การสะสมของเรณูในดินเหนียวกรุงเทพจากอำเภอองครักษ์ จังหวัดนครนายก และนัยที่เกี่ยวเนื่องกับสภาพภูมิศาสตร์พืชโบราณ

นางสาวปรมิตา พันธ์วงศ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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POLLEN DEPOSIT IN BANGKOK CLAY FROM ONG KHARAK DISTRICT, NAKHON NAYOK PROVINCE, AND THEIR IMPLICATION ON PALEOPHYTOGEOGRAPHY

Miss Paramita Punwong

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By	Miss Paramita Punwong
Field of Study	Botany
Thesis Advisor	Assistant Professor Tosak Seelanan, Ph.D.
Thesis Co-advisor	Assistant Professor Chumpol Khunwasi, Ph.D.

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

S. Hannongbua .... Dean of the Faculty of Science
(Professor Supot Hannongbua, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Associate Professor Preeda Boon-Long, Ph.D.)

.... Thesis Advisor
(Assistant Professor Tosak Seelanan, Ph.D.)

Chumpol Khunwasi .... Thesis Co-advisor
(Assistant Professor Chumpol Khunwasi, Ph.D.)

Sasitorn Poungparn .... Member
(Sasitorn Poungparn, Ph.D.)

W. Songtham .... Member
(Wickanet Songtham, Ph.D.)

ปรมิตา พันธ์วงศ์ : การสะสมของเรณูในดินเหนียวกรุงเทพจากอำเภอองครักษ์ จังหวัดนครนายก และนัยที่เกี่ยวเนื่องกับสภาพภูมิศาสตร์พืชโบราณ (POLLEN DEPOSIT IN BANGKOK CLAY FROM ONG KHARAK DISTRICT, NAKHON NAYOK PROVINCE, AND THEIR IMPLICATION ON PALEOPHYTOGEOGRAPHY) อ. ที่ปรึกษา : ผศ.ดร. ต่อศักดิ์ สีลานันท์, อ. ที่ปรึกษาร่วม : ผศ.ดร. ชุมพล คุณวาสี, 117 หน้า.

ป่าบรรพกาลบริเวณที่ราบลุ่มภาคกลางตอนล่างของประเทศไทยอนุมานจากการวิเคราะห์เรณูและสปอร์ที่สกัดจากตัวอย่างดินในอำเภอองครักษ์ จังหวัดนครนายก ชั้นดินในพื้นที่เก็บตัวอย่างดินจำแนกลำดับชั้นตะกอนได้เป็น 3 ชั้น ได้แก่ ตะกอนไพลสโตซีน ตะกอนทะเลโฮโลซีนหรือดินเหนียวกรุงเทพ และตะกอนน้ำท่วมปัจจุบัน อย่างไรก็ตาม เฉพาะตะกอนดินเหนียวกรุงเทพเท่านั้นที่พบว่ามีเรณูและสปอร์ รวมถึงซากพืชและซากสัตว์ปะปนอยู่ จากการตรวจวัดอายุซากพืชและซากสัตว์ด้วยวิธีคาร์บอน-14 พบว่าชั้นล่างสุดของตะกอนกรุงเทพมีอายุ 7,620 $\pm$ 360 ปี สังคมพืชบรรพกาลที่อนุมานจากเรณูและสปอร์สามารถจัดกลุ่มโดยอ้างอิงกับสังคมพืชในปัจจุบันออกเป็นสามกลุ่ม ได้แก่ ป่าชายเลนด้านหน้าติดทะเล ป่าชายเลนด้านหลัง และป่าที่ระดับต่ำ ซึ่งพบว่าพื้นที่บริเวณนี้ในอดีตได้รับอิทธิพลจากน้ำทะเลและมีสังคมพืชแบบป่าชายเลนซึ่งประกอบด้วยพืชในวงศ์ Rhizophoraceae วงศ์ Sonneratiaceae และวงศ์ Avicenniaceae นอกจากนี้การเปลี่ยนแปลงของสัดส่วนเรณูระหว่างกลุ่มป่าชายเลนด้านหน้าติดทะเลและกลุ่มป่าชายเลนด้านหลังชี้ว่าระดับของน้ำทะเลบริเวณที่ราบลุ่มภาคกลางตอนล่างในสมัยโฮโลซีนเกิดเปลี่ยนแปลงขึ้น-ลงมาโดยตลอดก่อนกลายเป็นที่ราบน้ำท่วมถึงในเวลาต่อมาจนถึงปัจจุบัน

ภาควิชา.......พฤกษศาสตร์.............ลายมือชื่อนิสิต ปรมิตา พันธ์วงศ์

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KEY WORD: POLLEN DEPOSIT / BANGKOK CLAY / LOWER CENTRAL PLAIN / HOLOCENE

PARAMITA PUNWONG: POLLEN DEPOSIT IN BANGKOK CLAY FROM ONG KHARAK DISTRICT, NAKHON NAYOK PROVINCE, AND THEIR IMPLICATION ON PALEOPHYTOGEOGRAPHY. THESIS ADVISOR : ASST. PROF. TOSAK SEELANAN, Ph.D., THESIS COADVISOR : ASST. PROF. CHUMPOL KHUNWASI, Ph.D., 117 pp.

Paleovegetation in Lower Central Plain of Thailand was deduced from pollen analysis. The site at Ong Kharak District, Nakhon Nayok Province, was chosen as a representative. The stratigraphy of sediment samples was divided into three units namely Pleistocene stiff clay, Holocene marine clay regarded to Bangkok clay, and recent floodplain deposit. However, it was only Bangkok clay unit from which pollen and spores as well as plant and animal remains were found and extracted. From ^{14}C radiometric dating of plant and animal remains, it was dated to be the Holocene (7,620 $\pm$ 360 BP) in age at the lowest layer of Bangkok clay. Pollen and spore assemblages suggested that as many as three plant communities including mangrove, back mangrove, and lowland forest might occupy this area. From the first two communities, they suggested that this area was influenced by sea water and mainly covered by mangrove plants, members of the family Rhizophoraceae, Sonneratiaceae, and Avicenniaceae. In addition, the fluctuation of pollen assemblages in mangrove and back mangrove vegetations indicated that the sea level in lower central plain during the Holocene epoch was fluctuated before turning into the flood plain much later on.

Department :	Botany	Student's signature :	Paramita Punwong
Field of study :	Botany	Advisor's signature :	[signature]
Academic year :	2007	Co-advisor'signature :	Chumpol Khunwasi

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CHAPTER I

INTRODUCTION

Palynology is a term used for the study of pollen and spores of plants. In wider sense, it also involves the study of other resistant microfossils such as spores of fungi and algae, dinoflagellate cysts, and animal remains (Erdtman, 1969; Faegri and Iversen, 1989; Moore, Webb and Collinson, 1991). The study of palynology can be used for a diverse range of applications related to multidisciplinary sciences including taxonomy, genetics and evolutionary studies, melissopalynology, forensics science and allergic studies (Moore, Webb and Collinson, 1991). One aspect of palynology which is the study of fossil pollen and spores, either in ancient or even fairly recent materials, is "Pollen analysis".

Pollen analysis is an invaluable tool for reconstructing patterns of environmental changes from the past to the present by means of the pollen and spore investigation (Faegri and Iversen, 1989; Chambers, 2002). These grains have been preserved in various geological deposits. They can be retrieved through various techniques in the field. They also can be identified and interpreted in the laboratory and in the stage of statistical techniques, respectively. This technique was first limited to the study of Late Quaternary lake and bog deposits. Today it is also analyzed in pre-Quaternary beds and in a wide range of deposits such as marine, lacustrine, and terrestrial sediments.

Pollen and spores are such a useful tool for the reconstruction of the past vegetation and environment due to their various features (Faegri and Iversen, 1989; Moore, Webb and Collinson, 1991). First they are resistant and much more easily preserved in any deposits than other parts of other biological materials, which would be destroyed, because of their structural chemistry of outer wall (the exine). The wall of pollen and spores is constructed of a complex material call sporopollenin, a polymer of carotenoids and carotenoid esters, which is resistant to decay from microbial activities or any acid situations.

The second value feature possessed by pollen and spore is their variation in the form and sculpture of the exine providing a means of identifying pollen and spore and a value character to use in taxonomic studies. This means that identification can be taken to family, generic or even species levels. This is again a major reason for the usefulness of pollen and spores in vegetation history studies and also in honey and in allergy investigations.

The third important feature of pollen and spores is their small size and therefore they are more widely and evenly spread than larger parts of plant and less dependent on their sources having been members of the community. This is valuable; on the other hand it can pose a problem. The property of transportation means that the pollen and spores falling upon a site suitable for their preservation did not all originate in their proximity of their parent plants. So the long distance transportation is therefore a factor which must be taken into account when interpreting pollen assemblages from the sediment.

Finally, they are produced in very large numbers and consequently, they can be statistically treated. In addition, their proportion released in the environment depends on the number of their parent plants and hence reflects vegetational composition.

Pollen analysis is a selected method to study past vegetation by extracting pollen and spores from the deposited sediments, identifying under microscope, and making pollen diagram. Pollen diagram provides the information about plant composition which helps to understand paleoenvironment. Pollen analysis in Thailand is rarely known even though it can be useful for multidisciplinary studies. Consequently, the study of pollen deposit in Bangkok clay from Lad Chang soil pit, Ong Kharak District, Nakhon Nayok Province will provide invaluable information including vegetational history, and the geological researches. It may also provide the missing data to fulfill "gap" in previous researches upon that site.

The aims of thesis

1. To study pollen and spore morphology in Bangkok clay from Ong Kharak District, Nakhon Nayok Province, lower central plain of Thailand.
2. To reconstruct paleovegetation and paleoenvironment during the Holocene by means of pollen analysis.

CHAPTER II

LITERATURE REVIEW

2.1 Study site

2.1.1 Location

The study area is a large soil pit producing soil for construction site surrounded by paddy field. The soil pit belongs to the Siribut Construction Co., Ltd. It is located on latitude 14° 00' 40" N longitude 100° 55' 30" E of the Royal Thai Survey Department map sheet 5137 II, scale 1: 50,000 (Nong Sua sheet) (Songtham *et al.*, 2007). It is about 500 meters east of Khlong Sip Si in the area of Ban Lad Chang, Tambon Chumphon, Ong Kharak District, Nakhon Nayok Province. Accessibility to the study area is possible by driving to the north along Phahonyothin Road (route no. 1). At about km 27-28 of the Phahonyothin Road, turn east into Lam Luk Ka Road (route no. 3312) via Lam Luk Ka District and further east until Khlong Sip Si. After Khlong Sip Si, at about km 34.6, turn north along the road parallel to Khlong Sip Si for about 5 kilometers, the study area is on the east of the road.

2.1.2 General information

The study area is on the lower central plain of about 200 kilometers long in north-south direction starting at Chainat Province where the Chao Phraya river flows southward through a flat plain until it reaches the Gulf of Thailand and of about 180 kilometers wide in east-west direction (Sinsakul, 2000). This plain is dissected by four rivers run through from north to south flowing out to the gulf including Maeklong, Tajeen, Chao Phaya, and Bang Pakong rivers arranging from west to east respectively. Large cities are located in the plain including the capital Bangkok, Pathumthani, Nontaburi, Samut Prakan, Samut Sakhon, Samut Songkarm, Nakhon Pathom, Supanburi, Ratburi, Ayuthaya, Angthong, Singburi, Chasoengsao, and with some parts of Petchaburi, Kanchanaburi, Prachinburi, Nakhon Nayok, and Chonburi Provinces as shown in Figure 3.1 (Songtham *et al.*, 2007) .

Due to its location in the lower central plain, the study area is under a tropical savanna climate being influenced by the monsoons. The northeast monsoon which is prevalent from November to April is divided into two periods of time, hot dry and cool dry that the terms summer and winter can be used, respectively. The southwest monsoon from May to October is the most active during September to October. This is regarded to the rainy season and causes heavy rainfall and flooding. The average annual rainfall is 2,014.4 mm, with 378-380 mm falling in the rainy season (Sinsakul, 1996).

2.1.3 General geology

The Quaternary geology of Nakhon Nayok Province studied by Sinsakul (1996) reveals that sedimentary deposit is mainly classified into three formations consisting of a series of thick Pleistocene sediment, capped by Holocene marine clay, and a thin layer of a recent fluvial deposit as shown in Figure 2.1

2.1.3.1 The Pleistocene sediment regards as alluvial and fluvial deposit characterizing oxidizing environment without any fossil reported. The Pleistocene sediment is red to orange in color of gravel, sand, and stiff clay.

2.1.3.2 The Holocene sediment ragarded as marine clay called “Bangkok clay” is dark gray to greenish gray of soft clay. In addition, basal peats which are decomposed organic matter soil materials with dark brown to black in color are also found at the bottom of the Holocene sediment sharply contrasted with the underlying Pleistocene sediment. It is characterized by abundant fragments of organic debris with some carbonized woods in the lower portion of the Bangkok clay layer. Its characteristics reveal depositional environment as mangrove forests.

This marine deposit covers the most area of Ong Kharak District with the thickness up to 20 meters and contains abundant marine animal remains such as marine mollusk shells, marine diatoms, and foraminifera. These animals are regarded to the shallow sea environment. The giant oysters (*Crassostrea gigas*) dating 6,750 $\pm$ 280 years BP were found with other shell fragments to 6,330 $\pm$ 290 years BP in the Ong Kharak District, Nakhon Nayok Province. These oysters indicate that Ong Kharak District is considered to the intertidal flat, shallow marine and the near coastline environment during the first transgressive phase (Sinsakul, 1992).

2.1.3.3 The youngest sediment is a thin layer of brown to light grey clay and varying in thickness from 1 to 4 meters. This sediment contains abundant roots and plant remains, but without marine animal remains regarding as a recent fluvial deposit which occurred after the marine regressions during the Holocene time.

2.2 Vegetation of Thailand

According to Santisuk (2007), vegetation of Thailand can be recognized by two major types based on climatic, edaphic, elevational, and biotic factors: evergreen forest and deciduous forests. The former is further subdivided into14 minor types including tropical rain forest, dry evergreen forest or seasonal rain forest, lower montane oak forest, lower montane pine-oak forest, lower montane coniferous forest, lower montane scrub forest, cloud forest, upper montane scrub, montane peat bog, mangrove forest, peat swamp forest, fresh water swamp forest, and strand vegetation. The latter is classified into three minor types consisting of mixed deciduous forest, dry dipterocarp forest, and pine-deciduous dipterocarp forest.

Among four main factors mentioned above that affect the distribution of the vegetation types, according Santisuk (2007), the elevation and moisture gradients are very prominent in indicating the types of forest. The diagram of forest types in Thailand (Figure 2.2) shows the distribution of forest types in Thailand with respect to the two factors.

2.2.1.1 The evergreen forests

- Tropical rain forest occupies all part of country particularly in southern and eastern parts with constant rainfall and moisture gradients all year. This forest has high species diversity. Plants of Dipterocarpaceae are typically found. Other floristic compositions are *Intsia palembanica, Parkia speciosa, P. timoriana, Archidendron jiringa, Cynometra malaccensis*, *Koompassia excelsa, Dialium indum* (Leguminosae), *Alstonia macrophylla, A. scholaris* (Apocynaceae) and Palmae. Lianas and epiphytes are also frequently found.

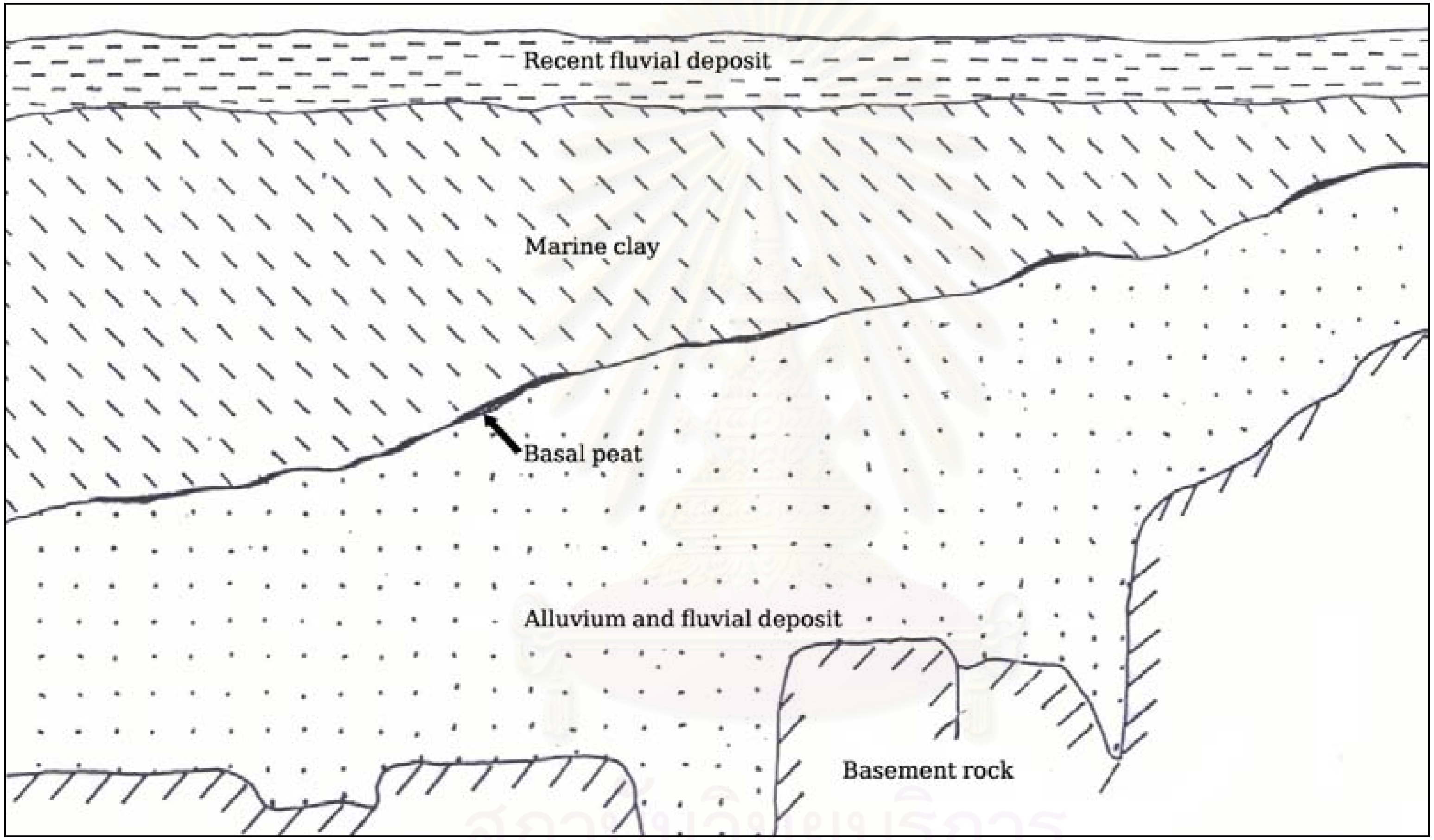

Figure 2.1 Stratigraphic profile showing the Quaternary deposits in Nakhon Nayok Province (from Sinsakul, 1996)

- Dry evergreen forest covers the areas not more than 950 meters above the mean sea level. In southern Thailand dry evergreen forest is found on sandstone ridges; in the north of Thailand dry evergreen forest is restricted to riparian galleries in regions of deciduous forests. Dry evergreen forest is closed canopy forest in which the main canopy is predominantly evergreen forest trees with scattered individuals of deciduous trees. Dipterocarpaceae forms an important component of the canopy, although the diversity of dipterocarp species is less in dry evergreen forests than in the tropical evergreen rain forest.

- The lower montane rain forest distributes in the area with 1,000 – 1,900 meters above the mean sea level. This forest is as dense as the tropical rain forest in the lowland, but it is different in its floristic composition. The flora consists of temperate and montane species which prefer a rather cool climate all year. Plant of Fagaceae, the conifer family, and Podocarpaceae are commonly found in this forest.

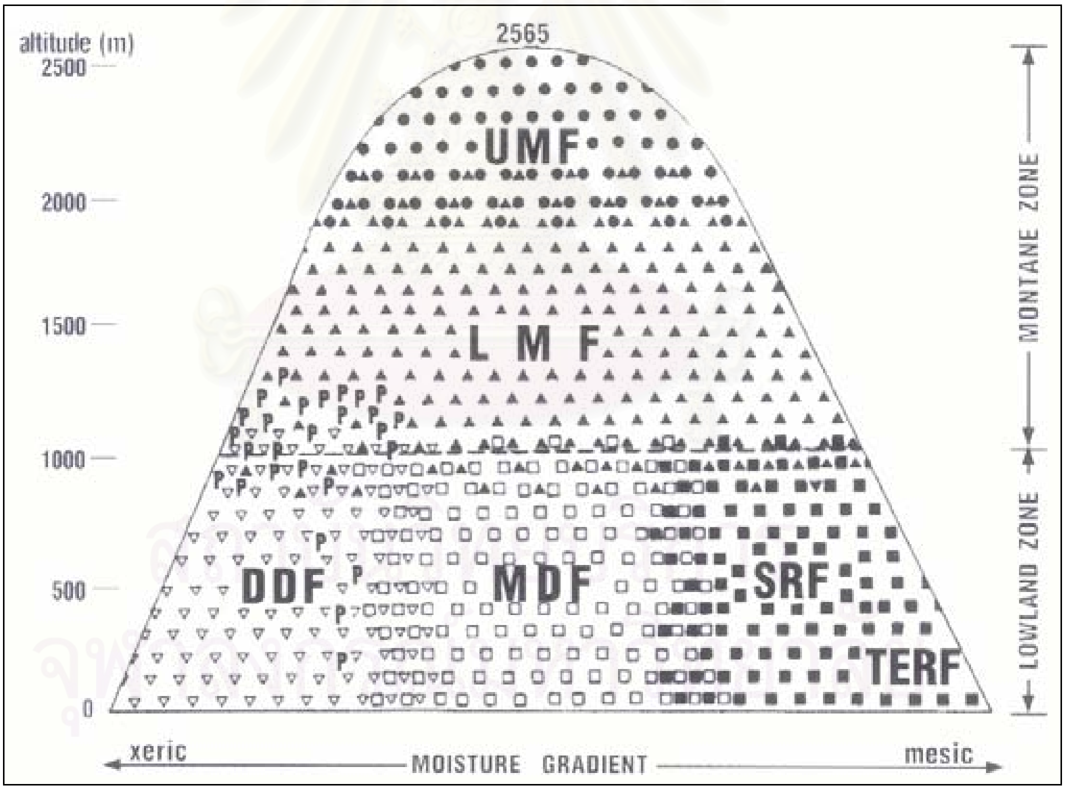

Figure 2.2 Diagram showing pattern of the forest type distribution in Thailand related to elevation and moisture gradients (from Santisuk, 2007). TERF = tropical evergreen rain forest, SRF = seasonal rain forest, MDF = mixed deciduous forest, DDF = dry dipterocarp forest, LMF = lower montane forest, UMF = upper montane forest, P= pines forest.

- The lower montane oak forest is commonly found in northern part with 900 meters above the mean sea level. The canopy is not as dense as the lower montane rain forest. This forest develops from the disturbance of the lower montane rain forest. Fagaceae, Theaceae, and Lauraceae are typically found in this forest.

- The lower montane pine-oak forest develops from the forest that affected by the human disturbances and fire. Pinaceae consisting of *Pinus kesiya* and *P.merkusii* and Fagaceae are commonly found in this forest.

- The lower montane coniferous forest is commonly found in sandstone in northeastern part with 1,100 – 1,300 meters above the mean sea level. Podocarpaceae and Fagaceae are typically found in this forest.

- The lower montane scrub forest is found in limestone outcrop. This forest type occupies in northeastern part with 1,000 – 1,500 meters above the mean sea level. This forest is covered by small trees with scattered small shrubs. Fagaceae and Ericaceae are commonly found in this forest.

- The cloud forest covers the area more than 1,900 meters above the mean sea level. This forest is closed canopy. The main canopy is predominantly evergreen forest trees which are not found in the lowland. Mosses, terrestrial and epiphytic ferns are also typically found.

- The upper montane scrub is uniquely found in hill ridges and limestone outcrop with 1,900 – 2,200 meters above the mean sea level. Shrubs, herbaceous and lithophytes are typically found in this forest.

- The montane peat bog is found at 1,200 meters above the mean sea level with cool climate all year. This forest is a wetland type that accumulates acidic peat, a deposit of dead plant materials covered by sphagnum mosses. Plants of Ericaceae are commonly found in this forest.

- Peat swamp forest distributes in the low areas near the sea and always flooded with fresh water which accumulates a deposit of dead plant materials. The vegetation is distinct with the adaptation of pneumatophores, buttresses, and stilt roots. The typical species are *Calophyllum teysmannii* (Guttiferae), *Blumeodendron kurzii* (Euphorbiaceae), *Eleiodoxa conferta* (Palmae), and *Neesia malayana* (Bombaceae).

- The fresh water swamp forest distributes in the low areas along the riverside without accumulation of any deposits of dead plant materials. The typical species are *Horsfieldia irya* (Myristicaceae), *Fagraea fragrans* (Gentianceae), *Homalium foetidium*, and *Scolopia macrophylla* (Flacourtiaceae)

- The mangrove forest is dominated by plants belonging to the family Rhizophoraceae. Mangrove communities usually occupy the mud flat areas along the seashores. They are frequently found at river mouths or estuaries. The amount of salinity which the different mangrove species can withstand affects their distribution.

Santisuk (1983) subdivided mangrove vegetation into two groups comprising of true mangrove or swampy mangrove forest and the back mangrove. The true mangrove or tidal mangrove forest is found along the border of the sea and in lagoons, extending as far as the river mouths where the water is still saline. These mangrove plants grow in swampy soils covered by the sea during high tide. The back mangrove is community reached by the sea only at very high tide, exceptional tides. They consist of other species which tend to occur in more inland areas such as freshwater swamps, peat swamps, and on dry land forest. Such plants associated with mangroves are classified as part of the back mangrove as shown in Table 2.1

- Strand vegetation is found along the seashores growing on sandy or rocky strand. The vegetation grows along the narrow littoral marine zone or on isolated patches. The typical herbaceous species are *Spinifex littoreus* (Poaceae) and *Ipomoea pes-caprae* (Convolvulaceae). The typical tree species are *Casuarina equisetifolia* (Casuarinaceae), *Terminalia catappa* (Combretaceae) and *Barringtonia asiatica* (Lecythidaceae).

2.2.1.2 The deciduous forests

- The mixed deciduous forest normally sheds the leaves in dry season. It occurs widely in northern, northeastern and central parts with not more than 1,000 meters above the mean sea level. Legominosae such as *Acacia tomentosa, A. harmandiana, Bauhinia malabarica, Cassia fistula, Senna garrettiana*, Combretaceae namely *Terminalia bellirica, T. chebula, T. alata, T. mucronata* and Verbenaceae are dominant. Bamboos are also commonly found.

- The dry dipterocarp forest sheds the leaves in dry season. It occurs widely in northern, northeastern and central parts with not more than 1,000 meters above the mean sea level. There are five dominant plants of Dipterocarpaceae consisting of *Dipterocarpus intricatus, D. obtusifolius, D. tuberculatus, Shorea obtusa* and *S. siamensis.*

- The pine-deciduous dipterocarp forest sheds the leaves in dry season. It occurs widely in northern, northeastern and central parts with 700 – 1,350 meters above the mean sea level. In addition to the dominant plants of Dipterocarpaceae consisting of *Dipterocarpus intricatus, D. obtusifolius, D. tuberculatus, Shorea obtusa* and *S. siamensis,* Pinaceae are also commonly found.

2.2.2 Paleovegetation studies in Thailand

Paleovegetation of Thailand as inferred from pollen analysis technique is sporadically studied. Thus, it is difficult to interpolate the paleovegetation of Thailand unless more studied sites are conducted. Furthermore, many studies were limited to not older than Pleistocene. Nonetheless, these studies still provide insigths into vegetation in different parts of Thailand during Pleistocene.

The sediments from nine Mid Tertiary period basins were obtained during the petroleum exploration, and were investigated by Watanasak (1990). Composition of pollen indicated that this basin experienced the temperate climate during an Upper Oligocene to early Lower Miocene age, and then tropical taxa during middle to late Lower Miocene age. There also exists the study of the relationship of palynology and climatic changes in some Tertiary basins of northern Thailand by Songtham *et al.* (2003) who reported that the vegetation and climate changes were consistent with Watanasak's (1990) suggestion. Songtham *et al.* (2003) suggested that the movement of the Southeast Asian landmass from high latitude to low latitude had led to the change of the vegetation patterns from temperate to tropical forests.

The Quaternary palynological study from the small peat swamp in northeastern Thailand indicated that the Fagaceous-Coniferous forest dominated in this area during 40,000 years BP, suggesting cooler and drier than the present climate. Then, the replacement by the tropical broad-leaf deciduous forest at about 12,000 – 10,000 years BP as the Pleistocene/Holocene boundary indicated warmer and humid climatic conditions with increasing precipitations (Penny, 2001). The palynology of flood plain sediment along the Mun River, Nakhon Ratchasima Province, (Bunchalee 2005) indicated that the palynostratigraphy of the Mong Korn sand pit consisted of *Ceratopteris* referred to tropical climate and subsequently replaced by *Pinus* zone referred to temperate climate during the Pleistocene time.

The palynological investigation of the Songkhla Province, southern Thailand, found that the mangrove pollen were dominant from the Late Pleistocene at 33,870 years BP. Moreover back mangrove, beach and lowland elements also occurred in this area (Rugmai, 2006). The study from Great Songkhla Lakes by Horton *et al.* (2005) revealed that this area was abundant of mangrove pollen during 8,420 – 8,190 years BP and subsequently replaced by freshwater swamps at 7,880 – 7,680 years BP due to the decline of marine influence.

Pollen analysis of intramontane peat bog at Doi Inthanon, Chiangmai Province, northern Thailand, indicated that the upper montane rain forest was dominant from 4,300 years BP up to present and the climate during that time was unstable according to the fluctuation of the temperate pollen (Poungtaptim, 1998). The Holocene study at Thung Salang Luang National Park, Pitsanulok Province, found that at the time of 1,150 years BP this area was covered by plant communities similar to the present plant community, i.e. consisting of sub-tropical forest, tropical forest, aquatic area, swamp, palms, ferns and grasses which appeared gradually since 877 years BP according to the forest fire (Wannakoaw, 2004).

The study of pollen and spores in Kanchanaburi Province, western Thailand, indicated that Bo Phloi Basin was covered by dry evergreen forest, swamp, and aquatic area at 4,500 years BP similar to its present vegetation (Hutangura, 2000).

The palynological study of Senanivate housing area, Bangkok, central Thailand, by Somboon (1988) revealed that the freshwater pollen consisting of grasses and sedges were dominant before 7,800 years BP and the mangrove pollen subsequently covered this area suggesting the marine environment during the Holocene time.

Table 2.1 List of recorded tree and shrub species and their ecological distribution in the mangrove formations in Thailand (modified from Santisuk, 1983).

Scientific name[1]	**Family**	**Ecological appearances**[2]	
		Swampy mangrove	**Back mangrove**
*Acanthus ebracteatus**	Acanthaceae		✓
*Acanthus ilicifolius**	Acanthaceae		✓
*Acrostichum aureum***	Pteridaceae		✓
*Acrostichum speciosum***	Pteridaceae		✓
*Aegialites rotundifolia**	Plumbaginaceae		✓
*Aegiceras corniculatum**	Myrsinaceae	✓	✓
*Allophyllus cobbe***	Sapindaceae		✓
*Amoora cucullata***	Meliaceae		✓
*Ardisia littoralis***	Myrsinaceae		✓
*Avicennia alba**	Avicenniaceae	✓	
*Avicennia marina**	Avicenniaceae	✓	
*Avicennia officinalis**	Avicenniaceae	✓	✓
*Barringtonia asiatica***	Barringtoniaceae		✓
*Barringtonia racemosa***	Barringtoniaceae		✓
*Brownlowia tersa***	Tiliaceae		✓
*Bruguiera cylindrica**	Rhizophoraceae	✓	✓
*Bruguiera gymnorrhiza**	Rhizophoraceae	✓	✓
*Bruguiera parviflora**	Rhizophoraceae	✓	✓
*Bruguiera sexangula**	Rhizophoraceae		✓
*Cerbera manghas***	Apocynaceae		✓
*Cerbera odollam***	Apocynaceae		✓
*Ceriops decandra**	Rhizophoraceae	✓	
*Ceriops tagal**	Rhizophoraceae	✓	✓
*Clerodendrum inerme***	Verbenaceae		✓
*Cycas rumphii***	Cycadaceae		✓

Table 2.1 Continued

Scientific name[1]	Family	Ecological appearances[2]	
		Swampy mangrove	Back mangrove
*Cynometra iripa***	Leguminosae		✓
*Derris indica***	Leguminosae		✓
*Diospyros forrea***	Ebenaceae		✓
*Dolichandrone spathacea***	Bignoneaceae		✓
*Excoecaria agallocha***	Euphorbiaceae		✓
*Ficus microcarpa***	Moraceae		✓
*Hibicus tiliaceus***	Malvaceae		✓
*Horsfiedia irya***	Myristicaceae		✓
*Intsia bijuga***	Leguminosae		✓
*Ipomoea pes-caprae***	Convolvulaceae		✓
*Kandelia candel***	Rhizophoraceae	✓	✓
*Lumnitzera littorea***	Combretaceae		✓
*Lumnitzera racemosa***	Combretaceae		✓
*Melaleuca leucadendron***	Myrtaceae		✓
*Melastoma villosum***	Melastomaceae		✓
*Nypa fructicans**	Arecaeae	✓	✓
*Oncosperma tigillaria***	Arecaeae		✓
*Pandanus odoratissimus***	Pandanaceae		✓
*Peltrophorum pterocarpum***	Leguminosae		✓
*Pemphis acidula***	Lythraceae		✓
*Phoenix paludosa**	Arecaeae		✓
*Planchonella obovata***	Sapotaceae		✓
*Pluchea indica***	Asteraceae		✓
*Premna obtusifolia***	Verbenaceae		✓
*Rapanea porteriana***	Myrsinaceae		✓

Table 2.1 Continued

Scientific name[1]	**Family**	**Ecological appearances**[2]	
		Swampy mangrove	**Back mangrove**
*Rhizophora apiculata**	Rhizophoraceae	✓	
*Rhizophora mucronata**	Rhizophoraceae	✓	
*Sapium indicum***	Euphorbiaceae		✓
*Scaevola taccada***	Goodeniaceae		✓
*Scyphiphora hydrophillaceae***	Rubiaceae	✓	✓
*Sonneratia alba**	Sonneratiaceae	✓	
*Sonneratia caseolaris**	Sonneratiaceae	✓	✓
*Sonneratia griffithii**	Sonneratiaceae	✓	✓
*Sonneratia ovata**	Sonneratiaceae	✓	✓
*Suaeda maritima***	Chenopodiaceae		✓
*Xylocarpus gangeticus***	Meliaceae		✓
*Xylocarpus granatum**	Meliaceae	✓	✓
*Xylocarpus moluccensis**	Meliaceae		✓

Notes:

[1] Species marked by '*' are true mangrove species while those marked by '**' are species belonging to littoral vegetation and/or inland vegetation regularly make their appearance in the back mangrove

[2] These terms – 'swampy mangrove' and 'back mangrove' – were used in Santisuk (1983) to refer to species inhabiting areas with inundation class 1-3 and inundation class 4 and 5 of Watson (1928), respectively.

CHAPTER III

MATERIALS AND METHODS

Methodology in this study was divided into 5 parts consisting of site selection, sample collection, organic sampling for isotope carbon-14 (^{14}C) dating, pollen and spore extraction, and pollen analysis.

3.1 Site selection

The study area is a large soil pit with 380 meters in width, 1,050 meters in length, and 27 meters in depth and located in Ban Lad Chang, Tambon Chumpon, Ong Kharak district, Nakhon Nayok province (latitude 14° 00' 40" N longitude 100° 55' 30" E) as shown in Figure 3.1.

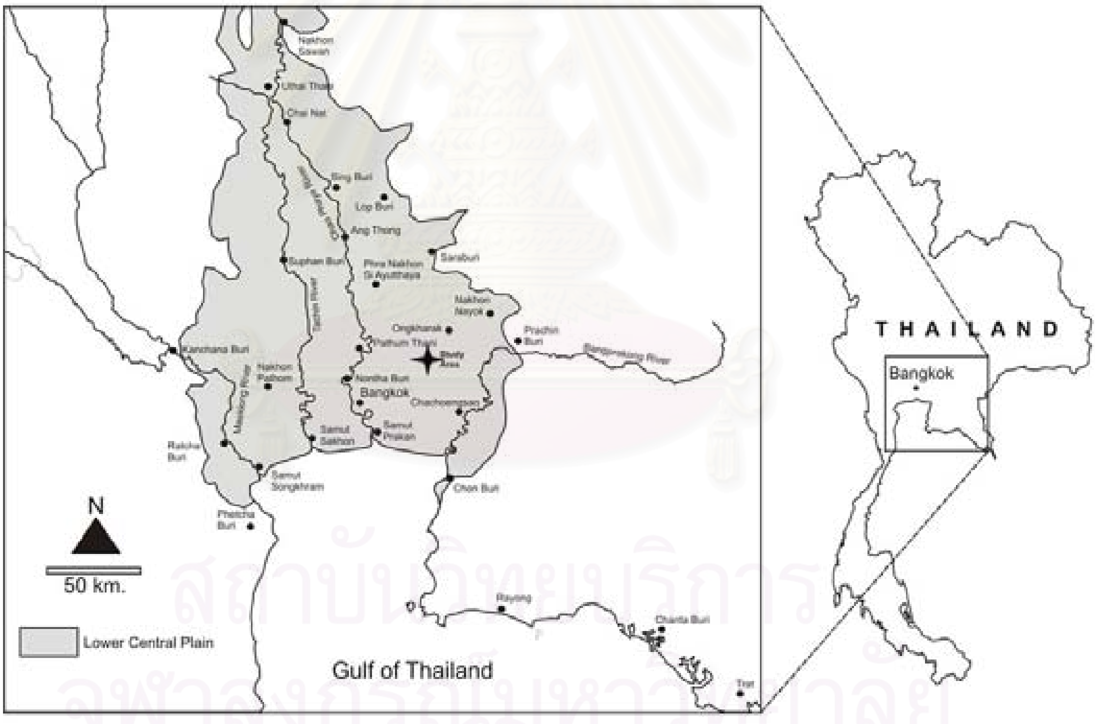

Figure 3.1 Locality of the study area (✦) located on the lower central plain of Thailand (the map was taken from Songtham *et al.*, 2007).

3.2 Sample collection

3.2.1 Equipment and supplies

- ½" PVC pipe
- Zipped plastic bags
- Chopsticks
- Hammers
- Screws

3.2.2 Soil collection

The clay samples were collected from the base to the top of the soil pit using ½" PVC pipe every approximately 10 centimeters. The stratigraphic depth of each sample was precisely located by Theodolite. The clay samples were kept in the plastic bags and labeled. The samples were then stored in the -20 °C freezer (Sanyo model MDF-435) to prevent the contamination and oxidation.

In addition, the lithological observation in the study site was made visually including texture, color and structure. The stratigraphic column of sediment was photographed and sketches were made.

3.3 Organic sampling for isotope carbon fourteen (^{14}C) dating

Organic matters such as carbonized woods and mollusk shells were intentionally looked for during clay sample collection. In this study, only four samples consisting of three samples of carbonized woods and one sample of marine mollusk shells were collected and wrapped with aluminum foil. The stratigraphic depth of each organic sample was precisely located by Theodolite. Radiometric dating of these materials was carried out by the Thailand Institute of Nuclear Technology (Public Organization) using isotope carbon fourteen dating method.

3.4 Pollen and spore extraction

3.4.1 Equipment and supplies

- Centrifuge (Hettich Tuttlingen model EBA 8S) and centrifuge tubes
- Vortex
- Flume hood
- Masks
- Hot plate
- Ultrasonic generator
- Rubber gloves
- 25, 50, 100, 250, and 500 ml glass beakers
- 250 ml polypropylene (PP) beakers
- Glass stirring rods
- 5 and 10 ml pipettes
- ½ dram vials
- Microscopic slides and cover glasses
- Goggles
- Parafilm
- Dissected needles
- Petti dishes
- Razor blade
- Light microscope (Olympus model CH30)

3.4.2 Chemicals

- Distilled water
- 10% and 37% HCl
- 48% HF
- conc. H_2SO_4
- 70%, 95% and absolute ethyl alcohol
- Glacial acetic acids (CH_3COOH)
- Acetic anhydride

- 33% $NaClO_3$
- $ZnCl_2$ solution(specific gravities of between 2.0 and 2.2)
- Benzene
- Silicone oil (AK 2000)
- Paraffin wax

3.4.3 Laboratory procedures

One hundred and ninety eight clay samples were treated according to methods modified from Poungtaptim (1998), Wannakoaw (2004) and Rukmai (2006) to extract pollen and spore from the sediments as follows (in orders):

3.4.3.1 Pretreatment

Each clay sample was subsampled and cleaned to eliminate contamination by trimming into one cubic centimeter of soil sample.

3.4.3.2 Removal of carbonate matter

Each sample was boiled in 10% HCl for 2-5 minutes and then washed with distilled water.

3.4.4.3 Removal of siliceous matter

The sample was transferred to a 250 ml polypropylene beaker, then 48% HF was added, and a beaker was sealed with parafilm. The sample was left for 2-3 days and stirred occasionally. The sample was washed with distilled water and left to settle to the bottom of the beaker and decanted the water out twice

3.4.4.4 Preventing the formation of fluoride crystals

The sample was transferred to 100 ml glass beaker, boiled in 10% HCl for 2-5 minutes and transferred to a centrifuge tube. To wash the sample, distilled water was added and centrifuged at 3,000 rpm for 1 minute, and supernatant was decanted; repeat once.

3.4.4.5 Removal of protein

The sample was treated with the mixture of 3 ml of 33% $NaClO_3$, 1.5 ml of glacial acetic acid and 3-4 drops of 37% HCl, place in hot water for 5 minutes. The sample was washed by adding distilled water and centrifuged at 3,000 rpm for 1 minute, and supernatant was decanted; repeat once. The sample was washed by adding glacial acetic acid and centrifuged at 3,000 rpm for 1 minute, and supernatant was decanted; repeat once.

3.4.4.6 Acetolysis method

The sample was treated with acetolysis solution [mixture of acetic anhydride : conc.H_2SO_4 (9:1)] and placed in hot water for 1 minute. Glacial acetic acid was added and centrifuged at 3,000 rpm for 1 minute, and supernatant was decanted; repeat once. Distilled water was added and centrifuged at 3,000 rpm for 1 minute, and supernatant was decanted; repeat once.

3.4.4.7 Organic-inorganic matter separation (optional)

In case that the mineral substance cannot be removed, a gravity separation technique was carried out by using heavy liquid such as zinc chloride solution at specific gravities of 2.0-2.2.

The sample was placed in the ultrasonic generator and agitated for 5 minutes to break up clumps of the residue sample and prevent reaggregation after the separation treatment (Funkhouser and Evitt, 1959). About 2 ml of zinc chloride solution was added to the sample tube and then water was carefully added to the tube. The sample was centrifuged for 1 minute. The organic suspension layer appeared at the boundary between heavy liquid and water. The organic suspension was then transferred to another tube. Distilled water was added and centrifuged at 3,000 rpm for 1 minute, and supernatant was decanted. Repeat washing once.

3.4.4.8 Removal of water

The residue sample was dehydrated using ethyl alcohol series of 70%, 95% and absolute ethyl alcohol. Part of sample stored in absolute alcohol was transferred to a vial for scanning electron microscope observation. The rest was removed from the tube to another vial by using benzene, and stored for ligth microscope observation.

3.4.4.9 Microscopic preparation

About 2-3 drops of silicone oil were added to the sample. The sample was left overnight to allow benzene to completely evaporate. The microscopic slide was made and sealed with paraffin. All extracted pollen and spore samples as well as voucher microscopic slides were deposited at Professor Kasin Suvatabhandhu Herbarium (BCU), Department of Botany, Faculty of Science, Chulalongkorn University.

3.5 Pollen analysis

3.5.1 Equipment

- Counter
- Stage micrometer scale 1:10 μm
- Light microscope (Olympus model CH30)
- Light microscope (Olympus model BX51) equipped with DP70 digital camera at the Central Laboratory, Department of Botany, Faculty of Science, Chulalongkorn University
- Scanning electron microscope (Jeol model JSM-5800LV) at the Technological Research Equipment Center, Chulalongkorn University

3.5.2 Chemicals

- Immersion oil

3.5.3 Pollen analysis

Pollen analysis was followed the method of Wattanasak (1997). Briefly, as many as 300 pollen and spores were observed for each soil sample, and taxonomic groups (to the lower rank possible) of each pollen and spore counted were determined. Then, pollen diagram was constructed, and used for interpreting plant community and dynamics.

The pollen and spores were investigated through light microscope (LM) and scanning electron microscope (SEM) for morphological observation, and photographs were taken. Palynological description and the taxonomic affinity of fossil pollen and spores were carried out followed by Erdtman (1952), Devi (1977), Huang (1972, 1981), Thanikaimoni (1987) and Tryon and Lugardon (1990). In addition, extant acetolyzed pollen and spores prepared by the author were also consulted (listed in Appendix A).

Pollen diagram was constructed using the computer software TILIA version 2.0.b.4 and TILIA*GRAPH version 2.0.b.4 (Grimm, 1991). The pollen and spore percentage was plotted against its stratigraphic depth. The constrained incremental sum of square cluster analysis (CONISS) was made by the CONISS program associated with TILIA software. The dendrogram was considered as a tool to define zone boundaries. Once decisions had been made, horizontal lines were drawn across the diagram. Zonations were defined in relation to the presence or absence of taxa in the pollen assemblage and made based on the representation of the pollen belonging to group 1-6 as mentioned above. The pollen diagram was then interpreted in the term of plant community. Plant community or type of vegetation inferred or deduced from the pollen diagram was determined by comparing “key species” found in pollen diagram to those in present vegetation as categorized by Santisuk (1983, 2007)

CHAPTER IV

RESULTS

The results were divided into four parts including stratigraphy of the study site, chronology of the sediment, pollen and spore descriptions, and pollen assemblages.

4.1 Stratigraphy of the study site

The stratigraphy of the study site is useful for understanding the environment at the times of deposition which is necessary for the interpretation of the pollen assemblages. The stratigraphy of the Lad Chang soil pit is constructed from the succession of sedimentary layers of about 26 meters in thickness and classified into six layers from the bottom to the top of the soil pit as shown in Figure 4.1. The lithologic description is based on texture, color, sedimentary structure, and animal and plant remains of each sedimentary unit

Sediment unit A

The unit in the lowermost part of the sequence is at below 19.061 meters under the mean sea level. This unit is orange in color of noncalcareous stiff clay without any plant or animal remains. This zone contains gypsum crystals and located at the eastward of the soil pit.

Sediment unit B

The unit overlies the sediment unit A with about 2.3 meters in thickness (at 16.762 to 19.061 meters under the mean sea level). This unit is yellow to pale orange in color of noncalcareous stiff clay with gradational contact boundary between the sediment unit A and B. This zone contains gypsum crystals and located at the eastward of the soil pit. No any animal or plant remain has been reported from this sediment unit.

Sediment unit C

The sequence is about 5.0 meters in thickness (at 11.769 to 16.762 meters under the mean sea level). This unit is maroon in color of noncalcareous stiff clay with sharp contact boundary between the sediment unit B and C. This zone contains gypsum crystals and located at the eastward of the soil pit. No any animal or plant remain has been found.

Sediment unit D

The sequence is about 4.5 meters in thickness (at 7.302 to 11.769 meters under the mean sea level). This unit is yellow in color of noncalcareous stiff clay with gradational to sharp contact boundary between the sediment unit C and D. This zone contains gypsum crystals and located at the eastward of the soil pit. No any animal or plant remain was discovered from this sediment unit.

Sediment unit E

The sequence is about 7.6 meters in thickness (at 7.302 meters under the mean sea level to 0.303 meters above the mean sea level). This unit is dark gray in color of soft clay with sharp contact boundary between the sediment unit D and E. This layer contains both animal and plant remains including pollen and spores. The plant remains were found in the basal part including abundant peat fragments with some small tree trunks that normally posed in the upright position with roots still attracted. Animal remains consisting of crabs, abundant marine mollusk shells *Cyrtopleura* cf. *C. costata* still occurred as a pair of valves as its original nature and its long axis orientated in vertical position as shown in Figure 4.2 This layer is regarded as the marine clay unit namely Bangkok Clay.

Sediment unit F

This unit is the uppermost portion of the sequence with varying in thickness ranging between 1.0 and 2.0 meters (at above 0.303 meters above the mean sea level). This unit is dark gray in color of soft clay and separated from the sediment unit E by the absence of marine mollusk shells. This layer is considered to be the flooding sediment.

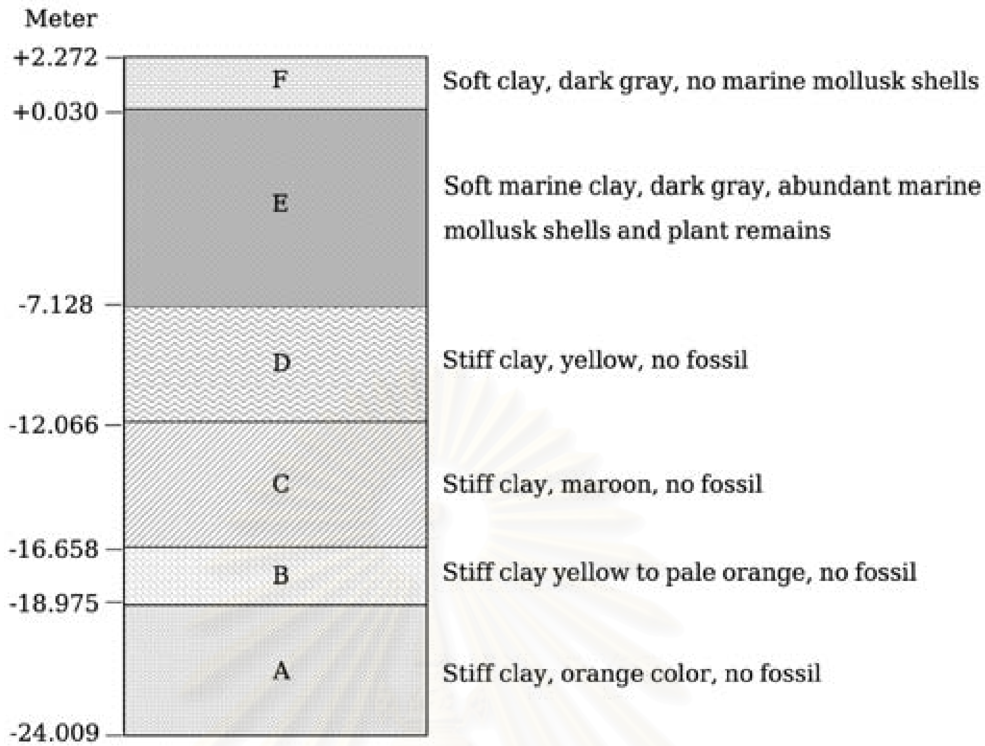

Figure 4.1 Vertical profile of the pit wall in the Lad Chang soil pit showing the stratigraphic column of the pit wall of Lad Chang soil pit

Figure 4.2 Mollusk shells of *Cyrtopleura* sp. cf. *C. costata* as *in situ* burrowing deposits in sediment unit E

4.2 Chronology of the sediment

The ages and stratigraphic depths of organic materials found in the study site were presented in Table 4.1 and Figure 4.3, respectively.

Table 4.1 Ages of four organic materials in sediment samples determined by radiometric dating using isotope carbon fourteen dating method.

Depth (meters under mean sea level)	Type of organic materials	Age (years BP)
4.428	Mollusk shells	5,050 ± 290
5.393	Carbonized wood	7,050 ± 350
6.039	Carbonized wood	7,460 ± 350
6.328	Carbonized wood	7,620 ± 360

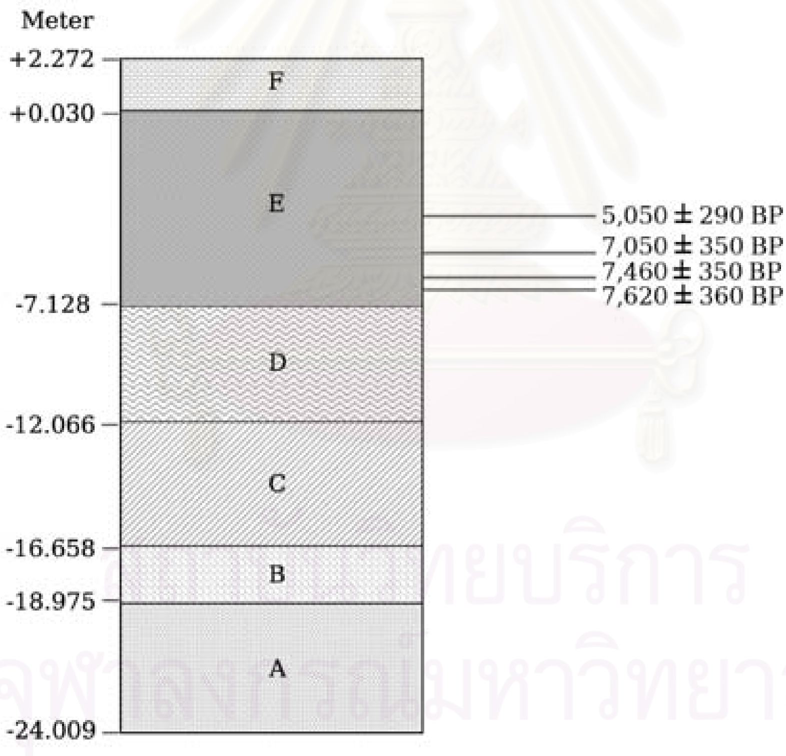

Figure 4.3 The stratigraphic depths of four organic materials along with ^{14}C-dating ages.

4.3 Pollen and spore descriptions

The descriptions of pollen and spores were given in short description. They were categorized into three groups: pteridophyte spores, gymnosperm pollen and angiosperm pollen. In each group, they were alphabetically arranged. Pollen and spore morphology was described based on polarity, size, shape, aperture and sculpture of the exine. The palynological descriptions and terminology were carried out followed those of Erdtman (1952), Devi (1977), Huang (1972, 1981), Thanikaimoni (1987), Tryon and Lugardon (1990), and Punt *et al.* (1994).

Almost pollen and spore were found in both LM and SEM observations, but some were present only in LM or SEM observation. The descriptions were therefore based on the characters occurring in each microscopic investigation.

4.3.1 Spore descriptions of pteridophytes

Blechnaceae

***Stenochlaena palustris* type**

Spore monolete, heteropolar; 18-27 × 30-42 × 14-30 µ, medium spore; amb ellipsoidal, slightly concave-convex in lateral view, laesura 15-18 µ, straight, simple commissure; tuberculate, tubercles 1-3 µ tall. (Plate 1, A-D; Plate 17, A-D)

Davalliaceae

***Davallia* type**

Spore monolete, heteropolar; 29 × 41-49 × 23-29 µ, medium spore; amb ellipsoidal, slightly concave-convex in lateral view, laesura 23-24 µ, straight, simple commissure; large verrucate. (Plate 1, E-H; Plate 17, E-F)

Gleicheniaceae

Gleicheniaceae type

Spore trilete, heteropolar; 31-41 × 31-39 µ, medium spore; amb trilobate, the proximal pole flat, the distal pole hemispherical, laesura arm 14-20 µ, straight, simple commissure; psilate with sparsely perforation. (Plate 2, A-D; Plate 17, G-H; Plate 18, A-B)

Parkeriaceae

***Ceratopteris* type**

Spore trilete, heteropolar; 88-120 × 53 µ, very large spore; amb rounded-triangular to triangular with concave or slightly straight sides, proximal pole flat, distal pole hemispherical, laesura arm 27-34 µ, straight, simple commissure; striate, muri 3 µ tall. (Plate 2, E-F; Plate 18, C-F)

Pteridaceae

Spore trilete, heteropolar; 30-53 × 33-40 µ; medium or large spore; amb rounded-triangular or subtriangular, laesura arm 16-21 µ, straight, simple commissure or lip-like margo; proximal face with or without ridges or elements different from distal face.

***Acrostichum* type**

Spore trilete, heteropolar; equatorial value = 40-53 µ, large spore; amb rounded-triangular, laesura arm 17-20 µ, straight, simple commissure; scabrate. (Plate 2, G-H; Plate 3, A-B)

cf. *Acrostichum* type

Spore trilete, heteropolar; 36-39 × 41-58 µ, large spore; amb rounded-triangular, the proximal pole slightly flat, the distal pole hemispherical, laesura arm 11-20 µ, straight, simple commissure; psilate. (Plate 3, C-F; Plate 18, G-H; Plate 19, A-D)

***Pteris* type A**

Spore trilete, heteropolar; 37-44 × 33-40 µ; medium spore; amb subtriangular with straight or slightly concave sides, laesura arm 16 µ, straight, simple commissure; proximal face tuberculate, distal face scabrate. (Plate 3, G-H; Plate 19, E-F)

Pteris type B

Spore trilete, heteropolar; 30-33 × 16-20 µ in proximal view; medium spore; amb subtriangular with straight or slightly concave sides, laesura arm 16-21 µ, straight, lip-like margo; proximal face convolute, distal face psilate. (Plate 4, A-B)

Schizaeaceae

Lygodium microphyllum type

Spore trilete, heteropolar; 65-67 × 52 µ, large spore; amb rounded triangular, the proximal pole flat, the distal pole hemispherical, laesura arm 20 µ, straight, simple commissure; reticulate, lumina elongated or rounded, 3 µ, muri 3-4 µ, muri as thick as or thicker than lumina. (Plate 4, C; Plate 19, G-H; Plate 20, A-C)

Unidentifiable spores

Monolete

Monolete type A

Spore monolete, heteropolar; 24-36 × 39-56 × 22-31 µ, large spore; amb ellipsoidal, slightly concave-convex in lateral view, laesura 14-33 µ, straight, simple commissure; psilate. (Plate 4, D-F; Plate 20, D-E)

Monolete type B

Spore monolete, heteropolar; 15-21 × 30-34 × 19-22 µ, medium spore; amb ellipsoidal, slightly concave-convex in lateral view, laesura 14-23 µ, straight, simple commissure; psilate. (Plate 4, G-H; Plate 5, A-B)

Trilete type A

Spore trilete, heteropolar; 19 × 40-46 µ, medium spore; amb subtriangular, laesura arm 16 µ, straight, simple commissure; the proximal pole flat, psilate, the distal pole hemispherical, convolute. (Plate 5, C-D; Plate 20, F)

Trilete type B

Spore trilete, heteropolar; 14 × 30-31 µ, medium spore; amb triquete, the proximal pole flat, laesura arm 14 µ, straight, simple commissure; the proximal pole flat; psilate. (Plate 5, E-F)

4.3.2 Pollen descriptions of gymnosperms

Pinaceae

Grain vesiculate, diploxylonoid or haploxylonoid, heteropolar; 30-44 × 24-35 × 3-12 μ for corpus, rounded, verrucate; 23-39 × 17-28 × 16-19 μ for sacci, rounded, microverrucate

***Pinus* type A**

Grain vesiculate, diploxylonoid, heteropolar; 30-44 × 24-32 × 3-12 μ for corpus, rounded, verrucate; 23-35 × 19-28 × 16-19 μ for sacci, rounded, microverrucate (in SEM). (Plate 6, A-F; Plate 21, A-H)

***Pinus* type B**

Grain vesiculate, haploxylonoid, heteropolar; 42 × 27-35 μ for corpus, rounded, verrucate; 36-39 × 17-20 μ for sacci, rounded, reticulate (Plate 6, G-H)

4.3.3 Pollen descriptions of angiosperms

Avicenniaceae

***Avicennia* type**

Grain monad, isopolar; 16-25 × 16-26 μ, small grain, oblate spheroidal to subprolate; amb circular-lobate; tricolporate, ectoaperture colpi, narrow, slightly shorter than polar axis, widened at the equator and tapering towards the pole, ends acute, 11–17 × 2–5 μ; endoaperture pori, lalongate or lolongate, rounded or ovate, 1-4 × 2-6 μ; microreticulate, lumina rounded or sometimes elonglated, 0.4-0.6 μ, muri 0.8-1.1 μ, muri thicker than lumina, small granules around aperture area. (Plate 7, A-D; Plate 22, A-H)

Cheonopodiaceae

***Suaeda maritima* type**

Grain monad, apolar**;** 14-16 μ, small grain, spheroidal; pantoporate, number of pori more than 40, 0.8-1 μ in diameter, rounded; psilate with scattered microspine. (Plate 7, E-H; Plate 23, A-B)

Combretaceae

Combretaceae type

Grain monad, isopolar; 19 × 16 μ, small grain, subprolate; amb rounded hexagonal; tricolporate alternate with tripsuedocolpi, ectoaperture colpi, slit-like, slightly shorter than polar axis, widened at the equator and tapering towards the pole, ends acute, 4 × 16 μ; endoaperture pori, lalongate, rounded, 2 μ; microreticulate, lumina elonglated or rounded, muri thicker than lumina (in LM). (Plate 8, A-B)

Dipterocarpaceae

Dipterocarpaceae type

Grain monad, isopolar; equatorial axis = 18-27 µ, amb trilobate; tricolpate, colpi slightly shorter than polar axis (in SEM), ca. 7 µ wide (in LM); fossulate. (Plate 8, C-D; Plate 23, C-D)

Fagaceae

Grain monad, isopolar; 15-26 × 10-19 µ, small to medium grain, prolate spheroidal to perprolate; amb circular; tricolporate, ectoaperture colpi, narrow or slit-like, slightly shorter than polar axis, parallel or widened at the equator and tapering towards the pole, ends acute, 14-22 × 2 µ, costa ectocolpi present; endoaperture pori; lalongate, elliptic, equatorial ends rounded, 1-3 × 3-6 µ; costa endopori present; scabrate or microrugulate.

***Quercus* type**

Grain monad, isopolar; 20-26 × 11-19 µ, medium grain, prolate spheroidal to prolate; amb circular; tricolporate, ectoaperture colpi, narrow or slit-like, slightly shorter than polar axis, parallel or widened at the equator and tapering towards the pole, ends acute, 16-22 × 2 µ, costa ectocolpi present; endoaperture pori; lalongate, elliptic, equatorial ends rounded, 2-3 × 5-6 µ; costa endopori present; scabrate or microrugulate. (Plate 8, E-F; Plate 23, E-H; Plate 24, A-H Plate 25, A-D)

Fagaceae type

Grain monad, isopolar; 15-22 × 9-11 µ, small grain, prolate to perprolate; amb circular; tricolporate, slit-like, slightly shorter than polar axis, parallel, ends acute, 14-16 µ, costa ectocolpi present; endoaperture pori; lalongate, elliptic, equatorial ends rounded, 1-2 × 3-5 µ; costa endopori present; microrugulate. (Plate 8, G-H; Plate 25, E-H)

Hamamelidiaceae

***Altingia* type**

Grain monad, apolar; 22-31 μ, medium grain, spheroidal; pantoporate, number of pori 10-15, 3-4 μ in diameter, annulate, rounded; perforate to microreticulate with scattered microspines, lumina elongated or rounded, 0.1-0.4 μ, muri 0.4-0.9 μ, muri as thick as or slightly thicker than lumina (Plate 9, A-D; Plate 26, A-H)

Leguminosae

***Caesalpinia* type**

Grain monad, isopolar; 16 × 30 μ, medium grain, oblate; amb circular; tricolporate, ectoaperture colpi, as long as polar axis, distinct, widened at the equator and tapering towards the poles, ends acute, 11 μ in width, colpus membrane microreticulate, lumina elongated, 0.2 μ, muri 0.3 μ in width, margo present; endoaperture pori ; reticulate with distinct colpus margin, lumina elongated or rounded, 0.8-1.4 μ, muri 0.4 μ in width, muri thinner than lumina (SEM). (Plate 27, A-B)

Meliaceae

***Xylocarpus* type**

Grain monad, isopolar; 18-25 × 20-28 μ, medium grain, oblate to oblate spheroidal; amb circular; tetracolporate, ectoaperture colpi, slit-like, parallel, ends acute, 8-12 μ; endoaperture pori, lalongate, rounded, 3-5 μ in diameter, costae endopori present; psilate to perforate. (Plate 9, E-H; Plate 10, A-B; Plate 27, C-D)

Mimosaceae

Grain polyad, 12-16 united grains, slightly elliptic or oblong, 19 × 23-33 μ; individual grains apolar, asymmetric, inaperturate, rounded-trapezoid or elliptic, 5-9 × 5-14 μ ; psilate

Mimosaceae type A

Grain polyad, 16 united grains, symmetric arrangement, slightly elliptic; 19 × 23 µ; individual grains apolar, asymmetric, inaperturate, rounded-trapezoid, 5-7 × 5-7 µ; psilate. (Plate 10, C)

Mimosaceae type B

Grain polyad, 12 united grains, symmetric arrangement, oblong; 19 × 33 µ; individual grains apolar, asymmetric, inaperturate, elliptic, 8-9 ×12-14 µ; psilate. (Plate 10, D)

Rhizophoraceae

Grain monad, isopolar; 10-20 × 8-17 µ, small grain, suboblate to prolate; amb semi-angular or circular; tricolporate, ectoaperture colpi, slit-like or margin parallel or widened at equator and tapering towards the poles or, ends obtuse or acute, 10-12 × 1-2 µ, costae ectocolpi present; endocinguli or endoaperture colpi, lalongate, elliptic, transversal parallel, equatorial ends diffused, 1-3 × 3-8 µ; costae endocolpi present distinct or indistinct; perforate or microreticulate, lumina elongated or rounded, 0.1-0.2 µ, muri 0.2-0.4 µ, muri thicker than lumina.

***Bruguiera* type**

Grain monad, isopolar; 12-14 × 12-14 µ, small grain, suboblate to oblate spheroidal; amb circular or semi-angular; tricolporate, ectoaperture colpi, slit-like, slightly shorter than polar axis, closed at the equator, ends acute, 10-12 × 1 µ, costae ectocolpus present; endoaperture colpi, lalongate, elliptic, transversal parallel, equatorial ends diffused, 1-2 × 3-6 µ; costae endocolpi present indistinct; perforate. (Plate 10, E-H; Plate 28, A-D)

***Rhizophora* type**

Grain monad, isopolar; 10-20 × 8-17 µ, small grain, prolate spheroidal to prolate; amb semi-angular or circular; tricolporate, ectoaperture colpi, margin parallel or widened at equator and tapering towards the poles, ends obtuse, 10-12 × 1-2 µ; costae ectocolpi present; endocinguli, 2 µ in width, or endoaperture colpi, lalongate, elliptic, transversal parallel, equatorial ends diffused, 1-3 × 5-8 μ; costae endocolpi present distinct; perforate or microreticulate, lumina elongated or rounded, 0.1-0.2 μ, muri 0.2-0.4 μ in width, muri thicker than lumina. (Plate 11, A-H; Plate 28, E-H; Plate 29, A-H; Plate 30, A-H)

Sonneratiaceae

Grain monad, isopolar; 23-44 × 16-28 μ, medium grain, prolate; amb subangular; triporate, pori protruding, dome-like polar cap, 3-meridional ridges; verrucate or regulato-verrucate at the equatorial area, psilate or regulate at polar cap.

***Sonneratia* type A**

Grain monad, isopolar; 23-35 × 16-24 μ, medium grain, prolate; amb subtriangular; triporate, pori protruding, 2-5 μ in diameter, dome-like polar cap, 3-meridional ridges; verrucato-rugulate at the equatorial area, psilate to regulate at polar cap. (Plate 12, A-H; Plate 31, A-H)

***Sonneratia* type B**

Grain monad, isopolar; 34-44 × 23-28 μ, medium grain, prolate; amb subangular; triporate, pori protruding, 4-6 μ in diameter, dome-like polar cap, 3-prominent meridional ridges; verrucate at the equatorial area, psilate at polar cap and ridges. (Plate 13, A-H; Plate 32, A-F)

Tiliaceae

***Brownlowia* type**

Grain monad, isopolar; equatorial axis = 19-29 μ, medium grain; amb circular; tricolporate, ectocolpi ca. 1-3 μ wide (in LM); costae ectocolpi distinct; microreticulate, lumina elongated or rounded, muri as thick as or slightly thicker than lumina (in LM). (Plate 14, A-D)

Arecaceae

***Oncosperma* type**

Grain monad, heteropolar; 14-21 µ wide, 20-27 µ in length in polar view, medium grain; amb elliptic, often broken into halves along sulcus; monosulcate, sulcus 16-20 µ in length; clavate. (Plate 14, E-H)

Cyperaceae

Cyperaceae type

Grain monad, heteropolar; polar axis = 27-30 µ, longest equatorial axis = 16-22 µ, medium grain, triangular, apex rounded; 4-aperturate, elongate, 14-17 µ; scabrate. (Plate 15, A-D)

Poaceae

Poaceae type

Grain monad, heteropolar; 16-41 µ, small to medium grain, spheroidal; amb circular; monoporate, pore 1-3 µ in diameter, annulate distinct, 1-2 µ in thickness; perforate, scabrate, verrucate or granulate. (Plate 15, E-H; Plate 27, E-H)

Unidentifiable pollen

Tricolporate type

Tricolporate type A

Grain monad, isopolar; 21-27 x 14-27 µ, medium grain, subprolate to prolate; tricolporate, ectoaperture colpi, slit-like, shorter than polar axis, 15-22 µ; costae ectocolpi present; endoaperture pori, lalongate, rounded, 2-3 µ; costae endopori present; microreticulate or microrugulate. (Plate 16, A-B)

Tricolporate type B

Grain monad, isopolar; 36 × 22 µ, medium grain, prolate; tricolporate, ectoaperture colpi, slit-like, slightly shorter than polar axis, 30 µ; costae ectocolpi present; endoaperture pori, lalongate, rounded, 3 µ; costae endopori present; microrugulate. (Plate 16, C)

Tricolporate type C

Grain monad, isopolar; 42 × 43 µ, medium grain, oblate spheroidal; tricolporate, ectoaperture colpi, slit-like, shorter than polar axis, 37 µ; costae ectocolpus present; endoaperture pori, lalongate, rounded, 4 µ; costae endopori present; microreticulate, lumina elonglated, muri thicker than lumina. (Plate 16, D)

Tricolporate type D

Grain monad, isopolar; equatorial axis = 22-23 µ, small grain; tricolporate, ectoaperture colpi, slit-like; costae ectocolpi present; scabrate. (Plate 16, E-F)

Tricolporate type E

Grain monad, isopolar; 23 × 16 µ, medium grain, prolate; tricolporate, ectoaperture colpi, slit-like, shorter than polar axis, 18 µ; costae ectocolpus present; endoaperture pori, endocinguli, 5 µ; costae endocinguli present; scabrate. (Plate 16, G)

Tricolporate type F

Grain monad, isopolar; 16 × 12 μ, small grain, prolate; tricolporate alternate with tripsuedocolpi, ectoaperture colpi, slit-like, slightly shorter than polar axis, parallel, ends acute, 13 μ; psuedocolpi slit-like, shorter than ectocolpi, ends obtuse, 11 μ (SEM); rugulate. (Plate 33, A-B)

Tricolporate type G

Grain monad, isopolar; 14-18 × 8-10 μ, small grain, prolate; tricolporate alternate with tripsuedocolpi, ectoaperture colpi, slit-like, slightly shorter than polar axis, parallel, ends acute, 14-16 μ; psuedocolpi slit-like, shorter than ectocolpi, end acute or obtuse, 10 μ; scabrate. (Plate 33, C)

Tricolporate type H

Grain monad, isopolar; 20 × 20 μ, small grain, spheroidal; amb rounded hexagonal; tricolporate with tripsuedocolpi, ectoaperture colpi, slit-like, slightly shorter than polar axis, widened at the equator and tapering towards the pole, ends acute, 15 μ; psuedocolpi slit-like, shorter than ectocolpi, end acute, 12 μ (SEM); perforate. (Plate 33, D)

Triporate type

Triporate type

Grain monad, isopolar; 31 × 35 μ, medium grain, oblate spheroidal; triporate, pore annulate, rounded, 9 μ in diameter; scabrate with spines, 2 μ tall. (Plate 16, H)

4.4 Pollen assemblages

4.4.1 Pollen diagram construction

A total of 198 sedimentary samples were collected, but only 61 samples from sediment unit E or the Bangkok clay layer yielded pollen and spores, therefore the pollen diagram (shown in Figure 4.4) was represented stratigraphic succession from the depth of 7.302 meters under mean sea level to 0.030 meters above mean sea level. From pollen diagram in Figure 4.4, there existed six pollen assemblages. They were:

Assemblage 1	The mangrove type, consisting of true mangrove such as *Avicennia*, *Bruguiera, Rhizophora*, *Sonneratia*, and *Xylocarpus.*
Assemblage 2	The back mangrove type, consisting of *Acrostichum*, *Brownlowia*, Combretaceae, *Oncosperma* and *Suaeda maritima.*
Assemblage 3	The lowland forest type, consisting of *Altingia,* Dipterocarpaceae, Fagaceae, Mimosaceae and *Pinus.*
Assemblage 4	The grass group, consisting of Cyperaceae and Poaceae.
Assemblage 5	Pteridophytes, consisting of *Ceratopteris*, *Davallia***,** Gleicheniaceae, *Lygodium*, *Pteris*, *Stenochlaena palustris*, monolete and trilete fern spores.
Assemblage 6	Unidentifiable pollen

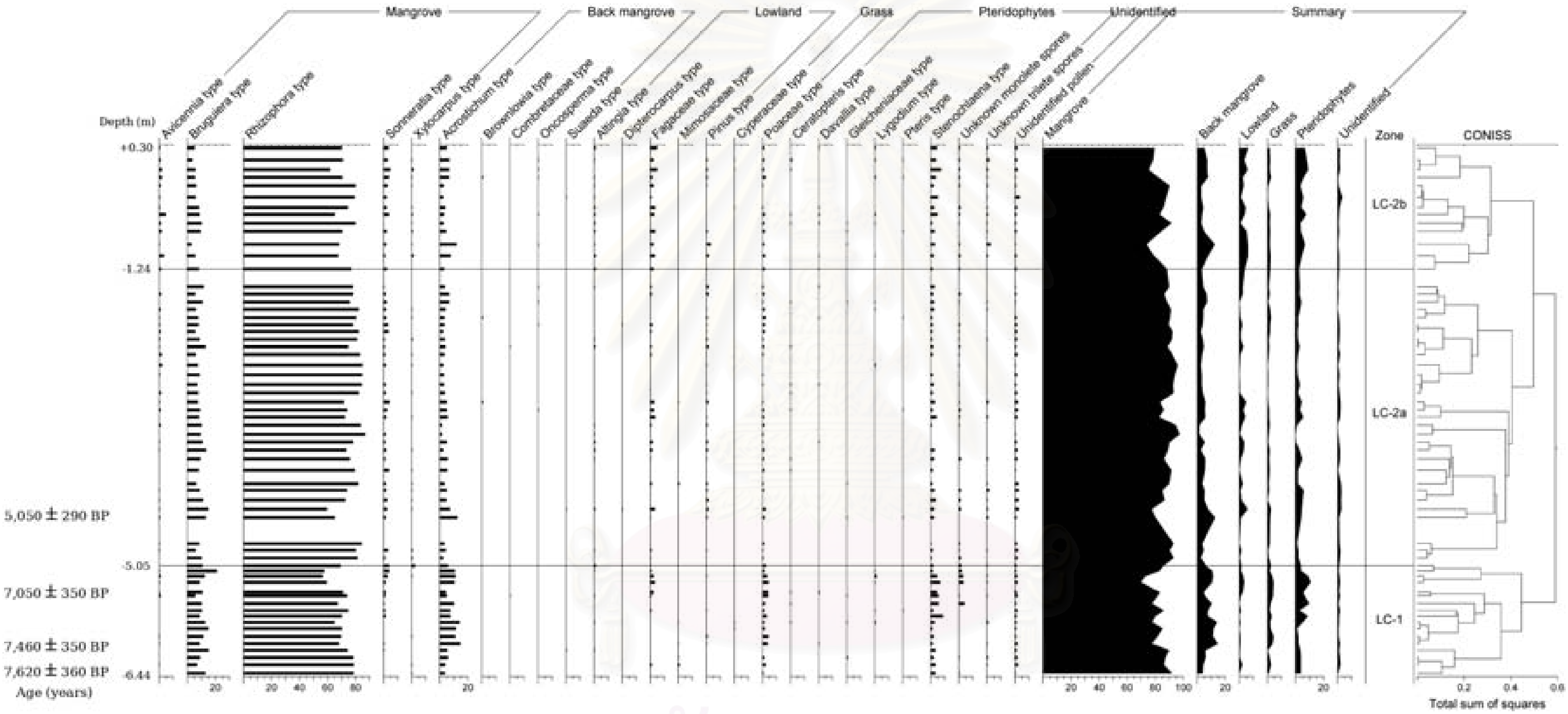

Figure 4.4 Pollen diagram constructed from pollen and spores from the sediment unit E. ((+) represents the depth at above mean sea level, (-) represents the depth at under mean sea level). The vertical axis (y) represents depth (meter) and age (year). The horizontal axis (x) displays the pollen percentage for each of the taxa (plant types) arranged in order of ecological group. Within a group, taxa were alphabetically arranged.

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4.4.2 Pollen diagram descriptions

The occurrence of pollen and spores in the Bangkok clay layer in this study site was at 0.30 meters in depth (above the mean sea level) to 7.302 meters in depth (under the mean sea level). The pollen diagram indicated that the dominant family was Rhizophoraceae, consisting of *Rhizophora* and *Bruguiera*, which appeared more than 60 percent as shown in Figure 4.4. These pollen percentages indicated that in the past mangrove forest was the most dominant ecosystem at this study site.

From the dendrogram in the pollen diagram, two zones were recognized, namely LC-1 and LC-2.The latter was further divided into two sub zones, namely LC-2a and LC-2b. Pollen and spore composition in each zone were described as follows:

Zone LC-1

This zone occupied sediment from 5.05 meters to the base of Bangkok clay layer at 6.44 meters in depth (under the mean sea level) with high percentages of Rhizophoraceae (68-91%) but gradually decreased at the uppermost horizon of the zone. In addition, other mangrove pollen was also present, though less than 4%, including *Avicennia, Sonneratia* and *Xylocarpus*. Spores of *Acrostichum* from the back mangrove were present in between 5-15% which gradually increased at the uppermost horizon of the zone. Pteridophytes such as *Davallia*, Gleicheniaceae, *Lygodium* and monolete fern spores were present between 7-11%, particularly high proportion of *Stenochlaena palustris* occurring in every layer. Grass assemblage was present in low percentages (about 5% of Poaceae). The presence of lowland forest pollen was very low percentages (less than 4%). Moreover, unidentifiable pollen was present in low percentages (less than 7%).

Zone LC-2

This zone was defined from 0.30 meters in depth (above mean sea level) to 5.05 meters in depth (under the mean sea level) with high percentages of Rhizophoraceae (65-95%). The presence of pollen and spores from back mangrove was between 2 -13 %. The content of Rhizophoraceae pollen enabled this zone to be divided into two sub zones as follows:

- Zone LC-2a occurred at the depth between 1.24 - 5.05 meters (under the mean sea level) with constant and very high percentages of Rhizophoraceae (74-95%). Other mangrove pollen were present composing of *Avicennia, Sonneratia* and *Xylocarpus* (less than 4%). The back mangrove was present in varying content between 2-12%. The back mangrove elements such as *Brownlowia*, Combretaceae, *Oncosperma*, and *Suaeda maritima* were occasionally present in very low percentages (less than 2%) but very high propotion of *Acrostichum*. Pteridophytes consisting of *Ceratopteris*, *Davallia*, Gleicheniaceae, *Lygodium*, *Pteris*, monolete fern spores and trilete fern spores were present in low percentages (less than 6%) with high proportion of *Stenochlaena palustris* almost occurring in every layer. The presence of pollen from grass assemblage almost occurring in every layer was present in low percentages (less than 3% of Poaceae). The presence of lowland forest pollen was low percentages (less than 6%) with high propotion of Fagaceae. In addition, the presence of unidentifiable pollen was present in very low percentages (less than 2 %).

- Zone LC-2b occurred from the top of Bangkok clay layer at 0.30 meters in depth (above the mean sea level) to 1.24 meters in depth (under the mean sea level) with declining percentages of Rhizophoraceae (67-86 %) from zone LC-2a. Other mangrove pollen were present less than 5% with the occurrence in every layer of *Avicennia* and *Sonneratia*. The back mangrove element namely *Acrostichum* was increasingly present from the lowermost horizon of the zone (13%) and then vary in content between 3-7%, while other elements of back mangrove such as *Brownlowia*, Combretaceae, *Oncosperma* and *Suaeda maritima* were occasionally present in very low percentages (less than 2%). Pteridophytic spores were present in varying content between 4-9% with periodic presence of *Ceratopteris*, *Davallia*, Gleicheniaceae, *Lygodium*, *Pteris* and monolete fern spores while high proportion of *Stenochlaena palustris* spores occurring in every layer. The presence of pollen from grasses assemblage consisting of Poaceae and Cyperaceae almost occurred in every layer and was present in low percentages (less than 3%). The presence of lowland forest pollen gradually increased from the lowermost horizon of the zone between 4-10% with high propotion of Fagaceae. The unidentifiable pollen were present in very low percentages (less than 3%).

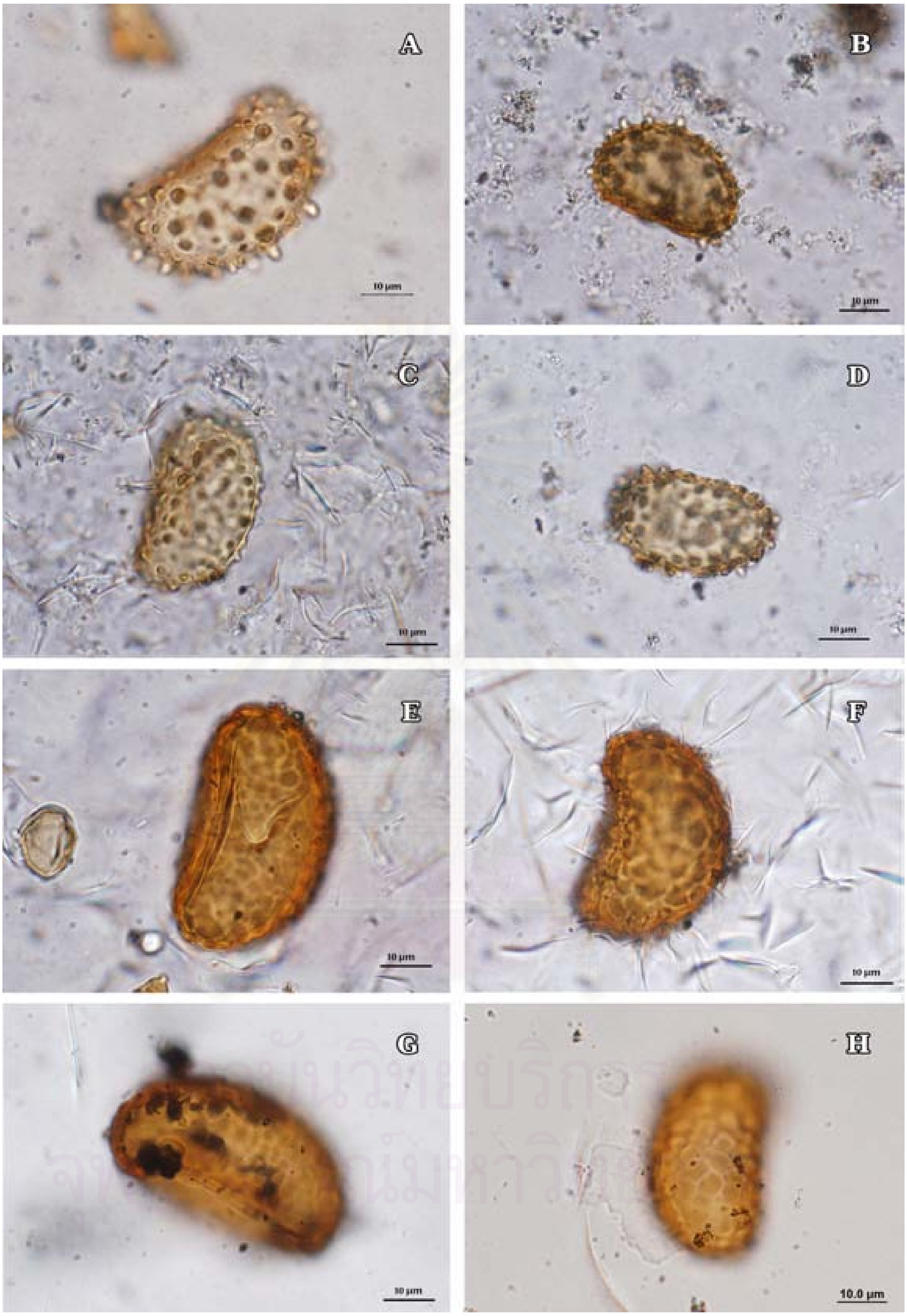

Plate 1 LM micrographs: A-D. ***Stenochlaena palustris*** (A-B) Lateral view; (C-D) Proximal view; E-H. ***Davallia* type**. (E-F) Lateral view, (G) Proximal view, (H) Distal view.

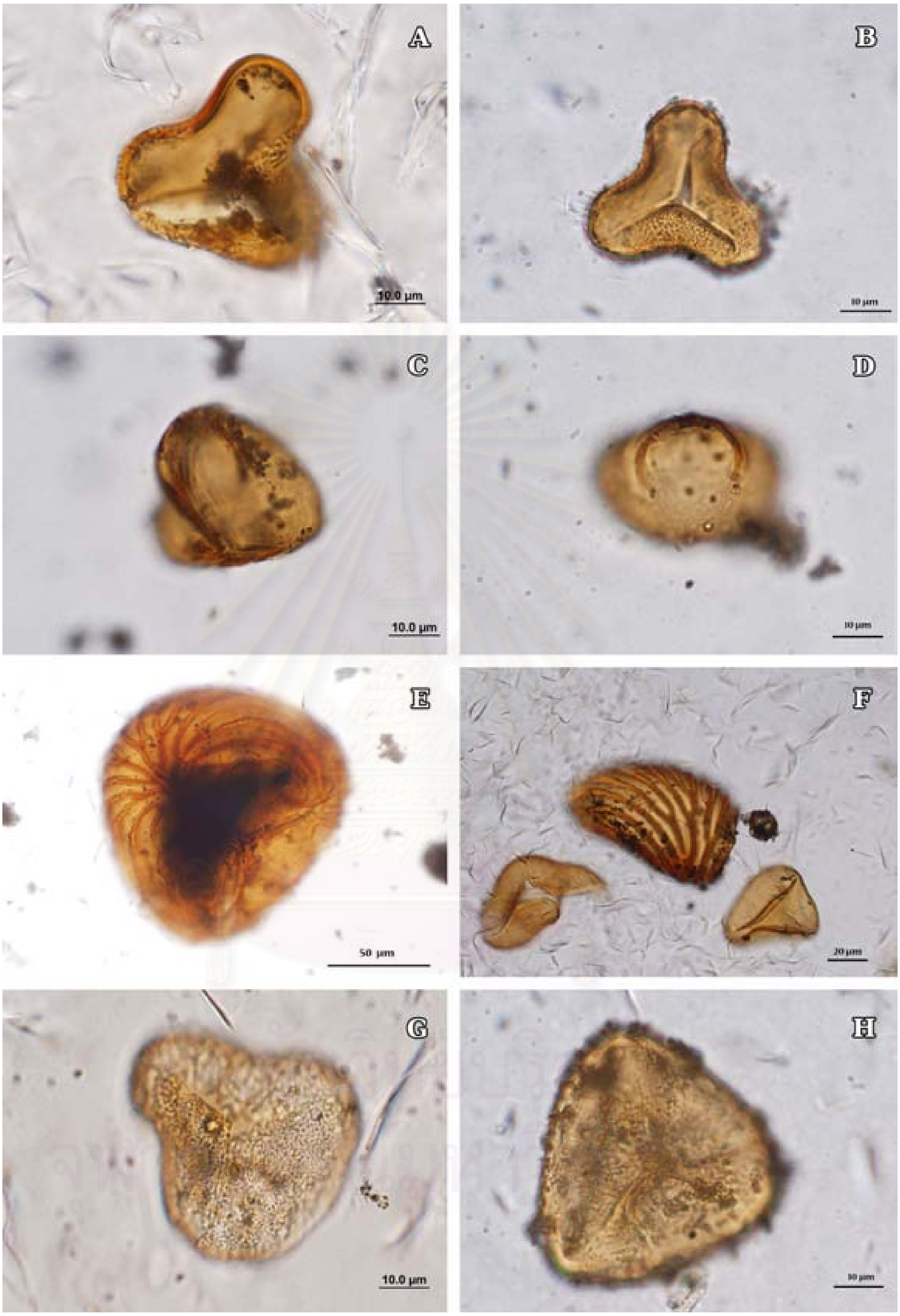

Plate 2 LM micrographs: A-D **Gleicheniaceae type** (A) Proximal view, (B-C) Distal view, (D) Lateral view; E-H. ***Ceratopteris type*** (E) Proximal view, (F) Lateral view; G-H ***Acrostichum* type**, proximal view.

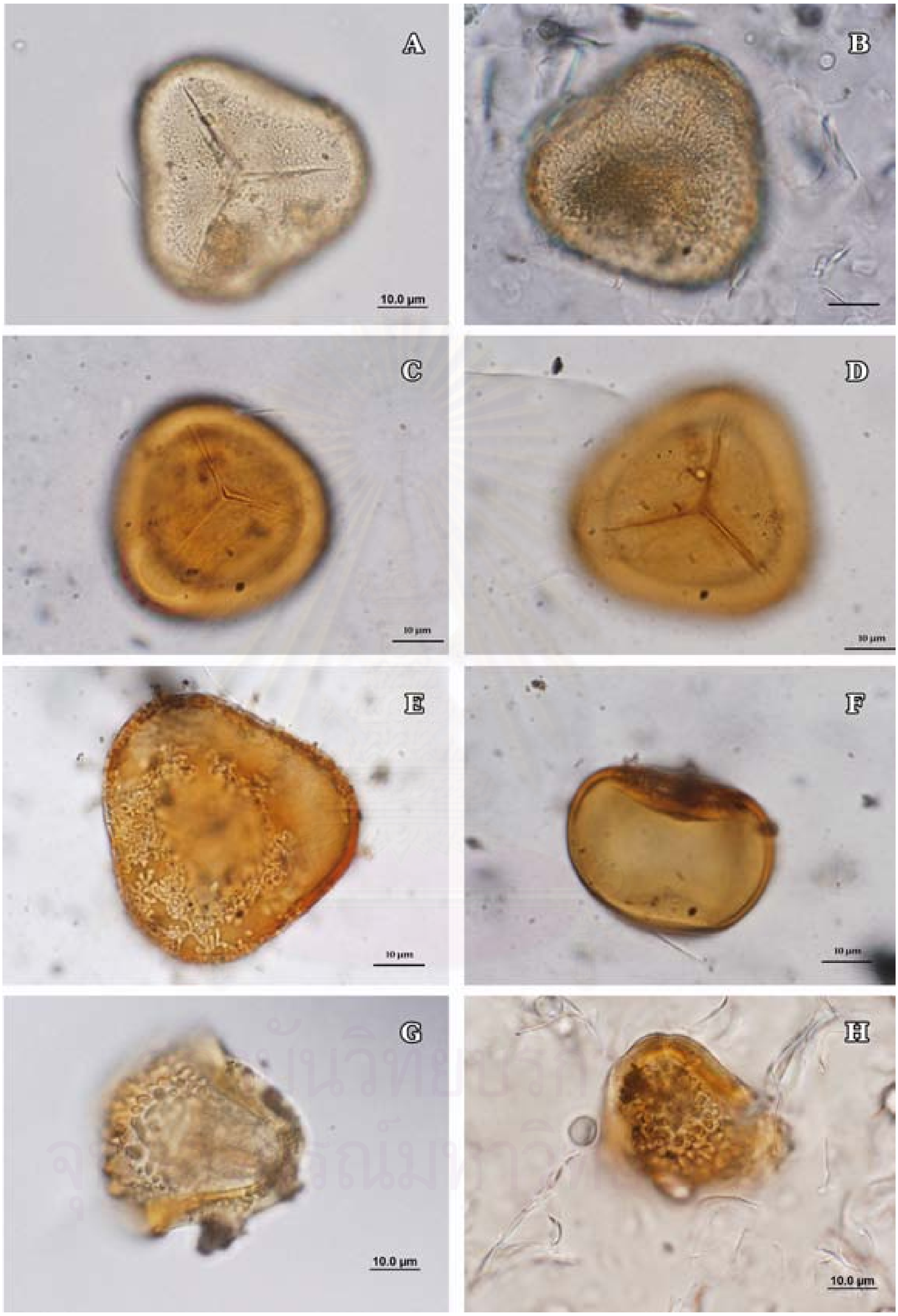

Plate 3 LM micrographs: A-B ***Acrostichum* type** (A) Proximal view, (B) Distal view; C-F **cf. *Acrostichum* type** (C-D) Proximal view, (E) Distal view, (F) Lateral view; G-H ***Pteris* type A**, proximal view.

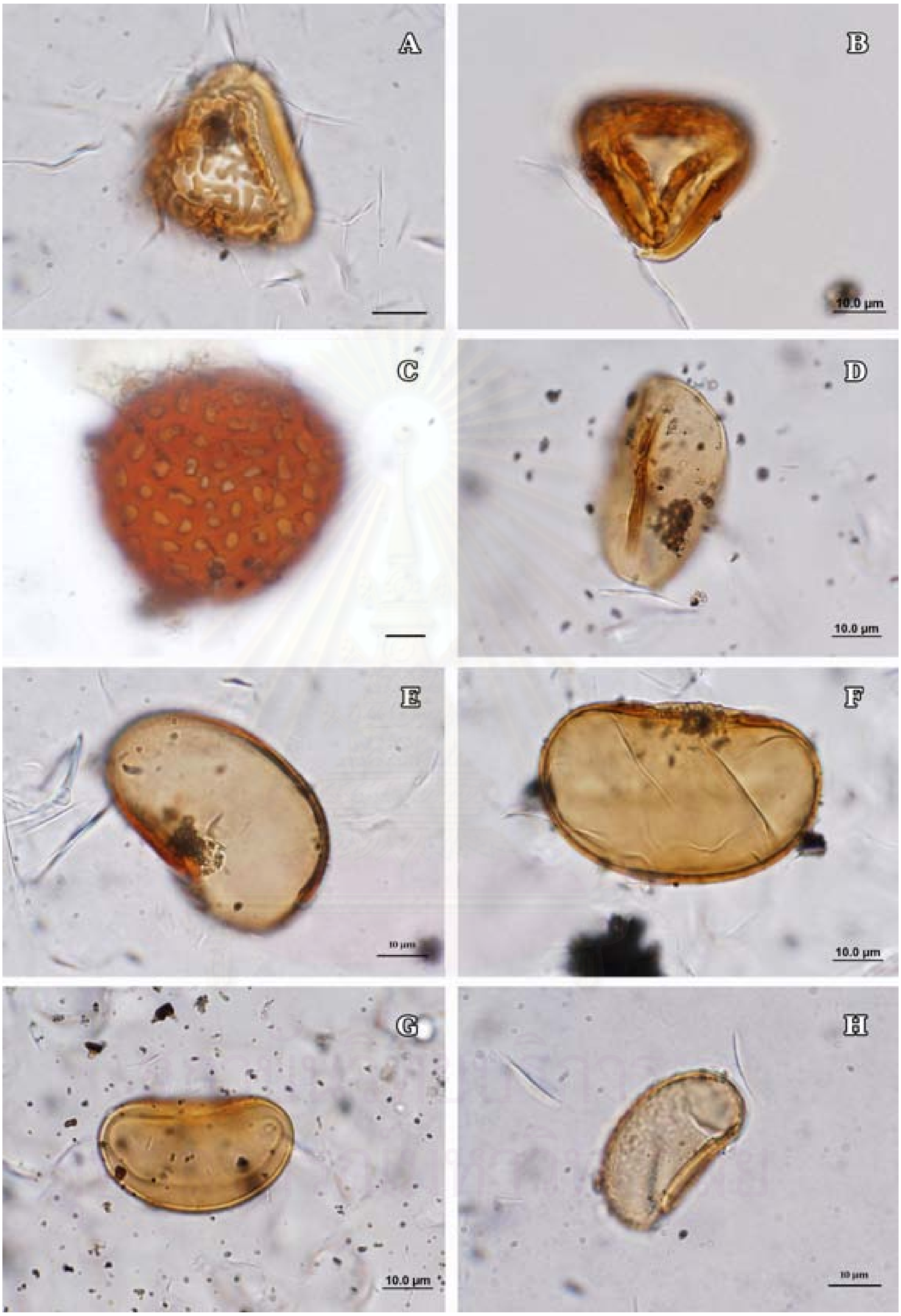

Plate 4 LM micrographs: A-B ***Pteris* type type B**, proximal view; C ***Lygodium microphyllum* type**, proximal view; D-F **Monolete type A**, (D) Proximal view, (E-F) Lateral view; G-H **Monolete type B**, (G) Lateral view, (H) Oblique lateral view.

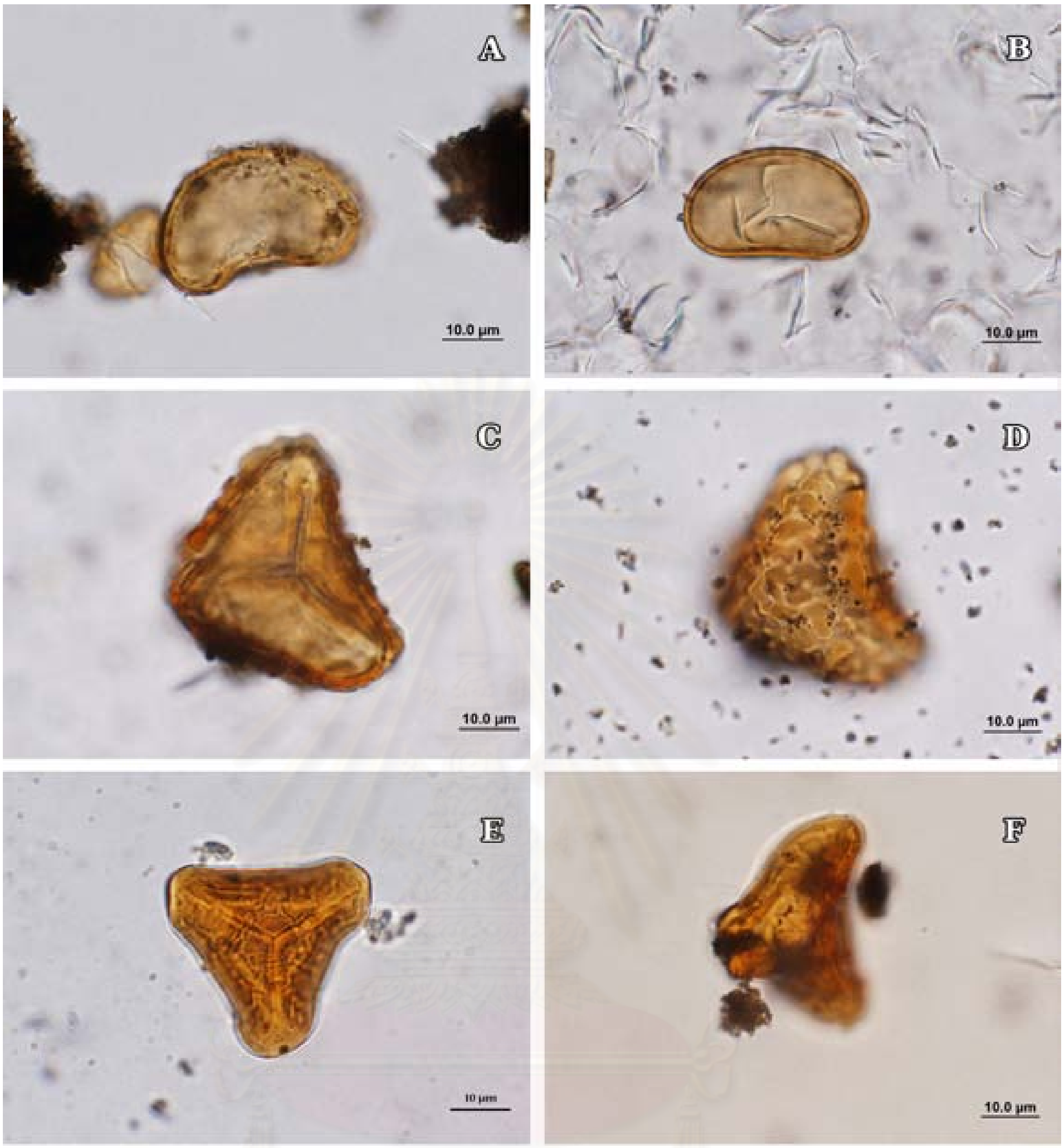

Plate 5 LM micrographs: A-B **Monolete type B**, lateral view; C-D **Trilete type A** (C) Proximal view (D) Distal view**;** E-F **Trilete type B**, proximal view.

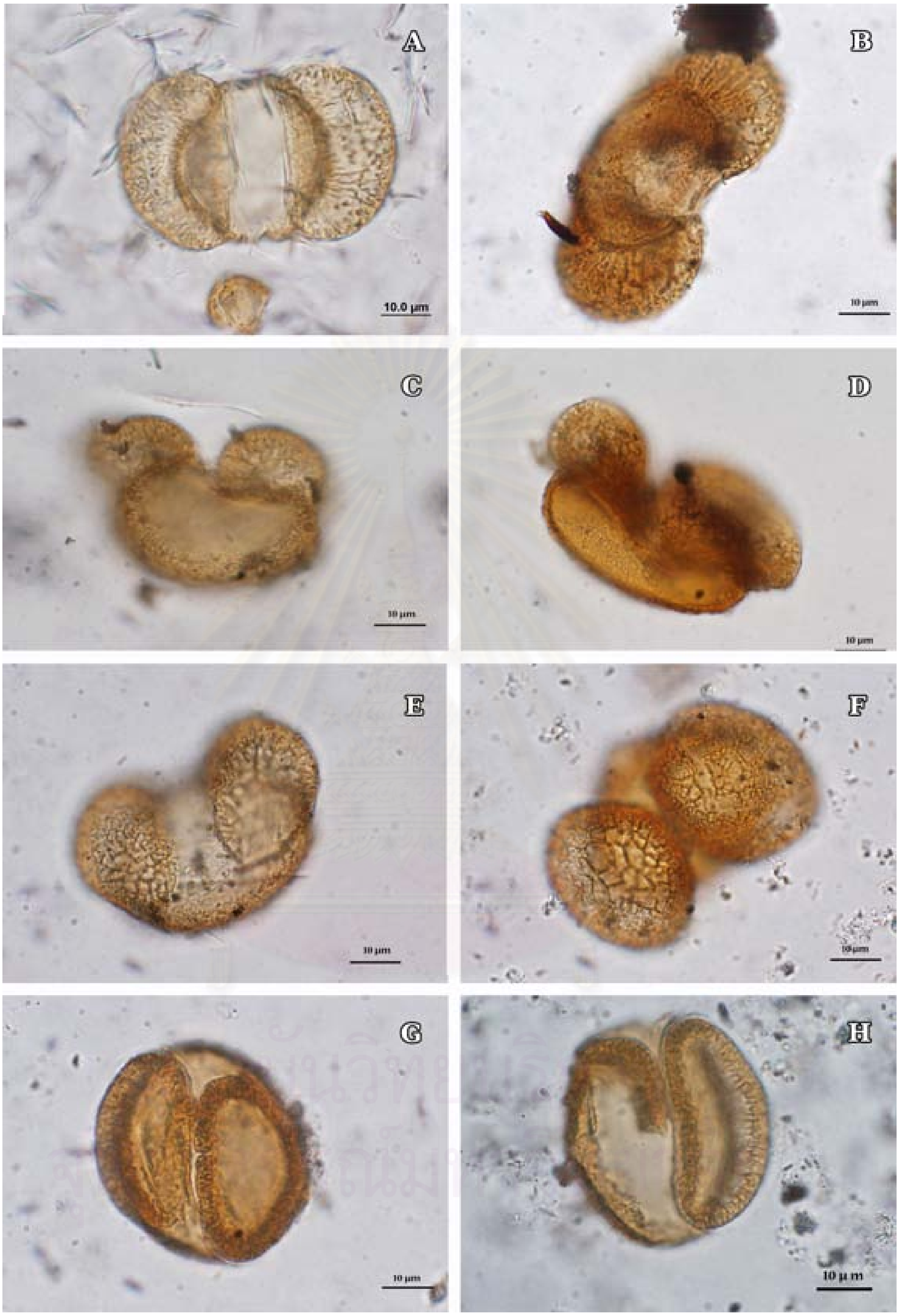

Plate 6 LM micrographs: A-F ***Pinus* type A,** (A-B) Proximal view, (C-D) Lateral view, (E) Oblique lateral view, (F) Distal view; G-H ***Pinus* type B**, distal view**.**

Plate 7 LM micrographs: A-D ***Avicennia*** type, equatorial view, (C) Oblique polar view, (D) Polar view; E-H ***Suaeda maritima* type**, pollen grain.

Plate 8 LM micrographs: A-B **Combretaceae type** (A) Equatorial view, (B) Oblique polar view; C-D **Dipterocarpaceae type**, polar view; E-F ***Quercus* type**, equatorial view; G-H **Fagaceae** type, equatorial view.

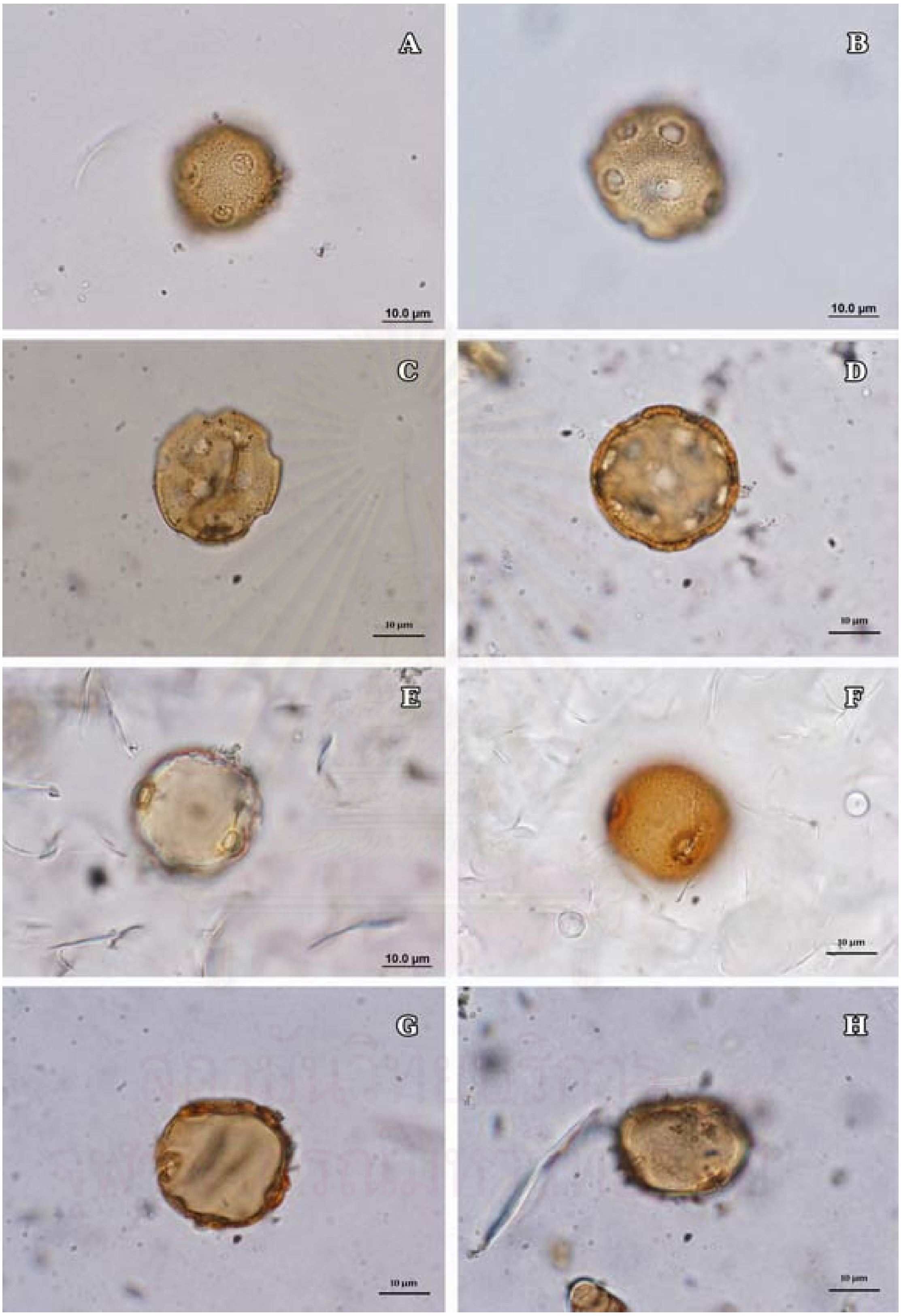

Plate 9 LM micrographs: A-D ***Altingia* type**, pollen grain; E-H ***Xylocarpus* type** (E-F) Equatorial view, (G-H) Polar view.

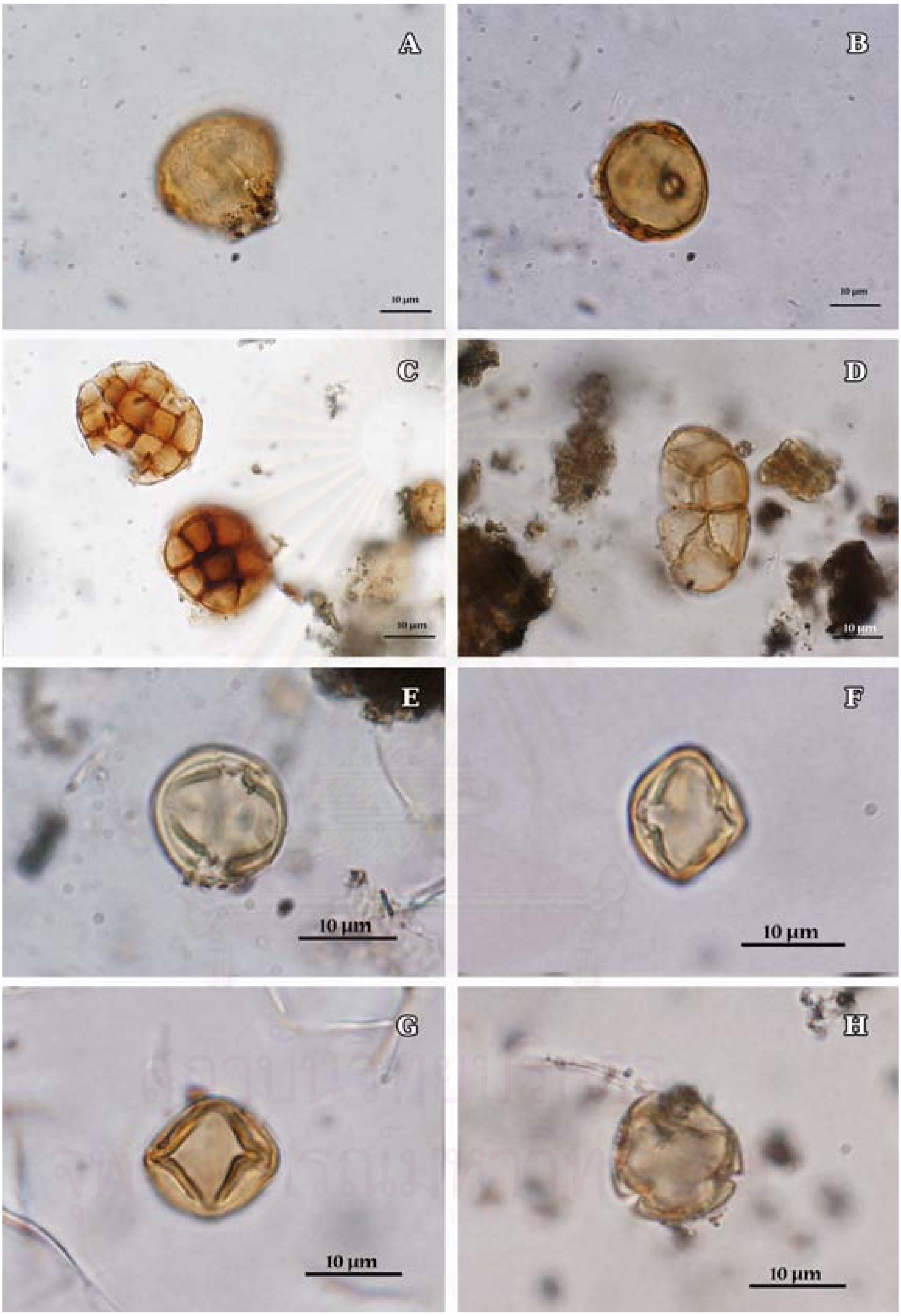

Plate 10 LM micrographs: A-B ***Xylocarpus* type**, equatorial view; C **Mimosaceae type A**, pollen grains; D **Mimosaceae type B**, pollen grains; E-H ***Bruguiera* type** (E-G) Equatorail view, (H) Polar view.

Plate 11 LM micrographs: A-H ***Rhizophora* type** (A-F) Equatorial view, (G-H) Polar view.

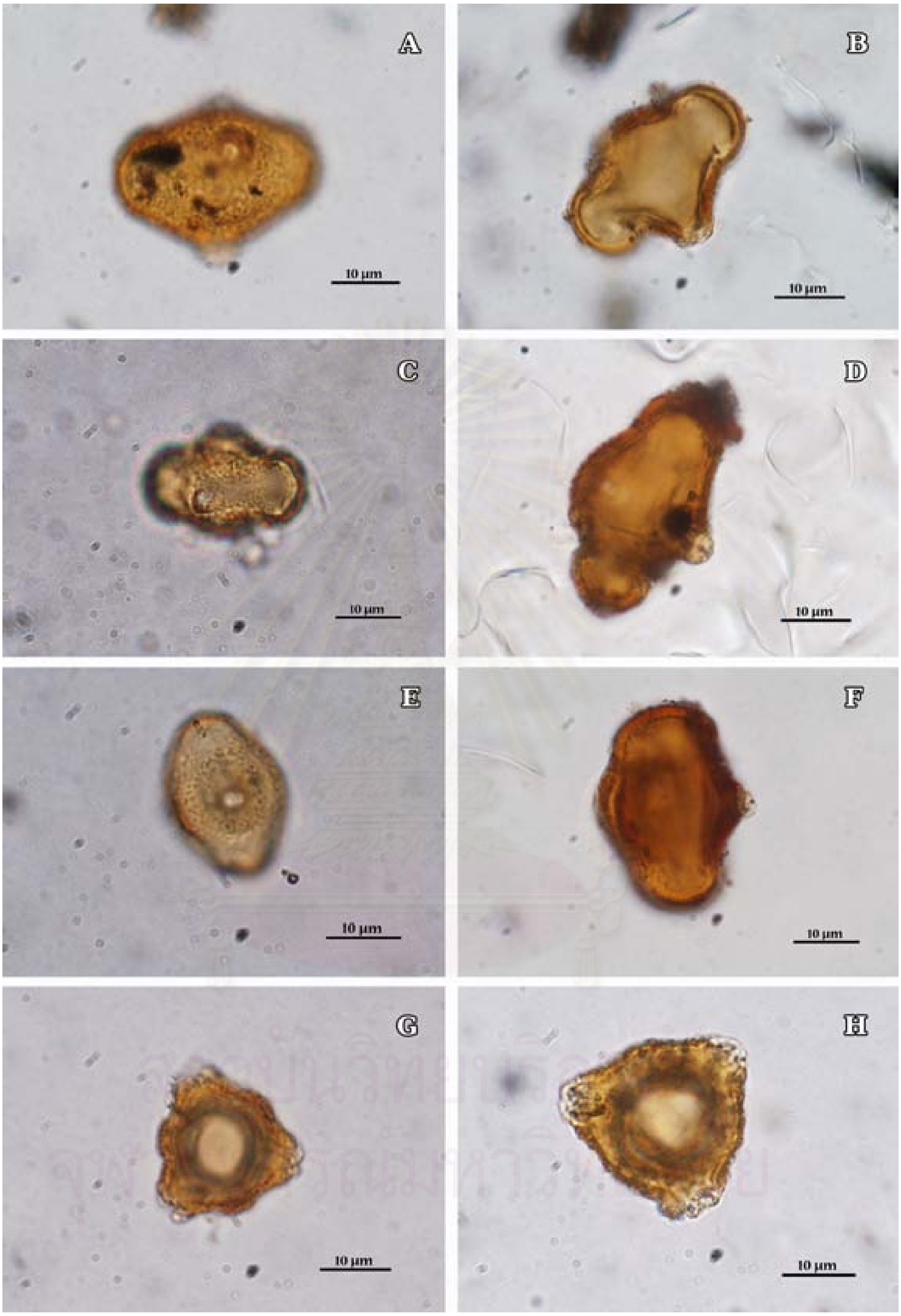

Plate 12 LM micrographs: A-H ***Sonneratia* type A** (A-F) Equatorial view, (G-H) Polar view.

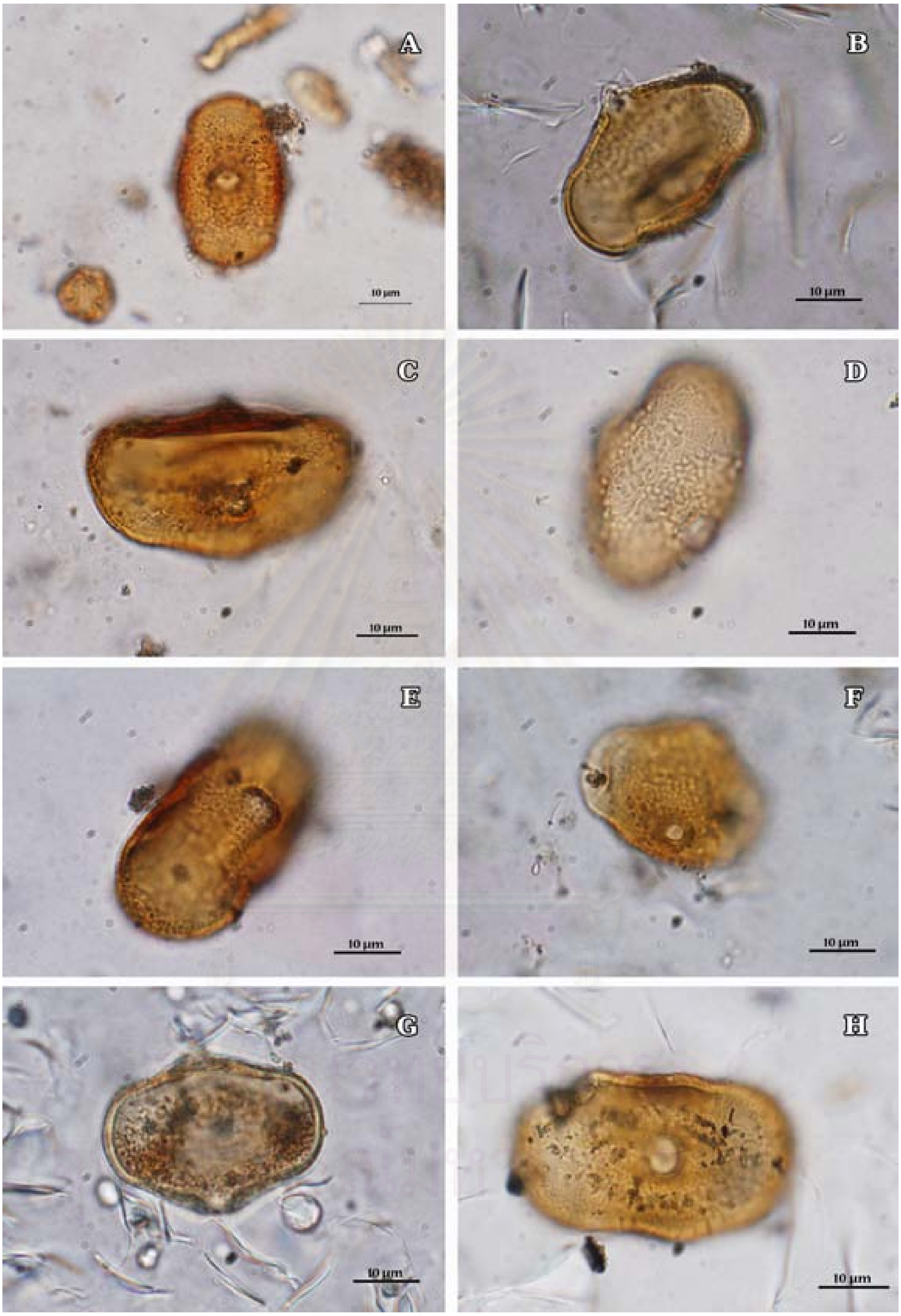

Plate 13 LM micrographs: A-H ***Sonneratia* type** B, equatorial view.

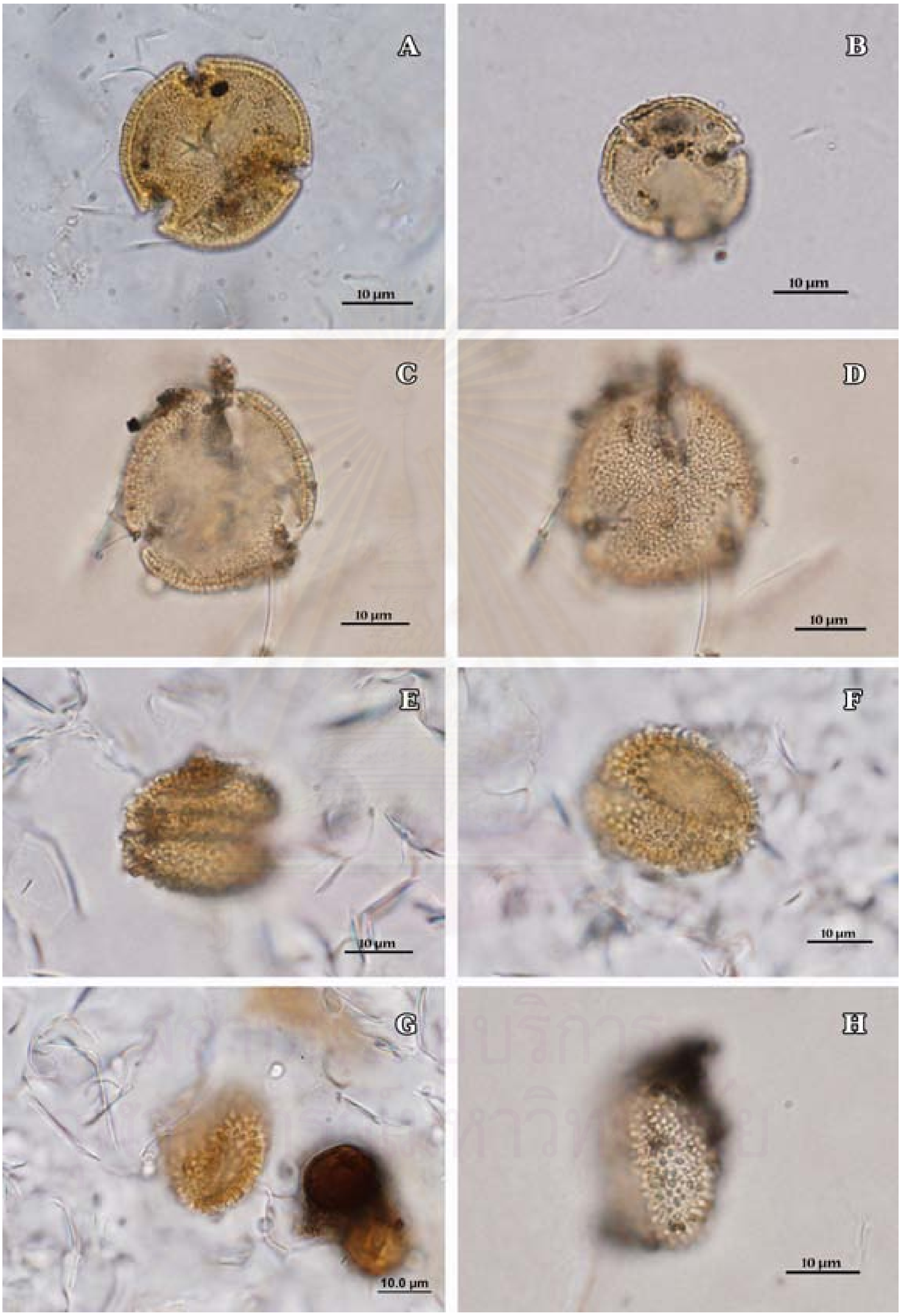

Plate 14 LM micrographs: A-D ***Brownlowia* type**, polar view; E-H ***Oncosperma* type**, polar view.

Plate 15 LM micrographs: A-D **Cyperaceae** type, equatorial view; E-H **Poaceae** type, pollen grain.

Plate 16 LM micrographs: A-B **Tricolporate type** A, equatorial view; C **Tricolporate type B**, equatorial view; D **Tricolporate type C**, equatorial view; E-F **Tricolporate type D**, polar view; G **Tricolporate type E**, equatorial view; H **Triporate** type, equatorial view.

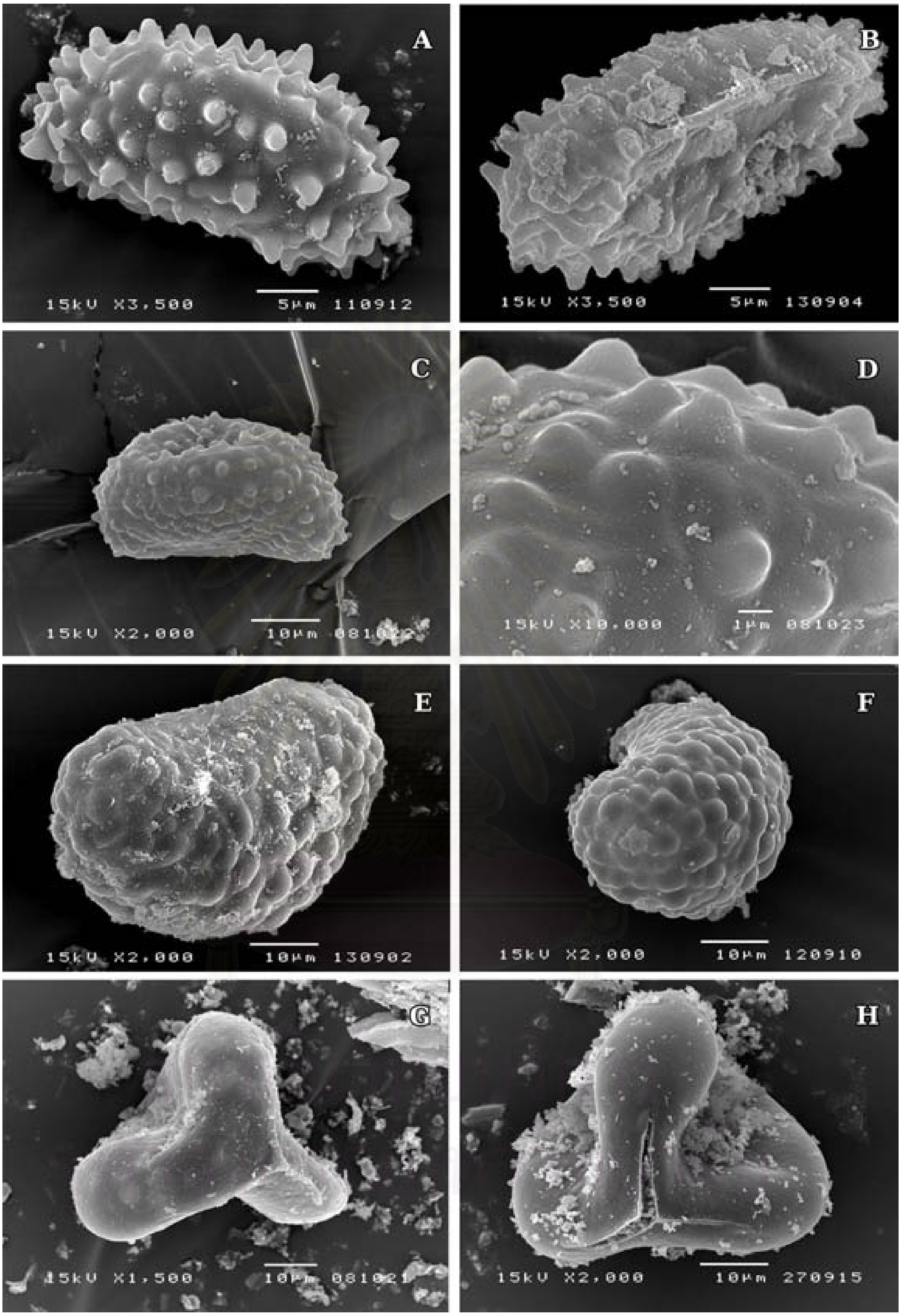

Plate 17 SEM micrographs: A-D. ***Stenochlaena palustris*** **type** (A) Distal view, (B) Proximal view, (C) Lateral view, (D) Verrucate sculpture; E-H. ***Davallia*** **type**. (E) Lateral view, (G) Distal view; G-H **Gleicheniaceae type**, proximal view.

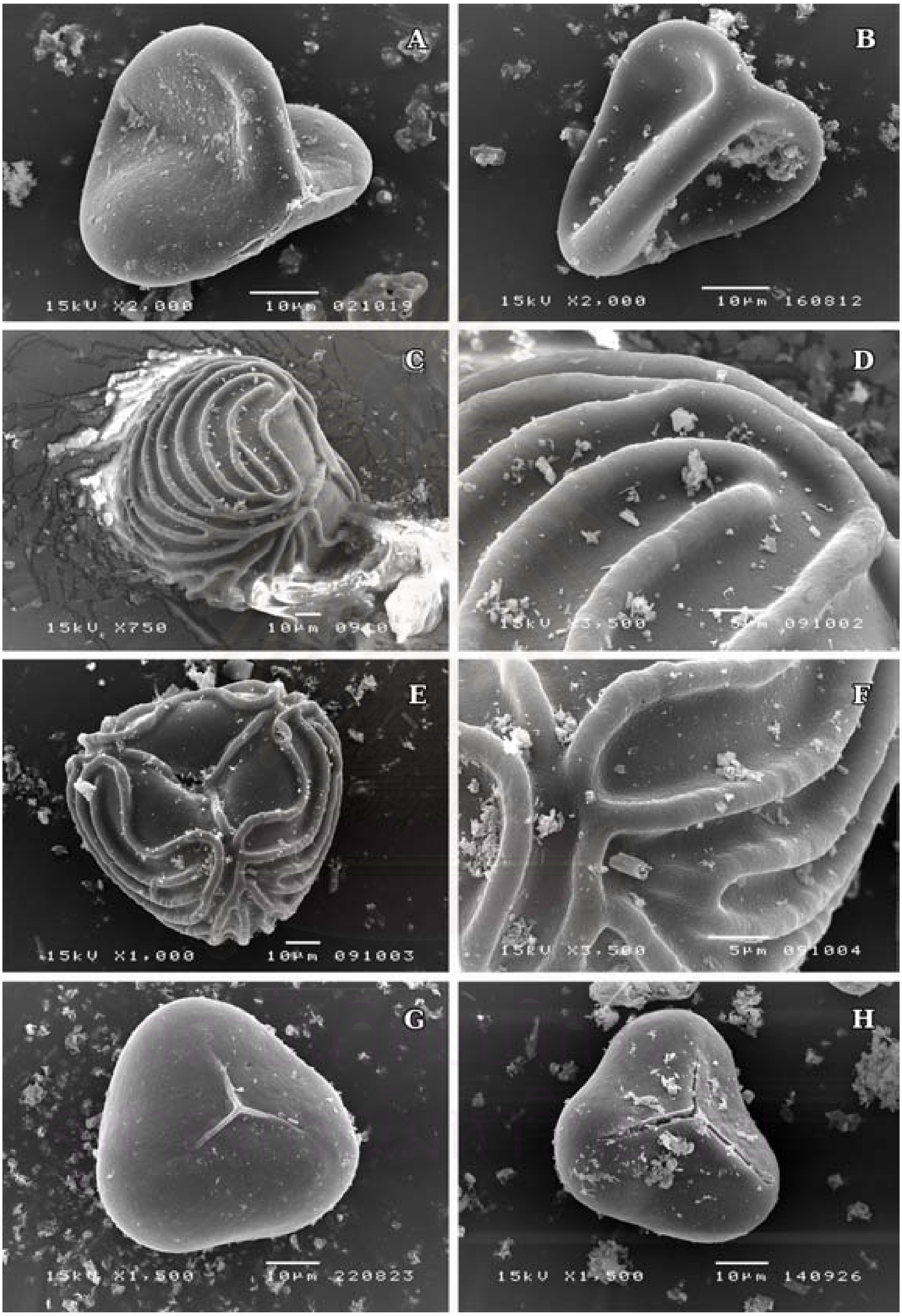

Plate 18 SEM micrographs: A-B **Gleicheniaceae type** (A) Proximal view, (B) Lateral view; C-F. ***Ceratopteris* type** (C) Lateral view, (D- F) Striate sculpture, (E) Proximal view; G-H **cf. *Acrostichum* type**, proximal view.

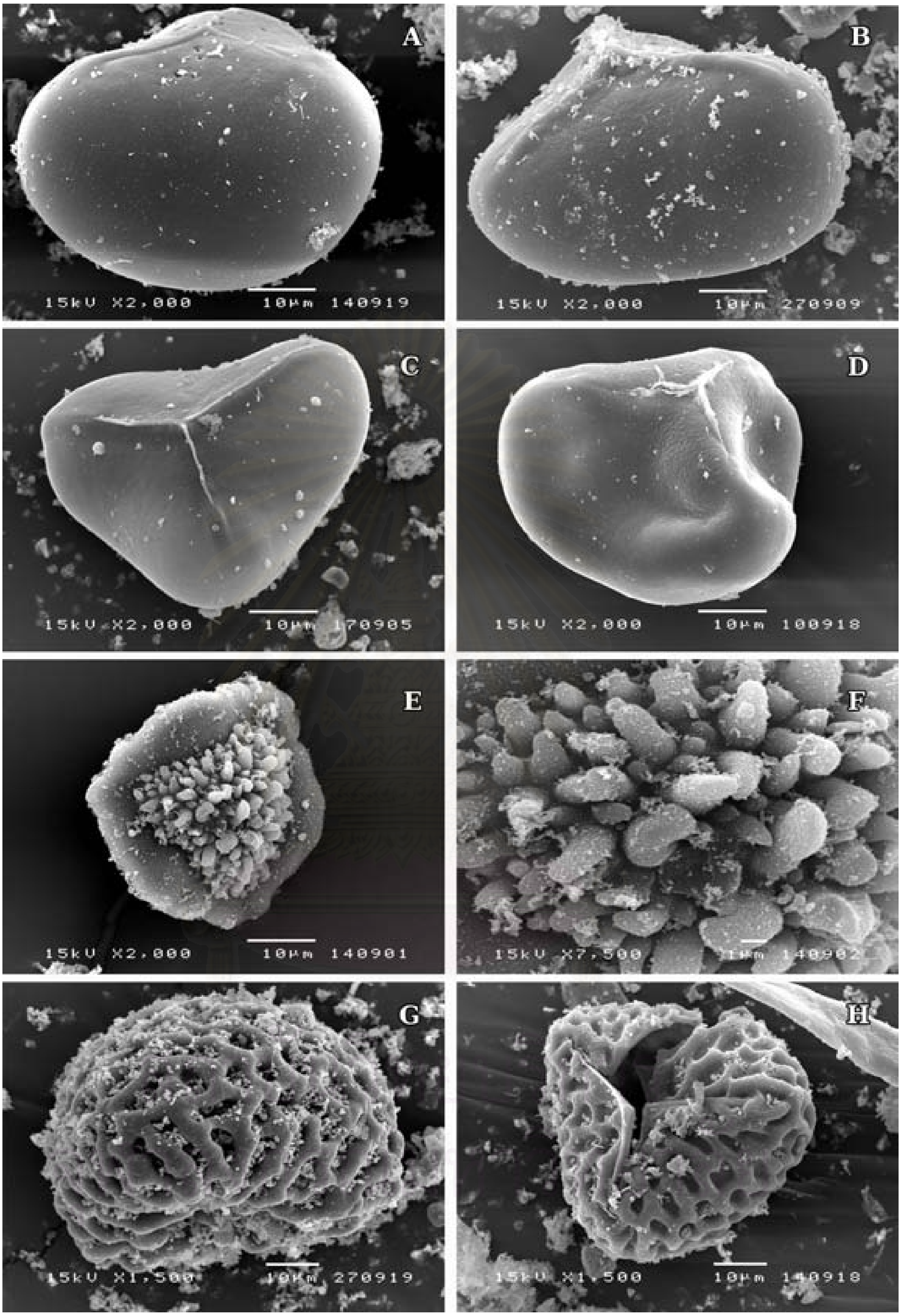

Plate 19 SEM micrographs: A-D **cf. *Acrostichum* type** (A-B) Lateral view, (C-D) Proximal view; E-F ***Pteris* type A** (E) Proximal view, (F) Tuberculate sculpture; G-H ***Lygodium microphyllum* type** (G) Lateral view, (H) Proximal view.

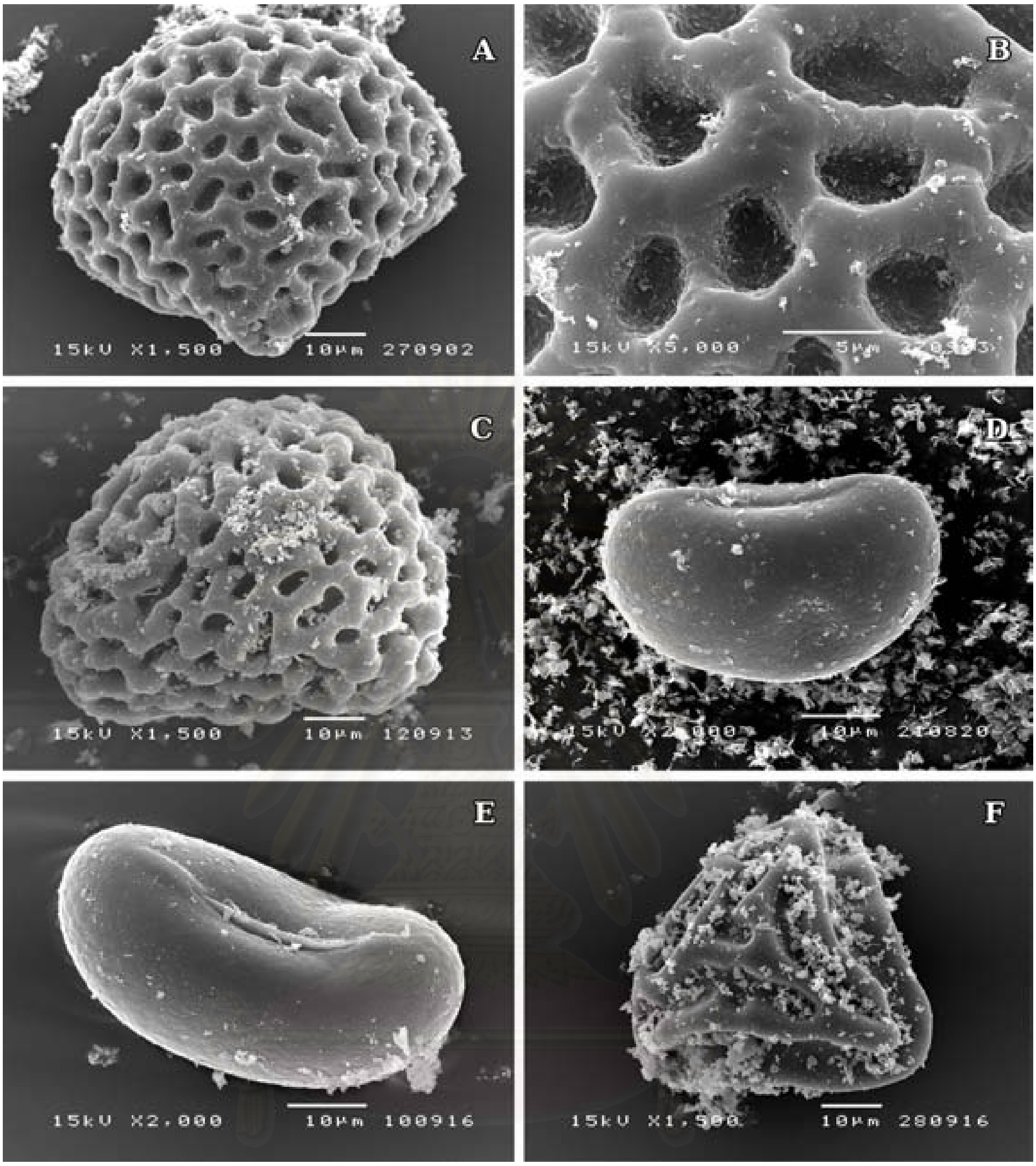

Plate 20 SEM micrographs: A-C ***Lygodium microphyllum* type** (A) Proximal view, (B) Reticulate sculpture, (C) Lateral view; D-E **Monolete type A**, (D) Lateral view, (E) Proximal view; F **Trilete** type, proximal view.

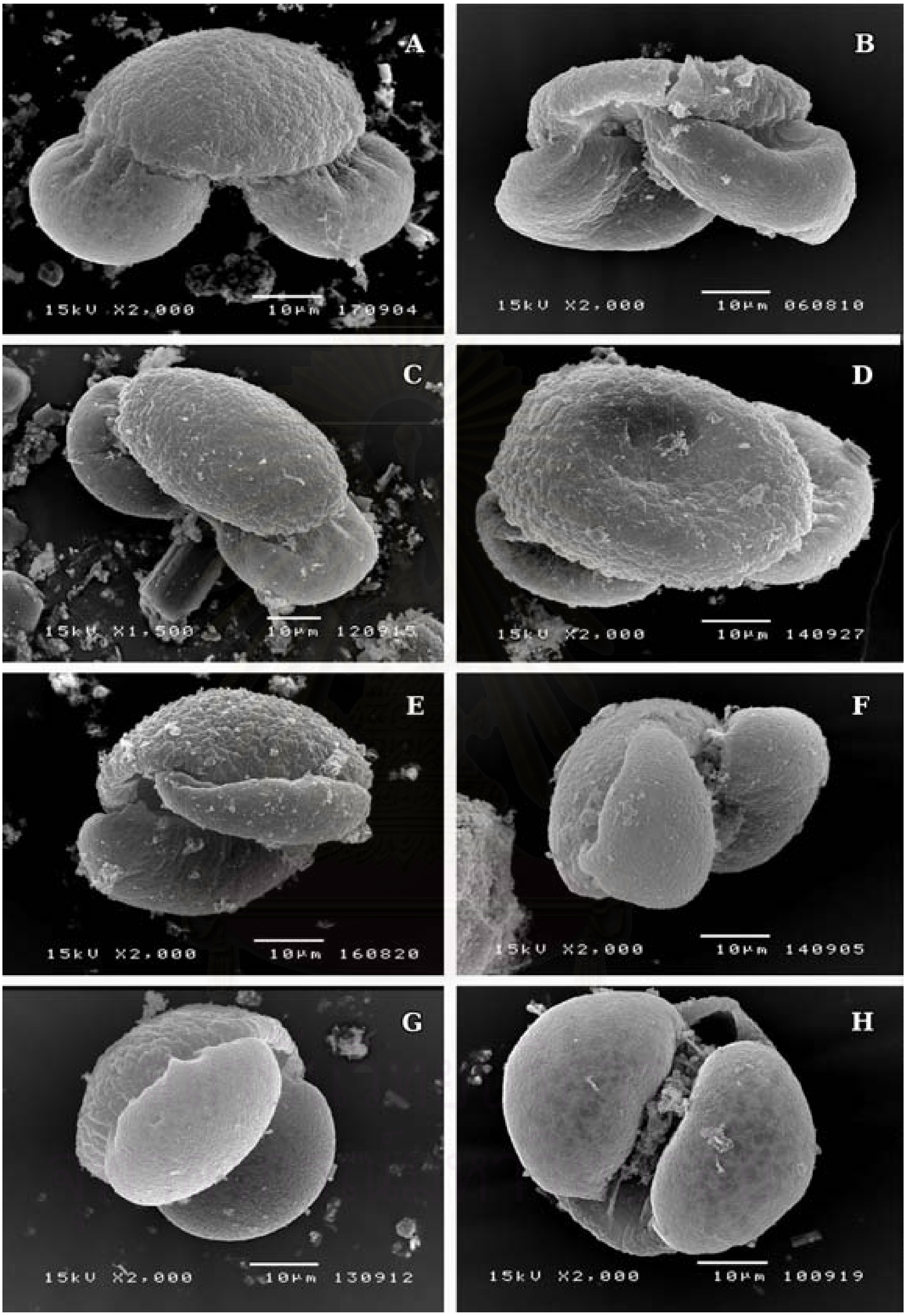

Plate 21 SEM micrographs: A-H ***Pinus* type A type** (A-B) Lateral longitudinal view, (C-D) Proximal view, (E-G) Oblique distal view (H) Distal view.

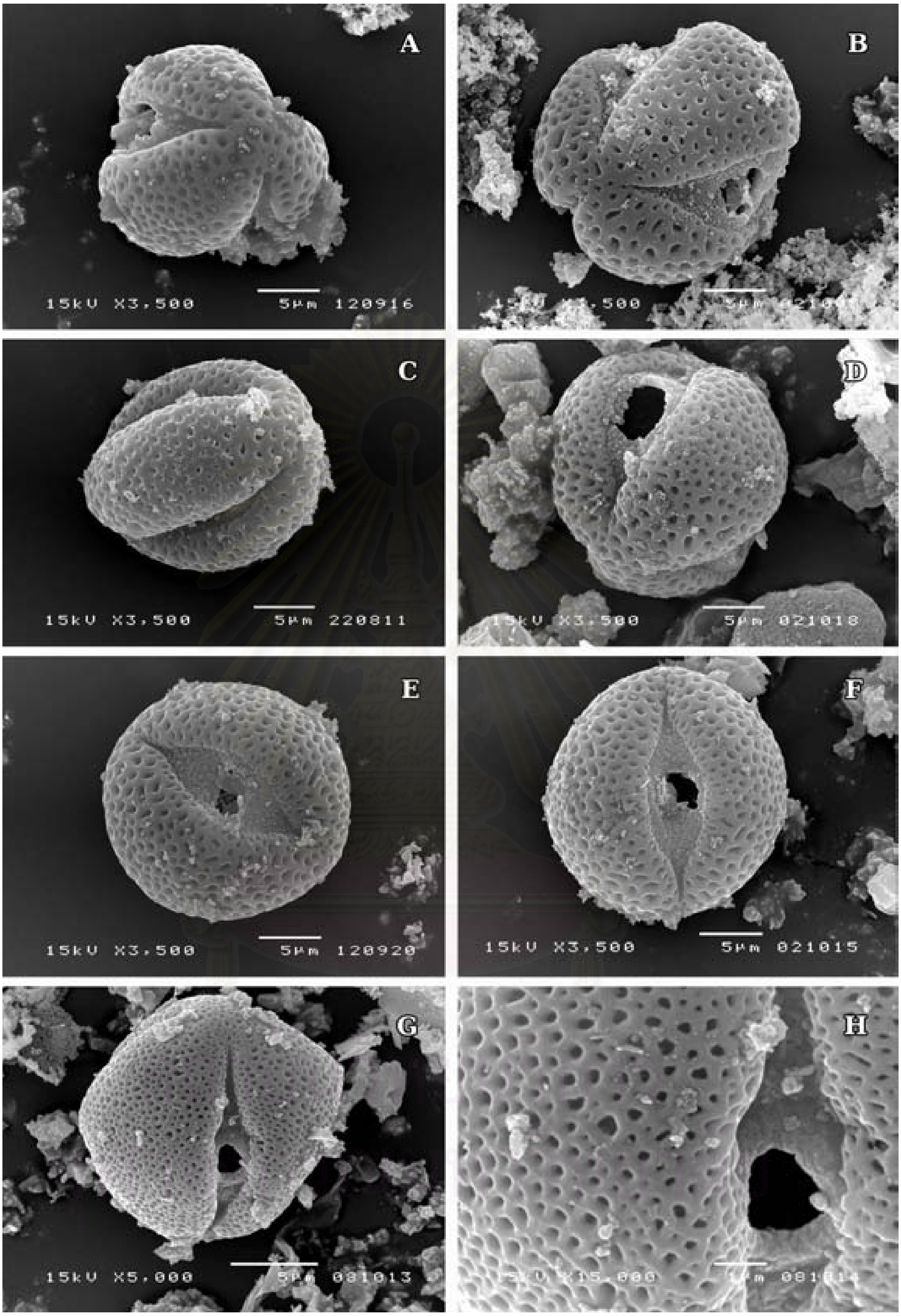

Plate 22 SEM micrographs: A-H ***Avicennia* type** (A-D) Oblique polar view, (E-F) Equatorial view, (H) Aperture and microreticulate sculpture.

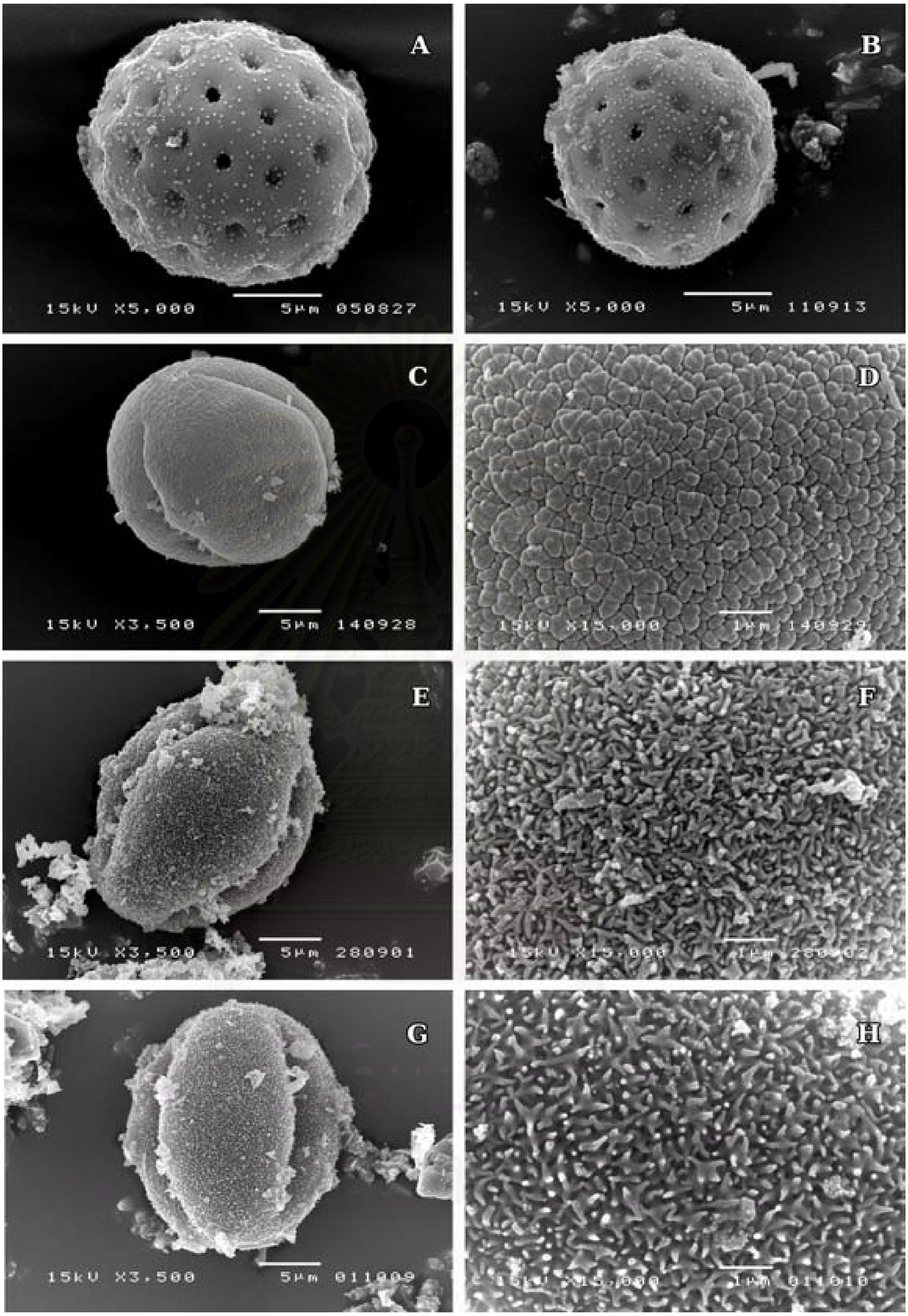

Plate 23 SEM micrographs: A-B ***Suaeda maritima* type**, pollen grain; C-D **Dipterocarpaceae type** (C) Oblique polar view, (D) Fossulate sculpture; E-F ***Quercus* type** (E, G) Equatorial view, (D, H) Microrugulate sculpture.

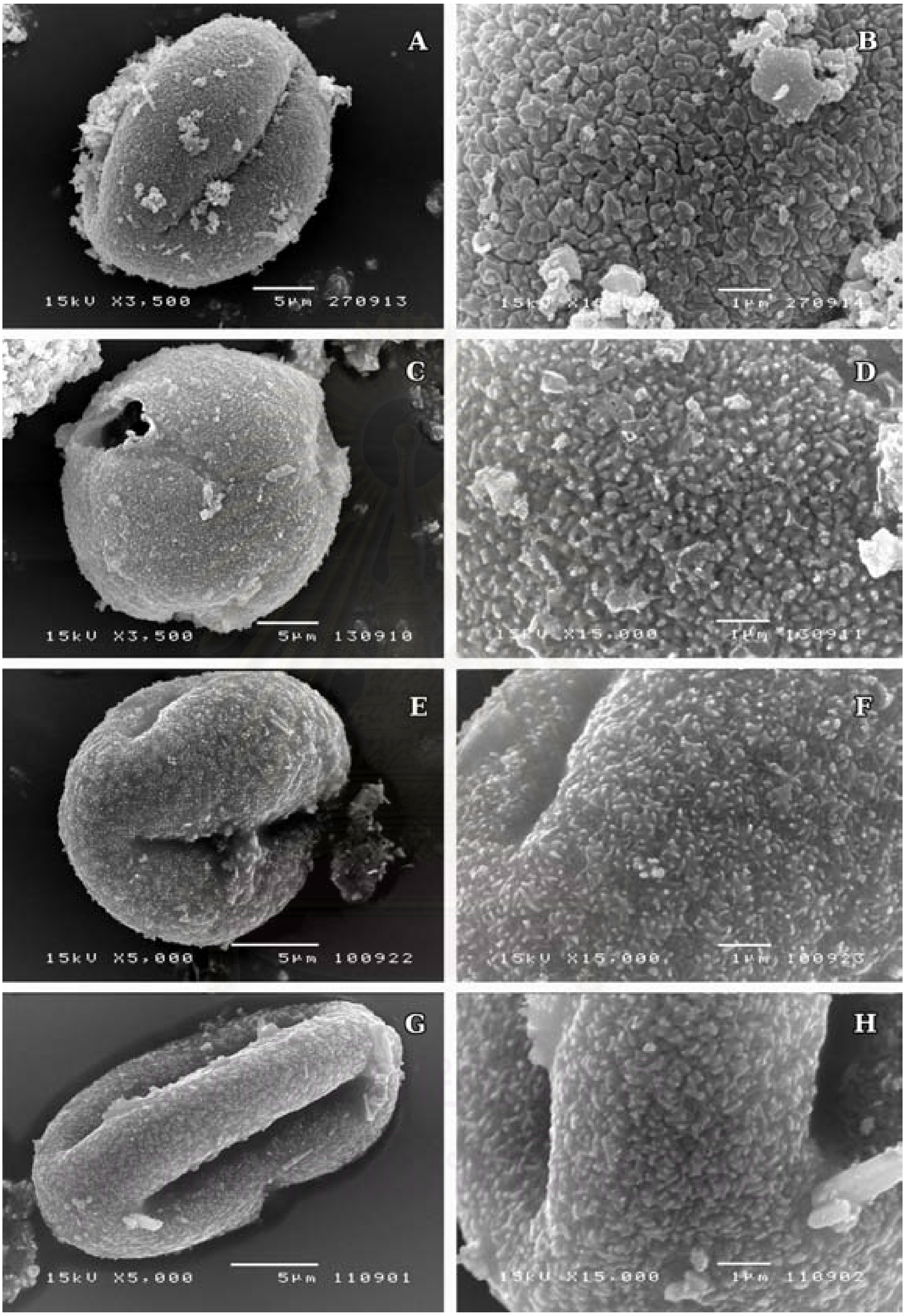

Plate 24 SEM micrographs: A-H ***Quercus* type** (A, E, G) Equatorial view, (B, D, F, H) Microrugulate sculpture, (C) Oblique polar view.

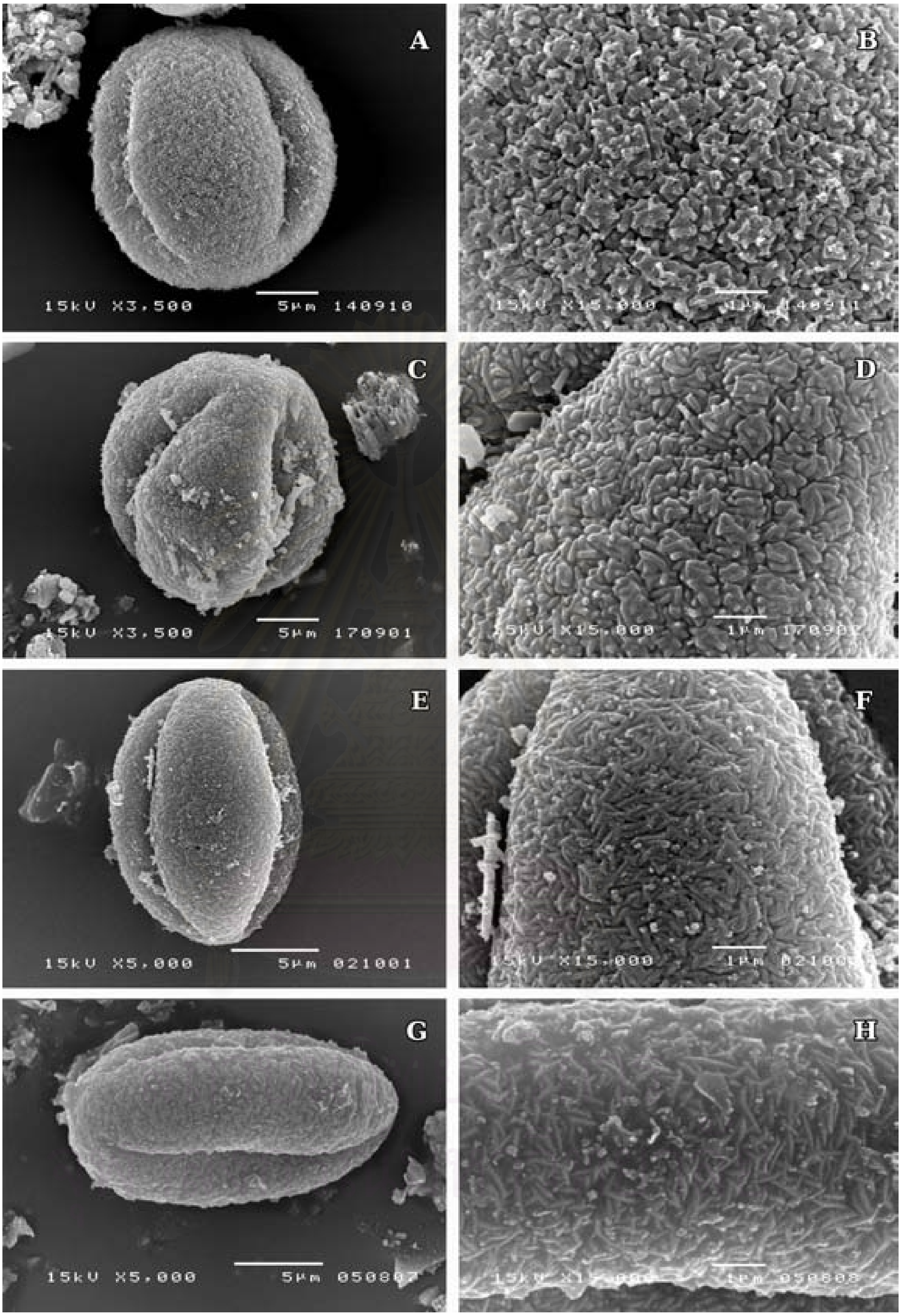

Plate 25 SEM micrographs: A-D ***Quercus* type** (A, C) Equatorial view, (B, D) Microregulate sculpture; E-H **Fagaceae type** (E, G) Equatorial view, (F, H) Microregulate sculpture.

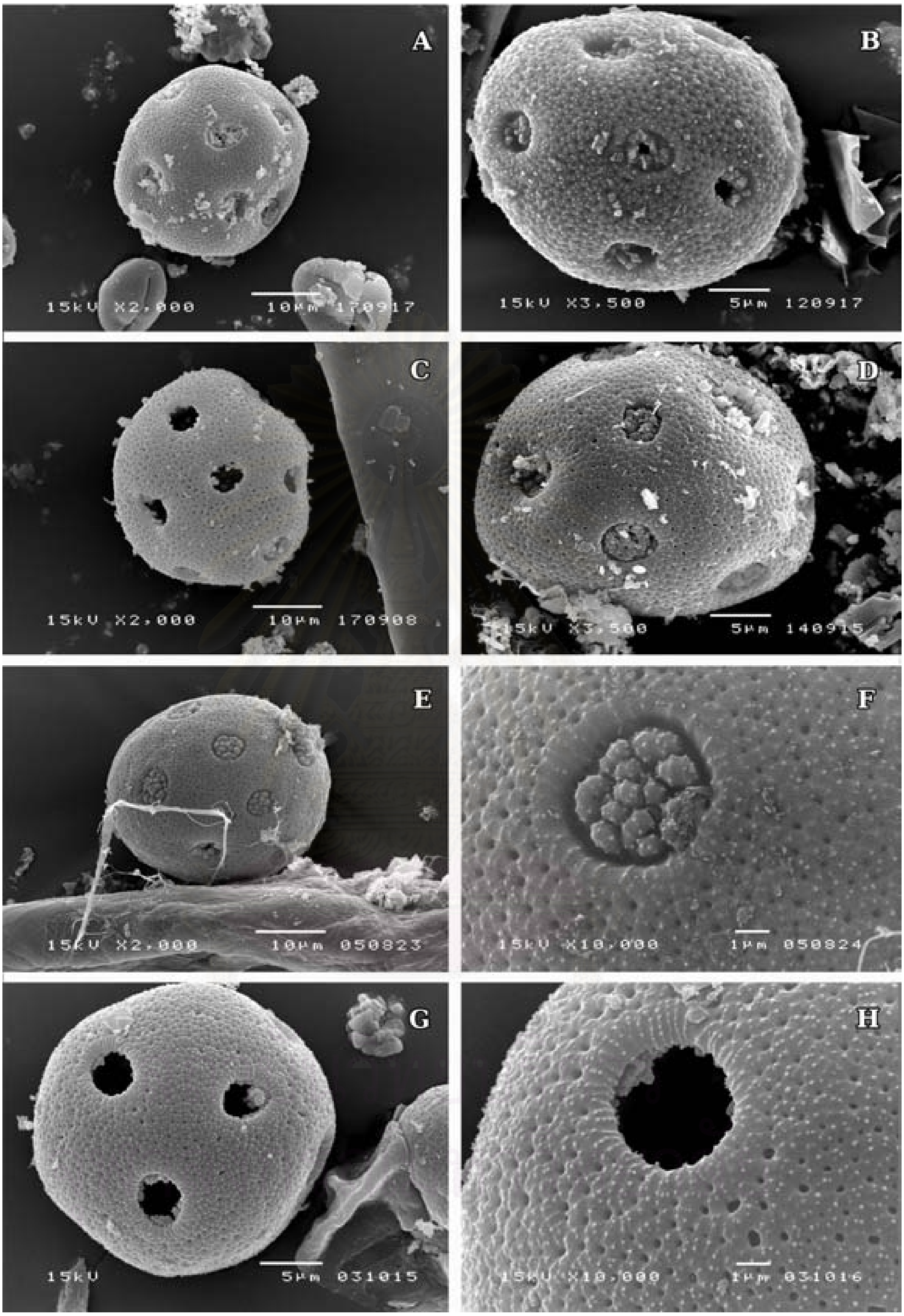

Plate 26 SEM micrographs: A-H ***Altingia* type** (A-D, E, G) Pollen grain, (F, H) Pori annulate and microreticulate sculpture.

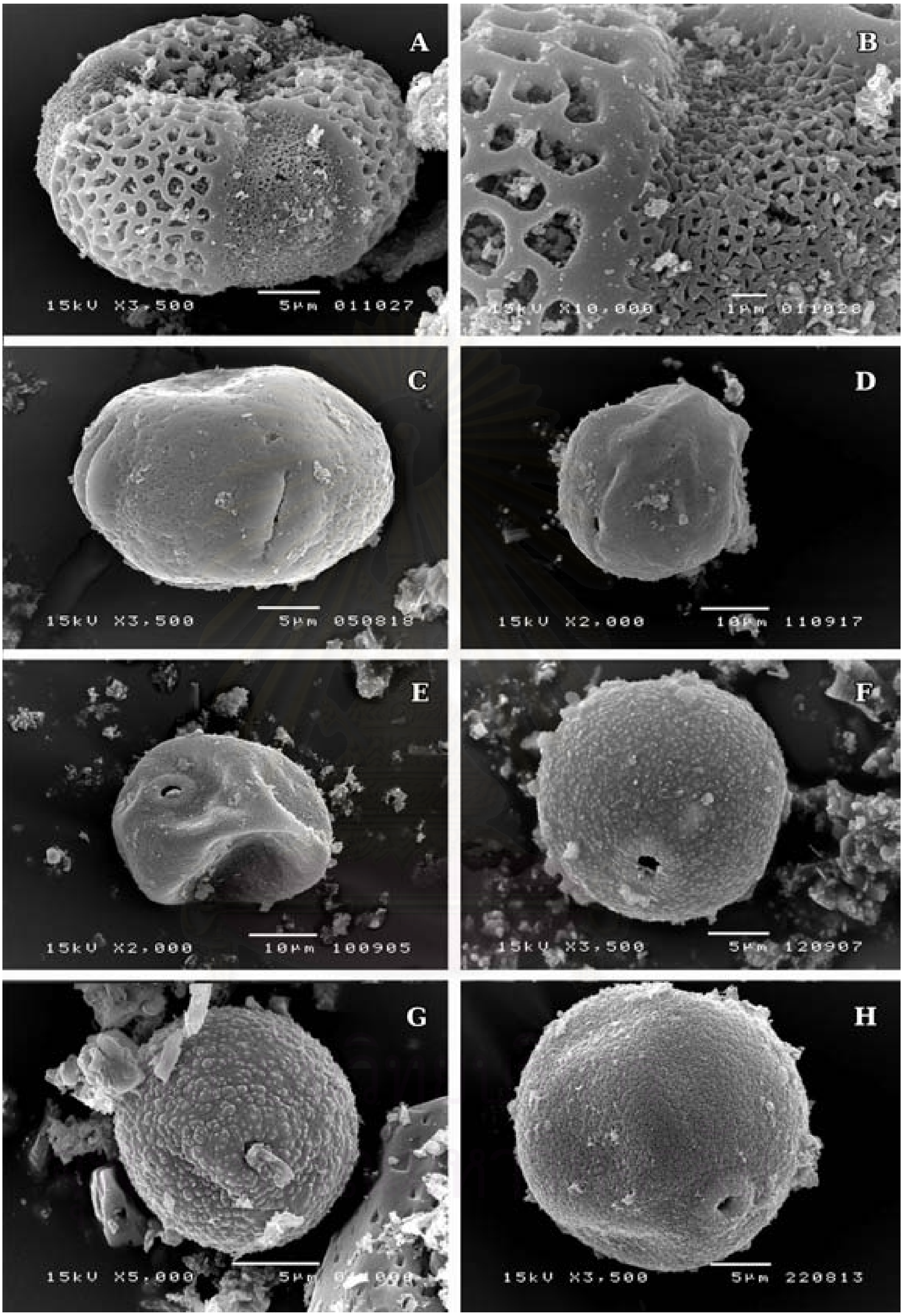

Plate 27 SEM micrographs: A-B ***Caesalpinia* type** (A) Equatorial view, (B) Reticulate sculpture; C-D ***Xylocarpus* type** (C-D) Equatorial view; E-H **Poaceae type**, pollen grain.

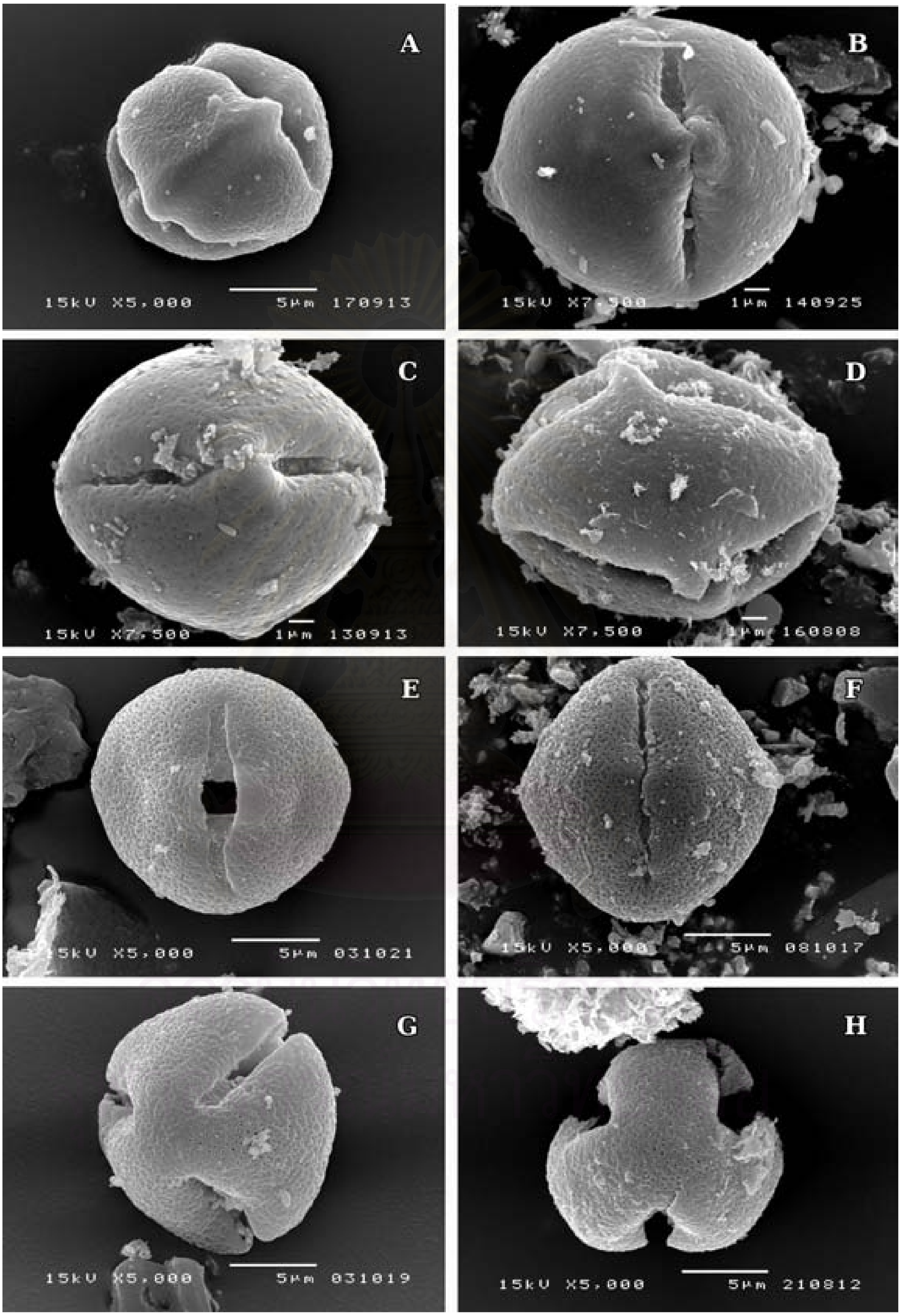

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Plate 28 SEM micrographs: A-D ***Bruguiera* type**, equatorial view; E-H ***Rhizophora* type** (E-F) Equatorial view, (G-H) Polar view.

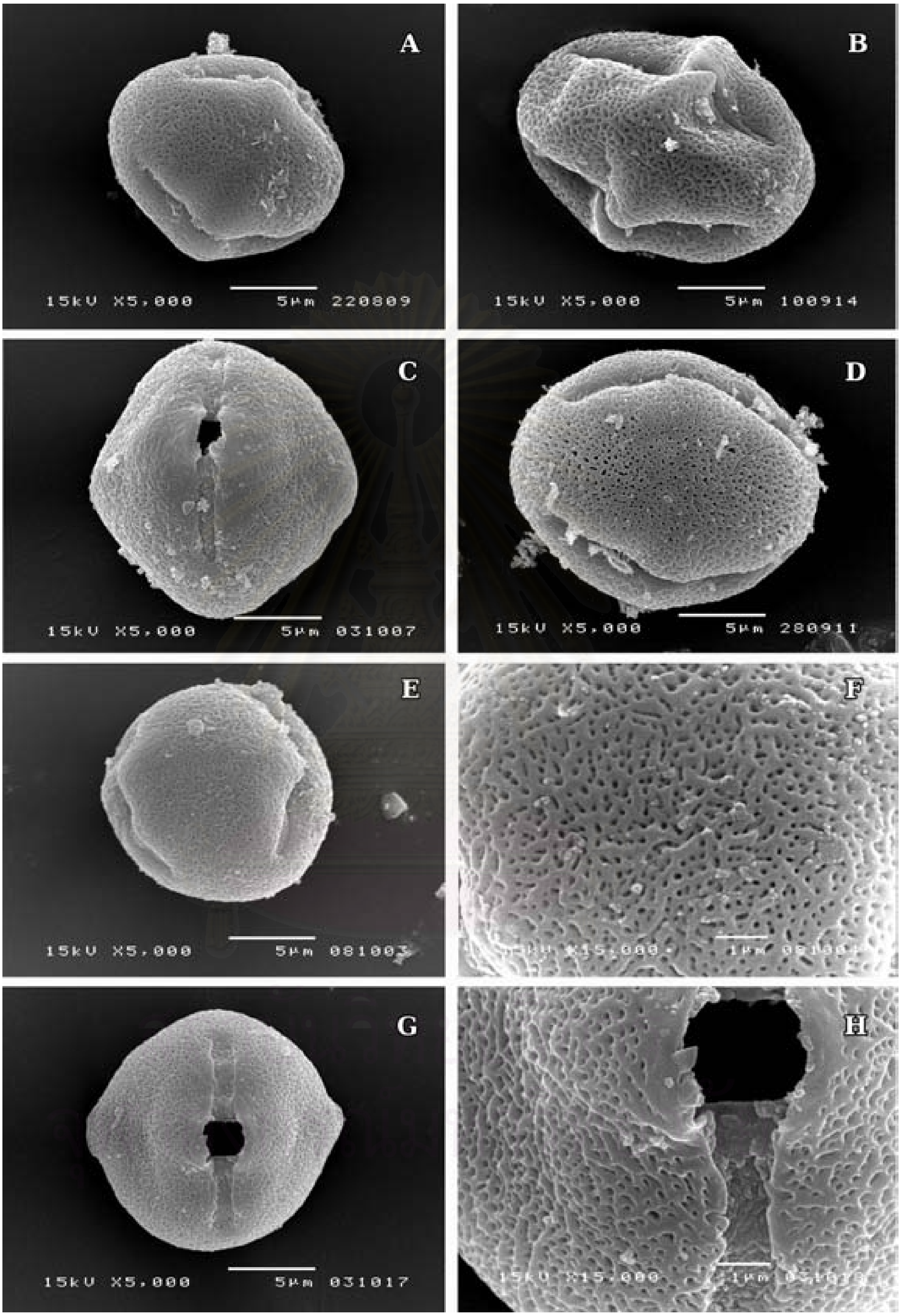

Plate 29 SEM micrographs: A-H ***Rhizophora* type** (A-E, G) Equatorail view, (F,H) Microreticute sculpture.

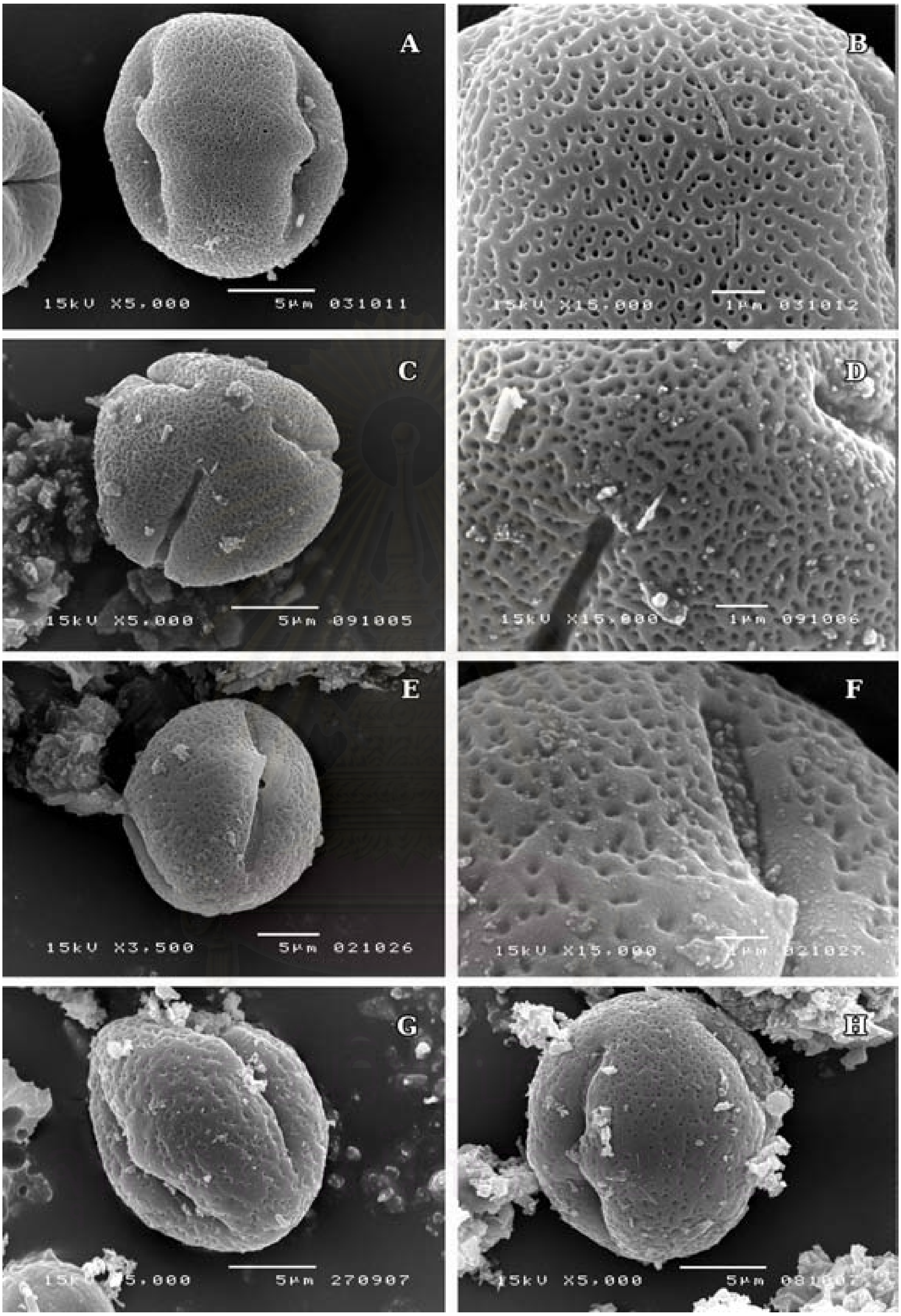

Plate 30 SEM micrographs: A-H ***Rhizophora*** **type** (A, E, G, H) Equatorial view, (C) Polar view, (B, D) Microreticulate sculpture, (F) Perforate sculpture.

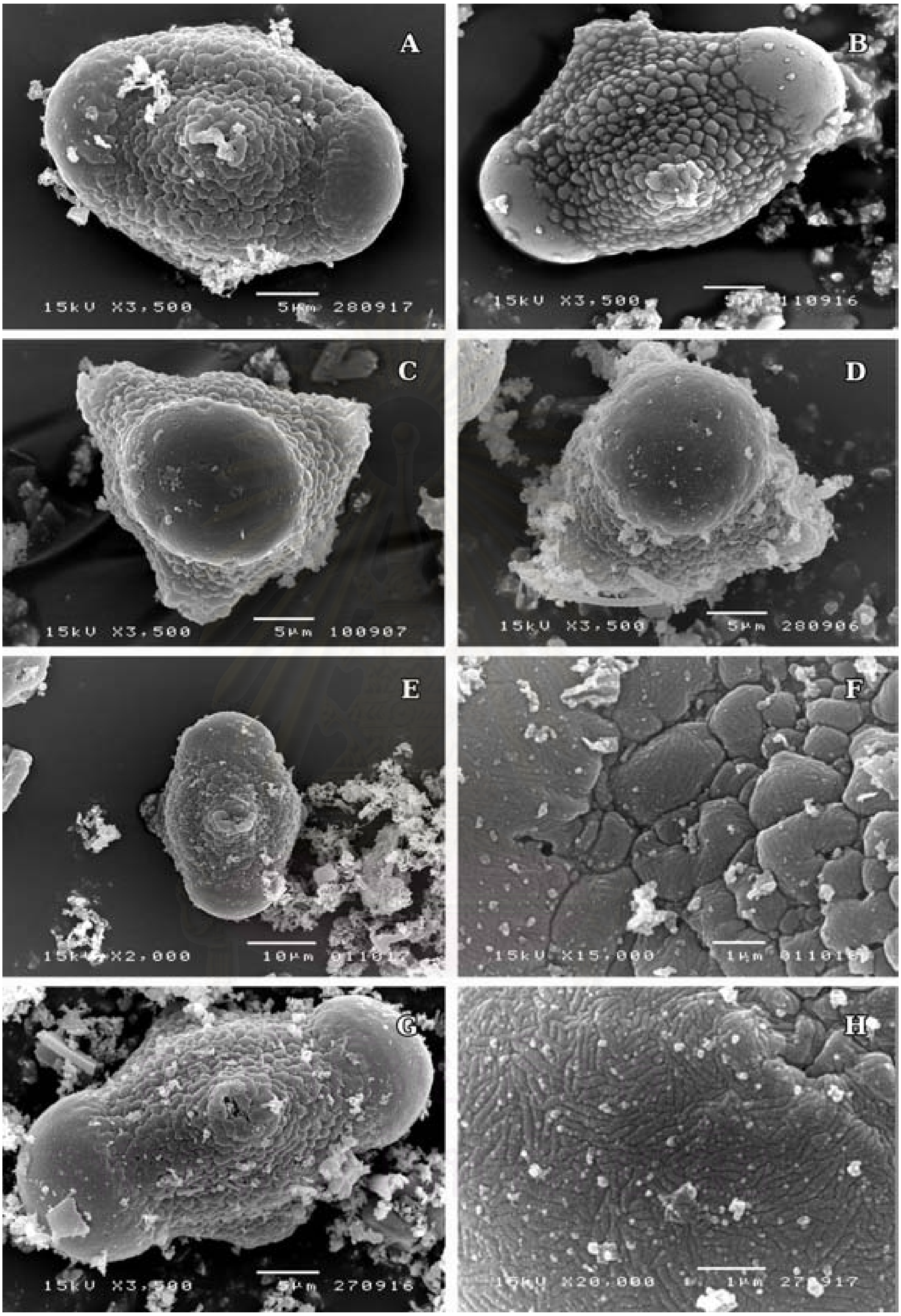

Plate 31 SEM micrographs: A-H ***Sonneratia*** **type A** (A, B, E, G) Equatorial view, (C-D) Polar view, (F, H) Verrucato-rugulate sculpture.

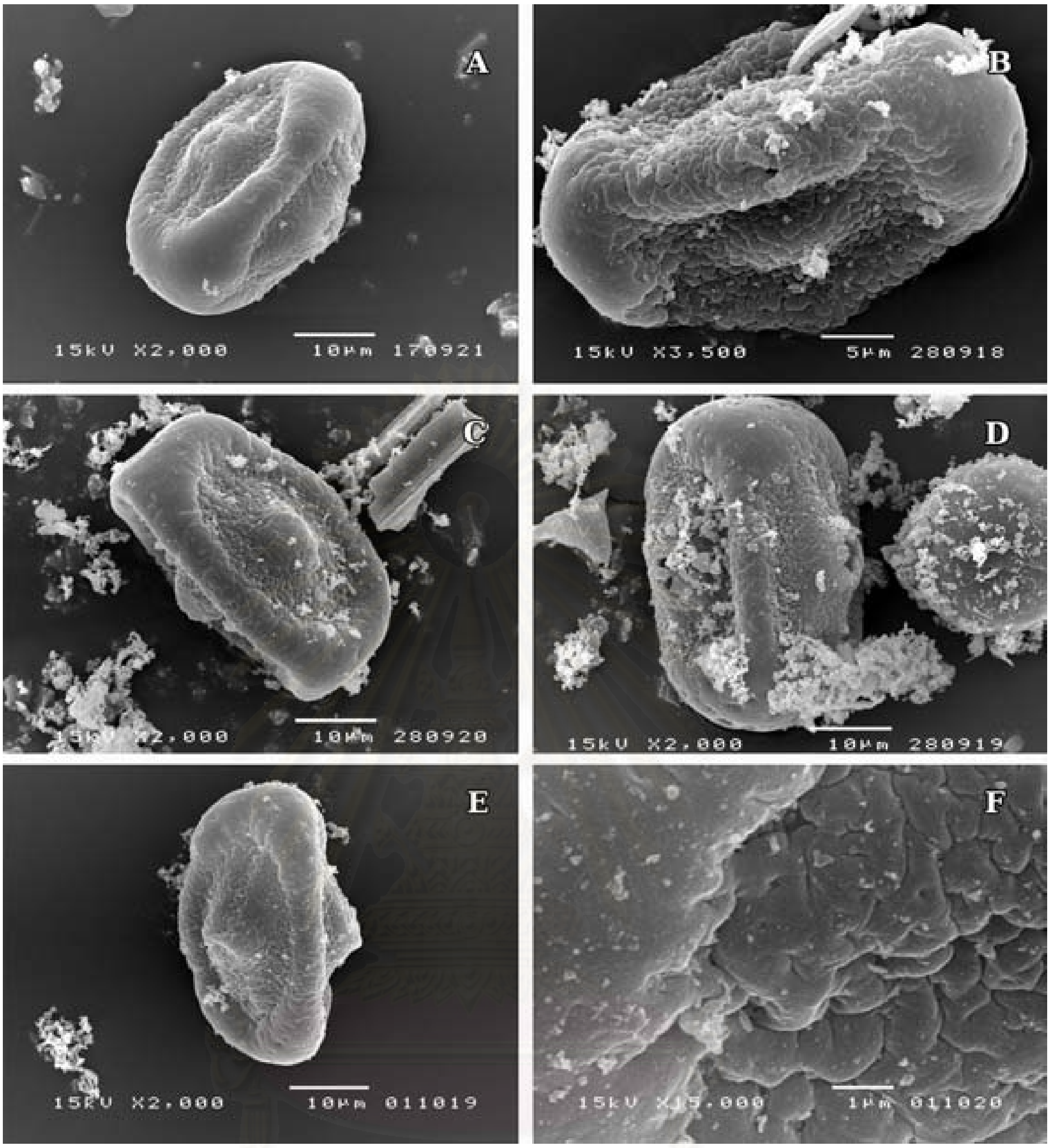

Plate 32 SEM micrographs: A-F ***Sonneratia* type B** (A-D) Equatorial view, (F) Verrucate sculpture.

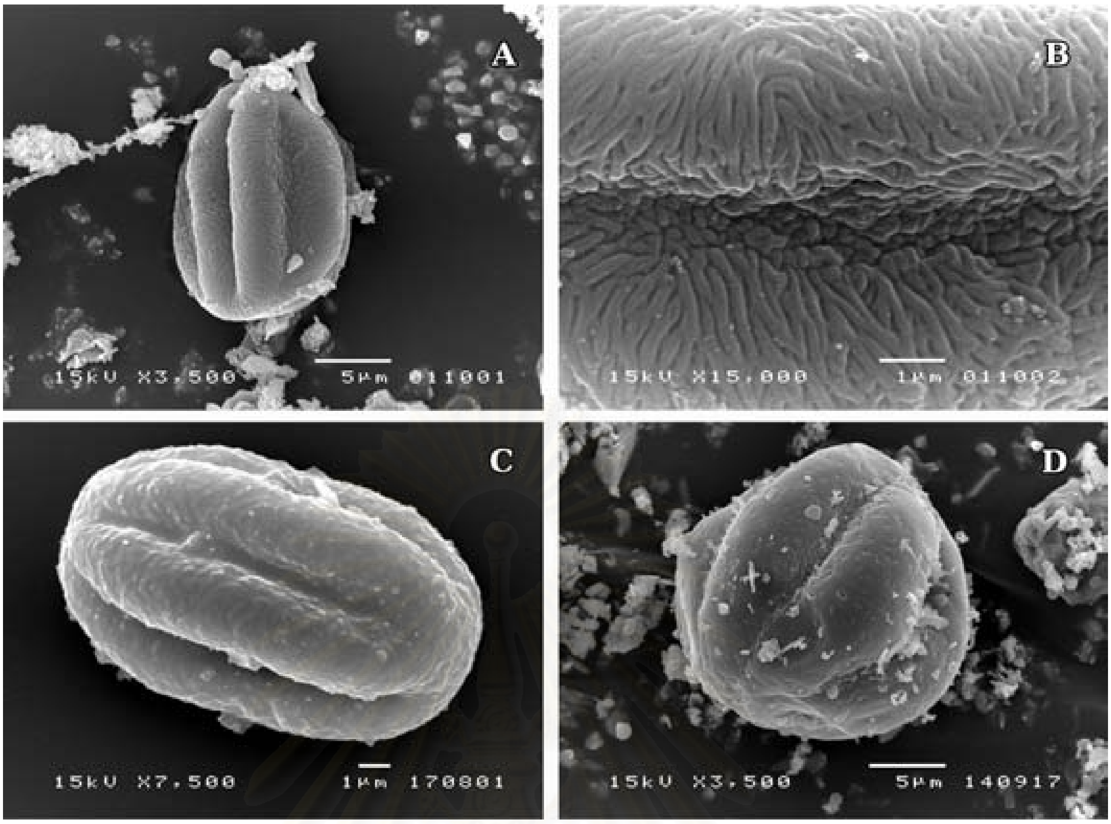

Plate 33 SEM micrographs: A-B **Tricolpolate type F** (A) Equatorial view, (B) Rugulate sculpture; C **Tricolpolate type** G, equatorial view**;** D **Tricolpolate type H**, equatorial view**.**

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Chronology and characteristics of the sediment

The biological evidences consisting of animal and plant remains were found in the sediment unit E or Bangkok clay layer. The sample at the lowermost dated layer was found to be 7,620 ± 360 years BP, and the uppermost dated layer was 5,050 ± 290 years BP which belonged to the Holocene epoch. Unfortunately, no chronological dating was given to any sediment units A to D (samples below 7.302 meters under the mean sea level) and sediment unit F (above 0.303 meters above the mean sea level) due to lack of any biological remains. Nonetheless, based on sedimentary characteristics and its stratigraphic position, it was possibly estimated that sediments A to D equivalent to the Late Pleistocene while the sediment unit F was estimated to late Holocene (Sinsakul, 1992, 2000; Songtham *et al.*, 2007). Presence or absence of biological remains in the sediment units may be correlated more or less to the geological phenomena which were influenced by the sea level history.

According to Heaney (1991), Maxwell (2001) and White *et al.* (2004), the sea level fell approximately 100 m and the shoreline was far away from the present coast during the Late Pleistocene. The entire Gulf of Thailand was dry and formed part of Sundaland with a major river, Siam river system, flowing out of the Chao Phraya Valley into a large embayment in the north of Borneo, where is now the South China Sea (Voris, 2000). This suggests that the old rivers occurred with the high energy deposition. The physical transportation of pollen in their alluvial sediments often leads to mechanical or chemical damages. The oxidation and microbial degradation are also likely to have led to further pollen deterioration (Moore *et al.*, 1991). Accordingly, the Late Pleistocene sediment was interpreted as alluvial deposit following channel migration and erosion of the land surface during the Late Pleistocene regression (Sinsakul, 1992, 2000; Tanabe *et al.*, 2003), thus creating oxidizing environment. Evidence for such oxidizing condition can be seen in the sediment units A-D (stiff clay) are yellow, orange and maroon in coloration. It should be noted that there may be vegetation occurring around this area during Late Pleistocene regression but the absence of pollen and spore including other remains might be due to such oxidizing condition that prevented the preservation of any biological remains.

The radiocarbon ages of the carbonized woods and marine mollusk shells found in the Bangkok clay layer belong to the Holocene epoch. This zone contains abundant mangrove pollen. These animal and plant remains indicated that during 7,600 and 5,000 years BP period of time the area was marine habitat. In Thailand, the Holocene transgression began between 9,000 and 8,000 years BP as inferred from mangrove peat (Sinsakul, 1992). From 7,600 to 7,000 years BP is then referred to the beginning of the marine invasion, abundant peat was accumulated in littoral zone under mangrove pollen suggesting mangrove forest occupation. The area was continuously flooded by seawater as the subtidal zone at about 5,000 years BP as indicated by a mollusk shell layer (Songtham et al, 2007). According to published regional geological studies, the maximum rise of the Holocene sea level is recognized from ^{14}C dating ranging from 7,600 to 5,000 years BP. (Chonglakmani *et al.*, 1983; Somboon, 1988; Somboon and Thiramongkol 1992; Sinsakul, 1992; Songtham, 2000). Occurrence of mangrove pollen in this sediment unit is in accordance with previous studies, suggesting that Nakhon Nayok area was the paleoembayment with the intertidal flat covered by the mangrove forest during the Holocene. From then on, there were fluctuations of the sea level. The last regression period occurred until about 1,500 years BP which the sea reached its present level (Sinsakul, 1992).

The sediment unit F at the uppermost layer is the other barren pollen zone. The characters of sediment as soft clay suggested that this layer was weathered clay and covered by a soil sequence of recent floodplain deposits that originated from Chao Phraya River and its distributaries (Haruyama, 1993; Sinsakul, 2000; Tanabe *et al.*, 2003). After the last regression, Nakhon Nayok became the low area and the mangrove forest was replaced by the fresh water swamp forest (Sinsakul, 1996) with the deposit accumulating during flood events. The absence of pollen and spore in this sediment unit may be due to flood which inhibits preservation of any organic remains.

5.2 Pollen analysis and the interpretation

5.2.1 Taxonomic identification of fossil pollen

The Holocene pollen and spores from Bangkok Clay in the Lad Chang soil pit, Ong Kharak District, Nakhon Nayok Province, Lower central plain of Thailand were from pteridophytes, gymnosperms, and angiosperms. While some of pollen and spores could be identified to the species level, most were assignable to generic or familial levels.

Pteridophyte spore types belonged to six families consisting of Blechnaceae with *Stenochlaena palustris* type, Davalliaceae with *Davallia* type, Gleicheniaceae with Gleicheniaceae type, Parkeriaceae with *Ceratopteris* type, Pteridaceae with *Acrostichum* type, *Pteris* type A and B, Schizaeaceae with *Lygodium* type, and unassignable pteridophyte spores including unknown monolete type A and B and unknown trilete type A, B, and C.

Two gymnosperm pollen types belonged to family Pinaceae represented by *Pinus* type A and B.

Angiosperm pollen types belonged to 15 families, namely, Avicenniaceae with *Avicennia* type, Cheonopodiaceae with *Suaeda maritime* type, Combretaceae with Combretaceae type, Dipterocarpaceae with Dipterocarpaceae type, Fagaceae with *Quercus* type and Fagaceae type, Hamamelidiaceae with *Altingia* type, Leguminosae with *Caesalpinia* type, Meliaceae with *Xylocarpus* type, Mimosaceae with Mimosaceae type A and B, Poaceae with Poaceae type, Rhizophoraceae with *Bruguiera* type and *Rhizophora* type, Sonneratiaceae with *Sonneratia* type A and B, Tiliaceae with *Brownlowia* type, Arecaceae with *Oncosperma* type, Cyperaceae with Cyperaceae type, and unknown tricolporate type A, B, C, D, E, F, G, and H and triporate type.

The presence of diverse pollen types from various families is the evidence for plant diversity in the area since the Holocene. The palynoflora found in this study is mostly similar to the extant mangrove flora in Thailand today.

5.2.2 Vegetational reconstruction

Presence of pollen and spores in pollen diagram retrieved from sediment unit E (Bangkok clay) at the Lad Chang soil pit, Ong Kharak District, Nakhon Nayok Province, was grouped into five pollen assemblages and an unidentifiable pollen assemblage. Of five assemblages, three were referable to three vegetations, namely mangrove, back mangrove, and lowland forest. The other two assemblages, however, provided no information on any type of vegetation; these were grass and pteridophyte assemblages.

Grass assemblage in this sense included pollen from family Poaceae and Cyperaceae, and was present in low percentages. Cyperaceae pollen were present sporadically in very low percentage and low absolute number. It was probably transported from its original place by streams, as the parent plant grows in places where surface runoff was prominent (Somboon, 1990). Poaceae pollen are quite common in the area with the low percentages. They normally occupy open areas and grow well in a dry climate (Chapman, 1998. Because grasses and Cyperaceae might appear in the landward side of mangrove associated with the back mangrove community or in the lowland forest, coupled with their pollen presence in low percentage, this pollen assemblage was not accounted in further discussion.

Pteridophyte assemblage was present by low percentages in the pollen assemblages. Among all, *Stenochlaena palustris* spores are the most dominated taxon in this group, along with a few amounts of *Ceratopteris*, *Davallia***,** Gleicheniaceae, *Lygodium*, and *Pteris*. This group of plants prefers high humidity habitats. *S. palustris* spores are present in high percentage of this group. It is common everywhere in the lowland and open areas where there is enough moisture. It is a climber which grows on mangrove trees (Holtum, 1968; Somboon, 1990), hence its spores can be shed directly into the sediments. The trends of spore deposition in *Lygodium* which is also a climber are similar to those of the *S. palustris* (Somboon, 1990). *Davallia* is common epiphytic fern which are very perfectly adapted to epiphytic condition (Holtum, 1968; Tagawa and Iwatsuki, 1985) and can stand more exposure than other epiphytes. This doubtless explains their occurrence of spores in mangrove forest. The presence of other ferns is probably related to the rich moisture of mangrove, brackish, freshwater habitats, and the lowland around the area, but they do not play a major role in the community. Also, similar to grass assemblage above, pteridophyte assemblage did not account for any type of vegetation, and it will be disregarded.

The followings are insights from pollen diagram that related to the ecosystems and environment of the study site in the particular period of time. They will be discussed in each vegetation.

Mangrove vegetation

The mangrove vegetation is present as the main group of the pollen assemblages in this study site with more than 70% of total identified pollen. This component is clearly dominated by the taxa of Rhizophoraceae with the lower percentages of *Avicennia* and *Sonneratia*, and minor amounts of *Xylocarpus.*

The *Rhizophora* trees mostly grow along the coasts and associated with soft mud under at least a daily tidal influence (Aksornkoae *et al.*, 1992) while the

Bruguiera trees prefer to habitat in less influence of inundating by spring tide. Both *Rhizophora* and *Bruguiera* are considered to be very prolific pollen-producers as wind-pollinated species (Muller, 1959; Somboon, 1990; Campo and Bengo, 2004). Their high production of pollen and small size allow them to be efficiently transported by water for longer periods and to be deposited after most of the larger pollen have settled associated with the littoral position of the mangrove ecosystem (Campo and Bengo, 2004). *Bruguiera* pollen are less dominant than *Rhizophora* pollen, probably because of the smaller number of parent plants (Somboon, 1990). This may explain why *Rhizophora* pollen is prominent in the sediments.

The *Avicennia* trees are tolerant of the wide salinity range and found as pioneer species. In addition to salinity factor, they prefer low sloping areas, so they are widely distributed in coastal regions and strand of mangrove. They are insect-pollinated species and under-represented in relation to the abundance of the source plants in the mangrove forests (Muller, 1959; Grindrod, 1985; Mildenhall and Brown, 1987; Thanikaimoni, 1987; Campo and Bengo, 2004). *Sonneratia* trees are the common colonizing element in the mangrove or are mainly found in areas of tidal creeks (Santisuk, 1992). Despite the fact that the *Sonneratia* is bat-pollinated with large-sized pollen, the pollen of this genus tends to be recorded in the areas where this genus is represented (Muller, 1987; Thanikaimoni, 1987).

Although Rhizophoraceae seemed to be the most dominant element of the mangrove assemblages, a number of their parent plants might not be abundant as many as their pollen deposit at the site because the studies on mangrove forest and recent marine sediment found that the pollen percentages always show the over-representation of Rhizophoraceae, but under-representation of *Avicennia* and *Sonneratia* compared to the actual vegetational composition (Thanikaimoni, 1987; Muller, 1959; Campo and Bengo, 2004). The presence of *Avicennia* and *Sonneratia* therefore suggests their existence in the area. It might be because the higher pollen productivity of plants of Rhizophoraceae allowed them to deposit more than the others.

The presence of these mangrove pollen types suggests marine or mangrove environment in this area at that time. The data of inundation frequencies of these mangrove plant species (Santisuk, 1983) support that this area used to be flooded by sea water and situated close to the shoreline. Furthermore, according to Somboon (1990) and Campo and Bengo (2004), the distribution pattern of mangrove pollen plants is likely to be deposited of proximity to their parent plants and thus reflect the actual vegetation.

Back mangrove vegetation

The back mangrove is represented by low percentage of *Acrostichum*, *Oncosperma*, and *Suaeda maritima* and very low absolute numbers of *Brownlowia*, and Combretaceae.

Spores of *Acrostichum* were present in high percentages of the back mangrove. These ferns are common in mangrove swamp and can tolerate saline soil. They also grow sometimes near the sea in the absence of mangrove or are found in the landward side of mangrove (Holtum, 1968; Tagawa and Iwatsuki, 1985). The *Acrostichum* spores occur relatively close to the parent plants, though some redistribution by water within the mangrove might have taken place. Due to the large spore size or high spore productivity, *Acrostichum* spores are responsible for their proximity to the source plant (Somboon, 1990).

Oncosperma is a palm tree and has both brackish and wetland representatives and occurs inland behind the mangrove zones. *Suaeda maritima* is the only native species of the genus *Suaeda* in Thailand. It is an herb, usually growing in saline soil of back mangrove habitat (Chayamarit, 2007). The very low percentages of distribution of pollen suggest that the pollen was transported by stream or wind from the parent plant (Somboon, 1990).

The presence of back mangrove pollen suggests that there were freshwater sources in the surrounding areas forming the brackish environment or inlands behind the mangrove environment (Santisuk, 1983). These evidences can indicate local environment at that time. When the study site is inundated by seawater, the area will be occupied by mangrove, so the back mangrove pollen is relatively poorly represented compared to periods of regression.

Lowland forest vegetation

The lowland forest comprised various pollen types, but each of them was found as low percentages from the following taxa: *Altingia* (Hamamelidaceae), Fagaceae, and *Pinus* and a few grains from Dipterocarpaceae and Mimosaceae.

Pinus is always found in dry deciduous dipterocarp forest and lower montane forest (Phengklai, 1970). The Fagaceae trees are also the major element of the lower montane forest (Santisuk, 2007). The *Altingia* trees are usually found near stream in evergreen forest at altitude 600-800 meters (Phengklai, 2004). These taxa are representatives of lowland forest.

Pollen of *Pinus*, Fagaceae and Hamamelidaceae are conifer pollen or pollen of tropical lowland forest trees, respectively, which are wind-pollinated species (Culley *et al.*, 2002; Rizzi-Longo *et al.*, 2005). According to Somboon (1990), their presence in low percentages of lowland forest pollen suggested that they were probably transported to the site of marine deposition by wind. This suggested that the lowland forest was established in the lower central plain at that time, and these pollen might have been transported by winds into the marine environment or these groups of pollen might have been transported from the distant mainland around lower central plain. Therefore, it could be the existence of lowland forest not too far from the seashore at that time.

It is of interests in the presence of pollen belonging to *Pinus*, Dipterocapaceae and Fagaceae because it indicates type of vegetation nearby the studied site, specifically Dipteracapaceae and Fagaceae pollen. Both Dipterocapaceae and Fagaceae are stenopalynous or nearly so, it is not feasible to identify genus or genera, from recovered pollen. Therefore, deduced vegetation could not be made with certainty. Nonetheless, because mangrove and back mangrove are considered as evergreen forests (Santisuk, 2007), it is likely, though not highly confident, that the adjacent vegetation may well be continuous, inland evergreen forest. As such, pollen of Dipterocapaceae and Fagaceae may likely be yielded from lowland evergreen forest.

Alternatively, the presence of pollen from Fagaceae and Dipterocapaceae may be from plants remotely scattering along or behind mangrove, not from nearby evergreen forest. According to an available record of the floristic study of the terrestrial coastal vegetation, some species of Fagaceae, e.g. *Lithocarpus wallichianus*, and Dipterocapaceae, e.g. *Dipterocarpus chartaceus*, *Hopea odorata, Shorea roxburghii*, *Vatica harmandiana*, can distribute along the coastal area in relativey small proportion (Laongpol *et al.*, 2005), and in the past there could be more species shared this habitat. These species therefore can attribute pollen to this pollen assemblage. This implies that pollen from these two families may not represent any types of forests, i.e. whether it was evergreen forest or deciduous forest.

5.2.3 The interpretation of ecological dynamics from pollen assemblage

The most dominant taxon is the Rhizophoraceae which is a major member of the mangrove vegetation. Based on mangrove evidences, the diagram suggested that there was mangrove community in this area in the Holocene epoch about 7,620 ± 360 years BP. This indicated the marine deposition in this area at that time in accordance with Somboon (1988), Somboon and Thiramongkol (1992), Sinsakul (1992), and Intasen *et al.* (1999) which suggested that there was a marine transgression during the early Holocene. Until 7,460 ± 350 years BP, the back mangrove vegetation, grasses and pteridophytes rose while the mangrove community declined suggesting the marine regression.

At the depth of 5.05 meters under mean sea level (at the beginning of zone LC-2a), the increase of mangrove community occurring with the highest percentage might be correlated to sea level which was consistent with the maximum peak of sea level in the lower central plain around 6,000 years BP (Somboon, 1988; Sinsakul, 1992; Songtham *et al.*, 2000). From then on, the mangrove community started to decline while the back mangrove community increased until about 5,050 years BP. This supported the regressive period after the maximum sea level which began to regress after 5,500 years BP until 4,700 years BP (Sinsakul, 1992).

After about 5,050 years BP, the mangrove community began to increase and then constantly appeared. There were a few fluctuations between the increase of mangrove community and the decrease of back mangrove community. This phenomenon supported that the sea level was generally constant, with some periods of fluctuations resulting in marine submersion and emersion (Somboon, 1988; Sinsakul, 1992).

From the depth of 1.24 meters under mean sea level to 0.30 meters above mean sea level (zone LC-2b), pollen of mangrove community started to decline while inland communities such as back mangrove, lowland forest, grasses, and pteridophytes increased. Decrease of mangrove pollen in sediment can indicate the retreating shoreline from the study site and suggests the last regression period in the Holocene (Sinsakul, 1992).

5.3 Conclusion

The results from stratigraphic positions and characteristics of the sediment indicated that Lad Chang soil pit consisted of the Late Pleistocene stiff clay, the Holocene marine clay, and the recent floodplain deposit. The first and the third strata correspond to the sediment below 7.302 meters under the mean sea level and the sediment above 0.303 meters above the mean sea level, respectively. Both contain no animal and plant remains. However, biological remains were found only in Holocene marine clay, known as Bangkok clay, corresponding to the sediment between 7.302 meters under the mean sea level and 0.303 meters above the mean sea level. These were dated, in ascending order of stratigraphic position, to be 7,620 ± 360 years BP, 7,460 ± 350 years BP, 7,050 ± 350 years BP, and 5,050 ± 290 years BP.

Pollen and spores retrieved from Bangkok clay were identified to 43 pollen types belonged to 6 families of pteridophytes, 1 family of gymnosperm, and 15 families of angiosperm. The dominant pollen with very high percentages (more than 60%) are from *Rhizophora* pollen. The pollen with moderate percentages between 5 and 22% are from pollen of *Bruguiera*, and spores of *Acrostichum* and *Stenochlaena palustris*. The pollen with low percentages between 1 and 4% are from pollen of *Avicennia, Sonneratia,* Fagaceae, Poaceae, and unidentifiable pollen. The pollen with very low percentages (less than 1%) are from pollen of *Altingia, Brownlowia*, Combretaceae, Dipterocarpaceae, Mimosaceae, *Oncosperma*, *Pinus*, *Suaeda maritime*, *Xylocarpus* and spores of *Ceratopteris*, *Davallia***,** Gleicheniaceae, *Lygodium*, *Pteris*, monolete fern, and trilete fern.

With no consideration of unidentifiable pollen assemblage, the pollen diagram suggested three plant communities based on the classification of modern vegetation as mangrove, back mangrove, and lowland forest and two pollen assemblages consisted of grass and pteridophytes. The most dominant taxon is the Rhizophoraceae which is a major member of the mangrove vegetation. This suggested that there was mangrove community in this area during the Holocene epoch.

It is noteworthy that the pollen assemblages in mangrove and back mangrove showed different direction of pollen deposit overtime between these two communities, indicating that the sea level in lower central plain during the Holocene epoch was fluctuated, resulting in invading and retreating of sea water, before turning into the flood plain which was used for agriculture with paddy rice and fruits and supported densely populated areas much later on.

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APPENDICES

APPENDIX A

LIST OF POLLEN AND SPORES FROM EXTANT PLANTS

Family	Plant species	Plate number	Source/Voucher specimen (BCU)
Blechnaceae	*Stenochlaena palustris* (Burm.) Bedd.	A1, A7	T. Boonkerd 5
Pteridaceae	*Acrostichum aureum* L.	A1	Identified by and obtained from Thaweesakdi Boonkerd
Pteridaceae	*Acrostichum speciosum* Willd.	A1, A7	R. Chareerach 2
Schizaeaceae	*Lygodium microphyllum* (Cav.) R.Br.	A1, A7	U. Damsri 735
Acanthaceae	*Acanthus ebracteatus* Vahl	A2	R. Chareerach 9
Avicenniaceae	*Avicennia alba* Blume	A2, A8	Identified by and obtained from Chumpol Khunwasi
Avicenniaceae	*Avicennia marina* (Forsk.) Vierh.	A2	C. Maneeratanarungrot 1
Combretaceae	*Lumnitzera racemosa* Willd.	A2, A8	Piyapun 2
Leguminosae	*Derris trifoliata* Lour.	A3	Herb.Trip 806 (8/2)
Malvaceae	*Hibiscus tiliaceus* L.	A3, A9	P. Trisarasri 299
Malvaceae	*Thespesia populnea* (L.) Soland. ex Correa	A3	P. Trisarasri 246
Melastomaceae	*Melastoma saigonense* (Kuntze) Merr.	A3	O. Thithong 670
Meliaceae	*Xylocarpus moluccensis* M.Roem.	A3	P. Trisarasri 76

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Family	Plant species	Plate number	Source/Voucher specimen (BCU)
Rhizophoraceae	*Bruguiera cylindrica* (L.) Blume	A4, A9	P. Trisarasri 301
Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam.	A4, A9	Piyapun 4
Rhizophoraceae	*Bruguiera sexangula* (Lour.) Poir.	A4, A10	Vasu 1
Rhizophoraceae	*Ceriops decandra* (Griff.) Ding Hou	A4, A10	P. Trisarasri 292
Rhizophoraceae	*Ceriops tagal* (Perr.) C.B.Rob.	A5, A11	Herb.Trip 888 (1/4)
Rhizophoraceae	*Rhizophora apiculata* Blume	A5, A11	P. Trisarasri 244
Rhizophoraceae	*Rhizophora mucronata* Lam.	A5, A12	P. Trisarasri 286
Sonneratiaceae	*Sonneratia caseolaris* (L.) Engl.	A5, A12	U. Damsri 49
Sonneratiaceae	*Sonneratia* cf *Sonneratia ovata*	A6, A12	Identified by and obtained from Chumpol Khunwasi
Verbenaceae	*Clerodendrum inerme* (L.) Gaertn.	A6	Itsara 3
Verbenaceae	*Premna obtusifolia* R.Br.	A6	Monruthai 3
Verbenaceae	*Vitex triflora* Vahl	A6	B. Na Songkhla et. al 224

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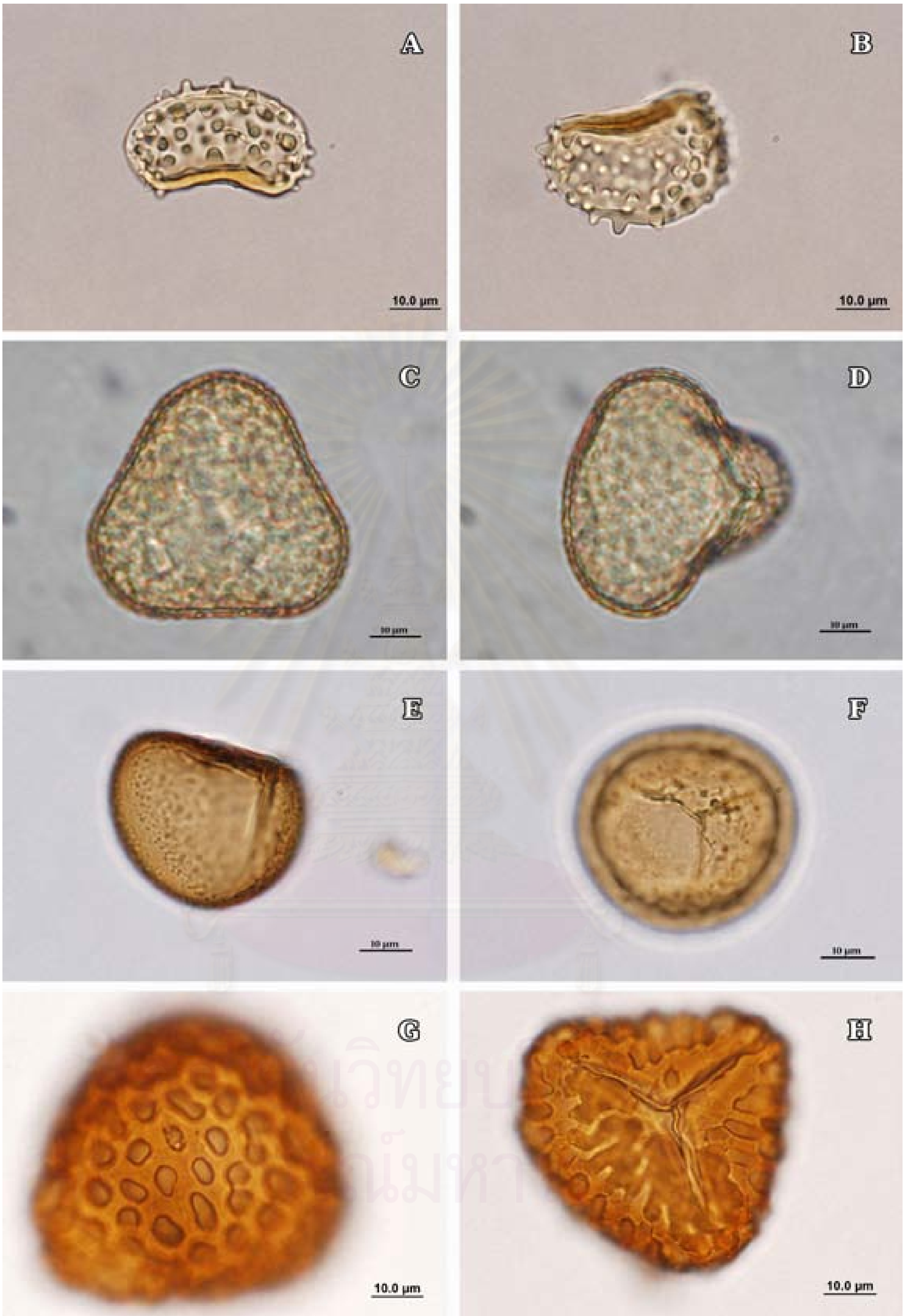


Plate A1 LM Micrographs: A-B. ***Stenochlaena palustris* (Burm.) Bedd.** (A-B) Lateral view; C-D ***Acrostichum aureum* L.** (C) Distal view, (D) Proximal view; E-H. ***Acrostichum speciosum* Willd.** (E) Lateral view, (F) Proximal view; G-H ***Lygodium microphyllum* (Cav.) R.Br.** (G) Proximal view , (H) Distal view.

Plate A2 LM micrographs: A-B ***Acanthus ebracteatus* Vahl** (A) Polar view, (B) Equatorial view; C-D ***Avicennia alba* Blume**, (C) Polar view, (D) Equatorial view; E-F ***Avicennia marina* (Forsk.) Vierh.** (E) Polar view, (F) Equatorial view; G-H ***Lumnitzera racemosa* Willd.** (G) Polar view, (H) Equatorial view.

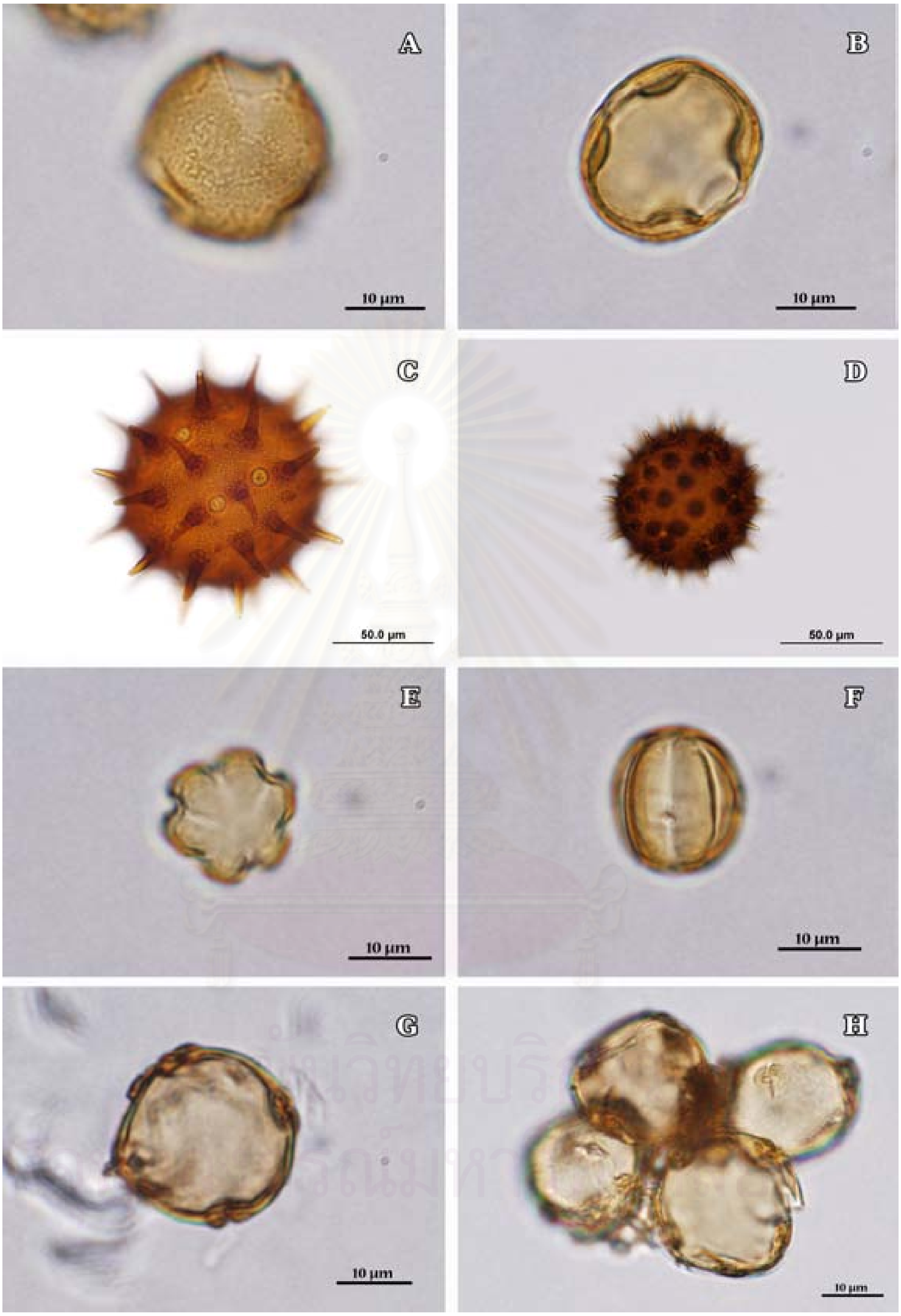


Plate A3 LM micrographs: A-B ***Derris trifoliata* Lour.** (A) Polar view, (B) Equatorial view; C ***Hibiscus tiliaceus* L**, pollen grain; D ***Thespesia populnea* (L.) Soland. ex Correa**, pollen grain; E-F ***Melastoma saigonense* (Kuntze) Merr.** (G) Polar view, (H) Equatorial view.; G-H ***Xylocarpus moluccensis* M.Roem.** (G-H) Polar view.

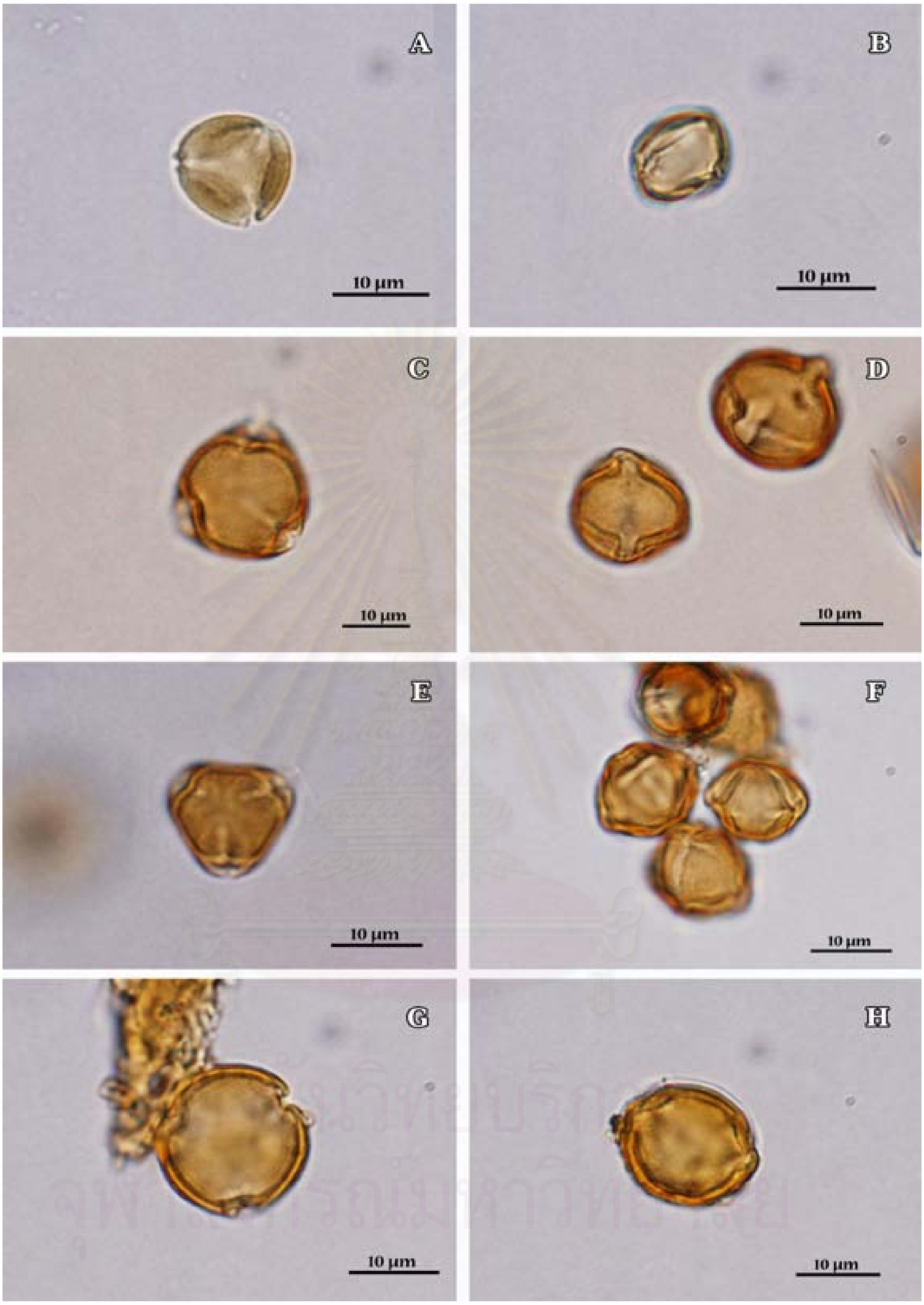


Plate A4 LM micrographs: A-B ***Bruguiera cylindrica* (L.) Blume** (A) Polar view, (B) Equatorial view; C-D ***Bruguiera gymnorhiza* (L.) Lam.** (C) Polar view, (D) Equatorial view; E-F ***Bruguiera sexangula* (Lour.) Poir.** (E) Polar view, (F) Equatorial view; G-H ***Ceriops decandra* (Griff.) Ding Hou** (G) Polar view, (H) Equatorial view.

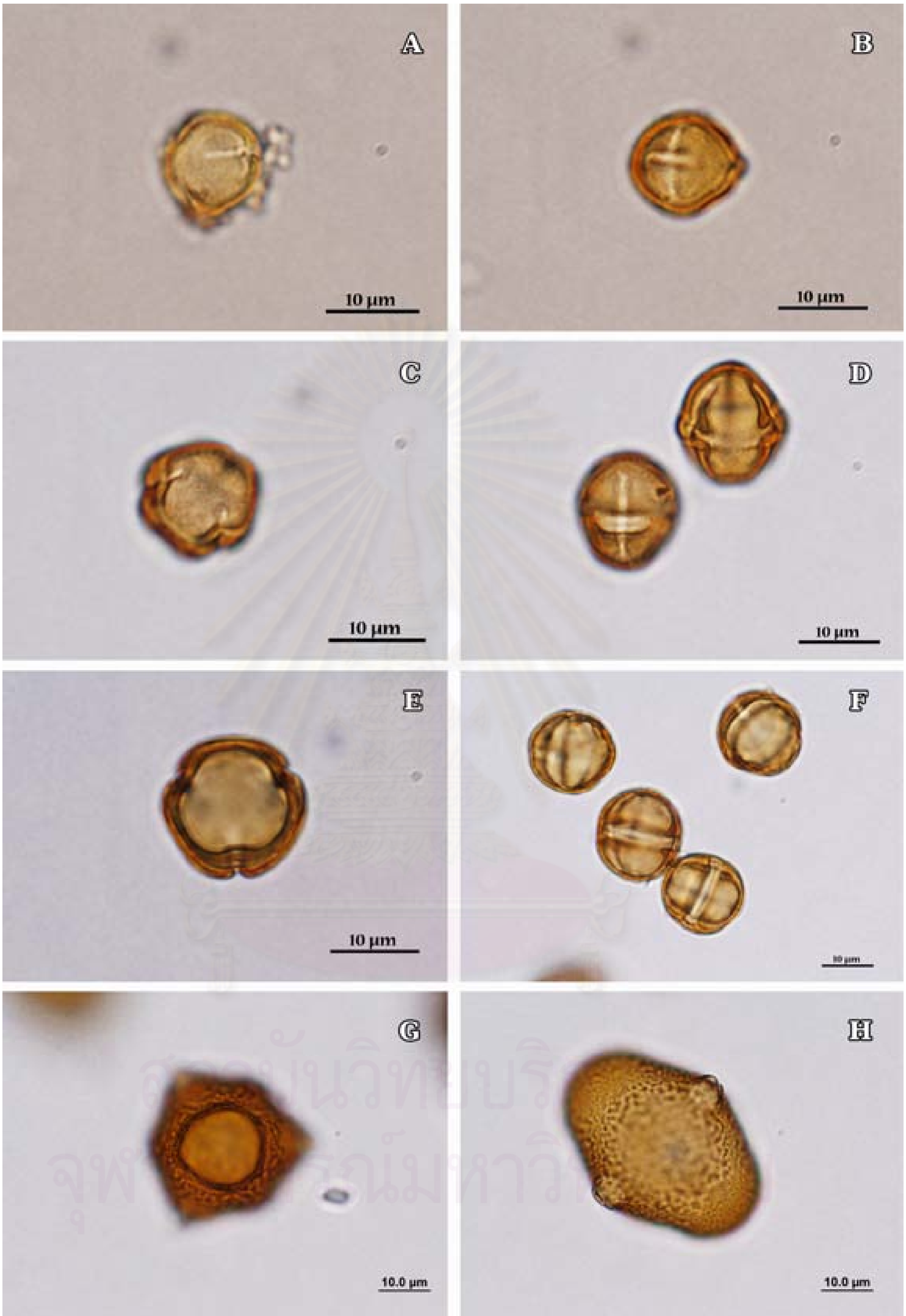


Plate A5 LM micrographs: A-B ***Ceriops tagal* (Perr.) C.B.Rob.** (A) Polar view, (B) Equatorial view; C-D ***Rhizophora apiculata* Blume** (C) Polar view, (D) Equatorial view; E-F ***Rhizophora mucronata* Lam.** (E) Polar view, (F) Equatorial view; G-H ***Sonneratia caseolaris* (L.) Engl.** (G) Polar view, (H) Equatorial view.

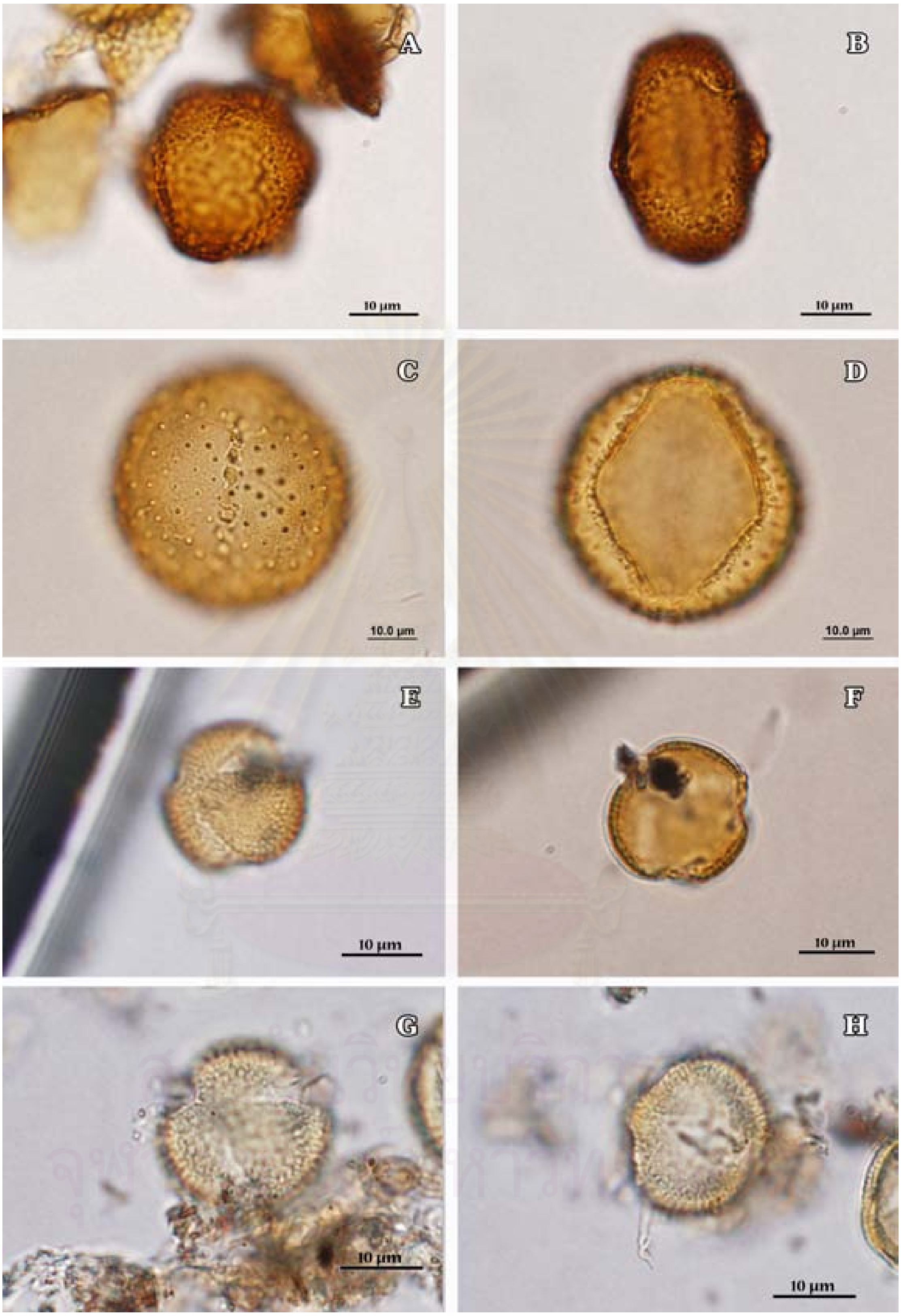


Plate A6 LM micrographs: A-B ***Sonneratia cf Sonneratia ovata*** (A) Polar view, (B) Equatorial view; C-D ***Clerodendrum inerme*** **(L.) Gaertn.** (C) Polar view, (D) Equatorial view; E-F ***Premna obtusifolia*** **R.Br.** (E) Polar view, (F) Equatorial view; G-H ***Vitex triflora*** **Vahl** (G) Polar view, (H) Equatorial view.

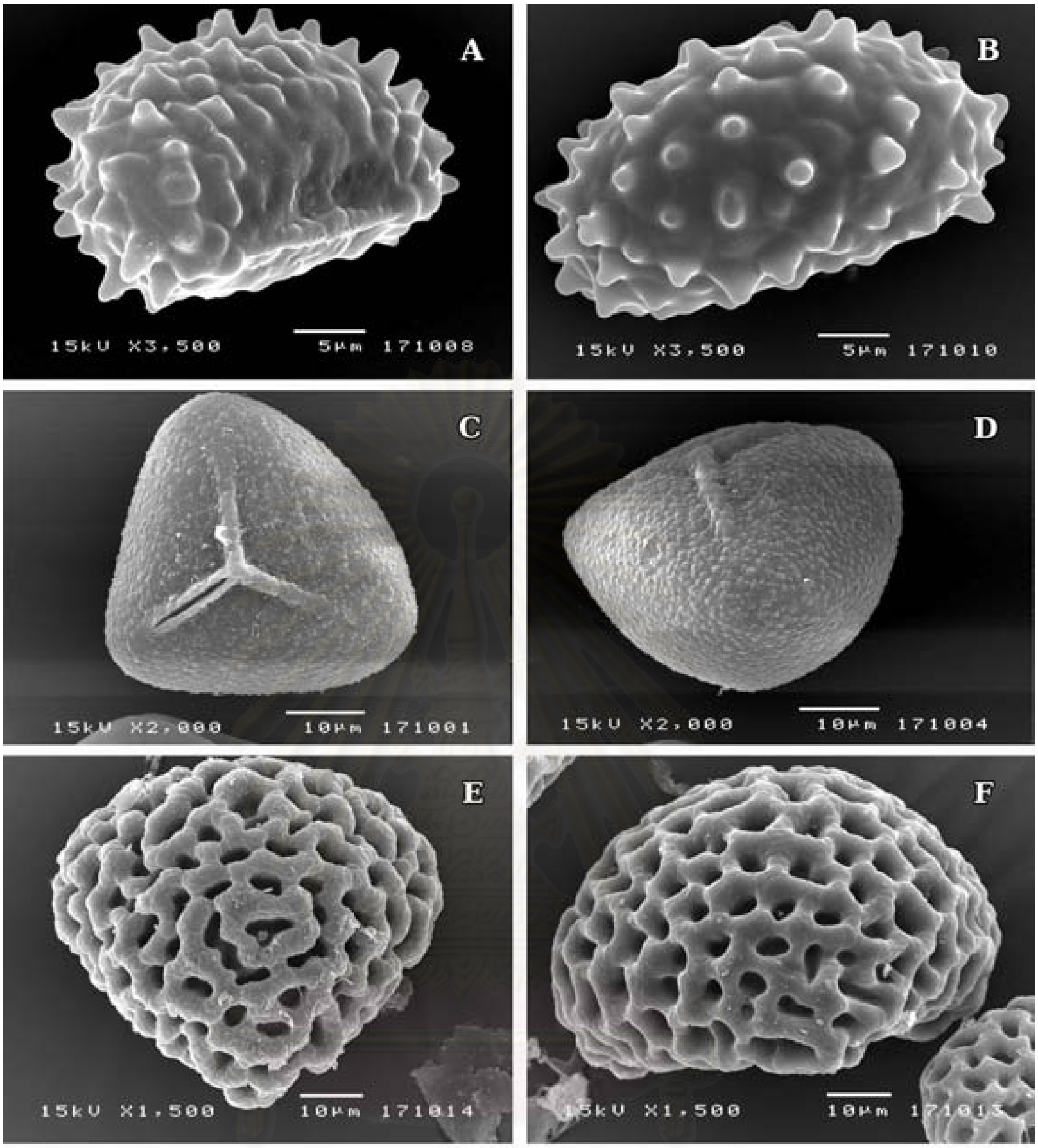


Plate A7 SEM Micrographs: A-B. ***Stenochlaena palustris*** **(Burm.) Bedd.** (A) Lateral view, (B) Proximal view; C-D ***Acrostichum speciosum*** **Willd.** (C) Proximal view (D) Lateral view; E-H ***Lygodium microphyllum*** **(Cav.) R.Br.** (E) Lateral view, (F) Proximal view.

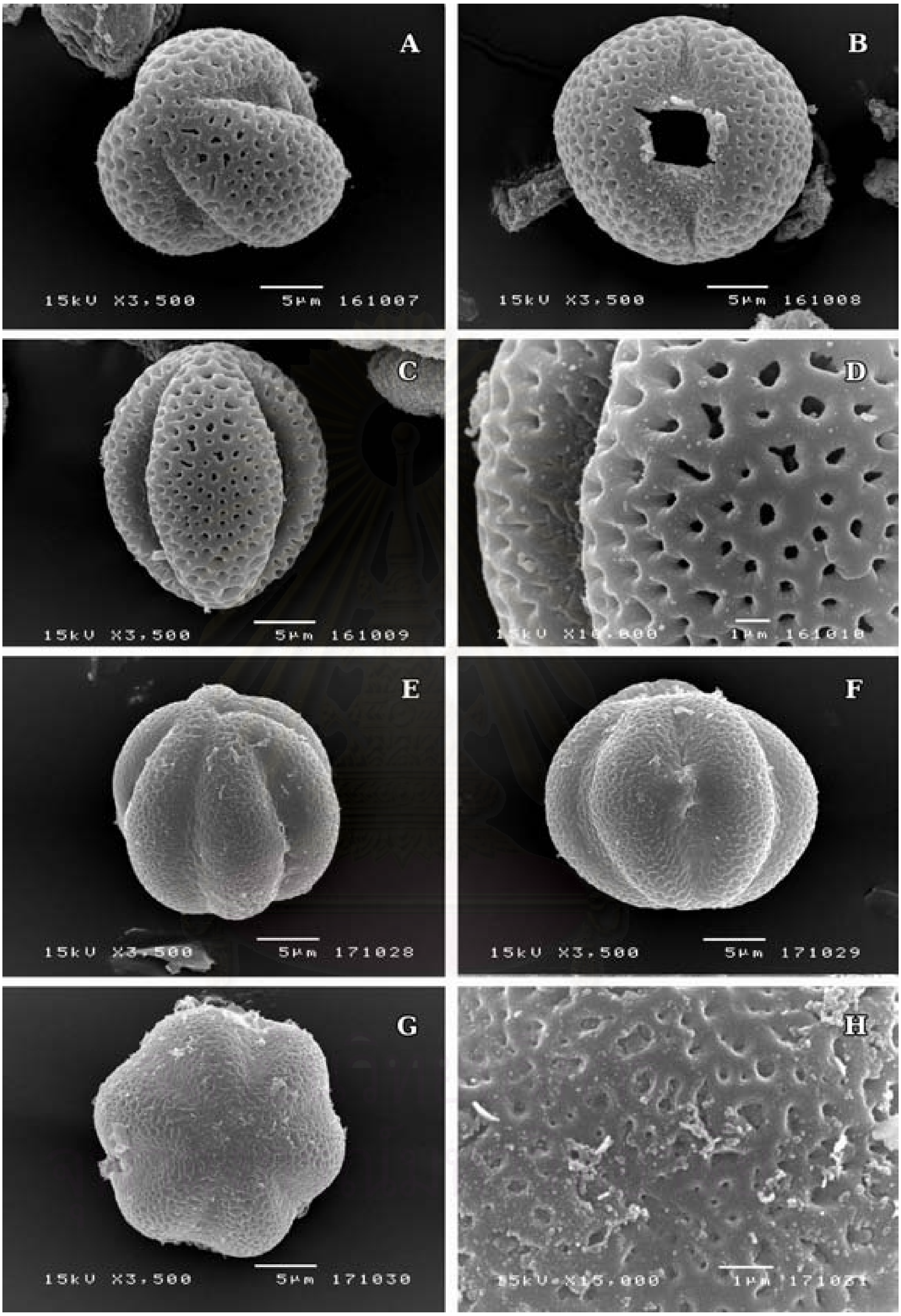


Plate A8 SEM micrographs: A-D ***Avicennia alba*** **Blume** (A) Oblique polar view, (C-B) Equatorial view, (D) Sculpture; E-H ***Lumnitzera racemosa*** **Willd.** (E-F) Equatorial view, (G) Polar view, (H) Sculpture.

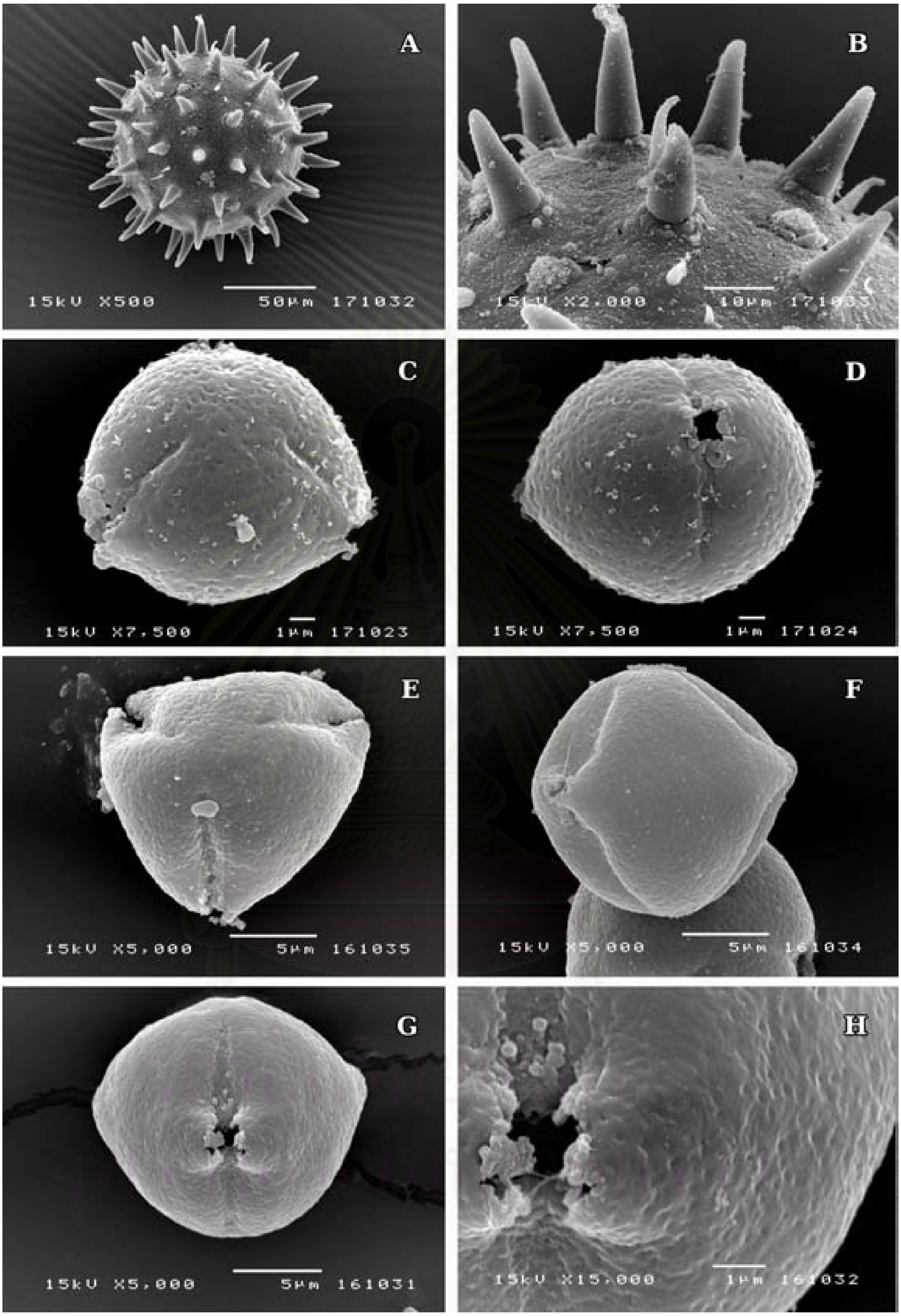


Plate A9 SEM micrographs: A-B ***Hibiscus tiliaceus* L.** (A) Pollen grain, (B) Sculpture; C-D ***Bruguiera cylindrica* (L.) Blume** (C) Polar view, (D) Equatorial view; E-H ***Bruguiera gymnorhiza* (L.) Lam** (E) Polar view, (F-G) Equatorial view, (H) Sculpture.

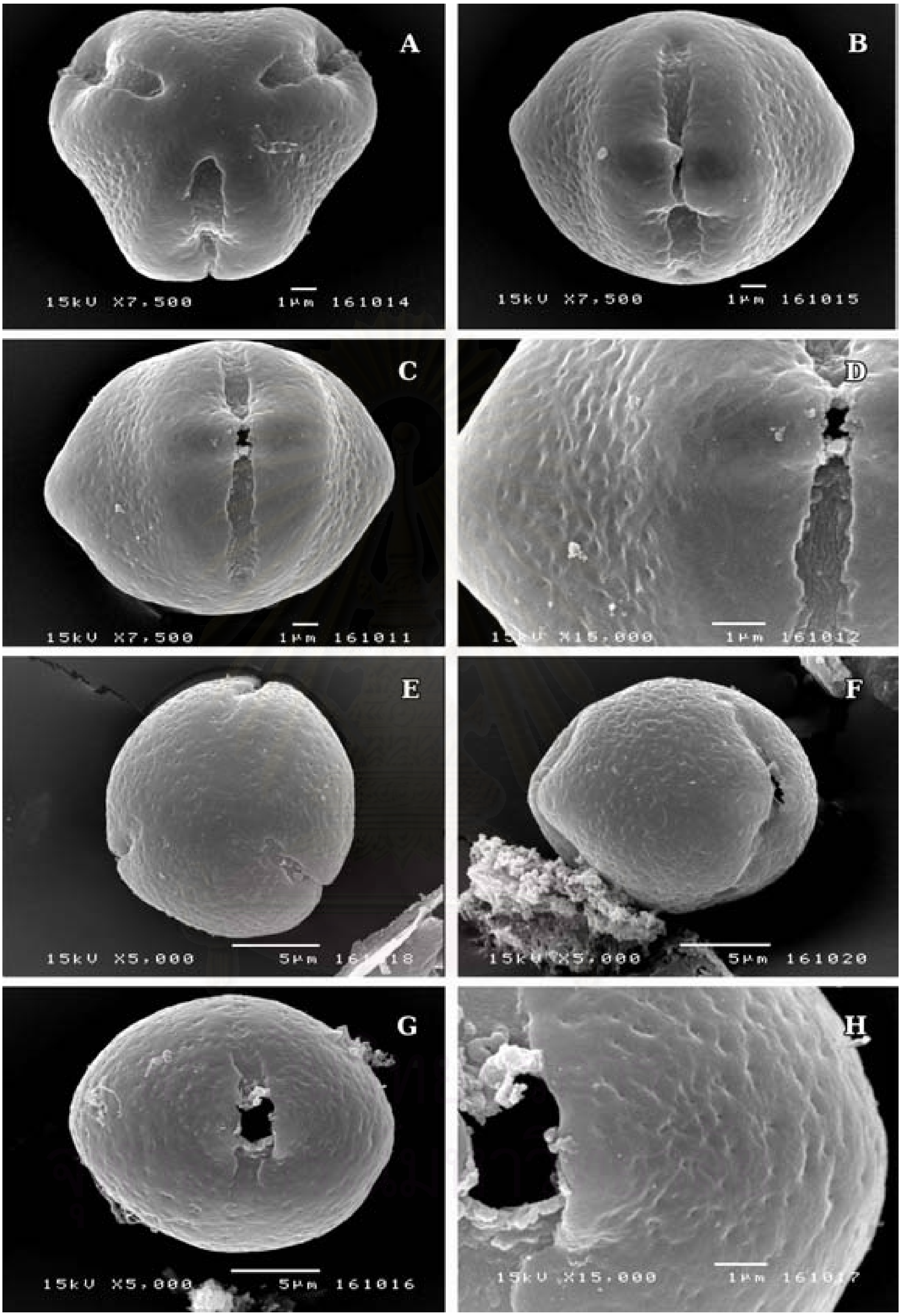


Plate A10 SEM micrographs: A-D ***Bruguiera sexangula* (Lour.) Poir.** (A) Polar view, (B-C) Equatorial view, (D) Sculpture; E-H ***Ceriops ecandra* (Griff.) Ding Hou** (E) Polar view, (F-G) Equatorial view (H) Sculpture.

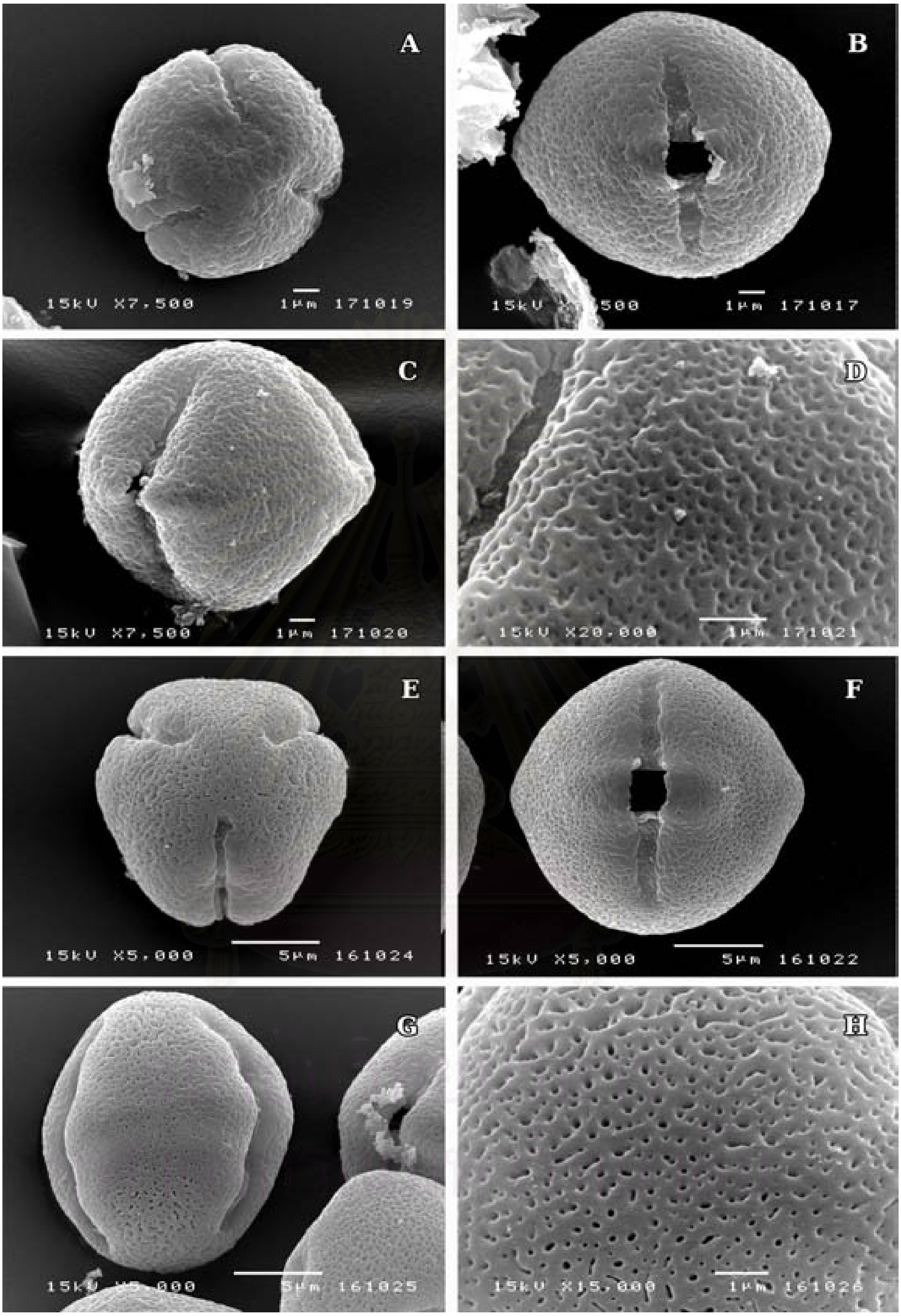


Plate A11 SEM micrographs: A-D ***Ceriops tagal* (Perr.) C.B.Rob.** (A) Polar view, (B-C) Equatorial view, (D) Sculpture; E-H ***Rhizophora apiculata* Blume** (E) Polar view, (F-G) Equatorial view (H) Sculpture.

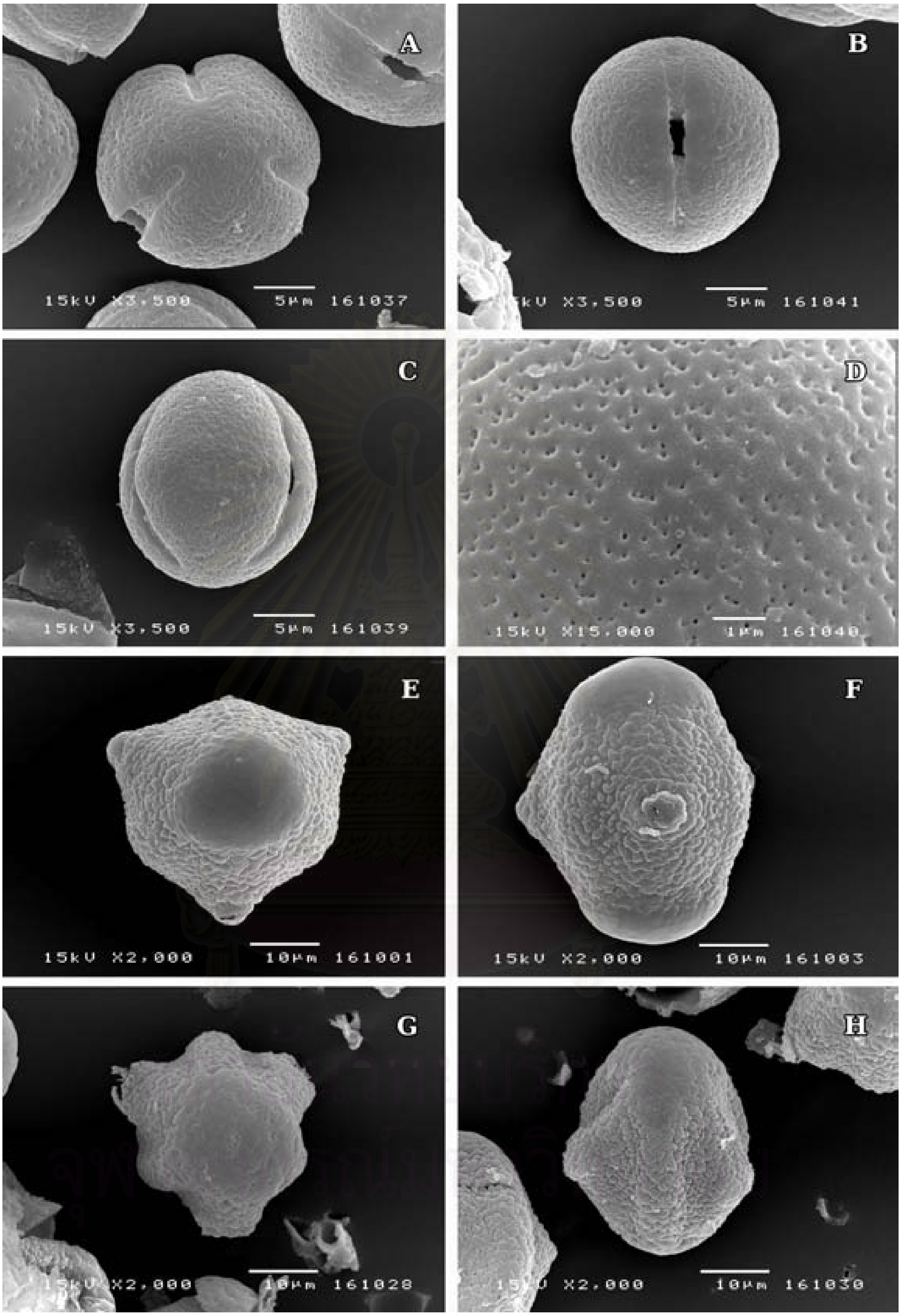


Plate A12 SEM micrographs: A-D ***Rhizophora mucronata* Lam.** (A) Polar view, (B-C) Equatorial view, (D) Sculpture; E-F ***Sonneratia caseolaris* (L.) Engl.** (E) Polar view, (F) Equatorial view; G-H ***Sonneratia* cf. *Sonneratia ovata*** (G) Polar view, (H) Equatorial view.

APPENDIX B

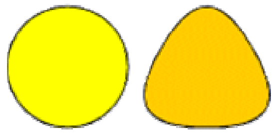
GLOSSARY

Acetolysis

A widely used technique for preparing pollen and spore exines for study.

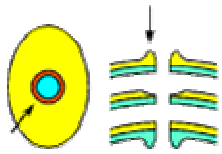
Amb

The outline of a pollen grain or spore seen in polar view.



Annulus (pl. annuli, adj. annulate)

An area of the exine surrounding a pore that is sharply differentiated from the remainder of the exine, either in ornamentation or thickness

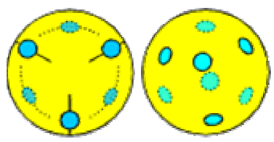


Aperture (adj. aperturate)

A specialized region of the (sporoderm, that is thinner than the remainder of the sporoderm and generally differs in ornamentation and/or in structure.

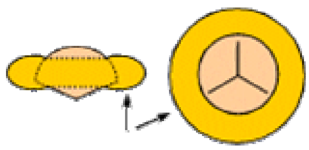
Apolar (adj.)

Describing pollen and spores without distinct polarity.



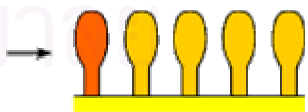
Cingulum (pl. cingula, adj. cingulate)

A thick outer structure of a spore that projects at the equator, but does not extend over the distal or proximal face..



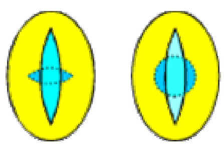
Clava (pl. clavae, adj. clavate)

A club-shaped element of the sexine/ectexine that is higher than 1μm, with diameter smaller than height and thicker at the apex than the base.



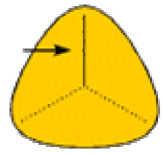
Colporus (pl. colpori, adj. colporate)

A compound aperture consisting of an ectocolpus with one or more endoapertures.



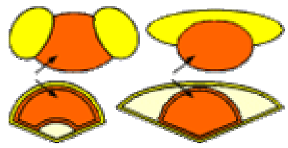
Commissure

The slit or line of dehiscence in the laesura.



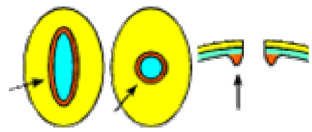
Corpus (pl. corpi)

The body of a saccate pollen grain or camerate spore.



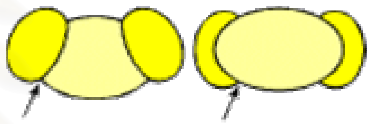
Costa (pl. costae, adj. costate)

A thickening of the nexine/endexine bordering an endoaperture, or following the outline of an ectoaperture.



Diploxylonoid (adj.)

Describing bisaccate pollen grains in which the outline of the sacci in polar view is discontinuous with the outline of the corpus so that the grains seem to consist of three distinct, more or less oval parts.



Dispersal unit

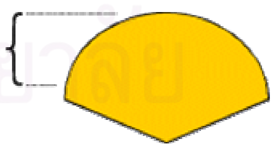
The morphological unit in which mature pollen grains or spores are shed, which may range from individuals (monads), to pairs (dyads), groups of four (tetrads), or groups of more than four (polyads). Larger, indeterminate numbers of pollen grains or spores may also be dispersed as pollinia or massulae.

Distal (adj.)

A common descriptive term used in contrast to proximal, applied in palynology to features on the surface that face outward in the tetrad stage.
Antonym: proximal.

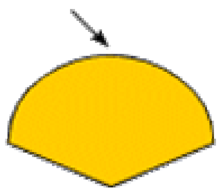
Distal face

That part of a palynomorph that faces outwards the centre of the tetrad, between equator and distal pole.
Antonym: proximal face.



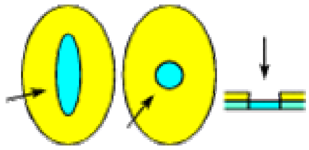
Distal pole

The centre of the surface of the distal face.
Antonym: proximal pole.



Ectoaperture

An aperture in the outer layer of the sporoderm.

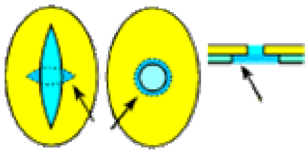


Ellipsoidal (adj.)

The shape of monolete spore in polar view with ratio of long axis/short axis falling between 1.25 to 2.

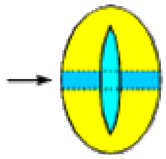
Endoaperture

An aperture in the inner layer of the sporoderm, often the inner aperture of a compound aperture.



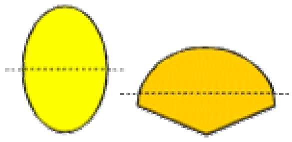
Endocingulum (pl. endocingula, adj. endocingulate)

A ring-shaped endoaperture continuous around a pollen grain and lying in the equatorial plane.



Equator

The dividing line between the distal and proximal faces of a pollen grain or spore.

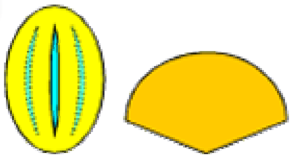


Equatorial axis

Often misappropriately used as a synonym of equatorial diameter.

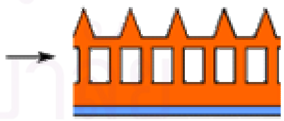
Equatorial view

The view of a pollen grain or spore where the equatorial plane is directed towards the observer. Antonym: polar view.



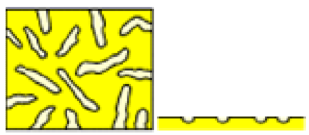
Exine (pl. exines, adj. exinal, exinous)

The outer layer of the wall of a palynomorph, which is highly resistant to strong acids and bases, and is composed primarily of sporopollenin.



Fossula (pl. fossulae, adj. fossulate)

A feature of ornamentation consisting of an elongated, irregular groove in the surface.



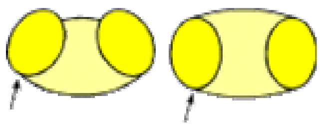
Granule (pl. granules, adj. granular, granulose)

General word for a small, rounded element.

Granulum (pl.granula, adj.granulate, granulose)

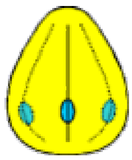
A very small and rounded element of the sexine/ectexine that is less than 1 µm in all directions.

Haploxylonoid (adj.)



Describing bisaccate pollen in which the outline of the sacci in polar view is more or less continuous with the outline of the corpus, so that the grains appear a more or less smooth ellipsoidal form.

Heteropolar (adj.)



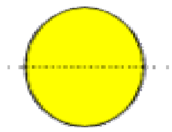
Describing pollen or spores in which the distal and proximal faces of the exine are different, either in shape, ornamentation or apertural system.

Antonym: isopolar.

Inaperturate (adj.) (Iversen and Troels-Smith, 1950)

Describing a pollen grain or spore without apertures.

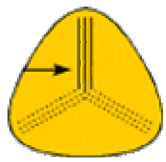
Isopolar (adj.)



Describing a pollen grain or spore in which the proximal and distal faces of the exine are alike.

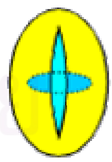
Antonym: heteropolar.

Laesura (pl. laesurae, suffix -lete)



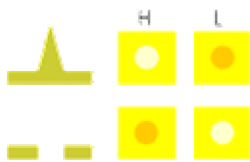
The arm of a proximal fissura or scar of a spore.

Lalongate (adj.)



Describing the shape of a transversely elongated endoaperture.

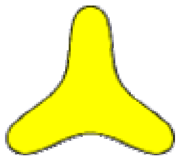
LO-analysis



A method for analyzing patterns of sexine organization by means of light microscopy.

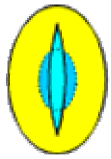
Lobate (adj.)

Describing an equatorially aperturate pollen grain with a lobed shape in polar view.



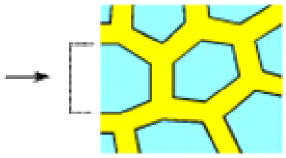
Lolongate (adj.)

Describing the shape of a longitudinally elongated endoaperture.



Lumen (pl. lumina)

The space enclosed by the muri.



Meridional (adj.)

Describing longitudinal features on the surface of a pollen grain or spore which run along lines perpendicular to the equator.

Micro-

A prefix for small. In palynology, generally used to denote features less than 1μm. Examples: microechinate, microverruca.

Microreticulum (adj. microreticulate)

A reticulate ornamentation consisting of muri and lumina smaller than 1μm. See also: reticulum.

Monad

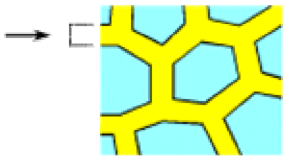
A pollen grain or spore dispersed as an individual unit, rather than in association with others, such as in a dyad, tetrad or polyad.

Monolete (adj.)

Describing a spore with a single laesura.

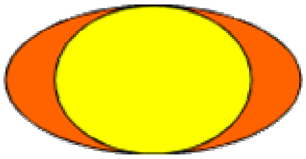
Murus (pl. muri)

A ridge that is part of the ornamentation and, for example, separates the lumina in a reticulate pollen grain or the striae in striate pollen grain.



Oblate (adj.)

Describing the shape of a pollen grain or spore in which the polar axis is shorter than the equatorial diameter as a ratio between the polar axis and the equatorial diameter of 0.50-0.75.



Oblate spheroidal (adj.)

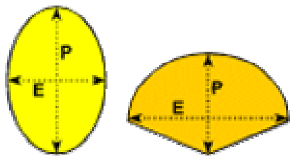
Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 0.88-1.00.

Outline

A general descriptive word. Applied in descriptive terms like equatorial outline and outline in polar view.

P/E ratio

The ratio of the length of the polar axis (P) to the equatorial diameter (E).



Palaeopalynology

The study of fossil palynomorphs.

Palynology

The study of pollen grains and spores and of other biological materials that can be studied by means of palynological techniques.

Palynomorph

A general term for all entities found in palynological preparations.

Comment: In addition to pollen grains and spores, the term encompasses acritarchs, dinoflagellates and scolecodonts, but not other microfossils, such as diatoms, that are dissolved by hydrofluoric acid.

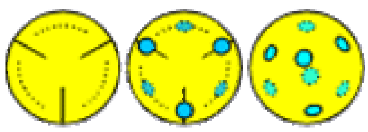
Panto-, Pan-

A prefix for global distribution.

Synonym of peri-.

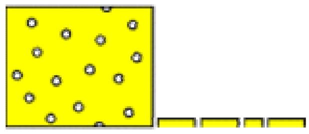
Pantoaperturate (adj.)

Describing a pollen grain with apertures spread over the surface sometimes forming a regular pattern.



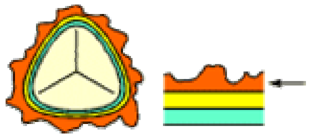
Perforate (adj.)

A general adjective indicating the presence of holes, applied in palynology to holes less than 1μm in diameter and generally situated in the tectum.



Perine

A sporoderm layer that is not always acetolysis resistant and is situated around the exine of many spores.

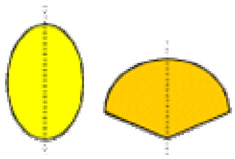


Polar view

A view of a pollen grain or spore in which the polar axis is directed towards the observer.

Polar axis (pl. polar axes)

The straight line between the distal and proximal poles of a pollen grain or spore.



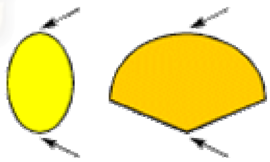
Polarity

The condition of having distinct poles

Comment: The polarity of palynomorphs may be determined from their orientation in tetrads, or by inference from the distribution of apertures, or other features.

Pole

Either of the two extremities of the polar axis.



Pollen

The microgametophyte of seed plants, developed from the microspore.

Pollen analysis

The study of assemblages of dispersed palynomorphs such as those isolated from samples of peat.

See also: palynology.

Pollen class (pl. pollen classes)

An artificial grouping of pollen grains that share a distinctive character, or suite of characters. Such classes are useful in identification keys and may be subdivided into more restrictive categories, pollen types and pollen groups. Example: tricolpate class.

Pollen group

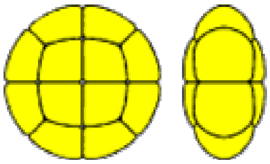
A pollen morphological category, subsidiary to a pollen type, including a number of pollen grains that show intergrading characters but no distinguishing characters.

Pollen type

A pollen morphological category, subsidiary to a pollen class, and including pollen grains which can be distinguished either by one distinct character or by a unique combination of characters.

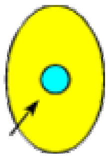
Polyad

A dispersal unit comprising more than four pollen grains.



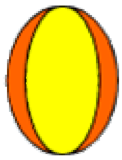
Pore (pl. pores, adj. porate)

A general term, applied in palynology to a circular or elliptic aperture with a length/breadth ratio less than 2



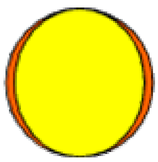
Prolate

Describing the shape of a pollen grain or spore in which the polar axis is larger than the equatorial diameter as a ratio between the polar axis and the equatorial diameter of 1.33-2.00.



Prolate spheroidal

Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 1.00-1.14.

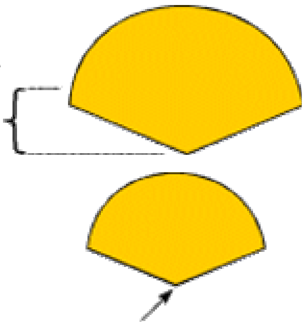


Proximal

A common descriptive term used in contrast to distal, applied in palynology to features on the surface that faces towards the centre of the tetrad during development.
Antonym: distal.

Proximal face

That part of a palynomorph which faces towards the centre of the tetrad, between equator and proximal pole.



Proximal pole

The centre of the proximal face.
Antonym: distal pole.

Pseudoaperture (adj. pseudoaperturate)

A thinning of the exine which, although superficially resembling an aperture, is not associated with a thickening of the intine and is presumed not to function as an exitus.

Pseudocolpus (pl. pseudocolpi, adj pseudocolpate)

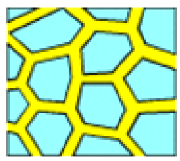
A colpus-like pseudoaperture.

Psilate (adj.)

Describing a pollen or spore with a smooth surface.

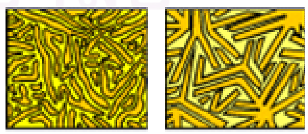
Reticulum (pl. reticula, adj. reticulate)

A network-like pattern consisting of lumina or other spaces wider than 1μm bordered by elements narrower than the lumina.



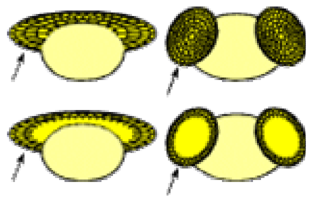
Rugulate (adj.)

Describing a type of ornamentation consisting of elongated sexine elements more than 1 μm long, arranged in an irregular pattern that is intermediate between striate and reticulate.



Saccus (pl. sacci, adj. saccate)

A sac formed by an expansion of the exine of a pollen grain and at least partly filled with an alveolate infrastructure.



Scabrate (adj.) (sing. scabra, pl. scabrae)

Describing elements of ornamentation, of any shape, smaller than 1 µm in all directions.

Comment: Ornamentation elements larger than 1µm are described according to their shape, for example, baculum, clava, gemma, verruca.

Sculpture

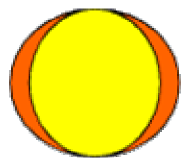
Orthogriphical variant of sculpturing.

Sculpturing (adj. sculptured)

The surface relief, or topography, of a pollen grain or spore.

Spheroidal

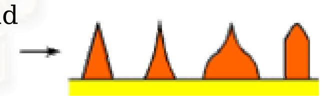
Describing the shape of a pollen grain or spore in which the polar axis and the equatorial diameter are approximately equal as a P/E ratio of 0.88-1.14.



Spine (adj. spiny/spinose)

A general word, applied in palynology to long and tapering pointed elements, exceeding 1 µm.

Comment: microspine was defined as less than is 1 µm



Spore

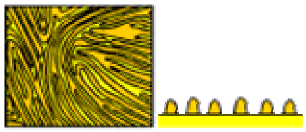
A general term for the usually microscopic, unicellular, asexual or sexual reproductive units of cryptogams and fungi.

Sporopollenin

The name given to the acetolysis resistant biopolymers which make up most of the material of the exine.

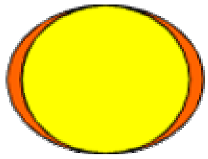
Striate (adj.)

A general descriptive term applied in palynology To elongated, generally parallel elements separated by grooves.



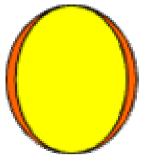
Suboblate (adj.)

Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 0.75-0.88.



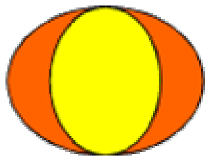
Subprolate (adj.)

Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 1.14-1.33.



Subspheroidal (adj.)

Describing the shape of a pollen grain or spore in which the ratio between the polar axis and the equatorial diameter is 0.75-1.33.

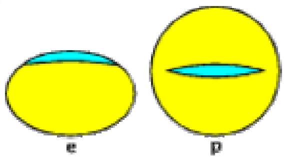


Subtriangular (adj.)

The shape of trilete spore in polar view with sides straight and angle rounded.

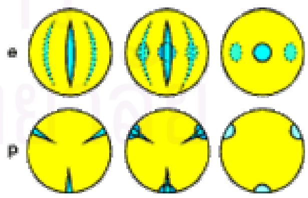
Sulcus (pl. sulci, adj. sulcate)

An elongated latitudinal ectoaperture situated at the distal or proximal pole of a pollen grain.



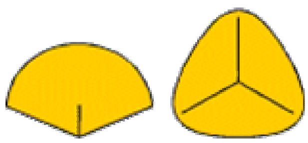
Tricolpate, tricolporate, triporate (adj.)

Describing pollen grains with three ectocolpi, three compound apertures or three pores.



Trilete (adj.)

Describing a spore with three laesurae, thus showing a trilete mark.



Trilobate (adj.)

The shape of trilete spore in polar view with sides deeply concave.

Trilobate (adj.)

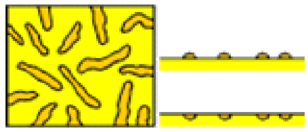
The shape of trilete spore in polar view with sides slightly concave.

Tuberculate (adj.)

Covered with knobbly projections.

Vermiculate

A general descriptive term used to describe winding features.

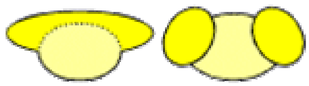


Verruca (pl. verrucae, adj. verrucate))

A wart-like sexine element, more than 1μm wide, that is broader than it is high and is not constricted at the base.

Vesiculate (adj.)

Synonym of saccate.



APPENDIX C

SIZE MEASUREMENT OF POLLEN AND SPORE

Size measurement of spore

The size of trilete spore = E×P

E = equatorial value in polar view

P = polar value in lateral view

The size of monolete spore = S×L×P

S = short axis in polar view

L = long axis in polar view or lateral view

P = polar value in lateral view

Size measurement of pollen

The size of saccate grain = A×B×C (for corpus) and D×E×F (for saccus);

A = breadth of corpus in polar view

B = depth of corpus in polar view

C = height of corpus in lateral longitudinal view

D = breadth of saccus in polar view

E = height of succus in lateral longitudinal view

F = depth of succus in lateral longitudinal view

The size of monosulcate = A×B×C

A = breadth in polar view

B = length in polar view

C = height in equatorial view

The size of subspheroidal grain = P×E

P = length of polar axis in equatorial view

E = breadth of equatorial axis in equatorial view

The size of polyad = A×B

A = breadth of polyad

B = length of polyad

BIOGRAPHY

Miss Paramita Punwong was born on March 30th, 1983 in Yala Province. She earned her Bachelor Degree in Science in Biology from the Department of Biology, Faculty of Science, Prince of Songkla University, Songkla, in 2004, then continued her study in Master of Science in Botany from the Department of Botany, Faculty of Science, Chulalongkorn University from 2005-2007.