SUID FOSSILS AND SEDIMENTOLOGY FROM THE CHALOEM PHRA KIAT AND PHIMAI SANDPITS, NAKHON RATCHASIMA PROVINCE

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ซากดึกดำบรรพ์สัตว์วงศ์หมู และตะกอนวิทยาจากบ่อทรายในอำเภอเฉลิมพระเกียรติ และอำเภอพิ
มาย จังหวัดนครราชสีมา

น.ส.ธัญชนก กาวิเนตร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Field of Study	Geology
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ธัญชนก กาวิเนตร : ซากดึกดำบรรพ์สัตว์วงศ์หมู และตะกอนวิทยาจากบ่อทรายในอำเภอเฉลิมพระเกียรติ และอำเภอพิมาย จังหวัดนครราชสีมา. (SUID FOSSILS AND SEDIMENTOLOGY FROM THE CHALOEM PHRA KIAT AND PHIMAI SANDPITS, NAKHON RATCHASIMA PROVINCE) อ.ที่ปรึกษาหลัก : ศ. ดร.มนตรี ชูวงษ์, อ.ที่ปรึกษาร่วม : อ. ดร.กันตภณ สุระประสิทธิ์

ซากดึกดำบรรพ์สัตว์วงศ์หมูเป็นจำนวนมากได้ถูกรักษาสภาพปะปนกับตะกอนน้ำพาจากบ่อทรายในอำเภอเฉลิมพระเกียรติและอำเภอพิมาย จังหวัดนครราชสีมา การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาลักษณะสัณฐานวิทยาภายนอกของสัตว์วงศ์หมู และเปรียบเทียบขนาดของฟันหมูกับตัวอย่างแบบฉบับที่มีชนิดสัมพันธ์กัน รวมทั้งศึกษาลำดับชั้นตะกอนจากสภาพแวดล้อมธารน้ำพา

ผลการศึกษาพบว่าตะกอนจากบ่อทรายดังกล่าว ประกอบด้วยตะกอนทรายที่มีขนาดเม็ดละเอียดถึงเม็ดหยาบพบในลำดับชั้นตะกอนมีความหนาตั้งแต่ 12-15 เมตร สามารถจำแนกลักษณะปรากฏของตะกอนเป็น 7 ชุดลักษณะ ได้แก่ matrix-supported gravel (Gmg), trough cross-bedded sand (St), ripple cross-laminated sand (Sr), planar cross-bedded sand (Sp), massive mud, silt (Fm), laminated sand, silt and mud (Fl), silt, clay (Fsm) และสามารถจัดกลุ่มลักษณะปรากฏของตะกอนเป็น 6 กลุ่ม ได้แก่ sandy bedforms (SB), lateral accretion deposits (LA), levee deposits (LV), crevasse channel deposits (CR), floodplain deposits (FF), and abandoned channel fills deposits (FF (CH))

ตัวอย่างซากดึกดำบรรพ์สัตว์วงศ์หมู จำนวน 38 ตัวอย่าง ที่ค้นพบจากบ่อทรายในบริเวณพื้นที่ศึกษา ระบุให้เป็นชนิด *Tetraconodon* cf. *intermedius*, *Conohyus* cf. *sindiense*, *Propotamochoerus* cf. *hysudricus*, *Hippopotamodon* cf. *sivalense* และมีความสัมพันธ์กับกลุ่มซากดึกดำบรรพ์ที่ค้นพบในพื้นที่เทือกเขาศิวะลิกบริเวณประเทศปากีสถาน บ่งบอกว่าในสมัยไมโอซีนตอนปลายมีการอพยพแลกเปลี่ยนของกลุ่มสิ่งมีชีวิตระหว่างอนุทวีปอินเดียและประเทศไทย

สาขาวิชา	ธรณีวิทยา	ลายมือชื่อนิสิต ....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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KEYWORD: stratigraphy, sedimentary facies, Suidae, Artiodactyla, fluvial environment, Chaloem Phra Kiat, Phimai, Nakhon Ratchasima

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The suid fossils were recorded in fluvial sediments at the Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province. In this study, numerous suid fossils were identified systematically by the measurement and description in detail of the external morphology of teeth, and comparison with other related species. Sedimentary facies and facies association from stratigraphy of fluvial depositional environment from sandpits have also been studied.

As a result, sediments from Chaloem Phra Kiat and Phimai sandpits comprise very fine to coarse-grained sand with dominate sedimentary structures of the fluvial deposits. The cumulative stratigraphical thickness of the studied successions was 12-15 m. Seven sedimentary facies have been identified within channel systems, including matrix-supported gravel (Gmg), trough cross-bedded sand (St), ripple cross-laminated sand (Sr), planar cross-bedded sand (Sp), massive mud, silt (Fm), laminated sand, silt and mud (Fl), silt, clay (Fsm). These facies are grouped into Six architectural elements as sandy bedforms (SB), lateral accretion deposits (LA), levee deposits (LV), crevasse channel deposits (CR), floodplain deposits (FF), and abandoned channel fills deposits (FF (CH)), each of which is unique in facies association and architectural elements. All of these sediments represent meandering river systems.

The thirty-eight specimens of suid fossils were collected and identified as belonging to four species: *Tetraconodon* cf. *intermedius*, *Conohyus* cf. *sindiense, Propotamochoerus* cf. *hysudricus,* and *Hippopotamodon* cf. *sivalense.* All these suid taxa are similar to the Siwalik faunas of Pakistan, suggesting a faunal exchange between the Indian subcontinent and Thailand during the Late Miocene.

Field of Study:	Geology		Student's Signature ....
Academic Year:	2019		Advisor's Signature ....
			Co-advisor's Signature ....

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Thunchanok Kawinate

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CHAPTER 1

INTRODUCTION

1.1 Background

The Khorat Plateau of northeast Thailand covers about one–third of the area of the entire country. The Quaternary deposits in the Khorat Plateau consist of two basins. Namely, the Khorat basin located in the south and the Sakon Nakhon basin situated in the north of the plateau. The Khorat basin is covered by two main rivers, namely Mun and Chi Rivers. Thick fluvial sediments of the Mun River are distributed on both sides of the river (Choowong, 2011). The Quaternary sediments in the basin sourced from the Mesozoic sedimentary rock of the Khorat group compose of sandstone, conglomerate, siltstone, and shale (Raksasakulwong et al., 2004): The stratigraphic sections from sandpits among the Mun River in Nakhon Ratchasima Province displays two sand units. The upper unit consists of yellowish sands, and the lower unit composes of organic-rich sands and gravels (Chaimanee et al., 2006; Duangkrayom et al., 2014). However, tektites deposited in association with pebbly laterites and enclosed with the pebbly laterites at the hardpan surface. Palaeomagnetic dating indicated that these flood pulses were contemporaneous with the tektite–forming event at *c.* 0.8 Ma. in northeastern Thailand (Howard et al., 2011; Haines et al., 2004).

According to many researchers, mammal fossil assemblages were discovered in the Mueang Nakhon Ratchasima, Chalerm Phra Kiat, Chumpuang and Phimai Districts, Nakhon Ratchasima Province, indicating a Late Miocene to Early Pleistocene age. This fauna consists of hominoid primates, *Khoratpithecus piriyai* (Chaimanee et al., 2004, 2006), *Sinomastodon* sp. (Thasod et al., 2011), *Aceratherium porpani* (Deng et al., 2013), *Merycopotamus thachangensis* (Hunta et al., 2008).

However, suid fossils specimen from the Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province, were found in abundance from the sandpits. Here we describe morphological features in comparison with other related species. Sedimentary facies and stratigraphy were studied in order to reconstruct the paleoenvironment where these fossils were found.

1.2 Study Area

The study areas are in the three sandpits at Phimai District; Mae Lae Butra, Rim Mai Sai Thong, Chai Anan (Figure 1.1), and in the sandpit at the Chaloem Phra Kiat District, Takut Khon (Figure 1.2), Nakhon Ratchasima Province. These areas are positioned at the latitudes 14° 56' 00" North to 15° 15' 00" North, and longitudes 102° 6' 00" East to 102° 30' 00" East. Two topographic maps with the scale 1:50,000 series L 7018 of the Royal Thai Survey Department (2000): the sheet numbers 5438 IV (Changwat Nakhon Ratchasima) and 5439 II (Amphoe Non–Sung) are conducted to gather base assessment and follow-up information on the study areas.

Mae Lae Butra sandpit (Figure 1.3–1.4) is located in Samrit Sub-district, Phimai District, Nakhon Ratchasima Province. The coordinates of the study area are approximately at latitude 15° 11' 11.8" North and longitude 102° 22' 57.3" East. The area encompasses the dimension of 300 m wide, 315 m long, and 14 m deep, with a total of 94,500 square meters, which is calculated using the Google Earth Pro (Available from https://www.google.co.th).

Rim Mai Sai Thong sandpit (Figure 1.5–1.6) is located in Than La Lot Sub-district, Phimai District, Nakhon Ratchasima Province. The coordinates of the study area are approximately at latitude 15° 08' 34.3" North and longitude 102° 24' 04.6" East. The area encompasses the dimension of 90 m wide, 100 m long, and 12 m Deep with a total of 9,000 square meters.

Chai Anan sandpit (Figure 1.7–1.8) is located in Than La Lot Sub-district, Phimai District, Nakhon Ratchasima Province. The coordinates of the study area are approximately at latitude 15° 07' 57.5" North and longitude 102° 23' 00.6" East. The area encompasses the dimension of 230 m wide, 240 m long, and 15 m Deep with a total of 55,200 square meters.

Takut Khon sandpit (Figure 1.9–1.10) is located in Tha Chang Sub-district, Chaloem Phra Kiat District, Nakhon Ratchasima Province. The coordinates of the study area are approximately at latitude 14° 59' 51.0" North and longitude 102° 14' 51.7" East. The area encompasses the dimension of 185 m wide, 190 m long, and 16 m Deep with a total of 35,150 square meters.

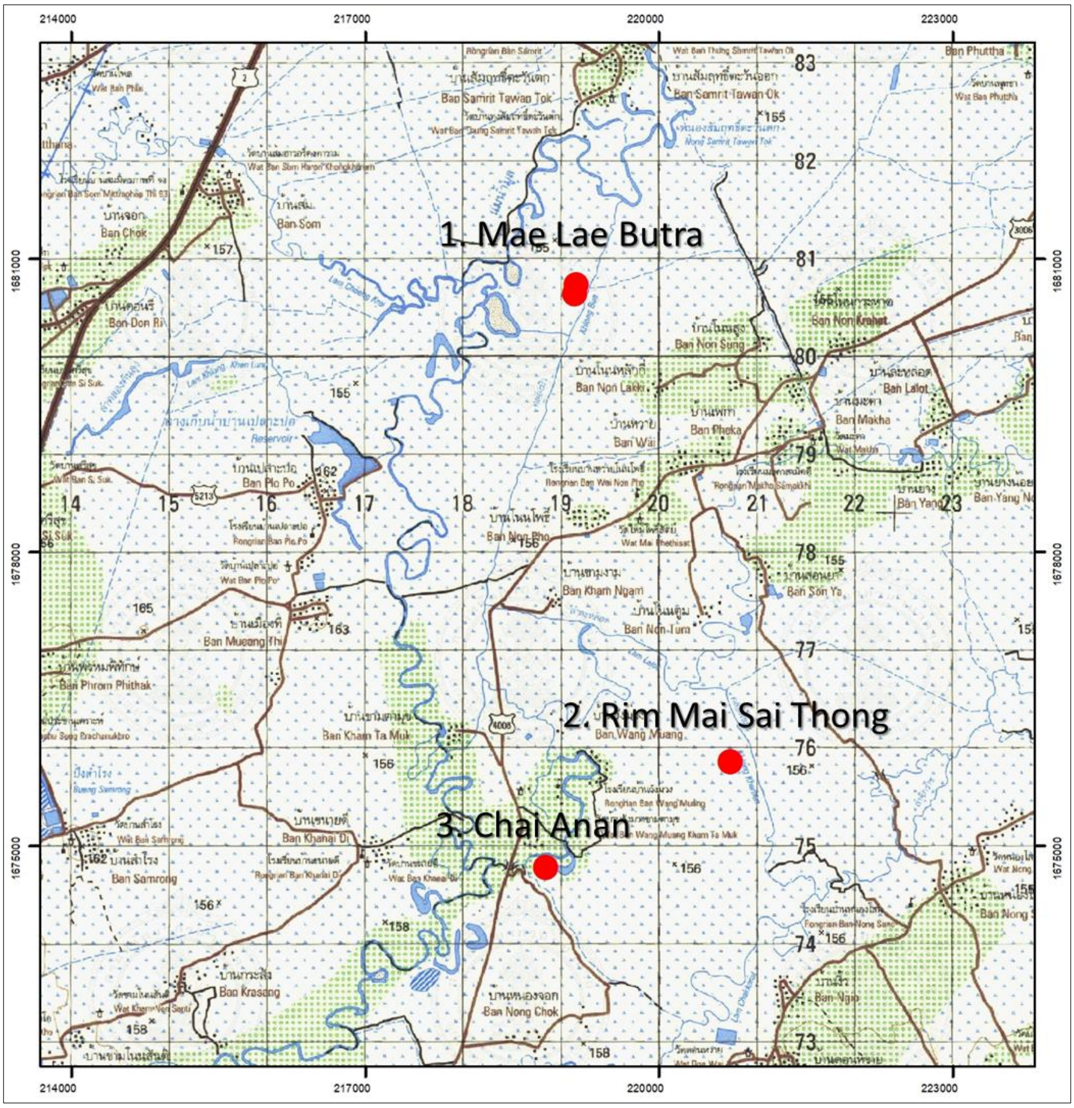

Figure 1. 1 Topographic map scale 1:50,000 showing of the study area; (1) Mae Lae Butra sandpit, (2) Rim Mai Sai Thong sandpit, (3) Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province, modified from Royal Thai Survey Department (2000).

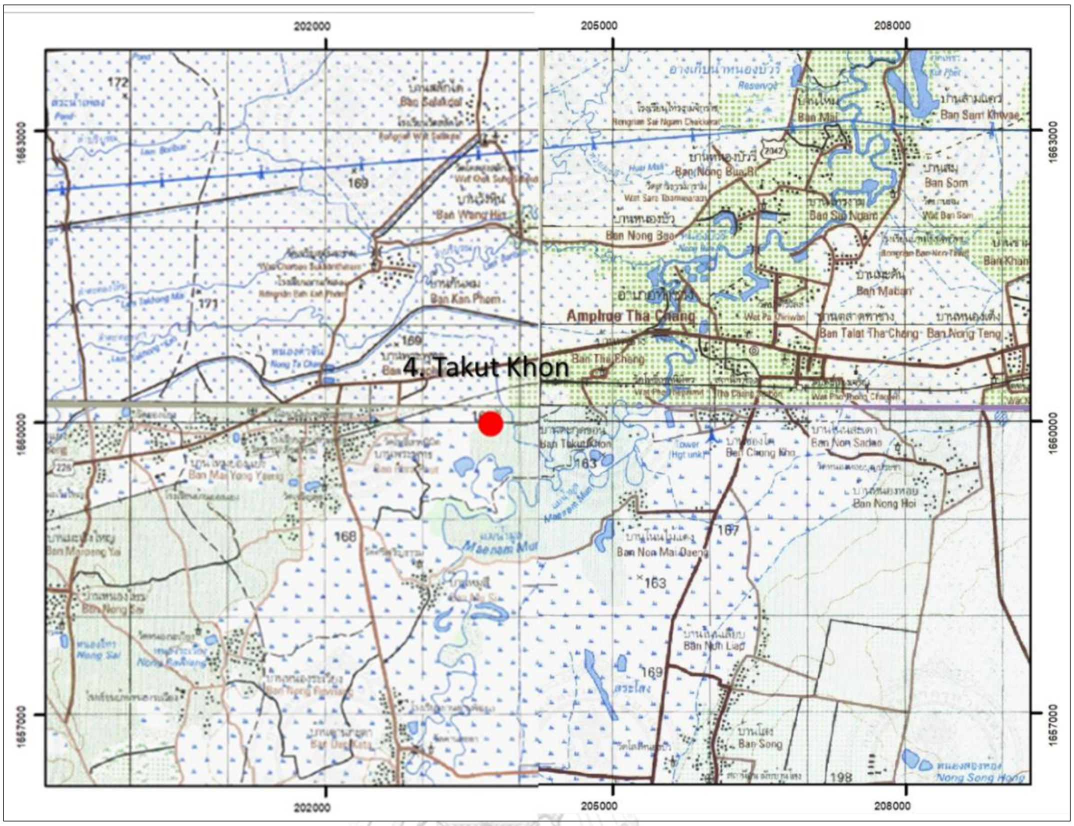

Figure 1. 2 Topographic map scale 1:50,000 showing of the study area; (4) Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province, modified from Royal Thai Survey Department (2000).

Figure 1. 3 View of the Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province.

Figure 1. 4 Aerial Photographs of the Mae Lae Butra sandpit covering the study area, Phimai District, Nakhon Ratchasima Province, modified from Google Earth Pro (Available from: https://www.google.co.th).

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Figure 1. 6 Aerial Photographs of the Rim Mai Sai Thong sandpit covering the study area, Phimai District, Nakhon Ratchasima Province, modified from Google Earth Pro (Available from: https://www.google.co.th).

Figure 1. 7 View of the Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province.

Figure 1. 8 Aerial Photographs of the Chai Anan sandpit covering the study area, Phimai District, Nakhon Ratchasima Province, modified from Google Earth Pro (Available from: https://www.google.co.th).

Figure 1. 9 View of the Takut Khon sandpit, Phimai District, Nakhon Ratchasima Province.

Figure 1. 10 Aerial Photographs of the Takut Khon sandpit covering the study area, Phimai District, Nakhon Ratchasima Province, modified from Google Earth Pro (Available from: https://www.google.co.th)Google (2019).

1.3 Objectives

The objectives purposes of this study can be divided into two points, as follows:

1. To study morphology and identify suid fossils.
2. To study sedimentology and fluvial environments.

1.4 Scope and limitation

The study focuses on suid fossils that were collected from the sandpit in the Phimai and Chaloem Phra Kiat Districts, Nakhon Ratchasima Province. The measurement and nomenclature are followed; Driesch, 1976; Jan Van Der Made, 1996; Pickford, 1988; and Thaung Htike et al., 2005, 2006.

The sediment and lithostratigraphic sections were collected from the area where fossils were found. Sedimentology and stratigraphy were explained together with the estimate fossils position. Description of paleoenvironment consists of facies analysis follows Miall (1977, 1985,1996) .

Aerial Photographs are shown in Figure 1.4, 1.6, 1.8, and 1.10, respectively, data in the year 2019 were used to interpret the stream geomorphology occupying the study areas.

1.5 Expected outputs

1. Species of suid fossils in this area.
2. Stratigraphy and paleoenvironments in this area.

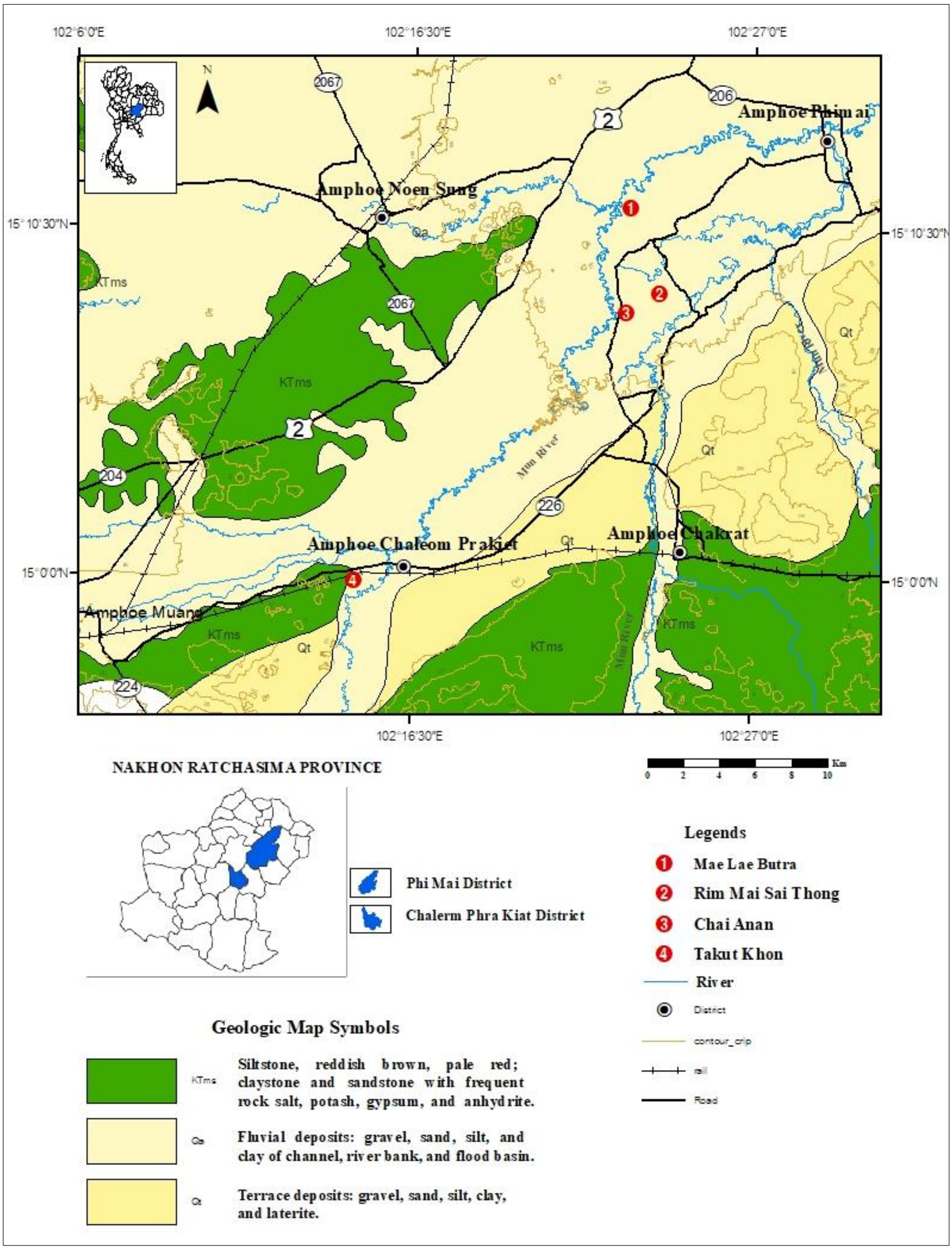

Figure 1. 11 Geological map in the study area; (1) Mae Lae Butra sandpit, (2) Rim Mai Sai Thong sandpit, (3) Chai Anan sandpit), (4) Takut Khon sandpit, modified from DMR, 2007.

CHAPTER 2
LITERATURE REVIEWS AND BACKGROUND

2.1 Classification of Lithofacies

The classification with the definition of lithofacies types has been used by dozens of researchers and has become a standard field methodology for the examination of fluvial deposits. The capital letter in the lithofacies code indicates dominant grain size G = gravel, S = sand, F = fine-grained facies. The lowercase letter serves as a mnemonic for the characteristic texture or structure of the lithofacies as, p = planar cross-bedding, ms = matrix supported.

The lithofacies are described in detail, as following:

1) Lithofacies Gh: Clast–supported, Horizontally stratified gravel

This lithofacies consists of clast–supported pebble and cobble gravel with crude horizontal stratification and an abundant sand matrix. Bed contacts may be obscure, and clasts are commonly imbricated.

2) Lithofacies Gt: Trough cross-bedded gravel

This lithofacies is distinguished by the presence of broad, shallow scoop-shaped bodies, typically 0.2–3 m deep and 1–12 m wide. The erosional base may be followed by a lag deposit of coarser grain size than the trough fill

3) Lithofacies Gp: Planar cross–bed gravel

Planar cross–bed sets in gravel are typically less than 1 m. Textural variation within these sets may be considerable, because of differences in sorting resulting from changing hydraulic conditions and gravel–clast overpassing.

4) Lithofacies Sp: Planar cross-bedded sand

These lithofacies are formed by the migration of 2–D dunes. Cross–bedding is typically at the angle of 15–35°, with sharp, angular, upper, and lower terminations, indicating avalanching of sand on foresets. The upper and lower bounding surfaces are typically flat, with little evidence of scouring. Planar cross–bed sets form in the sand of very fine to very coarse grain size, the thick of 0.5 to 1.5 m are typical of most fluvial sandstones.

5) Lithofacies St: Trough cross-bedded sand

These facies are present by the migration of 3–D dunes. They occur in fine – to very coarse-grained sand. Pebbles may be present, and there is commonly a lag of poorly sorted sand with intraclasts of siltstone or mudstone at the base of the trough. The fluvial sandstones, trough sets are rarely larger than 1 m in thickness, indicating correspondingly greater water depths and dune heights.

6) Lithofacies Sr: Ripple cross-laminated sand

These lithofacies is characteristic of a variety of asymmetric ripple. Sand grain size ranges from coarse to very fine, but fine to medium-grained sand is most typical. A wide variety of internal structures may be generated from ripple migration, depending on flow velocity and the rate of sediment supply.

7) Lithofacies Sh: Horizontally–bedded sand

Lithofacies Sh is distinguished by flat, parallel lamination, with parting lineation occurring on bedding planes. This structure is generated by small longitudinal vortices at the base of the inner turbulent layer and provides an excellent paleocurrent indicator.

8) Lithofacies Sl: Low angle cross-bedded sand

The lithofacies is the presence of low angle cross-bedding, dipping at < 15°and normally < 10°. The cross-bedding is commonly asymptotic. Parting lineation may be present, with an orientation parallel or oblique to the dip of the cross-bedding.

9) Lithofacies Se: Erosional scours

This lithofacies characteristic comprises an erosional scour surface followed by up to 0.25 m of massive, coarse-grained sandstone containing intraclasts of mudstone and siltstone.

10) Lithofacies Ss: Scour–fill sand

These Lithofacies commonly are a few decimeters to a meter of very coarse to coarse-grained, poorly sorted sand, which may show poorly defined cross-bedding and contain abundant intraclasts and other lag materials. The bedding may drape over the irregular shape of the basal bounding surface. The characteristics of lithofacies Ss indicate rapid deposition of poorly sorted, coarse bed load.

11) Lithofacies Sm: Massive sand

These lithofacies, Sandstone may present massive beds, if weathering does not pick out the lamination. They may show grading, or reveal very faint, patchy lamination.

12) Lithofacies Fl: Laminated sand, silt, and mud

These lithofacies, sand is the interlamination of mud, silt, and very fine-grained sand in overbank areas and represents deposition from suspension and weak traction currents. Undulating bedding, scattered bioturbation, desiccation cracks, plant roots, coal streaks, and scattered pedogenic nodules may be present. The thick of bed typical of continuous Fl deposits ranges from a few centimeters to many meters, depending on sediment supply, fluvial style, and basin subsidence rates.

13) Lithofacies Fsm: Siltstone, claystone

The main feature of this lithofacies, which distinguishes it from Fl, is the absence of sand beds.

14) Lithofacies Fm: Massive mud, silt

These lithofacies for the mud drapes that commonly occur within gravelly and sandy braided sediments, where they represent the deposits from standing pools of water during low–stage channel abandonment. Thicknesses of a few millimeters to a few centimeters are typical. Carbonaceous streaks, plant rootlets, and desiccation cracks are common.

15) Lithofacies Fr: Root bed

These are common in vegetated floodplains. This lithofacies represents soil development in a humid climate.

2.2 Classification of architectural elements

According to Miall (1985, 1966), the fluvial deposits comprise of eight basic architectural elements in fluvial deposits: Channels (Element CH); Gravel bars and bedforms (Element GB); Sediment–gravity-flow deposits (Element SG); Sandy bedforms

(Element SB); Downstream–accretion macro forms (Element DA); Lateral–accretion deposits (Element LA); Laminated sand sheets (Element LS), and Hollows (Element HO) (Figure 3.3). These element types are details as below:

1) Element CH: Channels

The channel's deposits are most coarse-grained (gravel, sand). Major channels are fifth-order surfaces bound. However, the minor channels include partially to completely abandoned channels, chute channels cutting across point bars, other channels crossing sandflats. Channel geometry is conveniently defined by depth, width/depth ratio, and sinuosity. These channels have concave–up erosional bases.

2) Element LA: Lateral accretion deposits

The lateral accretion deposits are the main flow of the channel is directed away from the bank, as, on the inside of a meander, surface flow impinges on the outer bank, leading to a "setup" The flow turns downward, developing a helical overturn pattern. The internal geometry and lithofacies composition is highly variable and depends on channel geometry and sediment load. Dips of up to about 25° have been recorded in some fine-grained point bars in rivers.

3) Element LV: Levee deposits

The levee deposits typically consist of rhythmically bedded units of silty, ripple–laminated sand a few decimeters thick. Bioturbation or root development commonly obscures lamination. Each sedimentary rhythm represents a flood event. The levee element constitutes a tapering wedge of deposit, thinning and fining away from the channel margin.

4) Element CS: Crevasse splay

The crevasse channel is ribbon-like bodies typically consisting mainly of fine – to medium-grained sandstone with trough cross-bedding and ripple cross–lamination. Internal scours are common. The scale of crevasse channels depends on the scale of the river.

5) Element FF: Floodplain Fines

This element consists of sheet-like units, many hundreds of meters or even several kilometers to a lateral extent.

6) Element FF (CH): Abandoned channel fills

The abandoned channel fills are components of many fluvial styles, particularly the finer-grained systems, including sandy meandering, fine-grained meandering, and anastomosed systems. The clay plugs commonly fill abandoned channels.

2.3 Sedimentology in the study areas

The geology and sedimentology of the sandpits in Nakhon Ratchasima Province have been described by various researchers (e.g., Howard et al., 2011; Haines et al., 2004; Raksasakulwong et al., 2004; Choowong, 2011; Duangktayom et al., 2014).

Choowong (2011) described the quaternary deposits of the Khorat Plateau of Northeastern Thailand are characterized by two basins; Khorat Basin in the south, the Mun, and the Chi Rivers have Quaternary fluvial landforms and deposits extensively along with the main rivers. Secondly, the Sakon Nakon Basin in the north of the plateau, the oldest Quaternary unit was preserved as a relict high–level terrace deposit. The gravel beds and sandstone clasts have originated from the Mesozoic sandstone basement.

Howard (2011) described the sand and gravel quarries in Nakhon Ratchasima Province. These quarries are situated on ancient channel deposits of the Mun River and these exposed sediments were deposited by high–energy flood pulses. The age of the gravel beds is considered to be the Middle-Upper Pleistocene. Moreover, Palaeomagnetic dating indicates that these flood pulses were contemporaneous with the tektite–forming event at *c*. 0.8 Ma.

Haines et al. (2004) reported the sand deposits in quarries near the village of Ban Tha Chang and the Chum Phung District. The deposit is comprising distinct lower and upper units, separated by a marked discontinuity. The upper unit has a brown-yellow color, consist of sand, fine gravel, and silt considered to represent normal channel and floodplain deposition produced by the migrating meander belts of the Mun River. This unit is oxidized and contains minimum organic matter, limited to minor isolated fragments and logs of wood, the latter possibly reworked from the underlying group. The lower unit is markedly different, a grey color, comprising crudely stratified and cross-bedded sands and gravels, with minor lenticular mud horizons. Some of the wood is partly or entirely replaced by silica and pyrite, but most are preserved as original woody tissue. The entire lower unit is chemically reduced and ubiquitous pyrite/marcasite present as disseminated material and as encrustations around wood and bone.

Raksasakulwong et al. (2004) reported the geologic map of the Changwat Nakhon Ratchasima (5438 IV), Amphoe Non–Sung, Amphoe Chum Phung, and Amphoe Muang Yang (5439 II) map sheets. The sedimentary rock in the upper of the Khorat group consists of Khok Kruat, Phu Phan, Maha Sarakham, and Phu Tok Formation. Quarternary Sediments are classified into Three units, such as terrace deposit unit (Qt), saprolite (Qr), and alluvial deposit (Qa).

Chaimanee et al. (2004) reported the mammal fauna in Amphoe Chaloem Phra Kiat was board correlated in terms of biostratigraphy to the upper Nagri and lower Dhok Pathan formations of Siwaliks in Pakistan. These faunas indicated to Late Miocene age, between 9 and 7 million years.

Chaimanee et al. (2006) reported the stratigraphic sections at the Somsak, which yielded the hominoid jaw and the Siam sandpits.

Duangkrayom et al. (2014) studied the sedimentary facies and paleoenvironment of a Pleistocene fossil site in Nakhon Ratchasima Province that the sediments in Khok Sung sandpit were deposits as two meandering channels two sets; The flora fossils suggest the presence of tropical mixed deciduous. Moreover, the fauna fossils indicate the climate differed from today, with heavier rainfall and more extensive grassland areas during the Pleistocene.

2.4 Paleontology in the study areas

The family Suidae, Order Artiodactyla is commonly called suids, hogs, or pigs that originated in the Oligocene at least 34 million years ago (Ma) (Frantz, 2015). Moreover, they have an extremely wide distribution across Africa and Eurasia.

According to Lekagul et al., 1977, the most distinctive external feature of this family is the elongated flexible snout, terminating in an expanded, truncated, necked, flat disc which is perforated by the nostrils, enabling a pig to get the best scent of his food while he is digging up the soft ground with his snout; the sense of smell is highly developed. The feet are narrow, with four completely developed toes on each foot. However, the hooves of the outer toes do generally not reach the ground on a hard surface, though they are certainly useful on soft ground or in the mud. Pig does not have a cannon bone; the metatarsals and metacarpals remain separated, the most primitive condition among the artiodactyls. The stomach has two chambers and is the simplest among the artiodactyls.

According to Made (1996), the suidae fossil from Miocene recognized at least four subfamilies; Tetraconodontinae, Suinae, Listriodontinaeand, Hyotheriinae. Hyotheriinae occurred in Europe during the early Middle Miocene and in China ranged up to the Late Miocene. They have no undisputed record in Africa or Pakistan and India. Tetraconodontinae is known from Europe and Anatolia and the from the Middle and Upper Miocene and from Africa from the Late Miocene and Pliocene. There is no record from China. Suinae is known in all these areas, and the first record of the group is from the Middle Miocene of Pakistan.

2.4.1 Subfamily Tetraconodontinae

The Subfamily Tetraconodontinae has been described previously by reserchers. Details of this subfamily are presented as follows;

Falconer (1868) studied specimens of *Tetraconodon* collected from near Hasnot in the Salt Range, Siwalik Hill, as *Tetraconodon magnus* is distinguished by the short, broad molars and the greatly enlarged $P^{3-4}/_{3-4}$ and crenulated posterior premolars.

Pilgrim (1910) described *Tetraconodon* collected from below Yenangyoung, Myanmar as *Tetraconodon minor* is characterized by its smaller than *Tetraconodon magnus*, but much larger than *Conohyus.* The premolars are relatively much smaller than in *T. magnus* but much larger than in *Conohyus.* Teeth hypsodont, palate wide. Skull similar to the skull of *T. magnus*.

Thaung Htike et al. (2005) described specimens of Miocene *Tetraconodon* Suid from central Myanmar. They compared the new species with the previous database of the length of lower M_1, three distinct species of *Tetraconodon* are recognized *T. minor*, *T. intermedius* and the new species, *T. malensis*, has characteristics of *Tetraconodon*, such as extremely enlarged P_4 and simple and relatively small M_3 and most primitive species of the genus *Tetraconodon*, indicative of the late Middle Miocene age.

Thaung Htike et al. (2006) described a large size *Tetraconodon*, which was collected from the lower part of the Irrawaddy Formation at the fossil locality Tebingan, Magway Division, central Myanmar. They compared these specimens with the *Tetraconodon* from the Indian subcontinent, and Myanmar, as *Tetraconodon* sp. cf. *T. magnus* because the specimens are similar to those of *Tetraconodon magnus* but smaller in the dimensions of last two premolars than *T. magnus*, indicative of Late Miocene age.

Thaung–Htike et al. (2007) described species of *Tetraconodon* as *T. irramagnus* sp. nov. Moreover, *T. irramedius* sp. nov., from the late Miocene of Myanmar. The dimensions of the last two premolars and the third molar concerning those of the first molar are distinctly smaller than those of the Siwalik specimens, as *T. magnus* and *T. intermedius*.

Thaung Htike et al. (2008) reported a new material of *Tetraconodon malensis* from Middle Miocene in Sagaing Division, central Myanmar.

Thaung–Htike et al. (2010) described fossil materials of *Sivachoerus* are recovered from the Irrawaddy Formation, indicative of the Pliocene age.

Khan et al. (2013) studied *Tetraconodon* from Dhok Pathan Formation of Pakistan, consisting of *Tetraconodon magnus*. Indicative of Late Miocene age.

2.4.2 Subfamily Suinae

The Subfamily Suinae has been described previously by reserchers. Details of this subfamily are presented as follows;

Colbert (1935) and Pickford (1988) are defined species as the *Propotamochoerus hysudricus,* such as no diastemata in upper or lower cheek tooth row; orbits open over talon of M3; midline of M1 display zygomatic arches leave face at; lower premolars compressed with a long and complex third molar.

Pickford (1988) described the type genus of *Propotamochoerus* indicative of the Late Miocene age in the middle Siwaliks. The age range is from that is from about 10 million to 6 million years.

Pickford (1988) described type genus of *Hippopotamodon* is characterized by giant Suinae in which the males have large flaring canines: molar enamel relatively thin: molars relatively simple with well–developed furchen plan: labial cusps in lower molars lower crowned than lingual ones: P4 with posterior accessory cusp almost as large as two main labial cusps: posterior choanae U–shaped, open immediately behind M3: p4 with prominent innenhugel and 2–3–4 cusp, anterior cingulum and accessory–1 cusp moderately high: diastema between C–P1–2 short: broad flat dorsal surface to brain case. *Hippopotamodon* is common in the upper Miocene of the siwaliks. It is almost always associated with *Hipparion,* and its range is very similar to that of *Propotamochoerus hysudricus* and *Microstonyx*.

2.4.3 Suid fossils of Thailand

The previous work on suid fossils In Thailand, such as Ducrocq et al., 1997, 1998; Orliac et al., 2011. Details of this subfamily are presented as follows;

Ducrocq et al. (1997) reported a new species of genus *Connohyus*, *C. thailandicus* from the Middle Miocene locality of Ban San Klang in northern Thailand is primitive than those known in Eurasia. The dental features displayed by this are very close to *C. sindiensis* and *C. simorresis.* The Thai species can be distinguished from all other known species mainly by its curved and poorly developed M_3.

Ducrocq et al. (1998) reported a new suid, *Siamochoerus bangmarkensis* gen. et. sp. nov., have been collected in the Late Eocene Krabi basin in southern Thailand. Primitive suid, close to *Propalaeochoerus pusillus* in size, and represents one of the oldest known suids.

Orliac et al. (2011) reported new remains of *Egatochoerus jaegeri* from the Late Eocene locality of Ban Mark in the Krabi basin, Thailand. The new material described makes *E. jaegeri* the best documented Eocene representative of Old World Suoidae at present.

2.4.4 Mammals fauna in the Nakhon Ratchasima Province

The previous work on mammal fossils of the Nakhon Ratchasima Province, such as Chaimanee et al., 2006; Hanta et al., 2008; Thasod et al., 2011; Deng et al., 2013.

Chaimanee et al. (2004 and 2006) described a new hominoid species, *Kharatpithecus piriyai*. From sandpit in Nakorn Ratchasima Province, indicative of Late Miocene age.

Hanta et al. (2008) reported a new Bothriodontinae species of *Merycopotamus thachangensis* from the Late Miocene of Nakorn Ratchasima Province.

Thasod et al. (2011) identified a new Proboscideans from Tha Chang, Chaloem Phra Kiat District, Nakorn Ratchasima Province as species *Prodeinotherium* (*P. pentapotamiae)*, Amebelodontinae (cf. *Protanancus macinnensi*), *Gomphotherium* (*Gomphotherium* sp. and a new species), *Tetralophodon* sp., *Sinomastodon* (*Sinomastodon* cf. *yangziensis* and *Sinomastodon* n. sp), *Stegolophodon* (*Stegolophodon stegodontoides* (and related forms), *Stegolophodon* n.sp.and *Stegolophodon* intermediate forms*), Stegodon* (*Stegodon elephantoides*, *Stegodon insignis*, *Stegodon* cf. *orientalis* and primitive form *Stegodon*) and *Elephas* sp. The fossil assemblage indicates the age from Middle Miocene to Pleistocene.

Deng et al. (2013) reported a new Rhinocerotidae species of *Aceratherium porpani* at Tha Chang, Chaloem Phra Kiat District, Nakorn Ratchasima Province. Indicative of Latest Miocene age of the associated fauna and flora in the Tha Chang sandpits.

Suraprasit et al. (2015) described a complete skull of *Crocuta crocuta ultimate* at Khok Sung, Nakorn Ratchasima Province, which indicates the late Middle Pleistocene age and paleoenvironments during the glacial-interglacial cycles in Mainland Southeast Asia.

Suraprasit et al. (2016) reported vertebrate fauna from Khok Sung, Nakorn Ratchasima Province, including primate, canid, hyaenid, proboscideans, rhinoceroses, suids, cervids, and bovids. Moreover, Three reptilian taxa; *Crocodylus* cf. *siamensis*, *Python* sp.and *Varanus* sp. The Khok Sung mammalian fauna indicated late Middle to early Late Pleistocene age.

Yang and Grote (2017) studies the Palynology locality at Ban Som Village, Tha Chang Subdistrict, Chaloem Phra Kait District Nakorn Ratchasima Province, interpreted as the reconstruction vegetation is closely related to glacial-interglacial events and the related sea-level changes.

Chaimanee et. al. (2019) described a new maxilla from the same sedimentary unit as the holotype mandible of *Khoratpithecus piriyai* from the late Miocene in Nakhon Ratchasima Province. The new maillary displays a unique subnasal morphology with derived characters being shared only with *Sivapithecus* and *Pongo,* confirming its attribution to the pongin clade, and understanding that *Ankarapithecus* occupies a more basal position within the pongine clade and supports the exclusion of *lufengpithecus* from this clade.

Duval et al. (2019) reported the US-ESR dating of the Pleistocene vertebrate assemblage to provide two possible ages of 130±29Ka and 217±36 Ka for the fossils from Khok Sung locality.

CHAPTER 3
METHODOLOGY

The Methodology of the study is presented here. First, Literature surveying of previous works on sedimentological and Paleontological reports was collected. The metrical method of fossil specimens was taken partly from Driesch (1976); Made (1999); Pickford (1988). Finally, the classification of Lithofacies and architectural elements analyses following Miall (1985, 1996). The tooth nomenclature and description morphology of suids follow Made, 1996; Pickford, 1988; Thaung Htike et al., 2005, 2006; Chit Sein, 2009.

The detailed study is divided into three parts: 1) the literature review of previous works, 2) the field investigation, and 3) the laboratory analyses (see below). The study process was summarized and shown in figures (Figure 3.1–3.2).

3.1 Literature review on previous works

Previous reports on the paleontological context, especially fossil suids, Quaternary sediments, stratigraphic sections, and depositional paleoenvironments in the study areas and the adjacent regions, were reviewed.

3.2 Field investigation

Three sandpits, Mae Lae Butra, Rim Mai Sai Thong and Chai Anan in Phimai District, and one sandpit Takut Khon in Chaloem Phrakiat District, Nakhon Ratchasima Province was investigated.

The detailed of field investigation can be divided in mainly two–parts as 1) The details of stratigraphic sections described here include the lithology, thickness, color, bedding characteristics, grain size, texture, sedimentary structures, layer contact, paleocurrent, biogenic structures, and fossils and sedimentology sampling. The representative sedimentary and fossil samplings were collected and carried out for the laboratory work.

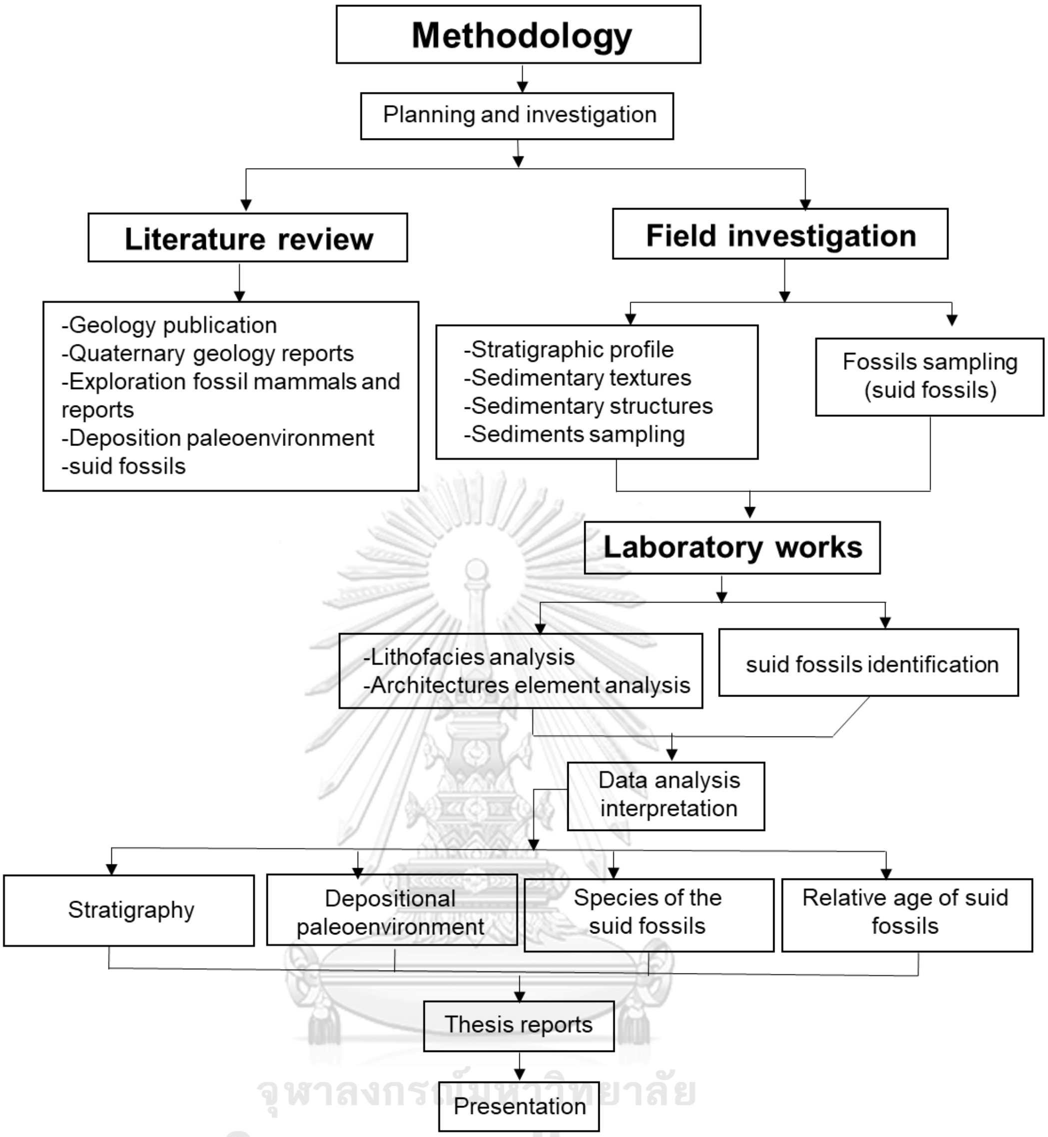

Figure 3. 1 Flow chart illustration of the methodology using for this research.

Figure 3. 2 Field investigation and fossils sampling in the study area.

3.3 Facies analysis

The sedimentary facies analysis is now recognized as a standard for the study of sedimentary rocks (Miall, 1977, 1985, 1996). The analysis of facies includes lithofacies, architectural elements, and facies models.

The classification of these lithofacies and architectural elements follows Miall (1977,1996) based on bedding, grain size, textures, and sedimentary structures. The scheme of lithofacies is represented in Table 3.1.

Table 3. 1 Lithofacies classification, from Miall, 1996.

Facies code	Facies	Sedimentary structures	Interpretation
Gmm	Matrix-supported, massive gravel	Weak grading	Plastic debris flow (high-strength, viscous)
Gmg	Matrix-supported gravel	Inverse to normal grading	Pseudoplastic debris flow (low strength, viscous)
Gci	Clast-supported gravel	Inverse grading	Clast-rich debris flow (high strength), or pseudoplastic debris flow (low strength)
Gcm	Clast-supported massive gravel	–	Pseudoplastic debris flow (inertial bedload, turbulent flow)
Gh	Clast-supported, crudely bedded gravel	Horizontal bedding, imbrication	Longitudinal bedforms, lag deposits, sieve deposits
Gt	Gravel, stratified	Trough cross-beds	Minor channel fills
Gp	Gravel, stratified	Planar cross-beds	Transverse bedforms, deltaic growths from older bar remnants
St	Sand, fine to very coarse, may be pebbly	Solitary or grouped trough cross-beds	Sinuous-crested and linguoid (3-D) dunes
Sp	Sand, fine to very coarse, may be pebbly	Solitary or grouped planar cross-beds	Transverse and linguoid bedforms (2-D dunes)
Sr	Sand, very fine to coarse	Ripple cross-lamination	Ripples (lower flow regime)
Sh	Sand, very fine to coarse, may be pebbly	Horizontal lamination parting or streaming lineation	Plane-bed flow (critical flow)
Sl	Sand, very fine to coarse, may be pebbly	Low-angle (< 15°) cross-beds	Scour fills, humpback or washed-out dunes, antidunes
Ss	Sand, fine to very coarse, may be pebbly	Broad, shallow scours	Scour fill
Sm	Sand, fine to coarse	Massive, or faint lamination	Sediment-gravity flow deposits
Fl	Sand, silt, mud	Fine lamination, very small ripples	Overbank, abandoned channel, or waning flood deposits
Fsm	Silt, mud	Massive	Backswamp or abandoned channel deposits
Fm	Mud, silt	Massive, desiccation cracks	Overbank, abandoned channel, or drape deposits
Fr	Mud, silt	Massive, roots, bioturbation	Root bed, incipient soil
C	Coal, carbonaceous mud	Plant, mud films	Vegetated swamp deposits
P	Paleosol carbonate (calcite, siderite)	Pedogenic features: nodules, filaments	Soil with chemical precipitation

The classification of architectural elements is shown in Figure 3.3; Table 3.2–3.3. According to Miall (1985, 1996) changes in the grain sizes, sedimentary structures, bedding characteristics, and other physical characteristics allow us to identify the different sedimentary facies and to interpret the depositional environments. The reconstruction of architectural elements was derived from the interpretation of outcrop profiles and photomosaic of continuous lateral outcrops using to describe the architectural elements. However, computer software programs are also used to explain and interpret the information obtained from field sampling. This software includes Adobe Illustrator and Sed-Log for profile drawing and final layout of the studies profiles and Rose diagram for a plot of paleocurrent measurements.

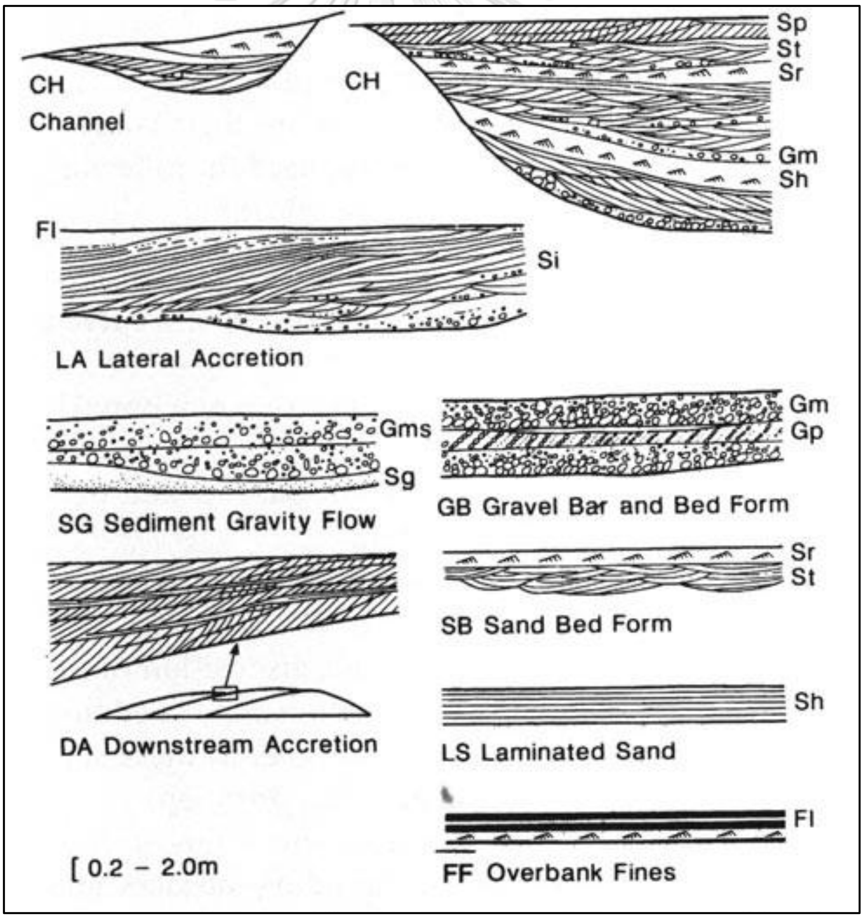

Figure 3. 3 The eight basic architectural elements in fluvial deposits, modified from Miall, 1996.

Table 3. 2 Architectural elements in fluvial deposits.

Element	Symbol	Principal facies assemblage	Geometry and relationships
Channels	CH	Any combination	Finger, lens or sheet; concave-up erosional base; scale and shape highly variable; internal concave-up 3rd-order erosion surfaces common
Gravel bars and bedforms	GB	Gm, Gp, Gt	Lens, blanket; usually tabular bodies; commonly interbedded with SB
Sandy bedforms	SB	St, Sp, Sh, Sl, Sr, Se, Ss	Lens, sheet, blanket, wedge, occurs as channel fills, crevasse splays, minor bars
Downstream-accretion macroform	DA	St, Sp, Sh, Sl, Sr, Se, Ss	Lens resting on flat or channeled base, with convex-up 3rd-order internal erosion surfaces and upper 4th-order bounding surface
Lateral-accretion macroform	LA	St, Sp, Sh, Sl, Se, Ss, less commonly Gm, Gt, Gp	Wedge, sheet, lobe; characterized by internal lateral-accretion 3rd-order surfaces
Scour hollows	HO	Gh, Gt, St, Sl	Scoop-shaped hollow with asymmetric fill
Sediment gravity flows	SG	Gmm, Gmg, Gci, Gcm	Lobe, sheet, typically interbedded with GB
Laminated sand sheet	LS	Sh, Sl; minor Sp, Sr	Sheet, blanket
Overbank fines	FF	Fm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

Facies classification from Miall (1978b).

Table 3. 3 Architectural elements of the overbank environment.

Element	Symbol	Lithology	Geometry	Interpretation
Levee	LV	Fl	Wedge up to 10 m thick, 3 km wide	Overbank flooding
Crevasse channel	CR	St, Sr, Ss	Ribbon up to a few hundred m wide, 5 m deep, 10 km long	Break in main channel margin
Crevasse splay	CS	St, Sr, Fl	Lens up to 10 × 10 km across, 2–6 m thick	Delta-like progradation from crevasse channel into floodplain
Floodplain fines	FF	Fsm, Fl, Fm, Fr	Sheet, may be many km in lateral dimensions, 10s of m thick	Deposits of overbank sheet flow, floodplain ponds and swamps
Abandoned channel	CH(FF)	Fsm, Fl, Fm, Fr	Ribbon comparable in scale to active channel	Product of chute or neck cutoff

3.4 Fossils identification

3.4.1 Material and methods

In this study, almost all the fossils have been found and collected by local villagers working in these sandpits, and later brought to public collections. These fossils were collected from Mae Lae Butra and Takut Khon sandpits, Nakhon Ratchasima Province. Stratigraphic sections have indicated that the lower of unit: medium to coarse-grained, light to dark gray color, thick of bed 6 m, solitary scoops with an erosional, wood, and wood fragment present. The internal structures are tough cross-bedding. According to Miall's 1977, 1985, 1996, the data suggest that Lateral accretion deposits or point bar deposits.

The specimens of suids from Chaloem Phra Kiat and Phimai District, Nakhon Ratchasima Province comprise three skull fragments; sixteen lower cheek teeth; Four upper cheek teeth; Four lower isolated teeth; and Eleven upper isolate teeth.

The skulls include three specimens: middle part of skull with left and right P^4–M^3 and alveoli of P^3, CUF–MB–1 from Mae Lae Butra sandpit, Phimai District; middle part of skull with left P^3–M^2 and right P^3–M^3, PPN01–000188 from Mae Lae Butra sandpit, Phimai District; part of left maxillary fragment with P^3–M^2, CUF–TKK–15 from Takut Khon sandpit, Chaloem Phra Kiat District.

The lower cheek teeth include sixteen specimens. Eleven specimens from Mae Le Butra sandpit in Phimai District; left mandibular fragment with P^3–P^4, PPN01–000166; left mandibular fragment with D_4 and P_4–M_2, PPN01–000151; left mandibular fragment with P_3–P_4; PPN01–000108; left mandibular fragment of M_1 and M_3, PPN01–000107; right mandibular fragment with P_3–M_3, PPN01–000186; right mandibular fragment with P_3–M_2 and alveoli of P_2, PPN01–000152; right mandibular fragment with M_2–M_3 and alveoli of M_1. PPN01–000150. And the nine specimens from Takut Khon sandpit, Chaloem Phra Kiat; right mandibular fragment with P_4–M_3, CUF–TKK–8; left mandibular fragment with M_2–M_3 and alveoli of M_1, CUF–TKK–9; mandibular with left and right P_3–M_3 and right alveoli of C and P_1–P_2, CUF–TKK–5; right mandibular fragment with P_3–M_3, CUF–TKK–10; right mandibular fragment with P_4–M_3 and alveoli of P_2–P_3, CUF–TKK–12; right mandibular fragment with P_4–M_2 and alveoli of P_3, CUF–TKK–7; left mandibular fragment with P_4–M_2 and alveoli of M_3, CUF–TKK–6; left mandibular fragment with P_3–M_2 and alveoli of P_2, CUF–TKK–14; left mandibular fragment with M_1–M_2 and alveoli of P_3–$P_{4,}$ CUF–TKK–13.

The upper cheek teeth include four specimens. Four specimens from Mae Lae Butra sandpit in Phimai District; right maxillary fragment with P^3–M^1, PPN01–000149; left maxillary fragment with P^2–P^3, PPN01–000167. Moreover, one specimen from Takut Khon sandpit, Chaloem Phra Kiat; maxillary with left P^4–M^3, CUF–TKK–11; left maxillary fragment with M^1–M^2, CUF–MB–42. All of these specimens are from Nakhon Ratchasima Province.

The lower isolated teeth include four specimens from Mae Lae Butra sandpit in Phimai District, Nakhon Ratchasima Province; right P_3, CUF–MB–37; right P_4, CUF–MB–36; left P_4, CUF–MB–35; right M_1, CUF–MB–43.

The isolated upper teeth include eleven specimens from Mae Lae Butra sandpit in Phimai District, Nakhon Ratchasima Province; left P^3, CUF–MB–31; right P^3, CUF–MB–32; right P^4, CUF–MB–33; left P^4, CUF–MB–34; left M^3, CUF–MB–38; right M^1, CUF–MB–40; left M^1, left M^3, CUF–MB–44; right M^3, CUF–MB–45; left M^1, PPN01–000153; left M^2, PPN01–000154; left M^1, PPN01–000155.

3.4.2 Nomenclature

Many researchers (e.g., Made,1996; Pickford, 1988; Thaung Htike et al., 2005, 2006, and Chit Sein, 2009) have defined the tooth nomenclature of suids. The nomenclature is shown in Figure 3.4 – 3.8 The uppercase letter represents the upper dentition (e.g., M^1), and the lower-case letter represents the lower dentition (e.g. M_1).

The lower molars can easily be extended to comprise all elements. The main cusps are called protoconid, metaconid, hypoconid, and entoconid; a paraconid is usually not developed. The crests are named similarly in both lingual and labial cusps: ectocristid (Antero–external side of the cusp), precristid (anterior–internal), endocristid (posterior–internal) and postcristid (posterior external). Cusps may rotate slightly according to their size and position in a molar.

In the lower premolars, the talonid cusp (hypoconid) extended lingually and a separate lingual cusp is formed (entoconid) and a small hypopreconulid is formd. The metaconids separate from the lingual side of the protoconids near the tips.

On the upper molars, there are four main cusps, the paracone (antero–buccal), metacone (postero–buccal), protocone (antero–lingual) and tetracone (or metaconule (postero–lingual). For the last cusp, the name “tetracone” is proposed.

The upper premolars have one main cusp (paracone) and a lingual or postero–lingual cingulum. The protocone is developed from the cingulum. The metacone is situated posterior to the paracone. The protocone is not always separated from the cingulum, and this cingulum is sometimes high.

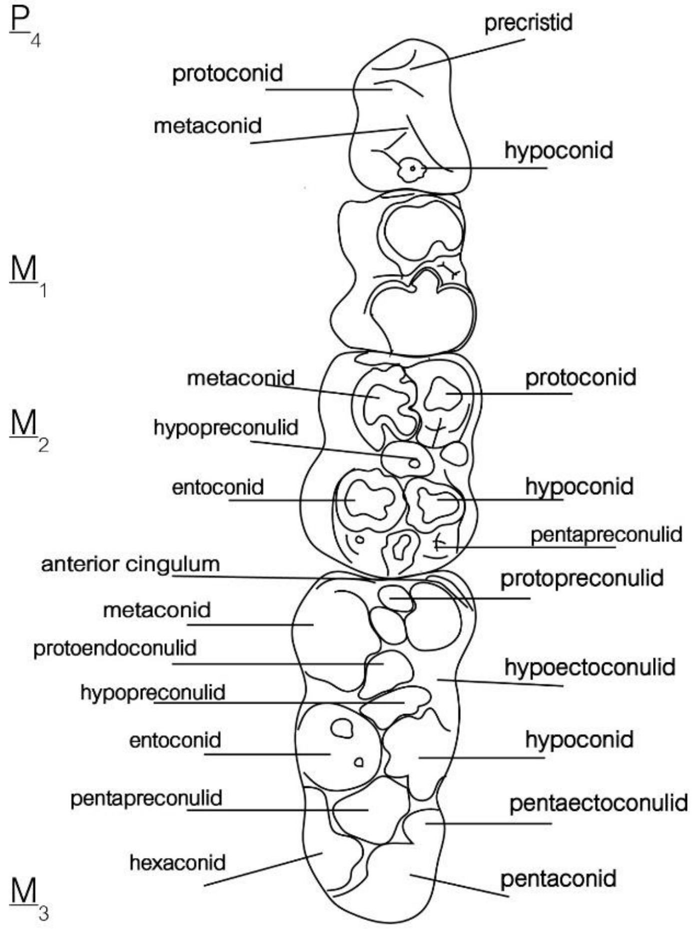

Figure 3. 4 The nomenclature lower dentition, right mandibular fragment with P_4–M_3 of the Genus *Hippopotamodon* from Phimai and Chaloem Phra Kiat District, Nakhon Ratchasima Province, following Made, 1996; Thaung Htike et al., 2006.

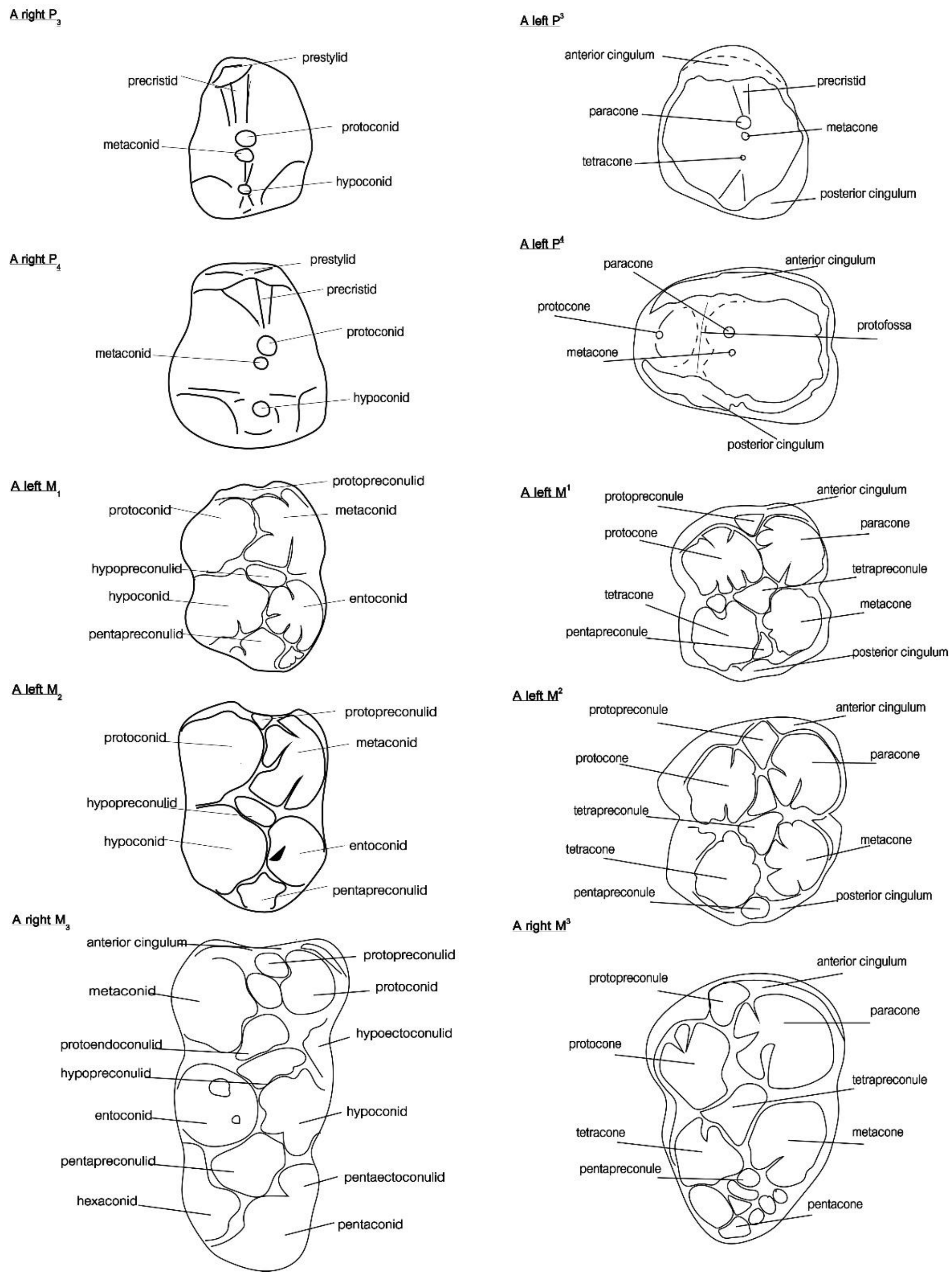

Figure 3. 5 The nomenclature upper and lower dentition of the Genus *Tetraconodon* from Nakhon Ratchasima province, following Made, 1996; Thaung Htike et al. 2005.

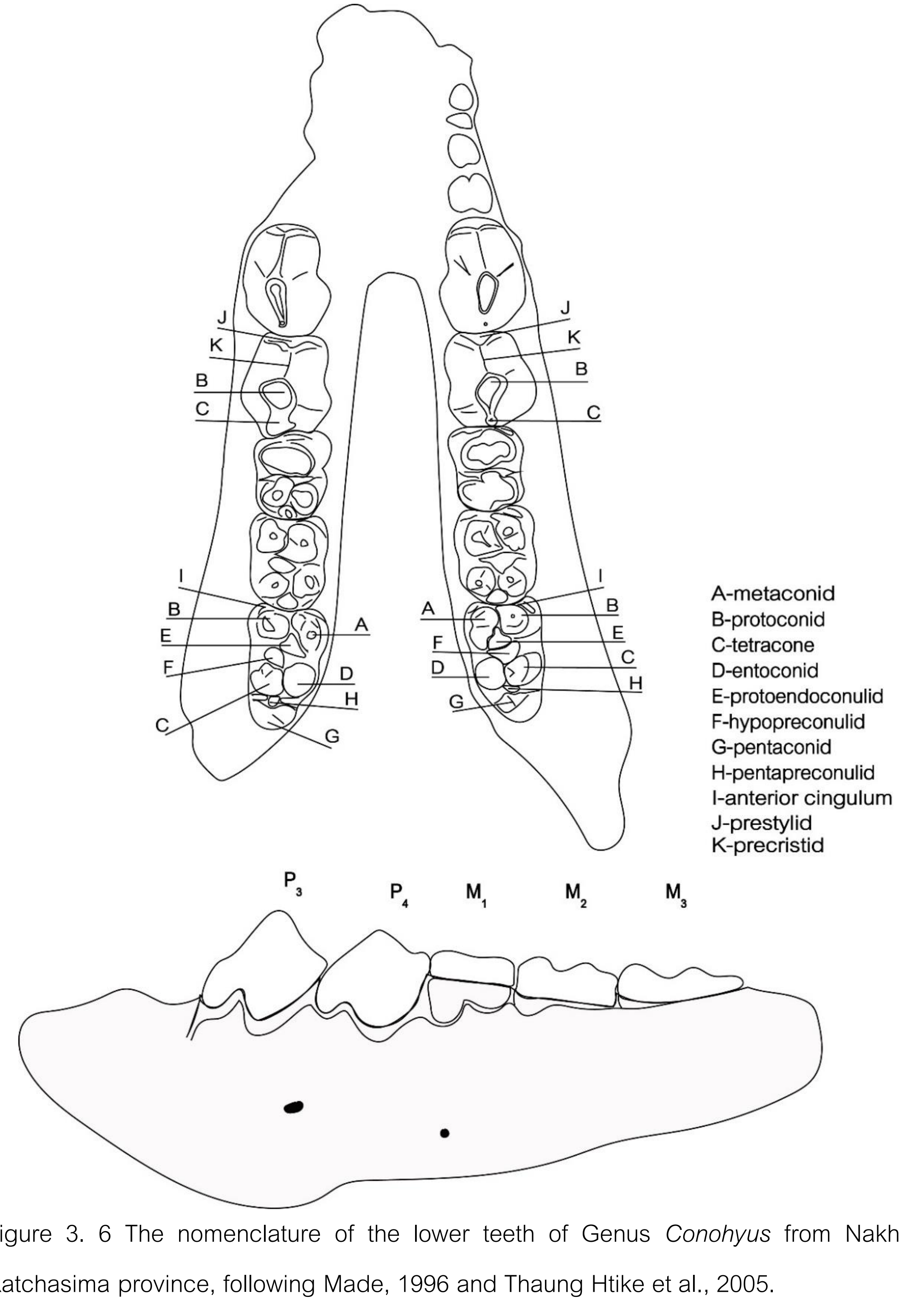

Figure 3. 6 The nomenclature of the lower teeth of Genus *Conohyus* from Nakhon Ratchasima province, following Made, 1996 and Thaung Htike et al., 2005.

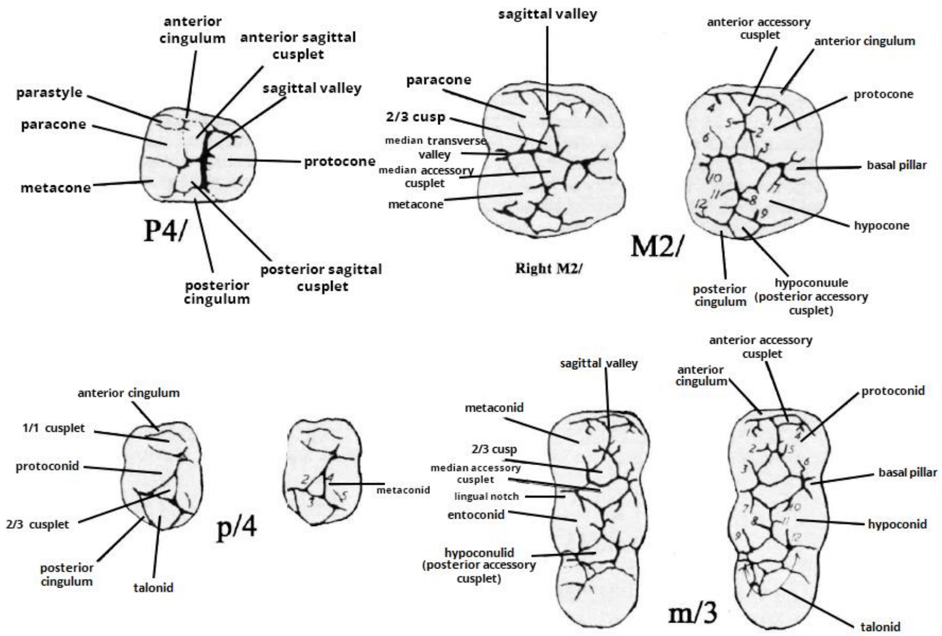

Figure 3. 7 The nomenclature upper dentition of the Genus *Hippopotamodon*, from Pickford, 1988.

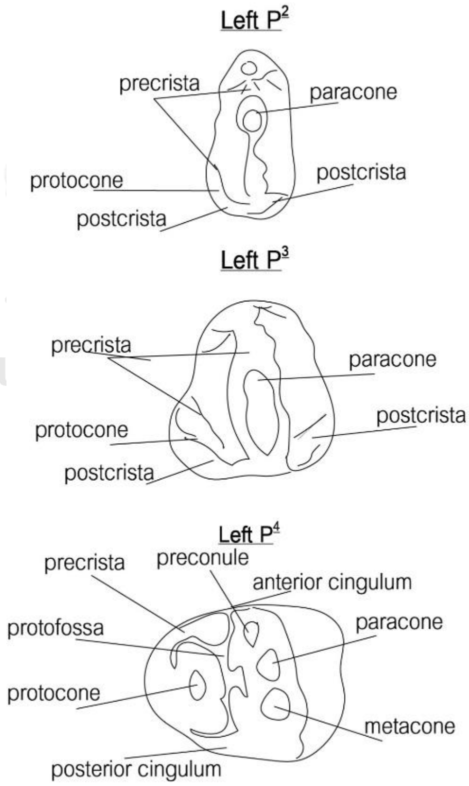

Figure 3. 8 Nomenclature upper dentition, left P^2-P^4, of the Genus *Propotamochoerus* from Phimai and Chaloem Phra Kiat District, Nakhon Ratchasima Province, following Made, 1996, and Thaung Htike et al., 2006.

3.4.3 Measurements and terminology

All specimens are measured. Tooth dimensions were taken with digital Vernier calipers, expressed in millimeters with an accuracy to 0.1 mm. The measurement is shown in Figure 3.9 – 3.11 follow Driesch, 1976; Made, 1996; Pickford,1988.

The measurement abbreviation following as:

DAP (L)	Anteroposterior or length of cheek teeth.
DAP' (L')	Length of a tooth expressed as a percent of the length of the first molar. DAP' = [(DAP/DAPM1) x 100%]
DT (W)	Transverse diameter (width) of cheek teeth.
DT' (W')	Width of a tooth expressed as a percentage of the width of the first molar. DT' = [(DT/DTM1) x 100%]
DTa (W1)	Width of the anterior lobe of cheek teeth.
DTp (W2)	Transverse diameter (width) of the second lobe of cheek teeth.
DTpp (W3)	Width of the third lobe. I = Index [(DAP (L)/DT (W)) x 100%]

3.4.4 Collections and their Abbreviations

Fossils are housed in the Department of Geology, Chulalongkorn University (CUF), and Prasert Prasarttong–Osoth Natural (PPN), Origin of life museum of Sukhothai Airport (pri-vatemuseum), Thailand

PPN	Prasert Prasarttong–Osoth Natural, Origin of life museum of Sukhothai Airport (pri-vatemuseum), Thailand
CUF	Chulalongkorn University Fossil collection
MB	Mae Lae Butra sandpit
TKK	Takut Khon sandpit
RM	Rim Mai Sai Thong sandpit
CN	Chai Anan sandpit

The specimens were cataloged, consisting of 3 series, i.e., name of the sandpit, and serial catalog number, show figures on the specimen (PPN01–000001, CUF–MB–01, CUF–TKK–01) detail as below:

PPN01–000001; PPN– Prasert Prasarttong–Osoth Natural, Origin of life museum of Sukhothai Airport (pri-vatemuseum), Thailand, 000001– serial catalog number.

CUF–MB–01; CUF– Institutional abbreviation “Department of Geology, Chulalongkorn University”, MB–sandpit abbreviation “Mae Lae Butra”, 01–serial catalogue number.

CUF–TKK–01; CUF– Institutional abbreviation “Department of Geology, Chulalongkorn University,” TKK–sandpit abbreviation “Takut Khon,” 01–serial catalog number.

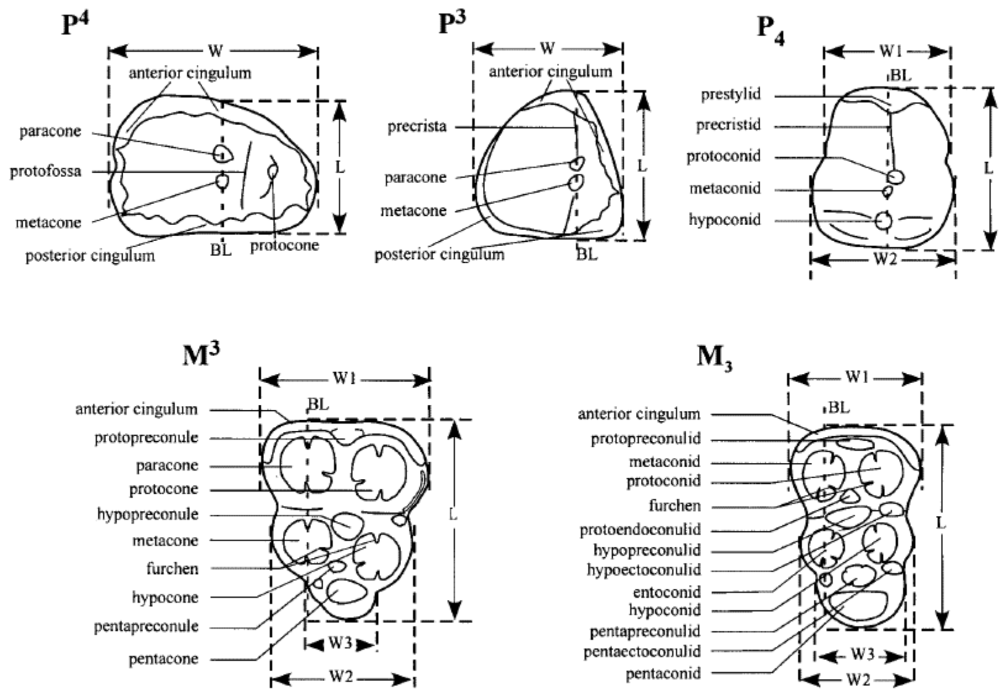

Figure 3. 9 Dental terminology and metrical method of Tetraconodontine teeth from Thaung Htike et al., 2005. All are occlusal views of right cheek teeth. Abbreviations; baseline (BL), length (L), maximum width (W), the width of the first lobe (W1), the width of the second lobe (W2), the width of the third lobe (W3) in M^3 and M_3.

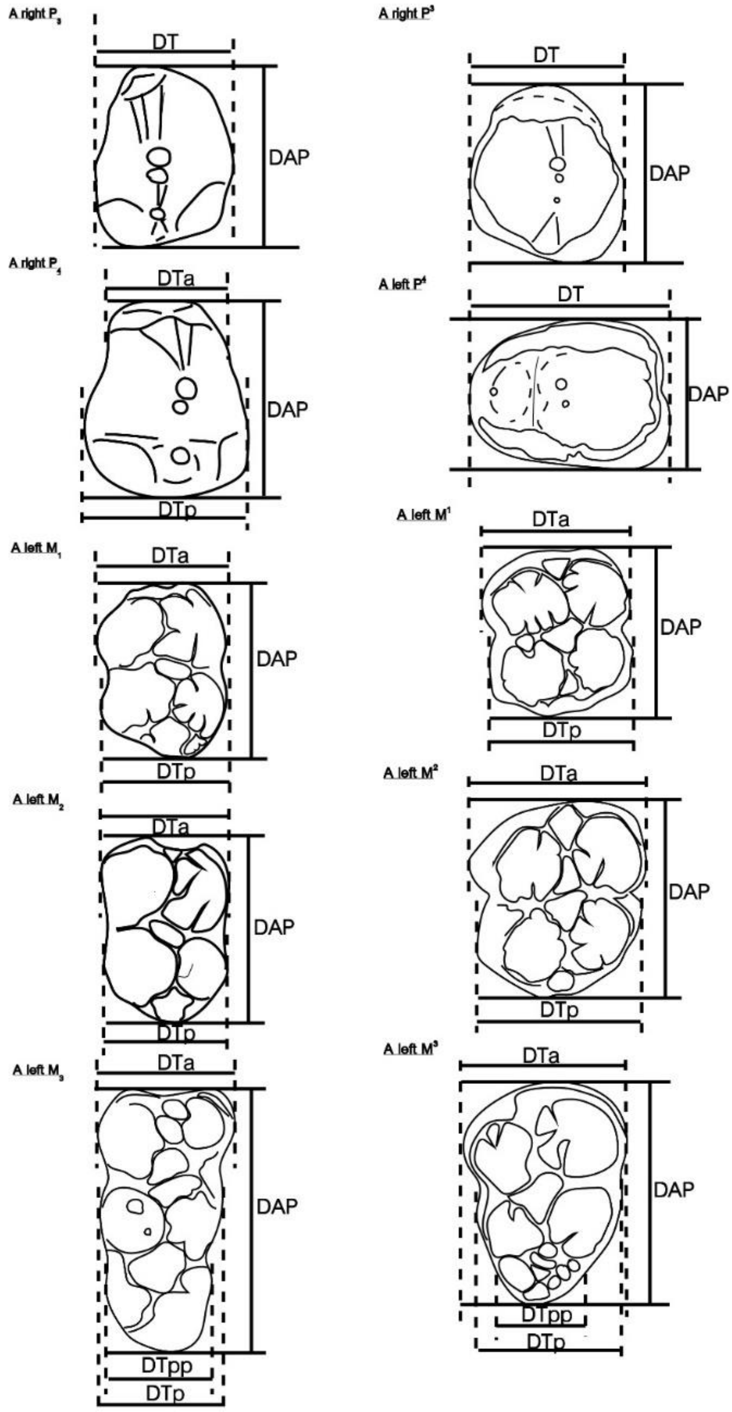

Figure 3. 10 Measurements of the upper and lower dentition of suids tooth from Nakhon Ratchasima Province following Made, 1996; Thaung Htike et al., 2005. Abbreviation: DAP: length; DT: maximum width; DTa: width of the first lobe in cheek teeth; DTp: width of the second lobe in cheek teeth; DTpp: width of the third lobe in M^3, M_3.

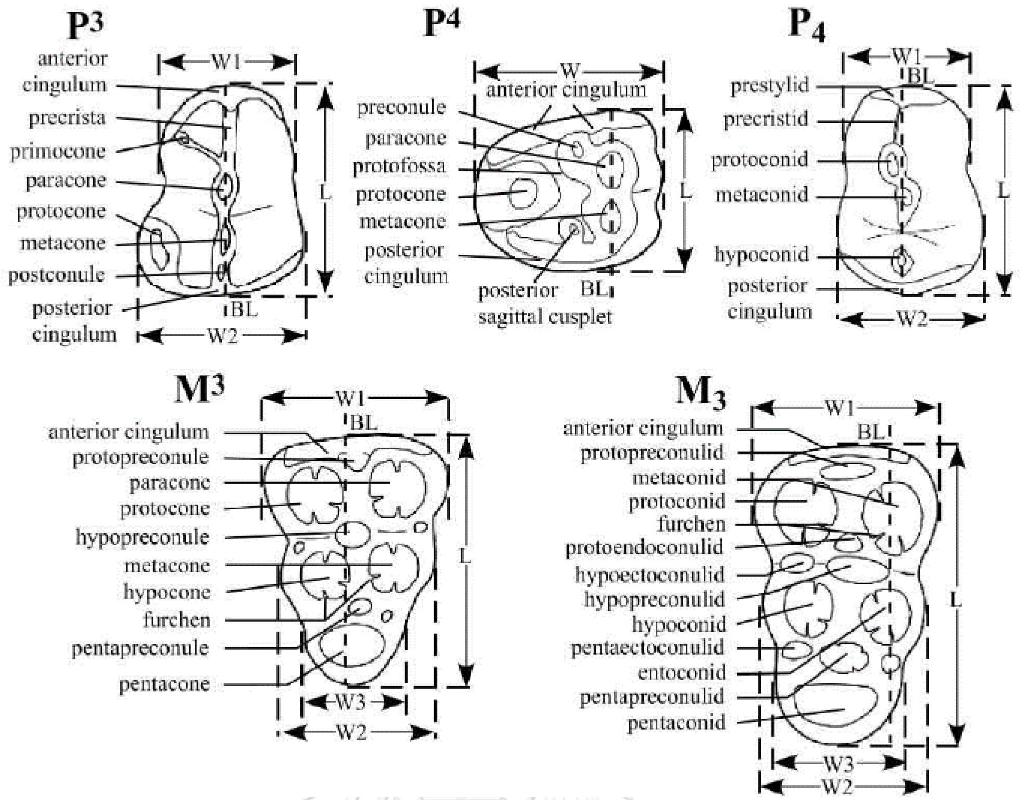

Figure 3. 11 Dental terminology and measurement of Propotamochoerine teeth from Thaung Htike et al., 2006. All are occlusal views of left cheek teeth. Abbreviations; baseline (BL), length (L), maximum width (W), the width of the first lobe (W1), the width of the second lobe (W2), the width of the third lobe (W3) in M^3 and M_3.

CHAPTER 4
SEDIMENTOLOGY FROM THE CHALOEM PHRA KIAT AND PHIMAI SANDPITS, NAKHON RATCHASIMA PROVINCE

4.1. Lithofacies of Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province

The studies outcrop of the Mae Lae Butra sandpit near Phimai District, Nakhon Ratchasima Province compose of fine to very coarse-grained sand, maybe cobbles and pebbles, and small-scale ripple. In the upper part of the section, the color of clay and silt are yellowish-brown to darker brownish with light gray mottles and bioturbation. In the lower part of the section, these are light gray to gray color with trough cross-bedding and wood fragment (Figure 4.1 – 4.2).

Base on lithofacies classified by Miall (1977, 1996), the fluvial deposits of the Mae Lae Butra sandpit can be divided into seven lithofacies. Such as one gravelly facies consist of matrix-supported gravel (Gmg). Three sandy lithofacies are recognized by trough cross-bedded sand (St), ripple cross-laminated sand (Sr), planar cross-bedded sand (Sp). Finally, three fine-grained clastic facies are subdivided into massive mud, silt (Fm), laminated sand, silt and mud (Fl), and silt, clay (Fsm) (Figure 4.3 – 4.5).

Seven lithofacies can be divided into three facies associations: gravelly lithofacies, sand lithofacies, and fine-grained clastic facies. The detail of these is described below. The Table summary of lithofacies description is shown in Figure 4.1 – 4.2.

<u>Association 1: Gravelly lithofacies</u>

1) Facies Gmg: Matrix- supported gravel (Figure 4.3 (C))

These facies are composed mainly of coarse to very coarse-grained maybe granules-pebble, moderately to poorly sorted, angular to subangular. The major sedimentary structures include cross-bedding and normal grading. The thickness of this facies is 0.1 m. These lithofacies reflect on the process of high-strength debris flows (Rust 1978b).

<u>Association 2; Sand lithofacies</u>

2) Facies St: Trough cross-bedded sand (Figure 4.3 (D-H))

These comprise fine to very coarse-grained sandstone with a concave shape. The thickness of this facies is 1 - 3 m. The major internal structures consist of trough cross-bedding, wedge-shaped cross-bedding, and low angle cross-bedded sand (Sl). The large-scale trough cross-beds may overlie the mud clasts. Basal boundaries are mostly erosional. According to Miall (1977, 1996), it is interpreted as sinuous-crested and linguoid (3-D) dunes that stack up to general bar forms in a channel.

3) Facies Sr: Ripple cross-laminated sand (Figure 4.4 (A-D))

These facies are composed of very fine to coarse-grained sand, maybe granule, rounded to well rounded, moderately to well sorted. The thickness of this facies is 2.0 m. These facies are overlain by the planar cross-bedded sand (Sp) and massive mud, silt (Fm) facies. According to Miall (1977) it is interpreted as ripples (lower flow regrim).

4) Facies Sp: Planar cross-bedded sand (Figure 4.4 (E-H))

These facies are characterized by planar-cross- bedded, fine to coarse-grained sand with a thickness of up to 0.7 to 1 m. According to Miall (1977, 1996), it is interpreted as a transverse bar underflow regime and linguoid and bedforms (2-D dunes).

<u>Association 3; Fine-grained clastic facies</u>

5) Facies Fm: Massive mud, silt (Figure 4.5 (A-C))

These facies are characterized by massive, lamination mud, silt, wood fragment, leaves, desiccation cracks, present. According to Miall (1977, 1996), it is interpreted as overbank deposits, abandoned channels, or drape deposits. Thus, it may represent the most distal floodplain.

6) Facies Fl: Laminated sand, silt, and mud (Figure 4.5 (D))

These facies are consisting of laminated sand, silt, mud, and small- scale ripples present in the sand and silt beds. The total thickness is 0.1 to 0.2 m. According to Miall (1977, 1996), these facies were deposited overbank, waning flood deposits.

7) Facies Fsm: silt, clay (Figure 4.5 (E-F))

These facies are characterized by massive, silt and mud, yellowish-brown with light gray, mottles zone, desiccation cracks. The thickness of this facies is 2.2 m. According to Miall (1977, 1996), it is interpreted as deposits in the back swamp, abandoned channel deposits, and a reducing and oxidizing environment.

Table 4. 1 The summary of lithofacies description and interpretation of the Mae Lae Butra (South wall) sandpit, Phimai District, Nakhon Ratchasima Province.

Facies	Lithofacies (codes)	Sedimentary structures	Description
Topsoil	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, darker brownish, desiccation cracks, up to 170 cm thick
MBS0	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silts, yellowish-brown with light gray, mottles, desiccation cracks, root and root traces, up to 150 cm thick
MBS1	Sand, clay, silt, (Fsm)	Massive, bioturbation	Sand, very fine to medium-grained sand, yellowish-brown to reddish-brown with light gray mottles, root traces, up 220 cm thick
MBS2	Gmg, Gravel	Matrix- supported gravel	Coarse to very coarse-grained, may be granules to pebbly, moderately to poorly sorted, rounded to well-rounded, black and iron-manganese concretion (Fe-Mn nodules), up to 5 to 40 cm thick; erosional surface at the base of the unit
MBS3, MBS5	Sand, silt (Sr, Fl)	Horizontal, fine lamination, small scale ripples	Alternation very fine-grained sand interbedded with thin bed mud, yellowish-brown to reddish-brown with light gray mottles, a layer of iron, up to 100 to 150 cm thick
MBS6.1	Sand (Sr, Fl)	lamination, small scale ripples	Alternation medium-grained sand interbedded with thin mud, yellowish-brown to reddish-brown with light gray mottles, up to 50 cm thick, erosional surface with coarse sand, maybe granules; well-sorted, rounded to well rounded, moderately to well-sorted, up to 10 cm thick at the base of the unit
MBS6.2	Sand (Sp)	Planar cross-bedded sand	Alternation fine-grained sand interbedded with thin mud, yellowish-brown to reddish-brown with light gray mottles, up to 70 cm thick,
MBS7	Sand (St)	Trough cross-bedded sand	Fine-grained sand, light gray, mud drapes, wood fragment, (diameters up to 10 cm), mud rip-up clasts, up to 150 cm thick, dip/dip direction; 10/115, 80/15
MBS8	Mud, silt (Fm, Fl)	Massive, lamination,	Mud, silt, very fine sand, thick bed, dark-colored, lenticular silt, lenticular, wood and wood fragment, leaves, mud rip-up clasts, up to 250 cm thick
MBS9	Sand (St)	Massive, Trough cross-bedded	Coarse-grained sand may be granules, dark gray, well-sorted, sub rounded to rounded, mud rip-up clasts, up to 60 cm thick, the erosional surface at the base of the unit
MBS10, MBS11, MBS12	Sand (St)	Trough cross-bedded sand, planar cross-bedded sand	Fine to coarse-grained sand, light to dark gray, solitary scoops with an erosional, mud rip-up clasts (25 cm thick), wood and wood fragment, up to >295 cm thick, the erosional surface at the base of the unit

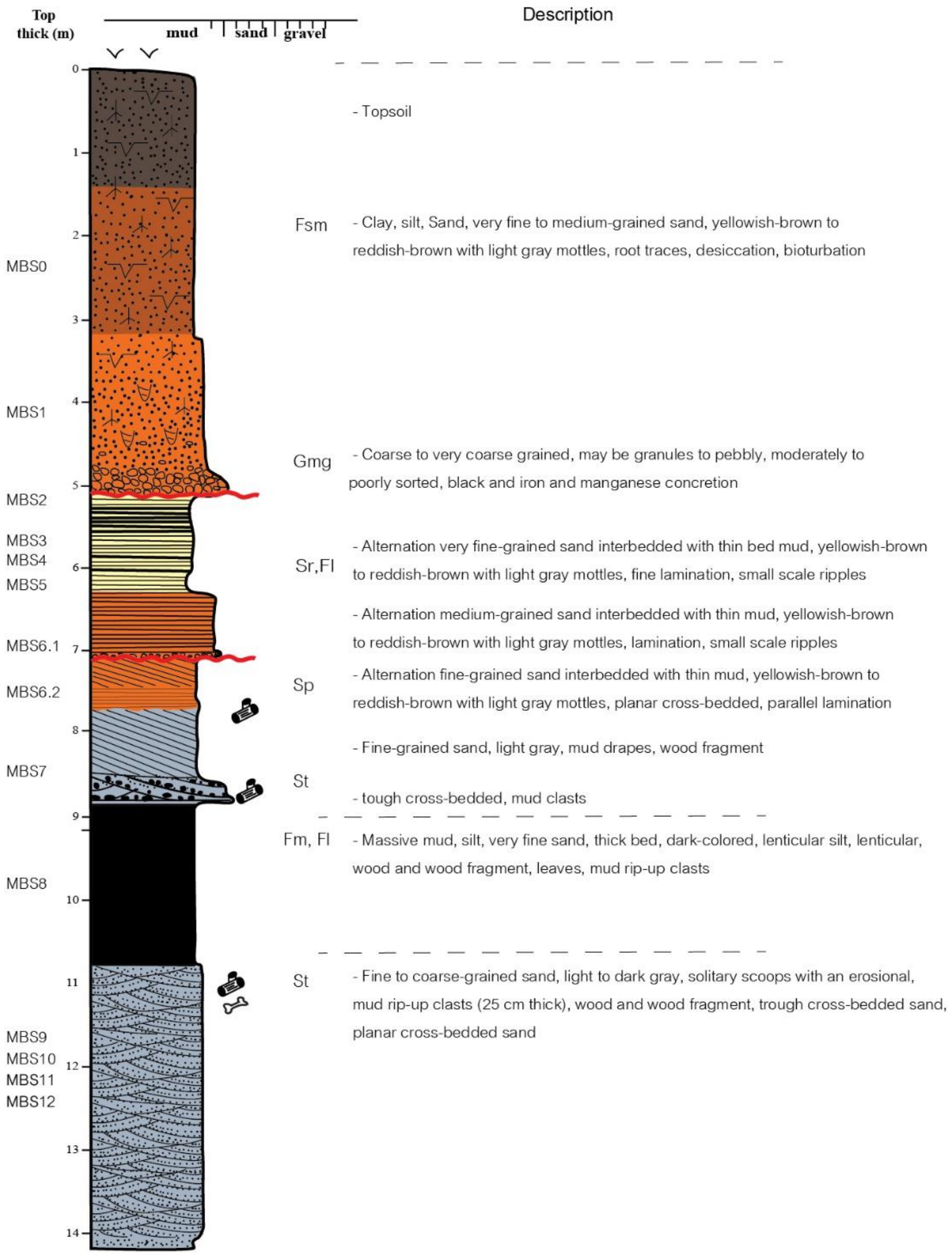

Figure 4. 1 Showing stratigraphic column of the Mae Lae Butra (South wall) sandpit, Phimai District, Nakhon Ratchasima Province.

Table 4. 2 The summary of lithofacies description and interpretation of the Mae Lae Butra (North wall) sandpit, Phimai District, Nakhon Ratchasima Province.

Facies	Lithofacies (codes)	Sedimentary structures	Description
Topsoil	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, darker brownish, desiccation cracks, up to 150 m thick
MBN0	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, darker brownish, desiccation cracks, root, and root traces, up to 150 m thick
MBN1	Clay, silt, (Fsm)	Massive, bioturbation	Medium to very coarse-grained sand may be granule to pebbly; yellowish-brown to reddish-brown with light gray mottles, sub rounded to rounded clasts, very poorly sorted, root and root traces, up 120 cm thick
MBS2, MBS3,	Granule to pebbly, (Gmg)	ripple cross-bedded	Granule to pebbly, rounded to well-rounded clasts, moderately sorted, black and iron-manganese concretion (Fe-Mn nodules), mud rip-up clasts
MBN4,MBN5 MBN6,MBN7	Sand (Sr, Fl)	Ripple cross-bedded	Alternation medium to coarse-grained sand interbedded with thin mud, maybe granule clasts, gray to light brown, sub rounded to rounded clasts, well-sorted, mud rip-up clasts, up 150 cm thick, the erosional surface at the base of the unit
MBN8, MBN9, MBN10	Sand (Sr, Fl)	Ripple cross-lamination	Alternation fine to coarse-grained sand, maybe granule clasts with thin mud, gray to light brown, normal grade bedding, subangular to sub rounded, well to moderately sorted, mud rip-up clasts, wood and wood fragment, up 250 cm thick, the erosional surface at the base of the unit
MBN11	Sand, (Sr)		Medium to coarse-grained sand, maybe pebbly, yellowish-brown to reddish-brown with gray mottles, mud rip-up clasts, subangular to sub rounded, well to moderately sorted, wood fragment, up 50 cm thick, the erosional surface at the base of the unit
MBN12	Massive, sand, mud, silt (Fm)	Desiccation cracks	Mud, silt, very fine to coarse-grained sand, gray, mud rip-up clasts, up 100 cm thick, the erosional surface at the base of the unit
MBN13	Sand (Sr, Fl)	Ripple cross-lamination	Alternation fine to coarse-grained sand, maybe granule clasts with thin mud, gray to light brown, normal grade bedding, mud rip-up clasts, wood fragment, up 200 cm thick, the erosional surface at the base of the unit
MBN14	Sand (Sp)	Planar cross-bedded	Very fine to medium-grained sand, gray to light brown, mud rip-up clasts, up 80 cm thick, the erosional surface at the base of the unit
MBN15, MBN16, MBN17 MBN18	Sand (St)	Massive, trough cross-bedded	Very fine to coarse-grained sand, gray to light brown, wood and wood fragment, mud rip-up clasts, up >250 cm thick, the erosional surface at the base of the unit

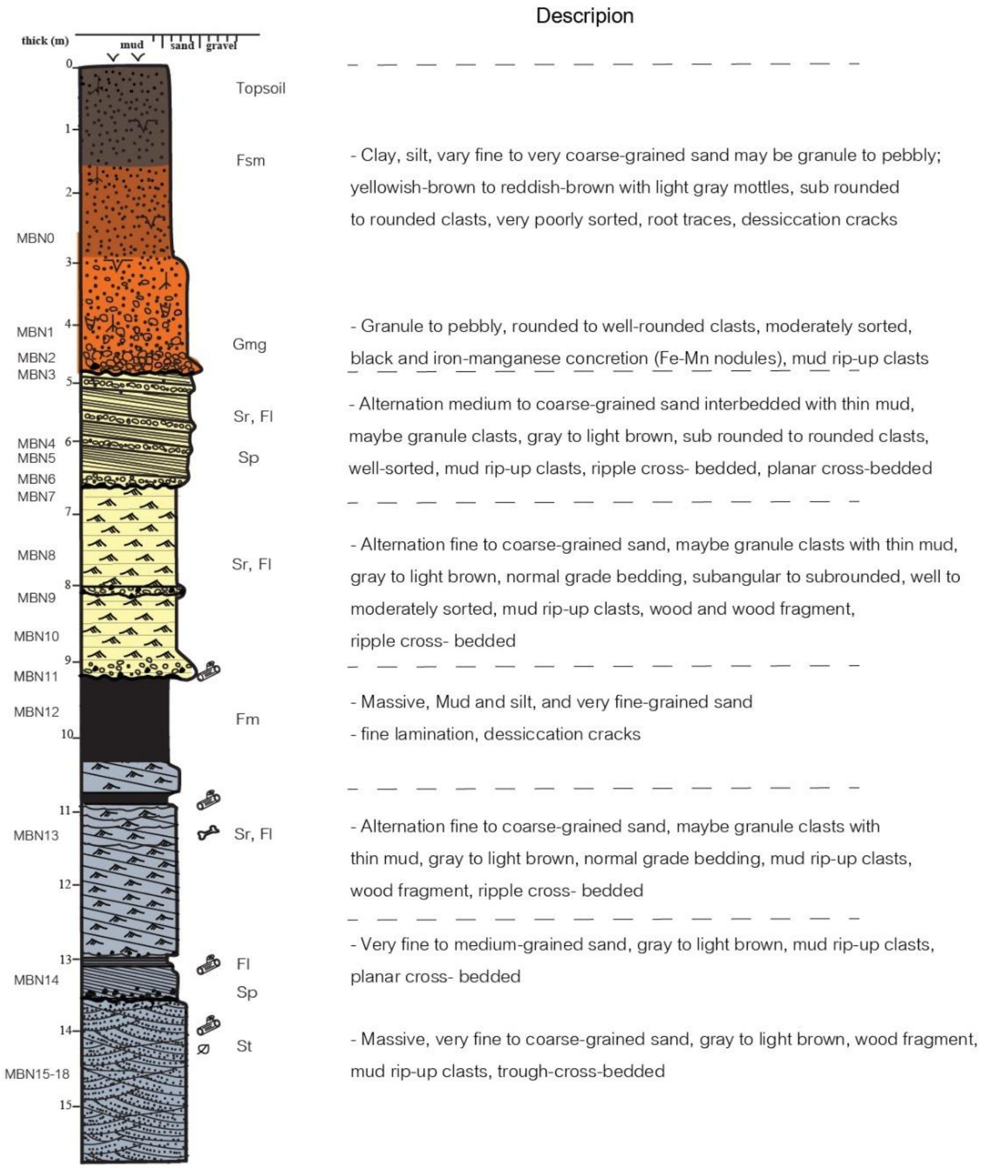

Figure 4. 2 Stratigraphic columns of the Mae Lae Butra (North wall) sandpit, Phimai District, Nakhon Ratchasima Province.

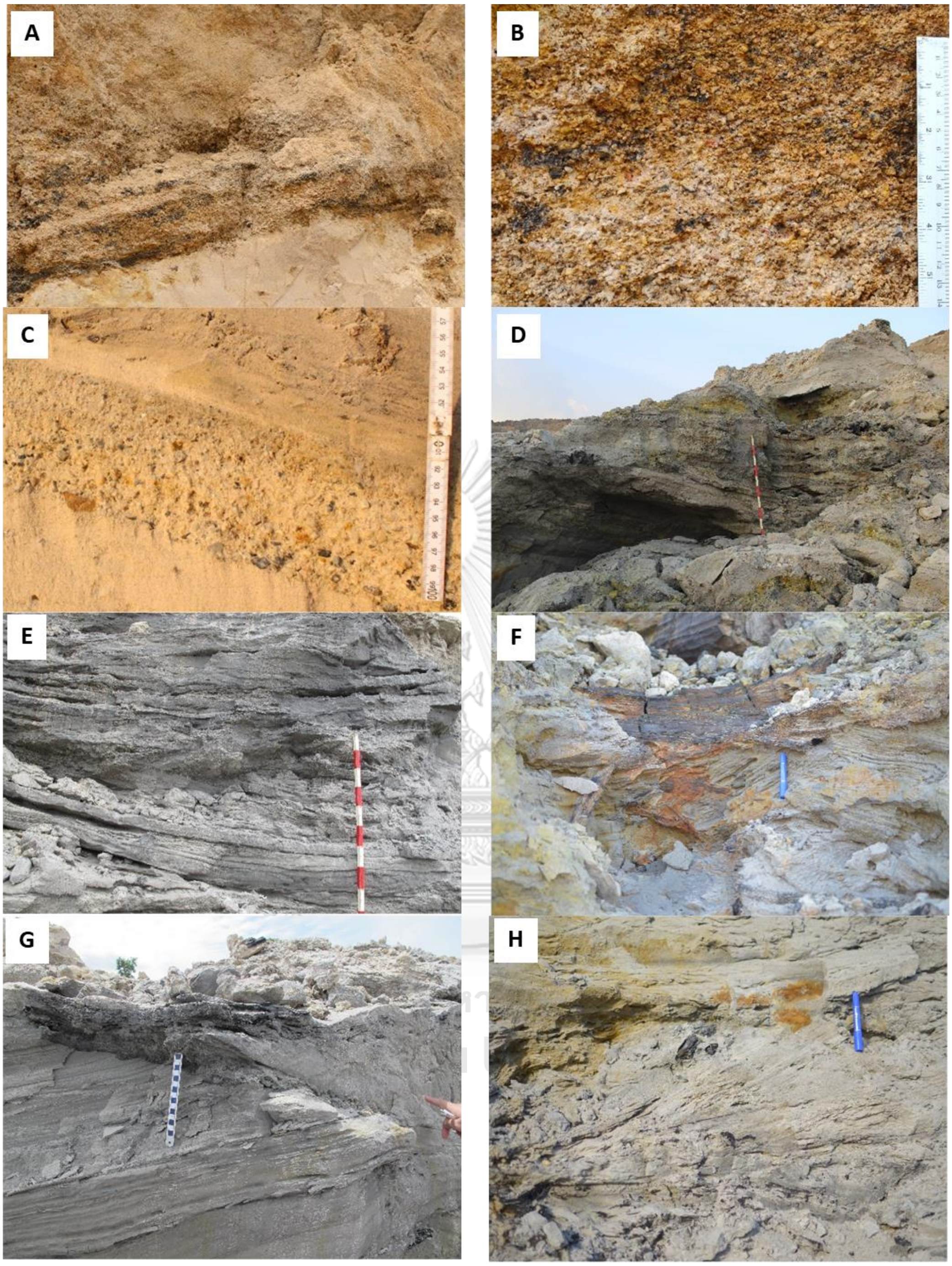

Figure 4. 3 Sedimentary facies recognized in the Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province. (A-C) matrix-supported gravel (Gmg), (D-H) trough cross-bedded sand (St).

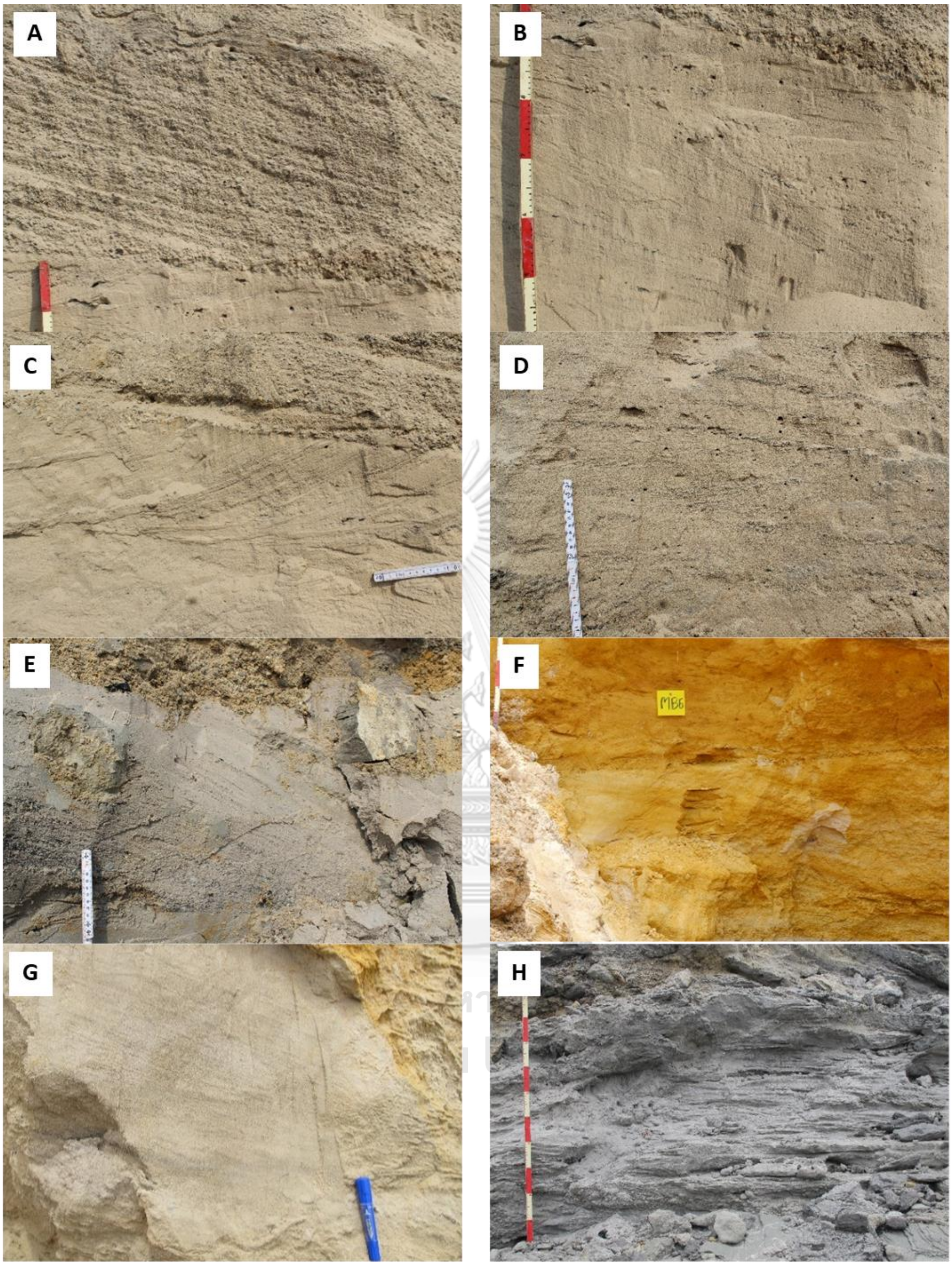

Figure 4. 4 Sedimentary facies recognized in the Mae Lae Butra sandpit, Phimai District, Phimai District, Nakhon Ratchasima Province. (A-D) Ripple cross-laminated sand (Sr); (E-H) Planar Cross-bedded sand (Sp).

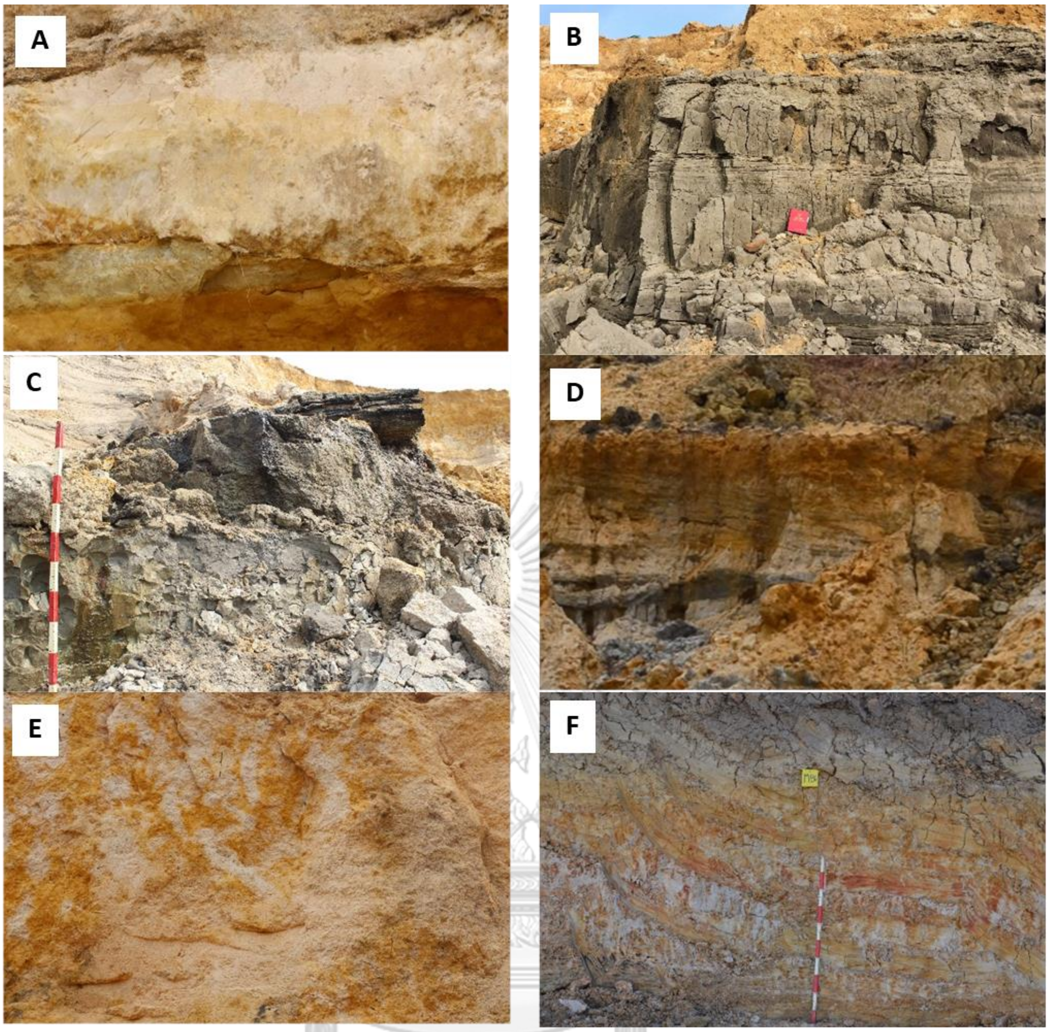

Figure 4. 5 Sedimentary facies recognized in the Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province. (A-C) Massive, lamination mud, silt (Fm, Fl); (D) Laminated sand, silt and mud (Fl); (E-F) massive, silt, clay (Fsm).

4.2 Architectural elements of Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province

Following Miall (1985,1996); Platt and Keller (1992), these elements defined by their geometries and bounding surfaces form the basis for interpreting the depositional environment. Five architectural elements were recognized: sandy bedforms (SB), lateral accretion deposits (LA), levee deposits (LV), floodplain Fines (FF), and abandon channel fill (FF(CH)). These features were observed in the outcrop from the Mae Lae Butra sandpit (Figure 4.6 – 4.8).

The architectural elements are described in detail below, and the summary of the architectural elements are shown in Table 4.3 - 4.4.

<u>Architectural elements formed within channels</u>

1) Element SB: Sandy bedforms

In the studies area, the sandy bedforms elements (SB) comprise of lithofacies St, Sp, Sr, and show linguoid (3-D) dunes of lithofacies St, and small ripples (lithofacies Sr) that occurs in shallow areas of active channels, particularly on bar tops. These small-scale structures are typically deposited during falling water. Whereas, Dunes (lithofacies St), characteristic of the deep portions of active channels.

2) Element LA: Lateral accretion deposits

In the studies area the lateral accretion deposits (LA) compose of sandy facies St, Sp, and subordinately of facies Gmg. This element appears typically in the sandstone-dominated part of the sequence, and is characterized by large scale, gently dipping third-order bounding surface, followed by fine-grained facies of the FF element. According to Miall (1985, 1996), it is interpreted as channel-fill and point-bar deposits.

<u>Architectural elements of the overbank environment</u>

3) Element LV: Levee Deposits

In the studies area, levee deposits (LV) compose of lithofacies Fl. The presence of Inter-laminate of mud or silt, and very fine-grained sand. The thickness is 0.1 to 0.2 m. their geometry is of the wedge-shaped ridges, showing interfingering and climbing ripples and parallel lamination. According to Miall (1985, 1996) Levees typically consists of rhythmically bedded units of silty, ripple-laminated sand a few decimeters thick. Bioturbation or root development commonly obscures lamination. The levee element constitutes a tapering wedge of deposit, thinning and fining away from the channel margin. Also, in this study, it is interpreted as overbank flooding when floodwaters of a stream overtop its banks.

4) Element FF: Floodplain fines

In the study area, Floodplain fines (FF) consist of lithofacies Fsm, Fl, Fm and mainly fine-grained clastic facies, showing desiccation cracks, diffuse root traces, mottles, and oxidize colors. According to Miall (1985, 1996), this section is interpreted to represent floodplain deposits, and oxidizing-reducing environment.

5) Element FF(CH): Abandon channel fills

In the studies area, Abandon channel fills compose of lithofacies Fsm, Fl, Fm. The presence of mud and silt, thin to thick-bedded. Their geometry is of the lenticular in cross-section, commonly interbedded with element SB. Following Miall (1985, 1996), abandoned channels are common components of many fluvial styles, particularly the finer-grained systems, including sandy meandering, fine-grained meandering, and anastomosed systems. In this study is interpreted as abandoned channels.

Table 4. 3 The summary of the architectural elements formed within channels in Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province.

Element	Code	Lithology	Geometry and relationships
Architectural elements formed within channels, Miall (1985, 1996)			
Sandy bedforms	SB	St, Sp, Sr	Lens, sheet, blanket, wedge, occurs as channel fills, crevasse splays, minor bars
Lateral-accretion macroform	LA	St, Gmg	wedge, sheet, lobe; characterized by internal-lateral-accretion 3rd-order surfaces
Overbank fines	FF	Fm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

Table 4. 4 The summary of the architectural elements of the overbank environment in Mae Lae Butra sandpit, Phimai District, Nakhon Ratchasima Province.

Element	Code	Lithology	Geometry	Interpretation
Architectural Elements of the Overbank Environment, Platt and Keller (1992)				
Levee Deposits	LV	Fl	Wedge up to 10 m thick, 3 km wide	Overbank flooding
Floodplain Fines	FF	Fsm, Fl, Fm	Sheet, maybe many km in lateral, dimensions, 10s of m thick	Deposits of overbank sheet flow, floodplain ponds, and swamps
Abandoned channel	CH(FF)	Fsm, Fl, Fm	Ribbon comparable in scale to an active channel	Product of chute or neck cutoff

Figure 4. 6 Showing lithofacies and architectural elements of Mae Lae Butra (South wall) sandpit, Phimai District, Nakhon Ratchasima Province.

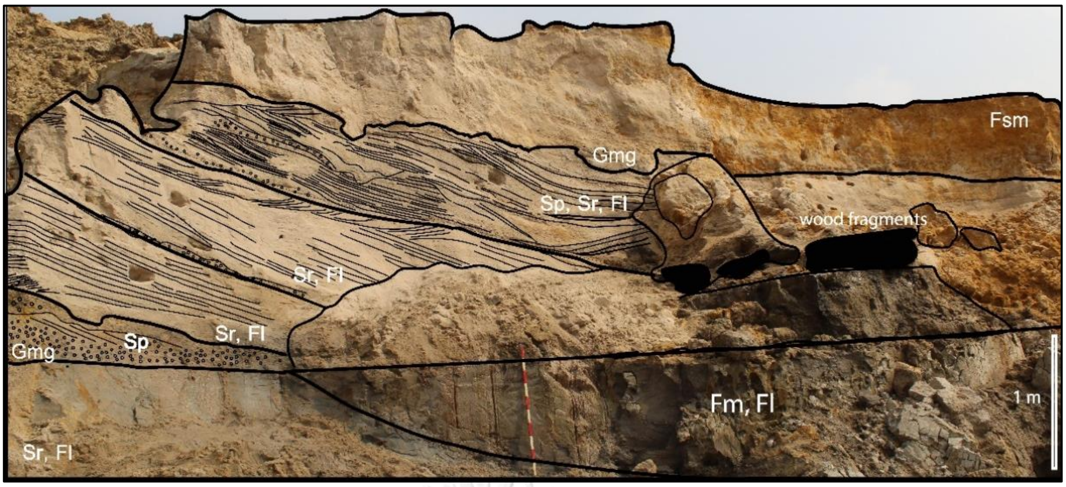

Figure 4. 7 Showing architectural elements of Mae Lae Butra (North wall) sandpit, Phimai District, Nakhon Ratchasima Province.

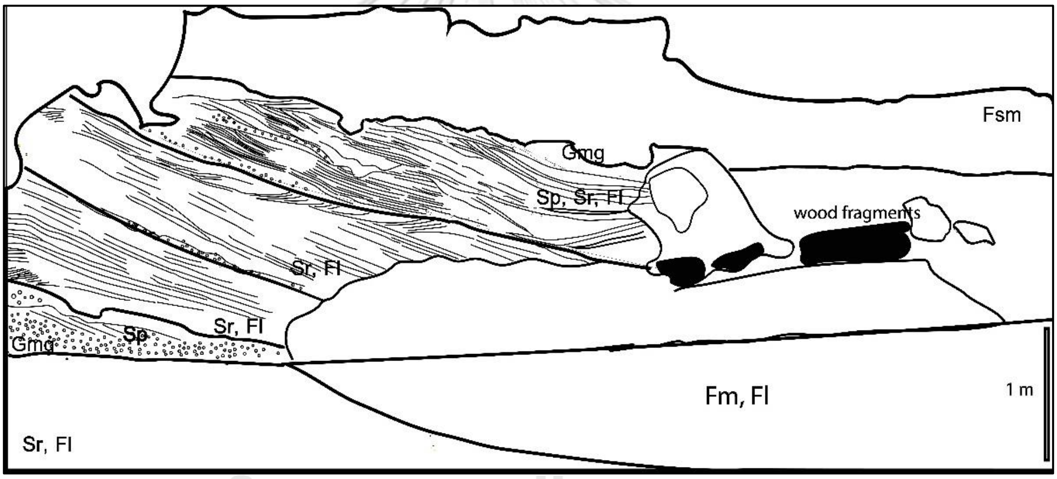

Figure 4. 8 Showing architectural elements of Mae Lae Butra (North wall) sandpit, Phimai District, Nakhon Ratchasima Province.

4.3 Lithofacies of Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province

The study outcrop of the Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province composes of very fine to coarse-grained sand may be granules. The upper part, the color of the sand is yellowish-brown with light gray mottles, and desiccation cracks. The lower part, these are light brown to dark gray with reddish-brown mottles, coarse to very coarse sand interbedded with thin mud.

Base on lithofacies classified by Miall (1997, 1996), the lithofacies of Chai Anan sandpit can be divided into seven lithofacies. One gravelly facies are recognized as matrix-supported gravel (Gmg). Three sandy lithofacies are subdivided into trough cross-bedded (St), ripple cross-laminated sand (Sr), planar cross-bedded sand (Sp). Finally, three fine-grained clastic facies consists of massive mud, silt (Fm), lamination mud, silt (Fl), massive, silt, clay (Fsm). The table summary of lithofacies description and interpretation is shown in Table 4.5.

Seven lithofacies can be grouped into three major facies associations: gravelly lithofacies, sand lithofacies, and fine-grained clastic facies. The detail of these is described below (Figure 4.9-4.12):

<u>Association 1: Gravelly lithofacies</u>

1) Facies Gmg: Matrix-supported gravel (Figure 4.10 (A))

These facies are characterized coarse-grained maybe granules, moderately to poorly sorted, sub rounded to rounded. The thickness of this facies is 0.7 m. These lithofacies reflect on the process of high-strength debris flows (Rust 1978b).

<u>Association 2; Sand lithofacies</u>

2) Facies St: Trough cross-bedded (Figure 4.10 (D-E))

These comprise Fine to medium-grained sand, maybe granules with a concave shape. The thickness of this facies is >1 m. The major internal structures consist of trough cross-bedding, wedge-shaped cross-bedding. The large-scale trough cross-beds may overlie the mud clasts. Basal boundaries are mostly erosional. According to Miall (1977, 1996), it is interpreted as sinuous-crested and linguoid (3-D) dunes that stack up to general bar forms in a channel.

3) Facies Sr: Ripple cross-laminated sand (Figure 4.10 (B-G))

These facies are characterized very fine to coarse-grained sand interbedded with thin mud, well-sorted, sub rounded to rounded. The internal structures are small ripple cross-lamination. The thickness of these facies about 1.0 – 1.5 m. According to Miall (1977) it is interpreted as ripples (lower flow regrim).

4) Facies Sp: Planar cross-bedded sand

These facies are characterized fine to coarse-grained sand maybe granules interbedded with thin mud, well sorted. The internal structures consist of planar cross-bedded, wavy bedding, normal grade bedding, and mud rip-up clasts. The thickness of up to 0.4 – 1.0 m. According to Miall 1977, 1996, it is interpreted as a transverse bar underflow regime and linguoid and bedforms (2-D dunes).

Association 3; Fine-grained clastic facies

5) Facies Fl: Laminated sand, silt and mud (Figure 4.11 (A-B))

These facies are characterized by laminated very fine sand, mud, and silt. The internal structures consist of flaser beds, lenticular and load structures. The total thickness is 0.5 m. According to Miall 1977, 1996, these facies were deposited overbank, waning flood deposits.

6) Facies Fm: Massive mud, silt (Figure 4.11 (C-D))

These facies are characterized by massive, lamination mud, silt, wood fragment, showing interfingering, present. According to Miall (1977, 1996), it is interpreted as overbank deposits. Thus, it may represent the most distal floodplain.

7) Facies Fsm: Silt, clay (Figure 4.10 (H))

These facies are characterized by massive clay, silt, and very fine-grained sand. The internal structures are desiccation cracks and mottling. The total thickness is 1.45 – 3.00 m. According to Miall 1977, 1996, it is interpreted as deposits in the back swamp and a reducing and oxidizing environment.

Table 4. 5 The summary of facies description and interpretation of the Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province.

Facies	Lithofacies (codes)	Sedimentary structures	Description
Topsoil	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, darker brownish, blocky, desiccation cracks, up to 300 cm thick
CN0	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, yellowish-brown with light gray mottling, root traces, up to 145 cm thick
CN1-1	Sand, clay, silt, (Fsm)	Massive, bioturbation, mottling	very fine to fine-grained sand, yellowish to reddish-brown with light gray mottling, up to 120 cm thick
CN1-2	Sand (Sr, Fl)	Ripple cross-lamination, flaser beds	Very fine to fine-grained sand, light brown with reddish-brown mottling, up to 20 cm thick
CN2	Sand (Sr), Mud (Fl)	Ripple cross-lamination, interfingering, load structures	Massive mud, and alternation very fine to fine-grained sand and thin mud, gray to light brown, up to 50 cm thick, the erosional surface at the base of the unit
CN3	Sand (Sr, Fl)	Ripple cross-lamination	Alternation Fine to coarse-grained sand interbedded with thin mud may be granules, light yellow to light brown, sub rounded to rounded, well-sorted, wavy bedding, mud ball, mud rip-up clasts, normal grade bedding, up to 240 cm thick, the erosional surface at the base of the unit
CN4, CN5	Sand (Sr, Fl)	Ripple cross-lamination	Alternation medium to coarse-grained sand interbedded with thin mud may be granules, light yellow to light brown with reddish-brown mottling, sub rounded to rounded, well-sorted, normal grade bedding, mud rip-up clasts, up to 120 cm thick, at the base of the unit the erosional surface
CN6	Sand (Sp, Gmg)	Planar cross-lamination	Alternation coarse to very coarse-grained sand interbedded with thin mud may be granules, light brown to medium gray with reddish-brown mottling, sub rounded to rounded, moderately to poorly sorted, normal grade bedding, mud rip-up clasts, wood fragment, up to 120 cm thick, the erosional surface at the base of the unit
CN7	Sand (Sr)	Ripple cross-lamination	Medium sand, light brown to gray with reddish-brown mottling, up to 100 cm thick, at the base of the unit the erosional surface
CN8	Matrix-supported gravel (Gmg)		Coarse-grained sand may be granules, light brown to dark gray with reddish-brown mottling, sub rounded to rounded, moderately to poorly sorted, mud grip-up clasts, up to 70 cm thick, the erosional surface at the base of the unit
CN9-13	Sand (St)	Trough cross-lamination,	Fine to medium-grained sand, maybe granules, light brown to dark gray with reddish-brown mottling, mud drape, sub rounded to rounded, well-sorted, normal grade bedding, mud rip-up clasts, wood, and wood fragment, up to >300 cm thick

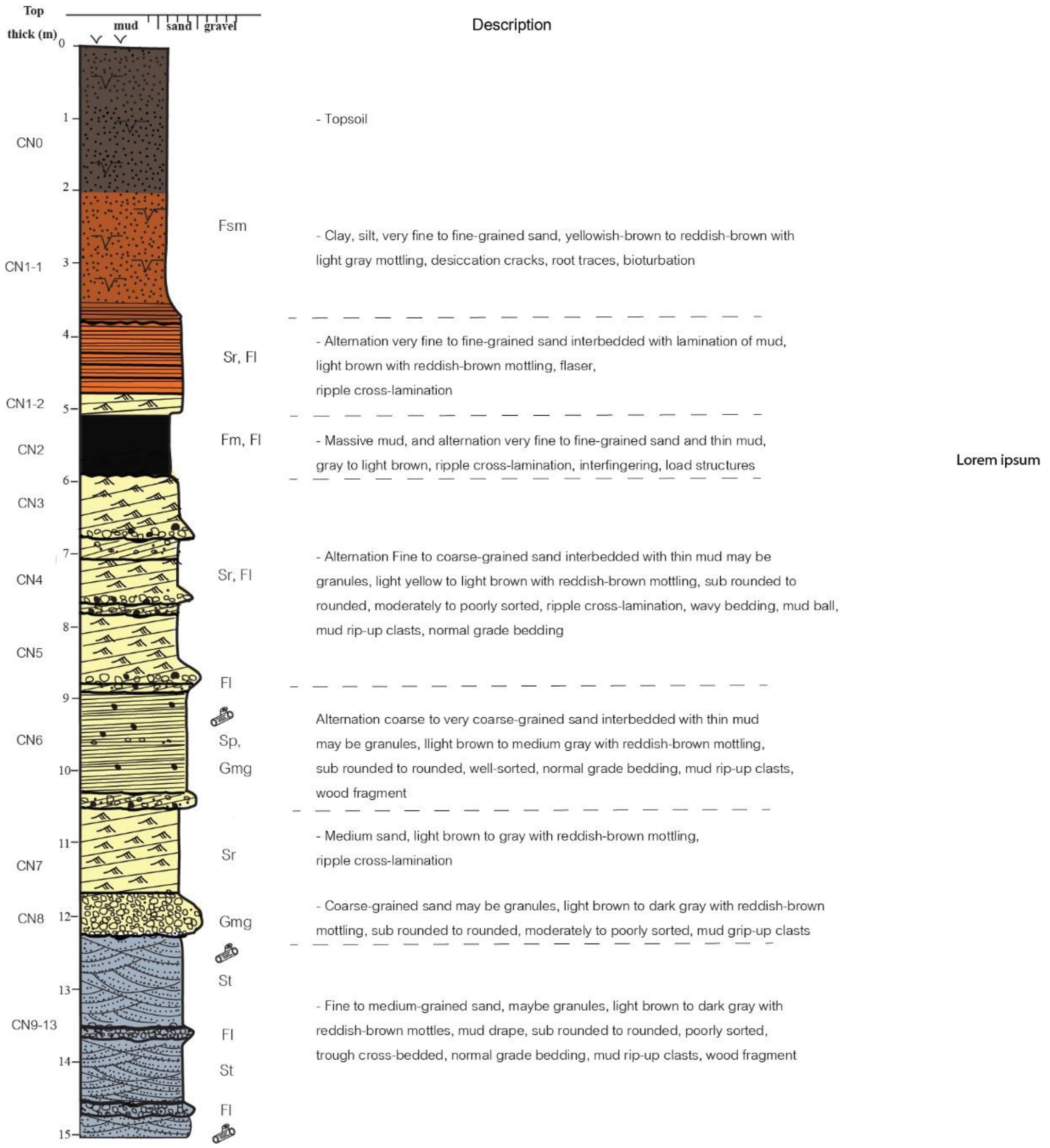

Figure 4. 9 Showing stratigraphic column of the Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province.

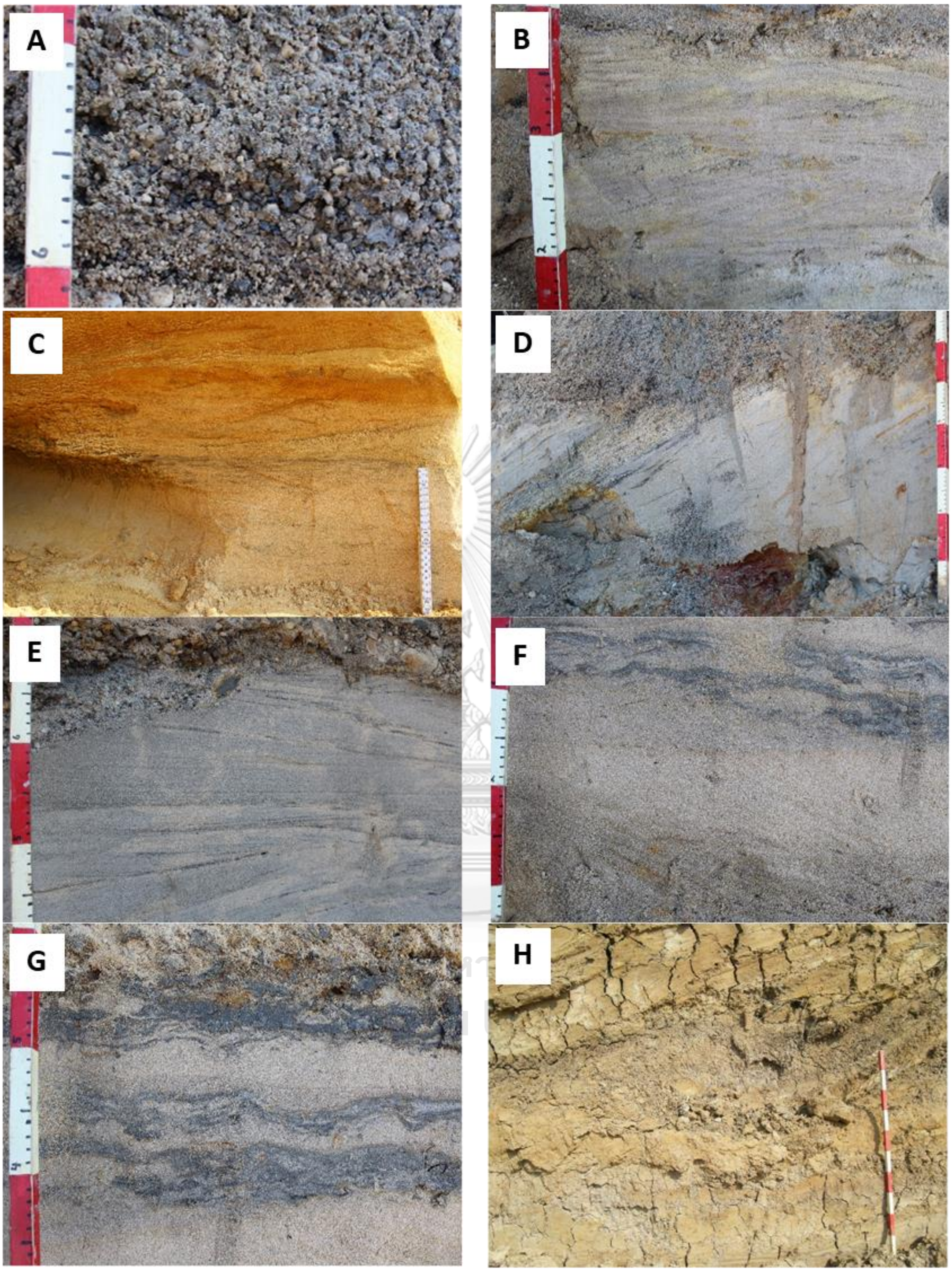

Figure 4. 10 Sedimentary facies recognized in the Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province. (A) Matrix-supported gravel (Gmg); (B-C) Ripple cross-laminated sand (Sr); (D-E) Trough cross-bedded; (H) Massive, silt, clay (Fsm).

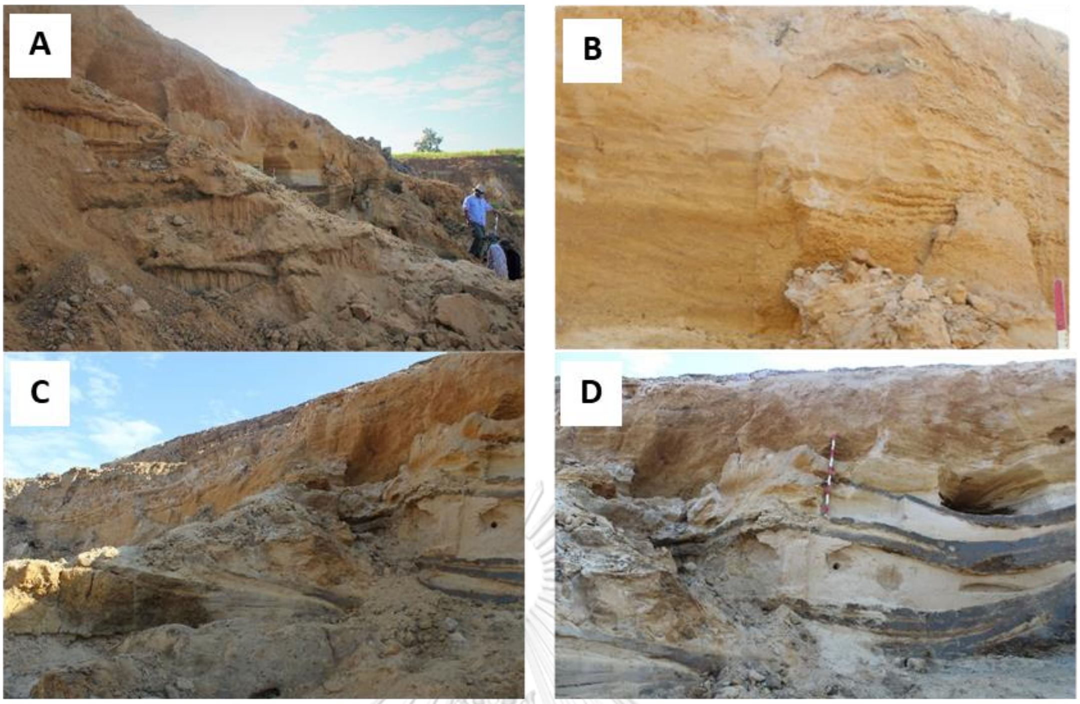

Figure 4. 11 Sedimentary facies recognized in the Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province. (A-B) Laminated very fine sand, mud, and silt (Sr, and Fl), (C) Massive mud, and silt (Fm), (D) Laminated very fine sand, mud, and silt, showing interfingering of silt, and mud.

4.4 Architectural elements of Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province

Following Miall (1985,1996); Platt and Keller (1992), these elements defined by their geometries and bounding surfaces form the basis for interpreting the depositional environment. Four architectural elements were recognized: sandy bedforms (SB), lateral accretion deposits (LA), floodplain Fines (FF), and levee deposits (LV). The architectural elements are described in detail below. The summary of the architectural elements is shown in Table 4.6-4.7.

<u>Architectural elements formed within channels</u>

1) Element SB: Sandy bedforms

In the studies section, the sandy bedforms elements (SB) comprise of lithofacies St, Sp, and Sr. Showing small scale cross-bedding that occurs in shallow areas of active channels, particularly on the bar tops and deposited during falling water.

<u>Architectural elements of the overbank environment</u>

2) Element LA: Lateral accretion deposits

In the studies section, the lateral accretion deposits (LA) comprise of lithofacies St, Sp, and subordinately of facies Gmg.

This element appears typically in the sandstone-dominated part of the sequence, and is characterized by large scale, gently dipping third-order bounding surface, followed by fine-grained facies of the FF element: desiccation cracks and mottling, and bioturbation. According to Miall (1985, 1996), it is interpreted as channel-fill and point-bar deposits.

3) Element LV: Levee Deposits

In the studies area, levee deposits are composing of lithofacies Fl. The presence of inter-laminate of very coarse to very coarse-grained sand maybe granules, showing interfingering and small ripples. The thickness is 0.05 - 0.2 m. Following Miall (1985, 1996), it is interpreted that floodplain deposits.

4) Element FF: Floodplain fines

In the studies area, Floodplain fines elements consist of lithofacies Fsm, Fl, and Fm, and showing desiccation cracks and mottling that indicate longer-term drying out of the floodplain. Following to Miall (1985, 1996), it is interpreted floodplain deposits.

Table 4. 6 The summary of the architectural elements formed within channels in Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province. (modified from Miall, 1985, 1996).

Element	Code	Lithology	Geometry and relationships
Architectural elements formed within channels, Miall (1985, 1996)			
Sandy bedforms	SB	St, Sp, Sr	Lens, sheet, blanket, wedge, occurs as channel fills, crevasse splays, minor bars
Lateral accretion deposits	LA	St, Sp, Gmg	wedge, sheet, lobe; characterized by internal-lateral-accretion 3rd-order surfaces
Overbank fines	FF	Fm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

Table 4. 7 The summary of the architectural elements of the Overbank Environment in Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province. (modified from Miall, 1985, 1996).

Element	Code	Lithology	Geometry	Interpretation
Architectural Elements of the Overbank Environment, Platt and Keller (1992)				
Levee Deposits	LV	Fl	Wedge up to 10 m thick, 3 km wide	Overbank flooding
Floodplain Fines	FF	Fsm, Fl, Fm	Sheet, maybe many km in lateral, dimensions, 10s of m thick	Deposits of overbank sheet flow, floodplain ponds, and swamps

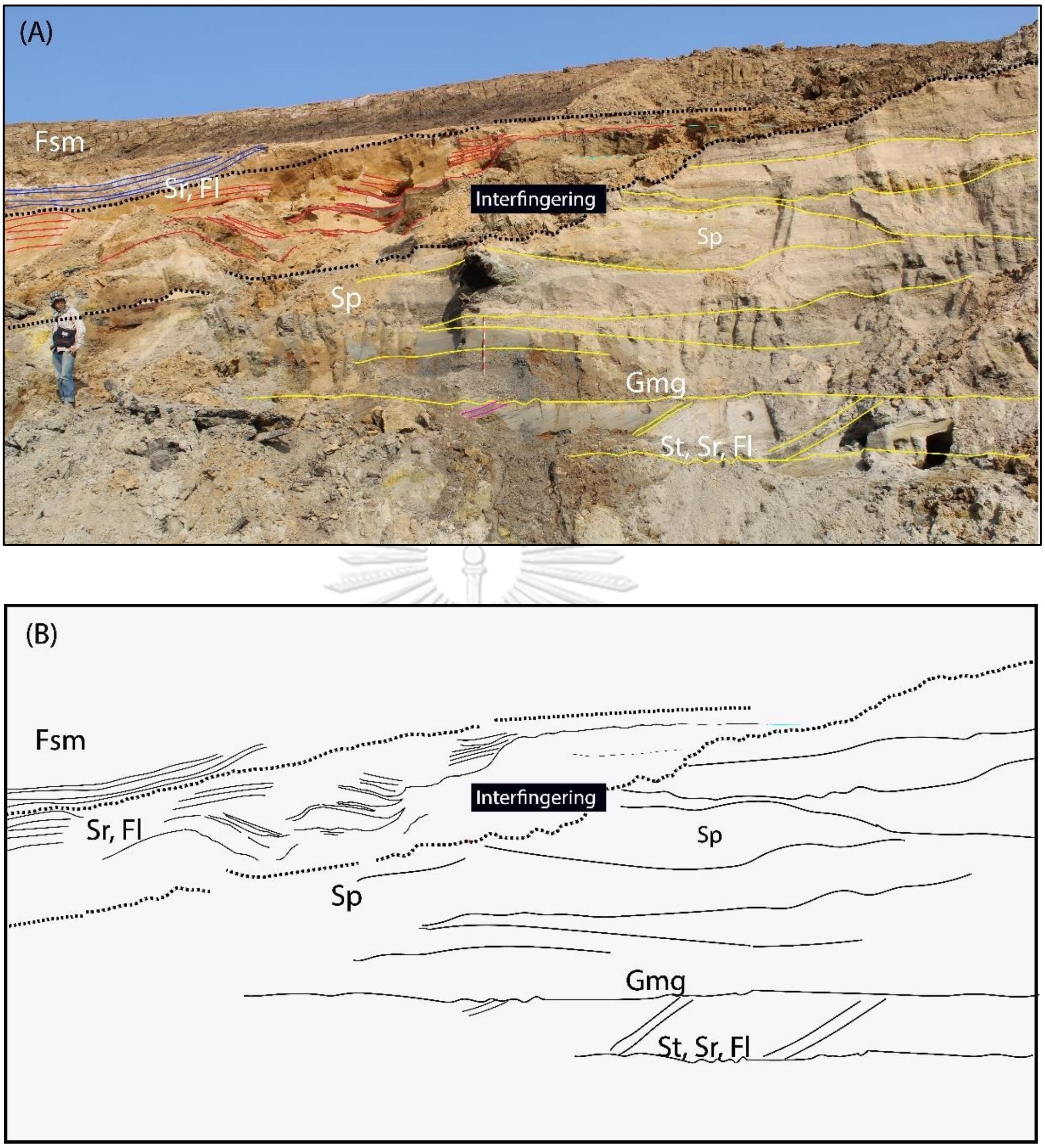

Figure 4. 12 (A-B) Showing lithofacies and architectural elements of Chai Anan sandpit, Phimai District, Nakhon Ratchasima Province.

4.5 Lithofacies of Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province

The studies outcrop of the Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province consists of fine to coarse-grained sand. The color of the sand is yellowish-brown to dark gray color. The upper part of the section, silt and clay are yellow-brown with light gray mottling and bioturbation. However, in the lower part of the section, these are light brown to dark gray, medium to coarse-grained sand alternation with thin mud (Figure 4.13).

Base on lithofacies classified by Miall (1977, 1996) the Rimmai Sai Thong sandpit can be divided into five lithofacies. One gravelly facies are recognized as matrix-supported gravel (Gmg). One sandy lithofacies consists of ripple cross-laminated sand (Sr). Finally, three fine-grained clastic facies subdivided into silts, clay (Fsm), massive, lamination mud, silt (Fl) and massive, mud, silt (Fm). The table summary of lithofacies is shown in and interpretation is shown in Figure 4.14- 4.15; Table 4.8.

Five lithofacies can be divided into three grouped facies associations: gravelly lithofacies, sand lithofacies, and fine-grained clastic facies. The detail of these is described below:

<u>Association 1: Gravelly lithofacies</u>

1) Facies Gmg: Matrix-supported gravel (Figure 4.15 (A))

These facies are characterized by medium to very coarse-grained sand maybe pebbly, moderately to poorly sorted. Most gravel are metrix (sand, silt) supported. The thickness of this facies 0.3 – 0.5 m. These lithofacies reflect on the process of high-strength debris flows (Rust 1978b).

<u>Association 2: Sand lithofacies</u>

2) Facies Sr: Ripple cross-laminated sand (Figure 4.15 (B-D))

These facies are characterized as medium to coarse-grained. The internal structures are mainly ripple cross-lamination, and climbing ripple lamination. The total thickness is 1.0 – 1.65 m. According to Miall (1977) it is interpreted as ripples (lower flow regrim)

Association 3: Fine-grained clastic facies

3) Facies Fm: Massive mud, silt (Figure 4.15 (E))

These facies are characterized by massive mud and silt with bioturbation and root traces are present. The thickness of this facies is 0.5 – 1.0 m. According to Miall (1977, 1996), it is interpreted as overbank deposits, it may represent the most distal floodplain.

4) Facies Fsm: Silt, clay

These facies are characterized yellowish-brown to darker brownish with light gray mottling clay and silt. The internal structures are present desiccation cracks and bioturbation and root traces. The total thickness is 1.5 m. According to Miall (1977, 1996), it is interpreted as deposits in the back swamp, and a reducing and oxidizing environment.

5) Facies Fl: Laminated sand, silt and mud (Figure 4.15 (F))

These facies are characterized by laminated very fine sand, mud, and silt. The internal structures consist of bioturbation, root traces, load structures. The total thickness is 0.5 m. According to Miall 1977, 1996, these facies were deposited overbank, waning flood deposits.

4.6 Architectural elements of Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province

Following Miall (1985,1996); Platt and Keller (1992), these elements defined by their geometries and bounding surfaces form the basis for interpreting the depositional environment. Three architectural elements were recognized; levee deposits (LV), and floodplain fines (FF). The detail of architectural elements is described below and shown in Table 4.9 - 4.10.

Architectural elements of the overbank environment

1) Element LV: Levee deposits

In the studies area, levee deposits elements (LV) compose of lithofacies Fl. The presence of inter-laminate of medium to coarse grained-sand and thin mud. The geometry is wedge-shaped and showing climbing ripple lamination. According to Miall (1985, 1996), it is interpreted as over bank flooding.

2) Element FF: Floodplain fines

In the studies area, the sandy bedforms elements comprise of massive mud and silt, bioturbation, root traces, small scale-cross bedding (lithofacies Sr), are present. These structures are typically deposited during falling water.

Table 4. 8 The summary of the facies description and interpretation of the Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province.

Facies	Lithofacies (codes)	Sedimentary structures	Description
Topsoil	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, darker brownish, desiccation cracks, up to 150 cm thick
RM0	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, yellowish-brown with light gray mottling, root traces, up to 150 cm thick
RM1	Sand, silt, and mud (Fsm, Fm)	Massive, bioturbation	Fine to medium-grained sand, light brown to darker brownish, load structure, mud rip-up clasts, root traces, bioturbation, up 150 cm thick, erosional surface
RM2, RM3, RM4, RM5	Sand (Sr, Fl)	Ripple cross-lamination	Alternation fine to coarse-grained sand, maybe granule clasts with thin mud, medium brown to gray with light brown mottling, sub rounded to rounded, well-sorted, up to 140 cm thick, erosional surface
RM6	Sand, silt, mud (Sr, Fl)		Medium to coarse sand interbedded with thin mud may be granules, brown to dark gray, sub rounded to rounded, well-sorted, up to 50 cm thick, erosional surface
RM7, RM8, RM9	Sand (Sr)	Ripple cross-lamination	Alternation medium to coarse-grained sand with thin mud, light brown to gray, mud rip-up clasts, mud ball, mud drapes, up to 120 cm thick, erosional surface
RM10	Sand (Sr)	Ripple cross-lamination	Medium-grained sand, light brown to gray to with reddish-brown mottles, mud rip-up clasts, up to 100 cm thick, erosional surface
RM11	Sand, Mud (Fm)	Massive	Massive mud, silt very fine-grained sand, light brown to dark gray with reddish-brown mottling, sub rounded to rounded, well-sorted, mud rip-up clasts, up to 50 cm thick, erosional surface
RM12, RM13	Sand (Sr)	Ripple cross-lamination, Climbing ripple lamination	Medium to coarse-grained sand, yellowish to brownish, mud rip-up clasts, wood fragment, up to 165 cm thick, erosional surface
RM14	Matrix-supported gravel (Gmg)	-	Medium to very coarse-grained sandstone may be pebbly, light brown to grey, moderately to poorly sorted , mud rip-up clasts, up to 30 cm, thick

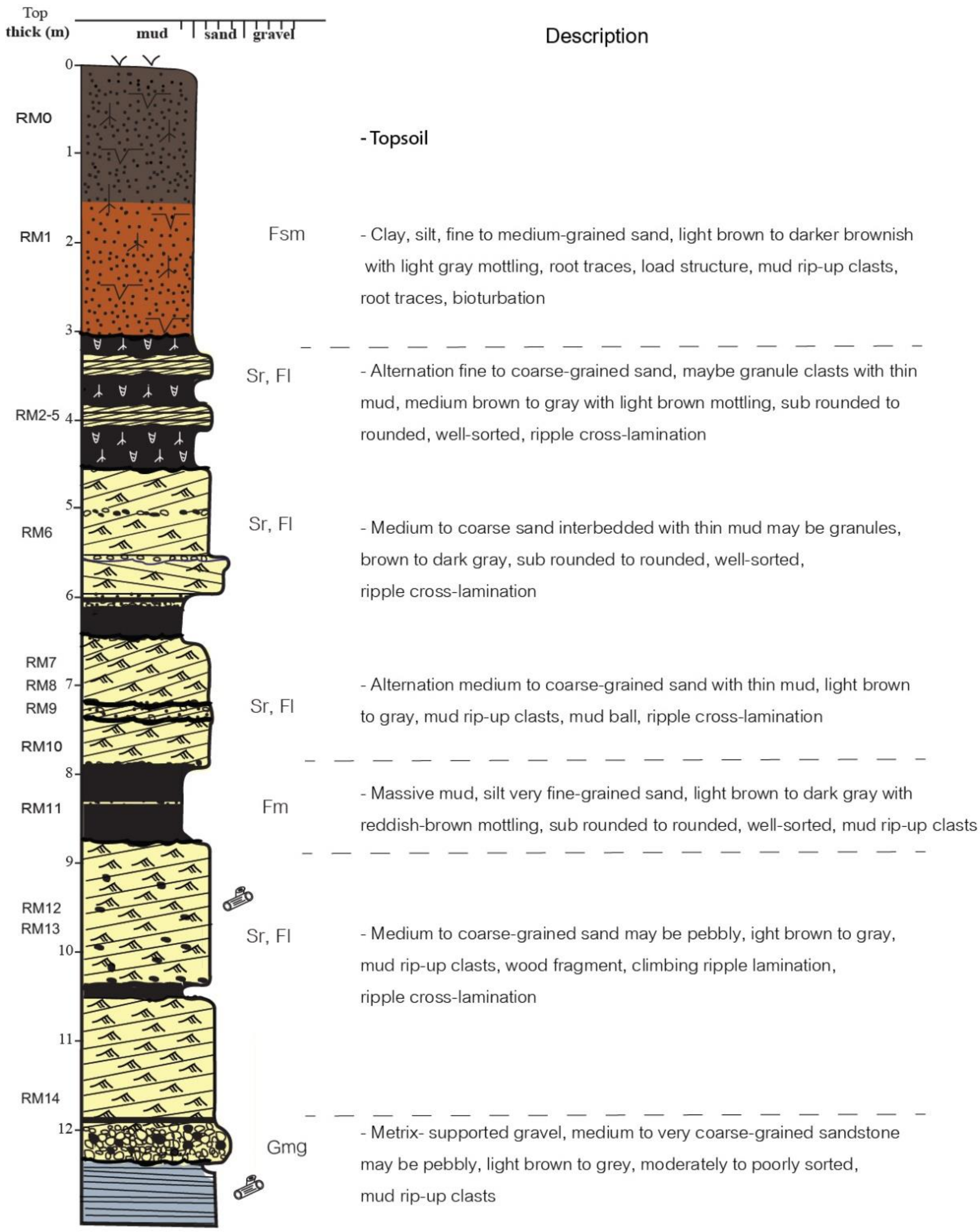

Figure 4. 13 Showing stratigraphic column of the Rim Mai Sai Thong, Phimai District, Nakhon Ratchasima Province.

Table 4. 9 The summary of the architectural elements formed within channels in Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province.

Element	Code	Lithology	Geometry and relationships
Architectural elements formed within channels, Miall (1985, 1996)			
Overbank fines	FF	Fm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

Table 4. 10 The summary architectural elements of the overbank environment in Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province.

Element	Code	Lithology	Geometry	Interpretation
Architectural Elements of the Overbank Environment, Platt and Keller (1992)				
Levee Deposits	LV	Fl	Wedge up to 10 m thick, 3 km. wide	Overbank flooding
Floodplain Fines	FF	Fsm, Fm, Fl	Sheet, maybe many km in lateral, dimensions, 10s of m thick	Deposits of overbank sheet flow, floodplain ponds, and swamps

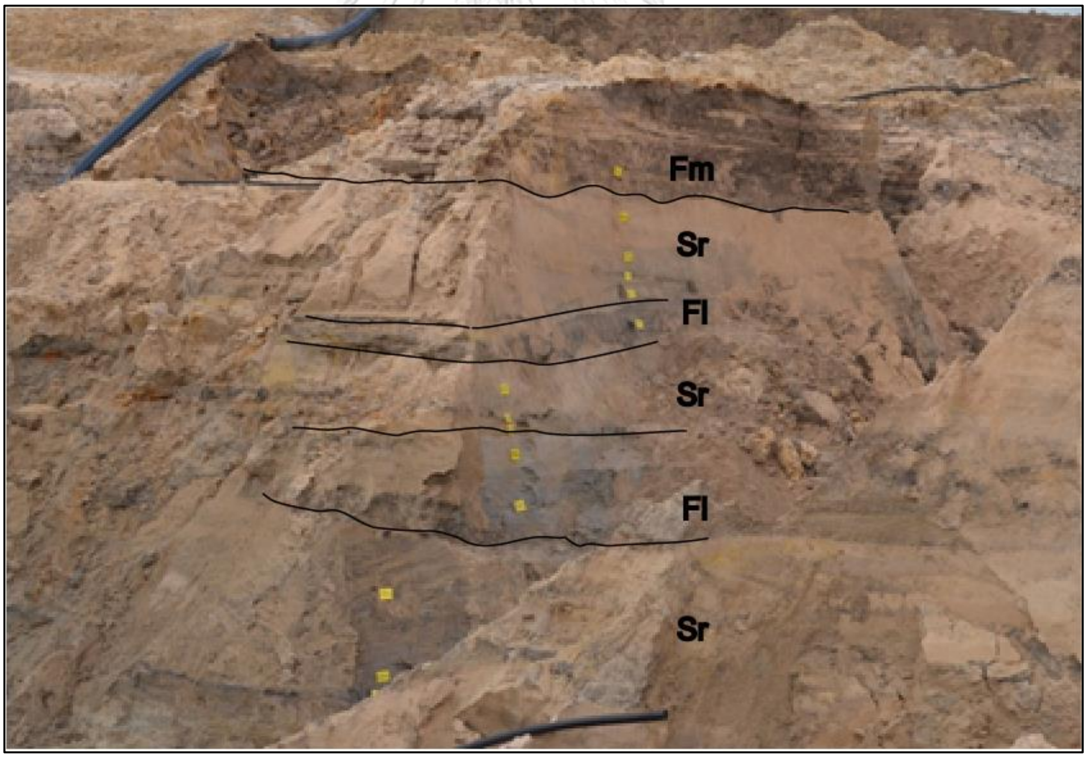

Figure 4. 14 Showing lithofacies of Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province.

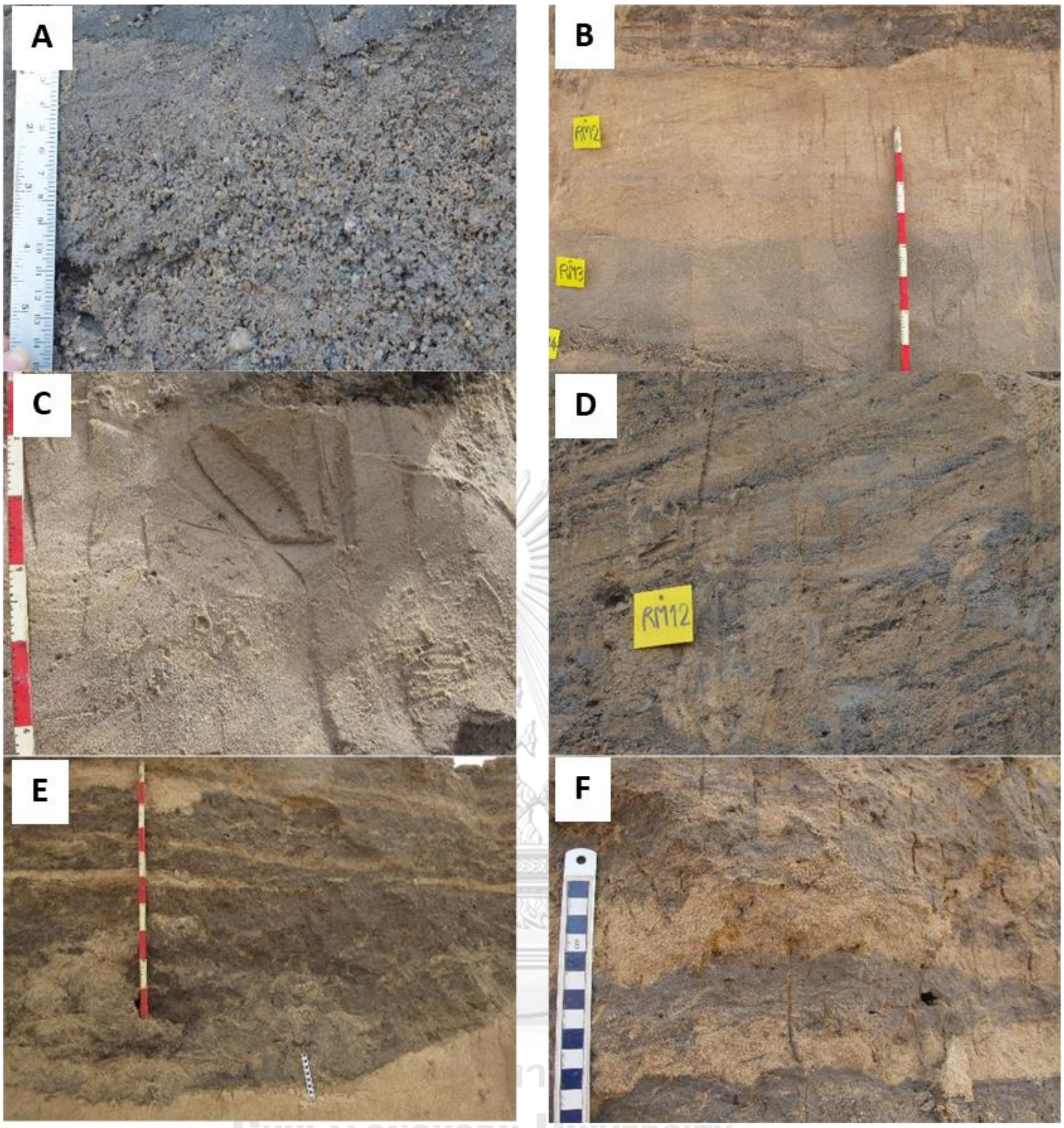

Figure 4. 15 Sedimentary facies recognized in the Rim Mai Sai Thong sandpit, Phimai District, Nakhon Ratchasima Province. (A) Matrix-supported gravel (Gmg); (B-D) Climbing ripple cross-bedded (Sr); (E) Massive mud, and silt (Fm, Fl); (F) Massive, silt, clay interbedded clay (Fl).

4.7 Lithofacies of Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province

The study outcrop of Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province comprise of very fine to very coarse-grained sand, may be pebbly. The upper part of the section, The color of clay and silt yellowish-brown to light grey, and mottles present. Whereas, the lower part of this section is light grey to darker grey.

Base on lithofacies classified by Miall (1977,1996) lithofacies of the Takut Khon sandpit can be divided into six lithofacies. One gravelly facies is recognized as matrix-supported gravel (Gmg). Three sandy lithofacies are subdivided into ripple cross-laminated sand (Sr), planar cross-bedded sand (Sp), and trough cross-bedded sand (St). Finally, two fine-grained clastic facies consists of massive, silt, clay (Fsm), and lamination mud, silt (Fl). The table summary of lithofacies is shown in Table 4.11.

Six lithofacies can be divided into three facies associations: gravelly lithofacies, sand lithofacies, and fine-grained clastic facies. The detail of these is described below:

<u>Association 1: Gravelly lithofacies</u>

1) Facies Gmg: Matrix-supported gravel (Figure 4.17 (A-B))

These facies are composed mainly coarse to very coarse-grained sand, maybe pebbly, moderately to poorly sorted, round to well round. Most gravel are matrix (sand and silt) supported. The thickness of this facies is1.5 m. The base of the unit is mostly erosional. These lithofacies reflect on the process of high-strength debris flows (Rust 1978b).

<u>Association 2: Sand lithofacies</u>

2) Facies St: Trough cross-bedded sand (Figure 4.18 (C-F))

These facies are very fine to very coarse-grained sand, maybe pebbly with the concave shape. The thickness of this lithofacies is 2.0 m. The major internal structures consist of trough cross bedding, and wedge-shaped. The base of the unit is erosional surface, and mud rip-up clasts present. According to Miall (1977, 1996), it is interpreted as sinuous-crested and linguoid (3-D) dunes that stack up to general bar forms in a channel.

3) Facies Sr: Ripple cross-laminated sand (Figure 4.17 (C-F))

These facies are characterized by small ripple cross-lamination, and medium to coarse-grained sand. These facies are composing of fine to coarse grained sand, maybe pebbly, rounded to well rounded, moderately to well sorted, wood fragment. The thickness of this lithofacies is 2.0 m. According to Miall (1977) it is interpreted as ripples (lower flow regrim)

4) Facies Sp: Planar cross-bedded Sand (Figure 4.18 (A-B))

These facies are characterized by planar cross-bedded, very fine to coarse-grained sand, with drape deposits. The thick of the bed is 0.5 – 1.5 m. According to Miall (1977, 1996), it is interpreted as a transverse bar underflow regime and linguoid and bedforms (2-D dunes).

Association 3: Fine-grained clastic facies

5) Facies Fsm: silt, clay

These facies are characterized by massive clay and silt, yellowish-brown to light gray, mottling and desiccation crack are present. The thickness of this is 1.5 – 3 m. According to Miall (1977, 1996), it is interpreted as deposits in the back swamp, abandoned channel deposits, and a reducing and oxidizing environment.

6) Facies Fl: Laminated sand, silt, and mud

These facies are characterized by laminated sand, silt, mud. The small ripples are present in the sand and silt beds. The total thickness is 0.2 - 0.5 m. According to Miall (1977, 1996), these facies were deposited overbank, waning flood deposits.

4.8 Architectural elements of Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province

Following Miall (1985,1996); Platt and Keller (1992), these elements defined by their geometries and bounding surfaces form the basis for interpreting the depositional environment. Four architectural elements were recognized: sandy bedforms (SB), Lateral accretion deposits (LA), Crevasse splay (CS), Floodplain fines (FF). These features were observed at each outcrop. The detail of architectural elements is described in Table 4.12 - 4.13 as follows;

Architectural elements formed within channels

1) Element SB: Sandy bedforms

In the studies area, the sandy bedforms element comprise of lithofacies St, Sp, Sr, and showing linguoid (3-D) dunes and small ripples cross-bedding (lithofacies Sr) that occurs in shallow areas of active channels, particularly on bar tops. However, linguoid dunes of lithofacies St characteristic of deep portions of active channels.

2) Element LA: Lateral accretion deposits

In the studies area, the lateral accretion deposits (LA) compose of St, and Sp. These elements are characterized by large scale, third-order bounding surface that corresponds to the successive increments of lateral growth. According to Miall (1985, 1996), it is interpreted as channel-fill and point-bar deposits.

Architectural Elements of the overbank environment

3) Element CS: Crevasse splay

In the studies area, the crevasse splay consists of lithofacies Sr, and Fl. These are ribbon-like bodies consisting of fine to medium-grained sand interbedded laminae of silt and mud with pebbly-sandstone lag at the base (Figure 4.19). Ripple cross-lamination is present.

4) Element FF: Floodplain fines

In the studies area, the floodplain fine comprises of lithofacies Fsm, and Fl. These are mainly fine-grained clastic facies, and showing desiccation cracks, and mottling indicate longer-term drying out of the floodplain.

Table 4. 11 The summary of the facies description and interpretation of the Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Facies	Lithofacies (codes)	Sedimentary structures	Description
Topsoil	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, darker brownish, desiccation cracks, up to 200 cm thick
TK0	Clay, silt, (Fsm)	Massive, desiccation cracks	Clay, silt, yellowish-brown with light gray mottling, desiccation cracks, root traces, up to 180 cm thick
TK1, TK2	Massive (Sr, Fl)	Ripple cross-lamination,	Alternation fine to medium-grained sand interbedded with thin mud, reddish-brown to gray, mottling, normal grade bedding, wood fragment, mud rip-up clasts, mud ball, up to 230 cm thick, erosional surface
TK3, TK5	Matrix-supported, gravel (Gmg)		Coarse to very coarse-grained sand, maybe a pebbly, gray to reddish-brown, rounded to well rounded, moderately to poorly sorted, mud rip-up clasts, up to 150 cm thick, erosional surface
TK 6, TK7	Sand, sitl (Sr, Fl)	Ripple cross-lamination	Medium to coarse-grained sand maybe granules interbedded with thin mud, light brown to reddish-brown, rounded to well rounded, sorted, normal grade bedding, mud rip-up clasts, up to 200 cm thick, the erosional surface at the base of the unit
TK8, TK9	Sand		Fine-grained sand interbedded with coarse-grained sand, light to dark gray, and mud rip-up clasts, wood fragment, up to 90 cm thick, erosional surface
TK10,	Sand		Very fine to fine-grained sand, reddish-brown to light gray, mottling, mud rip-up clasts, up to 80 cm thick, erosional surface
TK11-TK12	Sand (Sp)	Planar cross-bedded	Very fine to fine-grained sand, light gray, mottling, rip up mud clasts, wood fragment, drape deposits, up to 100 cm thick, erosional surface
TK13, TK14, TK15, TK16	Sand (St)	Trough cross-bedded, planar cross-bedded	Very fine to fine-grained sand, light gray to gray, wood fragment, leaves, mud rip-up clasts, trough cross-bedded, up to 300 cm thick, erosional surface
TK17	Sand, massive		Coarse to very coarse, maybe pebbly, light gray to dark gray, and mud rip-up clasts, wood fragment, drape deposits, up to 50 cm thick, erosional surface
TK18, TK19, TK20	Massive, sand (St)	Trough cross-bedded	Fine to medium sand, light gray to dark gray, mud rip-up clasts, wood fragment, up to >200 cm thick

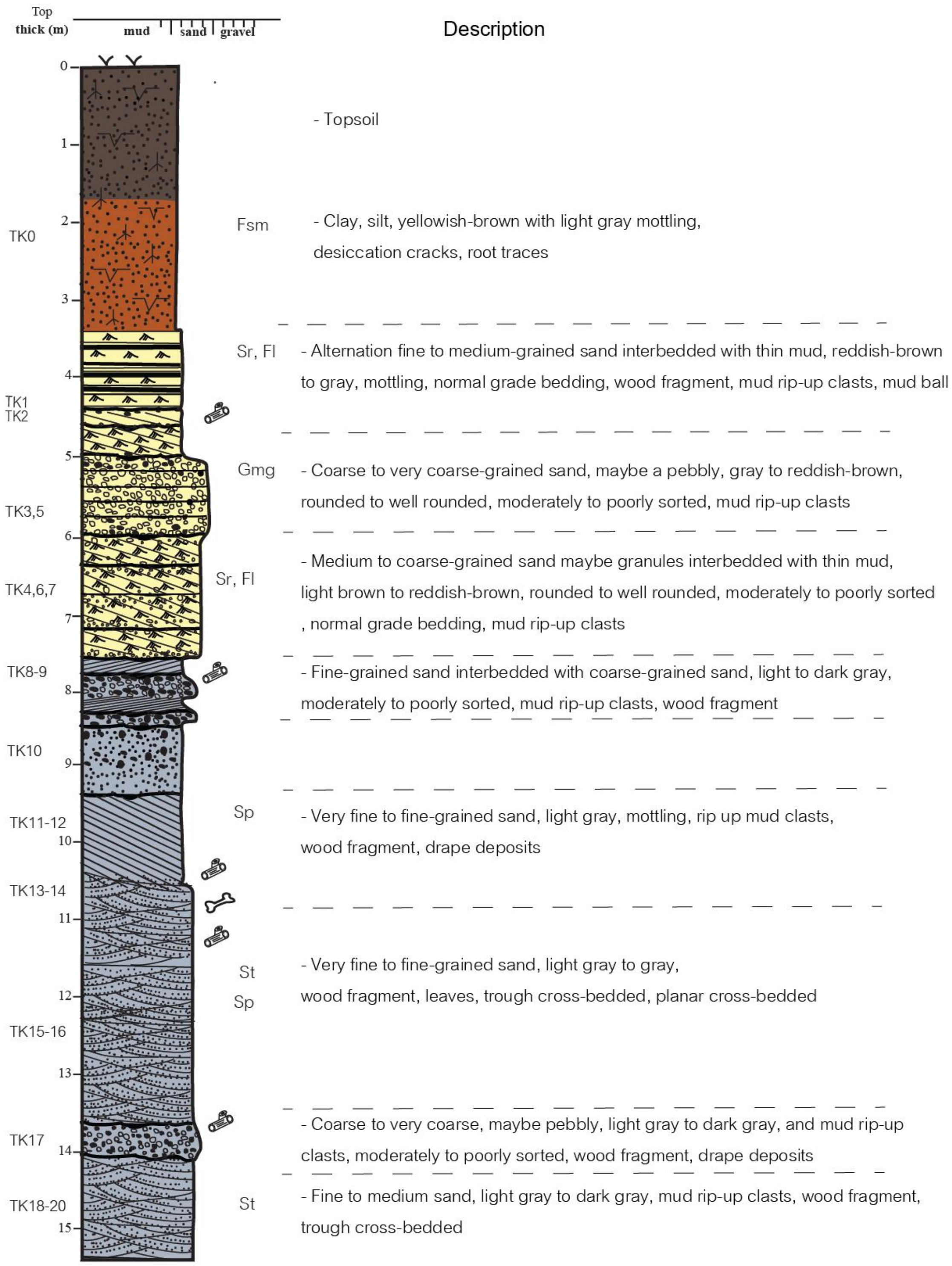

Figure 4. 16 Showing stratigraphic column of the Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

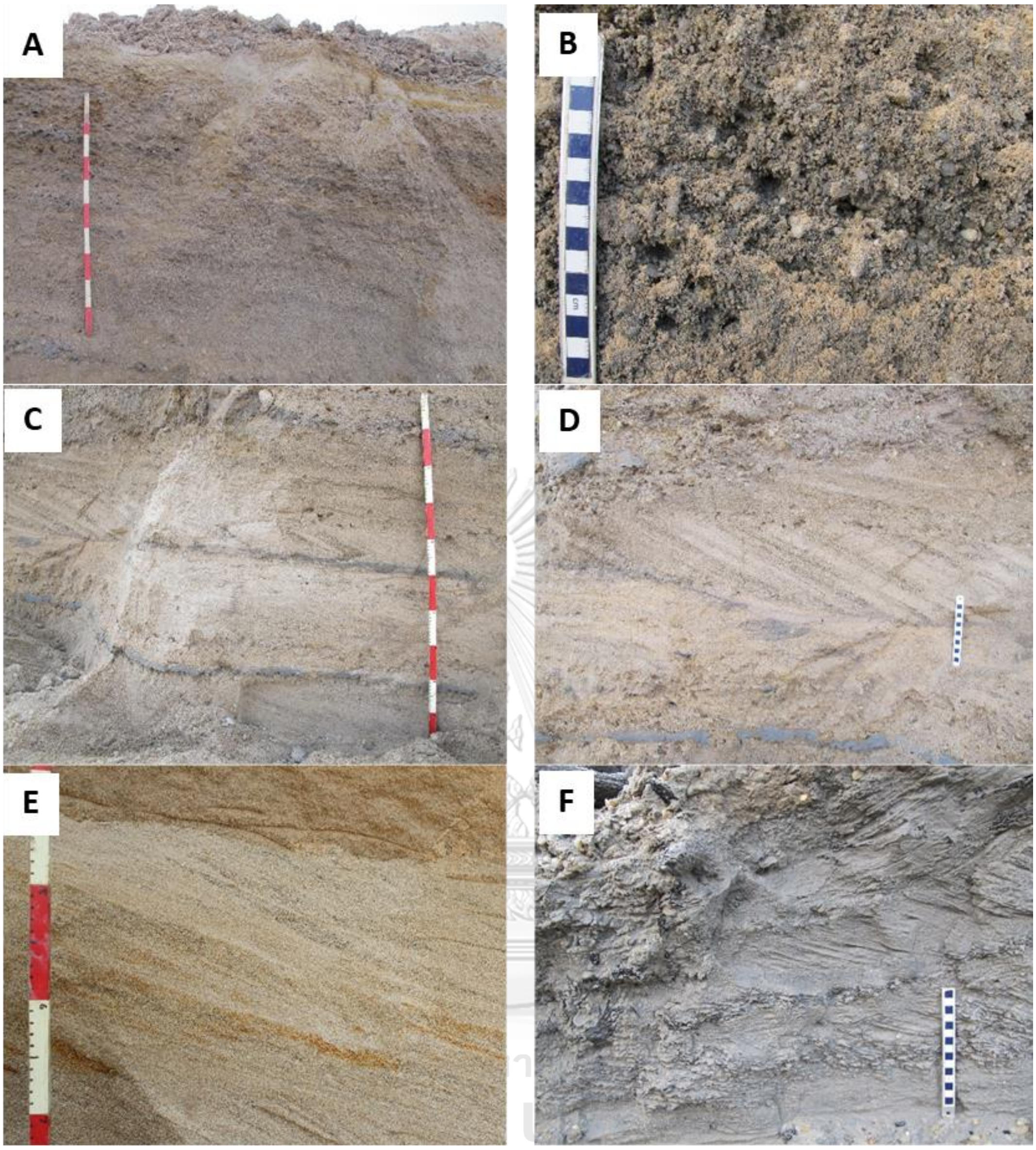

Figure 4. 17 Sedimentary facies recognized in the Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province. (A-B) Matrix-supported gravel (Gmg), (C-F) Ripple Cross-Laminated Sand (Sr).

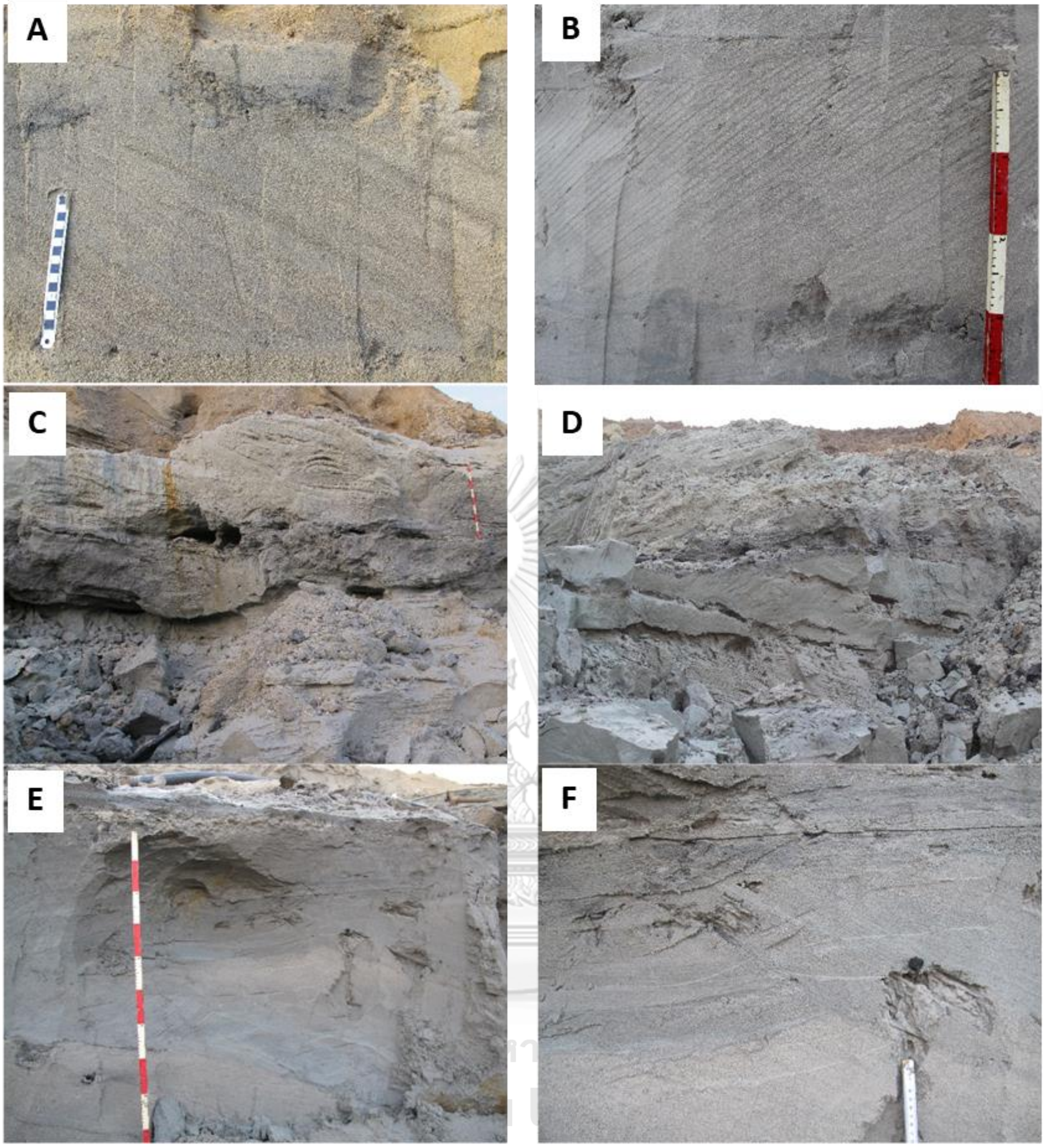

Figure 4. 18 Sedimentary facies recognized in the Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province. (A-B) Planar cross-bedded Sand (Sp), (C-F) Trough cross-bedded sand (St).

Table 4. 12 The summary of the architectural elements formed within channels in Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Element	Code	Lithology	Geometry and relationships
Architectural elements formed within channels, Miall (1985, 1996)			
Sandy bedforms	SB	St, Sp, Sr	Lens, sheet, blanket, wedge, occurs as channel fills, crevasse splays, minor bars
Lateral-accretion macroform	LA	St, Sp, less commonly Gmg	wedge, sheet, lobe; characterized by internal-lateral-accretion 3rd-order surfaces
Overbank fines	FF	Fsm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

Table 4. 13 The summary of the architectural elements of the Overbank Environment in Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Element	Code	Lithology	Geometry	Interpretation
Architectural Elements of the Overbank Environment, Platt and Keller (1992)				
Levee Deposits	LV	Fl	Wedge up to 10 m thick, 3 km wide	Overbank flooding
Crevasse splay	CS	St, Sr, Fl	Lens up to 10x10 km across, 2-6 m thick	Delta-like progradation from crevasse channel into the floodplain
Floodplain Fines	FF	Fsm, Fl	Sheet, maybe many km in lateral, dimensions, 10s of m thick	Deposits of overbank sheet flow, floodplain ponds, and swamps

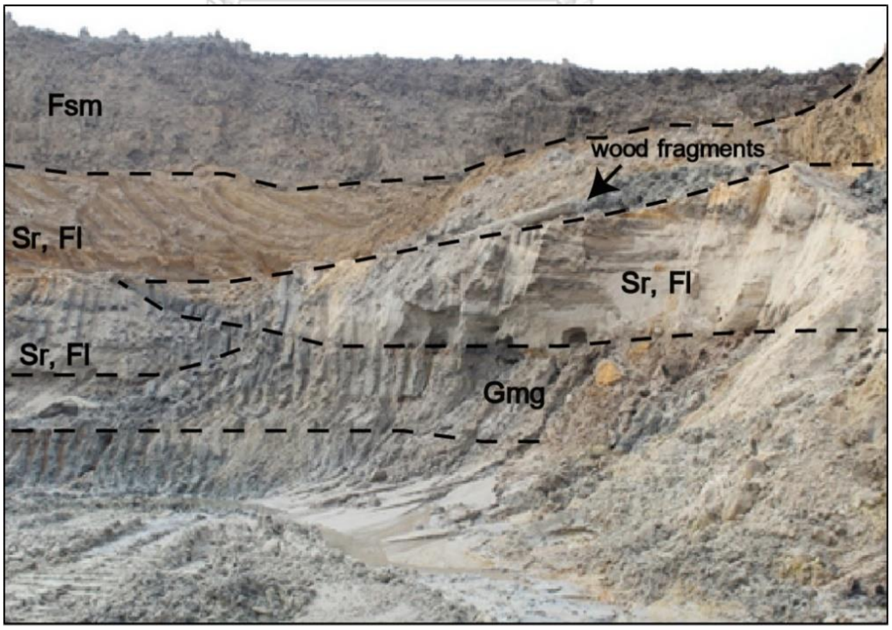

Figure 4. 19 Showing lithofacies of Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

CHAPTER 5

SYSTEMATIC PALEONTOLOGY OF SUID FOSSILS FROM THE CHALOEM PHRA KIAT AND PHIMAI SANDPITS, NAKHON RATCHASIMA PROVINCE

There are thirty-eight specimens of suids that were collected from sandpits in Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province. We describe the tooth morphology and compare them with the various fossil assemblages known from the Indian subcontinent, south China, Myanmar, and Thailand.

Tetraconodon has extremely enlarged premolars, relatively small last molae; thick and highly wrinkled enamel in P3 and P4; DAP’ x DT’ of the P_3 and P_4 about 160 x 150 and about 140 x 150, respectively; *T. minor* is a small *Tetra*conodon, M1 length about 23 mm.; *T. intermedius* is intermediate size, M1 length about 27 mm.; *T. magnus*, is a large *Tetraconodon,* M1 length about 33 mm (Made,1999).

Conohyus is distinguished by the enlargement of the premolars and by the shortness of the last molars. The third and fourth premolars are single cones, the latter having an elevated posterior ridge. The first and second molars have four cusped, with slight anterior and posterior cingula, while the third molar has in addition to the four cusps, a short talon, separated from the body of the tooth by a single median cusp. The first two lower molars are quadricuspid, and the third molar has, in addition to the talonid, two median conules (Pilgrim,1926).

The fourth upper premolar (P^4) of *Propotamochoerus* have two cusplets in the sagittal valley, and no cingula on the buccal or lingual side. The anterior and posterior cusps of premolars are variable. The molar enamel has a moderate thickness, and no cingula. The furchen is shallow, except for occasional basal pillars at the end of median valleys. The talon/talonid of the last molar is relatively simple, and no extra cusp pairs. The mandible has deep and robust following Pickford (1988).

Hippopotamodon is a giant suinae. Molar enamel relatively thin; molars relatively simple with well–developed furchenplan; buccal cusps in lower molars noticeably lower crowned than lingual ones; The premolars have strong and stout. The last premolar has posterior accessory cusp almost as large as two main buccal cusps. The sagittal cusplets present in the central valley between the protocone and the paracone–metacone. The last lower premolar has prominent innenhugel and 2–3–4 cusp., while the anterior cingulum and ac–1 cusp are moderately high following Pickford (1988).

Propotamochoerus, Pilgrim 1926, and *Hippopotamodon* Lydekker, 1877 are different in several aspects. To begin with, the last upper promolar of *Propotamochoerus* has two cusplets in the sagittal valley. On the other hand, the last upper promolar of *Hippopotamodon* has posterior accessory cusp almost as large as two main labial cusps. Also, the last lower promolar of *Propotamochoerus* has variable innenhugel and low to medium hypsodont anterior cusp and cingulum, the the last lower promolar of *Hippopotamodon* prominent innenhugel and 2-3-4 cusp, anterior cingulum and ac-1 cusp moderately high. Third, the molars of *Propotamochoerus* have enamel moderate thickness, and no cingula, and the furechen are shallow. The molar of *Hippopotamodon* are relatively thin, However the furchenplan is well-developed. Finally, the premolars of *Hippopotamodon* have strong and stout, while the premolars of *Propotamochoerus* have anterior and posterior cusp variable.

5.1 Genus *Tetraconodon* Falconer, 1868

SYSTEMATIC PALEONTOLOGY

Order Artiodactyla Owen, 1848

Family Suidae Gray, 1821

Subfamily Tetraconodontinae Lydekker, 1876

Genus ***Tetraconodon*** Falconer, 1868

Generic diagnosis: Tetraconodontinae with extremely enlarged P3 and P4 and relatively small M3. DAP' x DT' of the P_3 and P_4: approximately 160 x 150 and approximately140 x 150, respectively from Made, 1999.

Type species: *Tetraconodon magnum* Falconer, 1868

Other species in the species:

Tetraconodon minor Pilgrim, 1926

Tetraconodon intermedius Made, 1999

Tetraconodon intermedius Thaung Htike et al. 2005

Tetraconodon malensis Thaung Htike et al. 2005

Tetraconodon irramagnus Thaung Htike et al. 2007

Tetraconodon irramedius Thaung Htike et al. 2007

Abbreviations used:

CUF–MB	Chulalongkorn University Fossils collection, Mae Lae Butra
D_4	fourth lower deciduous
P_3–P_4	third to fourth lower premolar
P^3–P^4	third to fourth upper premolar
M^1–M^2	first to second upper molar
M^1–M^3	first to third upper molar
r	right
l	left

Tetraconodon cf. *intermedius* Made, 1999

Figures 5.1 – 5.13

Tetraconodon intermedius Made 1999, p. 203–205.

Tetraconodon intermedius Thaung Htike et al., 2005, p. 247–248.

Tetraconodon mirabilis Pilgrim, 1926, p.16, pl. 3, fig. 4.

Tetraconodon cf. *mirabilis* Pilgrim, 1926, p. 16–17, pls. 4 & 6.

Materials:

1. CUF–MB–31, left P^3 from Phimai District, Nakhon Ratchasima Province.
2. CUF–MB–32, right P^3 from PhimaiDistrict, Nakhon Ratchasima Province.
3. CUF–MB–33, right P^4 from PhimaiDistrict, Nakhon Ratchasima Province.
4. CUF–MB–34, left P^4 from Phimai District, Nakhon Ratchasima Province.
5. CUF–MB–35, left P_4 from Phimai District, Nakhon Ratchasima Province.
6. CUF–MB–36, right P_4 from Phimai District, Nakhon Ratchasima Province.
7. CUF–MB–37, right P_3 from Phimai District, Nakhon Ratchasima Province.
8. CUF–MB–40, right M^1 from Phimai District, Nakhon Ratchasima Province.
9. CUF–MB–42, left maxillary fragment with M^1–M^2 from Phimai District, Nakhon Ratchasima Province.
10. CUF–MB–43, right M^1 from Phimai District, Nakhon Ratchasima Province.
11. CUF–MB–44, left M^3 from Phimai District, Nakhon Ratchasima Province.
12. CUF–MB–45, right M^3 from Phimai District, Nakhon Ratchasima Province.
13. PPN01–000151, left mandibular fragment with D_4 and P_4–M_2 from Phimai District, Nakhon Ratchasima Province.
14. PPN01–000166, left mandibular fragment with P_3–P_4 from Phimai District, Nakhon Ratchasima Province.

Diagnosis: *Tetraconodon* of intermediat size, M1 length about 27 mm (Made, 1999).

Holotype: IM B 675, a fragmentary skull with right and left P^3–M^3

Type locality: Jammu

Description:

The lower third premolar (P_3) of specimens no. PPN01–000166 (Figure 5.1) and CUF–MB–37 (Figure 5.2 (A–C)) are conical. They are distinctly larger than P_4, and the distal part is broader than in their mesial part. The protoconid is largest and located at the center of the crown. It is short and small grooves. The metaconid is close to the distal part of the protoconid and almost fused with the protoconid. The hypoconid is located on the most distal part of the crown. The anterior prestylid and precristid are distinct.

The lower fourth premolar (P_4) of specimen no. PPN01–000166 (Figure 5.1), CUF–MB–36 (Figure 5.2 (D–F)), CUF–MB–35 (Figure 5.2 (G–I)) and PPN01–000151 (Figure 5.3 (A–C)) are enlarged and rugose. The protoconid is larger and taller than M_1. The distal part is broader than its mesial part. The metaconid is well identified and located on the distal part of the protoconid. The hypoconid is well develpoed, with short and small grooves on its buccal and lingual sides. The anterior precristid and prestylid are distinct. The enamel is thick and strongly wrinkled.

The lower first to second molar (M_1–M_2) of specimen no. PPN01–000151 (Figure 5.3 (A–C)) and CUF–MB–43 (Figure 5.3 (D–F)) are almost rectangular in occlusal view with four main cusps comprising the protoconid, metaconid, hypoconid, and entoconid. Furchen is distinct. The first lobe is longer and broader than the second lobe. The protopreconulid, hypopreconulid and pentapreconulid are present.

The upper third premolar (P^3) of specimen no. CUF–MB–31 (Figure 5.4 (A–C)) and CUF–MB–32 (Figure 5.5 (A–C)) are triangular in occlusal view. It is longer than broad. The paracone is the main cusp and located at the center of the crown. The precristid is well developed. The metacone is distinctly separated from the paracone and is located next to it. The anterior and posterior cingula are distinct and surround the crown. The enamel is thick and wrinkled.

The upper fourth premolar P^4 of specimen no. CUF–MB–33 (Figure 5.4 (D–F)) and CUF–MB–34 (Figure 5.5 (D–F)) have wrinkled enamel and are broader than long. It is larger than M^1. They have three main cusps consisting of the paracone, metacone, and protocone. The protofossa will separate the protocone and the paracone, but It is not well expressed. The anterior cingulum and posterior cingulum are distinct and surround the crown continuously. The enamel is thick and highly wrinkled.

The upper first to second molar (M^1–M^2) of specimen no. CUF–MB–42 (Figure 5.4 (G–I)) and CUF–MB–40 (Figure 5.5 (G–I)) are almost rectangular in occlusal view. They have four main cusps comprising the paracone, metacone, protocone, and tetracone. The protopreconule and tetrapreconule are distinct in M^2 whereas they are weak in M^1. The pentacone is absent. The median valley is deep. M^1 is smaller than M^2.

The upper third molar (M^3) of specimens no. CUF–MB–44 (Figure 5.4 (J–L)) and CUF–MB–45 (Figure 5.5 (J–L)) are triangular in occlusal view. The two anterior lobes are similar in morphology to those of M^1–M^2. Also, they are small minor cuspid. The pentacone is small. The anterior and posterior cingulum are distinct but less developed than those of premolars.

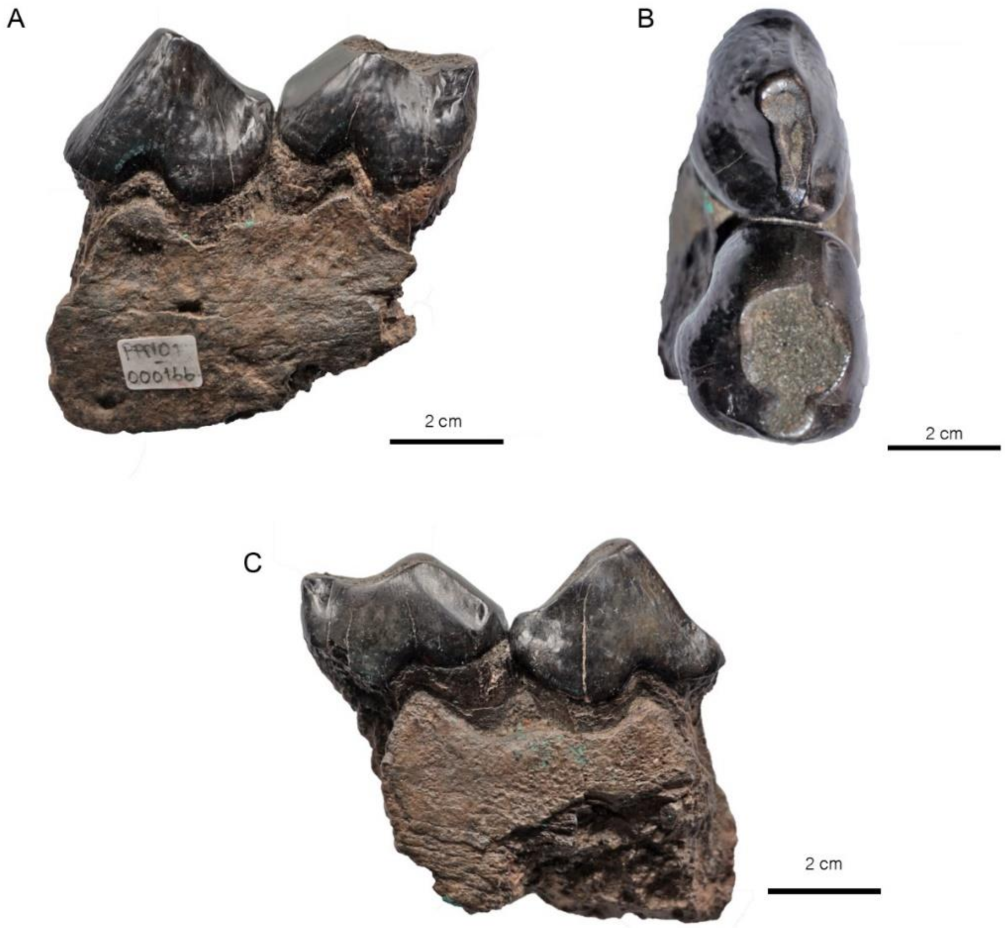

Figure 5. 1 Lower cheek teeth of *Tetraconodon* cf. *intermedius* from the Phimai District, Nakhon Ratchasima Province. A–C, PPN01–000166, left mandibular fragment with P_3–P_4: A, lingual view; B, occlusal view; C, buccal view.

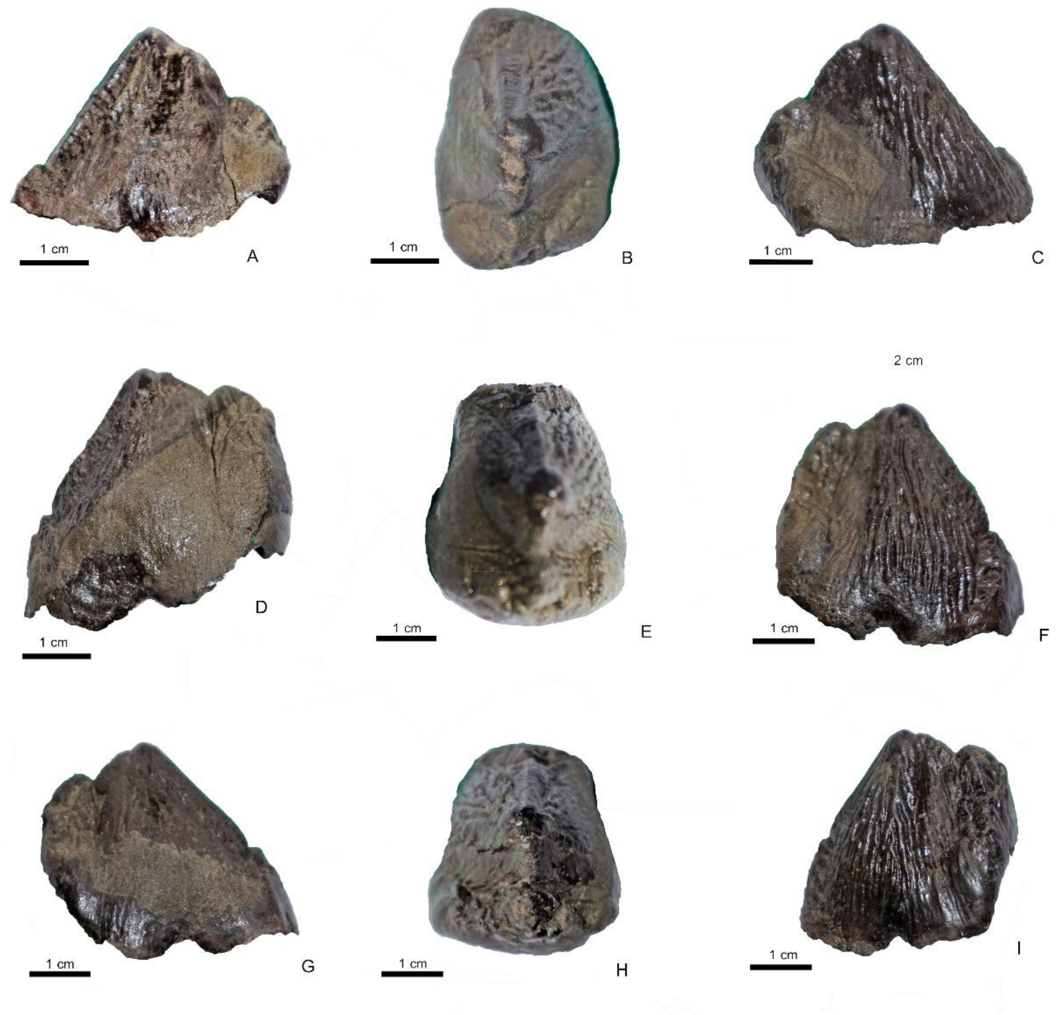

Figure 5. 2 Lower cheek teeth of *Tetraconodon* cf. *intermedius* from the Phimai District, Nakhon Ratchasima Province. A–C, CUF–MB–37, right P_3: A, lingual view; B, occlusal view; C, buccal view. D–F, CUF–MB–36, right P_4: D, lingual view; E, occlusal view; F, buccal view. G–I, CUF–MB–35, left P_4: G, lingual view; H, occlusal view; I, buccal view.

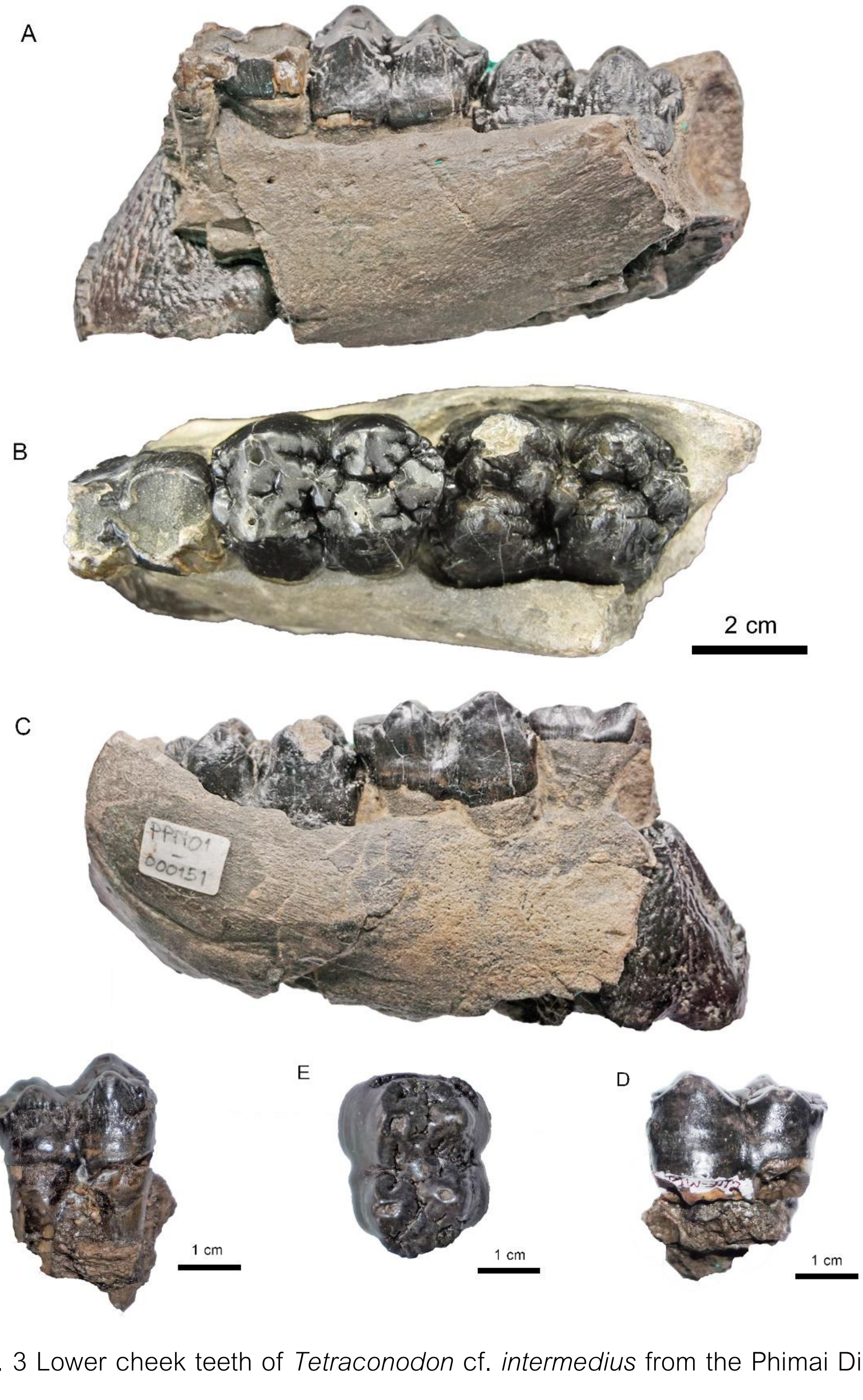

Figure 5. 3 Lower cheek teeth of *Tetraconodon* cf. *intermedius* from the Phimai District, Nakhon Ratchasima Province. A–C, PPN01–000151, left mandibular fragment with D_4 and P_4–M_2: A, lingual view; B, occlusal view; C, buccal view. D–F, CUF–MB–43, right M_1: D, lingual view; E, occlusal view; F, buccal view.

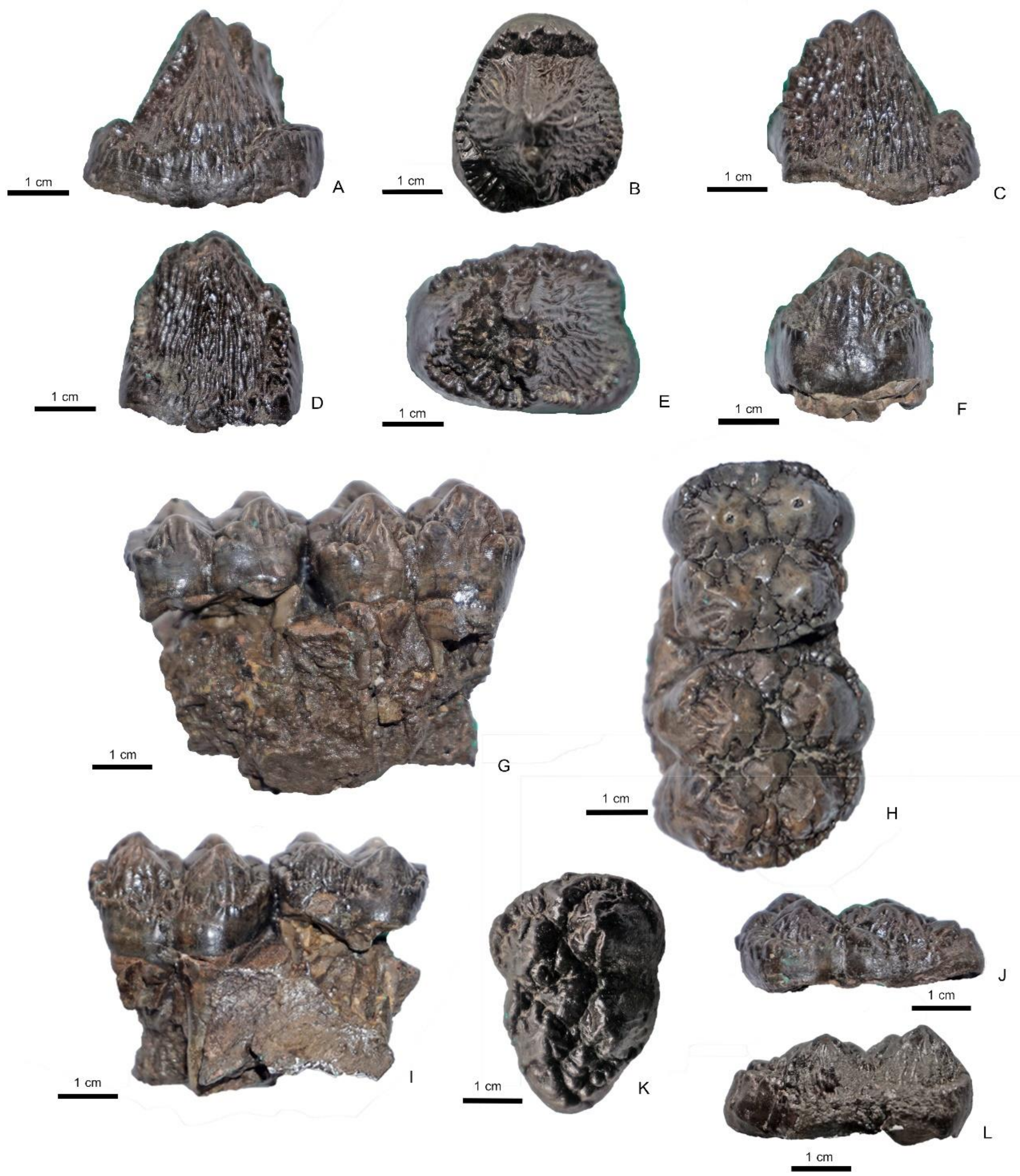

Figure 5. 4 Upper cheek teeth of *Tetraconodon* cf. *intermedius* from the Phimai District, Nakhon Ratchasima Province. A–C, CUF–MB–31, left P^3: A, lingual view; B, occlusal view; C, buccal view. D–F, CUF–MB–33, left P^4: D, lingual view; E, occlusal view; F, buccal view. G–I, CUF–MB–42, left maxillary fragment with M^1–M^2: G, lingual view; H, occlusal view; I, buccal view. J–L, CUF–MB–44, left M^3: J, lingual view; K, occlusal view; L, buccal view.

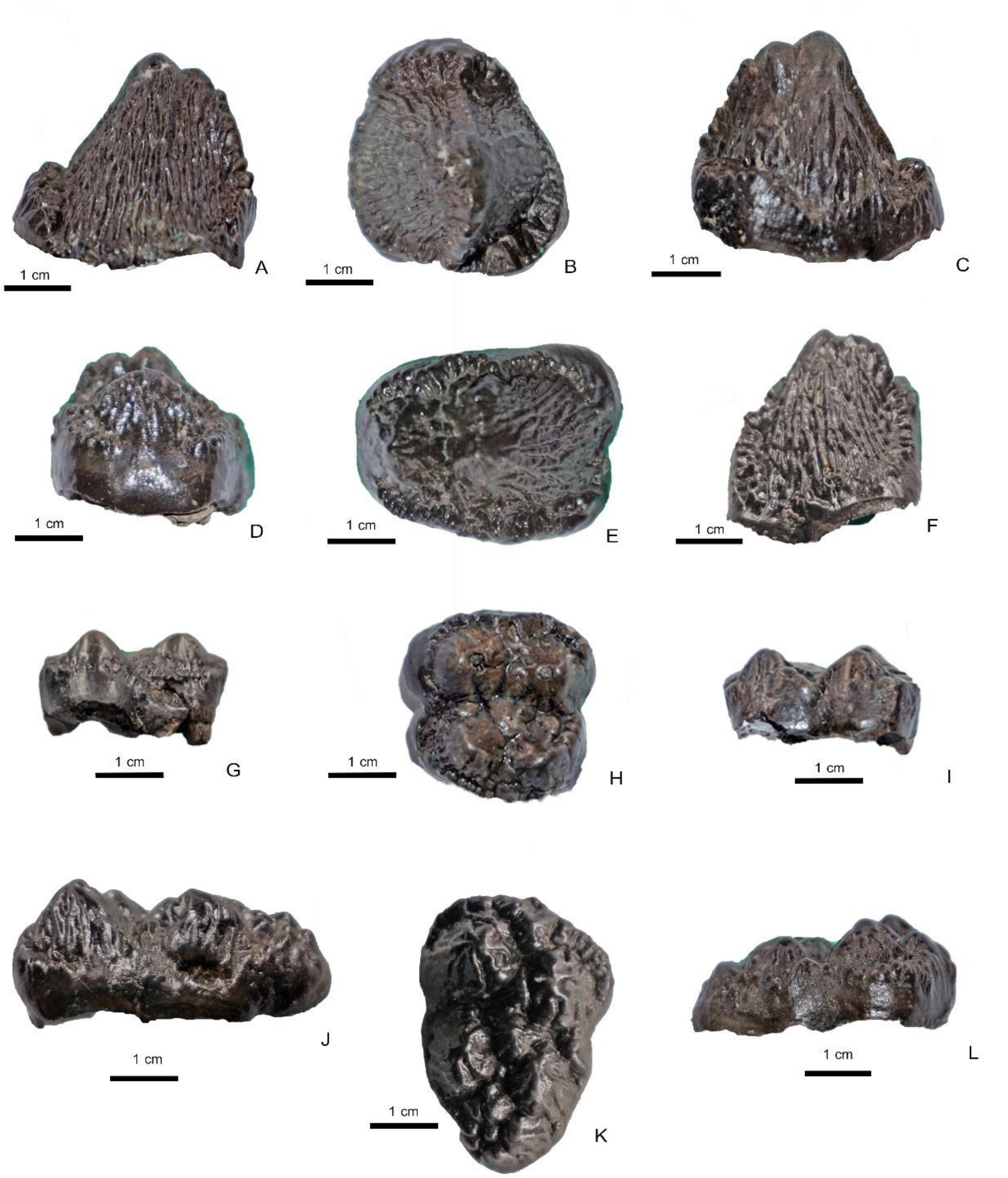

Figure 5. 5 Upper cheek teeth of *Tetraconodon* cf. *intermedius* from the Phimai District, Nakhon Ratchasima Province. A–C, CUF–MB–32, right P^3: A, buccal view; B, occlusal view; C, lingual view. D–F, CUF–MB–34, right P^4: D, buccal view; E, occlusal view; F, lingual view. G–I, CUF–MB–40, right M^1: G, buccal view; H, occlusal view; I, lingual view. J–L, CUF–MB–45, right M^3: J, buccal view; K, occlusal view; L, lingual view.

Table 5. 1 Measurements (in mm) of the upper of the *Tetraconodon* cf. *intermedius* from Phimai District, Nakhon Ratchasima Province.

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
CUF–MB–32	rP^3	33.68	22.15	31.89	–
CUF–MB–33	lP^4	28.23	–	36.45	–
CUF–MB–40	rM^1	26.51	26.29	21.36	–
CUF–MB–45	rM^3	40.04	28.33	24.20	17.62
CUF–MB–31	lP^3	33.65	20.04	30.07	–
CUF–MB–34	rP^4	28.01	–	36.65	–
CUF–MB–42	lM^1	26.24	27.14	23.76	–
CUF–MB–42	lM^2	30.48	29.12	31.48	–
CUF–MB–44	lM^3	39.86	28.94	24.03	16.40

DAP (L), Anteroposterior or length of cheek teeth; **DTa (W1)**, Width of the anterior lobe of cheek teeth; **DTp (W2)**, Transverse diameter (width) of the second lobe of cheek teeth; **DTpp (W3)**, Width of the third lobe.

Table 5. 2 Measurements (in mm) of the lower of the *Tetraconodon* cf. *intermedius* from Phimai District, Nakhon Ratchasima Province.

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
CUF–MB–37	rP_3	36.52	20.88	24.98	–
CUF–MB–36	rP_4	36.98	25.46	31.23	–
CUF–MB–35	lP_4	37.02	25.02	30.85	–
PPN01–000166	lP_3	35.16	18.39	24.61	–
PPN01–000166	lP_4	31.79	21.47	27.77	–
PPN01–000151	lD_4	>19.04	>15.96	15.89	–
PPN01–000151	lP	36.56	27.05	31.55	–
PPN01–000151	lM_1	27.85	21.92	21.37	–
PPN01–000151	lM_2	32.55	23.29	20.44	–
CUF–MB–43	rM_1	27.03	21.56	20.54	–

DAP (L), Anteroposterior or length of cheek teeth; **DTa (W1)**, Width of the anterior lobe of cheek teeth; **DTp (W2)**, Transverse diameter (width) of the second lobe of cheek teeth; **DTpp (W3)**, Width of the third lobe.

Table 5. 3 Comparison of the upper premolar and molar of the *Tetraconodon* cf. *intermedius* from Phimai District, Nakhon Ratchasima Province with related suids (in mm).

	P^3		P^4		M^1		M^2		M^3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
CUF–MB–32	33.7	31.9	–	–	–	–	–	–	–	–
CUF–MB–31	33.7	30.0	–	–	–	–	–	–	–	–
CUF–MB–33	–	–	28.2	36.5	–	–	–	–	–	–
CUF–MB–34	–	–	28.0	36.7	–	–	–	–	–	–
CUF–MB–40	–	–	–	–	26.5	26.3	–	–	–	–
CUF–MB–42	–	–	–	–	26.2	27.1	30.5	31.5		
CUF–MB–45	–	–	–	–	–	–	–	–	40.0	28.3
CUF–MB–44	–	–	–	–	–	–	–	–	39.9	28.9
T. irramagnus,YUDG–Mge 089 [1]	39.1	38.2	29.0	47.1	31.6	32.2	35.9	37.1	–	34.2
T. irramagnus,YUDG–Mge 091 [1]	–	–	–	–	–	–	35.2	36.98	39.0	34.3
T. irramedius, NMMP–KU–IR0225[1]	33.4	34.1	24.4	37.2	26.7	27.7	30.6	32.6	33.3	26.8
T. magnus[2]	–	–	–	–	–	–	–	–	52	37.6
T. malensis, YUDG–N1[3]	–	–	–	–	14.1	15.2	14.5	16.5	16.2	15.3
T. malensis, YUDG–N1[3]	20.4	15.1	13.5	17.9	13.8	14.1	14.8	15.5	16.7	14.3
C. sindiense, Amer.Mus.No.19739[4]	16	16.3	11.5	17.5	12.8	16.5	18	18	20	17
T. magnus Ind. Mus. B 675[5]	47	40	34	49	26	31	30	33	40	32
T. intermedius, GSI B 675[6]	46.5	41.4	37.4	49.4	26.0	27.5	31.1	35.8	43.0	32.0

*The studied specimens; 1 Thaung Htike et al., 2007; 2 Falconer 1868; 3 Thaung Htike et al., 2008; 4 Colbert 1933; 5 Colbert 1935; 6 Made 1999; DAP, length of premolar and molar; DT maximum width of a cheek tooth.

Table 5. 4 Comparison of the lower premolar and molar of the *Tetraconodon* cf. *intermedius* from Phimai District, Nakhon Ratchasima Province with related suids (in mm).

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
CUF–MB–37*	36.5	25.0	–	–	–	–	–	–	–	–
CUF–MB–36*	–	–	36.9	31.2	–	–	–	–	–	–
CUF–MB–35*	–	–	37.0	30.9	–	–	–	–	–	–
CUF–MB–43*	–	–	–	–	27.0	21.6	–	–	–	–
PPN01–000166*	35.2	24.6	31.8	27.8	–	–	–	–	–	–
PPN01–000151*	–	–	36.6	31.6	27.9	21.9	32.6	23.3		
T. irramedius, NMM 839/80[1]	–	–	37.7	37.4	26.5	25.8	31.6	30.4	43.8	28.0
T. minor, GSI B 711[1]	–	–	34.6	31.1	24.0	20.4	–	–	–	–
T. minor, NMM AN–1[1]	–	–	30.8	29.3	23.3	22.0	26.3	24.4	–	–
T. malensis, NMM KPG–1[1]	–	–	18.2	16.5	13.9	12.2	–	–	–	–
C. indicus, GSI B 710[1]	–	–	16.6	11.8	16.6	12.6	–	–	–	–
C. indicus[2]	24.4	16.2	17.2	15.7	17.3	13.0	–	–	–	–
C. sindiense, Amer,Mus,19739[3]	18	14	16	15	14	11.7	18	15	26	14.7
C. thailandicus, TF2577[4]	24	16.3	19.5	15.8	14.5	13.3	16.6	13	19.3	13.5
C. thailandicus[5]	–	–	19	16	15	11	16	13	15	11
T. magnus, A. M. 9937[5]	58	49	49.5	56.5	30	29	36.5	32	48.5	32
T. magnus, GSI B 71[5]			53.4	56.4	31.1	28.7	–	–	–	–

*The studied specimens; 1 Thaung Htike et al., 2007; 2 Falconer 1868; 3 Thaung Htike et al., 2008; 4 Ducrocq et al., 1997; 5 Colbert 1935; DAP, length of premolar and molar; DT maximum width of a cheek tooth.

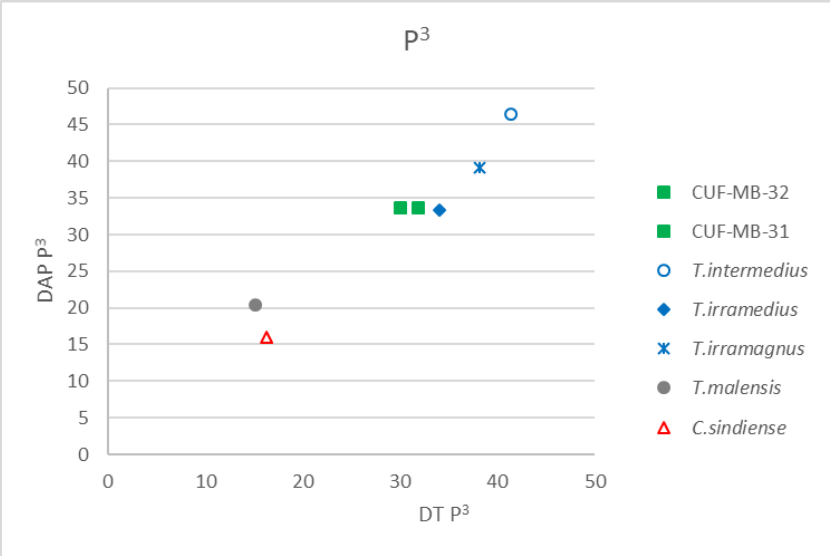

Figure 5. 6 Bivariate plot (DAP versus DT) for the P^3 of *Tetraconodon* cf. *intermedius* specimen no. CUF – MB – 31, and CUF – MB – 32 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

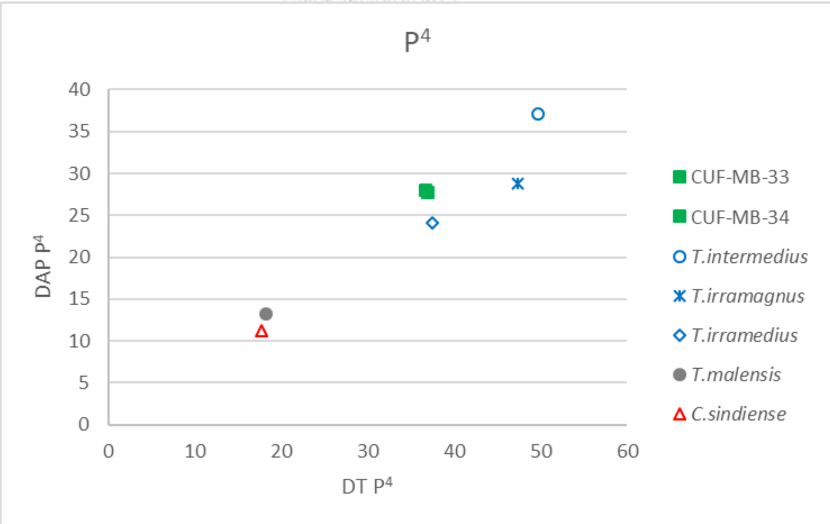

Figure 5. 7 Bivariate plot (DAP versus DT) for the P^4 of *Tetraconodon* cf. *intermedius* specimen no. CUF – MB – 33, and CUF – MB – 34 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

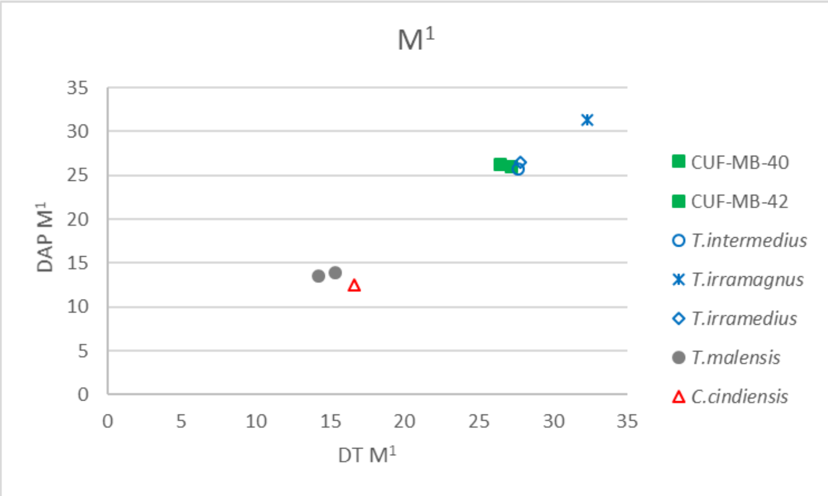

Figure 5. 8 Bivariate plot (DAP versus DT) for the M^1 of *Tetraconodon* cf. *intermedius* specimen no. CUF – MB – 40, CUF – MB – 42 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

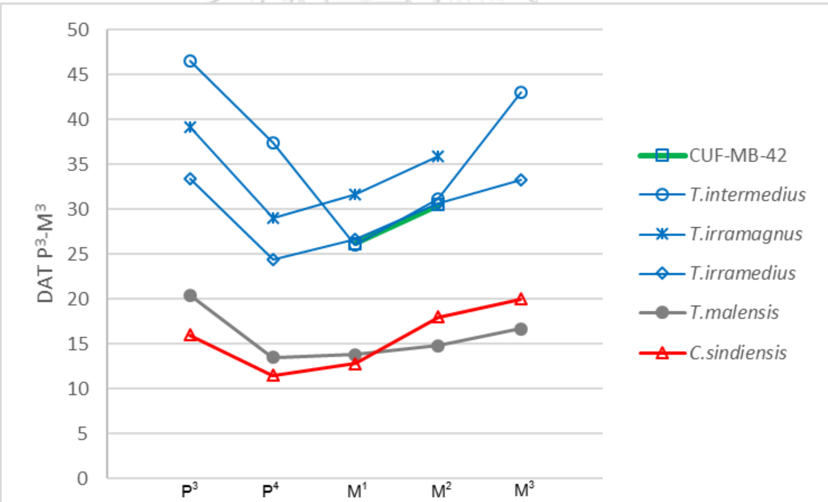

Figure 5. 9 Relative length of lower cheek tooth sizes from P^3–M^3 of *Tetraconodon* cf. *intermedius* from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

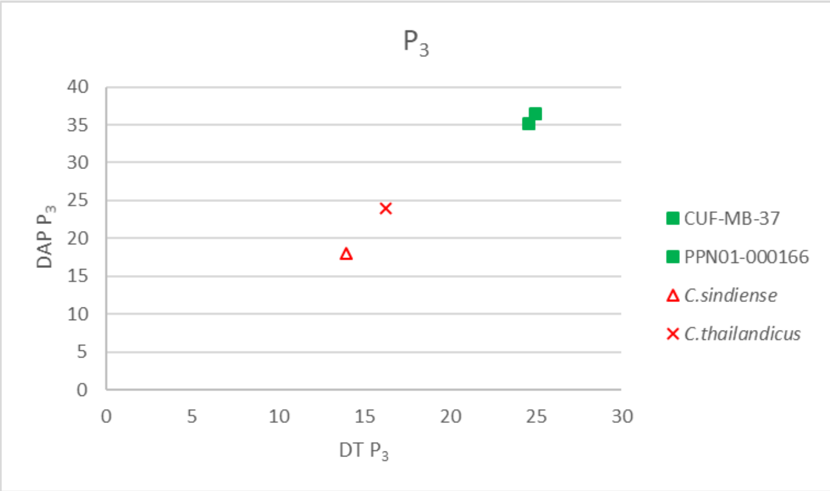

Figure 5. 10 Bivariate plot (DAP versus DT) for the P_3 of *Tetraconodon* cf. *intermedius* specimen no. PPN01–000166 and CUF – MB – 37 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studied specimens and other symbols with different colors from the previous studies.

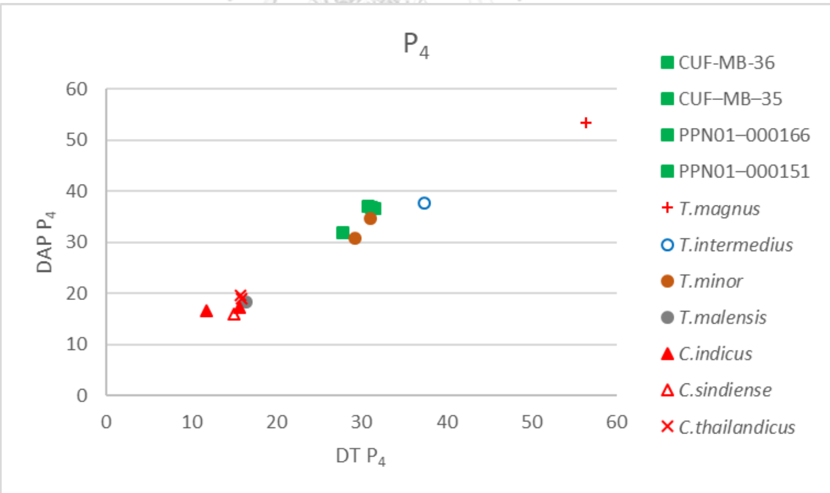

Figure 5. 11 Bivariate plot (DAP versus DT) for the P_4 of *Tetraconodon* cf. *intermedius* specimen no. PPN01–000166 and CUF – MB – 35; CUF – MB – 36; PPN01–000151 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studied specimens and other symbols with different colors are from previous studies.

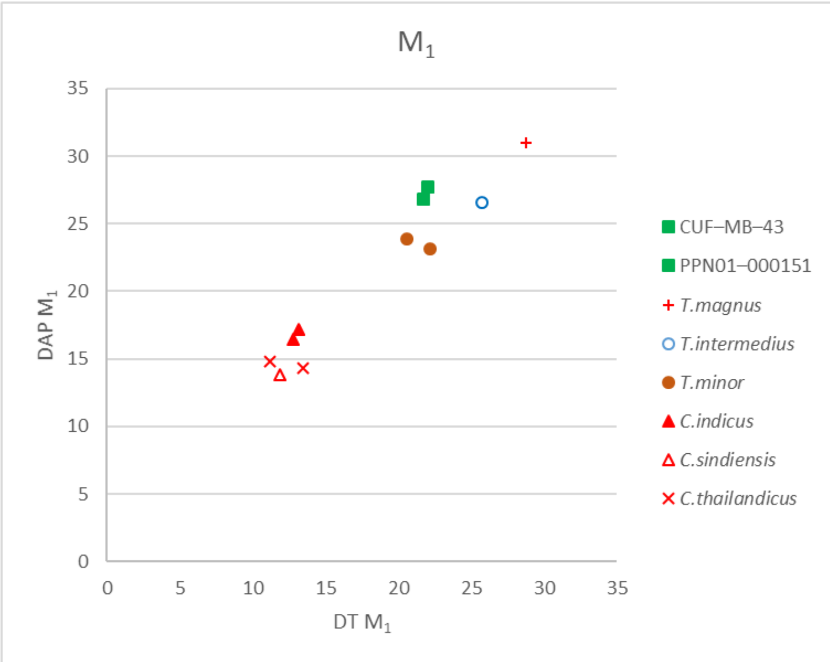

Figure 5. 12 Bivariate plot (DAP versus DT) for the M_1 of *Tetraconodon* cf. *intermedius* specimen no. PPN01–000151 and CUF – MB – 43 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studied specimens and other symbols with different colors are from previous studies.

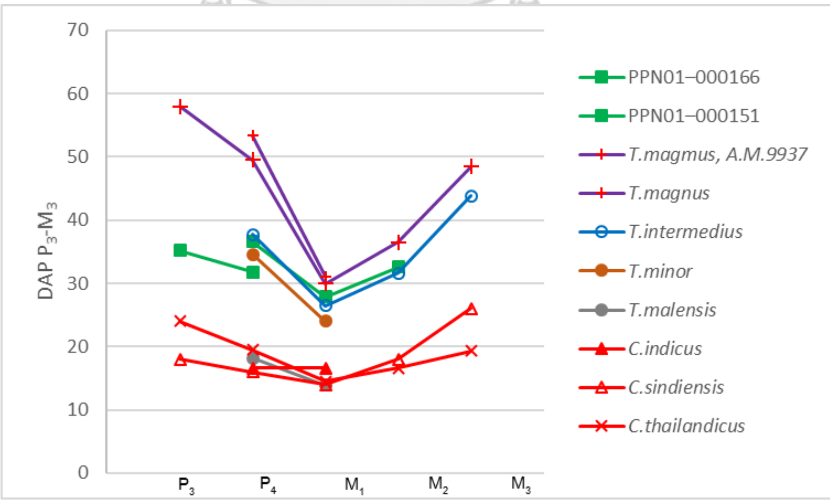

Figure 5. 13 Relative length of lower cheek tooth from P_3–M_3 of *Tetraconodon* cf. *intermedius* from Phimai District, Nakhon Ratchasima Province in comparison with other related species.

5.2 Genus *Conohyus* Pilgrim, 1925

SYSTEMATIC PALEONTOLOGY

Order Artiodactyla Owen, 1848

Family Suidae Gray, 1821

Subfamily Tetraconodontinae Lydekker, 1876

Genus *Conohyus* Pilgrim, 1926

Diagnosis: Made (1999), relatively small suids, not very elongate and simple M^3; Third lobe of the M_3 with large pentaconid and no, or a small, hexaconid; M_3, DAP' about 140–200, Index (I) about 160–190.

Abbreviations used:

CUF–TKK	Chulalongkorn University Fossils, Takut Khon sandpit
PPN	Prasert Prasarttong–Osoth Natural, Origin of life museum of Sukhothai Airport (pri-vatemuseum), Thailand
P_3–P_4	third to fourth lower premolar
M_1–M_3	first to the third lower molar
r	right
l	left

Conohyus cf. *sindiense*, Pilgrim, 1926

Figures 5.14 – 5.22

Materials:

1. CUF–TKK–5, mandibular with left and right P_3–M_3 and right alveoli of C and P_1–P_2 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.
2. CUF–TKK–7, right mandibular fragment with P_4–M_2 and alveoli of P_3 P_2 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.
3. CUF–TKK–12, right mandibular fragment with P_4–M_3 and alveoli of P_2–P_3 P_2 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.
4. CUF–TKK–10, right mandibular fragment with P_3–M_3 P_2 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.

5. PPN01–000107, left mandible fragment with M_1 and M_3 from Phimai District, Nakhon Ratchasima Province.
6. PPN01–000108, left mandibular fragment with P_3– P_4 from Phimai District, Nakhon Ratchasima Province.

Description:

The third lower premolar (P_3) of specimen no. CUF–TKK–5 (Figure 5.15 (A–C)), CUF–TKK–10 (Figure 5.16 (A–C)), and PPN01-000108 (D-F) are similar and higher than the P_4 and are conical in occlusal view. The distal part is broader than the mesial part. The protoconid is larger and located in the center of the crown. The metaconid is absent because it is worn. The hypoconid is tiny and displays small grooves. The anterior crowns of P_3 and P_4 are worn. The enamel is weakly wrinkled.

The fourth lower premolar (P_4) of specimen no. CUF–TKK–5 (Figure 5.15 (A–C)), CUF–TKK–10 (Figure 5.16 (A–C)), CUF–TKK–12 (Figure 5.14 (A–C)), and PPN01-000108 (D-F) are relatively enlarged and taller than M_1. The tip of the protoconid is worn and located at the center of the crown. The metaconid is absent due to wear. The hypoconid is slightly worn and located on the distal part of the crown. The anterior precristid and prestylid are distinct. The enamel is weakly wrinkled.

The first to second lower molar (M_1– M_2) of specimen no. CUF–TKK–5 (Figure 5.14 (A–C)), CUF–TKK–7 (Figure 5.14 (D–F)), CUF–TKK–10 (Figure 5.16 (A–C)), and CUF–TKK–12 (Figure 5.14 (A–C)) are almost rectangular in occlusal view. They are narrower and shorter than the premolars. They have four main cusps composed of the protoconid, metaconid, hypoconid, and entoconid. The small M_1 is worn. Furchen is indistinct. The anterior lobe is wider than the posterior lobe. The cingulum can be observed on both the mesial and distal faces. The hypoconid and pentaconid are distinct. The protopreconulid is weekly developed. The hypoectoconulid is small. The anterior cingulum and posterior cingulum are small and distinct. The enamel is thick.

The third lower molar (M_3) of specimen no. CUF–TKK–5 (Figure 5.15 (A–C)), CUF–TKK–7 (Figure 5.14 (D–F)), CUF–TKK–10 (Figure 5.16 (A–C)), CUF–TKK–12 (Figure 5.15 (A–C)), and PPN01–000107 (Figure 5.16 (G-H)) are triangular in occlusal view. The trigonid is broader than the talonid. The buccal wall of the crown is curved, and the lingual wall is straight. In addition, M_3 has a pentaconid. The pentapreconulid is well developed but is smaller than the hypopreconuid. Small accessory cusplets are present in the anterior lingual part of the pentaconid. The hypoectoconulid and pentaectoconulid are small.

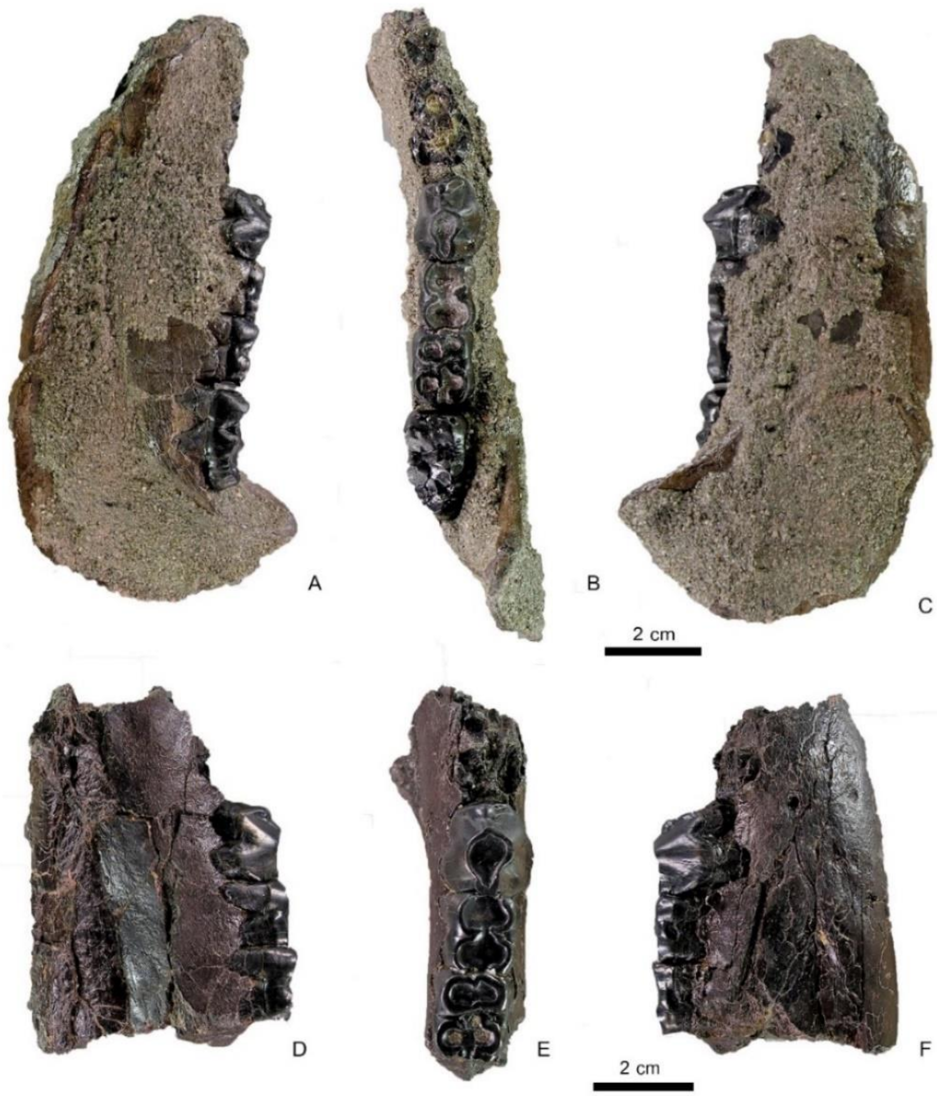

Figure 5. 14 Lower cheek teeth of *Conohyus* cf. *sindiense* from the Chaloem Phra Kiat District, Nakhon Ratchasima Province. A–B, CUF–TKK–12, right mandibular fragment with P_4–M_3 and alveoli of P_2–P_3: A, lingual view; B, occlusal view; C, buccal view.; D–F, CUF–TKK–7, right mandibular fragment with P_4–M_2 and alveoli of P_3: D, lingual view; E, occlusal view; F, buccal view.

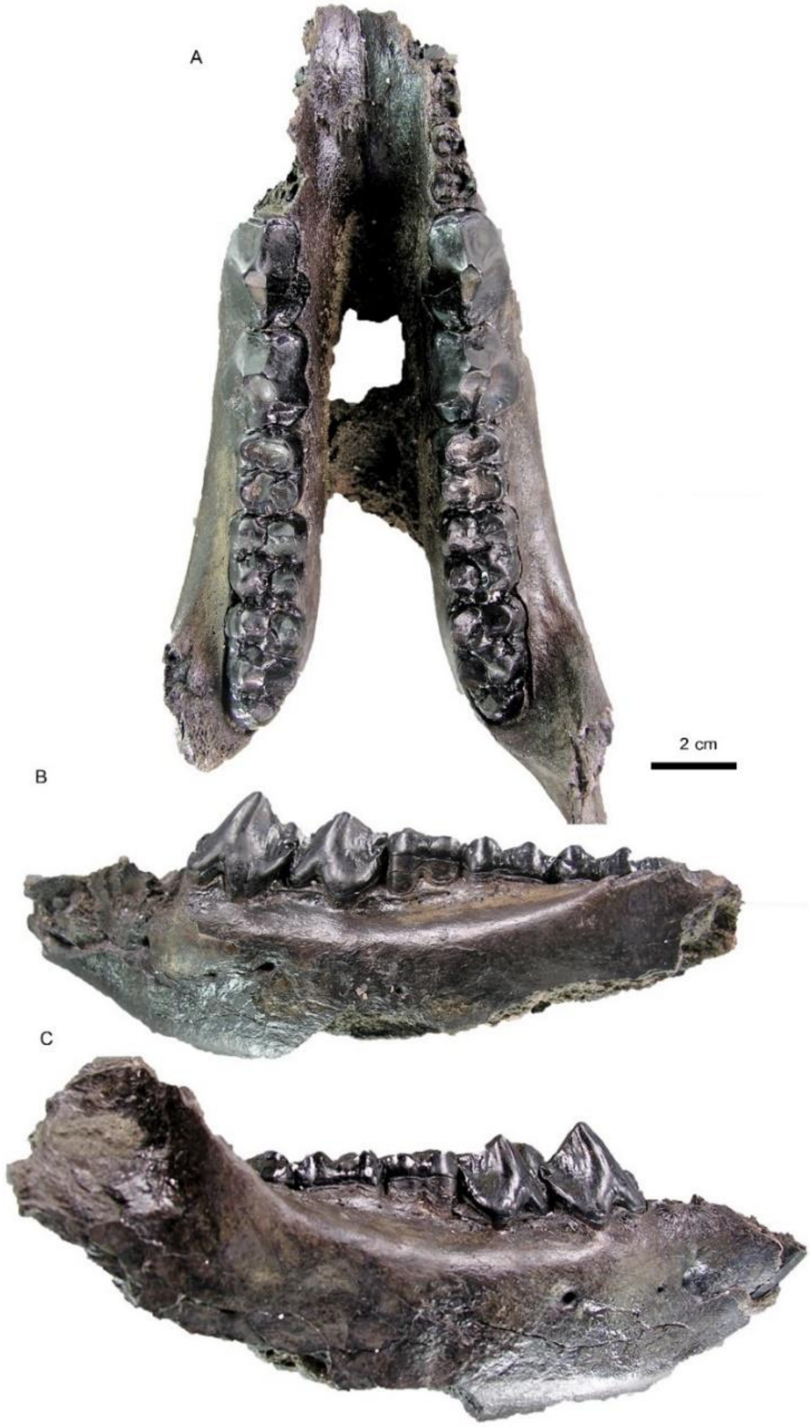

Figure 5. 15 Specimens of *Conohyus* cf. *sindiense* from the Chaloem Phra Kiat District, Nakhon Ratchasima Province. A–C, CUF–TKK–5, mandibular with left and right P_3–M_3 and right alveoli of C and P_1–P_2: A, occlusal view; B, buccal view of left mandible C, buccal view of the right mandible.

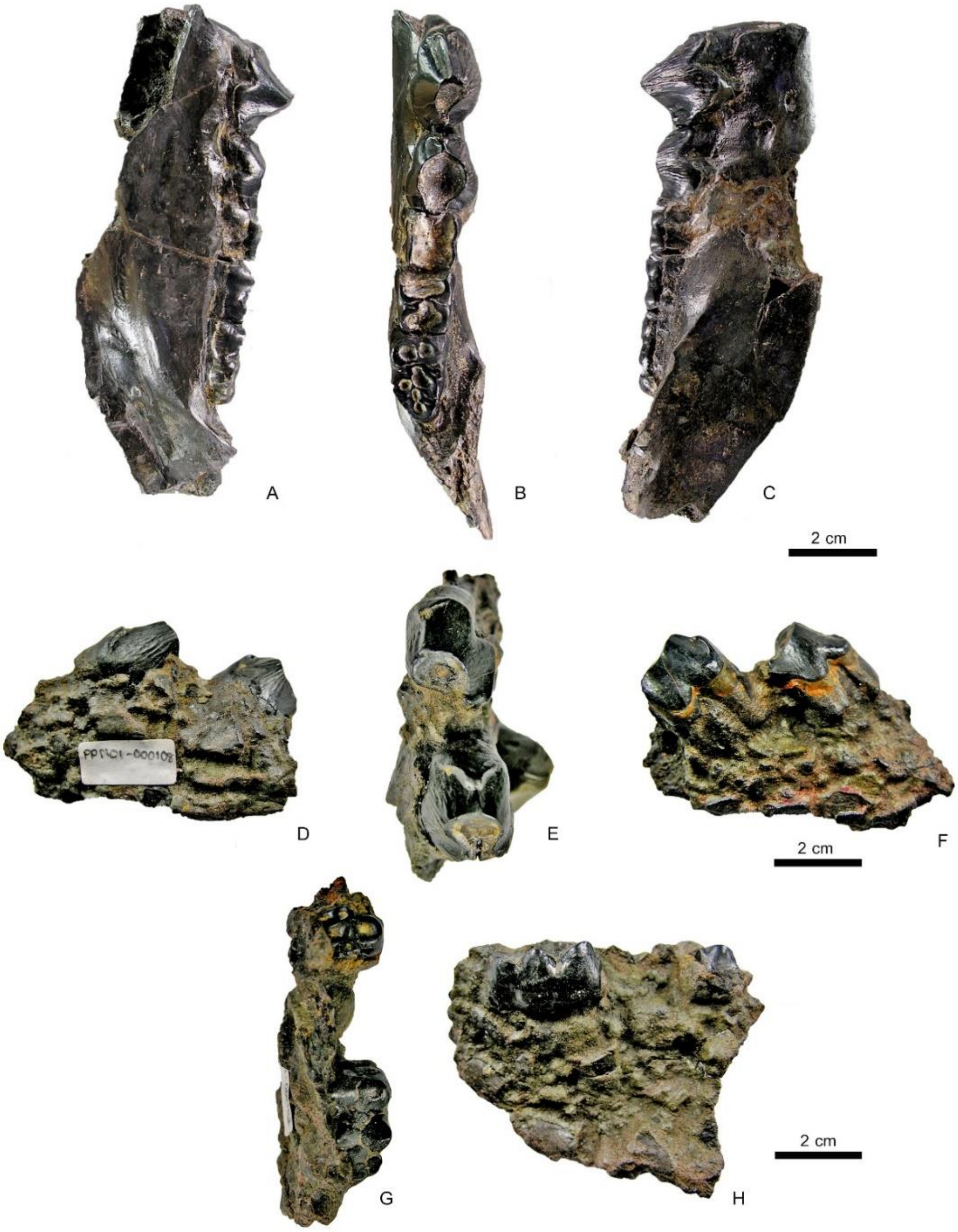

Figure 5. 16 Lower cheek teeth of *Conohyus* cf. *sindiense* from the Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province. A–C, CUF–TKK–10, right mandibular fragment with P_3–M_3: A, lingual view; B, occlusal view; C, buccal view; D–F, PPN01–000108, left mandibular fragment with P_3–P_4: D, buccal view; E, occlusal view; F, lingual view.; G–H, PPN01–000107, left mandibular fragment with M_1 and M_3: G, occlusal view; H, lingual view.

Table 5. 5 Measurements (in mm) of the upper of the *Conohyus* cf. *sindiense* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province.

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
CUF–TKK–5	rP_3	20.24	13.33	16.53	–
CUF–TKK–5	rP_4	17.05	13.65	17.42	–
CUF–TKK–5	rM_1	15.22	12.45	12.15	–
CUF–TKK–5	rM_2	16.97	13.84	13.61	–
CUF–TKK–5	rM_3	22.71	14.62	12.87	8.39
CUF–TKK–5	lP_3	19.84	13.47	15.74	–
CUF–TKK–5	lP_4	17.62	14.07	17.29	–
CUF–TKK–5	lM_1	15.71	12.97	12.22	–
CUF–TKK–5	lM_2	16.54	14.17	13.24	–
CUF–TKK–5	lM_3	23.14	14.55	12.84	8.41
CUF–TKK–7	rP_4	19.48	14.08	18.34	–
CUF–TKK–7	rM_1	14.79	14.06	13.02	–
CUF–TKK–7	rM_2	17.07	14.92	14.01	–
CUF–TKK–12	rP_4	18.38	12.86	15.76	–
CUF–TKK–12	rM_1	13.83	12.15	11.99	–
CUF–TKK–12	rM_2	16.35	13.75	13.37	–
CUF–TKK–12	rM_3	23.47	14.03	12.84	8.57
CUF–TKK–10	rP_3	22.70	13.56	16.94	–
CUF–TKK–10	rP_4	18.30	12.82	16.97	–
CUF–TKK–10	rM_1	12.72	12.72	12.03	–
CUF–TKK–10	rM_2	14.6	13.74	12.09	–
CUF–TKK–10	rM_3	20.5	13.56	11.86	7.60
PPN01–000108	lP_3	19.14	12.54	14.94	–
PPN01–000108	lP_4	17.58	12.68	15.19	–
PPN01–000107	lM_1	>10.33	–	>13.97	–
PPN01–000107	lM_3	22.86	11.17	10.25	5.25

DAP (L), Anteroposterior or length of cheek teeth; **DTa (W1)**, Width of the anterior lobe of cheek teeth; **DTp (W2)**, Transverse diameter (width) of the second lobe of cheek teeth; **DTpp (W3)**, Width of the third lobe.

Table 5. 6 Comparison of the lower premolar and molar of the *Conohyus* cf. *sindiense* from Chaloem Phra Kiat and Phimai Districts with related suids.

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
CUF–TKK–5–R*	20.2	16.5	17.1	17.4	15.2	12.5	16.9	13.8	22.7	14.6
CUF–TKK–5–L*	19.8	15.7	17.6	17.3	15.7	12.9	16.5	14.2	23.1	14.6
CUF–TKK–7*	–	–	19.5	18.3	14.8	14.9	17.1	14.9	–	–
CUF–TKK–12*	–	–	18.4	15.8	13.8	12.2	16.4	14.0	23.5	14.0
CUF–TKK–10*	22.7	16.9	18.3	16.9	12.7	12.7	14.6	13.7	20.5	13.6
PPN01–000108	19.1	14.9	17.6	15.2						
PPN01–000107									22.9	11.2
C. sindiense, Mus. 19739[1]	–	–	16	15	14	11.7	18.0	15.0	26.0	14.7
C. sindiense,AMNH 19386[1]	–	–	16	15	14	13	–	–	–	–
C. sindiense, A.M.19511[1]	20.0	12.5	17.0	13.0	14.0	11.7	16.0	13.0	21.0	13.0
C. sindiense, A.M.19387[1]	21.2	14.2	16.0	14.5						
C. sindiense, A.M.9929[1]			17.0	14.0	12.0	11.0	16.0	13.7	24.5	13.7
C. thailandicus,TF2577[2]	24	16.3	19.5	15.8	14.5	13.3	16.6	13	19.3	13.5
C. thailandicus[3]	–	–	19	16	15	11	16	13	19	11
C. indicus[4]	24.4	16.2	17.2	15.7	17.3	13				
C. indicus, GSI B 710[5]			17	12	17	13				
T. malensis[5]	–	–	18.2	16.5	13.9	12.2	16.7	14.2	20.1	12.5

*The studied specimens from Chaloem Phra Kiat and Phimai Districts; 1 Colbert 1935; 2 Ducrocq et al., 1997; 3 Chavasseau et al., 2006; 4 Pickford & Gupta 2001; 5 Thuang Htike 2005; **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

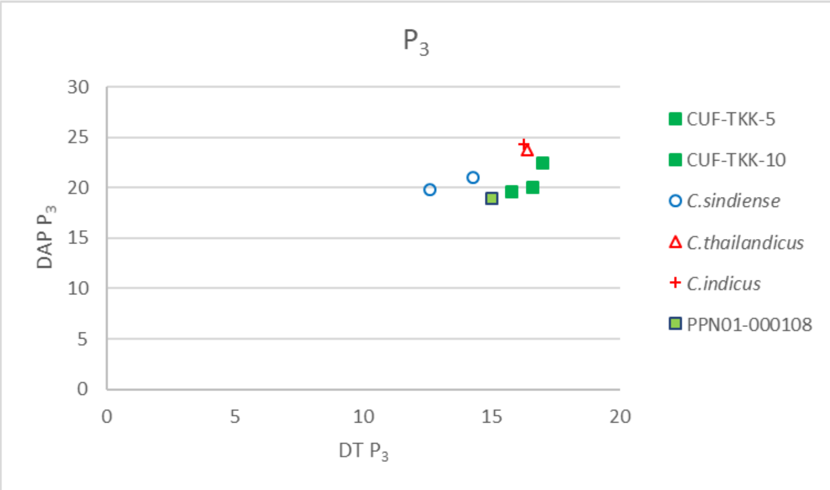

Figure 5. 17 Bivariate plot (DAP versus DTa) for the P_3 of *Conohyus* cf. *sindiense*: TKK–5, and CUF–TKK–10 From Chaloem Phra Kiat District, and PPN01–000108 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

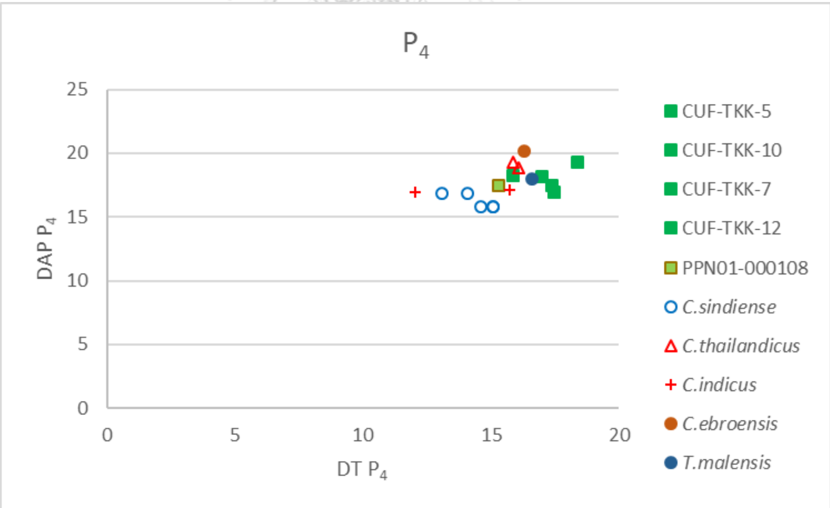

Figure 5. 18 Bivariate plot (DAP versus DTa) for the P_4 of *Conohyus* cf. *sindiense*: CUF–TKK–5, CUF–TKK–7, CUF–TKK–10, and CUF–TKK–12 from Chaloem Phra Kiat District, and PPN01–000108 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

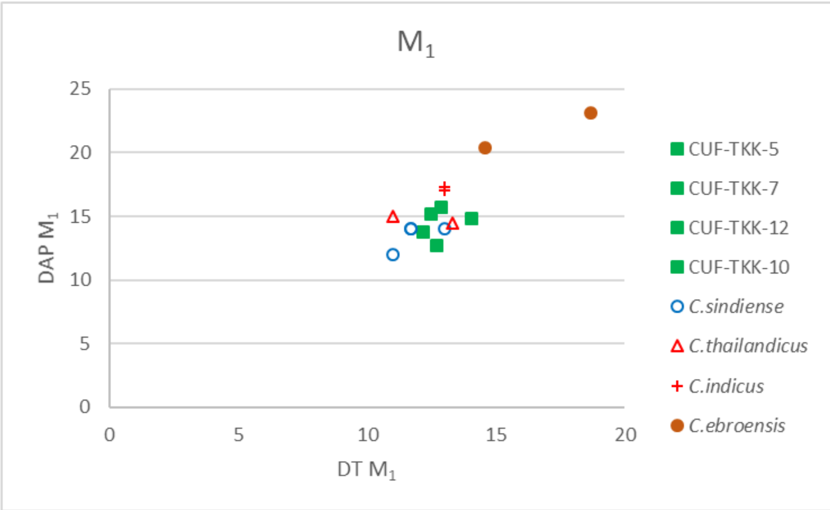

Figure 5. 19 Bivariate plot (DAP versus DTa) for the M_1 of *Conohyus* cf. *sindiense*: CUF–TKK–5, CUF–TKK–7, CUF–TKK–10, CUF–TKK–12 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

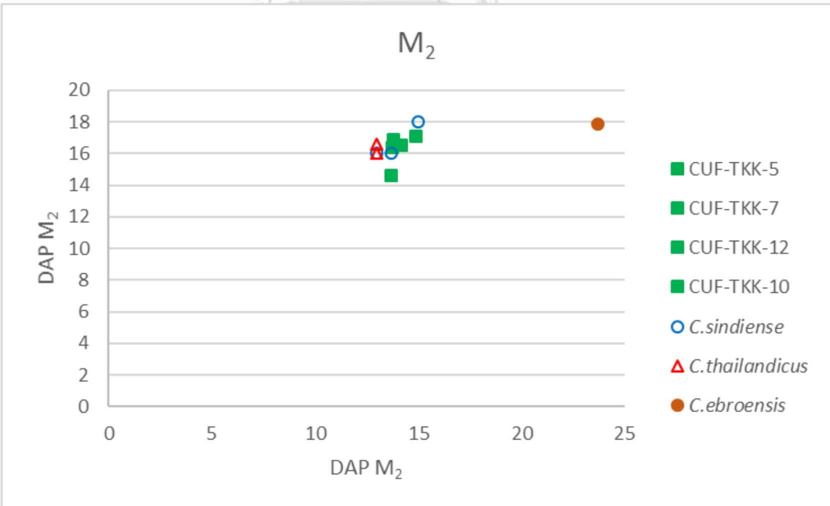

Figure 5. 20 Bivariate plot (DAP versus DTa) for the M_2 of *Conohyus* cf. *sindiense*: CUF–TKK–5, CUF–TKK–7, CUF–TKK–10, CUF–TKK–12 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

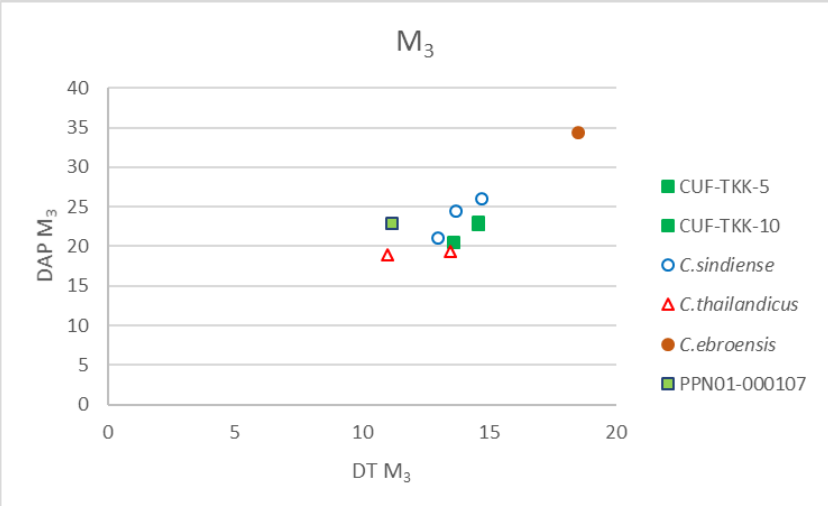

Figure 5. 21 Bivariate plot (DAP versus DTa) for the M_3 of *Conohyus* cf. *sindiense*: CUF–TKK–5, CUF–TKK–7, CUF–TKK–10, and CUF–TKK–12 from Chaloem Phra Kiat District, PPN01–000107 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

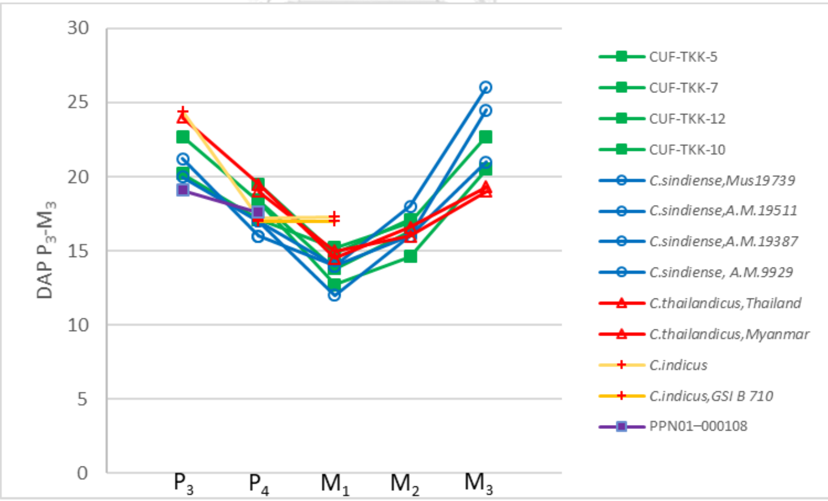

Figure 5. 22 The relative length of lower cheek tooth sizes from P_3–M_3 of *Conohyus* cf. *sindiense* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

5.3 Genus *Propotamochoerus* Pilgrim, 1925

SYSTEMATIC PALEONTOLOGY

Family Suidae Gray, 1821

Subfamily Suinae Grey, 1821

Genus *Propotamochoerus* Pilgrim, 1925

Generic diagnosis: 2 cusplets in sagittal valley of P^4; no labial or lingual cingula on P^4; no diastemata in upper or lower cheek tooth row; lower premolars compressed with a long; molar enamel thickness moderate (2±0.4 mm); furchen shallow; no cingular on molars, except for occasional basal pillars in ends of median valleys; talon/talonid of M^3/M_3 relatively simple, Pickford (1988).

Type species: *Propotamochoerus hysudricus* (Stehlin, 1900)

Type specimen: GSI 30, right mandible ramus in worn condition having P^3–M^3 dentition.

Abbreviations used:

CUF–TKK	Chulalongkorn University Fossils, Takut Khon sandpit
PPN	Prasert Prasarttong–Osoth Natural, Origin of life museum of Sukhothai Airport (pri-vatemuseum), Thailand
P_3–P_4	third to fourth lower premolar
M_1–M_3	first to the third lower molar
P^2–P^4	second to fourth upper premolar
M^1–M^3	first to third upper molar
r	right
l	left

Propotamochoerus cf. *hysudricus* (Stehlin, 1900)

Lower cheek teeth; Figures 5.23–5.31

Upper cheek teeth; Figures 5.32–5.44

Material: Lower cheek teeth

1. PPN01–000150, right mandibular fragment with M_2–M_3 and alveoli of M_1 from Phimai District, Nakhon Ratchasima Province.
2. PPN01–000152, right mandibular fragment with P_3–M_2 and alveoli of P_2 from Phimai District, Nakhon Ratchasima Province.
3. PPN01–000186, right mandibular fragment with P_3–M_3 from Phimai District, Nakhon Ratchasima Province.
4. CUF–TKK–6, left mandibular fragment with P_4–M_2 and alveoli of M_3 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.
5. CUF–TKK–13, left mandibular fragment with M_1–M_2 and alveoli of P_3–P_4 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.
6. CUF–TKK–14, left mandibular fragment with P_3–M_2 and alveoli of P_2 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Diagnosis: As in Pickford (1988)

Description: Lower cheek teeth

P_3 of specimens no. PPN01–000152 (Figure 5.24 (D–F)), PPN01–000186 (Figure 5.24 (A–C)), and CUF–TKK–14 (Figure 5.25 (A–C)) display a flattened protoconid with anterior and posterior crests.

P_4 of specimens no. PPN01–000152 (Figure 5.24 (D–F)), PPN01–000186 (Figure 5.24 (A–C)), CUF–TKK–6 (Figure 5.25 (D–F)), and CUF–TKK–14 (Figure 5.25 (A–C)) are broader than the P_3. The main cusp is the protoconid, located centrally of the crown. The metaconid is located slightly behind the protoconid. The prestylid is distinct. The posterior cingulum is extended at both ends of the crown. Small grooves are formed on the buccal and lingual side between the metaconid and hypoconid.

M_1–M_2 of specimens no. PPN01–000152 (Figure 5.24 (D–F)), PPN01–000186 (Figure 5.24 (A–C)), CUF–TKK–6 (Figure 5.25 (D–F)), CUF–TKK–13 (Figure 5.23 (D–F)) are almost rectangular in occlusal view. There are four main cusps: the protoconid, metaconid, hypoconid, and entoconid. The furchen is well developed and shallow. The posterior lobe is slightly broader than the anterior lobe. The anterior cingulum is small and weak. The protopreconulid, protoendoconulid, hypopreconulid and pentapreconulid are well developed and distinct. The size of M_1 is smaller than that of the M_2.

M_3 of specimens no. PPN01–000186 (Figure 5.24 (A–C)), and PPN01–000150 (Figure 5.23 (A–C)) have similar anterior and posterior lobes like those of M1–M2. The third lobes are narrower. The pentapreconulid is distinct and Larger than the hypopreconulid and protopreconulid.

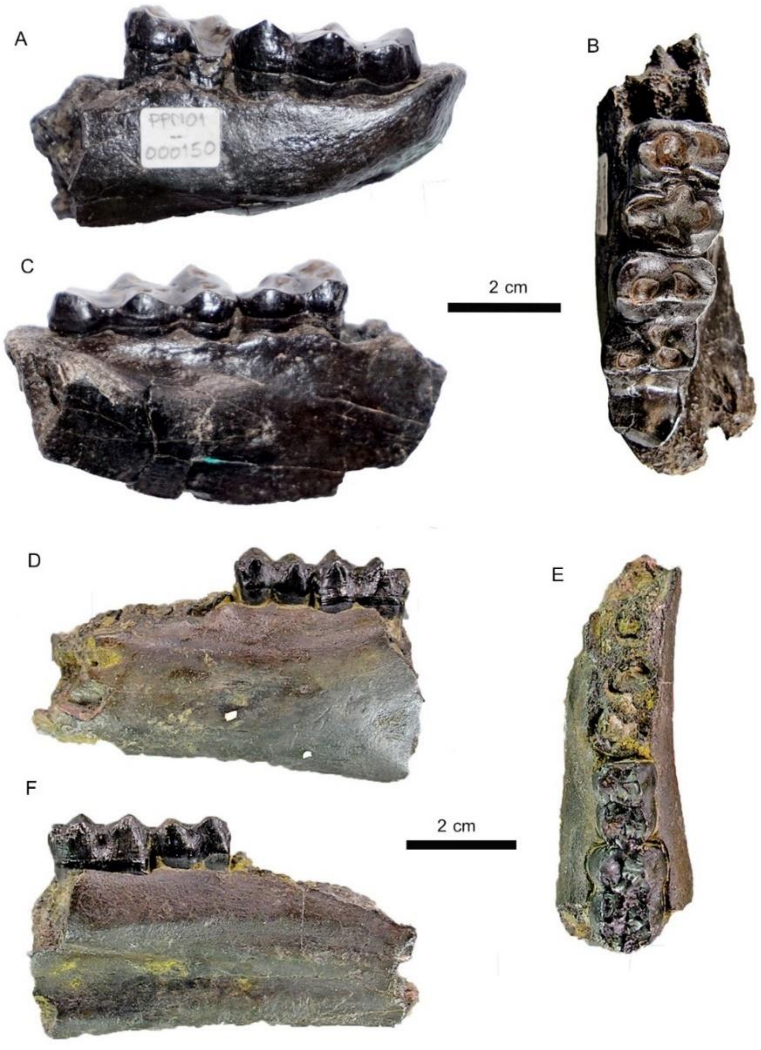

Figure 5. 23 Lower cheek teeth of *Propotamochoerus* cf. *hysudricus* from the Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province. A–C; PPN01–000150, right mandibular fragment with M_2–M_3 and alveoli of M_1: A, lingual view; B–C, occlusal view; I, buccal view. D–F; CUF–TKK–13, left mandibular fragment with M_1–M_2 and alveoli of P_3–P_4: D, buccal view; E, occlusal view; F, lingual view.

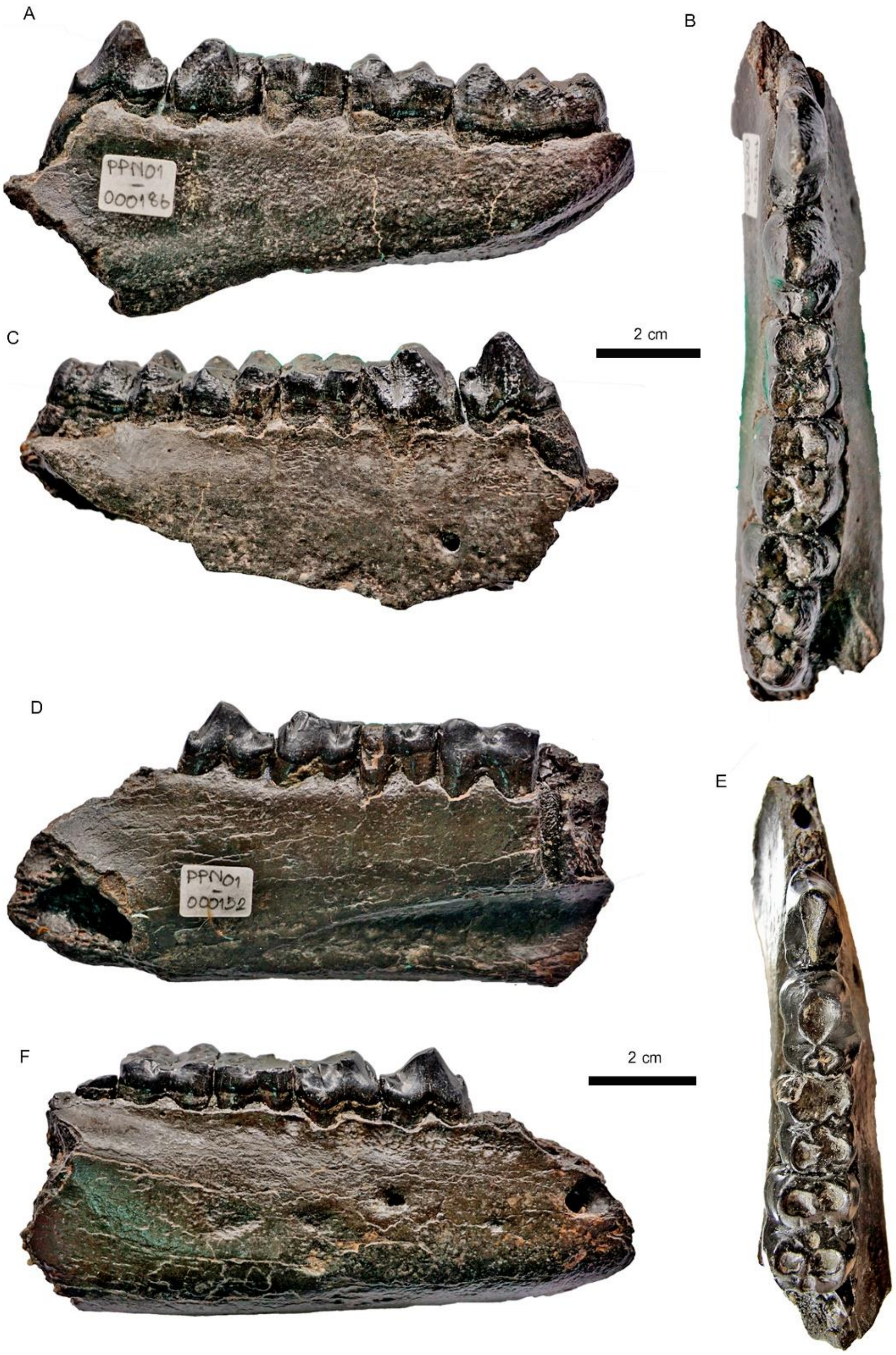

Figure 5. 24 Lower cheek teeth of *Propotamochoerus* cf. *hysudricus* from the Phimai District, Nakhon Ratchasima Province. A–C; PPN01–000186, right mandibular fragment with P_3–M_3: A, lingual view; B, occlusal view; C, buccal view. D–F; PPN01–000152, right mandibular fragment with P_3–M_2 and alveoli of P_2: D, lingual view; E, occlusal view; F, buccal view.

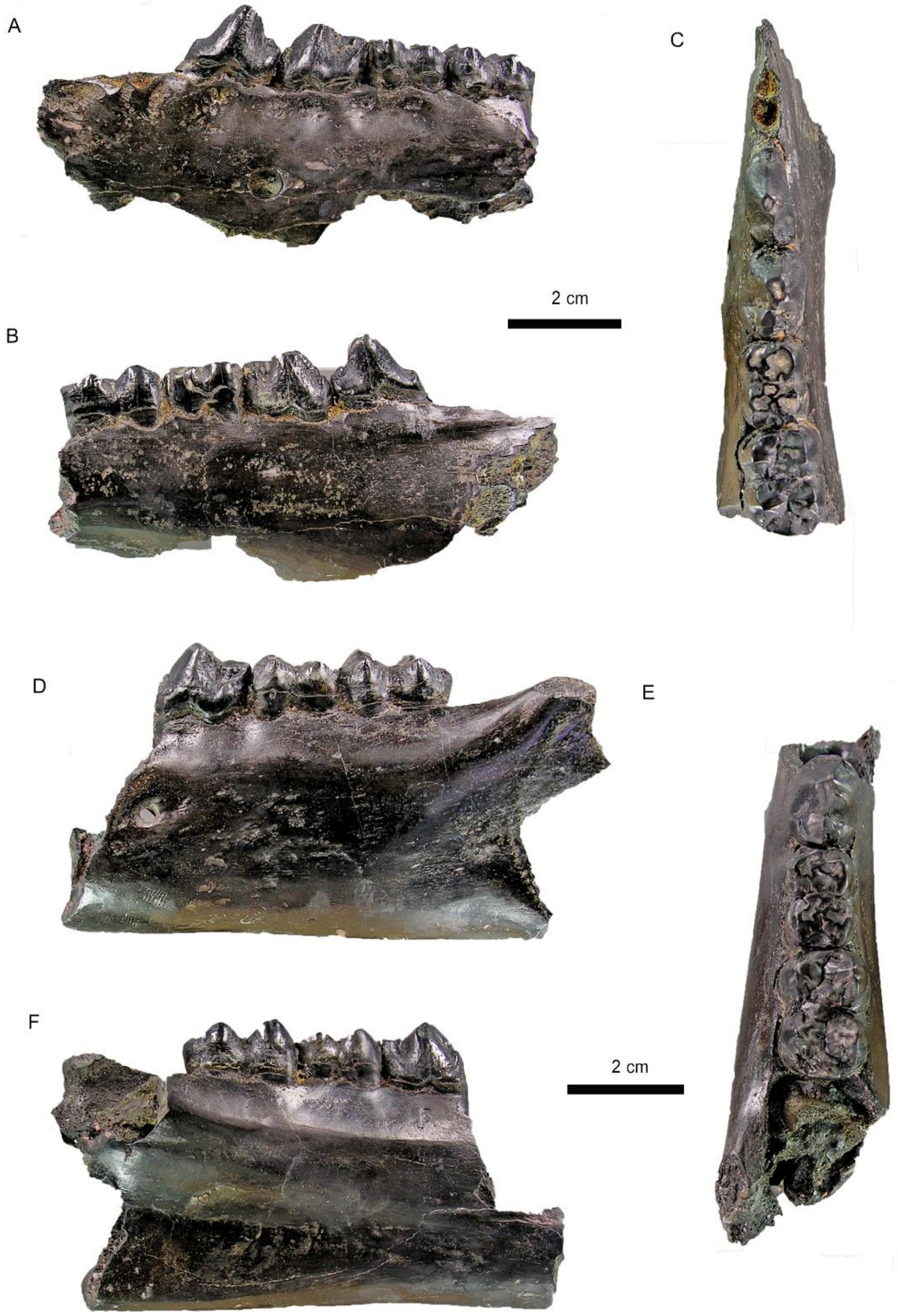

Figure 5. 25 Lower cheek teeth of *Propotamochoerus* cf. *hysudricus* from the Chaloem Phra Kiat District, Nakhon Ratchasima Province. A–C; CUF–TKK–14, left mandibular fragment with P_3–M_2 and alveoli of P_2: A, buccal view; B, occlusal view; C, lingual view. D–F; CUF–TKK–6, left mandibular fragment with P_4–M_2 and alveoli of M_3: D, buccal view; E, occlusal view; F, lingual view.

Table 5. 7 Measurements (in mm) of the lower of the *Propotamochoerus* cf. *hysudricus* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province.

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
PPN01–000186	rP_3	16.97	7.78	8.95	–
PPN01–000186	rP_4	16.55	11.03	12.57	–
PPN01–000186	rM_1	14.85	11.70	11.54	–
PPN01–000186	rM_2	18.84	14.7	14.41	–
PPN01–000186	rM_3	25.99	15.68	13.80	10.21
PPN01–000152	rP_3	15.93	7.87	9.72	–
PPN01–000152	rP_4	15.91	11.29	12.84	–
PPN01–000152	rM_1	14.36	12.47	12.15	–
PPN01–000152	rM_2	17.71	15.52	14.97	–
PPN01–000150	rM_2	18.55	14.83	14.58	–
PPN01–000150	rM_3	30.59	15.77	14.72	11.60
CUF–TKK–14	lP_3	16.77	7.62	8.68	–
CUF–TKK–14	lP_4	16.07	10.69	11.59	–
CUF–TKK–14	lM_1	14.92	11.4	11.24	–
CUF–TKK–14	lM_2	18.98	14.63	14.23	–
CUF–TKK–6	lP_4	16.85	11.51	12.39	–
CUF–TKK–6	lM_1	17.05	12.57	11.63	–
CUF–TKK–6	lM_2	22.58	15.72	11.60	–
CUF–TKK–13	lM_1	15.63	11.24	10.88	–
CUF–TKK–13	lM_2	21.33	14.37	13.88	–

DAP (L), Anteroposterior or length of cheek teeth; **DTa (W1)**, Width of the anterior lobe of cheek teeth; **DTp (W2)**, Transverse diameter (width) of the second lobe of cheek teeth; **DTpp (W3)**, Width of the third lobe.

Table 5. 8 Comparison of the lower premolar and molar of the *Propotamochoerus* cf. *hysudricus* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province with related suids.

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
PPN01–000186*	16.9	8.9	16.6	12.6	14.9	11.7	18.8	14.7	26.0	15.7
PPN01–000152*	15.9	9.7	15.9	12.8	14.4	12.5	17.7	15.5		
PPN01–000150*	–	–	–	–	–	–	18.6	14.8	30.6	15.8
CUF–TKK–14*	16.8	8.7	16.1	11.6	14.9	11.4	19.0	14.6	–	–
CUF–TKK–6*	–	–	16.9	12.4	17.1	12.6	22.6	15.7	–	–
CUF–TKK–13*	–	–	–	–	15.6	11.2	21.3	14.4	–	–
P. hysudricus, PUPC15/19[1]	–	–	–	–	–	–	28.9	15	–	–
P. hysudricus, PUPC15/20[1]	–	–	–	–	21.4	14.3	–	–	–	–
P. hysudricus, GSP39[2]	–	–	–	–	–	–	30	15	–	–
P. hysudricus, GSP2807[2]					20.6	14.3				
P. hysudricus, YUGD–092 [3]					19.1	15.5				
P. hysudricus, YUGD–095[3]			12.8	9.3						
P. hysudricus, PC–GCUF 11/186 [4]	13.7	7.7	15.3	9.5						
P. hysudricus, PC–GCUF 11/181[4]			15.3	9.5						
P. hysudricus, PC–GCUF 10/83[4]							21	15.3		
P. hysudricus,PC–GCUF 12/17[4]							29.4	14.1		
P. hysudricus[5]	15.5	9.7								
P. hysudricus, Vozarci–n N[5]	16.5	10								
P. hysudricus, PUPC 99/02[5]			15	9.5						
P. hysudricus, PUPC 94/65[5]			15	9.5						
P. hysudricus, GSP 17[5]			15.6	12.6						
P. hysudricus, GSP2503[5]			13.6	11.6						
P. hysudricus, GSP 10998[5]			15.5	11.6						
P. hysudricus, GSP 12343[5]			16.7	9.2						
P. hysudricus, GSP 5823[5]			14.4	11.3						
P. hysudricus, GSP 9355[5]			16.6	11.4						
P. hysudricus, GSP 12732[5]			16	9.4						
P. hysudricus, PUPC 07/32[5]			14.4	10.5						

*The studied specimens; 1 Sarwar etal., 2016; 2 Pickford,1988; 3 Chit sein et al., 2009; 4 Batool et al., 2015; 5 Batool et al., 2015 refers to data from Colbert (1935), Pickford (1935), Geraads et al. (2008), Khan (2010); **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

Table 5.8 Continued

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
P. hysudricus, GSP 10998 [5]	–	–	–	–	17.6	13	–	–	–	–
P. hysudricus, GSP 2807 [5]	–	–	–	–	16	12	–	–	–	–
P. hysudricus, GSP 457 [5]	–	–	–	–	16.8	11.5	–	–	–	–
P.hysudricus, GSP 6226 [5]	–	–	–	–	16.7	12	–	–	–	–
P. hysudricus, GSP 7017 [5]	–	–	–	–	14.6	13	–	–	–	–
P. hysudricus, GSP 6727 [5]	–	–	–	–	16.3	11.4	–	–	–	–
P. hysudricus, GSP 4773 [5]	–	–	–	–	16.6	12.5	–	–	–	–
P. hysudricus, GSP 5112 [5]	–	–	–	–	18.4	11.7	–	–	–	–
P. hysudricus, GSP 7384 [5]	–	–	–	–	17.5	12.4	–	–	–	–
P. hysudricus, GSP B742 [5]	–	–	–	–	–	–	–	–	31	16
P. hysudricus,GSP B39 [5]	–	–	–	–	–	–	–	–	30	15
P. hysudricus, GSP 9145 [5]	–	–	–	–	–	–	–	–	31.3	17
P.hysudricus, GSP 9405 [5]	–	–	–	–	–	–	–	–	34	19
P. hysudricus, GSP 9403 [5]	–	–	–	–	–	–	–	–	35.5	18
P. hysudricus, GSP 11684 [5]	–	–	–	–	–	–	–	–	32.5	18
P. hysudricus, GSP 9355 [5]	–	–	–	–	–	–	–	–	34.5	18.5
P. hysudricus,GSP 10224 [5]	–	–	–	–	–	–	–	–	34	17.9
P. hysudricus, GSP 10225 [5]	–	–	–	–	–	–	–	–	34.7	18.8
P. hysudricus, GSP 6944 [5]	–	–	–	–	–	–	–	–	32.5	17.6
P. hysudricus, GSP 10231 [5]	–	–	–	–	–	–	–	–	31.4	18.5
P. hysudricus, GSP 7318 [5]	–	–	–	–	–	–	–	–	35	18.5
P. hysudricus, GSP 2807 [5]	–	–	–	–	–	–	–	–	28.5	15.8
P. hysudricus, GSP 6226 [5]	–	–	–	–	–	–	–	–	31.7	16
P. hysudricus, GSP 9145 [5]	–	–	–	–	–	–	–	–	31.3	17
P. hysudricus, GSP 9405 [5]	–	–	–	–	–	–	–	–	34	19
P. hysudricus,[5]	–	–	–	–	–	–	–	–	32	18.1
P. hysudricus,Vozarci–563 [5]	–	–	–	–	–	–	–	–	33.8	18.8
P. hysudricus,Vozarci–564[5]	–	–	–	–	–	–	–	–	34.5	18.7
P. hysudricus,PUPC–07/32 [6]	–	–	14.4	10.5	16	12	20.5	15.4	28	16.4

*The studied specimens; 1 Sarwar etal., 2016; 2 Pickford,1988; 3 Chit sein et al., 2009; 4 Batool et al., 2015; 5 Batool et al., (2015) refers to data from Colbert (1935), Pickford (1935), Geraads et al. (2008), Khan (2010); 6 Khan, 2010; **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

Table 5.8 Continued

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
P. hysudricus, PuPC99/02[6]	–	–	14.5	11	14.5	11	–	–	–	–
P. hysudricus, PUPC94/65[6]	–	–	15	9.5	16	12	21	15	–	–
P. hysudricus, PUPC97/15[6]	–	–	–	–	–	–	–	–	32.5	15.5
P. hysudricus, GSP5230[6]	–	–	16.4	10.8	–	–	–	–	–	–
P. hysudricus, B742[6]	–	–	15.3	9.9	–	–	20	13.9	–	–
P. hysudricus, B32[6]	–	–	18	12	–	–	–	–	36	18
P. hysudricus, B715[6]	–	–	17.5	12.5	–	–	–	–	35.5	19.5
P. hysudricus, GSP594[6]	–	–	–	–	16.5	11.9	–	–	–	–
P. hysudricus, GSP10082[6]	–	–	–	–	17	13	22	17.3	35.5	19
P. hysudricus, GSP4088[6]	–	–	–	–	18.8	12.3	–	–	–	–
P. hysudricus, GSP149[6]	–	–	–	–	16	10.8	–	–	–	–
P. hysudricus, GSP9146[6]	–	–	–	–	16	11	–	–	–	–
P. hysudricus, GSP18082[6]	–	–	–	–	16	12.5	–	–	–	–
P. hysudricus, B32[6]	–	–	–	–	17	13	23	17	–	–
P. hysudricus, B715[6]	–	–	–	–	16.7	13	23	16.4	–	–
P. hysudricus, B742[6]	–	–	–	–	14.5	11	–	–	31	16
P. hysudricus, B50[6]	–	–	–	–	16.7	11.6	–	–	–	–
P. hysudricus, GSP12201[6]	–	–	–	–	–	–	22.5	16.5	34	17.8
P. hysudricus, GSP6011[6]	–	–	–	–	–	–	22.3	16.3	–	–
P. hysudricus, GSP2503[6]	–	–	–	–	–	–	21	17	–	–
P. hysudricus, GSP5212[6]	–	–	–	–	–	–	24	18	30	15
P. hysudricus, B39[6]	–	–	–	–	–	–	19	14.5	–	–
P. hysudricus, GSP12787[6]	–	–	–	–	–	–	–	–	32.7	17.8
P. hysudricus, GSP7348[6]	–	–	–	–	–	–	–	–	31.8	17
P. hysudricus, GSP2303[6]	–	–	–	–	–	–	–	–	32.5	19.3
P. hysudricus, GSP11007[6]	–	–	–	–	–	–	–	–	31.1	17.7
P. hysudricus, GSP2453[6]	–	–	–	–	–	–	–	–	32	16.7

*The studied specimens; 6 Khan, 2010; **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

Table 5.8 Continued

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
P. hyotherioides, ZT–2015–649 [8]	17.7	9.2	19.3	12.1	21.6	13.3	26.7	17.2	–	–
P. hyotherioides, ZT–2015–0798[8]	–	–	17	11.4	20.5	13.3	25.7	16.8	39	19.4
P. hyotherioides, ZT–2015–2130[8]	16.3	8	18	10.6	21.8	18.7	–	–	–	–
P. hyotherioides, ZT–2015–2544[8]	–	–	–	–	–	–	19	15	–	–

*The studied specimens; 8 Huo (2018); **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

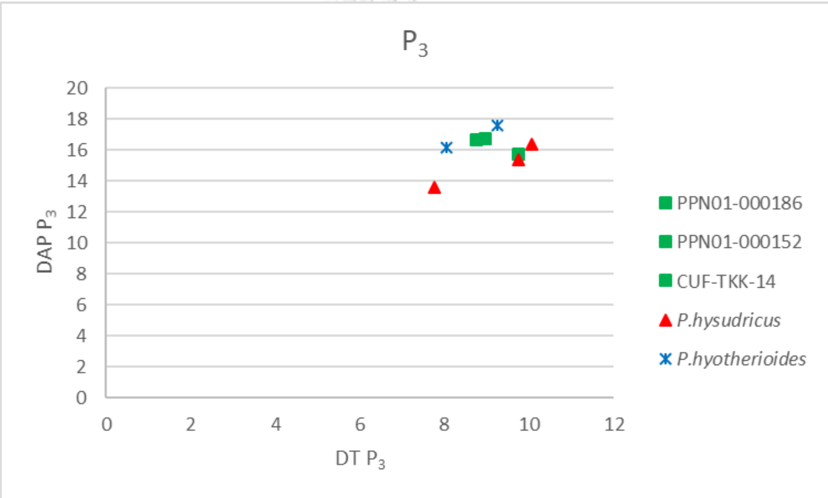

Figure 5. 26 Bivariate plot (DAP versus DTp) for the P_3 of *Propotamochoerus* cf. *hysudricus*: specimen no. PPN01–000186, and PPN01–000152 from Phimai, and CUF–TKK–1 4 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

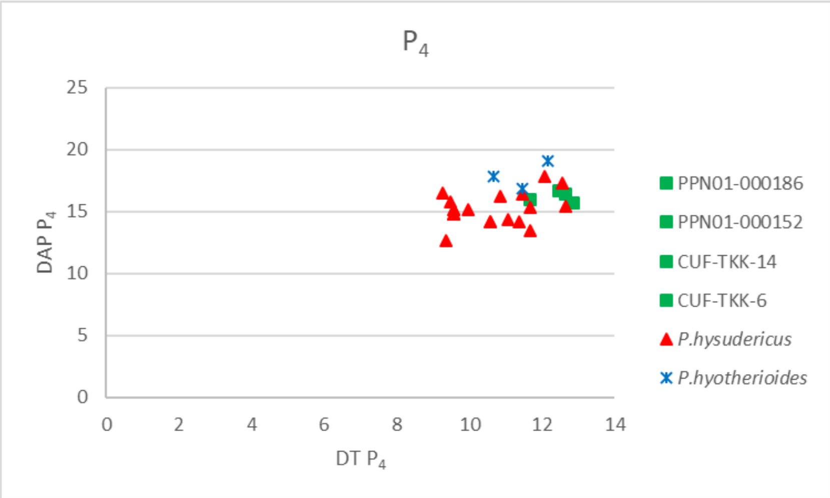

Figure 5. 27 Bivariate plot (DAP versus DTa) for the P_4 of *Propotamochoerus* cf. *hysudricus*: specimen no. PPN01–000186, and PPN01–000152 from Phimai District, CUF–TKK–14, and CUF–TKK–6 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

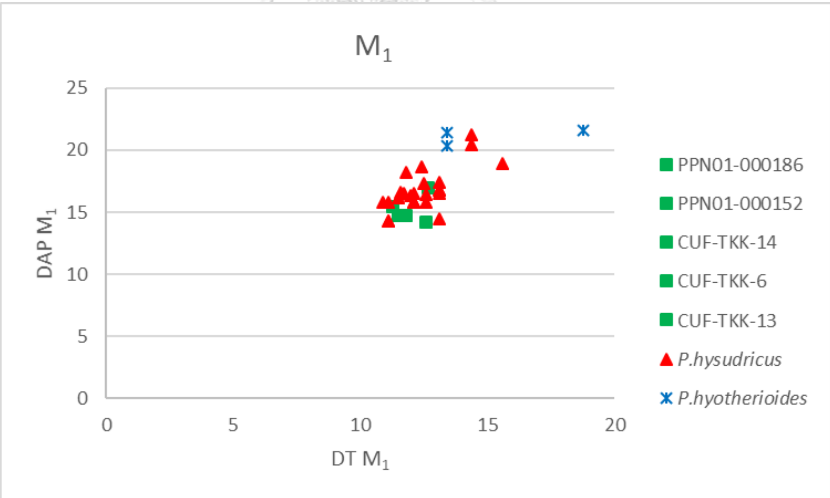

Figure 5. 28 Bivariate plot (DAP versus DT) for the M_1 of *Propotamochoerus* cf. *hysudricus*: specimen no. PPN01–000186, and PPN01–000152 from Phimai District, CUF–TKK–14, CUF–TKK–13, and CUF–TKK–6 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

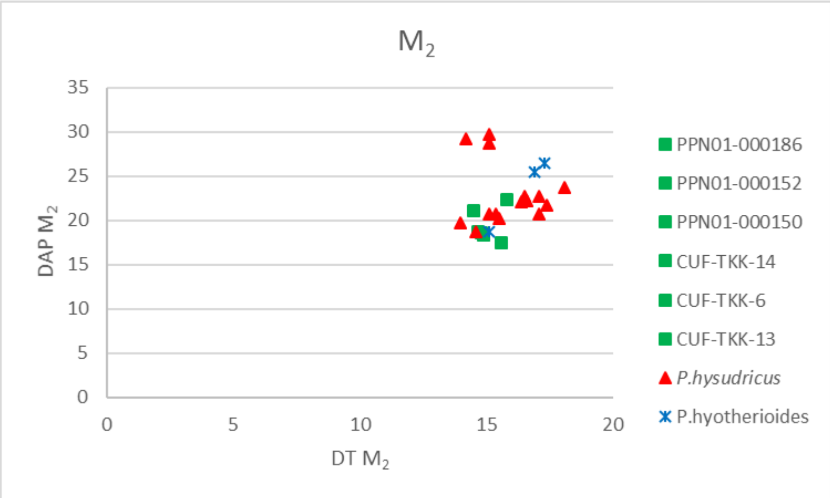

Figure 5. 29 Bivariate plot (DAP versus DT) for the M_2 of *Propotamochoerus* cf. *hysudricus*: specimen no. PPN01–000186, PPN01–000152, and PPN01–000150 from Phimai District, CUF–TKK–14, CUF–TKK–6, and CUF–TKK–13 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

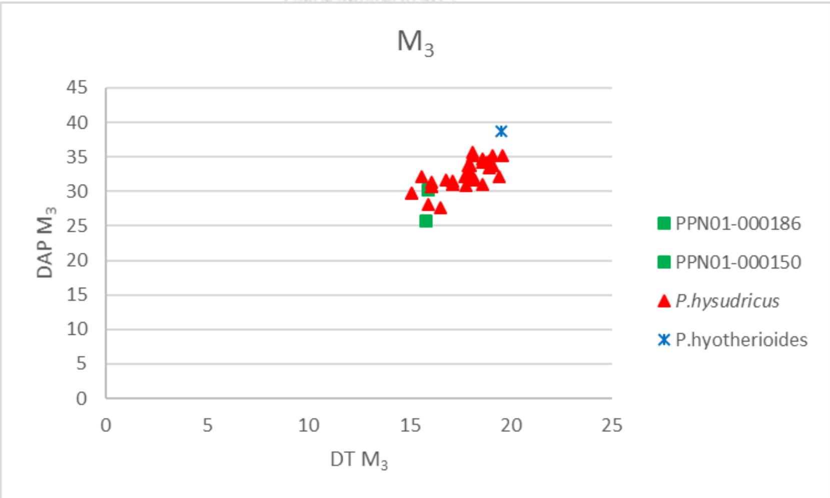

Figure 5. 30 Bivariate plot (DAP versus DT) for the M_3 of *Propotamochoerus* cf. *hysudricus*: specimen no. PPN01–000186, and PPN01–000150 from Phimai District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

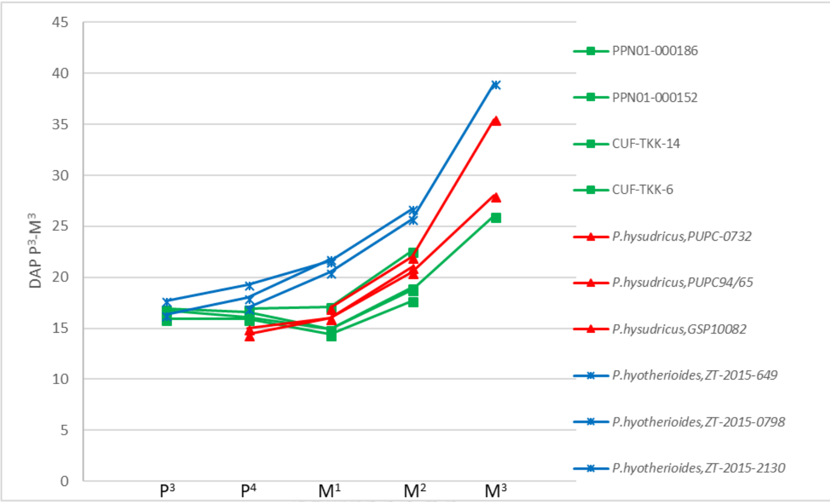

Figure 5. 31 Relative length of lower cheek tooth sizes from P_3–M_3 of *Propotamochoerus* cf. *hysudricus* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

Material: Upper cheek teeth

1. CUF–MB–1, maxillary with left and right P^4–M^3 and alveoli of P^3 from Phimai District, Nakhon Ratchasima Province.
2. PPN01–000188, maxillary with left P^3–M^2 and right P^3–M^3 from Phimai District, Nakhon Ratchasima Province.
3. PPN01–000149, right maxillary fragment with P^3–M^1 from Phimai District, Nakhon Ratchasima Province.
4. PPN01–000167, left maxillary fragment with P^2–P^3 from Phimai District, Nakhon Ratchasima Province.
5. PPN01–000155, left M^1 from Phimai District, Nakhon Ratchasima Province.
6. PPN01–000153, left M^1 from Phimai District, Nakhon Ratchasima Province.
7. PPN01–000154, left M^2 from Phimai District, Nakhon Ratchasima Province.
8. CUF–MB–38, left M^3 from Phimai District, Nakhon Ratchasima Province.
9. CUF–TKK–11, right maxillary fragment with P^4–M^3 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.
10. CUF–TKK–15, left maxillary fragment with P^3–M^2 from Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Description: Upper cheek teeth

The P^2 of specimen no. PPN01–000167 (Figure 5.35 (D–F)) has an elongated oval outline in the occlusal view and triangular in lateral view. There is one single main cusp. Anterior cingulum and posterior cingulum develop at the base of the main cusp.

The P^3 of specimens no PPN01–000167 (Figure 5.35 (D–F)), PPN01–000149 (Figure 5.35 (A–C)), PPN01–000188 (Figure 5.32 (A–C)), and CUF–TKK–15 (Figure 5.38 (D–F)) are triangular both in occlusal and lateral views. The crown made from the main cusp (paracone) and anterior cingulum and posterior cingula at the base of the paracone. The cusplets at the base of the main cusp are well developed. The paracone is inflated. The precristid is worn. The protocone is well developed at the mesiolingual extension of the posterior cingulum.

P^4 of specimens no PPN01–000149 (Figure 5.35 (A–C)), PPN01–000188 (Figure 5.32 (A–C)), CUF–MB–1 (Figure 5.33 (A–C)), CUF–TKK–11 (Figure 5.37 (A–C)), and CUF–TKK–15 (Figure 5.38 (D–F)) have roughly square outline in occlusal view. The lingual side is slightly shorter than the buccal one. The crown comprises three main cusps. A single lingual cusp, the protocone, and two buccal cusps are composing of the paracone and metacone, respectively. The anterior and posterior cingulum is distinct. The preconule is small and weak. At the lingual part of the metacone, A posterior sagittal cusplet developed in the deep protofossa.

M^1–M^2 of specimens no. PPN01–000149 (Figure 5.35 (A–C)), PPN01–000155 (Figure 5.34 (A–C)), PPN01–000188 (Figure 5.32 (A–C)), CUF–MB–1 (Figure 5.33 (A–C)), PPN01–000153 (Figure 5.36 (A–C)), PPN01–000154 (Figure 5.36 (D–F)), CUF–TKK–11 (Figure 5.37 (A–C)), and CUF–TKK–15 (Figure 5.38 (D–F)). They are almost rectangular in occlusal view. The crown is consisting of four main cusps, protocone, and tetracone on the lingual side, paracone, and metacone on the buccal side. The lingual cusps are large than the buccal ones. The basal pillar is present on the buccal side at the end of the median valley whereas it is absent on the lingual side. The anterior cingulum extends over the entire width of the tooth where the posterior one is narrower and beaded posteriorly. The protopreconule is fused to the anterior cingulum. The hypopreconule and pentapreconule are well developed. The size of M^1 is smaller than that of M^2.

M^3 of specimens no. PPN01–000188 (Figure 5.32 (A–C)), CUF–MB–38 (Figure 5.36 (G–I)), CUF–MB–1, (Figure 5.33 (A–C)), and CUF–TKK–11 (Figure 5.37 (A–C)) is nearly triangular in occlusal view. The first and second lobes are similar to those of M^1–M^2, and the third lobe is narrow distally. The pentacone is present and distinct. There are small cusplets on the mesio–buccal side of the pentacone.

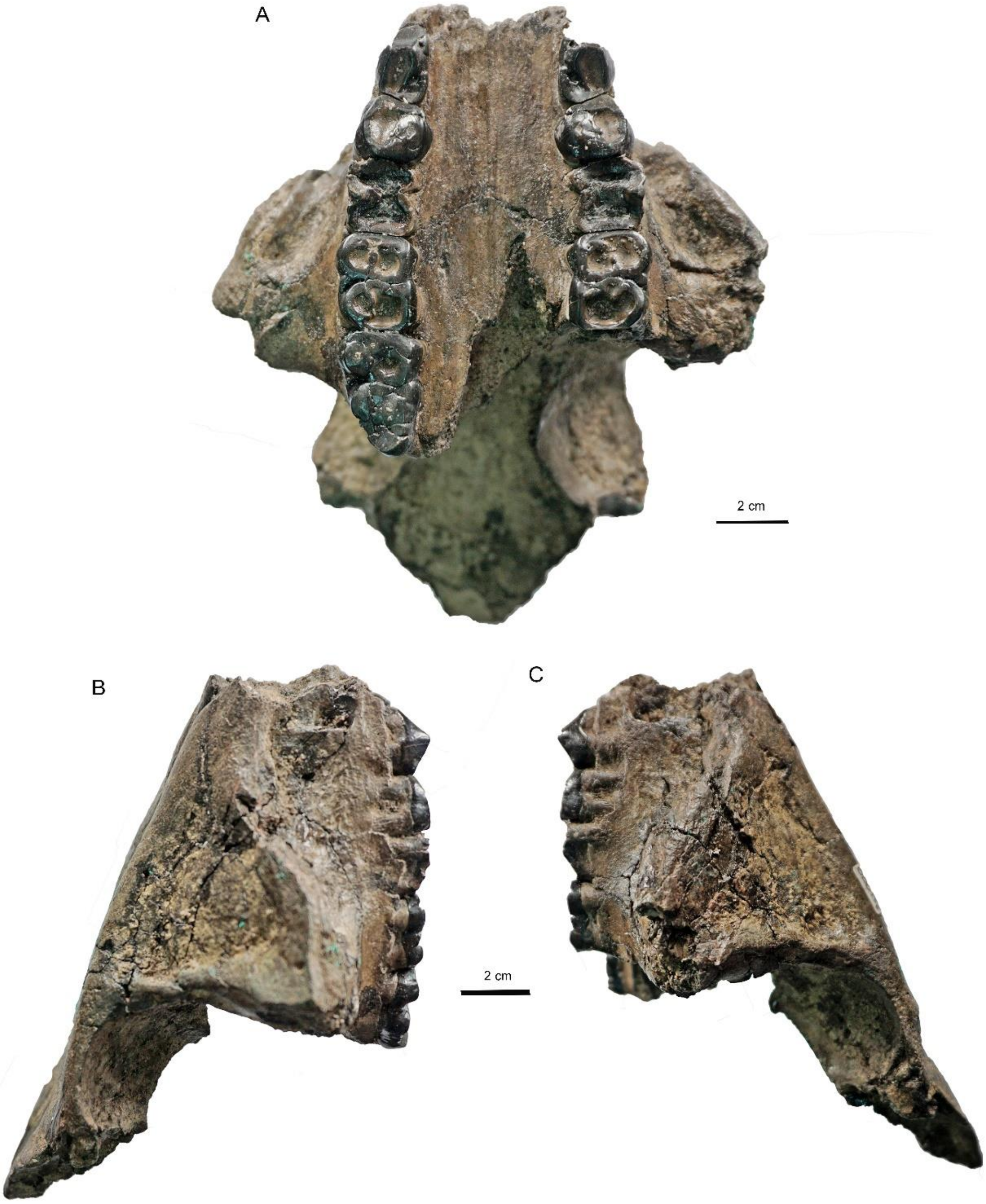

Figure 5. 32 Upper cheek teeth of, *Propotamochoerus* cf. *hysudricus* from the Phimai District, Nakhon Ratchasima Province. A–C; PPN01–000188, maxillary with left P^3–M^2 and right P^3–M^3: A, occlusal view; B, C, lateral view.

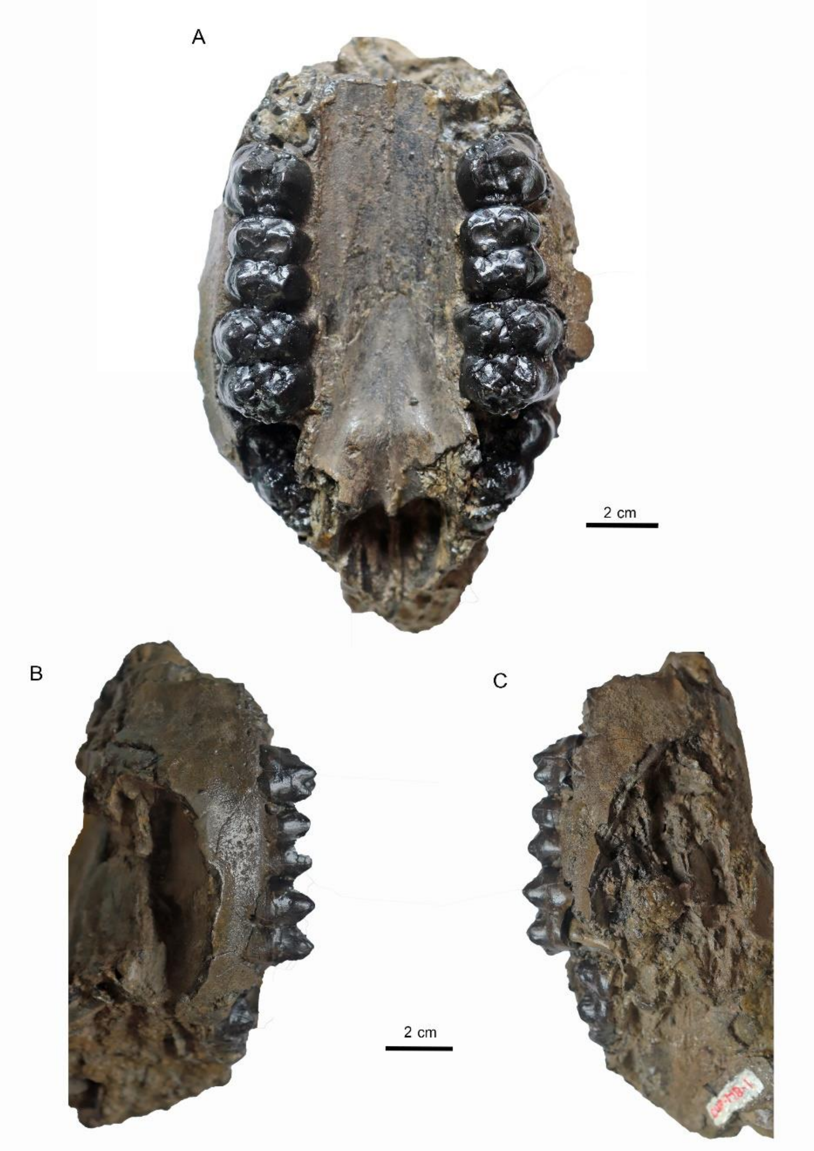

Figure 5. 33 Upper cheek teeth of *Propotamochoerus* cf. *hysudricus* from the Phimai District, Nakhon Ratchasima Province. A–C; CUF–MB–1, maxillary with left and right P^4–M^3 and alveoli of P^3: A, occlusal view; B, C, lateral view.

Figure 5. 34 Specimens of *Propotamochoerus* cf. *hysudricus* from the Phimai District, Nakhon Ratchasima Province. A–C; PPN01–000155, left M^1: A, lingual view; B, occlusal view; C, buccal view.

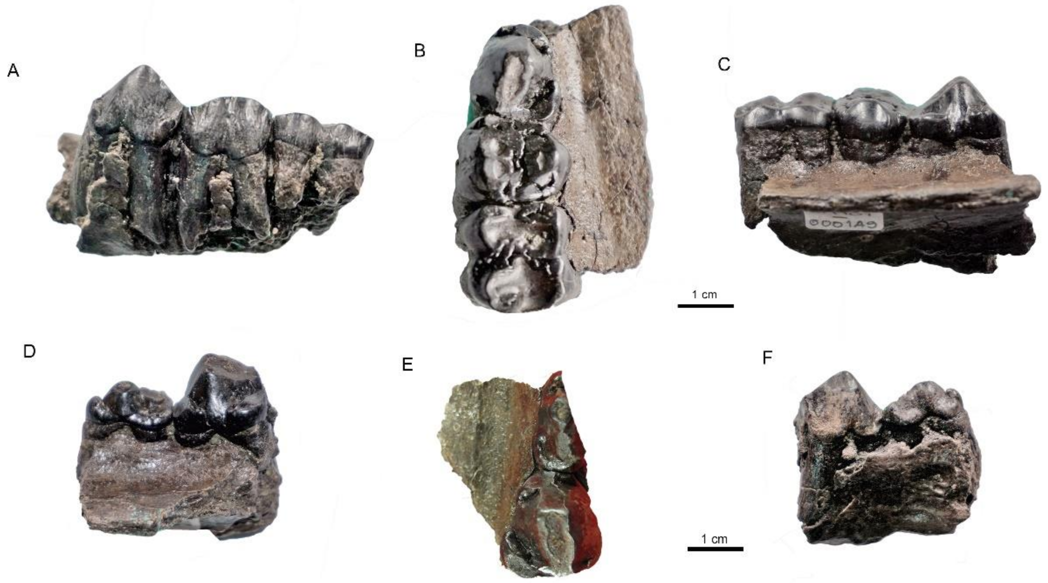

Figure 5. 35 Upper cheek teeth of *Propotamochoerus* cf. *hysudricus* from the Phimai District, Nakhon Ratchasima Province. A–C; PPN01–000149, right maxillary fragment with P^3–M^1: A, buccal view; B, occlusal view; C, lingual view. D–F; PPN01–000167, left maxillary fragment with P^2–P^3: D, lingual view; E, occlusal view; F, buccal view.

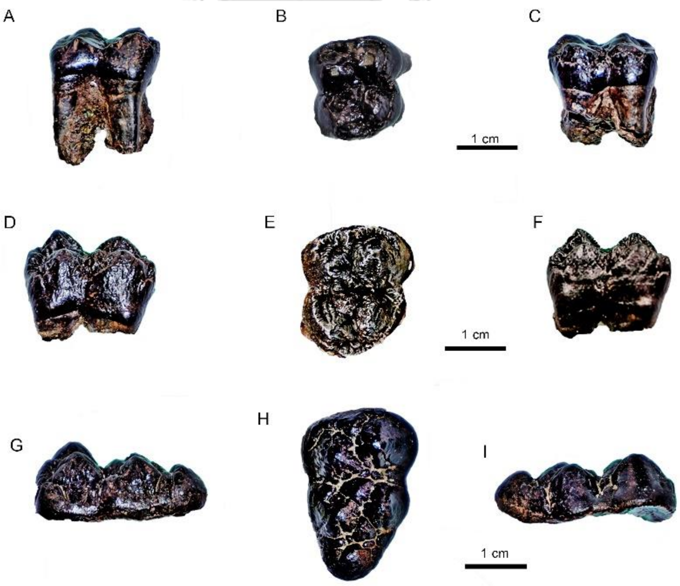

Figure 5. 36 Specimens of *Propotamochoerus* cf. *hysudricus* from the Phimai District, Nakhon Ratchasima Province. A–C; PPN01–000153, left M^1: A, lingual view; B, occlusal view; C, buccal view. D–F; PPN01–000154, left M^2: D, lingual view; E, occlusal view; F, buccal view. G–I; CUF–MB–38, left M^3: G, lingual view; H, occlusal view; I, buccal view.

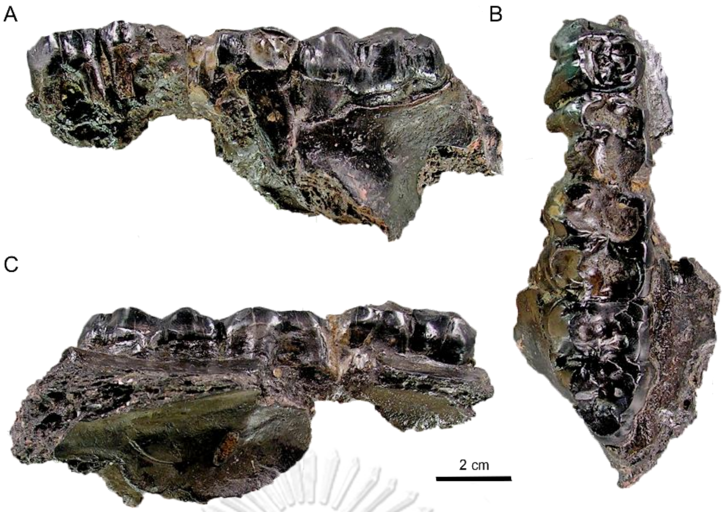

Figure 5. 37 Upper cheek teeth of *Propotamochoerus* cf. *hysudricus* from the Chaloem Phra Kiat District, Nakhon Ratchasima Province. A–C; CUF–TKK–11, maxillary with left P^4–M^3: A, buccal view B, occlusal view. C, lingual view.

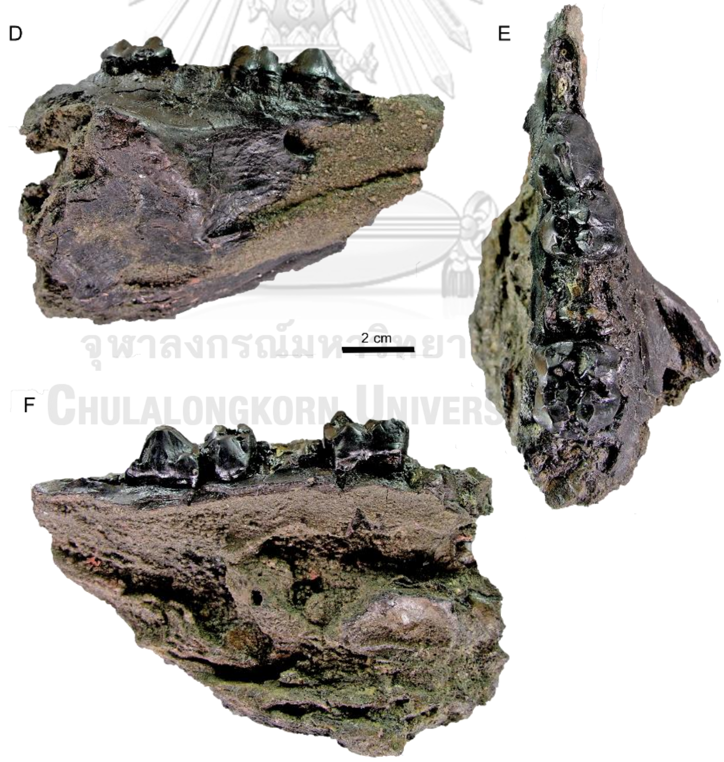

Figure 5. 38 Upper cheek teeth of, *Propotamochoerus* cf. *hysudricus* from the Chaloem Phra Kiat District, Nakhon Ratchasima Province. D–F, CUF–TKK–15, left maxillary fragment with P^3–M^2: D,buccal view; E, occlusal view; F, lingual view.

Table 5. 9 Measurements (in mm) of the upper of the *Propotamochoerus* cf. *hysudricus* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province.

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
CUF–MB–1	rP^4	13.30	–	15.57	–
CUF–MB–1	rM^1	16.39	14.28	14.52	–
CUF–MB–1	rM^2	20.40	16.44	16.50	–
CUF–MB–1	lP^4	13.41	–	15.64	–
CUF–MB–1	lM^1	16.37	14.52	14.57	–
CUF–MB–1	lM^2	19.60	17.65	16.63	–
PPN01–000188	rP^3	15.76	9.36	11.70	–
PPN01–000188	rP^4	13.04	–	16.03	–
PPN01–000188	rM^1	13.82	14.59	14.45	–
PPN01–000188	rM^2	17.45	17.01	16.95	–
PPN01–000188	rM^3	23.55	17.66	14.59	9.58
PPN01–000188	lP^3	16.11	9.57	12.84	–
PPN01–000188	lP^4	11.35	–	15.97	–
PPN01–000188	lM^1	12.99	15.02	14.61	–
PPN01–000188	lM^2	18.21	17.10	16.43	–
PPN01–000149	rP^3	16.45	11.38	15.17	–
PPN01–000149	rP^4	14.39	–	17.89	
PPN01–000149	rM^1	17.72	16.54	16.51	–
PPN01–000167	lP^2	15.49	6.51	8.31	–
PPN01–000167	lP^3	16.42	11.79	15.25	–
PPN01–000155	lM^1	17.77	16.49	>11.96	–
PPN01–000153	lM^1	15.93	14.32	13.51	–
PPN01–000154	lM^2	19.93	17.87	16.61	–
CUF–MB–38	lM^3	27.03	17.35	14.61	8.97
CUF–TKK–11	rP^4	14.02	17.59	–	–
CUF–TKK–11	rM^1	17.20	17.07	16.95	–

DAP (L), Anteroposterior or length of cheek teeth; **DTa (W1)**, Width of the anterior lobe of cheek teeth; **DTp (W2)**, Transverse diameter (width) of the second lobe of cheek teeth; **DTpp (W3)**, Width of the third lobe.

Table 5.9 Continued

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
CUF–TKK–11	rM^2	21.23	19.03	19.53	–
CUF–TKK–11	rM^3	28.35	20.00	16.30	7.83
CUF–TKK–15	lP^3	20.21	11.43	14.88	–
CUF–TKK–15	lP^4	15.82	18.14	–	–
CUF–TKK–15	lM^2	20.88	18.33	19.11	–

DAP (L), Anteroposterior or length of cheek teeth; **DTa (W1)**, Width of the anterior lobe of cheek teeth; **DTp (W2)**, Transverse diameter (width) of the second lobe of cheek teeth; **DTpp (W3)**, Width of the third lobe.

Table 5. 10 Comparison of the upper premolar and molar of the *Propotamochoerus* cf. *hysudricus* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province with related suids (in mm).

	P^3		P^4		M^1		M^2		M^3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
CUF–MB–1–r*	–	–	13.3	15.6	16.4	14.5	20.4	16.5	–	–
CUF–MB–1–l*	–	–	13.4	15.6	16.4	14.6	19.6	17.6	–	–
PPN01–000188–r*	15.8	11.7	13.0	16.0	13.8	14.6	17.5	17.0	23.6	17.7
PPN01–000188–l*	16.1	12.8	11.4	16.0	13.0	15.0	18.2	17.1	–	–
PPN01–000149*	16.5	15.2	14.4	17.9	17.7	16.5	–	–	–	–
PPN01–000167*	16.4	15.3								
PPN01–000155*					17.8	16.5				
PPN01–000153*					15.9	14.3				
PPN01–000154*							19.9	17.8		
CUF–MB–38*									27.0	17.4
CUF–TKK–11*	–	–	14.0	17.6	17.2	17.1	21.2	19.5	28.4	20.0
CUF–TKK–15*	20.2	14.9	15.8	18.1	–	–	20.9	19.1	–	–
P. hysudricus,PUPC15/17[1]							24.7	20		
P. hysudricus,PUPC15/18[1]									26	16
P. hysudricus,10486[2]							25	21.5		
P. hysudricus,GSP7017[3]									26.5	18.7
P. hysudricus,MGW0003[3]	15.3	11.4	12.9	14.6	15.6	15.2	21.7	18.6	29.5	20.1

*The studied specimens; 1 Sarwar,2016; 2 Pickford, 1988; 3 Thaung Htike et al., 2006; **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

Table 5.10 Continued

	P^3		P^4		M^1		M^2		M^3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
P. hysudricus,MGW0004[3]			15.6	10.9	14.7	11.8	20.5	15.1	32.5	16.9
P. hysudricus,NMMP–KU–IR0190[3]	16.2	7.57	15.3	10.9	16	11.8	19.7	14.4	–	–
P. hysudricus,YUGD–094[4]	–	–	–	–	19	13.3	–	–	–	–
P. hysudricus,YUGD–095[4]	–	–	12.8	9.3	14	10.5	19	13.3	–	–
P. hysudricus,PC–GCUF 11/182[5]	15	11.2	–	–	–	–	–	–	–	–
P. hysudricus,PC–GCUF 11/162[5]	13.2	11.4	12.7	14.4	–	–	–	–	–	–
P. hysudricus,PC–GCUF 12/03[5]	–	–	12.3	14.5	–	–	–	–	–	–
P. hysudricus,PC–GCUF 10/78[5]	–	–	–	–	–	–	19.5	20	–	–
P. hysudricus,PC–GCUF 11/156[5]	–	–	–	–	–	–	21.5	29.1	–	–
P. hysudricus,PC–GCUF 12/34[5]	–	–	–	–	–	–	23.4	18.8	29.5	19
P. hysudricus,PC–GCUF 12/24[5]	–	–	–	–	–	–	–	–	26.8	17.2
P. hysudricus,Vozarci–271[5]	14.5	13.1	13.2	16.6			22.3	21.3	29.5	21.1
P. wui[6]	10.8	10.1	9.7	12.1	13.6	12.3	17.2	15.9	17.4	14.9
H. ultimus, IVVP18400.1[7]	18.3	15.1	16.3	19.3	23.1	23.5	27	26.3	39.3	27.7
H. ultimus, IVVP18400.2[7]	–	–	–	–	22.3	20.9	–	–	–	–
H.ultimus, IVVP18400.3[7]	–	–	–	–	22.5	21.9	–	–	–	–
H. ultimus IVVP18400.4[7]	–	–	–	–	23.2	23.7	–	–	–	–
H. ultimus IVVP18400.[7]5	–	–	–	–	–	–	27.8	12.2	–	–
H. ultimus IVVP18400.6[7]	–	–	–	–	–	–	26.8	23.2	–	–
H. ultimus IVVP18400.7[7]	–	–	–	–	–	–	26.2	20.3	–	–
H. ultimus IVVP18400.8[7]	–	–	–	–	–	–	–	–	38.2	24.0
H. ultimus, IVVP18400.9[7]	–	–	–	–	–	–	–	–	37.6	24.2
H. ultimus, IVVP18400.10[7]									41.6	24.7
cf. *H. sivalensis*,[8]	–	–	–	–	–	–	23.4	19.0	–	–
cf. *H. sivalensis*[8]	–	–	–	–	–	–	–	–	32.1	20.4
cf. *H. sivalensis*[8]	–	–	–	–	–	–	28.0	21.5	42.0	22.0
cf. *H. sivalensis*[8]	–	–	–	–	–	–	24.6	19.8	33.5	21.4
cf. *H. sivalensis*[8]	–	–	–	–	–	–	24.3	21.0	–	–
cf. *H. sivalensis*[8]	–	–	–	–	–	–	22.4	23.2	38.0	24.5
cf. *H. sivalensis*[8]	–	–	–	–	–	–	–	–	35.0	22.7

*The studied specimens; 4 Chit Sein et al., 2009; 5 batool et al., 2015; 6 Thaung Htike et al., 2005; 7 Wei et al., 2014; 8 Pickford, 1988; Batool, 2015; **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

Table 5.10 Continued

	P3		P4		M1		M2		M3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
H. sivalense, P.U.P.C.No.67/134[9]	24	22	20.9	27.2	24.8	29	–	–	–	–
H. sivalense, P.U.P.C.No.69/137[9]	23.5	26.4	24	29	30	37	–	–	–	–
Dicoryphoerus titan, Amer.Mus.No.19380[10]	–	–	–	–	–	–	–	–	52	31
Dicoryphoerus titan, Amer.Mus.No.19699[10]	–	–	–	–	–	–	–	–	52	37
Dicoryphoerus titan, Amer.Mus.No.19742[10]	–	–	–	–	–	–	–	–	57	38

*The studied specimens; 9 Ahmed (2008); 10 Colbert (1935); **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

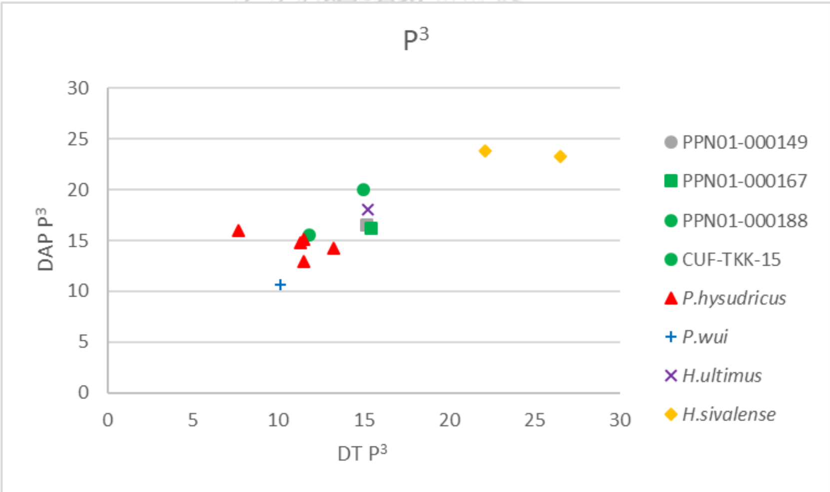

Figure 5. 39 Bivariate plot (DAP versus DT) for the P^3 of *Propotamochoerus* cf. *hysudricus*: specimen no. PPN01–000167, PPN01–000149, PPN01–000188 from Phimai District and CUF–TKK–15 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green rectangular is studying specimens and other symbols are different colors from the previous study.

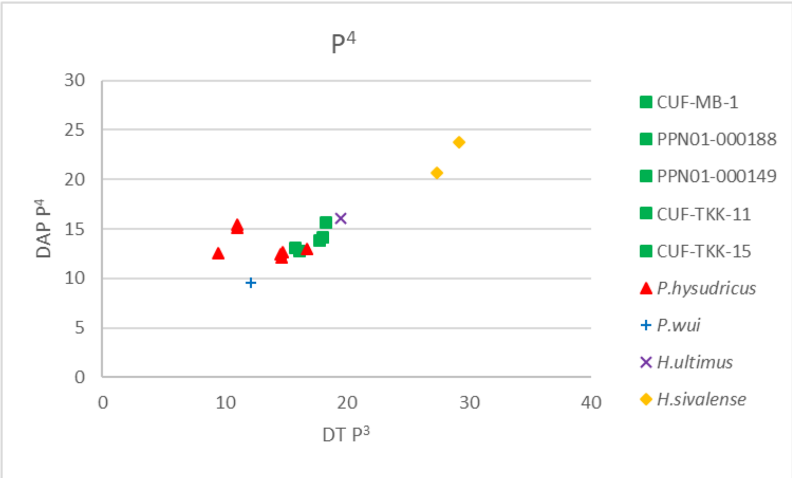

Figure 5. 40 Bivariate plot (DAP versus DT) for the P^4 of *Propotamochoerus* cf. *hysudricus*: specimen no. CUF–MB–1, PPN01–000149, PPN01–000188 from Phimai District, and CUF–TKK–11, and CUF–TKK–15 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

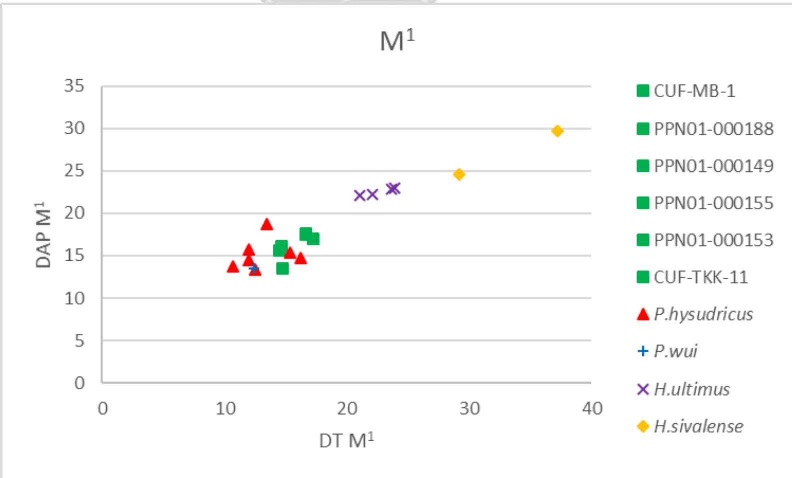

Figure 5. 41 Bivariate plot (DAP versus DT) for the M^1 of *Propotamochoerus* cf. *hysudricus*: specimen no. CUF–MB–1, PPN01–000149, PPN01–000188, PPN01–000153, PPN01–000155, from Phimai District, and CUF–TKK–11 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

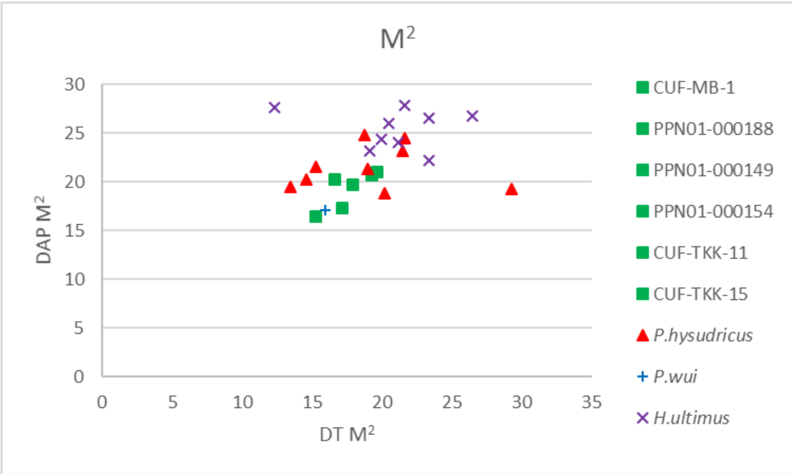

Figure 5. 42 Bivariate plot (DAP versus DT) for the M^2 of *Propotamochoerus* cf. *hysudricus*: specimen from CUF–MB–1, PPN01–000149, PPN01–000188, PPN01–000154, from Phimai District, CUF–TKK–11, and CUF–TKK–15 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

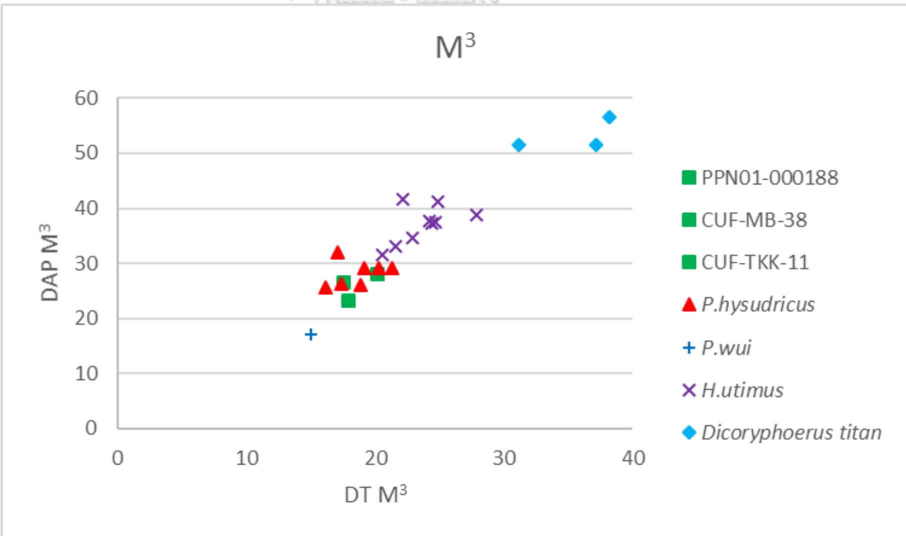

Figure 5. 43 Bivariate plot (DAP versus DT) for the M^3 of *Propotamochoerus* cf. *hysudricus*: specimen from no. PPN01–000188, CUF–MB–38, from Phimai District, and CUF–TKK–11 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

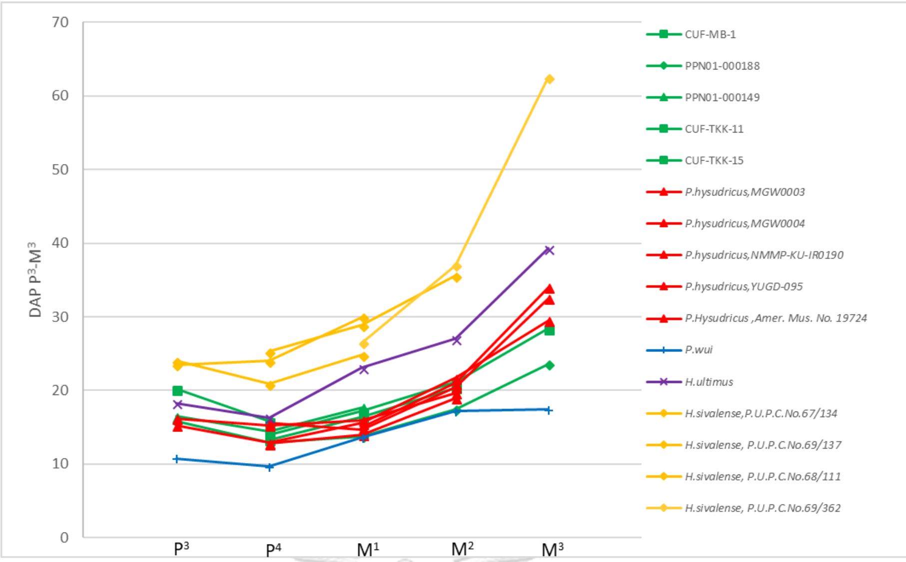

Figure 5. 44 Relative length of lower cheek tooth sizes from P^3–M^3 of *Propotamochoerus* cf. *hysudricus* from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

5.4 Genus *Hippopotamodon* Lydekker, 1877

SYSTEMATIC PALEONTOLOGY

Family Suidae Gray, 1821

Subfamily Suinae Gray, 1821

Genus *Hippopotamodon* Lydekker, 1877

Generic diagnosis: Large Suinae in which the males have flaring canines; molar enamel relatively thin; molars structurally simple; well–developed furchenplan; buccal cusps in lower molars noticeably lower crowned than lingual ones; P^4 with posterior accessory cusp almost as large as two main buccal cusps; sagittal cusplets present in central valley between the protocone and the paracone–metacone; posterior choanae U–shaped, open immediately behind M^3; P_4 with prominent innenhugel (metaconid) and 2–3–4 cusp, anterior cingulum and ac–1 cusp moderately high; diastema between C_1–P_1–P_2 short; broad flat dorsal surface to braincase; the maxillae of males possess a large supracanine flange with a highly rugose dorsal surface, females do not have such a flange (Pickford 1988).

Type species: *Hippopotamodon sivalense* Lydekker, 1877

Abbreviations used:

CUF–TKK	Chulalongkorn University Fossils, Takut Khon sandpit
P_3– M_3	third to third lower molar
M_2–M_3	second to the third lower molar

Other species in the genus:

Sus titan Lydekker, 1884

Potamochoerus titan (Lydekker) Stehlin,1899–1900

Dicoryphochoerus titan (Lydekker) Pilgrim,1926

Dicoryphochoerus titan (Lydekker) Colbert,1935

Hydaspitherium megacephalum (Lydekker) Colbert,1935

Dicoryphochoerus titan (Lydekker, Schmidt–Kittler)

Hippopotamodon ultimus (Han, 1903)

Hippopotamodon major (Gervais, 1850)

Hippopotamodon cf. *sivalense* Lydekker, 1877

Figures 5.45 – 5.49

Material:

1. CUF–TKK–8, right mandible fragment with P_4–M_1 from Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.
2. CUF–TKK–9, left mandible fragment with $M_{2–3}$ and alveoli of M_1 from Takut Khon sandpit, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Diagnosis: Give detailed information Pickford (1988)

Description:

The P_4 of specimen no. CUF–TKK–8 (Figure 5.45 (A–C)) is comprised of two main cusps (protoconid and metaconid, respectively), anterior and posterior. The anterior one being larger than the posterior one. The protoconid is worn. However, the buccal side is heavily worn, and the dental morphology cannot be seen.

The M_1–M_2 of specimens no. CUF–TKK–8 (Figure 5.45 (A–C)), and CUF–TKK–9. (Figure 5.45 (D–F)) are trapezoidal in occlusal view and comprised of four main cusps. The protoconid and hypoconid are on the buccal side — also, the metaconid and entoconid on the lingual side.

M_3 of specimens no. CUF–TKK–8 (Figure 5.45 (A–C)), and CUF–TKK–9 (Figure 5.45 (D–F)). Displays two anterior lobes that are morphologically similar to those of the M_1-M_2. The anterior cingulum is weak at the anterior base of the anterior lobe. The protopreconulid, hypopreconulid, and pentapreconulid are distinct. The third lobe of the tooth or talonid is morphologically more variable.

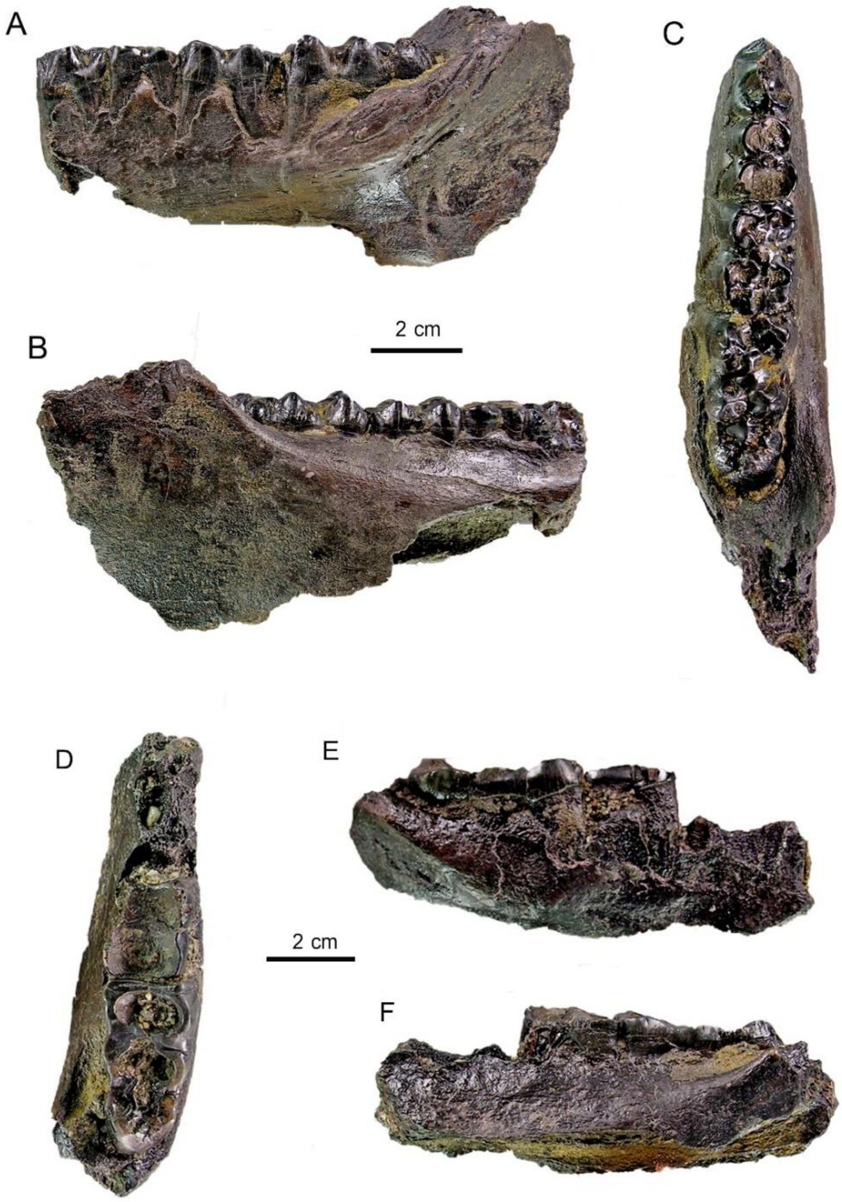

Figure 5. 45 Lower cheek teeth of *Hippopotamodon* cf. *sivalense* from the Chaloem Phra Kiat District, Nakhon Ratchasima Province. A–B, CUF–TKK–8, right mandibular fragment with P_4–M_3: A, lingual view; B, occlusal view; C, buccal view. D–E, CUF–TKK–9 , left mandibular fragment with M_2–M_3 and alveoli of M_1: D, buccal view; E, occlusal view; F, lingual view.

Table 5. 11 Measurements (in mm) of the lower dentition of the *Hippopotamodon* cf. *sivalense* from Chaloem Phra Kiat and Phimai District, Nakhon Ratchasima Province.

		DAP (L)	DTa (W1)	DTp (W2)	DTpp (W3)
CUF–TKK–8	rP_4	17.68	>10.77	13.07	–
CUF–TKK–8	rM_1	16.93	12.74	13.95	–
CUF–TKK–8	rM_2	24.35	17.02	17.95	–
CUF–TKK–8	rM_3	39.65	19.51	17.21	14.91
CUF–TKK–9	lM_2	21.91	>16.33	18.38	–
CUF–TKK–9	lM_3	40.8	20.88	19.11	15.85

Table 5. 12 Comparison of the upper premolar and molar of the *Hippopotamodon* cf. *sivalense* from Chaloem Phra Kiat District, Nakhon Ratchasima Province with related suids (in mm).

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
CUF–TKK–8*	–	–	17.7	13.1	17.0	14.0	24.4	18.0	40.0	19.5
CUF–TKK–9*	–	–	–	–	–	–	21.9	18.4	40.8	20.9
H. sivalense, P.U.P.C.No.68/111[1]	–	–	25.3	19.4	28.9	18.5	35.6	24	–	–
H. sivalense, P.U.P.C.No.69/362[1]	–	–	–	–	26.5	19.6	37.0	26.0	62.5	31.5
H. sivalense, P.U.P.C.No.69/365[1]	–	–	–	–	–	–	34	26.5	60.0	32.5
H. ultimus, IVVP18400.11[2]	–	–	–	–	23.9	18.4	–	–	–	–
H. ultimus, IVVP18400.12[2]	–	–	–	–	22.4	16.5	–	–	–	–
H. ultimus, IVVP18400.13[2]	–	–	–	–	23.0	16.9	–	–	–	–
H. ultimus, IVVP18400.14[2]	–	–	–	–	22.9	16.8	–	–	–	–
H. ultimus, IVVP18400.15[2]	–	–	–	–	24.5	16.2	–	–	–	–
H. ultimus, IVVP18400.16[2]	–	–	–	–	–	–	25.9	17.6	39.5	19.3
H. ultimus, IVVP18400.17[2]	–	–	–	–	–	–	26.4	17.1	39.4	20.4
H. ultimus, IVVP18400.18[2]	–	–	–	–	–	–	24.4	18.8	41.2	19.9
H. ultimus, IVVP18400.19[2]	–	–	–	–	–	–	–	–	38.9	19.1
H. sivalense, PC–GCUF 12/27[3]	–	–	–	–	24.3	20.3	–	–	–	–
H. sivalense, GSP 330[3]	–	–	–	–	28.6	19.4	–	–	–	–
H. sivalense, GSP 4086[3]	–	–	–	–	28.7	19.5	–	–	–	–

*The studied specimens; 1 Ahmed (2008); 2 Wei et a., (2014); 3 batool et al. (2015), refered data from Colbert (1935); Pickford (1988); **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

Table 5.12 Continued

	P_3		P_4		M_1		M_2		M_3	
	DAP	DT	DAP	DT	DAP	DT	DAP	DT	DAP	DT
H. sivalense, K47/798[3]	–	–	–	–	28.5	19	–	–	–	–
H. sivalense, B435[3]	–	–	–	–	27.5	20.5	39	26	–	–
H. sivalense, B2[3]	–	–	–	–	26.6	18.5	36	25	54.5	29.6
H. sivalense, B358[3]	–	–	–	–	24	18	30	23	53.5	26.6
H. sivalense, B25[3]	–	–	–	–	29.6	20	–	–	–	–
H. sivalense, B3539[3]	–	–	–	–	25	20	–	–	–	–
H. sivalense, GSP 4673[3]	–	–	–	–	26.8	17.5	–	–	–	–
H. sivalense, B714[3]	–	–	–	–	25	16.8	31.5	22	–	–
H. sivalense, B539[3]	–	–	–	–	–	–	35.5	25	56.6	27.2
H. sivalense, B397[3]	–	–	–	–	–	–	30	24		
H. sivalense, B21[3]	–	–	–	–	–	–	–	–	57	29
H. sivalense, B22[3]	–	–	–	–	–	–	–	–	62.5	31
Dicoryphochoerus titan, Amer. Mus. No. 19679[4]	–	–	–	–	–	–	–	–	56.0	29.0
P. hysudricus, Amer. Mus. No. 19724[4]	–	–	–	–	–	–	22	17	34	19
P. hysudricus, Amer. Mus. No. 19703[4]	–	–	–	–	–	–	-	–	–	–
P. hysudricus, Amer. Mus. No. 19728[4]	–	–	–	–	15	12.5	22	18	40	20
P. hysudricus, Amer. Mus. No. 19534[4]	–	–	–	–	15	12.5	21	17	36	18.5
P. hysudricus, Amer. Mus. No. 19698[4]	–	–	–	–	-	-	-	-	33	18
P. hysudricus, Amer. Mus. No. 19707[4]	–	–	–	–	-	-	-	-	31.5	16.5

*The studied specimens; 3 batool et al. (2015), refered data from Colbert (1935); Pickford (1988); 4 Colbert (1935); **DAP**, length of premolar and molar; **DT** maximum width of a cheek tooth.

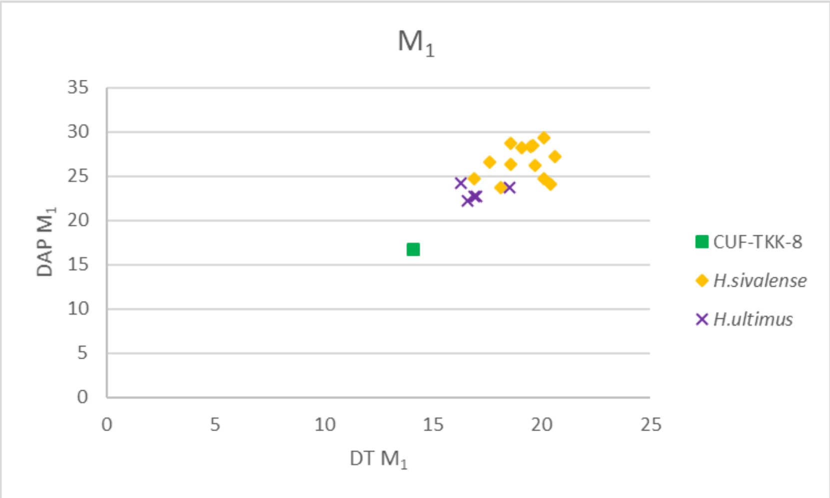

Figure 5. 46 Bivariate plot (DAP versus DT) for the M_1 of *Hippopotamodon* cf. *sivalense*: specimen no. CUF–TKK–8 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

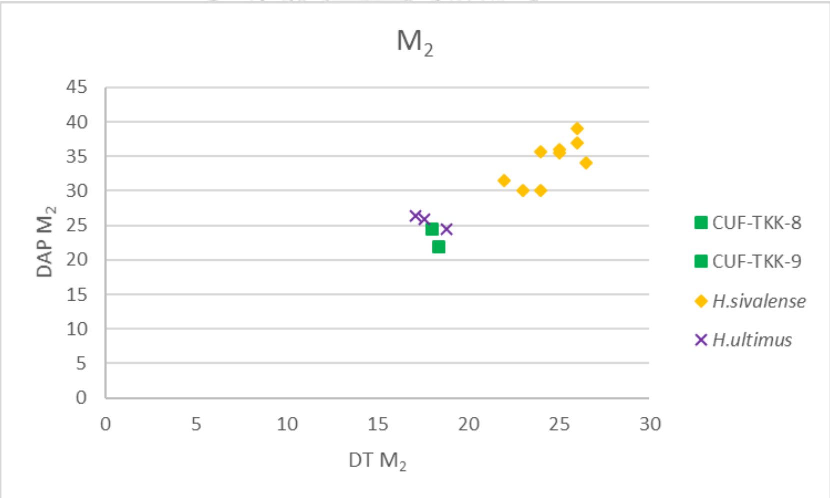

Figure 5. 47 Bivariate plot (DAP versus DT) for the M_2 of *Hippopotamodon* cf. *sivalense*: specimen no. PPN01–000186, PPN01–000152, CUF–TKK–6, CUF–TKK–8, CUF–TKK–13, CUF–TKK–14 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

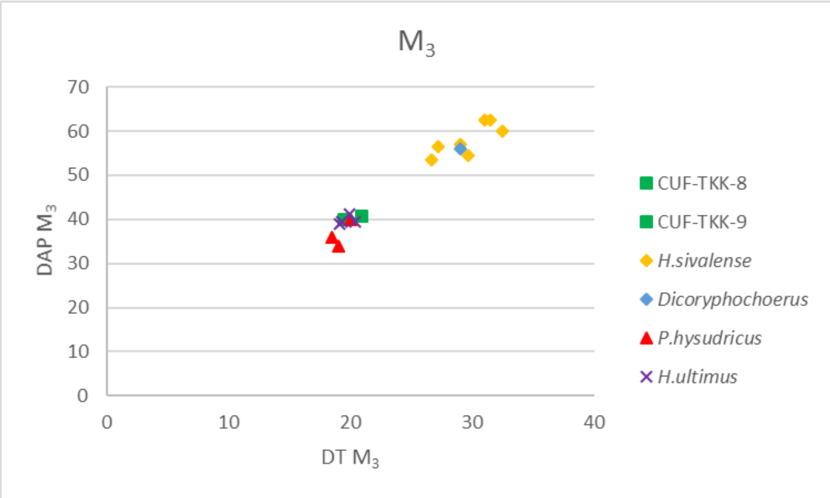

Figure 5. 48 Bivariate plot (DAP versus DT) for the M_3 of *Hippopotamodon* cf. *sivalense*: specimen no. PPN01–000186, PPN01–000152, CUF–TKK–6, CUF–TKK–8, CUF–TKK–13, CUF–TKK–14 from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

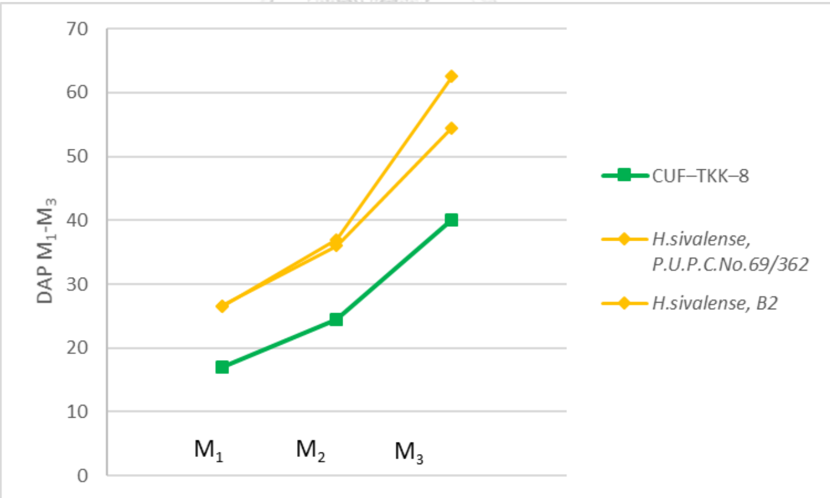

Figure 5. 49 Relative length of lower cheek tooth sizes from M_1–M_3 of *Hippopotamodon* cf. *sivalense* from Chaloem Phra Kiat District, Nakhon Ratchasima Province in comparison with other related species. Green square represents studying specimens and other symbols with different colors are from previous studies.

5.5 Comparisons

5.5.1 Comparisons of genus *Tetraconodon* Falconer, 1868

Cheek teeth described here are bunodont with the enlargement of third and fourth premolars and display highly wrinkled enamel (Falconer, 1868; Colbert, 1935; Made, 1999; Thaung Htike et al., 2005, 2007.2008). The first upper molar (M^1) corresponds to *T. intermedius*, GSI B 675 (Made, 1999) or *T. magnus,* Indian Museum B 675 (Colbert, 1935) from Jammu and *T. irramedius*, NMMP–KU–IR0225 from Myanmar (Thaung Htike et al., 2007) (Table 5.1, 5.3), smaller than *T. irramagnus* (YUDG-Mge 089; YUDG-Mge 091) from Myanmar (Thaung Htike et al., 2007). However, they are larger than the *T. malensis*, YUDG-N1, YUDG-N2 from Myanmar (Thaung Htike et al., 2008) and *C. sindiense*, Amer. Mus. No. 19739 a primitive suid from the Siwalik beds and india (Colbert, 1935).

The lower molar (Figure 5.13) is similar in size to those of *T. irramedius* (NMM 839/80) from Myanmar (Thaung Htike et al., 2007), smaller than those of the *T. magnus* (GSI B 71; A.M. 9937) from Pakistan (Colbert, 1935) (Table 5.2, 5.4). However, the molar size is relatively longer than those of *T. minor* (GSI B 711; NMM AN-1) and *T. malensis* (NMM KPG-1) from Myanmar, *C. indicus* (GSI-10), *C. sindiense* (Amer.Mus.19739) from Pakistan smaller than *T. magnus* (A.M. 9937, GSI. B. 71) from Pakistan.

According to, the morphometrical features, and compared with other related species can be assigned to *Tetraconodon* cf. *intermedius* Made, 1999.

5.5.2 Comparisons of genus *Conohyus* Pilgrim, 1925

The studied specimens have enlargement of third and fouth premolas, and the last lower molar is short (Lydekker, 1884; Pilgrim, 1926; Ducrocq, 1997; Chavasseau et al. (2006). They have similarities in morphology and size to those of *C. sindiense* (A.M. 19739; A.M. 19386; A.M. 19511; A.M. 19387; A.M. 9929) from Lower Siwalik beds of northern India (Colbert, 1935), *C. thailandicus* (TF 2577) Ducrocq, 1997 from Thailand, and Chavasseau et al. (2006) from Myanmar, *T. malensis* Thaung Htike (2005) from Myanmar (Table 5,5 – 5.6), While, smaller than those of *C. indicus* from Pakistan (Pickford & Gupta, 2001) . The third crown of lower molar (M_3) is well-developed and corresponds to *C. sindiensis* in length. However, those are longer than those of *C. thailandicus*.

According to, the morphometrical features, and compared with other related species of suid fossils from Nakhon Ratchasima are similarities to *C. sindiensis* from the Indian subcontinent, can be assigned to *Conohyus* cf. *sindiense* Pilgrim, 1926.

5.5.3 Comparisons of genus *Propotamochoerus* Pilgrim, 1925

For the morphology of the third and fourth (P_3-P_4) lower premolar, the main cusp (protoconid) is located centrally in the occlusal surface of the crown, and the metaconid is slightly situated behind the protoconid. In the lower third premolar (P_3), the protoconid displays a flattened with anterior and posterior crests. The lower molar (M_1-M_3) is bunodont with four main cusps arranged in two lophs (Pilgrim, 1925; Pickford, 1988; Thaung Htike et al., 2006; Chit Sein, 2009;).

The morphological of the third upper premolar (P^3) is stout and rounded. The fourth upper premolar (P^4) have two cusplets in the sagittal valley, and no cingula on the buccal or lingual side. The anterior and posterior cusps of premolars are variable. The molar (M^1 – M^3) has no cingula. The furchen are shallow, except for occasional basal pillars at the end of median valleys, Pickford (1988). Comparing with other related species, they are similar in size (P^3-M^3) to *P. hysudricus* from Pakistan (Pickford,1988; Thaung Htike, 2005; Chit sein et al., 2006; Sarwar et al., 2016; Batoo et al., 2015) and are smaller than *H. sivalense* from Pakistan (Pickford, 1988; Batool, 2015) and *H.ultimus* from China (Wei et al., 2014). However, they are larger than the *P. wui* from China (adopted from Thaung Htike et al., 2005).

According to, the morphometrical features, and compared with other related species the lower cheek teeth of suid fossils from Nakhon Ratchasima corresponds to *Propotamochoerus hysudricus* from Siwaliks, Pakistan (Colbert, 1935; Pickford, 1988; Batool et al., 2015; Sarwar et al., 2016), and from Myanmar (Thaung Htike et al., 2006; Chit Sein et al., 2009). However, They are smaller than those of the *P.hyotherioides* from Yunnan Province, China described by Hou in 2018. (Table 5.7–5.8). Moreover, the morphological features and metrical values of the upper cheek teeth corresponds to those of *Propotamochoerus* cf. *hysudricus*, can be assigned to P*ropotamochoerus* cf. *hysudricus* (Stehlin, 1900).

5.5.4 Comparisons of genus *Hippopotamodon* Lydekker, 1877

The lower fourth premolar (P_4) has two main cusps, the anterior one being larger than the posterior one. The lower first and second molars (M_1–M_2) are trapezoidal in occlusal view and comprise of four main cusps. The last lower molar (M_3) displays two anterior lobes that are morphologically similar to those of the M_1-M_2. In the third lobe, the talonid is morphologically variable (Pickford 1988).

The lower molor (M_1-M_3) have smaller than *H*. *sivalense* from Pakistan (Pickford, 1988; Batool et al., 2015). However, they are similar to *H. ultimus* from China (Wei et al., 2014), showing in Table 5.11-5.12.

According to, the morphometrical features, and compared with other related species of suid fossils from Nakhon Ratchasima can be assigned to *Hippopotamodon* cf. *sivalense* Lydekker, 1877.

CHAPTER 6
DISCUSSION AND CONCLUSIONS

This chapter presented the result of the studies. The results consist of species of suids, and sedimentological information from Mae Lae Butra sandpit, Chai Anan sandpit, Rim Mai Sai Thong sandpit, and Takut Khon sandpit from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province.

6.1 Paleobiogeographic records and contributions to the age

6.1.1 Paleobiogeographic records and contributions to the age of the genus *Tetraconodon* Falconer, 1868

The original genus *Tetraconodon* was decribed by Falconer in 1868. It is represented by four species: *Tetraconodon magnus*, *Tetraconodon minor*, *Tetraconodon intermedius*, and *Tetraconodon malensis.* These fossils are known from the Indian subcontinent (Falconer, 1868; Colbert, 1935; Made, 1999), and Myanmar (Thaung Htike et al., 2005, 2007, 2008). The record of these genera is probably from the Middle and Upper Miocene of the Indian subcontinent. There is no record form China Following Made (1996). In Pakistan, the genus of *Tetraconodon* is represented by *T. magnus* (Falconer, 1868) was erected based on the maxillary with right M^2 – M^3 from near Hasnot, Siwalik Hill. In the Indian subcontinent, Colbert (1935) were reported the maxillary of *T. magnus* (Mus. B. 675), and mandibular fragment (A.M. 9937), later Made (1999) created the *T. intermedius* on the basis of skull fragment (IM B 675) with right and left P^3 – M^3 from Jammu, probably Dhok Pathan equivalent, indicating Late Miocene age. In the Myanmar *Tetraconodon* is represented by two species; *T. malensis* was described by Thaung Htike et el., 2005 which was created on the basis of right mandibular fragment with P_4 – M_3 (NMM KPG-1, NMM KPG-2), and *T. minor* which was created on the basis of left mandibular fragment with P_3 – P_4 (GSI. No. B. 677) by Pilgrim (1910) from Yenangyoung, Central Myanmar, suggesting that it is from the Early – Late Middle Miocene deposits.

6.1.2 Paleobiogeographic records and contributions to the age of the genus *Conohyus* Pilgrim, 1925

The genus *Conohyus* was created by Pilgrim in 1926. It is represented by three species; *Conohyus sindiense*, *Conohyus thailandicus*, *Conohyus indicus*. The fossil of the genus is known from the Indian subcontinent (Colbert, 1935; Pilgrim, 1926; Pickford & Gupta, 2001), Thailand (Ducrocq et al., 1997), Myanmar (Chavasseau et al., 2006). The older record of the genus is probably from the Middle Miocene age, found in the Lower Siwalik beds of northern India (Pilgrim, 1926). In the Indian subcontinent, the fossils *Conohyus* is represented by *C. sindiense* (Pilgrim, 1926) which was created the base on the basis of maxillary fragments with left M^2 -M^3 by Pilgrim 1926. Colbert (1935) reported the maxillary fragment (A.M. 19616), and mandibular fragments (A.M.19386; A.M.19511; A.M.19387). Pickford et al. (2001) informed base on the basis of the mandibular fragment with premolar and the first molar.

6.1.3 Paleobiogeographic records and contributions to the age of the genus *Propotamochoerus* Pilgrim, 1925

The genus erected by Pilgrim in 1926. Later, the detailed diagnoses were described in Pickford (1988). It is represented by three species, *P. hysudricus, P. hyotherioides, P.wui.* The type species of the genus is *P. hysudricus* (GSI. No. B. 30) known from Potwar District, Punjab, Pakistan, indicated Upper Miocene age (Pickford, 1988). The fossils of the species are known from the Indian subcontinent (Sarwar, 2016; Pickford, 1988; Batoo, 2015), Myanmar (Thaung Htike et al., 2006; Chit Sein et al., 2009), and China (Hou et al., 2018). In Pakistan, *Propotamochoerus* is represented by the species of *P. hysudricus* which was created on the mandibular ramus fragment (GSI. No. B 30) by Pilgrim in 1926. Colbert (1935) reported mandibular fragments (A.M. No. 19724; A.M. No. 19728; A.M. No. 19703; A.M. No. 19534; A.M. No. 19698; A.M. No. 19707), and maxillary fragments (A.M. No. 19724; A.M. No. 19703). In Myanmar, fossil *Propotamochoerus* was described as *P. hysudricus* by Thaung Htike et al., 2016; Chit Sein et al., 2009). These fossils (NMMP-KU-IR-0190; MGW 0003; MGW 0004) were recovered from the Lower part of the Irrawaddy group, probably equivalent to the Dhok

Pathan Formation of the Middle Siwalik, which is Upper Miocene age. Chit Sein et al. (2009) reported the maxillary fragment (YUDG-Mge 094), and the mandibular fragments (YUDG-Mge 092; YUDG-Mge 093) from the Irrawaddy formation at Tebingan, suggesting the Late Miocene age. In China, *Propotamochoerus* is represented by species *P. hyotherioides* which recovered from the latest Miocene site of Shuitangba, Zhaotong basin, Yunnan Province. The genus was described by Hou et al. (2018), corresponds to Chinese Miocene Suinae

6.1.4 Paleobiogeographic records and contributions to the age of the genus *Hippopotamodon* Lydekker, 1877

The original genus *Hippopotamodon* was created by Lydekker in 1877 on the basis of the maxillary fragment (GSI B 7) with P^4, broken M^1 and M^2, as *Hippopotamodon sivalense*. The fossils record of the genus is common in the Upper Miocene of the Siwalik of Pakistan (Pickford, 1988; Ahmed, 2008; Dar, 2019), China (Wei et al., 2014). In China, *Hippopotamodon* is represented by species *H.ultimus* (IVPP V 18400.1) which was erected on the basis of the broken skull, and six isolate teeth from Sanhe cave of Chongzuo in Guangxi. The genus was described by Han (1987); Wei (2014), corresponding to the Early Pleistocene age. In Southeast Asia, the genera of Suinae: *Hippopotamodon,* and *Propotamodon* are common in Pakistan after 10.2 – 7.2 Ma (Chaimanee et al., 2006; Pickford, 1988; Barry et al., 2002).

According to, Duval et al. (2019) reported the US-ESR dating of the five teeth of *Stegodon* cf. *orientalis*, *Bubalus arnee*, *Bos sauveli* from Khok Sung locality that the fossil layer is located within an 8 m thick fluvial terrace. The fossil fauna provides two possible ages of 130±29 Ka and 217±36 Ka for the fossils (Figure 6.1).

However, Chaimanee et al. (2004,2006), *Khoratpithecus piriyai* were collected from the lower sand unit (>7.6 m, below the topsoil) of sandpit in Nakhon Ratchasima Province indicated an early Late Miocene age, between 9 – 7 Ma, and 9 – 6 Ma, respectively. These fossils correspond to Upper Nagri and Lower Dhok Pathan Formation of Siwalik. In addition, The pig *Hippopotamodon sivalense* is common in

Pakistan between 10.2 – 7.2 Ma (Chaimanee et al., 2006; Pickford, 1988; Barry et al., 2002). These fossil with age length this can likely be use as index fossils.

The suid fossils from the Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province correspond to four genera: *Tetraconodon* cf. *intermedius*, *Conohyus* cf. *sindiense*, *Propotamochoerus* cf. *hysudricus*, and *Hippopotamodon* cf. *sivalense* corresponds to Dhok Pathan Formation of Siwalik in Indian subcontinent (Falconer, 1868; Lydekker, 1884, 1885, 1886, 1887; stehlin, 1899-1900; Pilgrim, 1910; Pilgrim, 1926; Matthew, 1929; Colbert, 1935; Schmidt-kittler, 1971; Thenius, 1972; Wilkinson, 1976; Made, 1999; Pickford & Gupta, 2001; Barry et al., 2002 ;Chaimanee et al., 2004; Chaimanee et al., 2006; Ahmed, 2008; Sarwar, 2016; Pickford, 1988; Batoo, 2015; Dar, 2019), Magway and Yenangyaung of the Lower Irrawaddy Formation in Myanmar (Pilgrim, 1910; Thaung Htike et al., 2005, 2006, 2007, 2008, 2016; Chit Sein et al., 2009; Chit Sein et al., 2009). These faunas assemblage indicates a Late Miocene age (Figure 6.2).

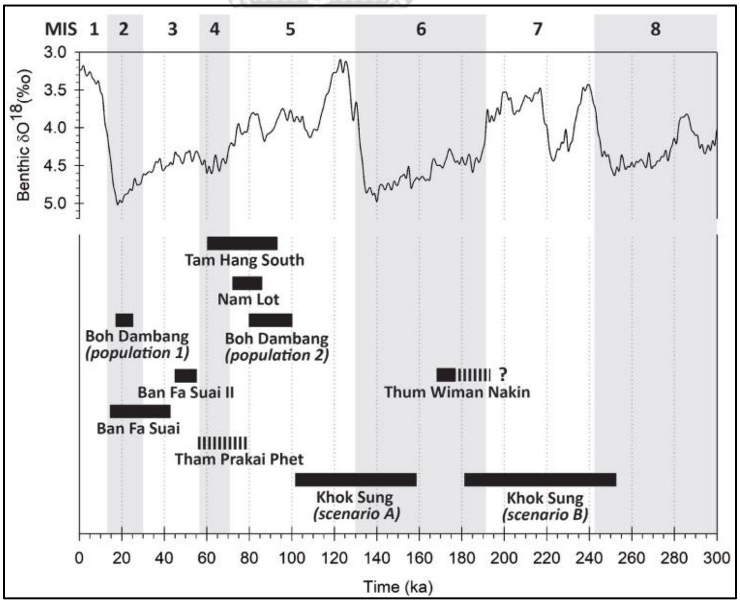

Figure 6. 1 Age range of the Pleistocene assemblage from Khok Sung locality in Nakhon Ratchasima Province, Thailand, MIS data from Lisiecki and Raymo (2005). (Duval et al., 2019).

Fauna assemblage	Country	Eocene			Miocene			Pliocene	Pleistocecn e		
		E	M	L	E	M	L		E	M	L
Tetraconodon magnus Falconer (1868)	Indian Subcontinent						■				
Tetraconodon magnus Khan et al. (2013)	Indian Subcontinent						■				
Propotamochoerus hysudricus Colbert (1935)	Indian Subcontinent						■				
Propotamochoerus hysudricus Pickford (1988)	Indian Subcontinent						■				
Conohyus sindiense (Pilgrim, 1926)	Indian Subcontinent					■					
Tetraconodon minor Pilgrim (1910)	Myanmar						■				
Tetraconodon malensis Thaung Htike et al. (2005)	Myanmar					■					
Tetraconodon magnus Thaung Htike et al. (2006)	Myanmar						■				
Tetraconodon magnus Thaung–Htike et al. (2007)	Myanmar						■				
Tetraconodon intermedius Thaung–Htike et al. (2007)	Myanmar						■				
Tetraconodon malensis Thaung Htike et al. (2008)	Myanmar					■					
Sivachoerus Thaung–Htike et al. (2010)	Myanmar							■			
Conohyus thailandicus Chavasseau et al., 2006	Myanmar					■					
Conohyus thailandicus Ducrocq et al. (1997)	Thailand					■					
Siamochoerus bangmarkensis Ducrocq et al. (1998)	Krabi, Thailand			■							
Egatochoerus jaegeri Orliac et al. (2011)	Krabi, Thailand			■							
Kharatpithecus piriyai Chaimanee et al. (2004)	Khorat, Thailand						■				
Kharatpithecus piriyai Chaimanee et al. (2006)	Khorat, Thailand						■				
Kharatpithecus piriyai Chaimanee et al. (2019)	Khorat, Thailand						■				
Merycopotamus thachangensis Hanta et al. (2008)	Khorat, Thailand						■				
Aceratherium porpani Deng et al. (2013)	Khorat, Thailand						■				
Crocuta crocuta ultimate Suraprasit et al. (2015)	Khorat, Thailand									■	
primate, canid, hyaenid, proboscideans, rhinoceroses, suids, cervids, and bovids Suraprasit et al. (2016)	Khorat, Thailand									■	■
P. hysudricus Sarwar (2016	Indian Subcontinent						■				
P. hysudricus Sarwar Pickford (1988	Indian Subcontinent						■				
P. hysudricus Batoo (2015	Indian Subcontinent						■				
Hippopotamodon sivalense Lydekker (1877)	Indian Subcontinent						■				
Hippopotamodon sivalense Pickford (1988)	Indian Subcontinent						■				
Hippopotamodon sivalense Ahmed (2008)	Indian Subcontinent						■				
Hippopotamodon sivalense Dar (2019)	Indian Subcontinent						■				
Hippopotamodon ultimus Wei et al. (2014)	China						■				
P.hyotherioides Made & Han (1994	China						■				
P.hyotherioides Hou et al. (2018)	China						■				

Note: E=Early, M=Middle, L=Late

Figure 6. 2 The age of suid fossils from the Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province compared with other related species from the Indian subcontinent, Myanmar, and China.

6.2 Sedimentology of the fluvial environment

Three sandpits from Phimai district and one from Chaloem Phra Kiat located in Nakhon Ratchasima Province comprise of very fine to coarse-grained sand maybe granules and pebbles with sedimentary structures deposits from the fluvial environments. The stratigraphic section in the study area can be divide into two units: the upper unit and the lower unit (Chaimanee et al. 2006; Duangkayom et al., 2014). The upper of the unit composed of very fine to medium-grained sand of yellowish brown to reddish brown with light gray mottling. The thickness of bed 3-7 m. The internal structures consist of small-scale (ripple) cross-lamination, climbing-ripple lamination and desiccation cracks, bioturbation, root traces, and wood fragments. However, the lower unit composes of medium to very coarse-grained sand maybe granules and pebbles of light gray to gray colour. The total thickness of the bed 7-15 m. The internal structures consist of tough cross-bedding, planar lamination, ripple cross lamination, mud clasts, wood fragments, and the basal boundaries are mostly erosional. The mammalian faunas can be founded in this lower part.

6.2.1 Discussion of lithofacies

The classification of the lithofacies in the study areas following Miall (1977, 1996) can be divided into seven lithofaies (Figure 6.3). Detail of lithofacies and the discussion on depositional machanism are described below:

1) Facies Gmg: Matrix- supported gravel

These lithofacies comprises of coarse to very coarse-grained maybe pebble or cobble gravel. The clasts are moderate to poorly sorted and are supported by a matrix of sand, silt, and mud. The beds show grading of clasts. The major sedimentary structures include cross-bedde sand, and normal grading. These characteristics reflect the lithofacies is the process of high-strength debris flows (Rust, 1978b).

2) Facies Sr: Ripple cross-laminated sand

These facies are charcterize a variety of asymmetric ripple types. The grain size ranges from medium to coarse-grained. The internal structures include small ripple cross-lamination, and climbing ripples cross-lamination. According to Miall (1977, 1996) corresponds to ripples (low flow regrim).

3) Facies St: Trough cross-bedded sand

These lithofacies develop by the migration of 3-D Dunes (Miall, 1996) comprises of fine to very fine coarse-grained sand. The thickness of these facies 1-3 m. The major structures include trough cross-bedded sand, indicating that it was not in equilibrium with flow conditions throughout its generation (Allen, 1984). The geometry is a concave shape, the base of lithofacies consiste of an erosion surface, although the massive bed sandd occur immediately above the base.

4) Facies Sp: Planar cross-bedded sand

These lithofacies forms by the migration of 2-D Dunes (Miall, 1996). The grain size range from fine to coarse-grained sand. The upper and lower bounding surfaces are typically flat or sharp scoured bases nad tops. The thickness of bed is 0.7 -1 m. According to Miall (1977, 1996), it is interpreted as transverse and linguoid bedform (2-D).

5) Facies Fl: Laminated sand, silt, and mud

These lithofacies is inter-lamination of mud, silt and very fine-grained sand. The internal structures include small-scale ripples, bioturbation, desiccation, and root traces. The thickness of bed is 0.5 – 0.5 m. According to Miall (1996), lithofacies Fl is commonly in overbank areas and represents deposition from suspension.

6) Facies Fsm: silt, clay

These lithofacies comprise of silt and clay. The main feature of this lithofacies includes desiccation cracks, bioturbation, root traces, and mottling. The thickness of bed is 3-5 m. According to Miall (1996) corresponds to deposits in the back swamp or abandoned channel deposits.

7) Facies Fm: Massive mud, silt

These lithofacies include bed of massive mud, and silt. The main features of this lithofacies include desiccation cracks, root traces. The geometry is wedge-shaped. The thickness of bed is 1 – 1.5 m. These lithofacies represent thedeposits from standing pools of water during low-stage channel abandonment. According to Miall (1996), it is interpreted as overbank or abandoned channel deposits.

6.2.2 Discussion of architectural elements

Six architectural elements were recognized (Figure 6.4), including sandy bedforms (SB), lateral accretion deposits (LA), levee deposits (LV), crevasse splay elements (CS), floodplain fines (FF), and abandoned channel (CH(FF)). These elements were defined by their geometries and bounding surfaces. The interpretation of the depositional environment from architectural elements in this study was using Miall (1985, 1996).

Sandy bedforms (SB): Sandy bedforms comprise lithofacies St, Sr, Sp. They are characterized by massive, cross-bedded structures, and sharp bases. The geometry of the channel appears sheet-like, predominated by vertical aggradation. They are usually about >10 m thick. This element is interpreted as sandy bedforms and probably deposited in a channel.

Lateral accretion deposits (LA): Lateral accretion deposits (LA) are composed mainly of sandy facies St, Sp, and Gmg. This element appears typically in the sandstone-dominated environment. They are characterized by concave shape and the base of these lithofacies consists of an erosion surface. The thickness of the bed is >7 m. It is interpreted as channel-fill and point-bar deposits that formed by the lateral migration of channels.

Levee deposits (lithofacies Fl), and Crevasse channel elements (lithofacies Sr, Fl): These are composed of lithofacies Sr, Fl. Their geometries are of the wedge-shaped, showing interfingering and small-scale ripples and climbing ripples. The thickness of the bed is 2 to 7 m. These elements are interpreted as overbank flooding when flood waters of a stream overtop its banks.

Floodplain fines (FF): Floodplain fines (FF) are represented mainly by silt, clay, fine-grained sand, and composed of lithofacies Fsm, Fm, and Fl. They show desiccation cracks, bioturbation, mottling, root traces, and iron concretion. The thickness of the bed is 3-5 m These elements are interpreted as overbank areas from suspension, floodplain deposits.

Abandoned channel fills (CH(FF)): Abandoned channel fills (CH(FF)) is composed of lithofacies Fsm, Fm, and Fl. The geometry is of the wedge-shaped, lenticular in cross-section, clay plugs interbedded with element SB. These elements are interpreted as abandoned channels.

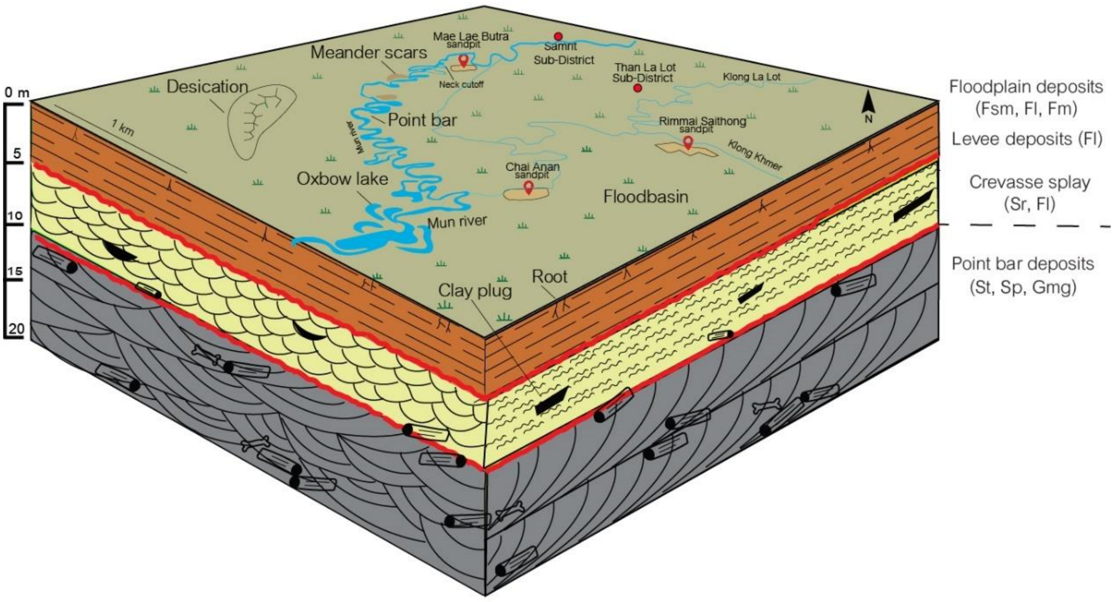

Figure 6. 3 Box diagram of the major morphological elements, and stratification in the study areas (modified from Model 6 of Miall, 1985).

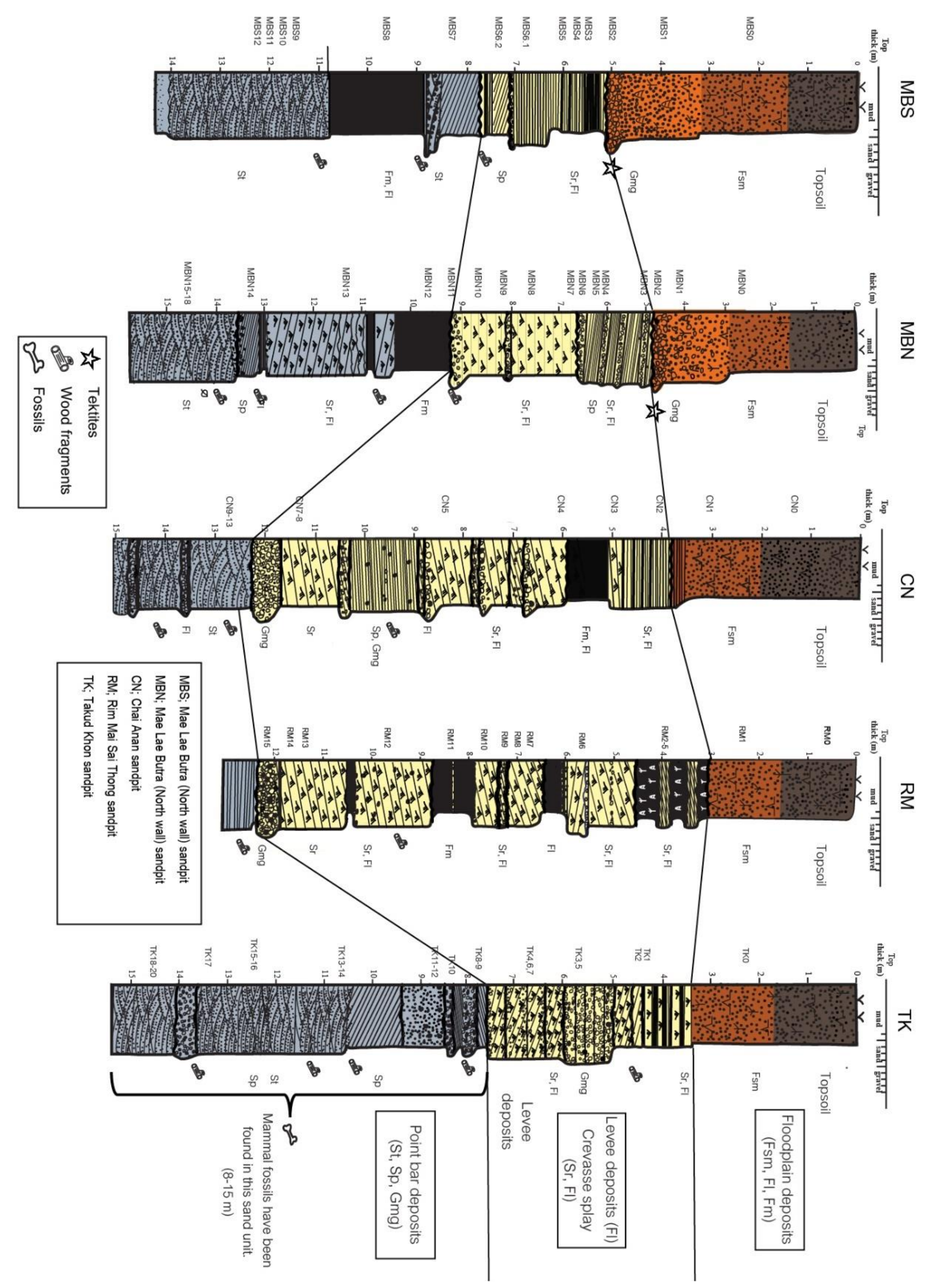

Figure 6. 4 Stratigraphic correlation of the sedimentary of fluvial deposits from Chaloem Phra Kiat and Phimai Districts, Nakhon Ratchasima Province.

6.2.3 Fossil occurrence and the age of sediment

These fossil occurrences in this sandpit are expected to have found between depth 8-15 m. The stratigraphy of the lower unit is characterized by medium to very coarse-grained sand, granules and pebbles with remarkable gray color of a sequence. This sand represents to point bar deposits or sandy bedform indicating that the depositional process of the meandering river corresponding to facies: trough cross-bedded sand (St), planar cross-bedded sand (Sp), ripple cross-laminated sand (Sr), Laminated sand, silt, and mud (Fl), Massive mud, silt (Fm). They consist of trough crossbeds, planar crossbeds, ripple marks, lamination, and massive.

The absolute age dating of deposition and fossil materials in the Khok Sung was suggested the late Pleistocene (Haines et al., 2004; Duval et al., 2019). However, the stratigraphy in this study area shows mostly similar sequence in comparison with the stratigraphy mentioned by Haines et al (2004) and Duval et al (2019). Therefore, it can be correlated with the upper part unit of the study area which is composed of very fine to medium-grained sand of yellowish brown to reddish brown. Based on straigraphical correlation, the age of this unit can be inferred as the late Pleistocene.

6.3 Conclusion

The lithofacies and architecture elements of ancient Mun River found in the stratigraphic unit from Nakhon Ratchasima sandpits consists of very fine to very coarse-grained sand maybe granules, pebbles with thick sand beds interbedded with thin mud to form numerous interfingering structures. Six architectural elements were classified correspondingly with depositional environments and mechanism including (1) sandy bedforms, (2) lateral accretion deposits, (3) levee deposits, (4) floodplain fines, (5) crevasse splay (CS) and (6) abandoned channel fills, respectively. A detail of architectural elements analysis from this study suggests that the sand-beds were mainly deposited by lateral migration of channels, reflecting growth, migration, abandonment and filling of channels in meandering river environment. All those lithofacies and architectural elements confirm the deposition environment of channel-fill and point-bar deposits in corresponds to the lateral migration of channels. The upper part of the stratigraphic unit comprises of fine-grained clastic facies suggesting the deposition from suspension as a low flow regime and low energy. However, the lower part is dominated by sand lithofacies, and less commonly gravel facies. It indicates high flow regime and rapid flow and high energy. Both of them were represented the meandering features of fluvial system with high sinuosity channels. The analysis in facies and architectural elements in this work improves our understanding of the depositional mechanism and environment of the ancient Mun River as well as providing stratigraphic key facies in the correlation of future fossil layers that may probably discover in the similar depositional features.

The suid fossils were collected form this lower part of the stratigraphic unit. All these study specimens are similar to those of the related species from the Indian subcontinent. These fossils can be identified into four species such as *Tetraconodon* cf. *intermedius*, *Conohyus* cf. *sindiense*, *Propotamochoerus* cf. *hysudricus*, and *Hippopotamodon* cf. *sivalense*. First, *Tetraconodon* cf. *Intermedius* is characterized by extremely enlarged premolars, relatively small M^3/ M_3, and wrinkle enamel. Next, Conohyus cf. *sindiense* is characterized by enlargement of the premolars and the shortness of the molars. In addition, *Propotamochoerus* cf. *hysudricus*, this species has two cusplets in the sagittal valley of P^4. The furchen are shallow, and no cingula on a molar, except for occasional basal pillars at the end of median valleys. The talon/talonid of M^3/M_3 is relatively simple. The anterior and posterior cusps of premolars are variable, but never reach the same height as the main cusps. Finally, *Hippotamodon* cf. *sivalense*, the posterior accessory cusp of P^4 is almost as large as two main buccal cusps. The sagittal cusplets are present in the central valley between the protocone and the paracone-metacone. The molar enamel is relatively thin, and structurally simple. The furchen are well-developed. The buccal cusps in lower molars are noticeably lower-crowned than lingual ones. The species of *Hippopotamodon sivalense* found in this lower sand unit maybe use as index fossils corresponds to the Late Miocene age (10.2 – 7.2 Ma).

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