SNSB-BSPG 2014 XI 19.

3.paratype, abapertural view, SNSB-BSPG 2014 XI 62.

4.paratype, apertural view, SNSB-BSPG 2014 XI 62.

5.paratype, apertural view, SNSB-BSPG 2014 XI 11.

6.holotype, apical view, SNSB-BSPG 2014 XI 47.

7.holotype, basal view, SNSB-BSPG 2014 XI 47.

8.holotype, abapertural view, SNSB-BSPG 2014 XI 47.

9.holotype, apertural view, SNSB-BSPG 2014 XI 47.

Figs. 10-15 ***Trachydomia takhliensis*** **n. sp.** .....page 87

10.paratype, apertural view, SNSB-BSPG 2014 XI 37.

11.paratype, abapertural view, SNSB-BSPG 2014 XI 37.

12.holotype, apertural view, SNSB-BSPG 2014 XI 41.

13.holotype, abapertural view, SNSB-BSPG 2014 XI 41.

14.apical view.

15.apertural view.

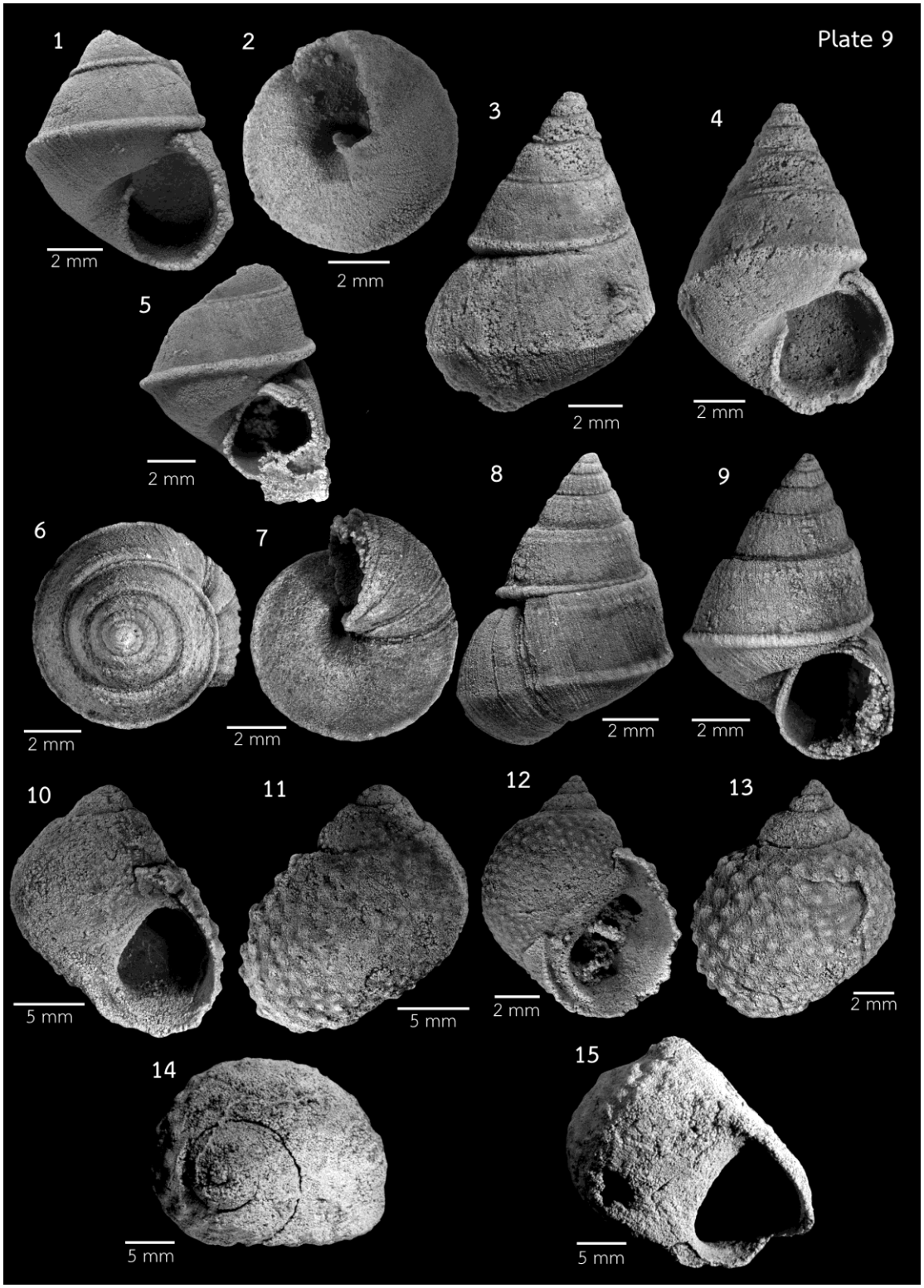
Plate 9
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
2 mm
5 mm

Explanation of Plate 10

Figs. 1-9 ***Naticopsis* spp.** .....page 86

1.apertural view, SNSB-BSPG 2014 XI 95.

2.abapertural view, SNSB-BSPG 2014 XI 95.

3.apical view, SNSB-BSPG 2014 XI 95.

4.apical view, SNSB-BSPG 2014 XI 72.

5.lateral view, SNSB-BSPG 2014 XI 72.

6.apertural view, SNSB-BSPG 2014 XI 57.

7.abapertural view, SNSB-BSPG 2014 XI 57.

8.lateral view, SNSB-BSPG 2014 XI 66.

9.apical view, SNSB-BSPG 2014 XI 66.

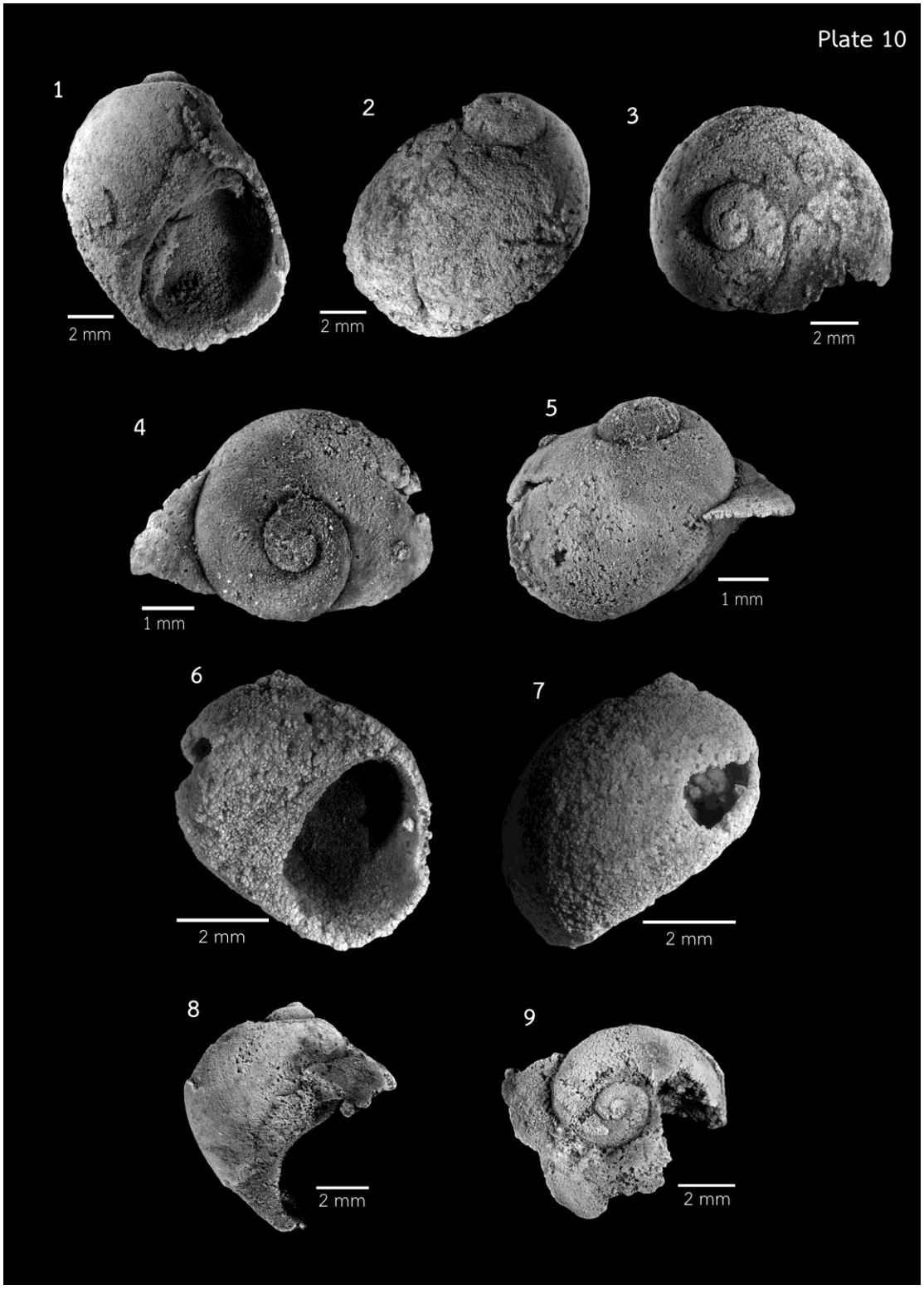
Plate 10
1
2 mm
2
2 mm
3
2 mm
4
1 mm
5
1 mm
6
2 mm
7
2 mm
8
2 mm
9
2 mm

Explanation of Plate 11

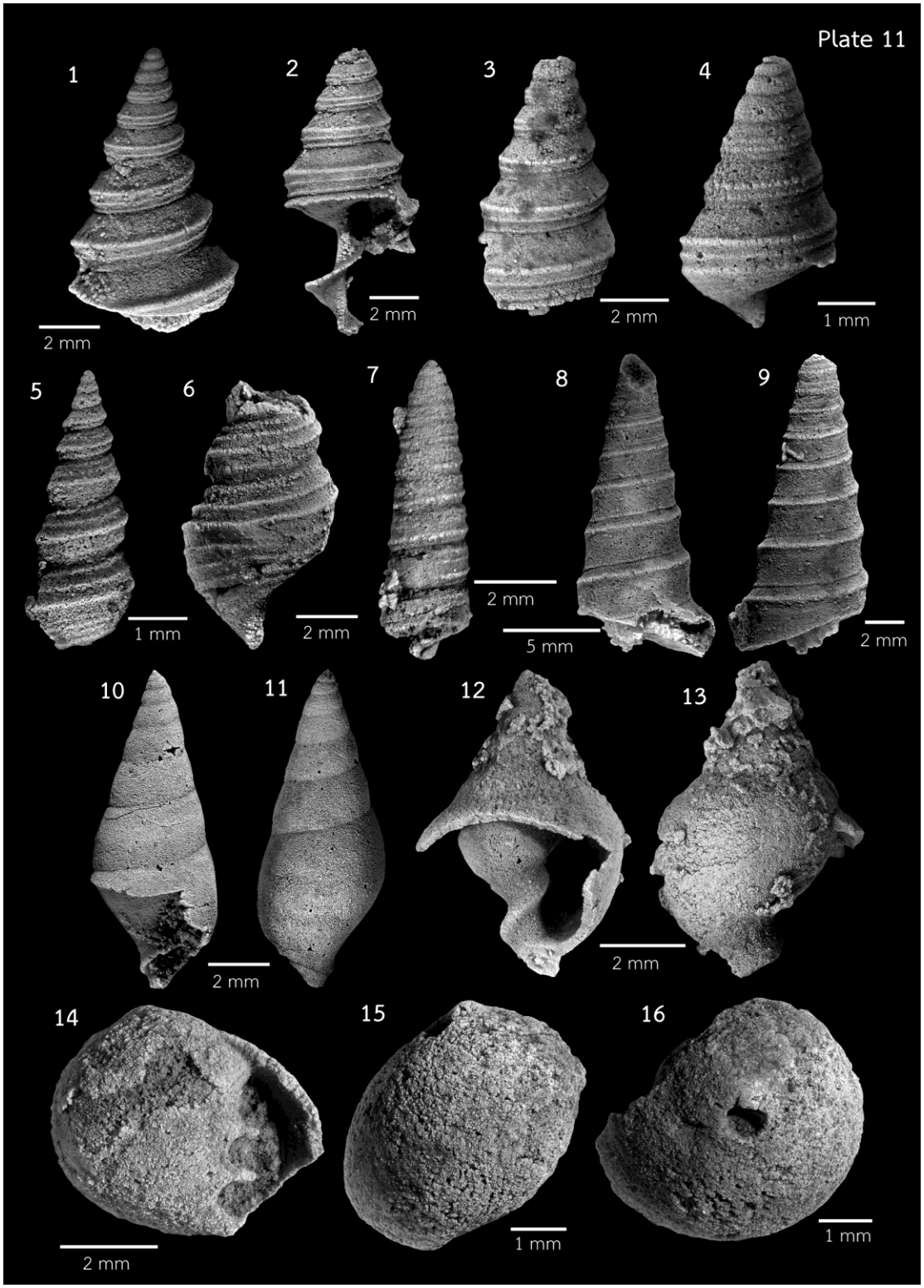
Plate 11
1
2
3
4
2 mm
2 mm
2 mm
1 mm
5
6
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8
9
1 mm
2 mm
2 mm
5 mm
2 mm
10
11
12
13
2 mm
2 mm
14
15
16
2 mm
1 mm
1 mm

Explanation of Plate 12

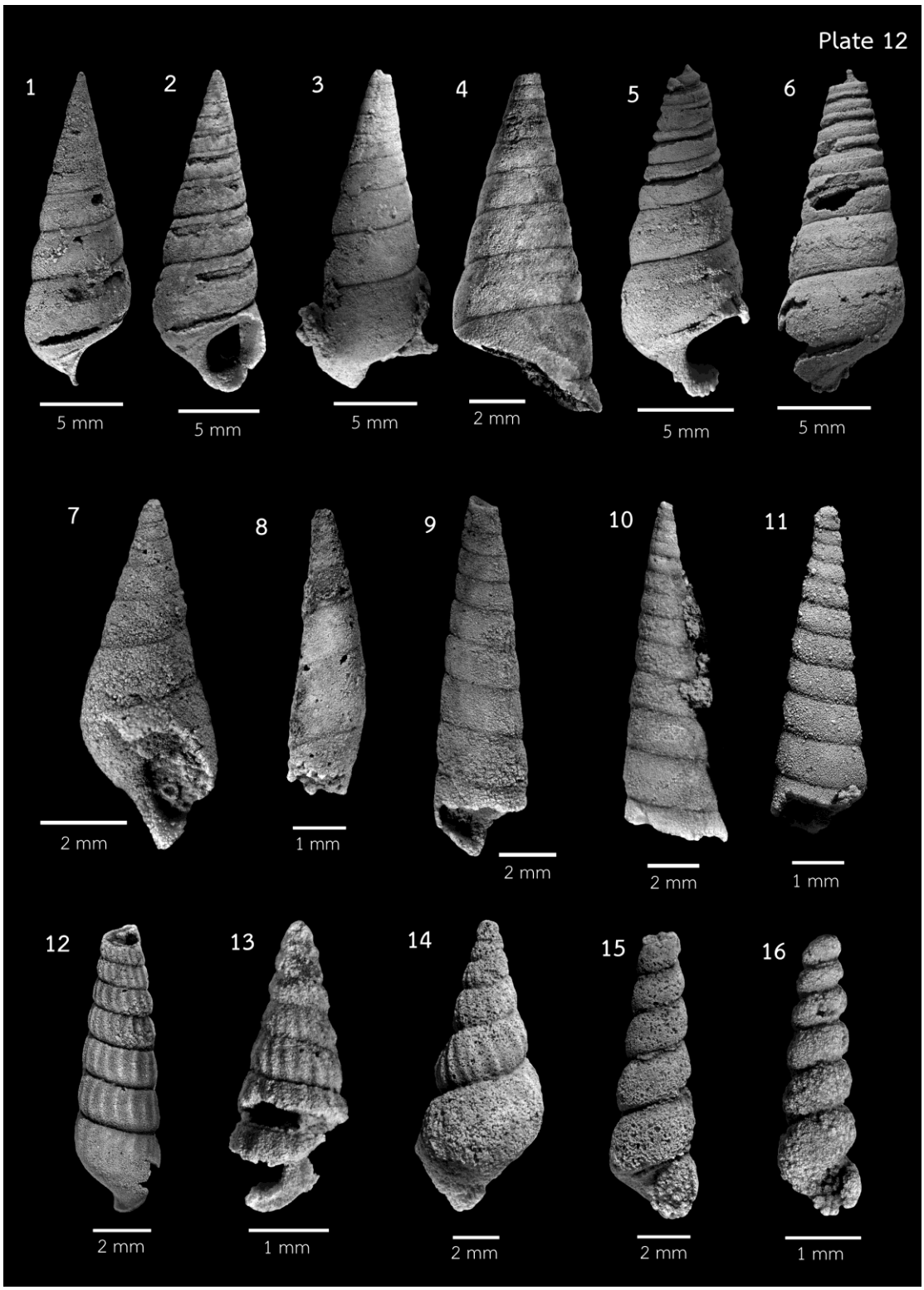
Plate 12
1
5 mm
2
5 mm
3
5 mm
4
2 mm
5
5 mm
6
5 mm
7
2 mm
8
1 mm
9
2 mm
10
2 mm
11
1 mm
12
2 mm
13
1 mm
14
2 mm
15
2 mm
16
1 mm

VITA

Mr.Chatchalerm Ketwetsuriya was born on June 2, 1992 in Bangkok, central Thailand. During 2010 to 2014, he has completed the Bachelor of Science Degree in Geology (2nd Class Honours) in 2014 from Department of Geology, Faculty of Science, Chulalongkorn University. From 2015, he has continued his study for Master program on Geology at Department of Geology, Faculty of Science, Chulalongkorn University.