

**PALYNOLOGICAL STUDY AT BAN THAM LOD AND BAN RAI
IN PANG MAPHA DISTRICT, MAE HONG SON PROVINCE,
NORTHERN THAILAND**

The image features a large, faint watermark of the Mahidol University logo in the background. The logo is circular with a gold border and contains a central emblem with Thai script. The text 'CHATSEE TRIKANCHANAWATTANA' is centered over the logo.

CHATSEE TRIKANCHANAWATTANA

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
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Thesis
Entitled

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IN PANG MAPHA DISTRICT, MAE HONG SON PROVINCE,
NORTHERN THAILAND**

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ABSTRACT

The objective of this research was to investigate the palaeovegetation and palaeoenvironment of Ban Tham Lod and Ban Rai in Pang Mapha district, Mae Hong Son Province, Northern Thailand. Soil samples were collected from archaeological excavation sites and surrounding areas of Tham Lod rock shelter and Ban Rai rock shelter. Additionally, charcoal samples were collected to determine the age of soil sample layers by radiocarbon dating. Palynological samples were treated by chemical processes and kept in silicone oil before slide preparation. Then identification and counting of pollen and spores were done in order to obtain the pollen diagrams.

Interpretation of the pollen diagrams of samples collected from Ban Rai rock shelter indicated that vegetation in the past was like the present, including tropical and sub-tropical flora. However, the environment tended to be cooler than at present, because of the reducing trend of sub-tropical plants as *Pinus* sp.. Moreover, decreases of *Circulisporites* sp. and *Concentricystes* sp., which can suggest humid or flooding conditions, and fern spores, together with an increase of grass pollen could indicate dryness and increasing open space. This is consistent with the interpretation of pollen diagrams of samples collected from Tham Lod rock shelter in that the climatic trend may have been cooler than at present. Increases of pollen found in dry land forest or secondary forest could suggest an increase of forest disturbance and dryness. These changes may have been caused by human activities, which could show the existence of humans in this area. It is probable that some characteristics of this area may have been suitable for seasonal land use for a long time. Although pollen diagram could not be constructed from samples from archaeological excavation sites at Tham Lod rock shelter and Ban Rai rock shelter, it could show that the vegetation in the past was similar to the present consisting of tropical and sub-tropical flora. The presence of *Pinus* sp. pollen, sub-tropical plants, in every sample layer could suggest a cool environment in the past. In addition, the results of palaeoenvironmental and palynological study could success from areas that may not be in archaeological excavation area. Therefore, it may be productive to study area around archaeological sites.

KEY WORDS: PALYNOLOGICAL STUDY/ POLLEN/ PALAEOENVIRONMENT

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การศึกษาเรณูวิทยาที่บ้านถ้ำลอดและบ้านไร่ ในอำเภอปางมะผ้า จังหวัดแม่ฮ่องสอน ภาคเหนือของไทย
(PALYNOLOGICAL STUDY AT BAN THAM LOD AND BAN RAI IN PANG MAPHA DISTRICT,
MAE HONG SON PROVINCE, NORTHERN THAILAND)

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาพืชพรรณและสภาพแวดล้อมในอดีตของพื้นที่บ้านถ้ำลอดและบ้านไร่ ในอำเภอปางมะผ้า จังหวัดแม่ฮ่องสอน ภาคเหนือของไทย ตัวอย่างดินได้นำมาจากแหล่งขุดค้นทางโบราณคดีและเก็บเพิ่มเติมจากพื้นที่รอบๆ เิงผาถ้ำลอดและเิงผาบ้านไร่ นอกจากนี้ได้เก็บตัวอย่างถ้ำเพื่อตรวจหาอายุของชั้นดินตัวอย่างโดยวิธีเรดิโอคาร์บอน ตัวอย่างที่จะนำมาศึกษาเตรียมโดยผ่านวิธีการทางเคมีและเก็บไว้ในซิลิโคนออยล์ก่อนนำมาทำสไลด์ จากนั้นทำการตรวจแยกชนิดและนับจำนวนละอองเรณูและสปอร์ เพื่อสร้างไคอะแกรมของละอองเรณู

ผลการตีความไคอะแกรมของละอองเรณู จากตัวอย่างบริเวณรอบๆ เิงผาบ้านไร่ พบว่า พืชพรรณในอดีตใกล้เคียงกับพืชพรรณในปัจจุบัน โดยมีทั้งพืชในเขตร้อนชื้นและเขตกึ่งร้อนชื้น แต่สภาพแวดล้อมมีแนวโน้มว่าจะเย็นกว่า เนื่องจากแนวโน้มที่ลดลงของเรณูสนซึ่งเป็นพืชในเขตกึ่งร้อนชื้นจากชั้นดินที่ตื้นไปสู่ชั้นดินที่ลึก นอกจากนี้ปริมาณ *Circulisporites* sp. และ *Concentricystes* sp. ซึ่งชี้ถึงความชื้นและสภาพน้ำขัง และสปอร์ของเฟิร์นที่ลดลง ร่วมกับการเพิ่มขึ้นของละอองเรณูหญ้า แสดงถึงความแห้งแล้งและพื้นที่เปิดโล่งเพิ่มขึ้น สอดคล้องกับผลการตีความไคอะแกรมของละอองเรณูจากบริเวณรอบๆ เิงผาถ้ำลอด พบว่า ภูมิอากาศมีแนวโน้มว่าจะเย็นกว่าในปัจจุบัน การเพิ่มขึ้นของละอองเรณูพืชที่พบในพื้นที่ป่าที่แห้งแล้งหรือถูกรบกวน แสดงถึงสภาพป่าที่ถูกรบกวนและความแห้งแล้งที่เพิ่มขึ้น การเปลี่ยนแปลงนี้น่าจะเนื่องมาจากกิจกรรมของมนุษย์ ซึ่งอาจแสดงถึงการเข้ามาของมนุษย์ในพื้นที่นี้ เป็นไปได้ว่าลักษณะบางอย่างของพื้นที่อาจมีความเหมาะสมที่จะถูกใช้ในบางช่วงเป็นระยะเวลาอันยาวนานมาแล้ว แม้ว่าผลการศึกษาละอองเรณูจากตัวอย่างในแหล่งขุดค้นทางโบราณคดีเิงผาถ้ำลอดและเิงผาบ้านไร่ จะไม่สามารถสร้างไคอะแกรมของละอองเรณูได้ แต่ก็พบว่าพืชพรรณในอดีตคล้ายคลึงกับในปัจจุบัน โดยมีทั้งพืชพรรณในเขตร้อนชื้นและกึ่งร้อนชื้น การปรากฏของเรณูพืชเขตกึ่งร้อนชื้นอย่างสนในทุกชั้นดินแสดงถึงสภาพแวดล้อมที่เย็น นอกจากนี้ ผลการศึกษาสภาพแวดล้อมในอดีตและการศึกษาทางเรณูวิทยาประสบความสำเร็จได้จากพื้นที่รอบๆ แหล่งโบราณคดีมากกว่าพื้นที่ขุดค้น

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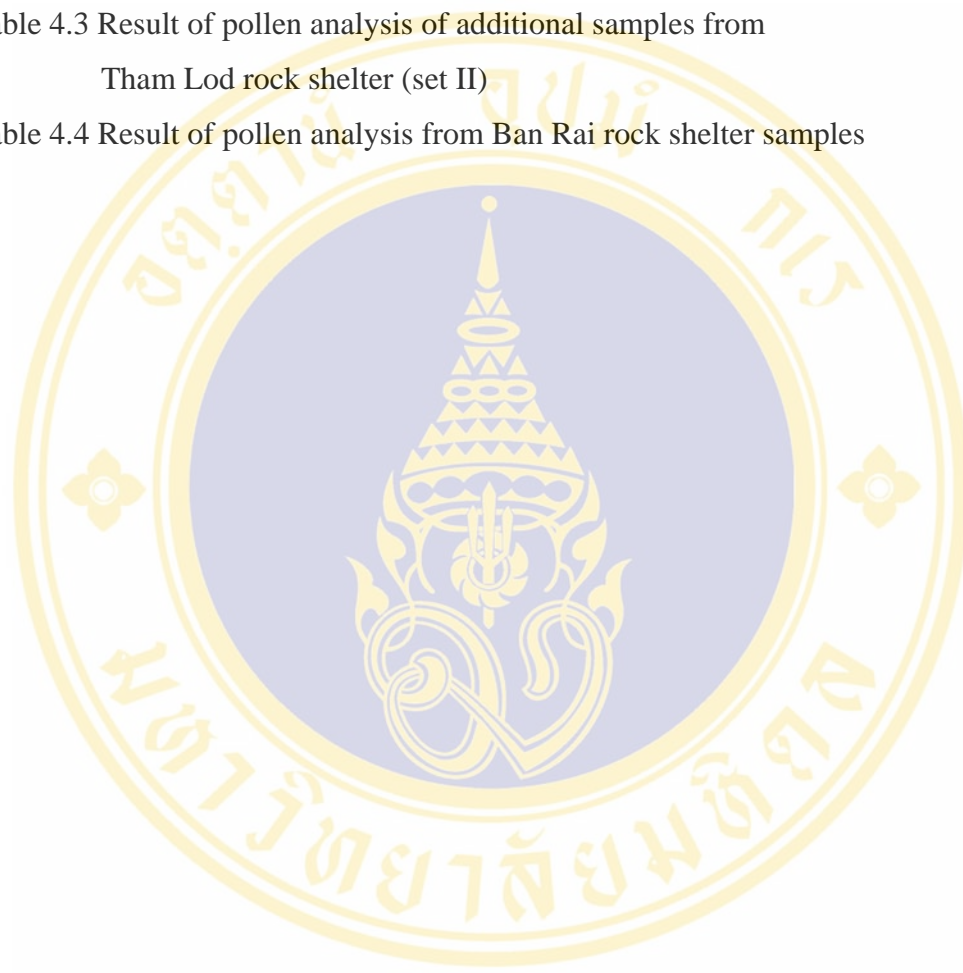
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CHAPTER I

INTRODUCTION

1.1 Background

Pang Mapha District of Mae Hong Son Province is situated in the interior of Southeast Asia. Due to its environmental circumscription, this area is not only internationally significant in physiological and biological diversity but in archaeology as well. There have some archaeological evidences, such as ten thousand years Paleolithic site and two thousand years Iron Age site indicating that human activities occurred in this area for over many thousand years ago.

The first excavation at spirit cave, Mae Hong Son Province, during 1965 to 1966, was driven based on the assumption that the Old World tropics, including Middle America, Southwest Asia and Southeast Asia are important as a center of early agriculture (1). Chester F. Gorman marked about the case in the Southeast Asian humid tropics that the late Pleistocene environment (approximately 12,000-7,600 BP) of this area was quite similar to that of present. Markedly, this conclusion was derived from only associated animal and plant remains inside the cave. The botanical evidences that Gorman used were of tropical species such as the genera *Lagenaria*, *Aleurites*, *Canarium*, *Trapa*, *Terminalia*, *Areca* and *Raphia* and faunal remains that were composed of modern species well back into the late Pleistocene. However, these botanical evidences presented only the edible plants but had less detail about the outside vegetation.

After that, there was very field research conducted in this area. Until in 1999-2000 the survey and Cave Information System Project was carried on. Then between 2001-2003 Highland Archaeological Project in Pang Mapha District, Mae Hong Son Province was conducted in order to investigate, study and integrate the knowledge of highland human and culture and palaeoenvironment as well as establish a local cultural chronology (2).

Two archaeological sites have been excavated during 2001-2002 including Tham Lod rockshelter and Ban Rai rockshelter. From the dendrochronological study of log coffins and radiocarbon ages of $2,260 \pm 240$ BP with calibrated age as BC900-AD300 (OAP2197) from Ban Rai rockshelter (3,) to $1,240 \pm 90$ BP with calibrated age as AD590-990 (AMS387) from Lod cave (4), it could be assumed that the forest in the past around 2,200-1,200 BP was more plentiful than the present (2, 5). Additionally, the preliminary pollen study was done from both excavated archaeological sites for pollen investigation (6). Although the result of pollen analysis from Tham Lod rockshelter yielded less information, the result from Ban Rai rockshelter could suggest that the climate in the past of this area was colder than the present. This primary conclusion was supported by Fagaceae pollen that its habitat is hill evergreen forest and *Pinus* sp. pollen that can be inferred as sub-tropical plants. From the studies above, it could be suspected that how the past natural environment especially the vegetation of this area was.

Palynology is known as an instrument to study the development of vegetation and climate. Based on the stability of pollen exine, pollen analysis can be used to investigate paleoenvironment at local scale. With regards to macro scale climate, environmental changes occurred many times especially in Late Pleistocene and Holocene era. As for Thailand, many studies found that there were effects of climate changes in Thailand both the interior and the peninsula (7, 8), but most published Holocene palynological studies in Thailand were derived from lowland and coastal sites with few available for inland northern regions except the study of pollen record at Doi Inthanon (9, 10) and palaeo-environmental data from lake sediments at Kwan Phayao (11).

To study the palaeoenvironment, it necessitates to be based on analogy concept. At present, the environs around Ban Tham Lod and Ban Rai are almost disturbed condition of mixed deciduous and dry dipterocarp forest. Referring to previous studies in Pang Mapha district including the excavation by Gorman (1) and preliminary pollen study and dendrochronological study of Ban Tham Lod and Ban Rai (2, 5), the hypothesis about the environment of Ban Tham Lod and Ban Rai is that the environment in the late Pleistocene could have been similar to the present and it may be more cool and plentiful forest than present around 2,200-1,200 BP. This study

will focus on the environs around Tham Lod rock shelter and Ban Rai rock shelter. Therefore, it is a good opportunity for this study to fulfill the local environmental data and be benefit for archaeological interpretation of this area.

1.2 Objectives of the study

1.2.1 To identify pollen grains from soil materials of Ban Tham Lod and Ban Rai in Pang Mapha district

1.2.2 To investigate the vegetation histories of Ban Tham Lod and Ban Rai in Pang Mapha district

1.2.3 To interpret palaeovegetation and palaeoenvironment around Tham Lod rockshelter and Ban Rai rockshelter in Pang Mapha district

1.3 Scope of the study

1.3.1 This study has focused on two locations that are Ban Tham Lod and Ban Rai in Pang Mapha District, Mae Hong Son Province.

1.3.2 Soil samples were collected from sampling sites in Ban Tham Lod and Ban Rai in Pang Mapha District, Mae Hong Son Province.

1.3.3 Archaeological soil samples were collected from archaeological excavated sites at Tham Lod rockshelter and Ban Rai rockshelter in Pang Mapha District, Mae Hong Son Province.

1.4 Conceptual diagram

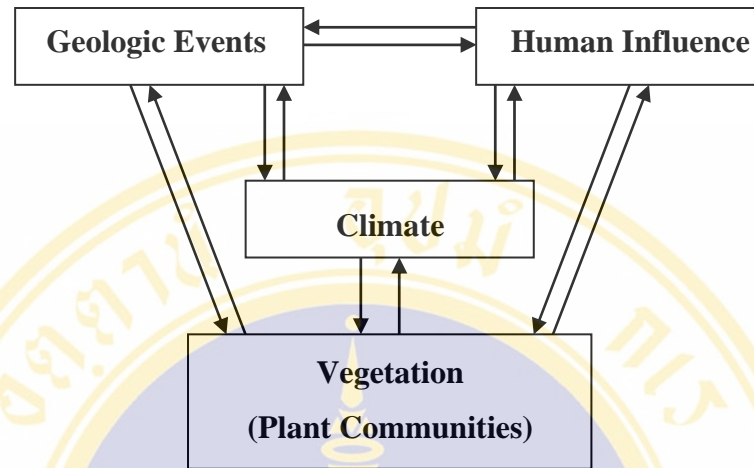


Figure 1.1 Conceptual diagram of the research

Figure 1.1 shows the principle of pollen analysis (12). The central object of the study is the vegetation which means the totality of plant species and their relative quantity at the site. Geologic events, climate and human influence are the factors that have an effect to the vegetation in each area. So it is possible to draw conclusion about the climatic and ecological condition prevailing at the time of deposition by knowing the ecological demands of plants community. However, pollen analysis can give the information on vegetation only, whereas conclusion about climate, human disturbance, etc., are secondary deductions from the vegetation record.

Although there had some studies about the past environment of Pang Mapha District, such as Gorman (1) and Pumijumng (6), there are still lack of information of the past environment in this area except from the dendrochronological studies (2). Due to many archaeological sites are in limestone areas that pollen cannot be preserved very well (13). The results from preliminary study by Pumijumng were rather according to previous palynological studies from archaeological sites; some studies gave less productive pollen results (14, 15). However, it is of necessity to obtain further information for partial understanding of the past environment in this area. Thereby, this study has been done under consideration to collect soil samples by

selecting the most possible and appropriate areas that expectantly can give the better result for pollen analysis.

1.5 Expected result

1.5.1 The result should provide useful information of plant vegetation in the past of study area

1.5.2 The result can be used as an environmental database of study area

1.5.3 The result can be linked as additional evidence to other studies in this area including archaeological interpretation and climate in the past

1.6 Definition

Pollen could be defined as the dusty or sticky material produced in the stamens of flowers. It is composed of microspores each of that contains two male nuclei and upon contact with a suitable stigma fertilizes the ovules to produce seed (16). Pollen particles are usually nearly invisible, except in large concentrations, due to their extremely small size. They can survive for hundreds of thousands of years in silts or anaerobic soils, such as mud sediments at the bottom of a lake. When excavated from early human sites, they can be used to reconstruct what the climate was like at the time of the occupations as well as relatively date them (17).

Pollen analysis, basically, is a technique for reconstructing former vegetation by means of pollen grains it produced (9). The term “pollen analysis” is used rather to signify the identification and characterization of pollen grains in soil layer, which can reflect environmental condition of the earth at the time each layer was formed (18).

Palynology is the study of pollen grain (produced by seed plants, angiosperms and gymnosperms) and spores (produced by pteridophytes, bryophytes, algae and fungi) (19). One aspect of palynology is the study of fossil pollen grains, either in ancient or even fairly recent materials, usually for the purpose of reconstructing ancient climates and dating soil strata (17).

Vegetation is defined as a collection of plants of diverse or the same species. It is classified in many different ways, according to origin, appearance and functional characteristics. Geographically, much emphasis is given to climax vegetation, which reflects the influence of climate, soils and humans (20).



CHAPTER II

LITERATURE REVIEW

2.1 Study Area

2.1.1 Location and Topography

Mae Hong Son Province is located in northwest of Thailand, 942 kilometers from Bangkok, and lies between latitudes 17° 38' N to 19° 30' N and longitudes 97° 20' E to 98° 39' E (21). Pang Mapha District (2) is situated around latitudes 19° N and longitudes 97° E in the northernmost of Mae Hong Son Province. The area of district covers approximately 92,480 hectares (924.8 square kilometers) (22). Pang Mapha District (23) is bordered on the north by Socialist Republic of the Union of Myanmar. Both the southern and the western area adjoin Muang district of Mae Hong Son Province. The eastern part of area borders on Pai District, Mae Hong Son Province. The highway No. 1095 can access the area starting from Mae Malai junction in Mae Tang District of Chiang Mai Province.

The prominent characteristic of local landscape is high mountain ranges, which cover 90 percent of total district area including 5 percent of intermontane area and 5 percent of drainage area (2). Thanon Thong Chai range, the important mountain range in Mae Hong Son Province and as well in this area, trends along a north-south orientation comprising of eastern, middle and western range (24). Pang Mapha District is located in the western Thanon Thong Chai range.

Landforms in the northern region of Thailand are believed to have been formed during Tertiary and Quaternary period (25). Geologically, there are 3 types of rock in this area consisting of igneous rock, sedimentary rock and metamorphic rock (26).

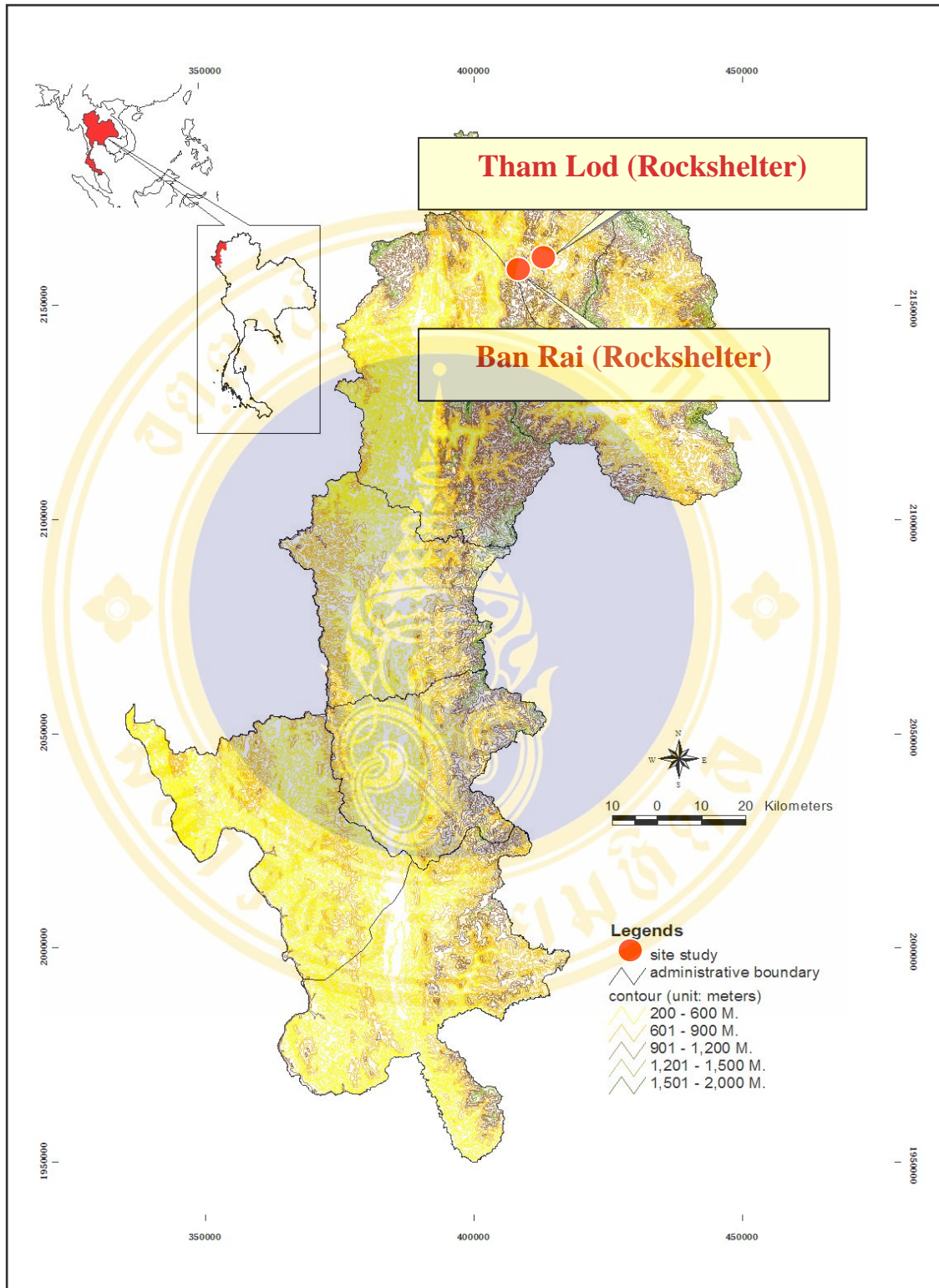


Figure 2.1 Location of study area, Pang Mapha District, Mae Hong Son Province (2)

As for geology and geological structure, there are classified as two types of topography. The first is karst topography such many limestone mountains in this area. Another one is non-karst topography, which the drainage pattern can be found in this type of topography. The four main streams in this region are Kong River, Huay Pong San Pig, Huay Mae La Na and Lang River (27).

2.1.2 Climate

The climate of Pang Mapha District can be sorted as Savanna climate: koppen “Aw” (28). Owing to the major topography is mountainous; the climate in this area can be dramatically divided into three distinct seasons as follow (29):

1. Rainy season starts from May to October. The temperature of this season was about 26.1-27.1 ° C. The average annual precipitation from 1986-1997 was approximately 1310.05 mm.
2. Cold season starts November to February. The average temperature of this season was 20.5-25.4 ° C and the average temperature in January was about 14 °C.
3. Hot season starts from February to May. The temperature of hot season was about 26.1-28.6 °C. As to the maximum temperature, it has ever reached 42 °C in April.

As followings, the average rainfall from 1911-2003 and the average temperature from 1951-2003 are demonstrated in Figure 2.2.

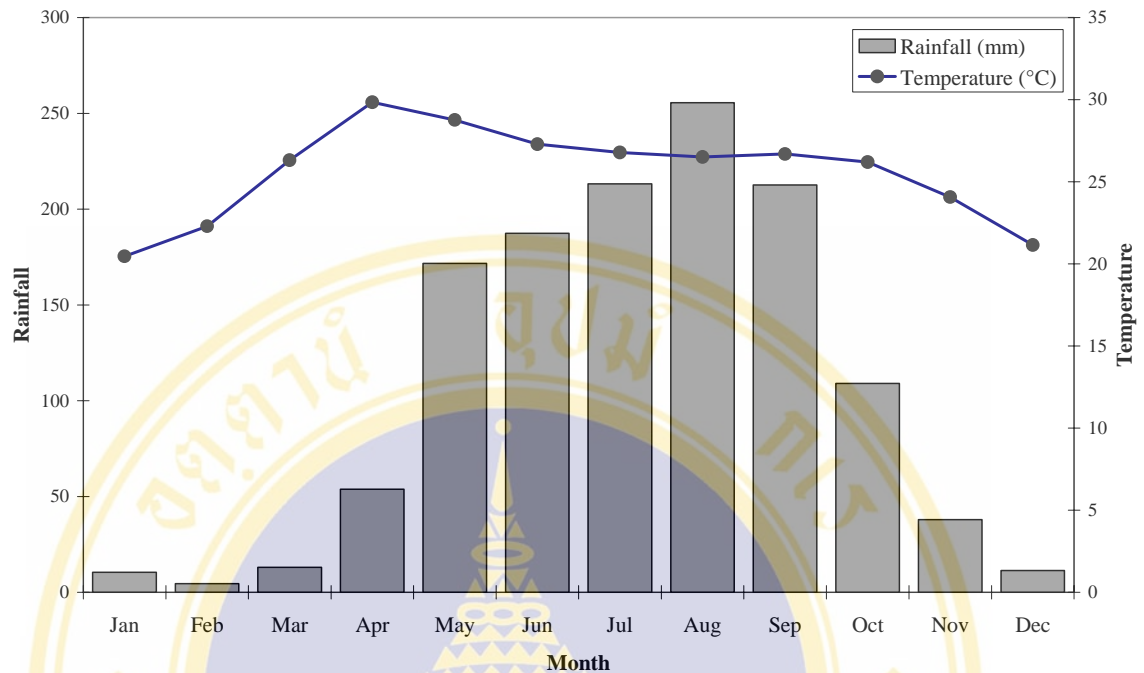


Figure 2.2 Average rainfall and temperature of Mae Hong Son Province

2.1.3 Vegetation

There are six primary forest types found in the study area (30, 31). Scientific names and local names follow Smitinand (32). The details of six forest types are followings.

1. **Mixed deciduous forest** - This forest type is commonly found lower than 900 meters AMSL in Pang Mapha District. The dominant species are Teak (*Tectona grandis* L.f.) and Dang (*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C. Nielsen). Other found species are Pra-Du (*Pterocarpus macrocarpus* Kurz), Teng (*Shorea obtosa* Wall.), Rang (*Shorea siamensis* Miq.), Kwow (*Adina cordifolia* Hook.f.), Ta-Bag (*Lagerstroemia calyculata* Kurz), and Ta-Kian-Nu (*Anogeissus acuminata* (Roxb. ex DC.) Guill. Perr. var. *lanceolata* C.B. Clarke), etc. In addition, the other important plants that can be found in this forest are Bamboo.

2. **Dry dipterocarp forest** - Dry dipterocarp forest is found in arid area lower than 1000 meters AMSL. Regarding the primary species, there are Teng (*Shorea obtosa* Wall.) and Rang (*Shorea siamensis* Miq.) in Dipterocarpaceae.

In Pang Mapha district, however, this forest type can occur with pine around 700-1,100 meters AMSL. It is termed as Pine-Dipterocarp forest. As this case, pine (*Pinus merkusii* Jungh. & de Vriese) is also a dominant species. Moreover, in some area, it can be found Pluang (*Dipterocarpus tubercula tus* Roxb.) together as one of dominant species with Teng (*Shorea obtosa* Wall.) and Rang (*Shorea siamensis* Miq.).

3. Hill evergreen forest - Hill evergreen forest is typically found above 1,000 meters AMSL in such northern area between Pai and Pang Mapha district and some area in the east and the west. The dominant species are *Castanopsis spp.*, *Quercus spp.*, *Lithocarpus spp.*, *Pinus kesiya* Royle ex Gordon and *Pinus merkusii* Jungh. & de Vriese.

4. Dry evergreen forest - This forest type can be found nearly moist area. The prominent species in this forest are Kra-Tum-Nam (*Mitragyna diversifolia* (Wall. Ex G.Don) Havil.), Chom-Poo-Nam (*Eugenia siamensis* Craib), Ma-Yom-pa (*Ailanthus triphyssa* (Dennst.) Alston), Ma-Had (*Celtis tetrandia* Roxb.), Som-Pong (*Tetrameles nudiflora* R. Br.), Ma-Muang-Paa (*Mangifera caloneura* Kurz), *Bambusa arundinacea* Willd. and *Dendrocalamus spp.*, etc.

5. Bamboo forest - Bamboo is not only found in succession stage in deforested area, but it can be found in mixed deciduous forest and dry evergreen forest also. Many kinds of bamboo standing in this forest are *Bambusa spp.*, *Cephalostachyum spp.*, *Dendrocalamus spp.*, *Gigantochloa spp.* and *Thyrsostachys spp.*

6. Limestone forest - The limestone forest can be widely found in limestone mountain. Plants that were found in this forest are as same as in deciduous forest. The important species are Teak (*Tectona grandis* Linn.), Rak (*Melanorrhoea glabra* Wall.), Teng (*Shorea obtosa* Wall.), Rang (*Shorea siamensis* Miq.), Dang (*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C. Nielsen), Ko-Phae (*Quercus kerrii* Craib), Jan-Pa (*Dracaena spp.*) and Salad-Dai (*Euphorbia spp.*).

2.1.4 Sampling locations

Two sampling locations in the study area are Ban Tham Lod and Ban Rai where many significant prehistoric archaeological excavations were conducted. Many

archaeological evidences for instances stone tools, grinding stones, earthenware, animal bones, wood coffins and plant seeds have been found (2). These evidences have been in pre-historical age to historical age. From these evidences, it is interesting to find out what the environment in the past was. As followings, there are some context of study areas including Ban Tham Lod and Ban Rai.

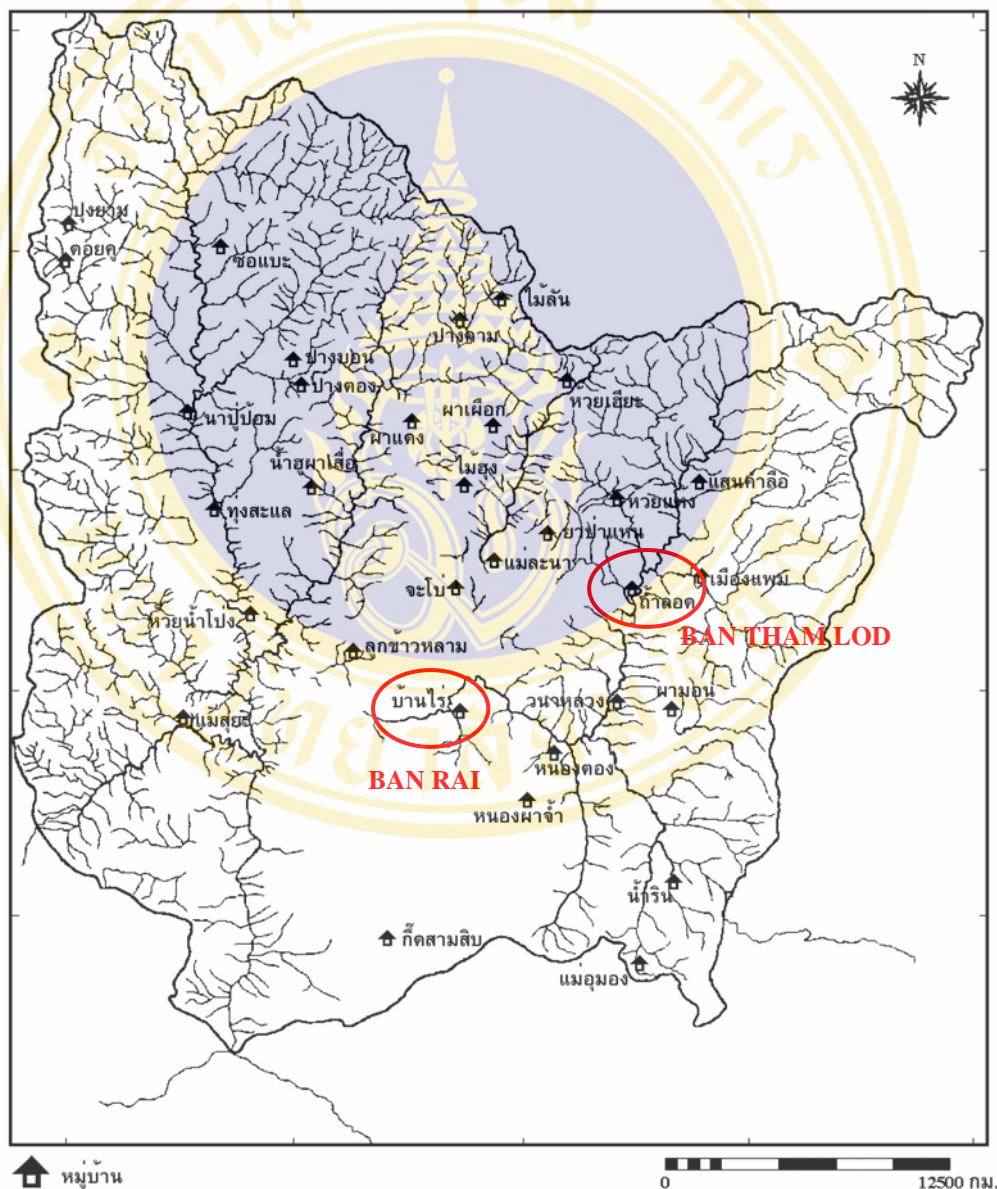


Figure 2.3 Sampling locations in Pang Mapha District, Mae Hong Son Province (2)

1. Ban Tham Lod

Ban Tham Lod is on the topographic map sheet No.4648II (Doi Phak Gud) at scale 1: 50,000. The average elevation of Ban Tham Lod is approximately 640 meters AMSL (2). In this area, Tham Lod rockshelter has been known as an important archaeological site in area of the Tham Lod Nature and Wildlife Education Center. With regard to a geographical perspective, Tham Lod rockshelter is located at the base of an over-hanging Permian limestone cliff, which is approximately 20 meters in height. As for geomorphology, Tham Lod rockshelter is located at doline and high terrace area (33).



Figure 2.4 Position of sampling sites at Ban Tham Lod (34)

At the present, the archaeological site is less than 100 meters away from Lang River and over 20 meters above the highest water level. Lang River which is the main river in this area follows along the fault line in north-south direction with heading southwest and flows into the west of Ban Rai rockshelter. Limestone mountain indicated the Permian age is in the western part of Lang River. Clastic rock mountain composed of sandstone, mudstone, shale and chert indicated the Permian-Carboniferous age is in the eastern part of Lang River. In addition, the terrace deposit and small floodplain was found in the western part of Lang River. The Quaternary sediments were appeared as a small area of deposited along Lang River. The sediment are recognized as semi-consolidated and unconsolidated as sand, silt, clay gravel, etc (33).

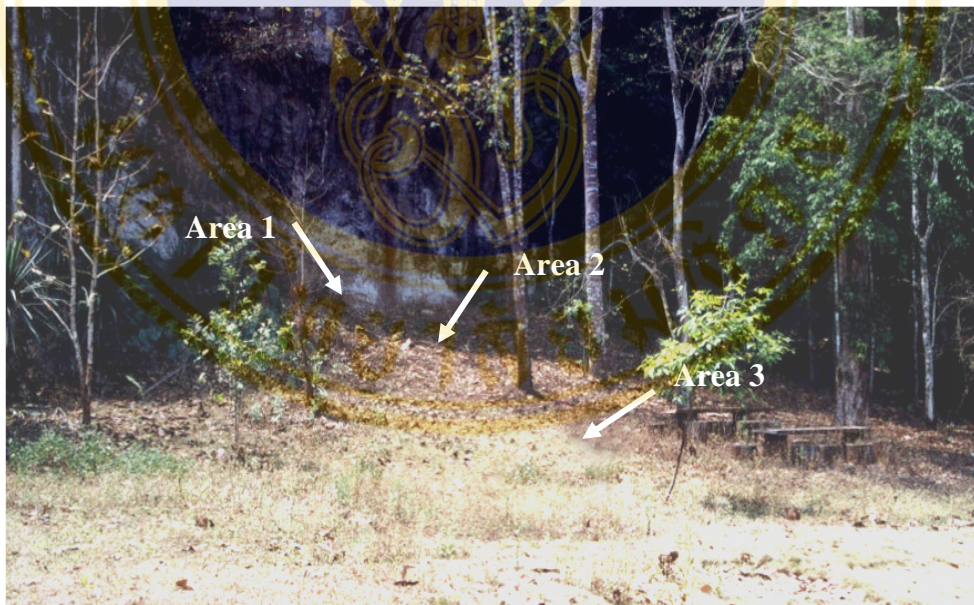


Figure 2.5 Excavation areas of Tham Lod rockshelter (2)

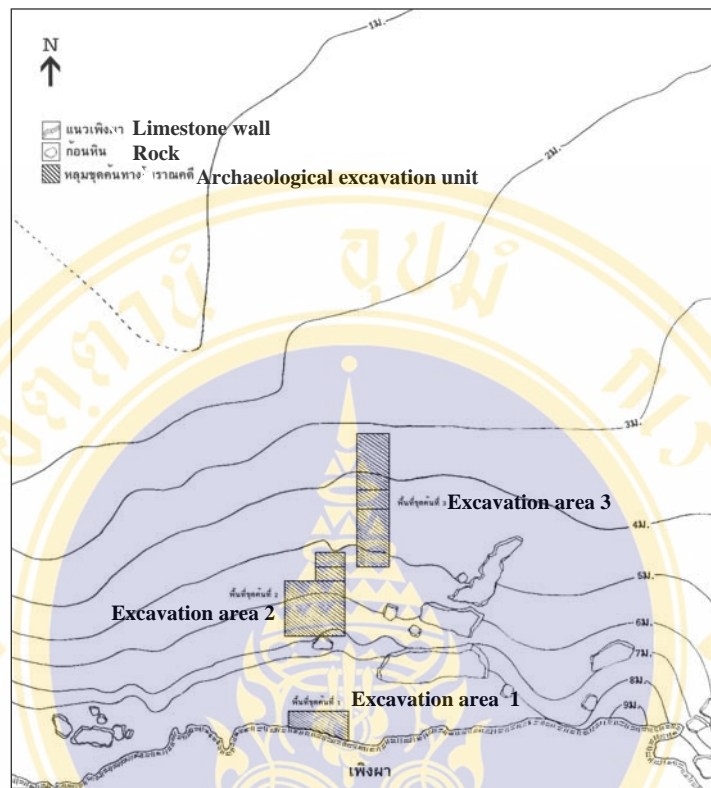


Figure 2.6 Plan of excavation areas of Tham Lod rockshelter (2)

Tham Lod rockshelter was excavated by the Highland Archaeological Project in Pang Mapha District, Mae Hong Son Province during April to July 2002. The excavation by Highland archaeological project in Pang Mapha District, Mae Hong Son Province illustrated the sequence of human activity in the area as three cultural periods (2). The first occupation period that was called as the period of the stone tool culture was approximately $22,190 \pm 160$ to $12,100 \pm 60$ BP (Beta-172226 and Beta-168223) in Late Pleistocene with the archaeological evidences of stone tools, animal remain and human skeletons. The second occupation period was approximately 2,500-500 BP in Late Holocene by relatively dating from the archaeological evidences such as potsherds, beads and iron tools. Additionally, the characteristics of the potsherds can be classified as of the Iron Age. The last period was determined by comparison of the characteristics of archaeological evidences such as the stoneware and beads that was approximately in the 20th-23rd Century of the Buddhist Era.

2. Ban Rai (Ban Huay Rai)

Ban Rai is on the topographic map sheet scale 1: 50,000 No.4648III (Ban Mae La Na). Ban Rai rockshelter, the interesting area in Ban Rai, is a large overhanging rock with a large amount of log coffins and some spectacular paintings. Ban Rai archeological site is located in Ban Rai village, Soppong subdistrict, Pang Mapha district, Mae Hong Son province. This rockshelter is approximately 793 meters AMSL on the unit of non-clastic rock mountain (karst topography) in Permian limestone. The rockshelter is an open horseshoe shape about 105 meters in width, 142 meters in length and 30 meters in height (2).

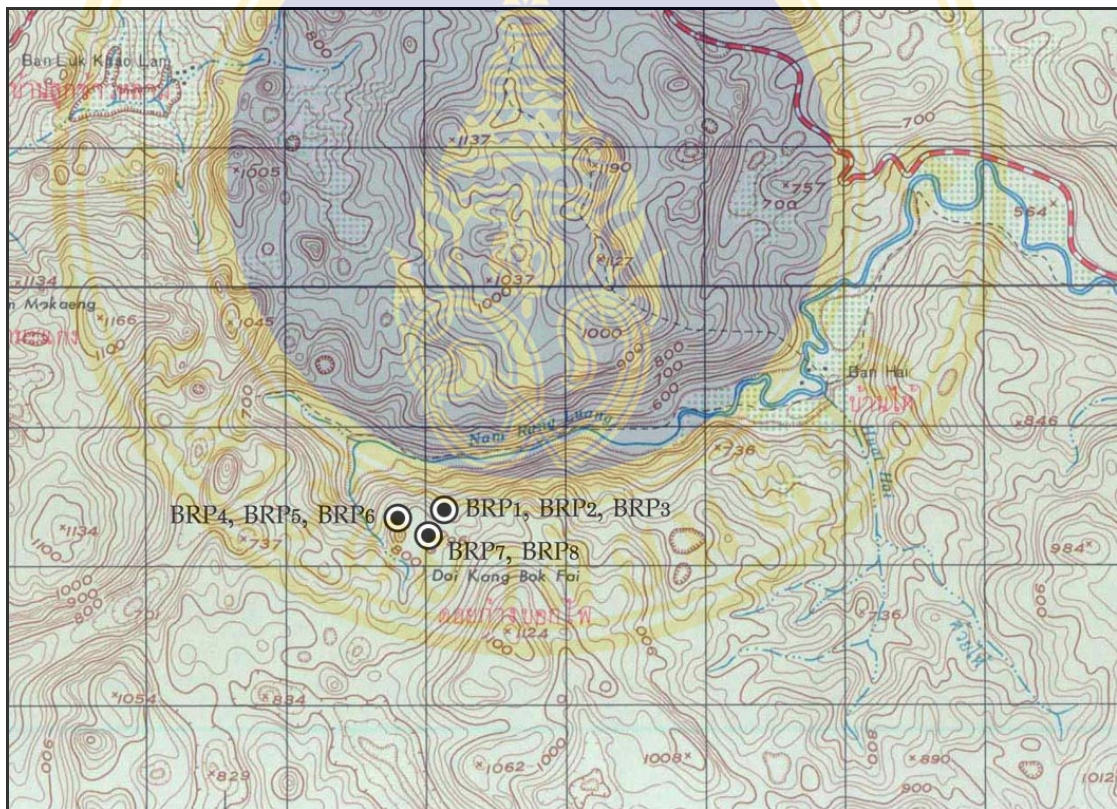


Figure 2.7 Position of sampling sites at Ban Rai (35)

The geomorphology of Ban Rai rockshelter is a sinkhole which is positioned near the top of mountain. In this area, soil sediment was mostly derived from erosions of lime stone which gave red soil and graveled soil which gave yellow soil.

Furthermore, there is a sinkhole in the middle of shelter where a small area of evergreen species has been found. The location of Ban Rai rockshelter is approximately 300-400 meters from Lang River, the main stream of this area (2).

The excavation by the Highland Archaeological Project in Pang Mapha District, Mae Hong Son Province, during December 2001 to January 2002, revealed the sequence of human activity in the area as two periods (2). The first period that was called as the period of the stone age culture was in Late Pleistocene to Early Holocene approximately $10,600 \pm 40$ to $10,210 \pm 50$ BP (Beta-168216 and Beta-168219) to $9,720 \pm 50$ to $7,250 \pm 40$ BP (Beta-168217 and Beta-168220). The evidences that were found in this period were human skeleton, stone tools, flakes and animal bones. Another period, the period of the log coffin culture, was approximately 2,200-1,200 BP (Late Holocene). The archaeological remains of this period were log coffins, earthenware, beads and iron tools.



Figure 2.8 The evergreen forest at a sinkhole in the middle of Ban Rai rockshelter



Figure 2.9 View of Ban Rai rockshelter (2)

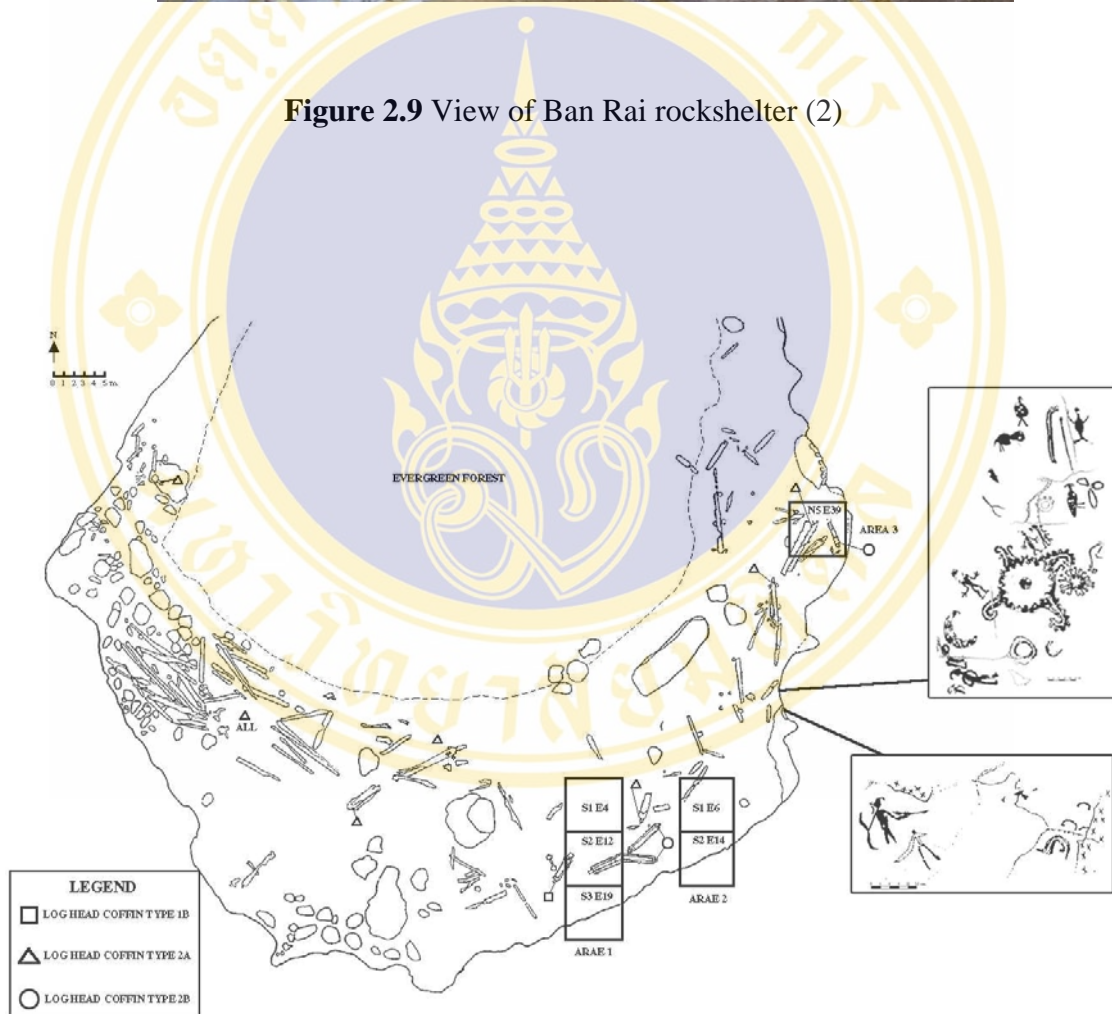


Figure 2.10 Plan of excavation areas of Ban Rai rockshelter (2)

2.2 Radiocarbon Dating

Radiocarbon dating is a radiometric dating method based on the fact that the amount of carbon-14 steadily decreases in all organisms after death. This technique is used to provide dating for organic materials such as bone, shell, wood, and charcoal (14).

Carbon has three naturally occurring isotopes, that is atoms of the same atomic number but different atomic weights. These are designated ^{12}C , ^{13}C and ^{14}C in scientific notation. Unlike ^{12}C and ^{13}C , ^{14}C is unstable and weakly radioactive. Hence this isotope, named as radiocarbon, is also called 'carbon fourteen'. The unstable isotope is brought to Earth by atmospheric activity, such as storms, and becomes fixed in the biosphere. Because it reacts identically to ^{12}C and ^{13}C , ^{14}C becomes attached to complex organic molecules through photosynthesis in plants and becomes part of their molecular makeup. Animals eating those plants in turn absorb ^{14}C as well as the stable isotopes. This process of ingesting ^{14}C continues as long as the plant or animal remains alive. When a plant or animal dies, it ceases to participate in carbon exchange with the biosphere and no longer takes in ^{14}C . Because ^{14}C concentration is not constant, so the level falls at a rate that can be determined by the law of radioactive decay and expressed as the half-life. For ^{14}C , the best estimate of half-life is approximately 5730 years (36).

Radiocarbon measurements are always reported in terms of years 'before present' (BP). This figure is directly based on the proportion of radiocarbon found in the sample. It is calculated on the assumption that the atmospheric radiocarbon concentration has always been the same as it was in 1950 and that the half-life of radiocarbon is 5568 years. So, ages are reported in years before present (BP) or it means years before 1950 (37).

Accelerator Mass Spectrometry (AMS) is a method of direct ^{14}C isotope counting. The great advantage of this technique is that it requires a far smaller sample size. This technique, AMS, may potentially provide dates going back to theoretical maximum age range around 100,000 years, current experimental conditions reduce this to between 40,000 and 60,000 years (37). At present, however, AMS dates

generally are for events less than 70,000 years old. The disadvantage of AMS is the high cost of establishing such a facility and of running it (36).

2.3 Palynology

2.3.1 Introduction to Palynology

The term 'palynology' was widely introduced to cover an aspect, not only pollen, but other resistant microfossils also: diatoms, cryptogam spores, animal remain, etc. The term 'pollen analysis' (unqualified) is reserved for the original concept of analysis of fossil pollen in a geologic context (12).

Pollen grain and spore are the result of plant reproduction stage, and require dispersal for their functions. The pollen grain is a container, which houses the male gametophyte generation of the angiosperm or gymnosperm. On the other hand, the spore is a resting and dispersal phase of cryptogam. The fact that both pollen and spores need dispersal for their adequate function has led to many analogies in their form (20). Pollen is deposited each year as pollen 'rain' on all exposed surfaces, and is well preserved in anaerobic deposits and other places where decay is inhibited (38).

In regard to pollen size, there is wide variation in the size of pollen among plant species (18). The smallest regular pollen grains measure about 5 micron, the largest more than 200 micron. The size of most pollen grain is in the order of 10-100 micron (12). However, it could be suggested that pollen is of similar size, often around 20-40 micron (19).

The living pollen grain of angiosperm has a wall that is made up of two layers. The outer layer is called the exine and is composed of unusual substance sporopollenin. The inner layer, or intine, of the pollen wall is made of cellulose. Actually, the exine can be divided into two layers, an endexine that forms the inner layer and ektexine that forms the outer layer. The greater the ektexine layer is, the more amount of sporopollenin it has (19). Exine is of great use in pollen identification. The outer surface of the exine is marked with various kinds of sculpture and ornamentation. The major chemical component of the exine, particularly in part of

ektexine, is sporopollenin, which is formed by oxidative polymerization of carotenoids and carotenoid esters. Sporopollenin, one of the most extraordinarily resistant materials, is resistant to a range of chemical reactions, such as HF and HCl, but it is susceptible to oxidation. Some chemical such as KOH can attack the exine of some species (38).

There is a great diversity of structure of pollen grains, with strong systematic characters, so making identification to family, genus and sometimes species possible (38). As for identification of pollen grains, it has necessitated the study in the morphology of pollen. There are three major morphologic characteristics that are valuable for pollen identification: a) apertures b) shape and c) sculpturing (19). As regards the term sculpturing, it is what the external features of exine that can be revealed by Scanning Electron Microscope (SEM). In many cases, both sculpturing and structure characters could be used to identify pollen. On the other hand, the term structure comprises the form and arrangement of the exine element that is not the same as sculpturing. Additionally, the size of pollen grain can be useful for identification as well (12).

2.3.2 Application of Palynology

The examination of pollen analysis, both recent and ancient, is of value in a range of scientific studies (19). These include taxonomy, genetic and evolutionary studies, honey studies (or called melissopalynology), forensic science, allergy studies, tracing vegetation history both in individual species and communities, correlating deposits and assigning tentative dates, climatic change studies, and the study of past human impact on vegetation. Additionally, fossil pollen can be used for studying plant ecology in the past (39).

This study will focus on microenvironment by studying plant ecology in the past or vegetation history. Then the interpretation of vegetation can be applied to study about cause of changes, which might relate with a human impact and/or climatic change.

2.3.3 Palynology and palaeoenvironment

Palynology was first developed in northern Europe. Palynology is a unique kind of paleontology. Most fossils are the bodies of organisms, each one being evidence of the former existence of an individual plant (40). Because the vegetation is directly affected by climatic, geographical and geologic changes, palynological studies may reveal the changes of environmental conditions over time (41). According to above, if it has enough evidence in the form of fossils, and in sedimentological, stratigraphical and biogeochemical data, then it is possible to reconstruct and interpret past environments and biotic communities based upon natural processes operative today (42). In the early days of such studies, the interest of natural historians was focused on human history and evidence of an ancient flood was eagerly sought, but others were trying to build up a time sequence of climatic change. Now it has come to be realized that the pollen record can reflect much more than how the climatically determined forests fluctuated in composition. It can be implied about man's effect on the forests; how his use of the land removed or reduced the forest and what he was doing in the countryside (38). Some relative studies in Thailand were done by Kealhofer and Penny (43) and Boyd and Mcgrath (44) which palynological data yielded the effects of human disturbance on forest disturbance and fire frequency.

Pollen analysis has now been applied from the arctic to the tropics and has vastly expanded our knowledge of past vegetation. Not only has pollen analysis made possible the identification of many taxa not previously recorded, but pollen is dispersed widely and presents a picture of the vegetation both of the collecting area itself and of the surrounding countryside as well (38). Palynology increases its potential for providing a detailed record of the environment of the past. Interpretations of fossil pollen are based on empirically determined relationships between modern pollen and modern vegetation. The climate, soils and even the degree of openness of ancient forests are reconstructed by analogy with the environments of modern populations of these same species of plant (39, 40).

With regard to the palaeoenvironment, palynology can be of great use as a method for investigating the past environment from its ability to identify the dominant vegetation on the landscape. However, conclusions of vegetation from pollen analysis

are less certain than the pollen identifications. Plants differ greatly in the amount of pollen they produce and the distance to which they distribute it. Wind-pollinated species broadcast large quantities of pollen and are best represented in the fossil record (45).

Pollen grains may be preserved in a variety of materials, from which they can be recovered and identified. The interpretation of these pollen assemblages must take into account the nature of the material from which they recover, because the arrival, movement and preservation of pollen grains can vary from one source to another source (19). Furthermore, different types of site and material have their own advantages and disadvantage. The sources of fossil pollen have a many different types of sites as peat deposits, lakes, ditches and moats, soil, alluvial and floodplain sediment, cave deposits, ice, and honey.

About definition, soils are unconsolidated bodies of organic and physical particles that support plant life or known as chemically and physically altered terrestrial sediment. Because of the way that they form, soils vary with the topography, vegetation, parent material and microclimate. Soils, therefore, provide information on the development and environment history of land-form and surfaces (46). From previous sentences, soil is one of pollen source that can be applied in this study.

2.4 Climate in the Past

2.4.1 Global climate in the past

Climate is the general weather condition over the long period of time which has been known as geologic time. The Quaternary is a subdivision of geologic time (the Quaternary Period) which covers the last two million years up to the present day (47). The Quaternary can be subdivided into two epochs; the Pleistocene that was defined as 1.8 million years to 11,500 years ago (48) and the Holocene that was defined as ten thousand years ago to the present day. As for Holocene, it can be divided in to Early Holocene (10,000-7,500 BP), Middle Holocene (7,500-2,500 BP) and Late Holocene (2,500 BP-present) (49)

The major climatic event of the last 25,000 years was the advance and retreat of the great continental ice sheet that marked the most recent glaciating of the Pleistocene Epoch. The Pleistocene was the time of cold, and the winter brought more snow than the summer could melt away. On high mountains and in the northernmost regions of North America, Europe, and Asia, the snow grew into great ice sheets that spread under their own weight (50).

The period from 7,000-5,000 years ago was warmer than our present time about two Celsius degrees, but the last 5,000 years or so has been marked by generally declining temperatures, with exceptionally cold interval about 2,800 and 350 years ago (50,51).

Then about 1,000 years ago, the earth was in a dry, warm period. After a partial return to more favorable conditions from AD 1,400-1,550 (550-400 BP), the climate grew colder again, and the 300-year cold spell which the climatologists has known as the "Little Ice Age" began. This period, from around AD 1,550-1,850 (400-100 BP) was marked by severely cold weather. European glaciers grew and Thames River in London began to freeze over with greater frequency than before. But after the middle of nineteenth century, the temperature began to moderate and soon the long warming trend of the first part of the twentieth century had begun (50).

2.4.2 Palaeoclimate in Thailand and some areas in Southeast Asia

Monsoon is a seasonal reversal of wind, which in the summer season blows onshore, bringing with it heavy rains, and in winter blows offshore - it is of greatest meteorological importance in southern Asia (52). Most of Southeast Asia has a monsoon climate characterized by a seasonal reversal of the atmospheric pattern. In winter, the region is affected by northeastern winds from central Asia, while in summer the effect is from southwestern winds from Africa and dry southeastern winds from Australia.

In mainland Southeast Asia, there is a variation of temperature during the days. In mountainous areas, there have a cycle of cloud movement up from the valley in the morning and down at night; cloud movement is referred as wind movement. Regarding climate study, evidence for climatic change from island and mainland

Southeast Asia comes from two main sources: geomorphic data and palaeoecological data, especially from pollen analyses (53).

In regard to the late Pleistocene environment of Southeast Asia and Thailand, the results of pollen data from Kwan Phayao (11), Northern Thailand, present dominance of pine and oak woodland throughout the late Pleistocene with the calibrated age of $19,180 \pm 120$ to $9,850 \pm 50$ BP that can indicate the occurrence of these highland plants at lower altitudes under a cooler than present temperature regime. Whereas data from Kumphawapi, Northeastern Thailand (54, 55), with radiocarbon age of $12,270 \pm 70$ BP, show fewer trees, bamboo, general herbaceous and grass types, but was abundant and diverse in Panicoidae grass types. Because of the lack of trees, it can suggest that the climate was more arid than today. At the same time, Panicoidae grasses can indicate that some locals were at least seasonally damp during the driest periods. The decreasing of trees and Panicoidae grasses together with the increasing of bamboo may reflect a short seasonally cold and dry interval. According to above, pollen data from southwestern China (56) can present that it was colder and drier than today from 11,000-9,100 BP by the domination of cold-tolerant species, such as *Abies*, *Betula*, and deciduous oaks.

During the Holocene, there were shifts in temperature, rainfall and season. A combined pollen and phytolith data from Lake Kumphawapi, Northeastern Thailand, reflect an increasing temperature and higher available moisture by the determined age of $8,610 \pm 100$ BP and $5,540 \pm 70$ BP (55). The climate in Holocene period may have been more humid climatic conditions as wet as or possibly wetter than present. This is marked by the shift in the grasses burnt from Panicoid which is indicative of savannah-adapted to Bambusoid which is suggestive of ground cover in dry dipterocarp forest. Additionally, pollen flora as well suggest a diversification of arboreal taxa, for instance, *Pinus*, *Quercus*, Combretaceae/ Melastomataceae type, *Elaeocarpus*, *Mollotus* and *Macaranga*. Coinciding with above, the study of Holocene monsoon changes in continental Southeast Asia from lake sediment from northeastern Cambodia showed that summer monsoon intensity increased over the period approximately 8400-5,300 BP (57). Before 8,400 BP, the northeastern Cambodia was cooler and drier than present, since Fagaceae and *Pinus* types can present at lower

elevation than today. The presence of evergreen types such as *Tetrameles*, *Anisoptera*, *Hopea* and palms and slightly drier types such as *Adina* and *Lagerstroemia* can imply the strong season and indicate relatively moist conditions during approximately 8,400-5,300 BP, which clearly support the inference of a strong summer monsoon in this period.

The significant vegetation changes in many areas were detected in Holocene period. Many studies have found that vegetation changes in middle to late Holocene were not caused clearly by climatic influence, but these changes were interpreted relatively as owing to human cause (54). Pollen and phytolith analyses from Lake Kumphawapi showed the disappearance or sporadic appearance of several forest taxa consisting of *Cassia*, *Celtis*, Combretaceae/Melastomataceae, *Dipterocarpus*, *Lagerstroemia*, *Macaranga*, *Mollotus*, *Myrica*, *Trema*, Urticaceae/Moraceae and *Quercus*, before 2,690±70 BP and reappearance after that. This is suggestive of recovery of secondary forest in dry land species after disturbance. The forest disappearance was interpreted as due to slash and burn cropping system, while the recovery was indicative of a shift in land use and cropping technology from upland toward wetland. This change was correlated well with archaeological evidences from Ban Chiang including the iron and water buffalo appearance that can indicate the beginning of intensification of wet rice agriculture.

From palynological record from lake sediment in Northeastern Cambodia (57), it suggested the transition to drier condition involving stronger seasonality and decrease of summer monsoon intensity from mid to late Holocene. Changes at approximately 5,000-4,700 BP are a drying trend in climate with the rise in *Adina* types, the large Combretaceae/Melastomataceae type, *Eugenia* and *Lagerstroemia*. Indicators of dry conditions as abundance of grasses, *Careya* and others continue from around 3,500-2,500 BP. After that, the recovery of *Tetrameles*, Palmae, *Ficus* and declines in grasses, *Trema*, *Adina* and small Combretaceae/Melastomataceae suggests an increase in available moisture. Then dense forest type by rise of *Ficus* and *Tetrameles* has recovered with annually burnt dry forest by a few Dipterocarps and a variety of Leguminosae. As mentioned, it is a weak argument to base the inference of climate change, because a reduction in the frequency of forest disturbance does not

necessarily reflect climatic change. So the regional disturbance was probably significantly affected by human activity.

Concordant with data from Northeastern Cambodia, the study from Tonle Sap in central Cambodia (58) indicated drier and more seasonal environment in the late Holocene as well. Before about 5,200 BP Pollen diagram has presented strong occurrence of *Rhizophora*; after that changes are apparent with increasing of *Macaranga*, the indicator of disturbance, and *Poaceae* pollen. This is interpreted as evidence of a shift toward a more seasonal and seasonally drier environment relative with the southwest monsoon weaken. Peaks of *Quercus* and *Pinus* suggest continued succession changes in dryland flora at around 4,900 BP. The dramatic increase in pollen of *Pinus merkusii* –fire-tolerant and markedly seasonal plant– from approximately 3,300 to present reflects changes in regional upland around the lake of expansion of its range under seasonal climate and increasingly widespread fires.

As for the upper Mae Nam Mun valley (59), this site has been known to be occupied at least since the Iron Age (around 2,500-1,700 BP). Pollen sequences represent a period in which the floodplain was initially dominated by native forest such as *Dipterocarpus*, *Elaeocarpus* and *Lithocarpus*, through two phases of the removal of forest and the replacement with woodland pioneers such *Macaranga* and *Celtis*, mosaics of grassland probable rice cultivation, arboricultural plants such as *Artocarpus*, *Bombacaceae*, *Ficus*, *Palmae*, *Syzygium* and *Terminalia* and its subsequent regeneration. These data not only indicate the fluctuation of landscape, but are compatible as well with archaeological record of human settlement reinforced by the conclusions from Lake Kumphawapi. In consequence, it may be said that the late Holocene vegetation is affected by human activities.

Coincidentally, the study from Kwan Phayao (11) shows a little change around $1,860 \pm 50$ BP. With high values of sedimentary charcoal and the increased occurrence of re-growth taxa, particularly *Macaranga* and *Trema*, it could suggest an increase in forest disturbance probably through burning after that time.

From these data, they show the cooler and drier climate in late Pleistocene to early Holocene period approximately before 8,000 BP followed by more humid in

Holocene period. Then, there was a more humid climate in the middle of Holocene approximately before 3,000 BP and, after that, it has become to drier and more fluctuated environment owing to disturbances.

2.5 Some Palynological Studies in Thailand

There are many palynological studies in Thailand. The results of studies were varieties depending on study areas and pollen floras collaborating with radiocarbon dating ages.

Pramojanee (60) investigated sea level changes in coastal area of southeast Thailand by using a combination of geomorphology, palynology and ^{14}C dating methods. The pollen analysis provided evidences of two sea level changes. It was concluded that the age of around $16,200 \pm$ BP was the beginning of the last regression during the last glacial event, Late Pliestocene. The second period, $8,400 \pm 1,300$ BP, is the start of Holocene transgression in Southeast Thailand. This research can show an environmental change in case of sea level by changes of mangrove and fresh water vegetation. Such as site CH3, there was considerably influenced by both tidal and freshwater vegetation; from pollen diagram, at deeper layer, this site became more back mangrove indicating a continuing rise in sea level, when some freshwater types persisted.

An interpretation of vegetation from a pollen record from Nong Thale Song Hong in Trang Province, Southern Thailand (61), clearly yielded that the vegetation has never been stable over the last 10,600 years. The evidence for climatic change is difficult to detect from the pollen diagram, and there are unresolved inconsistencies in the radiocarbon dates. However, it is possible that swamp forest, consisting of *Lagerstroemia speciosa*, *Elaeocarpus* spp., *Fagraea fragrans*, *Alstonia spathulata*, *Eugenia* spp., *Saraca* spp. and many types of cane, existed for all of the 10,650-year continuous record. In addition, the lack of Hymenophyllaceae (filmy fern) spores shows not very wet condition. Pteridophyte spores were abundant in around 5,100-4,800 BP (not calibrated age). At about 4,000 BP (not calibrated age), the palm

Borassodendron machadonis faded from record. It could be due to human cause or natural causes or both of them. The rise of *Artocarpus* type pollen could be argued that horticulture was practiced at the same time.

Hutangkura (62) studied the vegetation during the Holocene period from alluvial sediment in Bo Ploi Basin, Kanchanaburi Province. It was concluded that the environment of the study area since $4,540 \pm 50$ BP has been similar to present, which consisted of dry evergreen to deciduous forest, swamp area and aquatic area. Only it was not clear about the source of pine pollen. The *Pinus* spp. can be found in sub-temperate or semi-tropical forest, but it can not be found in the study area at the present.

Poungtaptim (9) aimed to reconstruct the plant community from sphagnum peat core from the intramontane peat bog at 2,565 meters AMSL at Doi Inthanon, Chiangmai Province. The age that this study can flash back is about 4,300 years ago. The upper montane rain forest dominated in this area. The reconstruction confirmed that the recently collected pollen grains and spores in the sampling site are as same as vegetation type from pollen analysis. This pollen record also indicated that the climate in this vicinity could be divided into six zones according to the change of cool and warm weather. This evidence further supported the theory that the Holocene climate was unstable by using the fluctuation of temperature plants as an indicator. In addition, the occurrence of *Polygonum* spp. and grass pollen grains in all zones might indicate the deforestation in this area by human activities.

The study of the sediment from Lomdong Lagoon from Mae Yom National Park, Prae Province by Komonjinda and Wattanakornsiri (63), aimed to investigate Holocene plant communities and palaeoecological changes, yielded that, about $1,386 \pm 34$ BP, the plant communities were similar with present forest, known as tropical forest, with minor influence of temperate microfloras. The tropical microfloras commonly found are *Bombax* sp., *Dipterocarpus* sp., *Hopea* spp., *Lagerstroemia* sp., Rubiaceae and Palmae. The temperate and sub-tropical microfloras are *Pinus* sp., *Betula* sp. and *Quercus* sp. As grass pollens have increased since the past, but, in the same time, fern spores have decreased. These can reflect wider open area, less density

forest and moisture decrease in this area. Human activity or forest fire may influence this ecological change.

Changchuen (10) studied pollen analysis of deposits from Ang Kar swamp, Doi Inthanon Summit in Chiangmai Province. The aim of the study was to investigate pollen floras and ecosystem for climatic comparison. For the result, some pollen and spores of the Semi-temperate Montane Hill Evergreen Forest including *Quercus* spp., *Betula* spp. and *Castanopsis* sp. have been found since 1,250±60 BP until present. Some pollen and spores such as Cyperaceae and Lycopodium sp. that appeared increasingly at 160±65 BP can reflect higher moisture in the area.

Pollen analysis of sediment profiles from lakes and wetland can provide information on past human land use and associated changes in vegetation. But, in the same time, lake and wetlands that are suitable for traditional stratigraphic pollen analysis are not always available. Some palynological works so studied from soil samples from archaeological sites, for instance, the study at in Moh Kiew cave in Krabi province with the occupation period around 37,000-4,200 BP and Sa Kai cave in Trang Province with the occupation period around 10,000-4,000 BP and the study at Sukhothai Historical Park.

Pollen analysis from cave in Southern Thailand including in Moh Kiew cave in Krabi province and Sa Kai cave in Trang Province by Watanasak (14) yielded few palynological productive samples which are 4 samples from 30 samples from Moh Kiew cave and 6 samples from 65 samples from Sa Kai cave. In this study, samples were collected from the entrance of cave. Dominant pollen grains from Moh Kiew cave were *Brownlowia* and ?*Cardamine*. Other pollen grains and spores were *Ammania*, *Quercus*, *Lagerstroemia*, *Acer* and Polypodiaceae type. As for the distribution and aggregation of *Brownlowia* pollen, it could be assumed that it was from human use. Regarding the study from Sa Kai cave, fern spores in Polypodiaceae and Cyatheaceae were more found than pollen grains of *Brownlowia*, ?*Cardamine*, *Quercus* and *Podocarpus* type. A large number of fern spores were assumed to be from human use as food or medicine. However, this study could indicate that plant types found were similar to the present.

With regard to the Palaeo-ecological reconstruction of Sukhothai World Heritage by Watanasak (15), there gave a similar result in few palynological productive samples. The excavation pits were used as sampling method. From all 251 pollen samples, palynological slides of 133 samples were identified, although these yielded only 2 palynological productive samples, which have more than 200 grains. From conclusion, 60 palynological taxa could be obtained from Sukhothai samples, which range the end of Sukhothai to post- Sukhothai period, including natural species and cultivated species, such as *Bombax* sp., *Borassus flabellifer*, *Cocos nucifera* and *Mangifera indica* and *Tamarindus indica*. Pine pollen found from five sites may be suggestive not clearly of cool climate or plantation due to the discontinuity in sequences.

These studies can present the environmental data in Thailand. Pollen data from Southeastern Thailand showed changes of sea level occurred at Late Pleistocene, approximately 20,000 BP, and Early Holocene, approximately 8,400 BP. Pollen data from Kwan Phayao in Northern and Lake Kumphawapi in Northeastern Thailand suggest cool and dry environment in Late Pleistocene. Whereas pollen data from Nong Thale Song Hong in Southern Thailand suggest that swamp forest has existed since Late Pleistocene with a non stability in forest composition; more forest disturbances were evident in Middle to Late Holocene and horticultural types have entered the record at around 4,000 BP. The studies of interior including Kanchanaburi in the western and many areas in the northern presented that vegetations in Middle to Late Holocene have been similar to present with moisture decreasing trend up to the present and disturbance by human activities.

Furthermore, from the excavation by the Highland Archaeological Project in Pang Mapha District in phase I, the preliminary study of pollen was conducted from both Tham Lod and Ban Rai rockshelter (2). The result of this preliminary study supported by a large number of pollen of Fagaceae and *Pinus* sp.. together with dendrochronological study from log coffins suggested the palaeoenvironment of this area was cooler and more plentiful than the present. There was more productive result from Ban Rai rockshelter and may be suggestive of hill evergreen, pine and deciduous forests around Holocene period compared with archaeological evidences.

It is important to note that same samples from the archaeological sites were analyzed by Dan Penny; the pollen analysis yielded less productive result like that preliminary study. These results revealed more productive pollen from samples from Tham Lod rockshelter. Nevertheless, approximately since Pleistocene age by comparison with archaeological evidences, pollen data showed that taxa types were similar to the present including tropical and sub-tropical flora (64), i.e. *Alnus* sp., *Arenga* sp., *Calocedrus* sp., *Carpinus* sp., *Celtis* sp., *Dillenia* sp., *Dipterocarpus* type, *Hopea/Shorea* type, *Pinus* sp., *Quercus* sp., Cyperaceae, Poaceae and fern spores. It may indicate that forest types were coincident with above preliminary study including hill evergreen, pine and deciduous forests. Together with Gorman's conclusion (1), it may suggest that the environment in Late Pleistocene was like the present. In sum, the past environment around Tham Lod and Ban Rai rockshelter may have been similar to the present since Late Pleistocene.

As all example researches cited above, they can illustrate palaeoenvironment of Thailand in even regional and local perspective. Although the palynological studies have an advantage in palaeoenvironment study both local and global levels, only one study can not cover whole picture. There are necessary to collect a small data so as to obtain and construct a wide picture. So this study aims to investigate vegetation in the past that could obtain a local environmental data from Mae Hong Son Province, Northern Thailand to participate the wide picture.

CHAPTER III

MATERIALS AND METHOD

In this chapter, the detail of study processes, which are comprised of field studies and laboratory studies, will be explained. Sample collection including soil sampling and modern pollen sample collection and field survey are called as field study. After sample collecting, laboratory study is the next step. In regard to laboratory study, pollen samples preparation should be a first step. The following steps are microscopic study for pollen counting and identification. After that, the results of counting and identification will be analyzed for interpretation of vegetation changes.

3.1 Sample collection and field survey

At first, the landforms of area were defined by interpretation of aerial photos and field check. Then sites were selected in consideration of the possibility of suitable sediments for pollen analysis. Considering the criteria of site selection, it required swamps or wetlands that are accepted as a suitable sampling site. Unfortunately, it is impossible to collect samples from swamps or wetlands within the study area, because not only there were dried during sampling in hot season (10-12 March 2004), but there were also found that sediments of both mountain marshes were mottled. The mottled soil could be implied to the oxidation in soil in which can not permit well condition of pollen preservation. Due to this limitation, there was no alternative to do; therefore the available selected sites should be considerably in closed areas that are lower than the neighbor areas as like as a sink.

There are two study areas to collect samples including Ban Tham Lod and Ban Rai. Within the study area at Ban Tham Lod, nineteen sequences from four sampling sites were collected, while at Ban Rai, eight sequences from three sampling sites were taken. Almost of sequences were taken by using hand-auger, except

sequence TLP2 which was taken by digging a pit. Samples from Ban Tam Lod were labeled as TLP and samples from Ban Rai were labeled as BRP.

The positions of all seven sampling sites were shown in figure 2.3 and 2.4 in chapter II. The location of sampling sites were presented in Table 3.1

Table 3.1 The selected sampling sites for the study in Pang Mapha District

Site No.	Sequence No.	Coordinate in UTM system	Altitude (meters AMSL)
1	TLP1, TLP2	0426461 N 2162848 E	976
2	TLP 3, TLP 4, TLP 5	0424916 N 2163660 E	642
3	TLP 6, TLP 7, TLP 8	0425553 N 2165241 E	763
4	TLP 9, TLP 10, TLP 11	0424974 N 2164130 E	636
5	BRP 1, BRP2, BRP 3	0414112 N 2158402 E	793
6	BRP 4, BRP 5, BRP 6	0413927 N 2158338 E	811
7	BRP 7, BRP 8	0414050 N 2158223 E	795

3.1.1 Samples from Ban Tham Lod

For Ban Tham Lod, there were four sites, the site No. 1, 2, 3 and 4, that were selected to collect sample. The surrounding of sites is explained as followings.

Site No.1 was a dry marsh on the mountain. The vegetation around area was dry dipterocarp forest mixed with Pine forest. List of some plants found around the site are Pine (*Pinus merkusii* Jungh. & de Vriese), Teng (*Shorea obtosa* Wall.), Rang (*Shorea siamensis* Miq.), Pluang (*Dipterocarpus tuberculatus* Roxb.), Rak (*Melanorrhoea glabra* Wall.), Ko-Ta-Mu (*Castanopsis* spp. maybe *C. cerebrina* or *C. fissa*), Ket-Dam (*Dalbergia assamica* Benth.), Ma-Kang-Dang (*Garcinia erythroclada* Kurze.), Kai (*Ternstroemia gymnanthera* Bedd.) and Ma-Khaam-Pom (*Phyllanthus emblica* L.).

Site No.2 was a terrace deposit that was next below the mountain, which mixed deciduous forest can be found. Teak (*Tectona grandis* L.f.) and Bamboos can be found around this site. Other species found in this area are Dang (*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen), Sa-Lao (*Lagerstroemia tomentosa* Presl.) and Ma-Muang-Paa (*Mangifera caloneura* Kurz).

Site No.3 was a dry marsh on the mountain. The vegetation found in this area was dry dipterocarp forest mixed with Pine forest or Pine-Dipterocarp forest. Plants found in this site are Pine (*Pinus merkusii* Jungh. & de Vriese), Teng (*Shorea obtosa* Wall.), Rang (*Shorea siamensis* Miq.), Ma-Muang-Hua-Maeng-wan (*Buchanania latifolia* Roxb.), Ko-Phae (*Quercus kerrii* Craib), Ket-Dam (*Dalbergia assamica* Benth.), Pluang (*Dipterocarpus tuberculatus* Roxb.), Ma-Kang-Dang (*Garcinia erythroclada* Kurze.), Waa (*Syzygium cumini* (L.) Skeels), Ma-Mao-Khao (*Antidesma laurifolium* Airy Shaw) and Ta-Khro (*Schleichera oleosa* Merr.)

Site No.4 was a terrace deposit that was next below the mountain. Lang river was away the site to the east approximately 40 m. The environment of area was mixed deciduous forest. Teak (*Tectona grandis* L.f.) and Bamboos can be generally found nearby the site. Other species found in this area are Po-Baan (*Sterculia pexa* Pierre), Sa-Lao (*Lagerstromia tomentosa* Presl), Tum-Kwaao (*Mitragyna brunonis* Craib) and Pai-saang (*Dendrocalamus* spp.)

The followings are descriptions of sequence TLP1-TLP11.

Table 3.2 Details of TLP 1

Sample Number	Depth of sampling(cm)	Description of layers
TLP 101	9-16	Grayish brown very fine sand
TLP 102	16-24	Dark grayish brown very fine sand with yellow mottling
TLP 103	24-30	
TLP 104	30-40	
TLP 105	40-58	

Table 3.3 Details of TLP 2

Sample Number	Depth of sampling(cm)	Description of layers
TLP 201	18-23	Pale yellow very fine sand with yellow mottling
TLP 202	26-31	

Table 3.4 Details of TLP 3

Sample Number	Depth of sampling(cm)	Description of layers
TLP 301	3-20	Dark grayish brown clay
TLP 302	20-40	
TLP 303	40-60	
TLP 304	60-80	Very dark gray sandy clay
TLP 305	80-100	
TLP 306	100-114	

Table 3.5 Details of TLP 4

There are two charcoal samples found in this sequence including TLP409 and TLP 410 in the depth of 80-95 and 95-110 cm respectively.

Sample Number	Depth of sampling(cm)	Description
TLP 401	3-20	Very dark grayish brown loamy clay
TLP 402	20-35	Very dark gray loamy clay
TLP 403	35-50	
TLP 404	50-65	
TLP 405	65-80	
TLP 406	80-95	
TLP 407	95-110	
TLP 408	110-124	
TLP 409	Charcoal sample found between 80-95 cm	
TLP 410	Charcoal sample found between 95-110 cm	

Table 3.6 Details of TLP 5

Sample Number	Depth of sampling(cm)	Description of layers
TLP 501	3-20	Very dark grayish brown loamy clay
TLP 502	20-35	Very dark gray loamy clay
TLP 503	35-50	
TLP 504	50-65	
TLP 505	65-80	
TLP 506	80-95	
TLP 507	95-109	

Table 3.7 Details of TLP 6

Sample Number	Depth of sampling(cm)	Description of layers
TLP 601	3-10	Very dark grayish brown clay
TLP 602	10-30	Light olive brown clay with red mottling
TLP 603	30-56	Red brown clay with red mottling
TLP 604	56-65	Light greenish gray clay with red mottling
TLP 605	65-80	
TLP 606	80-110	Red brown clay with red mottling

Table 3.8 Details of TLP 7

Sample Number	Depth of sampling(cm)	Description of layers
TLP 701	5-24	Dark grayish brown clay
TLP 702	24-36	Brownish yellow clay with red mottling
TLP 703	36-48	Pale yellow clay with red mottling
TLP 704	48-60	Light greenish gray clay with red mottling
TLP 705	60-72	
TLP 706	72-84	

Table 3.9 Details of TLP 8

Sample Number	Depth of sampling(cm)	Description of layers
TLP 801	5-24	Dark olive brown clay
TLP 802	24-36	Yellowish brown clay with red mottling
TLP 803	36-48	
TLP 804	48-60	Very pale brown clay with red mottling
TLP 805	60-72	Light greenish gray clay with yellow mottling
TLP 806	72-90	

Table 3.10 Details of TLP 9

Sample Number	Depth of sampling(cm)	Description of layers
TLP 901	3-24	Very dark grayish brown loamy clay
TLP 902	24-36	Very dark gray loamy clay
TLP 903	36-48	
TLP 904	48-60	Dark gray loamy clay
TLP 905	60-72	
TLP 906	72-84	
TLP 907	84-96	
TLP 908	96-108	
TLP 909	108-120	
TLP 910	120-122	

Table 3.11 Details of TLP10

Sample Number	Depth of sampling(cm)	Description
TLP 1001	3-12	Very dark grayish brown loamy clay
TLP 1002	12-24	
TLP 1003	24-36	
TLP 1004	36-48	
TLP 1005	48-60	
TLP 1006	60-72	
TLP 1007	72-84	Dark reddish brown sandy clay
TLP 1008	84-96	
TLP 1009	96-108	
TLP 1010	108-119	

Table 3.12 Details of TLP 11

There is charcoal sample, TLP1110, found in layer 24-36 cm. In a layer of sample TLP 1108, this is the beginning of water level. Gravels were found at the depth of 190 cm.

Sample Number	Depth of sampling(cm)	Description of layers
TLP 1101	3-12	Very dark grayish brown loamy clay
TLP 1102	12-24	
TLP 1103	24-36	Very dark gray loamy clay
TLP 1104	36-48	
TLP 1105	48-60	Dark reddish brown sandy clay
TLP 1106	60-72	
TLP 1107	72-96	
TLP 1108	96-144	
TLP 1109	144-192	
TLP 1110	Charcoal sample found in layer 24-36 cm	

3.1.2 Samples from Ban Rai

As regards Ban Rai sampling, there were three sites, the site No. 5, 6 and 7, that soil samples were collected from. The description of environs is as followings.

Site No.5 was a sinkhole in front of Ban Rai rockshelter. Because of the humid condition of sinkhole area, mixed deciduous forest surrounded the sampling site can be found with mixing of some species in dry evergreen forest. The examples of found species were Teak (*Tectona grandis* L.f.), Po-Baan (*Sterculia pexa* Pierre), Po-Tuup-Huu-Chaang (*Sterculia villosa* Roxb.), Ta-Kian-Nu (*Anogeissus acuminata* (Roxb ex DC.) var. *lanceolata* Clarke), Dang (*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C. Nielsen), Yaang-Naa (*Dipterocarpus alatus* Roxb.), Ma-Kok (*Spondias pinnata* Kurz), Waai-Khom (*Calamus rotang* L.) and Bamboos.

Site No.6 was situated above Ban Rai rockshelter. Surrounding area was an ecotone of dry dipterocarp forest and mixed deciduous forest. The dominant species were Teng (*Shorea obtosa* Wall.) and Rang (*Shorea siamensis* Miq.). The other species were Teak (*Tectona grandis* L.f.), Ko-Phae (*Quercus kerrii* Craib), Rak (*Melanorrhoea glabra* Wall.), Ket-Daeng (*Dalbergia dongnaiensis* Pierre), Po-Faii (*Sterculia hypochra* Pierre) and Po-Tuup-Huu-Chaang (*Sterculia villosa* Roxb.).

Site No.7 was a plain between mountainous areas. A trace of burning was found in the area. Regarding the environs, there was an ecotone of dry dipterocarp forest and mixed deciduous forest surrounding the site. Teak (*Tectona grandis* L.f.) and Bamboo were commonly found. .). The other species were Teng (*Shorea obtosa* Wall.), Rang (*Shorea siamensis* Miq.), *Bambusa* spp. and *Dendrocalamus* spp..

Descriptions of sequence TLP1-TLP11 are as the followings.

Table 3.13 Details of BRP 1

There is charcoal sample, BRP123, found at layer 172-180 cm.

Sample Number	Depth of sampling(cm)	Description of layers
BRP 101	3-12	Dark reddish brown loamy clay
BRP 102	12-21	
BRP 103	21-30	
BRP 104	30-39	
BRP 105	39-48	
BRP 106	48-57	

Sample Number	Depth of sampling(cm)	Description of layers
BRP 107	57-66	Dark reddish brown loamy clay
BRP 108	66-75	
BRP 109	75-84	
BRP 110	84-92	
BRP 111	92-100	
BRP 112	100-108	
BRP 113	108-116	
BRP 114	116-124	
BRP 115	124-132	
BRP 116	132-140	
BRP 117	140-148	
BRP 118	148-156	
BRP 119	156-164	
BRP 120	164-172	
BRP 121	172-180	
BRP 122	180-188	
BRP 123	Charcoal sample found in layer 172-180 cm	

Table 3.14 Details of BRP 2

The charcoal sample, BRP217, was found at layer 49-58 cm.

Sample Number	Depth of sampling(cm)	Description of layers
BRP 201	3-13	Dark reddish brown loamy clay
BRP 202	13-22	
BRP 203	22-31	
BRP 204	31-40	
BRP 205	40-49	
BRP 206	49-58	
BRP 207	58-67	
BRP 208	67-76	
BRP 209	76-85	
BRP 210	85-94	
BRP 211	94-103	
BRP 212	103-112	
BRP 213	112-121	
BRP 214	121-130	
BRP 215	130-139	
BRP 216	139-148	
BRP 217	Charcoal sample found in layer 49-58 cm	

Table 3.15 Details of BRP 3

Sample Number	Depth of sampling(cm)	Description of layers
BRP 301	3-10	Dark reddish brown loamy clay
BRP 302	10-17	
BRP 303	17-24	
BRP 304	24-31	
BRP 305	31-38	
BRP 306	38-45	
BRP 307	45-53	
BRP 308	53-61	
BRP 309	61-69	
BRP 310	69-77	
BRP 311	77-85	
BRP 312	85-93	
BRP 313	93-101	
BRP 314	101-109	
BRP 315	109-117	
BRP 316	117-125	
BRP 317	125-133	
BRP 318	133-141	
BRP 319	141-149	
BRP 320	149-157	
BRP 321	157-165	
BRP 322	165-173	
BRP 323	173-181	

Table 3.16 Details of BRP 4

Sample Number	Depth of sampling(cm)	Description of layers
BRP 401	3-12	Dark reddish brown loamy clay
BRP 402	12-20	Reddish brown loamy clay
BRP 403	20-28	
BRP 404	28-36	
BRP 405	36-44	
BRP 406	44-52	
BRP 407	52-60	
BRP 408	60-68	
BRP 409	68-76	
BRP 410	76-84	
BRP 411	84-92	
BRP 412	92-100	
BRP 413	100-109	
BRP 414	109-118	
BRP 415	118-127	
BRP 416	127-136	
BRP 417	136-145	
BRP 418	145-154	
BRP 419	154-163	
BRP 420	163-172	
BRP 421	172-181	
BRP 422	181-190	
BRP 423	190-199	
BRP 424	199-208	
BRP 425	208-217	
BRP 426	217-226	

Table 3.17 Details of BRP 5

Sample Number	Depth of sampling(cm)	Description of layers
BRP 501	3-13	Reddish brown loamy clay
BRP 502	13-22	
BRP 503	22-31	
BRP 504	31-40	
BRP 505	40-49	
BRP 506	49-58	
BRP 507	58-67	
BRP 508	67-76	
BRP 509	76-85	
BRP 510	85-94	
BRP 511	94-103	
BRP 512	103-112	
BRP 513	112-121	
BRP 514	121-130	
BRP 515	130-139	
BRP 516	139-148	

Sample Number	Depth of sampling(cm)	Description of layers
BRP 517	148-157	Reddish brown loamy clay
BRP 518	157-166	
BRP 519	166-175	
BRP 520	175-184	
BRP 521	184-193	
BRP 522	193-202	
BRP 523	202-211	
BRP 524	211-220	
BRP 525	220-229	
BRP 526	229-238	

Table 3.18 Details of BRP 6

Sample Number	Depth of sampling(cm)	Description of layers
BRP 601	3-14	Reddish brown loamy clay
BRP 602	14-25	
BRP 603	25-35	
BRP 604	35-45	
BRP 605	45-55	
BRP 606	55-65	
BRP 607	65-75	
BRP 608	75-85	
BRP 609	85-95	
BRP 610	95-105	
BRP 611	105-115	
BRP 612	115-125	
BRP 613	125-135	
BRP 614	135-145	
BRP 615	145-155	
BRP 616	155-165	
BRP 617	165-175	
BRP 618	175-185	
BRP 619	185-195	
BRP 620	195-205	
BRP 621	205-215	
BRP 622	215-225	
BRP 623	225-235	
BRP 624	235-245	

Table 3.19 Details of BRP 7

There are 2 charcoal samples in BRP 7 including BRP 725 and BRP 726 found between 31-40 cm and 40-49 cm respectively.

Sample Number	Depth of sampling(cm)	Description of layers
BRP 701	3-13	Brown loamy clay
BRP 702	13-22	
BRP 703	22-31	
BRP 704	31-40	Very dark gray loamy clay
BRP 705	40-49	
BRP 706	49-58	Reddish yellow loamy clay
BRP 707	58-67	
BRP 708	67-76	
BRP 709	76-85	Brown loamy clay
BRP 710	85-94	
BRP 711	94-103	Dark brown loamy clay
BRP 712	103-112	
BRP 713	112-121	
BRP 714	121-130	
BRP 715	130-140	
BRP 716	140-150	
BRP 717	150-160	
BRP 718	160-170	
BRP 719	170-180	
BRP 720	180-190	
BRP 721	190-200	
BRP 722	200-210	
BRP 723	210-220	
BRP 724	220-230	
BRP 725	Charcoal sample found in layer 31-40 cm	
BRP 726	Charcoal sample found in layer 40-49 cm	

Table 3.20 Details of BRP 8

In this sequence, charcoal sample, BRP 820, was found in the depth of 81-88 cm.

Sample Number	Depth of sampling(cm)	Description
BRP 801	3-11	Brown loamy clay
BRP 802	11-18	
BRP 803	18-25	
BRP804	25-32	
BRP 805	32-39	Dark brown loamy clay
BRP 806	39-46	
BRP 807	46-53	
BRP 808	53-60	
BRP 809	60-67	
BRP 810	67-74	
BRP 811	74-81	
BRP 812	81-88	
BRP 813	88-95	
BRP 814	95-103	
BRP 815	103-111	
BRP 816	111-119	
BRP 817	119-127	
BRP 818	127-135	
BRP 819	135-143	
BRP 820	Charcoal sample found in layer 81-88 cm	

3.1.3 Samples from archaeological excavation sites

Other than soil samples described above, this study has analyzed soil samples collected from archaeological sites since 2001, which were studied in preliminary study. Palynological study of soil samples from archaeological sites has been done in consideration to recognize the result for more accuracy. There are eighteen samples from excavation area of Tham Lod rockshelter and Ban Rai rockshelter which ever were palynological productive mentioned in final report of Highland Archaeological Project in Pang Mapha district, Mae Hong Son province.

Five samples from excavation area of Tham Lod rockshelter are shown in Table 3.21. Depth as cm (centimeter) of sampling used in the table means the depth level from soil surface.

Table 3.21 Details of samples from Tham Lod rockshelter

Sample Number	Depth (cm)
Excavation site S23W10 Area 1	
TLA1#33	50-60
TLA1#39	120-130
TLA1#51	240-250
Excavation site S21W10 Area 2	
TLA2#73	35-45
Excavation site S20W9 Area 3	
TLA3#187	100-120

As followings, there are thirteen samples from excavation area of Ban Rai rockshelter shown in Table 3.22.

Table 3.22 Details of samples from Ban Rai rockshelter

Sample Number	Depth (cm)
Excavation site S2E12 Area 1	
BRA1#152	0-12
Excavation site S1E4 Area 1	
BRA1#109	8-54
BRA1#115	22-32
BRA1#160	22-32
BRA1#162	42-52
Excavation site S1E6 Area 2	
BRA2#802	0-32
BRA2#770	32-42
Excavation site S2E14 Area 2	
BRA2#882	30-90
Excavation site N5E39 Area 3	
BRA3#1384	25-30
BRA3#1388	45-50
BRA3#1393	45-50
BRA3#1389	50-55
BRA3#1394	50-55

Moreover, because of interesting dating results by thermoluminescence method (33), additional fourteen soil samples from the excavation site S20W9 area3,

SWQ3, West profile of Tham Lod rockshelter were prepared for palynological study as well.

Table 3.23 Details of additional samples from Tham Lod rockshelter

Sample Number	Depth (cm)
Excavation site S20W9 Area 3 West Profile layer 2 (2,933±83 BP)	
TLA3#180	75-85
TLA3#181	85-95
TLA3#182	95-105
TLA3#183	105-115
TLA3#184	115-125
TLA3#185	125-135
Excavation site S20W9 Area 3 West Profile layer 3a (10,582±49BP)	
TLA3#192	195-205
TLA3#193	205-215
TLA3#194	215-225
TLA3#195	225-235
TLA3#196	235-245
TLA3#197	245-255
TLA3#198	255-265
TLA3#199	265-275

3.1.4 Modern pollen sample collection

Because palynological study is based on comparison with modern plants, so modern pollen is of great value in identification and interpretation of palynological samples obtained from field. Modern pollen could be derived from present flora within study areas located around sampling sites.

1. All samples including pollen and spores in form of flowers and fern leaflets should be kept in white-paper envelopes and labeled their details.
2. Then all samples have to be dried in oven with 50-60 °c for 3 days.
3. These dried samples are ready to prepare by acetolysis method.

3.2 Laboratory processes for pollen analysis

The pollen samples were processed at the Palynological Laboratory of Botany Department, Faculty of Science, Chulalongkorn University. The laboratory processes followed the standard palynological method.

3.2.1 Preparation of pollen samples

The aim of preparation is to extract concentrated pollens and spores in the sediment by removing extraneous matter both mineral and organic matter from the samples. It has been known that there is no standard set of treatment to prepare palynological samples; a better understanding of the potential and limitation of different treatments and components of the residues can maximize productivity of palynomorph.

Though the recommended quantity of soil material for pollen extraction is small amount (19), the amount of soil and chemical treatments can be adapted suitably. After each step in chemical processes, centrifuging samples at 2500 r.p.m. for 3 minutes is preferred. For preparation processes, the consideration of safety is so much important because many dangerous chemicals are use in chemical processes such as HCl, HF and Conc. H₂SO₄. Steps of processes are followed the standard techniques of many authors (12, 19, 65, 66).

1. Removal of carbonate

- Adding 10 % HCl is used to test calcium carbonate. Then concentrated HCl should be slowly added to remove calcium carbonate in the samples. When effervescence stops, the samples must be washed with distilled water. After washing, the samples were centrifuged and decanted the liquid off the tube. The washing must be repeated 3 times.

- It is essential to remove all calcium carbonate at this stage, because the later addition of HF will result in the formation of insoluble calcium fluoride. Anyhow if there is no reaction, the process goes forward to the next step.

2. Removal of silicate minerals

- For HF treatment, it is required to do in a suitable fume cupboard. Adding concentrated HF and leaving tubes overnight are necessary in order to dissolve any silicate minerals. At this step, it is no need to measure out a precise volume of HF.

- Then the residues were centrifuged, decanted and washed with distilled water repeatedly 3 times.

3. Removal of organic matter

- Generally the residues contain unwanted organic particles. So in this step, these unwanted organic particles should be oxidized by concentrated HNO₃ for 10 minutes. This treatment gives a dark brown color of humic acid as a result.

- After HNO₃ treatment, the residues were centrifuged, decanted and washed with distilled water for 3 times.

4. Removal of humic acid

- In order to remove humic acid, 5 % KOH was poured in sample tubes. Then samples tubes were placed in a hot water bath about 10 minutes. After that, it is required to wash samples with distilled water, centrifuge and decant for 3 times.

- It is necessary to avoid prolonged boiling as it may attack the exine of some species and make pollen grains swell. The darkness of the supernatant is used as a measure of the degree of humification of the sample. If the sample contains much of humic acid, it can give a very dark brown solution and it may be necessary to repeat the treatment carefully.

5. Screening

- After KOH treatment, it is a removal of coarse particles. The residues should be washed through a fine screen (136 microns) with a jet of distilled water.

- The suspension passing through the sieve should be collected in a polypropylene centrifuge tube, centrifuged and decanted.

6. Mounting

- As this step, samples were twice washed with absolute ethanol to dehydrate, then centrifuged and decanted.

- The minimum amount of tertiary butyl alcohol was dropped into centrifuge tube. Then the sample was transferred to a small vial. Silicone oil is used as a mounting media. After adding of silicone oil, it is required to leave an uncovered vial to allow evaporation of tertiary butyl alcohol for 2 days in a fume cupboard. After this, samples are readily reserved for slide preparation.

- Slides can be prepared by dropping the suspension onto a slide and covering with a cover slip.

3.2.2 Preparation of modern pollen

Considering laboratory preparation, acetolysis method has been conventionally known as a preparation procedure of modern pollen. Acetolysis method (66) consists of the following steps.

1. The first step is adding 10 % KOH in a sample tube for deflocculation and warming for a minute.

2. Next step, sample should be centrifuged and washed with distilled water.

3. Dehydration with glacial acetic acid is necessary to do before adding acetolysis mixture, because the reagents used in acetolysis, concentrated sulfuric (H_2SO_4) and acetic anhydride, are not only corrosive, but react vigorously with water (12).

4. Acetolysis mixture should be made up freshly each day by mixing acetic anhydride with concentrated H_2SO_4 in the ratio 9:1 by volume. Adding H_2SO_4 should be done carefully drop by drop to acetic anhydride and stirred. This operation should be processed in a fume cupboard.

5. After pouring acetolysis mixture into a sample tube, a sample tube should be placed in a hot water bath for a minute.

6. Then a sample was centrifuged and washed with glacial acetic acid, and later washed with distilled water for 3 times.

7. A sample has to be dehydrated by adding tertiary butyl alcohol and then centrifuged.

8. A pollen sample should be kept in silicone oil in a labeled vial readily for slide preparation.

3.2.3 Microscopic and counting techniques

The counting and identification of spores and pollen grains should be done through light microscope (LM). It is usually possible and convenient to identify and count samples from prepared slides by scanning at a magnification of x400 (12, 19). This provides sufficient magnification for routine identification, and has advantage that the field of view resulting from the use of x40 objective lens is usually appropriate for slides with a reasonable pollen density. Additionally, the use of x100 objective lens has to be recommended for ambiguous grains.

The number of pollen and spore should be counted in order to represent the pollen sum. Commonly counting pollen for analysis requires at least 200 pollen grains per sample (13). Nevertheless, it should be counted as much as possible. In this study, pollens and spores should be counted at least 200 grains from 4 slides per sample to calculate as percentage to obtain the proportion of pollen taxa and make a pollen diagram. However, if it can not be reached, counting result will show the result of total counting from 6 slides.

3.2.4 Identification

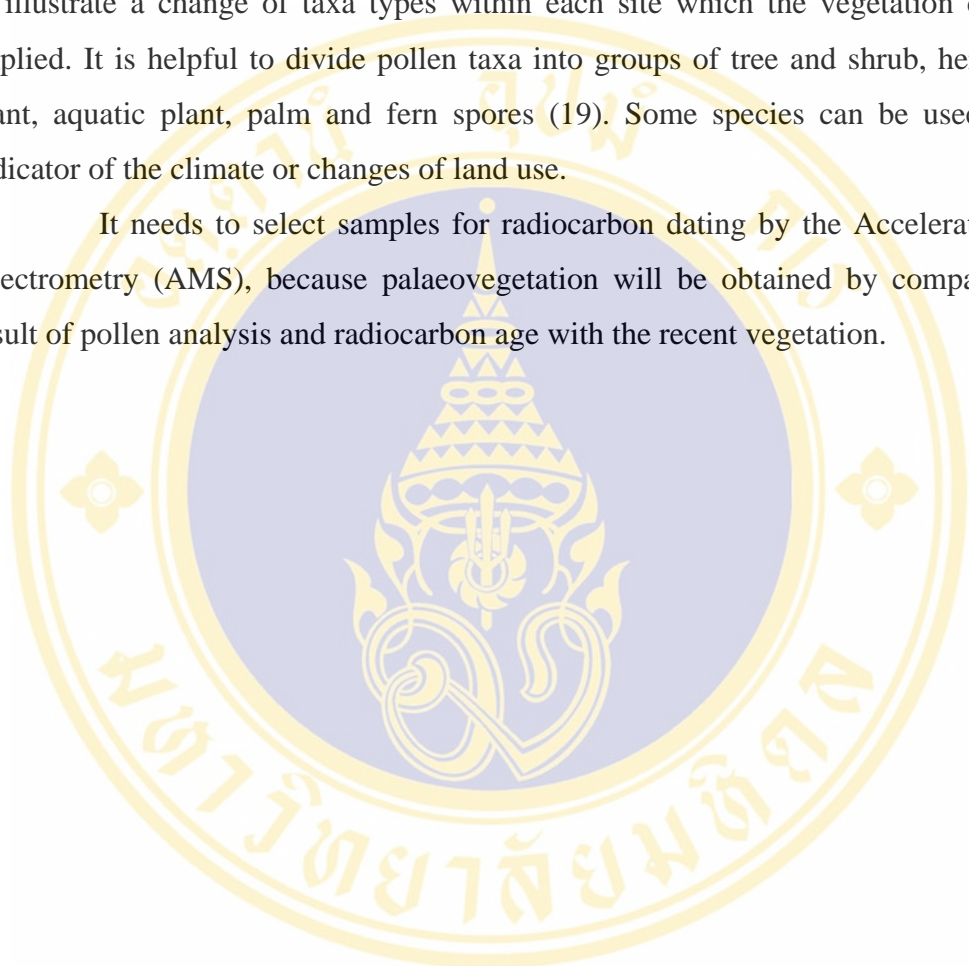
The ease and accuracy with which pollen grains can be identified varies from family to family, but accurate identification to genus can be made by light microscopy for most the flowering plants.

It is necessary to take microphotographs for making pollen and spore key cards to illustrate type material as an aid to rapid identification. Modern pollen specimens, palynological books (12, 19, 67), previous palynological studies (9, 10, 62, 63) are of great value for pollen identification.

3.3 Interpretation

The results of pollen counting and identification will be calculated and presented as a percentage of each species. Pollen diagrams were constructed in order to illustrate a change of taxa types within each site which the vegetation could be implied. It is helpful to divide pollen taxa into groups of tree and shrub, herbaceous plant, aquatic plant, palm and fern spores (19). Some species can be used as an indicator of the climate or changes of land use.

It needs to select samples for radiocarbon dating by the Accelerator Mass Spectrometry (AMS), because palaeovegetation will be obtained by comparing the result of pollen analysis and radiocarbon age with the recent vegetation.



CHAPTER IV

RESULTS AND DISCUSSION

The results of modern pollen study, radiocarbon dating and pollen analysis of soil samples from both archaeological sites collected in 2001 and recent soil samples from coring sites collected in 2004 will be presented and discussed in this chapter.

4.1 Modern pollen study

All 52 samples were collected for modern pollen preparation. Samples that were collected around soil sampling sites at Ban Tham Lod and Ban Rai are labeled as STL and SBR respectively. In addition, samples which were taken around office of highland archaeological project near Tham Lod rockshelter are labeled as SMT. The result will be showed as followings.

Table 4.1 The number of modern pollen samples

Site Number	Herbaceous plants		Shrubs		Trees		Others	
	Collected sample	Pollen sample	Collected sample	Pollen sample	Collected sample	Pollen sample	Collected sample	Pollen sample
Site no.1 (STL1)	2	2	1	1	1	1	-	-
Site no.2 (STL2)	-	-	-	-	-	-	-	-
Site no.3 (STL3)	9	6	-	-	2	2	2	-
Site no.4 (STL4)	3	3	-	-	1	1	-	-
Site no.5 (SBR1)	5	3	4	1	1	1	1	-
Site no.6 (SBR2)	2	2	1	1	1	1	-	-
Site no.7 (SBR3)	-	-	1	1	-	-	-	-
SMT samples	12	10	1	1	-	-	2	2
Total	33	26	8	5	6	6	5	2

From 52 samples, pollen and spores can be found from 39 samples. Most of modern pollen samples that were collected and can yield pollen are of herbaceous plants owing to their flowering period is more frequent than trees or shrubs. In addition, 2 fern samples were collected to study. Negative pollen result of some samples can be defined as because collected flowers are too young or too old to result in giving very little pollen to prepare slide. It may be suggestive of having more experience and awareness to prepare slides of modern pollen. Nevertheless, these modern pollen slides are of paramount use for pollen identification. Pictures of modern pollen will be presented in Appendix.

4.2 Radiocarbon dating result

From all sample cores derived from four coring sites of Ban Tham Lod and three coring sites of Ban Rai, there are only two sites of Ban Tham Lod and one site of Ban Rai that can give productively palynological results. There are site No. 2, 4 from Ban Tham Lod and site No. 7 from Ban Rai. Soil samples of TLP4, TLP10 and BRP8 has given the best result for pollen counting, so they were selected representatively from each site for pollen analysis. Moreover, there are only two charcoal samples taken from TLP4 and BRP8 which were sent to determine radiocarbon dating by Accelerator Mass Spectrometry (AMS).

Regarding the results of radiocarbon dating, TLP410, the charcoal sample from TLP4 at the depth of 95-110 cm, yielded that the conventional radiocarbon age is approximately as 120 ± 40 BP. The calendar age range with 2 sigma calibrated result with 95% probability is AD 1670 to 1950 or BP 280 to 0 (Beta-206533).

As for BRP820, the charcoal sample from BRP8 at the depth of 81-88 cm, it yielded the conventional radiocarbon age as 650 ± 40 BP. And for the calendar age range with 2 sigma calibrated result with 95% probability of charcoal sample from BRP8, it is in the period of AD 1280 to 1400 or Cal BP 670 to 550 (Beta-206534).

4.3 Pollen analysis from Ban Tham Lod

From three sites, soil sequences of TLP1, TLP2, TLP6, TLP7 and TLP8 show mottling and oxidation giving fewer remains for making slides, while some samples in sequences of TLP9 and TLP11 yielded too little remains after chemical treatments for making slides. These sequences, therefore, are negligible to study except TLP10. Whereas TLP3, TLP4 and TLP6 supplied better consequence, sequence TLP4 is the best to analysis because charcoal sample for age determination was obtained from this sequence. Hence, the consequence of pollen productive sequences of TLP4 and TLP10 will be demonstrated below.

As cited above, soil samples selected from two coring sites were studied. Those are eight samples from core TLP4 and ten samples from core TLP10. Furthermore, the result from archaeological samples will be presented as well. The result of palynological study will be showed as followings.

4.3.1 The result of pollen analysis from TLP4

Groups of classified pollen and spore which were obtained from TLP4 are presented as these followings.

Tree and Shrub: Annonaceae, *Calocedrus* sp., *Castanopsis* sp., *Glochidion* sp., Lauraceae, *Pinus* sp., *Shorea* sp. and Ulmaceae

Herbaceous plant: Acanthaceae, Amaranthaceae, Chenopodiaceae, Compositae, Cyperaceae, Malvaceae, Poaceae and *Polygonum* sp.

Fern and fern allies: cf. *Bolbitis* sp., *Cheilanthes* sp., *Cyathea* sp., Lycopodiaceae, *Lygodium* sp., *Microlepia* sp., *Ophioglossum* sp., Polypodiaceae, Psilotaceae, *Pteris* sp., Schizaeaceae and Pteridophytic spore

Palm: Palmae

Aquatic plant: cf. *Blyxa* sp.

Algae: *Circulisporites* sp. and *Concentricystes* sp.

From these pollen and spore groups, it can be separated into two characteristics of ecological system that are categorized as tropical and sub-tropical flora (64, 68).

Tropical flora: Annonaceae, *Glochidion* sp., Lauraceae and *Shorea* sp.

Sub-tropical flora: *Calocedrus* sp., *Castanopsis* sp., *Pinus* sp., Ulmaceae, *Cheilanthes* sp. and *Microlepia* sp.



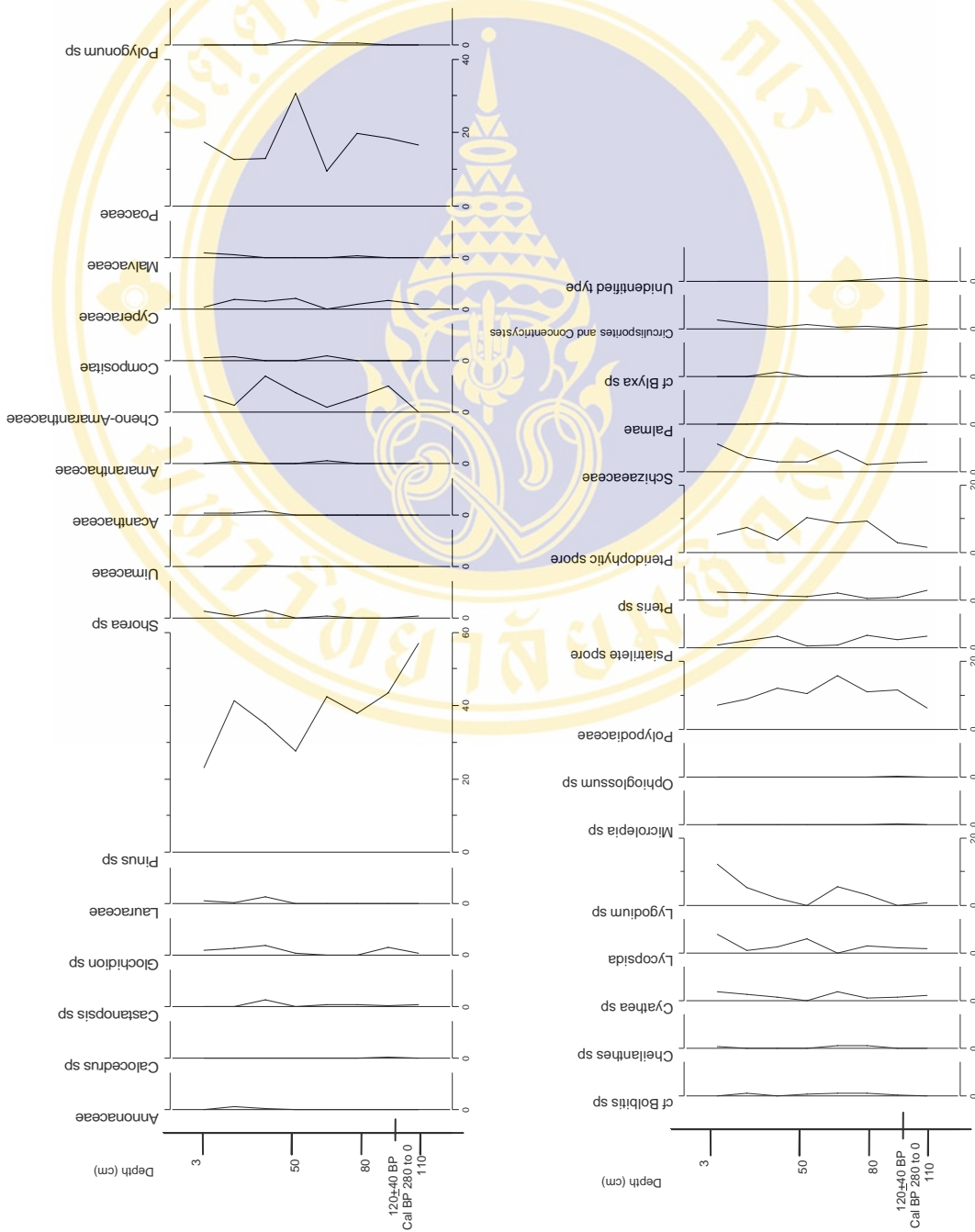


Figure 4.1 Pollen diagram of TLP 4

At the depth of 95-124 cm, group of tree and shrub presents the prevalence of pine reaching 57.1 percent in the lowermost part together with the scatter of sub-tropical flora, *Calocedrus* sp. and *Castanopsis* sp., and tropical floras as *Glochidion* sp. and *Shorea* sp.. Ferns show lower as 20.8-24 percent than the upper. At this depths, zygosporangium of *Circulisporites* sp. and *Concentricystes* sp., which is included in the green algae family of Zygnemataceae (69), can be found with cf. *Blyxa* sp., the aquatic plant, may indicate seasonal flooding and stagnant water.

Whereas in the middle sequence approximately 50-95 cm, pine still shows dominantly among tree and shrub group with fewer percentages than the lower and the little values of *Castanopsis* sp., *Glochidion* sp. and *Shorea* sp. still show as well. At the depth of 50-65 cm, it was found markedly that *Glochidion* sp. has started to present, when Poaceae can reach the highest value with 30.6 percent, but pine drops to 27.7 percent. Considering forest fire ecology (70), fire can stimulate the flowering of grass. In agreement with being secondary forest types of *Glochidion* sp. (64), it would support that forest fire may occur around this period. Albeit higher than the lowermost part at 95-124 cm, percentages of ferns are rather lower at 50-65 cm, the same depth that *Glochidion* sp. starts to occur, than the depth of 65-95 cm. This may accord to the assumption of fire. At the same time, *Polygonum* sp. is present as well as *Circulisporites* sp. and *Concentricystes* sp., while cf. *Blyxa* sp. is absent. This may reflect damp condition without stagnant water (71).

For the uppermost of 50 cm to the top, as yet not only has pine dominated, many types of tropical floras, that are Annonaceae, *Glochidion* sp., Lauraceae and *Shorea* sp., have presented also more than the lower along with rare occurrence of *Castanopsis* sp. and Ulmaceae. Palm is sporadically found with very little percentage in this sequence. In addition, the great variety of herbaceous plant occurs in this level, i.e. Acanthaceae, Amaranthaceae, Chenopodiaceae, Compositae, Cyperaceae and Malvaceae. It would again agree with fire occurrence, because forest fire can influence on more species of herbaceous plant than no fire (70). Notably, at the depth of 35-50 cm, the occurrence cf. *Blyxa* sp. gives the result in little fewer of total ferns than the upper depth. This may probably illustrate a periodic flooding with condition of stagnant water.

In regard to pollen diagram of TLP4, pine pollen (*Pinus* sp.) was continuously and dominantly found throughout sequence with strongest presentation among trees and shrubs. Additionally, pine pollen percentage is rather higher at the lower part than the upper part. It might reflect that pine forest in the past was more plentiful than present; its percentage below 65 cm. is higher than the upper part. Together with radiocarbon result, the climatic condition before 280 to 0 BP (Beta-206533, calibrated age) may be cooler than present. However, from field survey it can be said that the major cause may be human activities particularly deforestation.

In lower sequence, pollen of tropical flora occurs less than the upper sequence. Annonaceae, Lauraceae and Ulmaceae pollen types that appear above 50 cm indicate the available moisture (64), while *Castanopsis* sp. and *Shorea* sp. can be implied as a form of dry deciduous forest (11). Furthermore, the presence of Chenopodiaceae, weedy plant, in concert with dry land plants, may be suggestive of open area (72).

Fern spores are found throughout the sequence with value of 20.8 to 44.7 percent. These can be interpreted a rather high humidity. Cyperaceae, *Polygonum* sp. and cf. *Blyxa* sp. may indicate wet condition. It is supported by the occurrence of *Circulisporites* sp. and *Concentricystes* sp., the shallow-water organism, which is included in Zygnemataceae –the family of hydro-terrestrial, filamentous green algae. The Zygnemataceae algae inhabit a great variety of freshwater habitats that may be swift flowing stream, stagnant pool; and moist soils and peats. They form zygospore in clean, oxygen rich, stagnant and shallow freshwater (69). As mentioned, it can indicate that this area –terrace deposit- may be flooded seasonally.

After 280 to 0 BP (Beta-206533, calibrated age) until present time, it could be concluded from pollen diagram of TLP4 that there may be cooler than today and this site may have been flooded continuously since 280 to 0 BP (Beta-206533, calibrated age) and be tended to be more open area.

4.3.2 The result of pollen analysis from TLP10

The palynological assemblage of this sequence can be divided into groups as followings.

Tree and Shrub: *Alnus* sp., *Betula* sp., *Castanopsis* sp., *Glochidion* sp., Leguminosae, *Phyllanthus* sp., *Pinus* sp., *Quercus* sp., *Shorea* sp., *Symplocos* sp., *Syzygium* sp., *Terminalia* sp., Urticaceae and *Xylia* sp.

Herbaceous plant: Acanthaceae, *Alternanthera* sp., Chenopodiaceae, Compositae, Cyperaceae, Liliaceae/Amaryllidaceae, Malvaceae, *Merremia* sp., Poaceae and *Polygonum* sp.

Fern and fern allies: *Cheilanthes* sp., *Cyathea* sp., *Davallia* sp., Lycopodiaceae, *Lygodium* sp., *Microlepia* sp., Monolete spore, *Ophioglossum* sp., Polypodiaceae, Psilate spore, *Pteris* sp., Schizaeaceae and Pteridophytic spore

Palm: cf. *Calamus* sp. and Palmae

Aquatic plant: cf. *Blyxa* sp.

Algae: *Circulisporites* sp. and *Concentricystes* sp.

From palynological assemblage of TLP10, it can be classed into two types of ecological system as tropical and sub-tropical flora (64, 68).

Tropical flora: *Glochidion* sp., Leguminosae, *Phyllanthus* sp., *Shorea* sp., *Symplocos* sp., *Syzygium* sp., *Terminalia* sp., Urticaceae and *Xylia* sp.

Sub-tropical flora: *Alnus* sp., *Betula* sp., *Castanopsis* sp., *Pinus* sp., *Quercus* sp., *Cheilanthes* sp., *Davallia* sp. and *Microlepia* sp.

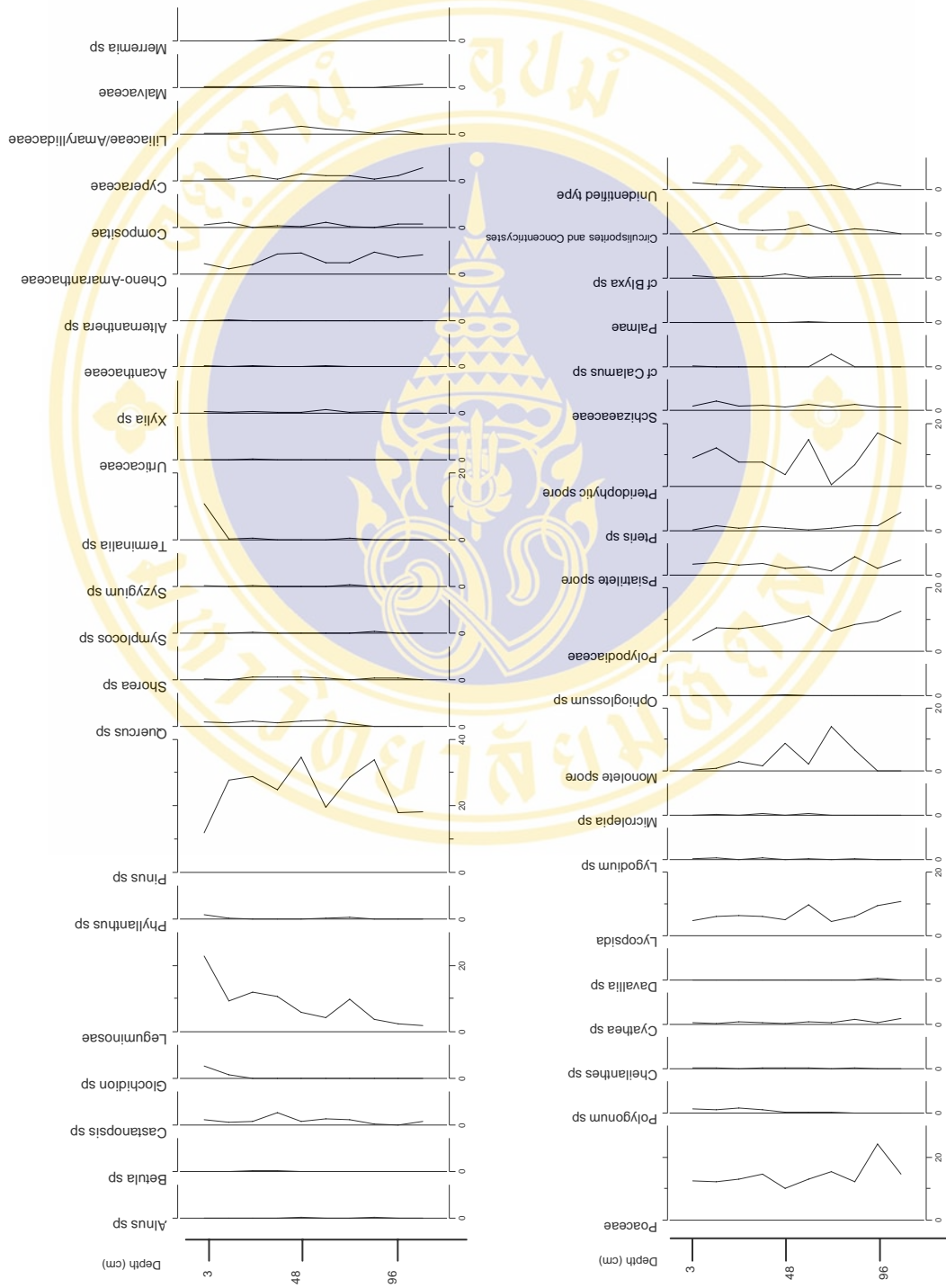


Figure 4.2 Pollen diagram of TLP 10

From this sequence, TLP10, not only more taxa can be identified, but pollen and spore concentration is higher than from TLP4 also. Nevertheless, there has not found any charcoal sample from this sequence. So it has no reference point of age for past vegetation. Trees group and fern group are equally dominant. Furthermore, it reveals more or less fluctuation in species composition.

Extracted from pollen diagram of TLP10, a trend of tree and shrub pollen in the lower part (96-119 cm) is apparently less than the upper part against fern spores. Besides, pine pollen is also the most dominant type again like in TLP4, but presents throughout the sequence with not clear changes of fluctuation. The dispersion of sub-tropical flora as *Alnus* sp., *Betula* sp., *Castanopsis* sp., *Quercus* sp., *Cheilanthes* sp., *Davallia* sp. and *Microlepia* sp. shows not much change.

Alnus sp. and *Betula* sp. are of sub-tropical or temperate type. The appearance of *Castanopsis* sp., *Glochidion* sp., Leguminosae, *Phyllanthus* sp., *Quercus* sp., *Shorea* sp. and *Terminalia* sp. could show dry land vegetation types (68), which increase continuously from the bottom to the top of sequence. *Xylia* sp., which exists above 96 cm through the uppermost of sequence, is of deciduous forest type. *Glochidion* sp., *Phyllanthus* sp., Leguminosae and Urticaceae are of secondary forest type or disturbance indicator (67). In consequence, all mentioned trees can imply as a result of area disturbance. Moreover, *Shorea* sp. in Dipterocarpaceae is interpreted as an indication of soil dryness (70).

There are although complex in composition of vegetation, however increasing trend of Leguminosae show preferably clear change. In agreement with those trees, they reflect more open area with disturbed environment in the upper part of diagram particularly above the depth of 84 cm. The reverse presence of fern spore is consistent with less humid environment in the upper sequence by the minor decreasing trend (73). Palms are scattered and few in the sequence, while herbaceous plants are generally found especially weed such as Chenopodiaceae. Poaceae appears throughout sequence with rather constant trend. It can be summarily pointed that the environment of this local area above the approximately depth of 72 cm trends to have less humidity.

Concerning with area condition, this site, TLP10, is a terrace deposit near the mountain and Lang River. The environs thereby are not too much dry. The

continual occurrence of cf. *Blyxa* sp. and *Circulisporites* sp. and *Concentricystes* sp. may illustrate the continuity of flooding condition in this site supported by Cyperaceae, Liliaceae/Amaryllidaceae and *Polygonum* sp. which prefer damp condition (71).

From this sequence, it may be summarized that the vegetation succession has become more dry condition increasing in this site owing to disturbance and open area, even though flooding may occur evidently throughout sequence.

4.3.3 The result of pollen analysis from Tham Lod rockshelter archaeological site

From five soil samples, there are only two samples that pollen can be found.

Table 4.2 Result of pollen analysis of samples from Tham Lod rockshelter (set I)

Sample Number	Depth (cm)	Result
Excavation site S23W10 Area 1		
TLA1#33	50-60	Tree and Shrub: <i>Calocedrus</i> sp. and <i>Pinus</i> sp. Herbaceous plant: Cyperaceae and Poaceae Fern and fern allies: <i>Cyathea</i> sp., <i>Ophioglossum</i> sp., Polypodiaceae and Pteridophytic spore Algae: <i>Circulisporites</i> sp. and <i>Concentricystes</i> sp.
TLA1#39	120-130	-
TLA1#51	240-250	-
Excavation site S21W10 Area 2		
TLA2#73	35-45	Tree and Shrub: <i>Calocedrus</i> sp., <i>Glochidion</i> sp. and <i>Pinus</i> sp. Herbaceous plant: Chen-Amaranthaceae, Compositae and Poaceae Fern and fern allies: <i>Cyathea</i> sp., <i>Davallia</i> sp., <i>Lygodium</i> sp., <i>Ophioglossum</i> sp., Polypodiaceae and Pteridophytic spore
Excavation site S20W9 Area 3		
TLA3#187	100-120	-

Because pollen can be found only from two samples from different excavated areas with a few number, so the obtained data are not suitable to construct the pollen diagram. This is according to most of pollen study from archaeological site especially from lime stone area (13) that there will give non-productive result to analysis owing to poorly preserved condition. A result of pollen counting is presented in Table B-7 in Appendix.

Sample TLA1#33 was from the depth of 50-60 cm from soil surface in the excavation area 1 that could be determined the age as 12,100±60 BP (Beta-168223) (2). It is determined as Pleistocene age which pollen data from Kwan Phayao suggested that there may be a cooler environment than the present (11), but obtained pollen data cannot imply to that condition. Whereas sample TLA2#73 was derived the excavation area 2 that was in Holocene age by evidences comparison according to evidence as earthenware, beads, shells and animal bones (2). Pollen and spores found from these samples are of modern taxa.

Besides, pollen data from Dan Penny showed like result in sample TLA1#33 and more tree taxa found in sample TLA1#73, i.e. *Alnus* sp., *Betula* sp., *Caesalpinia* sp., *Carpinus* sp., *Dillenia* sp., *Hopea/Shorea* type, *Lagerstroemia* sp., *Macaranga* sp., *Pinus* sp. and *Quercus* sp.

Regarding primary analysis of animal bones derived from excavated area 1 at layer3, the results of many animal bones of Carvidae (i.e. deer), Bovidae (i.e. cow and bull), Ursidae (i.e. wild bear), common wild pig, serow and Hystricidae can recommend forest types of deciduous, dry dipterocarp, bamboo and grass land. Additionally from primary analysis of animal bones, animal bones of Cercopithecinae (i.e. monkey), Colobinae (i.e. langur) and Ursidae (i.e. wild bear) can recommend hill evergreen forest (74).

Compared with pollen group found from sequence TLP4 and TLP10, pollen and spores from excavated sites are of modern taxa.

This pollen data are not against to previous assumption about palaeoenvironment (1, 2). If analysis is from this data, it may conclude that the environs of Tham Lod rock shelter have been alike to the present with fewer disturbances maybe as hill evergreen, pine and deciduous forest (2). Nevertheless,

because of the few amount of pollen recovered from this layer, this conclusion is not strong.

With regard to the result of additional samples from Tham Lod rockshelter, which dating ages are derived from thermoluminescence method, all samples yielded negative results in palynological study as in figure 4.3.

Table 4.3 Result of pollen analysis of additional samples from Tham Lod rockshelter (set II)

Sample Number	Depth (cm)	Result
Excavation site S20W9 Area 3 West Profile layer 2 (2,933±83 BP)		
TLA3#180	75-85	-
TLA3#181	85-95	-
TLA3#182	95-105	-
TLA3#183	105-115	-
TLA3#184	115-125	-
TLA3#185	125-135	-
Excavation site S20W9 Area 3 West Profile layer 3a (10,582±49BP)		
TLA3#192	195-205	-
TLA3#193	205-215	-
TLA3#194	215-225	-
TLA3#195	225-235	-
TLA3#196	235-245	-
TLA3#197	245-255	-
TLA3#198	255-265	-
TLA3#199	265-275	-

The result of additional samples set II from Tham Lod rockshelter supports the result of samples set I in that the positive palynological result could be obtained from the samples of which depth are not over 90 cm.

4.4 Pollen analysis from Ban Rai

4.4.1 The result of pollen analysis from BRP8

About sequences from Ban Rai, almost sequences, BRP1, BRP2, BRP3, BRP4, BRP5 and BRP6 were oxidized and yielded that pollen can be found only in the upper part of sequence with very few amount. BRP7 and BRP8 can present better consequence. Owing to BRP7 show less productive result than BRP8 together with the deeper level of charcoal sample in BRP8, thus, sequence of BRP8 was selected to present in this study.

Pollen assemblage of BRP8 sequence can be identified and grouped as the followings.

Tree and Shrub: Annonaceae, cf. *Bauhinia* sp., *Castanopsis* sp., *Jatropha* type, Leguminosae, *Pinus* sp. and *Xylia* sp.

Herbaceous plant: Chenopodiaceae, Compositae, Cyperaceae, Malvaceae and Poaceae

Fern and fern allies: cf. *Bolbitis* sp., *Cheilanthes* sp., *Cyathea* sp., *Davallia* sp., Lycopodiaceae, *Lygodium* sp., *Microlepia* sp., *Ophioglossum* sp., *Osmunda* sp., Polypodiaceae, Psilate spore, *Pteris* sp., Schizaeaceae and Pteridophytic spore

Algae: *Circulisporites* sp. and *Concentricystes* sp.

In consideration of ecological system, palynological assemblage of BRP8 can be categorized into two types as tropical and sub-tropical flora (64, 68).

Tropical flora: Annonaceae, cf. *Bauhinia* sp., *Jatropha* type, Leguminosae and *Xylia* sp.

Sub-tropical flora: *Castanopsis* sp., *Pinus* sp., *Cheilanthes* sp., *Cheilanthes* sp., *Microlepia* sp. and *Osmunda* sp.

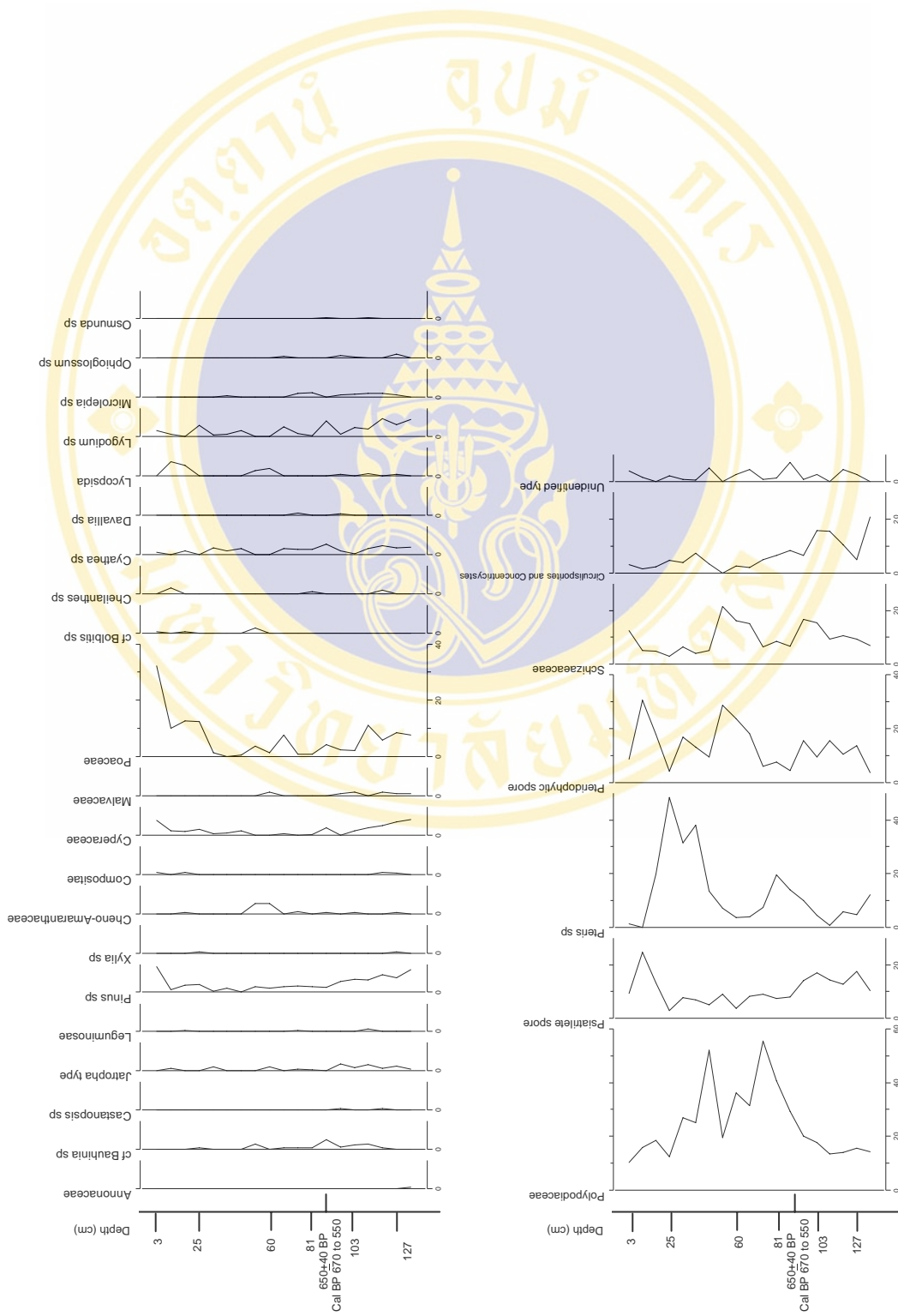


Figure 4.3 Pollen diagram of BRP 8

From the diagram, fern spores are remained outstandingly higher than both pollen groups of tree and shrub and herbaceous plant. Within ferns group, Polypodiaceae, Psilatrite spore, *Pteris* sp., Schizaeaceae and Pteridophytic spore present with high value.

At the depth of 81-143 cm, among tree and shrub group, pine pollen is dominant and reaches a maximum of only 8.1 percent in the bottom. Then it tends to slightly decrease. Regards as other tree and shrub, Annonaceae, cf. *Bauhinia* sp., *Castanopsis* sp., *Jatropha* type, Leguminosae and *Xylia* sp. can be found even with not high percentages. Poaceae is as well prominent among herbaceous plant, while fern spores appear with lower percentage than the upper. However, the occurrence of some sub-tropical genera ferns, including *Cheilanthes* sp., *Davallia* sp., *Microlepia* sp. and *Osmunda* sp., is rather higher in the this lower sequence than the upper. Polypodiaceae and *Pteris* sp. become increase from 119 to 81 cm depth, whereas Schizaeaceae presents opposite to. Furthermore, *Circulisporites* sp. and *Concentricystes* sp. show with higher percentages in this level than the upper.

In regard with the depth of 25-81 cm, pine is still prevalent among tree and shrub group, while cf. *Bauhinia* sp. and *Jatropha* type are scattered. Polypodiaceae reaches the maximum of 55.6 and 52 percent at the depth of 74-81 and 46-53 cm respectively. Then Schizaeaceae increases between these peaks of Polypodiaceae to the maximum of 21.4 percent at the depth of 53-60 cm, whereas *Circulisporites* sp. and *Concentricystes* sp. apparently reverse. This appearance could indicate the decrease of soil moisture in this level (69, 73). After that, *Pteris* sp. becomes increase to the maximum of 48.5 percent at 25-32 cm depth, while in agreement with the increase of *Circulisporites* sp. and *Concentricystes* sp., it can suggest the increase of soil moisture, because *Pteris* sp. is absent in very dry region, but grows terrestrially in more or less shade locations on all kind of soils (73). Nevertheless, this moisture does not mean much humid condition. At the same time, pollen of Poaceae begins to increase at 25-32 cm depth also.

In the upper part of sequence at the depth of 3-25 cm, fern spores reduce, when Poaceae not only increases, but reaches the maximum percent of 32.4 percent as well. If does it be considered with ferns, drops of Polypodiaceae, Psilatrite spore, *Pteris* sp. and Pteridophytic spore are notable against rises of Poaceae and

Schizaeaceae. Because grass (Poaceae) is of pioneer type and Schizaeaceae members can be found on drier soil (73), it therefore would be suggestive of change to have less in soil moisture. This may indicate condition of disturbance in this site.

By the way, it is so ambiguous in the case that, in the uppermost sequence, why only pine pollen in the top layer is of highest value with 9.2 percent, although it tends to decrease from the lowermost through above layers. In this case, in spite of there was no pine forest in this mountainous area, the reason why pine pollen can be found as majority among trees and shrubs pollen group is that pine pollen is wind-transported pollen (12). So it is possible certainly that it may be transported by itself from pine forest at the mountains near sampling site. It is quite different from TLP4 and TLP10 in which pine forest is around those sites, but this site is a valley between mountainous areas.

With regard to the case why pine pollen in top layer is highest, this may be possible that pollen can not be preserved well in lime-stone area (13), but the uppermost is of very new age. So it possibly contains more pollen in than the lower parts which are implied the longer of preservation period. From these obtained data along with radiocarbon age, *Pinus* sp. was slightly higher before 670 to 550 BP (Beta-206534, calibrated age) than after that period.

Furthermore, *Circulisporites* sp. and *Concentricystes* sp. may illustrate that seasonal flooding was stronger or longer before 670 to 550 BP (Beta-206534, calibrated age) than after that presented by higher percentages of it before that time. This is supported by ecology of habitat of Zygnemataceae algae, of which *Circulisporites* sp. and *Concentricystes* sp. are members.

Regarding the environment after 670 to 550 BP (Beta-206534, calibrated age) from radiocarbon dating result of charcoal sample in the depth of 81-88 cm, it can be suggested that there was less dry than present. As about the abundance of grass pollen above the depth of 32 cm, it may be much possibly from natural forest fire, deforestation or other human activities, not climatic change. In addition, non-arboreal vegetation interspersed by sub-tropical plants may indicate cooler condition before 670 to 550 BP (Beta-206534, calibrated age).

It is of great interest that although this site is an ecotone of dry dipterocarp forest and mixed deciduous forest, there is no pollen even one in that forest was found. This aspect will be discussed in the part of discussion.

4.4.2 The result of pollen analysis from Ban Rai rockshelter archaeological site

Thirteen samples from Ban Rai rockshelter were analyzed for palynological study. The result yielded that it can be seen pollen and spores from eight samples. The detail of taxa groups will be illustrated as followings.



Table 4.4 Result of pollen analysis from Ban Rai rockshelter samples

Sample Number	Depth (cm)	Result
Excavation site S2E12 Area 1		
BRA1#152	0-12	Tree and Shrub: <i>Bombax</i> sp., <i>Castanopsis</i> sp., Leguminosae, <i>Nyssa</i> sp., Oleaceae, <i>Pinus</i> sp., <i>Pterocarpus</i> sp., <i>Shorea</i> sp., <i>Symplocos</i> sp. and <i>Terminalia</i> sp. Herbaceous plant: Acanthaceae, Chenopodiaceae, Malvaceae and <i>Merremia</i> sp. Fern and fern allies: <i>Cyathea</i> sp., <i>Lygodium</i> sp., Polypodiaceae, <i>Pteris</i> sp. and Pteridophytic spore
Excavation site S1E4 Area 1		
BRA1#109	8-54	Tree and Shrub: <i>Pinus</i> sp. Herbaceous plant: Poaceae
BRA1#115	22-32	-
BRA1#160	22-32	Tree and Shrub: <i>Nyssa</i> sp. and <i>Pinus</i> sp.
BRA1#162	42-52	Tree and Shrub: <i>Pinus</i> sp. Fern and fern allies: <i>Lygodium</i> sp., Polypodiaceae and <i>Pteris</i> sp.
Excavation site S1E6 Area 2		
BRA2#802	0-32	Tree and Shrub: <i>Pinus</i> sp. Herbaceous plant: Acanthaceae and Poaceae Fern and fern allies: <i>Davallia</i> sp., <i>Lygodium</i> sp., Polypodiaceae, <i>Pteris</i> sp. and Pteridophytic spore
BRA2#770	32-42	Tree and Shrub: <i>Pinus</i> sp.
Excavation site S2E14 Area 2		
BRA2#882	30-90	Tree and Shrub: <i>Pinus</i> sp.
Excavation site N5E39 Area 3		
BRA3#1384	25-30	Tree and Shrub: <i>Castanopsis</i> sp., Leguminosae, <i>Pinus</i> sp., <i>Pterocarpus</i> sp. and <i>Shorea</i> sp. Herbaceous plant: Chenopodiaceae and Poaceae Fern and fern allies: Polypodiaceae and <i>Pteris</i> sp.
BRA3#1388	45-50	-
BRA3#1393	45-50	-
BRA3#1389	50-55	-
BRA3#1394	50-55	-

These results suggest similar taxa with a result of preliminary study. Regards as a study from Dan Penny, there was only one productive sample that is the same as BRA1#152.

From this table, *Pinus* sp. can be found in every sample. Most of plant is similar to the present, which some plants are different from BRP8. Although

BRA1#152 yielded so many taxa with a high number, it could not deduct the conclusion of past vegetation from these taxa. Due to this sample was from the top soil with the depth of 0-12 cm; pollen can be reasonably obtained with a large number. It is because Ban Rai rockshelter is a sink hole giving specific environment from surrounding. *Bombax* sp. and *Pterocarpus* sp. are deciduous plants, while *Nyssa* sp., Oleaceae and *Symplocos* sp. are in hill-evergreen forest. This is consistent with the present environment around rockshelter, which are deciduous plants mixed with evergreen plants (2).

Except BRA2#882, all samples that gave productive results are dated to the Holocene age by comparison with archaeological evidences. In layer of BRA2#882, according to age determination, it is revealed in the age of $10,210 \pm 50$ BP (Beta-168219) (2). In this layer, only *Pinus* sp. was found.

BRA3#1384 submitted very large amount of pollen especially *Pinus* sp.. Although there is no point of reference age for more explanation, this sample is in the age of Holocene by comparison with archaeological evidences. All taxa are of modern types. So this can suggest a similar taxa type with the present.

As regards other samples, it can be said that plants which were found have not been different with the present vegetation around Ban Rai rockshelter.

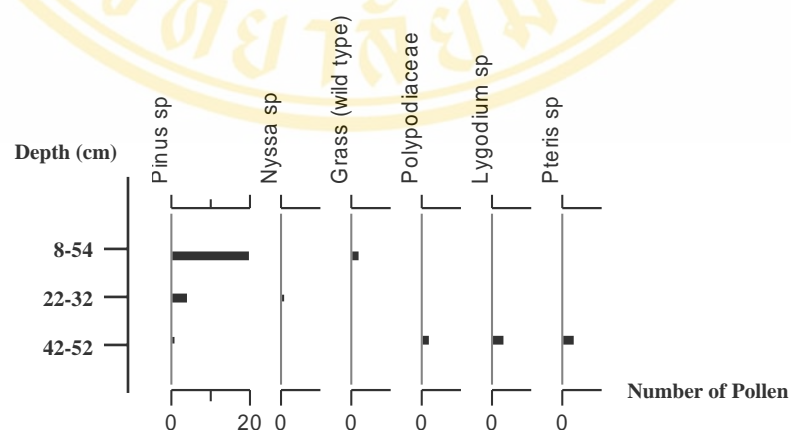


Figure 4.4 Pollen diagram of samples from excavation site S1E4 Area 1, Ban Rai rockshelter

Pollen diagram of samples from Ban Rai rockshelter shows a result in a number of pollen counting. It is different from three previous diagrams, because it can not show percentage as same as coring samples due to a very few number of pollen. Besides, this diagram presents a discontinuous trend of pollen in each level, which makes it is difficult to interpret. So this diagram can only display a number of found pollen.

Howsoever, if the interpretation is from this diagram, it could be suggestive of humid condition in lower layer and dry condition in upper with no age determination. And, thereby, the summary from these data could be that the environs of Ban Rai rock shelter has not dramatically changed since $10,210 \pm 50$ BP (Beta-168219) (2) and they seem to be similar to present since that time. This pollen data are not against to previous assumption about palaeoenvironment (1, 2). Nevertheless, it could not indicate the plenty of forest from this data.

Considering from Table 4.2 and 4.3 together with Table 4.4, it shows negative result of samples in the depth below 90 cm approximately.

4.5 Discussion of Ban Tham Lod and Ban Rai

4.5.1 Pollen analysis result

From modern pollen study, most of samples collected were from herbaceous plants, although samples of trees, shrubs and ferns are useful. The collection the samples cannot cover all the year round implied to cover the most of flowering period, because flowering period of tree and shrubs are different from herbaceous plants in frequency, period and season. This is the limitation of this study.

With regard to different sources of palynological sediment, different type of soil can be comparison. Soil samples from TLP4 and TLP10, which are dark reddish brown to very dark grayish brown clay, contain more organic matter and well preservation of pollen, whereas samples from BRP8, which are brown to dark brown clay, gives less pollen than. Sampling sites of that TLP4 and TLP10 were derived from, are terrace deposit (33), which is a segment of floodplain. These areas are adjacent to streams subject to periodic flooding and alluvial deposition (46). Alluvial deposits contain fossil pollen and their gross trends can provide a record of vegetation

history not an immediate reflection of contemporaneous vegetation (19). As for the site that BRP8 came from, soil sediment was mostly derived from erosion of limestone area (2), which pollen may not be preserved very well. However, BRP8 can yield preserved pollen and spores, they yield some interesting result also.

Taxa from BRP8 are less diversity than TLP4 and TLP10 with high appearance of fern spores. It is doubtful, because this site is an ecotone of dry dipterocarp forest and mixed deciduous forest, but no pollen even one in this type forest, i.e. especially Dipterocarpaceae, was found. From the study of palynomorph preservation in mosses, soils and surface lake sediments, a number in records of corroded exine of pollen and spores from soil is higher than other sources (75). So it may be probable that some types of pollen grains are sensitive to be corroded in soil. There are differences of pollen and spores in preservation among taxa and between depositional layers of different ages and chemical and physical composition (46). However, it requires further study in ecological condition of pollen preservation with more variety of pollen types concerned with pollen production, preservation and form of deposition resulting from dispersal factor (72).

Regarding samples from archaeological sites, although it is rather accepted that samples from archaeological sites give in more negative result, it could be pointed out from this study that pollen grains were not found at the depth approximately below 90 cm. In addition, pollen cores from the collection points that are close to an archaeological site are more successful (46). Even though the relationship between environmental and archaeological context at that period may be not drawn directly, the environmental context can be more or less deduced to indirectly support.

4.5.2 Palaeovegetation and palaeoenvironment

From both Ban Tham Lod and Ban Rai, pollen and spores of two characteristics of ecological system consisting of tropical and sub-tropical floras are found together with difference in species composition. All three sequences, including TLP4, TLP10 and BRP8, suggest drier condition in the upper parts due to more open area.

For TLP4 and TLP10, the vegetation may present with pine, dry deciduous forest types, i.e. *Castanopsis* sp., *Glochidion* sp., Leguminosae, *Phyllanthus* sp.,

Quercus sp., *Shorea* sp., and *Xylia* sp., and evergreen forest types, i.e. Annonaceae, *Calocedrus* sp., Lauraceae and Ulmaceae. These forest types can be found commonly in Pang Mapha district (31, 32) and northern Thailand (67). The presence of some taxa types can indicate condition of open area or disturbance; most of these types are deciduous taxa such as *Glochidion* sp., Leguminosae, *Phyllanthus* sp. and *Terminalia* sp. (11, 54, 57, 59, 64).

Pine family forms a dominant element in north temperate area but very rare in the tropic; only 1 genus as *Pinus* sp. with 2 species are native to northern Thailand (64). Thailand is a distribution border of *Pinus* sp.; natural pine forests have been found in the north and northeastern of Thailand where are of sub-tropical climate. In the ordinary way, pines grow well in cool environments which long periods of cool weather with not much moisture are characteristically placed (76). In Pang Mapha district, the existence of *Pinus* sp. is reported at 700-1,100 meter AMSL with dry dipterocarp forest and above 1,000 meter AMSL in hill evergreen forest co-dominantly with members of Fagaceae (30, 31). Pine forest stands not far from both sampling sites that TLP4 and TLP10 were collected, for instance in site no.1 and no.3 reported in chapter III. Nevertheless, pine pollen in BRP8 seems to be further from pine forest than sampling sites of TLP4 and TLP10.

The prevalence of Leguminosae in the upper part of sequence TLP10 was interesting. Although legume seeds have ever been claimed by some archaeologist (77), pollen identified as Leguminosae is not enough to be implied as edible or cultivated type. It needs more study of pollen in this family, because it consists of a large number of members, which their pollen types are little known.

As for Poaceae, it is known to be a ground cover in deciduous and dry dipterocarp forest (68, 71). From field study, bamboos were found in all sites that TLP4, TLP10 and BRP8 were collected from; particularly these sites are defined as mixed deciduous forest, which bamboos are accepted to be important in disturbed area (67). So changes in percentage of Poaceae pollen may indicate area disturbance with supporting data of other taxa. With regard to pollen size, while cultivated rice is self-pollinated and produce not much pollen, the wild species appear to be wind-pollinated or produce a lot of pollen. Albeit bamboo size is giant herbs, the bamboos have rather small pollen grains (72). In this case, this may conclude that grass pollen found from

these sequences tends to be of bamboos and wild species maybe not from wild rice. It can be supported from above data of Poaceae analyzed with concept of pollen production, preservation, deposition and dispersal factor including area characteristics (72). However, dry rice cultivation and depositional process of it are still not known.

Sequences of TLP4 and BRP 8, with determined age of 280 to 0 BP (Beta-206533, calibrated age) and 670 to 550 BP (Beta-206534, calibrated age) respectively, indicate more or less cooler condition in the past, but suggest the drier condition at present time, which may be caused by changes in the vegetation due to more open area and forest disturbance. Considering with periods of cooler condition, both radiocarbon ages as 280 to 0 (Beta-206533, calibrated age) and 670 to 550 BP (Beta-206534, calibrated age) are coincident with the return of cold climate in Europe around AD 1,400-1,550 (550-400 BP) and the period of Little Ice Age around AD 1,550-1,850 (400-100 BP) (50, 51). However, if it is possible, more environmental study at these periods are required for more explanation.

The result of pollen analysis from Tham Lod rock shelter discussed with animal bone analysis consistent with preliminary study (2) can implied the forest types as deciduous, dry dipterocarp, bamboo, grass land and hill evergreen forest. Even though, only pollen data can not strongly support those mentioned forest types, they can only suggest that plants in past vegetation, approximately $12,100 \pm 60$ BP (Beta-168223) to Holocene age (2), were similar to the present and climate may be likely to the present also, even if it can point neither the major change nor fluctuation.

The results from Ban Rai rock shelter together with preliminary study (2) can present taxa in tropical and sub-tropical flora that are similar to the present but less detail in other ways, while only pine pollen can be found in BRA2#882 dating to $10,210 \pm 50$ BP (Beta-168219). It is affected of discontinuity in pollen data.

Referred to pollen data in Late Pleistocene period (8, 11, 54, 55, 61), they could present that plants are of modern type. Considering with previous assumption of palaeoenvironment (1, 2), this study could not explain deeply in the vegetation aspect not like pollen data from Kwan Phayao in Northern and Lake Kumphawapi in Northeastern Thailand that can suggest a cool and dry environment in Late Pleistocene, but it would submit that the environment of Ban Tham Lod and Ban Rai was similar to the present in Late Pleistocene and Holocene period. The presence of

Pinus sp. in every sample from archaeological site although may indicate a cool condition, it necessitates more data to support the conclusion.

Finally, comparison between radiocarbon age and the depth of sample can suggest that deposition rate at site no.2 is higher than site no.7. This is coincident with the characteristic of areas in that the deposition rate in terrace area could be high because flowing water may influence periodically this area (46).



CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The majority of pollen grains and fern spores can be identified from samples from both Ban Tham Lod and Ban Rai. The study of modern pollen is of use for identification, but it requires much time. Small numbers of pollen grains and fern spores were grouped as unidentified type. The identified pollen grain and spores were classified into a group of tree and shrub, herbaceous plant, fern and fern allies, palm, aquatic plant and algae, and they are grouped as tropical and sub-tropical flora for the environment analyses.

Vegetation changes can be obtained from samples from area around Tham Lod and Ban Rai rockshelter, but cannot be obtained from samples from the excavation areas. Considering the results of pollen analysis from eight samples of TLP4, ten samples of TLP10 and nineteen samples of BRP8, it can be suggested that the palaeovegetation of study area including Ban Tham Lod and Ban Rai in Pang Mapha district has been similar with the present forest types. Pollen diagrams present changes of species composition in each site.

According to palynological data of TLP4 after 280 to 0 BP (Beta-206533, calibrated age), they show that vegetation around this site may be of deciduous and pine forest together with taxa those are preferable damp condition and aquatic type. Vegetation change can indicate that the land use of the study area has changed to be more open space. Whereas for TLP10, the vegetation around this site may be of deciduous, pine and secondary forest type together with taxa those are preferable damp condition and aquatic type like that in TLP4. In addition, it presented a change with decreasing of ferns that can be implied to less moisture by more open area. On the other hand, this could be concluded that these sites are dry land vegetation that tended to be more open area.

Palynological data of BRP8 could not show a change in species composition of deciduous forest and dry dipterocarp forest which are the present characteristic of this site. This site is of deciduous vegetation type which the distance of pine forest from this site is more than from sites at Ban Tham Lod. However, palynological data of the upper part of BRP8 sequence through the uppermost showed the dramatically increasing of grass pollen affected by forest disturbance; herbaceous plants and ferns can present that this site was also tended to be more open area. Human activity is the most possible factor related this change.

About interpretation from both TLP4 and BRP8, it could be suggestive of slightly cooler condition before 2 intervals in the past from the decreasing trend of *Pinus* sp. in BRP8 after 670 to 550 BP (Beta-206534, calibrated age) and in TLP4 after 280-0 BP (Beta-206533, calibrated age). Nevertheless, it is not clear about the cause of vegetation changes in both study areas. It may be from natural forest fire, climatic change, deforestation or other disturbances from human activities. However, it can be indicated that nowadays the forest was more disturbed than before.

Pollen analysis of samples from the excavation sites gave less detail in palaeovegetation and palaeoenvironment. This study could suggest that the environment of Ban Tham Lod and Ban Rai was similar to the present in Late Pleistocene and Holocene period. Regarding archaeological context and preliminary study (2) along with pollen data, it may conclude that the environs of Tham Lod rock shelter has been alike as present. However, this conclusion is not strong because of a very little amount of pollen. The environs of Ban Rai rock shelter have not dramatically changed approximately since 10,210 \pm 50 BP (Beta-168219) to Holocene period. Nevertheless, it could not indicate type or the plenty of forest from this data.

Besides, it may suggest that palynological study can be succeeded from area around archaeological site more than excavation area.

5.2 Recommendation

From this study, it can compare between sites that terrace deposit yields more concentration and diversity of pollen than the valley between mountainous areas with high deposition rate than as well. As a result from Ban Rai site, it is interesting

that why pollen of dry dipterocarp and mixed deciduous forest, particularly teak and dipterocarp, was not found. Thus it may suggest studying the condition of pollen preservation to explain this event.

To interpret pollen diagram, it is necessary to analysis, compare and link the palaeoenvironment of each area with chronological series and other subject such as plant ecology and history of each area to obtain the better interpretation of palaeoenvironment.

The limitation of time is of paramount importance for palynological study. Owing to the diversity of tropical floras, it needs to spend more time to be familiar with and expert in pollen identification. Such as from identification, there are many types of fern spores that can not be classified.

Moreover, there is a lack of basic data of palynological morphology especially Thailand flora and it needs to have modern pollen reference as much as possible for more accuracy in identification and interpretation. Because the study of modern pollen is very helpful for identification, if it is possible, modern pollen collection all year round from the study area is suggested to do.

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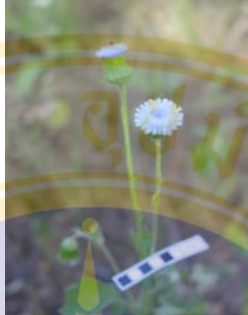





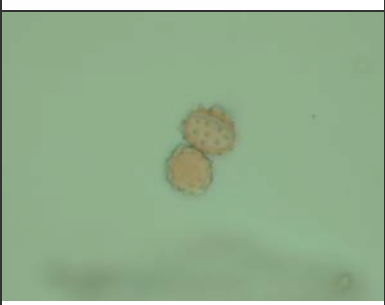

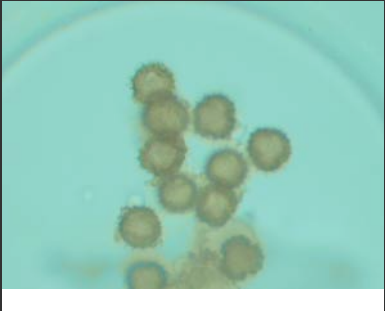
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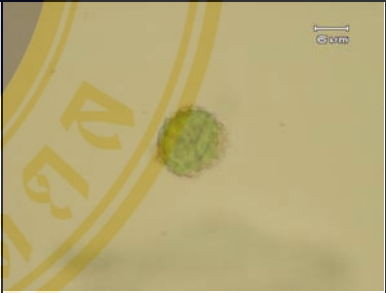

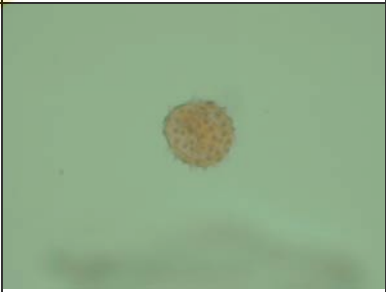


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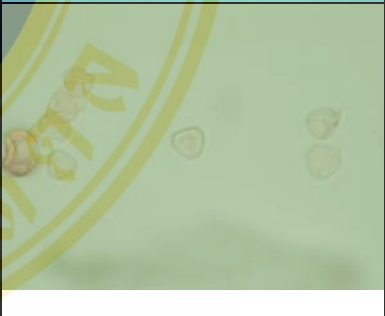
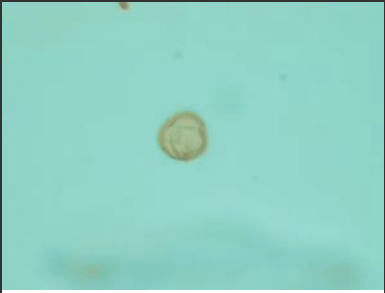


APPENDIX A: Modern Pollen Result

Table A-1 Result of modern pollen around Tham Lod sites

Sample no.	Plant habits and taxa	Plant sample	Pollen result
STL1-001	Herbaceous plant- Compositae		
STL1-002	Shrub- Leguminosae		
STL1-003	Shrub		
STL1-004	Herbaceous plant- Compositae		
STL3-001	Herbaceous plant- Compositae		

Sample no.	Plant habits and taxa	Plant sample	Pollen result
STL3-002	Herbaceous plant- <i>Fissondocarpus linifolia</i> Bennet Onagraceae		
STL3-003	Herbaceous plant- Acanthaceae		
STL3-004	Herbaceous plant- Compositae		
STL3-005	Herbaceous plant- Compositae		
STL3-006	Herbaceous plant- Compositae		

Sample no.	Plant habits and taxa	Plant sample	Pollen result
STL3-007	Orchidaceae		
STL3-008	Herbaceous plant-		
STL3-009	Herbaceous plant- Compositae		
STL3-010	Tree- <i>Syzygium cumini</i> (Linn.) Skeels or <i>Euginia cumini</i> Druce Myrtaceae		
STL3-011	Herbaceous plant- Compositae		
STL3-012	Tree- <i>Shorea obtuse</i> Dipterocarpaceae		



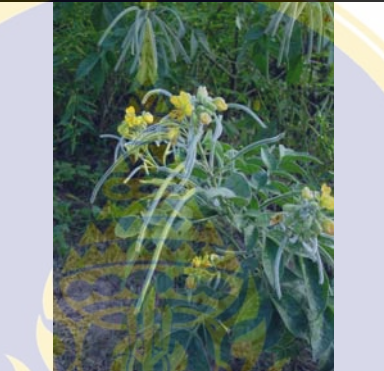




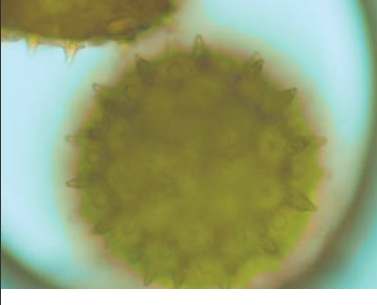

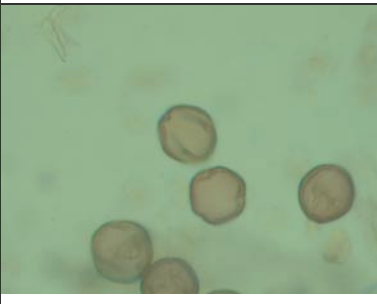






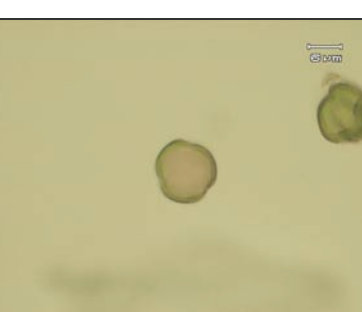


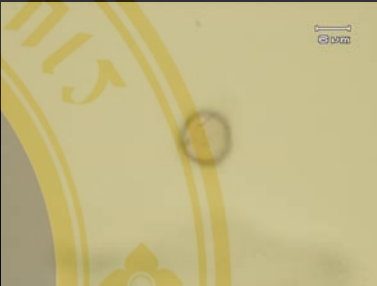





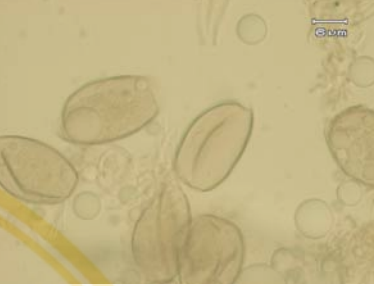





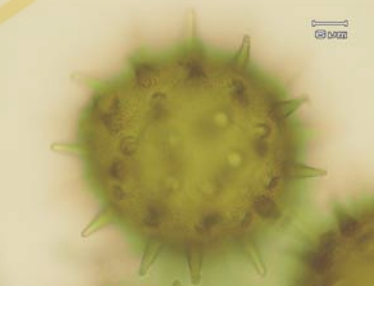

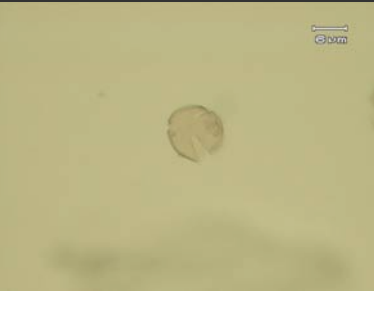
Sample no.	Plant habits and taxa	Plant sample	Pollen result
STL3-013	Orchidaceae		
STL4-001	Herbaceous plant- <i>Cleome viscosa</i> L. Capparaceae		
STL4-002	Herbaceous plant- <i>Spilanthes acmella</i> Murr. Compositae		
STL4-003	Herbaceous climber- <i>Ipomoea</i> sp. Convolvulaceae		
STL4-004	Tree- <i>Sterculia pexa</i> Sterculiaceae		

Table A-2 Result of modern pollen around Ban Rai sites

Sample no.	Plant habits and taxa	Plant sample	Pollen result
SBR1-001	Herbaceous plant- Acanthaceae		
SBR1-002	Herbaceous plant		
SBR1-003	Herbaceous plant		
SBR1-004	Herbaceous plant- Zingiberaceae		
SBR1-005	Shrub		

Sample no.	Plant habits and taxa	Plant sample	Pollen result
SBR1-006	Shrub		
SBR1-007	Tree- <i>Sterculia villosa</i> Sterculiaceae		
SBR1-008	Shrub		
SBR1-009	Shrub		
SBR1-010	Palm- Palmae		

Sample no.	Plant habits and taxa	Plant sample	Pollen result
SBR1-011	Herbaceous plant		
SBR2-001	Shrub- Malvaceae		
SBR2-002	Herbaceous plant- Leguminosae		
SBR2-003	Herbaceous plant- Malvaceae		
SBR2-004	Tree- <i>Shorea siamensis</i> Dipterocarpaceae		


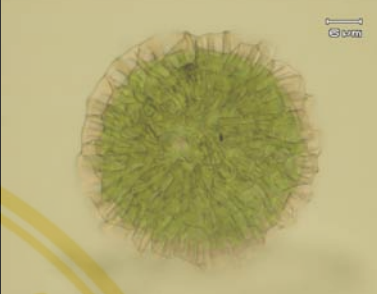

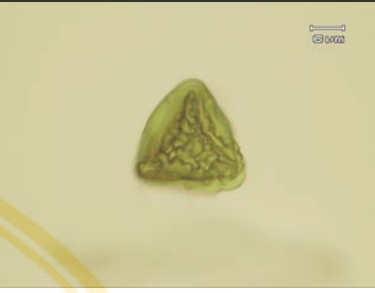

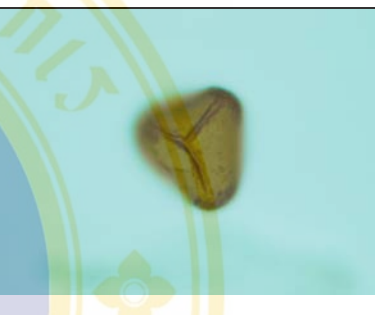
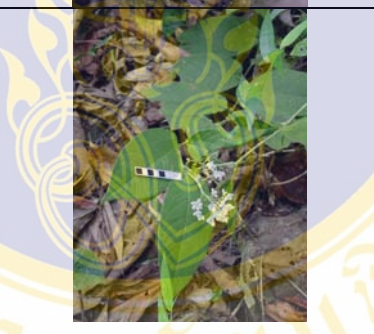
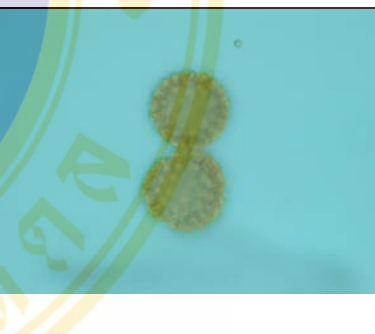

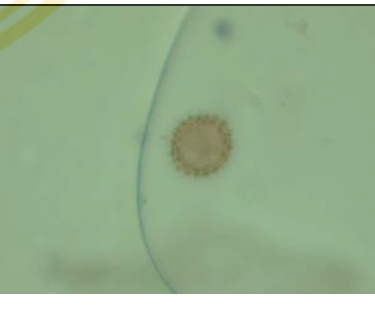





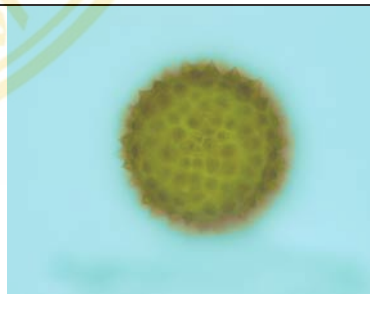

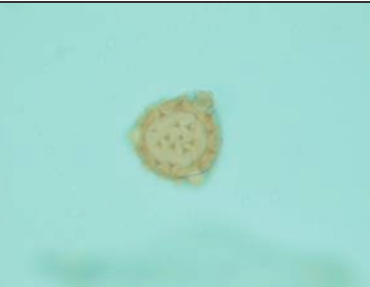









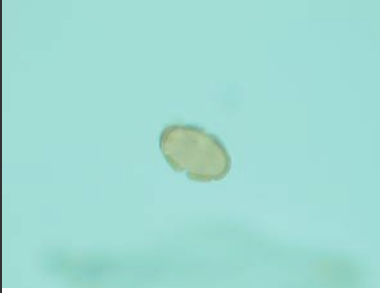
Sample no.	Plant habits and taxa	Plant sample	Pollen result
SBR3-001	Shrub- <i>Barleria</i> sp. Acanthaceae		



Table A-3 Result of modern pollen around Tham Lod rock shelter

Sample no.	Plant habits and taxa	Plant sample	Pollen result
SMT-001	Fern- <i>Pteris</i> sp. Pteridaceae		
SMT-002	Fern- <i>Adiantum</i> sp. Pteridaceae		
SMT-003	Shrub		
SMT-004	Herbaceous plant- <i>Spilanthes acmella</i> Murr. Compositae		
SMT-005	Herbaceous plant- Poaceae		

Sample no.	Plant habits and taxa	Plant sample	Pollen result
SMT-006	Herbaceous plant-		
SMT-007	Herbaceous plant- Acanthaceae		
SMT-008	Herbaceous plant- <i>Asystasia</i> sp. Acanthaceae		
SMT-009	Herbaceous plant- Malvaceae		
SMT-010	Herbaceous plant- <i>Tithonia diversifolia</i> (Hemsley) A. Gray Compositae		

Sample no.	Habitat and taxa	Plant sample	Pollen result
SMT-011	Herbaceous plant- <i>Ageratum conyzoides</i> L. Compositae		
SMT-013	Herbaceous plant- <i>Alternanthera frutescens</i> R. Br. Amaranthaceae		
SMT-014	Herbaceous plant		
SMT-015	Herbaceous plant - Acanthaceae		
SMT-016	Herbaceous plant - Labiatae		

APPENDIX B: Pollen Counting Data

Table B-1 Data of pollen and spore from samples sequence TLP4

Sample No.	Depth(cm)	Tree & Shrub										Herbaceous plant										Fern and fern allies										Palms	Aquatic plant	Algae	Unidentified type	Total count
		<i>cf. Calocedrus</i> sp.	<i>Annonaceae</i>	<i>cf. Calocedrus</i> sp.	<i>Castanopsis</i> sp.	<i>Glochidion</i> sp.	<i>Lauraceae</i>	<i>Pinus</i> sp.	<i>Shorea</i> sp.	<i>Ulmaceae</i>	<i>Acanthaceae</i>	<i>Amaranthaceae</i>	<i>Cheno-Amaranthaceae</i>	<i>Compositae</i>	<i>Cyperaceae</i>	<i>Malvaceae</i>	<i>Poaceae</i>	<i>Polygonum</i> sp.	<i>cf. Bobbitis</i> sp.	<i>Chelidonium</i> sp.	<i>Cyathus</i> sp.	<i>Lycopodiaceae</i>	<i>Lycopodium</i> sp.	<i>Mikrotropis</i> sp.	<i>Ophioglossum</i> sp.	<i>Polypodaceae</i>	<i>Pteridaceae</i>	<i>Pteris</i> sp.	<i>Psittacanthaceae</i>	<i>Schizaeaceae</i>	Palms					
TLP401	3-20	0	0	0	0	3	2	51	4	0	1	0	10	2	1	3	39	0	0	1	6	12	27	0	0	16	2	5	12	18	0	0	6	0	221	
TLP402	20-35	2	0	0	0	5	1	110	1	1	1	5	3	7	2	34	0	2	0	5	2	14	0	0	24	6	6	20	11	0	0	4	0	266		
TLP403	35-50	1	0	12	16	12	229	14	1	7	0	64	0	13	0	85	0	0	0	7	12	14	0	0	78	23	8	25	18	1	8	3	0	651		
TLP404	50-65	0	0	0	1	0	58	0	0	0	11	0	6	0	64	3	1	0	0	0	9	0	0	0	22	1	2	22	6	0	0	3	0	209		
TLP405	65-80	0	0	1	0	0	103	1	0	0	3	0	0	23	1	23	1	2	2	6	0	13	0	0	38	2	5	21	15	0	0	1	0	242		
TLP406	80-95	0	0	1	0	0	86	0	0	0	9	0	3	1	45	1	2	2	2	2	5	7	0	0	25	8	1	21	5	0	0	2	1	227		
TLP407	95-110	0	1	1	7	0	153	0	0	0	25	0	8	0	65	0	1	0	4	6	0	1	1	1	41	8	3	10	9	0	2	1	4	351		
TLP408	110-124	0	0	1	1	0	137	1	0	0	0	0	3	0	40	0	0	0	4	3	2	0	0	0	15	8	7	4	7	0	3	1	240			

Table B-2 Percentage of pollen and spore from samples sequence TLP4

Sample No.	Depth(cm)	Tree and Shrub										Herbaceous plant								Fern and fern allies										Palm		Aquatic plant		Algae	
		Annonaceae	Castanopsis sp.	Glochidion sp.	Lauraceae	Pinus sp.	Shorea sp.	Ulmaceae	Acanthaceae	Amaranthaceae	Cheno-Amaranthaceae	Compositae	Cyperaceae	Malvaceae	Poaceae	Polygonum sp.	cf. Bobbitz sp.	Chelidonium sp.	Cyathus sp.	Lycopodiaceae	Lygodium sp.	Microlepia sp.	Ophioglossum sp.	Polypodaceae	Parlatia spore	Pteris sp.	Peridophytic spore	Schizaceae	Palmace	cf. Blyxa sp.	Chrookiales and Concentricytes	Unidentified type			
TLP401	3-20	0	0	1.4	0.9	23.1	1.8	0	0.5	4.5	0.9	0.5	1.4	17.6	0	0	0	0.5	2.7	5.4	12.2	0	0	7.2	0.9	2.3	5.4	8.1	0	0	2.7	0			
TLP402	20-35	0.8	0	1.9	0.4	41.3	0.4	0	0.4	1.9	1.1	2.6	0.8	12.8	0	0.8	0	1.9	0.8	5.2	0	0	9	2.2	2.2	7.5	4.1	0	0	1.5	0				
TLP403	35-50	0.2	0	2.5	1.8	35.1	2.2	0.2	1.1	0.9	0	2	0	13	0	0	0	1.1	1.8	2.2	0	0	12	3.5	1.2	3.8	2.8	0.2	1.2	0.5	0				
TLP404	50-65	0	0	0.5	0	27.7	0	0	0	5.3	0	2.9	0	30.6	1.4	0.5	0	0	4.3	0	0	10.5	0.5	1	10.5	2.9	0	0	1.4	0					
TLP405	65-80	0	0	0	0	42.6	0.4	0	0	1.2	1.2	0	0	9.5	0.4	0.8	0.8	2.5	0	5.5	0	0	15.7	0.8	2.1	8.7	6.2	0	0	0.4	0				
TLP406	80-95	0	0	0	0	37.9	0	0	0	4	0	1.3	0.4	19.8	0.4	0.9	0.9	0.9	2.2	3.1	0	0	11	3.6	0.4	9.3	2.2	0	0	0.9	0.4				
TLP407	95-110	0	0.3	2	0	43.5	0	0	0	7.1	0	2.3	0	18.5	0	0.3	0	1.1	1.7	0	0.3	0.3	11.7	2.3	0.9	2.8	2.6	0	0.6	0.3	1.1				
TLP408	110-124	0	0	0.4	0	57.1	0.4	0	0	0	0	1.3	0	16.7	0	0	0	1.7	1.3	0.8	0	0	6.2	3.3	2.9	1.7	2.9	0	1.3	1.3	0.3				

Figure B-1 Percentage of plant groups of TLP4

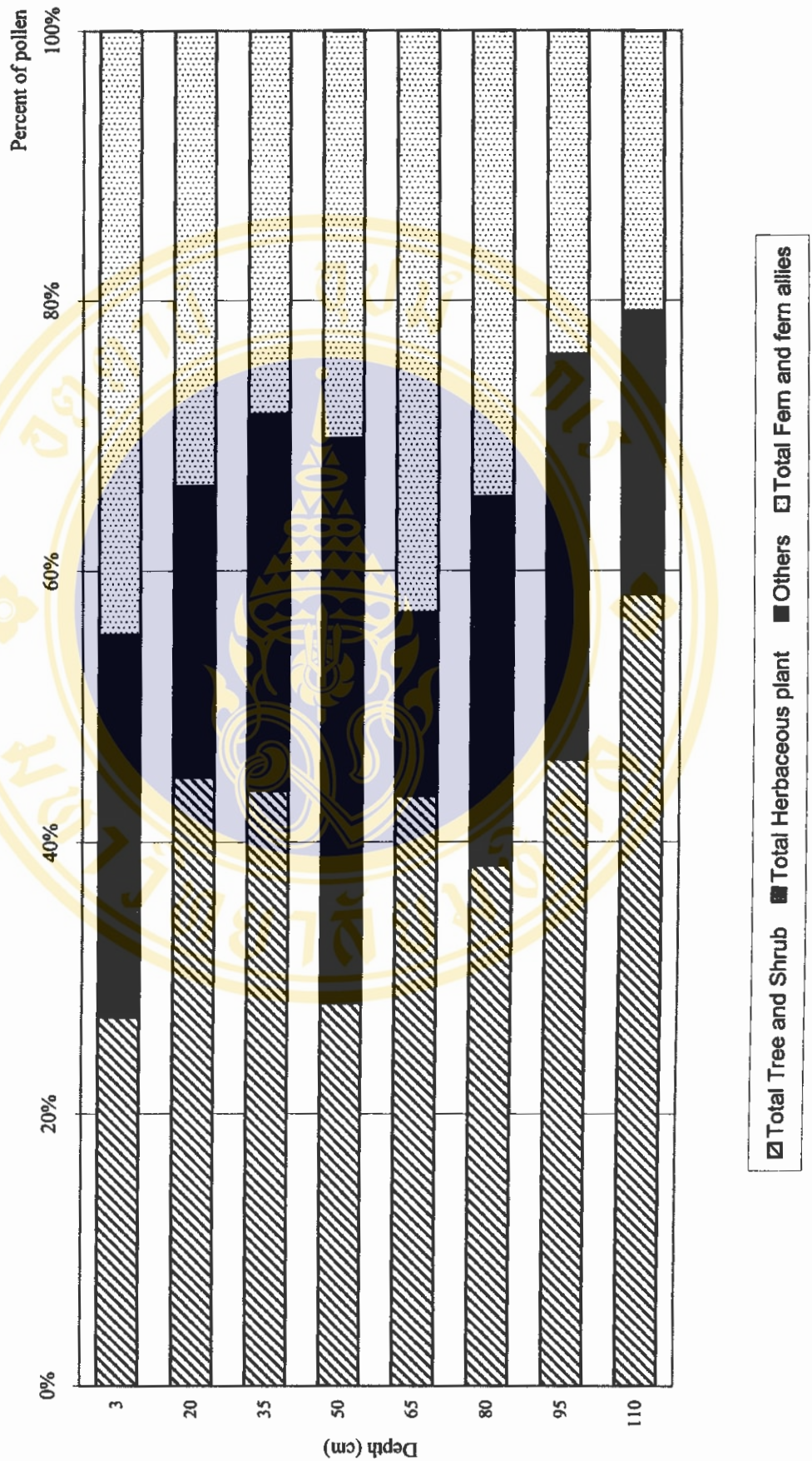


Table B-3 Data of pollen and spore from samples sequence TLP10

Sample No.	Depth(cm)	Tree & Shrub															Herbaceous plant															Fern and fern allies										Pa lm		Aquatic plant		Algae		Total count
		Alnus sp.	Betula sp.	Castanopsis sp.	Glochidion sp.	Leguminosae	Phyllanthus sp.	Pinus sp.	Quercus sp.	Shorea sp.	Symplocos sp.	Syzygium sp.	Terminalia sp.	Urticaceae	Xylin sp.	Acanthaceae	Alternanthera sp.	Cheno-Amaranthaceae	Compositae	Cyperaceae	Tiliaceae/Amaryllidaceae	Malvaceae	Moraceae	Polygonum sp.	Chenanthus sp.	Cyathus sp.	Davallia sp.	Lycopodiaceae	Lygodium sp.	Mitrocladia sp.	Mnolete spore	Ophioglossum sp.	Polyodiaceae	Pteridiate spore	Pteris sp.	Pteridophytic spore	Schizaceae	cf. Calamus sp.	Palmae	cf. Blyxa sp.	Cryptophytes and Concentricytes	Unidentified type						
TLP1001	3-12	0	0	9	19	117	7	61	6	1	0	1	56	0	3	2	0	16	4	3	1	1	0	64	6	1	2	0	24	1	0	18	18	1	47	7	1	0	4	2	11	515						
TLP1002	12-24	0	0	3	4	37	1	110	4	0	0	1	0	1	0	1	6	6	2	1	1	0	49	4	1	1	0	24	2	1	3	0	29	16	7	49	12	0	1	14	6	397						
TLP1003	24-36	0	2	8	1	99	1	242	13	7	2	2	4	2	5	2	0	25	1	13	4	2	0	109	13	0	7	0	53	0	0	60	27	6	65	12	0	3	12	10	836							
TLP1004	36-48	0	1	19	0	55	0	130	6	4	0	0	0	0	1	0	0	32	3	3	8	2	2	77	5	1	3	0	32	2	2	41	20	7	40	8	0	2	6	4	524							
TLP1005	48-60	1	0	5	0	27	0	162	7	3	0	0	0	0	1	0	0	30	1	10	11	1	0	47	1	1	1	0	24	0	0	43	10	3	18	5	0	6	2	468								
TLP1006	60-72	0	0	6	0	14	1	66	6	2	0	0	0	0	4	1	0	11	5	5	5	0	0	44	1	1	3	0	33	1	2	7	0	37	9	1	50	6	0	1	10	2	335					
TLP1007	72-84	0	0	8	0	49	2	145	4	0	0	2	2	0	2	0	0	18	1	8	5	0	0	78	1	0	3	0	23	0	0	32	7	4	20	6	1	0	3	6	504							
TLP1008	84-96	1	0	1	0	17	0	160	0	2	2	0	0	0	3	0	0	31	0	3	1	0	0	57	0	1	7	0	28	1	0	39	27	8	32	9	0	0	2	8	0	471						
TLP1009	96-108	0	0	0	0	5	0	36	0	1	0	0	0	0	0	0	0	10	2	3	2	1	0	48	0	0	1	1	19	0	0	19	4	3	34	2	0	0	2	2	4	199						
TLP1010	108-119	0	0	1	0	2	0	19	0	0	0	0	0	0	0	0	0	6	1	4	0	1	0	15	0	0	2	0	11	0	0	13	5	6	14	1	0	0	1	0	1	103						

Table B-4 Percentage of pollen and spore from samples sequence TLP10

Sample No.	Depth(cm)	Tree and Shrub															Herbaceous plant										Fern and fern allies											Pa hm		Aquatic plant		Algae	
		Alnus sp.	Betula sp.	Castanopsis sp.	Glochidion sp.	Leguminosae	Phyllanthus sp.	Pinus sp.	Quercus sp.	Shorea sp.	Symplocos sp.	Syzygium sp.	Terminalia sp.	Urticaceae	Xylin sp.	Acanthaceae	Altemanthera sp.	Cheno-Amaranthaceae	Compositae	Cyperaceae	Liliaceae/Amaryllidaceae	Marvaceae	Merrillia sp.	Poraceae	Polygonum sp.	Chelidonium sp.	Cyathea sp.	Davallia sp.	Lycopodiata	Lygodium sp.	Microrlepis sp.	Monolete spore	Ophioglossum sp.	Polypodaceae	Psittacete spore	Prick sp.	Pteridophytic spore	Schizaceae	cf. Calamus sp.	Palmae	cf. Blyxa sp.	Undetermined type	
TLP1001	3-12	0	0	1.7	3.7	22.7	1.3	11.8	1.2	0.2	0.2	10.9	0	0.6	0.4	0	3.1	0.8	0.6	0.2	0.2	0	0	12.4	1.2	0.2	0.4	0	4.7	0.2	0	0.2	0	3.5	3.5	0.2	9.1	1.3	0.2	0	0.8	0.4	2.1
TLP1002	12-24	0	0	0.7	1	9.3	0.3	27.7	1	0	0	0.3	0	0.3	0	0.3	1.5	1.5	0.5	0.3	0.3	0	0	12.3	1	0.3	0.3	0	6	0.5	0.3	0.7	0	7.3	4	1.7	12.3	3	0	0	0.3	3.5	1.5
TLP1003	24-36	0	0.2	1	0.1	11.9	0.1	29	1.6	0.8	0.2	0.5	0.2	0.6	0.2	0	3	0.1	1.6	0.5	0.2	0	0	13	1.6	0.2	0.8	0	6.4	0	2.9	0	7.2	3.2	0.7	7.8	1.4	0	0	0.4	1.4	1.2	
TLP1004	36-48	0	0.2	3.6	0	10.5	0	24.8	1.1	0.8	0	0	0.2	0.2	0	6.1	0.6	0.6	1.5	0.4	0.4	0.4	14.7	1	0.2	0.6	0.6	6.1	0.4	1.5	0	7.8	3.8	1.3	7.6	1.5	0	0	0.4	1.1	0.8		
TLP1005	48-60	0.2	0	1.1	0	5.8	0	34.6	1.5	0.7	0	0	0.2	0.2	0	6.4	0.2	2.1	2.4	0.2	0	0	10	0.2	0.2	0.2	0	5.1	0	8.8	0.2	9.2	2.1	0.7	3.8	1.1	0	0	1.3	0.4			
TLP1006	60-72	0	0	1.8	0	4.2	0.3	19.7	1.8	0.6	0	0	1.2	0.3	0.3	3.3	1.5	1.5	1.5	0	0	13.1	0.3	0.3	0.9	0	9.8	0.3	0.6	2.1	0	11	2.7	0.3	14.9	1.8	0	0.3	0.3	3	0.6		
TLP1007	72-84	0	0	1.6	0	9.7	0.4	28.7	0.8	0	0.4	0.4	0.4	0	0	3.5	0.2	1.6	1	0	0	15.4	0.2	0	0.6	0	4.5	0	14	0	6.3	1.4	0.8	0.4	1.2	4	0	0.6	0.6	1.2			
TLP1008	84-96	0.2	0	0.2	0	3.6	0	34	0.4	0.4	0	0	0.6	0	0	6.6	0	0.6	0.2	0	0	12.1	0	0.2	1.5	0	6	0.2	6.6	0	8.3	5.8	1.7	6.8	1.9	0	0	0.4	1.7	0			
TLP1009	96-108	0	0	0	0	2.5	0	18.1	0	0.5	0	0	0	0	0	5	1	1.5	1	0.5	0	24.1	0	0	0.5	0.5	9.6	0	0	0	9.6	2	1.5	17.1	1	0	0	1	1	2			
TLP1010	108-119	0	0	1	0	1.9	0	18.4	0	0	0	0	0	0	0	5.8	1	3.9	0	1	0	14.6	0	0	1.9	0	10.7	0	0	0	12.6	4.8	5.8	13.6	1	0	0	1	0	1			

Figure B-2 Percentage of plant groups of TLP10

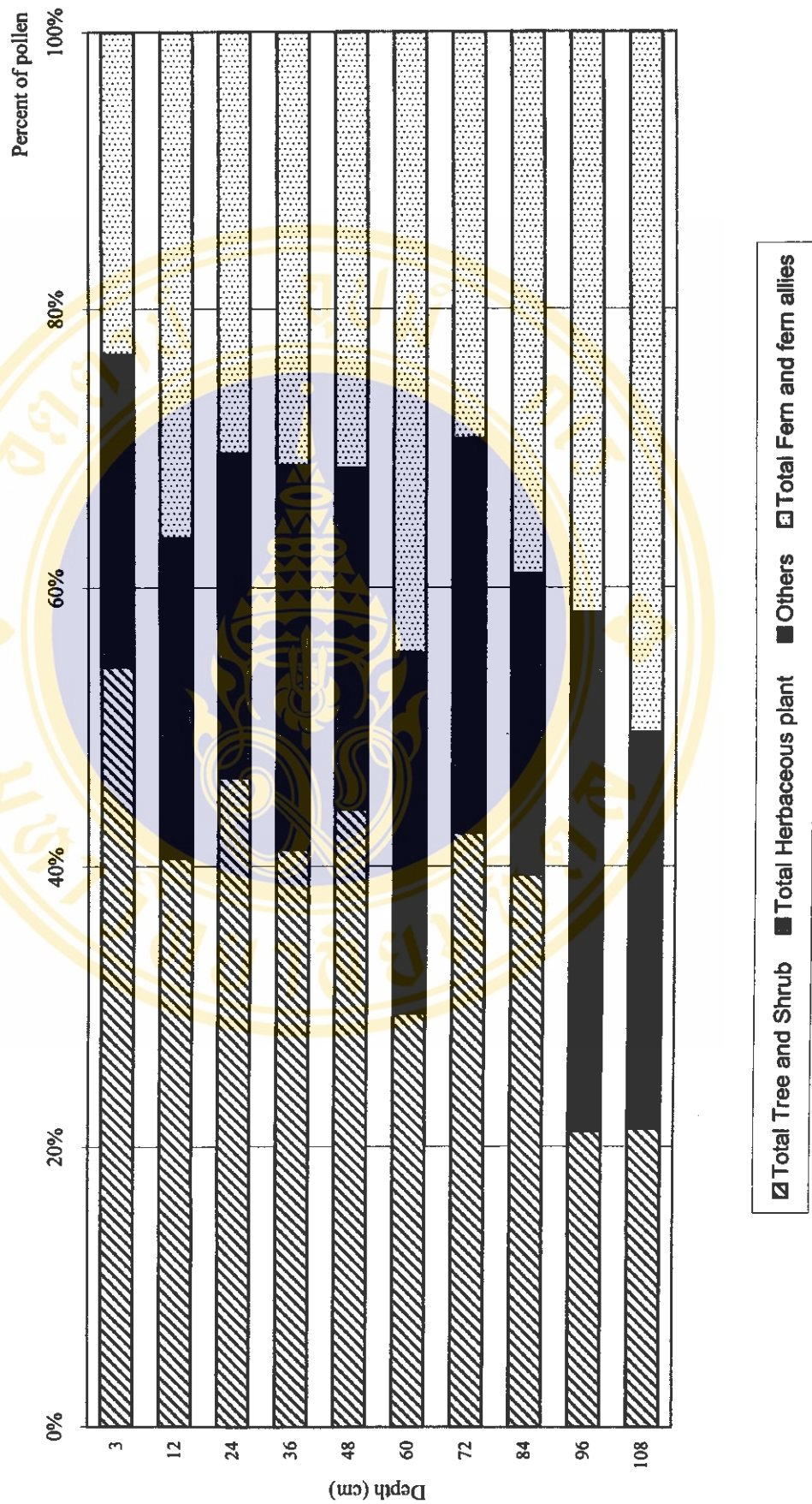


Table B-5 Data of pollen and spore from samples sequence BRP8

Sample No.	Depth(cm)	Tree & Shrub										Herbaceous plant						Fern and fern allies											Algae		Total count
		Annaceae	cf. Bauhinia sp.	Castanopsis sp.	Jatropha type	Leguminosae	Pinus sp.	Xylia sp.	Cheno-Amaranthaceae	Compositae	Cyperaceae	Malvaceae	Poaceae	cf. Bobbitis sp.	Chelidonium sp.	Cyperus sp.	Davallia sp.	Lycopodiaceae	Lygodium sp.	Microlepia sp.	Ophioglossum sp.	Osmunda sp.	Polypodiaceae	Psittaculaceae	Pteris sp.	Schizaceae	Pteridophytic spore	Cryptophytes and Concomitantes	Unidentified type		
BRP801	3-11	0	0	0	0	0	23	0	0	2	13	0	81	1	0	2	0	0	5	0	0	0	26	23	3	31	22	8	10	258	
BRP802	11-18	0	0	0	1	0	1	0	0	2	0	14	0	3	0	0	0	7	1	0	0	0	22	34	0	7	42	2	2	138	
BRP803	18-25	0	0	0	0	1	6	0	1	2	3	0	31	1	0	3	0	9	0	0	0	0	46	33	49	12	44	6	0	247	
BRP804	25-32	0	1	0	0	0	6	1	0	0	5	0	29	0	0	0	0	0	9	0	0	0	29	7	113	7	10	11	5	233	
BRP805	32-39	0	0	0	0	3	0	1	0	0	1	0	3	0	0	6	0	0	1	0	0	0	69	20	80	16	43	10	2	255	
BRP806	39-46	0	0	0	0	0	0	0	0	0	2	0	0	0	3	0	0	2	1	0	0	55	15	84	9	29	16	1	220		
BRP807	46-53	0	1	0	0	0	1	0	0	0	3	0	1	0	0	4	0	0	4	0	0	93	9	24	9	17	6	9	179		
BRP808	53-60	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	29	3	3	13	19	2	2	80		
BRP809	60-67	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	64	17	8	31	37	4	9	204	
BRP810	67-74	0	1	0	0	0	4	0	0	0	1	0	16	0	0	4	0	0	7	0	1	0	155	25	21	18	17	14	2	279	
BRP811	74-81	0	1	0	1	1	6	0	2	0	0	2	0	0	5	2	0	3	4	0	0	175	32	84	37	33	29	5	429		
BRP812	81-88	0	2	0	1	0	8	0	0	1	0	3	0	10	0	9	0	0	13	0	0	1	70	19	33	16	11	20	17	238	
BRP813	88-95	0	8	0	0	0	4	0	1	0	6	0	10	0	0	0	0	0	0	0	0	42	30	21	35	33	14	2	211		
BRP814	95-103	0	2	1	5	0	8	0	0	0	0	2	5	0	0	3	1	1	2	2	2	0	55	53	14	48	30	48	8	311	
BRP815	103-111	0	5	0	3	0	14	0	2	0	5	4	7	0	0	1	0	0	10	3	1	0	30	32	2	21	35	0	224		
BRP816	111-119	0	4	0	5	2	10	0	0	0	6	0	25	0	0	5	0	2	6	3	0	1	30	32	2	21	35	0	224		
BRP817	119-127	0	1	1	2	0	14	0	0	2	8	3	13	0	3	7	0	0	14	3	0	0	32	29	13	24	24	10	227		
BRP818	127-135	0	0	0	4	0	13	1	1	1	12	2	22	0	0	6	0	1	11	2	3	0	40	45	12	24	35	13	7	255	
BRP819	135-143	1	0	0	1	0	21	0	0	0	14	2	20	0	0	7	0	0	16	0	0	0	37	27	32	18	10	54	0	269	

Table B-6 Percentage of pollen and spore from samples sequence BRP8

Sample No.	Depth(cm)	Tree and Shrub							Herbaceous plant					Fern and fern allies											Algae				
		Amoracaceae	cf. Bauhinia sp.	Castanopsis sp.	Jatropha type	Leguminosae	Pinus sp.	Xylia sp.	Cheno-Amaranthaceae	Compositae	Cyperaceae	Malvaceae	Poaceae	cf. Bolbitis sp.	Chelanthus sp.	Cyathia sp.	Davallia sp.	Lycopoda	Lygodium sp.	Microlepia sp.	Ophioglossum sp.	Osmunda sp.	Polyodiaceae	Psittacite spore	Pteris sp.	Peridophytic spore	Schizaceae	Unidentified type	
BRP801	3-11	0	0	0	0	0	0	0	0.8	5.2	0	32.4	0.4	0	0.8	0	0	2	0	0	0	0	10.4	9.2	1.2	8.8	12.4	3.2	4
BRP802	11-18	0	0	0	0.7	0	0.7	0	0	1.5	0	10.1	0.4	0	0	0	5.1	0.7	0	0	0	0	15.9	24.6	0	30.4	5.1	1.5	1.5
BRP803	18-25	0	0	0	0	0.4	2.4	0	0.4	0.8	1.2	0	12.6	0	0	1.2	0	3.7	0	0	0	0	18.6	13.4	19.8	17.8	4.9	2.4	0
BRP804	25-32	0	0.4	0	0	0	2.6	0.4	0	0	2.2	0	12.4	0	0	0	0	3.9	0	0	0	0	12.4	3	48.5	4.3	3	4.7	2.2
BRP805	32-39	0	0	0	1.2	0	0.4	0	0	0	0.4	0	1.2	0	0	0	0	0.4	0	0	0	0	27	7.8	31.4	16.9	6.3	3.9	0.7
BRP806	39-46	0	0	0	0	0	1.4	0	0	0	0.9	0	0	0	0	0	1.4	0	0	0.9	0.4	0	25	6.8	38.2	13.2	4.1	7.3	0.4
BRP807	46-53	0	0	0	0	0	0	0	0	0	1.7	0	0.6	0	0	0	2.2	0	0	2.2	0	0	52	5	13.4	9.5	5	3.4	5
BRP808	53-60	0	1.8	0	0	0	1.8	0	3.6	0	0	0	3.6	1.8	0	0	1.8	0	0	0	0	0	19.6	8.9	7.1	28.6	21.4	0	0
BRP809	60-67	0	0	0	1.3	0	1.3	0	3.7	0	0	1.3	1.3	0	0	0	2.3	0	0	0	0	0	36.2	3.7	3.7	23.7	16.3	2.5	2.5
BRP810	67-74	0	0.5	0	0	0	2	0	0	0	0.5	0	7.8	0	0	0	3.4	0	0.5	0	0.5	0	31.4	8.3	3.9	18.1	15.2	2	4.4
BRP811	74-81	0	0.4	0	0.4	0.4	2.1	0	0.7	0	0	0	0.7	0	0	1.8	0.7	0	1.1	1.4	0	0	55.6	9	7.5	6.1	6.4	5	0.7
BRP812	81-88	0	0.5	0	0.2	0	1.9	0	0	0	0.2	0	0.7	0	0	0.7	1.9	0	0.2	1.6	0	0	40.8	7.5	19.6	7.7	8.6	6.7	1.2
BRP813	88-95	0	3.4	0	0	0	1.7	0	0.4	0	2.5	0	4.2	0	0	3.8	0	0	5.5	0	0	0.4	29.4	8	13.9	4.6	6.7	8.4	7.1
BRP814	95-103	0	0.9	0.5	2.4	0	3.8	0	0	0	0	0.9	2.4	0	0	1.4	0.5	0.9	0.9	0.9	0.9	0	20	14.2	10	15.6	16.6	6.7	0.9
BRP815	103-111	0	1.6	0	1	0	4.5	0	0.6	0	1.6	1.3	2.2	0	0	0.3	0	3.2	1	0.3	0	17.7	17	4.5	9.6	15.4	15.7	2.5	
BRP816	111-119	0	1.8	0	2.2	0.9	4.4	0	0	0	2.7	0	11.2	0	0	2.2	0	0.9	2.7	1.4	0	0.4	13.4	14.3	0.9	15.6	9.4	15.6	0
BRP817	119-127	0	0.4	0.4	0.9	0	6.2	0	0	0.9	3.5	1.3	5.7	0	0	1.3	3.1	0	6.2	1.3	0	14.1	12.8	5.7	10.6	10.6	10.6	4.4	
BRP818	127-135	0	0	0	1.6	0	5.1	0.4	0.4	0.4	4.7	0.8	8.6	0	0	2.4	0	0.4	4.3	0.8	1.2	0	15.7	17.6	4.7	13.7	9.4	5.1	2.7
BRP819	135-143	0.4	0	0	0.4	0	8.1	0	0	0	5.4	0.8	7.7	0	0	2.7	0	0	6.1	0	0	14.2	10.4	12.3	3.8	6.9	20.8	0	

Figure B-3 Percentage of plant groups of BRP8

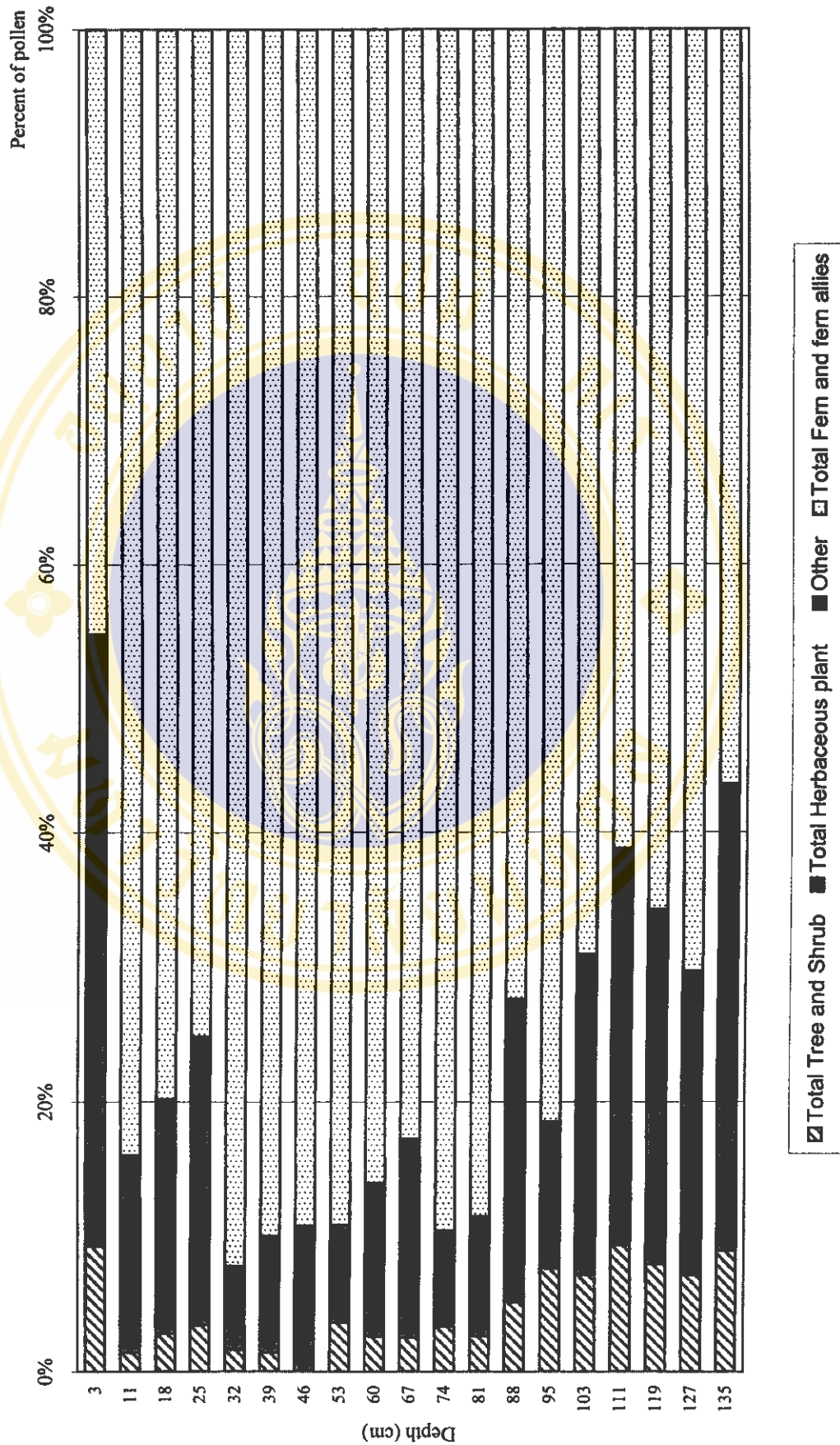
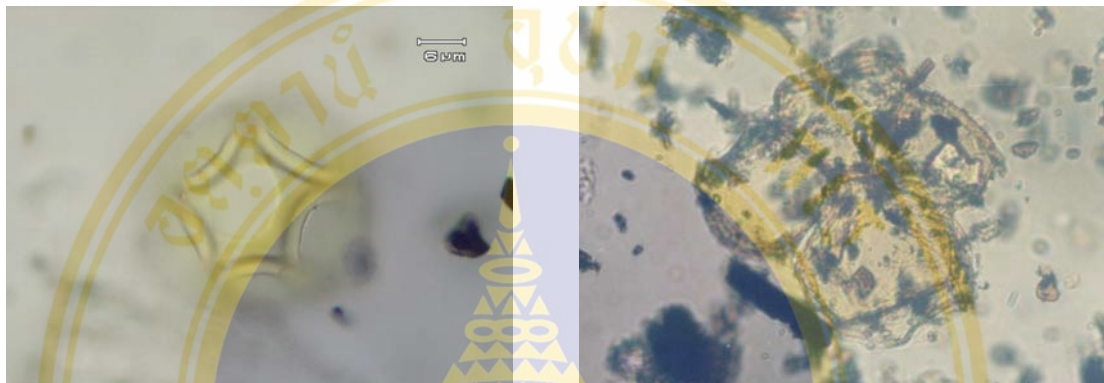


Table B-7 Data of pollen and spore from archaeological samples

Sample No.	Depth(cm)	Tree & Shrub														Herbaceous plant										Fern and fern allies						Algae		Total count
		Bombax sp	Calocedrus sp	Castanopsis sp	Glochidion sp	Leguminosae	Nyssa sp	Oleaceae	Pinus sp	Pterocarpus sp	Shorea sp	Symplocos sp	Ternstroemia sp	Acanthaceae	Cheno-Amariaceae	Compositae	Cyperaceae	Malvaceae	Merrillia sp.	Poaceae	Cyrtia sp.	Davallia sp.	Lycopodium sp.	Ophioglossum sp.	Polypodiaceae	Pteris sp.	Peridophyte spore	Chlorophyta and Cyanophyta	Unidentified type					
TLA1#33	50-60	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	7	1	0	0	1	1	0	1	1	0	17			
TLA2#73	35-45	0	2	0	1	0	0	8	0	0	0	0	0	0	1	4	0	0	0	3	1	1	3	2	3	0	4	0	0	33				
BRA1#152	0-12	2	0	29	0	165	2	90	15	230	24	9	3	117	0	0	0	13	4	0	1	0	2	0	1	2	1	0	4	739				
BRA1#109	8-54	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	22				
BRA1#160	22-32	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5				
BRA1#162	42-52	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	3	0	0	9					
BRA2#602	0-32	0	0	0	0	0	48	0	0	0	0	0	1	0	0	0	0	0	0	4	0	1	6	0	4	15	1	0	80					
BRA2#770	32-42	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1					
BRA2#882	30-90	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12					
BRA3#1384	25-30	0	0	5	0	9	400	7	12	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	3	1	0	0	440					

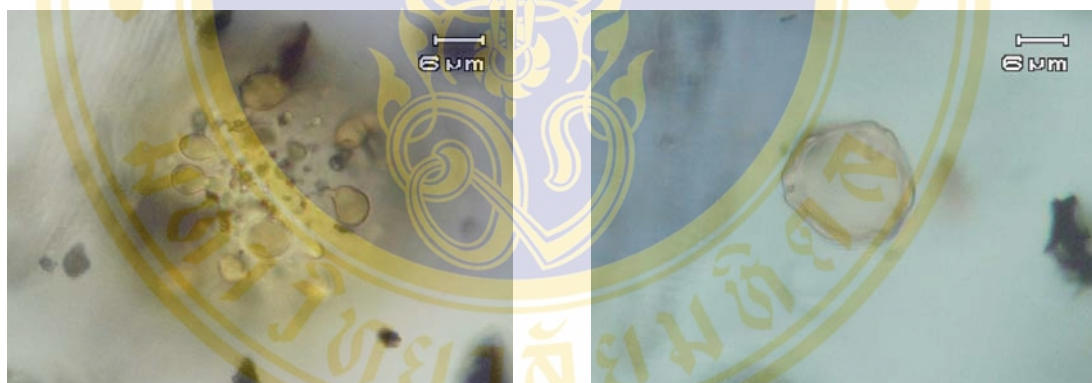
APPENDIX C: Pictures of pollen and spores

TREE AND SHRUB



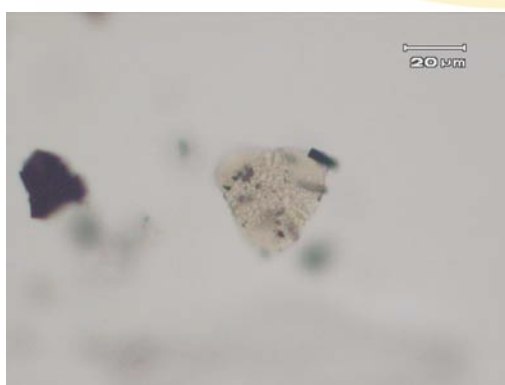
Alnus sp.

Annonaceae



cf. *Bauhinia* sp.

Betula sp.

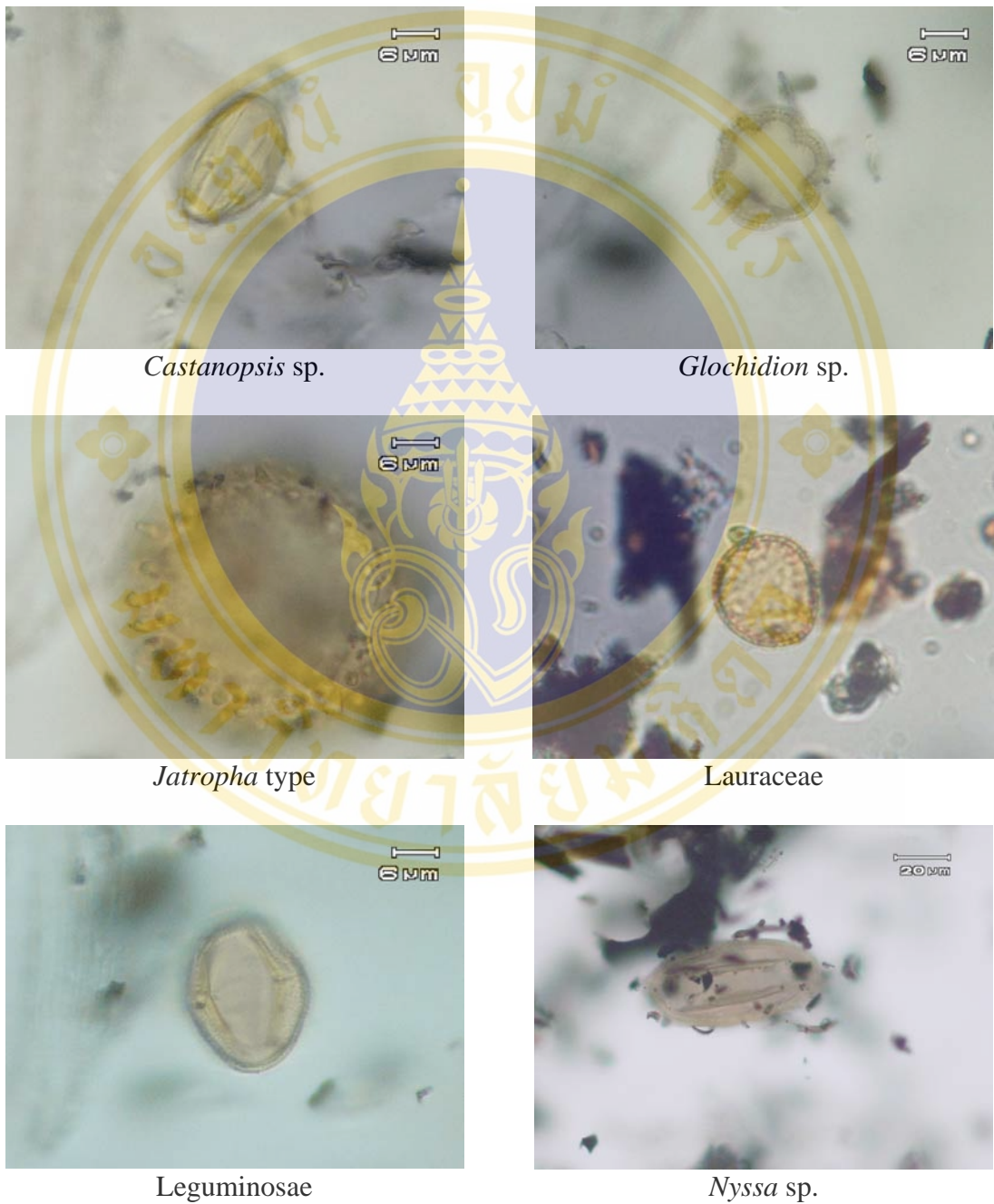


Bombax sp.

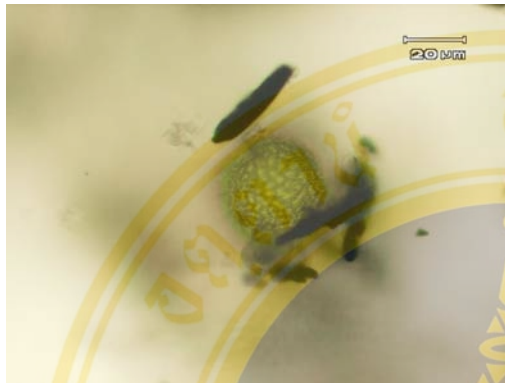


cf. *Calocedrus* sp.

TREE AND SHRUB



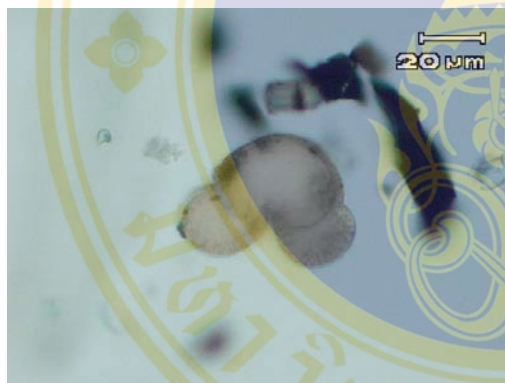
TREE AND SHRUB



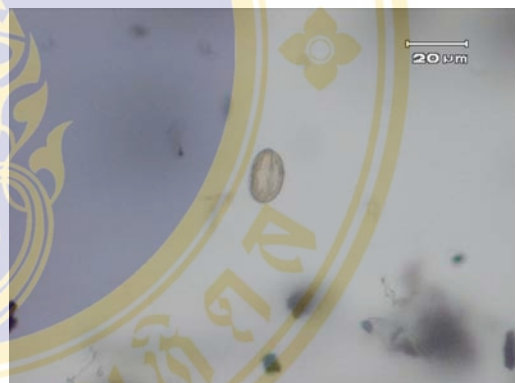
Oleaceae



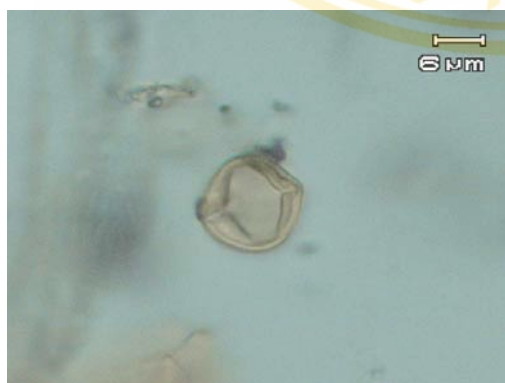
Phyllanthus sp.



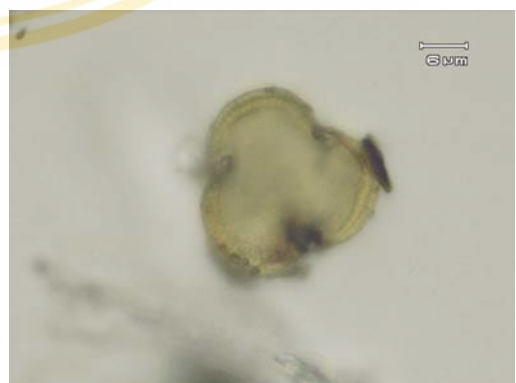
Pinus sp.



Pterocarpus sp.

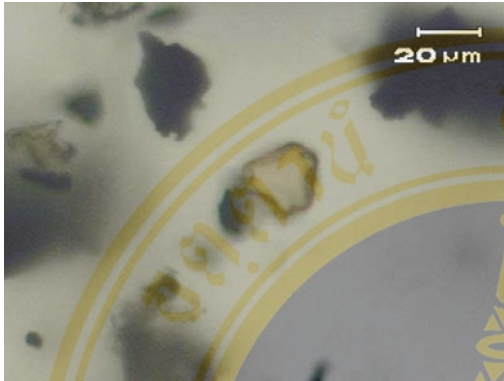


Quercus sp.

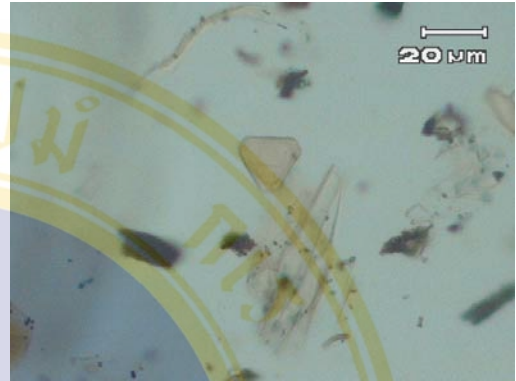


Shorea sp.

TREE AND SHRUB



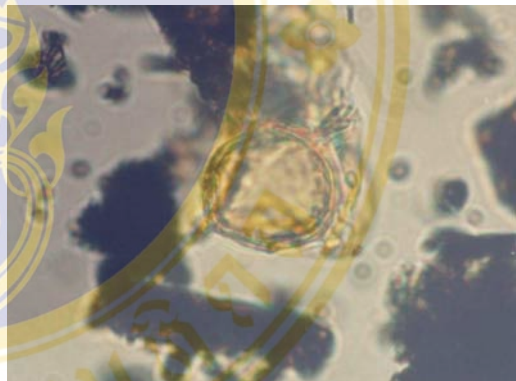
Symplocos sp.



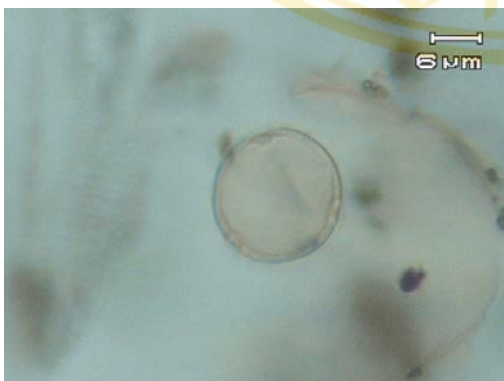
Syzygium sp.



Terminalia sp.



Ulmaceae

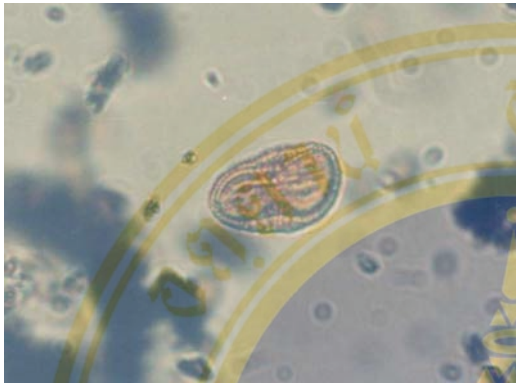


Urticaceae



Xylia sp.

HERBACEOUS PLANT



Acanthaceae



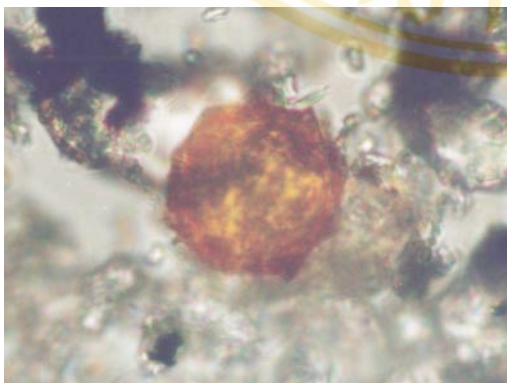
Acanthaceae



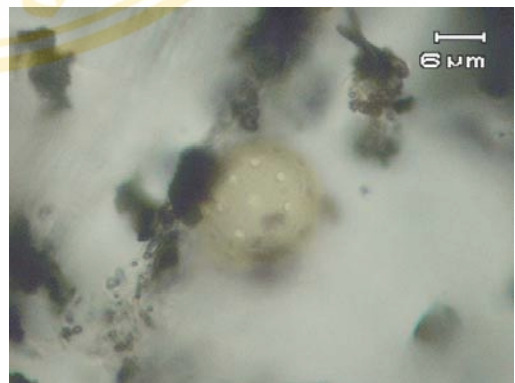
Acanthaceae



Alternanthera sp.

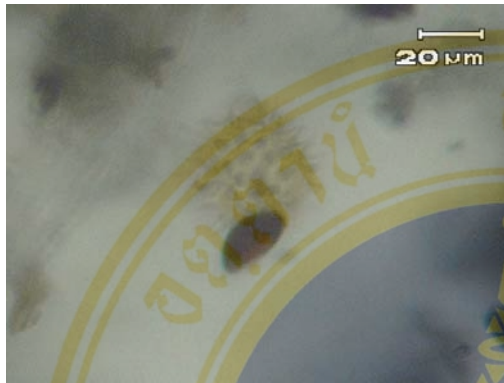


Amaranthaceae

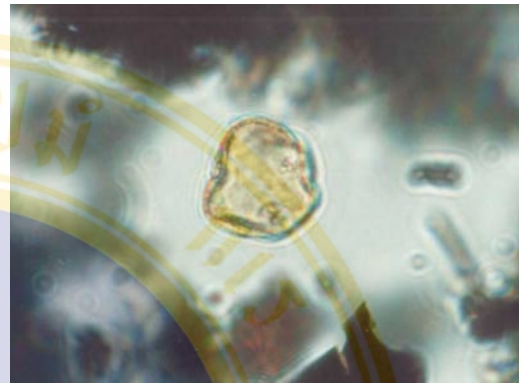


Cheno-Amaranthaceae

HERBACEOUS PLANT



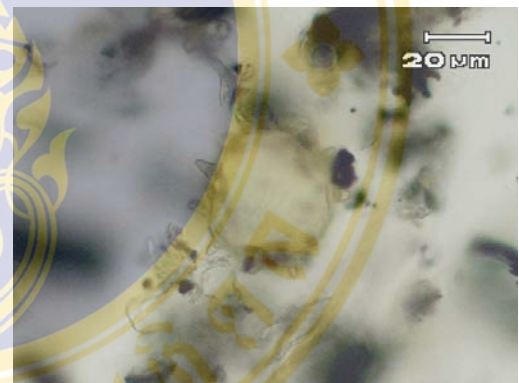
Compositae



Cyperaceae



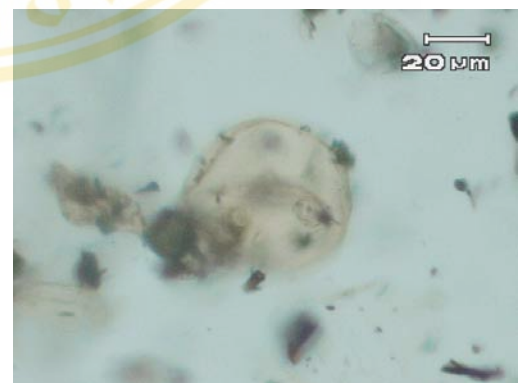
Liliaceae/Amaryllidaceae



Malvaceae

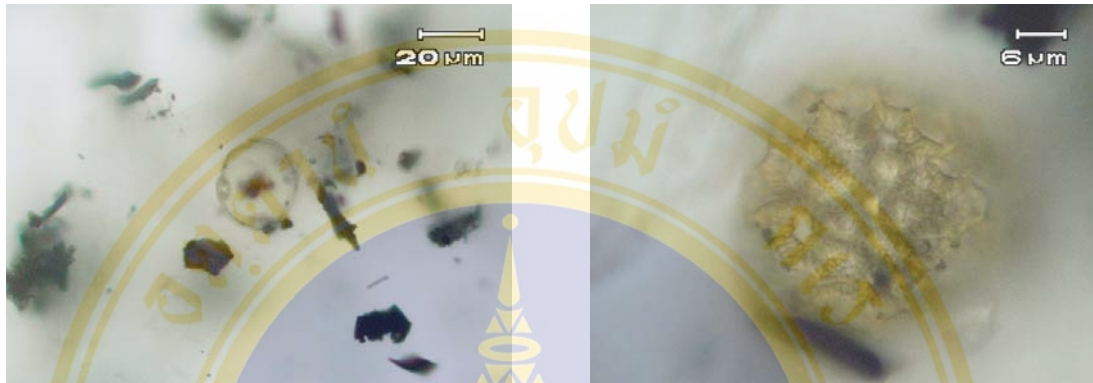


Merremia sp.



Poaceae (cultivated type)

HERBACEOUS PLANT



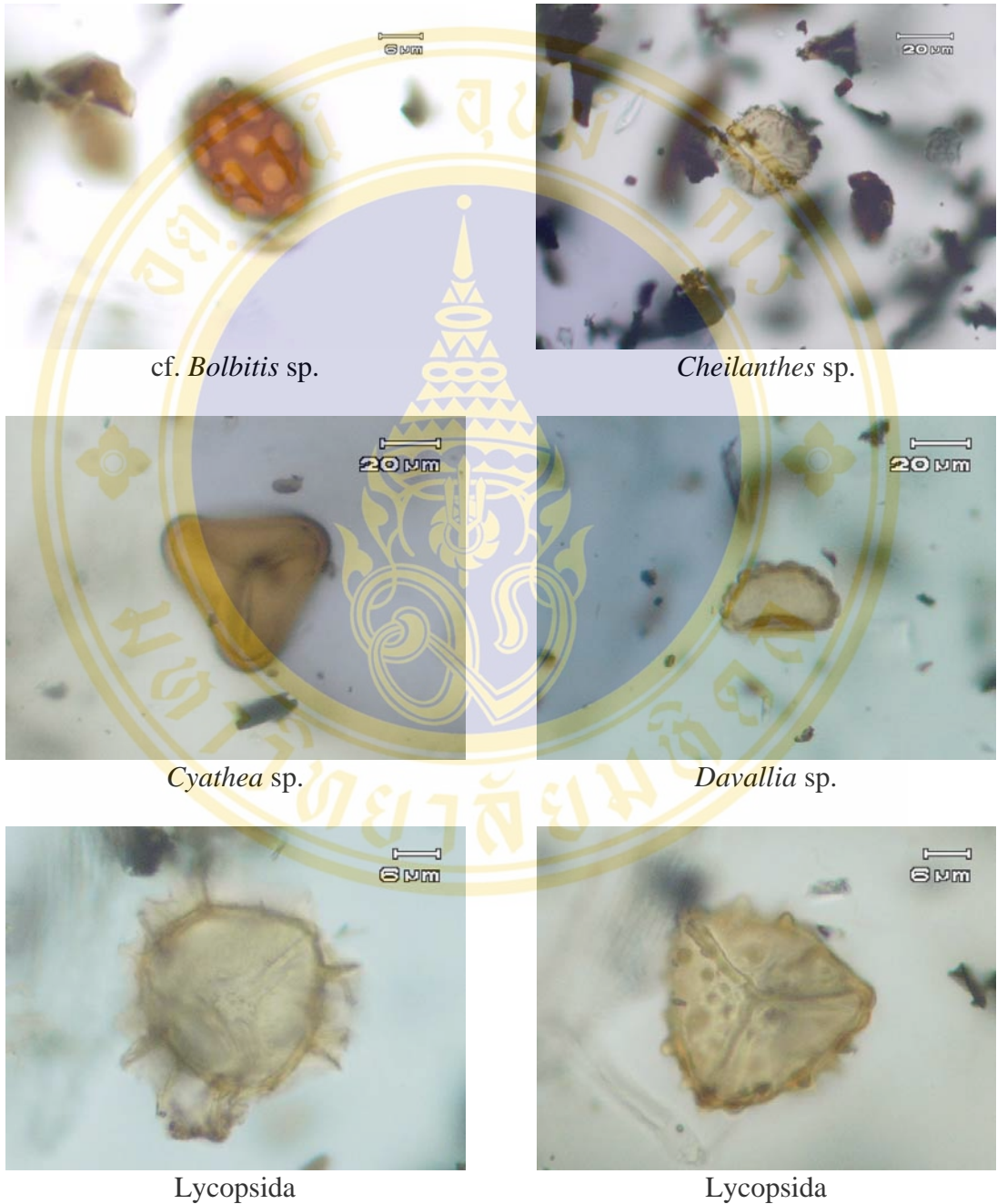
Poaceae (wild type)

Polygonum sp.

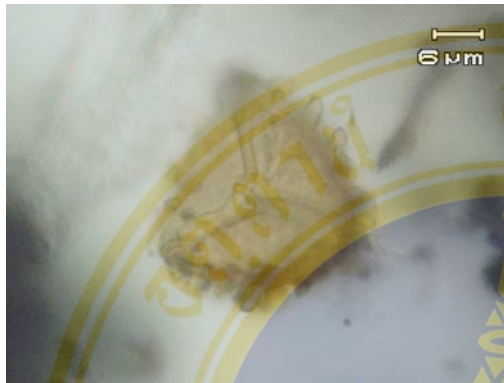


Thunbergia (Acanthaceae)
/ Eriocaulon

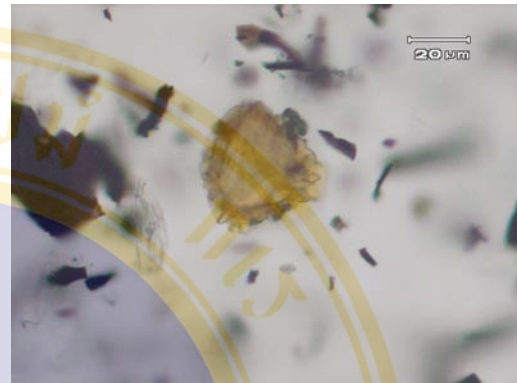
FERN AND FERN ALLIES



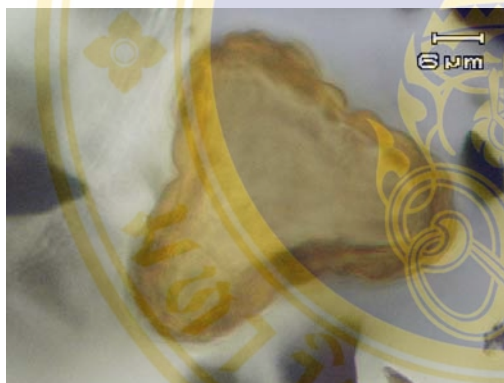
FERN AND FERN ALLIES



Lycopsidea



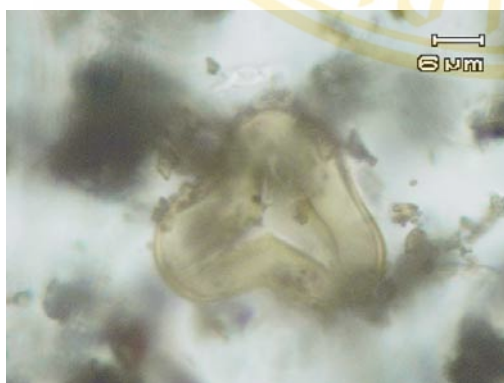
Lygodium sp.



Lygodium sp.



Microlepia sp.

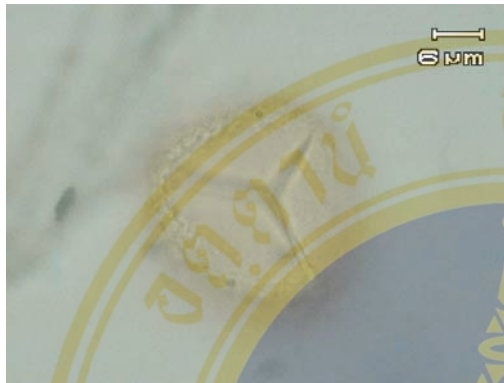


Microlepia sp.

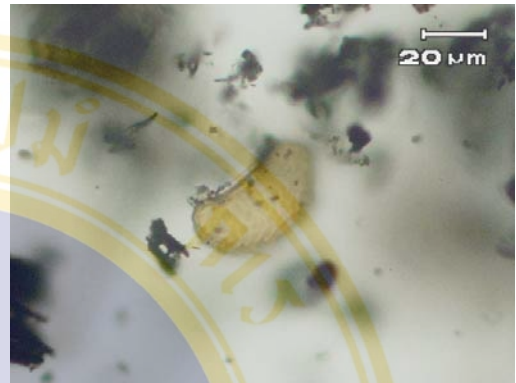


Ophioglossum sp.

FERN AND FERN ALLIES



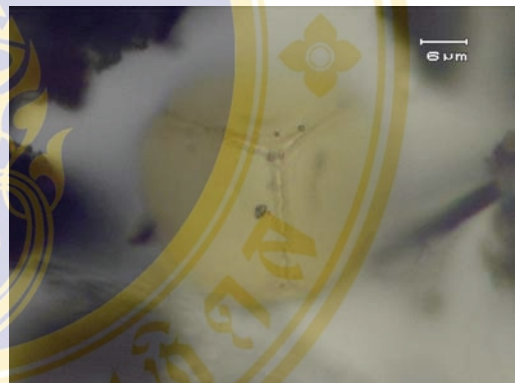
Osmunda sp.



Polypodiaceae



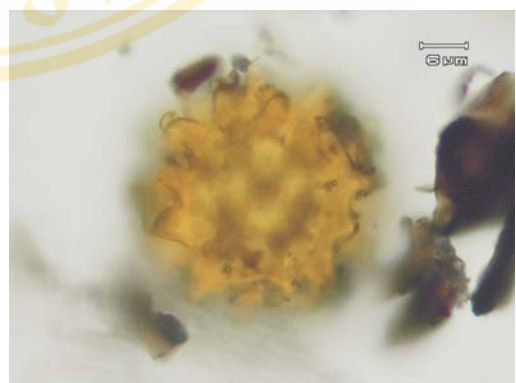
Polypodiaceae



psilate trilete spore

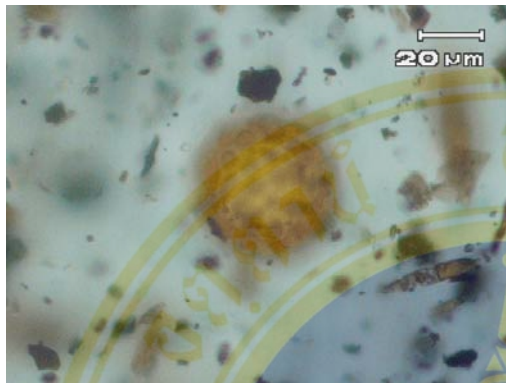


Pteridophytic spore

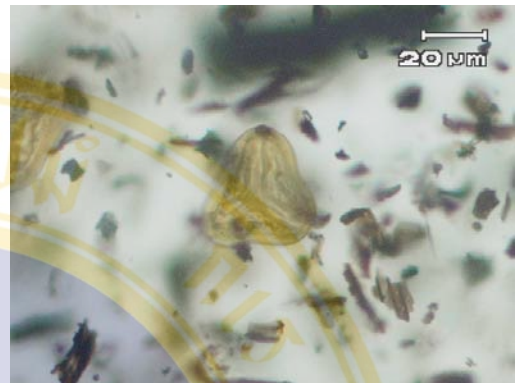


Pteridophytic spore

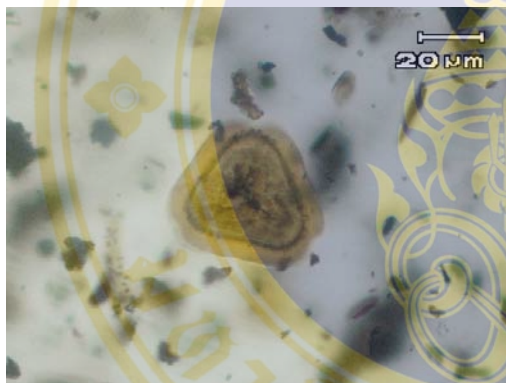
FERN AND FERN ALLIES



Pteridophytic spore



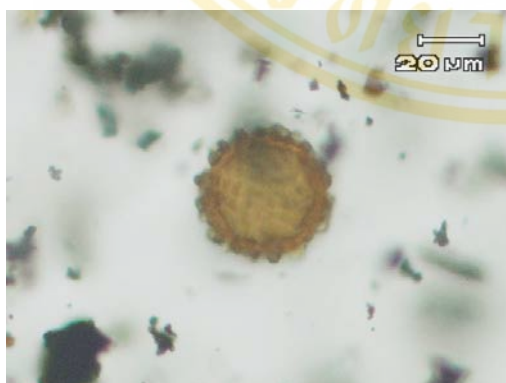
Pteris sp.



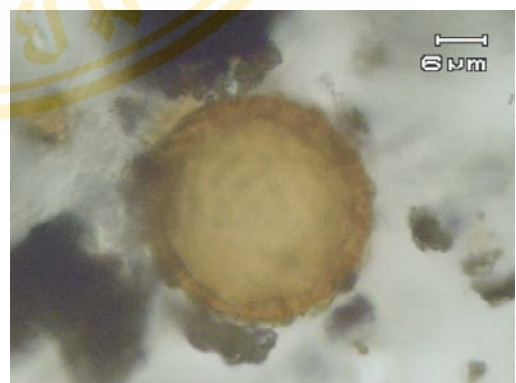
Pteris sp.



Schizaeaceae



Schizaeaceae

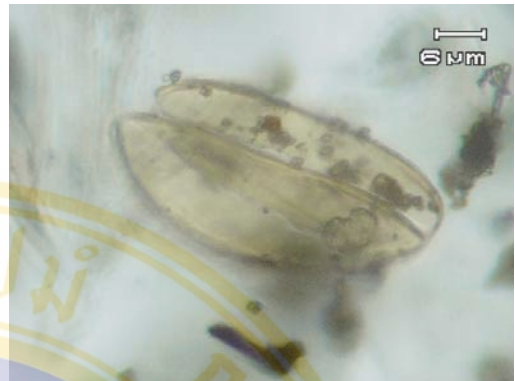


Schizaeaceae

PALM

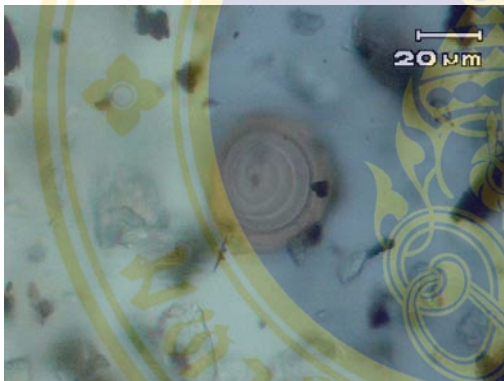


cf. *Calamus* sp.

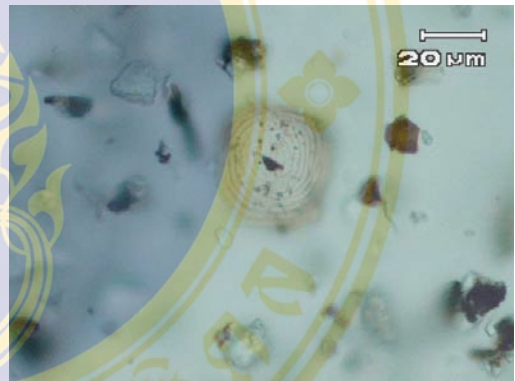


Palmae

ALGAE

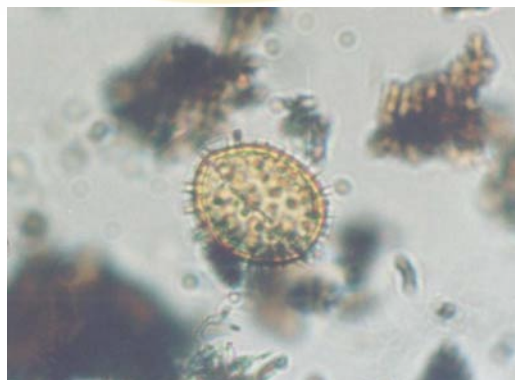


Circulisporites sp.



Concentricystes sp.

AQUATIC PLANT



cf. *Blyxa* sp.

APPENDIX D: Report of Radiocarbon Dating Results

Sample Data	Measured Radiocarbon Age	$^{13}\text{C}/^{12}\text{C}$ Ratio	Conventional Radiocarbon Age(*)
Beta - 206533 SAMPLE : TLP410 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (wood): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1670 to 1950 (Cal BP 280 to 0)	160 +/- 40 BP	-27.3 o/oo	120 +/- 40 BP
Beta - 206534 SAMPLE : BRP820 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (organic sediment): acid washes 2 SIGMA CALIBRATION : Cal AD 1280 to 1400 (Cal BP 670 to 550)	620 +/- 40 BP	-23.1 o/oo	650 +/- 40 BP

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27.3;lab. mult=1)

Laboratory number: Beta-206533

Conventional radiocarbon age: 120±40 BP

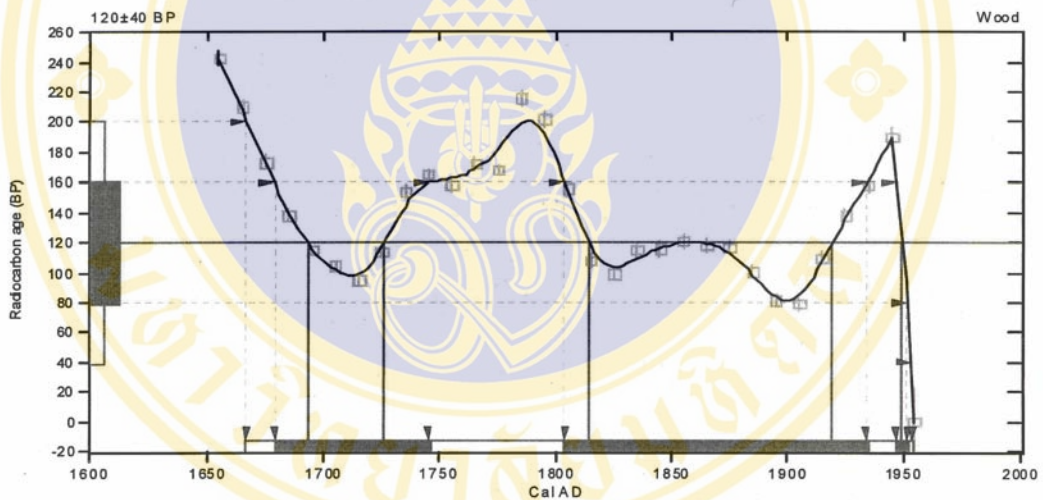
**2 Sigma calibrated result: Cal AD 1670 to 1950 (Cal BP 280 to 0)
(95% probability)**

Intercept data

Intercepts of radiocarbon age
with calibration curve:

Cal AD 1690 (Cal BP 260) and
Cal AD 1730 (Cal BP 220) and
Cal AD 1810 (Cal BP 140) and
Cal AD 1920 (Cal BP 30) and
Cal AD 1950 (Cal BP 0)

1 Sigma calibrated results: Cal AD 1680 to 1740 (Cal BP 270 to 200) and
(68% probability) Cal AD 1800 to 1930 (Cal BP 150 to 20) and
Cal AD 1950 to 1950 (Cal BP 0 to 0)



References:

Database used
INTCAL98
Calibration Database
Editorial Comment
Stuiver, M., van der Plicht, H., 1998, *Radiocarbon* 40(3), pxi-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et al., 1998, *Radiocarbon* 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, *Radiocarbon* 35(2), p317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.1:lab. mult=1)

Laboratory number: Beta-206534

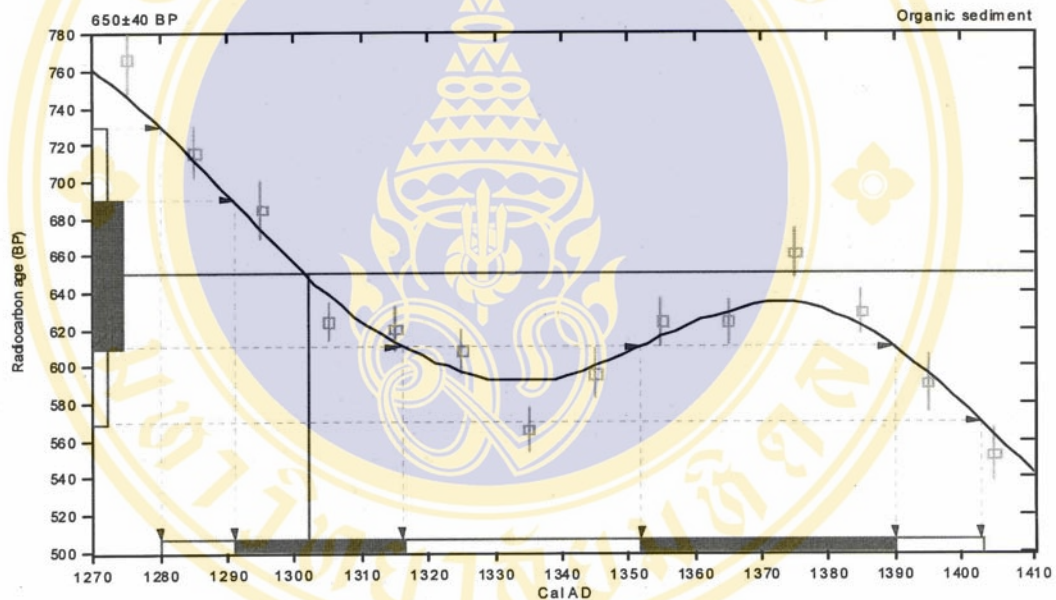
Conventional radiocarbon age: 650±40 BP

**2 Sigma calibrated result: Cal AD 1280 to 1400 (Cal BP 670 to 550)
(95% probability)**

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1300 (Cal BP 650)

**1 Sigma calibrated results: Cal AD 1290 to 1320 (Cal BP 660 to 630) and
(68% probability) Cal AD 1350 to 1390 (Cal BP 600 to 560)**



References:

Database used

INTCAL98

Calibration Database

Editorial Comment

Stuiver, M., van der Plicht, H., 1998, *Radiocarbon* 40(3), pxi-xii

INTCAL98 Radiocarbon Age Calibration

Stuiver, M., et al., 1998, *Radiocarbon* 40(3), p1041-1083

Mathematics

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