# บรรพชีวินวิทยาของซากดึกดำบรรพ์โปรบอสซิเดียนในบริเวณบ่อทรายไทยสิน อำเภอเฉลิมพระเกียรติ จังหวัดนครราชสีมา

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# PALEONTOLOGY OF PROBOSCIDEAN FOSSILS FROM THAISIN SANDPIT, AMPHOE CHALOEM PHRA KIAT, CHANGWAT NAKHON RATCHASIMA

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บ่อทรายไทยสิน ในตำบลท่าช้าง อำเภอเฉลิมพระเกียรติ จังหวัดนครราชสีมา ประกอบด้วยตะกอนหลากหลายขนาด การแปลภาพถ่ายทางอากาศแสดงให้เห็นว่า บ่อทรายไทยสินตั้งอยู่ในบริเวณที่เป็นรอยโค้งตวัด การลำดับชั้นหินที่ต่อเนื่องนำเสนอถึงสภาพแวดล้อมบรรพกาลของบ่อทรายไทยสินเป็นการสะสมตัวของสิ่งทับถมทางน้ำพาด้วยหลายเหตุการณ์ สามหน่วยตะกอนถูกนำมาแปลผล หน่วยที่หนึ่ง อยู่ด้านบน คือ ชั้นตะกอนประกอบด้วยตะกอนลำน้ำซึ่งมีการคัดขนาดที่ไม่ดี ทรายขนาดปานกลางจนถึงหยาบ กรวด ร่วมกับโครงสร้างชั้นเฉียงระดับและเศษซากพืช หน่วยที่สอง ประกอบด้วยตะกอนสะสมตัวในที่ราบน้ำท่วมถึง ตะกอนมีการคัดขนาดดี พบลักษณะโครงสร้างรากไม้, ร่องรอยรบกวนของสิ่งมีชีวิต และเศษซากพืช หน่วยที่สาม อยู่ล่างสุด ประกอบด้วยตะกอนในช่วงน้ำหลาก มีขนาดของตะกอนที่หลากหลาย พบโครงสร้างชั้นเฉียงระดับ ท่อนไม้ขนาดใหญ่ตกจมร่วม ตะกอนละเอียดเนื้อเหนียว และชั้นถ่านหินเลนขนาดบาง

ตัวอย่างซากดึกดำบรรพ์ฟันโปรบอสซิเดียนจำนวนเจ็ดชิ้น คือ 2TE1, 3TE1, 3TE2, 4TE1, 6TE1, 6TE2 และ 9TE1 ถูกค้นพบจากบ่อทรายไทยสิน พวกมันถูกศึกษาและระบุประเภท โดยวิธีการเปรียบเทียบลักษณะสัณฐานวิทยาภายนอกของฟัน และการวัดค่าขอบเขตมิติของฟัน ซากดึกดำบรรพ์โปรบอสซิเดียนจำนวนสองสกุลถูกจัดจำแนกให้อยู่ในสกุลสเตโกโลโฟดอนและสกุลสเตโกดอน การวิเคราะห์ทางสถิติโดยวิธีคลัสเตอร์ถูกนำมาใช้ร่วมเพื่อจัดกลุ่มซากดึกดำบรรพ์เป็นกลุ่มย่อย โดยผลการแบ่งตามค่าความกว้างของฟัน ความสูงของยอดฟัน และความหนาของเคลือบฟันได้เป็นสองกลุ่ม กลุ่มแรกประกอบด้วยซากดึกดำบรรพ์ 2TE1, 3TE1, 3TE2 และ 9TE1 อีกกลุ่มประกอบด้วยซากดึกดำบรรพ์ 4TE1, 6TE1 และ 6TE2 ซึ่งจากวิธีจำแนกโดยใช้สัณฐานวิทยาภายนอกของฟันและการวิเคราะห์คลัสเตอร์ พบว่ามีผลการจำแนกเหมือนกัน

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SUTIPA ARSIRAPOJ: PALEONTOLOGY OF PROBOSCIDEAN FOSSILS FROM THAISIN SANDPIT, AMPHOE CHALOEM PHRA KIAT, CHANGWAT NAKHON RATCHASIMA. ADVISOR: ASST. PROF. THASINEE CHAROENTITIRAT, Ph.D., CO-ADVISOR: YUPA THASOD, Ph.D., 104 pp.

Thaisin sandpit in Tambon Tha Chang, Amphoe Chaloem Phra Kiat, Changwat Nakhon Ratchasima consists of various sizes of sediments. Aerial photograph interpretation shows that Thaisin sandpit is located in Meander scar. Stratigraphic successions suggested that paleoenvironment of Thaisin sandpit was fluvial deposit with various events. Three units were interpreted. Unit 1 is the upper unit, sedimentary layers are composed of channel sediments with poorly-sorted, medium to very coarse sand and gravel with cross-bedding structure and plant fragments. Unit 2, consists of sediments deposited in flood plain environment with well-sorted, root traces, bioturbation structure and few plant fragments. Unit 3, the lower most part, contains sediments in flood situation with varied size of sediments, cross-bedding and large plant fragment, tight pack dark gray color sediments with peat at the bottom.

Seven proboscidean fossils teeth specimens, 2TE1, 3TE1, 3TE2 4TE1, 6TE1, 6TE2 and 9TE1, were found from Thaisin sandpit. They were studied and identified by comparison of their external morphology and measurement methods of teeth. Two genera of proboscidean fossils were classified; Stegodon and Stegolophodon. Statistical analysis was also used for clustering fossils into groups. Maximum width, crown height and enamel thickness of teeth into two groups. The first group is composes of T2TE1, 3TE1, 3TE2 and 9TE1, another group contains 4TE1, 6TE1 and 6TE2. The results of both external morphology and the clustering analysis are similar.

Paleoecology was described from the relationship between fossil and its environment. The dietary of proboscidean shows the evolution trend of teeth. Stegodon shows the higher crown, wider tooth and thicker enamel than Stegolophodon. These indicated they were the grasser than browser. The proboscidean might live not far from the forest and river, while the turbulence weather was carried bones and trees along the river then deposited rapidly.

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CONTENTS

Page

THAI ABSTRACT .......... iv
ENGLISH ABSTRACT .......... v
ACKNOWLEDGEMENTS .......... vi
CONTENTS .......... vii
LIST OF TABLES .......... 1
LIST OF FIGURES .......... 2
CHAPTER I INTRODUCTION .......... 1
1.1 Rationale .......... 1
1.2 Objectives .......... 2
1.3 Scope and limitation .......... 2
1.5 Expected outputs .......... 4
1.6 Research methodology .......... 5
1.7 Literature reviews .......... 7
1.7.1 Geology and Stratigraphy Khorat Plateau .......... 7
1.7.2 Paleontology of Proboscidean fossils .......... 12
1.7.2.1 Teeth morphology .......... 13
1.7.2.2 Teeth measurements .......... 15
1.7.2.3 Classification of Proboscidean fossils .......... 16
1.7.2.4 Cluster analysis .......... 18
1.7.3 Paleoenvironment .......... 20
1.7.4 Paleoecology .......... 22
CHAPTER II GEOLOGICAL REVIEWS OF STUDY AREA .......... 23
2.1 Geology of study area .......... 23
2.2 Mapping and field investigations .......... 24
2.3 Fossil locality at Thaisin Sandpit .......... 28
CHAPTER III STRATIGRAPHY AND SEDIMENTOLOGY .......... 35
3.1 Geomorphology around Thaisin sandpit .......... 35

Page

3.2 Sedimentology and stratigraphy of Thaisin sandpit .......... 37
3.3 Paleoenvironment .......... 43
CHAPTER IV SYSTEMATIC PALEONTOLOGY OF PROBOSCIDEAN FOSSILS .......... 47
4.1 Systematic Paleontology .......... 47
4.1.1 Terminology .......... 47
4.1.1.1 General dentition terminology .......... 47
4.1.1.2 Terminology of proboscidean teeth .......... 50
4.1.2 Identification and classification of proboscidean fossils .......... 52
4.1.2.1 External morphology of teeth .......... 52
4.1.2.2 Teeth Measurement .......... 53
4.2 Results .......... 54
4.2.1 External morphology descriptions .......... 54
4.2.2 Teeth measurement .......... 63
4.2.2.1 Scatter diagrams .......... 66
4.3 Statistical method for cluster analysis .......... 69
4.3.1 Correlations statistic .......... 69
4.3.2 Cluster Analysis .......... 72
CHAPTER V DISCUSSIONS AND CONCLUSIONS .......... 75
5.1 Systematic paleontology of proboscidean fossils from Thaisin sandpit .......... 75
5.1.1 Classification by external morphology .......... 75
5.1.2 Teeth measurement .......... 75
5.1.3 Statistical analysis of proboscidean fossils .......... 76
5.2 Sedimentology and stratigraphy .......... 77
5.3 Paleoenvironment of Mun River at Thaisin sandpit .......... 78
5.4 Paleoecology of proboscidean fossils from Thaisin sandpit .......... 78
REFERENCES .......... 80
APPENDIX .......... 84

Page

Appendix A: Mining process ........................................................................................ 85

Appendix B: Fossils in Thaisin sandpit........................................................................ 88

Appendix C: Raw data for statistical analysis.............................................................. 95

Appendix D: Condition test for correlation ................................................................. 96

VITA.................................................................................................................................. 104

# LIST OF TABLES

**Page**


Table 3.1 Lithostratigraphic descriptions at southern part of Thaisin sandpit ............... 42

Table 4.1 Teeth measurement method using for proboscidean fossils from Thaisin sandpit ............... 53

Table 4.2 Checklist for the characteristic of proboscidean teeth from Thaisin sandpit ............... 63

Table 4.3 Teeth measurement ............... 64

Table 4.4 Suitable values of teeth (mm) ............... 65

Table 4.5 Parametric correlation tables ............... 70

Table 4.6 Nonparametric correlations table ............... 71

Table 4.7 Proximity Matrix table ............... 72

Table 4.8 Agglomeration Schedule ............... 73

Table 4.9 Cluster Membership ............... 73

# LIST OF FIGURES

**Page**

Figure 1.1 Geological setting of the study area from google earth aerial photo ............ 4
Figure 1.2 Flowchart of work ............ 6
Figure 1.3 River and mountain range map of Northeastern, Thailand. ............ 8
Figure 1.4 Geologic map of Nakhon Ratchasima ............ 9
Figure 1.5 Proboscidean dental trends and evolutions ............ 14
Figure 1.6 Pattern of loph in Asian Stegodontidae ............ 15
Figure 2.1 Topographic and digital elevation model mapping of Thaisin sandpit ............ 25
Figure 2.2 Old sandpit in Tha Chang district that contact with recent river in the Northeast corner ............ 26
Figure 2.3 Ban Tanot in the low terrace but still have some places like wetland area ............ 26
Figure 2.4 Nong song hong, the swamp area that surround with terrace ............ 27
Figure 2.5 Ban map makha that is located in high elevation ............ 27
Figure 2.6 Diagram of Thaisin sandpit. ............ 28
Figure 2.7 Eastern part of Outcrop at Thaisin sandpit ............ 29
Figure 2.8 Southern part of Outcrop at Thaisin sandpit ............ 30
Figure 2.9 Northern part of Outcrop at Thaisin sandpit ............ 31
Figure 2.10 Western part of Outcrop at Thaisin sandpit ............ 32
Figure 2.11 Cross-bedding, clay block and peat ............ 33
Figure 2.12 Tektite and Bioturbation ............ 33
Figure 2.13 Iron oxide, Sulphur and Pyrite ............ 34
Figure 3.1 Geomorphology of Mun River in Amphoe Chaloem Phra Kiat ............ 36
Figure 3.2 Grain size chart ............ 37
Figure 3.3 Stratigraphic column at eastern part of Thaisin sandpit ............ 38
Figure 3.4 Stratigraphic column at southern part of Thaisin sandpit ............ 39
Figure 3.5 Stratigraphic column at northern part of Thaisin sandpit ............ 40
Figure 3.6 Stratigraphic column at western part of Thaisin sandpit ............ 41
Figure 3.7 Total stratigraphic columns of Thaisin sandpit ............ 44
Figure 4.1 General dentition of proboscidean tooth ............ 48

Figure 4.2 Anatomical orientation of mammal .................................................................. 49
Figure 4.3 Anatomical orientation of proboscidean, Maxilla are from *Stegolophodon cautleyi* and Mandible are from *Stegodon insignis* ................................................ 49
Figure 4.4 Elephant Teeth replacement diagram a. Cross section b. Tooth replacement in horizon ........................................................................................ 50
Figure 4.5 Elephant tooth morphology.................................................................................. 51
Figure 4.6 Fossil 4TE1; A: occlusal view, B: lingual view?, C: buccall view? ................... 54
Figure 4.7 Fossil 6TE1 ; A: occlusal view, B: buccal view, C: lingual view....................... 55
Figure 4.8 Fossil 6TE2 ; A: occlusal view, B: buccal view, C: lingual view....................... 56
Figure 4.9 Fossil 2TE1 ; A: occlusal view, B: lingual view?, C: buccal view? ................... 58
Figure 4.10 Fossil 3TE1; A: occlusal view, B: buccal view? C: lingual view?, D: Stufenbildung............................................................................................................ 59
Figure 4.11 Fossil 3TE2 ; A: occlusal view, B: buccal view?, C: lingual view? ................. 60
Figure 4.12 Fossil 9TE1; A: occlusal view, B: lingual view?, C: buccal view?, ................. 61
Figure 4.13 Scatter Diagram between maximum width and enamel thickness ............ 66
Figure 4.14 Scatter Diagram between maximum width and crown height..................... 67
Figure 4.15 Scatter Diagram between crown height and enamel thickness .................. 68
Figure 4.16 Dendrogram from Hierarchical clustering of proboscidean fossils ............. 74

# CHAPTER I
# INTRODUCTION

Fossils are very important information, they can tell the story of animals which lived in the past. In Quaternary, Thailand had a wide range of fauna with a high biodiversity. Elephants are large mammals belonging to order Proboscidea (animals having trunks). The common ancestor of elephants probably was amphibious, staying near and in rivers.

The Mun River is the major river of Nakhon Ratchasima, and drains into the Khorat Basin, a suitable environment for mammals and an area conducive to sedimentary deposition. In 1986, sand-mining started near the Mun River in Amphoe Chaloem Phra Kiat, Nakhon Ratchasima, and the group of fossil communities was found. Most of the fossils are ancient elephants. Teeth and bones are the most important specimens to identify the type of mammals, especially morphology of teeth which could tell about the diet of the animals and the evolution of elephants. Paleontology and stratigraphy are needed to reconstruct the paleoecology and paleoenvironment where the proboscideans had been living.

## 1.1 Rationale

According to the records of the sand-mining company, the sand layers were removed to about 5-30 m depth near the Mun River and the group of fossils communities was found. Most fossils are ancient elephants from the Tertiary Age, from 8 genera of a total of 38 genera worldwide; the others are 40 species of vertebrate animals and the Plio-Pleistocene petrified wood (Benyasuta, 2003). The sedimentary basin of Mun River, specifically in Nakhon Ratchasima, was deposited from Tertiary to Quaternary.

The abundance of proboscidean fossils from sandpits in Tambon Tha Chang, Amphoe Chaloem Phra Kiat, Changwat Nakhon Ratchasima were reported by many researchers. Nowadays proboscidean fossils near the Mun River areas are still being found in the sandpits. In this study, the proboscidean fossils are from the Thaisin sandpit which is the newest fossil collection and identification locality. The external morphology of proboscidean fossil teeth and the teeth measurements are generally methods used to classify the proboscidean fossils. This study will include trial statistical classification by numerical values to cluster groups of fossils and will then be compared with other methods.

Sedimentology and stratigraphy are also studied in order to explain the paleoenvironment and paleoecology. The living environment and habitat of ancient elephants may be the same to that of modern elephants. Because of a physical resemblance it can be assumed that they also lived in plains areas with plentiful fruits and grasses. They also lived near the river. To consume large amounts of water. This explains why fossils are discovered in communities of fossils (synpaleoecology).

## 1.2 Objectives

The purposes of this study are

- To identify the proboscidean fossils found in Thaisin sand pits.
- To construct stratigraphy in study area.
- To reconstruct paleoenvironment when proboscidean had been living.
- To reconstruct paleoecology of proboscidean fossils.

## 1.3 Scope and limitation

From Thaisin sandpit in Amphoe Chaloem Phra Kiat, Changwat Nakhon Ratchasima, proboscidean teeth fossils were collected from the sandpit between July 2011 to May 2012. Description of proboscidean fossils are based on terminology by lShoshani and Tassy (1996). External morphology of teeth and teeth measurement methods are used to identification and classification of proboscidean fossils. The results from both identification methods will be brought to compares with the result from cluster analysis, as the classification by statistical method.

Lithostratigraphic sections were collected by considered from the almost obvious part of the sand layers in four directions around the sandpit, near the area that fossils were found. Sedimentology and stratigraphy were explained together with the estimate fossils position and others objects that found in the sandpit by the graphic pictures of columns.

Google Earth satellite data in the year 2014 was used to interpret the geomorphology near the study area, combining with lithostratigraphic columns in order to describe the paleoenvironment in Thaisin sandpit.

The definition of ecology is the relationship between organisms and environment. This study will use the paleoenvironment and paleontology of proboscidean teeth from Thaisin sandpit to explain the paleoecology in the study area.

### 1.4 Location of the study area

The study area is located in Tambon Tha Chang, Amphoe Chaloem Phra Kiat, situated in Changwat Nakhon Ratchasima. The coordinates of the study area are approximately defined as 200000 E, 1665000 N on the northwestern edge and 210000 E, 1656000 N on the southeastern edge in Universal Transverse Mercator projection. The geological features of the study area consist of wide flood plain areas cover with Quaternary sediments of Mun River. Stratigraphic columns were collected from four directions as shown in the map below (Figure1.1).

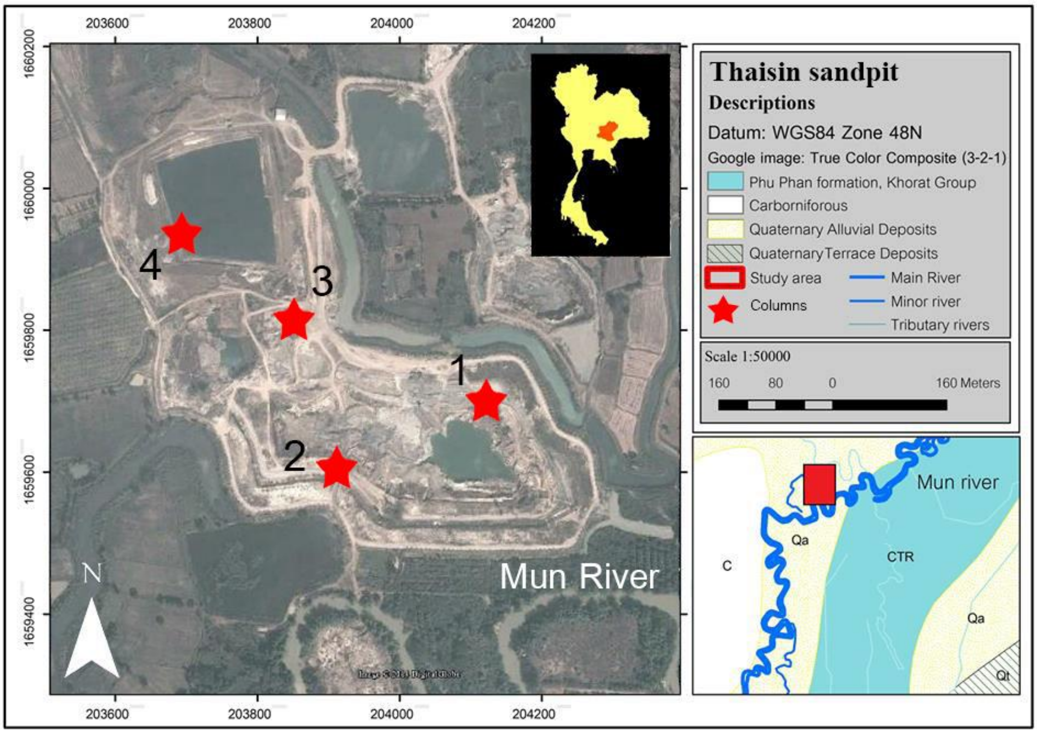


**Figure 1.1** Geological setting of the study area from google earth aerial photo (www.google.com).

### 1.5 Expected outputs

1. Complete Stratigraphic section of the Thaisin sandpit
2. Taxonomy of proboscidean fossils from the Thaisin sandpit
3. Reconstruct the paleoenvironment of the Thaisin sandpit
4. Paleoecology of proboscideans in the Thaisin sandpit

These results should provide data on other sandpits from the Mun river area to demonstrate the sedimentary deposition of the paleo - Mun river in Quaternary and its surrounding environment. Specifically, the ecology of large mammals living near the paleo - Mun River, and elephants.

## 1.6 Research methodology

1. Preparation
   1.1 Literature review of paleontology of proboscidean fossils.
   1.2 Literature review of sedimentology, stratigraphy and lithology of the Khorat Basin.
   1.3 Literature review of using cluster analysis method in ecology.

2. Mapping and field investigation
   2.1 Preparing geological maps combining geographical mapping and transportation data by using a GIS program.
   2.2 Field investigations to find the fossils location.

3. Sample collection and making lithostratigraphic columnar sections
   3.1 Collecting samples in July 2011 to May 2011.
   3.2 Making lithostratigraphic columnar sections while collecting samples.

4. Reconstruction of paleoenvironments
   4.1 Preparation of columnar sections from the study area
   4.2 Identification of the sedimentary structure
   4.3 Sedimentological analysis of sediments
   4.4 Reconstruction of paleoenvironments from the sedimentological analysis of the Mun river sediments

5. Identification and classification
   5.1 Paleontological study of the fossils, external morphology, measurement, description and identification
   5.2 Classification by using dental nomenclature (Tassy, 1996).

6. Reconstruct the paleoecology by using cluster analysis
   6.1 Data preparation
   6.2 Analyze data to find the relationship of fossils and drawing diagrams.

7. Discussion, conclusion and writing of the thesis

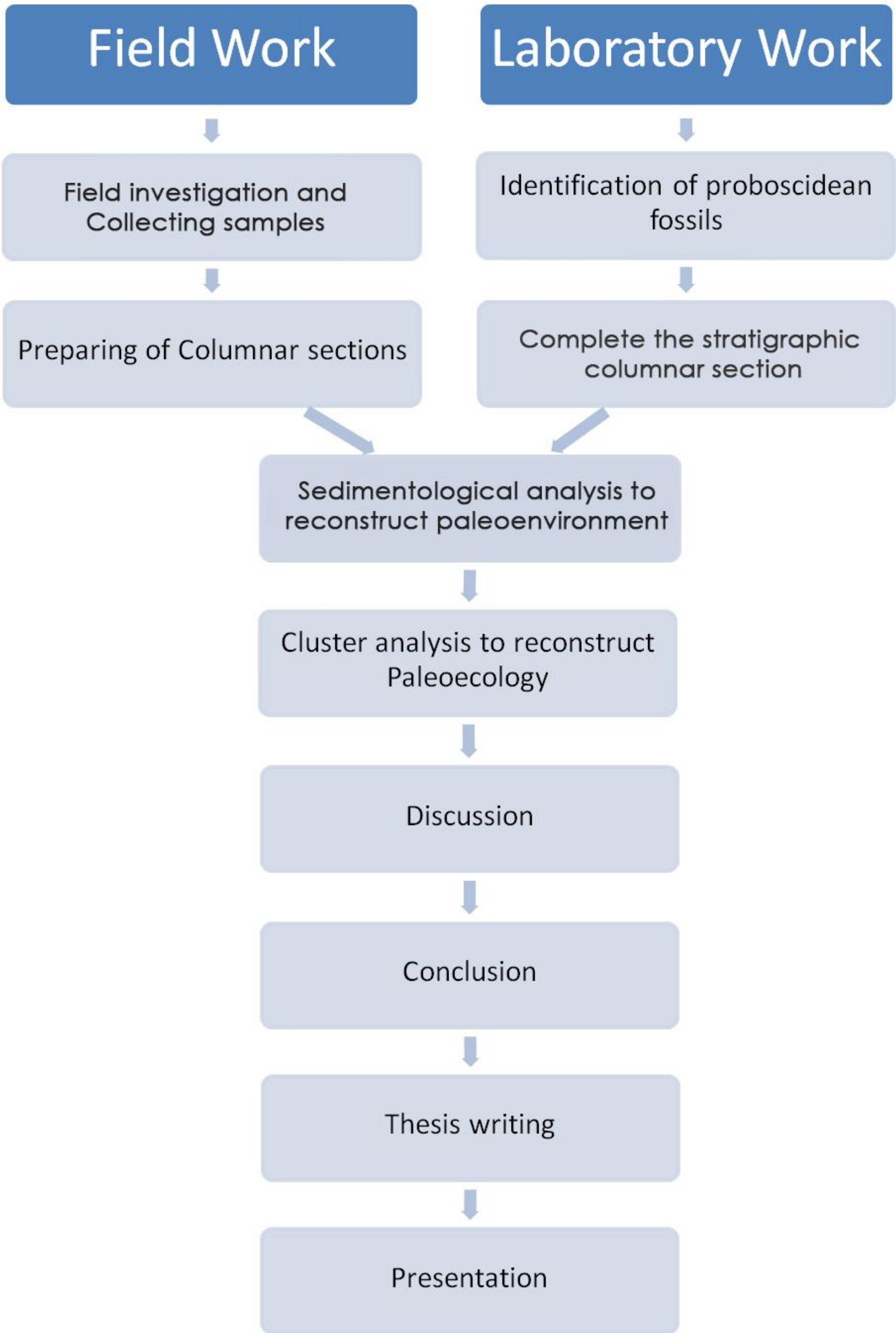


**Figure 1.2** Flowchart of work.

## 1.7 Literature reviews

### 1.7.1 Geology and Stratigraphy Khorat Plateau

Isan is the northeastern region of Thailand. It is located between latitude 14°07' and 18°26' N, longitude 100°54’ and 105°38’ E, approximately an area of about 150,000 square kilometers. The geological features of Isan have its own characters, and are also known as the Khorat Plateau which includes all the area in the northeastern part of Thailand.

Many studies were done in the Khorat plateau, located in Northeastern part of Thailand. It has a “sauce-pan” morphology (Piyasin, 1995) ascribed from the shape that is rimmed by mountains that have a height of about 600-1,000 m. above mean sea level, Phetchabun and Dong Phayayen Ranges are found on its western margins, San Kamphaeng and Phanom Dong Rak Ranges on its southern margins. The central area of the Khorat plateau is divided by the Anticlinorium Phu Phan range from northwest-southeast into two depositional basins, the Sakon Nakhon basin in the north that is smaller than the Khorat basin in the south. Both basins are composed of floodplain, non-floodplain and undulating plateau elevated 150 to 500 meters above mean sea level and then gently sloping Northward and Eastward to the Mekong River (Figure 1.3).

The area of the Khorat basin is about 33,000 square kilometers. By the effect of the Mun and Chi Rivers, Quaternary depositional process took place through the weathering and erosion of the Khorat group in Tertiary to Early Quaternary. The residual deposit are composed of sand and clayey sand. The general geology of the Khorat Group is the red thick bed of continental sediments from Mesozoic age, consisting of sandstone, silt, clay and conglomerate transported by fluvial deposit. The thickness of Khorat group is about 4,000 meters. The lithologic description of the Khorat group can separateit into nine formations, Huai Hin Lat, Nam Phong, Phu Kradung, Phra Wihan, Sao Khua, Phu Phan, Khok Kruat, Mahasarakham and Phu Tok, respectively (Figure 1.4)

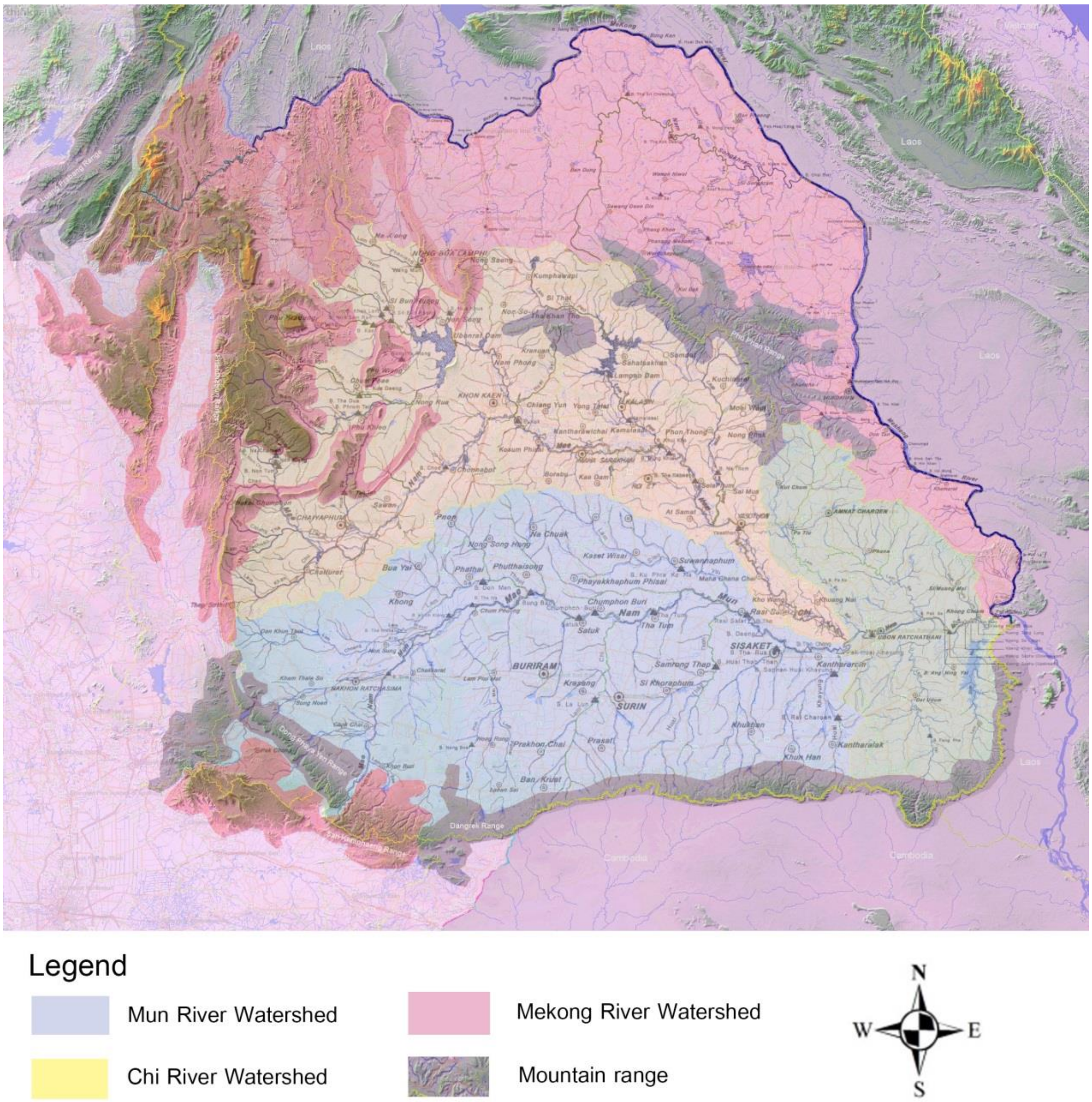




**Figure 1.3** River and mountain range map of Northeastern, Thailand.
(http://www.geocities.jp)

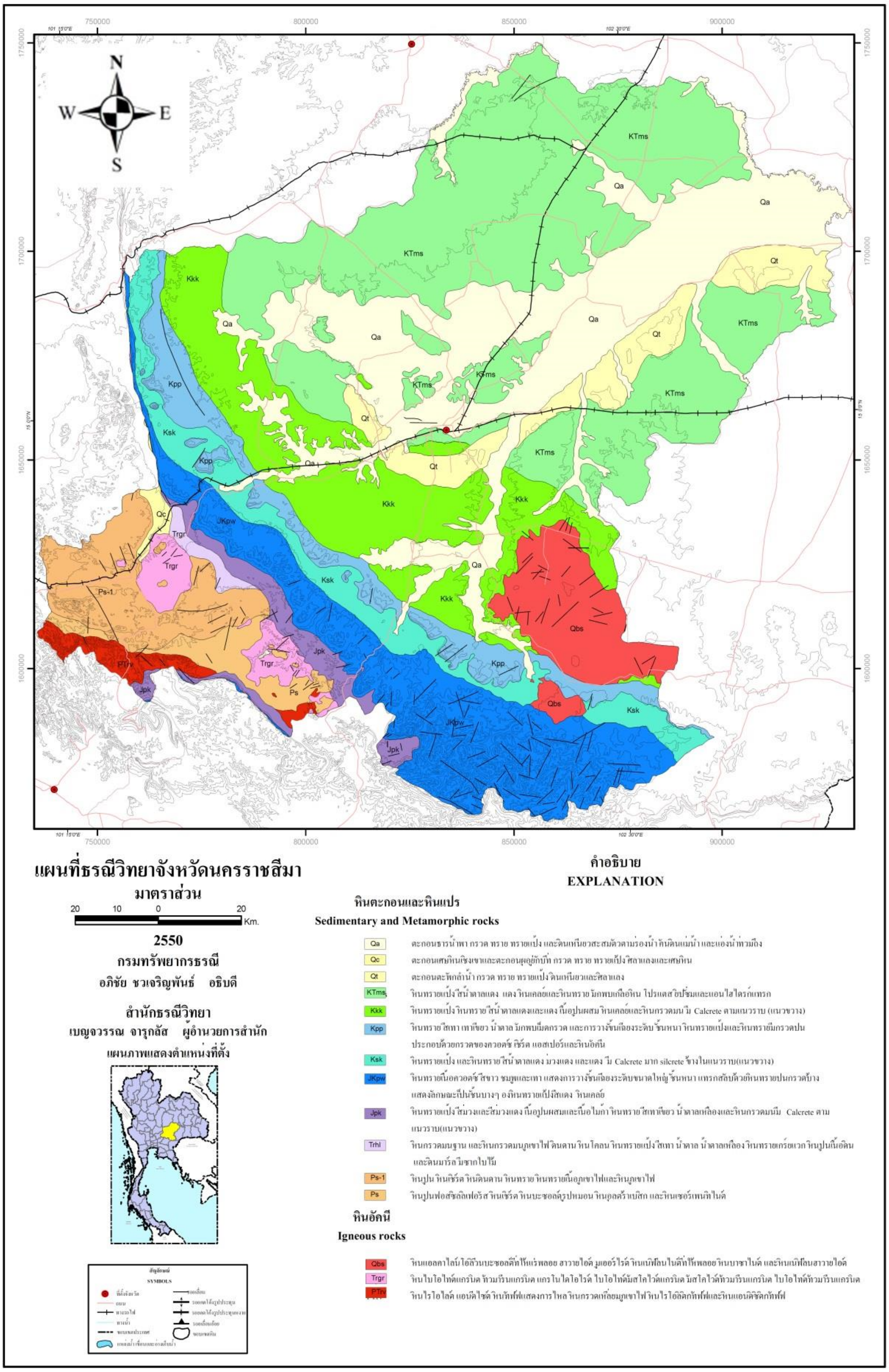


**Figure 1.4** Geologic map of Nakhon Ratchasima (DMR, 2550).

The upper Mahasarakham Formation consists of red brick mudstone, siltstone, red sandstone and a thin lenticular layer of gypsum, layered unconformity on the Mahasarakham Formation.

Above the Khorat Group is Cenozoic rock layer but there is no evidence of Tertiary rock layers. Except by assuming age from the unconsolidated Cretaceous sediments layer above the rock salt of Mahasarakham Formation and Quaternary gravel layer that found petrified woods. On the Khorat Plateau also Quaternary sediments are found below ground level as shown by information from boreholes made while drilling potash holes in the Na Chueak district, Mahasarakham Province. Marl stone was found at a depth of 32-70 meters, and the percentage of phosphate is very low. This is similar to the surface of outcrops in the west of Roi Et province.

Kobayashi and Huzioka (1961) also found fossil fragments of shells and herbivorous mammals from the Quaternary. Quaternary sediments such as gravel bed and lateritic soil along the Northern and southern edges of Khorat Basin. Petrified wood was found in the Upper Cretaceous to Lower Quaternary gravel bed. In addition, Tektites were found and their ages about 0.7 million years in the gravel beds in Khon Kaen Province. These results show that the gravel beds and laterite layers were coverd in the Northeast, where Tektites are embedded. The gravel bed that found in almost every part on the Khorat Plateau may suggests to be older than 0.7 million years.

Some areas of the Northeast are covered with reddish brown and yellow loess. The age of the sediments was determined to be 8,190 $\pm$120 years. Sandpits in Tambon Tha Chang, Amphoe Chaloem Phra Kiat in the northeast district of Nakhon Ratchasima, showed reddish brown loess sediments accumulation over 8 meters thick. Fossil teeth of ancient elephants, *Zygolophodon (Sinomastodon)* and *Stegolophodon (Eostegodon)* in Pleistocene age were found associated with a piece of petrified wood.

In some areas of Buriram, Surin and Sisaket provinces, there is evidence of basalt flow over the Khorat group. The age of the basalt is about 920,000 yr. B.P. and it is most likely a Lower Pleistocene deposit. Deposition continued in the Quaternary, and variations of sedimentary sequences depend upon climatic changes and existing geomorphic features.

In Mun river floodplain, terrace deposits are also caused by geomorphic features, where the level of terrace is dividing by type of sediments, High terraces composed of semi consolidated sand and gravels, with the fragments of petrified wood, founded together with gravels set in sand and silt matrix, with the hard pan layer of laterite on the upper part. Age of deposition is assumed from tektites in the gravel to be within 700,000 yr. B.P. (DMR, 2002, Sattayarak*, et al.*, 1998)

Sattayarak*, et al.* (1998) were describing the Geological evidence on the Khorat plateau in the early Tertiary to Quaternary as follows. The effect of the collision of the Indian plate and the Eurasian plate, Phu Phan Anticlinorium was uplifted. Large ancient rivers were drained into the Khorat basin, and eroded rock salts and the Phu Tok Formation. After the Eocene, the ancient rivers began to deposit colluvial and alluvial sediments through wind and flash floods, and appear to be the new younger red beds. The unconformity of siliceous bed lying on the new younger red beds at Ban Krok Duen Ha, Nakhon Ratchasima province, that are covered by poorly sorted gravel beds is suspected to have come from hydrothermal events at about 11 Ma. By the flew of hydrothermal events, maybe the cause of being petrified wood in that area. The gravel bed in the top of the upper sediments is comprised of white quartz, gray chert and round fragment pieces of petrified wood. The petrified woods were classified to be highly developed Dicotyledons, estimated age Tertiary. Concluding from the geological evidence above, these upper gravel beds may have been caused by reworked event of sediments from the changed of slope at about 600,000 – 700,000 years ago. This corresponds to the subsidence event in central part of Nakhon Ratchasima about 700,000 years ago.

### 1.7.2 Paleontology of Proboscidean fossils

Elephants are large mammals belonging to Order Proboscidea, meaning animal having a trunk (Illiger, 1811) and includes extinct and living elephants. The important characteristic of Proboscideans is that they have trunks, long tubular noses composed of muscle without bone. It consists of the upper lips and nostril combined together. Incisors evolved into tusks, they have no canines, and the molars have many rows of cusps or ridges. An elephant has two sets of teeth (Diphyodont). The deciduous or milk teeth in the immature proboscidean, and permanent teeth for the mature proboscidean will uses for rest of their lifetime. The replacements of molars in primitive elephants are located vertically but in modern elephants they are evolved into horizontal replacements, from posterior to anterior. Because of the large body, the skull of the elephant is also big to be able to support the weight of tusk and trunk.

Teeth and bones are the most durable parts of animals tooth specimens are important to identify the type of mammals. The orphology of teeth can tell researchers about the diet of the animals and shows the evolutionary process by comparing primitive or advanced characteristics with the holotype. The chemical composition of tooth enamel can be dated by using stable isotopes (Fox and Fisher, 2001).

The classification of elephant fossils has a long history. In the beginning, the method of identification used were characteristics such as the position of tusk and size and shape of the skull which can indicate the characteristics of the trunk. But the discovery of a complete skull and tusks is very rare compared to the discovery of teeth. This led to the identification of the morphology of the teeth, which can indicate evolution. Later measuring the composition of the teeth was added for comparison and was statistically calculated to be more efficient in identification.

### 1.7.2.1 Teeth morphology

The dental characteristics of proboscidean taxa have changed dramatically during the past 50-45 million years. The trends of change are related to an increase in body size and type of food consumed. The number of cheek teeth in adult did not change, but canines were lost, and the incisors or tusks were reduced in number (Shoshani and Tassy, 1996). Proboscidean dental trends were increases in size, number of ridges and complexity. Primitive proboscideans had low crowned teeth with three or four plates per upper third molar, some taxa had canine teeth, replacement of teeth followed a vertical displacement, different from more modern proboscideans, the upper third molars had many more plates with high crowned teeth, and the replacement had changed to horizontal displacement. Also, the composition of the teeth were changed in each ancient elephants' genus such as the presence or absence of Anterior - Posterior central conules. (Shoshani, 1998).

Falconer (1868) was the first person to start using teeth morphology to classify the proboscideans by y counting the number of ridges on the upper molar teeth. He also classified the mastodons into 2 sub-genera, Trilophodon which have 3 lophs in intermediate molar teeth (dp4, M1, M2) and Tetralophodon, which have 4 lophs in intermediate molar teeth. He also used ridges of teeth to classifymembers in sub-genera: Trilophodon into two groups where the real Mastodon has open ridges, and the other group has small conules inserted in the ridges and are called Gomphothere.

Osborn (1942) used the morphology of molars and tusks to classify proboscideans into 4 Superfamilies or Suborders consisting of Moeritheroidea, Deinotheriodea, Mastodontoidea and Elephantoidea. He separated the Mastodontoid into 4 Families: Mastodontidae (Mammutid or real mastodons), Serridentidae (Gomphothere with serrated teeth), Bunomastodontidae (Gomphothere with Bunolophodon teeth) and Humboldtidae (new world Gomphothere).

Shoshani (1998) suggested shared-derived characteristics for proboscideans which include enlarged second incisors forming tusks, loss of the first premolar tooth, tooth enamel with a keyhole prism cross section and the radius positioned or fixed in a pronation position. Two important proboscidean features observed in advanced taxa, a fully developed proboscis, and teeth with numerous plates and complex chewing surfaces were present in the Gomphotheres. Concomitant with size increase were other changes, such as in the size and shape of the skull, cheek teeth, tusks, soft tissue and physiological modifications. Horizontal tooth displacement, a derived condition in which the size of the mandible is too short to accommodate all premolars and molars at once. Type of teeth in the row will be changes in size, from the smaller intermediate molar to larger M3 molar. Other dental trends include increases in size, number of transverse plates or ridges and complexity. Primitive proboscideans had low crowned teeth (brachyodont) with three or four plates per upper third molar, and some taxa had canine teeth. While in the more modern proboscidean, upper third molars had seven plates and were brachyodont or hypsodont (high crowned). In the recent proboscidean, they had up to 30 plates and were hypsodont (high crowned).

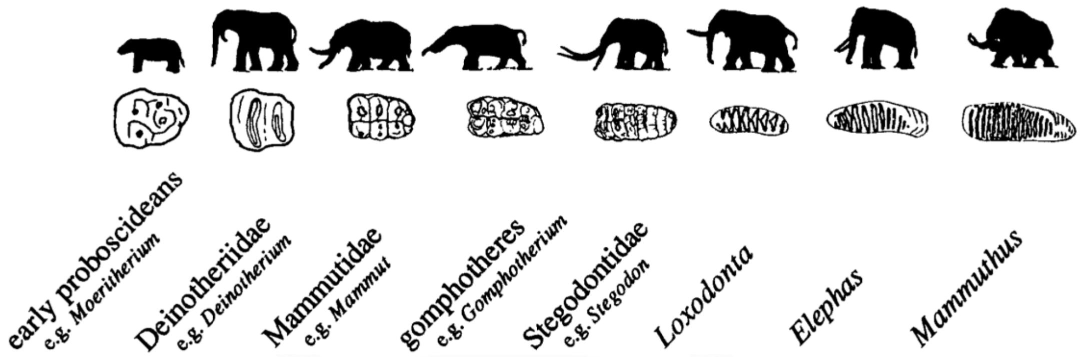


**Figure 1.5** Proboscidean dental trends and evolutions (Shoshani, 1998).

Saegusa, Thasod and Ratanasthien (2005) studied stegodontids in Asia based on the recognition of gradual change in molar evolution. The structure of loph(id)s in stegodontids is used as the major parameter  in their work. Loph(id)s of stegodontids can be considered as mesio-distally compressed versions of those of gomphotheres. From the degree of the degeneration and the displacement of the central conules, they classified structural pattern of loph(id)s into several types. They were defining genus Stegodon as stegodontids that do not have a posterior pretrite central conule on m3.

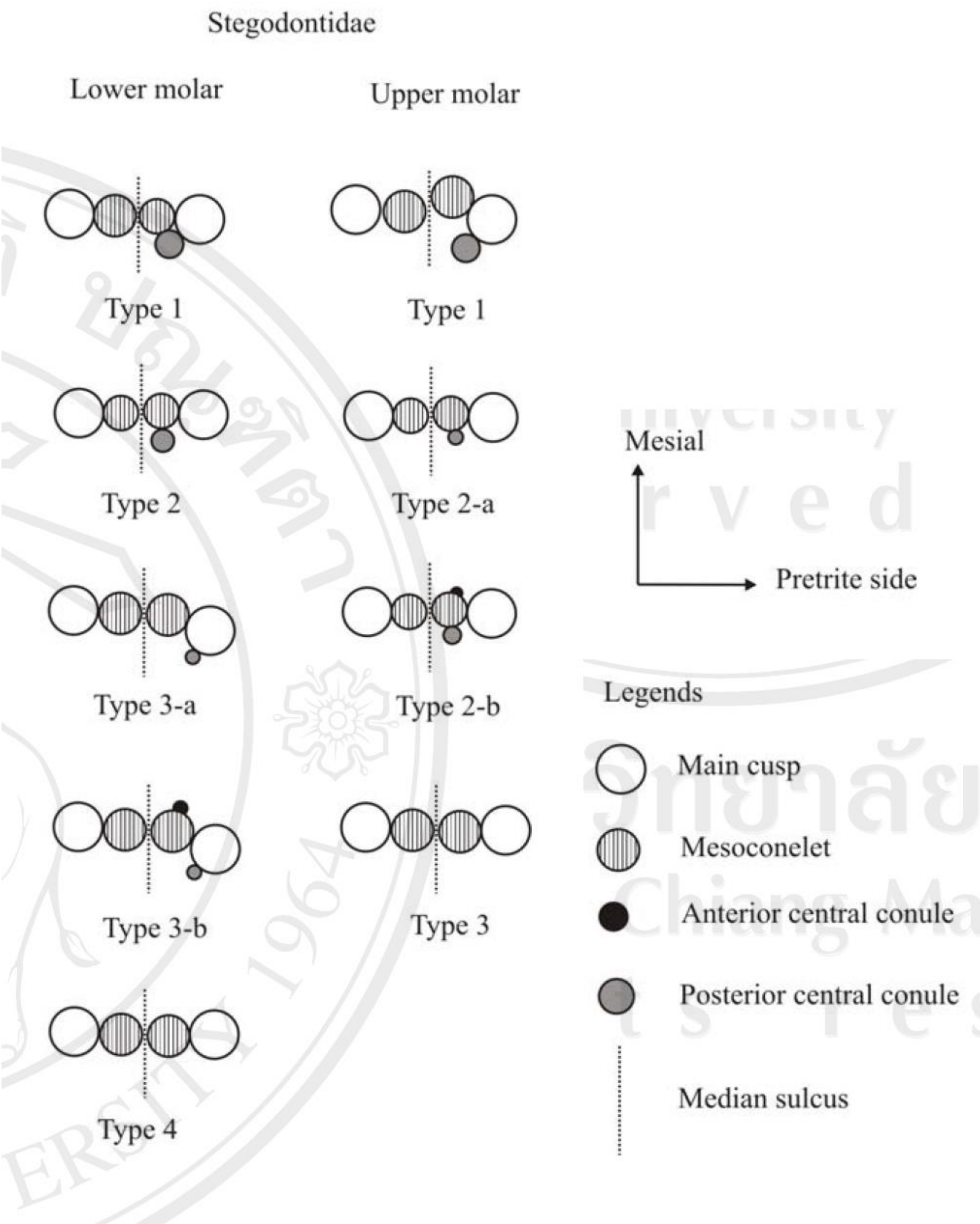


**Figure 1.6** Pattern of loph in Asian Stegodontidae (Saegusa*, et al.*, 2005).

**1.7.2.2 Teeth measurements**

A useful method to classify mammals and also proboscidean fossils (Beden, 1979, Osborn, 1942) is by measuring the maximum width, maximum length, maximum height of the tooth body, the height of the loph, the height of the crown, enamel thickness and plate frequency. Records and comparisons use the changing trends follow the evolution of the animals.

Mazo and Montoya (2003) used tooth measurements to group the Tetralophodon fossils founded in the Crevillente area, Spain. They were measuring every loph and plotting in the scattering diagram of length and width of teeth, combined with the descriptions of teeth to identifying the proboscidean. In the Upper Miocene of Crevillente (Alicante) two types of proboscideans have been found, mastodonts and deinotheres. The mastodonts from Crevillente 2 are assigned to *Tetralophodon* cf. *longirostris* and those from Crevillente 16 to *Tetralophodon longirostris*. The deinotheres from Crevillente 2 and Crevillente 15 are, respectively, identified as *Deinotherium giganteum* and *Deinotherium* sp.

Hiroaki, Katsuyoshi and Masaki (2010) used the tooth measuring method to identify a new species of stegodon from the Kazusa Group of Japan. They compared the new species with the previous database of plate formula, length of crown, width of crown, height of crown, plate frequency and enamel thickness. They also calculated the bivariate plot between enamel thickness and plate frequency, to show the relation between species and groupings.

#### 1.7.2.3 Classification of Proboscidean fossils

Animals in the order Proboscidean were found from the Eocene age to the present. They were widespread in North-South America, Eurasia and Africa. With large bodies, their shoulder height was about 1 m to over 4 m. In the past there were about 162 species, but at present only two species exist that are not extinct, African elephants and Asian elephants (or Indian elephants). Proboscideans can be classified in 3 Sub-orders, 10 Families and 38 Genera (Shoshani and Tassy, 2005). Thasod, Jintasakul and Ratanasthien (2011) are discovered in Nakhon Ratchasima for 4 families and 8 genera, as following.

1. Family Deinotheriidae

Deinotheriidae are classified into two genera *Deinotheruim* and *Prodeinotherium*. General appearance is one pair of long curved tusks to the ground. Body size of *Prodeinotherium* is smaller than *Deinotheruim*. Simple lophodont teeth with only 2-3 lophs, some are found with Brachyodont teeth. The enamel thickness is about 5-8 mm. Vertical displacement of molar teeth which is a primitive characteristics. Fossils are found in every continent. Taxon existed in the Early Miocene to Pliocene age. In Thailand, lower premolar teeth of prodeinotherium were found in Phayao Provincecorresponding to the middle Miocene age.

2. Family Gomphotheriidae

Gomphotheriidae are classified into 2 subfamilies.

Subfamily Amebolodontinae comprising 5 genera.

Genus *Archaeobelodon* Tassy, 1984

Genus *Serbelodon* Frick, 1933

Genus *Protanancus* Arambourg, 1945

Genus *Amebelodon* Barbour, 1927

Genus *Platybelodon* Borissiak, 1928

Subfamily Cuvieroniinae comprising 4 genera.

Genus *Cuvieronius* Osborn, 1923

Genus *Stegomastodon* Pohlig, 1912

Genus *Haplomastodon* Hoffstetter, 1950

Genus *Notiomastodon* Cabrera, 1929

And other 4 genus not in subfamily.

Genus *Sinomastodon* Tobien, Chen, and Li, 1986.

Genus *Eubelodon* Barbour 1914

Genus *Rhynchotherium* Falconer, 1868

Genus *Gnathabelodon* Barbour and Sternberg, 1935.

Another 3 Genera could not be classified to family level.

Genus *Tetralophodon* Falconer, 1857

Genus *Anancus Aymard*, 1855

Genus *Paratetralophodon* Tassy, 1983

General appearance of this family are the high skull base and the cross section of tusk which has a pyriform appearance. Bunodont mastodons have low-crowns and primitive vertical replacement of teeth. Premolar teeth have 2 lophs and 3-4 lophs in molar teeth. Fossils found in Europe, Asia, North and South America.

Taxon existed in Early Oligocene to Holocene age. In Thailand, the Genus Gomphotherium and Genus Protanancus (Subfamily Amebolodontinae) are foundin the north and northeast.

3. Family Stegodontidae

Stegodontidae are classified into 2 Genera, *Stegolophodon* and *Stegodon*. General appearance was more like present-day elephants, tusks have a little twist outward. Tooth characteristic is brachyodon, but in stegolophodon they have bunodont teeth in the first and second lophs. There are 2 layers of enamel and when it is worn it appears as the step-like structure called stufenbildung. Fossils are found in Asia. Taxon existed during the Early Miocene to early Holocene age. Both Stegolophodon and Stegodon are found in the North and Northeast of Thailand.

4. Family Elephantidae

Elephantidae are classified into 1subfamily Elephantinae, having 4 genera.

Genus *Stegotetrabelodon* Petrocchi, 1941

Genus *Stegodibelodon* Coppens, 1972

Genus *Palaeoloxodon* Matsumoto, 1924

Genus *Mammuthus* Brookes, 1828

and 2 recent elephants

Genus *Loxodonta* Anonymous, 1827

Genus *Elephas* Linnaeus, 1758

General appearance, shoulder height from 1 - 3.5 meters. Characteristics of teeth is strongly lophodon. Fossils found in Europe, Asia, East India, Africa and North America.

**1.7.2.4 Cluster analysis**

Cluster analysis (CA) is the method that uses to divide data into groups (clusters). The objects in the same group will be similar (or related) to one another and different from (or unrelated to) the objects in other groups. The dense areas of the data space, intervals or particular in each data or cluster is mean to statistical distributions. One of Cluster analysis is Hierarchical clustering; it can produce a set of clusters organized as a hierarchical tree. This can be visualized as a dendrogram.

There are 2 types of hierarchical cluster analysis; Agglomerative and Divisive. Agglomerative is the more popular hierarchical clustering technique, they merge the closest pair of cluster until only one cluster left. And Divisive method is opposite way, they start in inclusive cluster and they split a cluster until each contains a point. In the procedure of clustering, the relationships of each variable are important in terms of explaining how each variable is weighted in the clustering. There are many applications use CA to analysis their data for example bioinformatics, medical or marketing.

Correlation is a statistical technique that can show whether and how strongly pairs of variables are related (positive or negative). Correlation works for quantifiable data as numbers are meaningful. The main result of a correlation is called the correlation coefficient (or "r"). In general, $r > 0$ indicates positive relationship, $r < 0$ indicates negative relationship while $r = 0$ indicates no relationship (or that the variables are independent and not related). Here $r = +1.0$ describes a perfect positive correlation and $r = -1.0$ describes a perfect negative correlation. The closer the coefficients are to +1.0 and -1.0, the greater is the strength of the relationship between the variables. After squaring r, ignore the decimal point, as it can change to explain to a percentage the relation between values. Statistical significance is another result of correlation; and it is suitable for small sample sizes.

Pearson Correlation is one of the measures of correlation; it is requires two conditions to satisfy before using the test. Firstly, the data must be a normal distribution that can be analyzed by using the test of normality, normal plotting and histogram graphs. Secondly, the linear relationship between each variable is required to investigate a relationship between two variables, and the data will be plotted graphically on a scatter diagram. But if the data does not fall completely within the two conditions, non-parametric statistic correlations such as Kendall’s and Spearman can be used to show the relations between the variables.

Winkler (1983) related abundance of each mammalian species as calculated from a sample representing 300 individual animals collected and separated into clusters formed by a group of the most common terrestrial herbivorous mammals and the crocodilian *Allognathosuchus,* and by a group of small, possibly arboreal herbivores and carnivores. Cluster analysis is used to relate occurrence of vertebrate taxa to define subsets of the early Eocene fauna that may represent animals living in different habitats.

### 1.7.3 Paleoenvironment

The environment of the north-eastern area during the Mesozoic age was a large flood plain, with large rivers with many branches. During the Triassic and Jurassic ages, the Northeast region was mostly flood plains. But from the Jurassic to early Cretaceous age, the large river system was succession and changed the depositional environment into various types, with the deposition of sediments in the trenches, dunes and flood plains. During the late Cretaceous, the depositional environment was changed by saltwater intrusion. Deposition in the fluvial system changed to sedimentation in salt lakes with still waters. After the saltwater intrusion, the basin was filled with eolian sediments and stopped the formation of rock salt deposits (Sattayarak*, et al.*, 1998).

About 60-65 million years ago, the trough area was compressed by the collision of the Indian-Australian plate and Eurasian plate making the northeast elevation into higher landform. The Phu Phan mountains appeared and the rock salt that used to cover an area of Phu Phan is currently being raised higher and eroded away (Udomchoke, 1989).

Subsequently a large river system came back to the Khorat Plateau and eroded the Phu Thok formation along the Khorat basin. Later, the water level of river went down, maybe due to the reduction of global sea levels, leaving the old gravel surface as the terrace. Since the Miocene age, river erosion has stopped and the sediments has accumulated by the effects of floods and leoss. This has become the new age red bed, consisting of clay, silt, sand and gravel in some areas. In Nakhon Ratchasima Province there was a land subsidence event in the middle of the Khorat basin about 700,000 years ago. The depositional environment changed into a big alluvium fan type which moved from the south side after the lifting of the plateau along the southern margin. Until now, the river still erodes the Khorat Group that rose up (Sattayarak, *et al.*, 1998).

Sedimentary in fluvial system can be preliminary interpret environment from some visual characteristics such as minerals, soils, water supplied of river and minerals compositions. Minerals compound forms will change by the oxidizing-reducing effect of environment. Oxisols soil type will be found in the humid tropical condition. Water supply of the river in tropical or temperate environment will almost the perennial stream with many evidences of channel fill and cut. By the minerals composition explain about the weathering and transporting effects that will increase or decrease depending on the environment (Nichols, 2009).

Benyasuta (2003) studied the 18 species, 15 genera, and 10 Families of petrified wood from Chaiyaphum, Khon Kaen and Nakhon Ratchasima and classified them into groups of Angiosperm and Monocotyledon plants. Petrified wood from Chaiyaphum and Khon Kaen is dated from the Plio-Pleistocene about 5 – 0.01 Ma., while petrified wood from Nakhon Ratchasima is dated from the Miocene – Present about 24 Ma – recent. Vozenin-Serra and Prive-Gill (2001) suggested that the type of fossilized plants from Tha Chang that dominated was Mixed deciduous forest, related to varieties of plants found in Burma and Bengal. (Benyasuta, 2003) suggested that varieties of related fossilized plants were dry evergreen forest and mixed deciduous forest, same as that of the present Khorat plateau. Both types of forest are suitable for mammalian life.

Sediments in the sandpit from Amphoe Chaloem Phra Kiat were interpreted to be large meandering channel deposits. The lower dark grey beds are contains proboscidean fossils that identified as Prodeinotherium pentapotamiae, Gomphotherium sp., Protanancus sp., Sinomastodon sp., Stegolophodon sp., and primitive and advanced forms of Stegodon (Nakaya, *et al.*, 2001). This fauna in Amphoe Chaloem Phra Kiat was board correlated in term of biostratigraphy to the upper Nagri and lower Dhok Pathan formations of Siwaliks in Pakistan. Indicated to Late Miocene aged, between 9 and 7 million year (Chaimanee, *et al.*, 2004).

Late Miocene palynological assemblages were studied by dark organic-rich claystones that collected from the lower reducing sand unit of Siam sandpit in Khorat. And was interpreted to the fluviolacustrine paleoenvironments alternatively covered by thermophilous trees and grasslands (Sepulchre*, et al.*, 2010).

**1.7.4 Paleoecology**

To the biologist, ecology is the study of interrelationship between organisms and their environment. Paleoecology is the study about the ecology of fossils species and their paleoenvironment. But the limitation of paleoecology is the inability to reconstruct the paleoenvironment and the incompleteness of fossils. By the way, the paleoecology is also used stratigraphic and sedimentologic technics to explain partial of ancient environment. And also used some habitat of animals to explain the relationship between paleoenvironment and fossils, such as dietary of organisms (Raup and Stanley, 1971).

There are some corresponding significant trends, where primitive proboscideans were mostly browsers, and the more modern were mostly grazers. The shift to a grassy diet is evident in the most advanced elephantid taxa, such as *Elephas* and *Mammuthus*, with complex chewing surfaces that enable them to cope with highly abrasive forage (Shoshani, 1998).

Kaiser*, et al.* (2003) used the Cluster analysis method to classify the worn effect on teeth of ungulate animals to know the type of diet, paleoecology. The types of wearing on the teeth was used for analysis, ie. the microwear was determined by using a microscope, identifications and counting and presented as hierarchical cluster diagram based on microwear features. Mesowear was determined by clustering results between hypsodonty index and mesowear variables (low, high, sharp, round and blunt) and divided ungulate fossils into 3 groups following their dietary patterns as grazers, browsers and mixed feeders and presented as a hierarchical cluster dendrogram.

# CHAPTER II

# GEOLOGICAL REVIEWS OF STUDY AREA

## 2.1 Geology of study area

Nakhon Ratchasima located at the southwest of Northeastern region of the Thailand. The province is Between latitude 14°97' N, longitude 102°10' E, with approximately area about 20,493.964 square kilometers. It is the largest province in Thailand, Nakhon Ratchasima has several kinds of geomorphology. Most of the areas are plain area with its height between 150-300 meters above sea level. There are *San* Kamphaeng and Phanom Dong Rak Mountains range on its southern part and western part margins, undulating plain at the southwest and north continue with alluvial flood plain of Mun River at the center to north.

Mun River is the major river of Nakhon Ratchasima, it's drained into Khorat basin and transports many sediments to deposit. Board flood plains, oxbow lakes, shallow lakes, and many features are appeared around this area according to the effect from meandering Stream of Mun River.

Sandpits in Tambon Tha Chang, Amphoe Chaloem Phra Kiat are in alluvial sediments. The depositional environments which are flood plains and swamp deposits consist of gravel, sand, silt and clay. These sediments are subdivided into two units; lower and upper. A lower reducing unit of comprises stratified to massive, cross-bedded sand and gravel and mud. The entire unit is reducing gray sediments. Mammals and plants fossils are found in this unit. (Chaimanee*, et al.*, 1997, Howard*, et al.*, 2003, Nagaoka and Suganuma, 2002, Nakaya*, et al.*, 2001, Sato, 2002). The upper unit is oxidized. In addition, this unit contains layers of sand, fine gravel and mud. The unit shows very recent time period as fragment of ceramics, polished stone tools are founded whereas this study rarely found small tree trunks, included *Elephas maximus* or recent Asian elephant. Depositional of this unit is channels and flood plains of the modern meandering Mun River in historical time (Howard*, et al.*, 2003, Sato, 2002).

The fossils communities are founded after the sand pits business begun near Mun River in Tha Chang. Mostly are proboscidean fossils in Tertiary age about 16 – 0.7 Ma. Ancient elephant teeth had been reported from Tha Chang, Nakhon Ratchasima by Chaimanee*, et al.* (2003), Chaimanee*, et al.* (1997), Nakaya*, et al.* (2001), Saegusa*, et al.* (2005) and Sato (2002). They were composed of *Sinomastodon sp., Amebelodontid gomphothere (Protanancus chinjiensis), Gomphotherium sp., Prodeinotherium sp., Stegolophodon cf. stegodontoides,* primitive *Stegodon, advanced Stegodon* and *Elephas* (Sreprateep, 2005).

Moreover, petrified woods and peats also are founded in Tha Chang area. They were studied by Vozenin-Serra and Prive-Gill. (1989) and classified into plant-like Pinus (Gymnosperm), Siamese sal, Makha (Angiosperm). Both Gymnosperm and Angiosperm are high developing plant, by the gymnosperm appeared first in Early Cretaceous about 130 Ma. The petrified woods from Tha Chang are in Plio-Pleistocene age or about 2 Ma. In 2001, Vozenin-Serra & Prive-Gill were classify others petrified wood species from Tha Chang to be Palm, Rok Fa and Rubber tree.

### 2.2 Mapping and field investigations

The areas that used to field investigation and to find fossil locality were beside Mun River in Tambon Tha Chang, Amphoe Chaloem Phra Kiat, Changwat Nakhon Ratchasima. This area was surveyed for 4 times to find and investigated fossil locality and examined the characteristics of geomorphology.

Three excursions were investigated to find and examined the fossil locality. Most of all sandpits that found fossils before are now in closing hours, such as Siam sandpit that was studied by Sreprateep, 2005. Excepted Thaisin sandpit that this study used as study area is a new locality.

Thaisin sandpit is located at coordinated 203856N ,1659850E and far from the west of Tha Chang railway station about 2 kilometers. The area of Thaisin sandpit is around 0.8 $km^2$. The branch of Mun River flows in southern of sandpit. This area was separated into many pits but finally they fused to a big pit. About 2 years of the operation, there were found mammalian fossils especially elephant and many petrified wood.

After field investigation, data and the coordinates were plotted in the topographic map and digital elevation model by using ArcGIS (Figure2.1). To shows some geographical characteristics of the study area from the survey photo, as follows.

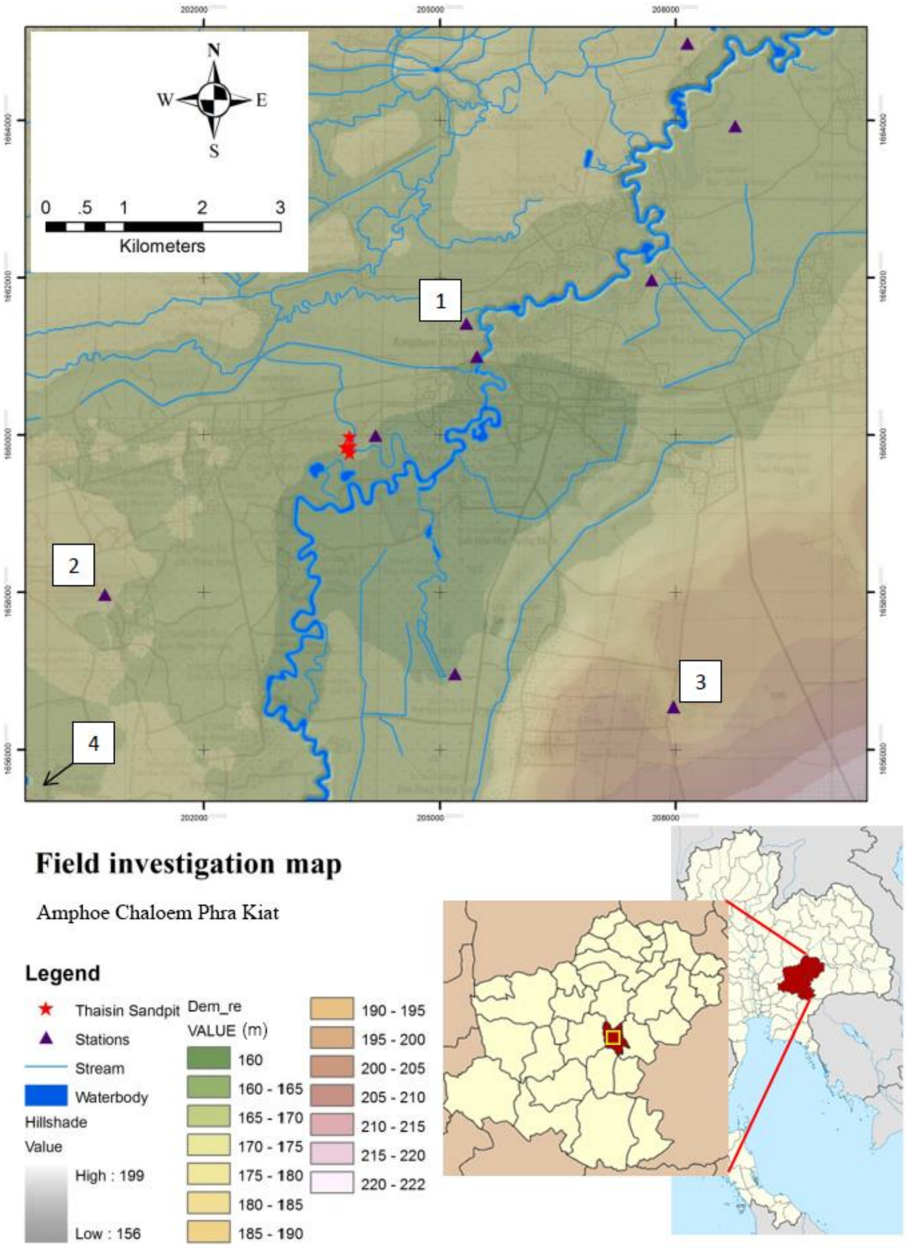


**Figure 2.1** Topographic and digital elevation model mapping of Thaisin sandpit.


**Figure 2.2** Old sandpit in Tha Chang district that contact with recent river in the Northeast corner


**Figure 2.3** Ban Tanot in the low terrace but still have some places like wetland area


**Figure 2.4** Nong song hong, the swamp area that surround with terrace


**Figure 2.5** Ban map makha that is located in high elevation

### 2.3 Fossil locality at Thaisin Sandpit

Schematic of Thaisin sandpit shows in the following map (Fig 2.6). Around the sandpit area comprises of 6 pits were dug. All fossils and columns were collected from pits number 4, 5 and 6 while pits number 1, 2 and 3 cannot access.

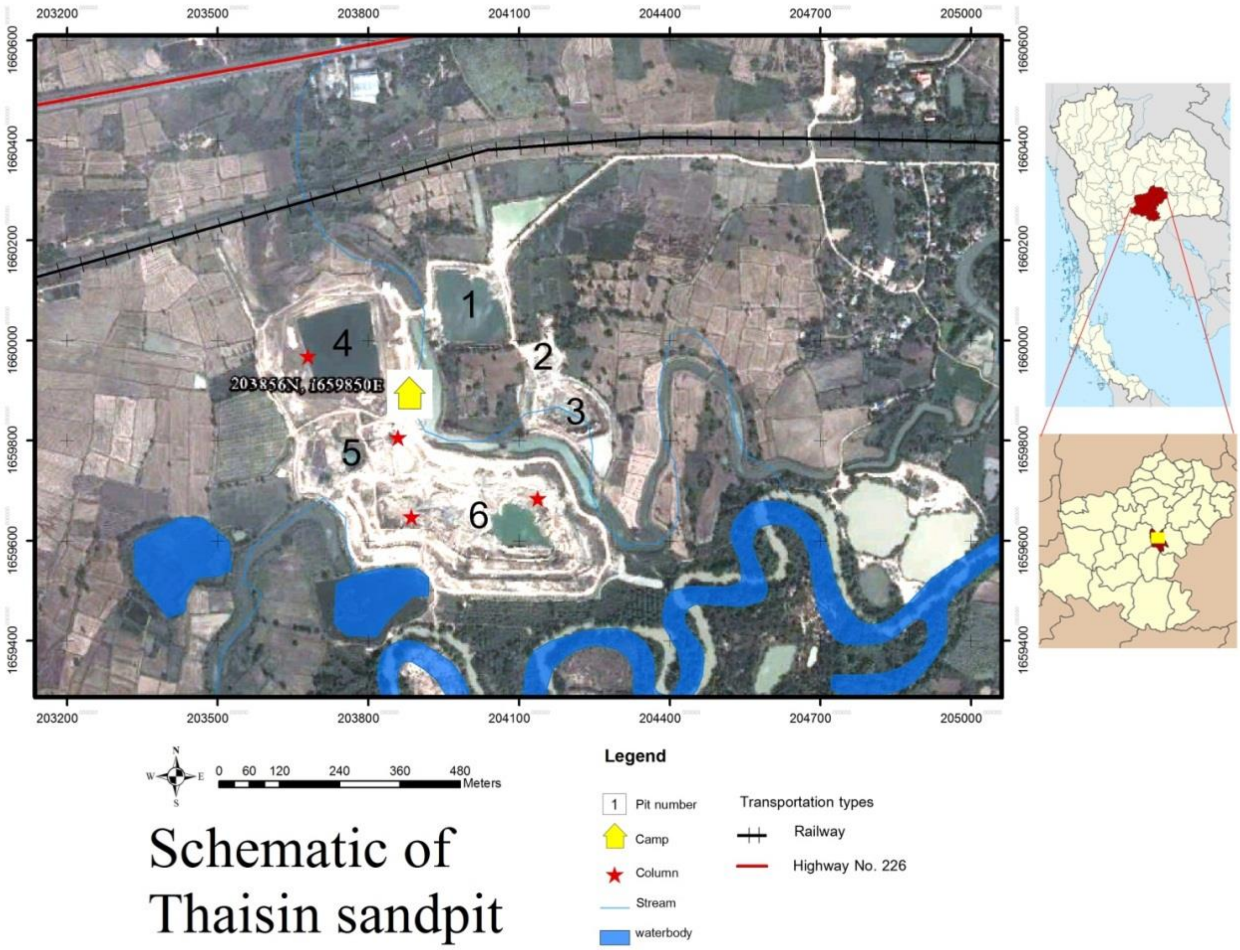




**Figure 2.6** Diagram of Thaisin sandpit.

**Figure 2.7** Eastern part of Outcrop at Thaisin sandpit**.**

Sedimentary layers from the eastern part of sand pit were not complicated. From the Figure 2.7, it shows the color of stratified sediments in which clearly includes sedimentary layers of the resistance gravel bed in depth about of 5 meters from the surface.

**Figure 2.8** Southern part of Outcrop at Thaisin sandpit**.**

In the southern of sandpit, sediments are complicatde in each layer. It contains the several sizes of sediments. From figure 2.8, many sand layers are mixes with the iron (red), sulphur (yellow) and with many plants and fossils fragments (black objects).

**Figure 2.9** Northern part of Outcrop at Thaisin sandpit.

Sediments in the northern of sandpit looks quite complicated. Each layers contains several sizes of sediments. Furthermore, the sand layer mixed with the iron (red), sulphur (yellow) and including some plants and fossils fragments are founded.

**Figure 2.10** Western part of Outcrop at Thaisin sandpit**.**

The sand sediments in the western part of sandpit are not complicated and found a little fossil fragments. More peat and gray sediments layer are found even in the less depth than in the others side.

Sedimentary structure that found are both small and large laminar cross-bedding with few trough cross-bedding in medium sand, some graded bedding, clay block in several layers, indicative of medium currents. The bioturbation traces in fine sediments, indicative of a static water environment. At the depth of 5-6 meters, this study found a few of tektites. Peats are also found in the bottommost part of the sandpit.

**Figure 2.11** Cross-bedding, clay block and peat.



**Figure 2.12** Tektite and Bioturbation.

Objects that found are mammalian fossils. Including small to large pieces of plants fragment, both the wood and transformed into petrified wood in almost every sedimentary layers. And in the sand layer that found many plants fragment also found some peats. Minerals compound are found scattered in some layer, such as pyrite ($FeS_2$), iron oxide ($Fe_2O_3$) and sulfur (S).

**Figure 2.13** Iron oxide, Sulphur and Pyrite**.**

Minerals compound forms are changed by the oxidizing-reducing effect of environment. Pyritization occur in the humid sediments near surface levels, some iron are requires as substant. Source of Sulphur may come from gypsum and anhydrite of Mahasarakham formation by the weathering and oxidation process.

# CHAPTER III
# STRATIGRAPHY AND SEDIMENTOLOGY

This Chapter concerns with the assessment of paleoenvironment in the Thaisin sandpit area by using sedimentology and stratigraphy combined with geomophology. The operation is based on field observations and mapping from program. Stratigraphic columns are recorded while working at the fossil locality.

## 3.1 Geomorphology around Thaisin sandpit

The geomorphology characteristic around the study area in Amphoe Chaloem Phra Kiat was defined by satellite images from Google Earth in 2011 and 2014. Elevation, slope, colors and land use are applied to classify type of geomorphology. After field investigation, the data of fossil localities were added into the map to study the origin source of fossils. (Figure3.1)

Geomorphology is classified into 3 types. Oxbow lake and meander scar are classified together in term of being the characteristic of ancient river. Considers from remaining of the water body that cutoff from the recent river, elevation (high-low) of area shows low lying areas of point bar. Too many oxbow lake and meander scar are found near the recent river. Flood plains are the low lying area press on two side of the river by the swaying effect of the river. This plain is classified from elevation which is lower than 170 meters, cooperate with colors and coverage objects in the area. River terrace are considered from digital elevation map (DEM) and the changing of slope, by using ArcGIS program together with land and plant coverage from field investigation. Fossil locality at Thaisin sandpit is located on the meander scar geomorphology type. From the geomorphology of present Mun River, sand layer, river structure show that Thaisin sandpit sediments was a Quaternary deposit of paleo-Mun River. This fossil locality is located on the meander scar geomorphology type.

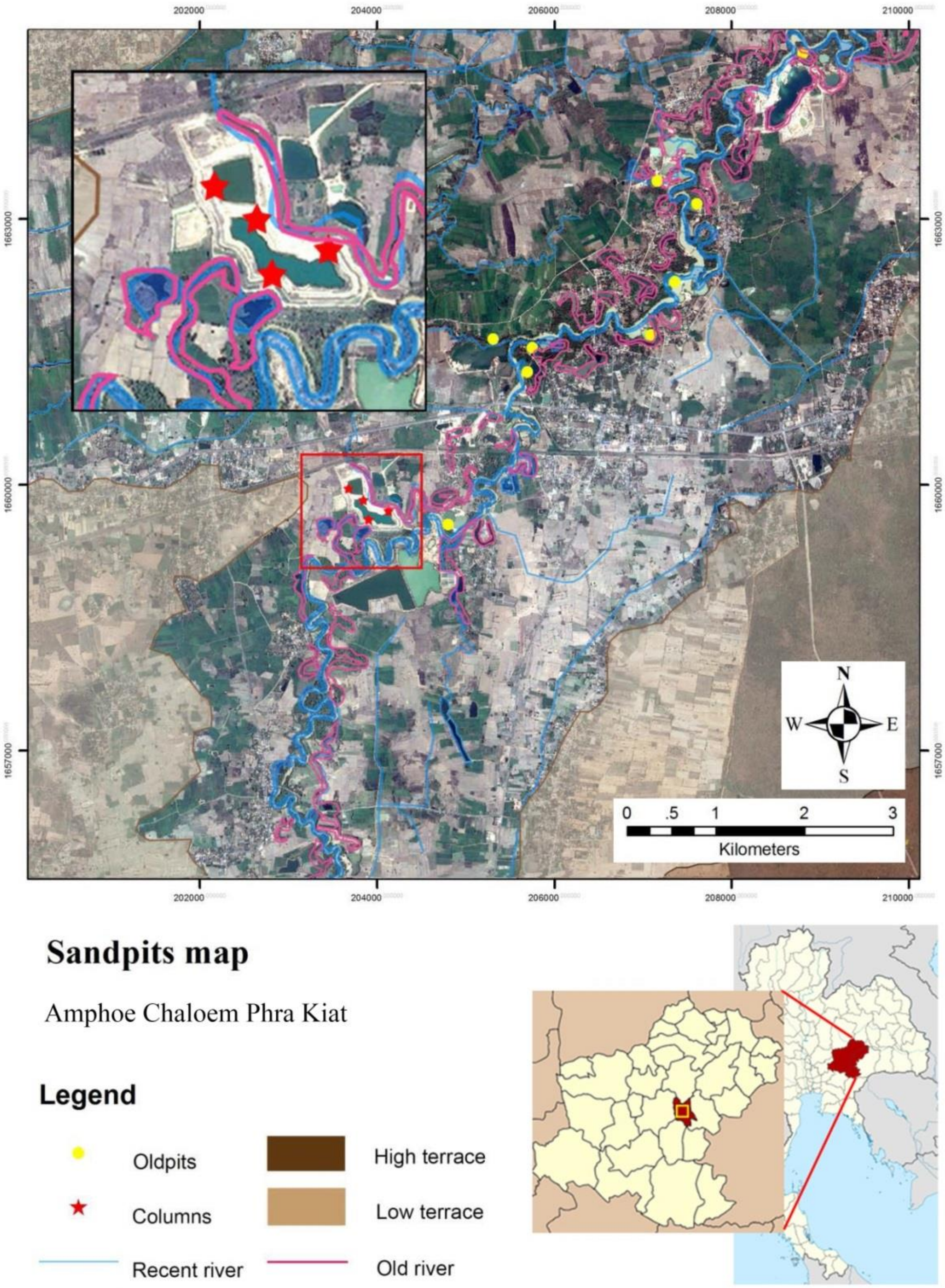


**Figure 3.1** Geomorphology of Mun River in Amphoe Chaloem Phra Kiat (Modified from sandpits map created by Nakhon Ratchasima Rajabhat University, 2549 at Tha Chang museum).

### 3.2 Sedimentology and stratigraphy of Thaisin sandpit

Thaisin sandpit locates in Tambon Tha Chang, Amphoe Chaloem Phra Kiat, Changwat Nakhon Ratchasima which covered area approximately 0.8 square kilometers.

The depth of sandpit range is between 10 to 32 meters. This study found many mammalian fossils and petrified woods. Moreover, the structures of sediments that show the fluvial deposit environment of paleo-Mun River are founded. The size of the sediments are diverted, most of the sediments are medium size. In addition, fine and coarse sediments are founded in the same area too. Plant fragments are also found in many sedimentary layers. Stratigraphic images were recorded while field work by using the Grain size chart from http://www.ga.gov.au.

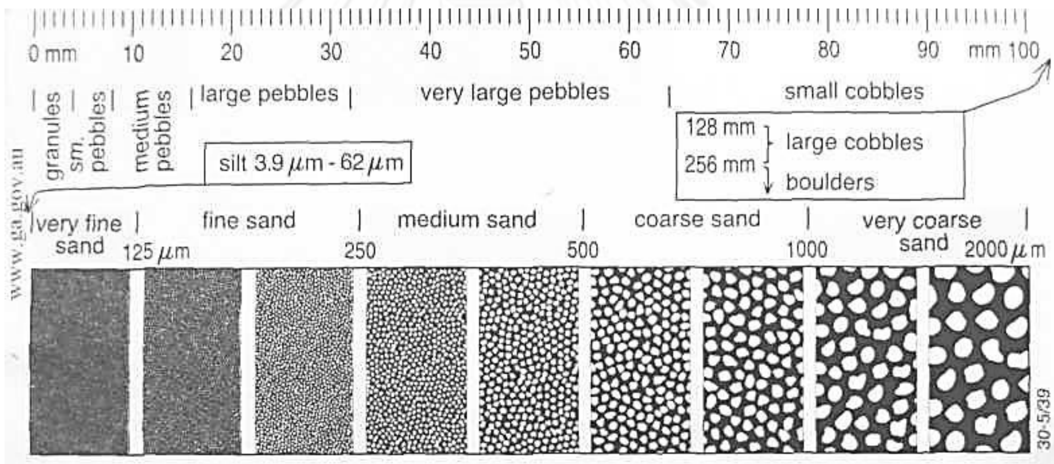




**Figure 3.2** Grain size chart from (http://www.ga.gov.au).

Sedimentary structures, color and other objects are used to consider the classification. Next was a writing step by step then completes the subtotal of each column in eastern, southern, northern and western of the sandpit along with digital photo record.

Lithostratigraphic column of Thaisin sandpit are rewritten by illustrator program, they consists of sand, silt, clay and gravel. This study is also founded mixed in almost every bed with a plant fragment and mammals fossils. The most complete bed is in the southern of the sand pit, it has 28 beds. Considering with the other column, this study found to have some common characteristics in some layers, as the following descriptions.

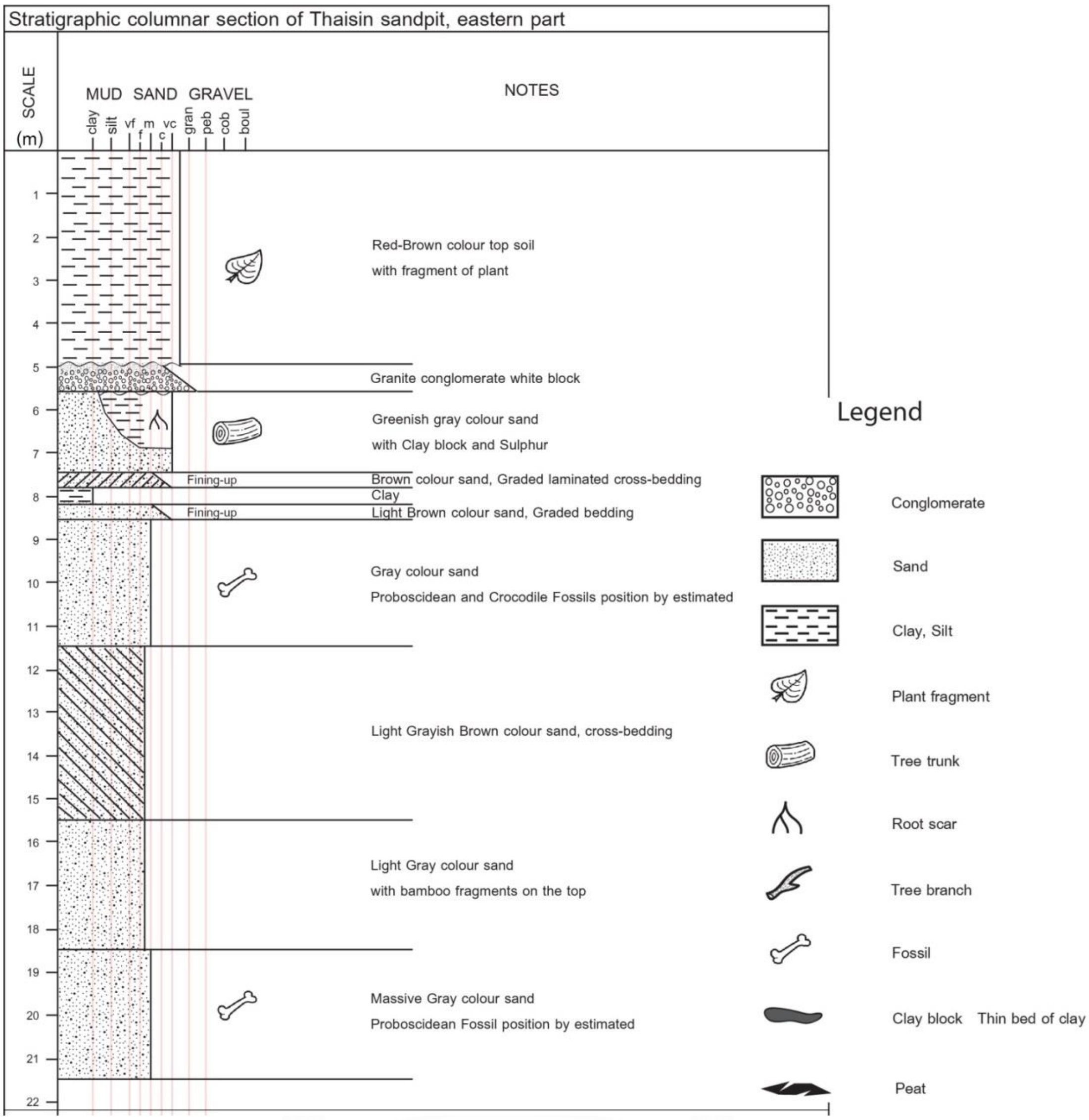


**Figure 3.3** Stratigraphic column at eastern part of Thaisin sandpit.

From the stratigraphic column, at 5-7 meters depth from the surface is the gravel bed that continues to the sand layer with clay block. Dividing by color of sedments, from the surface to 8.5 meters is the upper layer of sand with brown color tone. The lower layer of grey tone sand starting at 8.5 meters to the bottommost of stratigraphic column. Estimate positions of fossils are founded in two ranges, between 5 to 11 meters depth and between 15 to 21 meters depth.

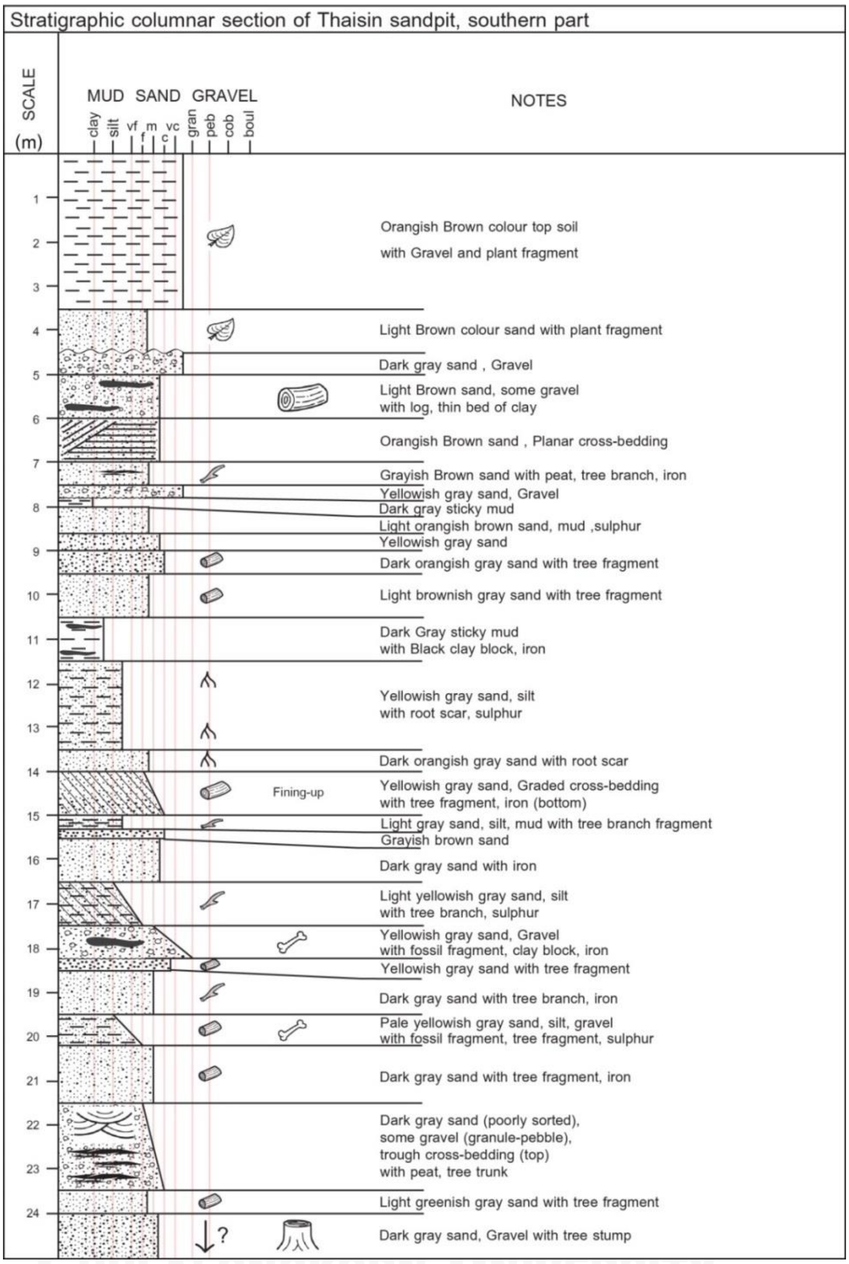




**Figure 3.4** Stratigraphic column at southern part of Thaisin sandpit.

Stratigraphic column in the southern part is complexity, from the surface to about 7.80 meters is the gravel and sand bed with cross-bedding, clay block and plant fragment. This shows to deposit in the strong river current. Estimate positions of fossils are founded in two ranges, between 14 to 18.5 meters depth and between 18.5 to 20 meters depth.

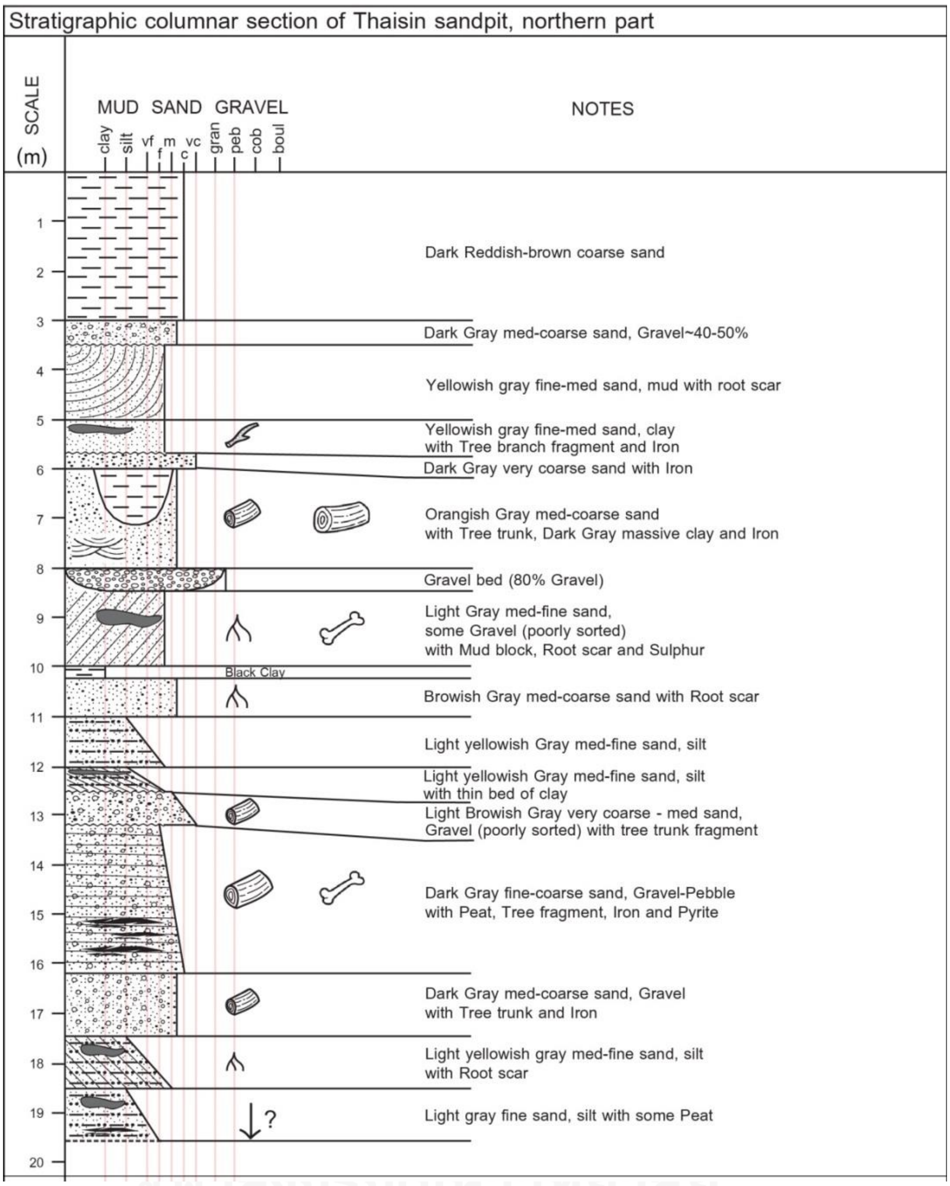


**Figure 3.5** Stratigraphic column at northern part of Thaisin sandpit.

Stratigraphic column in the northern part is quite complexity with many sedimentary structures. The sedimentary layers are found repeated and difficult to subdividing by the grain size. Gravels are found as a component in many layers. Some peat layers are founded in the lower dark grey sediments. Estimate positions of fossils are founded in two ranges, between 5.7 to 10 meters depth and between 11 to 16 meters depth.

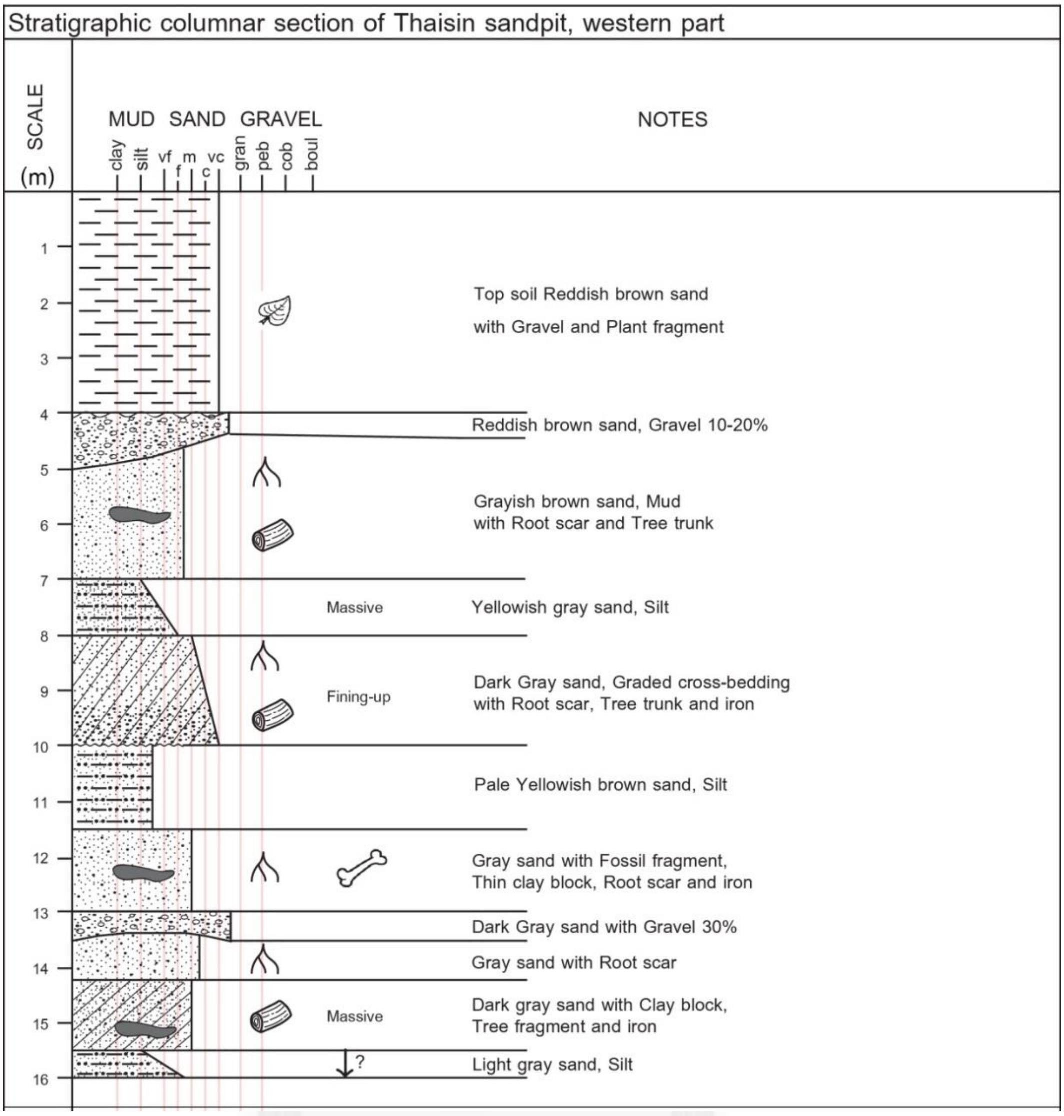


**Figure 3.6** Stratigraphic column at western part of Thaisin sandpit**.**

Stratigraphic column in the western part is quite similar to the eastern part. Gravels are also founded as a component in two layers, at 4 meters depth and 13 meters depth. Estimate position of fossil is founded between 10 to 13 meters depth.

**Table 3.1** Lithostratigraphic descriptions at southern part of Thaisin sandpit.

| No. of Layer | Lithology | Thickness (m) |
|---|---|---|
| TS1 | Gravel and v. coarse sand, Orangish brown, plant fragment | 3.5 |
| TS2 | Medium to fine sand, Light Brown with plant fragment | 1.0 |
| TS3 | V. coarse sand and gravel, Dark gray | 0.5 |
| TS4 | Medium to coarse sand and gravel, Light Brown with log, thin bed of clay | 1.0 |
| TS5 | Medium to coarse sand, Orangish Brown, Planar cross-bedding | 1.0 |
| TS6 | Medium to fine sand, Grayish Brown with peat, tree branch, iron | 0.5 |
| TS7 | V. coarse sand and gravel, Yellowish gray | 0.3 |
| TS8 | Mud (Sticky), Dark gray | 0.2 |
| TS9 | Medium to fine sand, mud, Light orangish brown with sulphur | 0.6 |
| TS10 | Medium to coarse sand, Yellowish gray | 0.4 |
| TS11 | Coarse sand, Dark orangish gray with tree fragment | 0.5 |
| TS12 | Fine to medium sand, Light brownish gray with tree fragment | 1.0 |
| TS13 | Mud (Sticky), Dark Gray with Black clay block, iron | 1.0 |
| TS14 | Fine sand, silt, Yellowish gray with root scar, sulphur | 2.0 |
| TS15 | Fine to medium, Dark orangish gray with root scar | 0.5 |
| TS16 | Coarse to fine, Yellowish gray, Graded cross-bedding (Fining up), tree fragment, iron (bottom) | 1.0 |
| TS17 | Fine sand, silt, mud, Light gray with tree branch fragment | 0.3 |
| TS18 | Coarse sand, Grayish brown | 0.2 |
| TS19 | Medium to coarse sand, Dark gray with iron | 1.0 |
| TS20 | Fine sand, silt, Light yellowish gray, Cross-bedding, tree branch, sulphur | 1.0 |
| TS21 | Medium to coarse sand and gravel, Yellowish gray with fossil fragment, clay block, iron | 0.7 |
| TS22 | Coarse to v. coarse sand, Yellowish gray with tree fragment | 0.3 |
| TS23 | Medium sand, Dark gray with tree branch, iron | 1.0 |
| TS24 | Fine sand and Gravel, silt, Pale yellowish gray with fossil fragment, tree fragment, sulphur | 0.7 |
| TS25 | Medium sand, Dark gray with tree fragment, iron | 1.2 |
| TS26 | Fine to coarse sand and gravel, poorly sorted, Dark gray, trough cross-bedding, peat, tree trunk | 2.0 |
| TS27 | Fine to medium sand, Light greenish gray with tree fragment | 0.5 |
| TS28 | Coarse to medium sand and gravel, Dark gray with tree stump | 2.0 + |

From stratigraphic column and lithostratigraphic descriptions of the Thaisin sandpit, this study found similar characteristics in some sedimentary layers. First is in the depth range from surface to about 10 meters of the sandpit in Eastern, Southern, Northern and Western part, respectively. Second is in the depth range about 7 to 14 meters from surface of the sandpit in Eastern, Southern, Northern and Western part, respectively. Third is in the bottommost part of the sandpit in Eastern, Southern, Northern and Western part, respectively.

## 3.3 Paleoenvironment

The sediments from Thaisin sandpit vary from gravel to clay but the most founded is sand. Following the structure and the objects of sediments, it can be interpreted the paleoenvironment as fluvial deposit in meandering stream type and flood plain deposit.

Each of sediments layers can be help identifing the environmental in the period that sediments was deposited but it cannot clearly identific. This is because the sediments is repeating and this study also cannot found the relationship between each sediments layers. When the sediment column around sandpit are considered by grain size and color, it can be classified the sediments of Thaisin sandpit into 3 units.

SCALE
LITHOLOGY
MUD SAND GRAVEL
FOSSILS
Fining-up
Massive
Black Clay
2TE1
3TE1,
3TE2
4TE1
6TE1,
6TE2
9TE1
Legend
Conglomerate
Sand
Clay, Silt
Plant fragment
Tree trunk
Root scar
Tree branch
Stump
Fossil
Clay block
Thin bed of clay
Peat
Cross - Bedding
Trough Cross - Bedding

Unit 1, in the depth range from surface to about 10 meters of the sandpit in Eastern, Southern, Northern and Western part, respectively, are characterized by mixed sediment sizes from Medium - Very coarse sand and lots of gravel, loosely arranged and poorly sorted. Sedimentary structures are cross-bedding and eroded trace at base of channel that indicated the flow of current. Include another components is clay block that carried by the river current and plant fragment from small to large size. Interpreted that seems to be Channel sediments.

Unit 2 is in the depth range about 7 to 14 meters from surface of the sandpit in Eastern, Southern, Northern and Western part, respectively. Sediment characteristics are relatively static. Sediment sizes are not much varied with most are well-sorted Medium - Fine sand. Some silts and muds that quite tightly pack, root scar and bioturbation are found in this sediment layer. Few plant fragments and fossil fragments are founded. Interpreted seems to be characteristic of the Flood plain sediments or Swamp.

Unit 3, in the bottommost part of the sandpit in Eastern, Southern, Northern and Western part, respectively, is the narrow range for the variability of sediment characteristics, from very coarse to fine grain, some gravel bed. Including structures and objects indicates the strength of the currents, such as cross-bedding and large plant fragment. However, in the lower part of this unit, there are some tight packs with dark gray color sediments. Including the peat layer may indicate the environment of this unit which is likely to be rapidly downstream of river that brings the sediments to deposit rapidly in the lower layer. The upper layer of sediment in the North may be eroded away. This layer has founded quite lots of plant fragment and fossil fragment. Probably interpreted that this unit is sediments deposit during the flood situation.

Considering the characteristics of sediments from four positions around the sandpit together combine with the meander scar geomorphology of Thaisin sandpit. The paleo-Mun river in the sandpit at Southern and Northern parts are probably the area where the paleo-Mun river flowed through the Channel. The most complete sedimentary column in the South seems to be area of the main deposition (pointbar). Section in the East and West seems to be a flood plain area and in the west seems to be flood plain area with a little slope sedimentary deposit.

However, Channel cut structure is not found and the stratigraphic correlations are cannot do. Because no clearly sediments can be used as criteria to separate and correlate with others columns in Thaisin sandpit area. So, we can only interpret the environment from a subset of the sediments layer to reconstruct the paleoenvironments but cannot specify the clearly model of paleo-Mun River.

# CHAPTER IV
# SYSTEMATIC PALEONTOLOGY OF PROBOSCIDEAN FOSSILS

This chapter addresses an assessment of systematic paleontology of proboscidean fossils from Thaisin sandpit. The processes comprise of identifying fossils, describing the external morphology of tooth, comparing with statistical analysis using numerical data from teeth measurement and clustering the fossils into the group by using all variables from teeth measurement consecutively.

## 4.1 Systematic Paleontology

### 4.1.1 Terminology

Proboscidean has 2 sets of teeth; deciduous and permanent as it is a diphyodont animal. Using technical terms is considered as an important part to describe this complex creature. For better understanding, a glossary should be prior reviewed. In this study, a basic glossary of mammalian tooth, anatomical directions and perspectives as well as a glossary of fossil proboscidean teeth are based on (Osborn, 1942) and (Shoshani and Tassy, 1996).

#### *4.1.1.1 General dentition terminology*

Mammalian teeth compositions are as following : Crown is at the most top of the tooth. In mammalian teeth, crown characteristics vary and indicate about dietary of that animal. Cervical line, which is divided between the crown and root. Main role of root is to sustain teeth. The middle of root has blood vessels and nerves to nourish the tooth as well. Dentine is the internal part of the tooth composition. In addition, enamel is the outer part that is very strong (Figure 4.1).

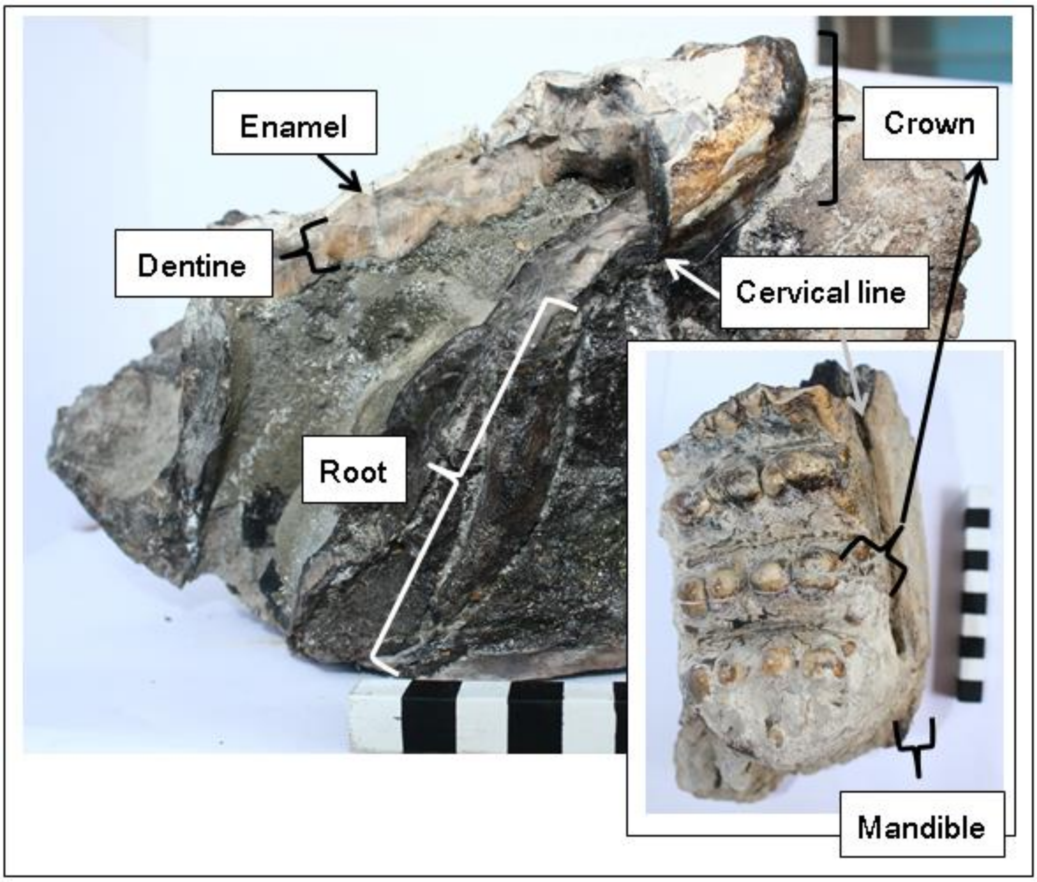


**Figure 4.1** General dentition of proboscidean tooth

The nomenclature of anatomical direction and perspective to specify the position of teeth fossils are described as following:

"Anterior" is the direction towards to the front of the skull while "Posterior" is in the opposite direction to the rear of the skull. In the part of tooth body, "Mesial" is using for specifying the front half of the tooth. "Distal" is using for specifying the hind half of the tooth. Usually it is using for determining the location of corrosion or worn. Viewpoint of the teeth are also important to describing the dimension for record the note or take a photo. "Occlusal" view is using for the upper topview. "Lingual view" is using for the view looking from the tongue and "Buccal view" is using for the view looking from the cheek (Figure 4.2 and Figure 4.3).

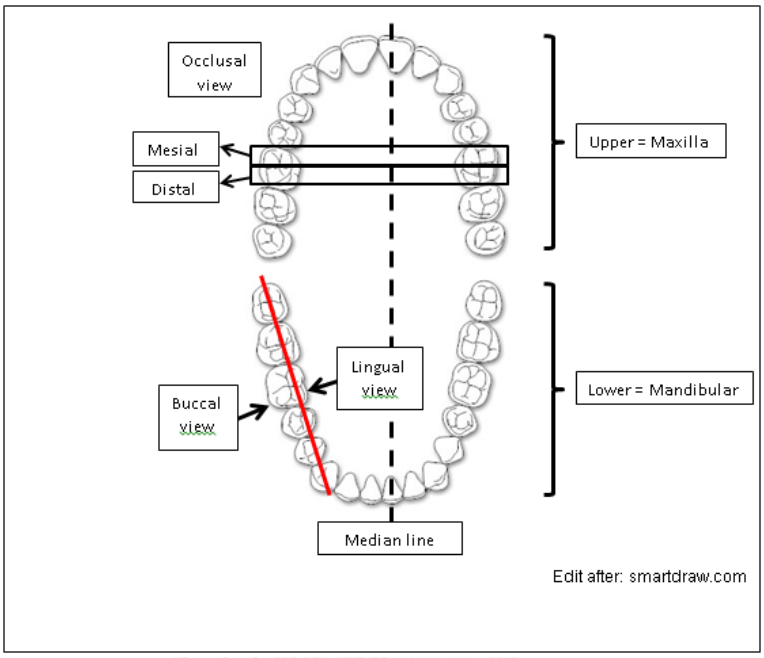


**Figure 4.2** Anatomical orientation of mammal

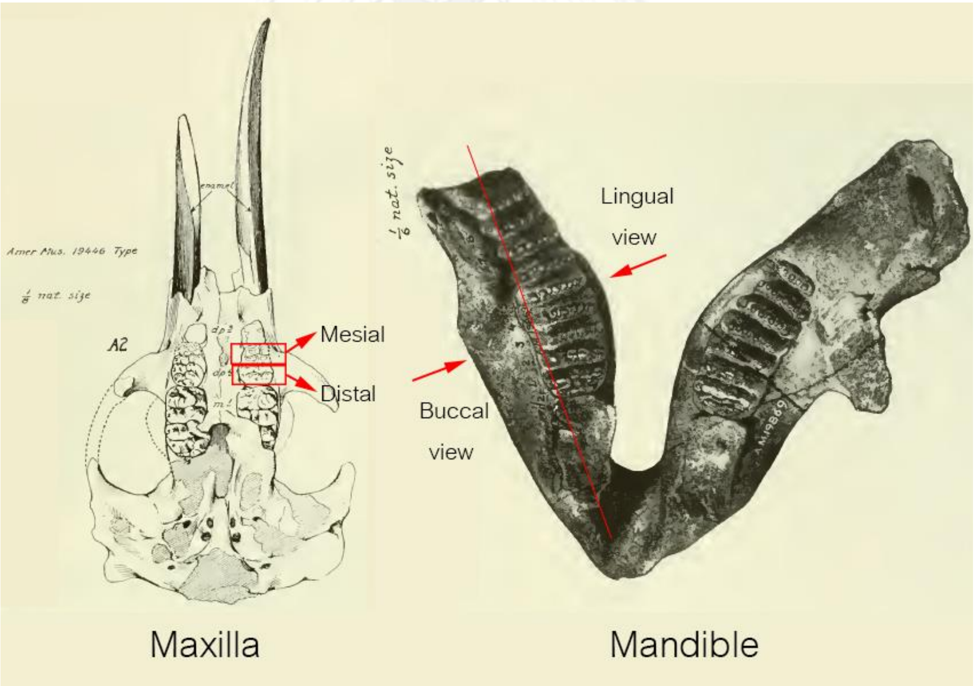


**Figure 4.3** Anatomical orientation of proboscidean, Maxilla are from *Stegolophodon cautleyi* and Mandible are from *Stegodon insignis* (adapted from Osborn, 1942)

*4.1.1.2 Terminology of proboscidean teeth*

Proboscidean has no canine. Some genus has incisor teeth in which developed to a tusk. Premolar and molar are differences in which change according to the genus of proboscidean. Premolar tooth looks less complex than molar. In some fossils, deciduous tooth can be discovered. It also looks less complicate than permanent teeth. The deciduous teeth are difficult to discover because the last deciduous teeth are lost since the elephants were very young. In case of Indian elephant, last deciduous teeth are lost in the age of 10 years. Primitive ancestor of proboscidean, the replacement of teeth are placed in vertical. The teeth are not complicated with only 2-3 lophs. While modern proboscidean, the replacement of tooth is in a horizontal line. The characteristics of one tooth consist of small plate of tooth; gradually increase until the full number of sets of teeth. In addition, it is gradually flowed in horizontal until drop away. A number of lophs vary depending on the genus of proboscidean. In more the modern the proboscidean, the more the number of lophs are found (Figure 4.4).

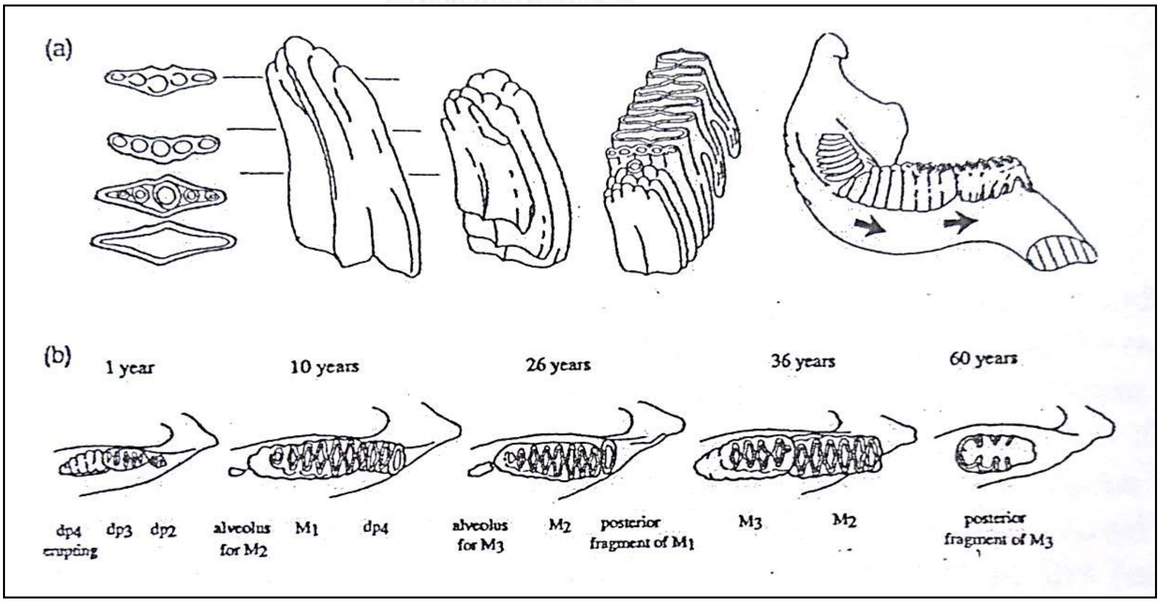


**Figure 4.4** Elephant Teeth replacement diagram a. Cross section b. Tooth replacement in horizon (Tassy and Shoshani, 1996)

From the terminology for describe the proboscidean teeth by Osborn (1942) and Shoshani and Tassy (1996), loph and lophid are cone-like elements arranged in a row. Loph is for Maxilla teeth and lophid is for Mandibular teeth. The number of lophs are counting only complete loph. Lophs at most anterior and posterior with poor develop small cusps is elaborated by using “X” letter as its label. Interloph or inter-valley is ridged between Loph(id). Median sulcus is the longitudinal line from anterior to posterior of teeth it’s divide teeth into two Half loph or Trefoil. Main cusps are big cones that always appear in fully develop teeth. Conelets are another cone that may appear or distince. Mesoconelets are conelets flank beside two side of median sulcus. Conules calls for others cone appear near the Loph(id). Talon or Talonid is the last loph at posterior of a tooth. Talon is for Maxilla teeth and Talonid is for Mandibular teeth. Pretrite is for main cusp that is more worn. Posttrite is for main cusp that is less worn. (Figure 4.5)

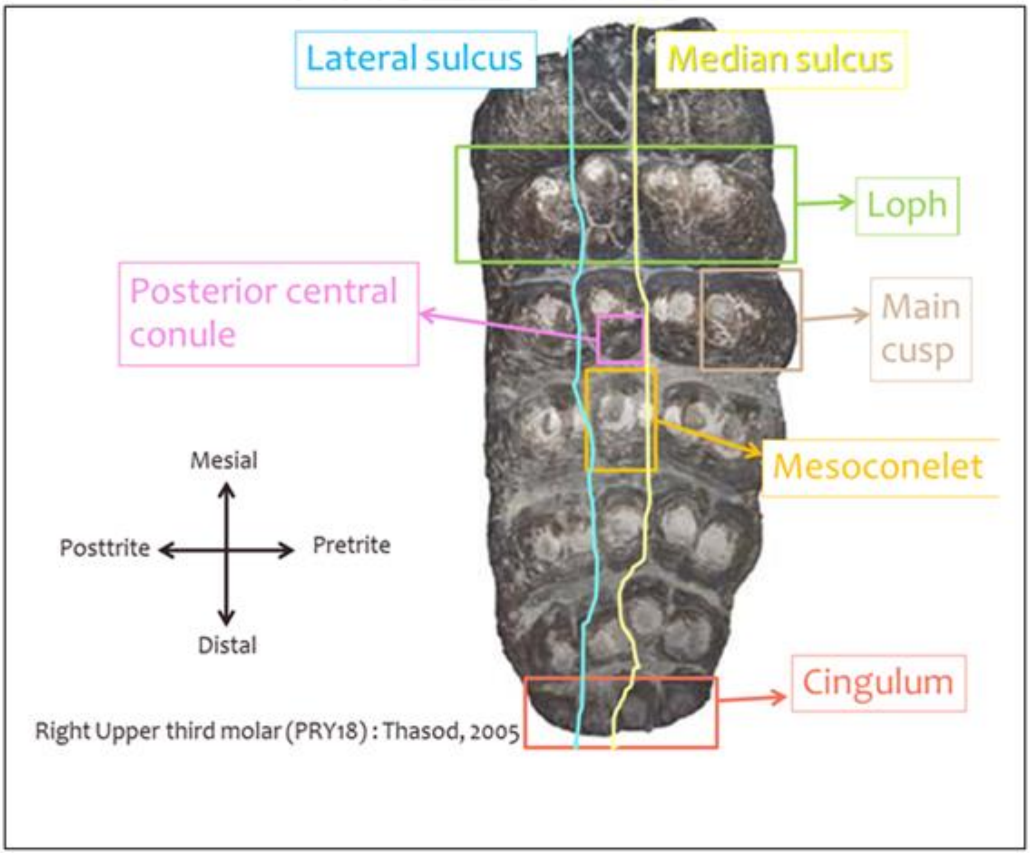


**Figure 4.5** Elephant tooth morphology, Dental terminology from Tassy (1996)

### 4.1.2 Identification and classification of proboscidean fossils

Fossil indentification in this study divided into two parts, external morphology of teeth and teeth measurement.

#### *4.1.2.1 External morphology of teeth*

Principle to identify proboscidean tooth is considering the changing trends of tooth such as increasing size of the teeth, number of loph(id), height of the teeth and other complexities morphology. In this study, the fossils morphology of each specimens are comparing with the previous studies. In addition, a comparison the photographs and fossils descriptions and an analysis of the measurements of the teeth are conducted.

Basic characteristics of each proboscidean teeth has been discussed in chapter 1. In Thaisin sandpit, all of the collected fossils resemble to the mammillae teeth are not high crown as the modern proboscidean. This is the remarkable feature of ancient proboscidean in the genus *Stegolophodon* and *Stegodon.* They are in Family Stegodontidae. Their general name is Stegodontids.

*Stegolophodon* has its life span of taxon in the Miocene – Pliocene age (23 - 1.8 million years ago). Its appearances are between mastodons and elephas (Asian elephants). It’s a direct ancestor of the *Stegodon*. It has 2 characteristics of tooth, the large cone-like cusp with low crown. A separation of cusp is not clearly. This characteristic is brachyodon teeth that found in the first 2 loph(id)s. Another characteristic is the cusp that clearly split into small cone-like. In Intermediate molar, contain the formula (number of loph) of tooth is X4X and the last molar has the formula from X4X to over X6X up (Shoshani and Tassy, 1996).

*Stegodon* has its life span of taxon in the late Miocene - early Holocene (11 – 0.008 million years ago) (Jintasakul, 2549) in which it later evolved from *Stegolophodon*. It has common characteristics between mastodons and elephas (Asian elephants). The cusps are clearly divided to a small button. Ridge between loph of teeth looks like a Y-shaped. The top view of ridge curved looks like roof top. In addition, *Stegodon* has a thin layer of cement. Intermediate molar teeth are contain X5X formula and more than X5X formula on the last molar.

#### *4.1.2.2 Teeth Measurement*

Teeth measurement and recording in the numeric value to detail identified in genera by using the basic numbers and statistic, then recorded as the database for comparison in order to use for studying in other ways. Hiroaki*, et al.* (2010) used the teeth measurement aiming to compares with previous researches and identified new species of *Stegodon* in Japan. The numerical values that measured in this study are as follows.

**Table 4.1** Teeth measurement method using for proboscidean fossils from Thaisin sandpit

| Variables | Methodology |
|---|---|
| Number of lophs or lophids | Counting the complete loph for identified by used standard teeth and writing the formula of teeth, shows primitive or modern proboscidean tooth |
| Length | Maximum length measured at longitudinal axis of the tooth |
| Width | Maximum width of the tooth measured on the widest loph(id) |
| Height | Maximum height of crown measured at the middle loph(id) from top of the cusps to the cervical line |
| Enamel thickness | Enamel thickness measured at the maximum enamel thick appear, aware about worn effect |
| Cusp | Measured at every cusps of teeth and average |

## 4.2 Results

### 4.2.1 External morphology descriptions

Class Mammalia Linnaeus, 1758

Order Proboscidea Illiger, 1811

Family Stegodontidae Osborn, 1981

Genus *Stegolophodon* Schlesinger, 1917

Type species: *Stegolophodon latidens*

Material 1: Mesial part of upper? M2?

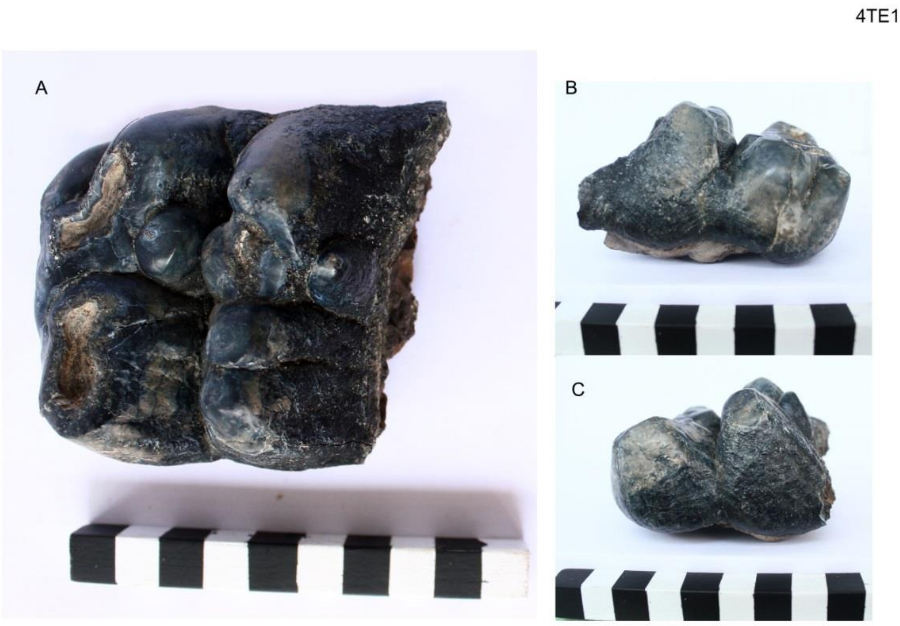




**Figure 4.6 Fossil 4TE1; A: occlusal view, B: lingual view?, C: buccall view?**

Description: This tooth fragment belongs to bunodont molar composed of 2 lophs. Its length is 76.4 mm and its width is 74.6 mm. There is a median sulcus that separates the pretrite and posttrite halves. They are brachyodonts. The lophs are composed of 2-4 round tubercles of the same height.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 20 meters depth from ground surface.

Comparison and Discussion: Because of damaged, this specimen is identified as *Stegolophodon* due to clear median sulcus and large central conules. This tooth may be M2 because of the brachyodont tooth characteristic in the first loph(id) and the separated tubercles with an equal height in the second loph. However, the subdivided of cusps are not clear. This is a possibility to be an intermediate molar. Body of tooth is slightly curve up. The complete molar must be at lease 4 loph(id)s.

Remarks: This specimen is quite small due to width of tooth but it reflects a well develop of conules.

Material 2: Distal part of lower left m3 with mandible

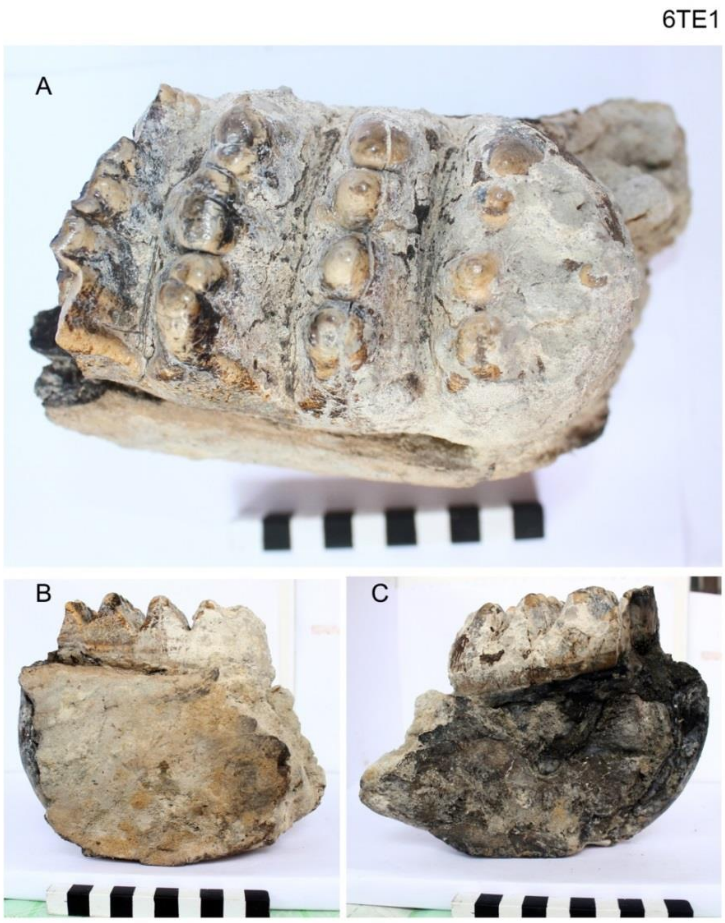


Figure 4.7 Fossil 6TE1 ; A: occlusal view, B: buccal view, C: lingual view

Description: This mandible and tooth fragment belong to bunodont molar composed of incomplete with broken anteriory 4 lophids. Its length is 107.2 mm and its width is 67.3 mm. The median sulcus is not quite clear. The conules are fusion with main cusps and mesoconelets. All tubercles in lophid row are in equal height.

The shape of a valley between lophs is in Y-shaped. The complete molar must be at lease 5 lophids.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 14.5 meters depth from ground surface.

Comparison and Discussion: This specimen may belong to an advanced *Stegolophodon* according to equal height of all tubercles in a lophid and the becoming disappearance of median sulcus. However, conules fusion with cusp in a row is existed and roof top shape in inter-valley is not shown like *Stegodon*. According to the structure and size of the conules of 4TE1, 6TE1, it suggest that the 6TE1 may advanced than the 4TE1.

Remark: Fossil 6TE1 was found together with Fossil 6TE2.

Material 3: Mesial part of lower left m2? with mandible


**Figure 4.8** Fossil 6TE2 ; A: occlusal view, B: buccal view, C: lingual view

Description: This mandible and tooth fragment belong to brachyodont molar composed of 2 lophids. Its length is 49.3 mm and its width is 61.7 mm. The median sulcus is not clear. Central conules appear between lophid. The tooth body is heavily worn.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 14.5 meters depth from ground surface.

Comparison and Discussion: This specimen is severely damaged. This tooth may be m2 because of the brachyodont molar characteristic and conules that still appear as trace between lophids. However, the subdivided of cusps are not clear according worning and damage, it can possibly be intermediate molar. The second lophid that broken has some structures look similar to be the tubercles. The complete molar must be at lease 5 lophids.

Remark: Fossil 6TE2 was found together with Fossil 6TE1.

*Stegolophodon* fossils founded in Thaisin sandpit may be at least 2 species. By fossil 4TE1 is more primitive species than 6TE1 and 6TE2. Corresponding to the depth in sand layer that fossils found, by 4TE1 fossil is in a deeper layer than 6TE1 and 6TE2.

Class Mammalia Linnaeus, 1758

Order Proboscidea Illiger, 1811

Family Stegodontidae Osborn, 1981

Genus *Stegodon* Falconer, 1857

Type species: *Stegodon elephantoides*

Material 1: Distal part of lower m3


**Figure 4.9** Fossil 2TE1 ; A: occlusal view, B: lingual view?, C: buccal view?

Description: This specimen is belongs to bunodont molar composed of 3 lophids with the posterior talonid. Its length is 151.6 mm and its width is 105.4 mm. The median sulci is indistinct and disappear. The fusion of main cusps and mesoconelets are complete. The shape of a valley between lophs is in a Y-shaped.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 20 meters depth from ground surface.

Comparison and Discussion: This distal part of m3 is bunodont teeth. The cusps are subdivided as equal height. Thin layer of cement is found. Transverse ridge curved like roof top is the characteristic of *Stegodon*.

Remark: The complete of the number of lophids maybe more than 5X because the broken position begin near the middle part of this tooth. The tooth body is less worn; it’s very possibly being the last molar.

Material 2: Anterior part of lower m3?

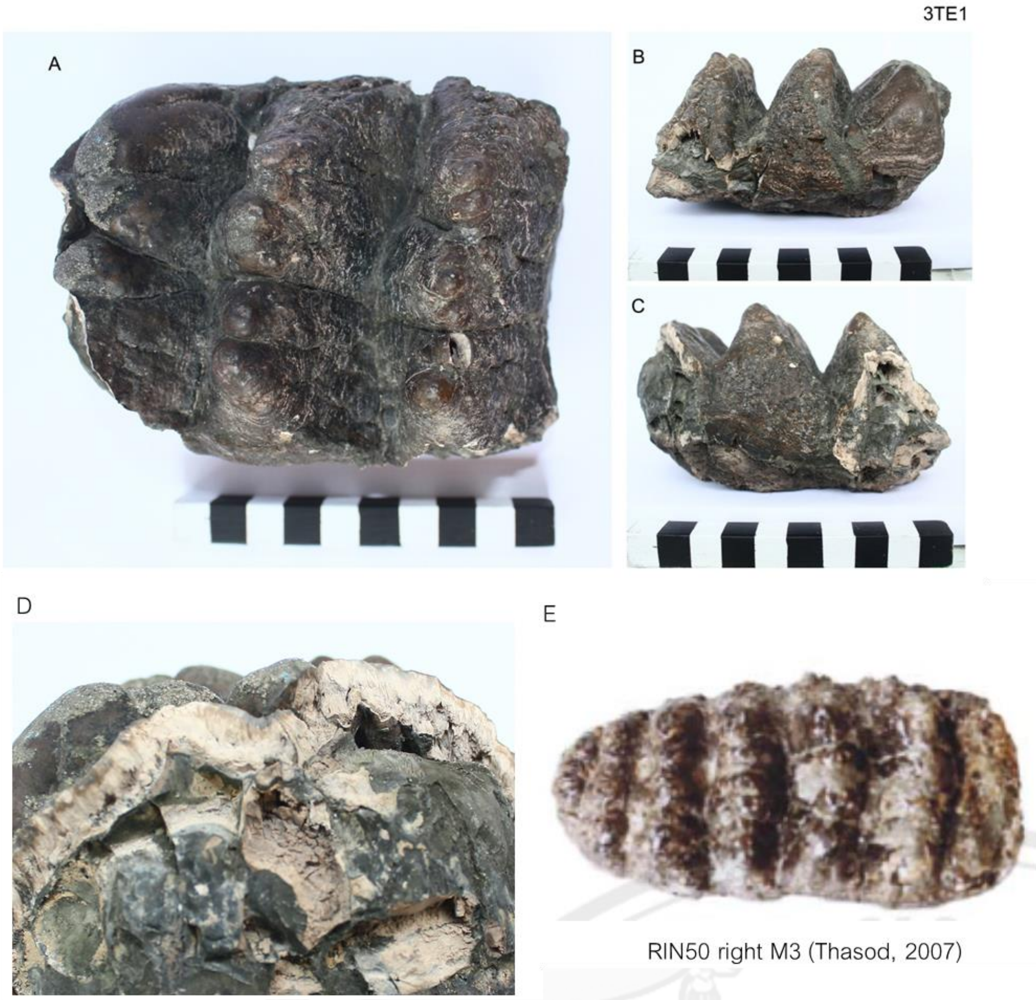


**Figure 4.10** Fossil 3TE1; A: occlusal view, B: buccal view? C: lingual view?, D: Stufenbildung



Description: This tooth fragment is belongs to bunodont molar composed of 3 lophids. Its length is 111.6 mm and its width is 94.8 mm. The median sulcus is indistinct. There are fusion of main cusps and mesoconelets. The shape of a valley between lophids are Y-shaped.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 18 meters depth from ground surface.

Comparison and Discussion: This specimen is bunodont tooth. The cusps are subdivided not so clear but the height of cusp are quite equal. Some lophids also found the element like conules fused in the row. Thin layer of cement and step-like worn structure (Stufenbildung) is found. Transverse ridge curved like roof top.

Remark: This tooth may have more than 4 lophids. This tooth condition is much more damage because of its soft skin that of easily to decay.

Material 3: Distal part of upper? M3

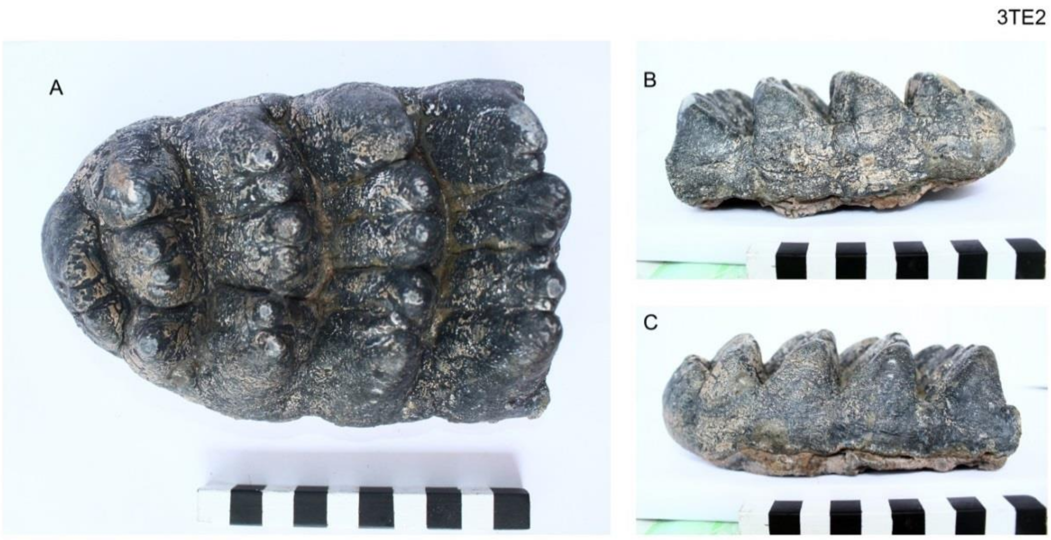


Figure 4.11 Fossil 3TE2 ; A: occlusal view, B: buccal view?, C: lingual view?

Description: This specimen belongs to bunodont molar composed of 4 lophs, which is incomplete. Its length is 152.5 mm and its width is 100.0 mm. The median sulci is indistinct. The fusion of main cusps and mesoconelets are complete. The shape of a valley between lophs is in a Y-shaped.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 18 meters depth from ground surface.

Comparison and Discussion: This specimen is bunodont tooth. The subdivision of cusps are clear with equal height cusp. Thin layer of cement is found and the transverse ridge curved looks like roof top. This specimen can be allocated to *Stegodon*.

Remark: The complete of the number of lophs may be more than 6X.

Material 4: Distal part of lower m2?

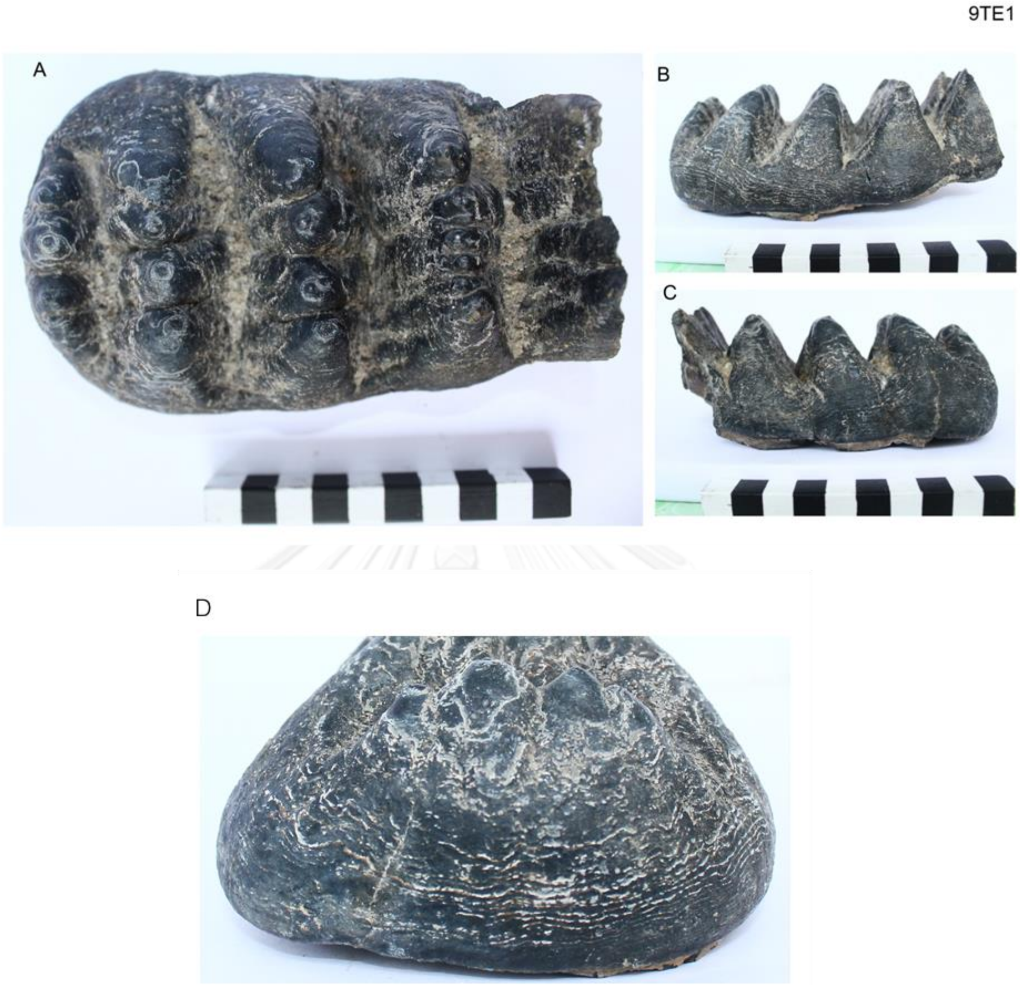


**Figure 4.12** Fossil 9TE1; A: occlusal view, B: lingual view?, C: buccal view?, D: contact trail



Description: This specimen belongs to bunodont molar composed of 4 lophids. Its length is 141.8 mm and its width is 80.8 mm. The median sulci is indistinct. The fusion of main cusps and mesoconelets are appearing. The distal margin is broad but from the fourth lophids distally there is gradually diminished in breadth. The shape of a valley between lophs is in a Y-shaped.

Fossil localities: Thaisin sandpit, Nakhon Ratchasima at about 12.5 meters depth from ground surface.

Comparison and Discussion: This specimen is bunodont tooth. It seems to has a median sulci and the transverse ridge is not clearly curved like roof top. However, the subdivided of cusps are clear and its height of cusps are equal. It maybe m2 tooth because of having the contact trail to the next tooth, but it is not clear. This specimen may be allocated to *Stegodon*.

Remark: The complete of the number of lophids maybe 5X. The width trend of tooth is getting wider in the distal part. This molar is possibly be an intermediate molar.

By considering the external morphology of teeth, the primitive to modern fossils can be arranged as follow. The 3TE1 fossil maybe the most primitive because of the big conule size that still not completely fuse with mesoconelet. While the 3TE2 and 9TE1 fossils are likely to be evolved in nearly same range time. Because the 3TE2 as M3 tooth and 9TE1 as m2 tooth still found some trace of fusion between conules and mesoconelets. But both 3TE2 and 9TE1, the subdivided of cusp are quite clear. The 2TE1 are likely to be the most advanced proboscidean teeth fossil that found in Thaisin sandpit because all the conules are disappear. The subdivided of cusp is very clear with very high crown height and roof top curve transverse ridge. But when compare with depth of the sandpit that fossils were founded, it's not corresponding to the relative age as compare by external morphology method. Furthermore, the fossil 9TE1, 3TE1, 3TE2 and 2TE1 are discovered at 12.5, 18, 18 and 20 meters depth from ground surface, respectively.

**Table 4.2** Checklist for the characteristic of proboscidean teeth from Thaisin sandpit

| Name | Depth (m.) | Bunodont | Brachyodont | Median sulcus | Conules | Separated tubercles With equal height | Cement | Curved ridge |
|---|---|---|---|---|---|---|---|---|
| 2TE1 | 20 | ✓ | | | | ✓ | ✓ | ✓ |
| 3TE1 | 18 | ✓ | | | | ✓ | ✓ | ✓ |
| 3TE2 | 18 | ✓ | | | | ✓ | ✓ | ✓ |
| 4TE1 | 20 | | ✓ | ✓ | ✓ | ✓ | | |
| 6TE1 | 14.5 | | | ✓ | ✓ | ✓ | | |
| 6TE2 | 14.5 | | ✓ | | ✓ | | | |
| 9TE1 | 12.5 | ✓ | | | | ✓ | ✓ | |

By the specially characteristics of *Stegolophodon* are brachyodont tooth in 1-2 lophs, clearly median sulcus and still appear the conules, checklist will shows as blue correct symbols. Specially characteristics of *Stegodon* are cement layer and curved ridge like a roof as shows in the checklist by green correct symbols. Another red correct symbol shows the common characteristics share together with two genera.

### 4.2.2 Teeth measurement

Vernier caliper is using for measure all the specimens. The dimensions of fossils are record as millimeters. Width of teeth is measure in the maximum width part of the teeth. Length of teeth is measure at the median line of teeth. Because of many fossils are more damaged, height of lophs are measure at the cervical line in every mature cusps of each loph then average them to crown height.

**Table 4.3** Teeth measurement

| Name | Length of tooth (mm.) | Formula of molar | Loph(id) | Width of Loph(id) (mm.) | 1 (mm.) | 2 (mm.) | 3 (mm.) | 4 (mm.) |
|---|---|---|---|---|---|---|---|---|
| Genus *Stegodon* | | | | | | | | |
| 2TE1 | 151.6 | x5x | -3x | 98.3 | 31.3 | 32.2 | 33.5 | 34.6 |
| lower m3 | | | x4x | 81.5 | 29.9 | 30.9 | 33.7 | 32.3 |
| | | | x5x | 65.3 | 28.0 | 29.7 | 27.1 | |
| | | | Talon | 41.2 | 20.1 | 19.7 | | |
| 3TE1 | 111.55 | x5x | -2x | 87.3 | 32.1 | 32.5 | | |
| lower m3 | | | x3x | 92.5 | 38.1 | 38.7 | 41.7 | 40.8 |
| | | | x4- | 84.3 | 36.1 | 34.7 | 34.0 | |
| 3TE2 | 152.45 | x6x | -3x | 97.6 | 30.2 | 32.4 | 32.9 | 29.3 |
| upper M3 | | | x4x | 96.8 | 28.0 | 29.4 | 33.8 | 28.0 |
| | | | x5x | 92.7 | 27.9 | 30.8 | 29.1 | |
| | | | x6x | 78.8 | 26.8 | 29.7 | 27.5 | |
| | | | Talon | 46.4 | 11.5 | 13.6 | 16.7 | |
| 9TE1 | 141.8 | x5x | -2x | | ~45.7~ | | | |
| lower m2 | | | x3x | 82.6 | 37.4 | 38.1 | 39.0 | 39.8 |
| | | | x4x | 87.8 | 33.8 | 33.4 | 33.0 | 32.2 |
| | | | x5x | 87.9 | 29.6 | 29.2 | 28.5 | 29.3 |
| | | | Talon | 58.1 | 24.5 | 26.7 | 29.6 | 23.9 |
| Genus *Stegolophodon* | | | | | | | | |
| 4TE1 | 76.35 | x4x | x1x | 74.7 | 28.9 | 27.5 | | |
| upper M2 | | | x2- | 76.8 | 32.9 | 31.7 | | |
| 6TE1 | 107.2 | x5x | -2x | | 25.6~ | | | |
| lower m3 | | | x3x | 65.8 | 32.7 | 30.3 | 29.4 | |
| | | | x4x | 68.8 | 29.2 | 28.1 | 29.5 | 28.2 |
| | | | x5x | 65.3 | 30.7 | 29.7 | 24.8 | |
| | | | Talon | | - | | | |
| 6TE2 | 49.3 | x5x | x1x | 62.2 | 21.6 | 21.2 | | |
| lower m2 | | | x2- | 62.1 | 22.3 | | | |

This is considered as a limitation because of the received fossils' conditions are severely damaged. The measurement values are selected with suitable characteristics or parameters. The measuring of enamel thickness, height and width are still able to use in the incomplete molar to consider with external morphology. But the height of cusp is more varied and didn't have the standard number to compare. Thus, it cannot be used to subdivide the group of fossils, but by averaged them to show the crown height of loph(id)s.

**Table 4.4 Suitable values of teeth (mm)**

| Name | Number of Loph(id) | Width (Max) | Enamel Thickness | Average Height of Lophids | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | T |
| Genus *Stegodon* | | | | | | | | |
| 2TE1 | 3+T | 98.3 | 6.1 | 32.9 | 31.7 | 28.3 | - | 19.9 |
| 3TE1 | 3 | 92.5 | 7.4 | 32.3 | 39.8 | 34.9 | - | - |
| 3TE2 | 4+T | 97.6 | 8.0 | 28.0 | 29.3 | 29.8 | 31.2 | 13.9 |
| 9TE1 | 4+T | 87.9 | 6.8 | 45.7(B) | 38.6 | 33.1 | 29.2 | 26.2 |
| Genus *Stegolophodon* | | | | | | | | |
| 4TE1 | 2 | 76.8 | 5.3 | 28.2 | 32.3 | - | - | - |
| 6TE1 | 4+T | 68.8 | 4.0 | 28.4 | 28.8 | 30.8 | 25.6 (B) | n |
| 6TE2 | 2 | 62.2 | 3.1 | 21.4 | 22.3 | - | - | - |

The measurements of fossil pieces 2TE1, 3TE1, 3TE2 and 9TE1 are found that the width of the teeth is in a range of 87.9 mm to 98.3 mm and the thickness of enamel are in a range of 6.1 mm to 8.0 mm. This is appropriate to classify as one group. The average height of loph is between 28.0 mm to 39.8 mm.

The measurements of fossil pieces 4TE1, 6TE1 and 6TE2 found that the width of the teeth is in a range of 62.2 mm to 76.8 mm and the thickness of enamel are in range of 3.1 mm to 5.3 mm. This is appropriate to classify as one group. The average heights of loph is between 21.4 mm to 32.3 mm.

The 4TE1, 6TE2 and 9TE1 are M2 molar, generally M2 molar is always smaller than M3 molar. When comparing the maximum width between 4TE1, 6TE2 and 9TE1, 9TE1 with 87.9 mm they are still bigger than 4TE1 and 6TE2 with 76.8 mm and 62.2 mm, respectively.

When considered with worn effect, 4TE1 and 6TE2 are the mesial part of teeth that got more worn effect than the distal part of teeth. The height values from all teeth measurement are not significance to use as standard number to compare.

#### 4.2.2.1 Scatter diagrams

Scatter graph plots from teeth measurement of *Stegolophodon* and *Stegodon* previous study (Blue) and from Thaisin sandpit (Red). From previous study, width and height are taken from doctoral dissertation of Thasod, 2007 and the enamel thickness from Master Thesis of Sreprateep, 2005.

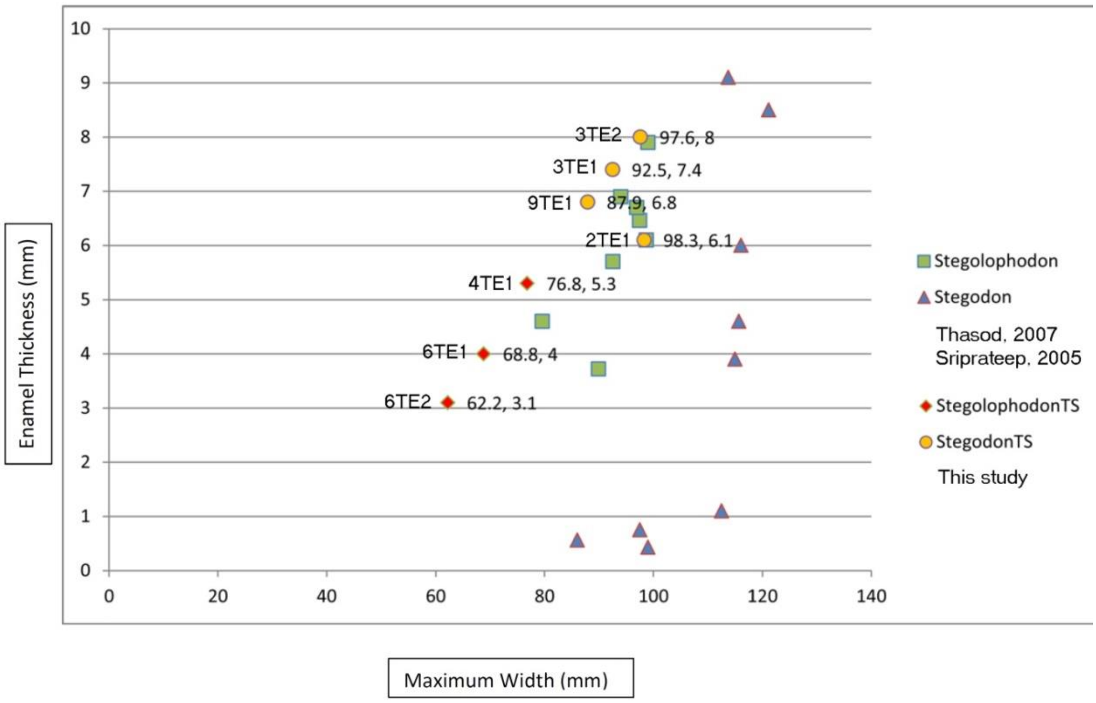


**Figure 4.13** Scatter Diagram between maximum width and enamel thickness

Scatter Diagram plotted between maximum width and enamel thickness of the proboscidean teeth fossils from Thaisin sandpit shows the linear relationship between the width and enamel thickness. This can be divided visually into two groups, that corresponding to the identification by external morphology of teeth. In a comparison to proboscidean teeth fossils from the doctoral dissertation of Thasod 2007 and Master Thesis of Sreprateep 2005, they showed the similar trend to the *Stegolophodon* group.

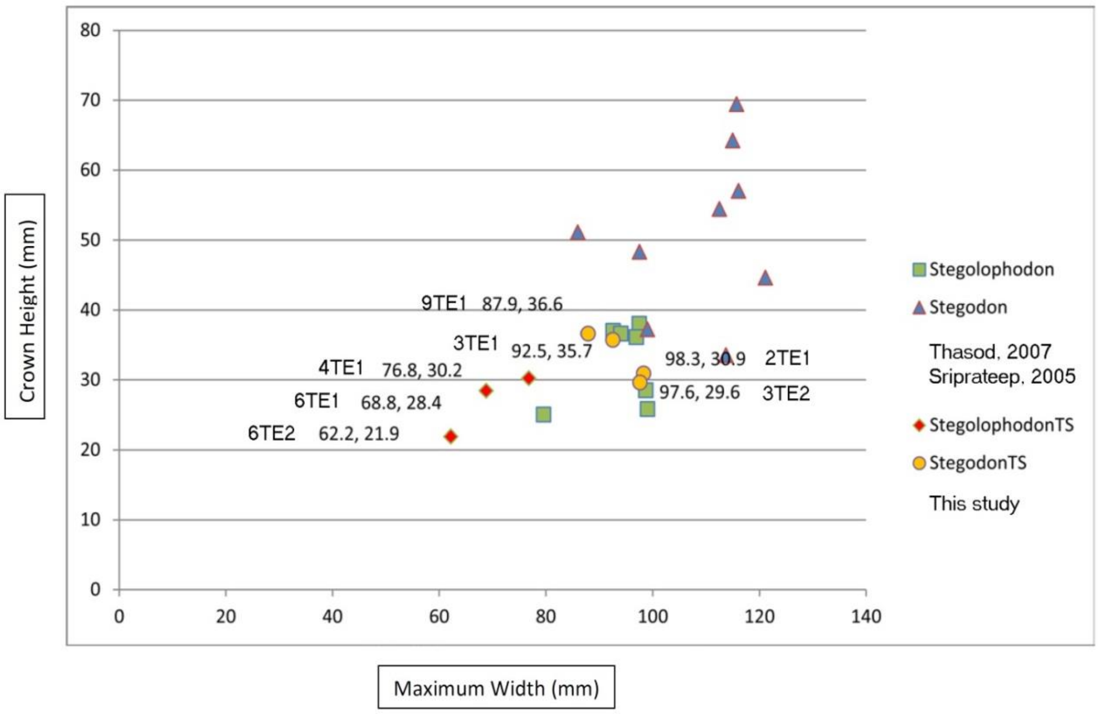


**Figure 4.14** Scatter Diagram between maximum width and crown height

Scatter Diagram plotted between maximum width and crown height of the proboscidean teeth fossils from Thaisin sandpit showed the similar trend to the *Stegolophodon* group, when compared to proboscidean teeth fossils from the doctoral dissertation of Thasod 2007 and Master Thesis of Sreprateep 2005. Considering overall of the plotted, it showed that the crown height and the maximum width of *Stegodon* teeth fossils tend to be higher and wider than the *Stegolophodon* teeth fossils.

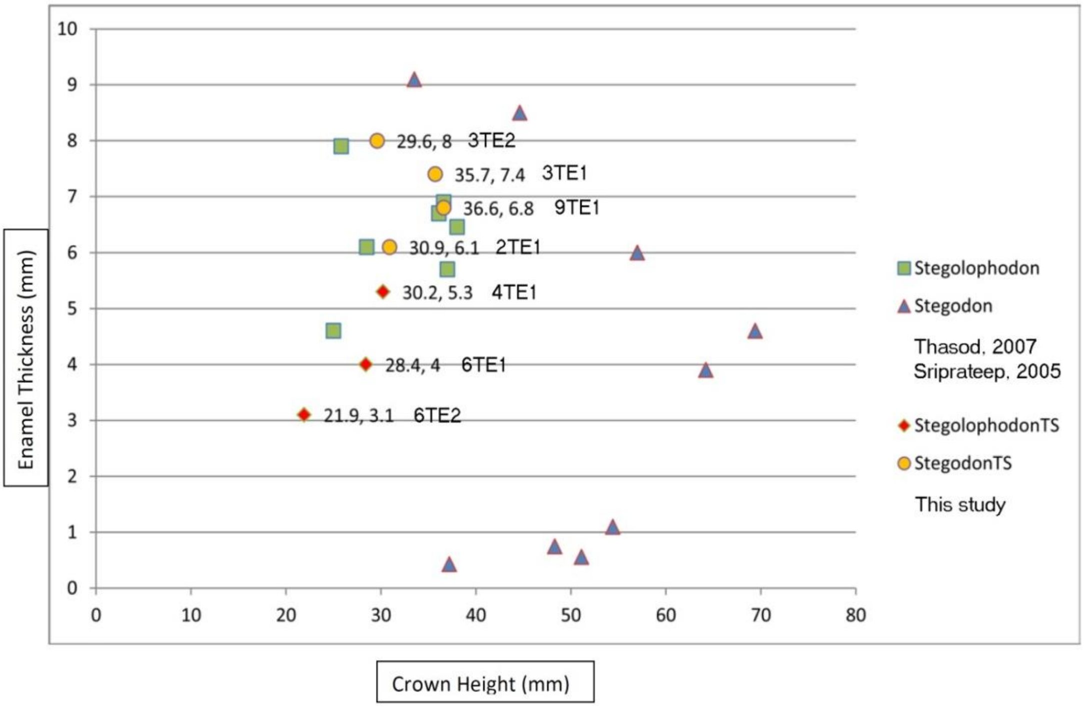


**Figure 4.15** Scatter Diagram between crown height and enamel thickness

Scatter Diagram plotted between crown height and enamel thickness of the proboscidean teeth fossils from Thaisin sandpit, when visually considered, the enamel thickness can be divided into two groups corresponding to the identification by external morphology of teeth. When compared to proboscidean teeth fossils from the doctoral dissertation of Thasod 2007 and Master Thesis of Sreprateep 2005, it showed a similar trend to the *Stegolophodon* group.

From three scatter graphs; its cannot grouping the fossils from this study when compared to the proboscidean teeth fossils from doctoral dissertation of Thasod 2007 and Master Thesis of Sreprateep 2005. By the way, similar trends shows that seven fossils from this study are distribute near the group of *Stegolophodon* genus from previous study.

The classification of fossils from Thaisin sandpit using external morphology results is correspondingly to the teeth measurement method by scatter diagram. It can be distinguished proboscidean fossils into two groups. Fossils 2TE1, 3TE1, 3TE2 and 9TE1 are the fossils of elephants in genus *Stegodon* whereas fossils 4TE1, 6TE1, 6TE2 are the fossils of elephants in genus *Stegolophodon*. The found fossils are not perfect due to the mining process. But considering detailed from measurements, it is also showed certain values that are constant parameter and can be analyzed. In addition, characteristics key of external morphology still appear. This makes it possible to classify in the genus level.

## 4.3 Statistical method for cluster analysis

Paleoecology is described between 2 genera by the difference in dietary as ecology after characteristic of teeth. Correlation statistic is used to examine the relationship between variations of the teeth measurement. Then following by the cluster analysis to group the specimens by the similarity.

### 4.3.1 Correlations statistic

Before using correlation statistic, all of the variables need to be verifyed in the condition of normal distribution whether it has a linear relationship or not. After checked with a test of normality, histogram and normal plot, it showed all variables (width, height and enamel thickness) have a normal distribution. In addition, a linear relationship between width Vs. enamel thickness is found, but the width Vs. height and height Vs. enamel thickness have no linear relationship. Using correlation statistic, this study applied all Pearson correlation, Kendall and Spearman method.

**Table 4.5** Parametric correlation tables

Descriptive Statistics

| | Mean | Std. Deviation | N |
|---|---|---|---|
| HIGH | 30.4782 | 4.91364 | 7 |
| ET | 5.8143 | 1.79205 | 7 |
| WIDTH | 83.4600 | 14.33291 | 7 |

Correlations

| | | HIGH | ET | WIDTH |
|---|---|---|---|---|
| HIGH | Pearson Correlation | 1 | .753 | .673 |
| | Sig. (2-tailed) | | .050 | .097 |
| | Sum of Squares and Cross-products | 144.863 | 39.809 | 284.429 |
| | Covariance | 24.144 | 6.635 | 47.405 |
| | N | 7 | 7 | 7 |
| ET | Pearson Correlation | .753 | 1 | .919** |
| | Sig. (2-tailed) | .050 | | .003 |
| | Sum of Squares and Cross-products | 39.809 | 19.269 | 141.596 |
| | Covariance | 6.635 | 3.211 | 23.599 |
| | N | 7 | 7 | 7 |
| WIDTH | Pearson Correlation | .673 | .919** | 1 |
| | Sig. (2-tailed) | .097 | .003 | |
| | Sum of Squares and Cross-products | 284.429 | 141.596 | 1232.594 |
| | Covariance | 47.405 | 23.599 | 205.432 |
| | N | 7 | 7 | 7 |

**. Correlation is significant at the 0.01 level (2-tailed).

From Pearson’s table of correlations

between the WIDTH and ET found that the r-value is 0.919.

By Sig. (2-tailed) = 0.003, sig<$\alpha$ at 0.01

So the WIDTH and ET are correlated at significance level 0.01.

**Table 4.6** Nonparametric correlations table

Correlations

| | | | HIGH | ET | WIDTH |
|---|---|---|---|---|---|
| Kendall's tau_b | HIGH | Correlation Coefficient | 1.000 | .524 | .429 |
| | | Sig. (2-tailed) | . | .099 | .176 |
| | | N | 7 | 7 | 7 |
| | ET | Correlation Coefficient | .524 | 1.000 | .714* |
| | | Sig. (2-tailed) | .099 | . | .024 |
| | | N | 7 | 7 | 7 |
| | WIDTH | Correlation Coefficient | .429 | .714* | 1.000 |
| | | Sig. (2-tailed) | .176 | .024 | . |
| | | N | 7 | 7 | 7 |
| Spearman's rho | HIGH | Correlation Coefficient | 1.000 | .607 | .571 |
| | | Sig. (2-tailed) | . | .148 | .180 |
| | | N | 7 | 7 | 7 |
| | ET | Correlation Coefficient | .607 | 1.000 | .786* |
| | | Sig. (2-tailed) | .148 | . | .036 |
| | | N | 7 | 7 | 7 |
| | WIDTH | Correlation Coefficient | .571 | .786* | 1.000 |
| | | Sig. (2-tailed) | .180 | .036 | . |
| | | N | 7 | 7 | 7 |

*. Correlation is significant at the 0.05 level (2-tailed).

From Kendall's table of correlations,



the WIDTH and ET found that the r-value is 0.714.

By Sig. (2-tailed) = 0.024, sig<$\alpha$ at 0.05

So the WIDTH and ET are correlated at significance level 0.05.

From Spearman's table of correlations,

the WIDTH and ET found that the r-value is 0.786.

By Sig. (2-tailed) = 0.036, sig<$\alpha$ at 0.05

So the WIDTH and ET are correlated at significance level 0.05.

There is a relation between maximum width Vs. enamel thickness. Due to the tendency of increasing size of the teeth. But when considering at maximum width Vs.

crown height and crown height Vs. enamel thickness, this is no relationship. This may be because it is the part of changing on evolution that it does not happen together. However, the test of normality, histogram and normal plot showed that all the variables (width, height and enamel thickness) have a normal distribution. This shows up the specific range of each variables and there is no remarkable in each variables in the teeth measurement of two genera of proboscidean fossils.

### 4.3.2 Cluster Analysis

Hierarchical cluster analysis is used to clustering the 3 variables to make a dendrogram showing the relationship. The method of hierarchical cluster analysis is best explained by describing the algorithm, or set of instructions, which creates the dendrogram results. Where the objects are joined together in a hierarchical fashion from the closest. That the closest is the most similar while the furthest apart is the most different.

**Table 4.7** Proximity Matrix table

| | Squared Euclidean Distance | | | | | | |
|---|---|---|---|---|---|---|---|
| Case | 1: 2TE1 | 2: 3TE1 | 3: 3TE2 | 4: 4TE1 | 5: 6TE1 | 6: 6TE2 | 7: 9TE1 |
| 1: 2TE1 | .000 | 1.617 | 1.207 | 2.476 | 5.874 | 12.580 | 1.998 |
| 2: 3TE1 | 1.617 | .000 | 1.797 | 3.811 | 8.538 | 18.160 | .249 |
| 3: 3TE2 | 1.207 | 1.797 | .000 | 4.407 | 9.077 | 16.049 | 2.966 |
| 4: 4TE1 | 2.476 | 3.811 | 4.407 | .000 | .975 | 5.451 | 2.994 |
| 5: 6TE1 | 5.874 | 8.538 | 9.077 | .975 | .000 | 2.234 | 7.024 |
| 6: 6TE2 | 12.580 | 18.160 | 16.049 | 5.451 | 2.234 | .000 | 16.516 |
| 7: 9TE1 | 1.998 | .249 | 2.966 | 2.994 | 7.024 | 16.516 | .000 |

This is a dissimilarity matrix

Proximity table is the table that shows the similarity of cases after comparing by matrix between each case. The even less value is even more similar and relationship in the group even closer together. As show in the dendrogram below.

**Table 4.8** Agglomeration Schedule

| Stage | Cluster Combined | | Coefficients | Stage Cluster First Appears | | Next Stage |
|---|---|---|---|---|---|---|
| | Cluster 1 | Cluster 2 | | Cluster 1 | Cluster 2 | |
| 1 | 2 | 7 | .249 | 0 | 0 | 4 |
| 2 | 4 | 5 | .975 | 0 | 0 | 5 |
| 3 | 1 | 3 | 1.207 | 0 | 0 | 4 |
| 4 | 1 | 2 | 2.095 | 3 | 1 | 6 |
| 5 | 4 | 6 | 3.843 | 2 | 0 | 6 |
| 6 | 1 | 4 | 8.959 | 4 | 5 | 0 |

Average Linkage (Between Groups) is shows in agglomeration schedule table, the more less value the more first come stage that each case are joint together in the dendrogram.

**Table 4.9** Cluster Membership

| Case | 4 Clusters | 3 Clusters | 2 Clusters |
|---|---|---|---|
| 1: 2TE1 | 1 | 1 | 1 |
| 2: 3TE1 | 2 | 1 | 1 |
| 3: 3TE2 | 1 | 1 | 1 |
| 4: 4TE1 | 3 | 2 | 2 |
| 5: 6TE1 | 3 | 2 | 2 |
| 6: 6TE2 | 4 | 3 | 2 |
| 7: 9TE1 | 2 | 1 | 1 |

From the cluster membership table, when clustering fossils into two groups, fossil number 1, 2, 3 and 7 are organized in the same group. Fossils 4, 5 and 6 are organized in the same group. It is suggested the same corresponds to the classification by external morphology of teeth.

## Dendrogram

H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S

Dendrogram using Average Linkage (Between Groups)

Rescaled Distance Cluster Combine

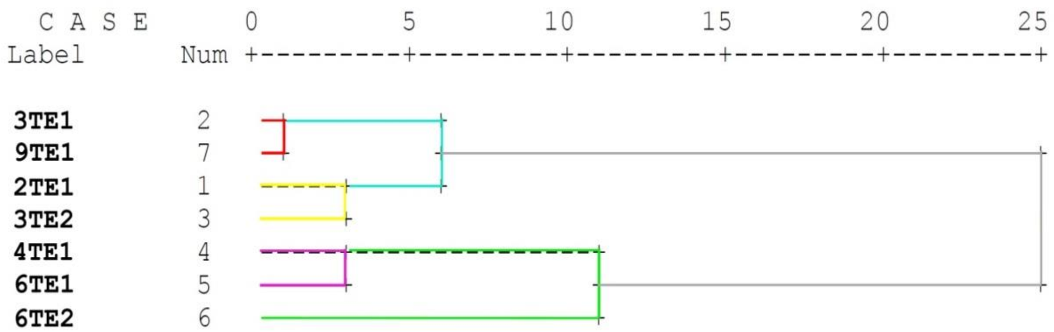


**Figure 4.16** Dendrogram from Hierarchical clustering of proboscidean fossils from Thaisin sandpit

Fossil 2 and 7 or 3TE1 and 9TE1 are the most similar as shown in red line. Fossil 1 and 3 or 2TE1 and 3TE2 are the secondary similar, while fossil 4 and 5 or 4TE1 and 6TE1 are also the secondary similar too. The next clustering, fossils number 2 and 7 are similar to fossils number 1 and 3. So this could be classified a group of fossils 3TE1, 9TE1, 2TE1 and 3TE2 together. Then the last clustering group of fossils in similarity are fossils number 4 and 5 in which similar to fossils number 6, this could be classified a group of fossils 4TE1, 6TE1 and 6TE3 together.

# CHAPTER V
# DISCUSSIONS AND CONCLUSIONS

## 5.1 Systematic paleontology of proboscidean fossils from Thaisin sandpit

### 5.1.1 Classification by external morphology

The results of the classification by external morphology show that proboscidean fossils found in Thaisin sandpit consist of two generas; *Stegolophodon* and *Stegodon*. External morphology of genus *Stegolophodon* shows that 6TE1 and 6TE2 have quite advance characteristics with the equal height and clearly subdivide of cusp, but both of them still shows the type 2 and type 3-a of posterior central conules (Thasod, 2007.). When compares to the (Saegusa*, et al.*, 2005); fossils 6TE1 and 6TE2 belonged to the *Stegolophodon* group4 or a large *stegolophodons* from the late Miocene of south and southeast Asia, including the type of *Sl. stegodontoides* and *Sl. cautleyi.* Fossil 4TE1 has more primitive characteristic; with median sulcus is clear and large conule still appear. It was also found in deeper than 6TE1 and 6TE2. Because of incomplete specimen and serious damaged, it is hard to compare with each previous study. The external morphology of fossils 2TE1, 3TE1, 3TE2 and 9TE1 from Thaisin sandpit shows the characteristic of genus *Stegodon*. The fossils 2TE1, 3TE1 and 3TE2, they do not have a posterior pretrite central conule on m3 (Saegusa*, et al.*, 2005).

### 5.1.2 Teeth measurement

In this study, scatter graphs were plotted from the measurement of teeth data. The result is consistent with the classification by external morphology of teeth. Other data using for comparing in scatter graph are by Thasod (2007). She identified *Stegolophodon cf. stegodontoides* from the sandpit in Tha Chang. Another genus of *stegodontids* was identified to be the primitive *Stegodon n. sp. 1*, the advance *Stegodon n. sp. 3* and *stegodon sp.* On the contrary, when comparison with this study, the scatter plot could not clearly divided. Addition from the external morphology, fossils 2TE1, 3TE1, 3TE2 and 9TE1 are identifying to the genus *Stegodon*, but crown of teeth are not quite height. Scatter diagram between values shows that fossils 2TE1, 3TE1, 3TE2 and 9TE1 from Thaisin sandpit are tending to be in the

*Stegolophodon* plots of the previous study (Sreprateep, 2005; Thasod, 2007). They maybe belong to primitive *stegodon*.

This may be because the two genera of proboscideans have close relationship in the phylogenetic. It might be clearer classification if there will be larger samples and more varieties of genera in phylogenetic (such as Gomphothare and Tetralophodon). Moreover, the data values can be different possibly caused by technical of the measurement.

### 5.1.3 Statistical analysis of proboscidean fossils

Due to the teeth measurement variables do not have a linear relationship in all variants, from the scatter plot to each couple variables. It cannot be grouped in the previous study (Sreprateep, 2005 and Thasod, 2007). Even though, all the variables have normal distribution. When uses all variables to perform clustering, the results are consistent with the classification of the external morphology of teeth. It implies that each variable has its own important value.

The trend of relationships of mammal teeth may tend to the numerical values of teeth. Due to the dendrogram from this study is dividing proboscidean teeth fossils into two groups by the evolution trend of teeth fossils, the *stegolophodon* is more primitive than *stegodon*. (Kaiser, *et al.*, 2003) was dividing the angulate teeth fossils into three groups following their dietary patterns as grazers, browsers and mixed feeders, by the mixed feeders is seem to be the most advance in the group.

If there will be sufficient amount of data, it would be possible to classify the variables into range of information for the preliminary identification before comparing with the holotype to more clearly classify.

At least two genus of elephant fossil found in Thaisin sandpit, *Stegolophodon sp.* and *Stegodon sp.* Identifying methods have the same results, both external morphology of tooth and teeth measurement. Statistical analysis can clustering 7 fossils into 2 groups and corresponds to the general identifying methods. From the external morphology identifying, fossils 6TE1 and 6TE2 are the quite advance *Stegolophodon* fossils while the 4TE1 is more primitive *Stegolophodon* fossils. The scatter diagram from teeth measurement method shows that *Stegodon* in Thaisin sandpit have not quite height of crown of teeth, may be able to be the primitive *Stegodon*.

As number and type of proboscidean molar tooth fossils, it is suggested that there should be at least 4 elephants were carried and deposited in this area. However, based on a very small and incomplete fossil samples, it is difficult to identify clearly in details. However, this study discovered some weathering trace on the fossil's skin. This implies that they were not transported for long distance from source.

**5.2 Sedimentology and stratigraphy**

The sediment characteristics in Thaisin sandpit show sediments structure that referred to the ancient river on which flowed over this area such as cross bedding, sand layers and gravel layers that indicated the environment of seasonal change. It is found that gravel layer is existed in flood season. A suspension fine sediments is existed in dry season. However, almost of the sediment size is medium which projected a medium current flow in other seasons. There are a few Tektites in the gravel layer but with the small amount of the sample; therefore its age cannot be identified. Petrified woods also founded in almost every layer of the sandpit.

Moreover, the subsidence event of central Nakhon Ratchasima at 0.7 Ma is a result of the accumulation of sediments into delta type of Ancient River. The characteristics of conglomeratic layers comprising with white quartz, gray chert indicate the variability of flows due to weather conditions. Some pieces of rounded surfaces petrified wood also found disperse around. Most are high evolved dicotyledon species indicates Tertiary age. It is suggested to be the part of rework sediments. An approximate age of these sediments are about 600,000-700,000 years before present. Its age is closely to Tektites (Bunopas*, et al.*, 1999).

Sediments in Thaisin sandpit are divided into 3 units; the upper part is characterized by mixed sediment sizes from medium to gravel, loosely arranged and poorly sorted. The lower part consists of 2 units with dark grey sediments divided by sedimentary structure and other objects. Chaimanee*, et al.* (2006) divided sediments form Somsak sandpit into two units. Upper sand unit consists of yellowish sand, silt, and gravel with cross-bedding structures indicates fluviatile deposits. Lower sand unit consists of grey organic-rich sand and gravel, with some clay lenses intercalated. Intense cross-bedding indicates fluviatile regime with intermittent swamp deposits. Almost vertebrate fossils were found in this unit the same as this study.

Geomorphological type was very similar to convex meander scar of the ancient Mun River. Then the river was cut off and redirected the new flow to the south as seen in the position of present Mun River. According to the columns collecting positions from Thaisin sandpit, the columns in North and South are complex while the column from East and West are simply. The result suggested that the sediments in northern and southern parts of Thaisin sandpit was deposited in pointbar areas while the ones in the eastern and western parts of Thaisin sandpit might be accumulated in the channel.

### 5.3 Paleoenvironment of Mun River at Thaisin sandpit

Geomorphology and sedimentology interpretations show the characteristic of the ancient river.

Proboscidean fossils found in Thaisin sandpit were alive during 16 to 0.7 million years ago. The fossils were washed away by the ancient river to be accumulated within point bar areas. From the geomorphology in sandpit area, it has a lot of curves of meandering river. By the slightly erosion, some teeth fossils also came together as a pair. This represented that they were carried not far away from source. However, Sreprateep (2005) described that the occurrence of proboscidean fossils and petrified wood were allochthonous with alluvial sediments.

### 5.4 Paleoecology of proboscidean fossils from Thaisin sandpit

The values of variables are likely to follow the evolution. For example, the more height crown of proboscidean teeth, the more solid plants they could eat. It shows that the dietary has a close relation between organisms and their environment. Shoshani (1998) suggested that it has a significant trend which the primitive proboscidean with low crown teeth was mostly browsers. While the advance proboscidean with high crown teeth and thick enamel was mostly grazers.

Chaimanee*, et al.* (2008) reported mid-Miocene *Stegolophodon cf. latidens*, the primitive *stegolophodon*, found in the Mae Moh Mine. During this time, Thailand is already situated within equator zone or tropical climate. Therefore, this could be one of the evidence to show that the Quaternary proboscidean fossils found in the Thaisin sandpit were in tropical forests. *Stegolophodon* found in Thaisin sandpit is considered to be more advance form than *Stegolophodon cf. latidens*. The teeth morphology trend shows that *Stegolophodon* and *Stegodon* fossils in Thaisin sandpit probably ate a harder food such as grasses.

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# APPENDIX

**Appendix A: Mining process**

**Figure A-1** Location at Thaisin sandpit

Mining process at Thaisin sandpit

1. Backhoe is used to open the sand layer step by step like the ladder.
2. Waterjet is used to leach the sand layer. Big rubber tube is used to pump the sand and water to the top edge of sandpit.
3. Sand are washing by the machinery and preparing to sell

**Figure A-2** Backhoe while digging the sand

**Figure A-3** Water jet stream to leach the sand layer

**Figure A-3** Sand washing machine

**Figure A-4** Fossils and plants fragment

**Appendix B: Fossils in Thaisin sandpit**

**Figure B-1** Collected fossils at the camp

There are so many fossils fragment from the sandpit. Some of them can be preliminary identify the type of animals, some are much damaged.

**Figure B-2** Rhinos tooth fossil (occlusal view)

**Figure B-3** Rhinos tooth fossil

**Figure B-4** Fragment of proboscidean tooth

**Figure B-5** Fragment of rhinos tooth

**Figure B-6** Mandible and maxilla of Crocodile

**Figure B-7** Shell of Soft-shelled turtle fossils

**Figure B-8** Vertebrate bone 1

**Figure B-9** Vertebrate bone 2

**Figure B-1**0 Joint part of leg fossils

**Figure B-11** Joint part of rib fossil

**Figure B-12** Ribs fossils

**Figure B-13** Fragment of fossil (unknown)

## Appendix C: Raw data for statistical analysis

From previous study, width and height are taken from doctoral dissertation of Thasod, 2007 and the enamel thickness from Master Thesis of Sreprateep, *2005.*

**Table C-1 Stegolophodon**

| Name | Number of Loph(id) | Width (Max) | Crown Heigth | Enamel Thickness | Average Height of Lophids | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| RIN3 right M3 | 5 | 97.45 | 38 | 6.46 | | | | | |
| RIN33 left M2 | X4X | 92.57 | 37 | 5.7 | | | | | |
| RIN55 right M2 | X4X | 89.92 | | 3.72 | | | | | |
| RIN61 left M3 | X6X | 98.68 | 28.5 | 6.1 | | | | | |
| RIN65 left M2 | X4X | 99.02 | 25.8 | 7.9 | | | | | |
| RIN66 left M2-3 (Fragmented) | X4X | 96.92 | 36.1 | 6.7 | - | 44.58 | 43.66 | 46.92 | |
| RIN 534 right M3 | X6X | 79.58 | 25 | 4.6 | | | | | |
| RIN804 right M3 | X5X | 94.00 | 36.6 | 6.9 | | | | | |

*Stegolophodon* cf. *stegodontoides*

**Table C-2 Stegodon**

| Name | Number of Loph(id) | Width (Max) | Crown Heigth | Enamel Thickness | Average Height of Lophids | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| RIN24 right M2 | X5X | 116.09 | 57 | 6.0 | - | 53.76 | 59.93 | 58.17 | 69.49 |
| RIN31 M2 (fragmented) | -4- | 112.5 | 54.4 | 1.1 | | | | | |
| RIN32 left M2** | X5- | 97.5 | 48.3 | 0.75 | | | | | |
| RIN35 right M2 | X6X | 121.13 | 44.6 | 8.5 | | | | | |
| RIN36 left M2 | X6X | 113.74 | 33.5 | 9.1 | | | | | |
| RIN46 left M3 | -7X | 115.00 | 64.2 | 3.9 | | | | | |
| RIN14: left M3 | X8- | 115.7 | 69.4 | 4.6 | | | | | |
| RIN27 M2 | -6X | 99.00 | 37.2 | 0.43 | | | | | |
| RIN28 M2 | -8X | 86 | 51.1 | 0.56 | | | | | |

*Stegodon* n. sp. 1

*Stegodon* n. sp. 3

*Stegodon* sp.

## Appendix D: Condition test for correlation

**Condition for Correlations, as following.**

**1.Normal distribution condition**

**High**

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| HIGH | 7 | 100.0% | 0 | .0% | 7 | 100.0% |

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| HIGH | Mean | | 30.4782 | 1.85718 |
| | 95% Confidence Interval for Mean | Lower Bound | 25.9339 | |
| | | Upper Bound | 35.0226 | |
| | 5% Trimmed Mean | | 30.6159 | |
| | Median | | 30.2400 | |
| | Variance | | 24.144 | |
| | Std. Deviation | | 4.91364 | |
| | Minimum | | 21.86 | |
| | Maximum | | 36.62 | |
| | Range | | 14.77 | |
| | Interquartile Range | | 7.31 | |
| | Skewness | | -.544 | .794 |
| | Kurtosis | | .779 | 1.587 |

Skewness < 0

Kurtosis > 0

Tests of Normality

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| HIGH | .193 | 7 | .200* | .931 | 7 | .561 |

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Hypothesis $H_0$ : High has normal distribution

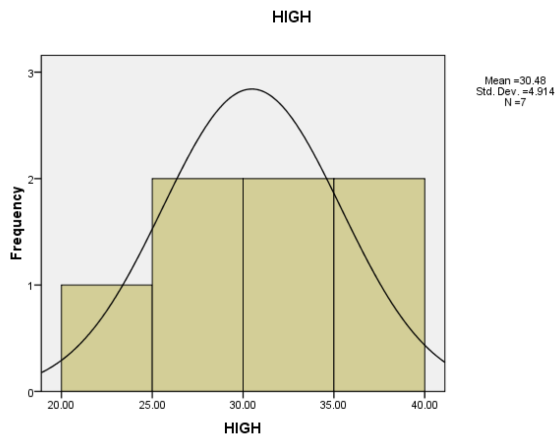
$H_1$ : High has no normal distribution

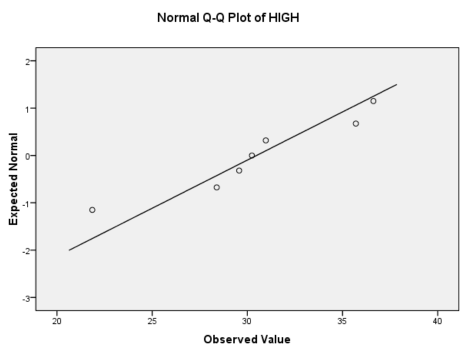
Significant at = 0.05

Kolmogorov-Smirnov test has Sig at = 0.200

Shapiro-wilk has Sig at = 0.561

sig>$\alpha$ shows to accept $H_o$ , High has normal distribution




Histogram shows the data near the Normal curve line

Normal Plot scatters near the normal line

ET

Case Processing Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| ET | 7 | 100.0% | 0 | .0% | 7 | 100.0% |

Descriptives

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| ET | Mean | | 5.8143 | .67733 |
| | 95% Confidence Interval for Mean | Lower Bound | 4.1569 | |
| | | Upper Bound | 7.4717 | |
| | 5% Trimmed Mean | | 5.8437 | |
| | Median | | 6.1000 | |
| | Variance | | 3.211 | |
| | Std. Deviation | | 1.79205 | |
| | Minimum | | 3.10 | |
| | Maximum | | 8.00 | |
| | Range | | 4.90 | |
| | Interquartile Range | | 3.40 | |
| | Skewness | | -.434 | .794 |
| | Kurtosis | | -1.089 | 1.587 |



Skewness < 0

Kurtosis < 0

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| ET | .137 | 7 | .200* | .957 | 7 | .797 |

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Hypothesis $H_0$ : High has normal distribution

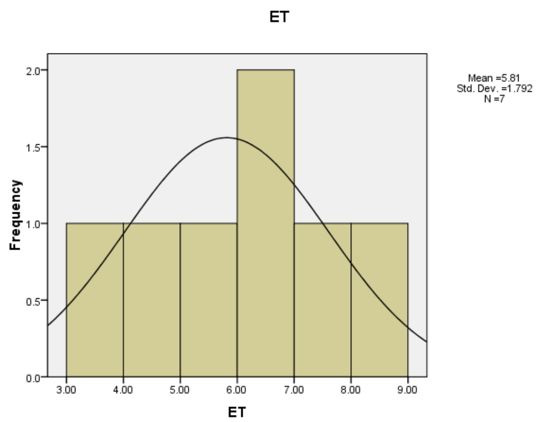
$H_1$ : High has no normal distribution

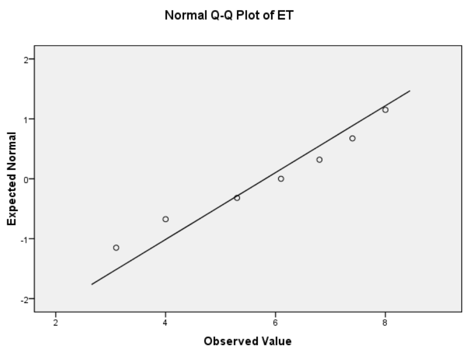
Significant at = 0.05

Kolmogorov-Smirnov test has Sig at = 0.200

Shapiro-wilk has Sig at = 0. 797

sig>$\alpha$ shows to accept $H_o$ , High has normal distribution




Histogram shows the data near the Normal curve line

Normal Plot scatters near the normal line

**Width**

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| WIDTH | 7 | 100.0% | 0 | .0% | 7 | 100.0% |

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| WIDTH | Mean | | 83.4600 | 5.41733 |
| | 95% Confidence Interval for Mean | Lower Bound | 70.2043 | |
| | | Upper Bound | 96.7157 | |
| | 5% Trimmed Mean | | 83.8156 | |
| | Median | | 87.9400 | |
| | Variance | | 205.432 | |
| | Std. Deviation | | 14.33291 | |
| | Minimum | | 62.22 | |
| | Maximum | | 98.30 | |
| | Range | | 36.08 | |
| | Interquartile Range | | 28.80 | |
| | Skewness | | -.480 | .794 |
| | Kurtosis | | -1.561 | 1.587 |



Skewness < 0

Kurtosis < 0

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| WIDTH | .194 | 7 | .200* | .907 | 7 | .372 |

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Hypothesis $H_0$ : High has normal distribution

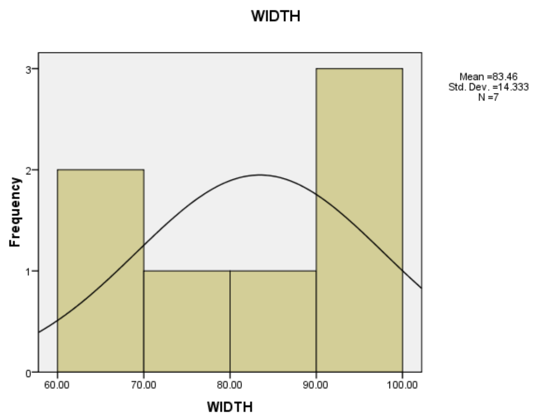
$H_1$ : High has no normal distribution

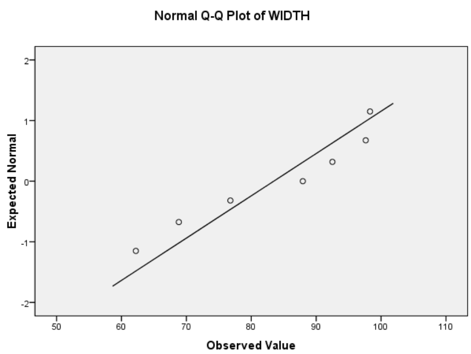
Significant at = 0.05

Kolmogorov-Smirnov test has Sig at = 0.200

Shapiro-wilk has Sig at = 0. 372

sig>$\alpha$ shows to accept $H_o$ , High has normal distribution

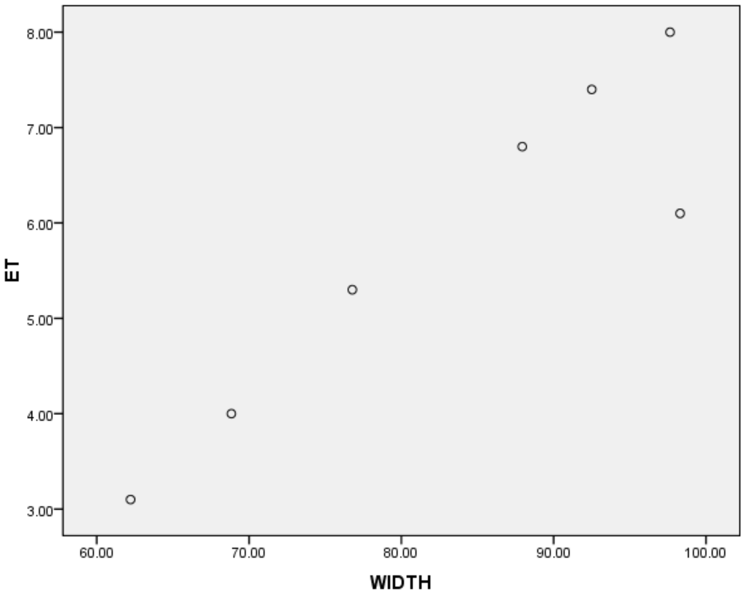


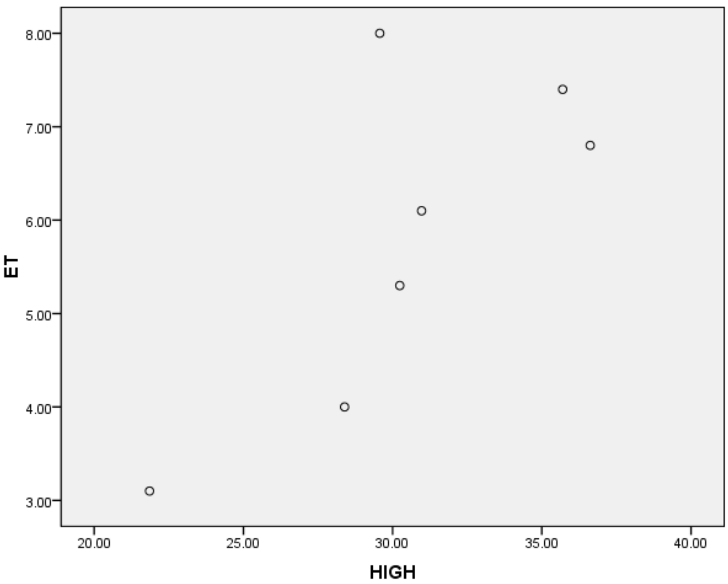

Histogram shows the data near the Normal curve line

Normal Plot scatters near the normal line

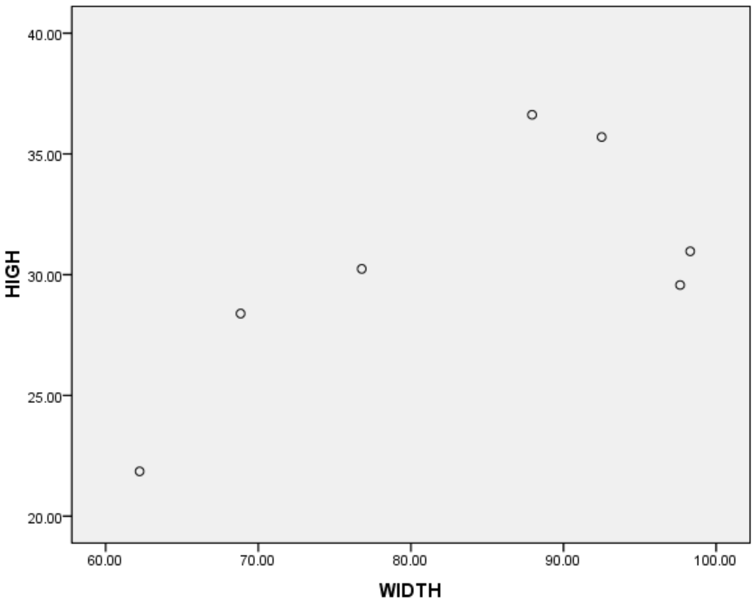
**2. Linear relations between pairs of value**




From the scatter graph, WIDTH and ET have a linear relation




From the scatter graph, HIGH and ET have no linear relations




From the scatter graph, HIGH and WIDTH have no linear relations

# VITA

Miss Sutipa Arsirapoj was born in Bangkok, Thailand on August, 4th 1986. She graduated Bachelor Degree of Science (Biology) in 2008 from Department of Biology, Faculty of Science, Kasetsart University. She started as a Master Degree student with a major of Earth Science, Department of Geology, Faculty of Science, Chulalongkorn University in 2010 and completed the program in July 2014.