

# Palynology of Coal-Bearing Units in the Mae Ramat Basin, Tak Province, Northern Thailand: Implications for the Paleoclimate and the Paleoenvironment

TIANPAN AMPAIWAN<sup>1</sup>, PUNYA CHURASIRI<sup>1\*</sup> AND CHUMPOL KUNWASI<sup>2</sup>

<sup>1</sup> Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, THAILAND

<sup>2</sup> Department of Botany, Faculty of Science, Chulalongkorn University, Bangkok 10330, THAILAND

**ABSTRACT.**—Ten representative samples were collected from a drilled core in the Mae Ramat coal-bearing Tertiary basin, for palynological study. The specimens analyzed were selected from coals and dark gray lignitic mudstone beds covering a successive interval of the rock sequence from 120 to 160 meters in depth. Totally 17 genera and 6 species of palynomorphs were identified, described, and counted. One biozone and two subzones were recognized: *Laevigatisporites* Biozone, which is dominated by spores of *Lavigatisporites* sp., *Magnastriatites grandiosus* Subzone, which is the abundance zone of *Magnastriatites grandiosus*, and *Trilites verrucatus* - *Graminidites* Subzone, which is the assemblage zone of *Polypodiisporites usmensis*, *Polypodiaceoisporites* sp., *Trilites verrucatus*, *Pinuspollenites* sp., *Graminidites* sp., *Momipites coryloides* and *Liquidambarpollenites* sp. Based on both palynological and lithological data, fresh-water lacustrine environment is indicated by the abundance of *Magnastriatites grandiosus*. Also, a humid temperate climate in the lower part of the sequence changing to warmer and more humid temperate climate trending to be subtropical climate was interpreted by the presence of temperate flora and the subsequent increase of subtropical flora. Although the exact age of the sequence cannot be definitely assigned, it was deduced from the paleoclimate and the time ranges of fossils as Early Miocene.

**KEY WORDS:** Palynology; Spores and Pollen; Tertiary; Paleoenvironment; Mae Ramat Basin

## INTRODUCTION

The Mae Ramat basin is a large coal bearing Tertiary basin located in Mae Ramat District, Tak Province, northern Thailand. A borehole (number MR7/43) was selected in this study

---

\* Corresponding author.

Tel: (662) 218-5456, (662) 218-5442,

(662) 218-5443

Fax: (662) 218-5464

E-mail: punya.c@chula.ac.th

and its location is shown in Figure 1. The Mae Ramat basin is regarded as an intermontane basin surrounded by the mountainous area in the Western Highland region. The lowest area is 186 meters above mean sea level. The east of the basin the area is flanked by the Thanon Thong Chai mountain range, of which the highest elevation is 908 meters above the mean sea level. To the west of the basin the area connects with the undulating terrain of the Socialist Republic of the Union of Myanmar.

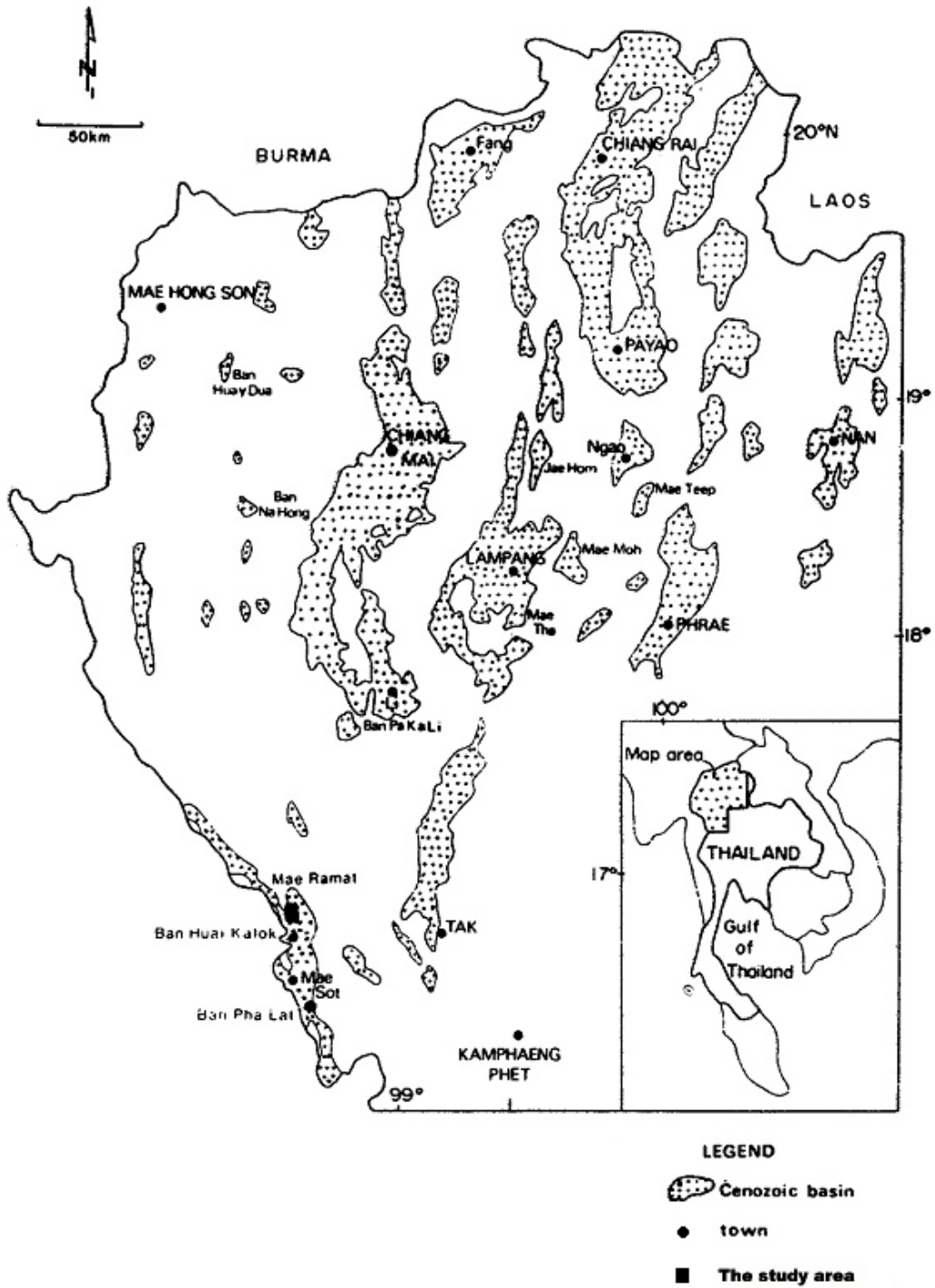


FIGURE 1. Map showing major Cenozoic basins in northwestern Thailand (Sherwood and Cook, 1984) and the location of the study area.

As for previous works on Tertiary spores and pollen in tertiary basins of Thailand, the spores and pollen have been analyzed by many previous investigators in several localities. In 1975, Paul and Lian studied palynomorphs in the Gulf of Thailand and established palynological zones consisting of *Podocarpus*, *Ducyrdium*, *Florschuetzia meridionalis*, *F. levipoli* and *F. trilobata* zones. After that, Ratanasthien (1984 and 1989) and Meesuk (1986) studied the palynology in various Tertiary basins of onshore Thailand, and interpreted their paleoenvironments. In 1989, Watanasak investigated palynomorphs in some Tertiary basins of onshore and offshore Thailand and also divided palynological zones into 2 zones: SIAM-I and SIAM-II zones. In 2000, Songtham analyzed palynomorphs in the Na Hong basin, northern Thailand, and interpreted a warm temperature for the paleoclimate during Late Oligocene to Early Miocene.

Most of the previous works in the study area as that of Chana and Kunawat (1976) and Suteethorn et al. (1984), as well as the stratigraphy of the basin as that of Thanomsap (1983) and Coal Survey and Evaluation Section (1993), concern the general geology of the area. Since the study basin is famous for fossil-fuel resource, particularly oil shale and coal, most of the works involve the occurrence and exploration of coal and oilshale (see Thanomsap, 1978; Thanomsap and Sitahirun, 1992). No systematic paleontology and palynology has been performed in this study area. Therefore, the main objective of this research is systematically describe and identify spores and pollen in coal bearing units, to create a biostratigraphy within the lithostratigraphic sequence based upon palynological data, to estimate the age of the rock sequence, and to suggest the paleoecology and paleoclimate of the stratigraphic unit.

## GEOLOGY AND STRATIGRAPHY

The Mae Ramat basin previously studied by Coal Survey and Evaluation Section, Mineral

Fuel Division, Department of Mineral Resources in 1993, is roughly 10-20 kilometers wide and 15-20 kilometer long. It connects with the Mae Sot basin. The margin of the basin is almost totally composed of coarse- to fine-grained sandstone, whereas the center of the basin contains mudstones, shale, coal, and medium- to fine- grained sandstone. The basin is characterized by a full garben structure with a N-trending dip slip component. The rock strike lies ma northwest-southeast easy direction and dips from the horizontal to a southern direction some 20-25°.

Based upon well-exploration data by the Mineral Fuels Division (Coal Survey and Evaluation Section, 1993), rocks of the basin can be grouped into 3 units in ascending order: unit A (>100 m thick), unit B (about 600 m thick), and unit C (100 m thick) (Figure 2). Unit A and unit C are coal-barren units, but unit B is a coal-bearing unit. Unit A, which overlies the basement, comprises conglomerates, conglomeratic sandstones and coarse-grained sandstone. Its thickness is more than 500 meters. Unit B, underlain by unit A, can be subdivided into 4 subunits in ascending order: unit B1, Unit B2, unit B3, and unit B4. Unit B1 and unit B3 are mainly made up of mudstone and fairly thick-bedded coals, but unit B2 and unit B4 contain generally mudstone, sandstone, and thin-bedded coal.

## MATERIALS AND METHODS

A total of ten samples used in this study were collected from a core sample of the MR7/43 borehole in the coal bearing unit of unit B3 (Coal Survey and Evaluation Section, 1993) between 120 and 160 meters from surface. The samples were coal and dark gray lignitic shale with successive intervals of mudstone and sandstone as shown in Figure 3.

In this research, only the method of palyological study is described in order, and this method is slightly modified from Brown (1960), Meesuk (1986), Traverse (1988), and Wood et al. (1996). The steps are explained below:

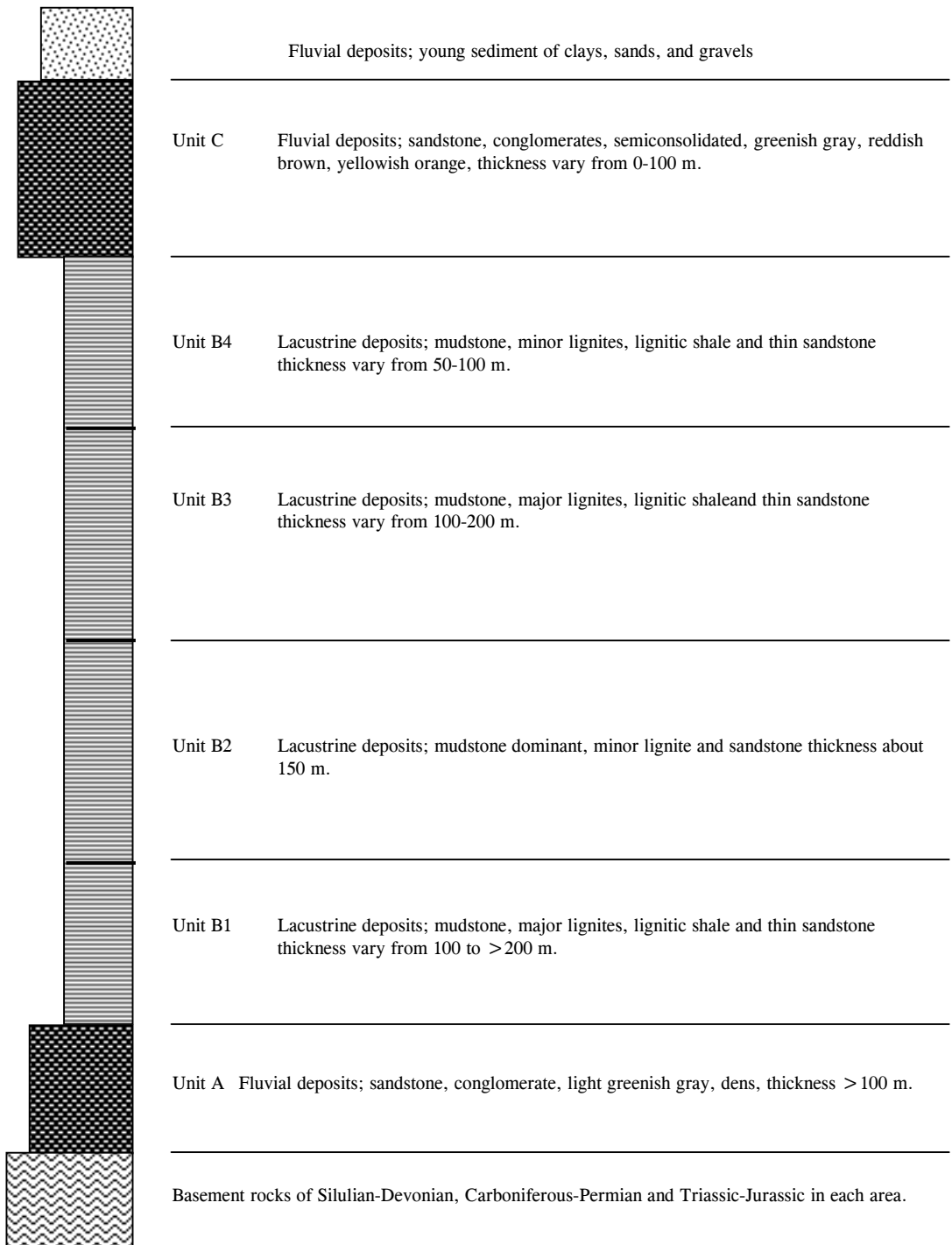


FIGURE 2. Stratigraphy column of Mae Ramat basin showing unit B3 in which this research concentrates (Coal Survey and Evaluation Section, 1993).

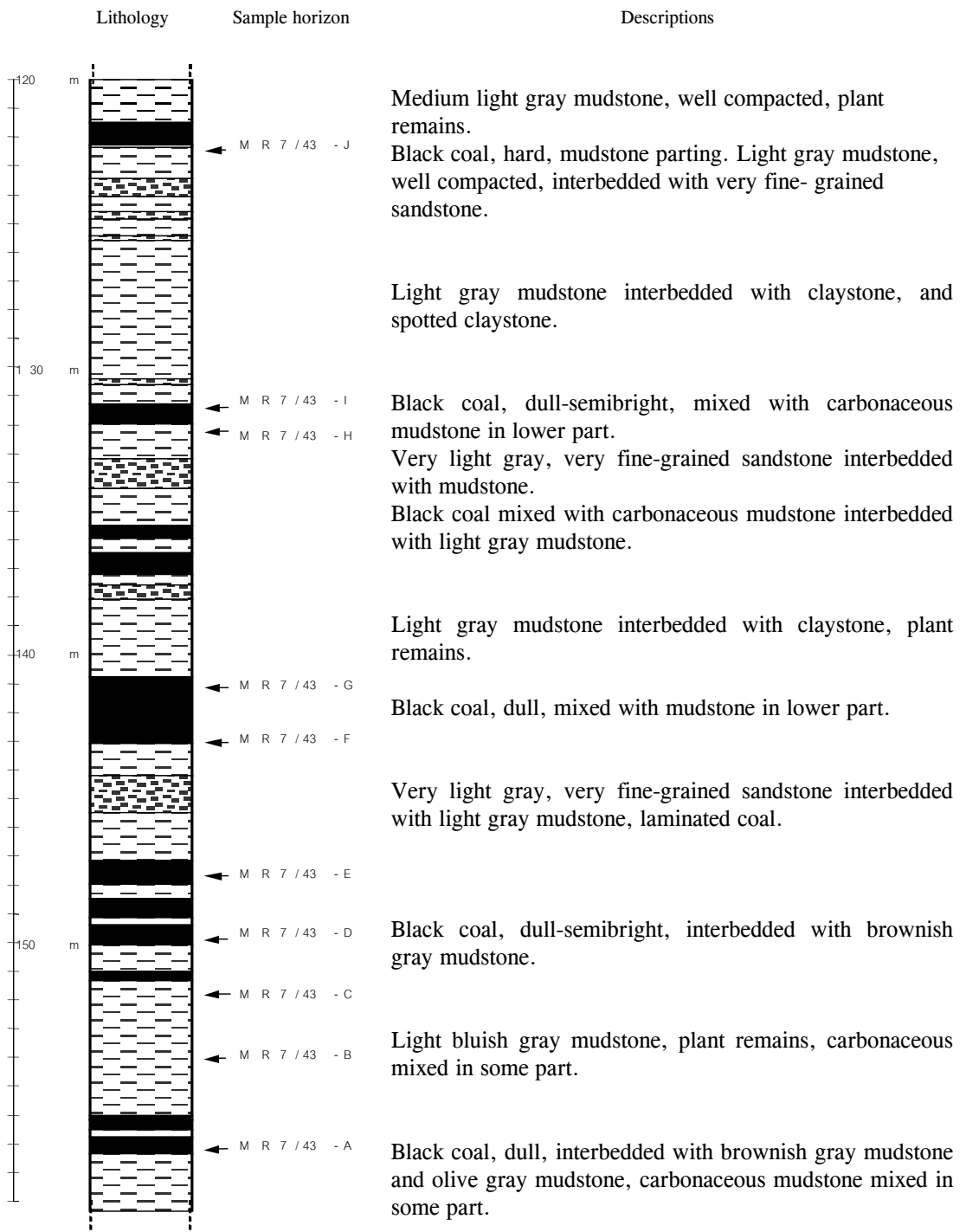


FIGURE 3. Lithostratigraphic sequence in a part of bore hole No. MR7/43 of Mae Ramat basin presenting the locations of samples. (symbol : mudstones; sandstones; coals)

1. About one hundred grams of each core sample was washed carefully with water and then was cut to eliminate the outer contaminated surface. The dried sample was crushed to a particle size of about 1-2 mm. and then kept in a clean dry, plastic bag.

2. About twenty-five grams of sample was put in an acid-resistant polythene bottle and was covered with 20% hydrochloric acid solution at room temperature for roughly 3 days. The solution was decanted after adding distilled water, until it was neutral.

3. The residue were flooded with 50 % hydrofluoric acid in a hot bath at 50-60°C for at least one week. The solution and residue was washed by centrifugal technique until the residues was neutral.

4. Unwanted organic debris still remained. It could be oxidized by slowly adding concentrated nitric acid for 6-10 hours. When the color of solution was altered from colorless to dark brown, the solution was washed with distilled water by centrifugal technique.

5. Unwanted organic matter was transformed into dark brown humic acid and expelled by using a 5% potassium hydroxide solution for 3 minutes. The residues was washed, until it was clear. Subsequently, palynomorphs were poured into a centrifugal tube.

6. The palynomorphs were dehydrated by filling, shaking, and then decanting 70%, 95% and 100% ethyl alcohol respectively in addition to covering with by benzene in a glass-storage tube. Afterwards, silicone oil No. AK2000 was dropped into it. The glass-storage tube was uncovered till the benzene was exhausted by vaporization.

7. A small drop of the silicone oil, containing the palynomorphs, was laid on a clean slide and then superimposed with a glass cover that was sealed with paraffin.

Palynomorphic identification and counting of over 250 specimens per sample was done under the microscope with x 1000 and x 400 magnification, respectively. Measurement was made under the microscope using a x 10 eyepiece micrometer calibrated with a 1000 microns slide micrometer and a x 40 and a x 100 objective lenses. Representative palynomorphs were selected and photographed. The position of individual representative palynomorphs was recorded as coordination of their "grid references". Some representative palynomorphs were examined for their surface morphology using a Scanning Electron Microscope.

#### SYSTEMATIC DESCRIPTION

In 1956, Potonié proposed the "turmasystem", an artificial classification which establishes and delimits fossil spores and pollen with in the hierarchy of classes. This system is generally like the formal taxonomic hierarchy; however it does not conform to the International Code of Botanical Nomenclature. Each species in the turmasystem belongs to a series of taxa of consecutively higher ranges namely Genus, Infraturma (or Subfamily), Subturma (Family), Turma (Order) and Anteturma (Class). According to the present study, 18 taxa of fossil palynomorphs are determined.

Anteturma SPORITES Potonié, 1893  
 Turma MONOLETES Ibrahim, 1933  
 Subturma AZONOMONOLETES Luber, 1935  
 Infraturma SCULPTATOMONOLETI Dyb. and Jach., 1957  
 Genus *Polypodiisporites* Potonié 1931 ? in Potonié and Gelletich, 1933 ex Potonié, 1956

Type species: *Polypodiisporites favus* Potonié and Gelletich, 1933 ex Potonié, 1956

- 1931 *Sporonites* Potonié
- 1931 *Polypodiisporonites* Potonié
- 1949 *Polypodiidites* Ross, p.33.
- 1953 *Verrucatosporites* Pflug and Thomson in Thomson and Pflug, p. 59.
- 1953 *Reticuloidosporites* Pflug in Thomson and Pflug, p. 60.
- 1956 *Verrumonoletes* Van der Hammen, p. 116.
- 1956 *Polypodiisporites* Potonié, p. 78.
- 1959 *Verrucatosporites* (Thomson and Pflug) Krutzsch, p. 204.
- 1960 *Polypodiidites* Potonié, p. 461.
- 1971 *Polypodiisporites* Potonié emend. Khan and Martin, p. 475-480.
- 1984 *Polypodiisporites* Potonié, 1931 emend. Pocknall and Mildenhall, p. 21.

*Polypodiisporites inangahuensis* Couper, 1953 emend. Pocknall and Mildenhall, 1984  
 Plate 1, figs 1-2

- 1953 *Polypodiidites inangahuensis* Couper
- 1956 *Polypodiites inangahuensis* (Couper) Potonié, p. 79.
- 1959 *Verrucatosporites inangahuensis* (Couper) Krutzsch, p. 205.
- 1960 *Polypodiidites inangahuensis* Couper in Couper, p. 39. pl. 1, fig. 7.
- 1967 *Verrucatosporites inangahuensis* (Couper) Krutzsch in Krutzsch, p. 196, pl. 74, fig. 1.
- 1984 *Polypodiisporites inangahuensis* Couper 1953 emend. Pocknall and Mildenhall

*Description.* Spore monolete, laesurae straight, relatively short, ca 2/3 the length. Polar view ellipsoidal; equatorial view bean-shaped with straight or slightly concave at proximal surface; bilateral symmetry. Sculpture verrucate, verrucae flat, 0.5-1  $\mu$  in height and  $\mu$  in basal diameter. Size 44-68 x 30-60  $\mu$ . Exine thickness 2-3  $\mu$ .

*Botanical affinities.* It probably belongs to the Family Polypodiaceae and is closely related to *Microsorium* aff. *diversifolium* (Willd.), an epiphytic ferns dispersing in pantropical regions (Tryon and Lugardon, 1991).

*Distributions.* Middle Eocene to Late Miocene from New Zealand (Pocknall and Mildenhall, 1984). The synonymous species *Polypodiidites inangahuensis* was reported from the Waitakian (Middle Oligocene) to the Lower Nukumaruan (Lower Pleistocene) of New Zealand (Couper, 1953). In this study, the specimens were found in sample no. MR7/43-A, MR7/43-D, MR7/43-E, and MR7/43-I.

*Polypodiisporites usmensis* Van der Hammen, 1956 emend. Khan and Martin, 1971  
 Plate 1, fig. 5

- 1956 *Verrumonoletes usmensis* Van der Hammen, p. 116, fig. 7
- 1968 *Verrucatosporites usmensis* (Van der Hammen) Germeraad, Hopping and Muller, p. 280, pl. 2, fig. 3

1971 *Polypodiisporites usmensis* Van der Hammen, 1956 emend. Khan and Martin, p. 478, pl. 2, fig. 10.

1972 *Polypodiidites usmensis* (Van der Hammen) Hekel, p. 6, pl. 1, figs 8-9

1982 *P. usmensis* (Van der Hammen) Hekel in Playford, p. 42, pl. 5, figs 4-7

*Description.* Spore monolete, laesura straight, relative opened about  $1\ \mu$  in width, ca  $2/3$  the length. Polar view ellipsoidal; equatorial view bean-shaped with straight or slightly concave at proximal surface; bilateral symmetry. Sculpture verrucate; verrucate cone-like, irregularly in shape and size,  $1-1.5\ \mu$  in height,  $1.5-2.5\ \mu$  in basal diameter. Size  $33-40 \times 23-30\ \mu$ . Exine thickness  $0.5-1\ \mu$ .

*Botanical affinities.* Germeraad et al. (1968) related this species to an Indo-Malasian epiphytic climbing fern species *Stenochlaena palustris*, family Polypodiaceae, distributed in pantropical regions and indicating the humid environment (Tryon and Lugardon, 1991).

*Distributions.* This species was occasionally found in Mae Teep, Mae Mo, Li, and Krabi samples (Meesuk, 1986). The same species was reported from the Eocene to Holocene of northern South America, Nigeria, and Borneo (Germeraad et al., 1968), and Neogene of Queensland (Hekel, 1972). In this study, the specimens were found rather abundantly throughout the sequence.

Infraturma LAEVIGATOMONOLETI Dyb. and Jach., 1957

Genus *Laevigatosporites* Ibrahim, 1933

Type species: *Laevigatosporites vulgaris* Ibrahim, 1933

1932 *Sporonites* Ibrahim

1933 *Laevigatosporites* Ibrahim, p. 39.

1937 *Polypodiumsporites* Raatz, p. 10.

1938 *Polypodiaceasporites* Thiergart, p. 297.

1940 *Phaseolites* Wilson and Coe, p. 182.

1944 *Laevigatosporites* Ibrahim emend. Schopf and others, p. 36.

*Laevigatosporites* sp.

Plate 1, figs 3-4

*Description.* Spore monolete, laesura straight,  $2/3$  to  $3/4$  the length. Polar view ellipsoidal; equatorial view bean-shaped with concave proximal surface; bilateral symmetry. Sculpture laevigate. Size  $35 \times 25\ \mu$ . Exine thickness less than  $0.5\ \mu$ .

*Botanical affinities.* A *Laevigatosporites* sp. occurs in the modern families Dryopteridaceae, Aspleniaceae, Blechnaceae, Gleicheniaceae, Lomariopsidaceae, Polypodiaceae, and Pteridaceae which are almost certainly herbaceous. (Frederiksen, 1980).

*Distributions.* In this study the specimens are abundant in all samples

Turma TRILETES (Reinsch) Dettmann, 1963

Subturma AZONOTRILETES Luber, 1935

Infraturma LAEVIGATI (Bennie and Kidston 1886) emend. Potonié, 1956

Genus *Laevigatisporites* (Bennie and Kidston) Ibrahim, 1933

Type speci: *Laevigatisporites primus* (wicher) Potonié and Kremp 1954

1933 *Laevigatisporites*, Ibrahim, p. 17.



*Laevigatisporites* sp.

Plate 1, figs 6-7

*Description.* Spore trilete, laesurae distinct, the arms straight, 2/3 to 3/4 the radius. Shape tetrahedral globose; proximal view triangular with straight to slightly convex side and round angles; radial symmetry. Sculpture laevigate. Equatorial diameter 42-50  $\mu$ . Exine thickness 1.2-1.5  $\mu$ .

*Botanical affinities.* It resembles to the genus *Lygodium* (Thomson and Pflug, 1953) of family Schizaeaceae, known as climbing ferns, distributed both in tropical and temperate regions.

*Distribution.* In this study, the genus is also relatively abundant in all samples.

Genus *Triplanosporites* Pflug (in Thomson and Pflug 1952) ex Thomson and Pflug, 1953

Type species: *Triplanosporites sinuosus* Pflug in Thomson and Pflug, 1953, p. 58, pl. 3, fig. 7  
1953 *Triplanosporites* Pflug (in Thomson and Pflug 1952) ex Thomson and Pflug, p. 58.

cf. *Triplanosporites* sp.

Plate 1, fig. 8

*Description.* Spore trilete, laesura straight, indistinct. Shape tetrahedral with convex sides and rounded angle, axial symmetry. Sculpture laevigate. Diameter ca 50  $\mu$ . Exine thickness 1.2-1.5  $\mu$ .

*Botanical affinities.* This genus probably relates to Gleichenoid fern (Thomson and Pflug, 1953).

*Distribution.* The specimens were found in the upper and lower parts of the sequence.

Genus *Concavisporites* Pflug, 1953

Type species: *Concavisporites exiguus* Pflug 1953, pl. 1, fig. 44.

1953 *Concavisporites* Pflug, p. 50.

*Concavisporites* cf. *minimodivisus* Nagy, 1963

Plate 1, fig. 9

1963 *Concavisporites minimodivisus* Nagy, p. 387, pl. 1, figs 1-4, text-fig. 1

*Description.* Spore trilete, laesulae well developed, the arms very long, nearly to or equal the radius. Thick wall on proximal surface looks like kyrtome. Shape tetrahedral. Proximal view triangular with straight, slightly concave or convex sides and rounded angle; radial symmetry. Sculpture laevigate. Equatorial diameter 42  $\mu$ . Exine thickness ca 1  $\mu$ .

*Botanical affinities.* It perhaps belongs to Family Gleicheniaceae

*Remark.* Kyrtome-like features found in these specimens may be caused by a folding of the spore wall. If so, these specimens may be identified as *Laevigatisporites* sp.

*Distribution.* In this study, the genus was found in sample no. MR7/43-B only.

Infraturma MURONATI Potonié and Krutzsch, 1954

Genus *Magnastriatites* Germeraad, Hopping and Muller, 1968

Type species: *Magnastriatites howardii* Germeraad, Hopping and Muller, 1968, pl. , fig. 1

1968 *Magnastriatites* Germeraad, Hopping and Muller, p.288.

*Magnastriatites grandiosus* (Kedves and Sole' de Porta) Duenas, 1980

## Plate 1, figs 10–13

1963 *Cicatricosisporites grandiosus* Kedves and Sole' de Porta, p. 59, pl. 7, figs 2-3.

1968 *Magnastriatites howardii* Germeraad, Hopping and Muller, p. 288-289, pl. 3, fig. 1.

1980 *Magnastriatites grandiosus* (Kedves and Sole' de Porta) Duenas, p. 331, pl. 1, figs 1-3.

*Description.* Spore trilete, laesurae straight, the arms 1/2 to 2/3 the radius. Shape tetrahedral globose to globose, proximal view subtriangular with convex sides; radial symmetry. Sculpture striate, coarse ridges radial from the angles in nearly parallel alignment; contact area of proximal surface psilate and surrounded by a circle of ridges. Ridge (or striae) 1.5  $\mu$  in width, 1-1.5  $\mu$  in height. Equatorial diameter 52-78  $\mu$ . Exine thickness 1.5-2  $\mu$ .

*Botanical affinities.* Virtually identical with the spore of the tropical-subtropical fresh-water, free-floating fern genus *Ceratopteris* of Parkeriaceae (Germeraad et al, 1968).

*Distributions.* Abundant from Mae Mo deposit (Meesuk, 1986). The same species was recorded from the Oligocene deposits of Borneo (Pantropical) area (Germeraad et al., 1968) and Miocene deposits in Taiwan (Huang, 1978). In this study, the specimens are abundant in sample nos. MR7/43-I and MR7/43-J, the upper part of the sequence.

Genus *Trilites* Erdtman ex Couper emend. Dettmann, 1963

Type species: *Trilites tubercurculiformis* Cookson, 1947, p. 136, pl. 16, fig. 61.

1947 *Trilites* Erdtman, p. 110.

1947 *Trilites* (Erdtman) Cookson, p. 136.

1951 *Lygodioisporites* Potonié, p. 144.

1953 *Trilites* Cookson ex Couper, p. 29.

1955 *Lygodioisporites* Potonié ex Delcourt and Sprumont, p. 33.

1963 *Trilites* Erdtman ex Couper emend. Dettmann,

*Trilites verrucatus* Couper, 1953

## Plate 1, fig. 14

1953 *Trilites verrucatus* Couper, p. 31, pl. 3, figs 26, 27.

*Description.* Spore trilete, laesura long, distinct. Shape tetrahedral globose to globose; polar view subtriangular with convex sides; radial symmetry. Sculpture verrucate, verrucae 1  $\mu$  in height, regularly distributed on both proximal and distal surface, somewhat reduced on proximal surface. Equatorial diameter ca 40  $\mu$ . Exine thickness 2-3  $\mu$ .

*Botanical affinities.* Unknown.

*Distribution.* In this study, the species is abundant in sample no. MR7/43-A, and MR7/43-E.

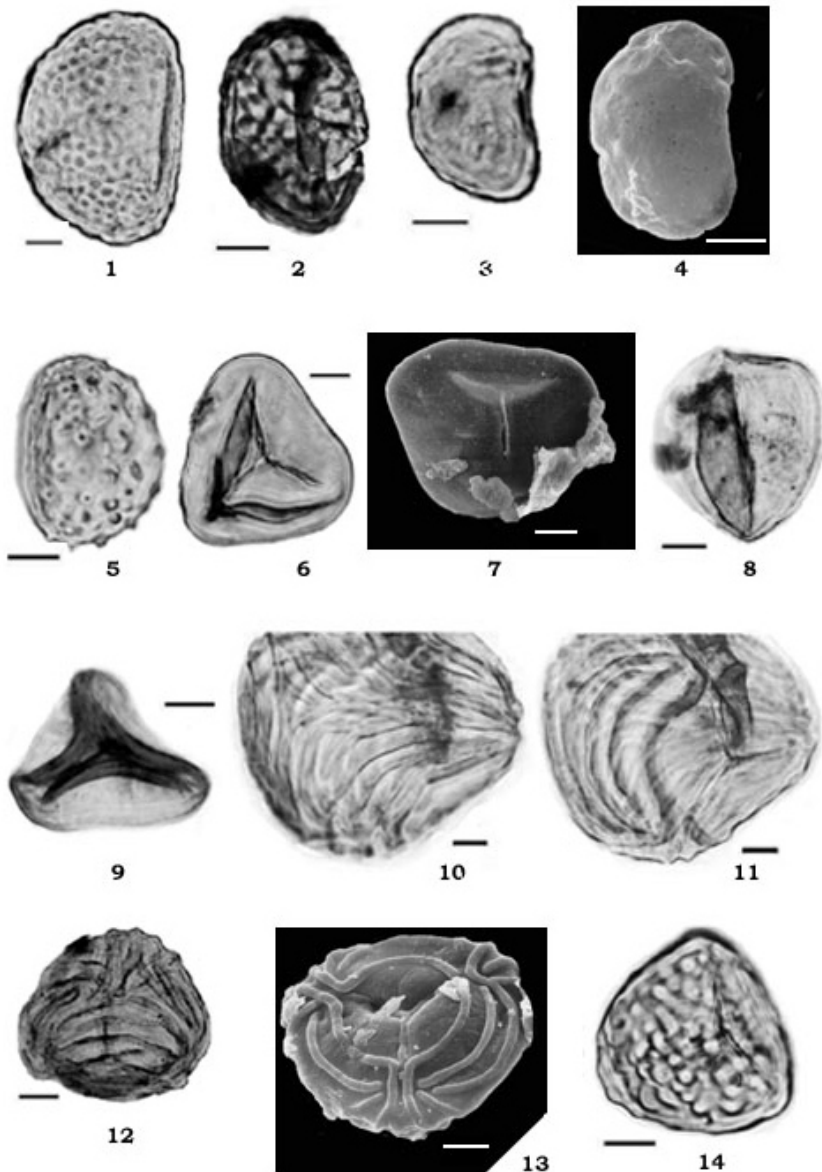


PLATE 1. (Figs 1-2) *Polypodiisporites inangahuensis*; (Figs 3-4) *Laevigatosporites* sp.; (Fig. 5) *Polypodiisporites usmensis*; (Figs 6-7) *Laevigatosporites* sp.; (Fig. 8) cf. *Triplanosporites* sp.; (Fig. 9) *Concavisporites* cf. *minimodivisus*; (Figs 10-13) *Magnastriatites grandiosus*; (Fig. 14) *Trilites verrucatus* (Bar scale = 10 microns).

Subturma ZONOTRILETES Waltz, 1935  
 Infraturma CINGULATI Potonié and Klaus, 1954  
 Genus *Polypodiaceoisporites* Potonié, 1951 ex Potonié, 1956

Type species: *Polypodiaceoisporites speciosus* (Potonié, 1934) ex Potonié, 1956

1950 *Polypodiaceoisporites* Potonié, p. 136.

1951 *Polypodiaceoisporites* Potonié, p. 63.

*Polypodiaceoisporites* sp.

Plate 2, figs 1-4

*Description.* Spore trilete, laesurae distinct, the arm ca 2/3 the radius. Shape tetrahedral to globose with equatorial to subequatorial flange (or cinculum); cinculum 2-4  $\mu$  in width; polar view triangular to subtriangular with straight to slightly convex sides and round angles; radial symmetry. Sculpture coarsely regulate, cinculum psilate. Equatorial diameter 30-40  $\mu$ .

*Botanical affinities.* It affiliates to *Pteris* sp. of family Adiantaceae, distributed in tropical and temperate regions. The genus lives in subtropical humid forest between 900-2,000 meters (Jones and Luchsinger, 1979).

*Distribution.* The numbers of the specimens are abundant in sample no. MR7/43-E, but rare in other samples

Anteturma POLLENITES Potonié, 1931  
 Turma SACCITES Erdtman, 1947  
 Subturma DISACCITES Cookson, 1947  
 Genus *Pinuspollenites* Raatz, 1937 ex Potonié, 1958

Type species: *Pinuspollenites labdacus* Raatz, 1937 ex Potonié, 1958

1931 *Pollenites* Potonié, p. 5, fig. 32.

1937 *Pollenites* Raatz, p. 15.

1953 *Pityosporites* (Potonié) Thomson and Pflug, p. 66, pl. 5, figs 60-62.

1958 *Pinuspollenites* Raatz, 1937 ex Potonié, p. 62.

1964 *Pityosporites* (Potonié) Thomson and Pflug in Stichlik, p. 26, pl. 9, figs 4-9

*Pinuspollenites* sp.

Plate 2, figs 5-6

*Description.* Pollen monad, heteropolar, bisaccate, bilateral symmetry. Corpus sub-circular in polar view. Proximal cap indistinct with faintly tuberculate sculpture. Dorsal outline even to slightly undulate, body outline slightly undulate in the region of sac attachment. Sacci fairly broadly attached to the corpus and not constricted at the attachment points. Sculpture of the sacci loosely reticulate. Corpus 45-53  $\mu$  in width and 35-40  $\mu$  in length, Sacci 20-25  $\mu$  in diameter.

*Botanical affinities.* It is very close to the genus *Pinus* of the family Pinaceae (Thomson and Pflug, 1953). The genus is abundant at elevations between 1,000 and 2,000 meters in Nepal (Mani, 1978).

*Distribution.* This genus has been found in all samples of the sequence and abundant in sample no. MR7/43-A, the lowest part of the sequence.

Turma POROSES Naumova emend. Potonié, 1960  
 Subturma MONOPORINES Naumova, 1939  
 Genus *Graminidites* Cookson, 1947 ex Potonié, 1960

Type species: *Graminidites media* (Cookson, 1947) Potonié, 1960

1947 *Monoporites* (*Graminidites*) Cookson, p. 134.

1954 *Monoporites* *Hammen*, p. 83.

1956 *Monoporopollenites* Meyer, p. 111.

1960 *Graminidites* Cookson 1947 ex Potonié, p. 111.

*Graminidites* sp.

Plate 2, fig. 7

*Description.* Pollen grain monoporate, pori circular, 1-2  $\mu$  in diameter, with distinct annulus of about 1.5-2  $\mu$  in width. Shape spheroidal (but always folded). Sculpture psilate. Diameter of grain 25-30  $\mu$ . Exine thickness less than 0.5  $\mu$ .

*Botanical affinities.* Family Gramineae. The genus disperses in all altitude ecosystem (Jones and Luchsinger, 1979).

*Remarks.* *Graminidites* sp. is decided as equivalence of *Monoporopollenites gramineoides*.

*Distribution.* In this study, the genus is abundant in the upper part of the sequence. Its synonym, *Monoporopollenites gramineoides*, distributes from Oligocene to Recent (Germeraad et al., 1968).

Subturma TRIPORINES Naumova, 1939

Genus *Momipites* Wodehouse, 1933 emend. Frederiksen and Christopher, 1978

Type species: *Momipites coryloides* Wodehouse 1933

1934 *Momipites* Wodehouse, p.511.

1973 *Momipites* Wodehouse emend. Nichols, p. 106-108.

1978 *Momipites* Wodehouse emend. Frederiksen and Christopher

*Momipites coryloides* Wodehouse, 1933

Plate 2, fig. 8

1935 *Momipites coryloides* Wodehouse, p. 511, fig. 43.

1952 *Tripoporopollenites coryloides* Pflug in Thomson and Pflug, p. 82 pl. 9, fig. 20.

1976 *Momipites* sp. (coryloid form) Potter, p.78, pl. 5, figs 112-114.

1980 *Momipites* Group A Wilkinson and Boulter, p. 52, pl. 5, figs 6-12.

*Description.* Pollen grain triporate, pori angulaperturate, subcircular, ca 1  $\mu$  in diameter. Polar view triangular to subcircular with convex sides, the grains are usually flattened. Sculpture psilate. Exine thickness ca 0.5  $\mu$ , thicker around pori. Equatorial diameter ca 17  $\mu$ .

*Botanical affinities.* It more or less resembles the genus *Corylus* (Thomson and Pflug, 1953) of the family Betulaceae. The genus is deciduous tree or shrub occurring particularly in the North Temperate Zone, but in the New World it extends into tropical mountains and along the Andes to Argentina (Jones and Luchsinger, 1979). It was suggested as a wind-pollinated parent plant (Frederiksen, 1980).

*Distributions.* The synonymous species *Tripoporopollenites coryloides* was common within the samples from the Na Hong deposit (Songtham, 2000), Li and Krabi deposit (Meesuk, 1986), and the

Middle to Upper Tertiary deposit of Central Europe (Thomson and Pflug, 1953). In this study, one specimen was found in sample no. MR7/43-F.

Subturma POLYPORINES Naumova, 1939  
Genus *Liquidambarpollenites* Raatz, 1937 ex Potonié, 1960

Type species: *Liquidambarpollenites stigmatosus* (Potonié 1931) Raatz, 1937

- 1931 *Pollenites stigmatosus* Potonié, p. 329.
- 1937 *Liquidambar-pollenites* Raatz, p. 17.
- 1953 *Periporopollenites* Pflug and Thomson in Thomson and Pflug, p. 111.
- 1960 *Liquidambarpollenites* Potonié, p. 134.
- 1960 *Caryophyllidites* Couper, p. 68.
- 1966 *Periporopollenites* Thomson and Pflug, amend. Krutzsch, p. 39.

*Liquidambarpollenites* sp.  
Plate 2, figs 9-10

*Description.* Pollen grain 12-14 pantoporate, poridistinct, elliptic, 1-1.5  $\mu$  in diameter. Shape circular. Sculpture psilate. Diameter of grain 18-20  $\mu$ . Exine thickness 0.5-1  $\mu$ .

*Botanical affinities.* Genus *Liquidambar* of the Family Hamamelidaceae, which recently settles in temperate areas of western North America, Asia Minor, and eastern Asia (Songtham, 2000).

*Distribution.* The genus disperses throughout the sequence.

Genus *Caryophyllidites* Couper, 1960

Type species: *Caryophyllidites polyoratus* Couper, 1960, pl. 10, fig. 14.

*Caryophyllidites* sp.  
Plate 2, figs 11-12

- 1960 *Caryophyllidites* Couper, p. 68.
- 1960 *Pollenites stellatus* Mamczar in Doktorowicz - Hrebicka and Mamczar

*Description.* Pollen grain pantoporate, number of pori more than 20, pori circular, surrounded by thin, slit-like structure. shape circular with faintly way outline. Sculpture psilate. Diameter of grain ca 23  $\mu$ . Exine thickness 0.5-1  $\mu$ .

*Botanical affinities.* Family Caryophyllaceae, annual or perennial herbs with swollen nodes, occurs in temperate area mostly in Northern Hemisphere (Benson, 1959). The genus is the subalpine taxon which distributes at high altitude regions between 3,000 and 3,600 meters above mean sea level (Mani, 1978).

*Distribution.* The genus was found in sample no. MR7/43-F only.

Turma PLICATES Naumova, 1939  
Subturma TRIPTYCHES Naumova, 1939  
Genus *Fraxinoipollenites* Potonié 1951 (Wien) ex Potonié, 1960

Type species: *Fraxinoipollenites pudicus* Potonié 1951 ex Potonié, 1960

- 1951 *Fraxinoipollenites* Potonié, p. 277.

1961 *Fraxinoipollenites* Potonié, p. 94.

*Fraxinoipollenites* sp.

Plate 2, fig. 13

*Description.* Pollen tricolporoidate, colpi slightly shorter than the polar axis, endoaperture hardly visible or indistinct. Shape in equatorial view prolate ellipsoid. Sculpture fine or faintly reticulate. Polar axis ca 30  $\mu$ , equatorial diameter ca 18  $\mu$ .

*Botanical affinities.* Genus *Fraxinus* of family Oleaceae. In eastern Nepal, this genus lives at high altitude, 2,500-3,000 meters above mean sea level (Mani, 1978). In general, the genus occurs in temperate regions (Benson, 1959).

*Distribution.* In this study, the genus was found in sample no. MR7/43-I, MR7/43-H, MR7/43-F.

Genus *Quercoidites* Potonié, Thomson and Thiergart, 1950 ex Potonié, 1960

Type species: *Quercoidites henrici* (Potonié, 1931) Potonié, 1960

1960 *Quercoidites* Potonié, Thomson and Thiergart 1950 ex Potonié, p. 92.

*Quercoidites* sp.

Plate 2, figs 14-15

*Description.* Pollen tricolpate (or tricolporoidate), colpi distinct, as long as or slightly shorter than polar axis. Shape in equatorial view prolate elliptic. Sculpture psilate, scabrate or granulate. Polar axis ca 23  $\mu$ , equatorial diameter ca 17  $\mu$ .

*Botanical affinities.* Genus *Quercus* of family Fagaceae. In eastern Nepal, this genus lives at 1,900-3,000 meters above mean sea level (Mani, 1978).

*Remark.* Some psilate-sculpture specimens are not similar to Potonié's (1960) description. The author identified some psilate-sculpture specimens as *Quercoidites* sp. because they are similar to those of Recent *Quercus* sp.

*Distribution.* In this study, the genus disperses throughout the sequence.

Other palynomorphs.

Genus *Fusiformisporites* Rouse, 1962

Type species: *Fusiformisporites crabbii* Rouse, 1962

1962 *Fusiformisporites* Rouse, v. 8, p. 210.

*Fusiformisporites* sp.

Plate 2, fig. 16

*Description.* Fungal spores, very distinctly fusiform in outline. The unit is split into two equal halves by an equatorial wall that appears to be continuous, thus completely dividing the unit. Longitudinal grooves spread out along the wall from either pole. Long axis 17-20  $\mu$ , short axis 8-10  $\mu$ .

Genus *Dyadosporites* Van der Hammen, 1954 ex Clarke, 1965

Type species: *Dyadosporites ellipsus* Clarke, 1965

1954 *Dyadosporites* Van der Hammen, v. 2, no. 2, p. 15.

1965 *Dyadosporites* Van der Hammen, 1954 ex Clarke, v. 2, no. 2, p. 90.

*Dyadosporites* sp.

Plate 2, fig. 17

*Description.* Fungal spores bilocular, two spores united. Elliptical, central septum simple,  $1\ \mu$  thick; cell wall psilate,  $1-2\ \mu$  thick; pore at apex of each cell,  $3-4\ \mu$  in diameter. Long axis  $28-30\ \mu$ , short axis  $13-15\ \mu$ .

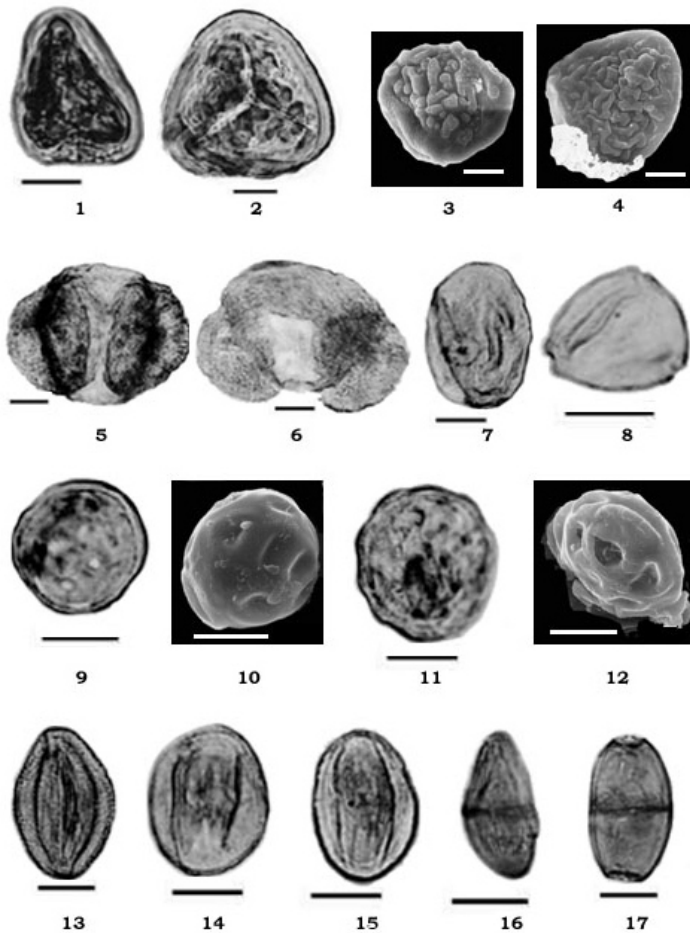


PLATE 2. (Figs 1-4) *Polypodiaceoisporites* sp.; (Figs 5-6) *Pinuspollenites* sp.; (Fig. 7) *Graminidites* sp.; (Fig. 8) *Momipites coryloides*; (Figs 9-10) *Liquidambarpollenites* sp.; (Figs 11-12) *Caryophyllidites* sp.; (Fig. 13) *Fraxinoipollenites* sp.; (Figs 14-15) *Quercoidites* sp.; (Fig. 16) *Fusiformisporites* sp.; (Fig. 17) *Dyadosporites* sp. (Bar scale = 10 microns)



## BIOSTRATIGRAPHY

Some palynomorphs from the 10 coal and mudstone samples prepared for palynological slide were identified and described as 12 genera 6 species. More or less 250 to 500 existing palynomorphs were counted and, subsequently, the relative frequency of each taxon in individual samples was calculated as percentage value.

Biostratigraphic zonations were grouped by means of recognizing distributions and abundance of the palynomorphs (Fig. 4). A biozone, *Laevigatisporites* Biozone, and two subzones, *Magnastriatites grandiosus* and *Trilites verrucatus - Graminidites* Subzones, were determined.

### *Laevigatisporites* Biozone.

The *Laevigatisporites* Biozone covers all of the stratigraphic column of the study area. This zone is defined as the abundance zone of *Laevigatisporites* sp. The lower and upper boundaries of this zone are not precisely recognized because the abundance of *Laevigatisporites* sp. in the lower and upper parts of the sequence continually appears further from the sequence of the study area in all probability.

This zone is significant for paleoecology and paleoclimate reconstruction but not for aspects of age because range of the genus is very wide. The zone can be subdivided into 2 subzone: *Trilites verrucatus - Graminidites* Subzone and *Magnastriatites grandiosus* Subzone, in ascending order.

### *Trilites verrucatus - Graminidites* Subzone

The *Trilites verrucatus - Graminidites* Subzone is located at the lower part of the stratigraphic sequence. The subzone is defined as the assemblage zone of *Polydiisporites usmensis*, *Polypodiaceoisporites* sp., *Trilites verrucatus*, *Pinuspollenites* sp., *Graminidites* sp., *Momipites coryloides* and *Liquidambarpollenites* sp. The lower boundary is defined by the first appearance of

*Polydiisporites usmensis*, *P. inangahuensis*, *Trilites verrucatus*, *Pinuspollenites* sp., *Graminidites* sp. and *Liquidambarpollenites* sp. The upper boundary is pointed by the last appearance of *Polypodiaceoisporites* sp. and *Graminidites* sp. This zone conformably underlies the *Magnastriatites grandiosus* Subzone.

### *Magnastriatites grandiosus* Subzone

The *Magnastriatites grandiosus* Subzone overlies the *Trilites verrucatus - Graminidites* Subzone. This zone is the upper part of the stratigraphy of the study area. The *Magnastriatites grandiosus* Subzone is defined as the assemblage zone of *Magnastriatites grandiosus*.

This zone is meaningful for paleoecology and paleoclimate reconstruction as well as age determination. The abundance of the species appears in Upper Oligocene to Miocene deposit of East and SE Asia (Germeraad et al., 1968; Huang, 1978; Ratanasthien et al., 1989).

## DISCUSSION

### Paleoclimate

About three-quarters of palynomorph assemblage contains fossil spores of a number of taxa, i.e. *Polydiisporites inangahuensis*, *Polydiisporites usmensis*, *Laevigatisporites* sp., *Laevigatisporites* sp., *Magnastriatites grandiosus* and *Polypodiaceoisporites* sp., which have close affinity to the recent taxa of ferns. The abundance of two species of the genus *Polydiisporites* (*P. inangahuensis*, *P. usmensis*) and *Laevigatisporites* sp., which are botanical affiliated to epiphytic fern of the family Polypodiaceae and climbing fern of the genus *Lygodium* sp., respectively, are invaluable indicators of a humid environment (Tryon and Lugardon, 1991).

The presence of mountainous, temperate taxa i.e. *Momipites coryloides*, *Liquidambarpollenites* sp., *Fraxinoipollenites* sp., *Caryophyllidites* sp., *Pinuspollenites* sp. and *Quercoidites* sp. (those of botanical

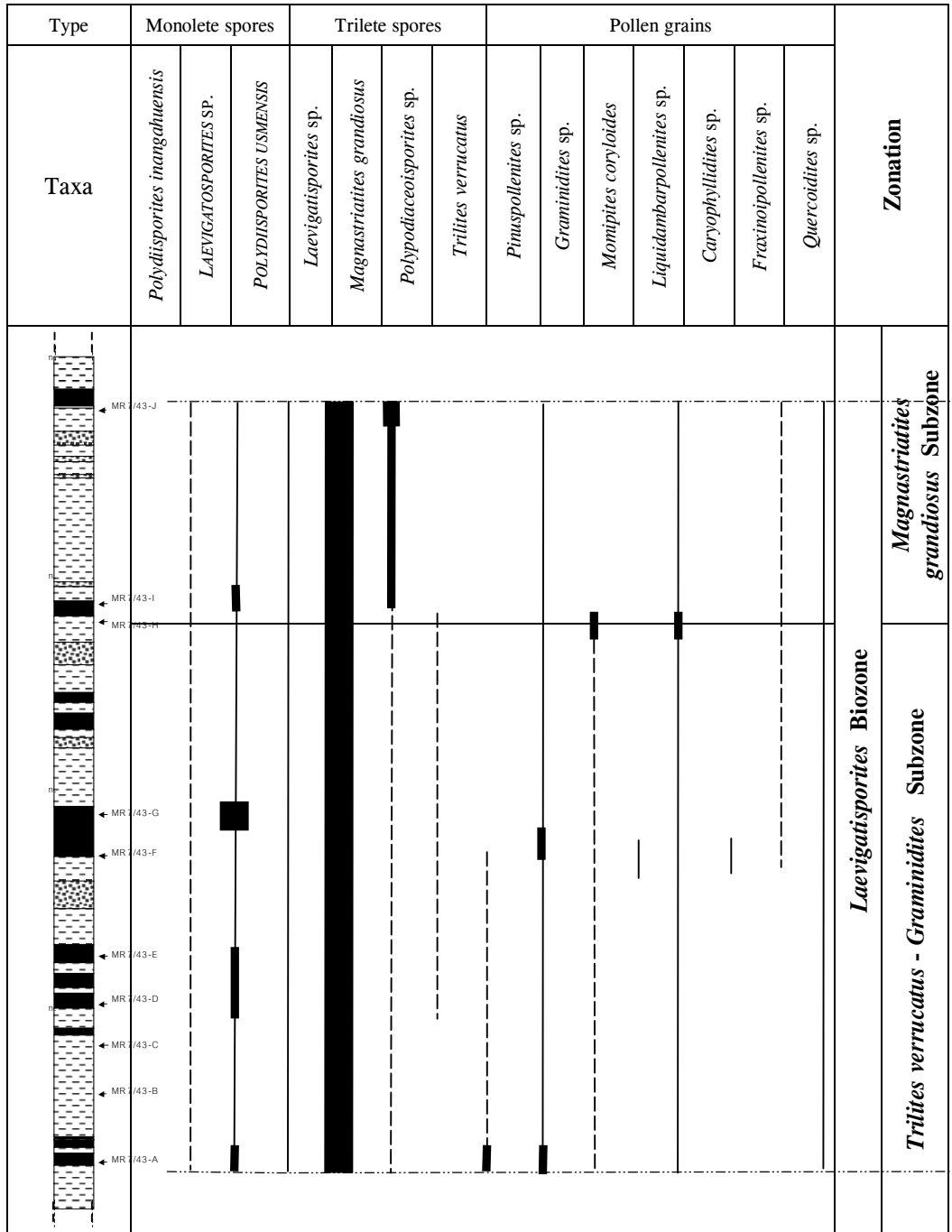


FIGURE 4. Biostratigraphic zonation of the study areas with references to the data of palynomorphs. (■ 25%; ■ 15-25%; ■ 5-15%; — 1-5%; --- sporadic)

affinities to *Corylus* sp., *Liquidambar* sp., *Fraxinus* sp., family Caryophyllaceae, *Pinus* sp. and *Quercus* sp., respectively) which mostly are wind-pollinated grains provide prime support for the idea that the palynomorphs were transported from temperate climate zones (may be pine-oak and coniferous forests). In the present day, the parent plants of the temperate taxa include those from areas 800-3,000 meters above mean-sea level in Nepal (Mani, 1978). This evidence strongly indicates the temperate climate zone in which the plants flourished.

In the upper part of the sequence, there is the increasing abundance of *Magnastriatites grandiosus* which have close affinity to those of the genus *Ceratopteris*, the tropical to subtropical fresh-water floating ferns (Germeraad et al., 1968); however, the temperate taxa are still present. The presence of *Magnastriatites grandiosus* is used as a zonal indicator in comparisons of Tertiary sediments from subtropical and tropical areas (Tryon and Lugardon, 1991). The palynological data suggest that the temperate flora assemblage in the lower part of the sequence was gradually changed to mixing temperate-subtropical flora assemblage in the upper part of it. This character is supported by the low influx of *Polypodiaceoisorites* sp., reliably assigned to modern genus of subtropical fern *Pteris* (Jones and Luchsinger, 1979; Graham et al., 2000) in the middle part of the sequence.

Consequently, the palynological assemblage in the upper part of the sequence reveals that the paleoclimate in this part was warmer than the temperate climate of the lower part and close to a subtropical climate. Moreover, the abundance of *Ceratopteris* sp. and also the abandonment of *Graminidites* sp. having close affinity to grass, indicates that the upper part was more humid than the lower part.

This warmer trending of the paleoclimate suggested in this study correspond to many previous discoveries. Endo (1964) suggested temperate climate during Paleogene from the evidence of fossil plants in Li Basin. Watanasak (1989) and Songtham (2000) explained that the paleoclimate of Thailand was temperate in

Oligocene and that it warmed to more tropical conditions during Early to Middle Miocene. Morley (1998) compiled distribution of tropical rain forest climates in Southeast and East Asia during the Tertiary based on palynological evidences and demonstrates that tropical rain forest climate distributes in Thailand during Middle to Late Miocene. On the basis of vertebrate fossils studied by Ducrocq et al. (1995), Middle Miocene vertebrates found in many Tertiary in northern Thailand occurred in a tropical climate. Thus the tropical climate in Tertiary of Thailand can be referable to Middle to Late Miocene age.

### Paleoenvironment

A fresh-water-lake deposit is evident by the absence of dinoflagellate and the abundance of fresh-water algae spores and spores of *Magnastriatites grandiosus*. Those spores have close affinity to those of the genus *Ceratopteris*, fresh-water floating ferns (Germeraad et al., 1968) strongly indicating lowland swamp (Graham, 1999). Such an interpretation corresponds well with sedimentary facies of the study area that displays lacustrine environment (Coal Survey and Evaluation Section, 1993). Spores of the genus are large size, with low spore productivity, and local dispersion in basin only. In this study, the *Magnastriatites grandiosus* zone represents an enlargement of lacustrine environment because an increase in the number of spores may indicate an increase humidity and also a change in environment from swamp to lake.

### Age suggestion

Generally, an age of deposition is obtained from time ranges of marker species assemblage that have a known, restricted age. From the lower limit of *Polypodiisorites inangahuensis* and the upper limit *Momipites coryloides* (fig. 5), age of the deposition of the study area can be reasonably confined as Middle Oligocene to Early Miocene age. Due to the assemblage of *Magnastriatites gradiosus* is equivalent with Germeraad et al.'s (1968) *Magnastriatites howardi* Zone, the age of the deposit is Late

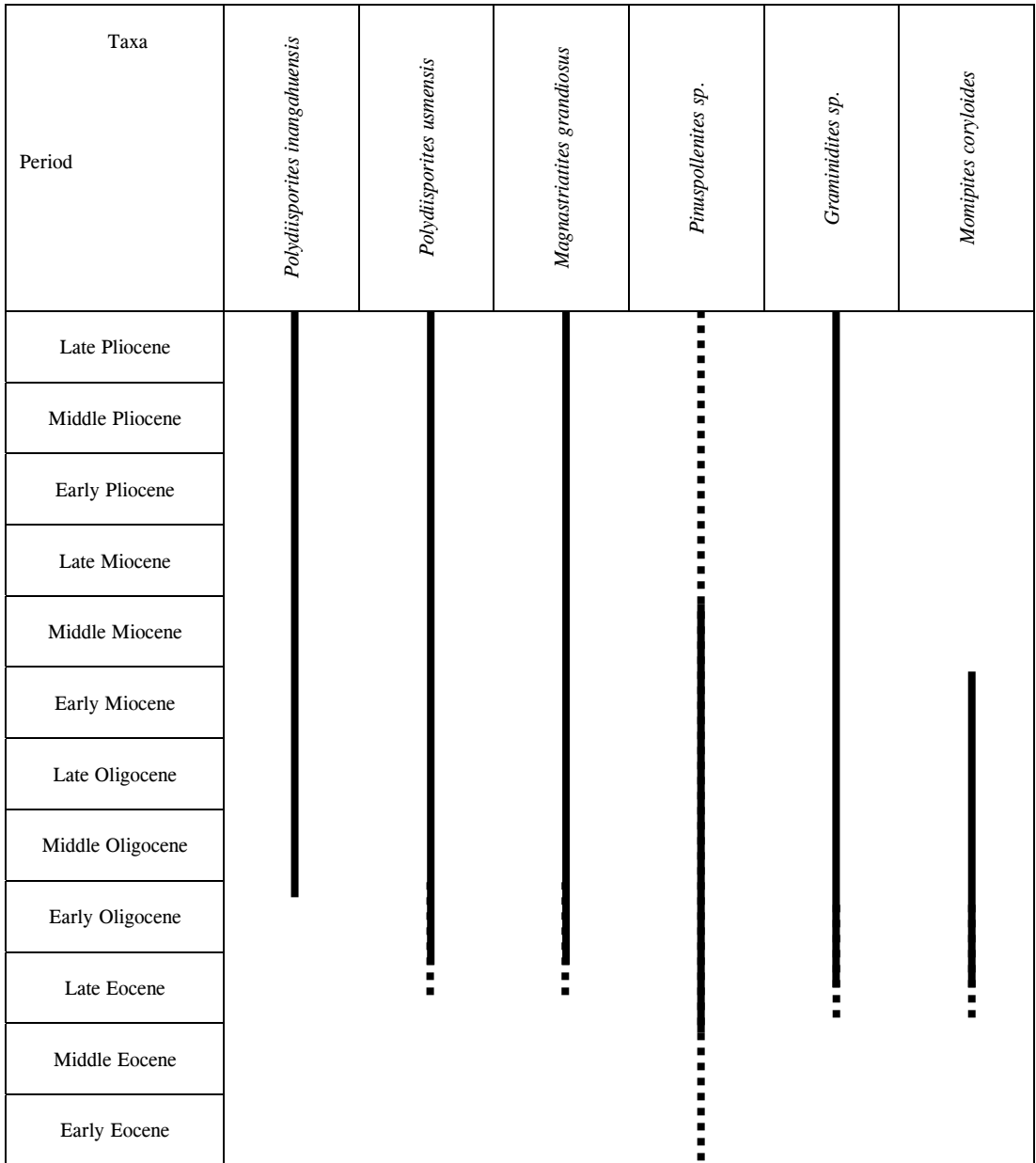


FIGURE 5. Range chart of some palynomorphs (Couper, 1953; Germeraad et al., 1968; Watanasak, 1989).

Oligocene to Early Miocene (Germaraad et al., 1968; Ratanasthien et al., 1989).

By means of correlation between the age of palynomorph assemblage (Middle Oligocene to Early Miocene) and the paleoclimate which warmed to near subtropical climate, Early Miocene is therefore a suitably suggested age of this stratigraphic sequence during the time of climate change from temperate to subtropical climates.

### CONCLUSIONS

The fossil palynomorphs in the study areas can be identified into 17 genera 6 species. According to the data of palynomorphs, one biozone and two subzones were recognized: *Laevigatisporites* Biozone, *Magnastriatites grandiosus* Subzone and *Trilites verrucatus* - *Graminidites* Subzone. Based upon our result on palynological together with lithological aspects, fresh-water lacustrine environment is indicated by the abundance of *Magnastriatites grandiosus*. The lake was largely developed in the upper part of the sequence. In addition, the change of paleoclimate from humid temperate climate to warmer and more humid temperate climate trending to be subtropical climate was interpreted by the presence of temperate flora and the subsequent increase of subtropical flora in *Magnastriatites grandiosus* Subzone. This result may be the evidence of the regional warming of Thailand during Miocene period. From the age of fossils and paleoclimate deduction, the age of the deposition of the study area is probably Early Miocene.

### ACKNOWLEDGMENTS

The authors wish to express deep gratitude to the Faculty of Science, Chulalongkorn University for financial support, and to the Department of Mineral Resources (DMR) for providing material for the research. Moreover, the authors feel very grateful to Assist. Prof. Dr. Malai Liengjarern of Department of Geology, Mr. Jittawat Meesuk and Dr.

Wickanet Songtham of DMR, and Assoc. Prof. Dr. Taweesak Bunkerd of Department of Botany for their advice and encouragement throughout this study.

### LITERATURE CITED

- Benson, L. 1959. Plant Classification. D.C. Heath and Company. 688 p.
- Brown, C.A. 1960. Palynological technique. Baton Rouge, USA, 188p.
- Chana, A. and P. Kunawat. 1976. Oil Shale Exploration near Huai Bong Village, Mae Jarao Subdistrict, Mae Ramat District, Tak Province, 37 p. (in Thai)
- Coal Survey and Evaluation Section. 1993. Report on Coal Survey at Mae Ramat Basin. Mineral Fuels Division, Department of Mineral Resources, 257 p. (in Thai)
- Couper, R.A. 1953. Upper Mesozoic and Cenozoic spores and pollen grains from New Zealand. New Zealand Geological Survey, Palaeontological Bulletin 22: 1-77.
- Ducrocq, S., Y. Chaimanee, V. Suteethorn and J. Jaeger 1995. Mammalian faunas and the ages of the continental Tertiary fossiliferous localities from Thailand. Journal of Southeast Asia Earth Sciences 12: 65-78.
- Endo, S. 1964. Some Older Tertiary Plants from Northern Thailand. Geology and Palaeontology of Southeast Asia 1: 113-117.
- Frederiksen, N. O. 1980. Sporomorphs from the Jackson Group (Upper Eocene) and adjacent strata of Mississippi and western Alabama: U.S. Geological Survey Professional Paper 1084: 75 p.
- Germaraad, J. H., C. A. Hopping and J. Muller 1968. Palynology of Tertiary from Tropical area. Review of Palaeobotany and Palynology 6: 189-348.
- Graham, A. 1999. An Oligo-Miocene palynoflora from Simojovel (Chiapas, Mexico). American Journal of Botany 86: 17-31.
- Graham, A., D. Cozadd, A. Areces-Mallea and N. O. Frederiksen. 2000. A palynoflora from the Middle Eocene Saramaguacán Formation of Cuba, American Journal of Botany 87: 1526-1539.
- Hekel, H. 1972. Pollen and spore assemblages from Queensland Tertiary sediments. Pubs. Geol. Surv. Qld. 335: 1-34.
- Huang, T. 1978. Flora of Taiwan 5: 632 p.
- Jones, S. B. and A. E. Luchsinger. 1979. Plant Systematics. McGraw-Hill. 388 p.

- Khan, A. M. and A. R. H. Martin. 1971. A note on genus *Polypodiisporites* R. Potonie. *Pollen et Spores* 13: 475-480.
- Mani, M. S. 1978. *Ecology and Phytogeography of High-altitude Plants of the Northwest Himalaya*. Chapman and Hall Ltd. 205 p.
- Meesuk, J. 1986. *Geology of the Tertiary coal basin of Thailand: Unpublished MPs thesis, University of Aston in Birmingham, England, 331 p.*
- Morley, R. J. 1998. Palynological evidence for Tertiary plant dispersal in the SE Asia region in relation to plate tectonics and climate. *Biogeography and Geological Evolution of SE Asia*: 211-234.
- Paul, D. D. and H. M. Lian. 1975. Offshore Tertiary Basins of Southeast Asia, Bay of Bengal to South China Sea. In *Proceedings of the 9<sup>th</sup> World Petroleum Congress, Japan*.
- Pocknall, D. T. and D. C. Mildenhall. 1984. Late Oligocene-Early Miocene spores and pollen from Southland. New Zealand. *New Zealand Geological Survey Palaeontological Bulletin* 32: 1-66.
- Potonié, R. 1956. Sgnoptic der gattungen der Sporaee disperse. I. Teil: Sporites. *Beih. Geol. Jb.* 23: 1-103.
- 1960. Sporologie der Eozanen Kohele von Kalewa in Burma. *Senck. Leth.*, 41: 451-481.
- Ratanasthien, B. 1984. Spore and Pollen Dating of some Tertiary Coal and Oil Deposits in Northern Thailand. In *Proceedings of the Conference on Applications of Geology and the National Development*, pp. 272-280. 19-22 November 1984, Chulalongkorn University, Bangkok.
- 1989. Depositional Environment of Mae Lamao Basin as Indicated by Palynology and Coal Petrography. In T. Thanasuthipitak, and P. Ounchanum (eds.), *Proceedings of International Symposium on Intermontane Basins: Geology and Resources*, pp. 205-215. 30 January – 2 February 1989, Chiang Mai University, Chiang Mai, Thailand.
- , Uttamo, W. and S. Chunhawatt. 1989. Age Dating and Relationship of Northern Thailand Tertiary Basins with Coal- and Oil-bearing Formations. *National Research Council of Thailand* 59 p.
- Sherwood, N. R. and A. Cook. 1984. Petrology of a suit of sedimentary rocks associated with some coal-bearing basin in Northwestern Thailand. *International Journal of Coal Geology* 4: 45-71.
- Songtham, W. 2000. *Palynological Investigation of Na Hong Basin, Mae Chaem District, Chiang Mai Province*. Unpublished report to Department of Mineral Resources, Thailand. 61 p.
- Suteethon, V., A. Meesuk and S. Sareerat. 1984. *Geologic map scale 1:250,000 of Moulmein sheet*. DMR.
- Thanomsap, S. 1978. Relationship between the Oil Yield of the Mae Sot Oil Shale and its Specific Gravity, Mae Sot District, Tak Province. 13 p. (in Thai)
- 1983. Stratigraphic Sequence and Facies Distribution in the Mae Sot Basin. *Proceedings of the Conference on Geology and Mineral Resources of Thailand, DMR*, 10 p.
- , and S. Sitahirun. 1992. The Mae Sot Oil Shale : In *Proceedings of National Conference on Geologic Resources of Thailand: Potential for Future Development*, pp. 676-691. 17-24 November, Department of Mineral Resources.
- Thomson, P. and H. Pflug. 1953. Pollen and sporen des mitteleuropaischen Tertiars. *Paleaontographica* 94: 1-138.
- Traverse, A. 1988. *Paleopalynology*. Unwin Hyman Ltd., London, 600 p.
- Tryon, A. F. and B. Lugardon. 1991. *Spores of Pteridophyta: surface, wall structure and diversity based on electron microscope studies*, Springer – Verlag, New York, 648 p.
- Watanasak, M. 1989. Palynological Zonation of Mid-Tertiary Intermountain Basin: In T. Thanasuthipitak, and P. Ounchanum (eds), *Proceedings of International Symposium on Intermontane Basins: Geology and Resources*, pp.216-225. 30 January – 2 February 1989, Chiang Mai University, Chiang Mai, Thailand.
- Wood, G. R., A. M. Gabriel and J. C. Lawson, 1996. Chapter III: Palynological techniques processing and microscopy. In J. Jansonius and D.C.McGregor (eds), *Palynology: principle and application*, pp. 29-50. American Association of Stratigraphic Palynologist Foundation 1, USA.

---

*Received: 27 August 2002*

*Accepted: 9 June 2003*