CHAPTER 4

DESCRIPTIVE PALYNOLOGY

This chapter is the descriptive part of the fossil sporomorphs in this study. The descriptions are arranged alphabetically under bold capital titles of microscopic algae, fungi, pteridophytic spores, gymnospermic pollen, and angiospermic pollen. Some indeterminant sporomorphs are described and illustrated in Appendix A. The informal terms used in the descriptions, including shapes, size, sculpture on the exine, structure of the exine, and aperture characteristics, are an attempt to avoid technical terms, except in cases of inevitability, when the terms used by Faegri and Iversen (1989) are applied.

There are many fossils having synonyms. The names used here are applied on the basis of principle of priority under the International Code of Botanical Nomenclature, Tokyo Code, 1994 (ICBN). Fossil names used herein consist of three epithets including generic epithet, species epithet, and author epithet. All epithets are latinized under the ICBN. References to the fossil names are, therefore, differ from references in the text. List of scientific names is given as index for searching in appendix B.

4.1 MICROSCOPIC ALGAE

Genus: ***Actinastrum*** Lagerheim

***Actinastrum* sp.**

Plate I, figures 1-5.

Description: The genus is characterized by a shuttle-like or cigar-like cell body. It is swollen in the middle part and tapered to both sides with blunt ends. The cell body is

PLATE I

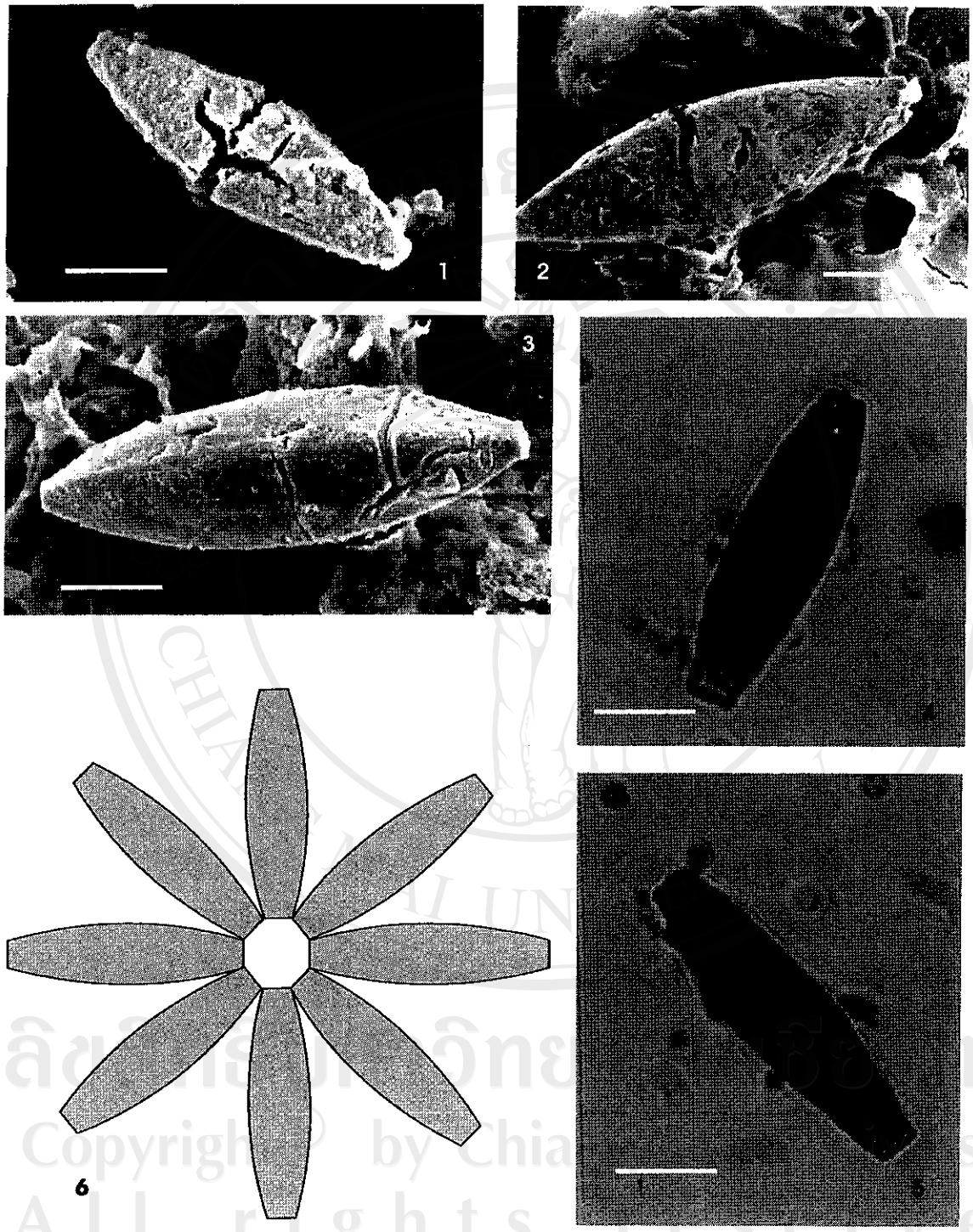


PLATE I: figures 1-5: *Actinastrum* spp., figure 1-3: SEM, figure 4-5: LM, figure 6: reconstructed *Actinastrum* colony of two-dimensional cell arrangement. All scale bars are 10 microns.

spherical or polygonal. The cell size between both ends ranges from 20 to 37 microns and 7 to 13 microns wide in the middle part of the cell body based upon 20 specimens measured. The size in the middle part of the cell is about one-third to the size between both ends.

Comparison: The fossil form is comparable to the extant freshwater green alga *Actinastrum*, family Scenedesmaceae, by general morphology (Wongratana, 2001). However, when compared to *Actinastrum gracillimum* Smith and *Actinastrum hantzschii* Lagerheim, the extant forms have a greater ratio between the size of the middle part and the length between both ends than the fossil forms. Actually, *Actinastrum* is a colonial alga comprising a fixed number of cells (4, 8, 16, 32, or more). The cells in the colony are arranged into 2 to 3 dimensions by adjoining one end of each cell together at a center point and the another end of each cell points outwards forming a circular or spherical colony (plate I, figure 6). However, fossil colonial forms have not been seen before probably because it was disarticulated forming individual cells during diagenesis or sample treatment.

Occurrence: The genus occurs abundantly in the overburden unit of the Chiang Muan, upper part of the upper coal zone of the Ban Pa Kha, and the unit "D" of the Mae Lamao coalfields.

Genus: ***Botryococcus*** Kützing

***Botryococcus* sp.**

Plate II, figure 1-5.

Description: The fossil form consists of small cells or cups aggregated into spheroidal multicellular colonies. The number of cells in a colony is indefinite. The cells are arranged from the center of the colony branching out in radial directions. Each main

PLATE II

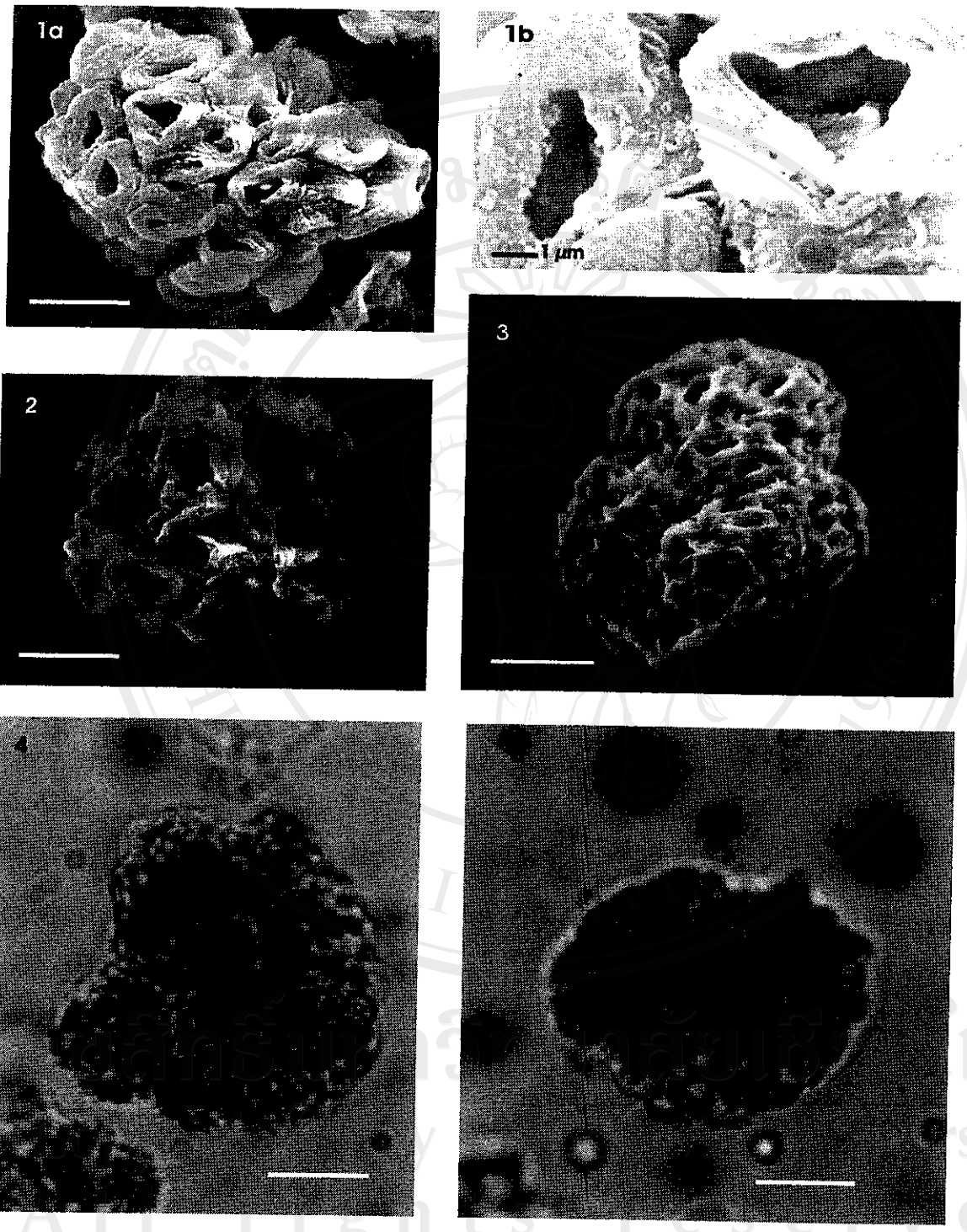


PLATE II: figures 1-5: *Botryococcus* spp., figures 1-3: SEM, figures 4-5: LM. All scale bars are 10 microns except where otherwise stated.

branch is further branched into sub-branches. The diameter of the colony ranges from 19 to 32 microns.

Comparison: Specimens illustrated under scanning electron microscopy from Na Sai are comparable to late Early Cretaceous (Albian) *Botryococcus* cf. *B. braunii* from the Mattagami Formation in Ontario (Zippi, 1998). Comparison among the fossil forms and the recent species reveals that the alga has changed little with time and no evolutionary pattern of morphological changes has been detected from the Precambrian to Recent (Guy-Ohlson, 1992). The occurrence of the fossil *Botryococcus* in association with alga *Pediastrum* from the Ban Pa Kha strongly suggests that the sedimentation occurred in a freshwater environment.

Occurrence: Common occurrences in the upper part of upper coal zone of the Ban Pa Kha, Na Sai, and from the lower coal zone of the Chiang Muan coalfields.

Genus: ***Closterium*** Nitzsch

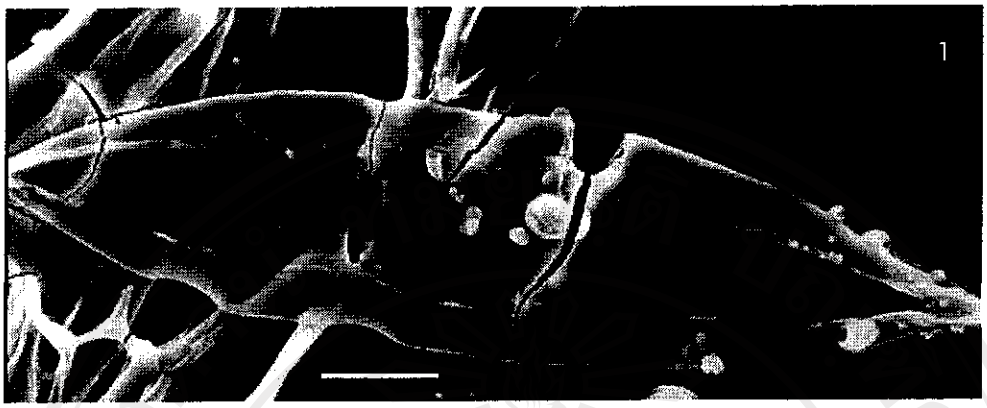
***Closterium* sp.**

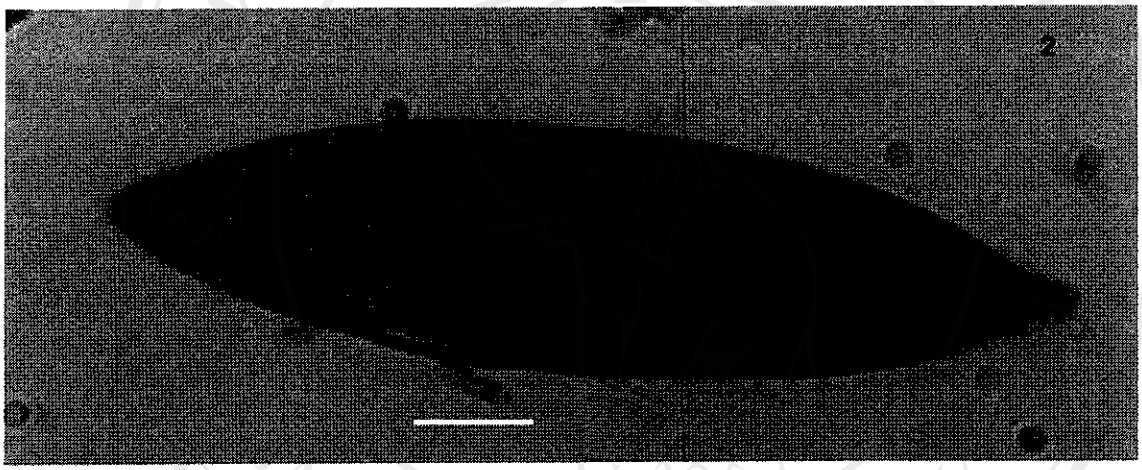
Plate III, figures 1-6.

Description: The genus is characterized by a single long straight cell. The cell wall is thin with a smooth surface with some longitudinal lines. The cell is usually flattened forming a long frond-like shape tapering at both ends. Both ends are sharp acute to small-rounded points. Size in the middle part of the cell ranges from 10 to 26 microns and size between both ends of the cell is 43 to 91 microns. The ratio between the sizes of the middle part and the length between both ends is about 1:4.5.

Comparison: The cell body of *Closterium* today is generally crescent shape. Only few species of the subgenus *Closterium* (*Holopenium*) are straight cell bodies including *Closterium libelluta* and *Closterium navicula*. The two modern forms are much bigger

PLATE III





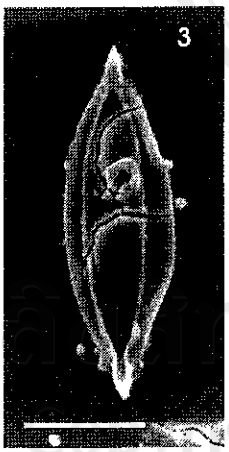


PLATE III: figures 1-6: *Closterium* spp., figures 1-2: a species under SEM and LM; figures 3-4: a species under SEM and LM; figures 5-6: a species under SEM and LM. The scale bars are 10 microns.

than the fossil forms from this study. The lengths of the cells of the modern species are more than 100 microns and probably up to 240 microns. *Closterium*, a phytoplankton, occurs in a freshwater environment and it belongs to the family Desmidiaceae (Wongratana, 2001).

Occurrence: They are abundant in the upper part of upper coal zone of the Ban Pa Kha, the lower coal zone of the Chiang Muan, the unit "D" of the Mae Lamao, and from the "J" coal zone of the Mae Moh coalfields.

Genus: ***Pediastrum*** Meyen

Discussion: Paleontologically, a coenobium that possesses a characteristically colorless thin flat star-like disc in plan view strongly suggests the living freshwater green alga *Pediastrum*. Biologically, *Pediastrum* is a unicellular alga but the cell walls always adjoin neighboring cells and arrange themselves into a with particular pattern and cell numbers in a one cell thick colony or a so-called coenobium. The cells or coenocytes are concentrically arranged forming a star-like coenobium with or without perforation. Shape of cells, with or without projections, and cell wall ornamentation are also indicative of species and/or variety of the genus *Pediastrum*.

Pediastrum is well known as a freshwater green colonial alga of the family Hydrodictyaceae, occurring in lakes, ponds, and rivers. Because of its unique characteristics, it is, unmistakable and can be identified precisely to the generic level even in the fossil form. The name *Pediastrum* was first erected by Meyen in 1829 for an extant microscopic alga. Four species of Tertiary *Pediastrum* were reported from Paleogene sediments from South Sumatra by Wilson and Hoffmeister (1953). They were dominated under the generic name *Pediastrum* Meyen including *P. kajaites*, *P. paleogeneites*, *P. bifidites*, and *P. delicatites* and were ascribed as freshwater

elements. Evitt (1963) reported freshwater *Pediastrum* from Cretaceous marine sediments from Pakistan having morphologies similar to those modern taxa like *Pediastrum boryanum*, and interpreted the freshwater algae as being carried by rivers to be deposited in the marine environment. Evitt also pointed out that the *Pediastrum* itself is not a reliable indicator of freshwater depositional environment for the strata in which it occurs. Singh and Khanna (1978) nominated seven new fossil species forms to the genus *Pediastrum* namely *P. compactum*, *P. wilsonii*, *P. indicum*, *P. pallidus*, *P. angulatus*, *P. magnus*, and *P. diffuses*. They mentioned that when *Pediastrum* occurs in association with continental assemblage without marine elements, the depositional environment is reliable as lacustrine. Meanwhile, when it occurs along with hystrichosphaerid dominated marine assemblages, the paleoecological significance of *Pediastrum* is uncertain. Ediger and Bati (1988) explained that fossil *Pediastrum* is classified primarily on morphology rather than on characteristics such as pigmentation, metabolic products, reproduction, life cycle, and so on, like the modern taxa, therefore the morphospecies concept may be reasonable for the fossil forms also. Zippi (1998) used modern taxa, *Pediastrum simplex* and *Pediastrum boryanum*, representing fossil algae he studied and claimed deposition occurred in a freshwater environment. However, the occurrence of the *Pediastrum* is not of much value in terms of stratigraphy (Yakzan and others, 1994).

Morphospecies is reasonable and acceptable, the morphogenus is also. Nevertheless, the *Pediastrum*-like sporomorphs is so far used the natural genus *Pediastrum*, the natural species is, thus, acceptable to representing the fossil forms. Therefore, the natural species of the genus *Pediastrum* as used by Zippi (1998) is applicable to this study.

Specimens described herein were derived from the Ban Pa Kha sediments. They were well preserved and easy to recognize and describe. Even though the occurrence of *Pediastrum* from Na Hong was abundant, the coenocytes were normally broken up and too difficult to describe. The descriptions below are, thus, based upon the specimens from the Ban Pa Kha coalfield.

Pediastrum simplex Meyen

Plate IV, figures 1-4.

Description: Coenobia range from 44 to 65 microns in diameter with 8 to 16 coenocytes adjoined to neighboring cells in a concentric arrangement. It forms one or two rings with small gaps between the cell walls or a single central space. A cell is well defined by a triangular shape, higher than broad. The marginal cells have somewhat straight conjunctive sides, prolonged into a single tapering process forming an acute tip. Central coenocyte is absent.

Occurrence: Abundant in the upper coal zone of Ban Pa Kha and unit A of Na Hong coalfields.

Pediastrum duplex Meyen

Plate IV, figures 5-6.

Description: Coenobia range from 52 to 60 microns in diameter with 8 cells adjoined to neighboring cells in a single concentric ring configuration forming a single circular central space. Each cell has somewhat straight conjunctive sides, more or less parallel with U-shape tear in the distal side forming two slender projections.

Occurrence: Common in the upper coal zone of Ban Pa Kha coalfield.

Pediastrum boryanum (Turpin) Meneghini

PLATE IV

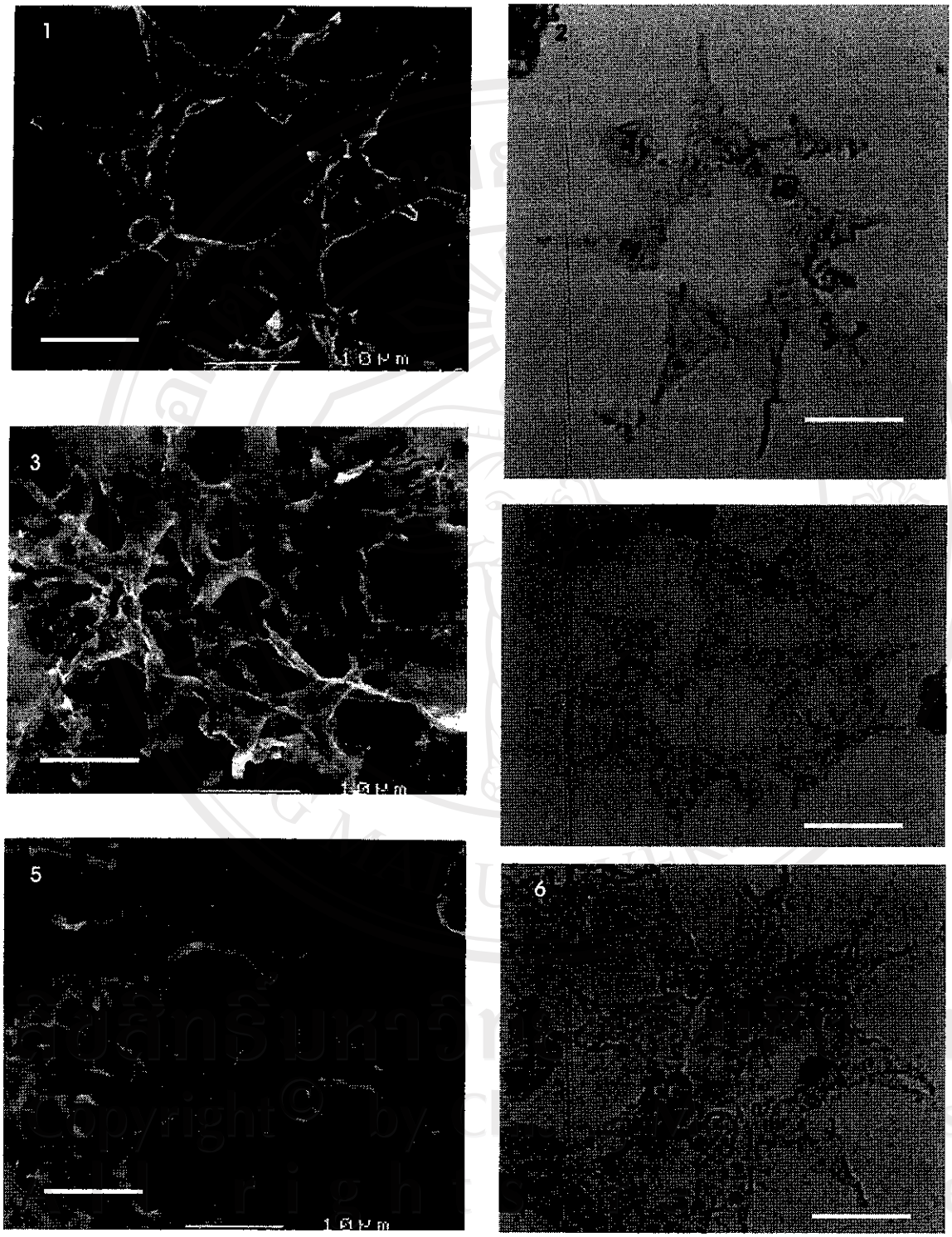


PLATE IV: figures 1-6: *Pediastrum* spp.;figures 1-2: *Pediastrum simplex*, one ring cell arrangement; figures 3-4: *Pediastrum simplex*, two rings cell arrangement; figures 5-6: *Pediastrum duplex*. All scale bars are 10 microns.

Plate V, figures 1-4.

Description: Coenobia range from 59 to 70 microns in diameter. The cells are arranged compactly in concentric rings without perforation. The cell shape is unrecognizable under scanning electron microscope but well defined by using the light microscope. The interior appears to have more or less 4 to 6 straight sides. Outer cells each contain two non-pronged slender processes on the outer side.

Occurrence: Common in the upper coal zone of Ban Pa Kha coalfield.

***Pediastrum* sp. 1**

Plate VI, figures 1-3.

Description: Coenobia range from 50 to 60 microns in diameter, compacted, and very thin. Interior cells are more or less polygonal but not clearly visible. Marginal cells contain two triangular processes with blunt narrow tips. Sculpture is smooth.

Occurrence: Rare to common in the upper coal zone of Ban Pa Kha coalfield.

***Pediastrum* sp. 2**

Plate VI, figure 4.

Description: Coenobia range from 40 to 50 microns in diameter, compacted. Shape of interior cells is undefined. The marginal cells are triangular with small rounded-knob tips.

Occurrence: Rare in the upper part of the upper coal zone of Ban Pa Kha coalfield.

4.2. FUNGI

Germlings of microthyriaceous fungi Dilcher

Plate VII, figure 1.

1916, *Pediastrum* David.

PLATE V

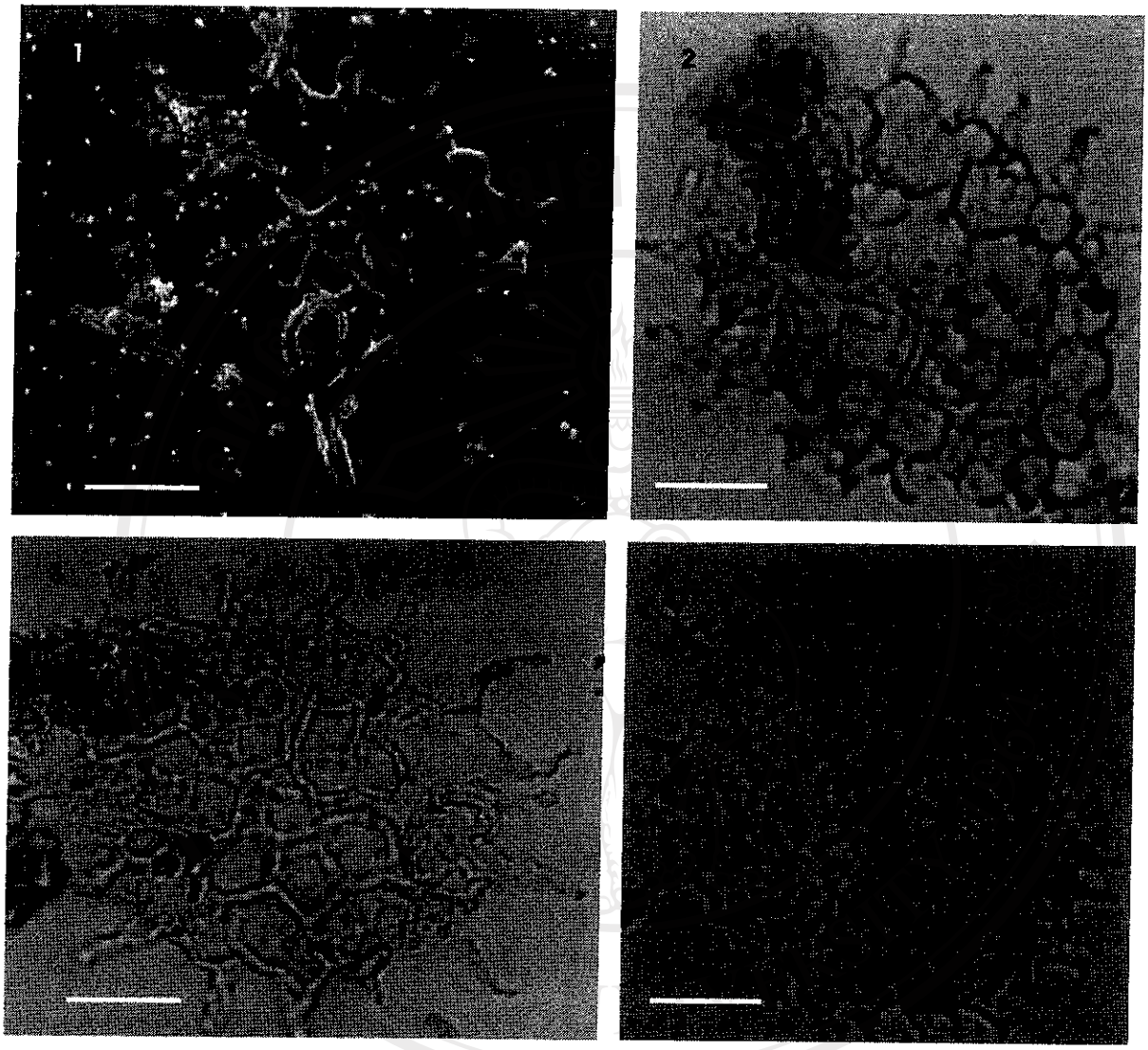


PLATE V: figures 1-4: *Pediastrum boryanum* (Turpin) Meneghini, figure 1: SEM, figures 2-4: LM showing inside coenocytes with polygonal cells and the marginal cells contain two non-pronged slender processions. The scale bars are 10 microns.

PLATE VI

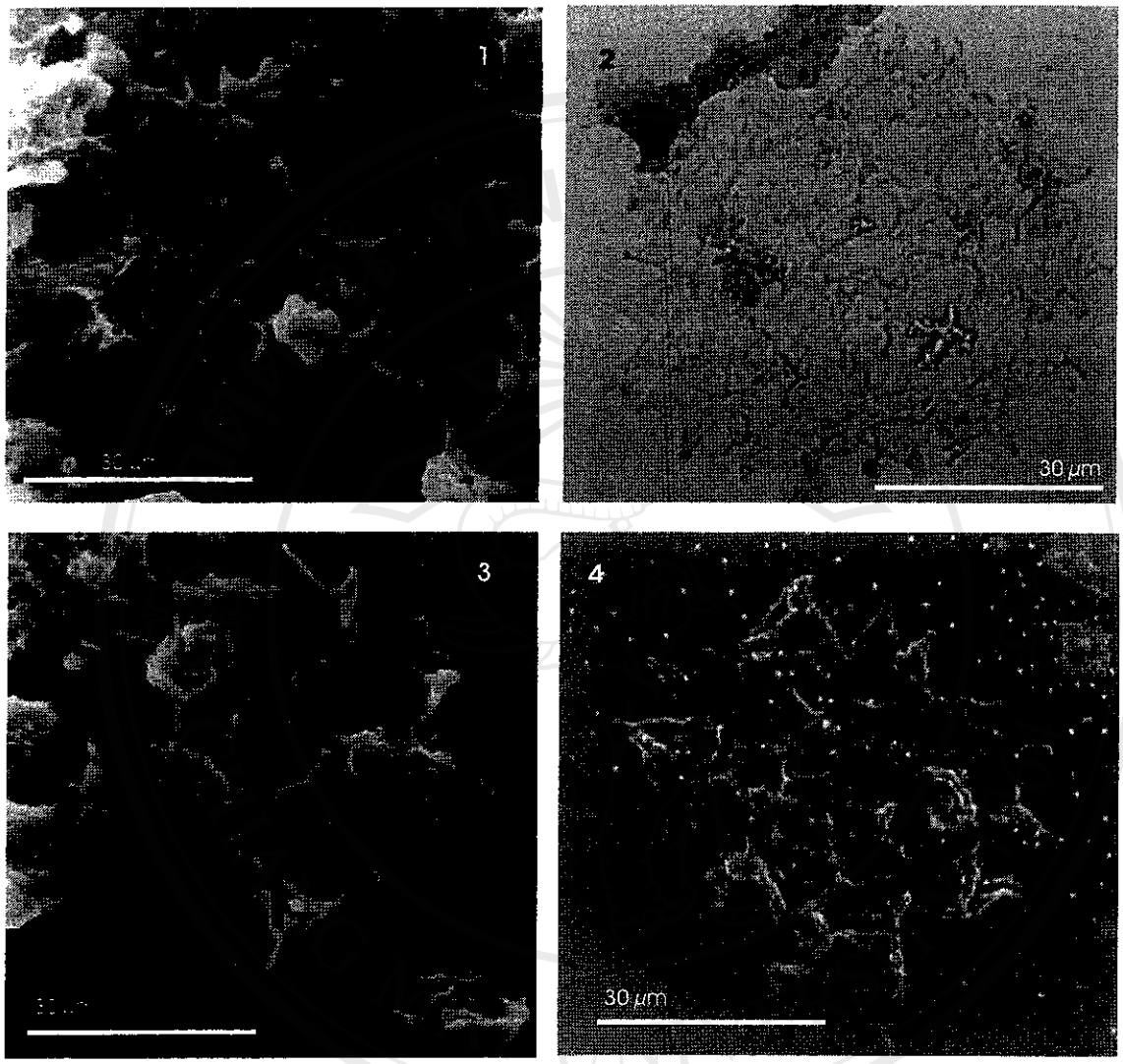
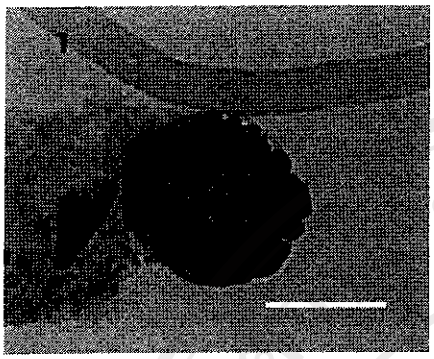
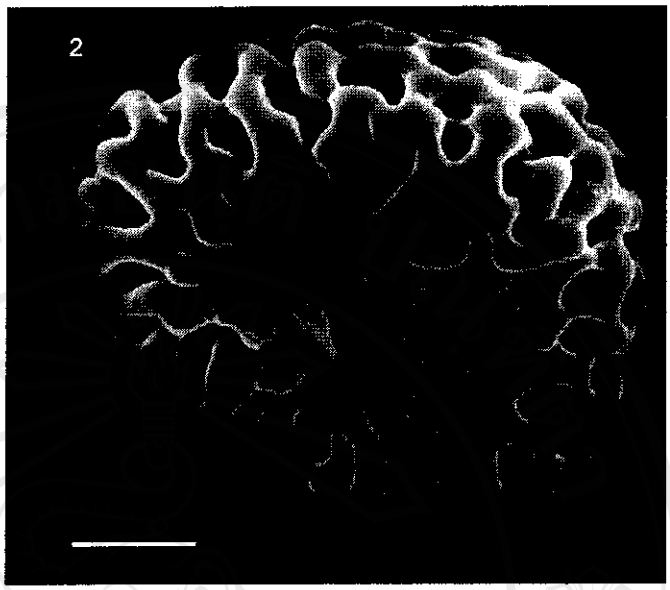


PLATE VI: figures 1-4: *Pediastrum* spp. indet.

PLATE VII





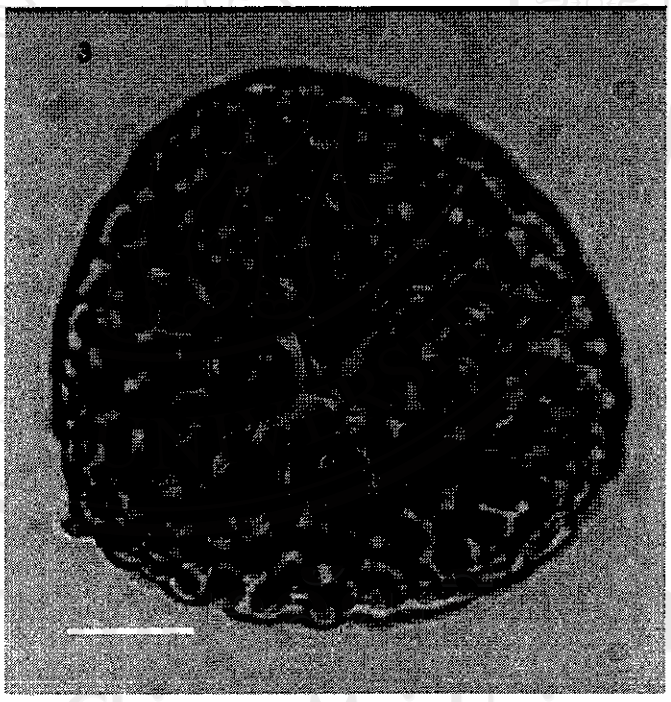


PLATE VII: figures 1: Germlings of microthyriaceous fungi Dilcher; figures 2-3: *Crassoretitriletes vanraadshoovenii* Germeraad *et al*, figure 2: SEM, figure 3: LM, The scale bars are 10 microns.

1922, *Phragmothyrites eocaenica* Edwards, pl. 8, figs. 5-6.

1951, *Phycopeltis eocaenica* Potonié, pl. 20, fig. 1.

1964, *Phycopeltis* Cranwell, pl. 1, fig. 2.

1965, Germlings of microthyriaceous fungi Dilcher, p. 10-13, pl. 4, figs. 18-29, 32-36, pl. 9, fig. 75.

1967, *Entophyctis willoughbyi* Bradley, p. 579-580, fig. 6.

1968, Germlings of microthyriaceous fungi Elsik, pl. 4, figs. 2-3.

1974, Germlings of microthyriaceous fungi Elsik and Dilcher, pl. 27, figs. 6-7.

1982, Germlings of epiphyllous fungi Playford, pl. 7, fig. 12.

1986, *Desmidiospora willoughbyi* (Bradley) Ethridge-Glass and others, p. 408, pl. 2, fig. 1.

Remarks: These forms of fossils were assigned and understood in various ways. Dilcher (1965) and Elsik and Dilcher (1974) explained that these forms could not be assigned into a format of scientific names (binomials) even though they are parts of fungi. They were produced during the process of germination of many kinds of fungi belonging to the family Microthyriaceae. They developed in the immature stage and after that they further developed to be fungi of various genera and species. Elsik and Dilcher criticized the fossils name *Entophyctis willoughbyi* erected by Bradley (1967) which they compared with an extant fungus *Entophyctis lobata*. They preferred to use the name germlings of microthyriaceous fungi to represent these fossil forms. The most update assignment by Ethridge-Glass and others (1986) as *Desmidiospora willoughbyi* is invalid. Ethridge-Glass and others also accepted that the structure of this type of fossil, though fungal in origin, could not be assigned with certainty, but it belonged to the family Microthyriaceae. The germlings of microthyriaceous fungi is herein accepted for this study.

Botanical affinity: The fossils cannot be assigned a certain taxonomic position at the species and even generic levels but they are certainly forms of fungus in the family Microthyriaceae. The form of germlings of microthyriaceous fungi is produced by

several leaf-inhabiting fungal groups, generally as holdfasts for attachments of the hypha to the leaf surface (Ethridge-Glass and others, 1986). Lange (1976) studied modern Australian leaf litter samples and showed that the more highly developed types of germlings are most common in areas of high rainfall.

Occurrence: Rare in Ban Pa Kha overburden sediments. Songtham (1996) also reported this form from Krabi.

4.3 PTERIDOPHYTIC SPORES

Genus: ***Crassoretitriletes*** Germeraad *et al*

Type species: *Crassoretitriletes vanraadshoovenii* Germeraad *et al*

Crassoretitriletes vanraadshoovenii Germeraad *et al*

Plate VII, figures 2-3.

1968, *Crassoretitriletes vanraadshooveni* Germeraad and others, p. 287, pl. 1, fig. 3.

Description: The grain is spherical to slightly triangular in polar view. It has broadly convex sides observable in polar view with a trilete mark on the proximal surface. The surface sculpturing is entirely coarsely reticulate with wide undulating muri covering the whole grain on both distal and proximal sides. The grain size ranges from 52 to 74 microns and about 62 microns on average based on 20 grains measured.

Remarks: Original assignment *Crassoretitriletes vanraadshoovenii* was erected by Germeraad and others (1968) spelling as *Crassoretitriletes vanraadshooveni*. The correct spelling is *Crassoretitriletes vanraadshoovenii*, with a double i. The reason is that because the language used is Latin that means that under the International Code of Botanical Nomenclature (article 60 in the 1994 version) any male name ending in a consonant, except "r", (in this case "n") must be followed by a double "ii" when used as a species epithet. This species epithet came from Mr. B. van Raadshooven, the species name is, therefore, *vanraadshoovenii* rather than *vanraadshooveni*.

Comparison: The characteristics described above well match the designation by Germeraad and others (1968) of *Crassoretitriletes vanraadshoovenii* as a type species. However, the first designation described the size as ranging from 58 to 101 microns. Germeraad and others considered the extant spores of *Lygodium microphyllum* (= *Lygodium scandens*) as its botanical affinity. They also criticized *Lygodium microphyllum* described by Nayar and others (1964) as being tuberculate on the distal side with a smooth proximal surface. Nayar and others' description did not match Germeraad and others' fossils. However, an unknown species of *Lygodium* was collected from Khao Saming District of Trat Province for comparison (plate VIII, figure 1; plate IX, figure 1). The spore characteristics of the unknown species match well Nayar and others' descriptions. It has tuberculate to verrucate sculpture on the round distal side. The proximal side has a smooth, slightly pointed proximal pole with a sharp trilete mark. The size ranges from 67 to 96 microns and 82.5 microns on average based on 20 grains measured. However, Augustinius and Macphail (1997) confirmed that the *Lygodium microphyllum* is botanical affinity of the fossil *Crassoretitriletes vanraadshoovenii*. The work of Germeraad and others is, thus, correct.

Botanical affinity: *Crassoretitriletes vanraadshoovenii* is comparable to the extant spores of *Lygodium microphyllum* of the family Schizaeaceae. *Lygodium* is a climbing fern, common in humid marsh and swamp forests in open to semi-open forests in tropical to subtropical areas of West Africa and Indo-Malesian areas, but absent today in South America. It appeared and disappeared in South America over a short period of time during the late Early Miocene. It occurred in Borneo and Nigeria a little bit earlier in the Early Miocene and has persisted up to the present day in the both areas. The cause of extinction of *Lygodium* from South America is still unanswerable.

PLATE VIII

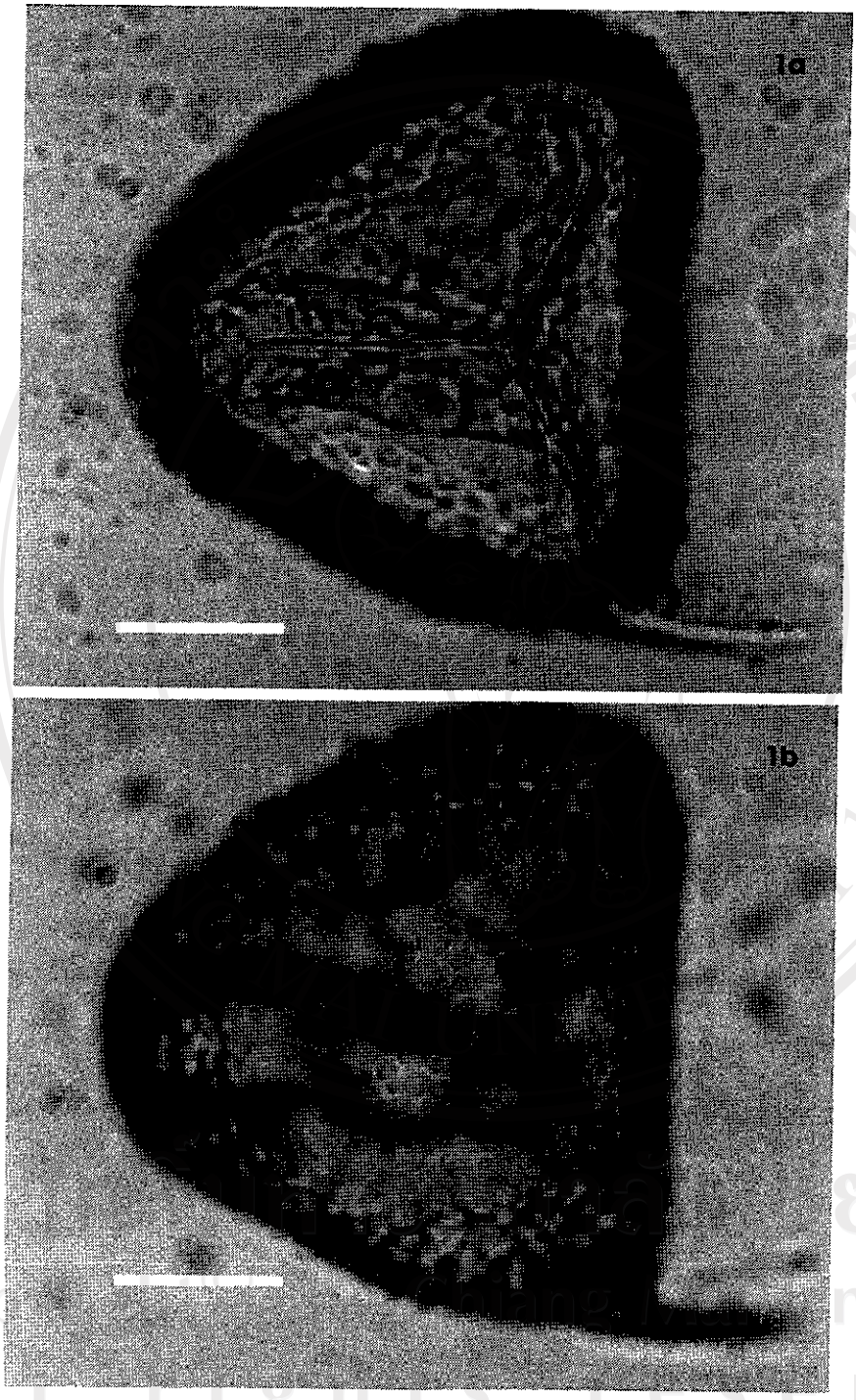
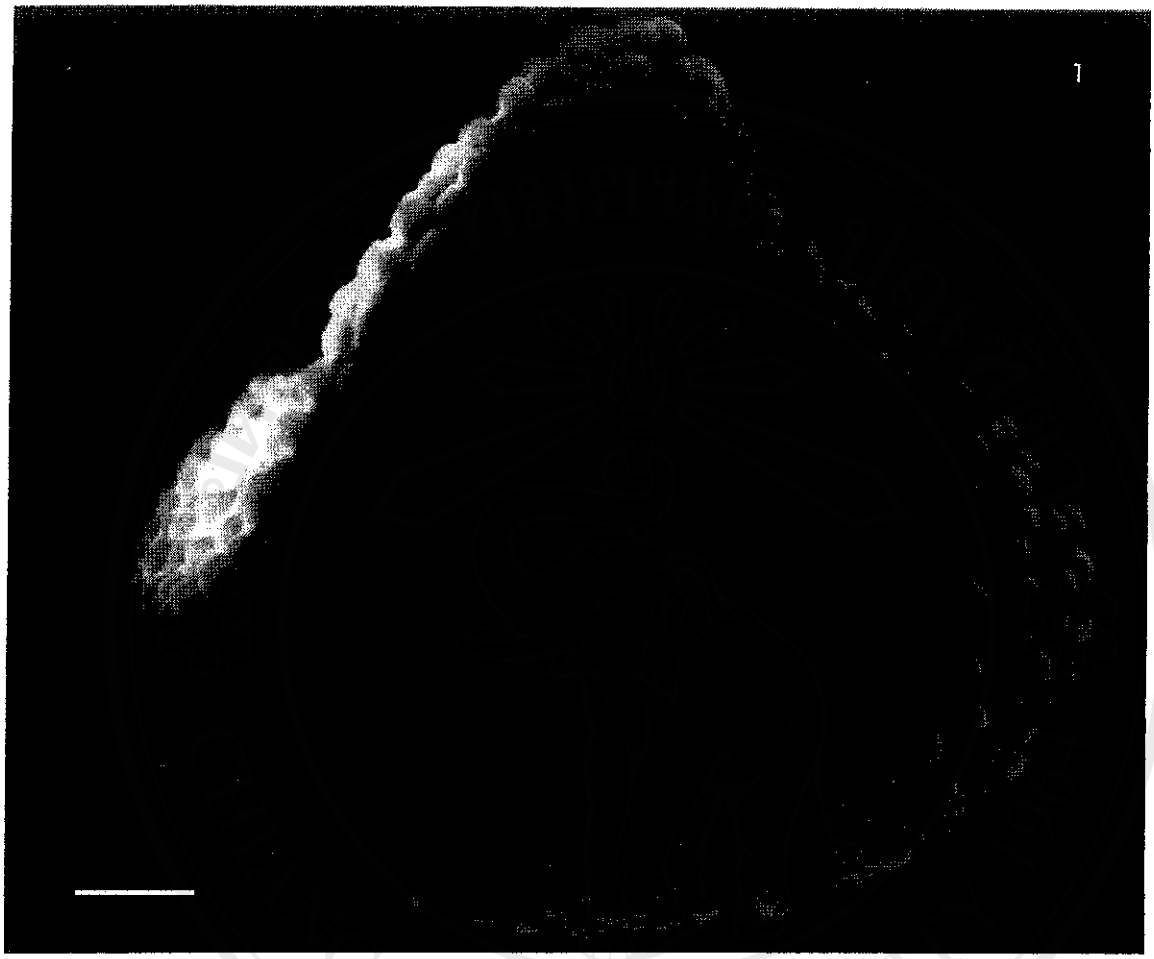
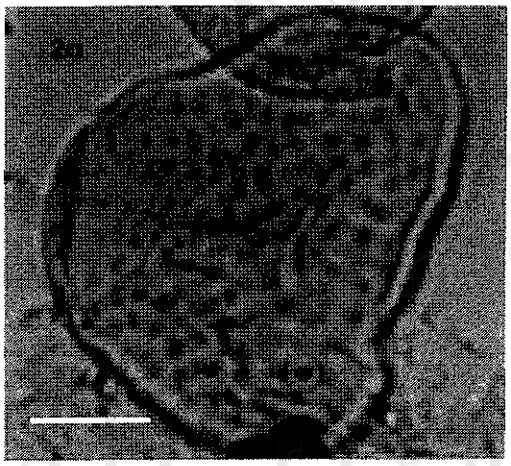


PLATE VIII: figure 1: *Lygodium* sp. a modern spore (LM); figure 1a: upper focus showing smooth proximal surface with a trilete mark; figure 1b: lower focus showing verrucate distal surface. The scale bars are 10 microns.

PLATE IX





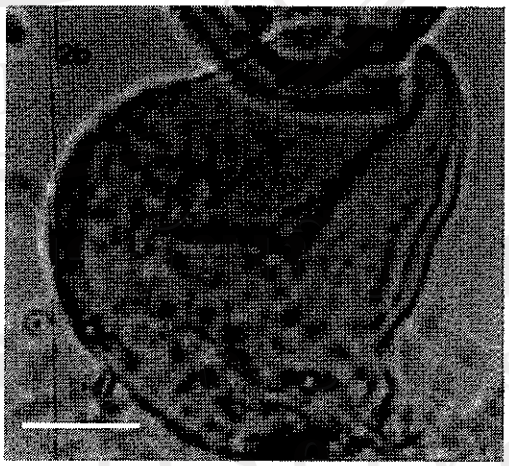


PLATE IX: figures 1: *Lygodium* sp., modern pollen, showing verrucate sculpture on distal side; figure 2: *Foveotriletes* sp. figure 2a and 2b are in different focuses. The scale bars are 10 microns.

Occurrence: The fossils were abundantly recovered from the U-1 and U-2 units of Chiang Muan coalfield in this study. Meesuk (1986) also reported these forms of sporomorph from the Mae Tip and Mae Moh basins in Lampang Province.

Genus: ***Foveotriletes*** van der Hammen ex Potonié

Type species: *Foveotriletes scrobiculatus* Potonié

1953, *Lygopodium* Couper, p. 18.

1956, *Foveotriletes* van der Hammen, p. 74 (nom. Nud.).

1956, *Foveotriletes* Potonié, p. 43.

1963, *Selagosporis* Krutzsch, p.

1984, *Foveotriletes* Pocknall & Mildenhall, p. 18.

***Foveotriletes* sp.**

Plate IX, figure 2.

Remarks: Specimen from this study is a trilete spore. It is triangular in polar view with bluntly truncated apices and concave inter-apices. The laesulae extend from the pole to nearly reaching the three apices. Foveolae are small less than 1 micron. This species differs from *Foveotriletes magaritae* reported from the Mae Moh (Watanasak, 1988), the *F. magaritae* has rounded apices and convex inter-apices with more densely foveolae. The species closely relates to New Zealand *Foveotriletes palaequetrus* reported by Pocknall and Mildenhall (1984). However, specimen from this study shows unclear to assign into species level.

Botanical affinity: This form of spore is clearly related to the extant spore of *Lycopodium* of the family of fern Lycopodiaceae and probably *Lycopodium fuegianum* (Pocknall and Mildenhall, 1984).

Occurrence: Rare from sample no. NH-9 and NH-19 of the Na Hong coalfield. Watanasak (1988) reported *Foveotriletes magaritae* from Mae Moh basin.

Genus: ***Laevigatosporites*** Ibrahim

Type species: *Lavigatosporites vulgaris* Ibrahim

Laevigatosporites haardtii (Potonié & Venitz) Thomson & Pflug

Plate X, figure 1-2.

1934, *Sporites haardti* Potonié & Venitz, p. 13, pl. 1, fig. 13.

1946, *Laevigatosporites gracilis* Wilson & Webster, p. 273, fig. 4.

1946, *Laevigatosporites ovatus* Wilson & Webster, p. 273, fig. 5.

1953, *Laevigatosporites haardti* (Potonié & Pflug) Thomson & Pflug, p. 59, pl. 3, figs. 27-38.

Description: The spore is a monolete bean-like grain with a smooth surface all over the grain. The size is from 40 to 76 microns in length and 30 to 58 microns in width. Its color is light yellow differing from the brown to dark brown fungal spores.

Remarks: The form genus *Laevigatosporites* Ibrahim was reserved for Carboniferous laevigate monolete spores by Potonié (1956). Similar spores from younger deposits were described and validated as *Polypodiaceaesporites* Thiergart. Manum (1962) criticized that geological age cannot be used as a diagnostic character for separating individual form genera. Since there are no morphological characteristics that distinguish *Polypodiaceaesporites* from *Laevigatosporites*, they must be regarded as synonyms and *Laevigatosporites* must be used because of its priority. The species in this genus are all laevigate monolete spores and do not show much variation in haptotypic features or in exine thickness. Any subdivision of this genus is usually made on overall size or on small variations in shape (Smith and Butterworth, 1967). There are three species of the genus *Laevigatosporites* including *L. haardtii* Thomson & Pflug, *L. ovatus* Wilson & Webster, and *L. gracilis* Wilson & Webster. The three species are all laevigate monolete spores. The definition of *L. haardtii* covers the size range from 20 to 70 microns, *L. ovatus* from 33 to 39 microns, and *L. gracilis* from 27

PLATE X

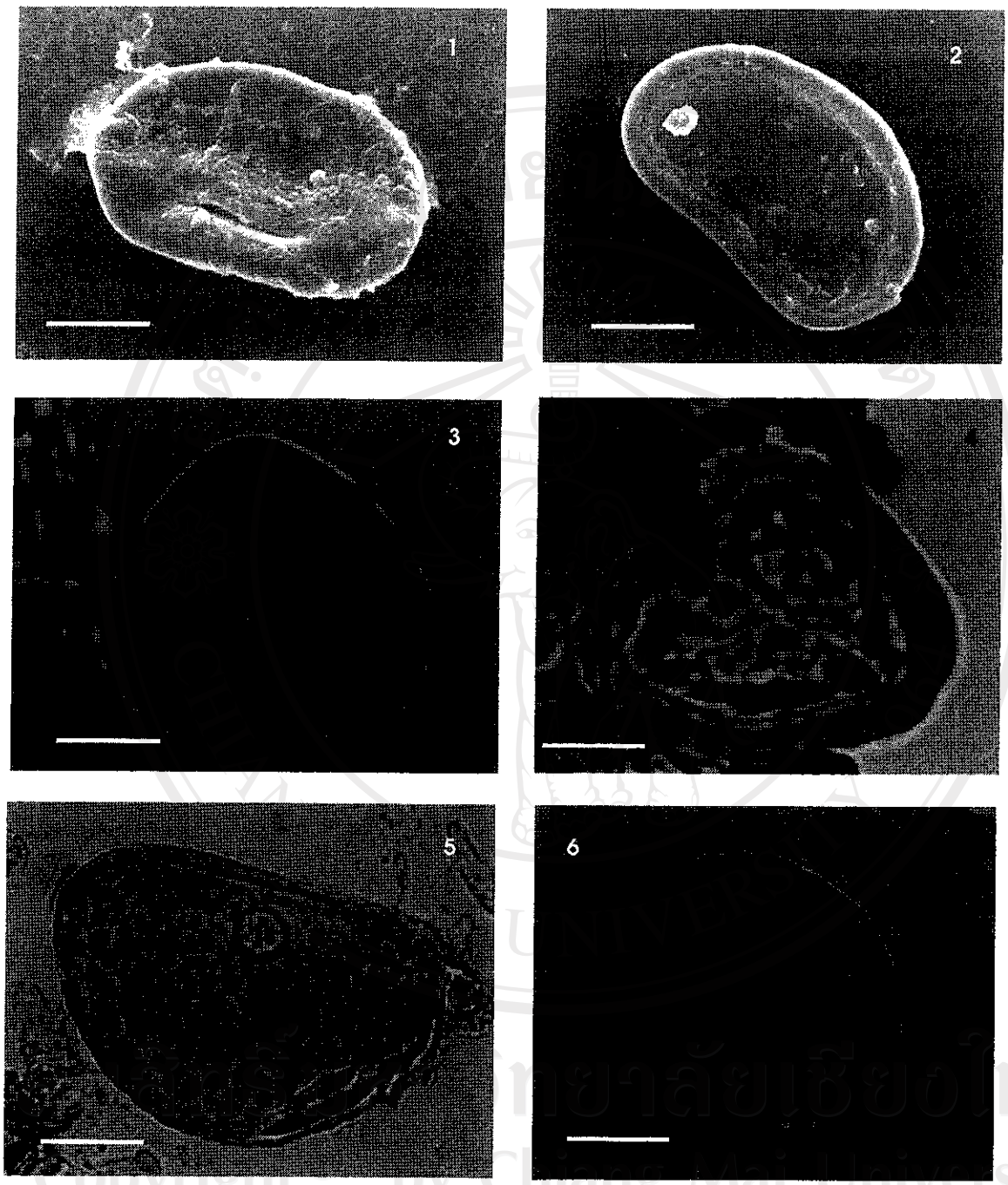


PLATE X: figures 1-2: *Laevigatosporites haardti* Ibrahim; figures 3-4: *Polypodiaceoisporites retirugatus* Muller; figure 5: *Polypodiisporites inangahuensis* Pocknall & Mildenhall; figure 6: *Polypodiisporites minimus* Pocknall & Mildenhall. The scale bars are 10 microns.

to 30 microns. The size range of the *L. haardtii* also covers the size ranges of *L. ovatus* and *L. gracilis*. Therefore, *Laevigatosporites haardtii* is used herein to representing all types of laevigate monolete spores excluding from particular laevigate monolete fungal spores. Reason of putting additional "i" for the former *L. haardti* being *L. haardtii* sees explanation in *Crassoretitriletes vanraadshoovenii*.

Botanical affinity: This fossil spore is comparable with extant spores of the fern *Niphidium* spp. and *Platycerium andinum*, Polypodiaceae (Tryon and Tryon, 1982).

Occurrence: Rare to abundant from almost productive samples from every basin in this study and also from other basins (Watanasak, 1988).

Genus: ***Polypodiaceoisporites*** Potonié ex Potonié

Type species: *Polypodiaceoisporites speciosus* Potonié ex Potonié

1951b, *Polypodiaceoisporites* Potonié, p. 136.

1956, *Polypodiaceoisporites* Potonié ex Potonié, p. 63

Polypodiaceoisporites retirugatus Muller

Plate X, figures 3-4.

1968, *Polypodiaceoisporites retirugatus* Muller, p. 7, pl. 1, fig. 8.

Remarks: This spore has a distinctive trilete form with a cingulum. Its shape is triangular to subtriangular with straight to slightly convex sides and rounded apices in polar view. The cingulum is smooth, 3 to 5 microns thick. The proximal surface has a trilete mark and rugulate sculpture with irregularly developed, smooth, and rounded rugae. The grain size ranges from 23 to 34 microns. These characteristics are described under the light microscope and differences between the distal and proximal sides were not recognizable from this study.

Botanical affinity: The fossil spore resembles spores of the extant fern *Pteris* spp., Pteridaceae.

Occurrence: Common in Ban Pa Kha and Na Hong. Rare in Mae Moh, Na Sai, and Mae Lamao in this study. It was also reported from Mae Moh by Watanasak (1988) and common in Krabi (Songtham, 1996).

Genus: ***Polypodiisporites*** Potonié emend. Pocknall & Mildenhall

Type species: *Polypodiisporites favus* Potonié

1931c, *Sporonites* Potonié.

1931d, *Polypodiisporonites* Potonié.

1949, *Polypodiidites* Ross, p. 33.

1953, *Verrucatosporites* Pflug & Thomson in Thomson & Pflug, p. 59.

1953, *Reticuloidosporites* Pflug in Thomson & Pflug, p. 60.

1956, *Verrumonoletes* van der Hammen, p. 116.

1971, *Polypodiisporites* Potonié emend. Khan & Martin, p. 475-480.

1984, *Polypodiisporites* Potonié emend. Pocknall & Mildenhall, p. 21.

Remarks: There are various contentions concerning the genus *Polypodiisporites*. Srivastava (1971) differentiated the genera *Polypodiisporites*, *Polypodiidites*, and *Verrucatosporites*, though these genera were grouped as being one genus, *Polypodiisporites*, by Khan and Martin (1971). Pocknall and Mildenhall (1982) put *Polypodiisporonites* Potonié and *Reticuloidsporites* Pflug into the genus *Polypodiisporites* since they are all verrucate monolete sporomorphs. It is considered that *Verrumonoletes* van der Hammen should also be put into the genus *Polypodiisporites*.

Polypodiisporites inangahuensis Couper emend. Pocknall & Mildenhall

Plate X, figure 5.

1953, *Polypodiidites inangahuensis* Couper, p. 29, pl. 2, fig. 16.

1956, *Polypodiisporites inangahuensis* (Couper) Potonié, p. 79.

1959, *Verucatosporites inangahuensis* (Couper) Krutzsch, p. 205.

1984, *Polypodiisporites inangahuensis* Couper emend. Pocknall & Mildenhall, p. 21, pl. 4, figs. 1-2.

Dimensions: 30 to 49 microns.

Remarks: Pocknall and Mildenhall (1984) explained that many workers used *Polypodiisporites inangahuensis* for many verrucate monolete spores because the first illustration of the holotype was a line drawing that confused workers. The species was later photographed and redescribed (Couper, 1960; see also Pocknall and Mildenhall, 1984). Pocknall and Mildenhall (1984) also listed synonyms that were rejected from *Polypodiisporites inangahuensis*.

Botanical affinity: probably Polypodiaceae.

Occurrence: Rare to common in Na Hong and Ban Pa Kha overburden unit.

Polypodiisporites minimus (Couper) Khan & Martin

Plate X, figure 6; Plate XI, figures 1-2.

1960, *Polypodiidites minimus* Couper, p. 40, pl. 1, figs. 9-10.

1971, *Polypodiisporites minimus* (Couper) Khan & Martin, p. 478.

1984, *Polypodiisporites minimus* (Couper) Khan & Martin emend. Pocknall & Mildenhall, p. 22, pl. 4, figs. 3-4.

Remarks: Pocknall and Mildenhall (1984) pointed out that this species is distinct from other species of *Polypodiisporites* because it is small, has a short laesura and lacks prominent laesura ridges. Detail description sees Pocknall and Mildenhall (1984).

Botanical affinity: Closely related to species of *Nephrolepis*, Davalliaceae.

Occurrence: Common in Ban Pa Kha overburden unit.

Polypodiisporites radiatus Pocknall & Mildenhall.

Plate XI, figure 3.

1984, *Polypodiisporites radiatus* Pocknall & Mildenhall, p. 23, pl. 5, figs. 1-3.

PLATE XI

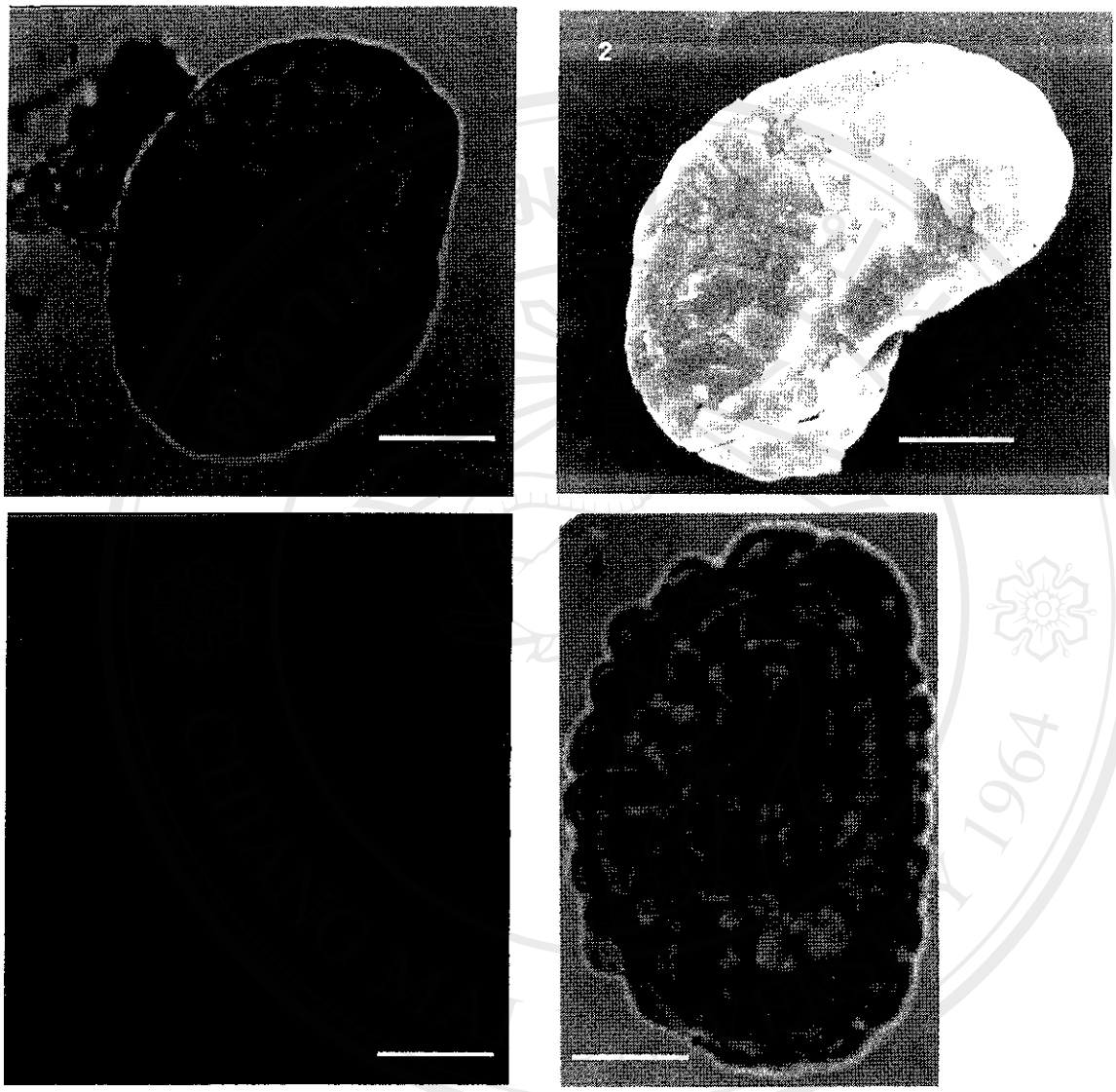


PLATE XI: figures 1: *Polypodiisporites minimus* Pocknall & Mildenhall; figures 2-3: *Polypodiisporites radiatus* Pocknall & Mildenhall; figure 4: *Polypodiisporites* sp. Indet. The scale bars are 10 microns.

Remarks: Pocknall and Mildenhall (1984) notified that this species has larger and more elongate verrucae arranged radially out from the laesura. Detail description sees Pocknall and Mildenhall (1984).

Botanical affinity: Polypodiaceae.

Occurrence: Common in Ban Pa Kha overburden unit.

***Polypodiisporites* sp.**

Plate XI, figure 4.

Remarks: Spore is about 45 microns length and 30 microns height. Length of laesura is about a half of the spore length. Sculpture is verrucate.

Occurrence: Very rare in sample no. NH-10 of Na Hong coalfield.

Genus: ***Striatriletes*** van der Hammen

Type species: *Striatriletes susannae* van der Hammen

1956, *Striatriletes* van der Hammen, p. 106.

1962, *Cicatricosisporites* Potonié & Gelletich in Biswas: p. 35.

1962, *Schizaeaceaesporites* Baksi, p. 19.

1962, *Parkeriaceaesporites* Baksi, p. 20.

1964, *Anemia* Ghosh *et al*, p. 24-26.

1964, *Mohria* Ghosh *et al*, p. 26.

1968, *Magnastriatites* Germeraad *et al*, p. 288.

Striatriletes susannae van der Hammen

Plate XII, figure 1.

1956, *Striatriletes susannae* van der Hammen, p. 107, pl. 2, figs. 5.

1963, *Cicatricosisporites grandiosus* Kedves & Porta, p. 59, pl. 7, figs. 2-3.

1968, *Magnastriatites howardi* Germeraad *et al*, p. 288, pl. 3, fig. 1.

1972, *Magnastriatites venustus* Salujha *et al*, p. 272, pl. 1, fig. 16.

1972, *Cicatricosisporites venustus* Salujha *et al*, p. 272, pl. 1, figs. 22-23.

PLATE XII

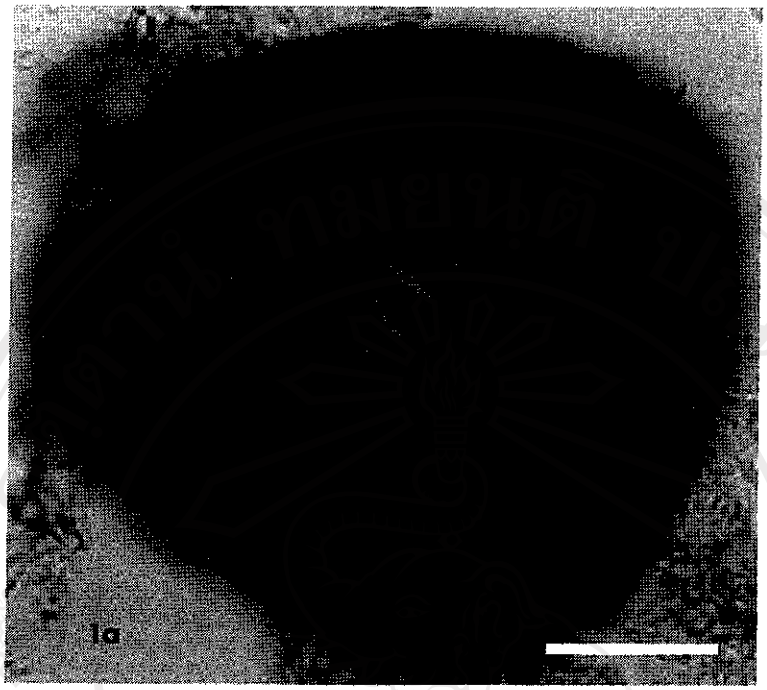


PLATE XII: figure 1: *Striatriletes susannae* van der Hammen; figures 1a and 1b are in different focuses; figure 1a: upper focus showing costate pattern on distal surface; figure 1b: medium focus with a blur trilete mark. The scale bars are 15 microns.

1979, *Striatriletes susannae* van der Hammen emend. Kar, p. 21-25, pl. 1, fig. 13.

1980, *Magnastriatites grandiosus* Kedves & Porta emend. Dueñas, p. 329-331, pl. 1, figs. 1-3.

Remarks: Various reports have assigned different names to this trilete spore with costate surfaces. These include *Striatriletes susannae*, *Cicatricosisporites grandiosus*, *Magnastriatites howardi*, *Cicatricosisporites venustus*, *Magnastriatites venustus*, and *Magnastriatites grandiosus*. The name *Striatriletes susannae* used herein is, however, considered to be following the principle of priority.

Botanical affinity: Kar and Ambwani (1991) studied and discussed fossil and extant spores having similarities including fossil *Striatriletes susannae*, *Striatriletes multicostatus*, *Striatriletes microverrucosus*, and *Malayaeaspora costata* and recent spores of *Ceratopteris thalictoides* and *Mohria caffrorum*. *Ceratopteris thalictoides* spores closely resemble *Striatriletes* especially *Striatriletes microverrucosus*. Kar and Ambwani further suggested that *Striatriletes* originated in the Indo-Malayan region during Middle to Upper Eocene time. It soon became pan-tropical and dominated in Oligocene and Miocene time in the flood plains and river sides of the tropics.

Occurrence: Rare in the overburden unit of Ban Pa Kha (sample OU-15) and lower coal zone of Chiang Muan coalfield (sample LS-B-1).

4.4 GYMNOSPERMIC POLLEN

Genus: ***Inaperturopollenites*** Pflug & Thomson in Thomson & Pflug

Type species: *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug

1934, *Pollenites magnus dubius* Potonié & Venitz, p. 17.

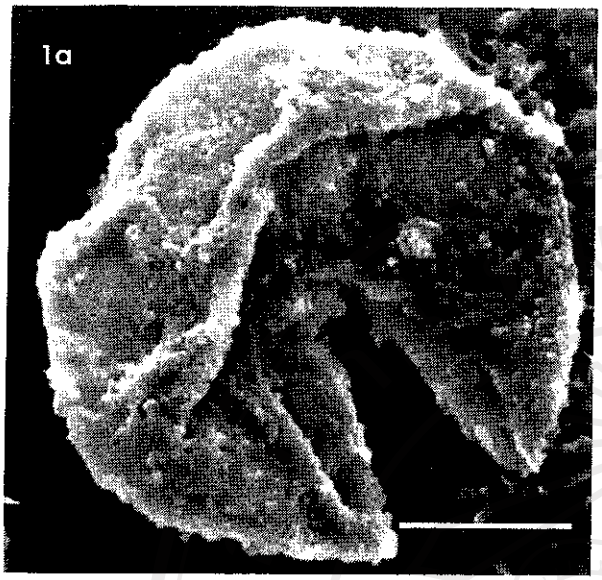
1953, *Inaperturopollenites* Potonié & Venitz ex Thomson & Pflug, p. 64.

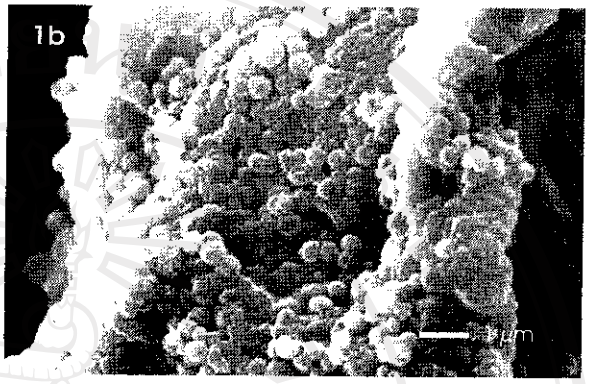
Inaperturopollenites dubius Potonié & Venitz ex Thomson & Pflug

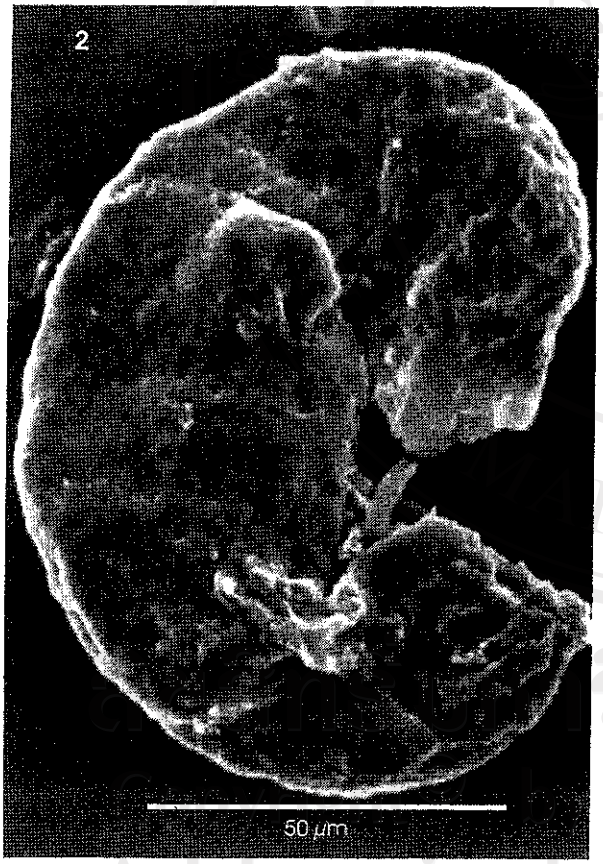
Plate XIII, figure 1.

1934, *Pollenites magnus dubius* Potonié & Venitz, p. 17, pl. 2, fig. 21.

PLATE XIII







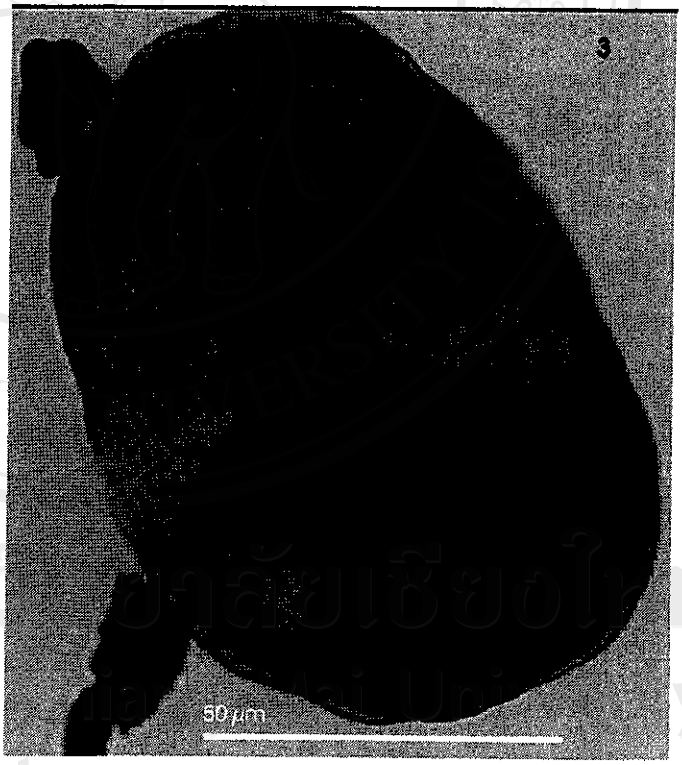


PLATE XIII: figure 1: *Inaperturopollenites dubius* Pflug & Thomson; figure 2-3: *Piceaepollenites* sp.; Figure 2: (SEM); figure 3: LM. All scale bars are 10 microns except where otherwise stated.

1953, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug, p. 64, pl. 4, fig. 89, pl. 5, figs. 1-13.

Remarks: *Inaperturopollenites dubius* represents a big group of inaperturate pollen comparable to the extant pollen belonging to conifer families Taxodiaceae and Cupressaceae. Thomson and Pflug (1953) considered *Sequoioidites*, *Taxodoidites*, and *Laricoidites*, assigned by Potonié and others, as being instead *Inaperturopollenites* since all of them have no aperture on their grains. The ornament of the fossil pollen under scanning electron microscope is densely verrucate, more closely comparable with the extant pollen of *Juniperus* and *Taxodium*. The fossil grains are often split with grain size ranging from 29 to 40 microns from this study.

Botanical affinity: The characteristics of the fossil pollen are comparable to extant pollen of Taxodiaceae and Cupressaceae.

Occurrence: Common in the lower coal zone to upper coal zone of Ban Pa Kha coalfield, abundant in the unit B of Na Hong coalfield.

Genus: ***Piceaepollenites*** Potonié

Type species: *Piceaepollenites alatus* Potonié

1931d, *Piceaepollenites* Potonié, p. 28.

1969, *Piceaepollenites* Hart, p. 271-289.

***Piceaepollenites* sp.**

Plate XIII, figures 2-3.

Remarks: General morphology of *Piceaepollenites* is of a large bisaccate pollen ranging in size from 100 to 125 microns. Comparison with *Pinuspollenites* shows that *Piceaepollenites* is clearly bigger. To differentiation among the fossil pollen of *Picea*, *Pinus*, and *Abies* see Weir and Thurston (1977).

Botanical affinity: The fossils resemble extant *Picea* pollen of the family Pinaceae. *Picea* is an evergreen conifer consisting of 34 species found throughout the northern temperate hemisphere except in Africa. It is absent from Thailand today.

Occurrence: Common from the lower and upper coal zones of Ban Pa Kha and common from unit B of Na Hong coalfields. These forms of *Piceaepollenites* were reported from Late Oligocene to Middle Miocene throughout Thailand (Watanasak, 1988; Songtham, 1996).

Genus: ***Pinuspollenites*** Raatz ex Potonié

Type species: *Pinuspollenites labdacus* Raatz ex Potonié

1937, *Pollenites labdacus* Raatz, p. 15.

1958, *Pinuspollenites* Raatz ex Potonié, p. 62.

***Pinuspollenites* sp.**

Plate XIV, figures 1-2.

Remarks: *Pinuspollenites* typically has a constriction between central body and bladders. Its distinctive characteristic is air chambers inside the pollen grains, clearly visible under a light microscope. The size ranges from 55 to 68 microns which distinctively smaller than *Piceaepollenites*.

Botanical affinities: *Pinuspollenites* is an ancestral form of extant *Pinus* of the family Pinaceae. *Pinus* is an evergreen conifer having 93 species, all in the northern hemisphere, occurring mainly in northern temperate regions, extending in America and eastern Asia to the seasonal tropics. There are two species of *Pinus* in Thailand dominant in mountains in the northern, northeastern, and western areas. They are *Pinus merkusii* and *Pinus kesiya* representing cold climate conditions depending on altitude of the mountains which are divisible into altitudinal zones (Santisuk, 1997).

PLATE XIV

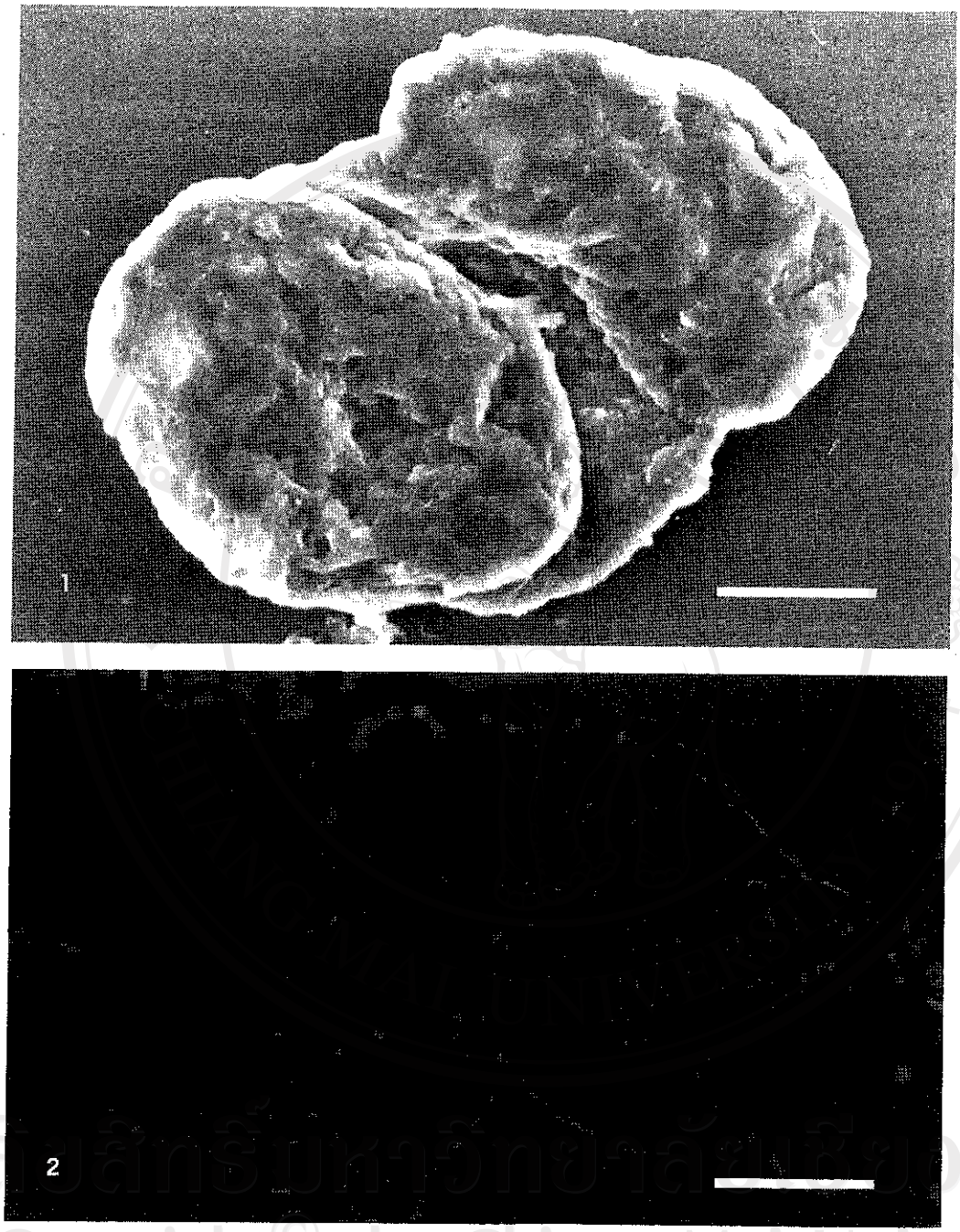


PLATE XIV: figures 1-2: *Pinuspollenites* sp.; figure 1: SEM; figure 2: LM; The scale bars are 10 microns.

Occurrence: Fossil pollen grains of *Pinuspollenites* are widely distributed over a wide age ranges. They are abundant in Na Hong, Ban Pa Kha, and Mae Lamao in this study. They are also from other localities but are rare to common including Na Sai, Mae Moh. Watanasak (1988) reported this genus from Late Oligocene to Middle Miocene throughout Thailand including Krabi (Songtham, 1996).

Genus: ***Podocarpidites*** Cookson ex Couper

Type species: *Podocarpidites ellipticus* Cookson ex Couper

1947, *Disaccites* (*Podocarpidites*) Cookson, p. 131.

1953, *Podocarpidites* Couper, p. 35.

***Podocarpidites* sp.**

Plate XV, figure 1.

Remarks: *Podocarpidites* was described as bisaccate pollen. The outline of the central body is oval to polygonal with large bladders. The depth of central body is always less than that of the bladders (Ting, 1968). This genus is known from the Jurassic of Australia and occurs in Mesozoic and/or Tertiary sediments of North America, Europe, East Asia, Papua New Guinea, Australia and New Zealand (Dettmann, 1963; Hughes, 1969; Penny, 1969; Filatoff, 1975; Tschudy and others, 1984; Pocknall and Mildenhall, 1984).

Botanical affinities: The fossil pollen is attributable to modern pollen of *Podocarpus* of the family Podocarpaceae. *Podocarpus* is a genus of evergreen trees and shrubs consisting of 94 species occurring in southern temperate regions and extending north into the tropics.

Occurrence: Rare in the overburden unit of Ban Pa Kha coalfield (sample OB-1) and rare in many basins of Thailand (Watanasak, 1988).

PLATE XV

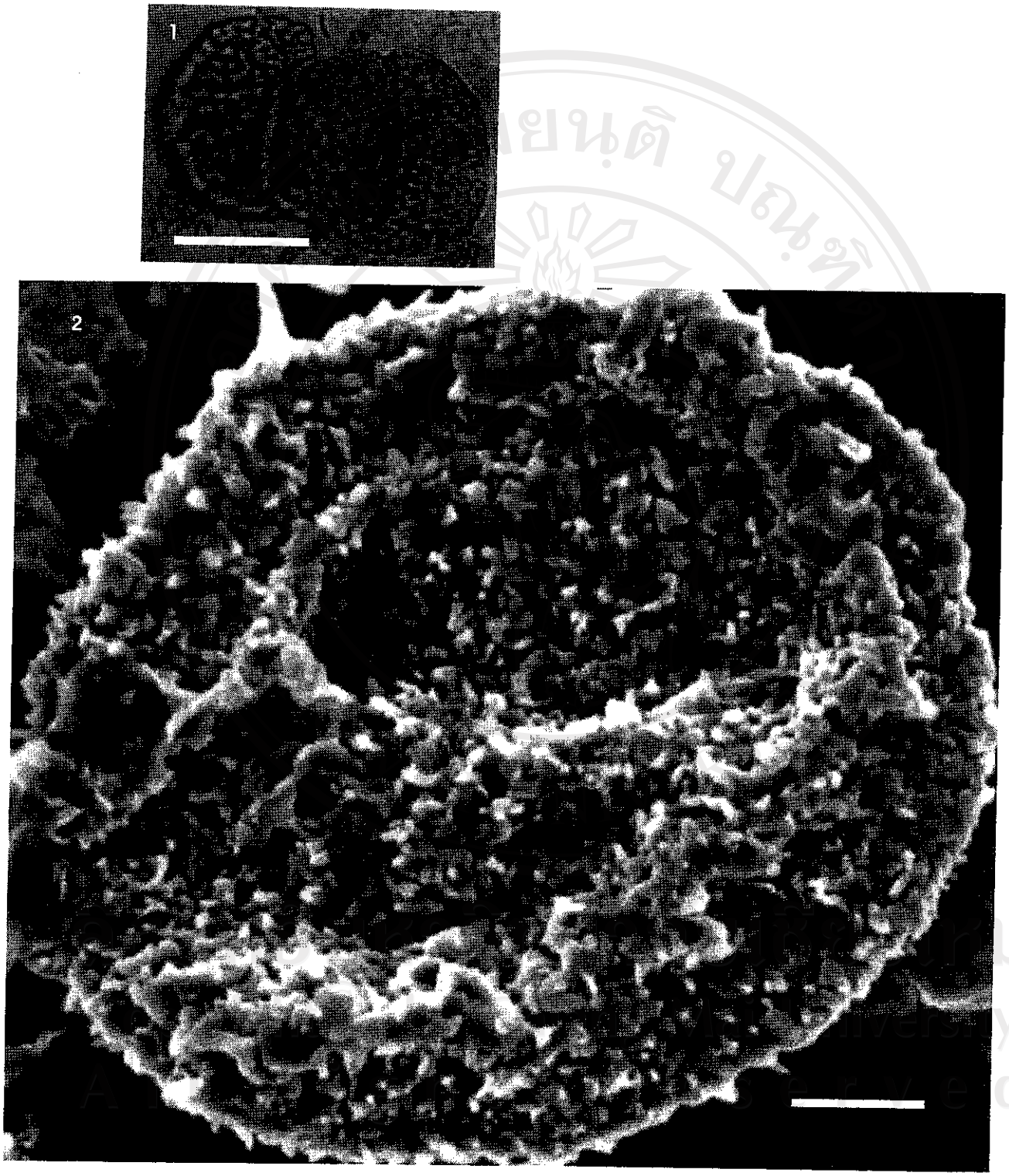


PLATE XV: figure 1: *Podocarpidites* Couper (LM); figure 2: *Tsugaepollenites igniculus* Potonié & Venitz (SEM). The scale bars are 10 microns.

Genus: ***Tsugaepollenites*** Potonié & Venitz ex Potonié

Type species: *Tsugaepollenites igniculus* (Potonié) Potonié & Venitz

Tsugaepollenites igniculus (Potonié) Potonié & Venitz

Plate XV, figure 2, plate XVI, figures 1.

1931c, *Sporonites igniculus* Potonié, p. 556, fig. 2.

1934, *Tsugaepollenites igniculus* Potonié & Venitz, p. 17, fig. 8.

1953, *Zonalapollenites igniculus* Thomson & Pflug, p. 66, pl. 4, figs. 75-79.

1958, *Tsugaepollenites igniculus* Potonié & Venitz ex Potonié, p. 48.

Remarks: There is considerable confusion regarding the use and content of the genus *Tsugaepollenites* and *Zonalapollenites*. Pocock (1968) explained that *Tsugaepollenites* and *Zonalapollenites* both circumscribe the species *igniculus* and both are intended to include pollen of a type produced by *Tsuga*. Pocock also pointed out that genus *Zonalapollenites* is regarded as an illegitimate name because of no bisynonym is given. *Tsugaepollenites* is, thus, used here because of its priority.

Botanical affinities: Fossil pollen *Tsugaepollenites igniculus* compare well to the extant *Tsuga* of the family Pinaceae. There are about 10 species of the genus *Tsuga*, some native to temperate North America, others to eastern Asia.

Occurrence: Rare to common in the Na Hong and Ban Pa Kha coalfields. Watanasak (1988) also reported from Ban Pu and Nong Ya Plong basins.

4.5 ANGIOSPERMIC POLLEN

Extant genus: ***Abelmoschus*** (Malvaceae)

cf. *Abelmoschus* sp.

Plate XVII, figure 1.

Remarks: A specimen from this study clearly shows periporate form looking similar to the extant pollen belonging to the family Malvaceae. The grain is covered by hairly

PLATE XVI

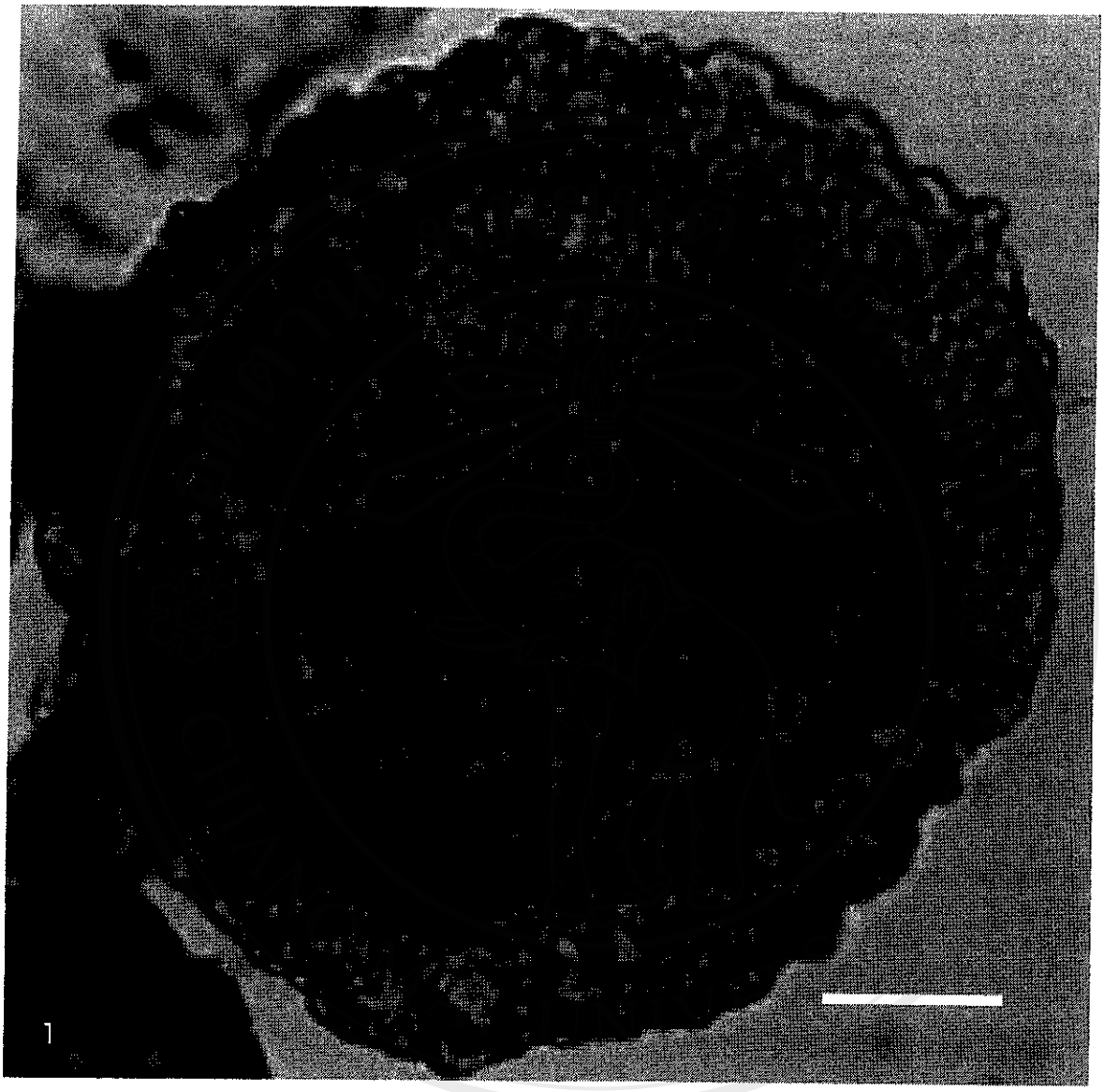


PLATE XVI: figure 1: *Tsugaepollenites igniculus* Potonié & Venitz (LM). The scale bar is 10 microns.

PLATE XVII

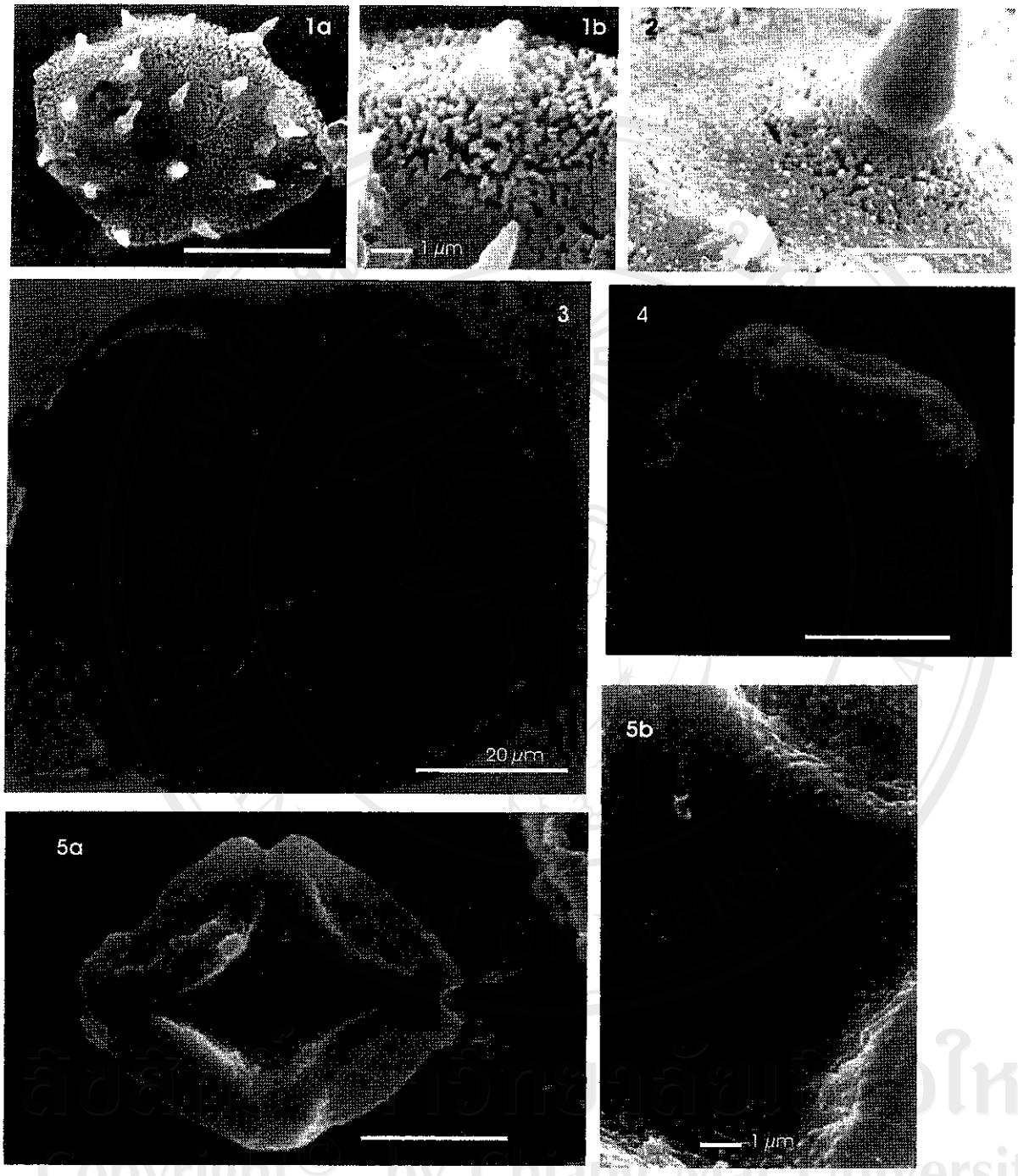


PLATE XVII: figure 1: *Abelmoschus* sp. (fossil pollen); figure 2: *Abelmoschus moschatus* (modern pollen); figure 3: *Alangiopollis* Krutzsch.; figures 4-5: *Alnipollenites verus* Potonié. All scale bars are 10 microns except where otherwise stated.

surface looking like a carpet floor with spines. Some apertures are recognizable with about 2.5 to 3 microns in diameter. The grain was probably broken but general features corresponding to recent species of *Abelmoschus* cf. *A. moschatus*, a species of Malvaceae. However, the recent species is much bigger than the fossil (Plate XVII, figure 2).

Botanical affinity: *Abelmoschus* of the family Malvaceae.

Occurrence: Common in Na Sai coalfield.

Genus: ***Alangiopollis*** Krutzsch

Type species: *Alangiopollis barghoornianus* (Traverse) Krutzsch

1955, *Alangium barghoornianus* Traverse.

1957, *Alangium javanicoides* Cookson.

1962, *Alangiopollis barghoornianus* Krutzsch.

1962, *Paleocaesalpiniaceaepites* Biswas.

1966, *Margocolporites* Ramanujam, p. 173-177, pl. 4, fig. 64-77.

1966, *Clavastephanocolporites ambigens* Leidelmeyer.

1969, *Pellicierroipollis langenheimii* Sah and Kar, p. 133, pl. 2, fig. 58-60.

1969, *Alangiopollis eocaenicus* Krutzsch.

1979, *Alangiopollis arcotense* Navale and Misra.

1982, *Lanagiopollis regularis* Morley, p. 68, pl. 1, pl. 3-4.

1996, *Clavastephanocolporites meleosus* Martin and others, p. 115, pl. 3, fig. 1-16.

***Alangiopollis* sp.**

Plate XVII, figure 3.

Remarks: Krutzsch (1962) instituted the form genus *Alangiopollis* on the morphological basis of trizonocolporate fossil pollen characterized by short, usually gaping exocolpi and large, more or less circular endopores and a reticulate-striate sculpture. Morley (1982) proposed three form genera including *Alangiopollis*

Krutzsch, *Lanagiopollis* Morley, and Form-genus A Morley to adequately cover the variation in the dispersed pollen having affinity with modern pollen of the genus *Alangium*, Alangiaceae. Because only one fossil grain was discovered under the light microscope it is not possible to say which form genus it should be placed in. On the principle of priority, *Alangiopollis* here is provisionally used as the fossil is comparable to the extant pollen of *Alangium*.

Botanical affinity: The form genus *Alangiopollis* Krutzsch is an ancestral form of the extant genus *Alangium* of the monogeneric family Alangiaceae. It occurs in tropical and subtropical regions of Africa, India, China, Japan, Southeast Asia, Australia, and some Pacific islands (Reitsma, 1970; Morley, 1982; Sharma and Gupta, 1996; Martin and others, 1996).

Occurrence: One grain of *Alangiopollis* came from the overburden unit of Ban Pa Kha coalfield in this study. Watanasak (1988) reported from Mae Moh.

Genus: ***Alnipollenites*** Potonié

Type species: ***Alnipollenites verus*** Potonié

Alnipollenites verus Potonié

Plate XVII, figures 4-5; Plate XVIII, figures 1-5.

1931a, *Pollenites verus* Potonié, p. 332, pl. 2, fig. 40.

1931b, *Alnipollenites verus* Potonié, p. 3, pl. 1, fig. 14.

1953, *Polyvestibulopollenites verus*, Thompson & Pflug, p. 90, pl. 10, fig. 62-76.

Remarks: The validity of publication of this species was discussed by Frederiksen and Ames (1979). The differentiation of this species from *Ulmipollenites krempii* is its possession of distinct arci, which *Ulmipollenites krempii* lacks (Farabee and Canright, 1986). The specimens in this study have a smooth surface under light microscope with strongly developed arci. The fossils have four to six apertures but five apertures are

PLATE XVIII

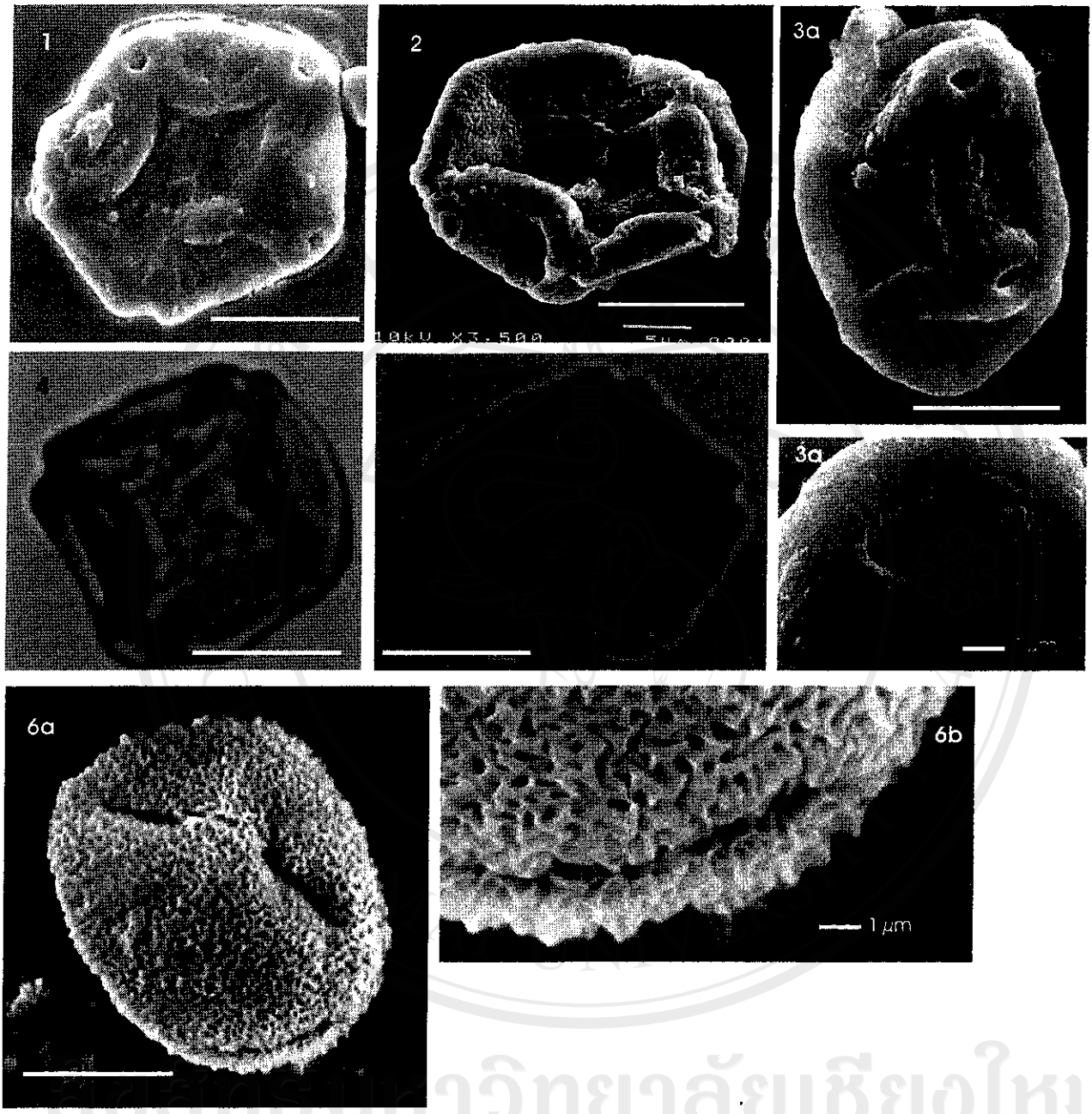


PLATE XVIII: figures 1-5: *Alnipollenites verus* Potonié; figures 1-3: SEM; figures 4-5: LM; figure 6: *Calophyllum* sp. (fossil pollen). All scale bars are 10 microns except where otherwise stated.

general. Morphology under scanning electron microscope shows some differences on the surface ornamentations among the forms from different localities. It varies from finely granulate to finely micro-echinate showing some differences in space between the sculptural elements. However, grain size falls within the range of 23 to 29 microns in all localities.

Botanical affinity: *Alnipollenites verus* is definitely comparable to recent pollen of *Alnus* of the family Betulaceae. The *Alnus* is a genus of deciduous trees which are common in wet places widely spread in the northern hemisphere from Northern Africa in the South up to 70° N in Europe and Asia. In south America, the species occur south from the equator in Peru as well as in the northern part of Argentina up to latitude 25° S. They usually grow in cold and moderate climate conditions, but can also be found in the warm regions of the Mediterranean. *Alnus* grows on the banks of streams and lakes in a humid habitat as a moisture-loving taxon. A few sporadic trees of *Alnus nepaulensis* have been observed recently along the sandstone cliff of Phu Luang Wildlife Sanctuary in northeastern Thailand (Songtham and others, 2000).

Occurrence: Abundant in Na Hong, Ban Pa Kha, and Mae Lamao coalfields, Oligocene to Early Miocene sediments. Watanasak (1988) also reported from Ban Pu and Nong Ya Plong basins.

Extant Genus: ***Calophyllum*** (Guttiferae)

***Calophyllum* sp.**

Plate XVIII, figure 6.

Remarks: This is a tricolporate fossil pollen form with finely reticulate surface sculpture. The colpi extend passed distinct pores to nearly reach the poles. Size ranges

from about 18 to 25 microns, about the same size as the extant species *Calophyllum inophyllum* (Plate XIX, figures 1-2).

Botanical affinity: It compares well to the recent pollen of *Calophyllum inophyllum* of the family Guttiferae. The genus is cosmopolitan in the tropical belt.

Occurrence: Common in Na Sai and the U-1 and U-2 units of Chiang Muan coalfields.

Genus: ***Caryapollenites*** Raatz ex Potonié

Type species: *Caryapollenites simplex* (Potonié) Raatz

1931b, *Pollenites simplex* Potonié, p. 3.

1937, *Carya-pollenites* Raatz, p. 19.

1950, *Carya-pollenites* Potonié *et al.*, p. 50.

1953, *Subtriporopollenites* Thompson & Pflug, p. 85.

1960, *Caryapollenites* Potonié, p. 123.

Caryapollenites simplex (Potonié) Raatz

Plate XIX, Figures 3-4.

1931b, *Pollenites simplex* Potonié, p. 3.

1953, *Subtriporopollenites simplex* Thompson & Pflug, p. 85.

1960b, *Caryapollenites simplex* Potonié, p. 123, pl. 7, fig. 162.

Remarks: Specimens of *Caryapollenites simplex* have 3 pores with a circular outline in polar view. The pores are situated in an equatorial zone which is slightly shifted to one side of the pollen grain. The pore is sunken, not protruding as in *Juglanspollenites* and *Pterocaryapollenites*. The grain size ranges from 24 to 42 microns. It is easy to recognize even under the light microscope. Surface ornamentation of the pollen grains of the family Juglandaceae is somewhat smooth under the light microscope but under the scanning electron microscope shows the surface to have micro-echinate elements

PLATE XIX

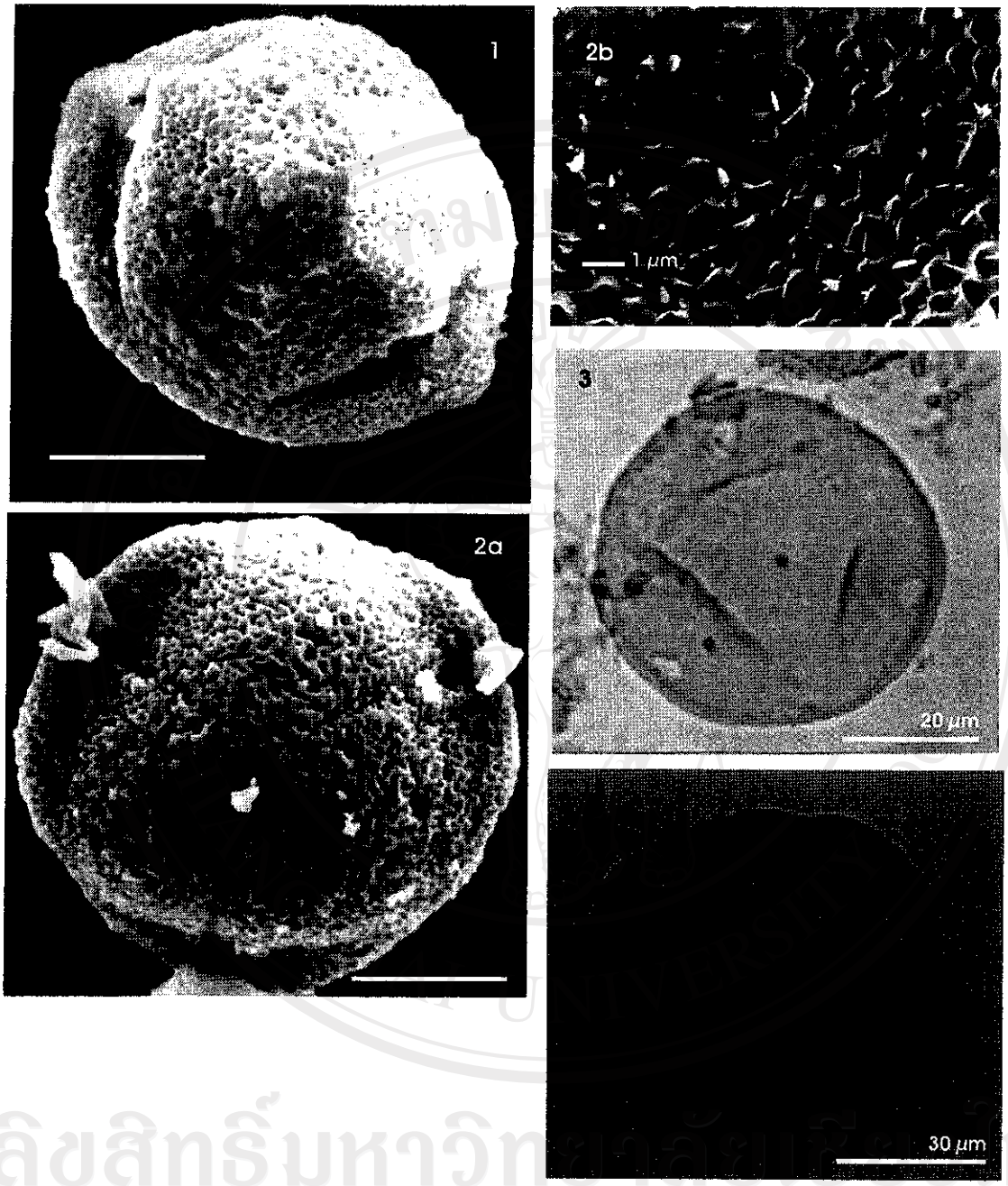


PLATE XIX: figures 1-2: *Calophyllum inophyllum* (modern pollen); figure 1:equatorial view; figure 2a: polar view; figure 2b: high magnefication showing detail surface sculpture; figure 3-4: *Caryapollenites simplex* Raatz showing polar view with three pores. All scale bars are 10 microns except where otherwise stated.

(Bos and Punt, 1991). Recent *Carya* pollen grains may contain 4 pores and the outline in the polar view may vary from elliptic to circular.

Botanical affinity: The fossils compare well to extant pollen of *Carya* belonging to the family Juglandaceae. It is a genus of trees comprising 17 species found in eastern Asia and North America.

Occurrence: Only rare occurrences came from Na Hong and Ban Pa Kha coalfields. This genus was reported from Ban Pu, Nong Ya Plong (Meesuk, 1986; Watanasak, 1988) and Krabi basins (Songtham, 1996).

Extant Genus: ***Combretum*** (Combretaceae)

***Combretum* sp.**

Plate XX, figure 1-2.

Remarks: The fossils are characterized by a tricolporate form with long colpi nearly reaching the poles and prominent pseudocolpi. Three pores are located in the equatorial zone. The surface ornamentation is slightly scabrate covering the whole grain. The size ranges about 22 microns along the polar axis and about 18 microns in equatorial diameter.

Comparison: Most features of the fossils resemble the extant *Combretum quadrangulare*, except the modern species is obviously smaller than the fossil. The surface sculpture of the recent species is a little bit more heavily scabrate (Plate XX, figure 3). The fossil and recent pollen have prominent tricolporate forms with pseudocolpi as a typical feature of the pollen belonging to the family Combretaceae.

Botanical affinity: The fossils compare well to the modern genus *Combretum* of the family Combretaceae.

PLATE XX

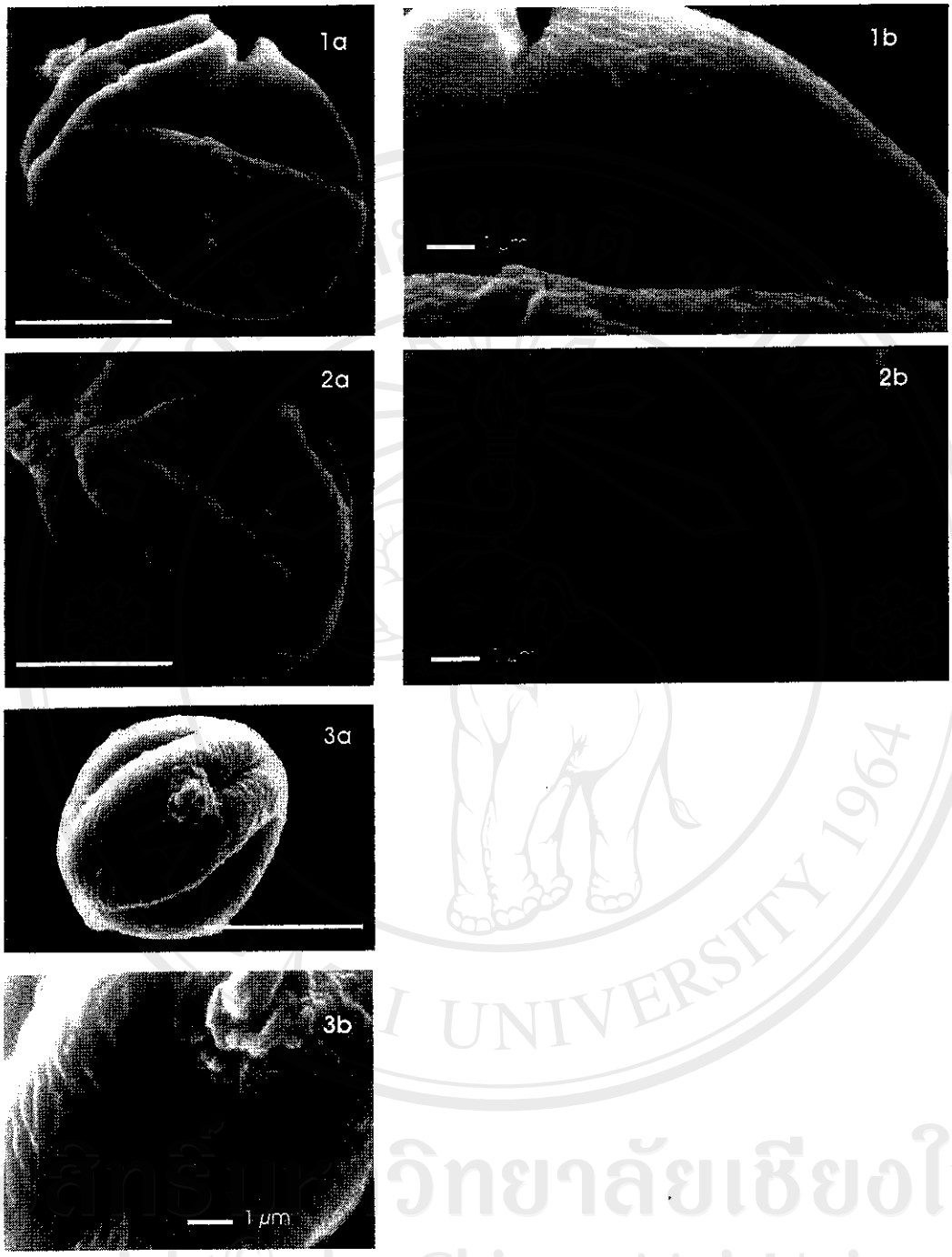


PLATE XX: figures 1-2: *Combretum* sp. (fossil pollen); figure 3: *Combretum quadrangulare* (modern pollen). All scale bars are 10 microns except where otherwise stated.

Occurrence: The fossils commonly occur in the lower coal zone of Chiang Muan coalfield.

Genus ***Faguspollenites*** Raatz

Type species: *Faguspollenites verus* Raatz

1937, *Faguspollenites* Raatz, p. 23.

***Faguspollenites* sp.**

Plate XXI, figures 1-2.

Remarks: *Faguspollenites* is a tricolporate pollen with endopores and clearly visible under the scanning electron microscope. The surface sculpturing of the fossils is impossible to recognize under the light microscope because of the very fine patterns. Under scanning electron microscope, the surface shows elongated rod-like elements with rounded ends, sometimes bifurcated. These features were also described by Gortemaker (1986) on both fossil and recent pollen species. The fossil specimens from this study are more or less 25 microns in equatorial diameter.

Botanical affinity: Morphology of the fossil *Faguspollenites* matches with the recent pollen *Fagus* of the family Fagaceae. *Fagus* is a genus of trees consisting of 10 species, occurring in northern temperate regions.

Occurrence: Common to abundant occurrences in the upper coal zone of Ban Pa Kha coalfield. Watanasak (1988) reported this genus from Late Oligocene to Middle Miocene throughout Thailand.

Genus: ***Florschuetzia*** Germeraad *et al.*

Type species: *Florschuetzia trilobata* Germeraad *et al.*

1968, *Florschuetzia trilobata* Germeraad and others, p. 306, pl. 7, figs. 2-4.

1968, *Florschuetzia semilobata* Germeraad and others, p. 307, pl. 7, figs. 6-8.

1968, *Florschuetzia levipoli* Germeraad and othets, pl. 307, pl. 7, fig. 9, pl. 8, figs. 1-2.

1968, *Florschuetzia meridionalis* Germeraad and others, p. 308, pl. 8, figs. 4-5.

1984, *Florschuetzia claricolpata* Yamanoi, p. 349, pl. 1, figs. 1-5; pl. 2, figs. 1-7; pl. 3, figs. 1-4.

cf. *Florschuetzia* sp.

Plate XXI, figure 3.

Remarks: Only one grain of cf. *Florschuetzia* from Chiang Muan coalfield was discovered under the scanning electron microscope (SEM). It is about 40 microns along the polar axis and about 30 microns in equatorial diameter. The grain under SEM is smooth on the polar caps and slightly rugulate to verrucate in the equatorial area. The specimen does not match any previous descriptions of *Florschuetzia* (Germeraad and others, 1968; Yamanoi, 1984) and is probably a new species. Its size is much smaller than the modern pollen *Sonneratia caseolaris* (Plate XXII, figure 1). The precise identification is impossible since there is only one specimen. The form genus *Florschuetzia* used here with uncertainty needs more investigation.

Botanical affinity: *Florschuetzia trilobata* was suggested as extinct ancestor of the recent genus *Sonneratia* and probably also evolved from a fossil *Lagerstroemia*. Morphology of *Florschuetzia semilobata* seems to match the pollen of Sonneratiaceae but matching with recent species has not been possible. *Florschuetzia levipoli* and *Florschuetzia meridionalis* are comparable to extant *Sonneratia caseolaris* and *Sonneratia alba* respectively. Only two the later species are acceptable as mangrove elements, the two former are not. Yamanoi (1984) claimed *Florschuetzia claricolpata* as a mangrove element since it occurred in association with a brackish water faunal assemblage. In conclusion, species identification is needed to determine if it is a mangrove element or not.

Occurrence: The one grain of cf. *Florschuetzia* came from the lower massive coal zone (sample number LM-A-6) of Chiang Muan coalfield. Watanasak (1988) reported

PLATE XXI

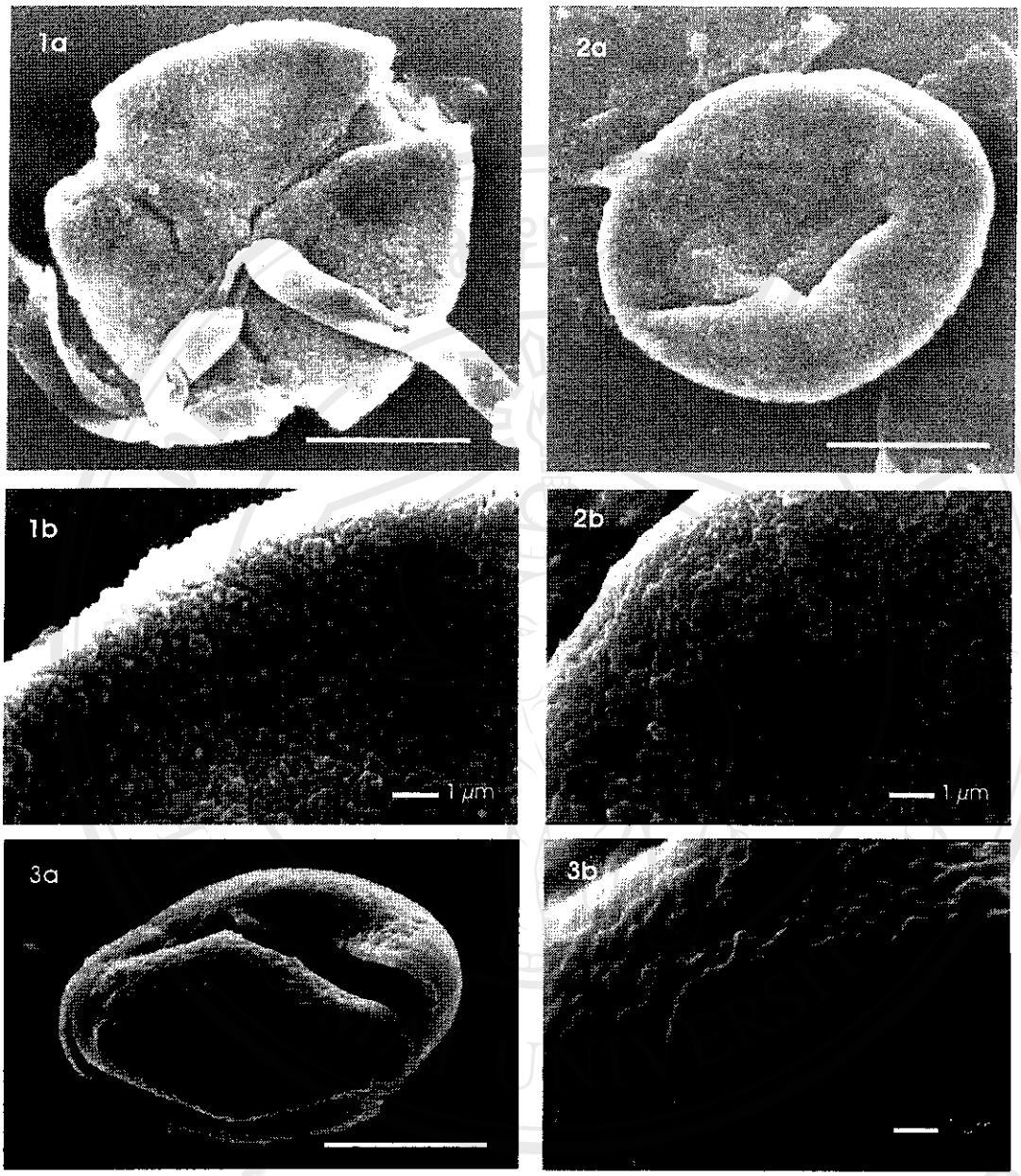


PLATE XXI: figures 1-2: *Faguspollenites* Raatz; figure 3: *Florschuetzia* Germeraad *et al.* All scale bars are 10 microns except where otherwise stated.

F. trilobata, F. semilobata, F. levipoli, and *F. **meridionalis*** from Miocene of the Gulf of Thailand and Andaman Sea. Watanasak also reported a form of this genus from Fang basin but did not identify into species.

Extant genus: ***Homonoia*** (Euphorbiaceae)

***Homonoia* sp.**

Plate XXII, figure 2.

Remarks: The fossil is a tricolporate form with densely and finely granulate to micro-echinate sculpture. Its size is about 20 microns, somewhat similar to the modern pollen of *Homonoia riparia* (Plate XXII, figure 3).

Botanical affinity: The fossil form compares well to the modern pollen species *Homonoia riparia* of the family Euphorbiaceae. The species occurs in tropical regions of India, Myanmar, and northern Thailand. It is always close to streams and often in large colonies. The modern pollen used in this study were collected from along a stream not very far from Ngao District in Lampang Province.

Occurrence: Rare in Mae Long locality and common in Chiang Muan coalfield.

Extant genus: ***Hopea*** (Dipterocarpaceae)

***Hopea* sp.**

Plate XXIII, figure 1.

Remarks: The genus contains pollen with a spherical tricolpate form. Sculpture is reticulate with finely granulated micro-sculpture on the muri. The sculpture is very close to that of the modern species *Hopea nervosa* (Plate XXIII, figure 2) but the muri of the modern species contain finely crenelated micro-sculpture at right angles to the ridge axes. Lumina of the reticulum of the fossil are obviously larger than of the

PLATE XXII

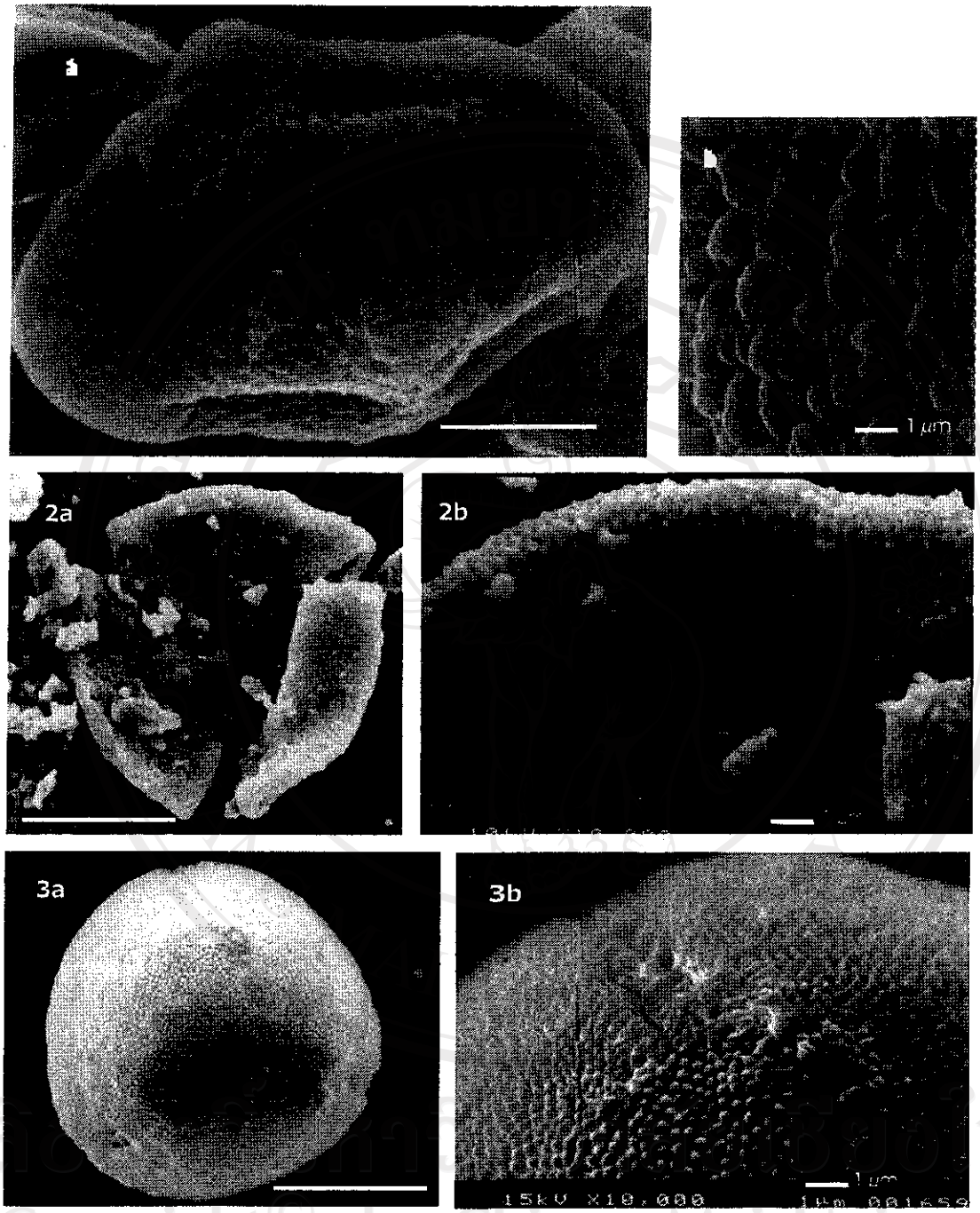


PLATE XXII: figures 1: *Sonneratia caseolaris* (modern pollen); figure 2: *Homonoia* sp. (fossil pollen); figure 3: *Homonoia riparia* (modern pollen). All scale bars are 10 microns except where otherwise stated.

PLATE XXIII

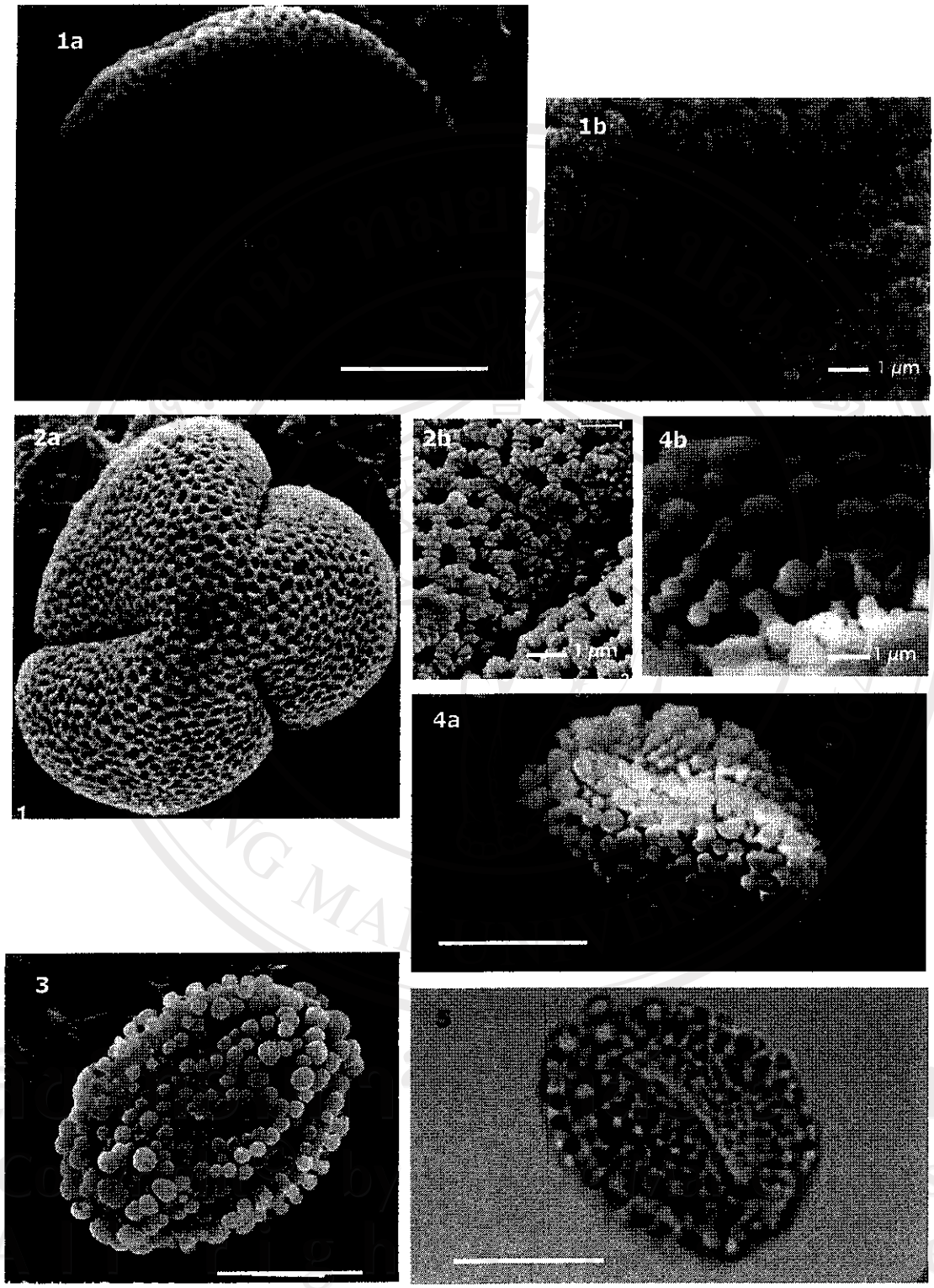


PLATE XXIII: figure 1: *Hopea* sp. (fossil pollen); figure 2: *Hopea nervosa* (after Maury and others, 1975); figures 3-5: *Ilexpollenites* Potonié; figures 3-4: SEM; figure 5: LM. All scale bars are 10 microns except where otherwise stated.

modern pollen. Grain size is about 25 microns somewhat matching the size of the modern species *Hopea nervosa.*

Botanical affinity: *Hopea* is a genus of the tropical family Dipterocarpaceae. The genus occurs in Thailand nationwide as well as in the Southeast Asian region as typical trees of tropical monsoon areas.

Occurrence: Rare in Chiang Muan and Mae Moh basin.

Genus: ***Ilexpollenites*** Thiergart ex Potonié

Type species: *Ilexpollenites iliacus* Thiergart ex Potonié

1960, *Ilexpollenites* Thiergart ex Potonié, p. 99.

***Ilexpollenites* spp.**

Plate XXIII, figures 3-5.

Remarks: *Ilexpollenites* is a distinctive tricolporate form and having clavate sculpture. At least two different forms are recognizable on the basis of their clavate element features. The forms occurring in association with warm temperate pollen assemblages were from Ban Pa Kha and Na Hong coalfields. Different forms from tropical pollen assemblages were from the Chiang Muan locality. Extant pollen of *Ilex aquifolium* collected from a temperate country show some characteristics differing from the specimens of this study by being much bigger.

Botanical affinity: Morphology of the *Ilexpollenites* fossils compares well to the recent genus *Ilex* of the family Aquifoliaceae. *Ilex* is a genus of trees and shrubs and is mostly evergreen. There are about 400 species. Their distribution is cosmopolitan in both tropical and temperate zones, but they are absent from North America.

Occurrence: The fossil *Ilexpollenites* came from Na Hong, Ban Pa Kha, Chiang Muan, and Mae Moh localities in this study. This genus was reported from Late

Oligocene to Miocene throughout Thailand (Meesuk, 1986; Watanasak, 1988; Songtham, 1996).

Genus: ***Juglanspollenites*** Raatz

Type species: *Juglanspollenites verus* Raatz

Juglanspollenites verus Raatz

Plate XXIV, figures 1-2.

1937, *Juglanspollenites verus* Raatz, p. 18, pl. 1, fig. 9.

Remarks: Specimens of fossil pollen in this study were observed only under the light microscope. Their size ranges are from 20 to 35 microns. Surface ornamentation is smooth in general. Pore features are very close to the pores of *Pterocarya* by having thickening around the pore margin. However, *Pterocarya* has only 4 to 6 pores on the equator of the grains whereas the *Juglans* has 8 to 23 pores on the distal side of the grain (Bos and Punt, 1991).

Botanical affinity: The botanical affinity of the *Juglanspollenites* is the extant genus *Juglans* of the family Juglandaceae. It is a genus of deciduous trees having 21 species occurring mainly in northern temperate regions, but extending to the tropics and native to Asia and America.

Occurrence: Common occurrences were from Na Hong and Ban Pa Kha localities in this study. It was also reported from Sin Pun basin in southern Thailand (Watanasak, 1988).

Extant genus: ***Lagerstroemia*** (Lythraceae)

***Lagerstroemia* sp.**

Plate XXIV, figures 3-4.

Remarks: Specimens of *Lagerstroemia* from this study were studied only under the light microscope. It is a prolate tricolporate grain characterized by a very thick exinal layer. The surface sculpture is smooth in general under the light microscope. Size of the grain ranges from 23 to 28 microns.

Botanical affinity: The fossils resemble pollen of extant *Lagerstroemia* spp. of the family Lythraceae. The genus occurs in tropical to subtropical regions of Asia and North Australia.

Occurrence: It is rare to common in Na Sai and Mae Moh coalfields and very rare in the overburden unit of Ban Pa Kha coalfield. Watanasak (1988) reported that this genus is rare to common from Early to Middle Miocene throughout Thailand including Krabi (Songtham, 1996).

Genus: ***Liquidambarpollenites*** Raatz ex Potonié

Type species: *Liquidambarpollenites stigmosus* (Potonié) Raatz

Liquidambarpollenites stigmosus (Potonié) Raatz

Plate XXIV, figure 5, Plate XV, figures 1.

1931a, *Pollenites stigmosus* Potonié, p. 332, pl. 2, fig. 1.

1937, *Liquidambarpollenites stigmosus* (Potonié) Raatz.

1953, *Periporopollenites stigmosus* Thomson & Pflug, p. 111, pl. 15, fig. 58.

Remarks: The typical characteristics of the form species *Liquidambarpollenites stigmosus* are its spherical shape with about 12 to 20 circular to elongated pores surrounding the grains (periporate pollen). The surface ornamentation is coarsely foveolar-reticulate with granules inside the pore areas. The grain size ranges from 30 to 40 microns.

Botanical affinity: These sporomorphs correspond well with modern pollen of *Liquidambar* of the family Hamamelidaceae. It is a genus of trees and shrubs

PLATE XXIV

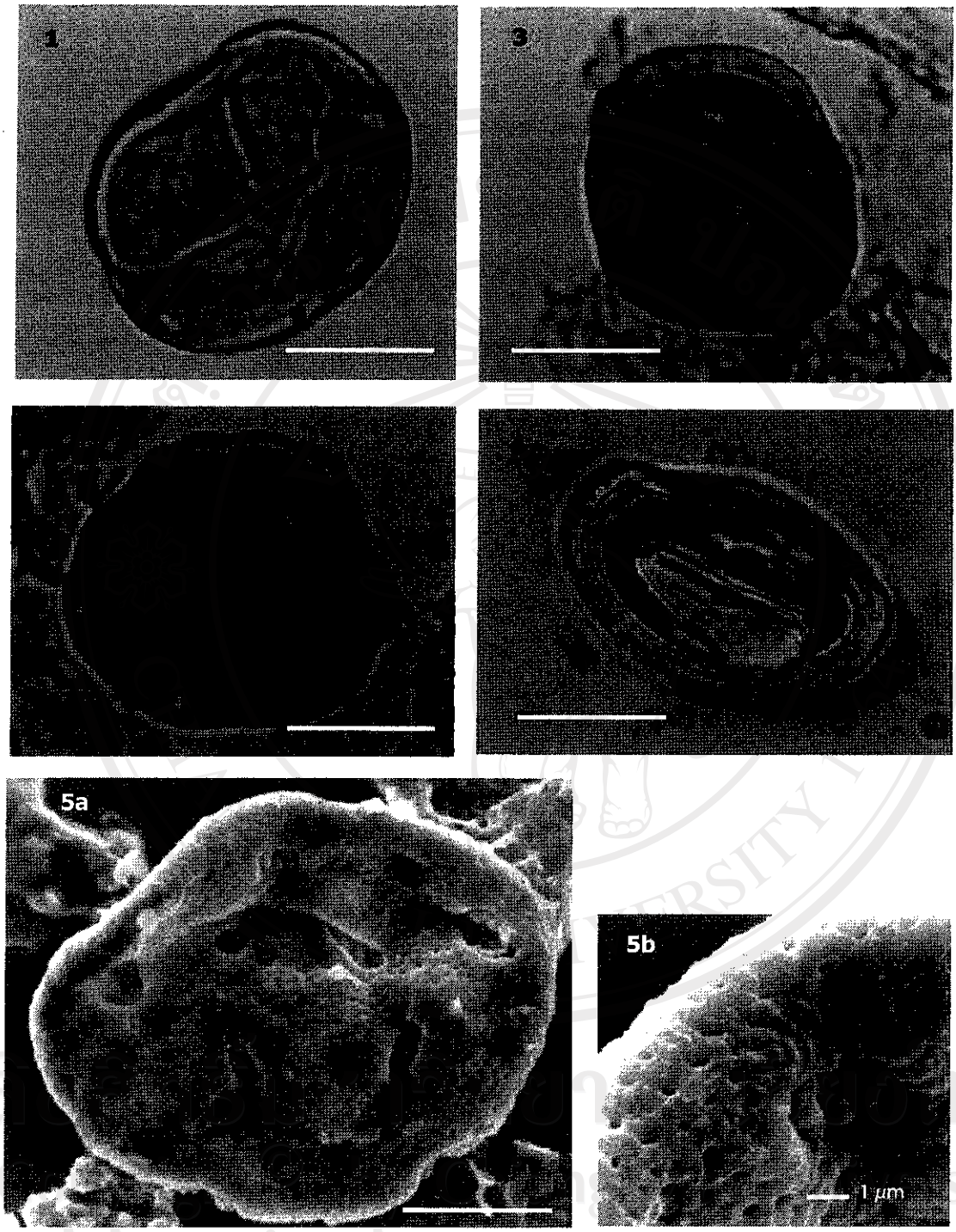


PLATE XXIV: figures 1-2: *Juglanspollenites verus* Raatz (LM); figure 3: *Lagerstroemia* sp. (fossil pollen); figure 4: *Lagerstroemia tomentosa* (modern pollen); figure 5: *Liquidambarpollenites stigmosus* Raatz (SEM). The scale bar is 10 microns except where otherwise stated.

consisting of 4 species, *L. orientalis*, *L. formosana*, *L. styraciflua*, and *L. macrophylla*, occurring in the areas of North and Central America, Asia Minor, and eastern Asia (Kuprianova, 1960).

Occurrence: The genus is common in Na Hong, Ban Pa Kha, and Mae Lamao coalfields. Watanasak (1988) reported this form as *Periporopollenites stigmosus* from Late Oligocene to Early Miocene throughout Thailand.

Genus: ***Momipites*** Wodehouse emend. Frederiksen & Christopher

Type species: *Momipites coryloides* Wodehouse

1933, *Momipites* Wodehouse, p. 511

1937, *Engelhardtiapollenites* Raatz, p. 20.

1950, *Engelhardtioidites* Potonié and others, p. 51.

1953, *Triatriopollenites* Thomson and Pflug, p. 76.

1960, *Engelhardtiopollenites* Potonié, p. 117.

1971, *Maceopolipollenites* Leffingwell, p. 29.

1973, *Momipites* Nichols, p. 106, emend.

1978, *Momipites* Frederiksen and Christopher, p. 128, emend.

Momipites coryloides Wodehouse

Plate XV, figures 2-3.

1933, *Momipites coryloides* Wodehouse, p. 511, fig. 43.

1969, *Engelhardtia* sp. Fairchild & Elsik, p. 83, pl. 37, figs. 8-9.

1970, *Momipites* sp. Tschudy & van Loenen, pl. 2, fig. 15.

1978, *Momipites coryloides* Frederiksen & Christopher, p. 128, pl. 1, fig. 1.

Description: Specimens from this study have three pores arranged equatorially with triangular outlines and convex sides. Surface sculpture is finely granulated which is clearly visible in the scanning electron microscope. The sizes of the grains range from 18 to 25 microns.

PLATE XXV

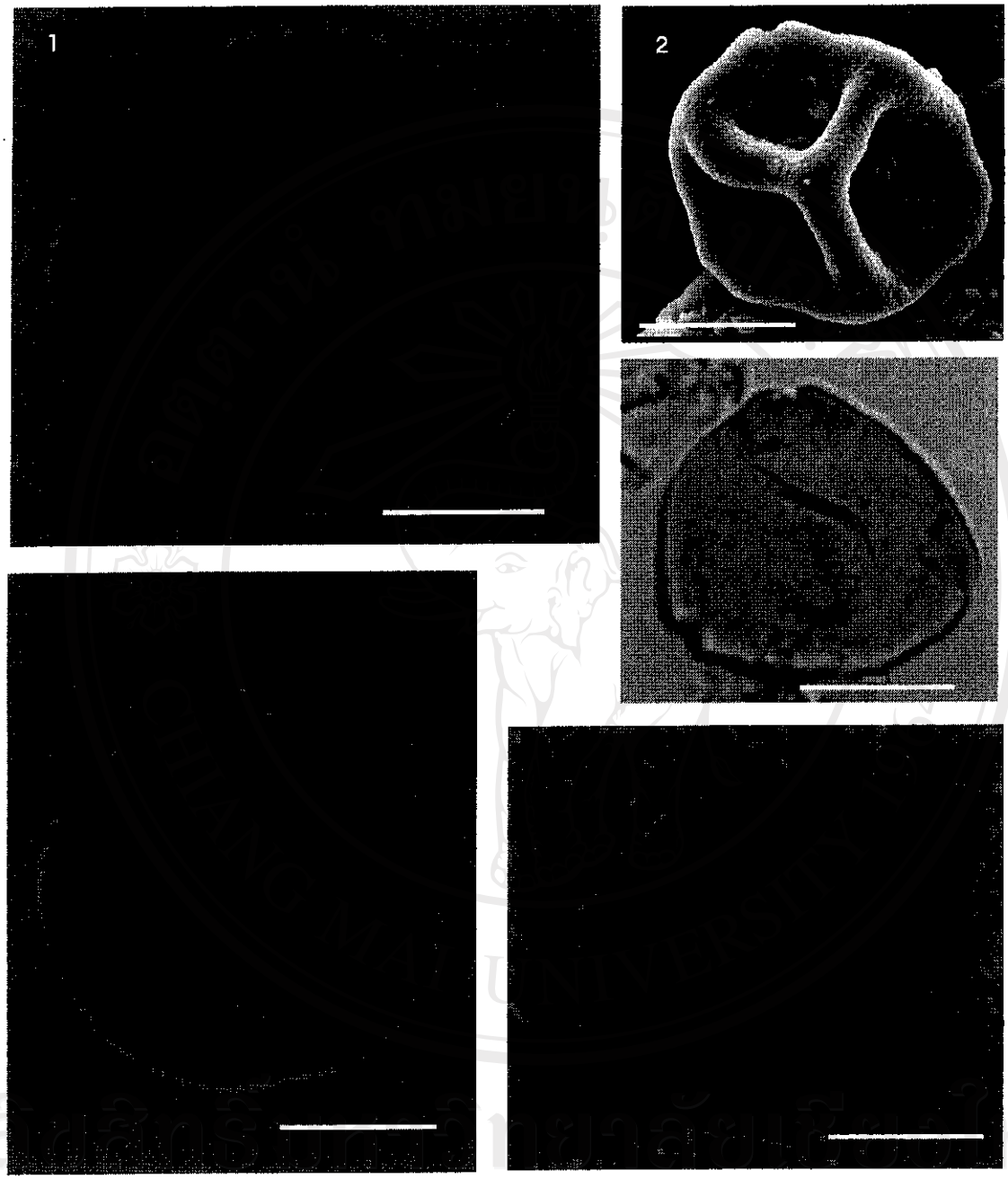


PLATE XXV: figure 1: *Liquidambarpollenites stigmosus* Raatz (LM); figures 2- 3: *Momipites coryloides* Wodehouse; figure 2: SEM; figure 3: LM; figure 4: *Perfotricolpites digitatus* Gonzalez (LM); figure 5: *Pterocaryapollenites stellatus* Raatz. The scale bar is 10 microns.

Remarks: This form genus is broadly characterized by triporate pollen grains, oblate to sub-oblate shape and outline generally semi-angular to sub-angular. Pores are located equatorially. Wodehouse (1933) first described fossil pollen with presumed affinities to the extant family Juglandaceae with type species *Momipites coryloides*, but he was uncertain whether the genus represented *Celtis* (Ulmaceae), *Corylus*, or *Engelhardtia*. Nichols (1973) amended Wodehouse's original diagnosis to include the fossil pollen *Engelhardtioipollenites* Potonié and three other related form genera. Nichols decided to split *Momipites* into seven morphological groups including *Coryloides*, *Tenuipolus*, *Triradiatus*, *Triorbicularis*, *Triletipollenites*, *Microcoryphaeus*, and *Dilatus* groups. Nichols and Ott (1978) further compared the pollen morphology between *Momipites* and *Caryapollenites*. The genus *Caryapollenites* appears to have been derived from the basic form of *Momipites* by changing size and development of heteropolarity. Frederiksen and Christopher (1978) further amended *Momipites* to exclude several of the group or subgenera used by Nichols. Some species excluded from *Momipites* were then included in *Plicatopollis* Krutzsch.

Botanical affinity: The fossil forms compare well to the extant pollen of *Engelhardtia* of the family Juglandaceae. It is a genus of trees consisting of 5 species occurring from the western Himalayas to New Guinea. The fossil forms from this study occur in association with warm temperate pollen assemblages and have never been found in association with any tropical pollen. The fossils are, thus, assumed to be warm temperate elements.

Occurrence: It commonly to abundantly occurs in Na Hong and Ban Pa Kha coalfields in this study.

Genus: ***Perfotricolpites*** Gonzalez-Guzman

Type species: *Perfotricolpites digitatus* Gonzalez-Guzman

Perfotricolpites* cf. *P. digitatus Gonzalez-Guzman

Plate XXV, figure 4.

1967, *Perfotricolpites digitatus* Gonzalez-Guzman, p. 34, pl. 6, fig. 1.

Remarks: One specimen from this study was compared with the description and illustration by Germeraad and others (1968). It is a tricolpate form with strongly intruding colpi. Its columellae are clearly digitate with finely reticulate-perforate exinal surface. The size, about 27 microns, is much smaller than 46 to 70 microns as given by Germeraad and others (1968)

Botanical affinity: It is comparable to modern pollen of *Merremia glabra* and *Merremia umbellata* of the family Convolvulaceae (Germeraad and others, 1968). *Merremia* is a genus of climbing herbs found in tropical areas and also in Thailand.

Occurrence: Only one grain came from the overburden unit (sample no. OU-26) of Ban Pa Kha coalfield. Waton (1996) reported this form from Miocene sediments of Phrae basin. *Perfotricolpites digitatus* was observed from Wai Lek coal mine, Krabi (self observed).

Genus: ***Pterocaryapollenites*** Raatz ex Potonié

Type species: *Pterocaryapollenites stellatus* (Potonié) Raatz

Pterocaryapollenites stellatus (Potonié) Raatz

Plate XXV, figure 5; Plate XXVI, figures 1-2.

1931d, *Pollenites stellatus* Potonié, p. 28, pl. 2, fig. 47b.

1937, *Pterocaryapollenites stellatus* (Potonié) Raatz, p. 18, fig. 8.

1953, *Polyporopollenites stellatus* Thomson & Pflug, p. 19, pl. 10, figs. 85-94.

Remarks: Norton and Hall (1969) described and illustrated *Pterocaryapollenites stellatus* as having five circular to slightly elliptical pores, thereafter Wilson (1978)

PLATE XXVI

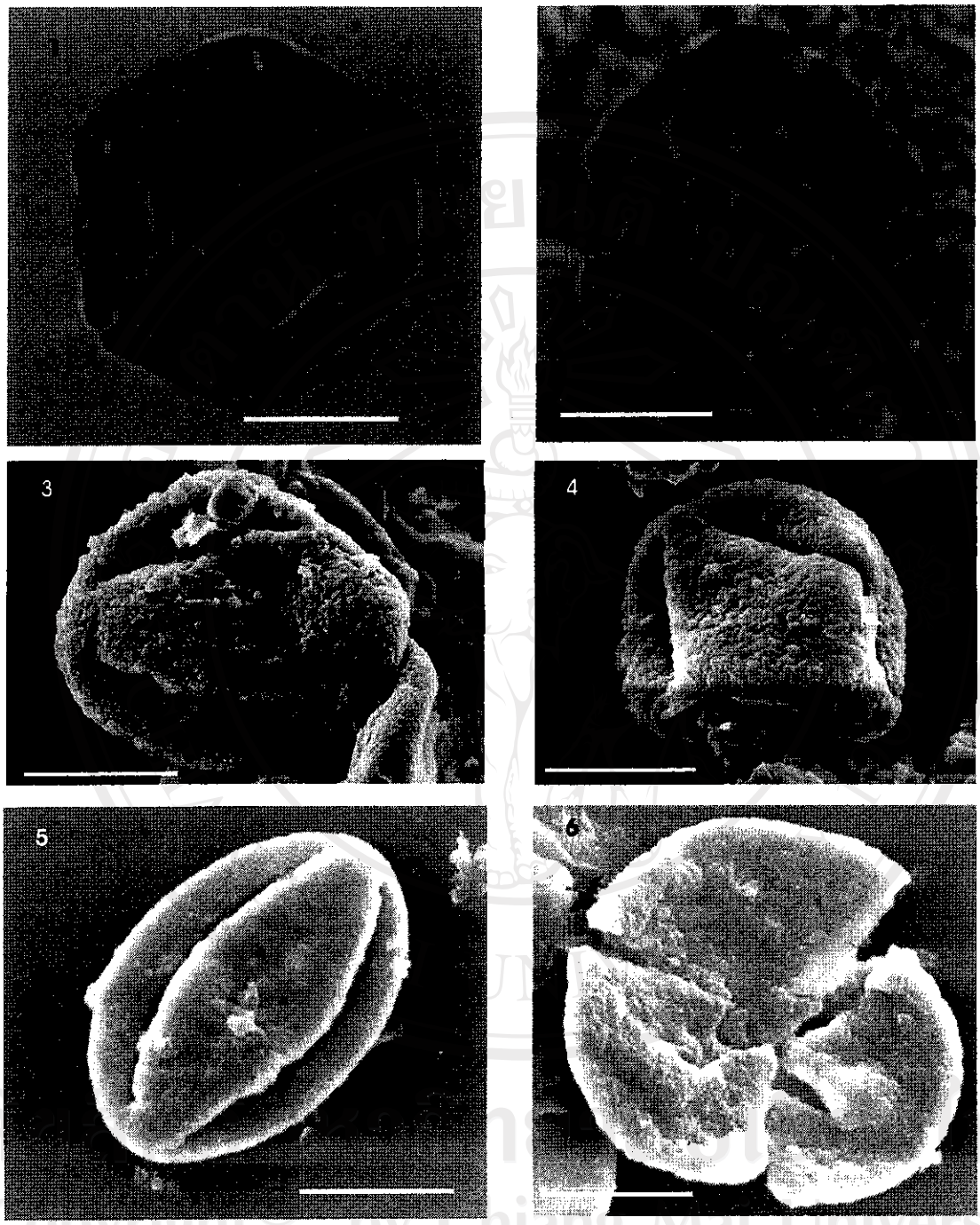


PLATE XXVI: figures 1-2: *Pterocaryapollenites stellatus* Raatz (LM); Figures 3-6: *Quercoidites* Potonié (SEM). All scale bars are 10 microns.

described *Pterocaryapollenites* as having six pores located equatorially. Specimens from Na Hong and Ban Pa Kha have six pores with smooth sculpture under the light microscope. A specimen from the Na Hong also shows smooth surface even in the scanning electron microscope. However, Wilson (1978) described grains varying from smooth to granulate and almost to finely rugulate in a few cases. In addition, Wilson suggested that the variation in ornamentation may be a result of preservational characteristics. Bos and Punt (1991) described modern *Pterocarya* having a scabrate surface under the light microscope but micro-echinate under the scanning electron microscope. Specimens from this study range in size from 23 to 29 microns with obviously protruding pores in some grains.

Botanical affinity: The fossil materials from this study are comparable to modern pollen of the genus *Pterocarya* of the family Juglandaceae. It is a genus of deciduous trees having six species occurring from the Caucasus to Japan.

Occurrence: Common occurrences came from Na Hong and Ban Pa Kha coalfields in this study.

Genus: ***Quercoidites*** Potonié

Type species: *Quercoidites henrici* Potonié

1960, *Quercoidites* Potonié, p. 29.

***Quercoidites* sp.**

Plate XXVI, figures 3-6.

Remarks: Fossil pollen of *Quercoidites* is tricolpate. The colpi extend almost to the poles. The pollen type shows variations in size and sculpture and are difficult to distinguish under the scanning electron microscope (Watanasak, 1988). Sculpture of the exine varies from psilate to scabrate under the light microscope but psilate to verrucate under the scanning electron microscope. In this study, *Quercoidites* is

distinguished from *Faguspollenites* on the fact that the sculpture surface of *Faguspollenites* has rod-like elements and distinctive pores, while *Quercoidites* does not. The size ranges are from about 20 to 35 microns in the longest diameter.

Botanical affinity: The fossil forms compare well to modern pollen of *Quercus* of the family Fagaceae. It is a genus of deciduous and evergreen trees and shrubs. There are about 600 species found in the north hemisphere temperate zone, subtropical, and tropical Asia, and the Andes.

Occurrence: Common occurrences came from Na Hong, Ban Pa Kha, and Mae Lamao coalfields.

Genus: ***Retitrecolpites*** Sah

Type species: *Retitrecolpites typicus* Sah

1967, *Retitrecolpites* Sah.

***Retitrecolpites* sp.**

Plate XXVII, figures 1-6.

Description: The grain is isopolar, spherical, tricolpate forms with about 25 to 29 microns in diameter. Colpi are wide in the equator and tapered toward the poles nearly reaching the poles. The grains are spherical to sub-spherical outline but are triangular in polar view with rounded apices and straight to slightly concave inter-apices. Surface sculpture is reticulate with polygonal lumina about 2 to 5 microns in diameter. Muri is thin baculate with about 0.5 to 1 microns wide and about 1 to 2 microns high.

Comparison: *Retitrecolpites* has general features very close to *Retitrecolpites globosus* (Takahashi and Jux, 1991) but its size is obviously smaller. Lumina of the reticulum are also smaller from the *Retitrecolpites globosus*.

PLATE XXVII

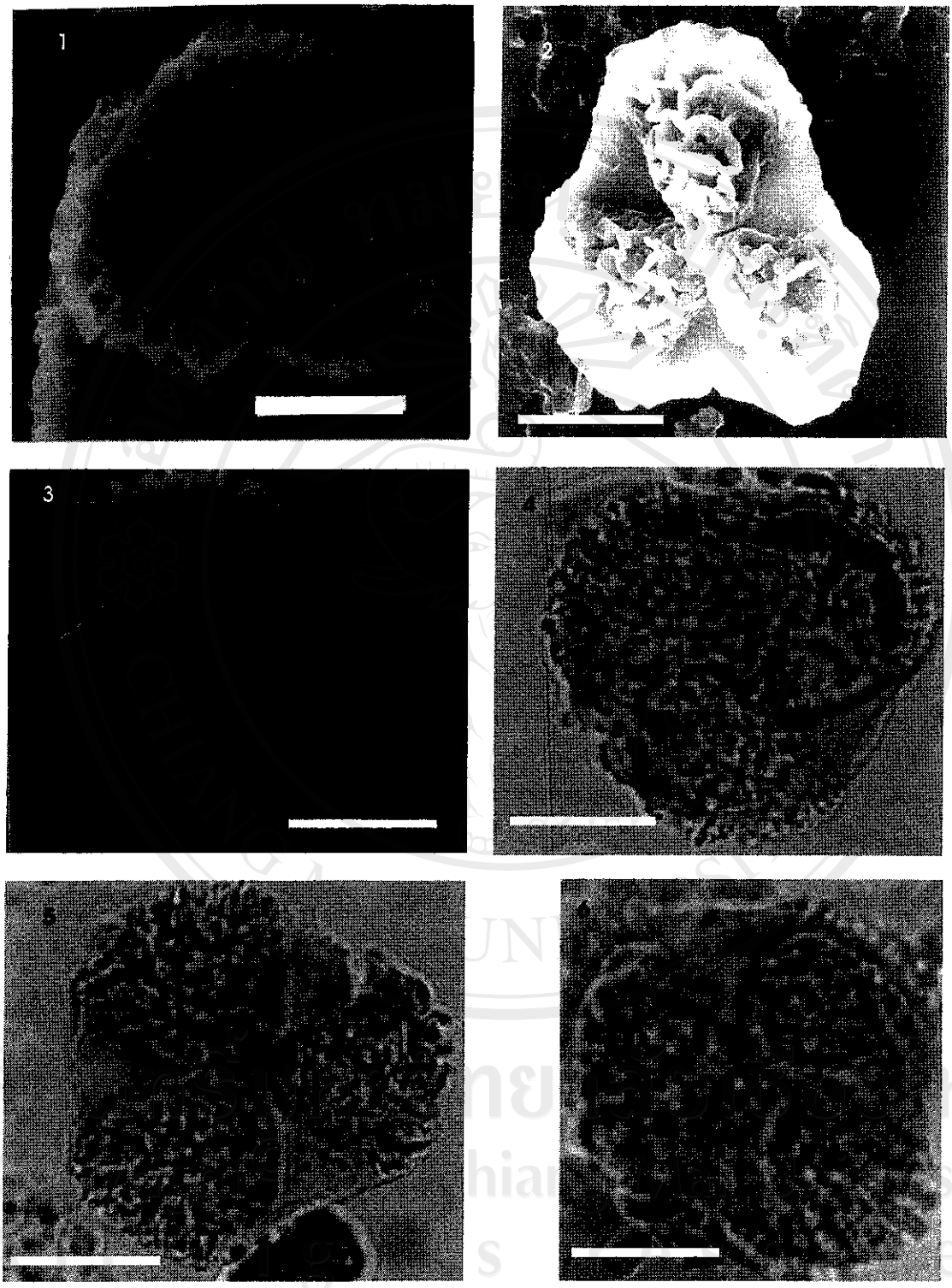


PLATE XXVII: figures 1-6: *Retitrecolpites* Sah; figures 1-3: SEM; figures 4-6: LM. All scale bars are 10 microns.

Botanical Affinity: It is referable to the pollen family Oleaceae (Takahashi and Jux, 1991). The Oleaceae is a family of trees or shrubs consisting of 24 genera, with 900 species, widely distributed but centered on Asia.

Genus: ***Rhoipites*** Wodehouse

Type species: *Rhoipites bradleyi* Wodehouse

1933, *Rhoipites* Wodehouse, p. 513.

1937, *Rhuspollenites* Thiergart, p. 320.

1947, *Tricolporites* Cookson, p. 195.

1950, *Rhooidites* Potonié *et al*, p. 57.

1951a, *Rhooipollenites* Potonié, p. 146.

1953, *Tricolporopollenites* Pflug & Thomson in Thomson & Pflug, p. 95.

1960, *Araliaceoipollenites* Potonié ex Potonié, p. 97.

Discussion: On the basis of the definition given by the original authors and by reference to illustrations of the type species, there appears to be little difference between the form genera *Rhoipites* Wodehouse and *Tricolporites* Cookson. *Rhoipites* has priority and is defined by a finely pitted tricolporate pollen grain that has long pointed apertures and conspicuous pores and furrow thickenting (Kemp and Harris, 1977; Farabee and Canright, 1986). *Rhoipites* is a reticulate tricolporate pollen whereas *Tricolporites* is a non-reticulate tricolporate pollen as a result of an amended diagnosis by Stover and Partridge (1973) which was supported by Pocknall and Crosbie (1982). *Rhuspollenites* Thiergart is not valid because it lacks a generic diagnosis, and the type species had been assigned by Potonié (1960) to *Rhoipites*. *Rhooidites* Potonié *et al*, *Rhooipollenites* Potonié, and *Tricolporopollenites* Pflug & Thomson have been accepted as junior synonyms of *Rhoipites* (Potonié, 1960). *Araliaceoipollenites* Potonié ex Potonié is suggested as being a junior synonym of *Tricolporopollenites*, which also then makes it a junior synonym of *Rhoipites*.

Hekel (1972) amended *Retitricolporites* van der Hammen to include Tricolporate, reticulate forms in which the lumina of the reticulum shows a progressive decrease in size toward colpi. The validity of this genus is, however, subject to the same reservations as those expressed by Srivastava (1966) and Dettmann (1973) for *Retitricolpites*.

Rhoipites retiformis Pocknall & Mildenhall

Plate XXVIII, figure 1.

1984, ***Rhoipites retiformis*** Pocknall & Mildenhall, p. 36, pl. 17, figs. 1-5.

Remarks: One specimen in this study matches well the original description and illustration of the type specimens from the Late Oligocene to Early Miocene in New Zealand studied by Pocknall and Mildenhall (1984). Watanasak (1988) reported this species from the Early to Middle Miocene of Fang and Mae Moh basins in northern Thailand, though its sculpture pattern was more finely reticulum.

Botanical affinity: Unknown.

Occurrence: very rare in sample no. NH-9 of the Na Hong basin. The species was reported by Watanasak (1988) from Early to Middle Miocene of Fang and Mae Moh basins.

Salixipollenites Srivastava

Type species: *Salixipollenites discoloripites* (Wodehouse) Srivastava

1933, *Salix discoloripites* Wodehouse, p. 506, figs. 34-35.

1966, *Salixipollenites discoloripites* (Wodehouse) Srivastava, p. 529.

***Salixipollenites* sp.**

Plate XXVIII, figure 2.

PLATE XXVIII

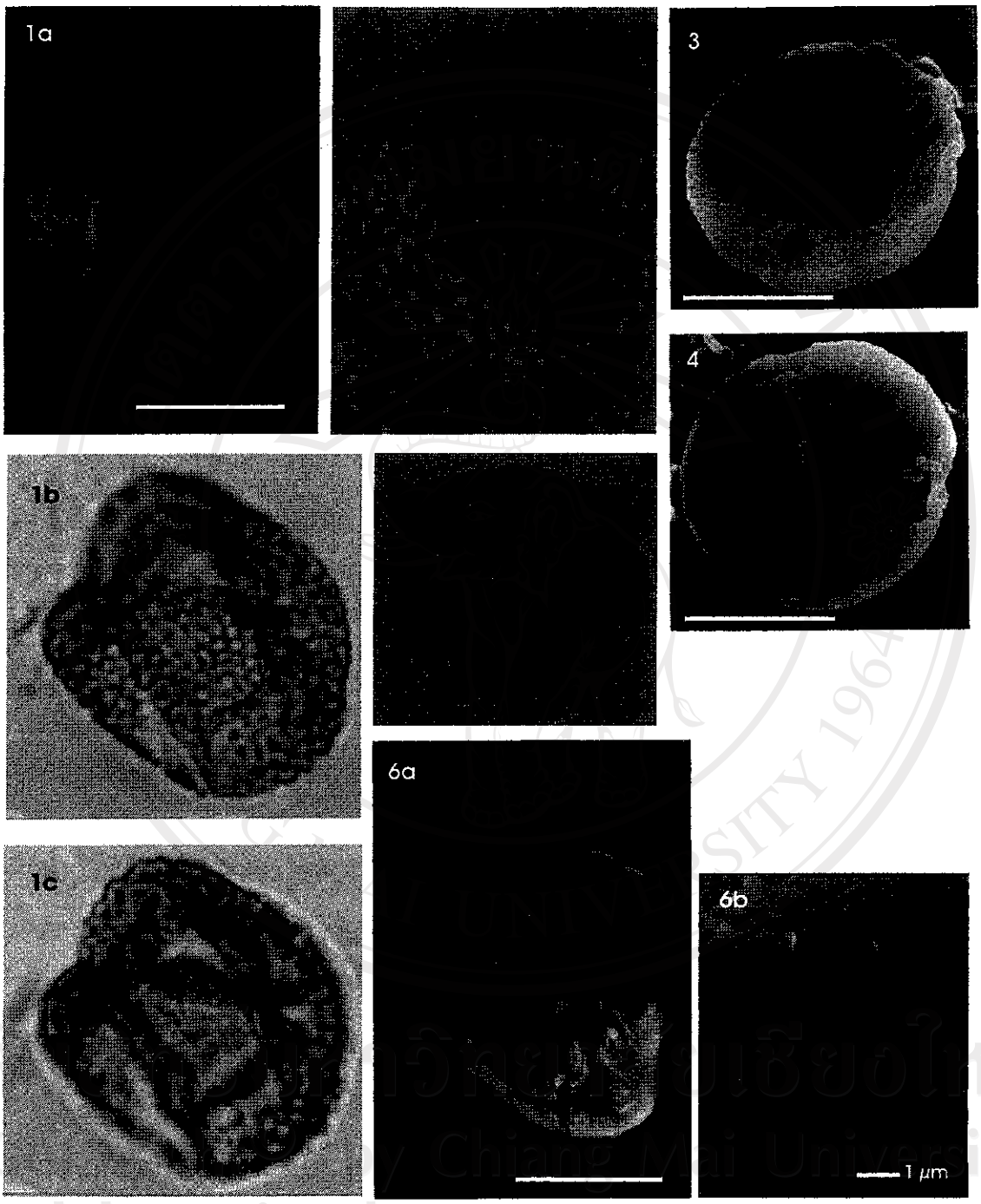


PLATE XXVIII: figure 1: *Rhoipites retiformis* Pocknall & Mildenhall; figure 1a: SEM; figure 1b and 1c: LM; figure 2: *Salixipollenites* Srivastava (LM); figures 3-5: ?*Scyphiphora* (fossil pollen); figures 3-4: SEM; figure 5: LM; figure 6: *Spondias* (fossil pollen). All scale bars are 10 microns except where otherwise stated.

Remarks: *Salixipollenites* is a pollen grain containing a reticulate surface sculpture and a tricolporate form. Colpi are thickened at the equator and extend nearly to the poles.

Botanical affinity: It is referable to the modern genus *Salix* of the family Salicaceae. It is a genus of trees consisting of about 300 species, occurring in northern temperate or arctic areas, but with a few tropical and southern temperate outliers. There is a species in Thailand, *Salix tetrasperma*, commonly occurring along streams, lakes, and ponds.

Occurrence: It occurs in the overburden unit near the boundary between the upper coal zone and the overburden unit of Ban Pa Kha coalfield. At the boundary, there are some localities containing abundant *Salix* leaves identified by a Japanese paleobotanist, Dr. Atsushi Yabe. Watanasak (1988) reported this form from Late Oligocene Ba Pu basin and Middle Miocene Fang basin.

Extant genus: ***Scyphiphora*** (Rubiaceae)

cf. *Scyphiphora* sp.

Plate XVIII, figures 3-5.

Remarks: The pollen grains are circular in outline in polar view. They are tricolporate with finely reticulate sculpture. The pores are rounded with protruding rims. Colpi cover the pores at the equator and taper towards the poles but do not reach the poles. Grain sizes range from 18 to 22 microns.

Botanical affinity: General features of the grains are considered characteristic of pollen belonging to the family Rubiaceae. *Scyphiphora* cf. *S. hydrophyllacea* was identified by Dr. Azmi Mohd Yakzan from the Petronas Research and Scientific Service, Malaysia. *Scyphiphora hydrophyllacea* is a mangrove shrub growing along coastal areas. This study uses cf. *Scyphiphora* as an uncertain identification.

Occurrence: Abundant occurrence came from the lowermost part of the overburden unit of Ban Pa Kha coalfield.

Extant genus: ***Spondias*** (Anarcardiaceae)

***Spondias* sp.**

Plate XVIII, figure 6.

Remarks: The tricolporate form and striate surface sculpture of this fossil was compared with three extant striate tricolporate pollen of *Spondias pinnata*, *Bauhinia variegata*, and *Crudia chrysantha*. The striate pattern of the fossil pollen matches the modern pollen of *Spondias pinnata* as well as the size of about 23 to 25 microns.

Botanical affinity: The fossils are relatable in some features with the modern species *Spondias pinnata* belonging to the family Anacardiaceae. *Spondias pinnata* is a species of big tree growing in tropical regions and also in Thailand nationwide.

Occurrence: The fossils are rare to common in the K-coal zone of Mae Moh coalfield.

Genus: ***Sporotrapoidites*** Klaus

Type species: *Sporotrapoidites illingensis* Klaus

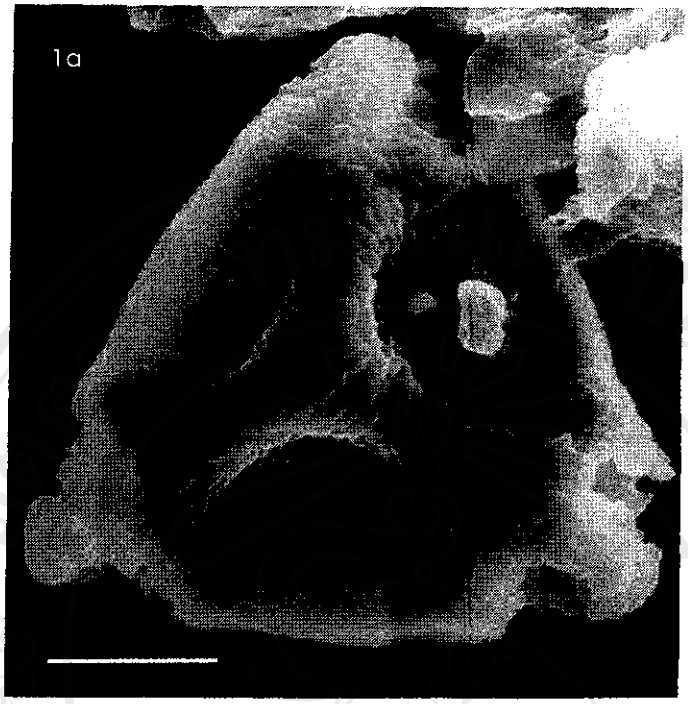
1954, *Sporotrapoidites illingensis* Klaus, p. 122, pl. 1, figs. 1-3.

***Sporotrapoidites* sp.**

Plate XXIX, figure 1; Plate XXX, figures 1-2.

Description: *Sporotrapoidites* is characterized by an oval to nearly rhombohedral shape in equatorial view, and more or less triangular shape in polar view with sides nearly straight to convex. The equatorial diameter ranges from 33 to 38 microns, and the polar diameter from 29 to 40 microns. There are three meridional crests connecting from pole to pole (3-zonocolpate), each crest meets at both poles forming a Y-mark clearly visible in polar views. The crest strip is about 6-7 microns wide, and

PLATE XXIX



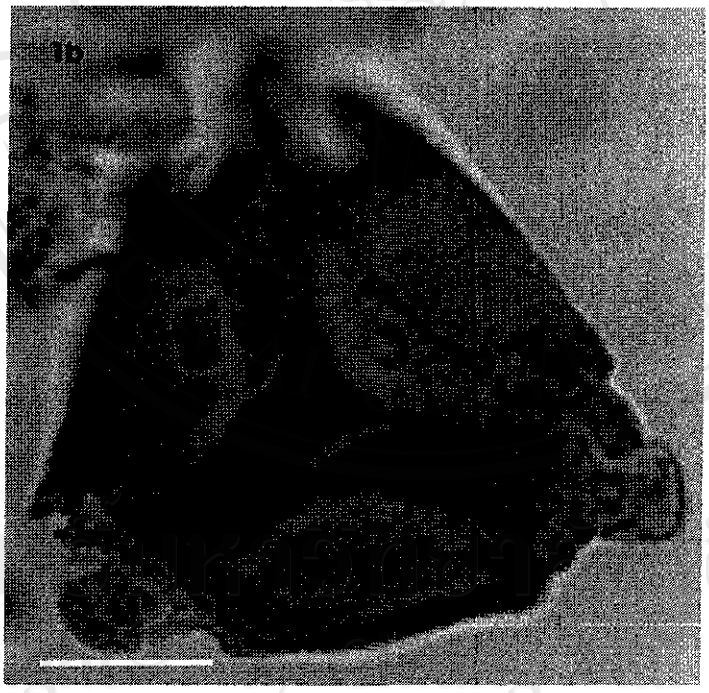
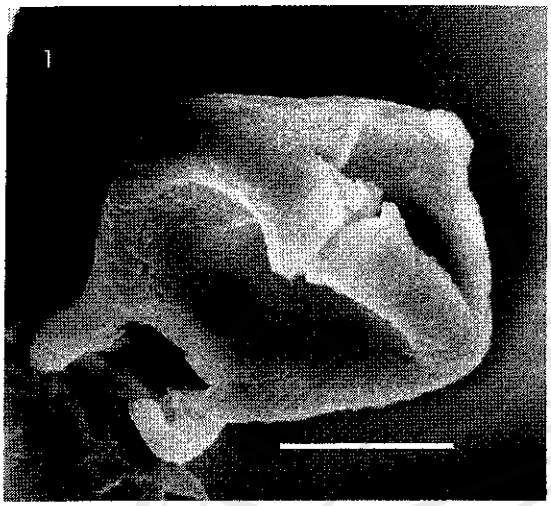
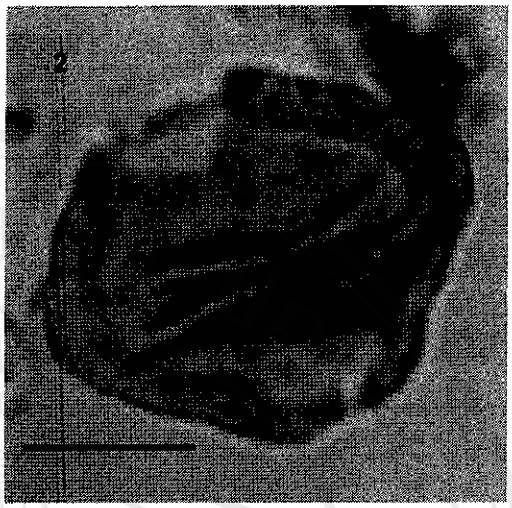


PLATE XXIX: figures 1: *Sporotrapoidites* Klaus (polar view); figure 1a:SEM; figure 1b: LM. All scale bars are 10 microns.

PLATE XXX





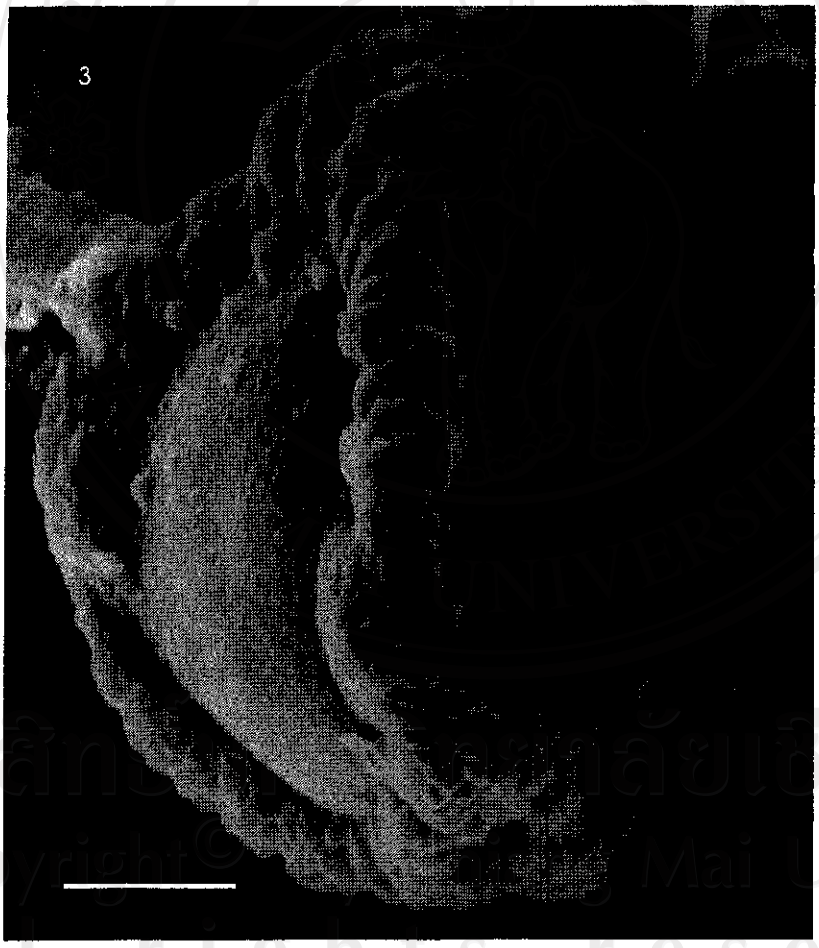


PLATE XXX: figures 1-2: *Sporotrapoidites* Klaus (equatorial view); figure 1:SEM; figure 2: LM; figure 3: *Trapa bicornis*, equatorial view, SEM (modern pollen). All scale bars are 10 microns.

about 3 to 3.5 microns thick. The crests are often broken up unevenly in the vicinity of the equator, where it is likely that pores or short colpi occur. However, aperture size and characteristics are difficult to recognize and impossible to describe from the specimens because the crests cover the apertures. The surface ornamentation is rather smooth (psilate) under the light microscope. However, the scanning electron microscope shows scabrate sculpturing, particularly on the crest surface which is lightly rippled. The thickness of the exinal layer is generally 1 to 1.5 microns, except on the crests and the polar areas where it is 3 to 3.5 microns.

Comparison: The form genus was first erected by Klaus (1954), base on specimens found in the Miocene of Austria, with *Sporotrapoidites illingensis* as its type species. The species is characterized by its large size, 62 to 81 microns, three meridional exinal ridges extending from each pole and three short, narrow meridional apertures on the equator, each enclosed by one of the meridional ridges. This genus has been only rarely been recorded by later paleopalynological workers. Potonié (1960) described *Sporotrapoidites illingensis* Klaus, and illustrated two line drawings of a grain in equatorial and polar views. He indicated that the fossil form had a botanical affinity with pollen of the recent genus *Trapa* (Trapaceae). Seven further species of the genus *Sporotrapoidites* have been described from China, Hungary, and Austria, namely *S. medius* Guan in Sing *et al*, *S. minor* Guan in Sing *et al*, *S. weiheensis* Guan in Sing *et al*, *S. erdtmanii* Nagy, *S. hungaricus* Nagy, *S. carlesii* Zetter & Ferguson, and *S. cesarei* Zetter & Ferguson (Song and others, 1985; Nagy, 1985; Guan and others, 1989; Wang and Zhang, 1990; Zetter and Ferguson, 2001). At least one of these species, *S. erdtmanii*, is related to the extinct Tertiary genus *Hemitrapa* Miki (Mohr, 1983). The Thai forms are closely relatable to the Chinese forms but the species is not assigned in this research.

Botanical affinity: If the crests were to be removed from the pollen of Trapaceae, the resulting pollen grains would have a strong resemblance to those of some of the Onagraceae. It seems likely that the Trapaceae evolved from the Onagraceae during the Paleogene (Zetter and Ferguson, 2001). Modern pollen of *Trapa bicornis* was collected from somewhere in Chao Phraya floodplain of Central Thailand (Plate XXX, figure 3). The pollen of *Trapa bicornis* is very similar to the ancestral form *Sporotrapoidites*, but the modern pollen is clearly larger. The equatorial diameter ranges from 50 to 62 microns, and the polar diameter is 50 to 80 microns, which is larger than the ancestral form by approximately 20 percent. Generally, the pollen is smooth, ovoid to spheroid in shape, with three broad, meridional crests connecting at each pole. Each crest meets the poles forming Y marks visible in polar view. The strips of the prominent crests are about 8 to 10 microns wide, and about 6 to 12 microns thick. The crest surface is wrinkled, and gradually more wrinkled towards the poles. The surface at the poles are characteristically heavily ornamented, whereas the ancestral form is still rather smooth at the poles. The thickness of the exinal layer is very thin at the equator, gradually increasing to 3 to 3.5 microns towards the poles. The apertures of the grain are unrecognizable under both scanning electron and light microscopes. However, Erdtman (1943) described *Trapa natans* pollen, excluding the crests, as a thick lens with three equatorial, equally spaced and meridionally elongated pores (short colpi). The grain may sometimes be flattened forming a characteristic triangular outline with its Y mark crest, visible particularly in polar view.

Noticeably, the exine of *Sporotrapoidites* and *Trapa* pollen is not very thick, as is usually the case with water dispersed pollen. However, both taxa may show an apparent very thick wall in equatorial view, which may sometimes lead to misidentification of fossil *Sporotrapoidites* pollen as pollen of *Lagerstroemia*

(Lythraceae), which is typically characterized by a very thick wall. The thick wall of *Sporotrapoidites* and *Trapa*, as seen in equatorial view, are actually the flattened meridional crests rather than the wall itself. The precise wall thickness can be measured in polar view from the exinal areas between the crests.

Trapa, or the water chestnut, is an aquatic herb found in quiet freshwater ponds or lakes under open vegetation and subject to high light intensity. The fossil form *Sporotrapoidites* extracted from the Tertiary sedimentary layers in this study were found in association with the widespread colonial green algae *Pediastrum*. The occurrence of these fossils is consistent with the suggestion that fossil *Sporotrapoidites* pollen was deposited autochthonously in a lacustrine environment. This was also discussed by Zetter and Ferguson (2001).

Occurrence: The fossil pollen of the form genus *Sporotrapoidites* were abundantly recovered from lower portion of unit A of the Na Hong coal deposit. Some rare occurrences were also from the overburden unit of Ban Pa Kha and the unit "A" of Mae Lamao coalfields.

Genus: ***Striatricolpites*** Gonzalez-Guzman

Type species: *Striatricolpites catatumbus* Gonzalez-Guzman

Striatricolpites catatumbus Gonzalez-Guzman

Plate XXXI, figure 1.

1967, *Striatricolpites catatumbus* Gonzalez-Guzman, p. 30, pl. 8, fig. 7.

Remarks: It is a tricolpate pollen with a striate surface sculpture. The striate elements are well matched with striate elements from extant pollen of *Crudia chrysantha* of the family Caesalpiniaceae (Plate XXXI, figure 2). Germeraad and others (1968) also described the one micron thick striae that are almost the same as specimens in this study and from *Crudia chrysantha*. The size along the polar axis is about 40 microns

PLATE XXXI

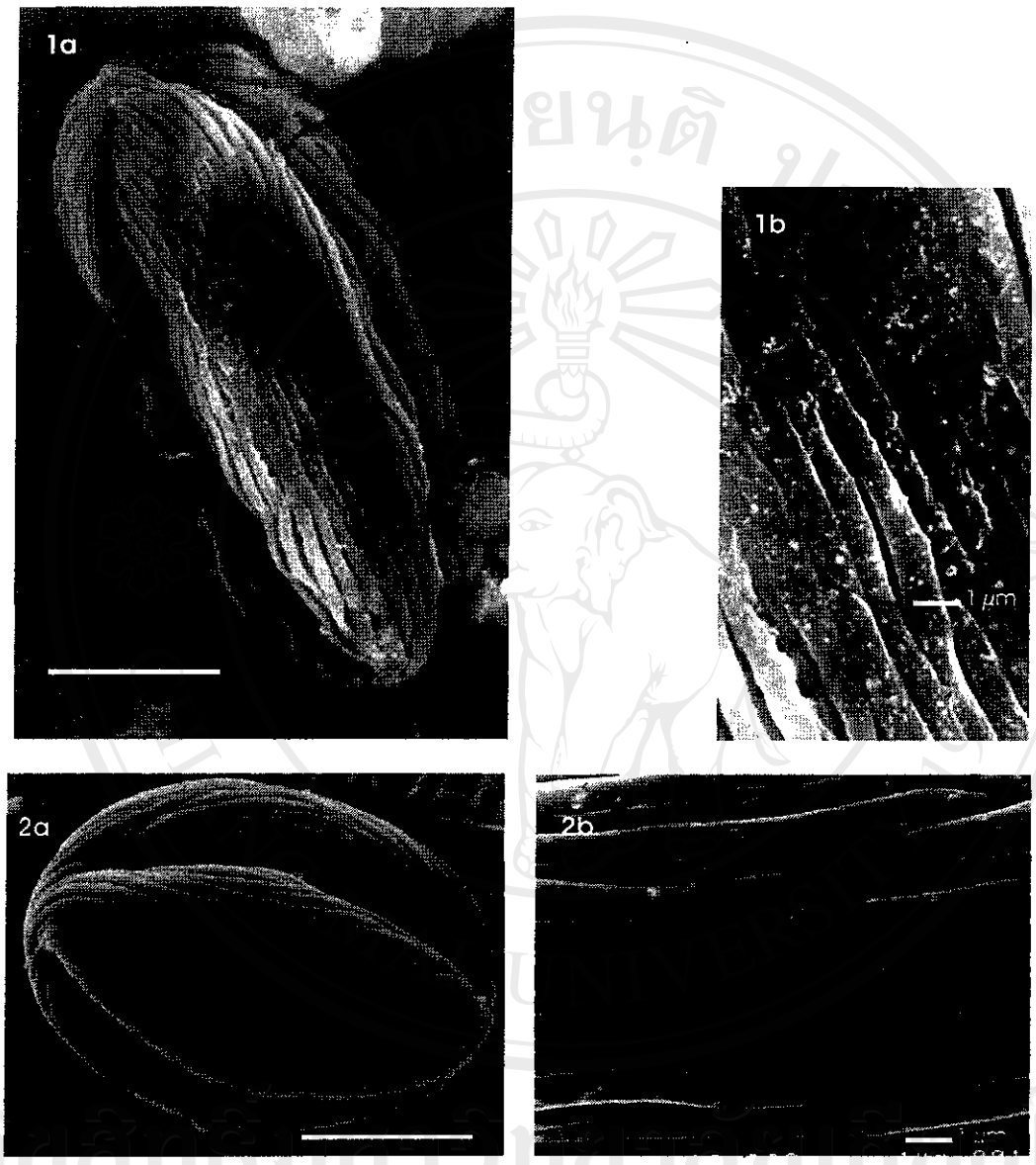


PLATE XXXI: figure 1: *Striatricolpites catatumbus* Gonzalez; figure 2: *Crudia chrysantha* (modern pollen). All scale bars are 10 microns except where otherwise stated.

which falls into the range of 33 to 50 microns described by Germeraad and others (1968).

Botanical affinity: Comparisons between the fossils and extant pollen containing striate surface sculptures were made under the scanning electron microscope including extant pollen from *Crudia chrysantha*, *Spondias pinnata*, and *Bauhinia variegata*. The comparisons showed with a high degree of confidence that the fossil forms compare well to *Crudia chrysantha*. *Crudia* is a tropical tree normally occurring along riverside areas in tropical Southeast Asian regions in both mainland and archipelago sites.

Occurrence: It was found only in Na Sai coalfield in the Li basin in this study. Meesuk (1986) also reported it from Mae Moh coalfield.

Genus: ***Trivestibulopollenites*** Pflug in Thomson & Pflug

Type species: *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug

1953, *Trivestibulopollenites* Pflug in Thomson & Pflug, p. 84.

1960, *Betulaceoipollenites* Potonié ex Potonié, p. 114.

1960, *Betulaepollenites* Potonié ex Potonié, p. 115.

Trivestibulopollenites betuloides Pflug in Thomson & Pflug

Plate XXXII, figure 1.

1953, *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug, p. 85, pl. 9, fig. 34.

1964, *Betulaceoipollenites* cf. *B. bituitus* Potonié; Engelhardt, p. 17, pl. 4, fig. 42.

1966, *Betula claripites* Wodehouse; Martin & Rouse, p. 197, pl. 8, figs. 72-73.

Remarks: This form of fossil resembles various forms of triporate pollen with triangular outline. Thomson and Pflug (1953) erected form genus *Trivestibulopollenites* representing triangular triporate fossil pollen with three vestibulate pores. The pore features resemble the pores belonging to *Alnipollenites verus* but *Trivestibulopollenites* has three pores and *Alnipollenites verus* has four to

six pores. This close relationship in the pore structure probably come from their botanical affinities, *Betula* and *Alnus* respectively, belonging to the same family, Betulaceae. *Betulaepollenites* and *Betulaceoipollenites* are considered as junior synonyms of the *Trivestibulopollenites*.

Botanical affinity: The species resemble extant pollen *Betula pendula*, Betulaceae and *Carpinus japonica*, Carpinaceae (Watanasak, 1988).

Occurrence: Rare in Na Hong coalfield. Watanasak (1988) reported this form from Late Oligocene to Middle Miocene throughout Thailand.

Genus: ***Ulmipollenites*** Wolff emend. Srivastava

Type species: *Ulmipollenites undulosus* Wolff

***Ulmipollenites* sp.**

Plate XXXII, figure 2.

1934, *Ulmipollenites undulosus* Wolff.

1962, *Ulmipollenites minor* Groot & Groot, p. 167, pl. 30, figs. 21-22.

Remarks: Only one grain was found from this study. It is visible in polar view showing four pores with a scabrate surface. The grain is clearly different from *Alnipollenites verus* on the basis of having no strongly formed arci as *Alnipollenites verus* has. *Ulmipollenites* pollen may contain 4 to 6 pores the same as in *Alnipollenites verus*. However, differentiation between the two genera is possible. First, *Alnipollenites verus* has vestibulate pores whereas there are no vestibulate pore on *Ulmipollenites*. Secondly, under the light microscope, *Alnipollenites verus* is smooth but *Ulmipollenites* is scabrate in polar view.

Ulmipollenites is distinctly ulmoid and quite variable. The number of pores varies from four to six and arci may be lacking, indistinctly and partially developed, or fully developed. Frederiksen (1980a,b) distinguishes *U. undulosus* from *Planera*

PLATE XXXII

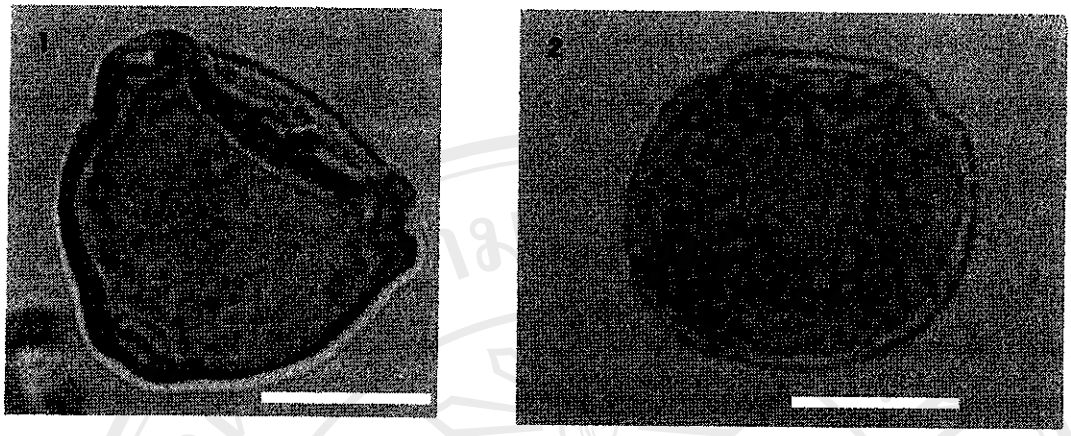


PLATE XXXII: Figure 1: *Trivestibulopollenites betuloides* Pflug, LM; figure 2: *Ulmipollenites* Srivastava, LM. The scale bars are 10 microns.

thompsoniana Traverse (1955) on the absence of arci in the former and their presence in the latter (Wingate, 1983). However, Wingate (1983) applies the form-species in his study to ulmoid pollen with four to six pores, with or without arci, recognizing they may represent *Ulmus*, *Planera*, or both, as well as *Zelkova*.

Botanical affinity: The fossil may represent *Ulmus* and *Zelkova*. *Ulmus* is a genus belonging to the family Ulmaceae. There are 18 species, occurring in the northern temperate zone, and in the mountains of the Asian tropics. *Zelkova* also belongs to the family Ulmaceae comprising 5 species occurring from the Mediterranean region to eastern Asia.

Occurrence: One grain of *Ulmipollenites* came from the overburden unit of Ban Pa Kha coalfield (sample no. OU-26).