

**POLLEN ANALYSIS FOR VEGETATIONS AND CLIMATIC
CHANGES IN HOLOCENE PERIOD AT THUNG SALANG LUANG
NATIONAL PARK, PITSANULOK PROVINCE**



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POLLEN ANALYSIS FOR VEGETATIONS AND CLIMATIC CHANGES IN HOLOCENE PERIOD AT THUNG SALANG LUANG NATIONAL PARK, PITSANULOK PROVINCE

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ABSTRACT

The study aimed to investigate palaeo-vegetation during the Holocene period. The sediment samples were collected from Thung Salang Luang National Park, Pitsanulok Provinces, northern Thailand. Those 90 samples were taken first for pollen analysis by chemical process. Subsequently, sieving cloth of 15 μm was applied. The extracted pollen and spores were counted to obtain pollen diagrams. In addition, *in situ*, carbon deposited was collected for radiocarbon dating.

The result of this study based on pollen diagrams showed that there were 7 palaeo-environments in the plant community: 1) sub-tropical forest 2) tropical forest 3) aquatic habitat 4) swamp habitat 5) grass group 6) palm group and 7) fern group. The radiocarbon dating of carbon sample was $1,150 \pm 40$ BP. at the depth of 97 cm. (SLL728). Linear extrapolation at the depth of 74 cm. (SLL729) was calculated as 877 ± 40 BP; the plant community was similar with present forest type as sub-tropical forest. Sub-tropical microfloras commonly found were *Pinus sp.*, Liliaceae and Iridaceae. Tropical microfloras found were Dipterocarpaceae, Polygonaceae and Compositae. Fern groups commonly found were Cyatheaceae, Pteridaceae, Polypodiaceae which may suggest humidity in this area. Moreover, grass pollen (Gramineae) appear increasing since 877 ± 40 BP. This may suggest forest fire and dominant pine forest occurred since 877 ± 40 BP.

KEY WORDS : POLLEN ANALYSIS/ PALAEO-VEGETATION/ PALAEO-ENVIRONMENTS/ HOLOCENE/ RADIOCARBON DATING

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เรณูวิเคราะห์เพื่อศึกษาสภาพสังคมพืชและสภาพภูมิอากาศในอดีตยุคโฮโลซีนบริเวณอุทยานแห่งชาติทุ่งแสลงหลวง จังหวัดพิษณุโลก (POLLEN ANALYSIS FOR VEGETATIONS AND CLIMATIC CHANGES IN HOLOCENE PERIOD AT THUNG SALANG LUANG NATIONAL PARK, PITSANULOK PROVINCE)

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อต้องการทราบถึงชนิดของสังคมพืชพรรณในอดีตยุคโฮโลซีน ตะกอนดินยุคโฮโลซีนได้ถูกเก็บจากบริเวณอุทยานแห่งชาติทุ่งแสลงหลวง จังหวัดพิษณุโลก ซึ่งตั้งอยู่ในภาคเหนือของประเทศไทย จำนวนตัวอย่างตะกอนดินทั้งหมด 90 ตัวอย่างจะนำไปผ่านกระบวนการทางเคมี จากนั้นนำไปกรองด้วยผ้ากรองขนาด 15 ไมครอน เพื่อกรองเอาแต่อนุภาคละอองเรณูหรือสปอร์ที่มีอนุภาคขนาดใหญ่กว่า 15 ไมครอน ทั้งนี้ เนื่องจากขนาดโดยเฉลี่ยของละอองเรณูหรือสปอร์นั้นมีขนาดอยู่ระหว่าง 15-80 ไมครอน จากนั้นจึงทำการนับจำนวนละอองเรณูและสปอร์ เพื่อสร้างเป็นกราฟของละอองเรณู (Pollen Diagram) นอกจากนี้ยังทำการเก็บตัวอย่างคาร์บอนเพื่อใช้ในการตรวจหาอายุชั้นของตะกอนดินโดยวิธี Radiocarbon Dating

ผลการศึกษาซึ่งวิเคราะห์จาก Pollen Diagram พบว่า สังคมพืชสามารถจำแนกเป็นกลุ่มได้ 7 กลุ่มใหญ่ คือ (1) กลุ่มพืชแบบป่าเขตร้อนชื้น (sub-tropical forest) (2) กลุ่มพืชแบบป่าเขตร้อนชื้น (tropical forest) (3) กลุ่มพืชที่เจริญเติบโตในน้ำ (aquatic habitat) (4) กลุ่มพืชที่เจริญเติบโตในหนองบึง (swamp habitat) (5) กลุ่มพืชจำพวกหญ้า (grass) (6) กลุ่มพืชจำพวกปาล์ม (palm) (7) กลุ่มพืชจำพวกเฟิร์น (fern group) สำหรับผลการตรวจหาอายุของตัวอย่างคาร์บอนโดยวิธี Radiocarbon Dating ที่ความลึก 97 cm. ของตัวอย่าง SLL728 ได้อายุประมาณ $1,150 \pm 40$ ปีก่อนปัจจุบัน และทำการคำนวณเทียบเพื่อหาอายุที่ความลึก 74 cm. ของตัวอย่าง SLL729 ได้อายุ 877 ± 40 ปีก่อนปัจจุบัน พบว่า สภาพพืชพรรณที่พบใกล้เคียงกับสภาพพืชพรรณในปัจจุบัน โดยมีสังคมพืชแบบป่าเขตร้อนชื้น พืชพรรณในป่าเขตร้อนชื้นได้แก่ *Pinus sp.*, Liliaceae and Iridaceae พืชพรรณในป่าเขตร้อนชื้น ได้แก่ Dipterocarpaceae, Polygonaceae and Compositae กลุ่มของเฟิร์นที่พบทั่วไปได้แก่ Cyatheaceae, Pteridaceae, Polypodiaceae ซึ่งแสดงให้เห็นว่ามีความชื้นเพิ่มขึ้นในพื้นที่ศึกษา และสำหรับหญ้า (Gramineae) พบว่ามีแนวโน้มเพิ่มขึ้นในช่วงอายุ 877 ± 40 ปีก่อนปัจจุบัน เนื่องจากมีไฟป่าเข้ามาในพื้นที่

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CHAPTER 1

INTRODUCTION

1.1 Background and rationale

Thung Salang Luang National Park is located in Phitsanulok and Petchaboon provinces covering an area of 780,000 rai. It is a part of Petchaboon mountain range and one of 55 nationwide national parks which has been legitimated since B.E. 2506. Geomorphology of Thung Salang Luang National Park is eroded cuesta landform look like turtle's back shape. It consists of three sub-basins including Khek, Klong Chompoo and Huay Kock. It is counted as a representative area for ecological system which consists of invaluable natural floras and faunas. Tropical forest of Thung Salang Luang National Park contains high biodiversity (1). The study area is very fine to fine sediment deposited. This has been deposited naturally with the no sign of human disturbance in that area.

Thung Salang Luang National Park has been one of the important tourist site. Tourists are increasing in the area. The Park allows camping set-up for tourists and this has been increasing in demand. Thus, if there is poor management, it may degrade environment and ecological system. It would also effect the studied site. Investigation on vegetation and climate change in the past will be useful for park management.

If the cause of changing is known, it is helpful to solve the problems correctly and appropriately. Palynology is a selected method to study of pollen analysis by digesting deposited sediments. Remaining residues will be useful to identify past vegetation which related to ecological and climatic changes. This is most suitable for Holocene sediments which unconsolidated carbonaceous fine sediments is full of pollen. Pollen exine is mainly preserved in sediments. Holocene palynological residues commonly remain well preserved. Therefore, pollen analysis can be used as an index for climate change in the period where pollen deposited. The examination technique and the obtained palynological data help to understand palaeoenvironment.

Palynological study in Thailand is rare eventhough it can be useful for multidisciplinaries including archaeology, geology, environment, botany...etc. Therefore, studies on palaeoecological changes of this study area would be an invaluable information for the natural resources and park management. It is a good opportunity for this study to obtain natural pollen deposits in the Thung Salang Luang National Park. Pollen analysis is the most suitable tool to investigate for palaeoecological changes of terrestrial ecosystems.

1.2 Research Framework

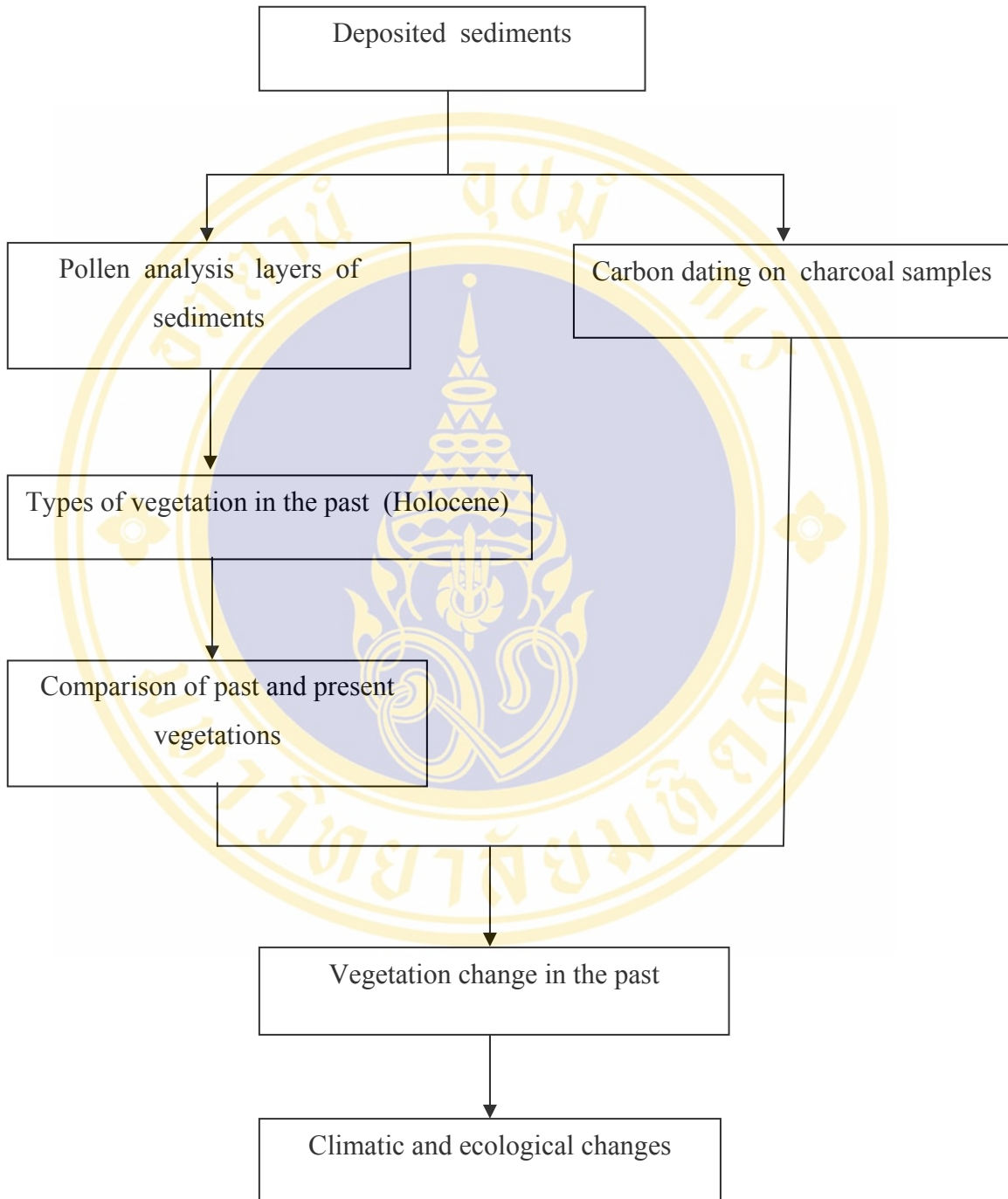


Figure 1-1 Research Framework

1.3 Research objectives

1.3.1 To study and identify pollen from Holocene sediments of Thung Salang Luang National Park.

1.3.2 To study vegetation changes and climate characteristics in Holocene deposits by pollen analysis.

1.4 Hypothesis

Palynological record should display changes in past vegetation. This may relate with differences in Holocene climate.

1.5 Scope of Study

1.5.1 Area of study

- Thung Salang Luang National Park, Pitsanulok province.

1.5.2 Palynological extraction is limit at the recent sediments of Holocene deposits.

1.5.3 Carbon dating is limited due to budget support. Only one sample was carried out of seven sampling sites in the studied area.

1.6 Expected Results

1.6.1 The obtained data will be used for study and research in order to be reference sources for other researchers in related fields.

1.6.2 The obtained data will be used for archaeology, such as study of environmental archaeology before historical periods which was related to human beings' activities in the past in making use of their products.

1.6.3 The obtained data can inform climate characteristics and environment in Holocene period of Thung Salang Luang National Park.

CHAPTER 2

LITERATURE REVIEW

2.1 Pollen

The word “Pollen” was firstly defined by Carl Linnaeus which meant group of yellow flour in flowers and contain in Division Spermatophyta. They are divided into two types as Gymnosperm and Angiosperm (2).

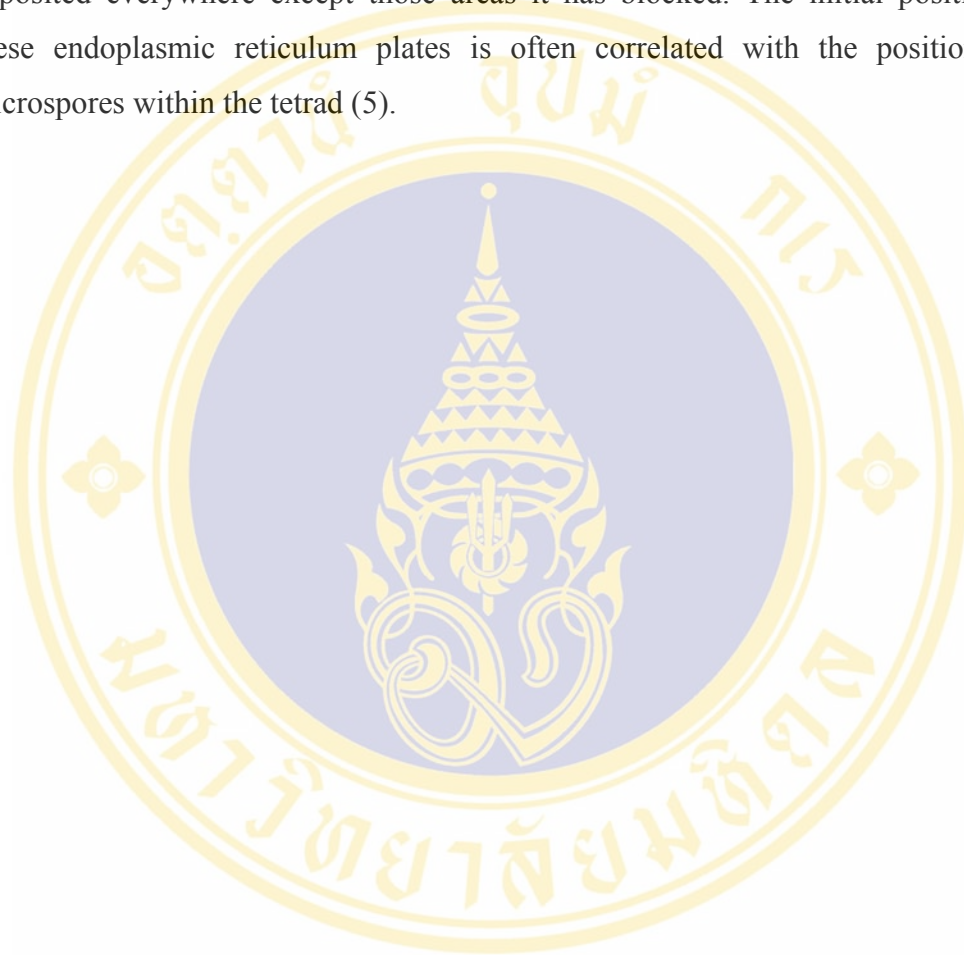
Pollen is composed of nucleus and generative nucleus, cytoplasm, cell tissues, and cell wall. There are chemical-elemented substance on pollen exine which is acid resistant ie. pectinous substance, sporopollenin or pollenin ($C_{90}H_{142}O_{36}$)ⁿ. There are chemical substances in the cytoplasm of pollen such as protein, amino acid, carbohydrate, monocarboxylic or dicarboxylic, fat acid, fat, vitamin, hormone, enzyme, and other elements of substance i.e. potasium, magnesium, copper, iron, silicon, phosphorous, sulfer, and chlorine (3).

Pollen could be distributed by wind, water, insects and human beings (3). When pollen and spores fall to ground, bogs, swamps, or lakes, they deposited in sediments and turned to be fossil record. Miospores and megaspores deposit in estuary or inner coastal zone but the small miospore may deposit at the outer coastal zone or in the ocean. For pollen do not deposit in the reduction condition could be oxidized and deteriorated (4).

2.2 Pollen Cell process

The process of pattern formation begins early in the tetrad period, as soon as each cell is independent and completely isolated from the other cells by a thick cellulose wall. A cellulose layer is then formed between the plasmalemma of the microspore and the investing cellulose wall. This cellulose layer formed a continuous

sheath to the grain, except over those areas which are destined to be apertures (pores or furrows) in the mature grain. In these areas a plate of endoplasmic reticulum is closely apposed to the plasmalemma, which in turn lies directly against the cellulose tetrad wall. Thus the endoplasmic reticulum acts as a stencil, allowing cellulose to be deposited everywhere except those areas it has blocked. The initial positioning of these endoplasmic reticulum plates is often correlated with the position of the microspores within the tetrad (5).



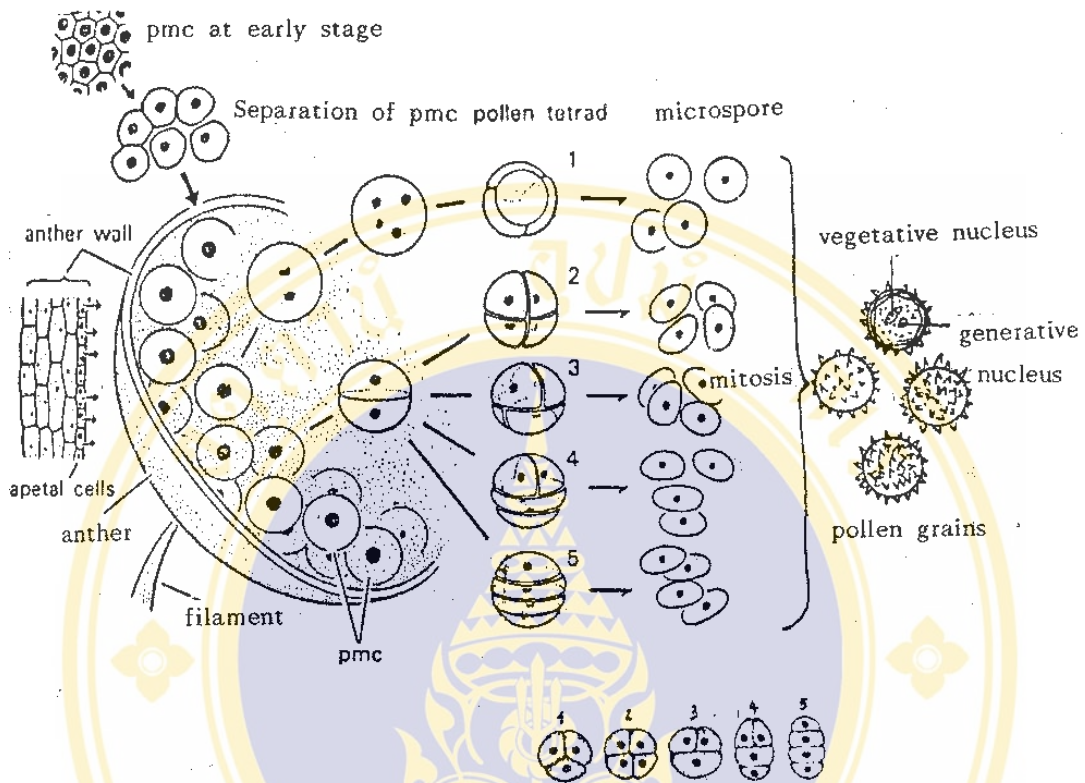


Figure 2-1: Cell of pollen development (2)
 number 1-5 shape of pollen tetrad
 1:tetrahedral, 2:isobilateral, 3:decussate, 4:T-shaped, 5:linear

2.3 Ecology and pollen pollination

The essence of pollination is transport, the transport of pollen from anther to stigma. The mode of transport and the adaptation of plants to them are fundamental for the evaluation of pollen analytical data. This transport takes place in different ways. The understanding of the transport processes in pollination ecology is one of the main keys to the understanding of pollen analysis and its results (6).

2.3.1 Pollination by water

A few aquatic plants are pollinated under water (hyp-hydrogamous: *Zostera*, *Ceratophyllum*, *Zannichellia*). There should be excellent opportunities for pollen of these species to be embedded in sediments and fossilized. Usually, such pollen grains have extremely thin exines and remains are not recognizable; the small group of hyp-hydrogamous species cannot be traced in pollen analysis (6).

2.3.2 Pollination by animals

In the very comprehensive group of zoophilous blossoms pollen is carried from the anther of one flower to the stigma of another by some animal vector: insect, bird, bat. In extreme cases these blossoms are highly specialized and pollen is released only when the right animal visits the blossom and behaves correctly. The pollen is deposited on the vector, and is removed from it by the stigma only. Unless the pollen-bearing animal itself perishes in a lake or bog, or whole flowers (or anther) drop accidentally into the water, pollen grains from this type of blossom have extremely small chances of being preserved as fossils in ordinary deposits. When they are occasionally found in peat or sediments, they are always infrequent; their occurrence is accidental and unreliable, even if their number in an exceptional sample may be high. Consequently they should not be treated on a par with grains of anemophilous species. Their occurrence may furnish indications of the greatest value, but nothing can be concluded from their absence (6).

2.3.3 Pollination by wind

Wind-pollinated plants produce very great quantities of pollen that is liberated into the air and scattered all over the surroundings as the pollen rain. A negligible fraction of this settles on bogs and in lakes. The typical pollen of wind-pollinated species is dry and the individual grains separate, thus producing the maximum number of pollen dispersal units and securing a regular distribution of the grains over a wide area. Pollination by wind tends to bring about a reduction of exine with an attendant

loss or reduction of its structure such as furrows, pores and sculpturing. Most of the pollen types of northern European wind-pollinated species are smooth or almost so, the strong sculpturing being characteristic of zoophilous species.

Pollen grains of zoophilous species frequently possess a heavily armoured surface. Layers of sticky oil on the surface of the grains cause them to stick better to each other and to the body of the animal. Extreme cases are the massulae of orchids and Asclepiadaceae or the viscin threads binding together pollen masses such as Ericaceae and Onagraceae. As such masses are dispersed as one unit, their existence tends to reduce heavily the number of pollen dispersal units. Also, units consisting of several grains stuck together are perforce heavier than individual grains, which restricts their possibility for wind dispersal (6).

2.4 Pollen production

The most characteristic feature of wind-pollinated plants is the great number of pollen grains produced per ovule. However, in pollen analysis the chief interest concerns the number of grains produced per area unit.

One single anther of hemp may contain 70,000 pollen grains. As each flower usually possesses a number of anthers, and each shoot many flowers. One shoot of hemp produces more than 500 million pollen grains, whereas a male plant of *Rumex acetosa* produces 400 million and a large panicle of a *Sorghum* cultivar over 100 million, but even a large specimen of *Linum catharticum* hardly reaches 20,000. Forest trees produce great quantities almost 600,000 pollen grains and a shoot 8-9 million. Ten years old branch system of beech produces more than 28 million; birch, spruce and oak a little more than 100 million. The production per hectare of forest runs into billions, the spruce forests of southern and middle Sweden produce 75,000 tonnes of pollen annually when flowering freely. Pine forest (*Pinus sylvestris*) produce between 10 and 80 kg of pollen per hectare per year, corresponding to 30,000 to 280,000 grains per cm² per season (6).

2.5 Precipitation and pollen dispersal

The effect of rain on pollen concentration in the air varies with the time of day. In the morning, pollen release time, when the maximum concentrations are still in the lower strata, rain washes pollen out very rapidly. In the night (after a dry day) when there is a great concentration of pollen in higher air strata, rain may cause an immediate temporary increase of pollen concentration near ground level (6).

Pseudotsuga pollen deposition with precipitation as throughfall is 50 times higher than with precipitation in the open. Most interestingly, very little pollen is transported with the stemflow. Probably, the throughfall pollen was initially deposited within the tree crowns. Since most deciduous trees flower before leafing this scavenging effect is probably smaller with them than with *Pseudotsuga* (6).

Rain-out of particulars from the air is an important factor in long-distance pollen transport: sooner or later, rain is generated in an air mass, and that will be the end of its pollen transport. Pollen grains may form condensation nuclei or at any rate primary inclusions in rain droplets, or they may be carried down by impact. This again would mean that only pollen grains that come up above the rain cloud strata have a chance of remaining in the air for longer periods (5).

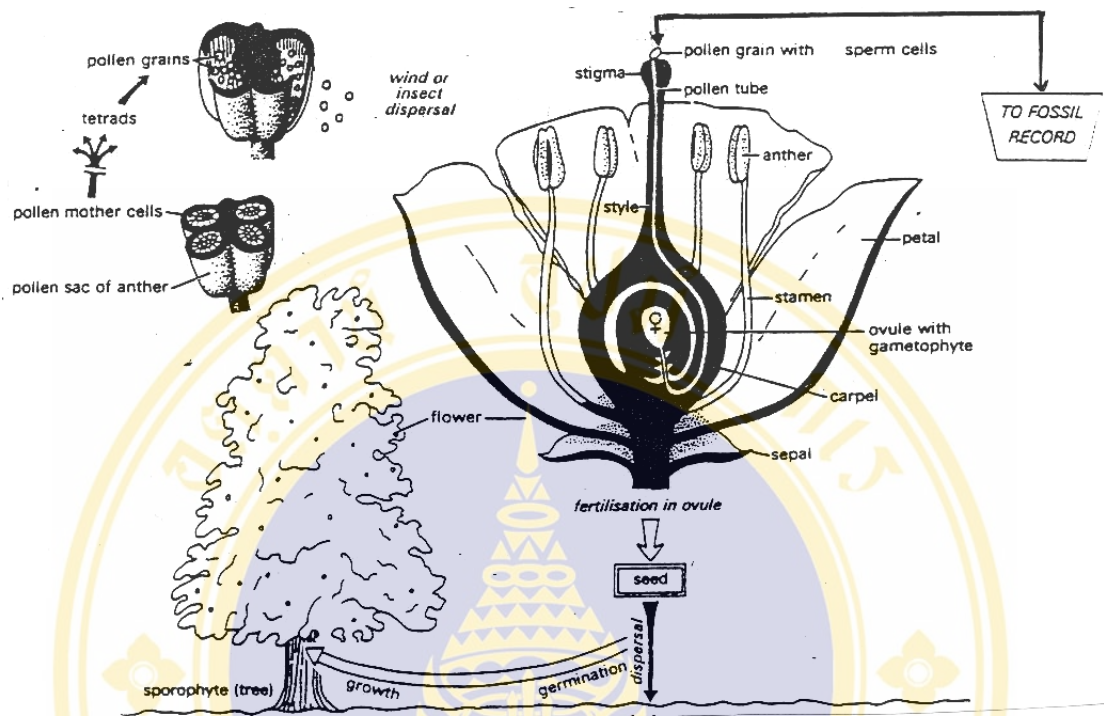


Figure 2-2 Life cycle of reproduction and distribution of pollen to natural deposit of angiosperm plants (4)

2.6 Holocene climate change

During Holocene period, there were environment and climate change. From the record, this period had change in temperature and humidity as a result of Holocene period include in the Quaternary period and after Last Glacial Maximum period (7). The study on the climate change in Thailand during the end of Quaternary period found that between 60,000 years before present to 30,000 years before present, climate characteristic was cold and dry. But between 30,000 years before present to 20,000 years before present, climate characteristic would be cold and warm again until 11,000 years before present, climate characteristic would be cold and humid again (8).

Early of Holocene period (11,000 years before present), around 180 kilometer between the coastal zone of Narathiwat to Malaysia, there was an accumulation of Litarite at the Pleistocene period. This had an impact on the higher of mean sea level (9) as well as the area in Narathiwat province. It found during 3,800 years before present, there is an increasing highest mean sea level. This area was peat swamp far from present coastal line which was a result after the highest increasing of mean sea level (10).



2.7 The relationship in palynology with climate and vegetation

In the southeast asia, the region mostly has been influenced from tropical monsoon climate. During winter season, the effect is from northeastern monsoon from central asia. In summer season, the effect is from southwestern monsoon from African Continent and Southeastern monsoon from Australia (11). In southeast asia Continent, there are a wide range of temperature during the day, and there is always the variation. In the mountain area, there is the movement of clouds from the valley in the morning and move down again at night. The movement of clouds is an indicator for wind movement. Plants in this areas will be dwarf plants, scrambler plants, moss and lichen (12). The interpretation from pollen diagram will be difficultly explain the climate change in this mountain area (13). In Mt Kinabalu, Sabah, there will be a lot of cloud movement and high humidity with the height range between 1,680 and 2,150 meters from mean sea level. This will effect the plant growth in the area.

The lack of data in the past of Southeast Asia Continent caused a problem in taking data to relate to the past data of other continents on earth. Therefore, there has been a study for climate in the past. However, in Indo-China Peninsula such as Thailand, Vietnam, Laos, Cambodia, and Myanmar, there are still a lack of past environment. These data relates to the understanding of past climate and geographical change. In addition, these data will develop the simulation model for climate prediction. In Indo-China Peninsula, there is a scope for Ever-wet tropical rain-forest in Indonesia and Temperate in East Asia (14). Data collecting in palynology and climate change in the Southeast Asia as Figure 2-3.

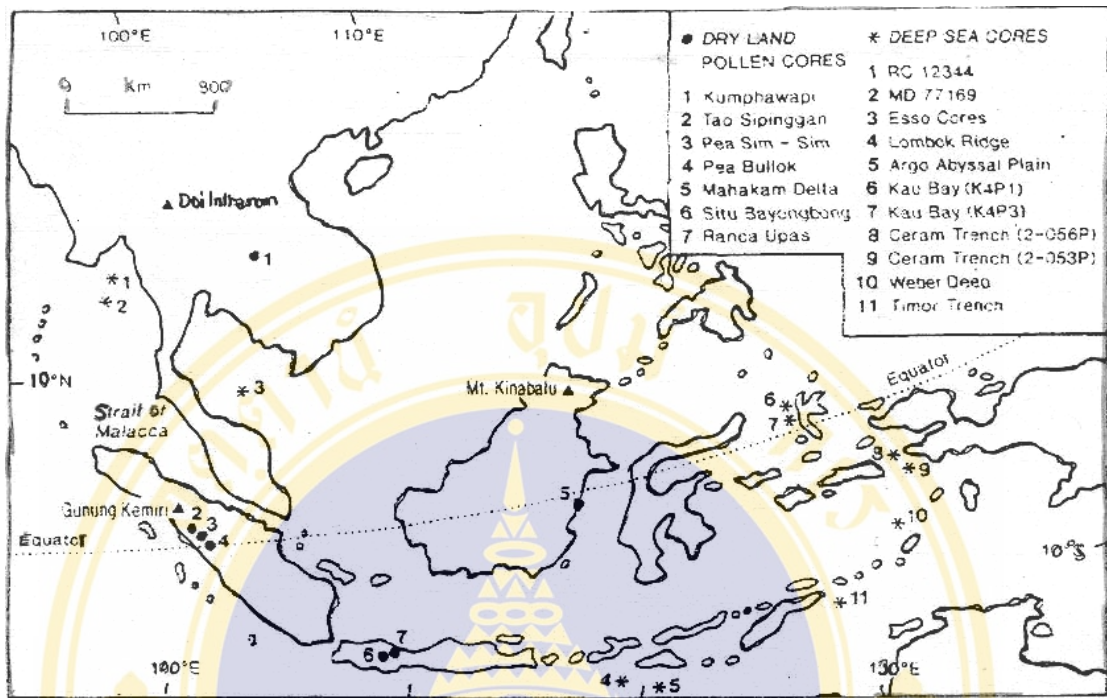


Figure 2-3: Study area in palynology and climate change in the past (9)

The study around Ceram Trench which is between Ceram and Irian Jaya, it found that palynology data indicate the distribution of lower montane oak forest around New Guinea Island at 10,000 years before present. It has become grassland and forest at 9,500 years before present. This indicates the change of Island which is rather dry. It found *Phyllocladus* in the past 10,000 years is an indicator for the increasing of mid-upper montane forest, while pteridophyte plants can be an indicator for the increasing of rainfall in Holocene period (15).

The study of the relationship of palynology and climate change in Yunnan Country, China, it found that the end of Pliocene period, the climate was cold and the temperature was less different from the present. Winter season was longer period than present. Palynology data is indicate for a short period before Last Glacial Maximum period. Plants in Menghai province is closely with modern plants. In addition, *Dacrycarpus* and *Dacrydium* indicated the climate change which is humid in the winter and dry in the spring. Kunming province, during 15,000-9,500 years before present, it found pollen of *Tsuga* which indicated the rainfall quantity more than

present and average temperature was 1-2.5 °C which is lower than present. In the valley found deciduous forest plants in the South, and the period of 9,500 years before present, most plants were like plants in 7,000 years before present. In addition, Er Yuan town, during 17,000-10,000 years before present, It found the pollen of *Picea* and *Abies* which were grow higher than 500 meters mean sea level and the temperature was 2.5-4°C which was lower than present (16).

Comparison with an area in the northeastern of Cambodia, the palynology data explained the plants change and lakes area. It found the period of 9,300 years before present was the Late Glacial condition. There are pollen of *Fagaceae* and *Pinus* which indicated the cold and dry climate. *Pinus merkusii* grow in highlands which can find distribution in the highland of the central of Vietnam (17), but it found in the east of Cambodia. For *Fagaceae* grow in submontane forests of Cambodia and Laos (17). Vegetation change of Cambodia is similar to Yunnan in the West of China, there was an influence of monsoon which blew in the coldness in the Late Glacial period (18). Shayema Lake in Sichuan country had start cold in 10,000 years before present and there was pollen of *Abies/Picea* in 4,000 years before present (19). Areas in Sichuan and Yunnan have similar climate change, with the humidity change and higher sea water level and there was pollen of Gramineae in 8,700 years before present.

Palynology study in Indonesia, it found pollen of Rhizophoraceae and *Sonneratia* which indicated mangrove forest nearly estuary. Pollen distribution by wind or water were deposited in the study area. In addition, there were pollen of Cyperaceae and Gramineae, they were rare appearance that can't indicate the past vegetation with long distance distribution (20).

In addition, pollen in mangrove forest of Southeast Asia, pollen of plants in mangrove will be generally distribute. In Malaysia, there was pollen of Rhizophoraceae near the area of Pekun Nanas in Johore State. That area might be deposit ecological system in three categories (21):

1. Riparian Forest
2. Swamp was affected by mangrove forest
3. Around peat swamp and riparian plants

For the area of Borneo, there is a study on peat from Marudi, in northwestern of Borneo Island, it was deposited with peat swamp of mangrove in 4,270 years before present. It found pollen of *Rhizophora*, *Nypa* and *Oncosperma*. For alluvial area of Mahakum in the east of Kalimantan in the period of 18,000-5,000 years before present, there was constant increase and decrease of sea level water because sea line lift up. It affected to changing areas were mangrove and increased brine sediments (22). The eastern of Kalimantan, it found dry climate in Quaternary period was caused by forest fire of rain forest in this study area which related El Nino-Southern Oscillation (23). The above hypothesis has been supported the area of Sabah which was influenced by forest fire in year A.D. 1915 (24) and eastern of Kalimantan in A.D. 1982-1983, both events were a result from the climate change by El Nino phenomena (23).

Around Strait of Malacca, mean sea level was down to 40-60 meters in period 36,000-10,000 years before present and increased rapidly in the early of Holocene period (15). From the sediment samples found mangrove pollen in 10,500 years before present and there is pteridophyte spores which indicated increasing rainfall.

The sediments in Java of Indonesia is older than Quaternary period (20). Pollen were the same plant in Australia and mangrove plants in Java were disturbed by human activities as well (25).

Around Poverty Bay of New Zealand is an Island in the north of the country. There were pollen of Avicenniaceae which indicated warm climate after Last Glaciation period from radiocarbon dating (^{14}C) in the period of $9,840\pm 190$ years before present (Holocene period). For Postglacial period in Poverty bay. This was the period for the complete sediments deposit and be erosion of sea water affect to geographical changing around coastal line (26).

2.8 Relationship of palynology with climate characteristics and vegetation in Thailand

From the study of Quarternary sea level changes in the coastal areas of Thailand, it found the rapid increasing of sea level higher than present 4 meters in 6,000-4,800 years before present in 4,000 years and 2,500 years before present. The level was 1.5 meter higher in 2,000 years before now (27) Figure 2-4.

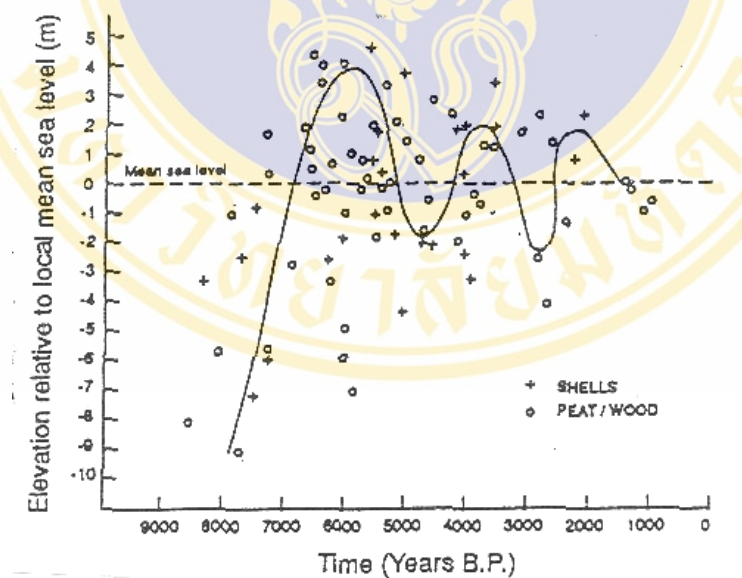


Figure 2-4 Changes in sea level of Holocene period in Thailand (27)

The study of vegetation in lately Holocene period found pollen and spores in higher montane forest as well as plants found in warm area such as *Quercus spp.*,

Rhododendron sp., *Betula spp.* and *Castanopsis sp.* which grew in 1,250±60 years before present. This can be indicated higher montane forest and semi-temperate forest (28).

In addition, the result of palynological study in Doi Intanon, Chiangmai in the North of Thailand shows that such ecological system started change in 160±65 years before present. Pollen of *Quercus spp.*, *Castanopsis sp.*, *Myrsinaceae*, *Ilex spp.*, *Ilex spp.*, *Euphobiaceae* and *Margocolporite vanwijhei* decrease quantity. But spores of *Cyperaceae* and *Lycopodium sp.* had increasing distribution which reflects the humidity change or sea level in the study area. This result was same as the relation of climate change in Doi Intanon Mountain which the climate is Montane ever-wet which is cold and humid all of year. Around 4,300 years before present, the climate was cold and dry more than present (29).

For the palynological study in climate change in Nong Talay Song Hoong, Trang province in the South of Thailand, and pollen of *Urticaceae/Moraceae* were abundant in 10,300 years before present. This shows the climate was cold and dry. Pteridophyte spores in were abundant in 5,100-4,800 years before present in the study area. Vegetation was not stable in 10,600 years before present. The increasing of *Artocarpus* pollen can indicate human agriculture. People planted useful species as *Areca*. For *Hymenophyllaceae* spores can indicate appropriate humidity forest which could grow in deciduous tropical moist forest related to the up and down of mean sea level (30).

The palynological study in Amphur Sating-pra, Songkhla province in the South of Thailand found the increasing of *Acrostichum* pollen which can grow in the destroyed area by human activities and there was landuse in planting *Borassus* which is a type of palm. Thus, there is plants in two types of environments as follows mangrove plants and fresh water swamp forest (21).

Around lower plain of Central Thailand, there has been a study that Senaniwet Village in Bangkok, there is pollen of mangrove and riverine water in 7,800 years before present. This shows the deposit of riverine which might be old river basin. Moreover, it found residues of shells in sediment samples. This may indicate the environment of fluvialtile (31).

The palynological study in Lomdong swamp at Mae Yom National Park, in Prae Province,. There is pollen of *Bombax sp.*, *Dipterocarpus sp.*, *Hopea spp.*, *Lagerstroemi*, *Betula sp.* and *Quercus sp.* in 1,368 years before present which there was a similarity with modern plants. The study area had decreasing humidity of by fern spores were indicator for the change in ecological system as the system was influenced by human and natural forest fire (32).

Around Bo Phloi swamp, there has been a vegetation study in Holocene period and there were four types of ecological system as followings:

1. Sub-temperate/semi-tropical forest
2. Dry evergreen to deciduous forest
3. Swamp area
4. Aquatic area

The result of wood investigation by radiocarbon dating (^{14}C) found in period $4,540\pm 50$ years before present. The paleo-environment of dry evergreen to deciduous forest, swamp area and aquatic area can also be found in Bo Phloi at present. While, sub-temperate/semi-tropical forest, pine pollen (*Pinus sp.*) was major group. This is not appearance at present. Therefore, that general environment of this areas consist of dry evergreen to deciduous forest more than sub-temperate/semi-tropical forest. However, the result of the study can not be clearly indicated because the study area is open area. There has been an exploitation by human. Thus, the interpret result must support on archaeology data (33).

In addition, there is a study on the simulation of climate change for the distribution of tropical dry forest in the northeastern of Thailand under the high temperature condition and rain fall. There is a replacement of sub-tropical moist Forest which can indicate the increasing of temperature and not related to the increasing rainfall quantity. There was a loss of water from evaporation (34) from fossil pollen in the early and the middle of Holocene period had more rainfall quantity, thus there was humid forest in northeastern region (an increase of lower-montane and riparian rainforest of *Dacrydiam* and *Elaeocarpus* at Nong Pra Ko in northeast area, Nong Kumpawapee area). Fossil pollen in 7,000 years before present related to dry evergreen/mixed deciduous forests (35). This indicate humidity forest of dry deciduous (monsoon) Forest and Savanna Forest which is a dominant forest in new environment (36).

Northeastern region it found pollen which indicated dry areas in Gracial period were *Pinus* and *Quercus*. Both of plants can adapt to dry climate. In addition, the rapidly vegetation change during the Plistocene period and Holocene period was influence from climate change between Plistocene period to early Holocene period. There was expansion of tropical broad-leaf and sub-tropical broad-leaf plants relate to humid climate. For vegetation development along the middle and the end of Holocene period was clear to influence from forest fire and climate change (37).

2.9 Radiocarbon dating by Accelerator Mass Spectrometry (AMS) method

Radiocarbon can be found in natural organic matters in 3 isotope characteristic as ^{12}C , ^{13}C , ^{14}C . They are all different atomic weight and neutron numbers. Normally, ^{12}C and ^{13}C were stable atoms, but ^{14}C will be non-stable atoms which are radiocarbon with half life in 5,730 years before present by a deterioration of nucleus process. Temperature or chemical bonds and earth atmosphere consist of ^{12}C 98.9%, ^{13}C 1.1% and ^{14}C 1.2 atoms in every one million atom carbon. These carbons in 3 isotope are in form of carbon dioxide. Plants will absorb carbon dioxide from atmosphere to photosynthesis in changing carbon dioxide into starches and glucose for the growth of plants in produce leaves, branches, and trunks. In food chain, tissues of both flora and

fauna will always be contain ^{14}C . Measuring residual ^{14}C can be done by Conventional radiocarbon dating according to the principle of nucleus of ^{14}C which is not stable will deteriorate in the nucleus process. Approximate the volume of ^{14}C decay products can know the amount of residual ^{14}C (28).

However, the check by conventional radiocarbon dating must use many sample amount and must be careful for contamination or impurity of samples. This aims at achieving the least error possible. Another type of measure is Accelerator Mass Spectrometry (AMS) which will measure atoms of ^{14}C directly. The samples can be only 2-3 milligrams in solid targets in graphite or iron carbide in order to stir up ionized and accelerated through a particle accelerator with terminal voltage of two million volts or more. The ions will pass to focusing magnets to segregate the types of ions and then measure by detectors in the volume of residual concentration ^{14}C or the ratio between $^{14}\text{C}/^{12}\text{C}$ which can be measured from the samples. This can indicate for the age of the samples. Calculating for radiocarbon dating, the amount of intensity of ^{14}C is stable and has equivalent value to the volume of particular standard reference material in atmosphere. The measures result is lower than the standard value, it can be estimated for the value of level of radiocarbon in atmosphere in the pre-industrial period. This means that the samples in the measurement is in the period before 1950 AD which was the year Before Present, years BP. The value is over the standard value, the samples were in the period after 1955 AD which was an rapid increasing level of radiocarbon from the test of nucleus weapons in atmosphere. The result report will show the measure in percent modern carbon.

Though radiocarbon dating (^{14}C) in both methods will have different processes, but the result of the measure is accepted for their reliability (28).

In addition to radiocarbon dating by the samples from Bavaria by Erlangen Accelerator mass Spectrometry method, the samples were from lake sediments and swamp sediments. The samples were extracted with chemical substance, eliminated the carbonate by HCl and eliminated the humic acid by NaOH. After that, there will be eliminated with HCl again at the temperature of 80 °C. A rinse of acid with distilled water by centrifuging and drain the rest of the water. Take samples to the oven at 900

°C by the use of CuO and gain the reaction by Reduction by H₂ and Iron at 625 °C, one will gain solid carbon for measurement in Accelerator Mass Spectrometry (AMS) method (38).

2.10 Studied area

2.10.1 Scope and location

Thung Salang Luang National Park covers 1,247 square kilometers or 779,375 rais and is located of 2 provinces, Phitsanulok and Petchaboon at latitude of 16° 25' - 16° 57' north and longitude of 100° 37' - 101° 00' east. Northern and western parts of the park are located in Amphur Nakornthai, Amphur Wangthong, and Amphur Neonmaprang of Phitsanulok. The eastern and southern are covered in Sub-amphur Kao Koh and Sub-amphur Wang Pong of Petchaboon. The office of the park is on the route 12 Phitsanulok-Lomsak-Chumpae-Khonkaen. This is the route combining the north and the northeast of kilometer at 80 and is 450 kilometers from Bangkok by road. Other nearby national park is Phuhinrongkla (Phitsanulok – Loei) in the north and Nam Nao National Park (Petchaboon-Chaiyaphum) in the East (1).

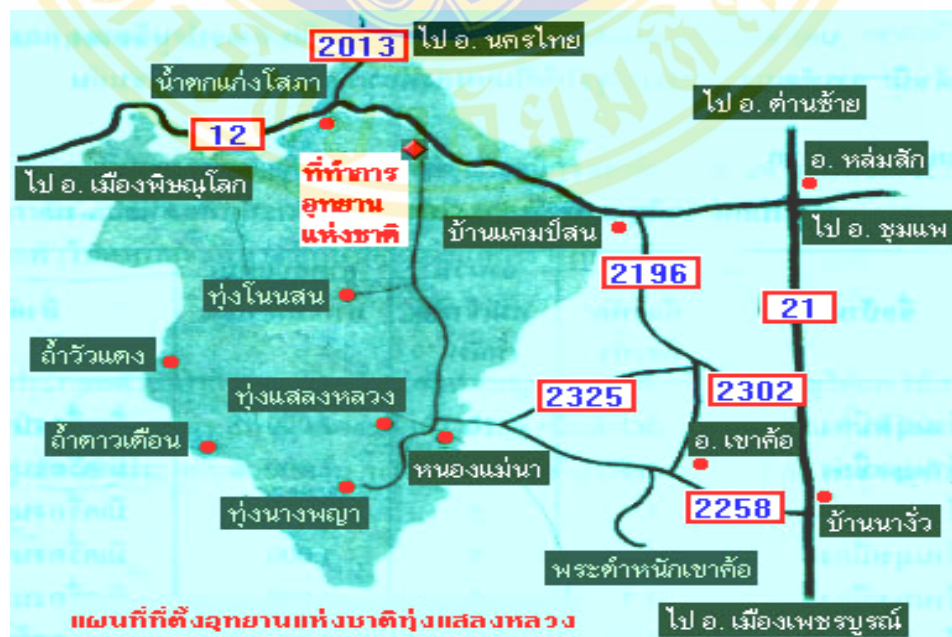


Figure 2-5 Route map of Thung Salang Luang National Park

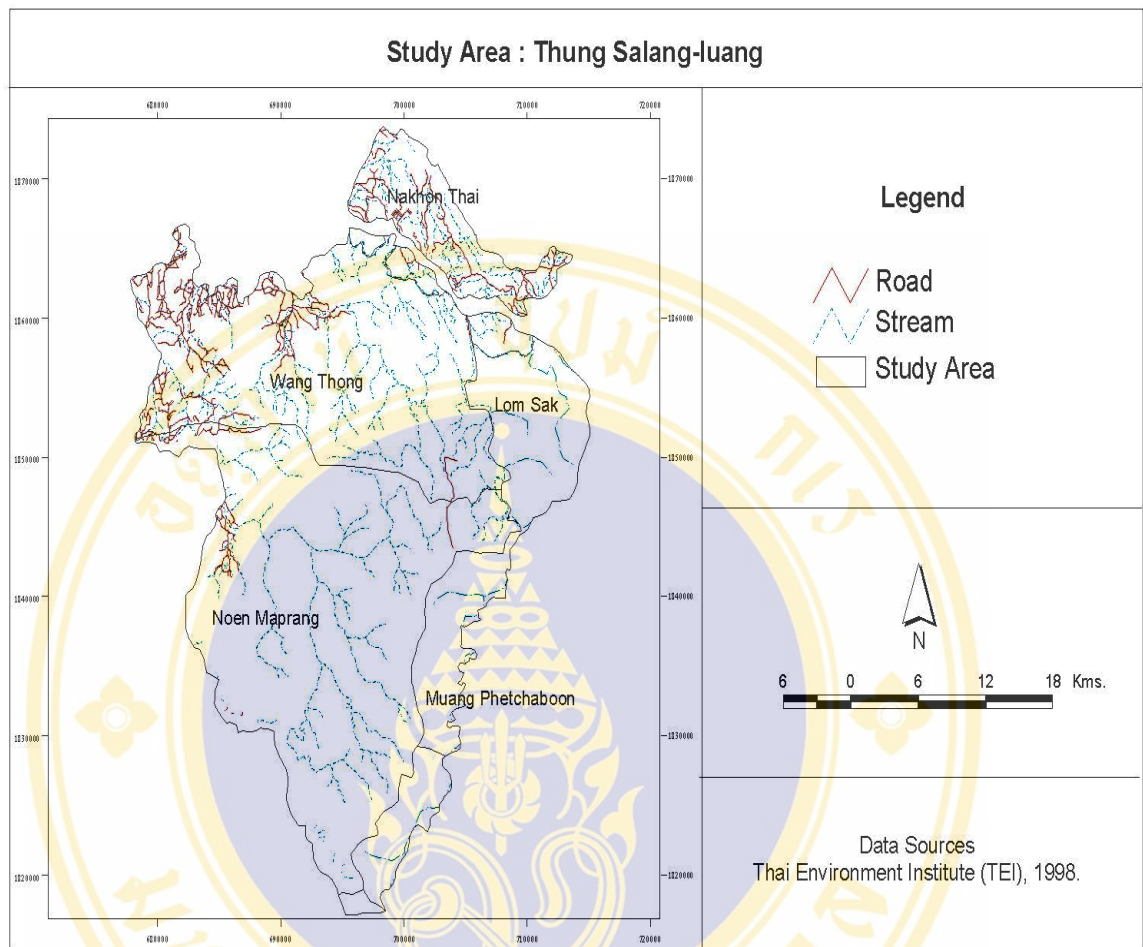


Figure 2-6 Map of Thung Salang Luang National Park, Phitsanulok province

2.10.2 Geography

Most of geography at Thung Salang Luang National Park are mountain areas from East to West which are hills and limestone hill. Most mountains are in Yod Duan Mountain with top mountain plain areas, with elevation of 400-1,003 meters from medium sea water level. Khao Phu is the highest peak with 1,003 meter height. Most of the area are forests. This geography could create many river basin and some important were Lam Nam Khek, Klong Chompoo, Huay Khok, and Huay Prom. Lam Nam Khek that could provide run-off about 635 million cubic meter per year (1).

2.10.3 Geological characteristics

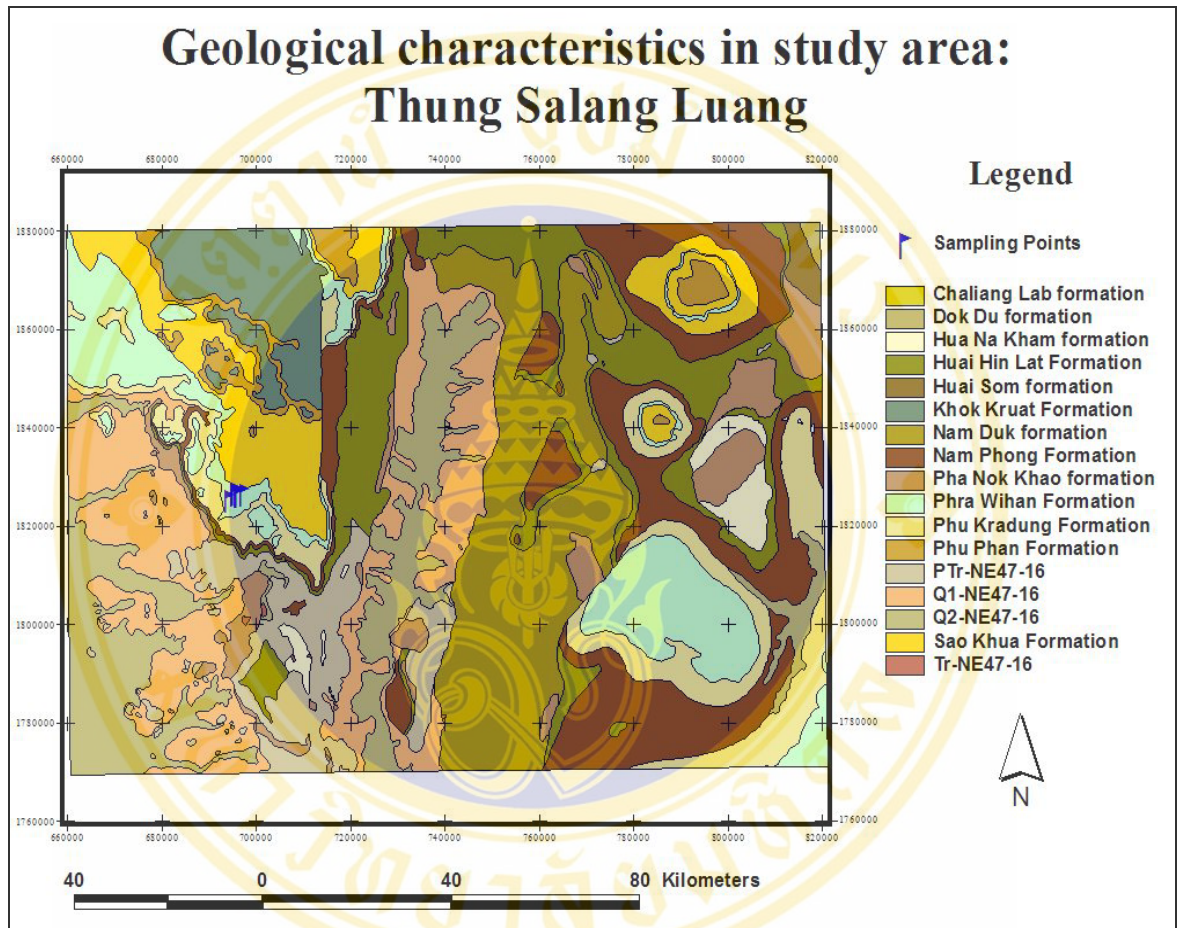


Figure 2-7 Geological characteristics of study area and sampling points

Geological characteristics of Thung Salang Luang National Park consist with **Nam Phong formation** (sandstone and siltstone, some shale, reddish-brown), **Phu Kadung formation** (siltstone intercalated and shale, micaceous cross-bedded with some lime-nodule conglomerate, reddish purplish-brown, some gray, non-resistant), **Phra wihan formation** (sandstone, micaceous, gray and white gray, orthoquartzitic, resistant massive cross-bedded, cropout in resistant or cliff, some intercalations of reddish brown and gray shale), **Sao Khua formation** (siltstone alternated sandstone, moderate resistant to non-resistant, reddish-purplish brown, brick

red, spread on top of the flat mountain), **Phu Phan formation** (pebbly sandstone, cross-bedded, pebbles consist of quartz, mostly white and colors chert, cap isolated peaks), **Khok Kruat formation** (claystone, clayshale, fine sandstone siltstone, rather soft, friable wea-thered, into small chips, palered, greenish red, reddish brown, slightly, calcareous siltstone, shale intercalated, wide spread caliche.

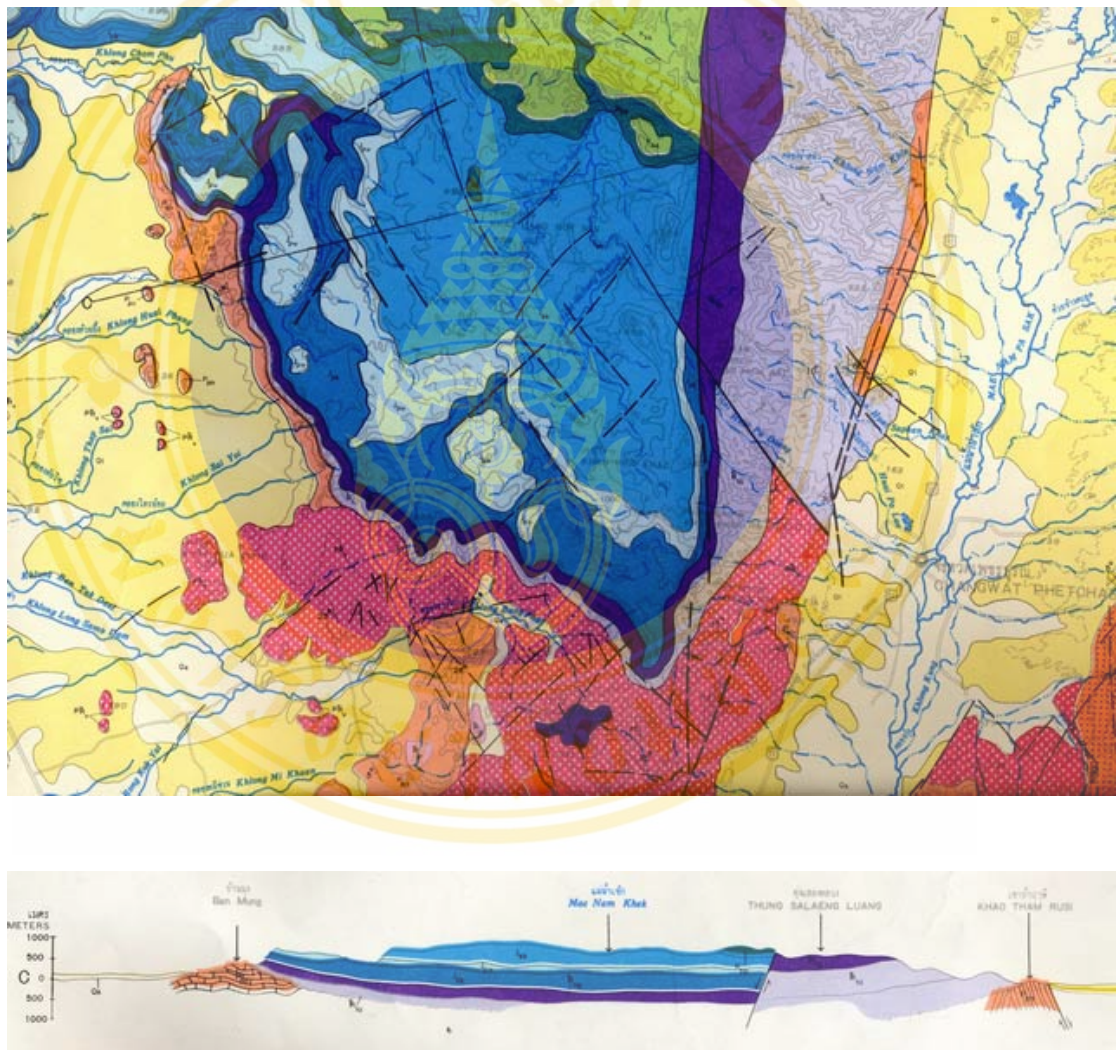


Figure 2-8 Geological map and cross section of Thung Salang Luang National Park

The area of Thung Salang Luang National Park was comprised of geological characteristics of Khorat group as these followings (figure 2-8):

1. Khok Kruat formation is composed of conglomerate, gray, reddish-brown: sandstone, gray reddish-brown shale, gray to black, reddish-brown, calcareous, mudstone and argillaceous limestone, gray; partly with tuff and agglomerate intercalated.

2. Phu Phan formation is composed of sandstone, reddish-brown, brown, cross-bedded, conglomerate, pebbles, consisting of quartz, quartzite, chert, red siltstone and sandstone, up to 10 cm. in diameter; shale and siltstone, brown, reddish-brown.

3. Phu Kradung formation is composed of shale, brown, reddish-brown, purplish-red, micaceous, small scale cross-bedding, with some lime-nodule conglomerate.

4. Phra Wihan formation is composed of sandstone, white pink, orthoquartzitic, cross-bedded, massive with pebbly layers on the upper bed; some intercalations of reddish-brown and gray shale.

5. Nam Phong formation is composed of sandstone, white pale orange, pebbly, cross-bedded, pebbles consisting of quartz, chert, red siltstone and igneous rocks, up to 5 cm. in diameter, with intercalations of shale and conglomerate.

6. Sau Khua formation is composed of sandstone, reddish-brown, micaceous, sandstone, grayish-brown, reddish-brown; shale, purplish, brick red, micaceous; and lime-nodule conglomerate.

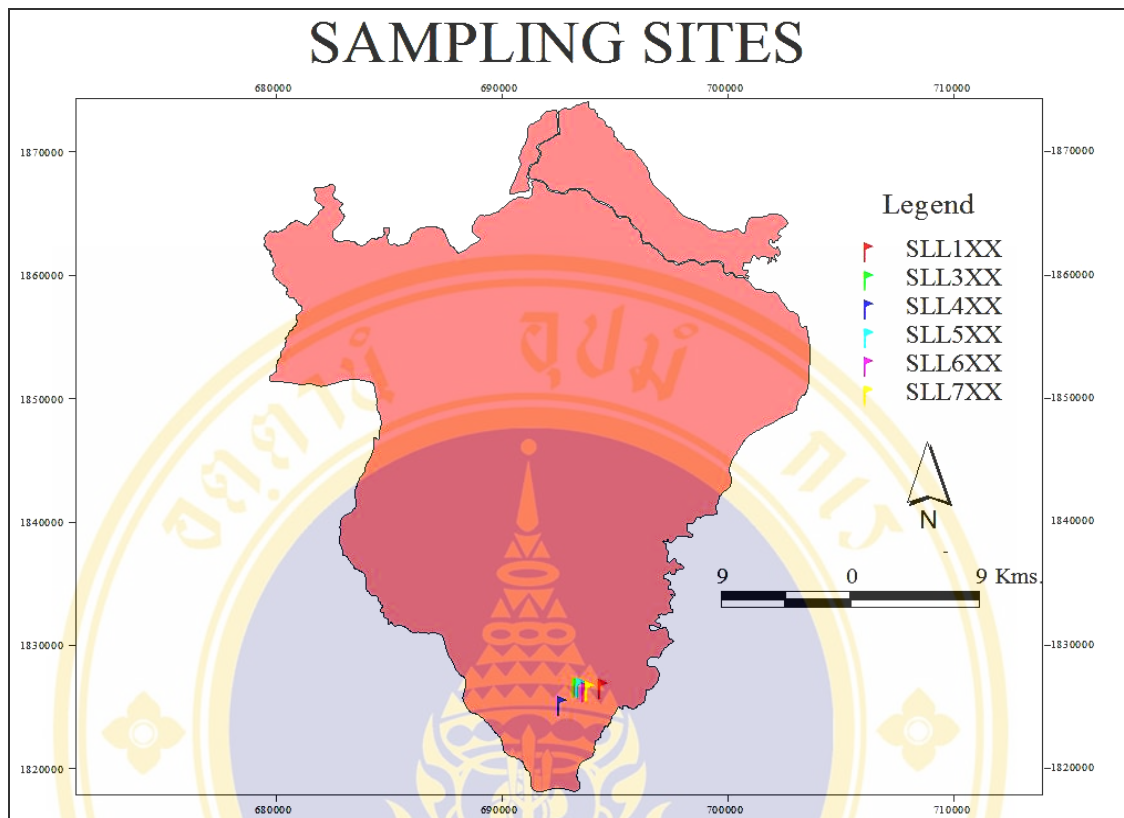


Figure 2-9 Sampling points of study area

2.10.4 Climatic characteristics

Thailand is located in the tropical area near equator. The climate is tropical under the influences of northeastern monsoon which brought dry and cold from China downward to Thailand during December to March. Meanwhile, the southwestern monsoon which brought humidity and rainfall.

Study area has collected climatic data record by Camp Son weather station of Meteorological Department has been located nearest to the area. Others Weather stations are in Phetchaboon and Phitsanulok provinces. They are on the southeastern and northwestern of area under study respectively. They are 80 kilometers apart.

From the statistics, climate characteristics in these three stations have similar variation of average value on a monthly but different quantity. Camp Son Weather

Station has higher value than the other two stations. Camp Son Station may locate in the higher level and near the high level of study area.

Therefore, analysis of climate characteristics of study area will use the result of Camp Son station which is more appropriate indicate of climate characteristic in the study area.

Climate characteristics for the study area are three seasons: rainy, winter, and summer seasons. Rainy season is between May and October for six months period. The most rainfall will be in August. General climate is humid and hot depend on the influence from southwestern monsoon. Winter season is between November and January for three month periods. For December and January, the weather is colder and drier than other seasons. Summer season is between February and April. April is the hottest for the year.

Climate characteristics for the study area as followings:

- Temperature: average temperature is 22.7 °C which is cold. The highest average temperature is in April and the lowest temperature is 9.8 °C in December.
- Rainfall: average rainfall in the year is 1,825.8 millimeters with variation between 1,223.1-2,512.8 millimeters. Most rainfall is in August at 369.6 millimeters and the least one is in January 8.7 millimeters.

Table 2-2: Annual average climate during 1951-1989 AD (39 years) in the North of Thailand (28)

Year	Average rain fall (millimeter/year)	Average surface temperature (°C)	Average highest surface temperature (°C)
1951-1989	1262.1	5.6	42.4

2.10.5 Forest Types

Forests in Thung Salang Luang National Park can be separated into 6 categories as followings:

2.10.5.1 Tropical Evergreen Forest is generally at 1,000 meters above mean sea level. But tropical evergreen forest of Thung Salang Luang National Park is at 800-1,000 meters from mean sea level. Forest sediments are deep, thick, high humidity, climate is humidity all year. Dominant plants species are temperate such as Fagaceae. They distribute around Lung Nonson hill and plu hill.

2.10.5.2 Pine Forest is locate between 700-900 meters from mean sea level. It is ecotone with grassland. At this National Park, there are *Dipterocarpus intricatus* with *Pinus murkusii*, *Careya arborea*. For ground plants are grass. It found mostly in Non Son Mountain, Thung Paya Muang Lane, and Thung Salang Luang.

2.10.5.3 Mixed Deciduous Forest are duciduous forest in dry climate and green-leave in rainy season. The sediment surface is deep with loamy sand. They are mostly found at 500-700 meters from mean sea level. Dominant plants species are *Xylia kurrii*, *Afzelia xylocarpus*, *Dalbergia oliveri*, *Gmelina arboreal*. Ground plants are mostly bamboo which are mostly found in Rong Rue Tah Muen Mountain, Klong Khek Yai, Tak Batr Mountain, and Hua Thung Paya Mountain.

2.10.5.4 Dry Dipterocarpus Forest are deciduous forest in dry climate. It locate at 700 meter at mean sea level. Soil fertility is very low. Soils are mixed with latterite and gravel. There are less soil humidity. Dominant plants species are *Shorea obtuse*, *Shorea siamensis*, *Dipterocarpus intricatus*, *Terminalia alata*. Ground plants are *Bambusa glaucescens* which found in Klong Nam Poy Yai, Ngob Noi Mountain, Song-ai –aueg Mountain.

2.10.5.5 Savannah is food sources for wild animals. Grasses are Nokyung grass, Pek grass, Konkainoi grass, Loklom grass, Kradumghun, Boa grass. They mostly found in Thung Salang Luang National Park, Thung Nong Jew, Thung Nong Yai, Thung Lom Pad Ta.

2.10.5.6 Abandoned Area are old forests for plantation, when soil is lossits fertility and people migrate from some area. Pioneer species and bushes with thorns are Kho grass, Pong grass, Kam and Loa. They found on both sides of Phitsanulok-Lomsak route with over 100,000 rais.

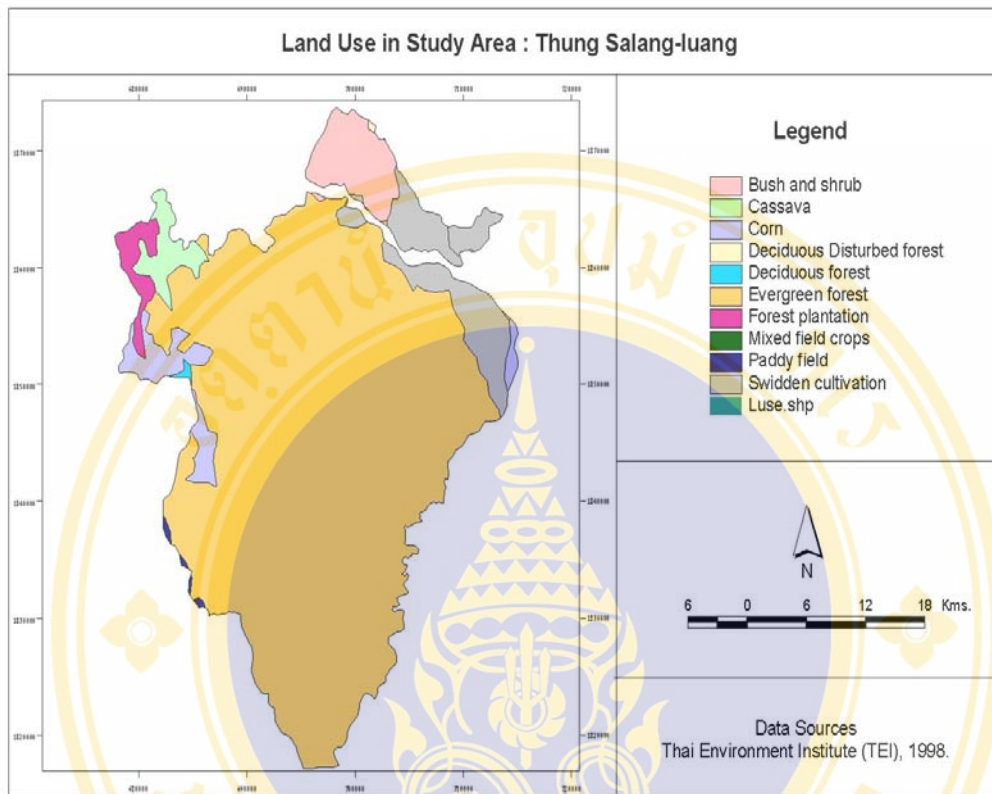


Figure 2-10 Land uses of Thung Salang Luang National Park

2.10.6 Forest characteristics in the study area

Forest characteristics in Thung Salang Luang can be categorized as followings:

- They are the sources of Koh (*Castania* spp., *Castanopsis* spp.) plant species from Indochina and India. They are expanded from India via Myanmar and meet at Petchaboon Mountain Range and mostly found in Phu Mountain.

- Savannah: around Thung Salang Luang, Thung Paya and Thung Non Sone which are not easily found in Thailand. There are natural grasses which grow early and end of rainy seasons.

- Historic importance: Thung Salang Luang is abandoned rice field by Communists who used the plantation area for food resources.

- Rare species found are:

- *Impatiens calcicola* is firstly found in Thailand at Kaeng Sopa of Thung Salang Luang National Park

- *Phoenix humilis* is palm species as the date plum. Its fruit can be food and the same taste as the date plum.

- *Pinus merkusii* found in Thailand at Thung Non Sone, Thung Paya.

- *Livistona speciosa* is a type of palm. They are found in the west of the park towards Kao Koh and is the origin of Kao Koh name.

- *Lycopodium* sp. is a type of fern which be found at Thung Salang Luang National Park.

CHAPTER 3

MATERIALS AND METHOD

3.1 Studied site selection

Investigation in the Thung Salang Luang National Park, site selection depend on pattern of accumulated sediments in sub-basin which relate to topography of study area. Random sampling in each sub-basin was carried out.

3.2 Sample collection

Palynological sites were selected on the basis of sub-basin environment, dark and fine grained sediments with organic remains and undisturbed environment. However, there were some footprints of elephants and other wild animals on the surface. Recent deposited sediments were soft and continuous sequence where located in the bottommost of valley.

3.2.1 Steps in sample collection for Holocene pollen analysis

1. Two methods of sediment collection for this study include:

- **Open pit excavation.**

This excavation technique was applied from archaeological study. The site was selected as mentioned above and located by GPS (Global Positioning System) and ground measurement. A rectangular block of 1.5 x 2 m². in North-South direction was fixed for excavation. Excavated block was unearthed layer by layer. Measurement of all layers were recorded. Sediments were randomly collected from layers of every ten centimeters. Some soil samples were collected continuously from the same profile. All samples were kept in plastic bags and labeled sample number,

depth and collection date. By this method, the deepest record was limited from water leaching into the pit or stratigraphic change sediments (sand or gravel).

- Profile coring.

Some sampling site, profile of sediments were cored by JMC Environmentalist's Sub-Soil Probe as shown in figure 9. The JMC Environmentalist's Sub-Soil Probe components composed of liner, hammer assembly and sampling tube. Boring sediments down to hardness layer or to sand or gravel levels. All sediment samples were cut every 10 cm. and kept in plastic tube 92 centimeters in length. During the sampling of sediments, try to avoid risks of contaminations either from air pollution or from cuttings and mud or from tools (eg. Knife).

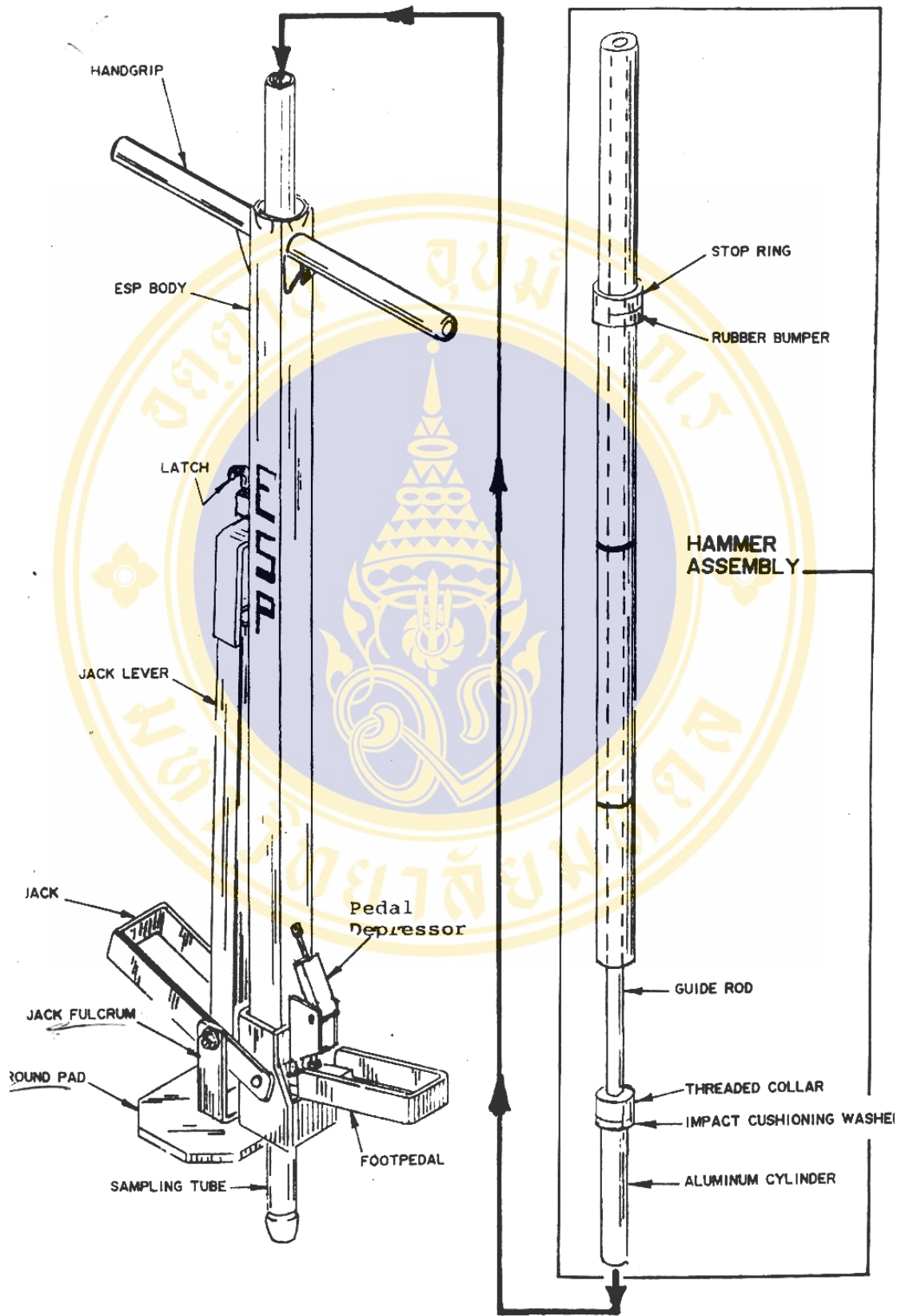


Figure 3-1 JMC Environmentalist's Sub-Soil Probe equipment

Using of JMC Environmentalist's Sub-Soil Probe equipment

1) Set up the environmentalist's Sub-Soil Probe (ESP) on the sampling site vertically. Insert a liner (one of the clear plastic or optional stainless steel tubes 36" long and 15/16" in diameter) into the top of your sampling tube.

2) Pick up both pieces of the hammer assembly. Insert the aluminum cylinder section of the guide rod into the top of the sampling tube. Make sure that the end of the hammer is in contact with the threaded collar adjacent to the aluminum cylinder. Move the pedal depressor into the driving mode position.

3) Tip the ESP and the hammer assembly as a single unit into a vertical position.

4) Double check that the pedal depressor remains in the driving mode position before using the hammer. Failure to do so may result in damage to both the sampling tube and the footpedal.

5) Position feet in a stance of 12 to 18 inches as illustrated. Grip the hammer with both hands like a baseball bat (Be sure to keep your hands positioned to avoid getting them pinched between the hammer assembly and the top of the treaded collar) Then, raise the hammer approximately 12 to 18 inches above its resting position. Drive the hammer sharply against the top of the sampling tube.

Assuming meet no obstacles, continue driving the sampling tube into the ground until the rubber bumper on the ESP body. At this point, the sampling tube is full and ready to be extracted from the ground.

6) Depress the footpedal so can swing the pedal depressor out of the way. The jack will not work with the pedal depressor in the driving mode position.

7) Release the jack level by pulling upward on the black plastic handle and pulling the jack level away from the ESP body. The jack level should then move into a position roughly 45 degrees to the ESP body making the probe like a lop-sided pogo stick.

8) To extract the sampling tube from the ground, put one foot on the jack level and leave the other on the ground. This will raise the sampling tube and ESP body approximately 1-1/2 inches. Next, shift your weight from the jack level to your other foot, but do not remove your foot from the jack level. While resting one foot lightly on the jack level, press down on the handgrips. The jack level returns to its former 45 degree angle position.

9) When can see the bottom of the hammer, remove the hammer assembly. Avoid pinching your fingers between the threaded collar and hammer with the other. Continue jacking until the sampling tube is out of the ground. Return the jacking level to its original upright position and secure it with the black plastic knob mounted on the side of the probe.

10) Lay the ESP horizontally on the ground. Insert the supplied dowel into the cutting end of the sampling tube and push out the soil core and liner. Then put caps over both ends of the liner.

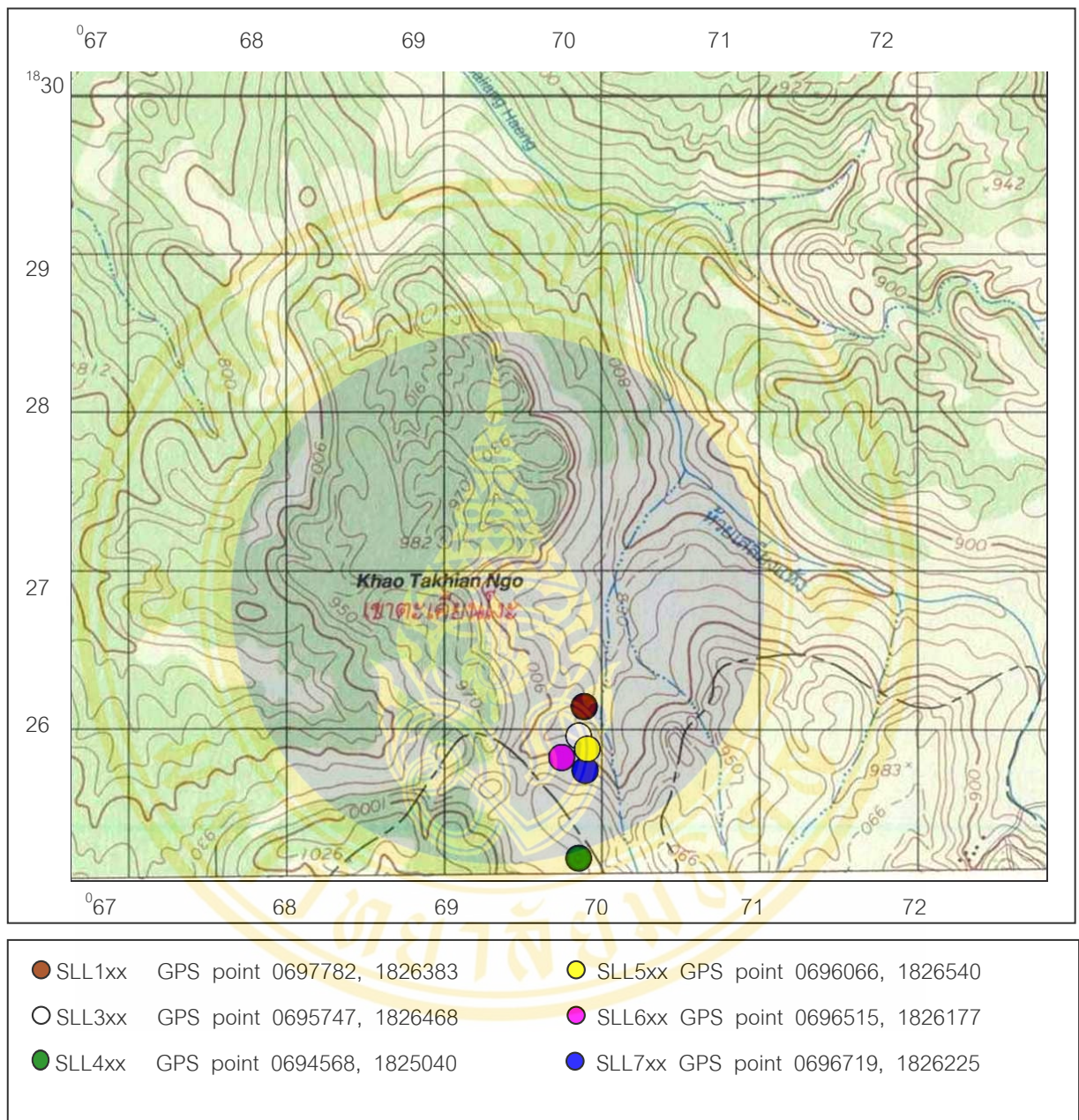


Figure 3-2 Study area and sampling sites for pollen analysis at Thung Salang Luang National Park (1:50,000 topographical map, sheet 5142 II)

The stratigraphic column of site SLL6xx (figure 3-3) shows loamy sand to sand in the lower sequence, and dark loamy clay in the upper sequence.

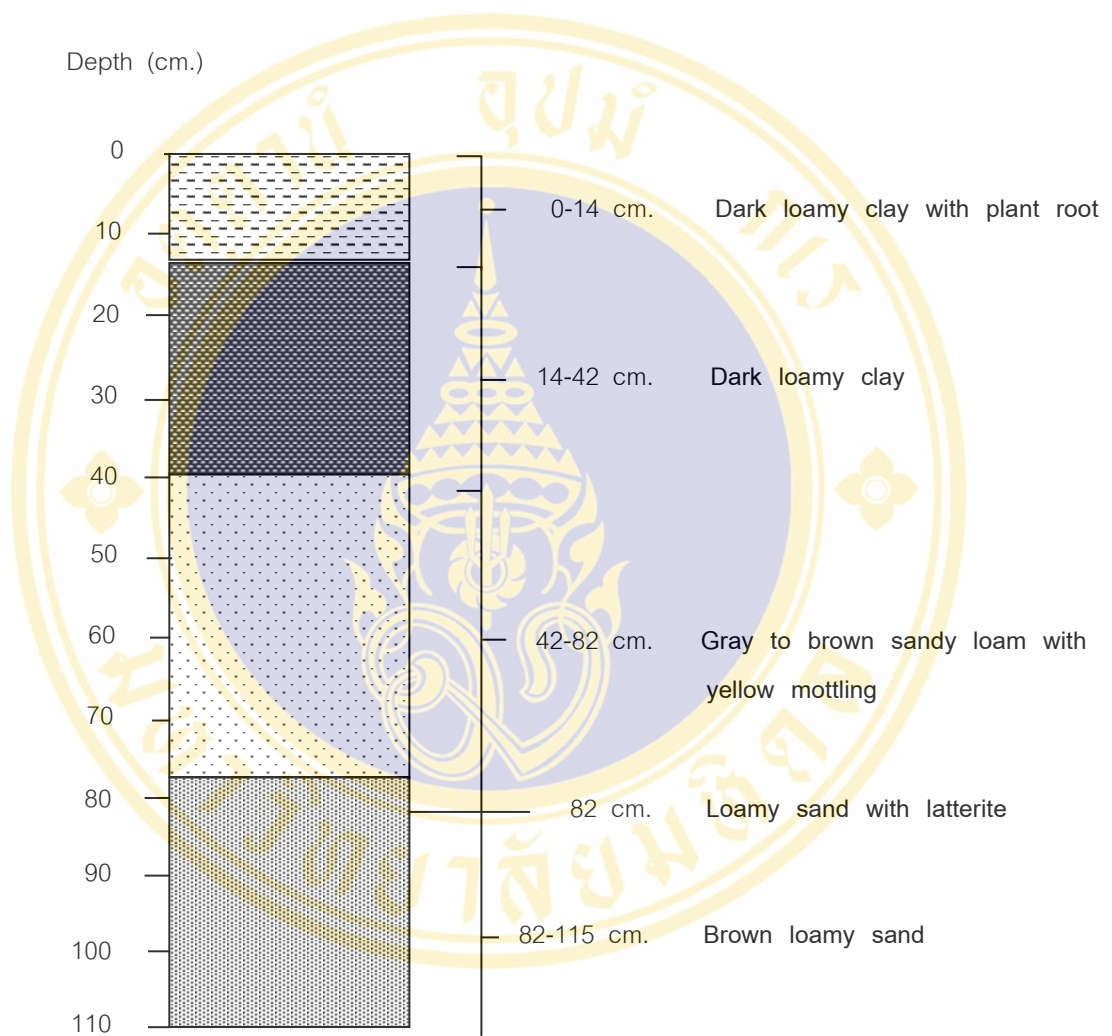


Figure 3-3 Stratigraphic column of samples from SLL6xx

The stratigraphic column of site SLL7xx (figure 3-4) shows dark carbonaceous mud 0-92 cm. in the length, there was continuously swampy environment as the sediment samples did not dry and loamy sand in the lower sequence.

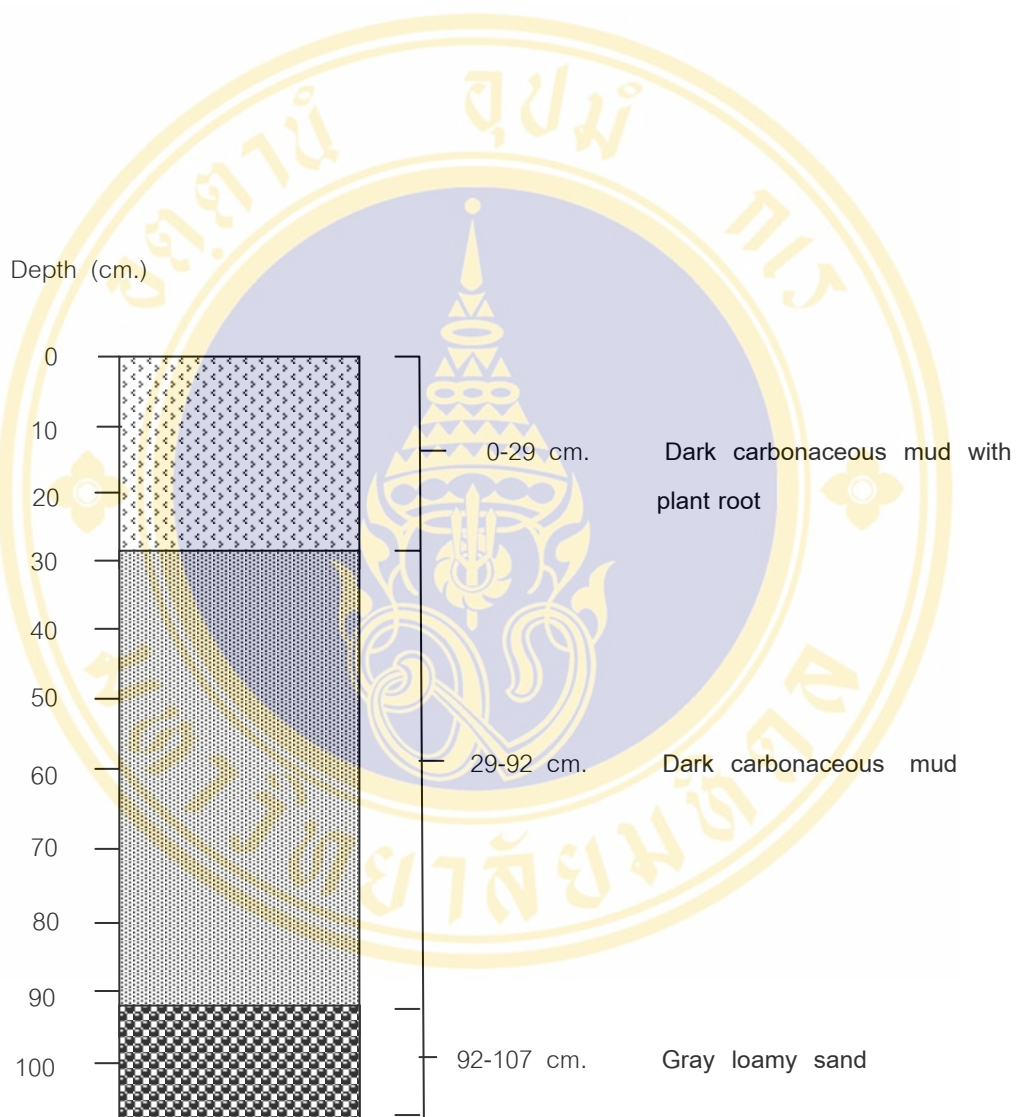


Figure 3-4 Stratigraphic column of samples from SLL7xx

3.2.2 Sample preparation

1. Extracting pollen grains

The resistant nature of the exine allows palynologists to use chemical reagents to remove most other mineral and organic matter from the samples. Sub-sampling of collected sediments, often 8-15 grams of material, is used. There are chemical and physical process to extracting pollen. To remove extraneous matter: Carbonates, siliceous matter, humic acid and organic matters, chemical process is introduced (33).

Each step in chemical process is usually followed by centrifuging to concentrate the pollen suspension. In the following, a centrifuge speed of approximately 2,500-3,000 r.p.m. for 2-3 minutes is presumed if nothing else described. Pollen grains sink fairly fast in aqueous suspension. Washing the residue with distilled water is a usual step. A processing sequence in this thesis is as followings:

a. Chemical Technique

1. Removal of carbonate: using 10% HCl to see if there is carbonates available. In case carbonates are presented, concentrated HCl is introduced. Heat in hot water bath for 30 minutes. If there is no sign for carbonate skip to next step.

2. Removal of siliceous matter: using 40% HF in hot water bath for 30 minutes. Siliceous matter: sand, clay, etc. is removed by hydrofluoric acid (HF) treatment. The HF treatment does not appreciably attack organic remains, pollen grains included, but grain size is affected.

3. Removal of colloidal SiO_2 and silicofluorides: using concentrated HCl in hot water bath for 30 minute.

4. Removal of organic matters: using HNO_3

5. Removal of humic acids: using 5% KOH boil in hot water bath for 3 minutes. The treatment is humic acid removal and deflocculation at the same time. The concentration of KOH should not exceed ca.10%. Long boiling with stronger solutions would attack the exine of some species. If the sample contains much humic acid it would be very dark brown to black solution, it may be necessary to repeat this step to remove more of it. In such highly humified material scarcely anything but pollen is left after treatment, and the following procedures are redundant (pollen size is affected).

b. Sieving Technique

Use 15 μ sieve clothes. Pour sediments into a sieving pot and spray distilled water on the sediments which pollen size more than 15 μ are collected on the top of sieving mesh (33).

2. Slide mounting

Pour the sediments from the sieving pot into a 10 mm. Tube. Drop bismark brown 2-3 drop into the tube, then centrifuge for 2 minutes. Pour the mixture out of the tube, pollen will be collected in the bottom of the tube, wash out the residue one time before pour PVA (Polyvinyl Alcohol) into the tube. Mix up and drop the mixture on coverslips which are on a hot plate and wait until they are dried. Drop some liquid permount on the coverslips for attaching with microscope slides. Code all the sample slides which generally make four slides per a palynological sample (33).

3. Pollen Analysis

The identification and counting of pollen grains is the basis of pollen analysis. Scan and count pollen grains from prepared slides by magnification of X400. This provides sufficient magnification for the use of a X40 objective lens is usually appropriate for slides with a reasonable pollen density. Oil immersion microscopy at X1000 will be necessary for dubious grains. It is necessary to count 150-200 grains in order to get reliable percentage which this study counts to 200 grains (33).

4. Interpretation of palaeo-vegetation and palaeo-environment

Calculate the counted 200 grains of pollen as percentage to obtain the proportion of each plant. Then, each percentage of plant was categorized, which based on its own forest type of habitat. Pollen diagram was reconstructed for palaeo-vegetation and palaeo-environment. Some certain plants can be indicators of sub-environment or forest types, which relate to palaeo-climate change. Compare groups of palaeo-vegetation, which obtained from pollen analysis, to groups of recent vegetation to see how they are different. If any groups of palaeo-vegetation is different from the recent, climatic change might be influent to this region. Nevertheless, if there is no different in major type of forest, climatic at that time might be similar to the recent (33).

3.3 Collecting samples of organic matter for radiocarbon dating analysis by Accelerator Mass Spectrometry (AMS)

Organic matter such as charcoal was intentionally look for during excavation or soil sample collection. The charcoal sample was kept in a separate plastic bag. Try to avoid contamination of modern charcoal and plant roots. Then, the sample was sealed and recorded code number depth, date, later, in the laboratory the charcoal sample was washed, air-dried and kept to

forward to the Beta Analytic, Inc. 4985 S. W. 74 th Court Miami, FL, USA. for dating. Minimum of 3 mg. was required for AMS dating.

3.3.1 Preparation and analysis for radiocarbon dating

3.3.1.1 Sample preparation

The samples are extracted from the inner part of the core which have to be treated chemical to convert them to graphitized carbon. In a chemical pretreatment two major components which may obscure the ^{14}C results are removed (38):

- Carbonates arising from the erosion of limestone are removed by heating the material with HCl.
- Humic acid which may be younger due to its high mobility is removed by heating it together with NaOH.

The second procedure is repeated until the brown color of the solution vanishes. This AAA pretreatment is finished by another heating in HCl, washing in distilled water and drying the remaining material in an oven.

The residue is put into a quartz tube together with copper oxide and silver wool. After evacuation the tube is sealed by melting. The conversion to carbon dioxide is performed by heating the sealed tube to $900\text{ }^{\circ}\text{C}$ for about an hour. After a slow cooling the tube is cracked in the reduction facility, where graphitization takes place by heating an appropriate mixture of hydrogen and carbon dioxide at $625\text{ }^{\circ}\text{C}$ with iron powder of 10 microns as a catalyst. Finally, the samples are used for the AMS measurement.

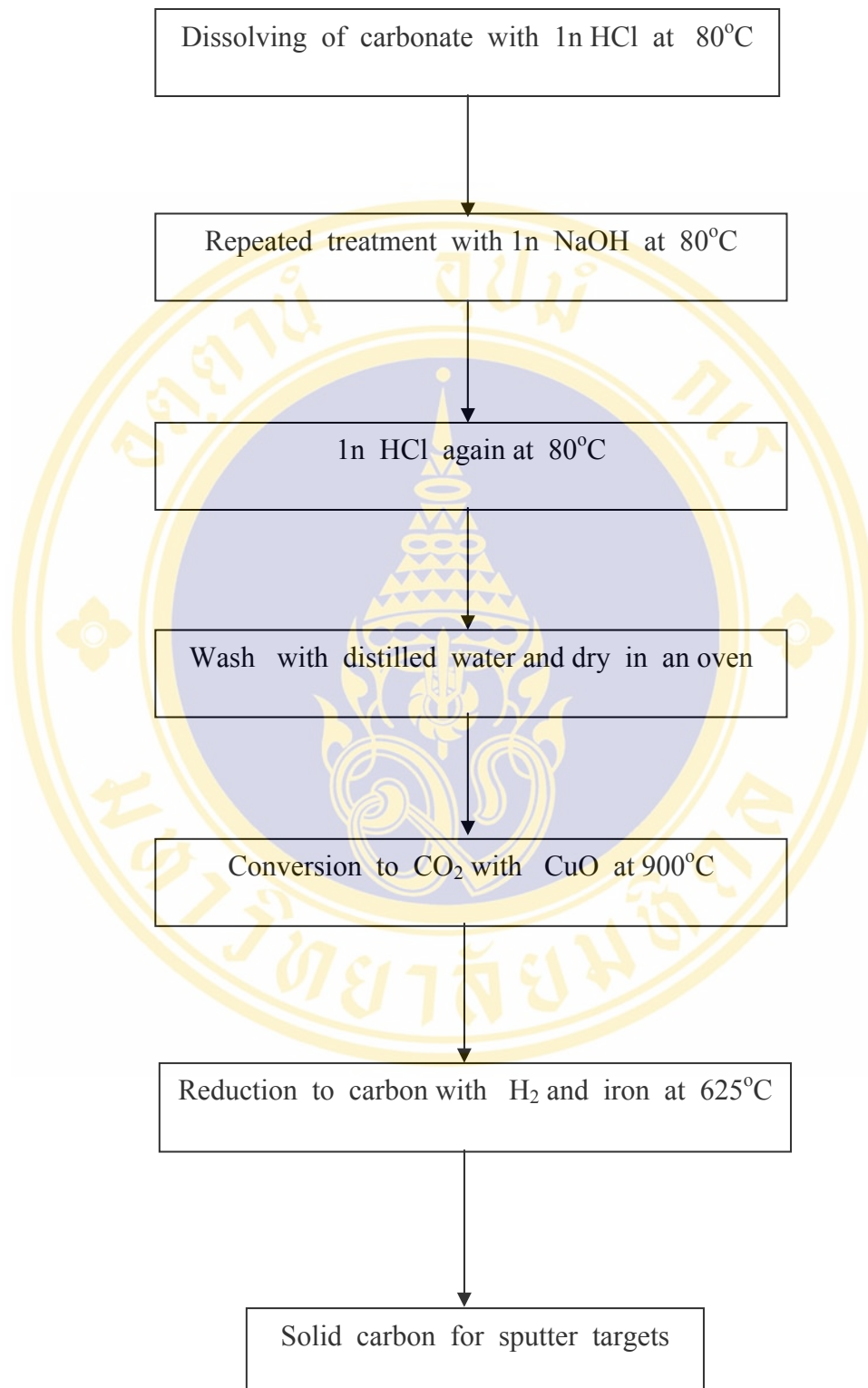


Figure 3-5 Preparation of sample for radiocarbon dating by AMS (38)

3.3.1.2 Operating of Accelerator Mass Spectrometry

The enormous advantage of using direct detection of ^{14}C atoms is that a substantial portion of the atoms in a sample can be counted, not just the very few that happen to spontaneously decay over the fewer days of gas or liquid scintillation counting.

Samples of a few milligrams are typically prepared as solid targets of graphite or iron carbide on a metal stub. They are placed as targets in a chamber with an ion-sputter source, ionized and accelerated through a particle accelerator with a terminal voltage of two million volts or more. The emerging ions are passed through focusing magnets, which selects their correct charge state and energy. Finally, these positive ions enter into the target room where they are measured directly to determine the amount of rare radioisotope in the original samples, or they bombard a specimen to determine its composition and structure (38).

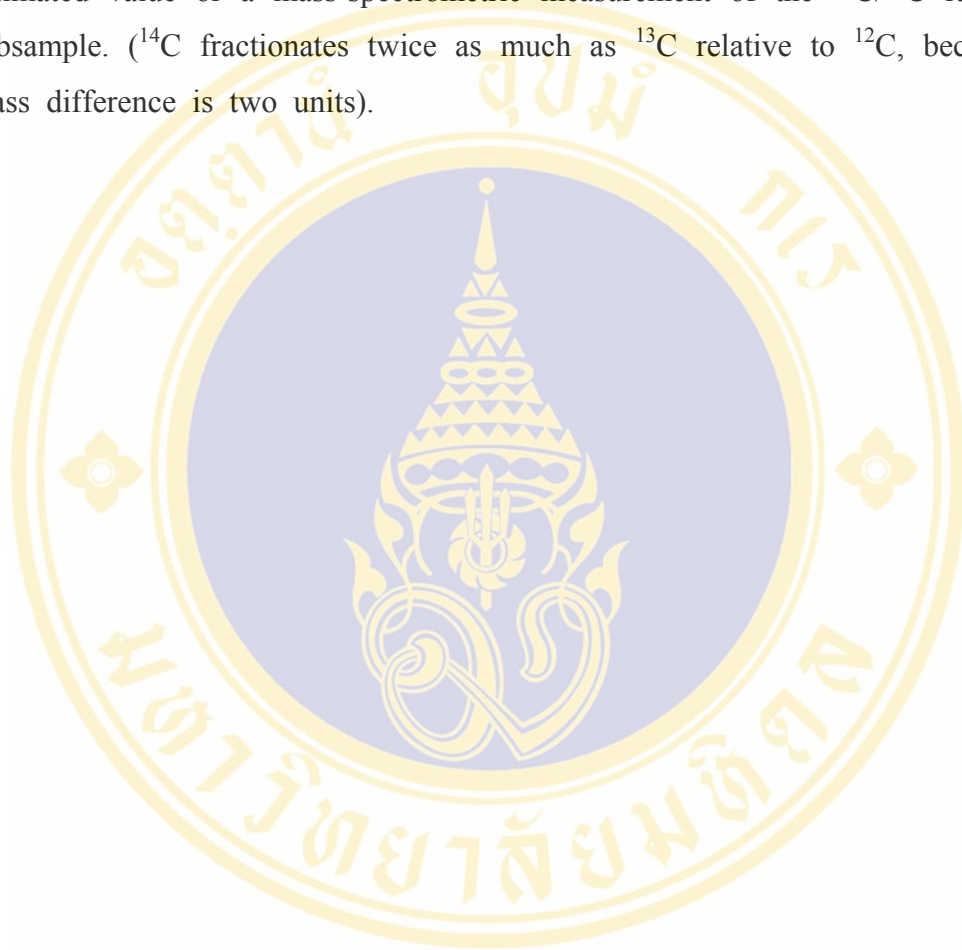
3.3.1.3 Age calculation

The residual concentration of ^{14}C or $^{14}\text{C}/^{12}\text{C}$ ratio, in old materials is an indicator of their age. Radiocarbon ages are traditionally calculated on the assumption that the atmospheric concentration of ^{14}C has always been constant, and equal to the value a particular standard reference material which is prepared and measured regularly by all radiocarbon laboratories.

Ages are reported in years before present which, again by international agreement, is not the most likely value (the correct value is probably closer to 5,730 years, but there is an uncertainty and the value is not determined precisely). An uncertainty, at the one standard deviation (68% confidence) level, is calculated from the statistics of standard, sample and

background measurement; it is typically ± 50 years for samples up to a few thousand years old.

Ages are corrected for isotopic fractionation, using either an estimated value or a mass-spectrometric measurement of the $^{13}\text{C}/^{12}\text{C}$ ratio of a subsample. (^{14}C fractionates twice as much as ^{13}C relative to ^{12}C , because the mass difference is two units).



CHAPTER 4

RESULTS AND DISCUSSION

Six sampling sites in this area were examined including four coring sites (SLL1xx, SLL3xx, SLL4xx, SLL5xx) and two excavation sites (SLL6xx and SLL7xx). After remaining about two years in laboratory, the coring samples were poorly preserved. It might have been oxidized and corroded. However, recent excavation of sites SLL6xx and SLL7xx (date 6/04/03, 7/04/03) were commonly productive and aimed for pollen analysis. On the other hand, very rare charcoal samples were founded from site SLL1xx, SLL3xx, SLL4xx and SLL5xx. But the SLL7xx yielded some good charcoal samples in the sequence. Therefore SLL7xx and SLL6xx are the main studied site aimed for this investigation.

4.1 Pollen analysis from SLL6xx samples

Fifty six samples of SLL6xx site were prepared. Twenty seven samples are productive. The results of pollen analysis for plant community (Figure 4-2) can be separated into two sequence including in the upper sequence (1-50 cm.) and lower sequence (50-112 cm.). Commonly found palynomorphs (Figure 4-1) are pine (Pinaceae), grass (Gramineae), sedge (Cyperaceae), *Lycopodium* spp., Polypodiaceae, *Polypodium* spp., Cyatheaceae, *Pteris* spp., *Selaginella* spp., kut (Thelypteridaceae) and *Montia* spp. They represent most modern plants grow around the site.

Pollen and spores founded from sediments of SLL6xx site are grouped as followings:

Tree: Pine (*Pinus* spp., Pinaceae), Kuam (Aceraceae) and Ko (*Quercus* spp., Fagaceae).

Herb: Wan Hua Suep (Liliaceae), Wan (Iridaceae), Phak Bung Som (Polygonaceae).

Ferns: Polypodiaceae, Soi Nari (*Lycopodium* sp., Lycopodiaceae), Kut (*Polypodium* sp., Polypodiaceae), Kut Ton (Cyatheaceae), Kut (*Pteris* sp., Pteridaceae), (*Selaginella* sp., Selaginellaceae), (*Tricomanes* spp., Hymenophyllaceae), *Montia* spp., Chenopodiaceae, Thelypteridaceae.

Palm: Palmae.

Grass and sedge: Gramineae, Cyperaceae and Ko Kadueng (*Carex* sp., Cyperaceae).

Aquatic plant: Sarai khao niao (*Utricularia* spp., Lentibulariaceae) and Lesser Duckweed (*Lemna* sp., Lemnaceae).

Unknown affinity: *Tricolporites* sp.

These pollen and spores can be categorized into **ecological system** as followings:

Sub-tropical forest

Tree, shrub and herb are defined as sub-tropical forest such as Pine (Pinaceae), Wan Hua Suep (Liliaceae), Wan (Iridaceae).

Tropical forest

Tree, shrub and herb are defined as tropical forest type such as Phak Bung Som (Polygonaceae), Kuam (Aceraceae).

Aquatic habitat

Sarai Khao Niao (*Utricularia* spp., Lentibulariaceae) and Lesser Duckweed (*Lemna* sp., Lemnaceae) grow naturally in aquatic habitat.

Swamp habitat

Cyperaceae and Ko Kadueng (*Carex* sp., Cyperaceae) are naturally in the swamp habitat.

Fern group

Fern spores found affiliate with modern Polypodiaceae, Soi Nari (*Lycopodium* sp., Lycopodiaceae), Kut (*Polypodium* sp., Polypodiaceae), Kut Ton (Cyatheaceae), Kut (*Pteris* sp., Pteridaceae), (*Selaginella* sp., Selaginellaceae), (*Tricomanes* spp., Hymenophyllaceae), *Montia* spp., Chenopodiaceae and Thelypteridaceae.

Grass Grass pollen affiliate with only Gramineae pollen.

Palm Very few palm pollen found in this site.

The appearance of pollen and spores in SLL6xx site can be discussed as followings:

4.1.1 Pine pollen and palaeoclimate

In the lower sequence (41-112 cm.), pine pollen (*Pinus* spp., Pinaceae) yields rarely. They were found at SLL653 (75 cm.); SLL604 (110 cm.); SLL603 (111 cm.). But pine pollen increases in the upper sequence (4-40 cm.) as a major pollen deposits. Upper sequence, pine pollen occurs commonly between 20-90% of total counts.

Tropical forest, Kuam pollen (*Acer* spp., Aceraceae) is rare appearance in the upper sequence. Only one sample (SLL623, 50 cm.) yield Kuam.

Lower sequence, pollen of sub-tropical forest is rare appearance and less than pollen of tropical forest. Upper sequence, found pollen of sub-

tropical forest and pollen of tropical forest both are high proportion. This suggest that in this study area has both ecological system of sub-tropical taxa and tropical taxa throughout the sequence. But in the upper sequence forest fire might have stimulated growing of grass and pine. This caused high proportion of grass, pine and sub-tropical pollen. However, recent deposits (at the top of sequence, 12-0 cm.) show sharp decreasing of tropical microfloras which suggests pine forest (sub-tropical) is dominant at the end of sequence.

4.1.2 Grass and forest fire

Modern forest fire occurs mainly in open area with grass Land (Graminae). Thung Salang Luang National Park has sporadically pine trees among grassland (with fern). Forest fire occurs annually during dry season. Grass pollen are commonly high in the upper sequence. This suggests that forest fire occurred in the upper sequence along with occurrences of grass and pine pollen. Heat from forest fire helps better germination of pine seedling. The pine has serotinous cone with resin and wax that is dehiscent when activated by forest fire. Slightly burn forest fire is the most favorable condition for pine cone dehiscence and germination (45). Grass are pioneer species following forest fire. Later, pine will insert and replace themselves in the grass land.

4.1.3 Fern group

Fern spores found in the sequence are Cyatheaceae, *Polypodium* spp., Polypodiaceae, *Pteris* spp., *Lycopodium* spp., *Tricomanes* spp. They appear abundantly throughout the sequence, and decreasing upward. In the lower sequence (90-112cm.), they yielded high proportion between 62-75% which could be interpreted that it had high humidity because of fern could grow on the ground and dead trees in the tropical rain forest. Its growth depend on temperature and humidity factors, for example appropriate day temperature is 19-27 °C and night temperature should be lower day temperature about 6 °C.

But growth of tender fern in this study area such as *Polypodium* sp. and *Pteris* sp. would be dropped when the temperature decrease to less than 16 °C. *Polypodium* sp. was classified as rock fern group which has the period resting stage and could adaptation on dry area in summer season. From this fact, it could be impossible find a few distribution of spores at the upper sequence that humidity was decreased (39).

However, from the modern fern in this study area, Cyatheaceae is the dominant species among ground vegetation and it had a little distribution at the upper sequence as well.

4.1.4 Swamp habitat

Cyperaceae pollen are rarely found in the sequence. Four samples (SLL630, 30 cm.; SLL655, 36 cm.; SLL638, 48 cm.; SLL653, 75 cm.) yielded 1-5% of total pollen counts. Modern habitat of Cyperaceae is swampy environment. Thus it may indicate that the deposit site SLL6xx was not continuously swampy environment.

4.1.5 Aquatic habitat

Sarai Khao niao (*Utricularia* spp., Lentibulariaceae) and Lesser duckweed (*Lemna* sp., Lemnaceae) are rarely found in the upper sequence. It might have been sporadically wet environment.

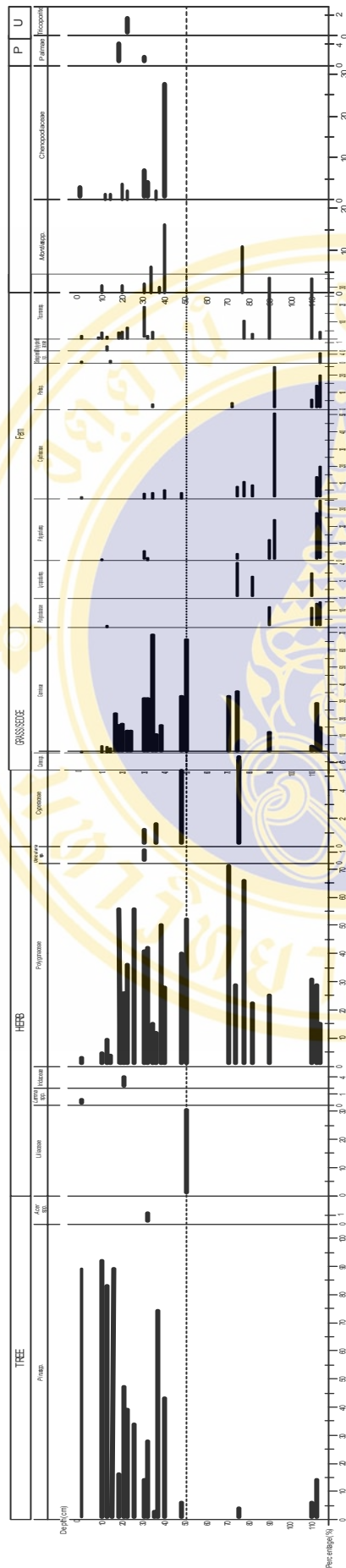


Figure 4-1 Result of pollen analysis from sediment sample SLL6xx

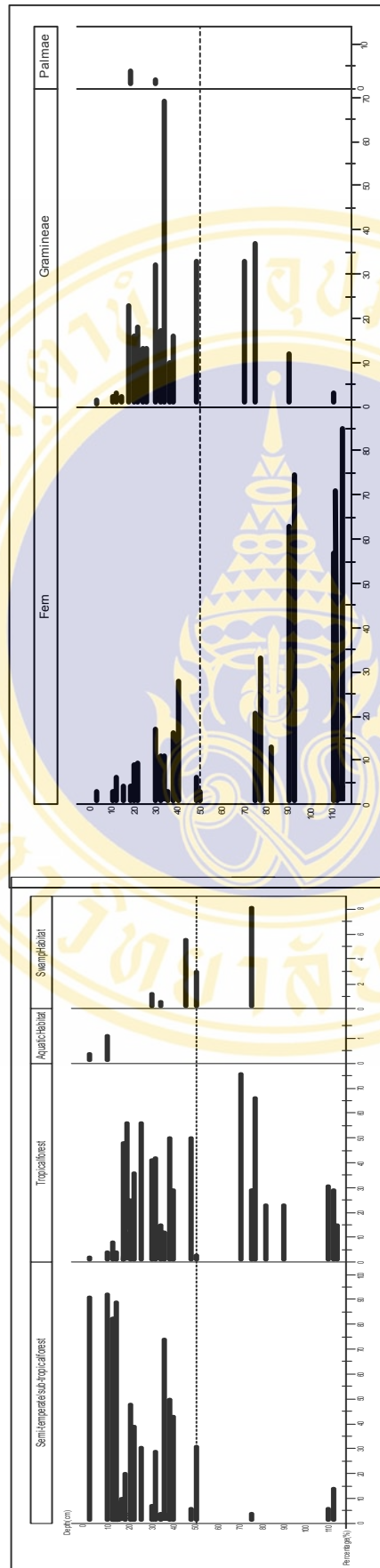


Figure 4-2 Result of plant community group from sediment sample SLL6xx

4.2 Pollen analysis from SLL7xx samples

The results of pollen analysis from all of 63 samples SLL7xx (Figure 4-3) which could be categorized pollen and spore founded from sediments of SLL7xx site are as followings:

Tree: Pine (*Pinus* spp., Pinaceae), Ko (*Quercus* spp., Fagaceae), Kamlangsoea Khrong (*Betula* spp.), Ko/Kaolat (*Castanopsis* sp., Fagaceae), Cayenne Cherry (*Eugenia* sp., Myrtaceae), Mak (Myricaceae), Iron Wood (*Hopea* spp., Dipterocarpaceae) and Son Phaeng (Cupressaceae).

Shrub: Philangkasa (Myrsinaceae).

Herb: Bundong Lueang (*Polygala* spp., Polygalaceae), Wan Hua Suep (Liliaceae), Thua-Duang (Labiatae), Wan (Iridaceae), Phak Bung Som (Polygonaceae), Yat Nam Khang (Droseraceae) and Compositae.

Ferns: Polypodiaceae, Soi Nari (*Lycopodium* sp., Lycopodiaceae), Chinnamon Fern (*Osmanda* sp., Osmandaceae), Kut (*Polypodium* sp., Polypodiaceae), Kut Ton (Cyatheaceae), Kut (*Pteris* sp., Pteridaceae), (*Selaginella* sp., Selaginellaceae), (*Tricomanes* spp., Hymenophylaceae), (*Woodsia* sp., Blechnaceae), *Montia* spp., Monolete Isoetaceae, Ribbon Fern (*Ophioglossum* spp., Ophioglossaceae), Aspleniaceae, Chenopodiaceae and Thelypteridaceae.

Palm: Palmae.

Grass and sedge: Gramineae, Ya Takan (*Ruppia* sp., Ruppiaceae), Cyperaceae and Ko Kadueng (*Carex* sp., Cyperaceae).

Aquatic plant: Sarai Khao Niao (*Utricularia* spp., Lentibulariaceae) and Lesser Duckweed (*Lemna* sp., Lemnaceae).

Unknown affinity: *Rhoipites* sp. and *Tricolporites* sp.

These pollen and spores can categorized **ecological system** as followings:

Sub-tropical forest

Tree, shrub and herb are defined as sub-tropical forest such as Pine (Pinaceae), Wan Hua Suep (Liliaceae), Wan (Iridaceae) Ko (*Quercus* spp., Fagaceae), Kamlangsuea Khrong (*Betula* spp.), Ko/Kaolat (*Castanopsis* sp., Fagaceae), Cayenne Cherry (*Eugenia* sp., Myrtaceae), Mak (Myricaceae), Son Phaeng (Cupressaceae) and Philangkasa (Myrsinaceae).

Tropical forest

Tree, shrub and herb are defined as tropical forest such as such as Phak Bung Som (Polygonaceae), Iron Wood (*Hopea* spp., Dipterocarpaceae), Thua-Duang (Labiatae) and Compositae.

Aquatic habitat

Sarai Khao Niao (*Utricularia* spp., Lentibulariaceae) and Lesser Duckweed (*Lemna* sp., Lemnaceae) grow naturally in aquatic habitat.

Swamp habitat

Cyperaceae are naturally in the swamp habitat.

Fern group

Polypodiaceae, Soi Nari (*Lycopodium* sp., Lycopodiaceae), Kut (*Polupodium* sp., Polypodiaceae), Kut Ton (Cyatheaceae), Kut (*Pteris* sp., Pteridaceae), (*Selaginella* sp., Selaginellaceae), (*Tricomanes* spp., Hymenophyllaceae), *Montia* spp., Chenopodiaceae, Thelypteridaceae, Monolete Isoetaceae, Ribbon Fern (*Ophioglossum* spp., Ophioglossaceae), Aspleniaceae.

Grass such as Gramineae and *Ruppia* sp.

Palm Pollen is in the family Palmae.

The appearance of pollen and spores in SLL7xx site can be discussed as followings:

4.2.1 Pine pollen

Tropical pine pollen, (*Pinus* spp., Pinaceae) are major pollen found in the upper sequence (7-74 cm.). They appear continuously in the upper sequence. Lower sequence (86-107 cm.) yielded sporadically pine pollen, they are rare appearance. Normally, pine trees grow in this study area. It grows in the highland of 300-1,800 m. above mean sea level (MSL) (40), found in India, Myanmar, Indo-china, Sumatra and Philippines (41)

Pine pollen could be indicate to changed after fire forest. there were wildy distribution of pollen still it became dominant species and replace the grass plant so it had been increasing in the upper sequence.

Two species of Fagaceae is *Quercus* spp. and *Castanopsis* sp. found in the upper sequence (10-70 cm.), they are rare appearance. In fact, they distribute on the warm climate area around the world and have more than 700 species. In the northern of Thailand, seven species found are dominant component of hill evergreen forest. Fagaceae are commonly found increasing proportion in the slightly burnt forest fire (42).

Liliaceae species and Iridaceae species found in the upper sequence. Normally, Iridaceae species is found in pine forest, mixed deciduous forest and deciduous dipterocarp forest that distribute at warm climate area of Himalaya mountain, the area that lie from the west to the east of Tibet, northern India and northern Thailand. And Liliaceae species is found in around of evergreen forest and distribute in Asia and Africa (41). Moreover, these two species are floriferous after influence of heat (46).

4.2.2 Fern group

Fern spore group such as *Ophioglossum* spp., *Polypodium* spp., *pteris* sp., *selaginella* sp., Thelypteridaceae, *Tricomanes* sp., *Woodsia* sp., *Montia* spp. found continuously appearance in the upper sequence (7-74 cm.). Lower sequence (86-107 cm.), they appear increasing because of the condition of study area had rather high humidity in the lower sequence. In addition to the ground plant as fern, it always aggregate growth in the humidity and always distribute mainly equatorial area of Asia (42).

However, there was some fern species such as Cyatheaceae was increasing trend in the upper sequence because it was dominant plant community of study area that had a growth along with pine so it was normally growth of this fern group.

4.2.3 Grass and forest fire

Grass pollen found continuously appearance in the upper sequence (7-74 cm.) and has decreasing in the top of sequence. Lower sequence, they are rare appearance. They may be Nokyoung grass, Pek grass, Konkainoi grass, Loklom grass, kradumghun, Boa grass which are modern grass in study area. They could be explained by the factor of grass floriferous respond from forest fire which occurs annually in the Thung Salang Luang national park during dry season (1). Moreover, from the study of community of grass species in New Zealand and USA found that forest fire is the stimulate factor on increasing of grass floriferous and the ratio of inflorescence number (44). Particularly, after forest fire occurrence in Illinois state, floriferous of grass was increasing to ten times (45).

4.2.4 Swamp habitat

Upper sequence (7-74 cm.), Cyperaceae pollen are continuously and commonly appear. Lower sequence (89 cm. and 99 cm.) is rare appearance of Cyperaceae pollen. Thus these may indicate that deposit site (SLL7xx) was continuously swampy environment in the upper sequence.

4.2.5 Aquatic habitat

Duckweed (*Lemna* spp.) and *Utricularia* spp., are major species, they are continuously appearances at the depth 39-107 cm. These plants can grow in aquatic and humidity area. In addition, they float with free-living on surface water (43).

From this result could be explained the condition was swamp and flooding along time so the water was drained slowly. It would appear pollen of aquatic plant and swamp plant in enough pollen quantity for indicate these plant group can grow because of the area had wet and humidity.

4.2.6 Palmae

Palm pollen found continuously throughout the sequence. They yielded proportion between 0.2-2.4 % of total pollen counts.

Nature of palm which can grow in moist forest and not forest fire area, generally, found distribution in tropical area on northern of Thailand has 8 genus 13 species (42).

From this result that could be interpreted that the study area have humidity because of palm pollen will increase when high humidity.

4.2.7 Result of Radiocarbon Dating (^{14}C) by Accelerator mass spectrometers (AMS)

Radiocarbon Dating from sample of SLL 728 (depth 97 cm.), the conventional radiocarbon age is $1,150 \pm 40$ BP. The intercept between the average radiocarbon age and the calibrated curve time scale is Cal AD 890 (Cal BP 1,060). The calendar age range in calendar years (AD) with 2 Sigma (95% probability calibrated result) is Cal AD 780 to 990 (Cal BP 1,170 to 960). However, for 1 Sigma calibrated result is Cal AD 870 to 960 (Cal BP 1,080 to 990).

Due to limitation of dating sample, Linear extrapolation is used to calculate other depth of SLL7xx. At the depth 74 cm., which major ecological changed. The conventional radiocarbon age is calculated as 877 ± 40 BP.

At the deepest sequence (107 cm.), the conventional radiocarbon age is calculated as 1268 ± 40 BP. And at the top of sequence (7 cm.), the conventional radiocarbon age is calculated as 83 ± 40 BP.

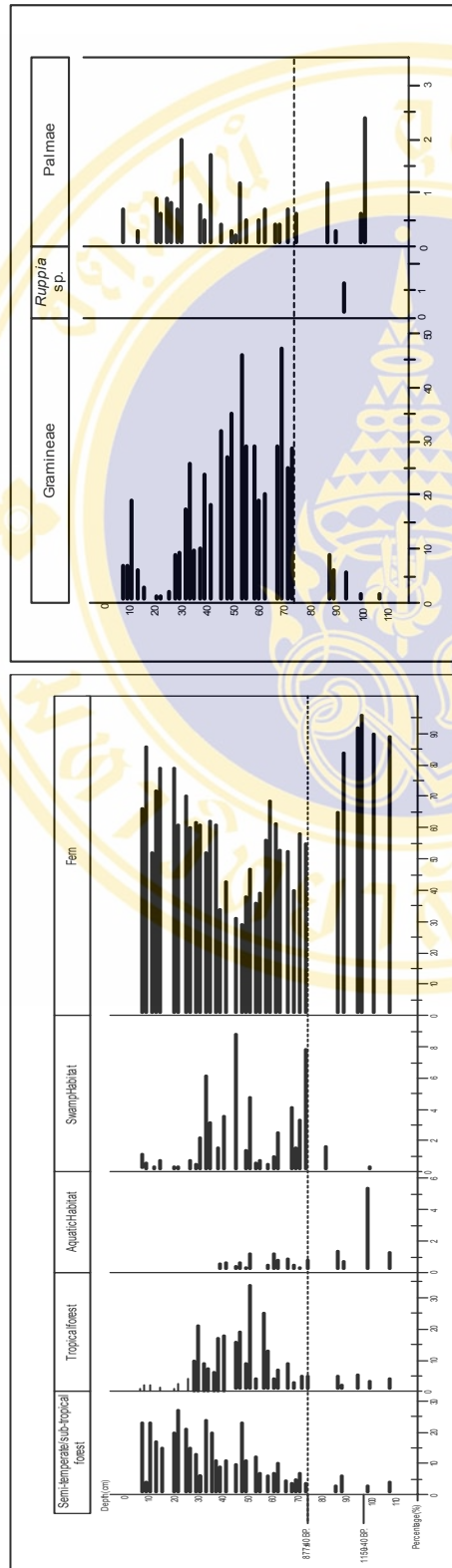


Figure 4-4 Result of plant community group from sediment sample SLL7xx

4.3 Discussion the results of pollen analysis between sediment sample from SLL6xx and SLL7xx

The results for pollen analysis of two sites, including SLL6xx and SLL7xx which could be categorized pollen and spores such as

Tree: Pine (*Pinus* spp., Pinaceae), Ko (*Quercus* spp., Fagaceae), Kamlangsuea Khrong (*Betula* spp.), Ko/Kaolat (*Castanopsis* sp., Fagaceae), Cayenne Cherry (*Eugenia* sp., Myrtaceae), Mak (Myricaceae), Iron Wood (*Hopea* spp., Dipterocarpaceae), Son Phaeng (Cupressaceae) and Kuam (Aceraceae).

Shrub: Philangkasa (Myrsinaceae).

Herb: Bundong Lueang (*Polygala* spp., Polygalaceae), Wan Hua Suep (Liliaceae), Thua-Duang (Labiatae), Wan (Iridaceae), Phak Bung Som (Polygonaceae), Yat Nam Khang (Droseraceae) and Compositae.

Ferns: Polypodiaceae, Soi Nari (*Lycopodium* sp., Lycopodiaceae), Chinnamon Fern (*Osmanda* sp., Osmandaceae), Kut (*Polypodium* sp., Polypodiaceae), Kut Ton (Cyatheaceae), Kut (*Pteris* sp., Pteridaceae), (*Selaginella* sp., Selaginellaceae), (*Tricomanes* spp., Hymenophyllaceae), (*Woodsia* sp., Blechnaceae), *Montia* spp., Monolete Isoetaceae, Ribbon Fern (*Ophioglossum* spp., Ophioglossaceae), Aspleniaceae, Chenopodiaceae and Thelypteridaceae.

Palm: Palmae.

Grass and sedge: Gramineae, Ya Takan (*Ruppia* sp., Ruppiaceae), Cyperaceae and Ko Kadueng (*Carex* sp., Cyperaceae).

Aquatic plant: Sarai Khao Niao (*Utricularia* spp., Lentibulariaceae) and Lesser Duckweed (*Lemna* sp., Lemnaceae).

Unknown affinity: Few tricolporite pollen found in the residues were poorly corroded and unable to identify.

The results of comparative studies on pollen analysis of both site SLL6xx and SLL7xx can be discussed as followings:

4.3.1 Palynostratigraphic correlation between SLL6xx and SLL7xx, show that changing ecological changes for SLL6xx is at 50 cm., and SLL7xx is at 74 cm. This is also can correlate with the conventional age was 877 ± 40 BP. Thus, it may indicate sediments of SLL7xx had been deposited slower than SLL6xx.

4.3.2 The changing of past plant community was similar to modern plant community at the period of 877 ± 40 BP. to present. It was clearly to change constant of the commonly modern plants which the modern plants could still grow in the study area nowadays.

4.3.3 Sediments from site SLL7xx, (depth between 90-0 cm.) is dark carbonaceous mud. This suggest wet area at upper sequence of site SLL7xx. For the depth between 42-0 cm. of site SLL6xx is dark loamy clay and 42-82 cm. is gray to brown sandy loam with yellow mottling which may suggest oxidize to drier sediment, the depth between 82-115 cm. is loamy sand with latterite that pollen and spores are rarely preserved.

4.3.4 The changing of pine pollen from both sites started to increase in the upper sequence which may suggest forest fire and drier climate of the area in the upper sequence.

4.3.5 The changing of grass pollen was increasing at the depth 50 cm. of SLL6xx and the depth 74 cm. of SLL7xx might have been resulted from forest fire in the study area. Presently, forest fire around the study area occurs regularly in the dry season. The perspective of ecological analysis of frequent forest fire is to maintain ecological system and plant species conservation. Forest fire also help natural plant succession in the area. Pine forest will replace more

proportion of grasses which may be Nokyoung grass, Pek grass, Konkainoi grass, Loklom grass, kradumghun, Boa grass. These are modern grass in the study area.

4.3.6 Considering fern spores of both sites show that the increasing in lower sequence. Normally, fern like to grow in high humidity condition and appropriate temperature. Some fern could not adapt themselves with frequent forest fire and decreasing proportion in plant community. Moreover, at the upper sequence, fern spores proportion is decreasing especially site SLL6xx which support forest fire and/or drier condition.

4.3.7 Considering aquatic plant group, there was pollen distribution at the lower sequence. In generally, this plant group like to grow in the flood area. Especially the duckweed (*lemna* spp.) could be interpreted to relate the most important with humidity area similar to fern group.

In conclusion, pollen of site SLL6xx show less preserved and low diversity but distinct change in comparison with site SLL7xx. Site SLL6xx has greater slope than site SLL7xx with result in higher deposition in site SLL7xx. Also, forest fire should be more influence on site SLL6xx than site SLL7xx. Thus, the site SLL7xx show better pollen preservation than site SLL6xx.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Result of Holocene pollen analysis of two sites, which are SLL6xx and SLL7xx, twenty seven samples of SLL6xx and sixty three samples of SLL7xx are productive. The palaeo-environment of Thung Salang Luang National Park had dominant both ecological system of sub-tropical forest and tropical forest. In the upper sequence of 877 ± 40 BP. The both of them suggests changing of palaeo-ecological system to drier environment in the upper sequence. Both pine and grass pollen are commonly found in the upper sequence. Moreover, these plant community still commonly found in the study area at present.

However, effect of forest fire lead to dry climate at this study area in the Holocene period of 877 ± 40 BP. Ferns were plants (SLL7xx). They were sensitive to dry climate in SLL6xx which yield low proportion. Fern such as *Lycopodium* spp., Polypodiaceae, *Polypodium* spp., Cyathaceae, *Pteris* spp., *Selaginella* spp., Kut (Thelypteridaceae) and *Montia* spp. were increasing, they may indicate that this study area were high moisture or humidity in the Holocene period between 877 ± 40 BP. to $1,150 \pm 40$ BP.

Considering to both study area sites, the SLL6xx show higher slope gradient rather than SLL7xx. SLL7xx was poorly drained water, and continuous wet sediments. In the rainy season, it may have been flooding area influence with the rapidly growth of aquatic vegetation and swamp vegetation. Moreover, it may indicate SLL7xx had sediments deposit rate longer time than SLL6xx.

5.2 Recommendation

Problem of some sediment samples (SLL1xx, SLL3xx, SLL4xx, SLL5xx) were collected and left for almost two years. Preparation of pollen analysis, pollen and spores were rarely found or disappear. It may suggest that sediment samples have been dried and oxidized. Thus, the collected sediment samples should be prepared and extracted pollen and spores in a short time. If it was necessary for a long time collecting, which should find method to fix sediment samples.

Pollen analysis should be studied to compare with sedimentation. Considering soil profile, soil texture and soil structure related to pollen preservation and plant community. Both studies of pollen analysis and sedimentation may suggest to better interpretation.

For limitation of budget for radiocarbon dating, in this research used one charcoal sample for analysis which select the deepest charcoal sample. Thus, further studies on radiocarbon dating analysis should be done with more charcoal dating samples because they should provide better and precise interpretation.

The study of pollen analysis for relate palaeoenvironment and climate change should investigate along with study of archaeology, dendrochronology in the same study area. Researches from multidisciplinary should provide a comprehensive database for the best palaeoenvironment study.

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Table A-1 percentage of pollen and spore of plant species from sediment sample SLL6xx

Sample No.	Depth(cm.)	TREE		HERB				G		FERM							P	U					
		Pinus spp.	Acer spp.	Liliaceae	Lernia spp.	Hydrocharitaceae	Utricularia spp.	Cyperaceae	Carex spp.	Gramineae	Polypodiaceae	Lycopodium spp.	Polypodium spp.	Diatrypaceae	Pteris spp.	Selaginella spp.			Thypteridaceae	Tricomones spp.	Mosses spp.	Chenopodiaceae	
SLL615	4.0	91.4		0.4	1.3					1.3			0.9					1.4		1.4			
SLL614	10.0	91.9			2.4					2.4									0.3	1.6			
SLL619	12.5	82.8			7.3					3.1									0.3	4.7		0.3	
SLL652	14.0	82.9			4.2					2.5	0.3								0.3	1.7		0.3	
SLL618	17.0	10.0			47.6					23.8										4.0			
SLL647	18.0	16.0			4.0	56.0				16.0												4.0	
SLL613	20.0	47.8			25.4					17.9										4.5	1.5	2.9	
SLL640	22.0	39.6			35.3					13.2										7.5		1.9	
SLL651	25.0	30.4			56.5					13.0													
SLL612	30.0	6.9			41.4					32.7										5.2	3.4		
SLL630	30.0	7.7	1.1		40.6					1.1										1.3			
SLL617	32.0	28.9			42.1					17.1													
SLL639	34.0	3.8			15.4					69.0										3.8	3.8		
SLL655	36.0	74.3			12.1					0.7												0.7	
SLL650	38.0				50.0					16.7												16.7	
SLL637	40.0	42.8			28.6																		
SLL638	48.0	5.6			50.0					5.5													
SLL610	50.0				42.8					66.7													
SLL634	70.0				66.7					33.3													
SLL653	75.0	4.2			29.2					4.2	4.2												
SLL644	77.0				66.7																		
SLL621	82.0				22.8																		
SLL606	90.0				25.0					12.5	12.5												
SLL633	93.0																						
SLL604	110.0	6.1			30.3					3.0	12.1												
SLL603	111.0	14.3			28.6						14.3												
SLL616	112.0				15.0						15.0												
T=	FREE	\$T=	Shrubby Tree	H=	Herb	G=	Grass	F=	Fern	P=	Palm	U=	Unknown affinity										

Table A-2 percentage of pollen and spore of ecological group from sediment sample SLL6xx

Sample No.	Depth(cm.)	Semi-temperate/sub-tropical forest			Tropical forest		Aquatic habitat		Swamp habitat		Fern																						
		TREE			Tol(%)	Acer sp.	Polygonaceae	Tot(%)	Lemna sp.	Utricularia sp.	Tot(%)	Cyperaceae	Carex sp.	Tot(%)	Polypodiaceae	Lycopodium sp.	Polypodium sp.	Cyatheaceae	Pteris sp.	Thypteridaceae	Tridomnes sp.	Monda sp.	Chenopodiaceae	Sagittaria sp.	Tot(%)								
		Dryas sp.	Liliaceae	Hydroceae																													
SLL615	4.0	91.4			91.4	1.3	1.3	0.4	0.4									0.9				1.4			4.6	1.8							
SLL614	10.0	91.9			91.9	2.4	2.4											0.3				0.8	1.6			3.2	2.4						
SLL627	10.0	88.3			88.3	5.8	5.8															2.5	2.5			5.0	0.8						
SLL619	12.5	82.8			82.8	7.8	7.8														0.8	4.7			6.3	3.1							
SLL652	14.0	88.9			88.9	4.2	4.2								0.8							1.7			4.1	2.5							
SLL656	14.0	11.1			11.1	44.4	44.4															11.1			11.1	33.3							
SLL618	17.0	10.0			10.0	47.6	47.6																				23.8						
SLL647	18.0	16.0			16.0	56.0	56.0															4.0			4.0	16.0	4.0						
SLL613	20.0	47.8			47.8	25.4	25.4															4.5	1.5	2.9			8.9	17.9					
SLL626	20.0	20.0			20.0																			20.0			20.0	60.0					
SLL631	20.0	69.8			69.8	35.8	35.8																	3.8			3.8	26.4					
SLL640	22.0	39.6			39.6	56.5	56.5															7.5		1.9			9.4	13.2					
SLL651	25.0	30.4			30.4	41.4	41.4																					13.0					
SLL612	30.0	6.9			6.9	39.0	39.0																					17.2	32.7	1.7			
SLL625	30.0	9.7			9.7	40.6	41.7																					18.1	32.9				
SLL630	30.0	7.7			7.7	42.1	42.1	1.1	1.1																			20.9	26.4				
SLL617	32.0	28.9			28.9	15.4	15.4																					11.8	17.1				
SLL639	34.0	3.8			3.8	77.8	77.8																					11.4	69.0				
SLL646	36.0					12.1	12.1																							11.1	11.1		
SLL655	36.0	74.3			74.3	50.0	50.0						0.7	0.7														2.1	10.7				
SLL650	38.0					90.0	90.0																					16.7	16.7		10.0		
SLL611	40.0					50.0	50.0																								50.0		
SLL624	40.0					28.6	28.6																						28.6		28.6		
SLL637	40.0	42.8			42.8	50.0	50.0																						5.6	33.3			
SLL638	48.0	5.6			5.6	42.8	42.8																						3.0	66.7			
SLL610	50.0					3.0	3.0																								3.0		
SLL623	50.0					66.7	66.7																								33.3		
SLL634	70.0					29.2	29.2																						20.9	37.5			
SLL653	75.0	4.2			4.2	66.7	66.7																						33.3		33.3		
SLL644	77.0					22.8	22.8																						2.8		14.3		
SLL621	82.0					25.0	25.0																								62.5	12.5	
SLL606	90.0																														75.0		
SLL633	93.0					30.3	30.3																								57.6	3.0	
SLL604	110.0	6.1			6.1	28.6	28.6																								71.5		
SLL603	111.0	14.3			14.3	15.0	15.0																								5.0		
SLL616	112.0																															85.0	



	BETA ANALYTIC INC. DR. M.A. TAMERS and MR. D.G. HOOD	UNIVERSITY BRANCH 4985 S.W. 74 COURT MIAMI, FLORIDA, USA 33155 PH: 305/667-5167 FAX: 305/663-0964 E-MAIL: beta@radiocarbon.com
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REPORT OF RADIOCARBON DATING ANALYSES

Dr. Manas Watanasak

Report Date: 7/13/2004

Mahidol University, Salaya, Phuttamonthon

Material Received: 6/17/2004

Sample Data	Measured Radiocarbon Age	¹³ C/ ¹² C Ratio	Conventional Radiocarbon Age(*)
Beta - 193220 SAMPLE : SLL728 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 780 to 990 (Cal BP 1170 to 960)	1200 +/- 40 BP	-27.8 o/oo	1150 +/- 40 BP

Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950A.D.). By International convention, the modern reference standard was 95% of the C14 content of the National Bureau of Standards' Oxalic Acid & calculated using the Libby C14 half life (5568 years). Quoted errors represent 1 standard deviation statistics (68% probability) & are based on combined measurements of the sample, background, and modern reference standards.

Measured C13/C12 ratios were calculated relative to the PDB-1 international standard and the RCYBP ages were normalized to -25 per mil. If the ratio and age are accompanied by an (*), then the C13/C12 value was estimated, based on values typical of the material type. The quoted results are NOT calibrated to calendar years. Calibration to calendar years should be calculated using the Conventional C14 age.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27.8;lab. mult=1)

Laboratory number: **Beta-193220**

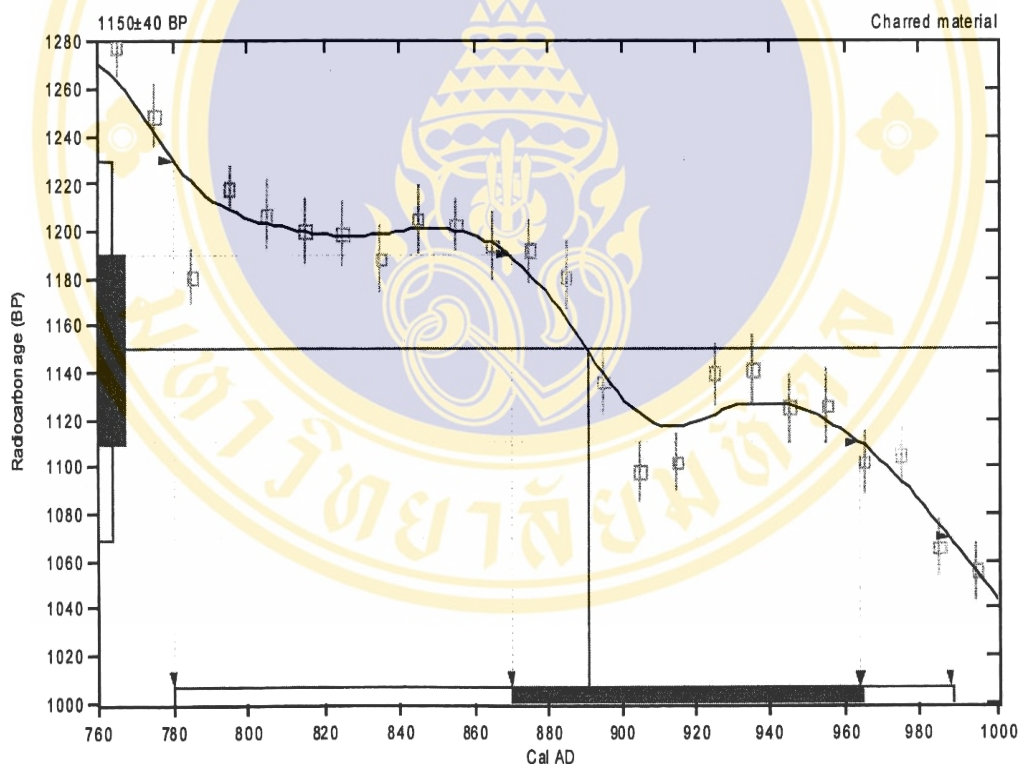
Conventional radiocarbon age: **1150±40 BP**

2 Sigma calibrated result: **Cal AD 780 to 990 (Cal BP 1170 to 960)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: **Cal AD 890 (Cal BP 1060)**

1 Sigma calibrated result: **Cal AD 870 to 960 (Cal BP 1080 to 990)**
(68% probability)



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

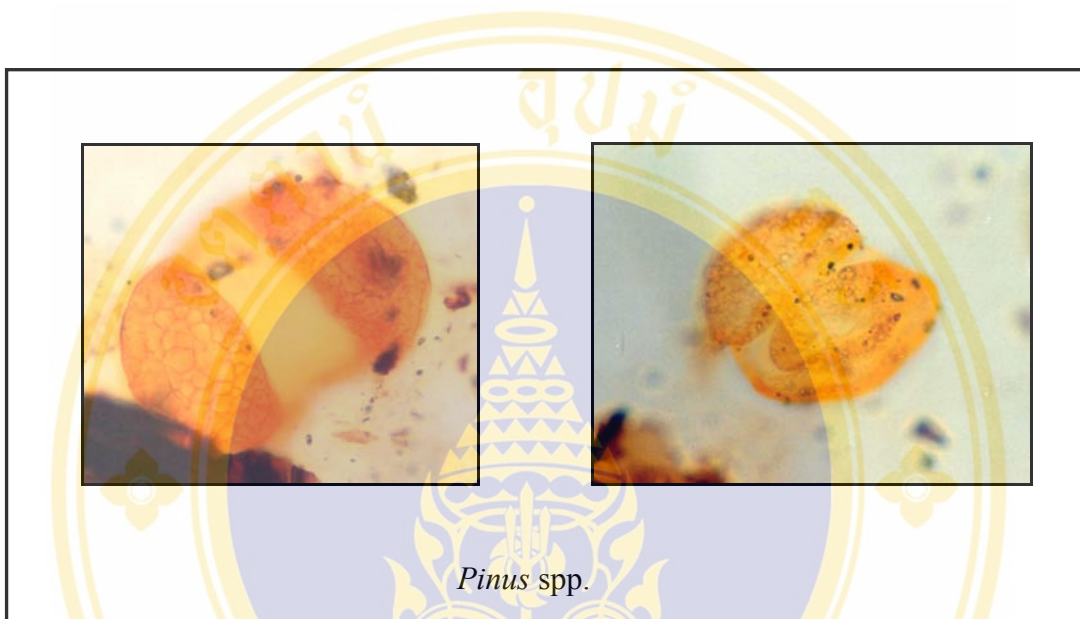
A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, *Radiocarbon* 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

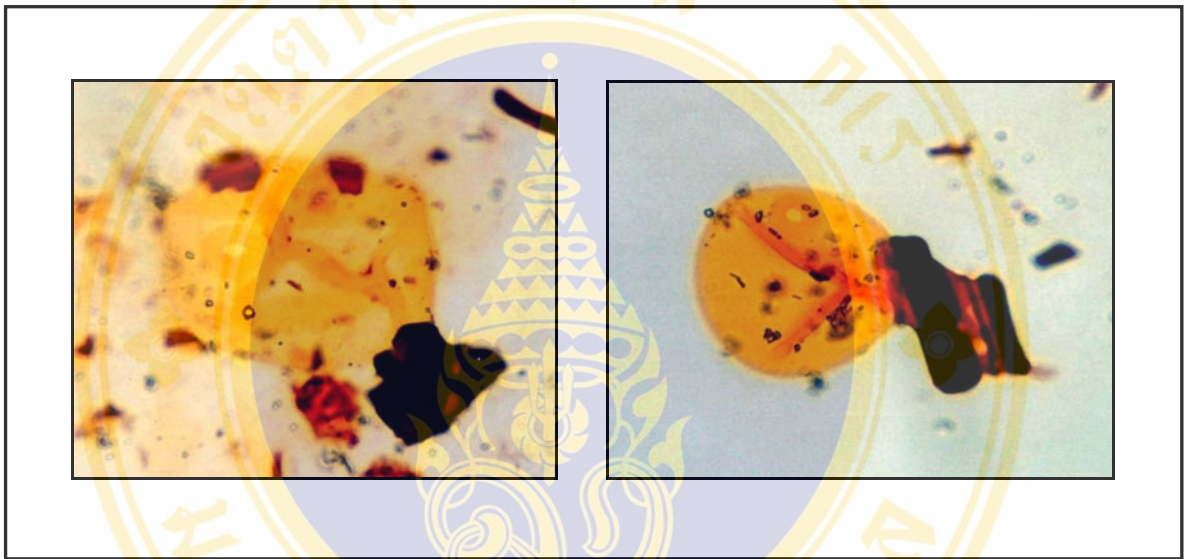
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PINACEAE

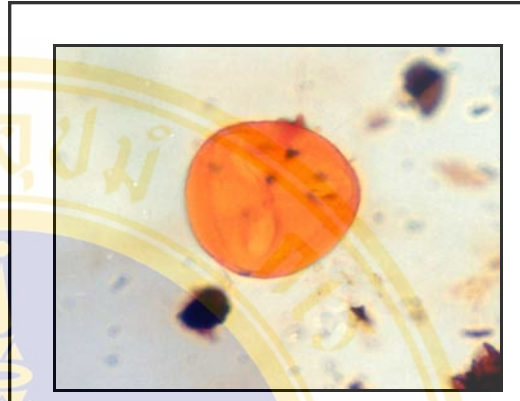
Description: Pollen grain free, heteropolar, bilateral, bisaccate. Corpus: ellisoidal to circular. Exine clearly stratified 2-3 μm .; sexine and nexine are about the same thickness. Cappa generally psilate but a few grain are microperforate, psilate to microverrucate. Sacci attached on distal part of the coppus, with reticulate internal structure and often folded. Longest dimension 48-80 μm .

GRAMINEAE

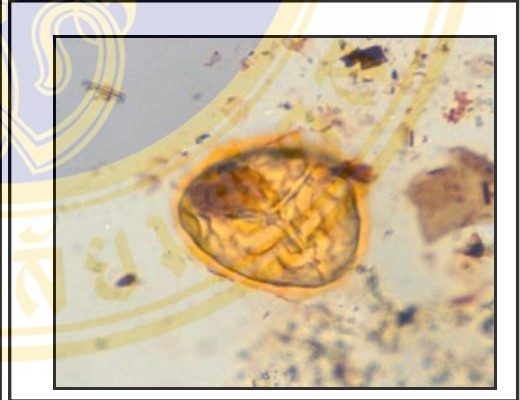
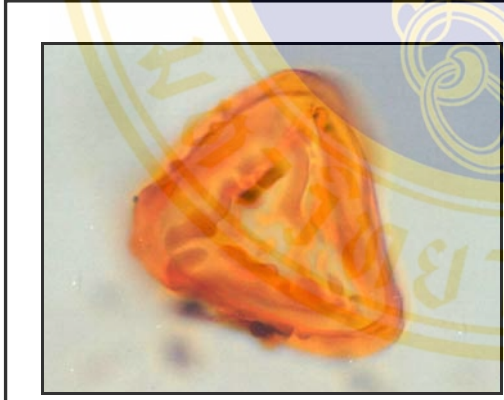


Description: Grain monoporate; shape oblate; size 15-35 μm .; sculpture laevigate to scabate.

FERN: Trilete spores



CYATHEACEAE



PTERIDACEAE

LYCOPODIACEAE



STUDY AREA



SLL6xx site



SLL7xx site

EXCAVATION

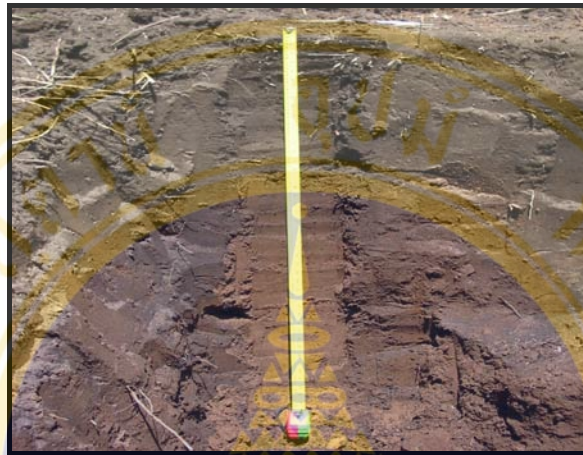


SLL6xx site



SLL7xx site

SOIL PROFILE



SLL6xx site



SLL7xx site

BIOGRAPHY

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