



MID-TERTIARY PALYNOLOGY
OF ONSHORE AND OFFSHORE THAILAND

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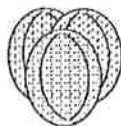
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ABSTRACT

Mid-Tertiary palynological assemblages from fourteen stratigraphic sequences in nine basins in Thailand have been investigated. Special emphasis has been given to the spore-pollen record and its stratigraphic distribution. The basis for defining zonations in this study depends on first or last appearances of key species including *Inaperturopollenites dubius*, *Alnipollenites verus* and *Echiperiporites* cf. *E. estelae*, and for the first time correlation with the marine sequences is achieved. Two regional zones (SIAM-1 and SIAM-2) have been established. SIAM-1 Zone is characterized by assemblages comprising high frequencies of gymnosperm pollen, and is provisionally correlated with the planktonic foraminiferal N3-N4 zones of the Trang-1 Borehole, Andaman Sea indicating a Late Oligocene to early Early Miocene age. SIAM-2 Zone is characterized by influxes of tropical taxa and decreasing proportions of the temperate taxa and is correlated with planktonic foraminiferal N5-N8 zones of the Mergui-1 Borehole, Andaman Sea indicating a middle to late Early Miocene age. The results of the palynostratigraphic study can be successfully applied to hydrocarbon resources exploration and it is shown that the Nong Ya Plong coal seam (pre SIAM-1) is older than Li coal seams (SIAM-1), Fang oil-bearing intervals (SIAM-2) and Mae Moh coal seams (post SIAM-2) respectively.

High influxes of species preferring temperate climates (including *Alnipollenites verus*, *Inaperturopollenites dubius*, and *Tsugaepollenites igniculus*) appear in Thailand during SIAM-1 Zone. Species preferring tropical environments make their first appearances and become abundant in the SIAM-2 Zone (including *Dipterocarpus* sp. 780, *Florschuetzia levipoli*, *Lanagiopollis nanggulanensis* and *Pandaniidites texus*). These patterns suggest that the palaeoclimate of Thailand was temperate in Late Oligocene times, and warmed to more tropical conditions during the Early to Middle Miocene. Frequencies of *Pediastrum* (algae) and spores, occurrences of mangrove pollen and dinoflagellates are useful for determination of palaeoenvironments in this study. High frequencies of *Pediastrum* or spores suggest lacustrine or swamp environments respectively. The occurrences of mangrove pollen and dinoflagellates suggest coastal or marginal marine environments.

Eighty three species comprising the principal taxa in the palynofloras are listed, and thirty two taxa of these are described using conventional light (LM) and scanning electron microscopy (SEM). A novel method is proposed for routine examinations of palynomorphs by both SEM and LM.



This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of the candidate's knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Manas Watanasak

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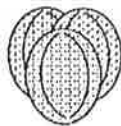
I am sincerely grateful to Prof. L. A. Frakes (Chairman, Department of Geology and Geophysics, University of Adelaide), Mr. W. K. Harris and Dr. C. B. Foster (Western Mining Corporation, WMC) and Dr. N. F. Alley (Biostratigraphy Section, South Australia Department of Mines and Energy, SADME) for their time, helpful guidance, advice and encouragement throughout the period of investigation.

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CHAPTER 1

INTRODUCTION

At present, Thailand produces about 20,000 barrels of oil and 400 million cubic feet of gas per day. The current Thai socio-economic plan places considerable importance on petroleum exploration and its relationship to socio-economic development. The history of petroleum exploration in Thailand began in 1921 at Fang Basin, in the northern part of the country. Thus far, most hydrocarbon resources discovered and exploited have been in the Tertiary basins. All oil, natural gas, coal and oil shale are in isolated Tertiary non-marine and marginal marine basins. The ages of these sediments are not well known and thus Tertiary regional biostratigraphy is in high demand by industry. Although palynology is likely to be the most suitable tool for dating in these basins, palynological information is very scant. Previous major Tertiary palynological studies in Thailand have centred on the Gulf of Thailand, due to extensive and successful petroleum exploration, but much of what is known is confidential to oil companies and the Government sector. Only a few taxa including *Florschuetzia* spp., *Dacrydium* sp., and *Podocarpus* sp. are known but the components of the assemblages, their systematic descriptions, frequencies, and photomicrography are lacking. The present study of "Mid-Tertiary Palynology of Onshore and Offshore Thailand" will provide basic scientific information and serve the needs of both industry and the country. It will be a key to open the Tertiary palynology of Thailand to the world, and also provide a framework for future studies both in detail and biogeographical relationship with other regions.

1.1 Objectives of the Study

The objectives are:

1. To determine and describe the principal palynofloras which occur in the studied Tertiary basins.
2. To develop a palynostratigraphic zonation and to demonstrate correlation of strata in isolated Tertiary basins both onshore and offshore.

3. To determine Tertiary palaeoecology, palaeoenvironments, palaeoclimates and palaeobiogeography of Thailand.

Because this is a pioneer systematic palynological study, a supplementary objective is aimed at establishing a palynological database for Tertiary Thailand including references and Scanning Electron Micrographs (SEM). The latter are of great value in investigation of fine sculpture and thus support identification and taxonomy, especially of small and complex pollen.

1.2 Scope and Limitations of the Study

As the main emphasis of this study is on the pollen and spores, no systematic treatment of algae and dinoflagellates is attempted, but selected illustrations are given on Plate 16.

There were some limitations encountered during this study relating to sample material, suitable references, access to palynological laboratory facilities, and availability of a high resolution light microscope. Since this study deals with a real problem in a developing country, nothing is expected to be perfect or systematic.

Systematic and reliable sample material particularly from core samples of marine sequences are important for any palynological study but are far from being achieved in this investigation. However, available cuttings samples are provisionally substituted and future research with more precise data may confirm or readjust the results.

Suitable palynological references and database to support this study are lacking. Palynological laboratory and high resolution light microscopes were accessed through either Western Mining Corporation (WMC), Adelaide; or the South Australia Department of Mines and Energy (SADME), Adelaide.

1.3 Materials and Methods

The basins studied (Figure 1-1, Table 1-1) are Fang, Li, Mae Moh, Mae Sot basins (northern Thailand); Nong Ya Plong Basin (central Thailand); Krabi, and Sin Pun basins, the Andaman Sea and the Gulf of Thailand (southern Thailand). Studied material has been derived from drillcore, surface sections and ditch cuttings.

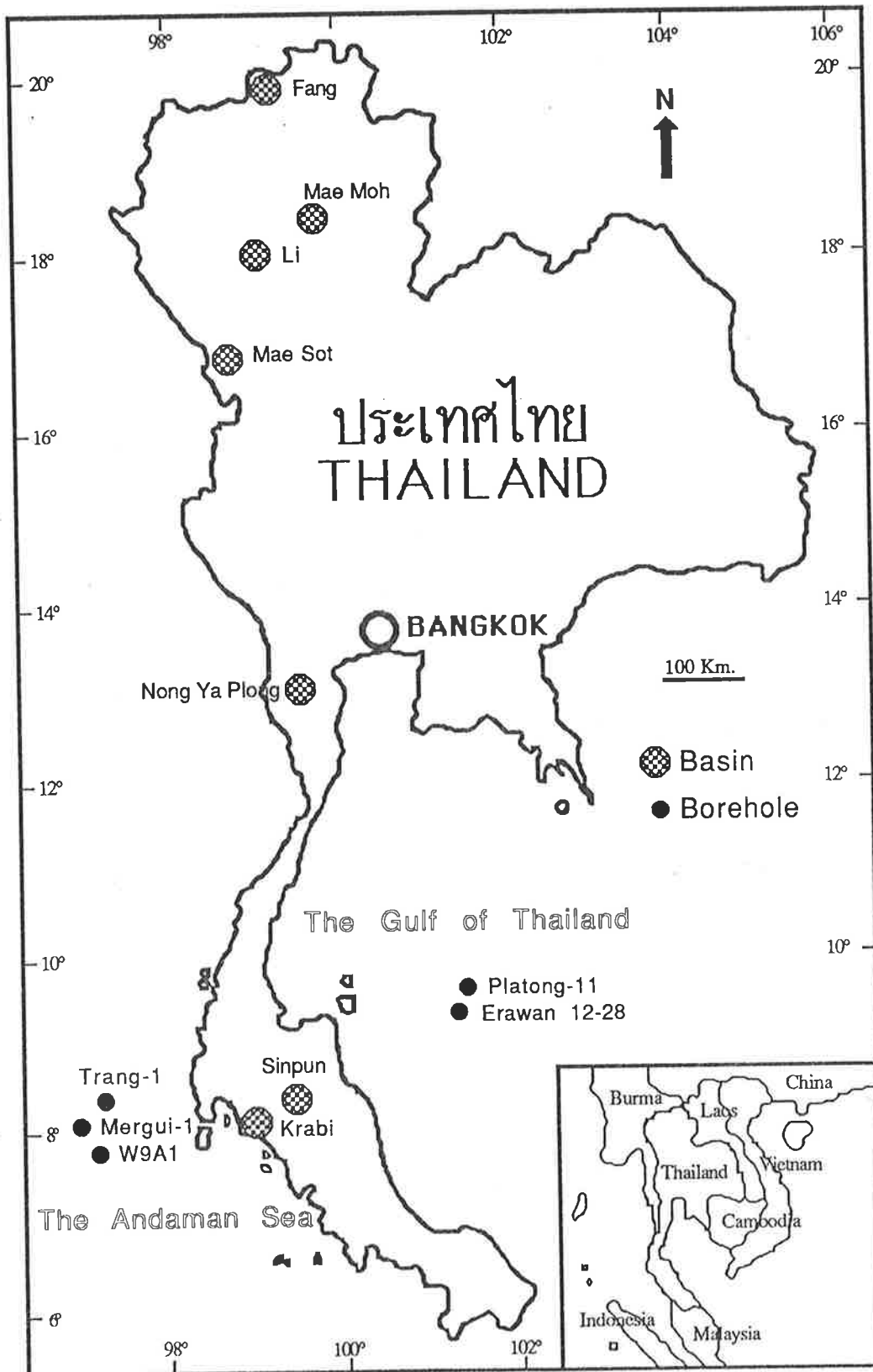


Figure 1-1. Map showing localities of the studied basins, and boreholes in the Andaman Sea and the Gulf of Thailand.

Table 1-1. Number of the studied samples.

Basin	Total Processing (samples)	Productive (samples)	Productive (%)
Fang	26	10	38.46
Li	19	16	84.21
Mae Moh	37	18	48.65
Mae Sot	31	9	29.03
Nong Ya Plong	9	7	77.78
Krabi	25	10	40.00
Sin Pun	20	4	20.00
Andaman Sea	47	20	42.55
Gulf of Thailand	40	10	25.00
Total	254	104	40.94

Most samples from offshore Thailand (the Andaman Sea and the Gulf of Thailand) were supplied by the Union Oil Company of Thailand but some were collected from the Department of Mineral Resources, Bangkok. Krabi surface samples were collected from the Klong Huai Wai Lek Mine, Krabi Basin (operated by the Electricity Generating Authority of Thailand, EGAT). Sin Pun core samples were collected from the Sin Pun Lignite Exploration Unit (EGAT) Krabi Province. Nong Ya Plong surface samples were collected from the Nong Ya Plong Mine, Phetchaburi Province (operated by the Asia Lignite Co. Ltd). Mae Moh core samples were collected from the Mae Moh Lignite Exploration Unit (EGAT) Lampang Province. Mae Sot core samples were collected from the Department of Mineral Resources (DMR), Phra Pradaeng warehouse, Samut Prakan Province. Li samples were collected from the Ban Pu Sub-basin, Li Basin, Lamphun Province, under operation by the Ban Pu Mine Co. Ltd. Fang core samples were collected from the Division of Raw Material Exploration and Production, Defense Energy Department, Fang District, Chiangmai Province.

The aims of palynological preparation are to remove mineral and unwanted organic matter, to concentrate palynomorphs, to avoid the loss and damage of palynomorphs, to avoid contamination, and to achieve accurate results quickly. The basic techniques used by palynologists are similar but variations are introduced to cope with differences in sample lithology, component of residues, and state of preservation of palynomorphs. Some useful

guides for palynological extraction which are taken into account in this study, are Gray (1965) and Phipps & Playford (1984).

Sample preparation was as follows:

-To prevent surface contamination with modern pollen, rock samples were cleaned or washed with distilled water.

-About 15-20 gm. of sediment was crushed for preparation.

-To remove carbonates, about 18% HCl was slowly added and then warmed for 20 minutes, following by washing with warm distilled water (3-4 times).

-To digest silicates and some other remaining minerals, concentrated HF was slowly added and warmed on a hot plate for about 30 minutes, followed by washing with warm distilled water (3-4 times).

-To remove fluorosilicates, concentrated HCl was slowly added and then warmed for 20 minutes, followed by washing with warm distilled water (3-4 times).

From this stage, variable treatments as noted above were often applied.

-To remove a high proportion of remaining minerals, heavy liquid separation with zinc bromide (S.G. 2.1) was employed.

-To remove a high proportion of remaining coarse debris, sieving with a 80 or 125 μm . nylon screen was employed.

-To remove a high proportion of remaining large clumps of debris, an ultrasonic vibrator was employed for breaking up, with subsequent short centrifuge cycles to separate fine unwanted matter from palynomorphs.

-To remove a high proportion of remaining organic matter, oxidation with Schulze solution (mixture of nitric acid and potassium chlorate) was used, and humic compounds were dissolved and removed with 5% potassium hydroxide.

-To remove a high proportion of remaining fine debris, sieving with 5 or 10 μm . nylon screen was employed.

All of these treatment stages were closely monitored to minimize loss and damage to palynomorphs. The final residues were stained with Bismark Brown and mounted with Eukitt (an embedding medium of the Zeiss Company).

Initial palynological preparations for this study were carried out at the palynological laboratory, Monash University, Melbourne, where about half of the studied samples were mineralogically digested. All subsequent palynological preparations were completed at the palynological laboratory, WMC, Adelaide. Some modern pollen specimens were prepared at the Department of Geology and Geophysics (DGG), Adelaide University (AU). Experimental processing of Mae Moh algal rich samples was carried out at the palynological laboratory, Biostratigraphy Section, SADME, Adelaide.

Oil shale samples from Mae Sot Basin yielded abundant amorphous organic matter containing few palynomorphs and it was difficult to isolate them mechanically and chemically. The lacustrine lithofacies (particularly from Mae Moh Basin) is also comparatively difficult to prepare. Due to a high proportion of large clumps of debris and abundant algae *Pediastrum* spp., chemical treatments resulted in residues containing rare pollen or being barren. Finally, a more suitable treatment involving mechanical breakdown of the debris and algae with an ultrasonic vibrator prior to chemical treatment was employed. The technique produces much higher yield of pollen.

In conclusion, there is no standard set of treatments to prepare palynological samples, and a better understanding of the potential and limitations of different treatments and components of the residues maximizes productivity of palynomorphs.

The Problem of Contamination. The possibility of contamination in cuttings is greater than in cores, but it can be reduced so that reliable results can be achieved. With care and appropriate procedures, relatively clean cuttings may be obtained (Martin, 1984). Most of the offshore samples studied were cuttings. Drilling mud was washed from the sample until it became clear and then finally washed with distilled water. Coarse fragments of similar lithology were selected for palynological preparation. If the cuttings yielded a mixture of many lithologies and/or fine fractions, the sample was rejected. A good example of an uncontaminated cuttings sample can be clearly seen from the Gulf of Thailand where the lower cuttings sample (E462) yields a non-marine assemblage even though mangrove assemblages occur in the upper sequence.

1.4 Microscopy and Photomicrography

Palynofloras were examined and counted on the Zeiss Research microscope at the DGG-AU. Image quality from the microscope was inadequate for small, highly similar and poorly preserved pollen grains. The image obtained was also inadequate for coated SEM specimens.

Most light photomicrography was undertaken on the Zeiss Photomicroscope III either at WMC, Adelaide, or at the Biostratigraphy Section, SADME, Adelaide.

Pollen and spores from drillcore or surface samples were counted to a total of 200, followed by a random scanning for rare species not observed in the count. The grains seen during scanning are denoted as "R" (rare) in palynological taxa appearance tables. Most cuttings samples were moderately to poorly productive, and thus taxa appearances were recorded as either "common" (≥ 5 specimens found) or "rare" (< 5 specimens found).

Notes on Identification. An abundance of small and complex pollen grains in this study led to the development of a simple technique for Scanning Electron Microscope (SEM) preparation by using microgrids and markers on stew specimens (Appendix A). A database of about 1500 SEM micrographs allowed investigation of fine sculpture which supported identification and taxonomy. Most of the SEM specimens were preserved for Light Microscope (LM) re-examination.

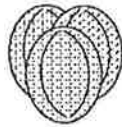
Residues containing prolific or interesting palynomorphs were regularly prepared for SEM examination. A technique to prepare specimens for SEM examination is described in Appendix A. The examination was taken on either ETEC Autoscan or Philips SEM505 of the Electron Optical Centre, AU.

A problem of morphological comparison at SEM level with previously described taxa has been mentioned by Kemp and Harris (1977). Gaps between conventional LM and SEM have been reviewed in this study including, firstly, the technological gap between LM and SEM. Some very small grains (about 10-15 μm .) are readily distinguished under SEM at more than 3000 times magnification but not so under LM, which has a maximum magnification of about 2000 times. Secondly, it is difficult to identify similar pollen types or poorly preserved and collapsed specimens under LM but most of these are clearly differentiated under SEM.

Finally, few SEM micrographs of closely comparable fossil pollen have been published. However, publications on extant species which are to some extent useful for comparison with fossil material, are extensive.

The principles, rules and recommendations which govern binomial nomenclature by ICBN are adhered to in this study, and are discussed in Chapter 3.

All slides and residues of the studied samples will be redeposited at the Faculty of Environment and Resource Studies, Mahidol University, Salaya Campus, Nakorn Patom Province, Thailand from early 1989.



CHAPTER 2

TERTIARY GEOLOGY OF THAILAND

2.1 Regional Geological Setting

Thailand can be subdivided geologically into four regions (Figure 2-1). In the north and west of the country, Palaeozoic to Triassic marine carbonates and clastics are widespread. Tertiary deposits are important in this region, including Fang, Li, Mae Moh, Mae Sot, Nong Ya Plong, Sin Pun and Krabi basins. A second province covering central Thailand and extending into the Gulf of Thailand is the Chao Phraya Depression which consists of a thick Quaternary sequence. The third province, Phetchabun Fold Belt is located between the Chao Phraya Depression and Khorat Plateau. This broad belt contains Palaeozoic-Mesozoic calc-alkaline volcanics, ophiolites, various marine clastics, limestones and continental redbeds. The fourth province, the Khorat Plateau of eastern Thailand, consists mainly of gently folded Late Triassic to Late Cretaceous continental redbeds. Occasional marine limestone intercalations and evaporites are present in the youngest part of the section.

Late Cretaceous-Early Tertiary tectonic movements were widespread and regionally variable. Such events led to folding and uplift of the Khorat Group and deformation of the Triassic and Cretaceous Granites (from Tak to Phuket; Suensilpong *et al.*, 1978). Major intrusive episodes include Late Cretaceous-Early Tertiary granites ranging in age from 70 to 57 Ma in northern Thailand (Braun *et al.*, 1976). Granites from south-eastern Thailand have been dated at 51 Ma (Workman, 1975).

Radiometric investigations on granites from the Malay-Thai peninsula reveal widespread Cretaceous to Tertiary activity, including some granite emplacement, which is possibly related to epirogenic movements. Uplifting of the Khorat Plateau at about the end of the Mesozoic probably was associated with the formation of the broad structural depression of the Chao Phraya and the Gulf of Thailand. Most of Thailand including the Gulf possibly lay above sea level during the Early Tertiary. Hilde & Engel (1967) reported a zone of Late

Cretaceous granites along the northeastern coast of the Gulf of Thailand. However, recorded field evidence and isotopic data by Burton & Bignell (1969) show that these granites are mainly Triassic or older.

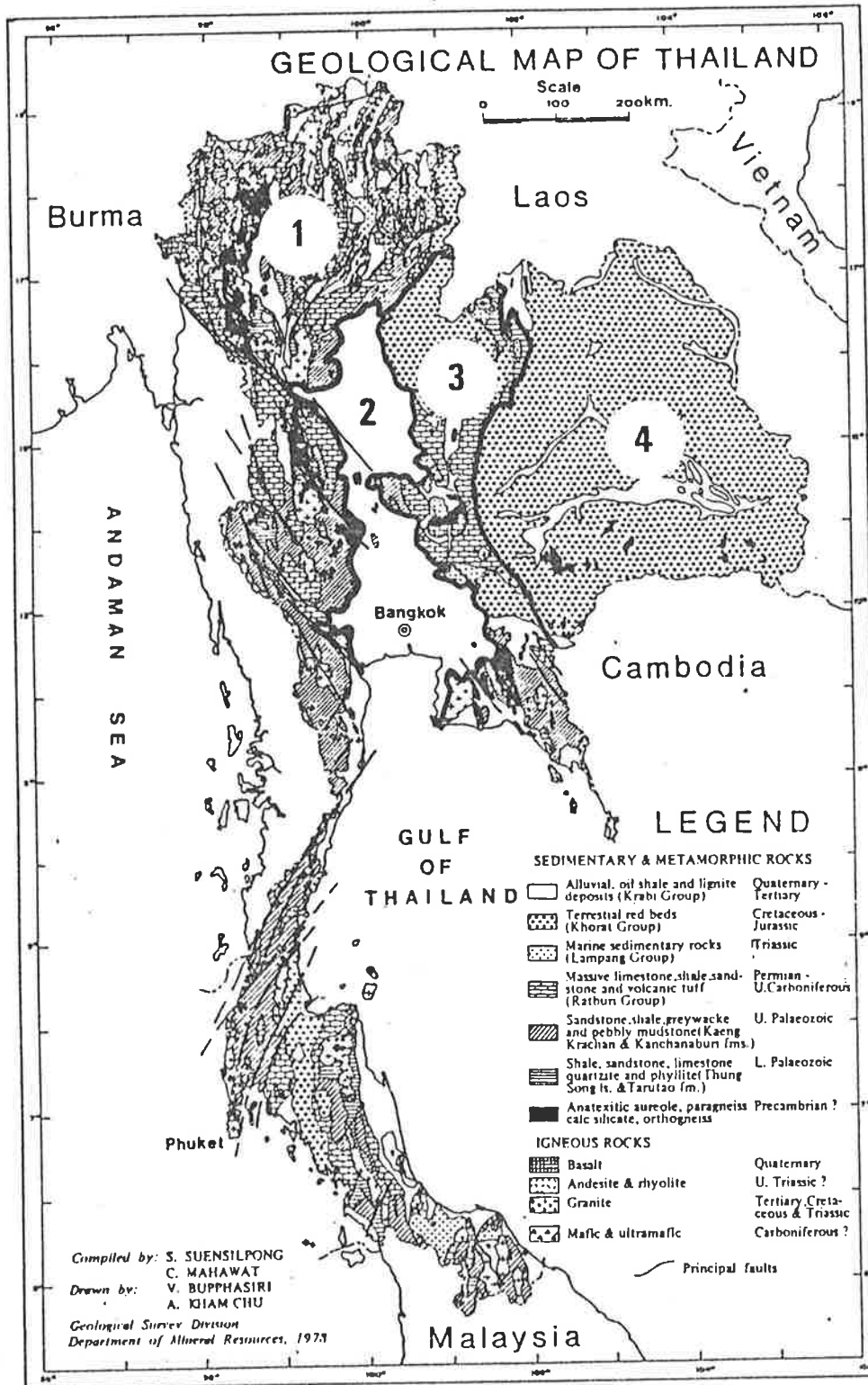


Figure 2-1. Geology of Thailand can be divided into 4 provinces. 1: North-west and Thai peninsula where most onshore Tertiary basins are located. 2: Chao Phraya Depression. 3: Phetchabun Fold Belt. 4: Khorat Plateau (Source of the geological base map: Suensilpong *et al.*, 1978).

2.2. Cenozoic Setting

The subduction of the Indian Ocean Plate beneath Sundaland has been developed since the Early Cretaceous but the collision of India with Eurasia occurred at about 50 Ma during the Eocene (Molnar & Tapponnier, 1975; Patriat & Achache, 1984; Polachan, 1988). The Tertiary basins in the Sunda region (Figure 2-2) are transtensional basins, developed in a strike-slip domain in response to the India-Eurasia collision. The main period of strike-slip tectonics began in the Late Oligocene when similar basins developed throughout the Southeast Asian region. Westward rotation and bending of Sundaland as a result of the impingement of India was the main process in the development of Tertiary basins in the region (Polachan, 1988). A significant thermal event during the Early Miocene is suggested by granites of northern Thailand, which yield K/Ar biotites ages of 18.6 and 19.6 Ma (Braun *et al.*, 1976).

Tertiary basins are mainly N-S trending fault-bounded grabens or half grabens. Tertiary strata lie unconformably on Mesozoic and older rocks and consist predominantly of lacustrine, swamp and fluvialite semiconsolidated to consolidated mudstone, siltstone, carbonaceous shale, coal, oil shale, sandstone, conglomerate, fresh water limestone and marl. Generally, non-marine Tertiary sequences (Figure 2-3) contain strata deposited in fluvialite environments (upper and lower parts of each sequence) and lacustrine, swamp and fluvialacustrine environments (middle part). Only middle sequences are palynologically productive. The results of this palynological study show that evolution of the studied basins began during Late Oligocene to Early Miocene. Marine transgression of Tertiary age is limited to the Andaman Sea sequences, and the upper sequence of the Gulf of Thailand. Marginal marine influence is evident in Krabi Basin where rare pollen of mangroves are found.

Unconformities at the Middle to Late Miocene boundary, as observed in both marine and non-marine strata of various basins in the Andaman Sea, the Gulf of Thailand and the Phitsanulok Basin, likely represent a regional unconformity which possibly coincides with the Middle to Late Miocene eustatic sea level fall of Haq *et al.* (1987). A K/Ar radiometric age (10.3 ± 0.2 Ma) of a basaltic lava encountered in the Ket Kason-1 Borehole, Phitsanulok Basin, northern Thailand, provides a dating for the basin-wide unconformity. The lava is observed on seismic to lie on the unconformity (Knox & Wakefield, 1983).

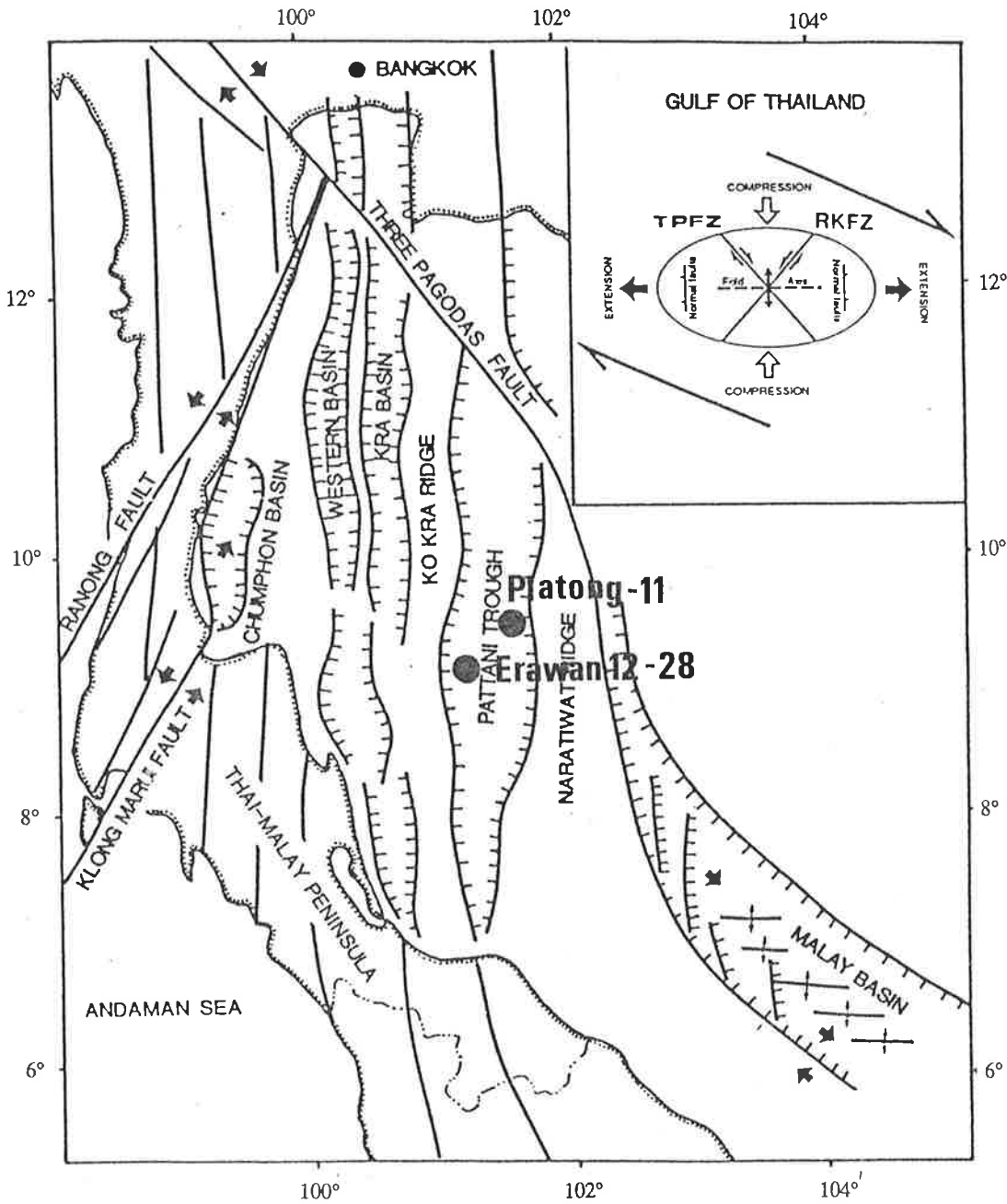


Figure 2-2 Structural map of the Gulf of Thailand showing localities of boreholes (•) and the dextral transtensional shear model (Polachan, 1988).

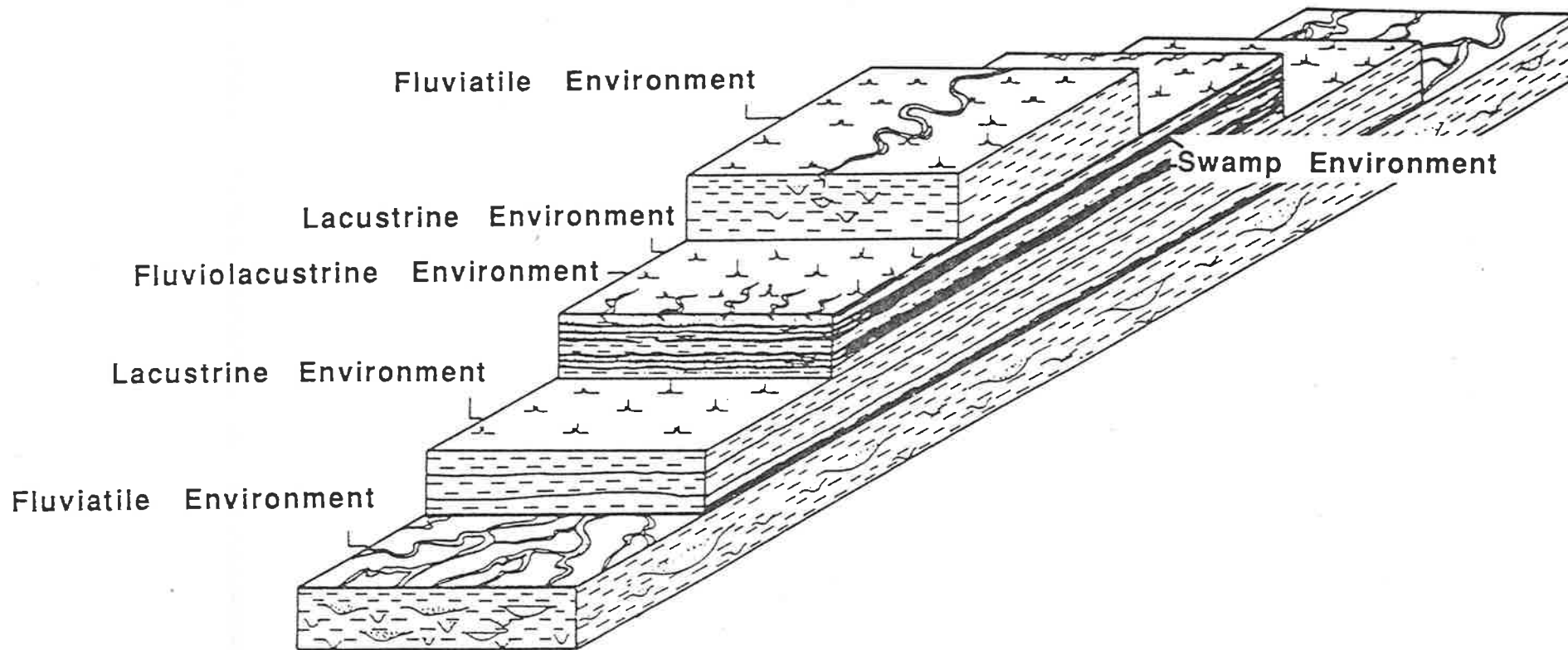


Figure 2-3 General sedimentological model for onshore Tertiary basins in Thailand (modified from Jitapunkul *et al.*, 1984).

The eustatic sea level rise from 29 Ma to 13 Ma of Vail & Mitchum (1979) may be represented by a widespread mid-Miocene transgression over Tertiary basins of Southeast Asia, which had developed earlier on continental crust. Sea level falls at 13, 9.8 and 6.6 Ma ago are inferred from widespread regressions in Indosinian and Malaysian basins (Hutchison, 1986).

The Upper Cenozoic basaltic rocks which are extensively distributed in Thailand and other parts of Southeast Asia range in age from about 12 Ma to less than 0.5 Ma (Suensilpong *et al.*, 1978; Barr & Macdonal, 1979, 1981a, 1981b; Jungyusuk & Sirinawin, 1983; Barr & Dostal, 1986). The earliest of these Late Cenozoic eruptions are likely coincident with a change in onshore basins from lacustrine and swamp to fluvial environments unproductive of palynomorphs.

Tertiary Plate Movements of Thailand. Southeast and East Asia have an extremely complex tectonic history (Haile, 1981). Due to very sparse palaeomagnetic data available, Tertiary plate movements affecting Thailand are under some dispute.

A 12° clockwise rotation of Thailand, opening of the Gulf of Thailand and subsidence of the Gulf and intermontane valleys occurred in the Early to Middle Tertiary (Bunopas 1981). Polachan (1988) pointed out that the western portion of Thailand and the Thai-Malay Peninsula have rotated westward nearly 25° clockwise with respect to the eastern Indochina block, which was relatively stationary during the late Neogene. Cenozoic global plate motions relative to hot spots were studied by Gordon & Jurdy (1986) and compared to plate motions with mean-lithosphere reference frame. The motions indicate that Thailand (a part of the Eurasian plate) moved south during the 48-25 Ma interval.

Although Stauffer (1974) postulated that the Southeast Asian blocks moved southward or southeastward during the Oligocene to Miocene interval, but rotating slightly counter-clockwise was suggested. Palaeomagnetic measurements by Haile *et al.* (1977) indicated that west Borneo of Indonesia and the Malay Peninsula have behaved as a unit since the Middle Cretaceous, have remained at about their present latitudes, but have rotated anti-clockwise about 50° since then.

In conclusion, the dispute on Tertiary plate movements of Thailand requires more study which should be based on independent dating. Nevertheless, more studies suggest that the Thai-Malay block moving southward from higher to lower latitude and rotating clockwise in

the Tertiary. Also, in this study show that the pattern of palaeoclimate of Thailand was temperate in Late Oligocene times, and warmed to more tropical conditions during the Early to Middle Miocene, and is situated in tropical region presently. The relationship between palynological result and palaeoclimate is more likely to suggest that the western portion of Thailand, the Gulf of Thailand and the Thai-Malay Peninsula (which the studied Tertiary basins are located) moving southward and/or rotating clockwise during or post mid-Tertiary.

2.3 Tertiary Stratigraphy of Thailand

Tertiary sequences in Thailand were mainly deposited in isolated non-marine basins. These strata consist predominantly of lacustrine, swamp and fluvial semiconsolidated to consolidated mudstone, siltstone, carbonaceous shale, coal, oil shale, sandstone, conglomerate, fresh water limestone and marl beds. Tertiary marine sequences are limited to the Andaman Sea and the Gulf of Thailand.

Dating of the Tertiary sequences is inadequate owing to isolation of the basins from one another and until now, the lack of palynological study. Moreover naming of Tertiary sedimentary rock units has been irregular (Figure 2-4), and this has also contributed to problems of correlation (Bunopas, 1976; DMR, 1979; Gibling & Ratanasthien, 1980; Ratanasthien, 1981; Snansieng & Chaodumrong, 1981). For example, the Mae Sot and Krabi Series (Brown *et al.*, 1951) were named for Tertiary rocks in northern and southern Thailand respectively. The Krabi Group (Javanaphet, 1969) was used for Tertiary sediments in Thailand. The Mae Moh Formation (Gardner, 1967) or Mae Moh Group (Piyasin, 1972) were both used for the Mae Moh Basin and adjacent areas. But Salt, Li, Mae Moh and Mae Taeng formations (Suensilpong *et al.*, 1978) were used in ascending order for general Tertiary sequences of Thailand. The Mae Sot, Mae Fang and Mae Taeng formations were used in ascending order for the Fang Basin and some northern basins by the Defense Energy Department (DED, 1979a, 1979b).

	Epoch	Brown et al. (1951)	Javanaphet (1969)	Buravas (1973)	Suensilpong et al. (1978)	
TERTIARY	Recent					
	Pleistocene	Krabi Series (southern Thailand)	Krabi Group	Mae Moh Formation	Mae Sot Formation	Mae Taeng Formation
	Pliocene				Mae Moh Formation	Mae Moh Formation
	Miocene	Mae Sot Series (northern Thailand)		Li Formation	Li Formation	Li Formation
	Oligocene				Nam Pat Formation	Salt Formation
	Eocene					
	Palaeocene					

Figure 2-4. A comparative stratigraphic classification of Tertiary sequences in Thailand (compiled from Suensilpong *et al.*, 1978 and Chaodumrong *et al.*, 1983).

2.4 Geology of the Studied Basins

2.4.1 Fang Basin

The Fang intermontane basin of northern Thailand (Figure 1-1) bears shallow oil fields and surface oil seepages which have been known for more than a century. Detailed exploration began in 1921. Fang oil fields are operated the Defense Energy Department (DED) and its production in 1984 was about one thousand barrels per day. It is a structural basin bounded on the west by major faults trending northeasterly. The basin is elongate, trending 35° E and is approximately 18 km. by 60 km. in size (about 575 km²; DED, 1979c). To the north and east, the basin is surrounded dominantly by pre-Tertiary intrusive rocks. To the west, it is bounded by Cambrian sandstone and Permian limestone. Other Palaeozoic and Mesozoic sedimentary rocks occur sporadically around the basin (Figure 2-5). The Tertiary beds dip on average about 15° to the west. To the east, the Tertiary strata overlap basement.

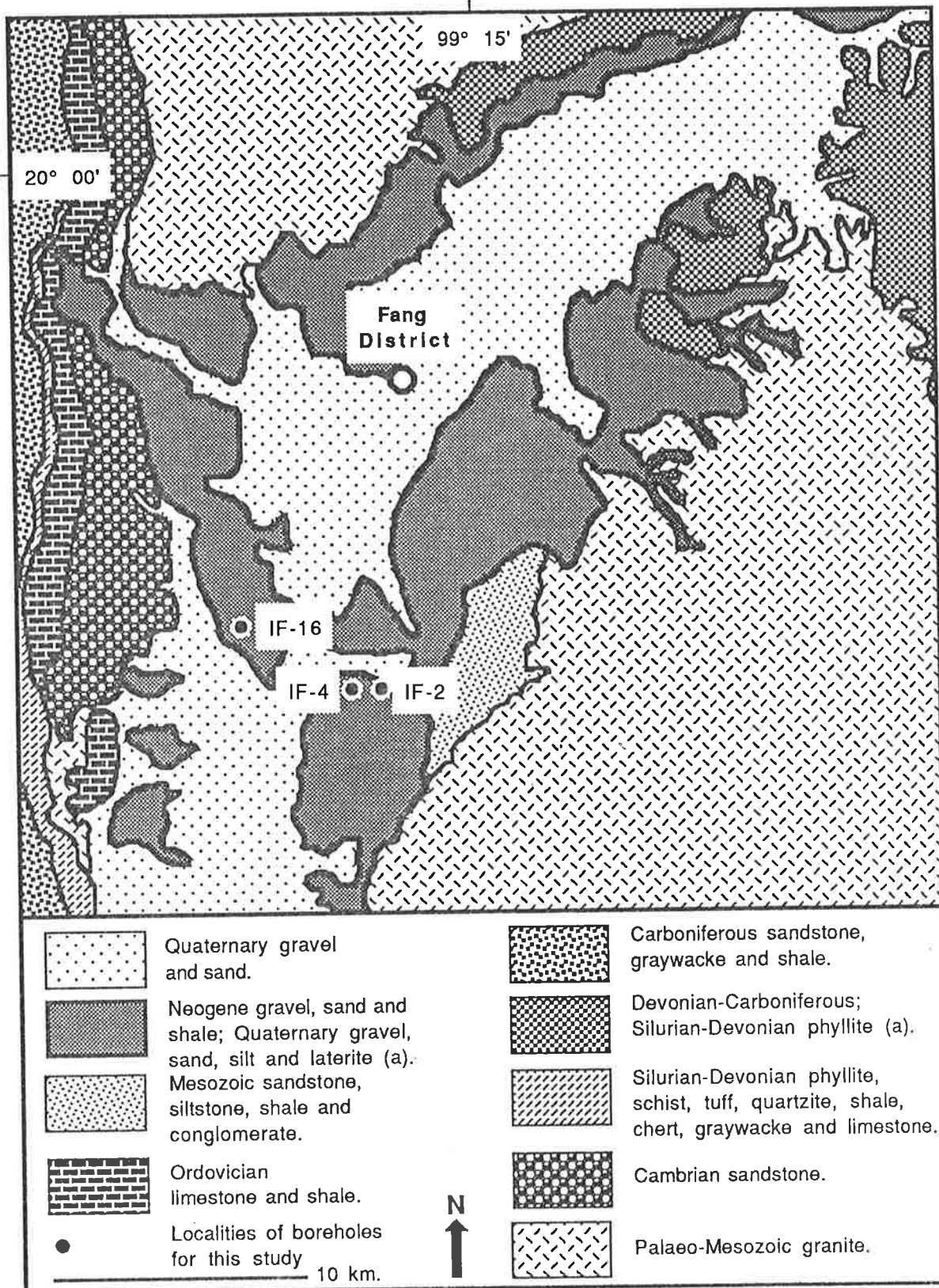


Figure 2-5. Geological map of Fang Basin, northern Thailand showing localities of boreholes in this study (modified mainly from Braun & Hahn, 1976; with few additions (a) from Suensilpong *et al.*, 1984).

On seismic profiles Cenozoic sediments are estimated to reach a maximum thickness of 2800 m (Piyasin, 1979). Within the basin the Tertiary sequence lies on complex basement

composed of andesite, serpentinite, Permian limestone and Mesozoic shale. Pompilian & Vasile (1980, 1981) described non-marine (lacustrine) deposits of Mio-Pliocene age lying unconformably on basement. The sediments consist of dark clays, sandy clays with lignite, shale and sands (Figure 6-5). This sequence is referred to as the Mae Sot Formation. Oudomugsorn (1986) reported small vertebrate bones and teeth, leaves, turtle's back plates and gastropods from Tertiary sediments and suggested a lacustrine origin of fresh to brackish water environment. Because precise stratigraphical relationship between megafossils and samples from this study is not achieved, a correlation cannot be determined, however, palynological results in this study (Section 6.5) indicate that the productive samples from Mae Sot Formation are correlated with the SIAM-2 Zone (middle to late Early Miocene).

The upper Cenozoic sequence (Mae Fang Formation) is composed of arkosic sands with fragments of carbonized wood, interbedded with sandy clays and assigned a Plio-Pleistocene age (Buravas, 1974).

There are six structural oil fields in the Fang Basin, including Mae Soon, Pong Nok, Chaiprakarn, Huay Born, Pa Ngiu and Pa Daeng. Sundharovat (1964) ruled out the possibility of pre-Tertiary source rocks in the basin and concluded that Mae Fang oil was non-marine in origin and accumulated during the Late Tertiary or later. However, Hashimoto *et al.* (1968) pointed out the possibility that the Mae Fang crude may have originated from pre-Tertiary graptolite shale beds. Oudomugsorn (1986) indicated that the crude is produced from Pliocene sand reservoirs occurring at depths ranging from about 150-900 m. Most of the oil has a paraffin base with API gravity about 28°-31°.

2.4.2 Li Basin

Li Basin (Figure 1-1) is a fault-bounded intermontane basin which is bounded by Ordovician limestone of the Thung Song Group to the north and northwest. To the east and west of the basin are Silurian-Devonian low grade metamorphic rocks of the Don Chai Group, which consist dominantly of slate and quartzite. The Don Chai Group conformably overlies the Thung Song Group (Figure 2-6).

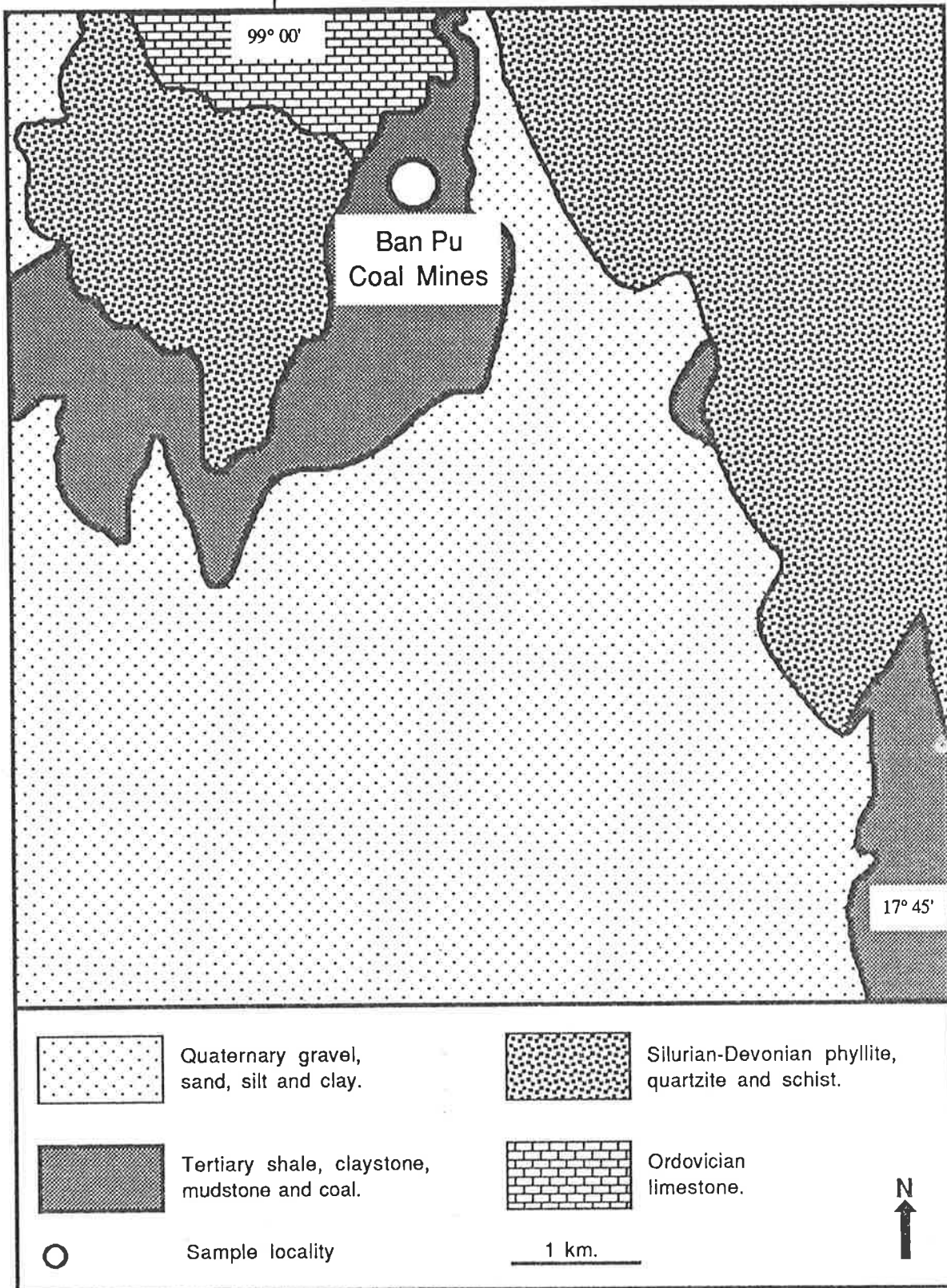


Figure 2-6. Geological map of Ban Pu Coal Mines, Li Basin, northern Thailand showing locality of samples (modified from DMR unpublished geological map of Li Basin).

Ban Pu Mines (1984) reported that fold and fault structures have been observed in the prospecting area. Coal beds to the north of central Ban Pu Sub-basin have been found in folds gently plunging to the south. Along the southwest rim of Ban Pu Sub-basin, a major normal fault trends NNW and dips to the east. Despite folding, coal beds are gently dipping (5° - 8°).

The Tertiary sequence of the Li Basin consists of three units (Figure 5-1). The lower and upper are made up of clay and claystone interbedded with semiconsolidated sandstone and conglomerate. The middle sequence comprises coal interbedded with clay, carbonaceous clay and shale

The main coal seam of the Ban Pu Sub-basin averages 25-35 metres thick and the maximum thickness of 55 metres has been recorded at BP 123 Borehole (Ban Pu Mine, 1984). Coal is ranked by ASTM standard as sub-bituminous. DMR (Chaodumrong *et al.*, 1982; Snansieng, 1983) reported that the total coal reserves of Ban Pu Sub-basin were 10 million tonnes. Unconsolidated Quaternary deposits of gravel, sand, silt, and clay unconformably overlie the Tertiary sequence.

The palaeobotany of the Li Basin has been examined by Endo (1964, 1966). The species reported include: *Alnus thaiensis* Endo, *Sequoia langsdorfii* (Brongniart) Heer, *Taxodium thaiensis* Endo, *Sparganium thaiensis* Endo, *Carpinus* (?) sp. *Glyptostrobus europaeus* (Brongniart) Heer, *Ficus eowithtiana* Endo, *Fagus feroniae* Ung., *Quercus lanceaefolia* Roxb., *Quercus* cf. *protoglauca* Endo, and *Salix* ? sp. Endo (1964) suggested a Palaeogene (Late Eocene) age and warm temperate palaeoclimate, and also made comparisons with the Early Oligocene Flushin flora of Northeast China. Ginsburg (1983) reported a discovery of mammal remains including a proboscidean tooth (cf. *Stegolophodon*), a deer antler (*Stephanocemas rucha*) and fishes from Li coal seams. Ginsburg refuted the possibility of a Palaeogene age and suggested that the Li coal seams appear to be late Middle Miocene in age. However, he agreed with Endo's palaeoclimatic reconstruction. On the other hand, Ratanasthien (1984) reported *Tricolpites* and *Tricolporites* pollen grains in two samples collected from the Ban Pu Sub-basin and suggested a Senonian or Palaeogene age. However, palynological evidence from this study shows the Ban Pu main coal seams (Li Basin; Section 5.1) to be of Late Oligocene age. Although a precise stratigraphic correlation of these fossils is not known but they are likely to derive from main coal seams or adjacent strata of Li Basin.

Fossil remains of plants, gastropods, arthropods, bivalves and fishes have been reported from Ban Pa Kha Subbasin, Li Basin (Gibling & Ratanasthien, 1981).

2.4.3 Mae Moh Basin

The Mae Moh Basin contains the largest proven coal reserves in Thailand and is located in Lampang Province, northern Thailand (Latitude 18° 18' 21"N, Longitude 99° 44' 02'E; Figure 1-1). Coal reserves have been estimated at about 1317.4 million tonnes (Supurtipanish *et al.*, 1983). Mae Moh coal ranges between lignite to sub-bituminous (ASTM) and heating value is low, 6450-9995 Btu/lb (Ratanasthien, 1983).

Mae Moh Basin is a graben with N-S normal faults which was infilled by Tertiary and Quaternary sediments. The basin is mainly bounded by marine Triassic rocks (Lampang Group) which consist mostly of limestone, shale and sandstone. But to the south, the basin is bounded by Quaternary basalt (Figure 2-7).

Tertiary deposits of Mae Moh Basin are mainly fine grained clastic sediments interbedded with coal, sand and rare conglomerate (Figure 6-3). Generally, the Tertiary stratigraphic sequence may be divided into three units (Jitapunkul, 1984 & Jitapunkul *et al.*, 1984). The Lower Unit consists of reddish semiconsolidated mudstone, siltstone, sandstone and conglomerate. This unit is about 15-150 metres thick. The sedimentological structures of this unit suggests fluvial deposition.

The Middle Unit is about 250-400 metres thick and consists of semiconsolidated grey claystone and occasionally siltstone, interbedded with coal seams. Five coal seams (namely S, R, Q, K and J in ascending stratigraphic order) may be found. Both K and Q seams are economic and are exploited for power generation. Fossil remains include: gastropods (*Viviparus* sp., *Millanoides* sp., *Physa* sp., etc.), ostracods, plants, fishes and reptiles. But age determination of the fossil remains is not available. The lithology and sedimentary structures of this unit suggest lacustrine environments with intercalation of swamp deposits in the middle part of the basin but fluviolacustrine and swamp deposits at north and south ends of the basin.

The Upper Unit is 5-250 metres thick and consists of reddish semiconsolidated and unconsolidated sediments of claystone, siltstone and mudstone intercalated with sandstone and

conglomerate lenses. This unit is named the Huai Luang Zone. The lithology and sedimentary structures of this unit suggest fluvial deposits.

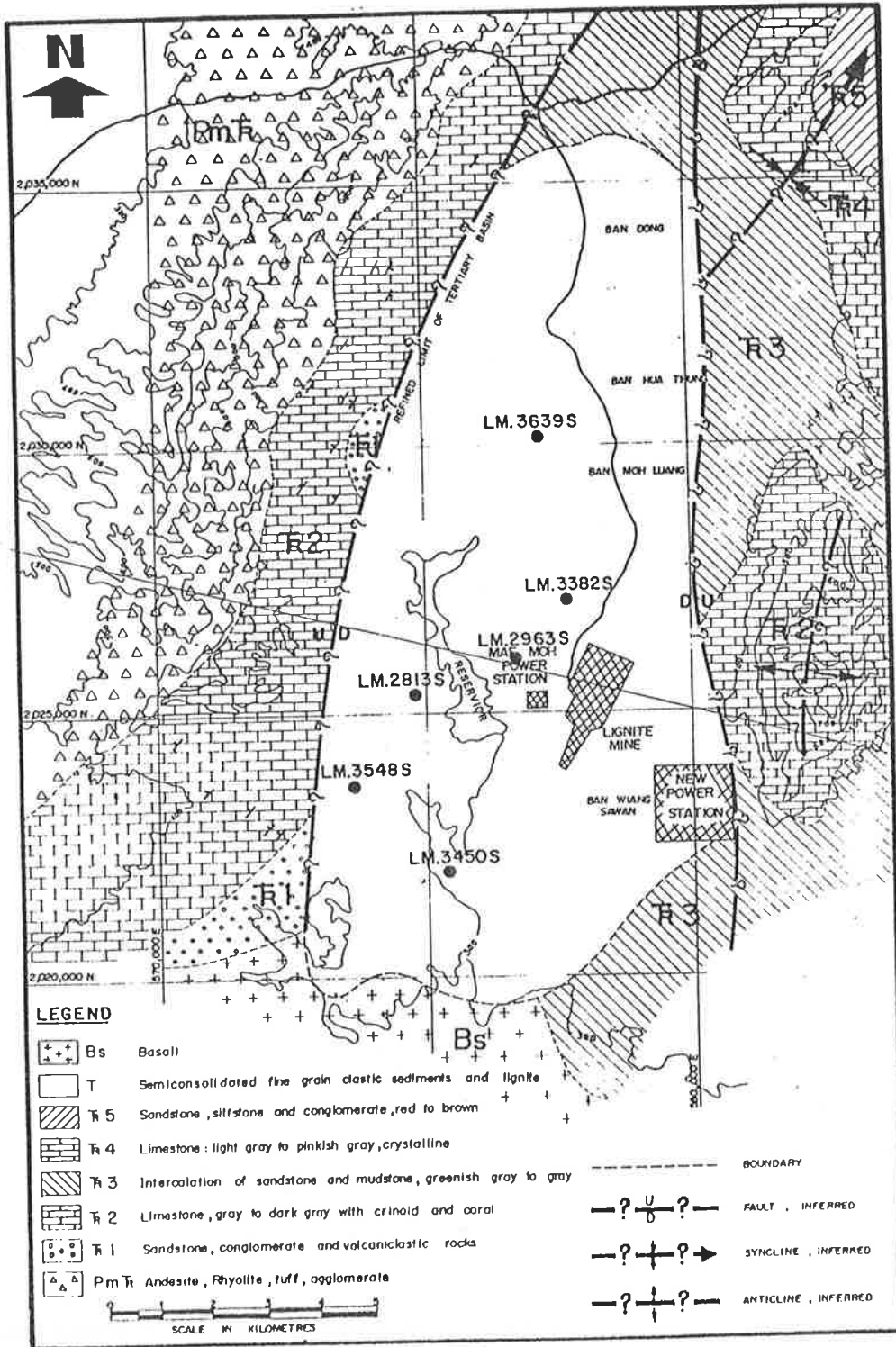


Figure 2-7. Geological map of Mae Moh Basin, northern Thailand showing locality of the LM2813S Borehole which was selected and sampled for this study (EGAT, 1984).

In conclusion, the Mae Moh Cenozoic sequence shows a change from initial fluvial environments, to swamp, lacustrine and fluviolacustrine, and then a return to fluvial environments.

Vertebrate fossil remains from the Mae Moh Basin (?main coal seams) including Mustelid (*Siamogale thailandica* Ginsburg *et al.* 1983), rhinoceros (*Rhinocerotini* indet. cf. *Gaioatherium*) and proboscidea (*Stegolophodon* sp.) are assigned as late Middle Miocene in age (Ginsburg, 1983). Palynological study of Mae Moh samples were attempted by Ratanasthien (1984) but poorly preserved palynomorphs were found. However, some experiments were carried out in this study to develop a suitable treatment for Mae Moh samples. With the new treatment, a number of Mae Moh samples yield highly diverse and well preserved palynomorphs. Palynological evidence from this study shows the Mae Moh main coal seams (Section 6.3) to be of Middle Miocene age.

2.4.4 Mae Sot Basin

The Cenozoic basin of Mae Sot is located in northwestern Thailand at about 16°N, 98°E (Figures 1-1, 2-8), and extends across the Moei River into Burma. Mae Sot oil shales are exceptional in their extent, at least 30 km along the basin axis, and in their laminated, carbonate-rich nature. They were deposited in an extensive lake in a large intermontane basin. Oil shale of Mae Sot Basin has been estimated to contain about 4,190 million tonnes in reserves (DMR, 1979). The rich organic oil shale consists mainly of lamalginite, and yields up to 341 litres of oil per tonne with average 167 litres of oil per tonne (Gibling *et al.*, 1985a; Strokes, 1988).

The basin is fault-bounded at least locally, and the mountains rise to over 1500 m above the basin floor. Bedrock on the eastern (Thai) margin consists mainly of Permian to Jurassic carbonate and clastic rocks, whereas a greater variety of rock types occurs on the western (Burmese) margin. Mae Sot Basin is a shallow syncline trending NE-SW, with dips averaging 15°-25°, locally up to 57°. Faulting is uncommon. Thanomsap (1983) noted that a Bouguer gravity map of the basin shows two synclinal and elongate subbasins with NW-SE axes.

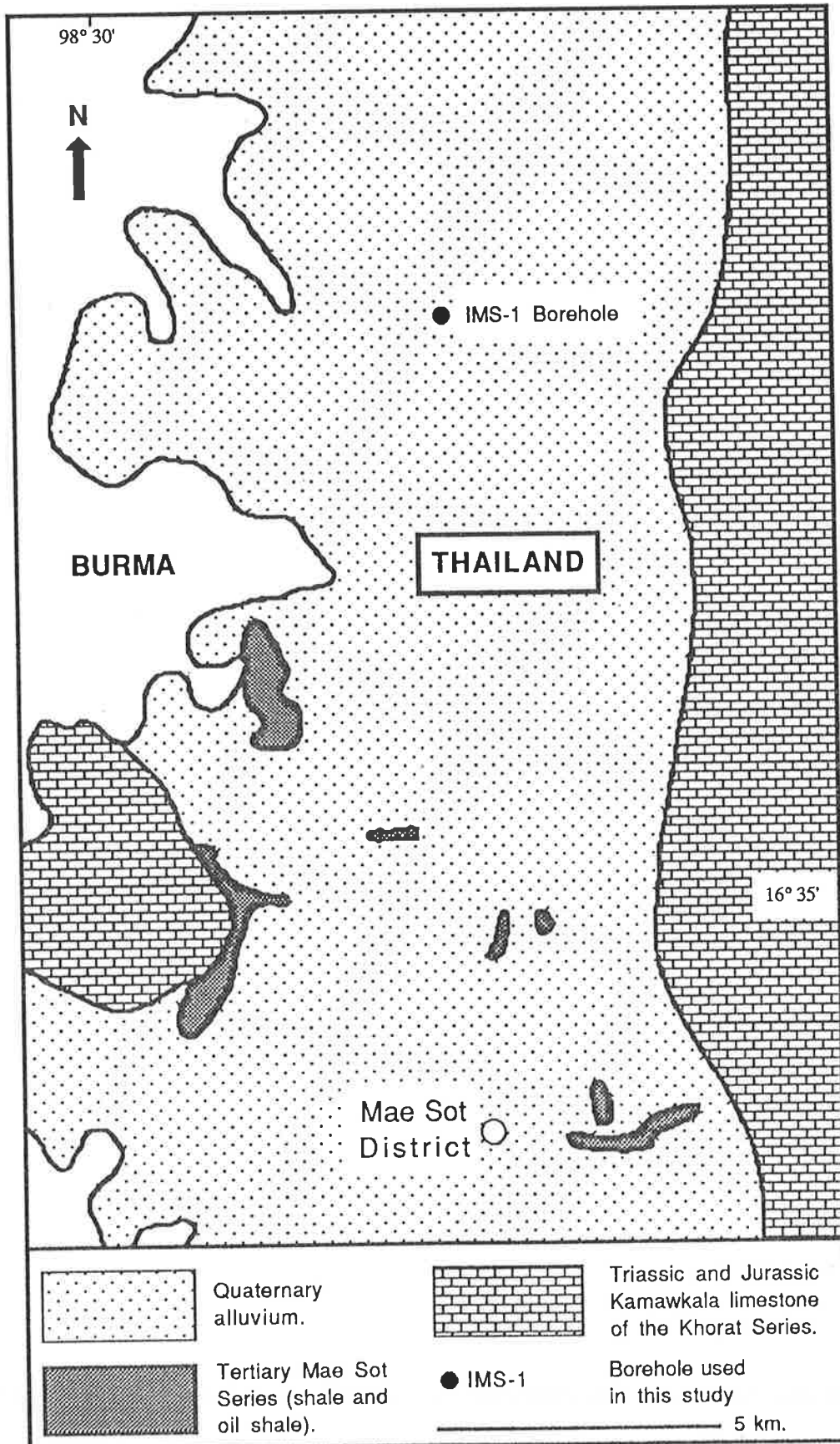


Figure 2-8. Geological map of Mae Sot Basin, northern Thailand (modified from Brown *et al.*, 1951 and unpublished DMR geological map of Mae Sot Basin), showing locality of the IMS-1 Borehole which was sampled for palynological study.

The Tertiary sequence of Mae Sot Basin (see also Figure 6-4) is subdivided into four units (1, 2, 3 and 4 in ascending stratigraphic order). Unit 1, which is more than 600 metres thick, lies unconformably on basement rocks and consists of sandstone, siltstone and fossiliferous limestone. Unit 2 is more than 900 metres thick and contains marlstone, mudstone, and interbedded shale and oil shale. Unit 3 is more than 500 metres thick and contains sandy shale, sandy marl, and interbedded shale. Unit 4 is about 300 metres thick and contains shale interbedded with mudstone and oil shale. Quaternary gravel beds unconformably overlie Unit 4 (Tantisukrit *et al.*, 1981a, 1981b; Chaodumrong *et al.*, 1983)

Oil shale sequences represent deeper lake environments with deposition under anaerobic conditions, as indicated by the good lamination and preservation of abundant organic matter (Tantisukrit *et al.*, 1981a). Oil shale is likely to be deposited if clastic input is low. The main source of organic material in the oil shale is planktonic and benthonic algal material. (Gibling *et al.*, 1985a, 1985b). The organic petrological studies of oil shale from Mae Sot Basin show that they contain abundant lamalginite. Trace amounts of telalginite, liptodetrinite, bitumen/resinite and huminite/inertinite are also present in some of the rocks. Vitrinite reflectance data from the oil shales and associated coals indicate a low level of maturity (Sherwood *et al.*, 1984).

Remains of fishes, plants and invertebrates are found in oil shale strata. Fishes are the most abundant fossils. Plant material is mainly woody fragments, with rare leaf fragments and seeds. Invertebrate fossils are rare. Fossils of gastropods and ostracods are also found in the basin (Gibling *et al.*, 1985a). Remains of fishes and gastropods from the Mae Sot Basin have been identified as freshwater types (Brown *et al.*, 1951). Cyprinid fishes discovered from Mae Sot Basin have been dated as Miocene age (Uyeno, 1969). However, palynological evidence from this study shows the Mae Sot oil shale strata (Section 6.4) to be of Middle Miocene age or younger.

2.4.5 Nong Ya Plong Basin

Nong Ya Plong Basin (Figures 1-1; 2-9) is a small coal-bearing and mainly fault-bounded half graben. To the west the basin is bounded by a mountainous range composed of the Carboniferous Kaeng Krachan Group (sandstone, orthoquartzite, tuffaceous shale and

pebbly mudstone). The Kaeng Krachan Group also lies unconformably beneath the Tertiary sequence in the basin.

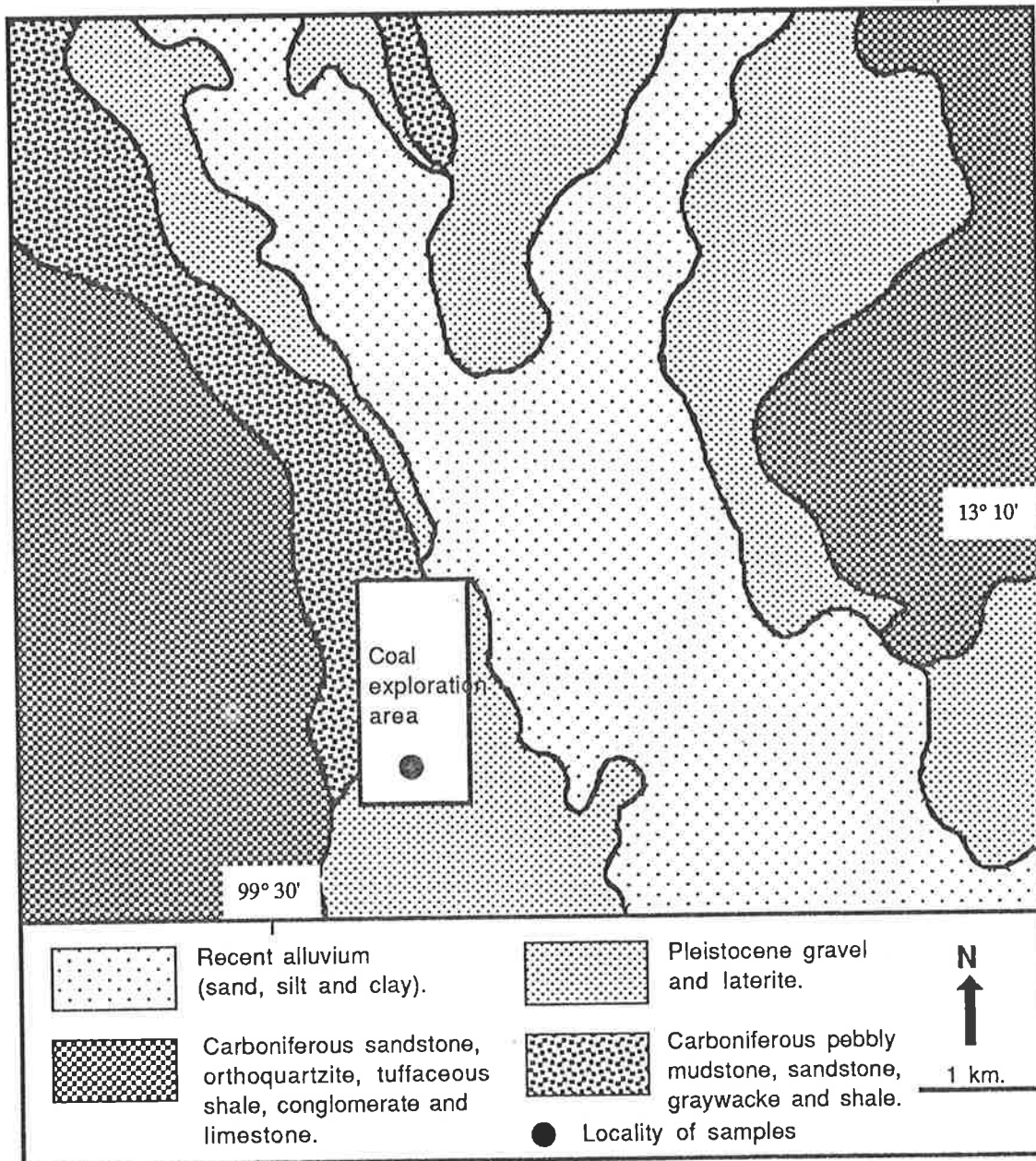


Figure 2-9. Geological map of Nong Ya Plong Basin, central Thailand (Supurtipanish & Pithchayakul, 1983), showing locality of samples for this study.

The Tertiary sequence (Figure 5-2) begins with mudstone interbedded with sandstone and conglomerate. Above this, carbonaceous content gradually increases and the sequence terminates with coal, mudstone and carbonaceous mudstone containing plant and fish remains. The thickness of the Tertiary deposits varies from 80 metres to more than 180 metres.

Quaternary alluvial deposits of unconsolidated reddish brown to brown sandy clay, siltstone and gravel overlie the Tertiary sequence.

Coal seam thickness ranges from 0.5 to 3 metres and the coal is ranked by ASTM standard as volatile B-C bituminous. Supurtipanish & Pithchayakul (1983) and Pithchayakul *et al.* (1986) reported on the exploration of the 1.65 km² prospecting area which is estimated to contain about 2 million tonnes of coal reserves.

Supurtipanish & Pithchayakul (1983) also reported an age determination (by R. Ingavat) of fish remains from Nong Ya Plong Basin indicating Miocene age. Because their fossils are unlocated precise relationship with samples from this study, a correlation cannot be determined. However, palynological evidence from this study shows the major coal seam of Nong Ya Plong Basin (Section 5.2) to be of pre SIAM-1 Zone, Late Oligocene age.

2.4.6 Sin Pun Basin

The Sin Pun Basin (Figure 1-1) lies in a provincial frontier area of Krabi, Surat Thani and Nakorn Si Thammarat in southern Thailand. It is mainly bounded by Mesozoic sandstone, siltstone and conglomerate, with some sporadic Permo-Carboniferous limestone (Figure 2-10). The Tertiary sequence lies unconformably on Mesozoic sandstone. The Sin Pun Tertiary sequence contains claystone, coal, sand and gravel (Figure 6-2); and is subdivided into five units including A, B, C, D and E in ascending stratigraphic order. Unit A is composed of semiconsolidated claystone and silty claystone. Unit B which is about 30 metres thick, is composed of semiconsolidated claystone, silty claystone, clayey sandstone and sandstone. Coal lenses are locally distributed in this unit. Unit C is composed mainly of coal seams interbedded with fossiliferous mudstone, claystone and carbonaceous claystone. The main coal seam is about 2-18 m. thick. Unit D, about 0-30 metres thick, is composed of claystone and shale with fossil remains of gastropods. The gastropod bed is at the base of this unit. Unit E, which is more than 150 metres thick, is composed of unconsolidated to semiconsolidated clay, silt, sand and gravel which occur alternately (Sriratpinyo, 1984). Although previous age determination of fossil remains is not available but palynological evidence from this study shows the major coal seam of Sin Pun Basin (Section 6.2) to be of upper SIAM-1 Zone, Early Miocene age.

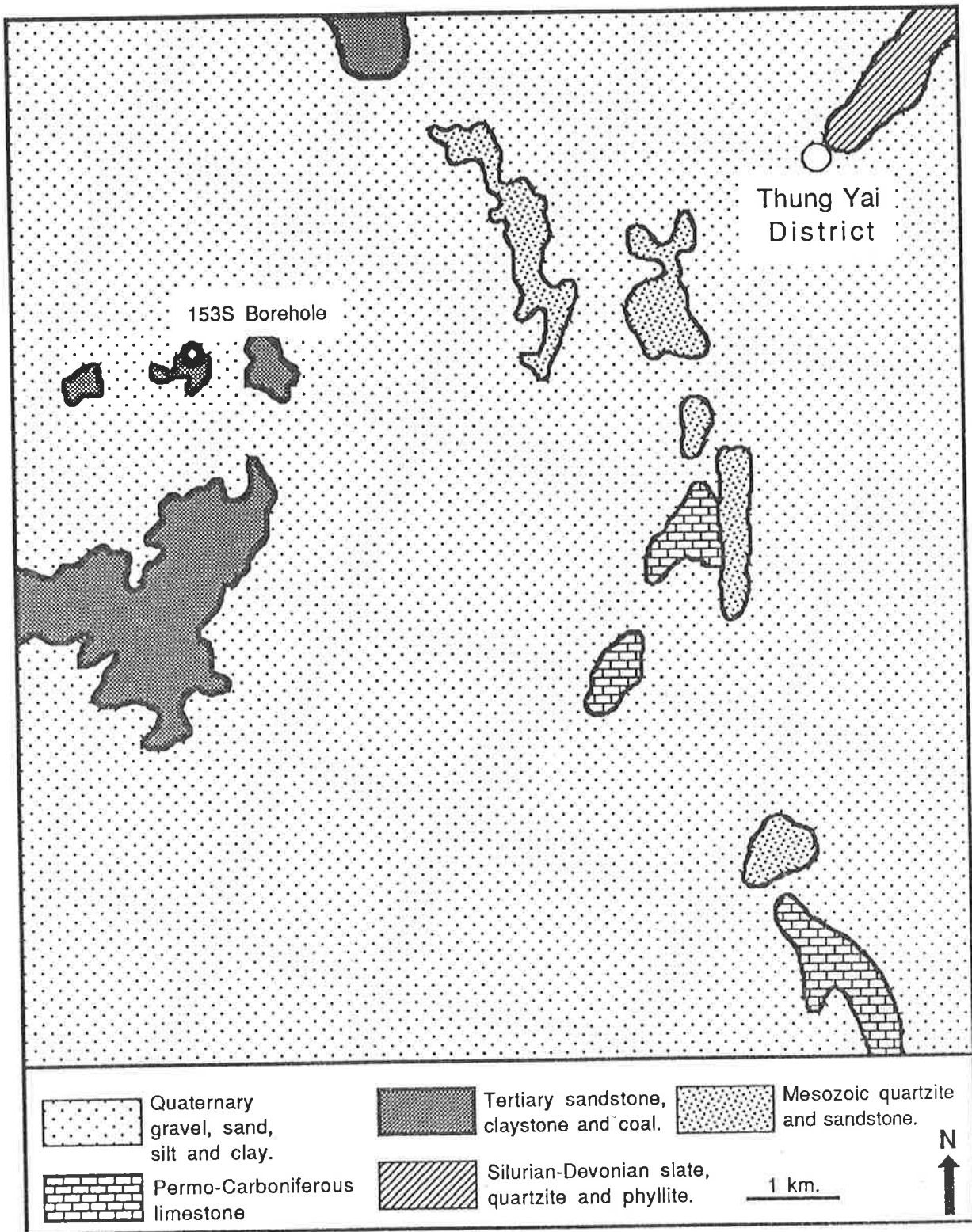


Figure 2-10. Geological map of Sin Pun Basin, southern Thailand showing the 153S Borehole locality (EGAT unpublished geological map).

2.4.7 Krabi Basin

Krabi is a coal bearing basin in southern Thailand (Figure 1-1). Coal reserves have been estimated at about 26 million tonnes (Supurtipanish *et al.*, 1983). Krabi Basin is mainly

bounded on the west by the Permo-Carboniferous Rat Buri Formation and the Triassic to Jurassic Phu Kradung Formation (Figure 2-11).

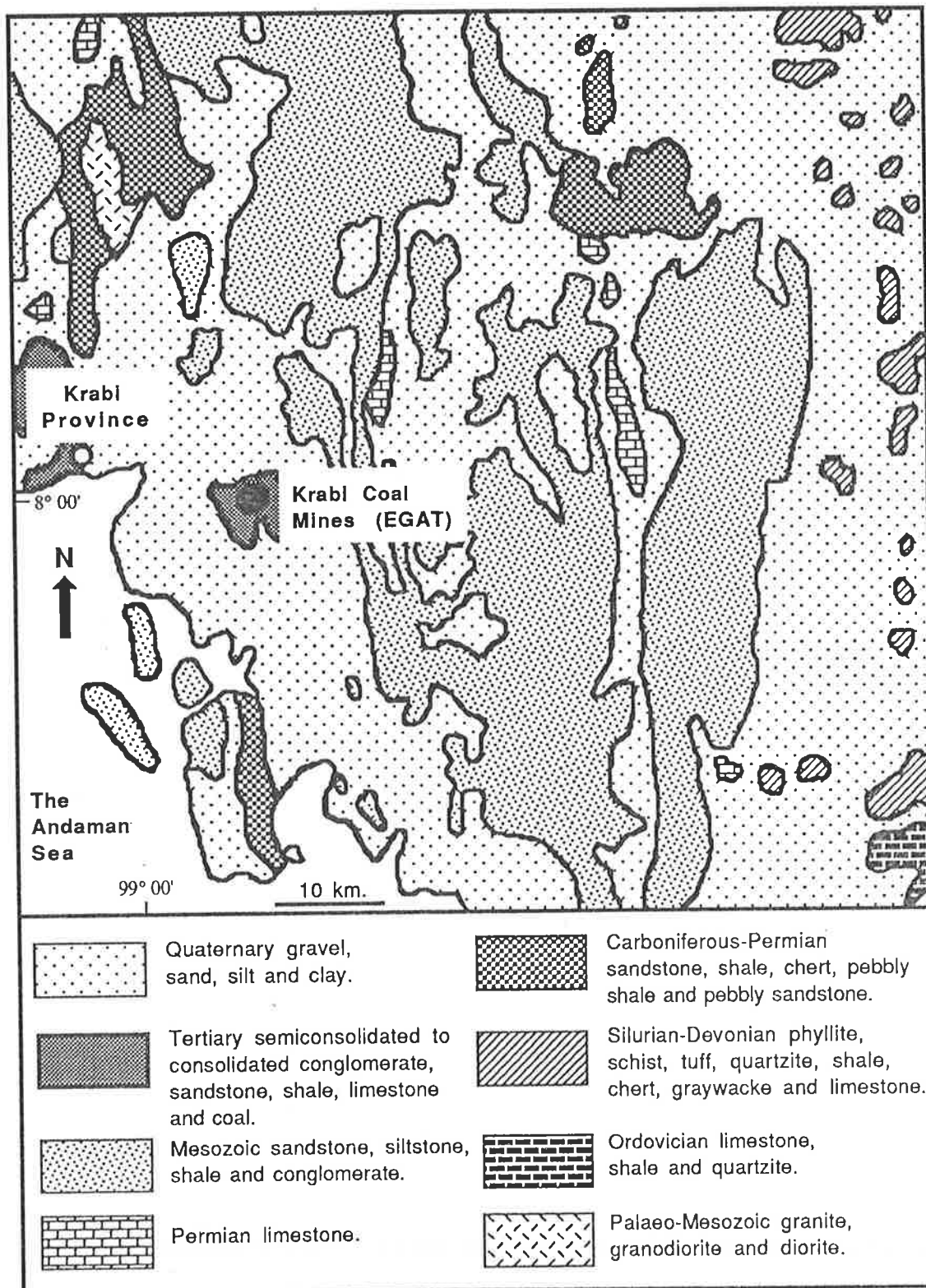


Figure 2-11. Geological map of Krabi Basin, southern Thailand (Suensilpong *et al.*, 1984), showing locality of Krabi coal mines which were sampled for this study.

Surveys show some geological structures including synclines, anticlines and faults which strike approximately N-S (Markirt *et al.*, 1984). Ratanasthien (1983) ascribed the origin of the Krabi Basin to sinistral faulting and oroclinal bending which occurred during the Jurassic and Cretaceous. The Tertiary sequence strikes approximately NNW to N and dips 45° to the east.

The Krabi Tertiary sequence can be subdivided into three parts (Figure 6-1). The lower sequence contains claystone and silty claystone intercalated with sandstone and siltstone. The middle sequence is the main coal seam, which consists of coal and carbonaceous claystone with plant remains and shell fragments. The main coal seam of the Huai Wai Lek Mine is approximately 15-25 m. thick. The upper sequence consists of silty claystone, gastropods and pelecypods fossiliferous limestones, calcareous sandstone and conglomerate interbedded with thin bedded coal and carbonaceous claystone. Quaternary or Recent sediments unconformably overlie the Tertiary sequence.

Sedimentary deposition in the basin is related to transgression and regression of the sea throughout the Tertiary Period. The ingression of sea water appears to have entered the basin from the south. The evidence suggests the depositional environment at Huai Wai Lek Mine was paralic tidal flat (Markirt *et al.*, 1984). The Huai Wai Lek subbasin contains a typical littoral coal-bearing formation and marine transgression and regression are indicated by fossils and depositional features, including fossiliferous limestone, sandstone and calcareous sandstone deposited by coastal winds (Ratanasthien, 1983).

Marine gastropods of Late Tertiary or possibly Pleistocene age are found in marl and limestone a few metres above the coal seam (Brown *et al.*, 1951). Because their fossils are unlocated precise relationship with samples from this study, a correlation cannot be determined. However, palynological evidence from this study shows the major coal seam of Krabi Basin (Section 6.1) to be of the upper boundary of the SIAM-1 Zone, Early Miocene age.

2.4.8 Andaman Sea

The Andaman Sea (Figure 2-12) is a tectonic basin bounded by Burma to the north, the Thai-Malay peninsula to the east, Sumatra to the south and the Andaman-Nicobar islands to the west. It encompasses a large area of about 800,000 km². The Andaman Sea is divided into two

parts by a pronounced north-south trending continental slope. The western part is mostly deeper than 1000 m., and much of it beneath 3000 m.; rift structures are present. The shallow eastern part of the Andaman Sea appears to be floored by an extension of the Palaeozoic-Mesozoic complex exposed on the adjacent peninsula (Rodolfo, 1969; CCOP/IOP, 1974).

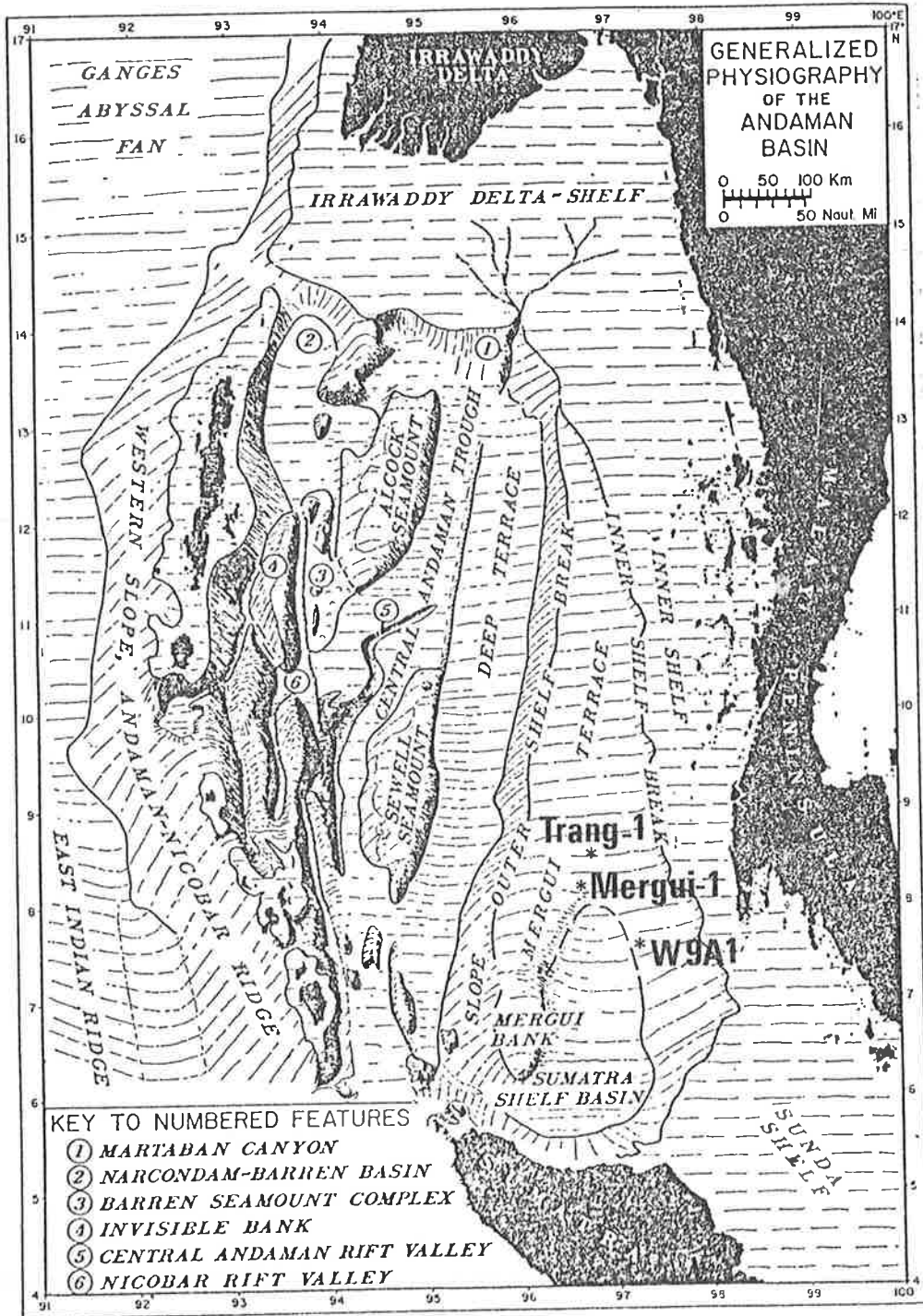


Figure 2-12. General physiography of the Andaman Sea (Rodolfo, 1969), showing localities of boreholes Trang-1, Mergui-1 and W9A1.

The refraction data of Curray *et al.* (1979) suggested that the Mergui-North Sumatra Basin is underlain by thin continental crust. This basin may be an Oligocene or Early Miocene extensional basin or a proto-Andaman Sea which aborted before drifting and formation of oceanic crust started. It was succeeded by the Middle Miocene oblique extension in a northwest-southeast direction on the west side of Mergui Ridge of the Andaman Sea.

Achalabhuti (1981b) reported that the basement configuration of the Andaman Sea is a series of north-south and northeast-southwest horsts and grabens. The Mergui ridge and Ranong ridge represent horsts while the Mergui Basin and Ranong Basin represent grabens in deep and shallow water respectively. Pre-Tertiary basement is composed of granite, limestone, low-grade metamorphic rocks of slaty shale and phyllite, and medium-grade metamorphic rock (chlorite schist). Infilling sediments more than 4 km. thick have been recorded in some places. The Tertiary sedimentary sequence ranges from Oligocene to Recent in age and consists of clastic sediments with local carbonate reefs. For example, Troelstra *et al.* (1976) reported that the Mergui-1 well penetrated a sequence of claystone, sandstones, siltstones, and shales ranging in age from Middle Miocene to ?Lower Miocene-?Oligocene (based on planktonic foraminiferal and nannofossil zonations).

Paul & Lian (1975) postulated that deposition in the southeast Andaman Sea began during the Oligocene with non-marine sandstone. Miocene marine sedimentation followed and at approximately the close of the Middle Miocene, minor uplift and erosion occurred. Upper Miocene and Pliocene sedimentation is believed to represent a regressive marine phase. Lateral changes in seismic reflection character indicate that the main provenance for sediments was to the northeast. Unconformities at the end of N 14 planktonic foraminiferal zone have been indicated in composite logs both Mergui-1 and Trang-1 wells (Atkinson *et al.*, 1976; Ayling *et al.*, 1976).

Six lithostratigraphic units have been established for the Andaman Sea (Andaman, Sadao, Kantang, Frang, Pavans and Takua Pa in ascending order). The lithostratigraphy of the Andaman Sea, Straits of Malacca and North Sumatra have been correlated by Nakanart & Mantajit (1983).

Microfossils which are possible to be found from the Tertiary sequences of the Andaman Sea include foraminifera, nannofossils, dinoflagellates, and palynofloras. Planktonic

foraminiferal zonation scheme (Blow, 1969) and calcareous nannoplankton zonation scheme (Bukry, 1973) are mainly applied for biostratigraphy. But to use dinoflagellates for biostratigraphy is not yet been found. Application of palynofloras for biostratigraphy in the Andaman Sea is uncommon and also there is no obvious palynological zonation scheme.

2.4.9 Gulf of Thailand

The tectonic evolution of the Gulf of Thailand is complex but it appears the Gulf is an intracratonic basin situated in the Eurasian Plate and which began to subside during the Late Cretaceous to Early Tertiary (Paul & Lian, 1975; Woollands & Haw, 1976; Achalabhuti, 1981b). It is flanked on the east by the Indo-China craton and on the west by the Thai-Malay peninsula. Woollands & Haw (1976) divided the Gulf into two structural provinces separated by the north-south trending Ko Kra Ridge. To the west of this ridge many narrow, elongate and partially isolated basins and grabens are separated by equally narrow north-south basement horsts. East of the Ko Kra Ridge in the central area of the Gulf of Thailand is one large basinal area in which three main basins can be recognized; namely, the Pattani trough and the Malay Basin (Figure 2-2). Tertiary basins in the Gulf, similar to the distant Fang Basin, are formed by N-S trending normal faults giving rise to grabens and half grabens with high geothermal gradients.

The Tertiary sequence, which comprises sandstone, shale, mudstone, coal, siltstone, conglomerate, and limestone; varies from less than 300 m. thick on the horsts to over 8 km. thick in the Malay Basin. Paul & Lian (1975) mentioned that basement in the central trough is buried as deep as 10 km. and generally cannot be detected on seismic records. Basement is composed of Mesozoic and Palaeozoic sedimentary and plutonic rocks.

Woollands & Haw (1976), postulated a schematic sedimentary model of the Gulf which highlighted three major sedimentary cycles, including two regressive sequences (I & II), and one transgressive sequence (III) in ascending order. The model was based on three wells (16-C-1, 4-B-1, 16-B-1) which were barren of both marine and terrestrial microfossils in cycle I and lower part of cycle II.

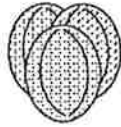
A regional unconformity is recognized within the upper Middle Miocene sequence but there is no pronounced lithological change at the unconformity (Paul & Lian, 1975; Achalabhuti, 1981a; ASCOPE, 1981; Hellinger *et al.*, 1981).

ASCOPE (1981) summarized information from well cuttings, cores, flora and electric logs and suggested that the Gulf of Thailand has been the site of fluvial, deltaic to shallow marine sedimentation from Oligocene to present. The depositional systems which formed the Tertiary clastic sequences were probably analogous to present depositional systems in the Gulf of Thailand. Hydrocarbon producing horizons are within deltaic sands of Lower and Middle Miocene age. Achalabhuti (1981b) pointed out that oil shows were also encountered in some wells and suggested a wide variation of organic sources ranging from continental woody material as primary sources to minor contributions of marine algae.

The high geothermal gradient of the Gulf has been documented by Paul & Lian (1975); the temperature gradient below 2600 m. is greater and on the order of 7.3°C per 100 m. The critical temperature of 176°C. is reached at about 3200 m., and gas is likely to be the only hydrocarbon found at greater depth. Woollands & Haw (1976) noted that drilling has been limited to less than about 3500 m. due to the high geothermal gradient. Hellinger, *et al.* (1981) indicated that the Pattani trough and the Malay Basin are both sites of higher than normal temperature gradients and heat flow values. Trevena & Clark (1986) concluded that Miocene sandstones from the Pattani Basin provide an example of rapid decline in porosity and permeability with increasing burial depth. This decline results from rapid burial diagenesis that is related to the very high geothermal gradients in the basin. The best porosities and permeabilities in Pattani Basin reservoirs are generally associated with large intergranular pores in sandstones at depths between 915 and 1980 m.

Microfossils which are possible to be found from the Tertiary sequences of the Gulf of Thailand include palynofloras and foraminifera. Palynomorphs and foraminifera have not been found in lower Tertiary sequences of the Gulf, possibly because of unsuitable sandy or oxidized lithology, a high geothermal gradient, or non-marine depositional environments. Palynofloras are dominated both middle and upper sequences but foraminifera occur mainly in

the upper sequences. Palynological zonation scheme of Morley (1978) is widely applied for biostratigraphy in the Gulf of Thailand.



CHAPTER 3

TERTIARY PALYNOLOGY OF THAILAND

3.1 Previous Mid-Tertiary Palynostratigraphic Studies

3.1.1 Southeast Asia

Tertiary palynological studies are uncommon in Southeast Asia except for the Borneo region. Palynological zonation of the region which do exist are largely based on coastal mangrove floras of the *Sonneratia* (*Florschuetzia*) pollen types (Germeraad *et al.*, 1968). The *Florschuetzia* zonation in Southeast Asia are similar to each other, with minor range modifications (Germeraad *et al.*, 1968; Woollands & Haw, 1976; Morley, 1978; Achalabhuti, 1981a, 1981b). The main discrepancy is in the age range of *Florschuetzia levipoli* Zone which later studies tend to expand both upper and lower limits (Figure 3-1). Because zonation schemes (Germeraad, 1968; Morley, 1978; Achalabhuti, 1981a) are based on taxa of mangrove palynofloras, viz. *Florschuetzia levipoli* Germeraad *et al.* 1968 and *Florschuetzia meridionalis* Germeraad *et al.* 1968, which occur only in coastal or marginal marine depositional environments. They are of little value for palynofloral zonation in terrestrial sediments. Such schemes are therefore limited to coastal or marginal marine facies.

Germeraad palynological zonation (1968) is the pioneer work for the Southeast Asian region. Appearances of *Florschuetzia trilobata* Germeraad *et al.* 1968, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Florschuetzia levipoli* Germeraad *et al.*, and *Florschuetzia meridionalis* Germeraad *et al.* 1968, are used as key species for zonation. The advantage of the Germeraad zonation (1968) lies in detailed statistical study of occurrences of *Florschuetzia* spp., in a complete taxonomy and in provision of a range chart. Since then such a detailed mid-Tertiary palynological study for Southeast Asia has not been published.

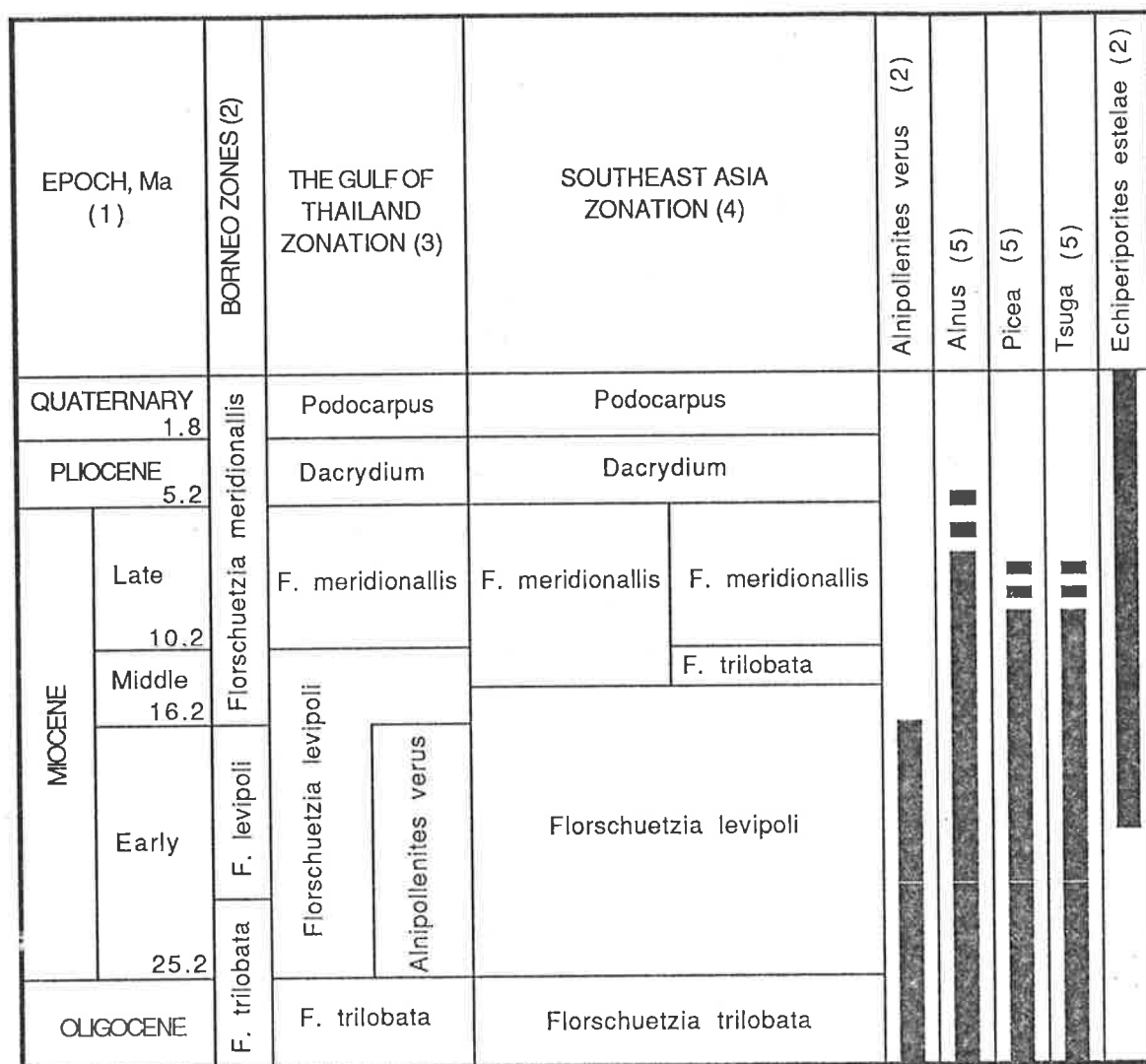


Figure 3-1. The palynological zonation and stratigraphic ranges of some selected taxa in Thailand and neighbouring Southeast Asia (Sources: 1: Haq *et al.*,1987; 2: Germeraad *et al.*,1968; 3: Achalabhuti, 1974, 1976, 1981a, 1981b; 4: Morley, 1978; 5: Muller, 1972).

The palynological zonation scheme of Morley (1978), for example, is possibly based on extensive proprietary data from biostratigraphical works in Southeast Asia including offshore Thailand but lacks of details in zonation scheme, photomicrography, systematic and quantitative palynology. The *Florschuetzia* palynological zonation scheme for Southeast Asia of Morley (1978) is similar to that of Germeraad *et al.* (1968). The new zonal markers, *Dacrydium* and *Podocarpus* have been introduced by Morley (1978) for Pliocene and Quaternary respectively for the section of the northern Sunda Shelf, and in the offshore of Thailand (Achalabhuti, 1976, 1981a, 1981b; ASCOPE, 1981). The concept that the *Podocarpus* migrated from southern lands (Australia) related to the Asia-Australia continental plate collision during the late Cenozoic, is ruled out in this study. Because the genus *Podocarpus* is widely

represented in the Tertiary of East Asia (Fuji, 1969a, 1969b; Takahashi & Kim, 1979; Sun *et al.*, 1981; Takahashi & Shimono, 1982; Huang & Huang, 1984) and in the Late Oligocene to Middle Miocene throughout Thailand (this study). *Dacrydium* occurs in the Early Miocene in Thailand. These evidences suggest the occurrences of *Dacrydium* and *Podocarpus* in Southeast Asia prior to the Asia-Australia continental plate collision during the late Cenozoic. See further discussion on *Dacrydium* and *Podocarpus* in Section 3.2.3.

Pollen records of montane floras including *Pinus*, *Picea*, *Tsuga*, *Alnus*, *Pterocarya* and *Ephedra*, have been reported from Oligo-Miocene sediments of Borneo; and none of these species exist presently in the region (Muller, 1972). Germeraad *et al.* (1968) mentioned that *Alnus* pollen in Borneo was abundant in the Oligocene and Early Miocene and there was a gradual decrease in frequency during the course of the later Miocene and Pliocene. There is also a discrepancy in the range of dispersed *Alnus* pollen type (Figure 3-1). The approach on occurrences of temperate palynofloras during mid-Tertiary in Southeast Asia was focused on palaeoenvironment and palaeoecology. For example, these palynofloras derived from temperate regions were named as "montane palynofloras". But in this study indicates that most palynofloras derived from temperate regions are not limited only to montane regions but are widely distributed throughout Thailand during mid-Tertiary (Figure 7-2). The occurrences of temperate palynofloras are also applied in the study for biostratigraphy and palaeoclimatic reconstruction.

3.1.2 Thailand

Even though Tertiary biostratigraphy of Thailand is in high demand by industry, only a few sporadic attempts on age correlation have been made, and these include schemes using macrofaunal remains (Ginsburg, 1983), palaeobotany (Endo, 1964; 1966) and palynology (Baum *et al.*, 1970; Buravas, 1975; Ratanasthien, 1984; Wolfart, 1987).

Palynological information concerning Thailand is very scant and much of what is known is largely kept as proprietary information in petroleum exploration company files.

Onshore palynological studies include Baum *et al.* (1970), Buravas (1975), Ratanasthien (1984) and Wolfart (1987). Palynological investigations by Müller on Fang Basin lignites suggest a Miocene/Pliocene age (Baum *et al.*, 1970). Palynology of Mae Soon core at

572 m. depth which was examined by Bunyananon, comprises *Microhenrici*, *Henrici*, *Corupheus*, *Salix*, *Pollenites fallax* and *Pinus haploxylon*, and suggests Oligocene to Recent ages (Buravas, 1975). A palynological study of samples from Fang, Mae Moh, Li, Mae Teep and Mae Tun basins, was carried out by Ratanasthien (1984). Taxa which have been found, include *Tricolpites* sp., *Tricolporites* sp., *Appendicisporites tricornitatus*, *Rugubivesiculites* sp., *Spinizonocolpites* cf. *S. echinatus*, *Cicatricosporites drumhellerensis*, *Plicatella* sp. *Verrumonoletes* sp., *Laevigatosporites* sp., *Lophotriletes* sp., *Alnipollenites verus* and *Pinuspollenites* sp. Marine incursions into the Fang Basin on the basis of occurrences of *Spinizonocolpites* cf. *S. echinatus* and *Rugubivesiculites* sp. were suggested. A Senonian or Palaeogene age for most of the studied samples was also proposed. Lignite from Sop Prap area, Lampang Province, contains sporomorphs of Polypodiaceae, *Alnipollenites*, *Psilahexacolpopollenites* indicating a Neogene age (Wolfart, 1987). Because stratigraphic relationships between samples used in this study and those of earlier workers cannot be determined. Moreover, because most previous studies use different systematics and lack of figures, thus the information cannot be used confidently. However, only a few genera including *Alnipollenites*, *Pinuspollenites*, *Spinizonocolpites* and *Laevigatosporites* from these studies are common to this study.

Although offshore Thailand has been actively explored for two decades, little has been published on palynology (Paul & Lian, 1975; Woollands & Haw, 1976; Achalabhuti, 1976, 1981a, 1981b; ASCOPE, 1981). A few taxa are used as zonal markers, including *Florschuetzia* spp., *Dacrydium* sp., and *Podocarpus* sp. The components of the assemblages, systematic descriptions, frequencies, and photomicrography are poorly known. The palynological zonation scheme of Morley (1978) is widely applied in the Gulf of Thailand and Andaman Sea.

Virtually nothing is known from the Andaman Sea except for a few studies from Andaman Islands and the Deep Sea Drilling Project in which very few taxa can be related to the studied taxa of Thailand. A palynological study of the Port Blair Formation, Andaman islands which was assigned a Palaeogene age (Banerjee, 1966), bears little relationship to this study. Deep sea palynological studies of the DSDP sites 214 and 254, Ninetyeast Ridge, Indian

Ocean, also, bear little relationship to this study but suggest a closer affinity with Australian elements (Harris, 1974; Kemp & Harris, 1977).

Even though the Gulf of Thailand has been actively explored and successfully exploited for petroleum resources for two decades and previous major Tertiary palynological studies in Thailand have centred on the Gulf of Thailand, only one palynological zonation scheme (Achalabhuti, 1974, 1976, 1981a, 1981b; Figure 3-1) is known. It is generally similar to the Morley (1978) zonation scheme, with the inclusion of *Alnipollenites verus* Subzone added to *Florschuetzia levipoli* Zone and the absence of *Florschuetzia meridionalis*-*Florschuetzia trilobata* Subzone. Again, however the components of the assemblages, their systematic descriptions, frequencies, and photomicrography are lacking, which diminishes its usefulness to this study.

3.2 Mid-Tertiary Palynological Zonation Scheme for Thailand: This Study

In Thailand, there is no palynological zonation for isolated onshore basins. Offshore palynological zonations are well established and are generally based on the distribution of a number of *Florschuetzia* species (Woollands & Haw, 1976; Achalabhuti, 1976, 1981a, 1981b). Most onshore palynological sequences of Thailand show no evidence of the coastal palynomorphs except for some influence in the Krabi sequence, southern Thailand. However, the appearance of *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953, *Alnipollenites verus* Potonié 1931, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Florschuetzia* spp., and tropical microfloral assemblages including *Lagerstroemia* sp. 325, *Ammania* sp. 381 and *Pandaniidites texus* Elsik 1968, provide a key for zonation and correlation between offshore and onshore sequences. The correlation between onshore basins relies on assemblages derived from drillcore and exposures in mines but most offshore material is based on cuttings.

Both *Alnipollenites verus* Potonié 1931 and *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 occur in terrestrial environments and rarely in coastal and marine environments. *Alnipollenites verus* Potonié 1931 is widespread in both onshore and offshore basins and is recorded in the Gulf of Thailand, including the lower Middle Miocene of 8-238/1X Well

(Heseldonckx *et al.*, 1975) and 7-103/1X Well (Cater *et al.*, 1973), agreeing with the range shown by Germeraad *et al.* (1968). In terrestrial sediments the frequency of *Alnipollenites verus* Potonié 1931 varies from rare to very common in the Late Oligocene including in Li Basin (northern Thailand) and Nong Ya Plong Basin (central Thailand). The species is common in the Early Miocene but is rare in Middle Miocene terrestrial sediments and Oligo-Miocene marine sequences.

Although *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 is widely distributed in most basins it is generally rare after the Early Miocene. Its first appearance is at about the same time as influxes of tropical elements during early Early Miocene.

It should be noted that mangrove palynofloras, viz. *Florschuetzia levipoli* Germeraad *et al.* 1968, *Florschuetzia trilobata* Germeraad *et al.* 1968, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Zonocostites ramonae* Germeraad *et al.* 1968 and *Avicennia* sp. 1492 occur only in coastal or marginal marine depositional environments in Krabi Basin, Andaman Sea and the Gulf of Thailand. These taxa are of no value for palynofloral zonation in terrestrial sediments.

Zonation Scheme. Conventional zonal names are often based on the name of one taxon, but this may be misleading when applying the zones. For example, the Southeast Asia zonation in Figure 3-1 shows two *Florschuetzia trilobata* zones which lack meaning and are confusing in application. Thus, in this study, the prefix "SIAM" is adopted to identify the regional palynological zonation scheme and two zones, SIAM-1 and SIAM-2 are established obvious from Figure 3-2.

The basis for defining zonations in this study depends on first and last appearances of a number of taxa. Although it may be possible to divide these zones into subzones by using relative frequencies of some taxa, this is not attempted in this study.

As stated earlier (Section 1.2), most samples from the marine sequences are cuttings, and thus correlations and age determinations based on these assemblages in the Andaman Sea, the Gulf of Thailand and onshore basins are provisional. Future research using core samples may provide more precise ages and confirm or readjust the zonations and correlations.

Although there may be variations in the latitudinal distribution of some key species, it is uncertain whether this results from diachroneity of the zonal boundaries. Firstly, the key species are composed of widely dispersed and climatically limited distributions. The

Echiperiporites cf. *E. estelae* Germeraad *et al.* 1968 has an affinity with pollen of extant Malvaceae which is distributed world-wide, but *Alnipollenites verus* Potonié 1931 and *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953 resemble modern pollen produced by *Alnus* (Betulaceae) and Taxodiaceae-Cupressaceae respectively in temperate regions. Secondly, species with latitudinally restricted distributions may be significant only in the medium and short term but the intervals occupied by the studied samples are likely to represent longer time-segments. Thirdly, most species preferring temperate conditions are widely distributed in Thailand during the mid-Tertiary. Some temperate species also occur in Borneo during the mid-Tertiary. In conclusion, changes in the distribution of some species is unlikely to be proven without more precise and detailed time control from independent sources. This study assumes that the zonation is not affected by such variations.

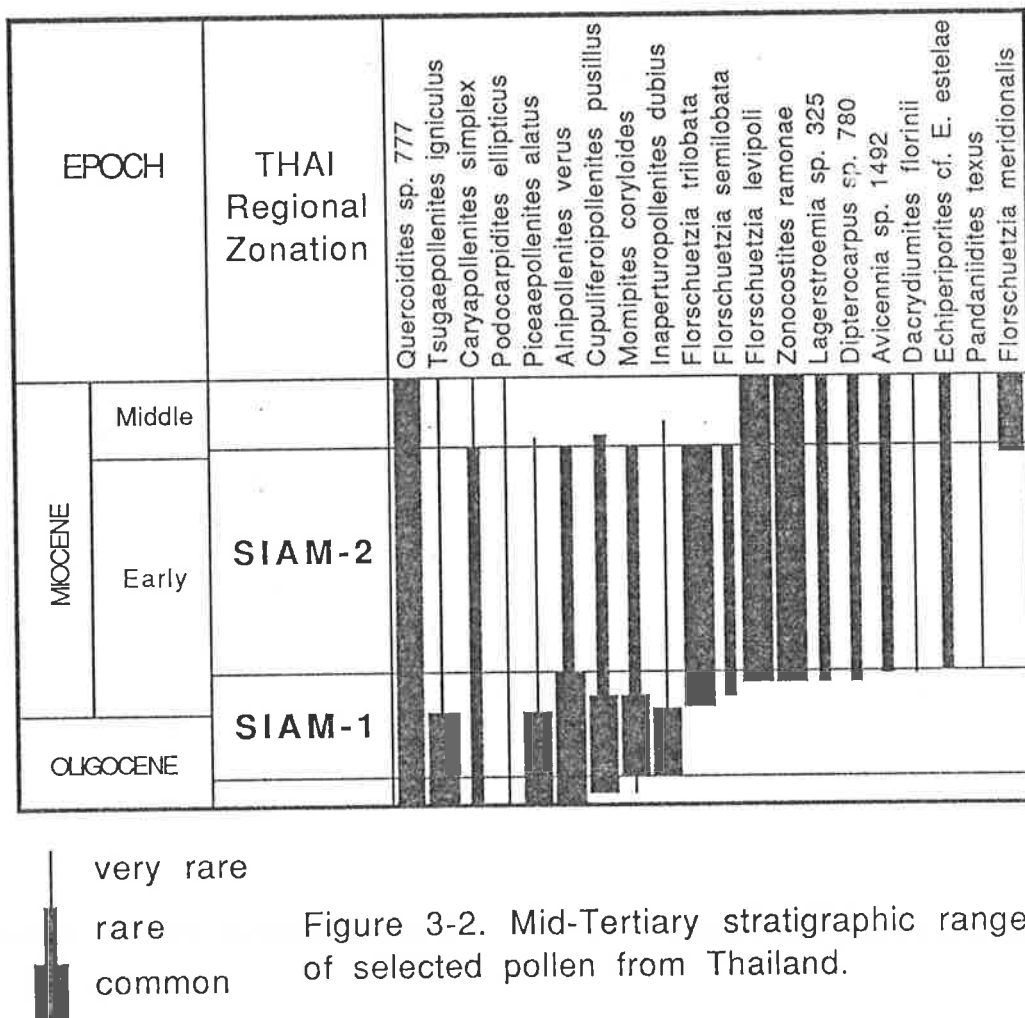


Figure 3-2. Mid-Tertiary stratigraphic ranges of selected pollen from Thailand.

3.2.1 SIAM-1 Zone

The lower limit of this zone is defined by the first appearance of *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953. Species making their first appearances at approximately the same time are *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960 and *Momipites coryloides* Wodehouse 1933 (Figure 3-2).

The upper limit of this zone is defined by the first appearance of *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968.

The reference section for this zone is in BP 120 Borehole between 32.2 to 2.6 m., Ban Pu Mine, Li Basin, northern Thailand.

SIAM-1 Zone is characterized by assemblages comprising high frequencies of *Pinuspollenites* sp. 1436, *Piceapollenites alatus* Potonié 1931, *Tsugaepollenites igniculus* Potonié ex Potonié 1958, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953, *Quercoidites* sp. 777, *Alnipollenites verus* Potonié 1931, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960 and *Momipites coryloides* Wodehouse 1933. Other commonly occurring species include: *Faguspollenites* sp. 845, *Florschuetzia trilobata* Germeraad *et al.* 1968, *Ilexpollenites iliacus* Potonié 1960, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Rhoipites* sp. 847, *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971 and *Laevigatosporites ovatus* Wilson & Webster 1946. Some rare species include: *Monoporopollenites gramineoides* Meyer 1956, *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953, *Caryapollenites simplex* Potonié 1960, *Aceripollis* sp. 853, *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953, and *Podocarpidites ellipticus* Cookson ex Couper 1953.

Late Oligocene and Early Miocene of the SIAM-1 Zone may be provisionally subdivided by using pollen frequency. Gymnosperm pollen frequencies are generally high during Late Oligocene but low during Early Miocene age. These criteria are tentatively used in this study.

The micropalaeontology and nannofossil analyses of the Union Oil Company of Thailand Trang No. 1 Well (Tidey *et al.*, 1976) was carried out from two conventional core samples, 55 sidewall core samples and 328 ditch cutting samples. The report shows that

samples between 3942.4-2225.6 m. depth are assigned with planktonic foraminiferal zones N3-N4 (Blow, 1969) comprising zonal index of *Globorotalia siakensis*, *Globigerinoides subquadratus*, *Globigerinita unicava unicava*, *Globirgerina ouachitaensis ciperensis forma atypica* and *Globorotalia peripheroronda*; and are also assigned mainly with nannofossil *Triquetrorhabdulus carinatus* Zone (Bukry, 1973).

The palynological assemblages of the SIAM-1 Zone are correlated with the palynological assemblages of Trang-1 Borehole between 3941.2-2231.7 m. depth, and also correlated with planktonic foraminiferal zones N3-N4 (3942.4-2225.6 m. depth). On this basis the SIAM-1 Zone is dated as Late Oligocene to Early Miocene age.

3.2.2 SIAM-2 Zone

The lower limit of this zone is defined by the first appearance of *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968. Some tropical taxa which make their first appearance near the base of or within this zone include: *Florschuetzia levipoli* Germeraad *et al.* 1968, *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Dipterocarpus* sp. 780, *Lagerstroemia* sp. 325, *Pandaniidites texus* Elsik 1968, *Excoecaria* sp. 1404, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Lanagiopollis nanggulanensis* Morley 1982 and *Ammania* sp. 382 (Figure 3-2).

The upper limit of this zone is defined by the last appearance of *Alnipollenites verus* Potonié 1931. This is approximately coincidental with the last appearance of *Piceapollenites alatus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Florschuetzia trilobata* Germeraad *et al.* 1968 and *Florschuetzia semilobata* Germeraad *et al.* 1968. A species first appearing at about the upper limit is *Florschuetzia meridionalis* Germeraad *et al.* 1968.

The reference section is at the Klong Huai Wai Lek Mine, Krabi Basin, southern Thailand.

SIAM-2 Zone is characterized by influxes of tropical taxa and decreasing proportions of temperate taxa. Commonly occurring species include: *Quercoidites* sp. 777, *Faguspollenites* sp. 845 *Florschuetzia trilobata* Germeraad *et al.* 1968, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson &

Pflug 1953, *Tricolporites* cf. *T. valvatus* Harris 1972, *Florschuetzia semilobata* Germeraad et al. 1968, *Avicennia* sp. 1492, *Pinuspollenites* sp. 1436, *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971, *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971 and *Cyathidites minor* Couper 1953.

Rare species are: *Alnipollenites verus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Caryapollenites simplex* Potonié 1960, *Ilexpollenites iliacus* Potonié 1960, *Zonocostites ramonae* Germeraad et al. 1968, *Excoecaria* sp. 1404, *Aceripollis* spp., *Margocolporites vanwijhei* Germeraad et al. 1968, *Pandaniidites texus* Elsik 1968, *Myricipites dubius* Wodehouse 1933, *Ammania* sp. 382, *Lagerstroemia* sp. 325, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Podocarpidites ellipticus* Cookson ex Couper 1953, *Dacrydiumites florinii* Cookson & Pike ex Harris 1965, *Piceapollenites alatus* Potonié 1931 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958.

The micropalaeontology, calcareous nannoplankton and stratigraphy of the Union Oil Company of Thailand Mergui-1 Well, Andaman Sea (Troelstra et al., 1976) was carried out from 52 sidewall core samples and 324 ditch cutting samples. The report shows that samples between depth 2564.0-1609.8 m. are assigned with planktonic foraminiferal zones N5-N8 (Blow, 1969) comprising zonal index of *Globorotalia siakensis*, *Globigerinoides subquadratus*, *Globigerinita dissimilis dissimilis*, *Globigerinoides sicanus*, *Globorotalia birnageae*, *Globorotalia peripheroronda* and *Globorotalia peripheroacuta*; and are also assigned with nannofossil *Sphenolithus belemnoides-Discoaster druggi* Subzone to *Helicopontosphaera ampliapertura* Zone (Bukry, 1973).

The palynological assemblages of the SIAM-2 Zone are correlated with the palynological assemblages of Mergui-1 Borehole between 2164.6 to 2000.0 m. depth, and also correlated with planktonic foraminiferal zones N5-N8 (2564.0-1609.8 m. depth). On this basis the SIAM-2 Zone is dated as middle to late Early Miocene age.

3.2.3 Remarks on Post SIAM-2

Post SIAM-2 is characterized by the disappearance of *Alnipollenites verus* Potonié 1931 but the upper boundary of this succeeding interval is unclear. Therefore, this study does

not define a post SIAM-2 zone. However, the upper boundary may be related to the regional unconformity during the late Middle Miocene. The unconformity has been recorded in the Phitsanulok Basin, the Gulf of Thailand and Andaman Sea (Paul & Lian, 1975; Ayling *et al.*, 1976; Atkinson *et al.*, 1976; Knox & Wakefield, 1983). This unconformity is likely to be coincidental with the late Middle Miocene global sea level low (Haq *et al.*, 1987). The relationship between palynostratigraphy and other geological events viz., the late Middle Miocene regional unconformity and plate tectonics requires more study.

The recognition of the Pliocene assemblages, during which *Dacrydium* is abundant, and of the Late Pliocene and Quaternary with increasing *Podocarpus*, probably originated from work in Robertson Research Co. (Morley, 1978). The proposed zonation was uncertain due to the lack of independent dating. Muller (1966) and Morley (1978) pointed out the difficulty in explaining the very late migration of the Australian species, *Podocarpus imbricatus*, into western Southeast Asia and which is presently widespread throughout montane Indochina. However, the occurrences of *Dacrydiumites florinii* Cookson & Pike ex Harris 1965 and *Podocarpidites ellipticus* Cookson ex Couper 1953 in Thai mid-Tertiary sequences may provide a better explanation for the source and present widespread distribution of the taxa in Indochina.

Both first appearance and frequency of these species are difficult to use for defining zonal boundaries. The first appearances of *Dacrydium* and *Podocarpus* as Pliocene and Quaternary markers is incorrect because they first appear in the mid-Tertiary. Also, the application of the frequency of *Dacrydium* and *Podocarpus* as Pliocene and Quaternary markers requires more study. Even though the significance of these Pliocene and Quaternary markers was uncertain, they have been applied extensively in palynological studies of the Gulf of Thailand (Cater *et al.*, 1973; Heseldonckx *et al.*, 1975; Woollands & Haw, 1976; Achalabhuti, 1981a, 1981b).

3.3 Approach to Systematic Palynology

Systematic palynology in this study is essential for comparison between the forms studied here and fossil taxa already described. The results are used for age determination and analysis of depositional environment and palaeoclimate. Because study time was limited, the Systematic Descriptions (Appendix C) are focused on common and significant taxa (to this

study) which are useful for biostratigraphy. Many rare grains examined under SEM and LM which are of no apparent biostratigraphical or botanical significance, are excluded from this study. Eighty three species are listed and thirty two of these are described in Appendix C, including a treatment of detailed palyno-morphology achieved through the use of SEM. In accordance with Article 29.1 of the ICBN (Voss *et al.*, 1983, p. 29), this study will be concluded in the form of an unpublished thesis, and thus no attempt to formalize new species is made here.

Taxonomy. The principles, rules and recommendations which govern binomial nomenclature by ICBN are adhered to in this study. Names of species of uncertain or unmatched affinity to existing published taxa, are followed by a number. Four taxonomic categories are used (Figure 3-3). Firstly, in the case of a clear identification with a valid taxon, the published binomial nomenclature is followed, eg., *Alnipollenites verus* Potonié 1931. These taxa are not described in the section on Systematic Descriptions (Appendix C) except for minor variations and additional observed details, which are noted in the "remarks".

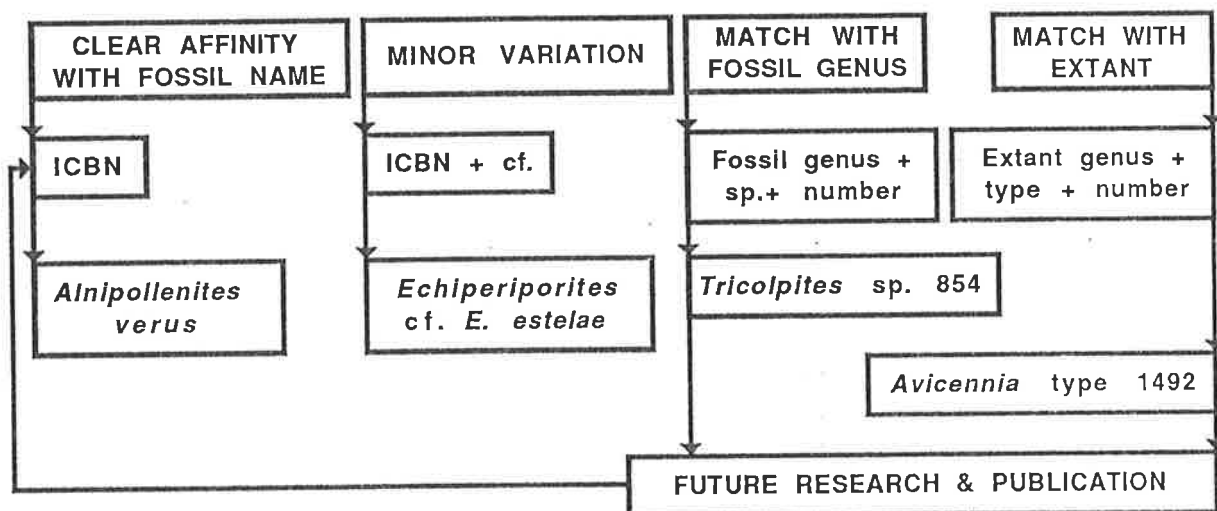


Figure 1-2. Nomenclature diagram for this study.

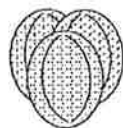
Secondly, if minor variation is observed between a valid taxon and a studied specimen, "cf." is included in the name, eg., *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968. Thirdly, specimens which appear to belong to a fossil genus but which cannot be assigned to a published species, are tentatively named after the fossil genus followed by "sp." and the SEM record

number of the specimen, eg. "*Tricolpites* sp. 854". Lastly, where a studied specimen is well matched with an extant genus (especially with SEM micrographs), the word "sp." with the SEM record number is used following the extant genus, eg. "*Avicennia* sp. 1492". Specimens which fall into categories two to four are described in the Systematic Descriptions (Appendix C).

The technical terms used in taxonomic descriptions have been kept to a minimum and follow the glossary in Kremp (1965).

Classification. The form classification referred to as suprageneric is widely used for pre-Tertiary palynology (Potonié, 1956, 1958, 1960b; Dettmann, 1963; Filatoff, 1975; Foster, 1975). It is a complicated system and does not convey much meaning as to phylogenetic relationships, and it may not be suitable for Tertiary palynology where there can be close relationships with extant species.

Truswell *et al.* (1985) arranged the botanical taxa of the Oligo-Miocene in the western Murray Basin of South Australia in alphabetical order within the broad phyletic suprageneric classification. As this study is concerned with mid-Tertiary taxa possibly related to extant species, the simple groupings including pteridophytes, gymnosperms and angiosperms are used in a similar way to those used by Truswell *et al.* (1985).



CHAPTER 4

APPLICATION OF NEW ZONES:

OLIGO-MIOCENE OFFSHORE

Thai offshore basins have been targeted for petroleum exploration for about two decades, in particular, two offshore regions, the Andaman Sea and the Gulf of Thailand. Extensive petroleum exploration has been centred on the Gulf of Thailand, where the well success rate has been high, but only non-commercial oil and gas shows have been found in the Andaman Sea. Five offshore sequences are studied here including Trang-1 Borehole, Mergui-1 Borehole, W9A1 Borehole (Andaman Sea); Platong-11 Borehole, and Erawan 12-28 Borehole (Gulf of Thailand).

4.1 Andaman Sea

4.1.1 Trang-1 Borehole (Union Oil)

The Trang-1 Borehole (Figures 1-1, 2-12, 4-1; Table 4-1) was operated under the Union Oil Company of Thailand concession. Selected samples were palynologically analysed by Robertson Research (Singapore) but poor results were obtained (Tidey *et al.*, 1976). In this study, ten out of eighteen samples from the Trang-1 Borehole are productive. Available samples in this study are mostly cuttings samples except at depth 3941.4 and 3942.1 m. where conventional core samples are obtained. The core sample at 3941.4 m. is barren of palynomorphs and the sample at 3942.1 m. yielded only rare palynomorphs. Only some pollen grains could be identified including *Piceapollenites alatus* Potonié 1931, *Tsugaepollenites igniculus* Potonié ex Potonié 1958, *Pinuspollenites* sp. 1436 and a poor preserved dinoflagellate. The palynomorph assemblage at 3942.1 m. is dominated by gymnosperm pollen and is comparable to assemblages from Nong Ya Plong and Li basins.

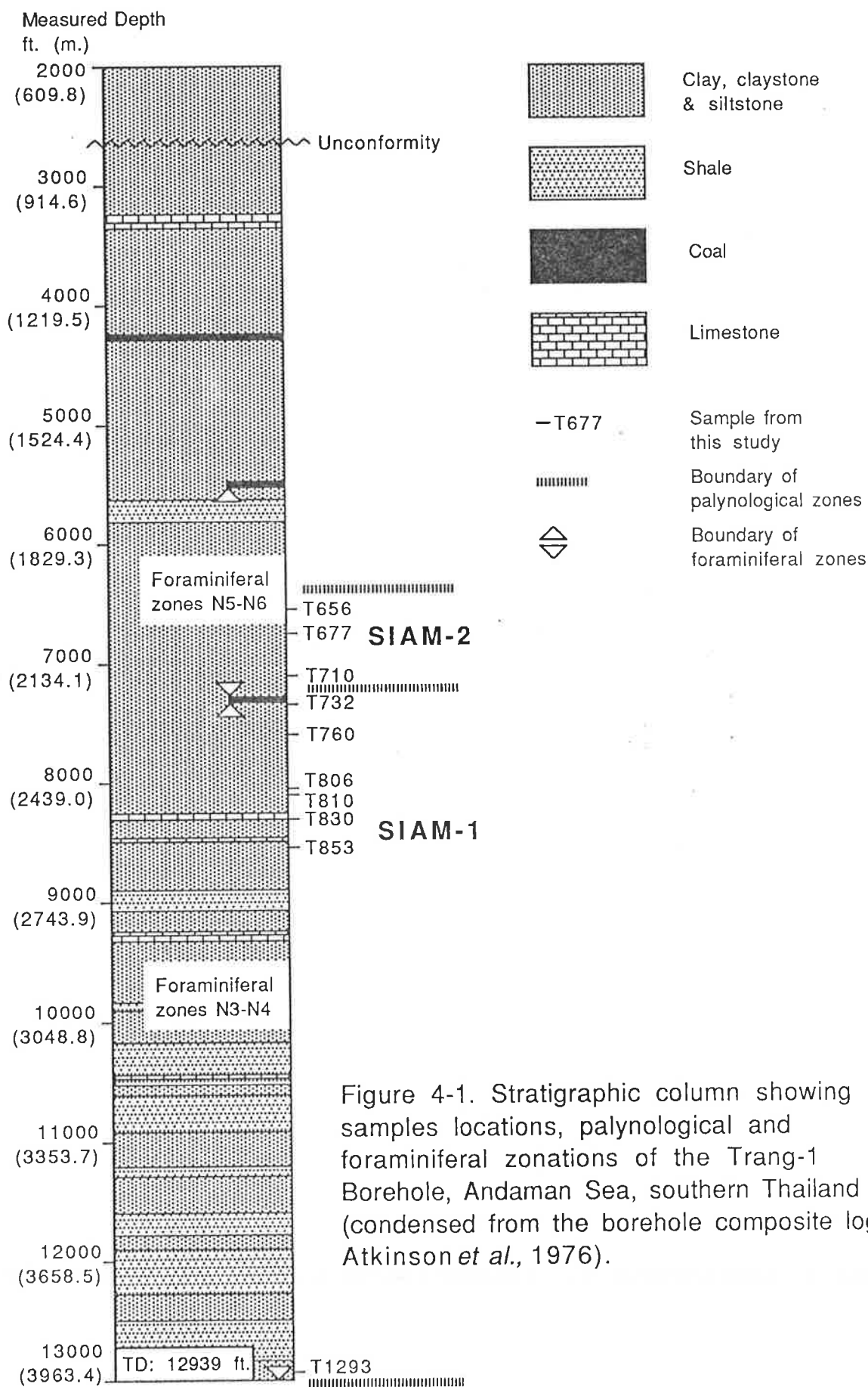


Figure 4-1. Stratigraphic column showing samples locations, palynological and foraminiferal zonations of the Trang-1 Borehole, Andaman Sea, southern Thailand (condensed from the borehole composite log by Atkinson *et al.*, 1976).

Table 4-1. Taxa range appearance from the Trang-1 Borehole, Andaman Sea, southern Thailand.

TAXA	ZONATION <<<<< <<<<< <<<<< SIAM-1 >>>>> >>>>> >>>>>							<<<<< SIAM-2 >>>>>			
	Depth (feet)	12930	8530	8300	8100	8060	7600	7320	7100	6770	6560
	Depth (metres)	3942.1	2600.6	2530.5	2469.5	2457.3	2317.1	2231.7	2164.6	2064.0	2000.0
ANGIOSPERMS											
Spinizonocolpites prominatus		rare	rare	common	rare	common	rare	common	common	rare	
Florschuetzia trilobata		common	common	rare	common	common	rare	rare		rare	
Momipites coryloides		rare	rare			common	common			common	rare
Caryapollenites simplex		rare				rare	rare				
Cupuliferoipollenites pusillus		rare				rare				rare	
Rhoipites cf. R. retiformis			rare					common		rare	rare
Rhoipites sp. 1267			rare	rare				common		rare	
Florschuetzia semilobata			rare			rare					
Alnipollenites verus			rare			rare	rare			rare	
Quercoidites sp. 777			rare						rare		
Aceripollis sp. 853				rare					rare		rare
Tiliaepollenites cf. T. indubitabilis				rare	rare	common	rare			rare	
Monoporopollenites gramineoides				rare		rare	rare				
Trivestibulopollenites betuloides					rare					rare	
Faguspollenites sp. 845						rare				rare	
Avicennia sp. 1492						rare	rare			rare	rare
Zonocostites ramonae						rare	rare	rare			
Radermachera sp. 1546						rare					
Florschuetzia levipoli							rare	rare	rare	rare	rare
Tricolpate sp. 854							rare	rare			
Tetracolporopollenites sapotoides								rare			rare
Ammania sp. 382								rare			
Echiperiporites cf. E. estelae								rare			
Margocolporites vanwijhei								rare			
Lagerstroemia sp. 325										rare	
Myricipites dubius										rare	rare
GYMNOSPERMS											
Pinuspollenites sp. 1436		rare	rare		rare	rare	rare	rare	rare	rare	rare
Tsugapollenites igniculus		rare					rare	common	rare	rare	rare
Piceapollenites alatus		rare	rare				rare			rare	
Dacrydiumpites florinii				rare	rare						
Podocarpidites ellipticus					rare				rare		
PTERIDOPHYTES											
Cyathidites minor		common	rare	rare	rare	common	common	common	common	rare	rare
Polypodiisporites alienus		rare	rare		rare	rare	rare	rare	rare	rare	rare
Polypodiaceoisporites spp.		rare		rare	rare	rare	rare	rare	rare		rare
Polypodiisporites usmensis		common	rare	rare	rare	rare	rare			rare	
Magnastriatites grandiosus		rare		rare	rare	rare	rare	rare	common		
Laevigatosporites ovatus				common	rare		rare	common	rare	common	common
Polypodiisporites pohangensis				rare							
OTHERS											
dinoflagellates		rare	common	common	rare	rare	rare	common	common	rare	common
Pediastrum sp.			rare				rare				

Remarks: Common ≥ 5 specimens, rare < 5 specimens.

The Trang-1 productive sequence (3941.2 to 2000.0 m.) can be divided into SIAM-1 Zone (3941.2 to 2231.7 m.) and SIAM-2 Zone (2164.6 to 2000.0 m.).

SIAM-1 Zone comprises common occurrences of *Florschuetzia trilobata* Germeraad *et al.* 1968, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Momipites coryloides* Wodehouse 1933, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Pinuspollenites* sp. 1436, *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971 and *Cyathidites minor* Couper 1953. Rare species are: *Caryapollenites simplex* Potonié 1960, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Alnipollenites verus* Potonié 1931, *Quercoidites* sp. 777, *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Trivestibulopollenites betuloides* Pflug *in* Thomson & Pflug 1953, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Tsugaepollenites igniculus* Potonié ex Potonié 1958, *Dacrydiumites florinii* Cookson & Pike ex Harris 1965 and *Podocarpidites ellipticus* Cookson ex Couper 1953. Dinoflagellates are common in this zone.

An unpublished report on the micropalaeontology and nannofossil analyses of the Union Oil Company of Thailand Trang No. 1 Well (Tidey *et al.*, 1976) shows that samples between depth 3942.4-2225.6 m. are assigned with planktonic foraminiferal zones N3-N4 (Blow, 1969). Some significant foraminiferal ranges occurring within these zones are *Globirgerina gortanii gortanii*, *Globirgerina* cf. *G. gortanii gortanii*, *Globorotalia kugleri* and *Globigerinita unicava unicava*.

Thus the palynological assemblages (3941.2 to 2231.7 m.; SIAM-1 Zone) are correlated with planktonic foraminiferal zones N3-N4 of Late Oligocene to early Early Miocene age (Tidey *et al.*, 1976).

SIAM-2 Zone of the upper sequence comprises common species of *Florschuetzia trilobata* Germeraad *et al.* 1968, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Momipites coryloides* Wodehouse 1933, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Laevigatosporites ovatus* Wilson & Webster 1946. Rare species are: *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Alnipollenites verus* Potonié 1931, *Quercoidites* sp. 777, *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Ammania* sp. 382, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Lagerstroemia* sp. 325, *Myricipites*

dubius Wodehouse 1933, and *Podocarpidites ellipticus* Cookson ex Couper 1953. Dinoflagellates are also common in this zone.

The report on the micropalaeontology and nannofossil analyses of Trang No. 1 Well (Tidey *et al.*, 1976) shows that samples between depth 2225.6-1670.7 m. are assigned with planktonic foraminiferal zones N5-N6 (Blow, 1969). Some significant foraminiferal ranges occurring within these zones are: *Globorotalia siakensis*, *Globigerinoides subquadratus*, *Globigerinita unicava unicava*, *Globirgerina ouachitaensis ciperiensis forma atypica* and *Globorotalia peripheroronda*.

Thus, the palynological assemblages (2164.6 to 2000.0 m.; SIAM-2 Zone) are correlated with planktonic foraminiferal zones N5-N6 of middle Early Miocene age (Tidey *et al.*, 1976).

The whole productive sequence of the Trang-1 (3941.2 to 2000.0 m.) suggests an age ranging from Late Oligocene to middle Early Miocene.

4.1.2 Mergui-1 Borehole (Union Oil)

The Mergui-1 Borehole (Figures 1-1, 2-12, 4-2; Table 4-2) was also operated under the Union Oil Company of Thailand concession. Nineteen processed samples in this study were ditch cuttings samples of which nine were productive. The assemblages can be divided into SIAM-1 Zone (3201.2 to 2966.5 m.) and SIAM-2 Zone (2414.6 to 1646.3 m.).

SIAM-1 Zone of the lower sequence comprises common species of *Florschuetzia trilobata* Germeraad *et al.* 1968, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Alnipollenites verus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Pinuspollenites* sp. 1436, *Piceapollenites alatus* Potonié 1931 and *Laevigatosporites ovatus* Wilson & Webster 1946. Rare species are: *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Ilexpollenites iliacus* Potonié 1960, *Quercoidites* sp. 777, *Trivestibulopollenites betuloides* Pflug *in* Thomson & Pflug 1953, *Caryapollenites simplex* Potonié 1960, *Tetracolporopollenites sapotoides* Pflug & Thomson *in* Thomson & Pflug 1953, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Podocarpidites ellipticus* Cookson ex Couper 1953,

Dacrydiumites florinii Cookson & Pike ex Harris 1965 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958. Dinoflagellates occur commonly in the lower sequence.

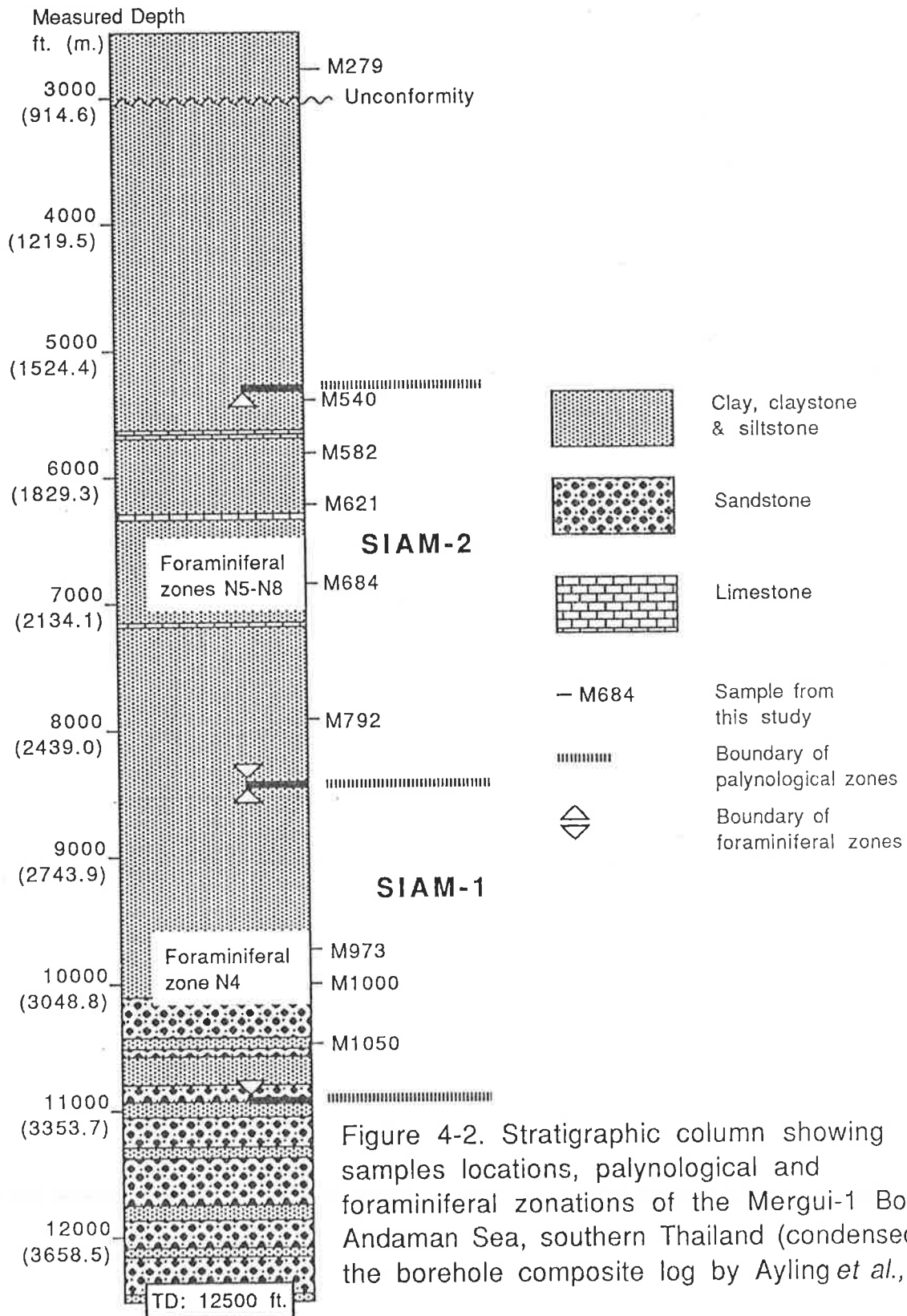


Figure 4-2. Stratigraphic column showing samples locations, palynological and foraminiferal zonation of the Mergui-1 Borehole, Andaman Sea, southern Thailand (condensed from the borehole composite log by Ayling *et al.*, 1976)

Table 4-2. Taxa range appearance from the Mergui-1 Borehole, Andaman Sea, southern Thailand.

ZONATION	<<<<< SIAM-1 >>>>>			<<<<< <<<<< SIAM-2 >>>>>					>>>>>
Depth (feet)	10500	10000	9730	7920	6840	6210	5820	5400	2790
Depth (metres)	3201.2	3048.8	2966.5	2414.6	2085.4	1893.3	1774.4	1646.3	850.6

TAXA

ANGIOSPERMS

Quercoidites sp. 777	rare	rare							rare
Florschuetzia trilobata	rare	rare	common	common	common	rare	rare	common	
Tilliaepollenites cf. T. indubitabilis	rare		rare	common	rare	rare	rare	rare	
Spinizonocolpites prominatus	rare	rare	rare	rare	rare			rare	
Alnipollenites verus	rare	common	rare					common	rare
Illexpollenites iliacus	rare		rare		rare				
Trivestibulopollenites betuloides	rare	rare							
Tetracolporopollenites sapotoides		rare	rare	rare	rare	rare	rare		
Momipites coryloides		common		rare	rare	common	common		
Tricolporites cf. T. valvatus		rare		rare	rare	rare	rare		
Caryapollenites simplex		rare			rare	rare	rare		
Tricolporate sp. 1263		rare						rare	
Avicennia sp. 1492			rare	rare	rare	rare	rare	common	rare
Zonocostites ramonae			rare	rare	rare			common	common
Florschuetzia levipoli			rare	rare	rare			rare	rare
Florschuetzia semilobata			rare	common	common			rare	
Excoecaria sp. 1404				rare	rare	rare			
Myricipites dubius				rare		rare			
Rhoipites sp. 847				rare					
Aceripollis spp.				rare	rare				
Margocolporites vanwijhei				rare					
Ammania sp. 382					rare			rare	rare
Triorites sp. 1373					rare				rare
Pandaniidites texus					rare				
Lagerstroemia sp. 325					rare				
Rhoipites cf. R. retiformis					rare				
Cupuliferoipollenites pusillus					rare				
Florschuetzia meridionalis								common	rare
Faguspollenites sp. 845								rare	rare

GYMNOSPERMS

Podocarpidites ellipticus	rare	rare			rare	common	rare	rare	rare
Pinuspollenites sp. 1436	rare	common		rare	rare	common	common		
Dacrydiumites florinii		rare			rare		rare	rare	rare
Piceapollenites alatus		common			rare		rare		
Tsugapollenites igniculus			rare		rare				rare

PTERIDOPHYTES

Laevigatosporites ovatus	common	common	rare	rare	common	common	rare	common	common
Cyathidites minor	rare	rare	rare	rare	rare	rare	rare	common	common
Polypodiisporites alieneus	rare	rare	rare	rare	rare	rare	rare	rare	rare
Polypodiisporites usmensis	rare			rare	rare	rare	rare	rare	rare
Magnastriatites grandiosus		rare	rare					rare	
Polypodiaceoisporites spp.								rare	rare

OTHERS

dinoflagellates	common	common	common	common	common	rare		common	common	rare
Pediastrum					rare					

Remarks: Common ≥ 5 specimens, rare < 5 specimens.

The unpublished report on micropalaeontology, calcareous nannoplankton and stratigraphy of the Union Oil Company of Thailand Mergui-1 Well (Troelstra *et al.*, 1976) shows that samples between depth 3321.6-2564.0 m. are assigned with planktonic foraminiferal zone N4 (Blow, 1969). Some significant foraminiferal ranges occurring within these zones are *Globorotalia siakensis* and *Globigerinoides subquadratus*.

Thus the palynological assemblages (3201.2-2966.5 m.; SIAM-1 Zone) are correlated with planktonic foraminiferal zone N4 of early Early Miocene age (Troelstra *et al.*, 1976).

SIAM-2 Zone of the upper sequence comprises common species of *Florschuetzia trilobata* Germeraad *et al.* 1968, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Pinuspollenites* sp. 1436, *Podocarpidites ellipticus* Cookson ex Couper 1953, *Laevigatosporites ovatus* Wilson & Webster 1946 and *Cyathidites minor* Couper 1953. Rare species include: *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Ilexpollenites iliacus* Potonié 1960, *Alnipollenites verus* Potonié 1931, *Tetracolporopollenites sapotoides* Pflug & Thomson *in* Thomson & Pflug 1953, *Caryapollenites simplex* Potonié 1960, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Ammania* sp. 382, *Excoecaria* sp. 1404, *Lagerstroemia* sp. 325, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Florschuetzia meridionalis* Germeraad *et al.* 1968, *Pandaniidites texus* Elsik 1968, *Faguspollenites* sp. 845, *Piceapollenites alatus* Potonié 1931 and *Dacrydiumites florinii* Cookson & Pike ex Harris 1965. Dinoflagellates also occur commonly in the upper sequence.

The report of the Union Oil Company of Thailand Mergui-1 Well (Troelstra *et al.*, 1976) shows that samples between depth 2564.0-1609.8 m. are assigned with planktonic foraminiferal zones N5-N8 (Blow, 1969). Some significant foraminiferal ranges occurring within these zones are: *Globorotalia siakensis*, *Globigerinoides subquadratus*, *Globigerinita dissimilis dissimilis*, *Globigerinoides sicanus*, *Globorotalia birnageae*, *Globorotalia peripheroronda* and *Globorotalia peripheroacuta*.

Thus the palynological assemblages (2414.6-1646.3 m.; SIAM-2 Zone) are correlated with planktonic foraminiferal zones N5-N8 of Early Miocene age (Troelstra *et al.*, 1976).

The assemblage at 850.6 m. is composed of *Quercoidites* sp. 777, *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Ammania* sp. 381, *Faguspollenites* sp.

845, *Florschuetzia meridionalis* Germeraad *et al.* 1968, *Podocarpidites ellipticus* Cookson ex Couper 1953, *Dacrydiumites florinii* Cookson & Pike ex Harris 1965 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958. This sample is located above Middle Miocene unconformity (Ayling *et al.*, 1976) and the appearance of *Florschuetzia meridionalis* Germeraad *et al.* 1968, may suggest a Late Miocene to Pliocene age for this assemblage.

4.1.3 W9A1 Borehole (Esso)

The Esso Exploration & Production Thailand Inc. explored in the Andaman Sea on block W9 during 1976. There were some conventional cores available at the Department of Mineral Resources (DMR) two years after the concession had been relinquished. Ten samples from four wells (W9A1, W9B1, W9C1 and W9E1) were collected but unfortunately, only one sample (W9A1 at 1389.6 m.) is productive. The rest of the samples (W9B1 at 2516.8, 2518.3 m.; W9C1 at 3061.6, 3064.0, 3069.5 m.; W9E1 at 3886.6, 3888.7, 3890.2 m.) did not respond to oxidation during preparation. Three kerogen slides (W9A1 at 1389.6 m.; W9C1 at 3061.6 m.; W9E1 at 3888.7 m.) were made for fluorescence microscopy. The productive sample (W9A1 at 1389.6 m.) shows bright yellowish fluorescence, and both unproductive samples (W9C1 at 3061.6 m.; W9E1 at 3888.7 m.) have nearly dull to dull (non fluorescing). It is suggested that the unproductive organic samples are over mature with respect to hydrocarbon generation, and this may explain the absence of recognizable palynomorphs

Although only one sample is productive, it yields an important palynological assemblage which belongs to SIAM-2. Four *Florschuetzia* pollen types have been identified. The assemblage of W9A1 at 1389.6 m. (Figures 1-1, 2-12; Table 4-3) is composed commonly of *Zonocostites ramonae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Florschuetzia trilobata* Germeraad *et al.* 1968, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Florschuetzia meridionalis* Germeraad *et al.* 1968, *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971 and *Laevigatosporites ovatus* Wilson & Webster 1946.

Rare species include: *Ammania* sp. 382, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Cephalomappa* sp. 590, *Lagerstroemia* sp. 325, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Faguspollenites* sp. 845, *Pandaniidites texus* Elsik 1968, *Alnipollenites verus*

Potonié 1931, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958. Dinoflagellates also occur commonly in the assemblage. The assemblage can be correlated with the uppermost SIAM-2 or post SIAM-2 (late Early to early Middle Miocene) and corresponds reasonably well with the Esso biostratigraphic zonation as late Early Miocene.

Table 4-3. Taxa percentage and range appearance from the Esso W9A1 Borehole, at 1389.6 m. depth, Andaman Sea, southern Thailand.

ZONATION	SIAM-2
TAXA	
ANGIOSPERMS	
Zonocostites ramonae	32.5
Avicennia sp. 1492	8.0
Florschuetzia trilobata	7.5
Florschuetzia levipoli	5.5
Tiliaepollenites cf. T. indubitabilis	4.0
Spinizonocolpites echinatus	3.5
Florschuetzia meridionalis	3.5
Tricolpites sp. 854	3.0
Ammania sp. 382	2.0
Florschuetzia semilobata	1.5
Aceripollis spp.	1.5
Tricolporopollenites sp. 810	1.5
Tetracolporopollenites sapotoides	1.5
Cephalomappa sp. 590	1.5
Lagerstroemia sp. 325	1.5
Cupuliferoipollenites pusillus	1.0
Faguspollenites sp. 845	1.0
Pandaniidites texus	1.0
Alnipollenites verus	1.0
Echiperiporites cf. E. estelae	0.5
Margocolporites vanwijhei	R
GYMNOSPERMS	
Tsugapollenites igniculus	0.5
PTERIDOPHYTES	
Polypodiisporites usmensis	6.0
Laevigatosporites ovatus	6.0
Cyathidites minor	2.5
Polypodiisporites alienus	1.0
Polypodiaceoisporites spp.	0.5
Polypodiisporites pohangensis	0.5
ANGIOSPERMS	83.0
GYMNOSPERMS	0.5
PTERIDOPHYTES	16.5
TOTAL	100.0
dinoflagellates	* *

Remarks: R = rare, ** = common. See more details about counting in Chapter 1.

4.2 The Gulf of Thailand

The Gulf of Thailand has been actively explored and exploited for petroleum resources for two decades. Natural gas is the main reserve which has been discovered in the Gulf and there are estimated total reserves of 7 Tcf. (Achalabhuti, 1981a). In the Gulf recently, oil reserves of 16 million barrels have been discovered from the 1 Nang Nuan Borehole, Chumporn basin (*Oil and Gas J.*, 1987, V. 85, No. 52, p. 21). There are four actively producing fields including Baanpot, Erawan, Platong and Satun in the Pattani Basin (the Gulf of Thailand).

4.2.1 Platong-11 Borehole (Union Oil)

All available samples of Platong-11 Borehole (Figure 1-1) from the Union Oil Company Of Thailand were cuttings. The section below the 24.45 cm. casing at 1640* m. was drilled with oil based mud. Unfortunately, all of the samples below the casing are not productive because of either unsuitable sandy or oxidized (mottling) lithology or an increasing degree of carbonization. Barren samples were not sensitive to oxidation and alkali reaction and seem to have been subject to high temperature. Only six out of twenty samples from the Platong-11 Borehole are productive (Figures 1-1, 2-2, 4-3, Table 4-4).

The assemblages of the productive sequence of Platong-11 between 1518.3 and 1280.5 m. are correlated with SIAM-2 Zone. Common species are: *Florschuetzia levipoli* Germeraad *et al.* 1968, *Zonocostites ramonae* Germeraad *et al.* 1968, *Excoecaria* sp. 1404, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Laevigatosporites ovatus* Wilson & Webster 1946, *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971 and *Cyathidites minor* Couper 1953. Rare species include: *Monoporopollenites gramineoides* Meyer 1956, *Quercoidites* sp. 777, *Avicennia* sp. 1492 and *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953.

The assemblages of post SIAM-2 Zone commonly contain *Florschuetzia levipoli* Germeraad *et al.* 1968, *Excoecaria* sp. 1404, *Zonocostites ramonae* Germeraad *et al.* 1968, *Xylocarpus* sp. 1526, *Cephalomappa* sp. 590, *Laevigatosporites ovatus* Wilson & Webster

* Depths mentioned in Section 4.2 are measured depths unless otherwise indicated.

1946, *Cyathidites minor* Couper 1953 and *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971.

The Platong-11 sequence is correlated with upper SIAM-2 Zone to post SIAM-2 Zone of late Early Miocene to Middle Miocene age.

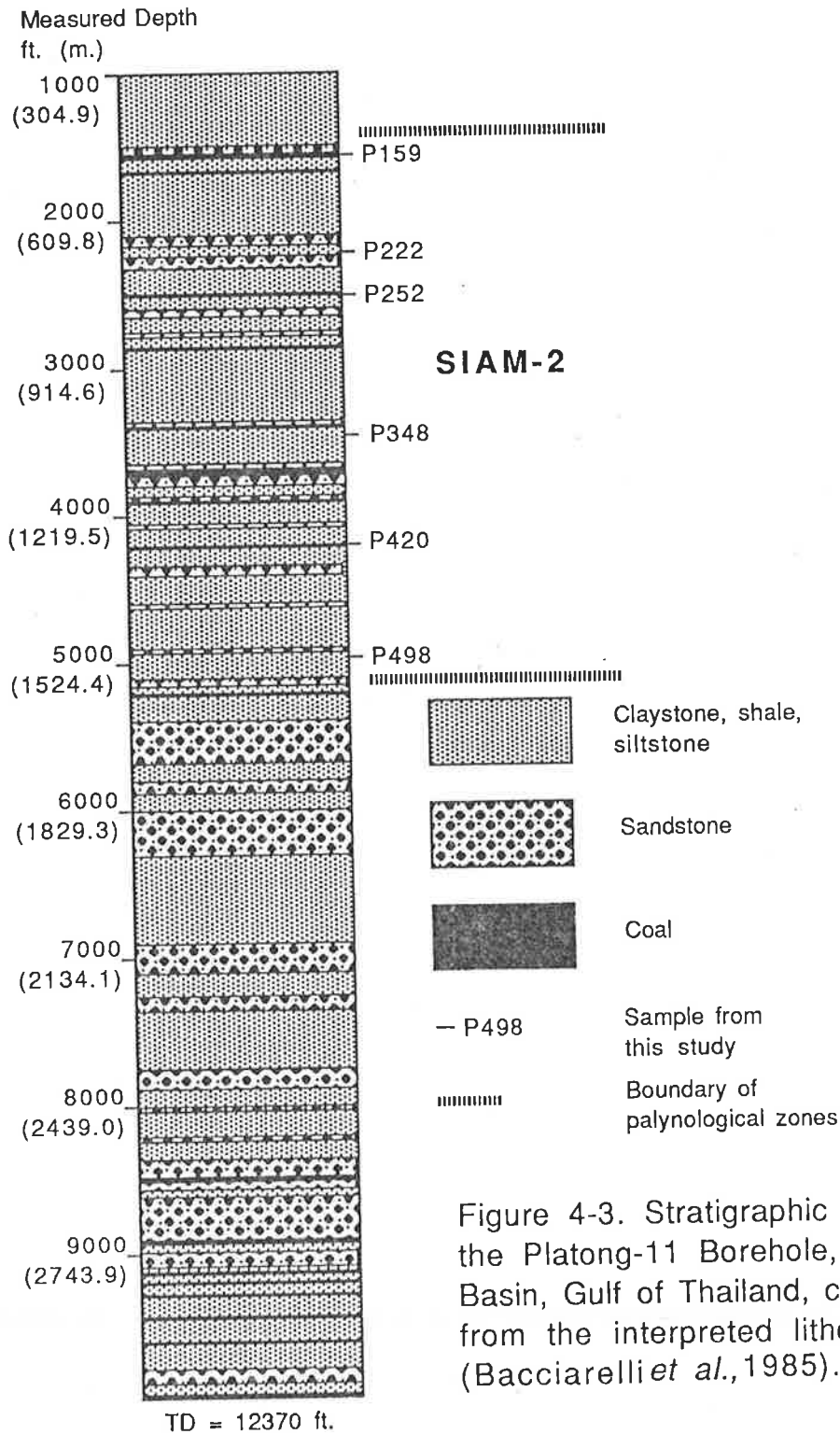


Figure 4-3. Stratigraphic column of the Platong-11 Borehole, Pattani Basin, Gulf of Thailand, condensed from the interpreted lithological log (Bacciarelli *et al.*, 1985).

Table 4-4. Taxa range appearance from the Platong-11 Borehole, Pattani Basin, the Gulf of Thailand

	ZONATION		SIAM-2 >>>>>>				
	Measured depth (feet)		3480	2520	2220	1590	
	Measured depth (metres)		1061.0	768.3	676.8	484.8	
TAXA							
ANGIOSPERMS							
Florschuetzia levipoli		common	common	rare	rare	rare	rare
Excoecaria sp. 1404		rare	rare	rare	rare	common	rare
Zonocostites ramonae		rare	rare	rare		rare	common
Echiperiporites cf. E. estelae		rare	rare			rare	rare
Monoporopollenites gramineoides		rare		rare			rare
Quercoidites sp. 777		rare					
Ilexpollenites iliacus			rare			rare	rare
Avicennia sp. 1492			rare	rare		rare	
Tetracolporopollenites sapotoides			rare		rare	rare	
Bursera sp. 1427			rare				
Xylocarpus sp. 1526				rare	rare	common	rare
Cephalomappa sp. 590				rare		rare	rare
Florschuetzia meridionalis				rare			rare
Aceripollis spp.				rare			
Florschuetzia semilobata				rare			
Spinizonocolpites prominatus					rare		
Ammania sp. 382					rare		
Triorites sp. 788							rare
PTERIDOPHYTES							
Laevigatosporites ovatus		common	common	rare	rare	rare	common
Cyathidites minor		common	rare	rare	rare		rare
Polypodiisporites usmensis		rare		rare	rare		rare
Polypodiisporites alieneus		common	rare				
Magnastriatites grandiosus			rare				
OTHERS							
Pediastrum sp.		rare		rare			
Remarks: Common \geq 5 specimens, rare < 5 specimens.							

4.2.2 Erawan 12-28 Borehole (Union Oil)

Palynological processing of samples from Erawan 12-28 Borehole (Figures 1-1, 2-2, 4-4; Table 4-5) yields similar results as Platong-11 Borehole and is productive only in the upper sequence. Only four out of twenty samples are productive. The lower sequence is unproductive possibly because it is either a sandy, oxidized lithology, or a high degree of carbonization as in Platong-11. The Erawan 12-28 productive sequence (1408.5 to 823.2 m.) can be divided into two zones including SIAM-1 Zone (1408.5 m.) and SIAM-2 Zone (1280.5-823.2 m.).

The lowermost sample in SIAM-1 Zone yields an assemblage dominated by species preferring temperate environments. Common species include: *Momipites coryloides* Wodehouse 1933, *Caryapollenites simplex* Potonié 1960, *Alnipollenites verus* Potonié 1931, *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953, *Quercoidites* sp. 777, *Quercoidites* sp. 777, *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953, *Pinuspollenites* sp. 1436 and *Piceapollenites alatus* Potonié 1931. The assemblage is similar to Sin Pun assemblages which can be classed as upper SIAM-1 Zone of early Early Miocene. Although palynofloral assemblages from this Borehole are cuttings the sample (1408.5 m.) yields a good example of a uncontaminated assemblage containing only non-marine palynofloras even though mangrove palynofloras occur in the upper sequence (1280.5-823.2 m.).

SIAM-2 Zone of the upper sequence is dominated by species preferring tropical environments and minor proportion of species preferring temperate environments. Common species in the assemblages are: *Excoecaria* sp. 1404, *Xylocarpus* sp. 1526, *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953, *Zonocostites ramonae* Germeraad *et al.* 1968, *Myrtaceidites mesonesus* Cookson & Pike 1954, *Cephalomappa* sp. 590, *Laevigatosporites ovatus* Wilson & Webster 1946, *Cyathidites minor* Couper 1953 and *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971. Rare species include: *Ammania* sp. 382, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Dipterocarpus* sp. 780, *Florschuetzia trilobata* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Dicolpopollis kalewensis* Potonié ex Potonié 1966, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 and *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953.

It can be concluded that the productive sequence of the Erawan 12-28 Borehole ranges in age from middle to late Early Miocene.

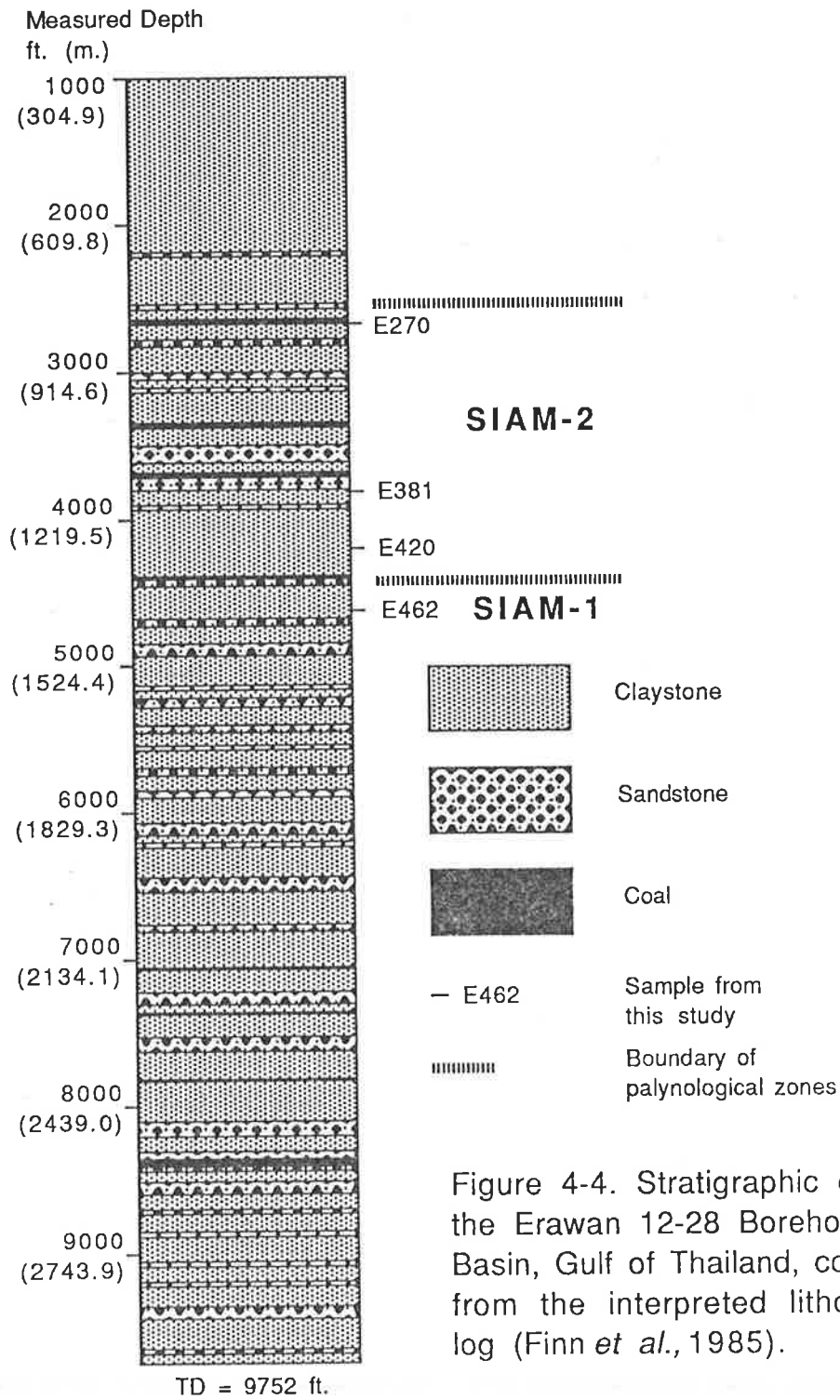


Figure 4-4. Stratigraphic column of the Erawan 12-28 Borehole, Pattani Basin, Gulf of Thailand, condensed from the interpreted lithological log (Finn *et al.*, 1985).

Table 4-5. Taxa range appearance from the Erawan 12-28 Borehole, Pattani Basin.

	ZONATION	SIAM-1	SIAM-2		
Measured depth (feet)	4620	4200	3810	2700	
Measured depth (metres)	1408.5	1280.5	1161.6	823.2	
TAXA					
ANGIOSPERMS					
Momipites coryloides		common			
Caryapollenites simplex		common			
Alnipollenites verus		rare			
Trivestibulopollenites betuloides		rare			
Quercoidites sp. 777		rare	rare		
Cupuliferoipollenites pusillus		rare			
Polyatriopollenites stellatus		rare			
Excoecaria sp. 1404			common	common	rare
Tetracolporopollenites sapotoides			rare	rare	common
Myrtaceidites mesonesus			rare	rare	rare
Zonocostites ramonae			rare	rare	common
Ilexpollenites iliacus			rare	rare	rare
Xylocarpus sp. 1526			rare	rare	common
Ammania sp. 382			rare		rare
Monoporopollenites gramineoides			rare		rare
Aceripollis spp.			rare		
Florschuetzia levipoli			rare		
Dipterocarpus sp. 780			rare		
Florschuetzia trilobata			rare		
Avicennia sp. 1492			rare	rare	
Cephalomappa sp. 590				rare	common
Dicolpopollis kalewensis				rare	rare
Tiliaepollenites cf. T. indubitabilis				rare	
Echiperiporites cf. E. estelae					rare
GYMNOSPERMS					
Pinuspollenites sp. 1436		common			
Piceapollenites alatus		rare			
Inaperturopollenites dubius				rare	
PTERIDOPHYTES					
Laevigatosporites ovatus		common	common	common	rare
Polyodiisporites usmensis		rare	rare	common	rare
Cyathidites minor		rare	rare	rare	rare
Rugulatisporites quintus		rare			
Baculatisporites primarius		rare			
OTHERS					
Pediastrum sp.				rare	
Remarks: Common \geq 5 specimens, rare < 5 specimens.					

4.3 Palynostratigraphic Correlation: Offshore Basins

Palynological correlation between offshore productive sequences (Figure 4-5) indicates an age range from Late Oligocene to Middle Miocene. The *Florschuetzia levipoli* Germeraad *et al.* 1968 occurs commonly both in the Andaman Sea and in the Gulf of Thailand, and is useful for correlation. Most of the assemblages fall within SIAM-2 Zone. The oldest productive assemblage is from the Trang-1 Borehole and the youngest is from the Platong-11 Borehole. As mentioned above, samples from the Gulf of Thailand are usually productive in the upper sequences thus a detailed correlation of petroleum (gas) bearing intervals (lower sequences) is far to achieve. However, most of gas bearing intervals are likely to occur below lower SIAM-2 Zone.

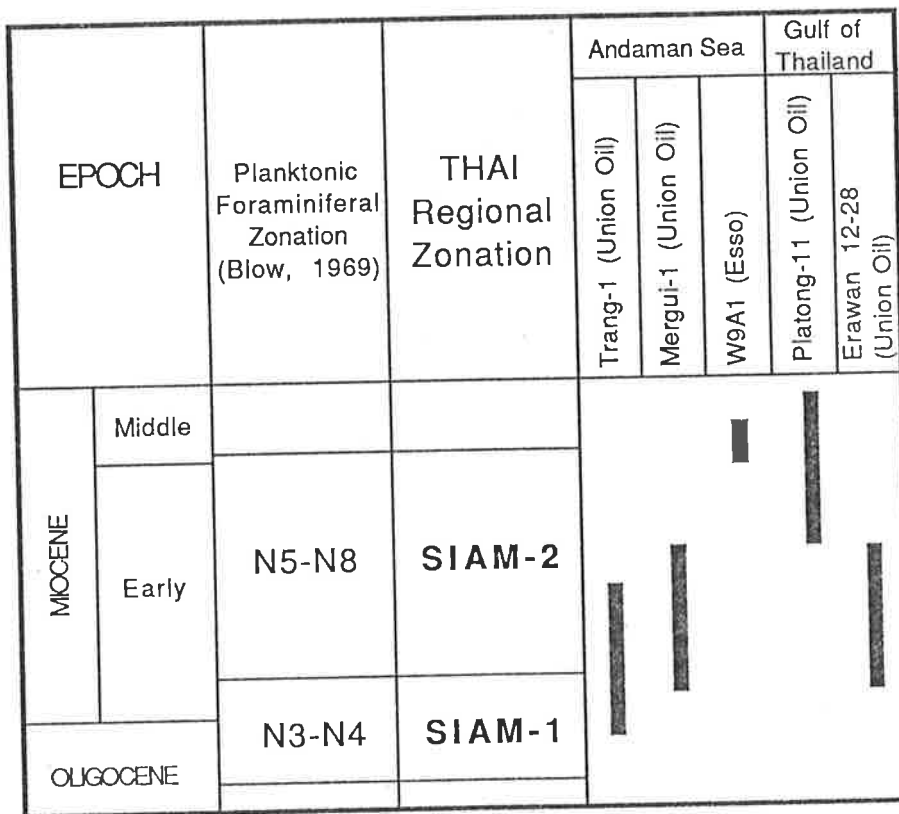
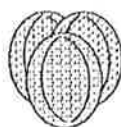


Figure 4-5. Palynological and foraminiferal correlation of the offshore Oligo-Miocene sequences from the Andaman Sea and the Gulf of Thailand.



CHAPTER 5

APPLICATION OF NEW ZONES:

OLIGOCENE ONSHORE

Two onshore basins yield Oligocene palynological assemblages including Li (northern Thailand) and Nong Ya Plong (central Thailand) basins.

5.1 Li Basin

Li is a small basin in northern Thailand (Figure 1-1) located at approximately Latitude 17° 48' and Longitude 99° 01'. Coal reserves of the Basin are being actively explored and exploited. The Li Basin may be divided into 5 sub-basins: Ban Pa Kha, Ban Pu, Huai Pong Khong, Ban Mae Long and Ban Na Sai. The Ban Pu sub-basin (operated by the Ban Pu Mines Co. Ltd.) was sampled for this palynological study.

Sixteen samples have been studied palynologically. Twelve samples are from exploration borehole BP 120. Since samples at depths between 6.5 and 27.0 meters (coal seam) were unavailable, four samples of coal seam from the mining pits have been substituted. Samples from the middle sequence of coal, carbonaceous clay and shale are generally prolific producers of pollen and spores, but samples from the upper and lower sequence are much less productive, probably because of the increasing coarseness of the deposits.

The assemblages of Li sequence (Table 5-1, Figure 5-1) are dominated by *Quercoidites* sp. 777 and gymnosperm pollen. Commonly occurring species include: *Quercoidites* sp. 777, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Faguspollenites* sp. 845, *Monoporopollenites gramineoides* Meyer 1956, *Alnipollenites verus* Potonié 1931, *Ilexpollenites iliacus* Potonié 1960, *Momipites coryloides* Wodehouse 1933, *Pinuspollenites* sp. 1436, *Tsugaepollenites igniculus* Potonié ex Potonié 1958, *Piceapollenites alatus* Potonié 1931, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953,

Polypodiisporites alienus Potonié emend. Khan & Martin 1971 and *Laevigatosporites ovatus* Wilson & Webster 1946.

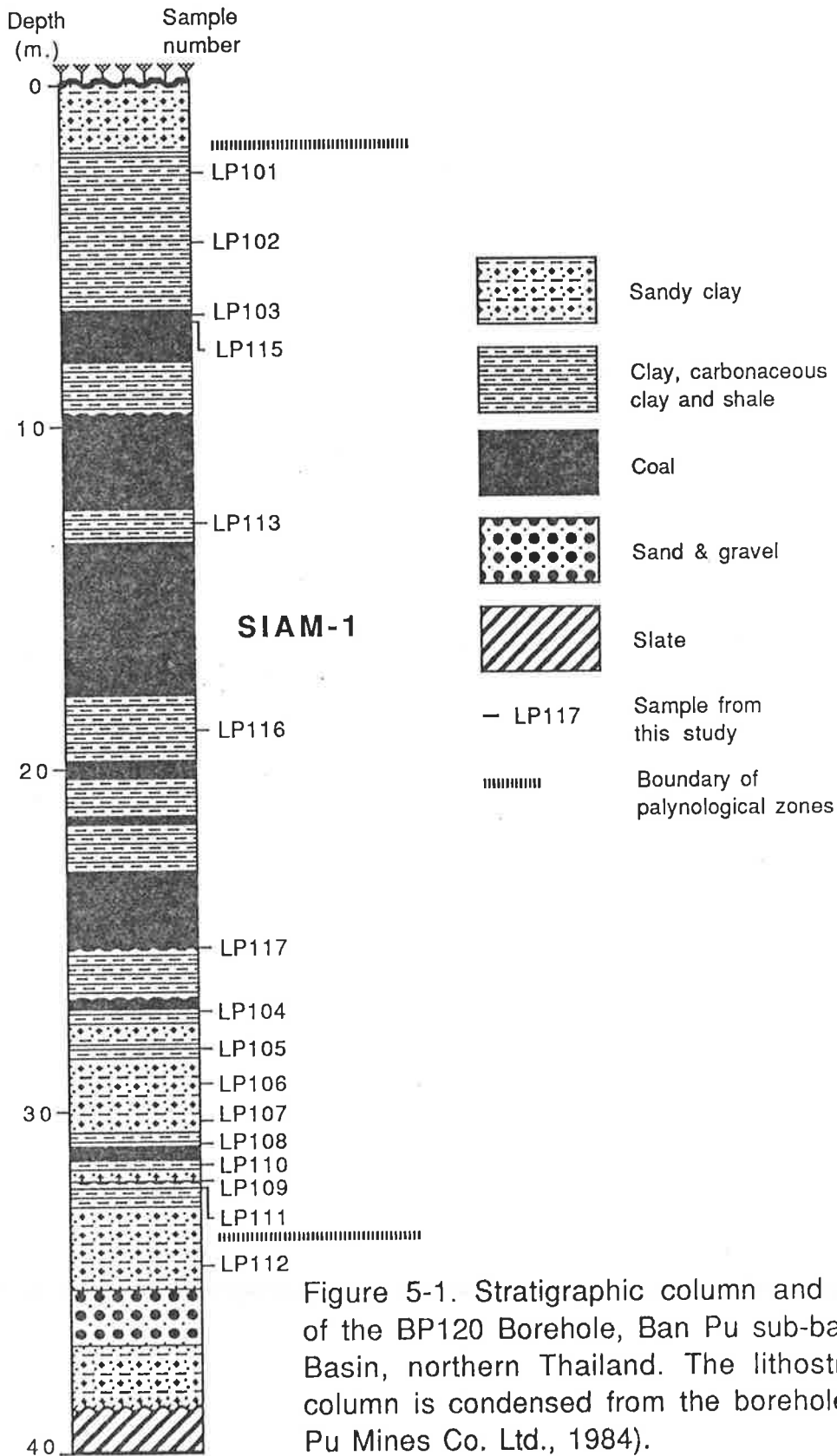


Figure 5-1. Stratigraphic column and zonation of the BP120 Borehole, Ban Pu sub-basin, Li Basin, northern Thailand. The lithostratigraphic column is condensed from the borehole log (Ban Pu Mines Co. Ltd., 1984).

Table 5-1. Taxa appearance in relative percentages from the BP 120 Borehole and mining pits, Ban Pu mine, Li Basin, northern Thailand.

ZONATION	SIAM-1															
Sample No.	LP112	LP111	LP109	LP110	LP108	LP107	LP106	LP105	LP104	LP117	LP116	LP113	LP115	LP103	LP102	LP101
Depth(metres)	34.5	32.2	31.9	31.5	30.9	30.3	29.1	28.1	27.1from mining pits.....			6.7	4.6	2.6	
TAXA																
ANGIOSPERMS																
Quercoidites sp. 777	25.5	69.0	28.5	40.0	32.5	25.5	12.5	24.5	38.5	41.5	3.5	21.5	30.0	8.0	27.0	26.0
Cupuliferoipollenites pusillus	4.0	R	12.5	2.0	9.0	6.5	R	3.5	R	R	R	2.5	2.5	0.5	30.5	1.5
Faguspollenites sp. 845	1.5	11.5	5.5	3.0	8.5	15.5	1.5	21.0	1.5	2.5	2.0	4.0	10.5	4.5	22.5	10.5
Monoporopollenites gramineoides	1.0	1.5	1.5			0.5	R		R	4.5			1.0	2.5		0.5
Alnipollenites verus	0.5	R	R	1.0	7.5	1.0	3.5	R	0.5	0.5	R	9.5	6.0	1.0	2.0	1.5
Ilexpollenites iliacus	0.5			1.0	1.0	0.5		3.5	0.5	11.5	3.5	0.5	1.0		R	1.0
Tricolporites cf. T. valvatus	0.5												1.0	0.5		
Periporopollenites stigmosus	R					R	R	R				0.5	0.5	1.0	1.0	23.5
Momipites coryloides		3.5	2.0	1.0	3.5	13.5	R	16.5	1.0	0.5		1.5	0.5	5.0	1.5	4.0
Rhoipites sp. 1263		1.0	6.0	1.0	1.0	2.0			0.5					1.0		
Rhoipites sp. 847		0.5	R	0.5	0.5	1.0	0.5	R	R		1.5	R	1.5	3.5	1.5	
Rhoipites cf. R. retiformis		R	9.5	1.0	2.0	1.5		0.5		6.5	R	1.0	2.0	23.5	3.0	5.5
Tetracolporopollenites sapotoides		R														
Florschuetzia sp. 647			0.5		0.5											
Rhoipites sp. 1207			R					0.5							0.5	
Caryapollenites simplex						1.0	R	R	R			R		1.5		
Tricolpites sp. 854						R		1.0								
Aceripollis sp. 853						R	R		R			0.5	0.5			
Tricolpites sp. 258							0.5					0.5			1.0	9.5
Polyatriopollenites stellatus							R									
Psilatricolporites operculatus																1.5
Salixipollenites cf. S. discoloripites										R						
GYMNOSPERMS																
Pinuspollenites sp. 1436	17.5	3.0	R	1.0	1.0	2.5	1.5	2.0	1.0	0.5	R	2.0	4.0	0.5	0.5	3.0
Tsugapollenites igniculus	9.0	1.0	0.5	1.5	2.0	1.0	2.0	4.5	6.5	3.5		0.5	1.5	1.0		0.5
Piceapollenites alatus	1.5	R	R	2.5	1.5	1.5	R	2.5	1.5	1.5	R	1.0	1.0	R		2.0
Podocarpidites ellipticus	R				R			R								
Inaperturopollenites dubius		7.5	8.0	38.5	22.0	17.5	75.0	16.0	43.0	9.5	79.5	9.0	2.0	37.5	3.0	1.0
PTERIDOPHYTES																
Polypodiisporites alienus	21.5	R	0.5	0.5	1.0	0.5	0.5		0.5	2.0			9.5	2.0		1.5
Laevigatosporites ovatus	13.0	0.5	21.0	5.5	4.0	7.5	2.5	4.0	4.0	11.0	8.0	45.0	14.0	4.5	5.0	6.0
Foveotriletes magaritae	1.5					0.5					R		2.0			
Polypodiisporites pohangensis	1.0	0.5	R				R		0.5	0.5	0.5		2.0	R		1.0
Retitriletes douglasii	1.0	R			R				R				1.0			
Polypodiaceoisporites spp.	0.5		1.0		1.0		R		R		1.0		1.0			
Magnastriatites grandiosus		0.5									1.0		1.0			
Cyathidites minor			3.0		1.5	R			0.5		0.5	0.5			0.5	
Undulatisporites unduliradius						0.5				3.0						
Baculatisporites primarius										1.0			2.0	0.5	0.5	
Rugulatisporites quintus													3.0	1.5		
ANGIOSPERMS	33.5	87.0	66.0	50.5	66.0	68.5	18.5	71.0	42.5	67.5	10.5	42.0	57.0	52.5	90.5	85.0
GYMNOSPERMS	28.0	11.5	8.5	43.5	26.5	22.5	78.5	25.0	52.0	15.0	79.5	12.5	8.5	39.0	3.5	6.5
PTERIDOPHYTES	38.5	1.5	25.5	6.0	7.5	9.0	3.0	4.0	5.5	17.5	10.0	45.5	34.5	8.5	6.0	8.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Remarks: R = rare. See more details about counting in Chapter 1.

Rarely occurring species are: *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953, *Caryapollenites simplex* Potonié 1960, *Aceripollis* sp. 853, *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953 and *Podocarpidites ellipticus* Cookson ex Couper 1953.

The first appearance of *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953 at 33.2 m. depth (LP111) is defined as the lower limit of the SIAM-1 Zone but the upper limit is not seen in the Li sequence. These assemblages between 33.2-2.6 m. depth (LP111-LP101) correlates with SIAM-1 Zone (Late Oligocene).

Although precise stratigraphical relationship between samples in this study and previous studies (Ratanasthien, 1984; Endo, 1964, 1966) are not known but they are likely to derive from the main coal seams or adjacent strata of Li Basin. Ratanasthien (1984) reported *Tricolpites* and *Tricolporites* pollen grains in two samples collected from the Ban Pu Sub-basin and suggested a Senonian or Palaeogene age. On the other hand, Endo (1964, 1966) examined megaflores of the Li Basin which comprise species of *Alnus thaiensis* Endo, *Sequoia langsdorfii* (Brongniart) Heer, *Taxodium thaiensis* Endo, *Sparganium thaiensis* Endo, *Carpinus* (?) sp. *Glyptostrobus europaeus* (Brongniart) Heer, *Ficus eowithtiana* Endo, *Fagus feroniae* Ung., *Quercus lanceaefolia* Roxb., *Quercus* cf. *protoglauca* Endo, and *Salix* ? sp. Endo (1964) suggested a Palaeogene (Late Eocene) age.

5.2 Nong Ya Plong Basin

Nong Ya Plong Basin is a small coal bearing basin in Petchaburi Province, about 130 kilometres southwest of Bangkok (Figure 1-1), at approximately latitude 13° 09' N and longitude 99° 41' E. The Nong Ya Plong coal is comparatively high grade (High volatile B bituminous) and is the closest resource to the city of Bangkok.

Seven samples are selected for this study from a total of nine available. They contain moderate to well preserved palynofloras. The assemblages of Nong Ya Plong sequence (Figure 5-2; Table 5-2) are dominated by *Alnipollenites verus* Potonié 1931, *Quercoidites* sp. 777, *Pinuspollenites* sp. 1436, *Baculatisporites primarius* Wolff ex Thomson & Pflug 1953 and *Rugulatisporites quintus* Pflug & Thomson in Thomson & Pflug 1953. Gymnosperm pollen sum (*Pinuspollenites* sp. 1436 and *Piceapollenites alatus* Potonié 1931) is generally rather high

proportion in the sequence. Other common species include: *Faguspollenites* sp. 845, *Piceapollenites alatus* Potonié 1931, *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971 and *Laevigatosporites ovatus* Wilson & Webster 1946.

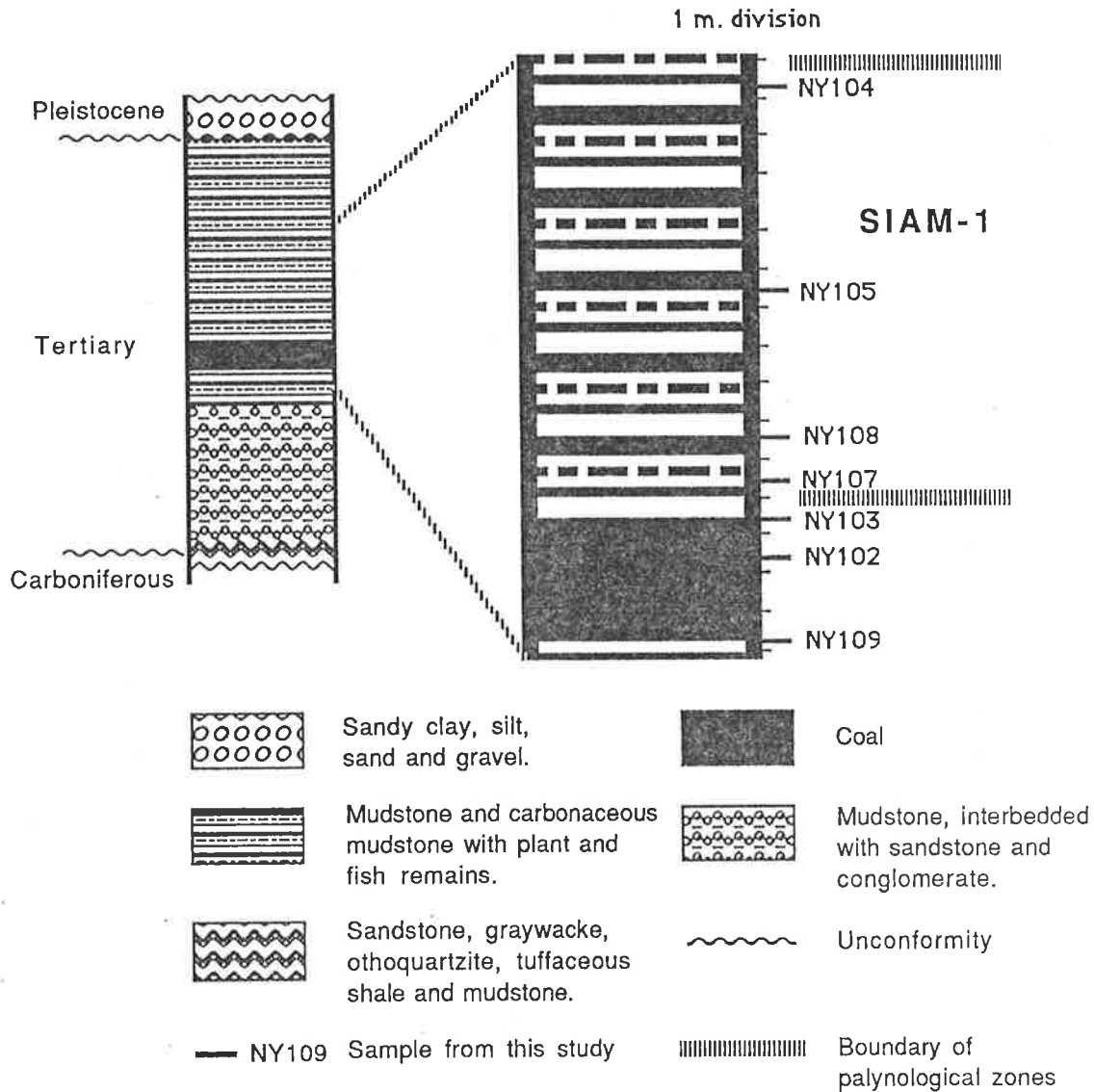


Figure 5-2. Generalized stratigraphic column (Supurtipanish & Pithchayakul, 1983), sample locations and zonation of Nong Ya Plong Basin, central Thailand.

Rarely occurring species are: *Momipites coryloides* Wodehouse 1933, *Caryapollenites simplex* Potonié 1960, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953, *Monoporopollenites gramineoides* Meyer 1956, *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953, *Tsugaepollenites igniculus* Potonié ex Potonié 1958,

Inaperturopollenites dubius Potonié & Venitz ex Thomson & Pflug 1953 and *Podocarpidites ellipticus* Cookson ex Couper 1953.

Table 5-2. Taxa appearance in relative percentages Nong Ya Plong Basin, central Thailand.

TAXA	ZONATION							
	Sample No. NY109	NY102	NY103	NY107	NY108	NY105	NY104	
	Sequence down.....			<<<<< SIAM-1 >>>>> >>>>>				up
ANGIOSPERMS								
Alnipollenites verus	14.5	3.5	8.0	36.0	37.5	18.5	R	
Quercoidites sp. 777	5.5	13.5	39.5	5.5	4.0	23.0	32.5	
Momipites coryloides	1.0		1.0	1.5		0.5		
Faguspollenites sp. 845	R	11.0	23.0	1.0	R	5.0	4.5	
Caryapollenites simplex		0.5	3.0			0.5	R	
Cupuliferoipollenites pusillus			R	1.0				
Tetracolporopollenites sapotoides			R					
Monoporopollenites gramineoides				0.5				
Periporopollenites stigmosus						0.5		
Trivestibulopollenites betuloides							1.5	
GYMNOSPERMS								
Pinuspollenites sp. 1436	4.5	1.5	7.0	2.5	3.5	29.5	49.0	
Piceapollenites alatus	R	1.0	14.0	1.0	2.5	20.0	11.0	
Tsugapollenites igniculus			R				R	
Inaperturopollenites dubius				1.5	1.5	R	R	
Podocarpidites ellipticus						1.5	R	
PTERIDOPHYTES								
Baculatisporites primarius	63.0	36.0	0.5	37.0	2.0	R		
Rugulatisporites quintus	8.0	30.0	R	7.0	2.5	R		
Polypodiisporites alieneus	2.0	1.5	R	0.5	13.0	R	1.0	
Laevigatosporites ovatus	1.5	1.5	4.0	5.0	33.5	1.0	0.5	
Polypodiaceoisporites spp.				R	R			
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Pediastrum sp.				R		**	***	

Remarks: R = rare, ** = common, *** = abundant. See more details about counting in Chapter 1.

On the basis of the first appearance of *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953 at sample NY107, the assemblages (NY107-NY104) can be correlated with SIAM-1 Zone (Late Oligocene). The lower assemblages (NY109-NY103) can be correlated with pre SIAM-1 Zone indicating a Late Oligocene age or older.

5.3 Palynostratigraphic Correlation: Oligocene Onshore Basins

The *Alnipollenites verus* Potonié 1931 in Nong Ya Plong Basin is comparatively higher in frequency than in the Li Basin but frequencies of *Momipites coryloides* Wodehouse 1933 and *Inaperturopollenites dubius* Thomson & Pflug 1953 are lower. This may suggest that Nong Ya Plong Basin is comparatively older than Li Basin.

The first appearance of *Inaperturopollenites dubius* Thomson & Pflug 1953 from the sample NY107 (Nong Ya Plong Basin) can be correlated with sample LP111 (Li Basin). Thus major coal seam of Nong Ya Plong Basin (NY109 to NY103) is older than major coal seams of Li Basin (LP117 to LP115). A palynological correlation of the productive sequences from Li and Nong Ya Plong basins is shown in Figure 5-3.

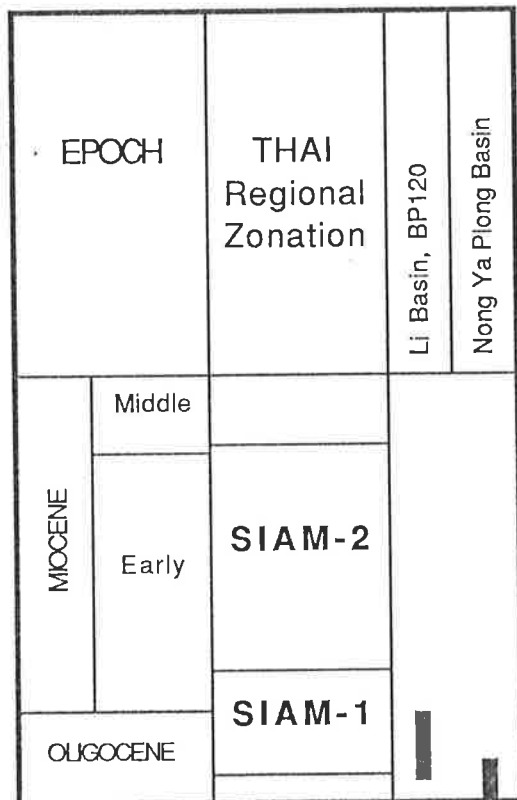
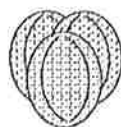


Figure 5-3. Palynological correlation of the onshore Oligocene sequences from Li and Nong Ya Plong basins.



CHAPTER 6

APPLICATION OF NEW ZONES:

MIOCENE ONSHORE

Five onshore basins (Krabi, Sin Pun, Mae Moh Mae Sot and Fang) yield correlative palynofloral assemblages ranging in age from Early to Middle Miocene. The characteristics of assemblages of these basins contain low frequencies and diversity of gymnosperm pollen, increased frequencies and diversity of angiosperm pollen and influxes of tropical pollen. Correlation of these sediments in isolated onshore basins is achieved by the appearance of some *Florschuetzia* spp. (Krabi Basin), *Alnipollenites verus* Potonié 1931 and *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968. Their distributions can be related to the offshore palynostratigraphy of the Andaman Sea.

6.1 Krabi Basin

Palynofloras from Krabi Basin, southern Thailand (Figures 1-1, 6-1; Table 6-1) mostly contain pollen derived from terrestrial floras, but also contain minor amounts of mangrove pollen. Palynological indicators including *Alnipollenites verus* Potonié 1931, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Florschuetzia trilobata* Germeraad *et al.* 1968, and *Florschuetzia meridionalis* Germeraad *et al.* 1968 have been recorded; and on this basis two zones can be recognized from the Krabi sequence including SIAM-1 Zone (KP113-KP116), and SIAM-2 Zone (KP118-KP128).

The lower sequence (KP113-KP116) contains *Alnipollenites verus* Potonié 1931 without *Echiperiporites* cf. *E. estelae* and suggests a correlation with SIAM-1 Zone (early Early Miocene). Common species include: *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Monoporopollenites gramineoides* Meyer 1956, *Tricolporites* cf. *T. valvatus* Harris 1972, *Trivestibulopollenites betuloides* Pflug *in* Thomson & Pflug 1953, *Alnipollenites verus* Potonié 1931, *Laevigatosporites ovatus* Wilson & Webster 1946 and *Cyathidites minor* Couper 1953.

Rare species are: *Caryapollenites simplex* Potonié 1960, *Aceripollis* sp. spp., *Momipites coryloides* Wodehouse 1933, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931 and *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953.

The middle sequence (KP118-KP128) comprises assemblages which include *Alnipollenites verus* Potonié 1931 and *Florschuetzia trilobata* Germeraad *et al.* 1968. Species making their first appearance in this zone include: *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Ammania* sp. 382, *Lagerstroemia* sp. 325, *Excoecaria* sp. 1404, *Zonocostites ramonae* Germeraad *et al.* 1968 and *Hopea* sp. 1299. The sequence is proposed as a reference section of the SIAM-2 Zone (middle to late Early Miocene). Common species include: *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Monoporopollenites gramineoides* Meyer 1956, *Tricolporites* cf. *T. valvatus* Harris 1972, *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953, *Alnipollenites verus* Potonié 1931, *Caryapollenites simplex* Potonié 1960, *Aceripollis* sp. spp., *Momipites coryloides* Wodehouse 1933, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Ammania* sp. 382, *Lagerstroemia* sp. 325, *Excoecaria* sp. 1404, *Pinuspollenites* sp. 1436, *Laevigatosporites ovatus* Wilson & Webster 1946, *Cyathidites minor* Couper 1953 and *Baculatisporites primarius* Wolff ex Thomson & Pflug 1953. Rare species are: *Ilexpollenites iliacus* Potonié 1960, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Florschuetzia trilobata* Germeraad *et al.* 1968, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953, *Lanagiopollis nanggulanensis* Morley 1982, *Dipterocarpus* sp. 780, *Zonocostites ramonae* Germeraad *et al.* 1968, *Florschuetzia meridionalis* Germeraad *et al.* 1968, *Podocarpidites ellipticus* Cookson ex Couper 1953, *Piceapollenites alatus* Potonié 1931 and *Dacrydiumites florinii* Cookson & Pike ex Harris 1965.

The upper sequence (KP130-KP135) is characterized by the disappearance of *Alnipollenites verus* Potonié 1931 and the first appearance of *Florschuetzia meridionalis* Germeraad *et al.* 1968 and is correlated with the post SIAM-2 Zone (Middle Miocene). Common species include: *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Ammania* sp. 382, *Laevigatosporites ovatus* Wilson & Webster 1946, *Cyathidites minor* Couper 1953, *Polypodiaceoisporites* spp., and *Baculatisporites primarius* Wolff ex Thomson & Pflug 1953.

Rare species are: *Caryapollenites simplex* Potonié 1960, *Aceripollis* spp., *Avicennia* sp. 1492, *Echiperiporites* cf. *E. estelae* Germeraad et al. 1968 and *Zonocostites ramonae* Germeraad et al. 1968.

In conclusion, the age of the stratigraphic sequence in Krabi Basin ranges between Early Miocene and Middle Miocene.

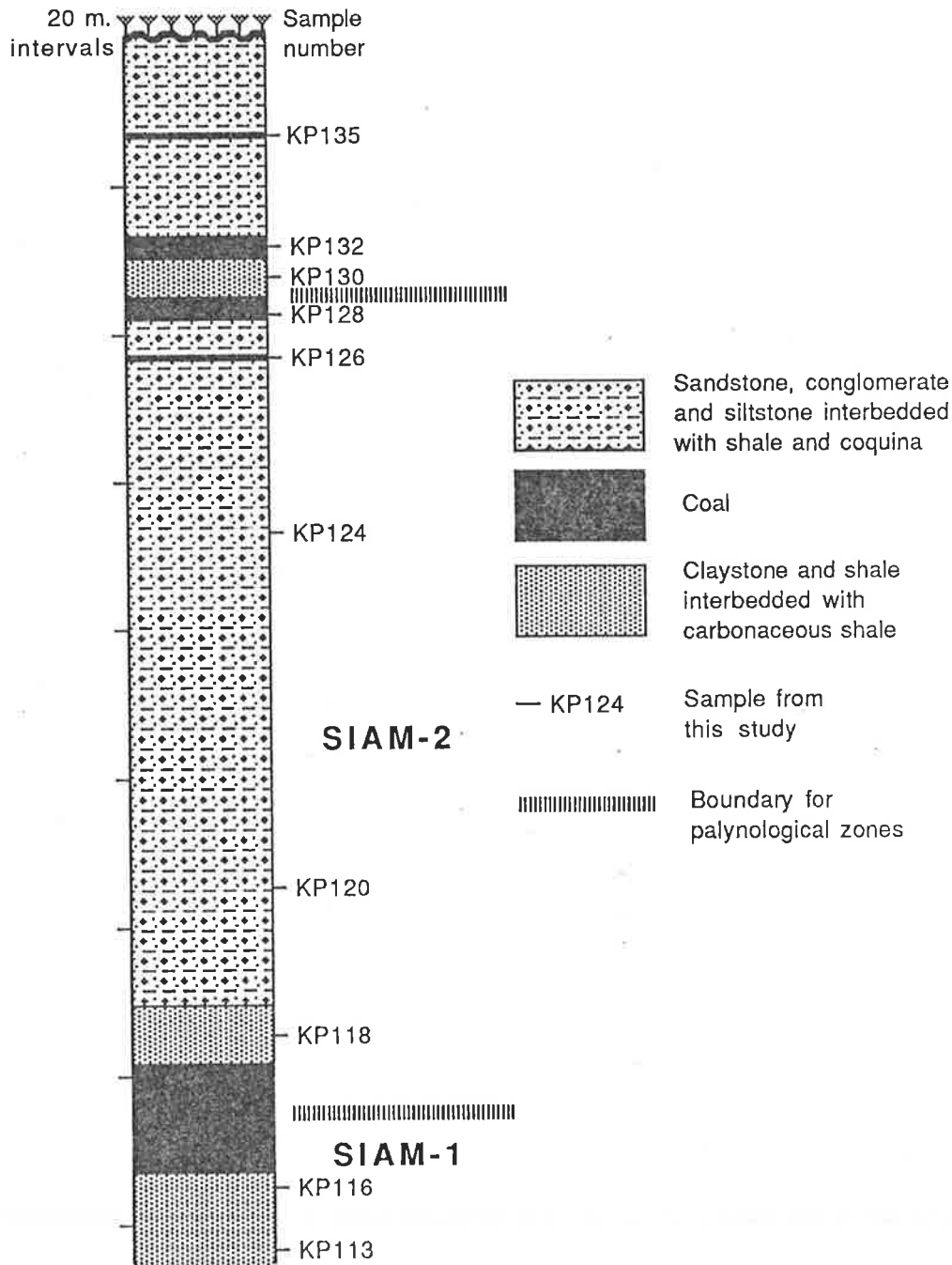


Figure 6-1. Stratigraphic column and zonation of the Huai Wai Lek Mine, Krabi Basin, southern Thailand.

Table 6-1: Taxa appearance in relative percentages from Krabi Basin, Southern Thailand.

TAXA	ZONATION <<SIAM-1>> <<<<<<<<<SIAM-2>>>>>>>>									
	Sample No. KP113	KP116	KP118	KP120	KP124	KP126	KP128	KP130	KP132	KP135
	Sequence down.....up									
ANGIOSPERMS										
Quercoidites sp. 777	3.0	34.5	45.5	24.5	46.0	14.5	13.0	8.0	22.0	35.0
Faguspollenites sp. 845	R	7.0	17.0	9.5	8.5	8.5		0.5	6.5	20.5
Monoporopollenites gramineoides	3.5	1.0	2.0	R		0.5	1.5	3.5		1.0
Tricolporites cf. T. valvatus	0.5	11.5			9.0	3.0	13.5	6.0		
Trivestibulopollenites betuloides	3.0	2.0			1.0	2.0				
Alnipollenites verus	1.5	R	R	1.5	0.5	0.5	R			
Caryapollenites simplex		2.0	2.0	8.5	1.0	1.0	2.5	0.5		3.5
Aceripollis spp.		3.5	4.0	3.0	0.5		1.5	2.5	3.5	
Momipites coryloides		R	2.0	2.0	R			R		
Tiliaepollenites cf. T. indubitabilis		2.5	6.5			4.0	6.5	15.5		4.0
Cardamine sp. 323		4.5					5.5	3.0		
Cyperaceapollis neogenicus		0.5								
Rhoipites cf. R. retiformis		R						1.0		
Tetracolporopollenites sapotoides		R				R		4.5		
Echiperiporites cf. E. estelae			1.5	1.5	1.0	R	R	1.0		1.0
Avicennia sp. 1492			R	4.0	2.0	3.5	1.5	1.0		3.5
Ammania sp. 382			6.0		7.0		2.0	2.5	4.5	9.5
Ilexpollenites iliacus			2.5							
Cupuliferoipollenites pusillus			1.0			1.0	0.5		R	R
Lagerstroemia sp. 325				6.5	3.5	3.0		4.0	6.0	
Tricolporopollenites sp. 810				2.5			0.5			
Juglanspollenites verus				1.5		2.5				
Hopea sp. 1299				1.5			0.5			
Florschuetzia trilobata				1.0		2.0	1.5			
Bursera sp. 1427				1.0						
Rhoipites sp. 1267				0.5				1.0		
Margocolporites vanwijhei				R		0.5				
Rhoipites sp. 1263				R						
Polyatriopollenites stellatus				R						
Zonocostites ramonae				R			1.0			R
Lanagiopollis nanggulanensis				R						
Excoecaria sp. 1404					5.0	9.0	39.5	1.0		
Dipterocarpus sp. 780								1.5		
Florschuetzia meridionalis								0.5		
GYMNOSPERMS										
Pinuspollenites sp. 1436		R	2.0	12.0	12.0	1.5		12.5		
Podocarpidites ellipticus		R		1.5				2.5		
Piceapollenites alatus				2.0				0.5		
Dacrydiumites florinii				0.5						
PTERIDOPHYTES										
Laevigatosporites ovatus	86.0	27.0	1.0	8.5	3.0	6.0	6.0	15.0	22.0	15.0
Cyathidites minor	1.5	3.0	6.0	3.0		2.0	2.0	5.0	3.5	
Polypodiaceosporites spp.	1.0							3.0	1.0	
Baculatisporites primarius		1.0	1.0	2.0		13.0			4.5	7.0
Polypodiisporites pohangensis				1.5			1.0			
Polypodiisporites alienus				R		R		3.0		
Rugulatisporites quintus						22.0			26.5	
Polypodiisporites usmensis								1.0		
ANGIOSPERMS	11.5	69.0	90.0	69.0	85.0	55.5	91.0	57.5	42.5	78.0
GYMNOSPERMS	0.0	0.0	2.0	16.0	12.0	1.5	0.0	15.5	0.0	0.0
PTERIDOPHYTES	88.5	31.0	8.0	15.0	3.0	43.0	9.0	27.0	57.5	22.0
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Pediastrum spp.		R	R	R	R	R	R	R	R	R
Remarks: R = rare. See more details about counting in Chapter 1.										

6.2 Sin Pun Basin

The only productive samples available are from a short sequence in 153S borehole, Sin Pun Basin (Figures 1-1, 6-2; Table 6-2). The sequence shows the appearance of *Alnipollenites verus* Potonié 1931 and the incoming of *Lagerstroemia* sp. 325 which can be related to the upper SIAM-1 Zone (early Early Miocene).

The assemblage diversity is low and mainly dominated by species preferring temperate climates. The *Quercoidites* sp. 777 is a dominated species in the assemblages. Gymnosperm pollen occur rarely in the sequence. Commonly occurring species include: *Momipites coryloides* Wodehouse 1933, *Alnipollenites verus* Potonié 1931, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Juglanspollenites verus* Raatz 1939, *Ilexpollenites iliacus* Potonié 1960, *Laevigatosporites ovatus* Wilson & Webster 1946 and *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971. Rare species are: *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953, *Lagerstroemia* sp. 325, *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953, *Margocolporites vanwijhei* Germeraad et al. 1968, *Myrtaceidites mesonesus* Cookson & Pike 1954, *Ammania* sp. 382, *Podocarpidites ellipticus* Cookson ex Couper 1953 and *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953.

A few tropical indicators including *Lagerstroemia* sp. 325 and *Ammania* sp. 382, make their first appearance in the sequence. The Sin Pun assemblages are similar to the assemblage of Erawan 12-28 Borehole at 1408.5 m.

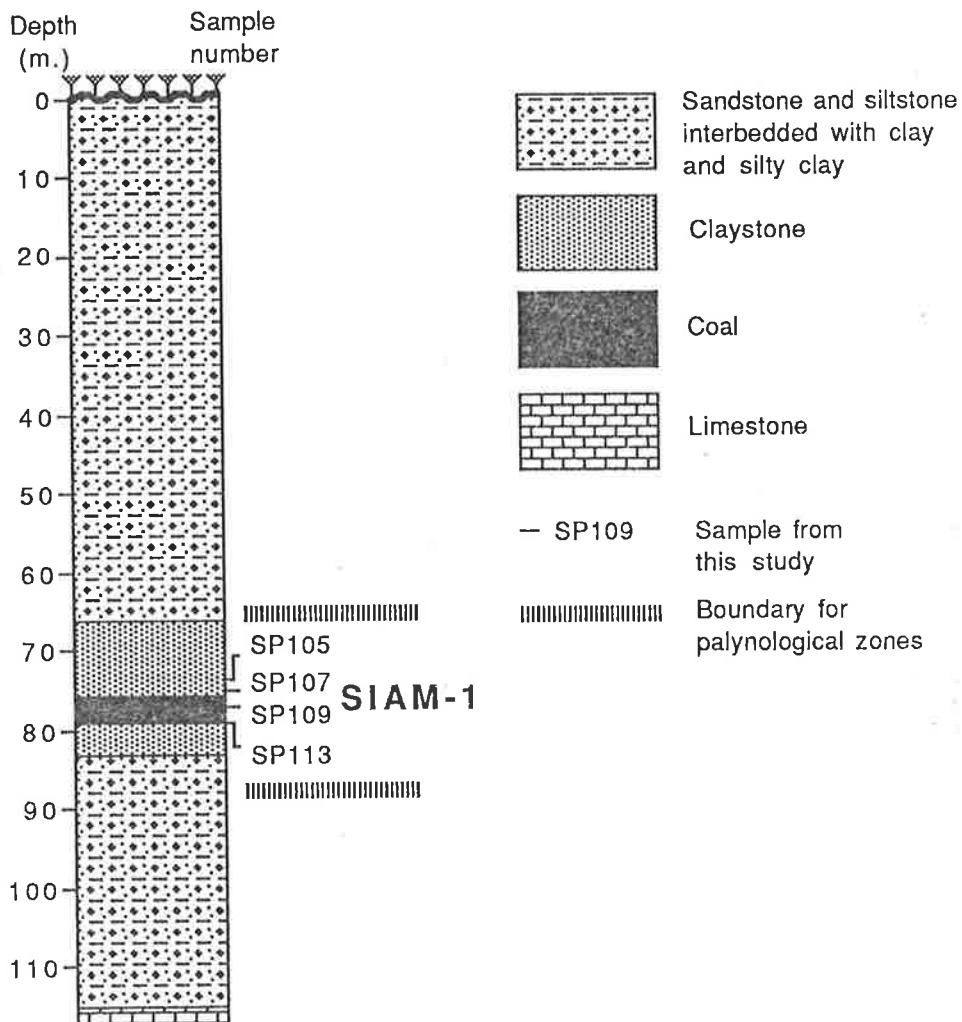


Figure 6-2. Stratigraphic column, localities of samples and zonation of the 153S Borehole, Sin Pun Basin, southern Thailand. The lithostratigraphic column is condensed from the borehole lithologic descriptive log (Chaninthorn, 1985).

Table 6-2: Taxa appearance in relative percentages from 153S Borehole, Sin Pun Basin.

ZONATION	<<<<<<<<<< <<SIAM-1>> >>>>>>>>> >>>>>>>>>			
Sample No.	SP113	SP109	SP107	SP105
Depth (metres)	78.9	76.9	75.6	74.5
TAXA				
ANGIOSPERMS				
Quercoidites sp. 777	26.5	47.0	61.0	64.0
Momipites coryloides	2.5	31.5	29.0	16.0
Alnipollenites verus	2.0	1.0	1.0	2.0
Tricolporopollenites sp. 908	0.5			7.0
Juglanspollenites verus	R			4.0
Rhoipites cf. R. retiformis	3.5	1.0	R	
Cupuliferoipollenites pusillus	1.5	0.5	2.0	
Ilexpollenites iliacus	1.0		0.5	
Trivestibulopollenites betuloides		2.0		R
Lagerstroemia sp. 325		3.0	0.5	
Tetracolporopollenites sapotoides		1.0		
Margocolporites vanwijhei		1.0		
Myrtaceidites mesonesus		1.0		
Ammania sp. 382			1.0	0.5
GYMNOSPERMS				
Podocarpidites ellipticus	1.0			1.0
Inaperturopollenites dubius				2.0
PTERIDOPHYTES				
Laevigatosporites ovatus	15.5	7.0	2.0	1.5
Polypodiisporites alienus	6.0	1.0	3.0	2.5
Cyathidites minor	2.5			1.5
Rugulatisporites quintus	36.5			
Baculatisporites primarius	1.0			
Polypodiaceoisporites spp.		3.0		
ANGIOSPERMS	37.5	89.0	95.0	93.5
GYMNOSPERMS	1.0	0.0	0.0	1.0
PTERIDOPHYTES	61.5	11.0	5.0	5.5
TOTAL	100.0	100.0	100.0	100.0

Remarks: R = rare. See details about counting in Chapter 1.

6.3 Mae Moh Basin

The productive sequence from the LM2813S Borehole, Mae Moh Basin (Figure 1-1) can be divided into two zones (Figure 6-3, Table 6-3) including SIAM-1 Zone (MM106-MM108) and SIAM-2 Zone (MM109-MM133).

The lower sequence (MM106-MM108, between 320.9-309.3 m. depth) contains *Alnipollenites verus* Potonié 1931 without *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 and on this basis can be correlated with the SIAM-1 Zone (early Early Miocene). Commonly occurring species include: *Monoporopollenites gramineoides* Meyer 1956, *Ammania* sp. 382, *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Hopea* sp. 1299, *Aceripollis* spp., *Lagerstroemia* sp. 325, *Caryapollenites simplex* Potonié 1960, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Alnipollenites verus* Potonié 1931, *Pinuspollenites* sp. 1436, *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971, *Laevigatosporites ovatus* Wilson & Webster 1946, *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971 and *Magnastriatites grandiosus* Kedves & Porta emend. Dueñas 1980. Rare species include: *Bombacacidites annae* Hammen ex Leidelmeier 1966, *Bursera* sp. 1427, *Salixipollenites* cf. *S. discoloripites* Srivastava 1966 and *Tricolporites* cf. *T. valvatus* Harris 1972. A few species preferring tropical environments making their first appearance in this zone include: *Lagerstroemia* sp. 325, *Dipterocarpus* sp. 780 and *Margocolporites vanwijhei* Germeraad *et al.* 1968.

The middle sequence (MM109-MM133, between 306.2-180.0 m. depth) comprises a number of commonly occurring species include: *Monoporopollenites gramineoides* Meyer 1956, *Ammania* sp. 382, *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Hopea* sp. 1299, *Aceripollis* spp., *Lagerstroemia* sp. 325, *Caryapollenites simplex* Potonié 1960, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Alnipollenites verus* Potonié 1931, *Bursera* sp. 1427, *Salixipollenites* cf. *S. discoloripites* Srivastava 1966, *Tricolporites* cf. *T. valvatus* Harris 1972, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Dipterocarpus* sp. 780, *Cyperaceapollis neogenicus* Krutzsch 1970, *Momipites coryloides* Wodehouse 1933, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968,

Trivestibulopollenites betuloides Pflug in Thomson & Pflug 1953, *Lanagiopollis nanggulanensis* Morley 1982, *Pinuspollenites* sp. 1436, *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971, *Laevigatosporites ovatus* Wilson & Webster 1946, *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971 and *Cyathidites minor* Couper 1953. Rare species are *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953, *Juglanspollenites verus* Raatz 1939, *Myrtaceidites mesonesus* Cookson & Pike 1954, *Ilexpollenites iliacus* Potonié 1960, *Pandaniidites texus* Elsik 1968, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953, *Podocarpidites ellipticus* Cookson ex Couper 1953, *Dacrydiumites florinii* Cookson & Pike ex Harris 1965 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958. Species preferring tropical environments which begin their first appearance in this zone include: *Pandaniidites texus* Elsik 1968 and *Lanagiopollis nanggulanensis* Morley 1982. The appearances of *Alnipollenites verus* Potonié 1931 and *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 in this sequence indicate a correlation with the SIAM-2 Zone (middle to late Early Miocene).

The assemblages from the upper sequence (MM136-MM149, between 161.8-43.5 m. depth), contain species common to the middle productive sequence but *Alnipollenites verus* Potonié 1931 disappears. They can be correlated with the post SIAM-2 Zone (Middle Miocene).

In conclusion, the stratigraphic sequence in LM2813S borehole, Mae Moh Basin contains SIAM-1 to post SIAM-2 zones ranging in age from Early to Middle Miocene.

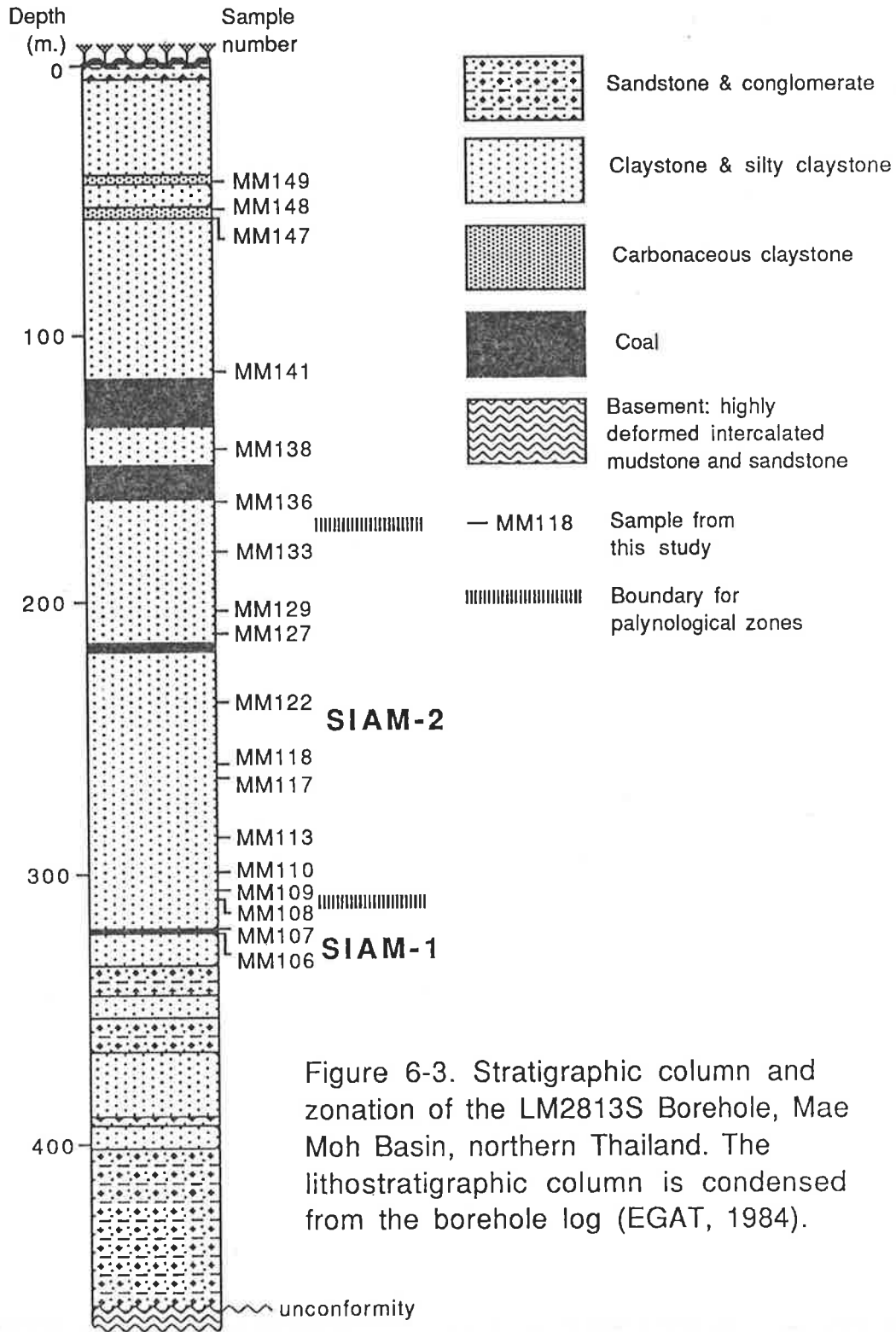


Figure 6-3. Stratigraphic column and zonation of the LM2813S Borehole, Mae Moh Basin, northern Thailand. The lithostratigraphic column is condensed from the borehole log (EGAT, 1984).

6.4 Mae Sot Basin

Only one zone (SIAM-2) can be recognized from the IMS-1 borehole (sample numbers MS382-MS368, between 866.8-487.2 m. depth), Mae Sot Basin (Figures 1-1, 6-4; Table 6-4).

Commonly species include: *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Alnipollenites verus* Potonié 1931, *Lagerstroemia* sp. 325, *Ammania* sp. 382, *Echiperiporites* cf. *E. estelae* Germeraad et al. 1968, *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953, *Pinuspollenites* sp. 1436, *Piceapollenites alatus* Potonié 1931, *Cyathidites minor* Couper 1953, *Laevigatosporites ovatus* Wilson & Webster 1946, *Magnastriatites grandiosus* Kedves & Porta emend. Dueñas 1980 and *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971. Rare species are: *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Caryapollenites simplex* Potonié 1960, *Cyperaceapollis neogenicus* Krutzsch 1970, *Margocolporites vanwijhei* Germeraad et al. 1968, *Ilexpollenites iliacus* Potonié 1960, *Tricolporites* cf. *T. valvatus* Harris 1972, *Tubulifloridites antipodica* Cookson ex Potonié 1960, *Aceripollis* spp., *Dipterocarpus* sp. 780, *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Monoporopollenites gramineoides* Meyer 1956, *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953, *Podocarpidites ellipticus* Cookson ex Couper 1953 and *Dacrydiumites florinii* Cookson & Pike ex Harris 1965. Some tropical species appearing in this sequence include: *Lagerstroemia* sp. 325, *Ammania* sp. 382, *Margocolporites vanwijhei* Germeraad et al. 1968 and *Dipterocarpus* sp. 780. The occurrence of *Alnipollenites verus* Potonié 1931 and *Echiperiporites* cf. *E. estelae* Germeraad et al. 1968 in this sequence indicates a correlation with SIAM-2 Zone (middle to late Early Miocene).

The assemblages from the upper sequence (MS365-MS359 between 477.1-455.8 m. depth) lack *Alnipollenites verus* Potonié 1931 and can be correlated with post SIAM-2 Zone (Middle Miocene).

In conclusion, the stratigraphic sequence from IMS-1 borehole, Mae Sot Basin ranges from SIAM 2 Zone and younger (middle Early to Middle Miocene).

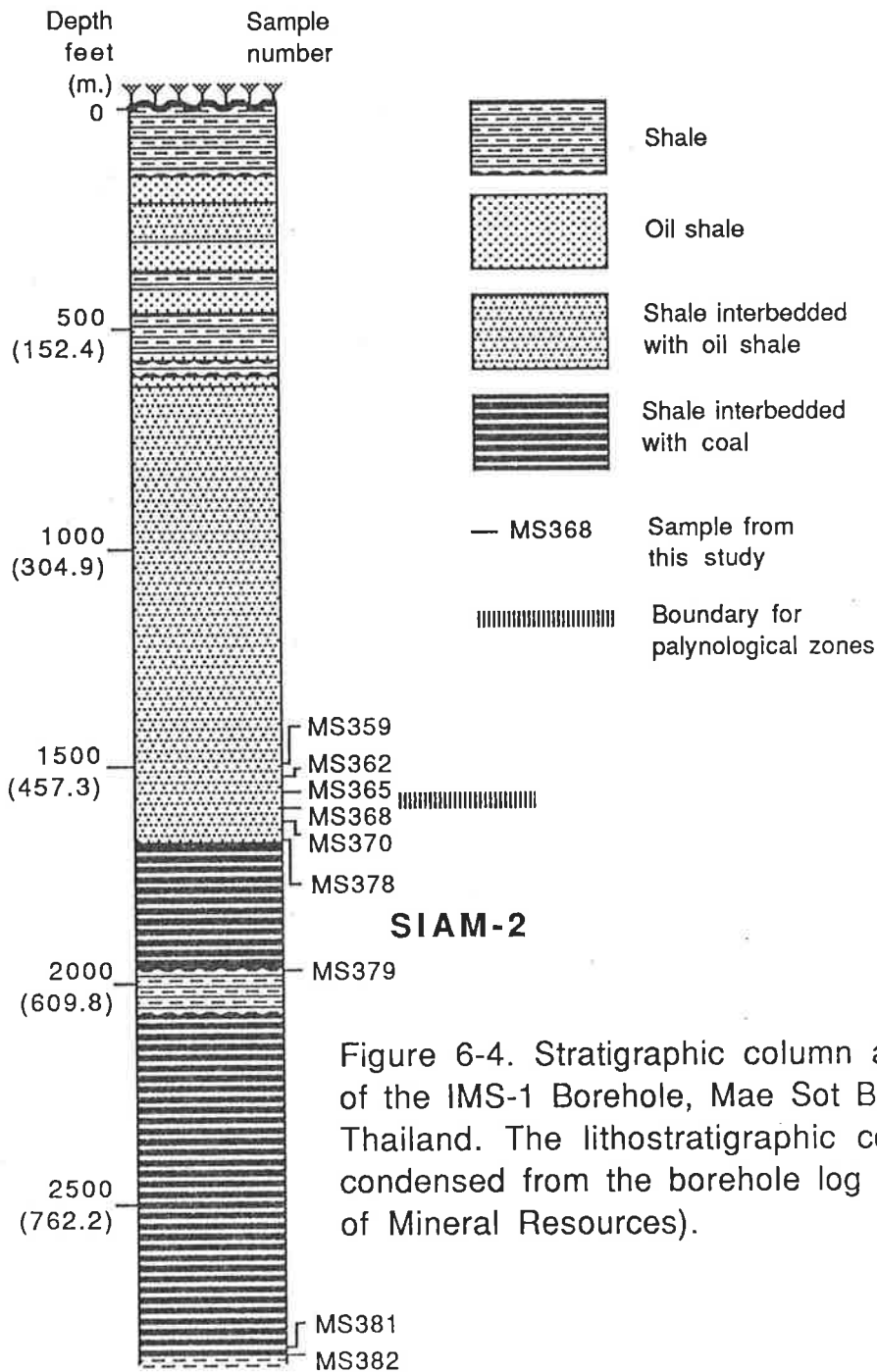


Figure 6-4. Stratigraphic column and zonation of the IMS-1 Borehole, Mae Sot Basin, northern Thailand. The lithostratigraphic column is condensed from the borehole log (Department of Mineral Resources).

6.5 Fang Basin

The Fang Basin (Figure 1-1) contains a shallow oil field, and is one of the oldest exploited fields in Thailand, but systematic core sampling for biostratigraphy has not yet been carried out. Ten productive samples from three boreholes (IF 2, IF 4 and IF 16) on the Pong Nok and Mae Soon structures have been selected for this study (Figure 6-5).

6.5.1 Pong Nok Structure (IF 2 and IF 4 boreholes)

Few samples are productive from the IF 2 and IF 4 boreholes (Tables 6-5, 6-6). The assemblages from both boreholes are similar, and contain the zonal species *Alnipollenites verus* Potonié 1931 and *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 and thus can be correlated with the SIAM-2 Zone (middle to late Early Miocene).

Commonly occurring species include: *Cupuliferoipollenites* Potonié ex Potonié 1960, *Myrtaceidites mesonesus* Cookson & Pike 1954, *Florschuetzia* sp. 647, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Faguspollenites* sp. 845, *Quercoidites* sp. 777, *Alnipollenites verus* Potonié 1931, *Caryapollenites simplex* Potonié 1960, *Dipterocarpus* sp. 780, *Ilexpollenites iliacus* Potonié 1960, *Aceripollis* spp., *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Pinuspollenites* sp. 1436 and *Laevigatosporites ovatus* Wilson & Webster 1946. Rare species are: *Momipites coryloides* Wodehouse 1933, *Lagerstroemia* sp. 325, *Monoporopollenites gramineoides* Meyer 1956, *Piceapollenites alatus* Potonié 1931, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953 and *Podocarpidites ellipticus* Cookson ex Couper 1953.

6.5.2 Mae Soon Structure (IF 16 Borehole)

Five samples from the IF 16 Borehole (Mae Soon Structure) are productive (Table 6-7) and contain assemblages similar to the Pong Nok assemblage. *Alnipollenites verus* Potonié 1931 and *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968 are rare but still suggest a correlation with the SIAM-2 Zone (middle to late Early Miocene).

Commonly occurring species include: *Quercoidites* sp. 777, *Faguspollenites* sp. 845, *Caryapollenites simplex* Potonié 1960, *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Monoporopollenites gramineoides* Meyer 1956, *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968, *Tubulifloridites antipodica* Cookson ex Potonié 1960, *Alnipollenites verus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Pinuspollenites* sp. 1436, *Piceapollenites alatus* Potonié 1931 and *Laevigatosporites ovatus* Wilson & Webster 1946. Some tropical species (*Dipterocarpus* sp. 780 and *Ammania* sp. 382) occur in these assemblages. Rare species are: *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931, *Cardamine* sp. 323, *Dipterocarpus* sp. 780, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953, *Aceripollis* spp., *Salixpollenites* cf. *S. discoloripites* Srivastava 1966, *Ammania* sp. 382, *Tsugaepollenites igniculus* Potonié ex Potonié 1958 and *Dacrydiumites florinii* Cookson & Pike ex Harris 1965.

The *Alnipollenites verus* Potonié 1931 is likely to occur in relatively high frequency in older sequences (Figure 3-2). Thus the very common occurrence of *Alnipollenites verus* Potonié 1931 in some Pong Nok samples and its rarity in all Mae Soon samples suggests that the Pong Nok sequences are older than those at Mae Soon.

It may be concluded that the productive samples from three boreholes (IF 2, IF 4 and IF 16) in Fang Basin are correlative with the SIAM-2 Zone (middle to late Early Miocene).

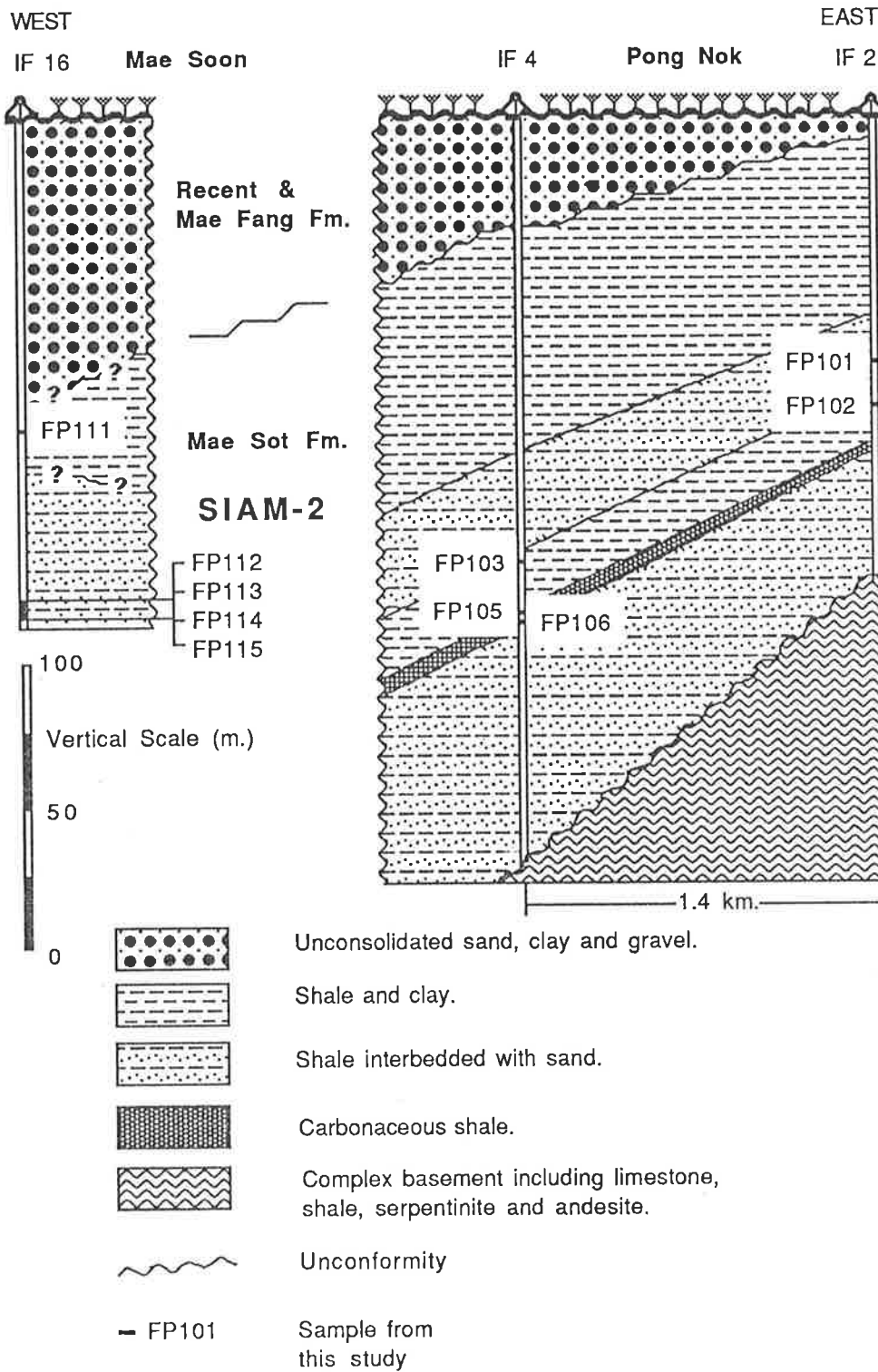


Figure 6-5. Borehole lithostratigraphic correlation, sample locations and zonation of the Fang Basin, northern Thailand (modified from Pompilian & Vasile, 1980; DED, 1982).

Table 6-5: Taxa appearance in relative percentages from the IF 2 Borehole, Fang Basin.

	ZONATION <<<<<<<<SIAM-2>>>>>>>>>>>>>>>>>>>>>>		
	Sample No.	FP102	FP101
Depth (metres)	408.5		339.9
TAXA			
ANGIOSPERMS			
Cupuliferoipollenites pusillus	25.0		6.5
Myrtaceidites mesonesus	21.0		13.0
Florschuetzia sp. 647	9.5		37.5
Rhoipites cf. R. retiformis	7.0		19.0
Faguspollenites sp. 845	1.5		3.5
Quercoidites sp. 777	5.0		2.0
Aceripollis spp.	R		1.0
Caryapollenites simplex	4.0		0.5
Echiperiporites cf. E. estelae	2.5		R
Ilexpollenites iliacus	2.0		1.0
Dipterocarpus sp. 780	R		R
Salixipollenites cf. S. discoloripites	R		R
Tiliaepollenites cf. T. indubitabilis	7.0		
Rhoipites sp. 1263	2.5		
Margocolporites vanwijhei	0.5		
Momipites coryloides	R		
Rhoipites sp. 1207	R		
Tubulifloridites antipodica	R		
Tricolporites cf. T. valvatus	R		
Alnipollenites verus			12.5
Tricolpites sp. 854			R
Tricolporopollenites sp. 810			R
GYMNOSPERMS			
Pinuspollenites sp. 1436	3.5		0.5
Podocarpidites ellipticus			R
PTERIDOPHYTES			
Laevigatosporites ovatus	6.5		0.5
Polypodiisporites alienus	1.0		1.0
Polypodiisporites pohangensis	1.0		
Polypodiaceoisporites spp.	0.5		
Magnastriatites grandiosus			1.5
ANGIOSPERMS	87.5		96.5
GYMNOSPERMS	3.5		0.5
PTERIDOPHYTES	9.0		3.0
TOTAL	100.0		100.0
Pediastrum spp.			R

Remarks: R = rare. See more details about counting in Chapter 1.

Table 6-6: Taxa appearance in relative percentages from the IF 4 borehole, Fang Basin.

ZONATION <<<<<<<<<<< <<SIAM-2>>>>>>>>>>>>>			
Sample No.	FP106	FP105	FP103
Depth (metres)	704.1	698.0	594.4
TAXA			
ANGIOSPERMS			
Quercoidites sp. 777	6.5	3.0	41.0
Faguspollenites sp. 845	7.5	7.5	17.0
Caryapollenites simplex	3.5	2.0	4.5
Ilexpollenites iliacus	3.0	R	0.5
Cupuliferoipollenites pusillus	1.5	24.5	0.5
Rhoipites cf. R. retiformis	0.5	4.0	3.0
Rhoipites sp. 1263	0.5	0.5	1.0
Alnipollenites verus	1.0	R	8.0
Dipterocarpus sp. 780	1.0	R	R
Tiliaepollenites cf. T. indubitabilis	2.0		0.5
Periporopollenites stigmosus	R		R
Tricolporites cf. T. valvatus		1.0	1.0
Monoporopollenites gramineoides		R	1.0
Momipites coryloides		0.5	0.5
Echiperiporites cf. E. estelae		R	0.5
Florschuetzia sp. 647		2.0	R
Margocolporites vanwijhei		R	R
Myrtaceidites mesonesus		35.0	
Tricolporopollenites sp. 862		R	
Aceripollis sp. 853			4.5
Rhoipites sp. 1207			1.0
Psilatricolporites operculatus			0.5
Cardamine sp. 323			R
Tricolpites sp. 258			R
Tricolpites sp. 854			R
Lagerstroemia sp. 325			R
GYMNOSPERMS			
Inaperturopollenites dubius	1.5		
Pinuspollenites sp. 1436		0.5	1.0
Piceapollenites alatus			1.0
PTERIDOPHYTES			
Laevigatosporites ovatus	68.5	15.5	8.5
Polypodiisporites alienus	1.0	1.0	2.5
Magnastriatites grandiosus	0.5		1.5
Cyathidites minor	1.5	1.5	
Retitriletes douglasii	R		
Undulatisporites unduliradius	R		
Polypodiaceoisporites spp.		1.5	0.5
Polypodiisporites pohangensis			R
Foveotriletes magaritae			R
ANGIOSPERMS	27.0	80.0	85.0
GYMNOSPERMS	1.5	0.5	2.0
PTERIDOPHYTES	71.5	19.5	13.0
TOTAL	100.0	100.0	100.0
Pediastrum spp.		R	***

Remarks: R = rare, *** = abundant. See more details about counting in Chapter 1.

Table 6-7: Taxa appearance in relative percentages from the IF 16 Borehole, Fang Basin.

TAXA	ZONATION <SIAM-2>					
	Sample No.	FP115	FP114	FP113	FP112	FP111
Depth (metres)	692.4	689.2	678.4	674.1	437.2	
ANGIOSPERMS						
Quercoidites sp. 777	39.0	85.0	33.5	73.0	38.5	
Faguspollenites sp. 845	5.5	3.0	9.5	3.5	10.0	
Caryapollenites simplex	4.0	2.0	1.5	1.0	2.0	
Rhoipites cf. R. retiformis	3.5	2.0	3.0	4.0	1.5	
Cupuliferoipollenites pusillus	2.0	1.0	2.0	1.0	18.5	
Triorites sp. 1373	R	R	R	0.5	R	
Myrtaceidites mesonesus	0.5	0.5			1.0	
Monoporopollenites gramineoides	1.5		8.0	1.5	6.0	
Ilexpollenites iliacus	1.0		2.0	1.0	3.0	
Echiperiporites cf. E. estelae	R		1.5		R	
Tubulifloridites antipodica	1.5		1.0		0.5	
Alnipollenites verus	R			0.5	1.0	
Psilatricolporites operculatus	1.0				0.5	
Momipites coryloides	R		0.5	R		
Tricolpites sp. 854	R			R		
Rhoipites sp. 1207	1.5		0.5			
Tricolporites cf. T. valvatus	R		2.0			
Tiliaepollenites cf. T. indubitabilis	R		1.0			
Cardamine sp. 323	0.5					
Polyadopollenites myriosporites	R					
Rhoipites sp. 1263	R					
Dipterocarpus sp. 780			R	3.0	0.5	
Margocolporites vanwijhei			R	R		
Trivestibulopollenites betuloides				R		
Aceripollis sp. 853					1.5	
Salixipollenites cf. S. discoloripites					0.5	
Ammania sp. 382					R	
Periporopollenites stigmosus					R	
GYMNOSPERMS						
Pinuspollenites sp. 1436	21.5	0.5	9.0	5.5	0.5	
Inaperturopollenites dubius	1.5				1.0	
Piceaepollenites alatus	0.5	R		0.5		
Tsugaepollenites igniculus			0.5			
Dacrydiumites florinii			0.5			
PTERIDOPHYTES						
Laevigatosporites ovatus	9.5	3.5	21.0	4.5	9.0	
Polypodiaceoisporites spp.	2.0	1.5	0.5		1.0	
Polypodiisporites alieneus	2.0	0.5	2.0		2.0	
Polypodiisporites pohangensis	1.0	0.5	0.5			
Cyathidites minor	0.5			0.5	1.0	
Retitriletes douglasii					0.5	
ANGIOSPERMS	61.5	93.5	66.0	89.0	85.0	
GYMNOSPERMS	23.5	0.5	10.0	6.0	1.5	
PTERIDOPHYTES	15.0	6.0	24.0	5.0	13.5	
TOTAL	100.0	100.0	100.0	100.0	100.0	
Pediastrum spp.	R	R	R		R	

Remarks: R = rare. See more details about counting in Chapter 1.

6.6 Palynostratigraphic Correlation: Miocene Onshore Basins

Tertiary lithostratigraphic correlation among the isolated onshore basins including Krabi, Sin Pun, Mae Moh, Mae Sot and Fang was, prior to this study, uncertain. Results from this work, however, indicate correlation between these sequences is possible. The palynostratigraphic correlation is shown in Figure 6-6. Some economically important strata can be related: major coal seams of Krabi and Sin Pun basins are about the same age (uppermost SIAM-1 Zone, early Early Miocene) but are older than major coal seams in the Mae Moh Basins (post SIAM-2, Middle Miocene). Two oil-bearing intervals in the IF 16 borehole are located within (?upper) SIAM-2 Zone of late Early Miocene age. The oil shale of Mae Sot Basin may correlate with upper or post SIAM-2 Zone or be younger.

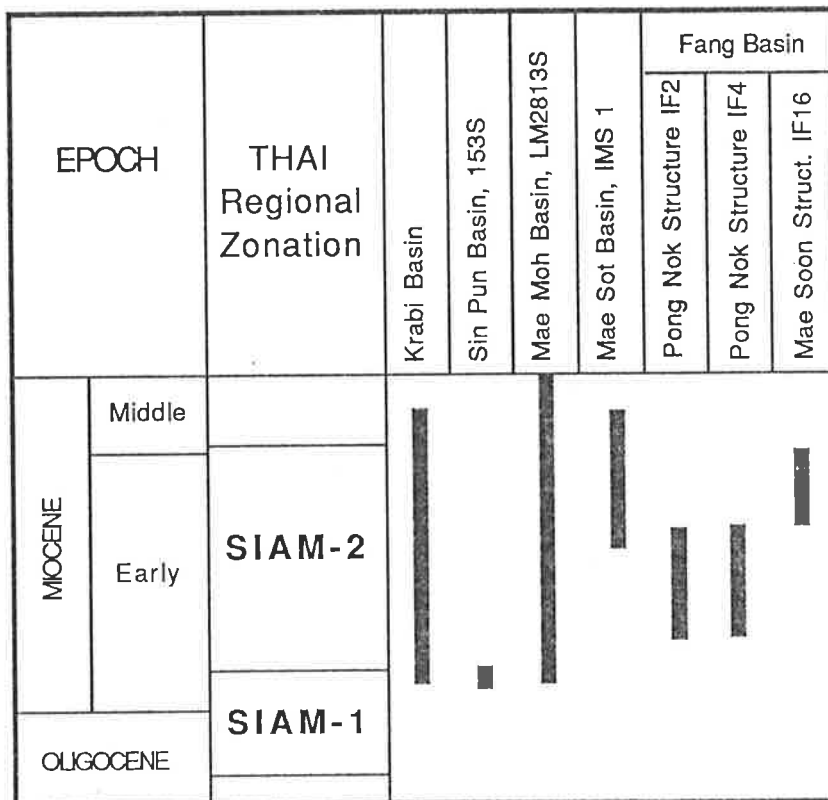
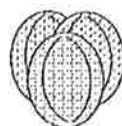


Figure 6-6. Palynological correlation of the onshore Miocene sequences from Krabi, Sin Pun, Mae Moh, Mae Sot and Fang basins.



CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 Correlation and Implications: Hydrocarbon Resources Exploration

Two regional palynofloral zones (SIAM-1 and SIAM-2) have been established from a biostratigraphic study of dispersed palynofloras from mid-Tertiary sediments of fourteen sequences from nine Thailand basins. The zones are independently dated from associated marine foraminiferal data (Tidey *et al.*, 1976; Troelstra *et al.*, 1976). The palynofloral zones remain provisional because, in some cases, they are based on the use of cuttings samples, but they are the most likely correlations using the available information. Future research with more precise data may confirm or readjust this pilot zonal scheme. The palynostratigraphic correlation of nine Tertiary basins in Thailand is shown in Figure 7-1.

To date correlation of Tertiary stratigraphic units in Thailand has depended upon ambiguous lithostratigraphic correlations, as mentioned in the Section 2.3. However, palynostratigraphic correlation of productive sequences in this study has been achieved and it provides means for resolving proposed lithostratigraphic correlations. It shows that all productive sequences fall within the Late Oligocene-Middle Miocene and the Nong Ya Plong sequence is the oldest record. The SIAM-1 Zone is recorded from Li, Nong Ya Plong, Sin Pun, Krabi, Mae Moh basins; Andaman Sea and the Gulf of Thailand. The SIAM-2 Zone is recorded from Fang, Mae Moh, Mae Sot and Krabi basins; Andaman Sea and the Gulf of Thailand. The palynological results are of considerable value in the correlation of hydrocarbon-bearing strata including coal, oil and oil shale. It is shown that the Nong Ya Plong coal seam (pre SIAM-1; Late Oligocene in age) is older than Li coal seams (SIAM-1; Late Oligocene in age). Major coal seams in Krabi and Sin Pun basins are approximately the same age and belong in the uppermost SIAM-1 Zone of the early Early Miocene. Major coal seams (Q and K seams) in Mae Moh Basin are correlated with post SIAM-2 Zone and are approximately Middle Miocene in age. Two oil-bearing intervals of the IF 16 Borehole are located within (?upper) SIAM-2 Zone of

late Early Miocene age. The oil shale of Mae Sot Basin may correlate with upper and post SIAM-2 Zone, indicating a Middle Miocene age or be younger.

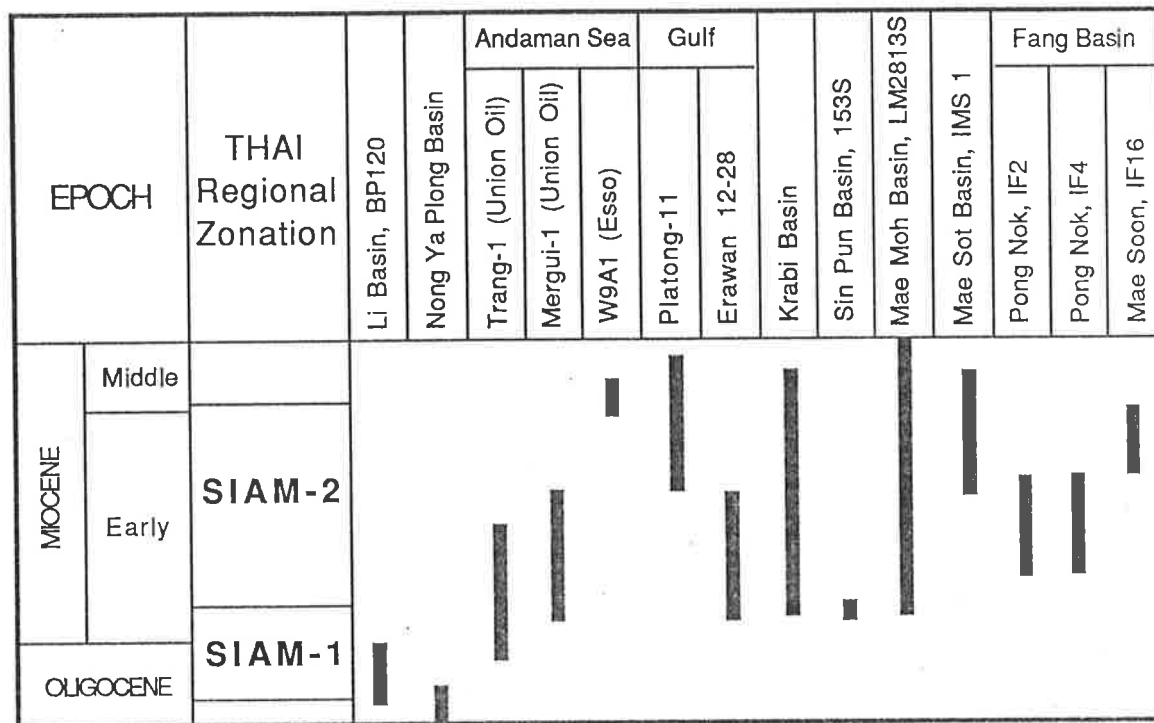


Figure 7-1. Palynological dating and correlation of mid-Tertiary sequences from Thailand.

7.2 Palaeoecology

Reconstruction of palaeoecology depends basically on an understanding of past and present (palyno)floras. In palynological studies only part of fossil taxa can be related to extant taxa. Variation of both fossil and extant palynomorphs contributes palaeoecological reconstruction more difficult. This is the first attempt at such reconstructions and although it lacks suitable references of modern distribution of pollen in the temperate-tropical Southeast Asian region, five related palaeoecological types are recognized here. These palaeoecological types are reconstructed on the basis of a broad comparison between fossil palynofloras (by using their extant affinities) with modern ecological types.

1. Temperate Forests. About one half to three quarters of palynofloral assemblages from Li and Nong Ya Plong basins contain *Quercoidites* sp. 777, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Faguspollenites* sp. 845, *Alnipollenites verus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Caryapollenites simplex* Potonié

1960, *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953, *Pinuspollenites* sp. 1436, *Tsugaepollenites igniculus* Potonié ex Potonié 1958, *Piceapollenites alatus* Potonié 1931 and *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953. These assemblages are similar to spectra from modern temperate forests and unlikely to fit with any composition of a specific forest type as described by Wolfe (1979). However, these assemblages approximate or vary within a group of forests including Microphyllous Broad-leaved Evergreen, Notophyllous Broad-leaved Evergreen, Mixed Broad-leaved Evergreen and Deciduous, Mixed Broad-leaved Evergreen and Coniferous, and Mixed Mesophytic (Wolfe, 1979). This group contains some related taxa include Betulaceae, Fagaceae, Aceraceae, Juglandaceae and coniferous elements.

2. Paratropical Rain Forest (Wolfe, 1979). Some characteristic plant taxa of the Paratropical Rain Forest include *Alnus*, *Acer*, *Myrica*, *Rhus*, *Salix*, *Pinus*, *Podocarpus* and Dipterocarpaceae (Wolfe, 1979). Although this association is probably close to or approximates the Dipterocarpetum Pinetum-merkusii Forest type (Stott, 1975), this study differs from the latter by containing *Alnus*. This forest type is distributed in northernmost Thailand, Burma, Laos, Vietnam and southern China (Wolfe, 1979).

Palynological assemblages which approximate this modern type include, for example, Mae Moh sequence between sample numbers MM106-MM133 (Table 6-3). These assemblages containing related species are *Alnipollenites verus* Potonié 1931, *Aceripollis* spp., *Salixipollenites* cf. *S. discoloripites* Srivastava 1966, *Dipterocarpus* sp. 780, *Bursera* sp. 1427, *Pinuspollenites* sp. 1436 and *Podocarpidites ellipticus* Cookson ex Couper 1953. The taxa comprise approximately one tenth of the assemblages.

3. Dipterocarpetum Pinetum-merkusii (Stott, 1975). This type is dominated by *Pinus merkusii* and *Dipterocarpus obtusifolius* (and *Dipterocarpus tuberculatus* in some areas). Members of Fagaceae including *Castanopsis*, *Lithocarpus* and *Quercus* are dominant at higher elevations. This forest type occurs in northern Thailand and the Khorat Plateau, typically on ridges and mountains over 750 m. in altitude but in some areas found at lower altitudes (less than 200 m.).

Examples of palynological assemblages related to this modern type are found in the Mae Moh sequence between sample numbers MM136-MM147 (Table 6-3) in which related

species such as *Quercoidites* sp. 777, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Dipterocarpus* sp. 780 and *Pinuspollenites* sp. 1436 are present. The taxa make up approximately one tenth to one fifth of the assemblages. A few species occurring in the assemblages and not found in present Thailand, include *Faguspollenites* sp. 845, *Caryapollenites simplex* Potonié 1960, *Juglanspollenites verus* Raatz 1939 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958.

4. Upper Tropical Rain Forest (Bangkurdpol, 1981). Vegetation association of the Upper Tropical Rain Forest type comprises a great proportion of oaks and chestnuts (*Quercus*, *Castanopsis* and *Lithocarpus*), and interspersed with *Dipterocarpus*, *Podocarpus*, *Syzygium*, *Areca*, *Calamus* and *Cyathea*, amongst others. This forest type occupies an altitude of 600-900 m. and is distributed in Chantaburi region (eastern Thailand) and in the far south of Thai Peninsular (Yala, Narathiwat, and Trang regions). Rainfall in these regions exceeds 2,500 mm. per annum. This forest type may be similar to the Montane Oak Forest in the Malesian region (Morley, 1976).

Palynological assemblages from Krabi Basin (KP132 and KP135) which are similar to the Upper Tropical Rain Forest type contain some related species such as *Quercoidites* sp. 777, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960 and *Cyathidites minor* Couper 1953. The taxa make up approximately one third of the assemblages.

5. Mangrove Forest (Stott, 1975; Bangkurdpol, 1981). Vegetation association of the Mangrove Forest type is composed of *Rhizophora apiculata*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza*, *Bruguiera caryophylloides*, *Bruguiera parviflora*, *Bruguiera eriopetala*, *Ceriops tagal*, *Ceriops ruxburghiana*, *Avicennia officinalis*, *Avicennia marina*, *Sonneratia alba*, *Sonneratia griffithii*, *Sonneratia caseolaris*, *Excoecaria*, *Lumnitzera* and *Nypa fruticans*. Mangroves usually occur in the intertidal environments along estuaries of the rivers and muddy coastal environments where soil is mainly alluvial with high salinity. Present mangroves are distributed along the coastal regions of both the Gulf of Thailand and the Andaman Sea.

Palynological assemblages from the Gulf of Thailand which are similar to the modern Mangrove Forest type include, for example, the whole productive sequence of the Platong-11 Borehole and the Erawan 12-28 sequence between 1280.5-823.2 m. depth (Tables 4-4, 4-5). These assemblages contain some related species such as *Excoecaria* sp. 1404, *Zonocostites*

ramonae Germeraad *et al.* 1968, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Florschuetzia meridionalis* Germeraad *et al.* 1968, *Florschuetzia semilobata* Germeraad *et al.* 1968, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973 and *Avicennia* sp. 1492. The mangrove taxa make up approximately one half of the assemblages. Some species (for example, *Alnipollenites verus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Caryapollenites simplex* Potonié 1960 and *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Pinuspollenites* sp. 1436) are not mangrove indicators and were probably transported from some distance away and deposited in the mangrove environments.

In summary, a distribution of five palaeoecological types during mid-Tertiary in Thailand is shown in Figure 7-2 which indicates that Temperate Forests type is distributed throughout Thailand. Mangrove Forest type is limited to the southern Thailand.

7.3 Palaeoclimate

Thailand is situated mainly within the tropics (Figure 1-1), and thus, high influxes of pollen from plants preferring temperate climates including *Alnipollenites verus* Potonié 1931, *Caryapollenites simplex* Potonié 1960, *Faguspollenites* sp. 845, *Inaperturopollenites dubius* Thomson & Pflug 1953, *Juglanspollenites verus* Raatz 1939, *Momipites coryloides* Wodehouse 1933, *Piceapollenites alatus* Potonié 1931, *Tsugaepollenites igniculus* (Pot.) Potonié & Venitz 1934 during the Late Oligocene to Early Miocene (SIAM-1 Zone) suggest more temperate conditions in Thailand at this time. Most of these species no longer exist in Thailand but are native to East China and Europe. Some modern species of *Quercus*, *Castanea* and *Pinus*, however, are now confined to mountainous regions in northern and north-eastern Thailand. Most of the temperate palynofloras range through the Oligo-Miocene in both intermontane and coastal environments throughout Thailand. Some temperate palynofloras extend their occurrences during mid-Tertiary southward to Borneo (Muller, 1966, 1972; Germeraad *et al.*, 1968). In addition, Endo (1964) suggested warm temperate palaeoclimate from the evidence on megafloral fossils from Li Basin (Section 2.4.2).

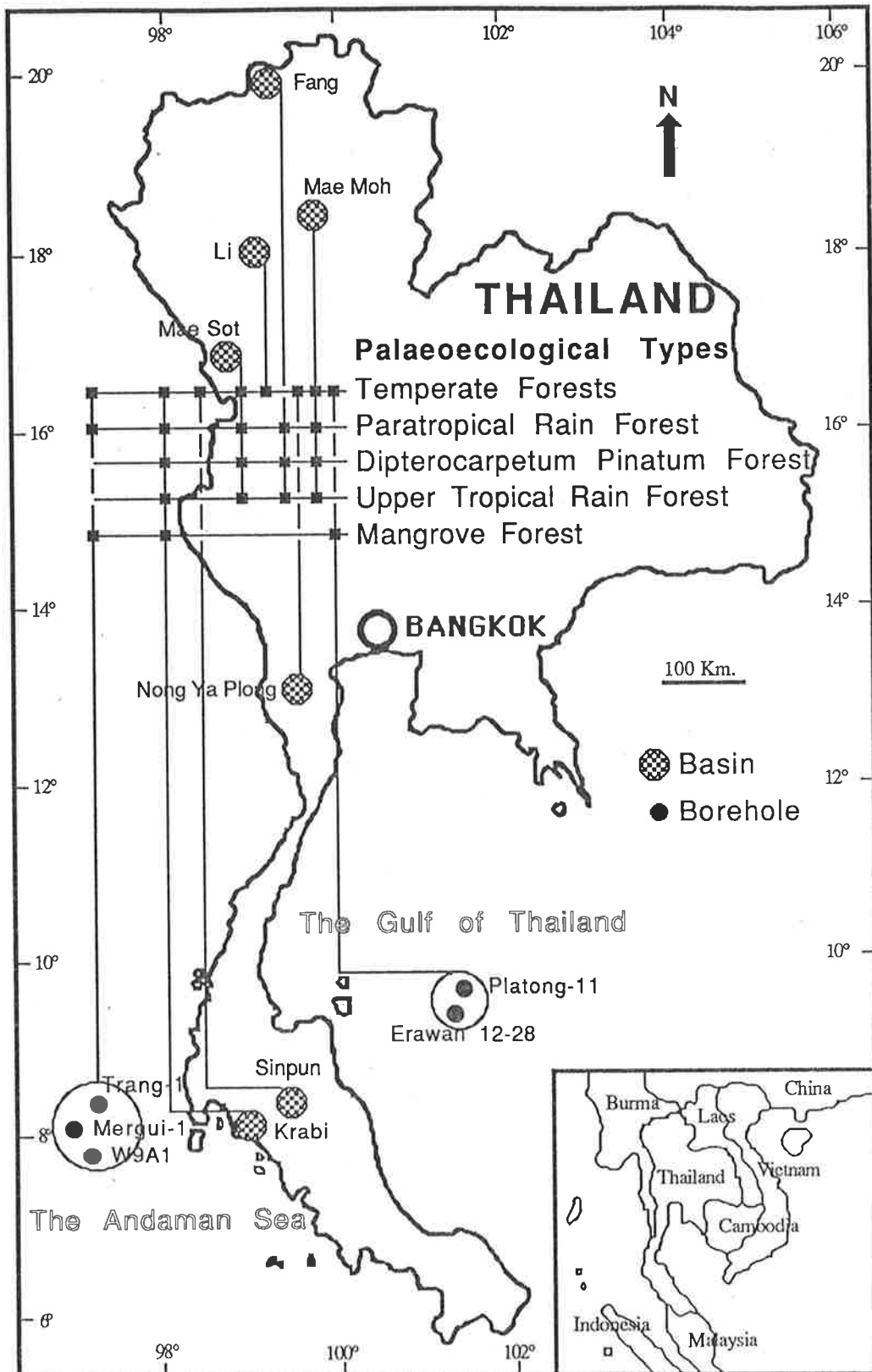
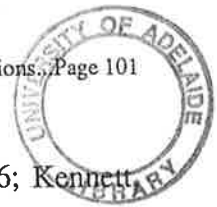


Figure 7-2. Map showing distributions of palaeoecological types.

Most species preferring tropical environments (including *Ammania* sp. 382, *Hopea* sp. 1299, *Florschuetzia levipoli* Germeraad et al. 1968, *Florschuetzia meridionalis* Germeraad et al. 1968, *Lagerstroemia* sp. 325, *Bombacacidites annae* Hammen ex Leidelmeyer 1966,

Margocolporites vanwijhei Germeraad *et al.* 1968, *Dipterocarpus* sp. 780, *Pandaniidites texus* Elsik 1968 and *Lanagiopollis nanggulanensis* Morley 1982) are lacking during the SIAM-1 Zone except for a few species that appear near the upper limit of the zone. Species preferring tropical environments and making their first appearances in the Early Miocene include *Avicennia* type 1492, *Ammania* type 381, *Bombacacidites annae* Hammen ex Leidelmeyer 1966, *Dipterocarpus* sp. 780, *Florschuetzia levipoli* Germeraad *et al.* 1968, *Lagerstroemia* type 325, *Lanagiopollis nanggulanensis* Morley 1982, *Pandaniidites texus* Elsik 1968 and *Zonocostites ramonae* Germeraad *et al.* 1968. Thus, the Early to Middle Miocene palynological assemblages (SIAM-2 Zone) exhibit decreasing temperate elements but increasing frequencies of tropical elements. The Mae Moh sequence (LM2813S Borehole) which yields a good palynostratigraphic record, is selected to illustrate this trend (Figure 7-3). Species indicating temperate climate are: *Faguspollenites* sp. 845, *Caryapollenites simplex* Potonié 1960, *Alnipollenites verus* Potonié 1931, *Momipites coryloides* Wodehouse 1933, *Juglanspollenites verus* Raatz 1939, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953, *Piceapollenites alatus* Potonié 1931 and *Tsugaepollenites igniculus* Potonié ex Potonié 1958. Some transitional species, mainly preferring temperate environments (with a few extant species still existing in tropical regions), are *Quercoidites* sp. 777, *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960, *Aceripollis* spp., *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953 and *Pinuspollenites* sp. 1436. These transitional species are not included with the temperate indicators on Figure 7-3. Species preferring tropical climate include: *Ammania* sp. 382, *Hopea* sp. 1299, *Lagerstroemia* sp. 325, *Bombacacidites annae* Hammen ex Leidelmeyer 1966, *Margocolporites vanwijhei* Germeraad *et al.* 1968, *Dipterocarpus* sp. 780, *Pandaniidites texus* Elsik 1968 and *Lanagiopollis nanggulanensis* Morley 1982. The species preferring tropical climate increase in the middle sequence (MM109-MM133) but become less frequent and then disappear at the top of the sequence (MM148-MM149). This disappearance is likely to coincide with climatic cooling and/or ending of lacustrine-swamp environments.

This study suggests that the palaeoclimate of Thailand was temperate in Late Oligocene times but warmed to more tropical conditions during Early to Middle Miocene times. The results from this study agree with the general trend of global cooling during the Late Oligocene and with a warming period in the Early-Middle Miocene (Savin *et al.*, 1975; Wolfe, 1978, 1985;



Woodruff *et al.*, 1981; Keigwin & Keller, 1984; Woodruff, 1985; Frakes, 1986; Kennett, 1986).

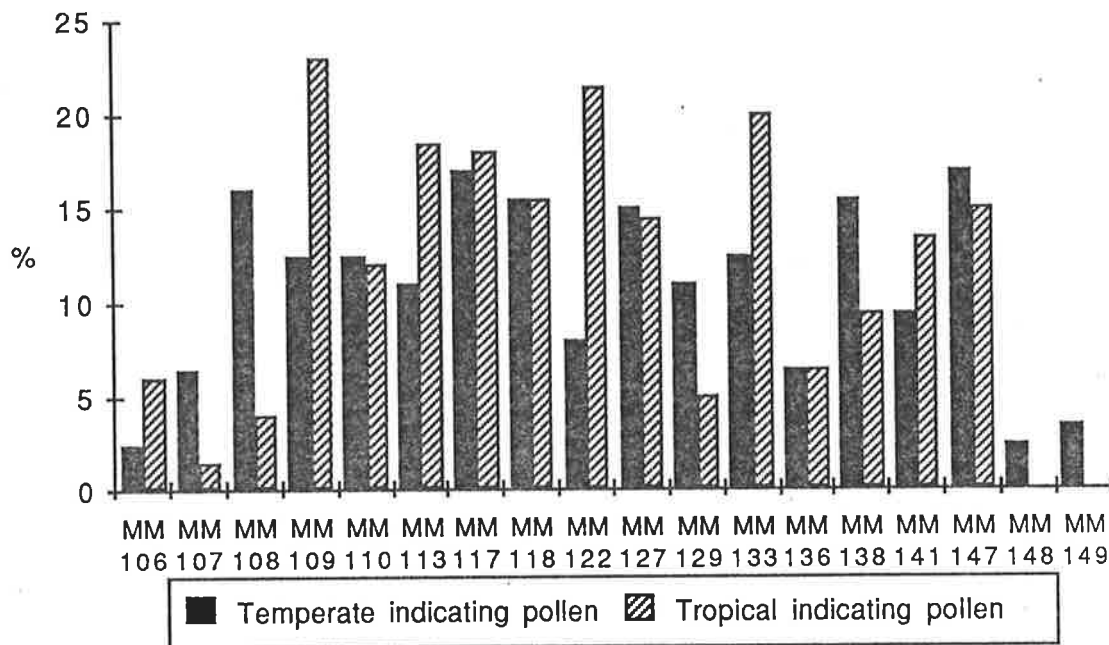


Figure 7-3. Proportions of temperate and tropical indicating pollen from the LM2813S Borehole, Mae Moh Basin (See: Table 6-3 for sample depth).

7.4 Palaeoenvironment

The studied basins can be divided into marginal marine and non-marine environments of deposition. Palynomorphs preferring marine environments have been recorded from the Andaman Sea, Krabi Basin and the Gulf of Thailand. The appearances of mangrove palynofloras such as *Florschuetzia levipoli* Germeraad *et al.* 1968, *Florschuetzia meridionalis* Germeraad *et al.* 1968, *Avicennia* sp. 1492, *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973, *Cephalomappa* sp. 590, *Dicolpopollis kalewensis* Potonié ex Potonié 1966, *Xylocarpus* sp. 1526 and *Zonocostites ramonae* Germeraad *et al.* 1968 suggest coastal or marginal marine depositional environments. Only mangrove palynofloras (without dinoflagellates) appearing during Early to Middle Miocene in the Krabi Basin and the Gulf of Thailand, suggest coastal or estuarine environments. Occurrences of dinoflagellates in

association with mangrove palynofloras dominate the Andaman Sea sequences during Early to Middle Miocene, and suggest marginal marine environments.

Non-marine environments lacking dinoflagellates and mangrove palynofloras, include Sin Pun, Nong Ya Plong, Mae Moh, Mae Sot, Li and Fang basins. Non-marine sequences are generally divided into three parts. Upper and lower sequences containing semi-consolidated sandstone and conglomerate, indicate fluvial environments and are palynologically unproductive. The middle sequence comprises claystone, mudstone, shale, siltstone and coal, implying a largely lacustrine environment with interbedded swamp and fluviolacustrine sediments. It is only the middle sequence which is palynologically productive. The assemblages containing high proportions and diversities of pollen and the algae *Pediastrum* spp. with low frequencies of spores, suggest lacustrine environments and probably reflect regional palynofloral spectra. It appears that the lacustrine environment also favoured deposition of wind-transported bisaccate pollen (*Pinuspollenites* sp. 1436 and *Piceapollenites alatus* Potonié 1931). Assemblages dominated by spores, with low frequencies and diversity of pollen, and the disappearance (or rare occurrences) of *Pediastrum* spp. in the coal and carbonaceous mudstones, suggest swamp environments dominated by local palynofloral spectra (Figure 7-4).

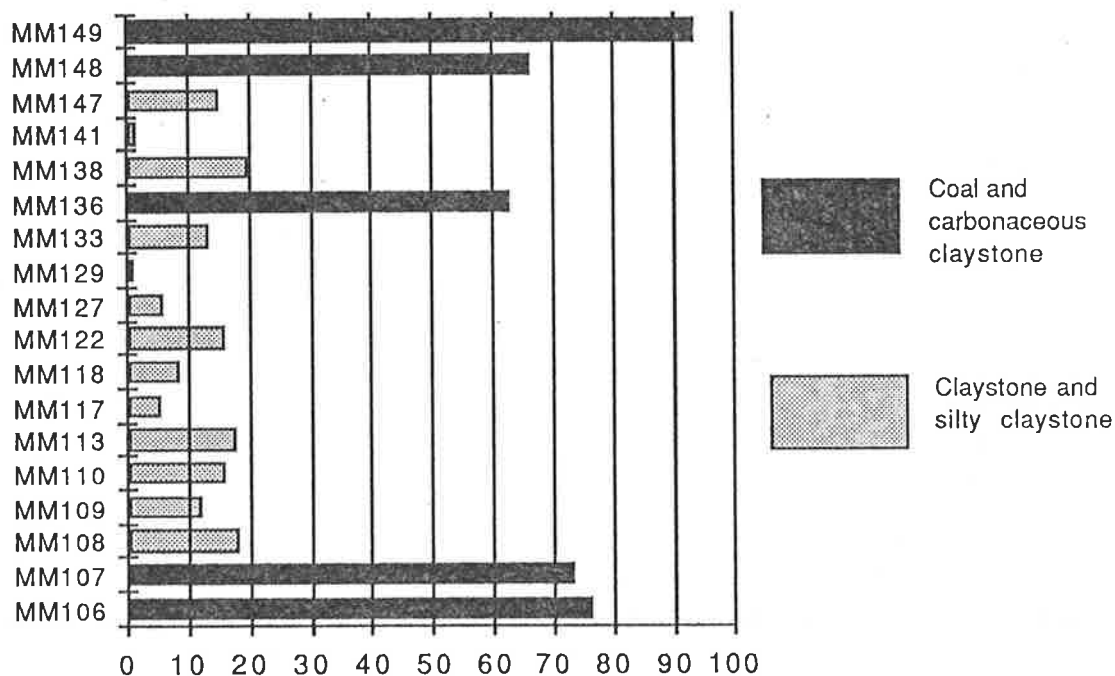


Figure 7-4. Relative percentages of spores from Mae Moh sequence (LM2813S Borehole) showing relationship to coal and carbonaceous samples, and swamp depositional environments.

7.5 Megafloras and Palynofloras

Even though plant fossils both megafloras and palynofloras have been useful for biostratigraphy, palaeoenvironment, palaeoecology and palaeoclimate but comparative study and relationship between megafloras and palynofloras are uncommon. However, a comparison between taxa recorded of both megafloras and palynofloras from Li Basin is attempted in this study (Table 7-1).

Megafloras found from Li Basin, northern Thailand have been reported by Endo (1964, 1966). This study provides a list of palynofloras found from the same basin. Although precise stratigraphic relationship between samples are not known nevertheless, the palynological result shows that seventy per cent (or seven genera including *Alnus*, *Fagus*, *Quercus*, *Salix*, *Glyptostrobus*, *Sequoia* and *Taxodium*) of the recorded megafloras is represented (Table 7-1). In addition, another thirty three species are also reflected by the palynological record. Moreover, the whole taxonomic group of pteridophytes is missing in the megafossil records but is found in the palynological record. These data show that the microfossil record allows for more precise biostratigraphic, palaeoecological, palaeoclimatic and biofacies reconstructions

Table 7-1. Comparative recorded taxa from Li Basin, northern Thailand, between megaflores, palynoflores and modern affinity.

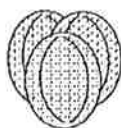
MEGAFLORAS (Endo, 1964, 1966)	MODERN AFFINITY	PALYNOFLORAS (This Study)
ANGIOSPERMS		
Alnus thaiensis	Alnus	Alnipollenites verus
Carpinus (?) sp.	Carpinus	
Fagus feroniae	Fagus	Faguspollenites sp. 845
Ficus eowithtiana	Ficus	
Quercus spp.	Quercus	Quercoidites sp. 777
Salix ? sp.	Salix	Salixipollenites cf. S. discoloripites
Sparganium thaiensis	Sparganium	
	Acer	Aceripollis sp. 853
	Carya	Caryapollenites simplex
	Castania-Castanopsis	Cupuliferoipollenites pusillus
	Ilex	Ilexpollenites iliacus
	Engelhardia	Momipites coryloides
	Graminea	Monoporopollenites gramineoides
	Pterocarya	Polyatriopollenites stellatus
	Sapotaceae	Tetracolporopollenites sapotoides
	Alchornea	Psilatricolporites operculatus
	unkown	Florschuetzia sp. 647
	unkown	Periporopollenites stigmaticus
	unkown	Rhoipites cf. R. retiformis
	unkown	Rhoipites sp. 1207
	unkown	Rhoipites sp. 1263
	unkown	Rhoipites sp. 847
	unkown	Tricolpites sp. 258
	unkown	Tricolpites sp. 854
	unkown	Tricolporites cf. T. valvatus
GYMNOSPERMS		
Glyptostrobus europaeu	Cupressaceae	Inaperturopollenites dubius
Sequoia langsdorfii	Taxodiaceae	Inaperturopollenites dubius
Taxodium thaiensis	Taxodiaceae	Inaperturopollenites dubius
	Picea	Piceapollenites alatus
	Pinus	Pinuspollenites sp. 1436
	Podocarpus	Podocarpidites ellipticus
	Tsuga	Tsugapollenites igniculus
PTERIDOPHYTES		
	Hymenophyllum	Baculatisporites primarius
	Dicranopteris	Cyathidites minor
	Dennstaedtia	Foveotriletes margaritae
	Niphidium	Laevigatosporites ovatus
	Ceratopteris	Magnastriatites grandiosus
	Pteris	Polypodiaceoisporites spp.
	Polypodiaceae	Polypodiisporites alienus
	Polypodiaceae	Polypodiisporites pohangensis
	Lycopodium	Retitriletes douglasii
	Osmunda	Rugulatisporites quintus
	unknown	Undulatisporites unduliradius

7.6 Biogeography

Thailand is biogeographically the only landmass with links between continental Asia and Malesia. During the Tertiary, Thailand was influenced by northern temperate palynofloras but whether there was any connection with Australian elements is uncertain. Some evidence related to the latter is discussed below.

Firstly, a tricolporate pollen type examined under light microscope and assigned to *Tricolporites prolata* Cookson 1947 (first described from a sample from Antarctica) was also examined under SEM, the latter revealing that it should be assigned to the *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960 and not to *Tricolporites prolata* Cookson 1947. Secondly, a triporate pollen which was first thought to have affinity with *Casuarina* pollen was examined under both SEM and LM and then assigned to *Myricipites dubius* Wodehouse 1933 and not to *Casuarina*. Dispersed *Casuarina* occurs commonly in the Tertiary of Australia and Ninetyeast Ridge (Deep Sea Drilling Project Sites 214 and 254; Kemp & Harris, 1977) but no record has confidently confirmed the Occurrence in Thailand. Thirdly, an inaperturate *Aruacaria* pollen type which appears commonly in the Late Oligocene of Thailand has been examined under SEM and appears to have a closer affinity with Taxodiaceae-Cupressaceae pollen type, *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953. Lastly, it should be noted that *Nothofagus* is mainly distributed in the Southern Hemisphere (Raven and Axelrod, 1972; Briggs, 1987). However, only one sample from Fang Basin yielded *Nothofagidites* sp. but later a reprocessing check from the same original rock sample yielded no *Nothofagidites* sp. It was assumed that the first sample preparation was contaminated by local residues.

In conclusion, this study shows that there is little evidence to suggest Thai-Australian floral connections during the mid-Tertiary.



APPENDIX A

A NEW TECHNIQUE FOR SEM PALYNO-PREPARATION

Introduction. Scanning Electron Microscopy (SEM) has been applied to palynological studies for two decades (Riegel, 1968; Muir, 1970). Its use allows detailed studies of both miospore sculpture and structure, and some advocate its extensive use (Batten, 1986). Virtually, it has become a conventional tool for palynologists. SEM research on modern pollen and spores is far more common than that of palaeopalynology because of availability of material. Modern pollen studies often deal with pollen from homogeneous a source (e.g. anther) and consequently preparation is simpler. By contrast, fossil palynomorph assemblages are often very heterogeneous, key species may be rare, and subsequent preparation is time consuming. Consequently, a simpler technique for both SEM and Light Microscopy (LM) is highly desirable.

Three types of SEM preparation methods for fossil palynomorphs have been suggested including dry isolation, wet isolation, and strew mounting with grid.

For dry isolation, residues are dehydrated with a volatile solution such as ethanol or acetone. The dry residues are searched under LM for desired miospores, then the selected specimens are transferred by using micromanipulator and are mounted on either a coverslip or SEM stub, viz., Leffingwell and Hodgkin (1971). Location of specimens during SEM examination is encountered into preparation, for example, Foster (1979) used the dry technique and placed specimens within the apices of a hexagon drawn on a coverslip in Indian ink.

Wet isolation, uses a micropipette to draw the desired miospores from either water or a mixture of water and glycerine under light microscope (LM), and then isolate the residue on coverslip or screen. Filatoff (1975), for example, suspended a small amount of residue with distilled water in a petri dish, picked up the desired grains by micropipette, and then deposited them on a coverslip. He claimed this technique was more efficient than the use of mechanical devices. Tomb (1982) used the tapering micropipette to pick up the desired specimens from a

mixture of glycerine and ethanol. The specimens are placed near the edge of the Nucleopore filter chips which are adhered with silver paste to the SEM stub.

The strew mount with grid was the first used by Liang (1974). He designed a thin nickel grid (11 mm. in diameter) which is used to relocate specimens for later studies. The grid is fixed by adhesive to a stub and then an aqueous suspension of residue is placed on a stub and allowed to dry. Later, Hughes *et al.* (1979) redesigned a new type of grid, Cambridge Geology Mark 2, with more location markers. The disadvantage of the technique, however, is that it does not allow LM examination either pre and post SEM examination. More recently, Zippi (1987) drew a grid pattern on a coverslip used for SEM strew mounting.

Yet another technique has been developed to include Transmission Electron Microscopy (TEM) for multiple examinations (LM-SEM-TEM) of a single grain. This method might be studied in different orders including LM-TEM-SEM sequence (Rowley and Járαι-Komlódi, 1976) or LM-SEM-TEM sequence (Daghlian, 1982). This method provides details of all aspects of a single grain but it is more complicated and requires considerable preparation time.

Materials and Method. During routine strew slide making, material can also be prepared for SEM as follows:

1. **Residue Mixture.** Palynological residues are admixed with an aqueous solution of polyvinyl alcohol (PVA). The PVA is diluted to approximately 0.004% W/V in distilled water. The PVA film provides an adequate adhesive for residues when it is dry. At this concentration, the PVA does not interfere with sculptural details.

2. **Isolation and Dehydration.** To isolate residue effectively, a suitable proportion between residue and PVA should be tested. A droplet of residue in PVA suspension is placed on a glass coverslip, which is warmed on heating plate (about 50 °C) until the residue is dry.

3. **Specimen Identification.** The coverslip is transferred, and temporarily stuck, onto a glass slide. Selected specimens are then searched under LM. The desired specimen is located by placing a microgrid over it using low magnification objectives, adjusting the microgrid to fit over the grain. Also, search is undertaken for other specimens which appear in other divisions and nearby the microgrid. More than one microgrid can be placed on a coverslip but too many may lead to confusion. Record the grid number and the division.

Four different types of microgrids, all of which are 3 mm. in diameter, have been tested. Two of these (square 50 and 75 mesh) are plain microgrids without alphabet division markers, and also are cheaper (Plate 1, Figures 4-6). Divisions are numbered by making a cut (using a scalpel) at any outer division bar, which is then numbered as the first division (Plate 1, Figure 5). Numbering system can be customized to the user. Other two types tested are finder grids, Maxtaform H-2 (Plate 1, Figures 7, 8, & 10) and H-6 (Plate 1, Figure 9). They are about three to five times more expensive than the plain microgrids but easier to search because they are marked more accurately (Plate 1, Figures 7-10).

After microgrids have been applied to selected specimens, the microgrids are numbered and arrows displaying working routes between microgrids can be drawn with a suitable marker (Plate 1, Figures 1-3).

4. Transfer Coverslip. The coverslip is carefully transferred and temporarily stuck onto a stub. A drop of silver dag is placed between coverslip and stub to avoiding charging problems. Gold-palladium is usually good enough for coating. If a charging problem is experienced, recoating of the specimen may be required. However, a thick coating will adversely affect LM re-examination.

5. SEM Examination. Specimens may be examined under SEM following the numbering sequence and arrow markers (Plate 1, Figures 1-3). The designated specimen can be easily searched. Residues in other divisions and around microgrids may also be observed for "beneficial grains" which should be kept close to microgrids for relocation. The specimen is retained on the stub until examination is completed.

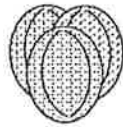
6. Preservation of Specimens. The examined specimens may be preserved as either on single coverslip or double coverslip mountings. To mount a single coverslip, the specimen coverslip is removed from stub and inverted to preserve in Eukitt mountant (manufactured by Carl Zeiss Pty. Ltd.) which is dropped onto a glass slide. To make double coverslip mounting, the specimen coverslip is inverted on Eukitt which is dropped on a new coverslip. During this step care should be taken to control the medium thickness because it influences the working distance under LM at high magnification.

Single coverslip mounting is an easier preparation than double coverslip mounting, but specimens of double coverslip mounting may be turned over for LM re-examination.

Discussion. Previous SEM preparation techniques have devoted too much time and effort on isolation, specimen location and adhesion. The present technique is simpler and more effective. The dilute PVA film provides good adhesion between specimens and coverslip. The finder grids are easier to locate the grains than those of plain microgrids. Adhesion between microgrids and coverslip or coverslip and stub may use common stationery glue.

The technique used during the course of this study was developed because it was difficult to observe small grains and to determine their sculpture using only the LM. It can also lead to a development of an extensive and routine SEM study producing a valuable so-called "SEM Database" The database is composed of SEM micrographs and the same specimens are preserved for LM re-examination. This study has recorded over 1500 SEM photographs of which most specimens are preserved for LM re-examinations.

Two problems encountered during the specimen preparation, were a grid bar overlapping a desired palynomorph (Plate 1, Figures 10 & 11), and glue overspread on a trilete spore (Plate 1, Figure 12).



APPENDIX B

ALPHABETICAL LIST

OF THE STUDIED SPECIES

- Aceripollis* sp. 727
- Aceripollis* sp. 842
- Aceripollis* sp. 853
- Aceripollis* sp. 1175
- Alnipollenites verus* Potonié 1931
- Ammania* sp. 382
- Avicennia* sp. 1492
- Baculatisporites primarius* Wolff ex Thomson & Pflug 1953
- Bombacacidites annae* Hammen ex Leidelmeyer 1966
- Bursera* sp. 1427
- Cardamine* sp. 323
- Caryapollenites simplex* Potonié 1960
- Cephalomappa* sp. 590
- Cupuliferoipollenites pusillus* Potonié ex Potonié 1960
- Cyathidites minor* Couper 1953
- Cyperaceapollis neogenicus* Krutzsch 1970
- Dacrydiumites florinii* Cookson & Pike ex Harris 1965
- Dicolpopollis kalewensis* Potonié ex Potonié 1966
- Dipterocarpus* sp. 780
- Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968
- Excoecaria* sp. 1404
- Faguspollenites* sp. 845
- Florschuetzia levipoli* Germeraad *et al.* 1968

- Florschuetzia meridionalis* Germeraad *et al.* 1968
Florschuetzia semilobata Germeraad *et al.* 1968
Florschuetzia sp. 647
Florschuetzia trilobata Germeraad *et al.* 1968
Foveotriletes magaritae Hammen ex Germeraad *et al.* 1968
Hopea sp. 1299
Ilexpollenites iliacus Potonié 1960
Inaperturopollenites dubius Potonié & Venitz ex Thomson & Pflug 1953
Juglanspollenites verus Raatz 1939
Laevigatosporites ovatus Wilson & Webster 1946
Lagerstroemia sp. 1459
Lanagiopollis nanggulanensis Morley 1982
Magnastriatites grandiosus Kedves & Porta emend. Dueñas 1980.
Margocolporites vanwijhei Germeraad *et al.* 1968
Momipites coryloides Wodehouse 1933
Monoporopollenites gramineoides Meyer 1956
Myricipites dubius Wodehouse 1933
Myrtacidites mesonesus Cookson & Pike 1954
Pandaniidites texus Elsik 1968
Periporopollenites stigmosus Potonié ex Thomson & Pflug 1953
Piceapollenites alatus Potonié 1931
Pinuspollenites sp. 1436
Podocarpidites ellipticus Cookson ex Couper 1953
Polyadopollenites myriosporites Cookson ex Partridge in Stover & Partridge 1973
Polyatriopollenites stellatus Potonié & Venitz ex Pflug 1953
Polypodiaceoisporites retirugatus Muller 1968
Polypodiaceoisporites sp. 125
Polypodiisporites alienus Potonié emend. Khan & Martin 1971
Polypodiisporites pohangensis Takahashi 1979
Polypodiisporites usmensis Hammen emend. Khan & Martin 1971

Psilatricolporites operculatus Hammen & Wymstra 1964

Quercoidites sp. 777

Radermachera sp. 1546

Retitriletes douglasii Dettmann 1986

Rhoipites cf. *R. retiformis* Pocknall & Mildenhall 1984

Rhoipites sp. 847

Rhoipites sp. 1207

Rhoipites sp. 1263

Rhoipites sp. 1267

Rhoipites sp. 1345

Rugulatisporites quintus Pflug & Thomson in Thomson & Pflug 1953

Salixipollenites cf. *S. discoloripites* Srivastava 1966

Spinizonocolpites prominatus (McIntyre) Stover & Evans 1973

Tetracolporopollenites sapotoides Pflug & Thomson in Thomson & Pflug 1953

Tiliaepollenites cf. *T. indubitabilis* Potonié 1931

Tricolpites sp. 258

Tricolpites sp. 854

Tricolpites sp. 1366

Tricolporites cf. *T. valvatus* Harris 1972

Tricolporopollenites sp. 810

Tricolporopollenites sp. 862

Tricolporopollenites sp. 908

Triorites sp. 788

Triorites sp. 1373

Trivestibulopollenites betuloides Pflug in Thomson & Pflug 1953

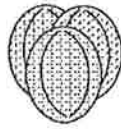
Tsugaepollenites igniculus Potonié ex Potonié 1958

Tubulifloridites antipodica Cookson ex Potonié 1960

Undulatisporites unduliradius Takahashi in Takahashi & Shimono 1982

Xylocarpus sp. 1526

Zonocostites ramonae Germeraad *et al.* 1968



APPENDIX C

SYSTEMATIC DESCRIPTIONS*

1 PTERIDOPHYTES

Genus: *Baculatisporites*

Pflug & Thomson in Thomson & Pflug 1953

Type Species: *Baculatisporites primarius* Wolff ex Thomson & Pflug 1953

Selected Synonymy:

1953 *Baculatisporites* Pflug & Thomson in Thomson & Pflug, p. 56.

Baculatisporites primarius

Wolff ex Thomson & Pflug 1953

Plate 2, Figure 1.

Selected Synonymy:

1934 *Sporites primarius* Wolff, p. 66, pl. 5, fig. 8.

1953 *Baculatisporites primarius* Wolff ex Thomson & Pflug, p. 56, pl. 2, fig. 51.

1966 *Osmunda cinnamomites*; Martin & Rouse, p. 189, pl. 4, figs. 25 & 27.

Longest Dimension: 48-68 μm . (7 specimens).

Distribution: This species occurs from Late Miocene to Early Pliocene of the Skonun Formation, Queen Charlotte Islands, British Columbia (Martin & Rouse, 1966); Late Miocene-Early Pliocene of the Indener strata, Rhenish brown coal region, western West Germany (Mohr, 1984); Late Oligocene and Early Miocene of Peninsular Thailand (this study).

Botanical Affinity: The fossil spore is comparable with the spores of extant species of: *Osmunda cinnamomea* (Martin & Rouse, 1966) and *Hymenophyllum fucoides*, Hymenophyllaceae

* See the Section 3.5 for a discussion on the approach and introduction to Systematic Palynology.

(Tryon & Tryon, 1982, p. 103-113, figs. 11.23-11.24). *Hymenophyllum* is a widely distributed pantropical genus, with some extensions into north and south temperate regions (Tryon & Tryon, 1982).

Remarks: The sculpture under SEM of this species is fairly uniform bacula, about 1µm. long and apart.

Genus: *Cyathidites* Couper 1953

Type Species: *Cyathidites australis* Couper 1953

Selected Synonymy:

1953 *Cyathidites* Couper, p. 27.

Distribution: This genus has been recorded from the Jurassic of Australia. It occurs world-wide in Mesozoic and Tertiary (Dettmann, 1963; Engelhardt, 1964; Hekel, 1972; Srivastava, 1975; Salujha *et al.*, 1980; Sun *et al.*, 1981).

Remarks: See the discussions on comparisons and affinities in Dettmann (1963).

***Cyathidites minor* Couper 1953**

Plate 2, Figure 2.

Selected Synonymy:

1953 *Cyathidites* Couper, p. 27, pl. 2, fig. 11.

See Dettmann, 1963, p. 22-23.

Longest Dimension: 36-54 µm. (11 specimens).

Distribution: This species occurs rarely to commonly from Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The possible affinity of the *Cyathidites* spores with extant spores of cyatheaceous and dicksoniaceaceous ferns has been mentioned by Couper (1953, 1958) and Dettmann (1963). However, this fossil spore is also comparable with the spore of extant *Dicranopteris nervosa*, Gleicheniaceae which is a widely distributed tropical and subtropical genus (Tryon & Tryon, 1982, p. 96, fig. 10.9).

Remarks: The sculpture under SEM of this species shows that the exine is psilate. Although size range of a few spores of this species overlaps with *Cyathidites australis* Couper 1953 but differentiation is not attempted in this study.

Genus: *Foveotriletes* Potonié 1956

Type Species: *Foveotriletes scrobiculatus* Potonié 1956

Selected Synonymy:

1956 *Foveotriletes* Potonié, p. 43.

1956 *Foveotriletes* Hammen, pl. 3, *nom. nud.*

Foveotriletes magaritae

Hammen ex Germeraad *et al.* 1968

Plate 2, Figure 3.

Selected Synonymy:

1954 *Triletes magaritae* Hammen, p. 102, pl. 17.

1968 *Foveotriletes magaritae* Hammen ex Germeraad *et al.*, p. 286, pl. 1, figs. 1 & 2.

Longest Dimension: 40-50 μm . (6 specimens).

Distribution: This species occurs from Late Cretaceous to Palaeocene of Nigeria and northern South America (Germeraad *et al.*, 1968); rarely from Early to Middle Miocene of Mae Moh Basin, northern Thailand (this study).

Botanical Affinity: The irregular foveolate character of this fossil trilete spore is comparable with the spores of the extant *Dennstaedtia smithii*, *Dennstaedtieae* (Tryon & Tryon, 1982, p. 377-383; fig. 55.12).

Remarks: The sculpture under SEM of this species is irregularly microperforate on the exine surface; foveolae vary from circular to elongate and are less than 1 μm . long.

Genus: *Laevigatosporites* Ibrahim 1933

Type Species: *Laevigatosporites vulgaris* Ibrahim 1933

Selected Synonymy:

1933 *Laevigato-sporites* Ibrahim, p. 39.

1944 *Laevigatosporites Ibrahim* emend. Schopf *et al.*, p. 36.

See Srivastava, 1975, p. 130.

Distribution: The genus has been recorded from Devonian to Recent and has a cosmopolitan distribution (Dettmann, 1963; Srivastava, 1971).

Botanical Affinity: Srivastava (1971) pointed out "It is difficult to assign any definite botanical affinity to *Laevigatosporites*. Many extant fern genera produce spores with a smooth endospore and a sculptured perispore which is easily lost. Thus, often similar forms may not be even closely related."

***Laevigatosporites ovatus* Wilson & Webster 1946**

Plate 2, Figures 4 & 5.

Selected Synonymy:

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

See Dettmann, 1963, p. 86; Gaponoff, 1984, p. 78.

Longest Dimension: 29-60 μm . (12 specimens).

Distribution: This species is rare to common and ranges from Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: This fossil spore is comparable with the spore of extant *Niphidium* spp. and *Platyserium andinum*, Polypodiaceae (Tryon & Tryon, 1982, p. 727-743; figs. 112.8, 112.10, 115.8).

Remarks: The exine is psilate under SEM.

Genus: *Magnastriatites* Germeraad *et al.* 1968

Type Species: *Magnastriatites grandiosus* Kedves & Porta emend. Dueñas 1980

Selected Synonymy:

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

Remarks: Dueñas (1980) claimed that the species *Magnastriatites howardii* Germeraad *et al.* 1968 and *Cicatricosisporites grandiosus* Kedves & Porta 1963 are identical and reassigned the type species to *Magnastriatites grandiosus* Kedves & Porta emend. Dueñas 1980.

Magnastriatites grandiosus

Kedves & Porta emend. Dueñas 1980.

Plate 3, Figures 1-3.

Selected Synonymy:

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

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

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

Longest Dimension: 50-70 μm . (8 specimens).

Distribution: This species ranges from Oligocene to Recent in pantropical regions (Germeraad *et al.*, 1968). It also occurs in the Tertiary of the South China Sea (Sun *et al.*, 1981); and in the Miocene throughout Thailand (this study).

Botanical Affinity: The fossil spores resemble the spore of extant *Ceratopteris thalictroides*, Pteridaceae (Tryon & Tryon, 1982, p.316, figs 44.9-44.10; Germeraad *et al.*, 1968, p. 288-290, pl. 4, fig. 1). The extant species is a tropical-subtropical fresh-water fern (Germeraad *et al.*, 1968, p. 290).

Remarks: The sculpture under SEM of this species shows ribs and furrows on the distal surface; there are four sets of ribs, each set comprises about five parallel ribs; ribs are smooth and 4-7 μm . wide; furrows are 5-10 μm . wide; proximal surface is smooth.

Genus: *Polypodiaceosporites* Potonié ex Potonié 1956

Type Species: *Polypodiaceosporites speciosus* Potonié ex Potonié 1956

Selected Synonymy:

1951 *Polypodiaceosporites* Potonié, p. 136, nom. nud.

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

***Polypodiaceosporites retirugatus* Muller 1968**

Plate 2, Figures 7-10.

Selected Synonymy:

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

Longest Dimension: 32-52 μm . (5 specimens).

Distribution: This species and other similar spores have been recorded from the Late Cretaceous into Tertiary of Europe and Asia (Muller 1968; Sun *et al.*, 1981; Mohr, 1984; Huang & Huang 1984). It occurs from the Middle Miocene of Mae Moh Basin, northern Thailand (this study).

Botanical Affinity: Muller (1968) considered this fossil spore to be comparable with spores of the extant *Pteris mohasiensis*, Pteridaceae.

Remarks: Under SEM of this species possesses a smooth cingulum and verrucae on the proximal surface; verrucae are circular to oval, 1-4 μm . long.

***Polypodiaceosporites* sp. 125**

Plate 2, Figures 11 & 12.

Description: Spores trilete, cingulate. Amb triangular with rounded apices. Sculpture irregularly rugu-verrucate on proximal side, some isolated verrucae but others coalesced forming rugulae; verrucae are 1-2 μm . wide; retrirugulate on distal side. Cingulum are 3-4 μm . wide, smooth at radial regions but with irregular bacula on the interradian regions. Laesurae extend onto cingulum.

Longest Dimension: 32-46 μm . (4 specimens).

Distribution: This species occurs from the Late Oligocene of Li Basin, northern Thailand (this study).

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

Genus: *Polypodiisporites*

Potonié emend. Khan & Martin 1971

Type Species: *Polypodiisporites favus* Potonié 1956

Selected Synonymy:

1933 *Polypodiisporites* Potonié in Potonié & Gelletich, p. 524.

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

See Srivastava, 1971, p. 262; Frederiksen, 1980, p. 28.

Remarks: Khan & Martin (1971) proposed a combination of the three fossil sporomorph genera including *Polypodiisporites*, *Polypodiidites* and *Verrucatosporites*, which are based on slight

variation of exine sculpture, into the one form genus *Polypodiisporites* emend. The genus *Polypodiisporites* Potonié emend. Khan & Martin 1971 is applied in this study.

Polypodiisporites alienus

Potonié emend. Khan & Martin 1971

Plate 3, Figure 5.

Selected Synonymy:

1953 *Verrucatosporites alienus* Potonié, p. 59, pl. 3, fig. 47.

1966 Dennstaedtiaceae-Polypodiaceae form 2; Martin & Rouse, p. 187-188, pl. 3, fig. 21-22.

1971 *Polypodiisporites alienus* Potonié emend. Khan & Martin, p. 478, pl. 2, fig. 13.

1984 *Verrucatosporites alienus* Krutzsch; Mohr, p. 52, pl. 5, figs. 5, 6.

See Frederiksen, 1980, p. 28.

Longest Dimension: 40-66 μm . (9 specimens).

Distribution: This species and other similar spores have been recorded from the Tertiary of North America, Europe and Australia (Martin & Rouse, 1966; Hekel, 1972; Mohr, 1984). It occurs rarely to commonly from Late Oligocene to Miocene throughout Thailand (this study).

Botanical Affinity: The fossil spore resembles spores from some species of extant Dennstaedtiaceae and Polypodiaceae (Martin & Rouse, 1966).

Remarks: The sculpture under SEM of this species shows both surfaces verrucate; verrucae on the proximal view are approximately circular and 5-8 μm . in diameter.

Polypodiisporites (Polypodiidites) pohangensis

Takahashi 1979

Plate 3, Figure 4.

Selected Synonymy:

1979 *Polypodiidites pohangensis* Takahashi in Takahashi & Kim, p. 25, pl. 1, fig. 22; pl. 2, fig. 1.

Longest Dimension: 45-70 μm . (4 specimens).

Distribution: This species occurs from Miocene formations in the Yeoungill Bay District, Korea (Takahashi & Kim 1979); very rarely from the Middle Miocene of Fang Basin, northern Thailand (this study).

Botanical Affinity: The fossil spore resembles spores from some species of extant Polypodiaceae (Takahashi & Kim, 1979).

Remarks: The *Polypodiidites pohangensis* Takahashi 1979 is a monolete spore, bean-shaped in lateral view, with verrucate sculpture; verrucae are round and less than 1 μm high. Thus this species can be recombined with the genus *Polypodiisporites* Potonié emend. Khan & Martin 1971.

Polypodiisporites usmensis

Hammen emend. Khan & Martin 1971

Plate 3, Figure 6.

Selected Synonymy:

1956 *Verrumonoletes usmensis* Hammen, p. 116, fig. 7.

1966 Dennstaedtiaceae-Polypodiaceae form 3, Martin & Rouse, p. 188, pl. 3, fig. 23-24.

1968 *Verrucatosporites usmensis* Hammen; Germeraad *et al.*, p. 290-291, pl. 2, fig. 3.

1971 *Polypodiisporites usmensis* Hammen emend. Khan & Martin, p. 478, pl. 2, fig. 10.

1972 *Polypodiidites usmensis* Hammen ex Hekel, p. 6, pl. 1, fig. 8-9.

Longest Dimension: 28-55 μm . (5 specimens).

Distribution: This species occurs world-wide from the Tertiary (Martin & Rouse, 1966; Germeraad *et al.*, 1968; Hekel, 1972; Sun *et al.*, 1981; Truswell *et al.*, 1985); rarely to commonly from Late Oligocene to Miocene throughout Thailand (this study).

Botanical Affinity: The fossil spore is comparable with spores of the extant species of *Polypodium aureum*, *P. virginianum* and *Phanerophlebia aureum* (Martin & Rouse, 1966); *Stenochlaena palustris*, Blechnaceae (Germeraad *et al.*, 1968).

Remarks: The sculpture under SEM is baculate on both surfaces; bacula are 3-4 μm . long, 1-2 μm . wide and 4-8 μm . apart.

Genus: *Retitriletes* Hammen ex Pierce

Type Species: *Retitriletes globosus* Pierce 1961

Selected Synonymy:

1956 *Retitriletes* Hammen, pl. 3, fig. 76, *nom. nud.*

1961 *Retitriletes* Hammen ex Pierce, p. 21.

***Retitriletes douglasii* Dettmann 1986**

Plate 2, Figure 6.

Selected Synonymy:

1986 *Retitriletes douglasii* Dettmann, p. 96-97, Figs. 6A-D.

Longest Dimension: 24-39 μm . (5 specimens).

Distribution: This species has been recorded from the Early Cretaceous of Victoria, Australia (Dettmann, 1986). It occurs from the Late Oligocene of Li Basin, northern Thailand (this study).

Botanical Affinity: This fossil spore is comparable with spores of the extant *Lycopodium clavatum*, Lycopodiaceae (Sengupta & Rowley, 1974, p. 144, fig. 1; Tryon & Tryon, 1982, p. 797-810; fig. 125.19).

Remarks: The sculpture under SEM is reticulate on both faces; muri thin and 2 μm . high; lumina circular to elongate and 3-7 μm . wide.

Genus: *Rugulatisporites*

Pflug & Thomson *in* Thomson & Pflug 1953

Type Species: *Rugulatisporites quintus*

Pflug & Thomson *in* Thomson & Pflug 1953

Selected Synonymy:

1953 *Rugulatisporites* Pflug & Thomson *in* Thomson & Pflug, p. 56.

Rugulatisporites quintus

Pflug & Thomson *in* Thomson & Pflug 1953

Plate 3, Figures 7 & 8.

Selected Synonymy:

1953 *Rugulatisporites quintus* Pflug & Thomson in Thomson & Pflug, p. 56, pl. 2, fig. 46.

1975 *Rugulatisporites* cf. *R. neuquensis* Volkheimer; Filatoff, p. 59-60, pl. 9, fig. 12; pl. 10, figs. 1-4.

Longest Dimension: 38-62 μm . (10 specimens).

Distribution: This species occurs from the Jurassic of Perth Basin, Western Australia (Filatoff, 1975); Oligocene to Pliocene of Germany (Thomson & Pflug 1953); Late Oligocene to Early Miocene of Peninsular Thailand (this study).

Botanical Affinity: Shape, trilete mark and rugulae of this fossil spore are comparable with spore of the extant *Osmanda regalis*, Osmandaceae (Tryon & Tryon, 1982, p. 54-57, figs. 5.7-5.8); except lacking microechinae on muri of the studied fossil.

Remarks: Sculpture under SEM is rugulate on both surfaces; ridges are irregular in shape and 0.5-1 μm . wide; furrows are 0.5-1 μm . wide.

Genus: *Undulatisporites* Pflug in Thomson & Pflug 1953

Type Species: *Undulatisporites microcutis* Pflug in Thomson & Pflug 1953

Selected Synonymy:

1953 *Undulatisporites* Pflug in Thomson & Pflug, p. 52.

Undulatisporites unduliradius

Takahashi in Takahashi & Shimono 1982

Plate 3, Figures 9-11.

Selected Synonymy:

1982 *Undulatisporites unduliradius* Takahashi in Takahashi & Shimono, p. 25, pl. 2, figs. 10-13.

Longest Dimension: 22-35 μm . (5 specimens).

Distribution: This genus has been recorded from the Maastrichtian Miyadani-gawa Formation, central Japan (Takahashi & Shimono, 1982); Tertiary of China (Sun *et al.*, 1981). It occurs rarely from the Late Oligocene of Li Basin, northern Thailand (this study).

Botanical Affinity: Unknown.

Remarks: Sculpture under SEM is microundulate on both surfaces; ripple marks are very small and 1-4 μm . long.

2 GYMNOSPERMS

Genus: *Dacrydiumites* Cookson ex Harris 1965

Type Species: *Dacrydiumites florinii* Cookson & Pike ex Harris 1965

Selected Synonymy:

1953 *Dacrydiumites* Cookson, p. 66, *nom. nud.*

1965 *Dacrydiumites* Cookson ex Harris, p. 86 & 87.

1973 *Lygistepollenites* Stover & Evans, p. 63 & 64, *nom. superfl.*

Distribution: This genus, and other dispersed pollen resembling modern pollen of *Dacrydium*, has been recorded from the Late Cretaceous of Australia (Martin, 1978; Helby *et al.*, 1987) as well as being widely distributed in the Tertiary sediments of Asia and New Zealand (Harris, 1965; Hekel, 1972; Harris, 1974; Yamanoi, 1974; Khan, 1976b; Morley, 1978; Sun *et al.*, 1981; Foster, 1982; Huang & Huang, 1984; Pocknall & Mildenhall, 1984).

Remarks: Jansonius & Hills (1976, p. 735, 1550) considered *Lygistepollenites* Stover & Evans 1973 as a junior synonym of *Dacrydiumites* Cookson ex Harris 1965. Although the genus *Lygistepollenites* Stover & Evans 1973 has been actively used in Australian palynological studies, the decision of Jansonius & Hills is followed herein.

Dacrydiumites florinii Cookson & Pike ex Harris 1965

Plate 4, Figures 1-3.

Selected Synonymy:

1953 *Dacrydiumites florinii* Cookson & Pike, p. 479, pl. 3, figs. 20-35, *nom. nud.*

1965 *Dacrydiumites florinii* Cookson & Pike ex Harris, p. 87, pl. 26, fig. 18.

1972 *Dacrydiumites* sp.; Hekel, p. 6-7, pl. 1, fig. 12.

1982 *Lygistepollenites florinii* (Cookson & Pike) Stover & Evans; Foster, pl. 12, fig. 4, 7.

See Kemp & Harris, 1977, p. 25, under *Lygistepollenites florinii*.

Longest Dimension: 36-60 μm . (6 specimens).

Distribution: This species occurs in the Tertiary of Australia (Harris, 1965; Hekel, 1972; Harris, 1974; Foster, 1982); Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen of *Dacrydiumpollenites florinii* which has been found in this study are comparable with the extant pollen of *Dacrydium cupressinum* Lamb (Pocknall, 1981a, p. 70, pl. 2, figs. f-i).

Remarks: Sculpture under SEM is coarsely rugulate over most of the grain with comparatively coarser elements on the sacci than corpus.

Genus: *Inaperturopollenites*

Pflug & Thomson in Thomson & Pflug 1953

Type Species: *Inaperturopollenites dubius*

Potonié & Venitz ex Thomson & Pflug 1953

Selected Synonymy:

1953 *Inaperturopollenites* Pflug & Thomson in Thomson & Pflug, p. 64.

Distribution: This genus, and other dispersed pollen having affinity with pollen produced by extant Taxodiaceae-Cupressaceae, has been recorded from the Late Cretaceous of Japan (Takahashi & Shimono, 1982) as well as being widely distributed in the Cenozoic of North America, Europe and East Asia (Thomson & Pflug, 1953; Martin & Rouse, 1966; Penny, 1969; Fuji, 1969a, 1969b, 1969c; Takahashi & Kim 1979; Sun *et al.*, 1981; Takahashi & Jux, 1982; Huang & Huang, 1984).

Remarks: Despite the obvious similarities between *Inaperturopollenites* Pflug & Thomson 1953, *Taxodiaceapollenites* Kremp ex Potonié 1958 and *Araucariacites* Cookson ex Couper 1953; it is not clear whether they are synonymous.

Inaperturopollenites dubius

Potonié & Venitz ex Thomson & Pflug 1953

Plate 4, Figures 4-6.

Selected Synonymy:

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

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

Longest Dimension: 30-45 μm . (11 specimens).

Distribution: This species occurs from the Late Oligocene of Li and Nong Ya Plong basins (this study).

Botanical Affinity: The inaperturate character of the studied specimens generally resembles pollen from most of Taxodiaceae-Cupressaceae viz. *Juniperus* spp. (Bassett *et al.*, 1978, p. 52-53, figs. 9a-e), *Juniperus virginiana* L. (Lieux, 1980a, p. 23, pl. 8, figs. 1-2). The ornament of the fossil pollen under SEM is sparsely tuberculate over a roughened surface (or densely verrucate surface) which is more closely comparable with the pollen of the extant *Juniperus occidentalis* (Garner & Bryant, 1973, pl. 2, figs. 1a, 1b, 2a, 2b) and *Taxodium distichum* Rich, Taxodiaceae (Lieux, 1980a, p. 22-23, pl. 7, figs. 1-2). Although, the extant *Taxodium* pollen is monoporate aperture, usually with an indistinct pore and ligula, these characteristics are not common in the fossil specimens either under LM and SEM in this study. This fossil pollen differs from the pollen of modern *Agathis australis* Salisb. (Pocknall, 1981b, p. 268, 272, figs. 3c-d) in the latter having much denser tubercula over the exine surface.

Remarks: Grains are often split.

Genus: *Piceapollenites* Potonié 1931

Type Species: *Piceapollenites alatus* Potonié 1931

Selected Synonymy:

1931 *Piceapollenites* Potonié, p. 28.

1969 *Piceapollenites*; Hart, p. 271-289.

See Srivastava, 1975, p. 133.

Distribution: This genus, and other dispersed pollen having affinity with extant pollen of *Picea*, has been recorded from the Permian of North America and the Late Cretaceous of Europe and East Asia (Hart, 1969; Srivastava, 1975; Takahashi & Shimono, 1982). It is also widely distributed in Cenozoic sediments of North America, Europe, East Asia and Southeast Asia (Martin & Rouse, 1966; Nagy, 1969; Penny, 1969; Fuji, 1969a, 1969b, 1969c, 1972; Machin, 1971; Muller, 1972; Takahashi & Kim, 1979; Sun *et al.*, 1981; Frederiksen, 1980).

***Piceapollenites alatus* Potonié 1931**

Plate 4, Figures 7-9.

Selected Synonymy:

1931 *Piceapollenites alatus* Potonié, p. 28, pl. 2, fig. V 70a.

1966 *Picea grandivescipites* Wodehouse; Martin & Rouse, p. 192, pl. 6, figs. 52, 55.

Longest Dimension: 48-80 μm . (6 specimens).

Distribution: This species occurs from the Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles that produced by extant species of *Picea* spp. (Pinaceae).

Remarks: Sculpture of under SEM is smooth over the whole grain, and microperforations can be seen on sacci.

Genus: *Pinuspollenites* Raatz ex Potonié 1958

Type Species: *Pinuspollenites labdacus* Raatz ex Potonié 1958

Selected Synonymy:

1931 *Pollenites* Raatz, p. 15.

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

See Srivastava, 1975, p. 133.

Distribution: This genus, and other dispersed pollen having affinity with extant pollen of *Pinus*, has been recorded from the Late Cretaceous of Europe and East Asia (Penny, 1969; Takahashi & Shimono, 1982). It is also widely distributed in the Cenozoic of the Northern Hemisphere (Ling, 1965; Martin & Rouse, 1966; Muller, 1966, 1972; Fuji, 1969a, 1969b, 1969c; Machin, 1971; Takahashi & Kim, 1979; Frederiksen, 1980, Sun *et al.*, 1981; Takahashi & Jux, 1982; Mohr, 1984).

***Pinuspollenites* sp. 1436**

Plate 4, Figures 11 & 12.

Selected Synonymy:

cf. 1966 *Pinus* sp.; Martin & Rouse, p. 191-192, pl. 6, figs. 44-45.

Description: Pollen grains free, heteropolar, bilateral, bisaccate. Corpus: ellipsoidal to circular. Exine clearly stratified, 2-3 μm .; sexine and nexine are about the same thickness. Cappa

generally psilate but a few grains are microperforate (LM), psilate to microverrucate (SEM). Sacci attached on distal part of the corpus, with reticulate internal structure and often folded.

Longest Dimension: 48-(60)-80 μm . (20 specimens).

Distribution: This species occurs from Late Oligocene to Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen is comparable with the pollen from extant species of *Pinus* spp., Pinaceae (Pl. 4, Fig. 13).

Genus: *Podocarpidites* Cookson ex Couper 1953

Type Species: *Podocarpidites ellipticus* Cookson ex Couper 1953

Selected Synonymy:

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

1953 *Podocarpidites* Cookson ex Couper, p. 35.

See Haskell, 1968, p. 220-221; Srivastava, 1975, p. 134.

Distribution: 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. (Balme, 1957; Dettmann, 1963; Haskell, 1968; Fuji, 1969a, 1969b; Hughes, 1969; Penny, 1969; Filatoff, 1975; Khan, 1976b; Takahashi & Kim, 1979; Sun *et al.*, 1981; Takahashi & Shimono, 1982; Tschudy *et al.*, 1984; Huang & Huang, 1984; Pocknall & Mildenhall, 1984).

***Podocarpidites ellipticus* Cookson ex Couper 1953**

Plate 4, Figure 10.

Selected Synonymy:

1947 *Disaccites* (*Podocarpidites*) *elliptica* Cookson, p. 131, pl. 13, figs. 5-7, non ICBN.

1953 *Podocarpidites ellipticus* Cookson ex Couper, p. 36.

1982 *Podocarpidites* sp.; Foster, pl. 12, fig. 5.

Longest Dimension: 35-50 μm . (5 specimens).

Distribution: This species occurs very rarely from Late Oligocene to Miocene throughout Thailand (this study).

Botanical Affinity: This fossil pollen resembles pollen of the extant *Podocarpus*, Podocarpaceae viz. *Podocarpus spicatus* Mirbel (Pocknall, 1981a, p. 80, fig. 9g).

Remarks: The sculpture under SEM of this species is fairly smooth over the whole grain.

Genus: *Tsugaepollenites* Potonié & Venitz ex Potonié 1958

Type Species: *Tsugaepollenites igniculus* Potonié ex Potonié 1958

Selected Synonymy:

1934 *Tsugaepollenites* Potonié & Venitz, p. 17, *nom. nud.*

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

See Dettmann, 1963, p. 99; Nagy, 1969, p. 378.

Distribution: Dispersed pollen of *Tsugaepollenites* Potonié & Venitz ex Potonié 1958, which are reminiscent of the pollen of the living *Tsuga*, first appears in the Late Triassic and becomes a common constituent of later Mesozoic and Tertiary assemblages of the Northern Hemisphere (Chaloner, 1969; Fuji, 1969a, 1969c; Penny, 1969; Takahashi & Kim, 1979; Sun *et al.*, 1981; Sun *et al.*, 1984). However, the genus *Tsugaepollenites* has also been applied to the Mesozoic of Southern Hemisphere (Dettmann, 1963).

Remarks: The genus *Tsugaepollenites* Potonié & Venitz ex Potonié 1958 which is widely used, has some similarities with other gymnosperm genera including *Tsugapollenites* Raatz 1937, *Zonalapollenites* Pflug *in* Thomson & Pflug 1953 and *Callialasporites* Dev 1961. *Tsugaepollenites* Potonié & Venitz ex Potonié 1958 and *Zonalapollenites* Pflug *in* Thomson & Pflug 1953 are about half size of *Tsugapollenites* Raatz 1937. The genus *Zonalapollenites* Pflug *in* Thomson & Pflug 1953 is regarded as illegitimate name by not giving the basionym (Pocock, 1968). The genus *Callialasporites* Dev 1961 tends to show separate bladders unlike the others which are monosaccate or possess a marginal frill. Dev (1961) and Filatoff (1975) stated that *Callialasporites* has been proposed for Mesozoic forms are probably unrelated to modern *Tsuga*. See Dettmann (1963, p. 99-100) for more discussion.

Tsugaepollenites igniculus Potonié ex Potonié 1958

Plate 4, Figures 14-16.

Selected Synonymy:

1931 *Sporonites igniculus* Potonié, p. 566, fig. 2 (V 80a).

1934 *Tsugaepollenites igniculus* Potonié & Venitz, p. 17, pl. 8, *nom. nud.*

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

1966 *Tsuga heterophyllites* Martin & Rouse, p. 192, pl. 6, figs. 46-47.

See Nagy, 1969, p. 378.

Longest Dimension: 65-89 μm . (11 specimens).

Distribution: This species occurs commonly from the Late Oligocene of Li (northern Thailand) and Nong Ya Plong (central Thailand) basins (this study).

Botanical Affinity: The fossil pollen with microechinae resembles the pollen of extant *Tsuga heterophylla* Sarg. (Bassett *et al.*, 1978, p. 91-93, 412, figs. 29c-d).

Remarks: The fossil pollen grains are generally microechinate around the grains but this is absent in few specimens. Although it may be possible to separate them into different species, only few grains are different in this study, and thus they are provisionally grouped together as a single species.

3. ANGIOSPERMS

Genus: *Aceripollis* Huang 1980

Type Species: *Aceripollis taiwanensis* Huang 1980

Selected Synonymy:

1980 *Aceripollis* Huang, p. 61.

Distribution: This genus, and other dispersed pollen resembling the extant pollen of *Acer*, has been recorded from the Eocene of Japan Tertiary sediments of the Northern Hemisphere (Penny, 1969; Huang, 1980; Takahashi & Kim, 1979; Muller, 1981b).

Remarks: The genera *Striatricolporites* Hammen ex Leidekmeyer 1966 and *Striatricolporites* (Hammen) González Guzmán 1967 are regarded illegitimate by Jansonius & Hills (1976, p. 2780, 2781). The genus *Aceripollenites* Nagy 1969 is confined to specimens which are tricolpate with baculate sexine. The genus *Tricolporites* Cookson 1947 is confined to specimens which are tricolporate only as required in this study. It seems that Huang (1980) established the genus *Aceripollis* to accommodate Aceraceae pollen types with both tricolpate and tricolporate aperture and with striate ornament. Despite both tricolpate and tricolporate grains being found in this study, the genus *Aceripollis* is more suitable to accommodate with their morphologies.

Aceripollis sp. 727

Plate 5, Figures 1-3.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi extending almost to poles. Exine 1-2 μm ., clearly stratified, sexine and nexine about the same thickness. Sculpture microreticulate (LM & SEM); ridges are 3-6 μm . long and 0.3 μm . wide; lumina irregular and less than 0.5 μm in diameter (SEM).

Longest Dimension: 26-33 μm . (5 specimens).

Distribution: This species occurs from the Late Oligocene of Li Basin, northern Thailand (this study).

Botanical Affinity: The SEM sculpture, aperture and size of this fossil pollen are very comparable with the pollen of extant *Acer saccharinum* L. (Bassett *et al.*, 1978, p. 107, figs. 39a-e).

***Aceripollis* sp. 842**

Plate 5, Figures 4 & 5.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, prolate. Colpi indistinct (LM), long and narrow extending almost to poles. Exine 1-2 μm ., stratified, sexine and nexine the same thickness, distinct columellae. Sculpture: reti-striate (LM & SEM); irregularly striate pattern, muri 0.3 μm . wide and more parallel near colpi, lumina irregular becoming smaller near colpi and more or less circular with 0.5-1 μm . diameter (SEM).

Longest Dimension: 26-30 μm . (4 specimens).

Distribution: This species occurs from the Middle Miocene of Mae Moh Basin, northern Thailand and Andaman Sea, southern Thailand (this study).

***Aceripollis* sp. 853**

Plate 5, Figure 6.

Selected Synonymy:

cf. 1968 *Striatricolpites catatumbus* Gonzales; Germeraad *et al.*, p. 391-392, pl. 12, fig. 4.

cf. 1980 *Aceripollis taiwanensis* Huang, p. 61-62, pl. 10, figs. 24-27.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi indistinct (LM), long and narrow extending almost to poles. Exine 2-3 μm ., tectate, sexine twice thickness of nexine, columellae distinct. Sculpture perfo-striate (LM); strongly striate, parallel ridges are 30-40 μm long and 1 μm . wide (SEM).

Longest Dimension: 19-40 μm . (8 specimens).

Distribution: This species occurs rarely to commonly from Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: This fossil pollen resembles the pollen of the extant species of *Acer circinatum* Pursh and *Acer macrophyllum* Pursh, Aceraceae (Bassett *et al.*, 1978, p. 98-100, figs. 33a-f; 34a-c).

***Aceripollis* sp.1175**

Plate 5, Figures 7 & 8.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi thickening at the equator to 3-4 μm .; long and narrow extending almost to poles. Pores weakly to clearly defined, circular, 4 μm . in diameter. Exine 1-2 μm ., stratified, sexine and nexine the same thickness. Sculpture weakly perforate-striate (LM); poorly developed, ridges are parallel to the polar axis, 0.1 μm . or less thick and 10 μm . long, ends of ridges are usually diverge or merge with others (SEM).

Longest Dimension: 22-34 μm . (10 specimens).

Distribution: This species occurs from the Miocene of Mae Moh Basin (northern Thailand), Krabi Basin and Andaman Sea (southern Thailand).

Botanical Affinity: This fossil pollen is comparable with the pollen of extant *Acer spicatum* Lam., Aceraceae (Bassett *et al.*, 1978, p. 111-112, figs. 41a-f).

Genus: *Alnipollenites* Potonié 1931

Type Species: *Alnipollenites verus* Potonié 1931

Selected Synonymy:

1931 *Alnipollenites* Potonié, p. 4.

1953 *Polyvestibulopollenites* Pflug *in* Thomson & Pflug, p. 90.

See Srivastava, 1975, p. 141, under *Polyvestibulopollenites* Pflug 1953.

Distribution: This genus has been recorded from the Late Cretaceous of Japan and Scotland (Muller, 1981b; Srivastava, 1975), and is widely distributed in the Tertiary of the Northern Hemisphere (Engelhardt, 1964; Ling, 1965; Martin & Rouse, 1966; Germeraad *et al.*, 1968; Fuji, 1969a, 1969b, 1969c; Nagy, 1969; Penny, 1969; Tschudy & Loenen, 1970; Machin, 1971; Salujha *et al.*, 1980; Takahashi & Kim, 1979; Huang, 1980; Sun *et al.*, 1981; Takahashi & Jux, 1982; Sun *et al.*, 1984; Pocknall, 1987).

Remarks: Two genera, *Alnipollenites* Potonié 1931 and *Polyvestibulopollenites* Pflug *in* Thomson & Pflug 1953 are widely used for dispersed pollen which resemble modern pollen of

the genus *Alnus*. Although Jansonius & Hills (1976, p. 71, 2117) considered the genus *Polyvestibulopollenites* Pflug 1953 was legitimate. But Jansonius & Hills (1980, p. 3633) agree with Frederiksen & Ames (1979, p. 557-561) that *Polyvestibulopollenites* Pflug in Thomson & Pflug 1953 is an obligate junior synonym of *Alnipollenites* Potonié 1931 and thus is used in this study.

Alnipollenites verus Potonié 1931

Plate 5, Figures 9 & 10.

Selected Synonymy:

1931 *Alnipollenites verus* Potonié, p. 4, pl. 2, fig. 40.

1953 *Polyvestibulopollenites verus* (Potonié) Thomson & Pflug, p. 90, pl. 10, fig 73.

1964 *Alnipollenites* cf. *A. verus* Potonié; Engelhardt, p. 21, pl. 5, fig. 57.

1980 *Polyvestibulopollenites formosensis* Huang, p. 68, pl. 1, figs. 6-16.

See Srivastava, 1975, p. 141, under *Polyvestibulopollenites verus* (Potonié) Thomson & Pflug 1953.

Longest Dimension: 18-(22)-26 μm . (15 specimens).

Distribution: This species is rare to common in Late Oligocene to Middle Miocene sediments throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles extant pollen of *Alnus* (Betulaceae) viz. *Alnus firma* Sieb & Zucc (Plate 5, Figures. 11 & 12), which is a temperate climate indicator.

Remarks: Sculpture under SEM is regularly microgranulate, some of the granules joining together to form subparallel elongate ridges (1 μm . long).

Extant Genus: *Ammania* (Lythraceae)

Ammania sp. 382

Plate 5, Figures 13-15.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate, 6 pseudocolpi. Colpi generally open, and half length of polar diameter, margins are straight. Pores circular, 1-2 μm . Exine indistinctly stratified, 1 μm . thick. Sculpture smooth to weakly microstriate (LM);

ridges are short and parallel to the polar axis, 0.1 μm . or less thick and 3 μm . long, ends of ridges usually diverge or merge together (SEM).

Longest Dimension: 13-17 μm . (6 specimens).

Distribution: This species occurs rarely to commonly from the Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Ammania coccinea*, Rottb., Lythraceae (Graham *et al.*, 1985, p. 1017-1019, fig. 29).

Extant Genus: *Avicennia* (Avicenniaceae)

***Avicennia* sp. 1492**

Plate 6, Figures 1-3.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to oblate. Colpi distinct, extending almost to poles, margins thicken at the oral rims which are 2-3 μm . thick and usually open. Pores circular, 2-4 μm . in diameter, and slightly annulate. Exine tectate, 1-3 μm ., sexine and nexine are about the same thickness. Sculpture microreticulate (LM & SEM); lumina more or less circular, less than 1 μm . in diameter and smaller at polar areas; muri smooth and of 1 μm . thick.

Longest Dimension: 18-25 μm . (10 specimens).

Distribution: The dispersed pollen of *Avicennia* is distributed from the Early Miocene to Recent in tropical Southeast Asia (Muller 1964, 1981b; Anderson & Muller, 1975). This species occurs in the Early-Middle Miocene from the Andaman Sea and the Gulf of Thailand (this study)

Botanical Affinity: The fossil pollen resembles extant pollen of *Avicennia* spp., Avicenniaceae (Bertrand, 1983, p. 148, figs. 1D-F; Tomlinson, 1986, p. 140-144, figs. 7.5: A-D) and is a mangrove indicative of tropical environment.

Genus: *Bombacacidites* Couper 1960

Type Species: *Bombacacidites bombaxoides* Couper 1960

Selected Synonymy:

1960 *Bombacacidites* Couper, p. 53.

Distribution: The dispersed pollen of the *Bombax* type has been recorded from the Late Cretaceous of U. S. A. and also occurs in the Tertiary of South America, Nigeria, Australia and New Zealand (Stover & Partridge, 1973; Muller, 1981b; Pocknall & Mildenhall, 1984; Lorente, 1986).

Remarks: Two genera of *Bombacacidites* Couper 1960 and *Bombapollis* Elsik 1974 possess similar apertural and ornamental characteristics. It is not clear whether *Bombapollis* Elsik 1974 is a junior synonym of *Bombacacidites* Couper 1960.

***Bombacacidites annae* Hammen ex Leidelmeyer 1966**

Plate 6, Figures 4 & 5.

Selected Synonymy:

1954 *Tricolporites annae* Hammen, p. 96, pl. 9, *nom. nud.*

1966 *Bombacacidites annae* Hammen ex Leidelmeyer, p. 55.

Longest Dimension: 36-53 μm . (5 specimens).

Distribution: This species occurs rarely in the Middle Miocene of Mae Moh Basin, northern Thailand (this study).

Botanical Affinity: The dispersed pollen of this species resembles extant pollen of *Bombax* spp., Bombacaceae (Germeraad *et al.*, 1968).

Remarks: The sculpture under SEM of this species is reticulate, in the polar areas muri smooth and less than 0.5 μm . wide, lumina circular to elongate and 0.5-1 μm . long, smaller in the equatorial mid-intercolpate areas.

Extant Genus: *Bursera* (Burseraceae)

***Bursera* sp. 1427**

Plate 6, Figure 6.

Selected Synonymy:

1974 *Bursera*; Elsik, pl. 3, fig. 79-80.

Description: Pollen grains free, triporate, subprolate, subtriangular to circular in polar view, isopolar, radiosymmetric. Pores circular, protruding 1-2 μm . Exine 1-2 μm ., sexine is the same

thickness or thicker than nexine. Sculpture reti-striate (LM); irregularly striate with very thin parallel muri which are about the same width as lumina (SEM).

Longest Dimension: 20-27 μm . (8 specimens).

Distribution: The dispersed pollen of *Bursera* has been recorded from the Eocene of Texas Gulf Coast, U.S.A. (Elsik, 1974) and elsewhere in the Tertiary of South America and France (Muller, 1981b).

Botanical Affinity: The dispersed pollen resembles pollen of extant *Bursera* sp., Burseraceae (Tsukada, 1964, p. 438, pl. 2, figs. 9-12).

Extant Genus: *Cardamine* (Cruciferae)

***Cardamine* sp. 323**

Plate 6, Figures 12 & 13.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, prolate. Colpi extending almost to poles. Exine 1-2 μm . thick, tectate, sexine and nexine about the same thickness. Sculpture reticulate (LM and SEM); lumina irregular in shape varying from circular to elongate and 0.2 to 2 μm . long, muri smooth and 0.2-0.4 μm . wide (SEM).

Longest Dimension: 23-(30)-45 μm . (15 specimens).

Distribution: This species occurs rarely to commonly from the Miocene throughout Thailand (this study).

Botanical Affinity: The dispersed pollen resembles pollen of extant *Cardamine pratensis* L., Cruciferae (Bassett *et al.*, 1978, p. 171-172, figs. 82: a-e).

Genus: *Caryapollenites* Potonié 1960

Type Species: *Caryapollenites simplex* Potonié 1960

Selected Synonymy:

1960b *Caryapollenites* Potonié, p. 123.

Distribution: This genus, and other dispersed pollen resembling extant pollen of *Carya*, has been recorded from the Palaeocene of U. S. A. and is widely distributed elsewhere in the Tertiary of Europe and East Asia (Engelhardt, 1964; Fuji, 1969a, 1969b, 1969c; Nagy, 1969; Penny, 1969; Tschudy & Loenen, 1970; Machin, 1971; Elsik, 1974; Elsik & Dilcher, 1974; Takahashi

& Kim, 1979; Muller, 1981b; Sun *et al.*, 1981; Takahashi & Jux, 1982; Mohr, 1984; Sun *et al.* 1984; Pocknall, 1987).

***Caryapollenites simplex* Potonié 1960**

Plate 6, Figures 7-11.

Selected Synonymy:

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

1964 *Carya* cf. *C. simplex*; Engelhardt, p. 19, pl. 1, fig. 6.

1974 *Carya* sp.; Elsik and Dilcher, pl. 29, fig. 119.

Longest Dimension: 23-(38)-50 μm . (18 specimens).

Distribution: This species occurs from the Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen is comparable with pollen of the extant *Carya* spp., Juglandaceae (Bassett *et al.*, 1978, p. 199-202, figs. 101a-e).

Remarks: Sculpture under SEM is evenly microscabrate.

Extant Genus: *Cephalomappa* (Euphorbiaceae)

***Cephalomappa* sp. 590**

Plate 6, Figures 14 & 15.

Description: Pollen grains free, triporate, peroblate, isopolar, radiosymmetric, circular amb. Pores annulate, circular, about 1 μm . in diameter, protruding about 2 μm . long. Exine stratified, 1-2 μm . thick, sexine the same thickness as nexine. Sculpture perforate to finely reticulate (LM & SEM); muri 1-2 μm . wide and possesses microspines on the surface, lumina very small (SEM).

Longest Dimension: 23-30 μm . (6 specimens).

Distribution: This species occurs from the Middle Miocene from the Gulf of Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Cephalomappa*, Euphorbiaceae (Anderson & Muller, 1975, p. 302, pl. 2, fig. 1). The modern genus is distributed around southern China and western Malaysia (Willis, 1985).

Genus: *Cupuliferoipollenites* Potonié ex Potonié 1960

Type Species: *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960

Selected Synonymy:

1960b *Cupuliferoipollenites* Potonié ex Potonié, p. 98, pl. 6, fig. 111.

Distribution: The dispersed pollen resembling extant pollen of *Castanea* has been recorded from the Albian (Penny, 1969). It is widely distributed in the Tertiary of the Northern Hemisphere (Engelhardt, 1964; Penny, 1969; Potter, 1976; Takahashi & Kim, 1979; Muller, 1981b; Sun *et al.*, 1981; Takahashi & Jux, 1982).

Botanical Affinity: The *Castanea* pollen type which include the genera *Castanea*, *Lithocarpus* and *Castanopsis*; cannot be reliably separated in the fossil state (Muller, 1981b).

***Cupuliferoipollenites pusillus* Potonié ex Potonié 1960**

Plate 7, Figures 1-3.

Selected Synonymy:

1960b *Cupuliferoipollenites pusillus* Potonié ex Potonié, p. 98.

1964 *Cupuliferoipollenites* cf. *C. insleyanus* Potonié; Engelhardt, p. 11, pl. 2, fig. 23.

1981 *Cupuliferoidaepollenites* spp.; Frederiksen, pl. 16-4, fig. 12.

Longest Dimension: 11-18 μm . (11 specimens).

Distribution: This species occurs from the Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Castanea* and *Castanopsis* (Fagaceae) pollen types viz. *Castanea crenata* Sieb & Zucc (Plate 7, Figures 4 & 5) and *Castanopsis hainanensis* Merr (Plate 7, Figure 6).

Remarks: The sculpture of this species appears smooth under LM but microrugulate under SEM. Ridges are about 3 μm . long and 0.1-0.2 μm . wide; lumina very small (SEM).

Genus: *Cyperaceaepollis* Krutzsch 1970

Type Species: *Cyperaceaepollis neogenicus* Krutzsch 1970

Selected Synonymy:

1970 *Cyperaceaepollis* Krutzsch, p. 66.

***Cyperaceaepollis neogenicus* Krutzsch 1970**

Plate 7, Figure 7.

Selected Synonymy:

1970 *Cyperaceaepollis neogenicus* Krutzsch, p. 66, pl. 7, figs. 6-8.

Longest Dimension: 39-55 μm . (5 specimens).

Distribution: The dispersed pollen resembling modern pollen of *Carex* (Cyperaceae) has been recorded from the Middle Eocene of central Europe and central Australia; and is distributed world-wide in Tertiary sediments (Muller, 1981b). This species occurs very rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: The *Cyperaceaepollis neogenicus* fossil pollen is comparable with extant Cyperaceae pollen types viz of *Carex aquatilis* Wahlenb. (Bassett *et al.*, 1978, p. 173-174, figs. 83a-c).

Remarks: This studied pollen is larger than the type species. The ornament under SEM of this species shows a microperforate exinal surface but with verrucae in the lacunae; verrucae are round to oval and 1-2 μm . wide.

Genus: *Dicolpopollis* Pflanzl 1956

Type Species: *Dicolpopollis kockelii* Pflanzl 1956

Selected Synonymy:

1956 *Dicolpopollis* Pflanzl, p. 241.

1960a *Disulcites* Erdtman ex Potonié, p. 464-465, junior synonym.

Distribution: This genus, and other dispersed pollen having affinity with modern pollen of the genus *Calamus*, has been recorded from Palaeocene to Eocene of Southeast Asia, Europe and North America (Potonié 1960a; Muller, 1979, 1981b; Takahashi 1982). It is also recorded in the Neogene sediments of India, South China Sea and Papua New Guinea (Kar & Jain, 1981; Sun *et al.*, 1981; Playford, 1982).

Remarks: Muller (1968) mentioned that the genus *Disulcites* Erdtman ex Potonié 1960 is an obligate junior synonym of the genus *Dicolpopollis* Pflanzl 1956.

***Dicolpopollis kalewensis* Potonié ex Potonié 1966**

Plate 7, Figures 10 & 11.

Selected Synonymy:

1960a *Disulcites kalewensis* Potonié, p. 464-465, pl. 2, figs. 27-43.

1966 *Dicolpopollis kalewensis* Potonié ex Potonié, p. 160.

Longest Dimension: 27-36 μm . (5 specimens).

Distribution: This species occurs from the Early Miocene of the Gulf of Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of extant *Calamus* sp., Palmae (Potonié 1960a).

Remarks: The sculpture under SEM of this species is microperforate on the surface; foveolae are very small and uniformly distributed about 0.5 μm . apart.

Extant Genus: *Dipterocarpus* (Dipterocarpaceae)

Distribution: The dispersed pollen resembling modern pollen of *Dipterocarpus* is limited to Southeast Asia and has been recorded from the Oligocene of Borneo (Muller 1968, 1981b).

Remarks: Muller (1981b) rejects any association between dispersed pollen of the genus *Dipterocarpacearumpollenites* Nagy 1969 and the extant genus *Dipterocarpus*.

***Dipterocarpus* sp. 780**

Plate 7, Figures 8 & 9.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, subprolate to oblate. Colpi extending almost to poles. Exine: 1 μm . thick, tectate, sexine and nexine are the same thickness. Sculpture perfo-verrucate (LM); prominently and uniformly convoluted ridges which are separated by fossulate depressions, ridge are about 1 μm . or less wide, lumina less than 1 μm . (SEM).

Longest Dimension: 17-32 μm . (10 specimens).

Distribution: This species occurs rarely from the Early Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of extant *Dipterocarpus humeratus* Slooten (Maury *et al.*, 1975, p. 243, pl. 2, fig. 1).

Genus: *Echiperiporites* Hammen & Wymstra 1964

Type Species: *Echiperiporites akanthos* Hammen & Wymstra 1964

Selected Synonymy:

1964 *Echiperiporites* Hammen & Wymstra, p. 239.

Distribution: The dispersed pollen resembling pollen type of *Hibiscus* (cf. *Echiperiporites estelae* Germeraad *et al.* 1968) has been recorded from the Late Eocene of Venezuela and Brazil and is distributed world-wide in the Oligo-Miocene (Muller, 1981b).

Remarks: The comparison of dispersed pollen belonging to the Euphorbiaceae with Malvaceae was carried out by (Martin, 1974). A close examination of the exine stratification and the base of the spines assists in the identification. On the malvaceous pollen, there is a small basal cushion beneath the spine into which the columellae extend, and the base to the spine is marked by a definite joint. In summary, most specimens of *Malvacipollis diversus* are euphorbiaceous (*Tetracoccus* pollen type) but a few are malvaceous. On the other hand, the genera *Echiperiporites* Hammen & Wymstra 1964 and *Malvacipollis* Harris 1965 are differentiated by the former having periporate apertures unlike the zoni-porate apertures of the latter.

***Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968**

Plate 7, Figures 14-16.

Selected Synonymy:

1968 *Echiperiporites estelae* Germeraad *et al.*, p. 318-319, pl. 10, fig. 1.

cf. 1972 *Malvacearumpollis estelae* (Germeraad *et al.*) Hekel, p. 18, pl. 6, fig. 27.

Description: Pollen grains free, periporate, spherical. Pores 4-8, circular, 3-4 μm ., with occasionally well defined annulus. Exine 2 μm . thick, stratified, sexine and nexine are about the same thickness. Sculpture finely reticulate interspersed with spines (LM); microscabrate with spines, scabrate-sculptural elements are 0.2-0.3 μm . long; spines are conical, 4-6 μm . long and 10 μm . apart (SEM).

Longest Dimension: 50-90 μm . (6 specimens).

Distribution: This species occurs from the Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen of *Echiperiporites estelae* is comparable with extant pollen of *Thespesia populnea*, Malvaceae (Germeraad *et al.* 1968).

Remarks: The exine stratification and the base of the spines found on the studied pollen here match present malvaceous pollen described by Martin (1974).

Extant Genus: *Excoecaria* (Euphorbiaceae)

***Excoecaria* sp. 1404**

Plate 7, Figures 12 & 13.

Description: Pollen grains free, tricolporate, isopolar, sub-prolate. Colpi clear, extending almost to poles, margins are straight, thickening at the oral rims to 1-2 μm . Pores poorly defined. Exine tectate, 1-2 μm ., sexine and nexine are the same thickness. Sculpture finely reticulate (LM & SEM); lumina circular to oval and 0.2-0.7 μm . long, muri smooth and 2-3 μm . wide (SEM).

Longest Dimension: 24-38 μm . (6 specimens).

Distribution: This species occurs from the Miocene of Krabi and Sin Pun basins, southern Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of extant *Excoecaria agallocha*, Euphorbiaceae (Tissot, 1980, p. 179-180, pl. 7, figs. 1-10; Thanikaimoni, 1987, p. 20, pl. 11, figs. 109-123).

Genus: *Faguspollenites* Raatz 1938

Type Species: *Faguspollenites verus* Raatz 1938

Selected Synonymy:

1938 *Faguspollenites* Raatz, p. 23.

Distribution: The earliest reliable record of dispersed pollen having affinity with modern pollen of *Fagus* is from the Early Oligocene of Canada. It is widely distributed in the Miocene and Pliocene of North America, Europe and East Asia (Fuji, 1969a, 1969c, 1972; Nagy, 1969; Takahashi & Kim, 1979; Muller, 1981b; Sun *et al.*, 1981; Mohr, 1984).

***Faguspollenites* sp. 845**

Plate 8, Figures 1 & 2.

Selected Synonymy:

cf. 1984 *Faguspollenites verus* Raatz; Mohr, p. 94-95, pl. 18, figs. 7, 10.1, 10.2, 12.

Description: Pollen grains free, tricolporate, isopolar, prolate to sub-prolate. Colpi long and narrow extending almost to poles, margins thicken at the oral rims. Pores weakly defined, circular to lalongate, 2.5-5 μm . wide and 5-6 μm . long. Exine 1.5 μm ., stratified, sexine and nexine the same thickness. Sculpture psila-scabrate (LM); microscabrate, scabrate elements are uniform and 0.3-0.5 μm . long (SEM).

Longest Dimension: 23-29 μm . (12 specimens).

Distribution: This species occurs commonly from the Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of extant *Fagus* (Fagaceae) viz. *Fagus crenata* Blume (Plate 8, Figure 3). Some SEM studies of modern *Fagus* spp. show identical microscabrate ornament of this genus (Hanks & Fairbrothers, 1976; Praglowski, 1982; Gortemer, 1986).

Genus: *Florschuetzia* Germeraad *et al.* 1968

Type Species: *Florschuetzia trilobata* Germeraad *et al.* 1968

Selected Synonymy:

1968 *Florschuetzia* Germeraad *et al.*, p. 304-306.

Botanical Affinity: In general, the genus *Florschuetzia* Germeraad *et al.* 1968 resembles the present sonneratiaceous pollen (mangrove microflora indicator) but the species *Florschuetzia trilobata* Germeraad *et al.* 1968, as noted by Muller (1981b), may combine both lythraceous and sonneratiaceous characters. *Florschuetzia* sp. 647 is also included in this genus but is unlikely to be a mangrove microflora indicator.

Remarks: The genus is distinguished from *Verrutricolporites* Hammen & Wymstra 1964 by the absence of colpi, the indistinct columellae and the absence of supratectate verrucate sculpture. The type specimens of *Santalumidites cainozoicus* Cookson & Pike 1954 have not been

preserved, and it cannot be ascertained whether the genus *Santalumidites* is a senior synonym of the genus *Florschuetzia* Germeraad *et al.* 1968 representing pollen of the sonneratoid type, or indeed a form genus for pollen of the extant *Santalum* (Germeraad *et al.*, 1968). However, *Santalumidites* Cookson & Pike 1954 emend. Partridge *in* Stover and Partridge 1973 differs from *Florschuetzia* Germeraad *et al.* 1968 by having short colpi and lacking sexine in the polar area. Later, a study (Muller, 1978) of the specimens from the Eocene North Maslin Sands, Willunga Basin, South Australia confirms the Partridge's emendation and his opinion about the *Santalumidites* and *Florschuetzia* are distinct.

***Florschuetzia levipoli* Germeraad *et al.* 1968**

Plate 8, Figures 6-9.

Selected Synonymy:

1968 *Florschuetzia levipoli* Germeraad *et al.*, p. 307 & 308, pl. 7, fig. 9, pl. 8, figs. 1 & 2.

Longest Dimension: 24-(24)-37 μm . (20 specimens).

Distribution: From several independent datings in Southeast Asia, Muller (1978) concluded that *Florschuetzia levipoli* Germeraad *et al.* 1968 first appears at the base of the Miocene. It is widely distributed from Miocene onwards in Southeast Asia and South China Sea (Germeraad *et al.*, 1968; Morley, 1978; Muller 1978, 1981b; Reimann & Thaug, 1981; Sun *et al.*, 1981). This species occurs from the Miocene of Andaman Sea and the Gulf of Thailand (this study).

Botanical Affinity: The fossil *Florschuetzia levipoli* pollen is comparable with pollen of the extant *Sonneratia caseolaris*, Sonneratiaceae (Germeraad *et al.*, 1968, p. 307-308, pl. 8, figs. 1-2, 6-7; Muller, 1978, pl. 1, figs. 1-8). The extant species is a tropical mangrove indicator.

Remarks: Sculpture of *Florschuetzia levipoli* fossil pollen under SEM (at about 3000X) shows smooth polar caps, and very fine striae may be seen on the surface of both polar fields and verrucae at high magnification (at about 10000X); verrucae are on equatorial area, round to oval shape and 0.5-3 μm . long.

***Florschuetzia meridionalis* Germeraad *et al.* 1968**

Plate 8, Figures 10 & 11.

Selected Synonymy:

1968 *Florschuetzia meridionalis* Germeraad *et al.*, p. 308-310, pl. 8, figs. 4-5.

Longest Dimension: 24-35 μm . (11 specimens).

Distribution: From several independent datings in Southeast Asia, Muller (1978) concluded that *Florschuetzia meridionalis* Germeraad *et al.* 1968 first appears in the late Middle Miocene. It is widely distributed from late Middle Miocene onwards in Southeast Asia (Germeraad *et al.*, 1968; Morley, 1978; Muller 1978; 1981b). This species occurs from the Middle Miocene of Andaman Sea and the Gulf of Thailand (this study).

Botanical Affinity: Fossil *Florschuetzia meridionalis* pollen is comparable with pollen of extant *Sonneratia alba*, Sonneratiaceae (Germeraad *et al.*, 1968, p. 308, pl. 8, figs. 3-5; Muller, 1978, pl. 2, figs. 1-4). The extant species is a tropical mangrove indicator.

Remarks: Fossil pollen of *Florschuetzia meridionalis* under SEM shows smooth polar caps, verrucae in the inter-meridional ridge areas similar to *Florschuetzia levipoli* although, verrucae on the meridional ridges are larger and appear to be fused together. Grain size of the studied specimens on average is smaller than Germeraad described.

Florschuetzia semilobata Germeraad *et al.* 1968

Plate 8, Figure 5.

Selected Synonymy:

1968 *Florschuetzia semilobata* Germeraad *et al.*, p. 307, pl. 7, figs. 6-8.

Longest Dimension: 14-25 μm . (6 specimens).

Distribution: This species occurs in the Early Miocene of Southeast Asia and South China Sea (Germeraad *et al.*, 1968; Morley, 1978; Sun *et al.*, 1981); Early Miocene of Andaman Sea (this study).

Botanical Affinity: The fossil pollen of *Florschuetzia semilobata* is comparable with modern sonneratiaceous pollen types but matching with an extant species has not been possible (Germeraad *et al.*, 1968).

Remarks: Fossil pollen of *Florschuetzia semilobata* under SEM is smooth with microperforations on polar caps and meridional ridges, and regular verrucae in the inter-meridional ridge areas similar to *Florschuetzia meridionalis*, but smaller in size.

***Florschuetzia* sp. 647**

Plate 8, Figures 12-15.

Description: Pollen grains free, triporate, prolate, isopolar, three meridional ridges. Pores circular, about 2 μm . in diameter. Exine not clearly stratified (LM), exine 1 μm . and nexine 0.5 μm . thick at inter-meridional ridge areas. Sculpture verrucate in the inter-meridional ridge areas with smooth meridional ridges (LM); pointed to rounded verrucae around inter-meridional ridge areas, verrucae are dense and 0.3-0.5 μm . wide, perforate-striate to smooth meridional ridges, ridges are 2-3 μm . wide (SEM).

Longest Dimension: 13-23 μm . (10 specimens).

Distribution: This species occurs from the Early Miocene of Fang Basin, northern Thailand and Krabi Basin, southern Thailand (this study).

Botanical Affinity: The morphology of the dispersed pollen of this species may be comparable with pollen from extant species of the genera sonneratiaceae and lythraceae.

Remarks: The morphology of dispersed pollen of this species agrees with the description of *Florschuetzia* Germeraad *et al.* 1968. However, a relationship of this species with other species or with mangrove environment has yet been proofed.

***Florschuetzia trilobata* Germeraad *et al.* 1968**

Plate 8, Figure 4.

Selected Synonymy:

1968 *Florschuetzia trilobata* Germeraad *et al.*, p. 306 & 307, pl. 7, figs. 2-4.

Longest Dimension: 18-28 μm . (8 specimens).

Distribution: This species first appears in the Oligocene or possibly early as Late Eocene of west Malesia. It is distributed in the Oligo-Miocene in Southeast Asia and South China Sea and is believed it becomes extinct during the (Middle) Miocene (Germeraad *et al.*, 1968; Morley, 1978; Muller, 1978, 1981b; Sun *et al.*, 1981). It occurs from the Early Miocene of Andaman Sea (this study).

Botanical Affinity: This species combines lythraceous and sonneratiaceous characters and may thus be an ancestor of Sonneratiaceae. However, no extant pollen type has yet been found to match the fossil (Germeraad *et al.*, 1968; Muller, 1981b).

Remarks: Sculpture of *Florschuetzia trilobata* fossil pollen under SEM is generally smooth to scabrate around the whole grain, colpi about 15 μm . long. Germeraad *et al.* (1968) described smooth sculpture and colpoid grooves (colpi?) as characters of *Florschuetzia trilobata*, but verrucate sculpture in the inter-meridional ridge areas for *Florschuetzia semilobata*. In this study, an intermediate type of colpoid groove with verrucae in the inter-meridional ridge areas has been found together on the same grain. It is not intended that the intermediate type be used to establish a new species and is thus grouped provisionally as *Florschuetzia trilobata*.

Extant Genus: *Hopea* (Dipterocarpaceae)

***Hopea* sp. 1299**

Plate 9, Figures 1-4.

Description: Pollen grains free, tricolporate, radiosymmetric, isopolar, prolate to sub-prolate. Colpi clear, extending almost to poles, margins are thickening at the oral rims. Pores lalongate, 2-3 μm . wide and 6-8 μm . long. Exine 1-2 μm . thick, stratified, sexine and nexine are the same thickness. Sculpture microreticulate, muri less than 1 μm . and contains transversal microridges and furrows on the surface, lumina very small (SEM).

Longest Dimension: 22-32 μm . (12 specimens).

Distribution: This species occurs rarely to commonly from the Miocene throughout Thailand (this study).

Botanical Affinity: Although the size and sculpture (under SEM) of the fossil pollen is similar to pollen of the extant *Hopea nervosa* King, Dipterocarpaceae (Maury *et al.*, 1975, p. 245-246, pl. 9, figs. 1-2, 4-6), the fossil type differs in having pores.

Genus: *Ilexpollenites* Potonié 1960

Type Species: *Ilexpollenites iliacus* Potonié 1960

Selected Synonymy:

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

Distribution: This genus, including dispersed pollen resembling extant pollen of *Ilex*, has been recorded from the Late Cretaceous in Australasia, Africa and North America (Muller, 1981b). It shows virtually a cosmopolitan distribution in the Tertiary (Engelhardt, 1964; Ling, 1965; Martin & Rouse, 1966; McIntyre, 1968; Fuji, 1969b; Stover & Partridge, 1973; Elsik, 1974; Martin, 1977, 1978; Takahashi & Kim, 1979; Huang, 1980; Sun *et al.*, 1981; Foster, 1982; Takahashi, 1982; Takahashi & Jux, 1982; Pocknall & Mildenhall, 1984; Mohr, 1984).

***Ilexpollenites iliacus* Potonié 1960**

Plate 9, Figures 10-12.

Selected Synonymy:

1960b *Ilexpollenites iliacus* Potonié, p. 99.

1964 *Ilexpollenites* cf. *I. iliacus* Thiergart; Engelhardt, p. 12; pl. 2, fig. 22.

1966 *Ilex iliacus* Martin & Rouse, p. 200, pl. 10, figs. 108, 110.

1974 *Ilexpollenites* sp.; Elsik, pl. 4, fig. 149-152, 155-156.

Longest Dimension: 17-36 μm . (6 specimens).

Distribution: This species ranges from rare to common in the Late Oligocene to Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Ilex* spp., Aquifoliaceae.

Remarks: The sculpture under SEM of this species is variably gemmate with round and smooth gemmae, 0.5 -3 μm . wide.

Genus: *Juglanspollenites* Raatz 1939

Type Species: *Juglanspollenites verus* Raatz 1939

Selected Synonymy:

1939 *Juglanspollenites* Raatz, p. 18.

Distribution: This genus, and other dispersed pollen resembling modern pollen of *Juglans*, has been recorded from the Palaeocene in U. S. A. (Frederiksen, 1979). It extends into the Eocene onwards in North America, Europe and East Asia (Nagy, 1969; Fuji, 1972; Penny, 1969; Machin, 1971; Elsik, 1974; Takahashi & Kim, 1979; Muller, 1981b; Sun *et al.*, 1981; Sun *et al.* 1984).

***Juglanspollenites verus* Raatz 1939**

Plate 9, Figure 9.

Selected Synonymy:

1939 *Juglanspollenites verus* Raatz, p. 18, pl. 1, fig. 9.

1974 *Juglans* sp.; Elsik, pl. 1, fig. 24.

Longest Dimension: 27-38 μm . (6 specimens).

Distribution: This species occurs from the Early Miocene of Sin Pun Basin, southern Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Juglans* spp. (Juglandaceae), viz., *Juglans californica* Wats. (Stone & Broome, 1975, p. 7, fig. 8a).

Remarks: Pollen grains are heteropolar with four to five pores on the equator and three or four pores around one hemisphere. Sculpture of the fossil pollen under SEM is uniformly microgranulate; granules are very small; pores are circular and 1-2 μm . in diameter.

Extant Genus: *Lagerstroemia* (Lythraceae)

***Lagerstroemia* sp. 325**

Plate 9, Figures 5-8.

Description: Pollen grains free, tricolporate, with six pseudocolpi which may not be clearly seen, three meridional ridges, isopolar, radiosymmetric, prolate to sub-prolate. Meridional ridges fusing at poles. Colpi long and narrow, margins are straight. Pores circular to lalongate, 1-2 μm . in diameter. Meridional ridges 2-4 μm ., stratified, sexine is thicker than nexine. Sculpture weakly verrucate (LM); densely rugu-verrucate, verrucae are circular in the inter-meridional ridge areas and about 1 μm . wide but fusing together to form elongate microridges on meridional ridges 3-5 μm . long, lumina circular and less than 1 μm . (SEM).

Longest Dimension: 24-(28)-29 μm . (15 specimens).

Distribution: This species occurs rarely to commonly from the Early to Middle Miocene throughout Thailand (this study).

Botanical Affinity: This fossil pollen is closely comparable with pollen of extant *Lagerstroemia* spp., Lythraceae (Muller, 1981a, p. 99-103, pl. 2, fig. 2, 4; Graham *et al.*, 1987, p. 835-837, fig. 41). The extant genus is a tropical indicator.

Genus: *Lanagiopollis* Morley 1982

Type Species: *Lanagiopollis regularis* Morley 1982

Selected Synonymy:

1982 *Lanagiopollis* Morley, p. 68 & 69.

Remarks: Morley (1982) proposed three form genera including *Alangiopollis* Krutzsch 1962, *Lanagiopollis* Morley 1982 and Form-genus A Morley 1982 to adequately cover the variation in the dispersed pollen having affinity with modern pollen of the genus *Alangium*, Alangiaceae. The genus *Alangiopollis* Krutzsch 1962 is assigned to accommodate tri- to tetracolporate pollen with a distinctly striate exine architecture and a thinner nexine than sexine. The genus *Lanagiopollis* Morley 1982 is assigned to accommodate tri- to tetracolporate pollen with reticulate or rugulate exine architecture. The form-genus A Morley 1982 which is not formally described due to poor material, is erected for tricolporate/porate pollen bearing large, discrete sexinous warts.

***Lanagiopollis nanggulanensis* Morley 1982**

Plate 9, Figures 13-15.

Selected Synonymy:

cf. 1957 *Alangium javanicoides* Cookson, p. 48.

1982 *Lanagiopollis nanggulanensis* Morley, p. 72 & 73, pl. 2, figs. 1-4.

Longest Dimension: 57-70 μm . (5 specimens).

Distribution: This species has been recorded from the Eocene of central Java and East Kalimantan. It is widely distributed in the Tertiary of Southeast Asia (Morley, 1982) but occurs rarely from the Middle Miocene of Mae Moh Basin, northern Thailand (this study).

Botanical Affinity: This fossil pollen resembles modern pollen attributed to *Alangium ebenaceum*, Alangiaceae (Morley 1982).

Remarks: The pollen type is occasionally tetracolporate. Morley (1982) pointed out that *Lanagiopollis nanggulanensis* may be a synonym of *Alangium javanicoides* Cookson 1957 pending further study of *Alangium javanicoides*. Sculpture under SEM of this species is reticulate-rugulate; lumina less than 2 μm . long and disappear at the polar areas but circular to elongate and 0.2-5 μm . long in the intercolpi areas; muri smooth and less than 1 μm . wide.

Genus: *Margocolporites* Ramanujum ex Srivastava 1969

Type Species: *Margocolporites tsukadai* Ramanujum ex Srivastava 1969

Selected Synonymy:

1966 *Margocolporites* Ramanujum, p. 173, *nom. nud.*

1969 *Margocolporites* Ramanujum ex Srivastava, p. 984.

Distribution: This genus, and other dispersed pollen resembling extant pollen of *Caesalpinia*, has been recorded from the Early Eocene of Assam. It is distributed in the Eocene and/or younger sediments of South America, Africa, India, East Asia, Southeast Asia, Papua New Guinea, Australia and New Zealand (Germeraad *et al.*, 1968; Huang, 1980; Muller, 1981b; Sun *et al.*, 1981; Playford, 1982; Pocknall, 1982; Truswell *et al.*, 1985).

***Margocolporites vanwijhei* Germeraad *et al.* 1968**

Plate 10, Figures 1-4.

Selected Synonymy:

1968 *Margocolporites vanwijhei* Germeraad *et al.*, p. 342, pl. 18, fig. 3.

Longest Dimension: 23-48 μm . (12 specimens).

Distribution: This species occurs rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: The *Margocolporites vanwijhei* pollen type is similar to extant pollen types of *Caesalpinia bonduc* and *C. coriaria*, Caesalpinaceae (Germeraad *et al.*, 1968).

Remarks: Sculpture under SEM of this species is very coarsely reticulate on the intercolpate and polar areas but abruptly changing to very finely reticulate around the colpi. Of the coarse reticula, lumina vary in size and shape and are 0.5-4 μm . long; muri smooth and 1-2 μm . wide.

Genus: *Momipites* Wodehouse emend. Nichols 1973

Type Species: *Momipites coryloides* Wodehouse 1933

Selected Synonymy:

1933 *Momipites coryloides* Wodehouse, p. 511.

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

Distribution: The dispersed pollen of the coryloides group has been recorded from the Late Cretaceous of Europe (Nichols, 1973). It is distributed in the Tertiary of North America, Europe and East Asia (Engelhardt, 1964; Penny, 1969; Machin, 1971; Potter, 1976; Takahashi & Kim, 1979; Huang, 1980; Muller, 1981b; Frederiksen, 1981; Sun *et al.*, 1981; Takahashi & Jux, 1982; Gaponoff, 1984).

Remarks: It is noted that triporate pollen grains with flattened triangular outline which include pollen of the extant genera *Betula*, *Myrica*, *Corylus*, *Engelhardia* and *Casuarina* need more detailed study to differentiate reliably between their pollen. The condition of poor preserved pollen grains, viewing from different aspects and experience of the examiner may cause some bias in identification. Basically, the pollen of *Momipites coryloides* Wodehouse 1933, is identified by slightly protruding pores, no vestibulum, and indistinctly tectate exine. Wodehouse (1933) pointed out that the grains of modern *Engelhardia spicuta* (Juglandaceae) are 19-22 μm . in diameter, which is somewhat smaller than those of *Corylus* (Betulaceae). Nichols (1973) emended the genus *Momipites* Wodehouse 1933 to include the genus *Engelhardtoidites* Potonié *et al.* 1950 and some other genera in one genus. Srivastava (1972, 1975) indicated that the genus *Momipites* Wodehouse 1933 (having affinity with *Corylus*) differs from *Engelhardtoidites* Potonié *et al.* 1950 (having affinity with *Engelhardia*) in possessing protruding pores with an annulus.

***Momipites coryloides* Wodehouse 1933**

Plate 10, Figures 5 & 6.

Selected Synonymy:

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

1975 *Triporopollenites mullensis* (Simpson) Rouse & Srivastava; Srivastava, p. 144, pl. 13, figs. 3-10, pl. 14, figs. 1-6.

1980 *Triporopollenites corylus*; Huang, p. 68, pl. 4, figs. 15-17.

See Frederiksen, 1980, p. 38.

Longest Dimension: 18-(23)-26 μm . (20 specimens).

Distribution: This species occurs rarely to commonly from the Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Engelhardia spicata* Bl. (Stone & Broome, 1975, p. 12, fig. 3g).

Remarks: In this study, the microgranules on the exine surface of *Momipites coryloides* Wodehouse 1933 is denser than those of *Engelhardtoidites granulatus* (Simpson) Sirvastava 1975.

Genus: *Monoporopollenites* Meyer 1956

Type Species: *Monoporopollenites gramineoides* Meyer ex Potonié 1960

Selected Synonymy:

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

1954 *Monoporites* Hammen, p. 83, *nom. illeg.* (ICBN Art. 13.3, Voss *et al.*, 1983).

1956 *Monoporopollenites* Meyer, p. 111.

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

Distribution: This genus, and other dispersed pollen resembling extant pollen of Gramineae, has been recorded from the Palaeocene of South America, Africa and Australia (Muller, 1981b). It is cosmopolitan in the Tertiary to Recent (Germeraad *et al.*, 1968; Penny, 1969; Huang, 1980; Muller, 1981b; Sun *et al.*, 1981; Takahashi, 1982; Mohr, 1984).

Remarks: At least three fossil genera including *Monoporites* Hammen 1954, *Graminidites* Cookson 1947 ex Potonié 1960b and *Monoporopollenites* Meyer 1956 are similar and resemble modern pollen of the Gramineae. Jansonius & Hills (1976; p.1075, 1155) considered the genus *Monoporites* Hammen 1954 was illegitimate because of the designation of pollen of the recent *Chusquea lehmannii* (Gramineae) as type species. Thus, it became a junior synonym of extant *Chusquea lehmannii*. They regarded the genus *Graminidites* Cookson 1947 was validly proposed as a form genus by Potonié (1960b). Consequently, this study considers that the

genus *Monoporopollenites* Meyer 1956 is the legitimate senior synonym. See also a discussion on some related genera under the genus *Graminidites* Cookson 1947 by Kar & Jain (1981).

***Monoporopollenites gramineoides* Meyer 1956**

Plate 10, Figure 10.

Selected Synonymy:

1947 *Monoporites (Graminidites) media* Cookson 1947, p. 134, pl. 15, figs. 41 & 42, non ICBN.

1956 *Monoporopollenites gramineoides* Meyer, p. 111, pl. 4, fig. 29.

1968 *Monoporites annulatus* Hammen 1954; Germeraad *et al.*, p. 294, pl. 3, fig. 3.

1984 *Graminidites subtiliglobosus* Krutzsch; Mohr, p. 62, pl. 8, figs. 3.

Longest Dimension: 18-34 μm . (9 specimens).

Distribution: This species occurs from very rarely to commonly in the Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant species of the Gramineae and further detailed identification is not well known.

Genus: *Myricipites* Wodehouse 1933

Type Species: *Myricipites dubius* Wodehouse 1933

Selected Synonymy:

1933 *Myricipites* Wodehouse, p. 505.

1953 *Triatriopollenites* Pflug *in* Thomson & Pflug, p. 76.

Distribution: This genus, including those dispersed pollen resembling modern pollen of *Myrica*, first appears from Santonian sequences of eastern U. S. A. It is distributed in the Tertiary of North America, Europe and Asia (Machin, 1971; Salujha *et al.*, 1980; Muller, 1981b; Sun *et al.*, 1981; Gaponoff, 1984). Coetzee & Praglowski (1984) using SEM micrographs are convinced that the dispersed pollen having affinity with modern pollen of the *Myrica* occur in Tertiary sediments of South Africa.

Remarks: There is a major problem distinguishing between pollen of *Myrica* (Myricaceae) and *Casuarina* (Casuarinaceae). Muller (1981b) and Coetzee & Praglowski (1984) pointed out some

diagnostic criteria to differentiate between these genera, but the problem needs more attention and fine-structure studies to obtain more reliable characteristics of dispersed pollen. The condition of poorly preserved pollen grains, viewing from different aspects and experience of examiner may cause some bias in identification. Basically, the pollen of *Myricipites dubius* Wodehouse 1933, is identified by slightly protruding pores, isolated spinules (not on ridges), thinner exine, and absent nexine.

***Myricipites dubius* Wodehouse 1933**

Plate 10, Figure 9.

Selected Synonymy:

1933 *Myricipites dubius* Wodehouse, p. 506, fig. 33.

1984 *Myrica* sp.; Coetzee and Praglowski, figs. 9: D-I.

Longest Dimension: 20-26 μm . (4 specimens).

Distribution: This species occurs very rarely from the Middle Miocene of southern Thailand basins (this study).

Botanical Affinity: The fossil pollen resembles pollen of extant *Myrica* spp., Myricaceae (Coetzee & Praglowski, 1984, p. 33, figs. 7A-E, 8A-J, 9A-C).

Remarks: The sculpture under SEM of this species is sparsely microspinulate.

Genus: *Myrtaceidites* Cookson & Pike 1954

Type Species: *Myrtaceidites mesonesus* Cookson & Pike ex Potonié 1960

Selected Synonymy:

1954 *Myrtaceidites* Cookson & Pike, p. 204.

Distribution: This genus, and other dispersed pollen having affinity with extant pollen of Myrtaceae, have been recorded from the Late Cretaceous of South America and Southeast Asia (Muller, 1981b). It is distributed in the Tertiary of North America, East Asia, Australia, New Zealand and Indian Ocean (Engelhardt, 1964; Penny, 1969; Kemp & Harris, 1977; Martin, 1978; Muller, 1981b; Sun *et al.*, 1981; Foster, 1982; Huang & Huang, 1984).

***Myrtaceidites mesonesus* Cookson & Pike 1954**

Plate 10, Figures 7 & 8.

Selected Synonymy:

1954 *Myrtaceidites mesonesus* Cookson & Pike, p. 205, pl. 1, fig. 36.

1964 *Myrtaceidites* sp. cf. *M. eugenioides* Cookson & Pike; Engelhardt, p. 18, pl. 4, fig. 46.

1977 *Myrtaceidites* sp. cf. *M. mesonesus* Cookson & Pike; Kemp & Harris, p. 44, pl. 7, figs. 11 & 12.

Longest Dimension: 11-15 μm . (6 specimens).

Distribution: This species occurs from the Early Miocene of Fang Basin, northern Thailand (this study).

Botanical Affinity: The fossil pollen is comparable with pollen of the extant Myrtaceae. Martin (1978) pointed out that further detailed identification of fossil myrtaceous pollen appears impossible.

Remarks: Sculpture under SEM of this species is psilate to weakly verrucate.

Genus: *Pandaniidites* Elsik 1968

Type Species: *Pandaniidites texus* Elsik 1968

Selected Synonymy:

1968 *Pandaniidites* Elsik, p. 314.

Distribution: This genus, and other dispersed pollen having affinity with extant pollen of *Pandanus*, have been recorded from the Cretaceous (Maastrichtian) of North America. It is distributed in the Tertiary of U. S. A., Eurasia, Africa, Southeast Asia, West Pacific (Potonié, 1960a; Elsik, 1968a; Anderson & Muller, 1975; Muller, 1981b; Jarzen, 1978, 1983).

Botanical Affinity: The fossil pollen of the *Pandaniidites* is comparable with *Pandanus* (Pandanaeae) which is coastal or marsh tree (Elsik, 1968a, p. 314, pl. 15, fig. 6). The extant species is a tropical indicator (Elsik, 1968a; Jarzen, 1983; Doggett, 1985).

***Pandaniidites texus* Elsik 1968**

Plate 10, Figures 11 & 12.

Selected Synonymy:

1968 *Pandaniidites texus* Elsik, p. 314, pl. 15, fig. 6.

Longest Dimension: 14-30 μm . (5 specimens).

Distribution: This species occurs very rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen of the *Pandaniidites texus* Elsik 1968 is comparable with pollen of the extant *Pandanus* (Pandanaeae). The extant species is a coastal or marsh tree and a tropical indicator (Elsik, 1968a, p. 314, pl. 15, fig. 6; Jarzen, 1983; Doggett, 1985).

Remarks: Overall sculpture of the fossil pollen under SEM shows fairly smooth surface with spinules; spines are conical, 1-2 μm . long and 3 μm . apart.

Genus: *Periporopollenites*

Pflug & Thomson in Thomson & Pflug 1953

Type Species: *Periporopollenites stigmosus*

Potonié ex Thomson & Pflug 1953

Selected Synonymy:

1953 *Periporopollenites* Pflug & Thomson in Thomson & Pflug 1953, p. 111.

Periporopollenites stigmosus

Potonié ex Thomson & Pflug 1953

Plate 10, Figures 13 & 14.

Selected Synonymy:

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

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

Longest Dimension: 28-37 μm . (6 specimens).

Distribution: This species occurs from Late Miocene to Early Pliocene of the Indener strata, Rhenish brown coal region, western West Germany (Mohr, 1984) and Late Oligocene to Early Miocene sequences of northern Thailand basins (this study).

Botanical Affinity: This fossil pollen resembles that produced by the extant species *Altingia* sp., Altingiaceae (Mohr, 1984).

Remarks: Sculpture under SEM of this perforate species is finely reticulate with circular and very small lumina; muri about 0.5 μm . wide and possess microgranules on the surface. There are some granules inside the porate areas.

Genus: *Polyadopollenites*

Pflug & Thomson *in* Thomson & Pflug 1953

Type Species: *Polyadopollenites multipartitus*

Pflug *in* Thomson & Pflug 1953

Selected Synonymy:

1953 *Polyadopollenites* Pflug & Thomson *in* Thomson & Pflug, p. 112.

1972 *Acaciapollenites* Mildenhall, p. 490, *nom. superfl.*

Distribution: Dispersed pollen resembling extant pollen of *Acacia* (including *Acaciapollenites* Mildenhall 1972 and *Polyadopollenites* Pflug 1953) has been recorded from the Late Eocene of Cameroon (Salard-Cheboldaeff, 1978); it occurs in the Oligocene and Miocene of Australia, New Zealand, Central America and South America (Cookson, 1954; Penry, 1969; Muller, 1981b; Pocknall, 1982; Pocknall & Mildenhall, 1984).

Botanical Affinity: The fossil pollen of *Acaciapollenites* sp. is comparable with pollen of the extant *Archidendron* and *Pithocellobium*, Leguminosae (Pocknall, 1982).

Remarks: Mildenhall (1972) established the genus *Acaciapollenites* and used the occurrence of a vestigial furrow on the distal surface of the individual cells as the criterion to differentiate from *Polyadopollenites* Pflug & Thomson 1953. Despite the great similarity of the two genera, this study considers that *Acaciapollenites* Mildenhall 1972 is superfluous.

Polyadopollenites myriosporites

Cookson ex Partridge *in* Stover & Partridge 1973

Plate 10, Figures 15.

Selected Synonymy:

1954 *Acacia myriosporites* Cookson, p. 55, pl. 1, figs. 1, 5-8.

1972 *Acaciapollenites myriosporites* Cookson ex Mildenhall, p. 490, figs. 1-13.

1973 *Polyadopollenites myriosporites* Cookson ex Partridge in Stover & Partridge, p. 275, pl. 27, fig. 11.

1984 *Acaciapollenites myriosporites* Cookson ex Mildenhall; Pocknall & Mildenhall, p. 47, pl. 26, fig. 6.

See Pocknall & Mildenhall, 1984, p. 47, under *Acaciapollenites myriosporites*.

Longest Dimension: 28-45 μm . (5 specimens).

Distribution: This species occurs very rarely from Early to Middle Miocene of Fang and Mae Moh basins, northern Thailand (this study).

Remarks: The sculpture under LM is smooth but under SEM the microperforate surface and a vestigial furrow on the distal surface of individual cells are clearly seen.

Genus: *Polyatriopollenites* Pflug 1953

Type Species: *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953

Selected Synonymy:

1953 *Polyatriopollenites stellatus* Pflug, p. 115.

1960b *Pterocaryapollenites* Potonié, p. 132.

Distribution: This species, and other dispersed pollen having affinity with modern pollen of *Pterocarya*, have been recorded from the Palaeocene in U. S. A. (Frederiksen, 1979); and occur in the later Tertiary in Europe and eastern Asia (Martin & Rouse, 1966; Fuji, 1969a; Nagy, 1969; Leopold, 1969; Penny, 1969; Machin, 1971; Elsik, 1974; Muller, 1981b; Sun *et al.*, 1981).

Polyatriopollenites stellatus

Potonié & Venitz ex Pflug 1953

Plate 11, Figure 3.

Selected Synonymy:

1934 *Pollenites stellatus* Potonié & Venitz, pl. 2, fig. 26.

1953 *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug, p. 115, pl. 5, fig. 24.

1966 *Pterocarya stella* Potonié; Martin & Rouse, p. 196, pl. 8, figs. 79-80.

1974 *Pterocarya* sp.; Elsik, pl. 1, fig. 23.

Longest Dimension: 26-32 μm . (4 specimens).

Distribution: This species occurs from the Early Miocene of Sin Pun Basin, southern Thailand; Middle Miocene of Mae Sot Basin, northern Thailand (this study).

Botanical Affinity: The fossil pollen is comparable with pollen of the extant *Pterocarya* spp. (Juglandaceae), viz., *Pterocarya delavayi* Franchet. (Stone & Broome, 1975, p. 5, fig. 6d). The modern genera *Pterocarya*, *Carya* and *Juglans* (Juglandaceae) are not listed as native genera of Thailand, except the genus *Engelhardia* (Juglandaceae) is native to northern Thailand (Smitinand, 1980).

Remarks: The fossil pollen under SEM shows uniform microgranulate sculpture. This species differs from *Alnipollenites verus* and *Caryapollenites simplex* in having about five annulate pores, isolated microgranules on exine and without arci.

Genus: *Psilatricolporites* (Hammen) Hammen & Wymstra 1964

Type Species: *Psilatricolporites operculatus* Hammen & Wymstra 1964

Selected Synonymy:

1956 subgen. *Psilatricolporites* Hammen, p. 91.

1964 *Psilatricolporites* (Hammen) Hammen & Wymstra, p. 236.

***Psilatricolporites operculatus* Hammen & Wymstra 1964**

Plate 11, Figures 1 & 2.

Selected Synonymy:

1964 *Psilatricolporites operculatus* Hammen & Wymstra, p. 236, pl. 1, fig. 13.

1968 *Psilatricolporites operculatus* Germeraad *et al.*, p. 328-330, pl. 15, fig. 3.

Longest Dimension: 22-32 μm . (4 specimens).

Distribution: This species occurs from the Neogene of Borneo (Germeraad *et al.*, 1968); and the Miocene of Fang and Mae Moh basins, northern Thailand (this study).

Botanical Affinity: This dispersed pollen resembles pollen produced by extant *Alchornea*, Euphorbiaceae (Germeraad *et al.*, 1968).

Remarks: The sculpture under SEM of this species shows roughened scabrate surface.

Genus: *Quercoidites* Potonié 1960

Type Species: *Quercoidites henrici* Potonié 1960

Selected Synonymy:

1960b *Quercoidites* Potonié, p. 92.

Distribution: This genus, and other dispersed pollen having an affinity with extant pollen of *Quercus*, has been recorded from the Eocene of Southeast Asia and U. S. A. and the Tertiary of Europe, Southeast Asia and eastern Asia (Potonié, 1960a; Engelhardt, 1964; Fuji, 1969a, 1972; Penny, 1969; Frederiksen, 1981; Muller, 1981b; Sun *et al.*, 1981; Takahashi, 1982; Takahashi & Jux, 1982; Sun *et al.*, 1984).

***Quercoidites* sp. 777**

Plate 11, Figures 4-7.

Selected Synonymy:

cf. 1964 *Quercoidites* cf. *Q. henrici* Potonié *et al.*; Engelhardt, p. 10, pl. 2, fig. 15.

Description: Pollen grains free with very rare tetrads, basically tricolpate although a few grains show poorly defined pores, isopolar, prolate rounded ellipsoid in equatorial view. Colpi almost reaching the poles. Pollen wall stratified, sexine about the same thickness as nexine, exine 1-2 μm . thick. Sculpture psilate to scabrate (LM); psilate to verrucate with microperforations, verrucae are rather flat, approximately round to elongate and 1-3 μm . long, (SEM). This pollen type shows variations in size and sculpture and are difficult to distinguish under LM.

Longest Dimension: 22-(24)-42 μm . (21 specimens).

Distribution: This species occurs commonly from Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen is comparable with pollen of the extant *Quercus*, Fagaceae viz. *Q. helferiana* A. DC. (Plate 11, Figure 8), *Q. phillyraeoides* Gray. (Plate 11, Figure 9) and *Q. serrata* Thumb (Plate 11, Figure 10 & 11).

Extant Genus: *Radermachera* (Bignoniaceae)

***Radermachera* sp. 1546**

Plate 11, Figure 12.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, prolate to subprolate. Colpi about 10 μm . long. Exine 1-2 μm . thick, tectate, sexine and nexine are the same thickness. Sculpture finely reticulate (LM & SEM); muri less than 0.5 μm . wide, lumina circular to oval and 0.5-1 μm . wide (SEM).

Longest Dimension: 14-22 μm . (6 specimens).

Distribution: This species occurs from the Middle Miocene of Andaman Sea and Gulf of Thailand (this study).

Botanical Affinity: Size, aperture and ornament of this fossil pollen is similar to pollen of the extant *Radermachera glandulosa* Miq. (Bignoniaceae).

Genus: *Rhoipites* Wodehouse 1933

Type Species: *Rhoipites bradleyi* Wodehouse 1933

Selected Synonymy:

1933 *Rhoipites* Wodehouse, p. 513.

See Pocknall & Crosbie, 1982, p. 7.

Remarks: The genus *Rhoipites* Wodehouse 1933 has a broad diagnosis and is here considered to accommodate, provisionally, unknown tricolporate pollen grains with reticulate-pitted ornament. The species under this genus may not be related to the modern pollen of *Rhus typhina* matched in the original diagnosis with *Rhoipites* Wodehouse 1933.

Rhoipites* cf. *R. retiformis

Pocknall & Mildenhall 1984

Plate 12, Figures 6-10.

Selected Synonymy:

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

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to subprolate. Colpi extending almost to poles. Pores circular, often indistinct. Exine tectate, 1 μm . thick, sexine and nexine are the same thickness. Sculpture finely reticulate (LM & SEM); muri smooth, and 0.3 μm . wide, lumina circular to elongate and 0.1-0.4 μm . long (SEM).

Longest Dimension: 14-(17)-20 μm . (15 specimens).

Distribution: This species occurs from Late Oligocene to Early Miocene in New Zealand (Pocknall & Mildenhall 1984); Early to Middle Miocene of Fang and Mae Moh basins, northern Thailand (this study).

Botanical Affinity: Unknown.

Remarks: It is noted that this species has some morphological similarity with *Salixipollenites* cf. *S. discoloripites*. It is difficult to distinguish them under LM but they are differentiated under SEM.

Rhoipites sp. 1207

Plate 13, Figures 3 & 4.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi extending almost to poles, margins are straight and thickening at the oral rims to about 2 μm . Pores circular, 4 μm . Exine tectate, 2 μm ., sexine and nexine are about the same thickness. Sculpture reticulate (LM & SEM); muri smooth and 0.5 μm . wide, lumina approximately circular, variable in size (less than 3 μm . in diameter), and smaller near colpi (SEM).

Longest Dimension: 28-37 μm . (5 specimens).

Distribution: This species occurs rarely from the Miocene of Mae Moh Basin, northern Thailand (this study).

Botanical Affinity: Unknown.

Rhoipites sp. 1263

Plate 11, Figures 13-15.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate. Colpi distinct, extending almost to poles; margins are of uniform thickness. Pores circular, 4 μm . wide. Exine tectate, 1-2 μm . thick, sexine and nexine are the same thickness. Sculpture perforate (LM & SEM); foveolae are less than 0.5 μm . wide and 0.5 μm . apart (SEM).

Longest Dimension: 24-36 μm . (10 specimens).

Distribution: This species occurs from the Late Oligocene to Miocene throughout Thailand (this study).

Botanical Affinity: Unknown.

***Rhoipites* sp. 1267**

Plate 12, Figures 13-15.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi distinct, extending almost to poles, margins thicken at the oral rims. Pores lalongate, 3-5 μm . wide and 5-8 μm . long. Exine tectate, about 1 μm . thick sexine and nexine are the same thickness. Sculpture finely reticulate (LM & SEM); muri smooth and 0.5 μm . wide, lumina circular to elongate and 0.3-1 μm . wide (SEM).

Longest Dimension: 24-32 μm . (8 specimens).

Distribution: This species occurs from the Miocene of Mae Moh Basin, northern Thailand; and the Gulf of Thailand (this study).

Botanical Affinity: Unknown.

***Rhoipites* sp. 1345**

Plate 13, Figures 1 & 2.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi clear, extending almost to poles, margins thicken at the oral rims. Pores weakly defined, circular to lalongate, 2-4 μm . Exine tectate, 2-3 μm ., sexine and nexine are about the same thickness. Sculpture reticulate (LM & SEM); muri about 1 μm . wide and possess transverse grooves and ridges on the surface (SEM).

Longest Dimension: 27-37 μm . (8 specimens).

Distribution: This species occurs from Early to Middle Miocene of Mae Moh Basin, northern Thailand; and Krabi Basin, southern Thailand (this study).

Botanical Affinity: Unknown.

***Rhoipites* sp. 847**

Plate 12, Figures 11-12.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi extending almost to poles, margins thicken at the oral rims. Pores poorly defined,

possibly lalongate. Exine tectate, about 1 μm ., sexine and nexine are about the same thickness. Sculpture reticulate (LM & SEM); muri tapering and 0.5-1 μm . apart, lumina circular and very small (SEM).

Longest Dimension: 18-27 μm . (9 specimens).

Distribution: This species occurs from the Late Oligocene of Li Basin, northern Thailand; Early to Middle Miocene of Mae Moh, northern Thailand and Sin Pun Basin, southern Thailand (this study).

Botanical Affinity: Unknown.

Genus: *Salixipollenites* Srivastava 1966

Type Species: *Salixipollenites discoloripites* Wodehouse ex Srivastava 1966

Selected Synonymy:

1966 *Salixipollenites* Srivastava, p. 529.

See Srivastava, 1972, p. 272.

Distribution: This genus, and other dispersed pollen having affinity with pollen of extant *Salix*, has been recorded from the Oligocene in Puerto Rico. and Miocene of North America and Europe (Leopold, 1969; Muller, 1981b).

Salixipollenites* cf. *S. discoloripites

Srivastava 1966

Plate 13, Figures 5 & 6.

Selected Synonymy:

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

1966 *Salixipollenites discoloripites* Wodehouse ex Srivastava, p. 529.

See Srivastava, 1972, p. 272.

Description: Pollen grain free, tricolp(or)ate. Colpi thicken at the equator. Pores not clearly defined, circular to lalongate, 3-4 μm . Exine tectate, about 1 μm . thick, sexine and nexine the same thickness. Sculpture reticulate (LM and SEM); lumina irregular and less than 1 μm . diameter; muri tapering, smooth and less than 0.5 μm . wide (SEM).

Longest Dimension: 13-19 μm . (7 specimens).

Distribution: This species occurs from the Late Oligocene of Li Basin and Middle Miocene of Fang Basin, northern Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen produced by the extant *Salix discolor* Muhl, Salicaceae (Bassett *et al.*, 1978, p. 242-244, fig. 130g).

Remarks: It is noted that this species has some morphological similarity with *Rhoipites* cf. *R. retiformis*. It is difficult to distinguish them under LM but they are differentiated under SEM.

Genus: *Spinizonocolpites* Muller 1968

Type Species: *Spinizonocolpites echinatus* Muller 1968 or

Spinizonocolpites prominatus (McIntyre) Stover & Evans 1973

Selected Synonymy:

1968 *Spinizonocolpites* Muller 1968, p. 11.

Distribution: This genus, and other dispersed pollen having affinity with pollen of extant *Nypa*, has been recorded from the Late Cretaceous of South America, Africa and Southeast Asia. It is distributed in the Tertiary of North America, Europe, Africa, India, Southeast Asia, Indian Ocean; and Australia (Muller, 1964, 1979, 1981b; Germeraad *et al.*, 1968; Hekel, 1972; Stover & Evans, 1973; Anderson & Muller, 1975; Morley, 1978; Kemp & Harris, 1977; Frederiksen, 1981; Kulkarni & Phadtare, 1981).

Remarks: Stover & Evans (1973) claimed that the genus *Spinizonocolpites echinatus* Muller 1968 was interpreted as conspecific with the taxa identified and described as *Monosulcites prominatus* McIntyre 1965 and as *Baltisphaeridium taylori* Cookson & Eisenack 1965. They did not compare the morphological details of those species and assigned a new combination of *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973.

Spinizonocolpites prominatus (McIntyre) Stover & Evans 1973

Plate 13, Figure 9.

Selected Synonymy:

1965 *Monosulcites prominatus* McIntyre, p. 214, figs. 33 & 34.

1968 *Spinizonocolpites echinatus* Muller, p. 11 & 12, pl. 3, fig. 2.

1973 *Spinizonocolpites prominatus* (McIntyre) Stover & Evans, p. 67, pl. 3, fig. 5.

Longest Dimension: 30-50 μm . (7 specimens).

Distribution: This species occurs from the Miocene of Andaman Sea and the Gulf of Thailand (this study).

Botanical Affinity: The fossil pollen of this species is comparable with pollen of the extant *Nypa fruticans* Wurm, *Palmae* (Germeraad *et al.*, 1968, p. 295-296, pl. 4, fig. 3; pl. 5, fig. 1; Tomlinson, 1986, figs. 3.3: A-C; Ferguson, 1986, p. 3087, figs. 41-45). The extant species is a mangrove tropical indicator.

Remarks: Sculpture under SEM is microreticulate with spines; muri smooth and about less than 0.5 μm . wide; lumina circular and less than 0.5 μm . in diameter; spines are conical and 3-5 μm . long.

Genus: *Tetracolporopollenites*

Pflug & Thomson *in* Thomson & Pflug 1953

Type Species: *Tetracolporopollenites sapotoides*

Pflug & Thomson *in* Thomson & Pflug 1953

Selected Synonymy:

1950 *Sapotaceoidaepollenites* Potonié *et al.*, p. 62, nom. nud.

1953 *Tetracolporopollenites* Pflug & Thomson *in* Thomson & Pflug, p. 108.

1960b *Sapotaceoidaepollenites* Potonié *et al.* ex Potonié, p. 109.

Distribution: This genus, and other dispersed pollen having affinity with extant pollen of Sapotaceae, has been recorded from the Late Cretaceous of Borneo, and the Tertiary of North and South America, Europe, Africa, India, Indian Ocean, Southeast Asia, South China Sea and Australia (Potonié, 1960a; Muller, 1968; Machin, 1971; Harris, 1972; Stover & Partridge, 1973; Anderson & Muller, 1975; Potter, 1976; Kemp & Harris, 1977; Martin, 1978; Muller, 1981b; Sun *et al.*, 1981; Takahashi, 1982; Rao & Ramanujam, 1982; Lorente, 1986).

Tetracolporopollenites sapotoides

Pflug & Thomson *in* Thomson & Pflug 1953

Plate 13, Figures 7 & 8.

Selected Synonymy:

1953 *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug, p. 110, pl. 15, figs. 6-12.

1972 *Sapotaceoidapollenites rotundus* Harris, p. 56, figs. 17 & 18.

1986 *Psilatricolporites pachydermatus* Lorente, pl. 22, p. 196-198, figs. 1A-C, 2A-C.

Longest Dimension: 23-32 μm . (6 specimens).

Distribution: This species occurs rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant Sapotaceae viz. *Palaquium* sp. (Anderson & Muller, 1975, p. 308, pl. 2, fig. 10) and *Planchonella myrsinoides* (Harley, 1986a, fig. 4; Harley, 1986b, fig. 1).

Remarks: Sculpture of the fossil pollen under SEM shows smooth exine with microperforations.

Genus: *Tiliaepollenites* Potonié 1931

Type Species: *Tiliaepollenites indubitabilis* Potonié 1931

Selected Synonymy:

1931 *Tiliaepollenites* Potonié, p. 4.

1934 *Tiliaepollenites* Potonié ex Potonié & Venitz, p. 37.

1953 *Intratripoporopollenites* Pflug & Thomson in Thomson & Pflug, p. 87.

1968 *Discoidites* Muller, p. 20.

Remarks: Muller (1968) differentiated the genus *Discoidites* Muller 1968 from *Tiliaepollenites* Potonié ex Potonié & Venitz 1934, on the basis of the presence of short colpi in the former and the absence of any indication of vestibulate pores. Although the exinal structure is similar, Jansonius & Hills (1976, p. 2903) reveal that the original combined description of the *Tiliaepollenites* Potonié 1931 is comparable with *Discoidites* Muller 1968. Jansonius & Hills (1976, p. 1340) regard the genus *Intratripoporopollenites* Pflug & Thomson 1953 as a junior synonym of the *Tiliaepollenites* Potonié 1931 which is followed in this study. However, the exinal ornament of the studied specimens (which is clearly finely reticulate under SEM) differs from granulate sculpture of *Tiliaepollenites* Potonié 1931 and the finely verrucate character of *Discoidites* Muller 1968.

***Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931**

Plate 13, Figures 11 & 12.

Selected Synonymy:

1931 *Tiliaepollenites indubitabilis* Potonié, p. 4, fig. 14.

cf. 1968 *Discoidites borneensis* Muller, p. 20, pl. 4, fig. 16.

cf. 1976b *Discoidites novaguineensis* Khan, p. 766-767, fig. 33.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, oblate. Colpi 5 μm . wide in polar view, slightly ragged margins. Exine 1-2 μm . thick, tectate, sexine and nexine the same thickness. Sculpture fairly uniform and finely reticulate (LM & SEM); lumina approximately circular and 0.5-1 μm . wide, muri smooth and 0.2-0.3 μm . wide (SEM).

Longest Dimension: 22-36 μm . (7 specimens).

Distribution: The dispersed pollen resembling the *Brownlowia* type, Tiliaceae (cf. *Discoidites borneensis* Muller 1968) has been recorded from the Palaeocene of Borneo (Muller, 1981b), the Pliocene of Papua New Guinea (Khan, 1976b). It occurs rarely to commonly from Early to Middle Miocene sediments throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Brownlowia* spp., Tiliaceae (Thanikaimoni, 1987, p. 20-21, pl. 30, figs. 611-628).

Genus: *Tricolpites* Cookson ex Couper 1953

Type Species: *Tricolpites reticulatus* Cookson ex Couper 1953

Selected Synonymy:

1947 *Tricolpites (Tubulifloridites)* Cookson, p. 134, non ICBN.

1953 *Tricolpites* Cookson ex Couper, p. 61.

See Srivastava, 1975, p. 143.

Remarks: The genus *Tricolpites* Cookson ex Couper 1953 with a broad diagnosis "Free, isopolar, tricolpate. Exine variable in thickness and sculpture. Size variable." is here employed to provisionally accommodate unknown tricolpate pollen grains.

***Tricolpites* sp. 1366**

Plate 14, Figure 10.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, prolate. Colpi extending almost to poles. Exine 1-2 μm . thick, stratified, sexine and nexine are the same thickness. Sculpture finely reticulate (LM & SEM); uniform reticulate, muri smooth and 0.5 μm . wide, lumina less than 0.5 μm . (SEM).

Longest Dimension: 25-35 μm . (6 specimens).

Distribution: This species occurs from the Middle Miocene of Mae Sot Basin, northern Thailand and Andaman Sea, southern Thailand (this study).

Botanical Affinity: Unknown.

***Tricolpites* sp. 258**

Plate 12, Figures 1-5.

Description: Pollen grains free, tricolpate, isopolar, radiosymmetric, usually oblate. Colpi widely opening, about 7/10 of the polar diameter. Exine 1-2 μm . thick, tectate, sexine and nexine are the same thickness. Sculpture reticulate (LM & SEM); muri 0.3-0.4 μm . wide and contain microgranules on the surface, lumina irregular, 0.5-2 μm . wide decreasing in size at the polar areas (SEM).

Longest Dimension: 28-35 μm . (5 specimens).

Distribution: This species occurs rarely from the Middle Miocene of Mae Moh Basin, northern Thailand (this study).

Botanical Affinity: Unknown.

***Tricolpites* sp. 854**

Plate 13, Figures 13-15.

Description: Pollen grains free, tricolpate, oblate, isopolar, radiosymmetric. Amb: circular. Colpi 2-3 μm . wide, varying from 1/5 to 3/5 of equatorial diameter, slightly ragged margins. Exine stratification is not seen. Sculpture microgranulate (LM and SEM); granules circular, uniform, less than 0.5 μm . in diameter and 0.5 μm . apart (SEM).

Longest Dimension: 18-26 μm . (10 specimens).

Distribution: This species is rare to common from the Miocene throughout Thailand (this study).

Botanical Affinity: Unknown.

Genus: *Tricolporites* Cookson 1947

Type Species: *Tricolporites prolata* Cookson 1947

Selected Synonymy:

1947 *Tricolporites* Cookson, p. 134.

***Tricolporites* cf. *T. valvatus* Harris 1972**

Plate 14, Figures 1-3.

Selected Synonymy:

1972 *Tricolporites valvatus* Harris, p. 54, figs. 8-9.

1982 *Tricolporites valvatus* Harris; Foster, pl. 2, fig. 10-11.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate. Colpi extending almost to poles, margins are straight and thickening at the oral rims to 4-6 μm . Pores circular, 2-3 μm . diameter. Exine indistinctly stratified, 1 μm . thick. Sculpture smooth (LM); but finely striate at high magnification (about 10000X), ridges less than 0.1 μm . wide (SEM).

Longest Dimension: 28-38 μm . (4 specimens).

Distribution: *Tricolporites valvatus* Harris 1972 has been recorded from the Palaeogene of Australia (Harris, 1972; Foster, 1982). The species occurs rarely from the Early to Middle Miocene of Fang and Mae Moh basins, northern Thailand (this study).

Botanical Affinity: Unknown.

Genus: *Tricolporopollenites*

Pflug & Thomson in Thomson and Pflug 1953

Type Species: *Tricolporopollenites dolium*

Potonié ex Pflug and Thomson 1953

Selected Synonymy:

1953 *Tricolporopollenites* Pflug & Thomson in Thomson and Pflug, p. 82.

Remarks: The genus *Tricolporopollenites* Pflug & Thomson with a broad diagnosis comprising (pollen) with three symmetrically distributed germinals, each consisting of a meridional colpus with an equatorial pore, is here used to accommodate provisionally unknown tricolporate pollen grains.

***Tricolporopollenites* sp. 810**

Plate 14, Figures 4 & 5.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi: about 7/10 of polar diameter. Pores weakly defined, possibly circular. Exine less than 1 μm ., stratification is not seen. Sculpture weakly striate (LM); stria-granulate, granules are 0.2-0.3 μm . in diameter, dense and arranged in parallel lines (SEM).

Longest Dimension: 13-25 μm . (7 specimens).

Distribution: This species occurs rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: Unknown.

***Tricolporopollenites* sp. 862**

Plate 14, Figures 6 & 7.

Description: Pollen grains free, tricolporate, isopolar, radiosymmetric, prolate to sub-prolate. Colpi clear, extending almost to poles and thickening at the oral rims. Pores lalongate, about 4 μm . wide and 7 μm . long. Exine indistinctly stratified, about 1 μm . thick. Sculpture weakly striate (LM & SEM); muri smooth and 0.3 μm . wide, lumina less than 0.3 μm . (SEM).

Longest Dimension: 33-44 μm . (6 specimens).

Distribution: This species occurs from Early to Middle Miocene of Fang and Mae Moh basins, northern Thailand (this study).

Botanical Affinity: Unknown.

***Tricolporopollenites* sp. 908**

Plate 14, Figures 8 & 9.

Description: Pollen grains free, tricolporate, occasionally tetracolporate, isopolar, radiosymmetric, oblate, sub-circular (polar views). Colpi indistinct, 1/6 of equatorial diameter.

Pores weakly defined, circular, 2 μm . in diameter. Exine tectate, 1 μm . thick, sexine and nexine of equal thickness. Sculpture finely reticulate (LM & SEM); muri 0.4 μm . wide with 4-5 small granules (around each lumina) attached on the surface, lumina circular to elongate and 0.2-1 μm . wide (SEM).

Longest Dimension: 25-32 μm . (5 specimens).

Distribution: This species occurs rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: Unknown.

Genus: *Triorites* Cookson 1950

Type Species: *Triorites magnificus* Cookson 1950

Selected Synonymy:

1950 *Triorites* Cookson, p. 175 & 176.

1953 *Triorites* Cookson ex Couper, p. 60, *nom. superfl.*

Remarks: The genus *Triorites* Cookson ex Couper 1953 is diagnosed broadly as "Free, isopolar, triporate, or a circular. Grain oblate to prooblate, triangular to sub-triangular in polar view. Exine psilate to sculptured. Size very variable." and is used here provisionally for any unknown triporate pollen grains.

***Triorites* sp. 1373**

Plate 14, Figures 11 & 12.

Description: Pollen grains free, triporate, isopolar, radiosymmetric, outline flattened circular to sub-triangular. Pores annulate, circular, 2-3 μm . in diameter. Exine not clearly stratified, 2 μm . thick. Sculpture reticulate (LM & SEM); muri smooth and 0.3 μm . wide, lumina shallow, approximately hexagonal and 3-5 μm . wide (SEM).

Longest Dimension: 22-30 μm . (7 specimens).

Distribution: This species occurs rarely from the Miocene throughout Thailand (this study).

Botanical Affinity: Unknown.

***Triorites* sp. 788**

Plate 15, Figures 1-3.

Description: Pollen grains free, triporate, isopolar, radiosymmetric, outline flattened circular in variable views. Pores annulate, circular, 2-4 μm . in diameter, protruding, 3-4 μm . long. Exine tectate, 2-3 μm . thick, sexine the same thickness as nexine. Sculpture coarsely reticulate (LM and SEM); muri 0.5-1 μm . wide and contain microgranulate elements on the surface, lumina approximately circular and 4-6 μm . in diameter (SEM).

Longest Dimension: 23-30 μm . (8 specimens).

Distribution: This species occurs rarely from the Miocene of Mae Moh and Mae Sot basins, northern Thailand; and Andaman Sea, southern Thailand (this study).

Botanical Affinity: Unknown.

Genus: *Trivestibulopollenites*

Pflug in Thomson & Pflug 1953

Type Species: *Trivestibulopollenites betuloides*

Pflug in Thomson & Pflug 1953

Selected Synonymy:

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

1960 *Betulaepollenites* Potonié 1934 ex Potonié, p. 115.

1960 *Betulaceoipollenites* Potonié 1951 ex Potonié, p. 114.

Distribution: This genus, and other dispersed pollen resembling extant pollen of *Betula*, has been recorded from the Late Cretaceous of Urals and Canada (Penny, 1969; Muller, 1981b) and is widely distributed in the Tertiary of Northern Hemisphere (Engelhardt, 1964; Martin & Rouse, 1966; Fuji, 1969a, 1969b, 1969c; Nagy, 1969; Penny, 1969; Potter, 1976; Takahashi & Kim, 1979; Muller, 1981b; Sun *et al.*, 1981; Takahashi & Jux, 1982; Mohr, 1984).

Remarks: The similarities between triporate pollen resembling extant genera *Betula*, *Corylus* and *Casuarina* needs more detailed examination to obtain more reliable identification of the dispersed pollen. The condition of poorly preserved pollen grains when viewed from different aspects in conjunction with the experience of the examiner may cause some bias in identification. In this study, the pollen of *Trivestibulopollenites betuloides* Pflug In: Thomson & Pflug 1953, is identified by its slightly protruding pores and vestibulate pore structure. Jansonius & Hills (1976; p. 260, 262, 3081) considered *Trivestibulopollenites* Pflug In: Thomson & Pflug 1953

to be the senior synonym of both *Betulaepollenites* Potonié 1934 ex Potonié 1960 and *Betulaceoipollenites* Potonié 1951 ex Potonié 1960.

Trivestibulopollenites betuloides

Pflug in Thomson & Pflug 1953

Plate 15, Figures 4 & 5.

Selected Synonymy:

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.

Longest Dimension: 18-28 μm . (5 specimens).

Distribution: This species occurs rarely from Late Oligocene to Middle Miocene throughout Thailand (this study).

Botanical Affinity: Aperture and sculpture under SEM of the dispersed pollen resemble pollen of extant species of *Betula pendula* Roth, Betulaceae (Plate 15, Figure 6) and *Carpinus japonica* Blume, Carpinaceae (Plate 15, Figures 7 & 8).

Remarks: The sculpture under SEM of this species shows most of the microgranules are on ridges.

Genus: *Tubulifloridites* Cookson ex Potonié 1960

Type Species: *Tubulifloridites antipodica* Cookson ex Potonié 1960

Selected Synonymy:

1947 *Tricolpites* (*Tubulifloridites*) Cookson, p. 134, *non* ICBN.

1960b *Tubulifloridites* Cookson ex Potonié, p. 106.

cf. 1960b *Compositoipollenites* Potonié ex Potonié, p. 105.

Distribution: The pollen of the Tubuliflorae type is distributed world-wide in the Oligocene and later (Muller, 1981b).

***Tubulifloridites antipodica* Cookson ex Potonié 1960**

Plate 15, Figures 9.

Selected Synonymy:

1960b *Tubulifloridites antipodica* Cookson ex Potonié, p. 106.

Longest Dimension: 18-28 μm . (5 specimens).

Distribution: This species occurs rarely from the Middle Miocene throughout Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant members of Tubuliflorae (Cookson, 1947).

Remarks: The sculpture under SEM of this species shows conical spines uniformly distributed over the surface. The spines are about 1 μm . long and 2-3 μm . apart.

Extant Genus: *Xylocarpus* (Meliaceae)

***Xylocarpus* sp. 1526**

Plate 15, Figures 10 & 11.

Description: Pollen grains free, tetra-colporate or pentacolporate, isopolar, radiosymmetric, sub-prolate. Colpi about 1/2 of polar diameter, margins are straight and thickening at the oral rims. Pores longitudinal, 3-6 μm . slightly protruding. Exine: stratified, about 3 μm . Sculpture smooth (LM); smooth with very small foveolae irregularly developed in the exine surface (SEM).

Longest Dimension: 30-45 (5 specimens).

Distribution: This species occurs from the Middle Miocene of the Gulf of Thailand (this study).

Botanical Affinity: The fossil pollen resembles pollen of the extant *Xylocarpus* spp. viz *X. australasicus*, Meliaceae (Thanikaimoni, 1987, p. 21, pl. 33, figs. 644-649).

Genus: *Zonocostites* Germeraad et al. 1968

Type Species: *Zonocostites ramonae* Germeraad et al. 1968

Selected Synonymy:

1968 *Zonocostites* Germeraad et al., p. 332.

Distribution: This genus, and other dispersed pollen having affinity with extant pollen of *Rhizophora* and *Bruguiera*, has been recorded from the Eocene of South America and India, the Oligocene of Australia and the Miocene and Pliocene of Southeast Asia, South China Sea and

Nigeria (Germeraad *et al.*, 1968; Hekel, 1972; Anderson & Muller, 1975; Morley, 1978; Muller, 1981b).

***Zonocostites ramonae* Germeraad *et al.* 1968**

Plate 15, Figures 12-14.

Selected Synonymy:

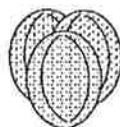
1968 *Zonocostites ramonae* Germeraad *et al.*, p. 333, pl. 15, figs. 6 & 7.

Longest Dimension: 13-17 μm . (7 specimens).

Distribution: This species occurs from Early to Middle Miocene of Andaman Sea and the Gulf of Thailand (this study).

Botanical Affinity: The morphology of modern pollen grains of the genera *Rhizophora* and *Bruguiera*, Rhizophoraceae, are alike in many aspects and can hardly be distinguished under LM. The fossil pollen *Zonocostites ramonae* is comparable with pollen of the extant genera *Rhizophora* and *Bruguiera*, Rhizophoraceae (Germeraad *et al.*, 1968, p. 332-333, pl. 15, figs. 6-9; Muller & Caratini 1977, pl. 3, figs. 1-2; Tissot, 1980, p. 157-175, pls. 2-6; Bertrand, 1983, p. 148, figs. 1A-C; Tomlinson, 1986, p. 140-141, figs. 73: A-B). The extant taxa grow in tropical mangrove environments.

Remarks: The microreticulate sculpture under SEM of this species is slightly variable.



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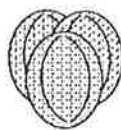
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GENERAL EXPLANATION OF PLATES

Specimen Location. Most palynomorphs are located by the England Finder, for example: H23/3, unless otherwise indicated.

SEM. The SEM is indicative of "Scanning Electron Micrograph" and followed with negative recording number, for example: SEM 1103. Most SEM bar scales are 10 μm ., unless otherwise indicated.

LM. The LM is indicative of "Light Micrograph" and followed with negative recording number, for example: LM 10607. All light micrographs displayed here were taken under differential interference contrast. Most light micrographs are approximately 1000 times magnification, unless otherwise indicated.

Recent Pollen. All scanning electron micrographs of Recent pollen grains displayed here were not preserved.

Miscellaneous Palynomorphs. Some miscellaneous palynomorphs found in this study may be useful for palaeoenvironmental indications. As the main emphasis of this study is on pollen and spores, no systematic treatment of algae and dinoflagellates is attempted, but some illustrations are given on Plate 16.

PLATE 1

Figures 1-3 Marker lines represent examination routes (arrow lines) between microgrids, and marker dots represent grid number. Figure 1: Slide KP126S2, SEM 399, 100 μm scale bar. Figure 2: Slide LP117S13, SEM 118, 100 μm scale bar. Figure 3: Slide FP10110, SEM 970, 1000 μm scale bar.

Figure 4 Slide FP10110, SEM 969, showing the plain 50 mesh microgrid which fixed cover slip by glue (dark), 1000 μm scale bar.

Figure 5 Slide KP126S2, SEM 400, showing the plain grids with a dividing bar cut for numbering divisions, 100 μm scale bar.

Figure 6 Slide NY10501, SEM 920, showing the plain 75 mesh microgrid adhered to cover slip by glue (dark), 1000 μm scale bar.

Figure 7 Slide FP10110, SEM 963, showing the Maxtaform H-2 finder grid overlying a strew residue, 1000 μm scale bar.

Figure 8 Slide LP117S13, SEM 117, showing a tricolporate grain located at the division "O/1" prior to making a higher magnification.

Figure 9 Slide MM10104, SEM 956, showing the Maxtaform H-6 finder grid overlies on strew residue, 1000 μm scale bar.

Figures 10-12 Some problems were encountered during the specimen preparation. Figure 10: Slide MM10104, SEM 399, showing grid bar overlapping palynomorphs, 100 μm scale bar. Figure 11: Slide FP101S4, SEM 140, showing grid bar overlapping a trilete spore. Figure 12: Slide MM116S2, SEM 181, showing glue overspread on a trilete spore.

PLATE 1

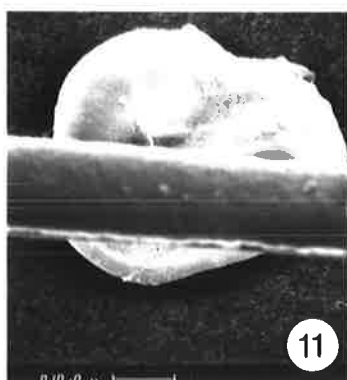
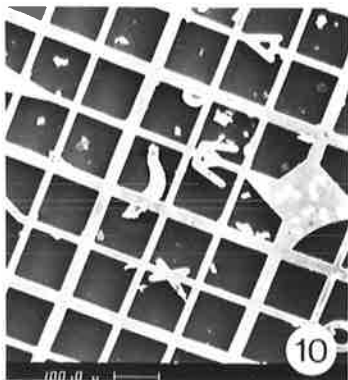
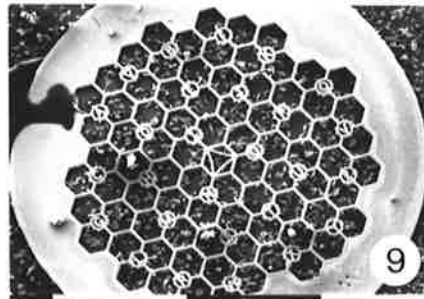
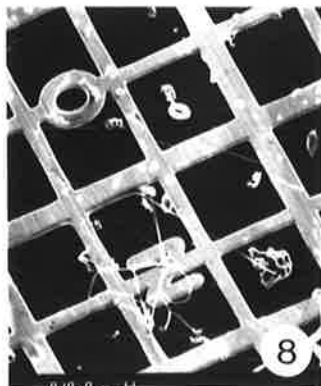
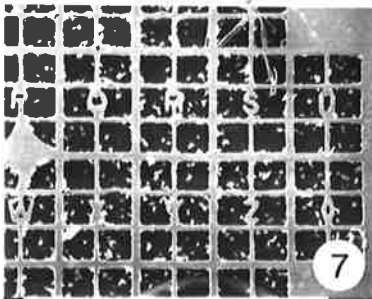
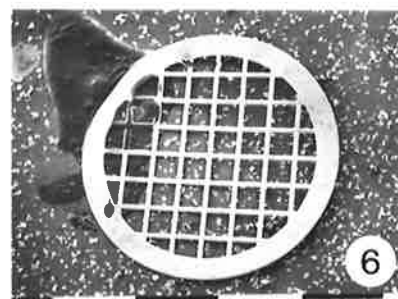
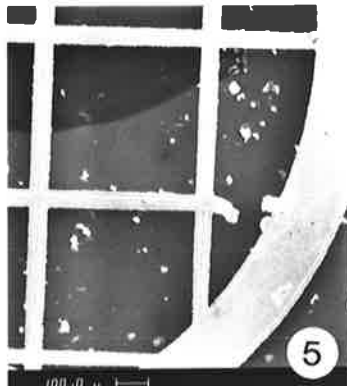
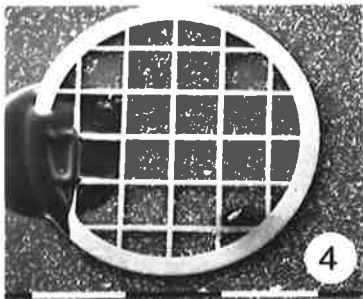
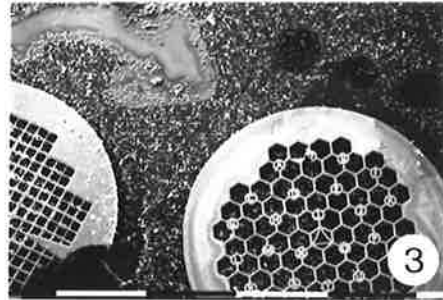
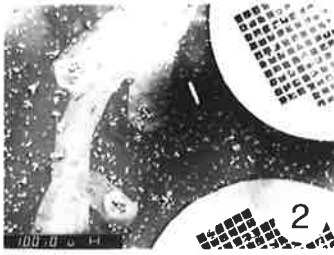
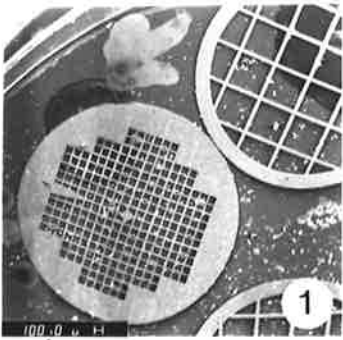


PLATE 2

Figure 1 *Baculatisporites primarius* Wolff ex Thomson & Pflug 1953. Slide NY10702, H23/3, SEM 1103, equatorial view showing densely baculate sculpture and indistinct trilete mark.

Figure 2 *Cyathidites minor* Couper 1953. Slide MM11801, O30/3, SEM 772, proximal view showing well developed trilete mark and lack of sculpture.

Figure 3 *Foveotriletes margaritae* Hammen ex Germeraad *et al.* 1968. Slide MM11803, L26/4, SEM 1266, proximal view showing well developed trilete mark and foveolate sculpture.

Figures 4 & 5 *Laevigatosporites ovatus* Wilson & Webster 1946. Figure 4: Slide FP105A1, O29/2, LM 10607, proximal view showing well developed monolete mark. Figure 5: Slide E462S3, O30/0, SEM 616, equatorial view showing smooth surface.

Figure 6 *Retitriletes douglasii* Dettmann 1986. Slide LP10403, K26/1, SEM 1052, proximal view showing well developed trilete mark and reticulate sculpture.

Figures 7-10 *Polypodiaceoisporites retirugatus* Muller 1968. Figures 7-9 are the same grain, Slide MM13301, N23/4. Figures 7 & 8: SEM 826 & 827, proximal view showing well developed trilete mark, verrucate sculpture and smooth cingulum at different magnifications, scale bar of Figure 8 is 1 μ m. Figure 9: LM 11800, distal proximal view showing rugulate sculpture. Figure 10: Slide FP113B1, C44/0, LM 10907, proximal view showing verrucate sculpture under LM to compare with under SEM.

Figures 11-12 *Polypodiaceoisporites* sp. 125. Figure 11: Slide LP104S2, this spore is in double cover slips mounting and located with microgrid at 1Q5, SEM 1052, proximal view showing well developed lips along with trilete mark and rugu-verrucate sculpture. Figure 12: Slide LP10603, M30/4, SEM 741, proximal view similar to Figure 11.

PLATE 2

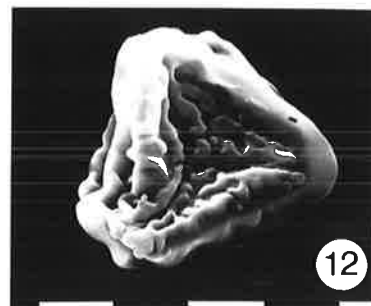
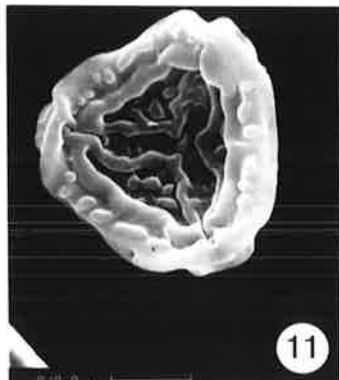
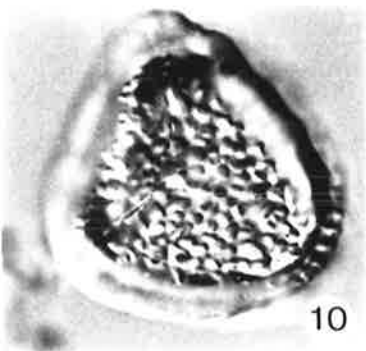
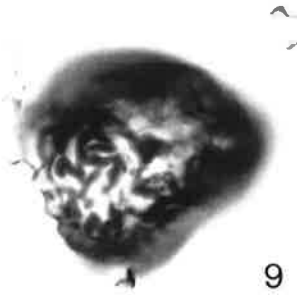
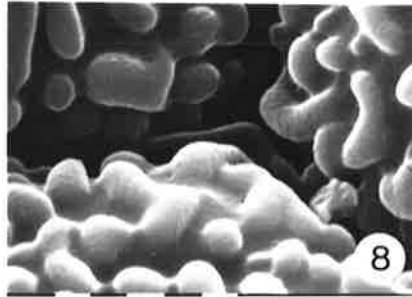
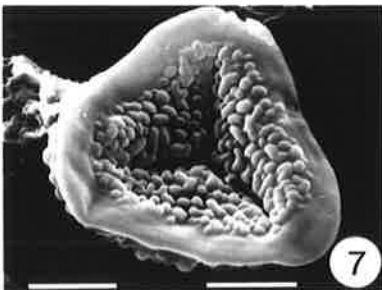
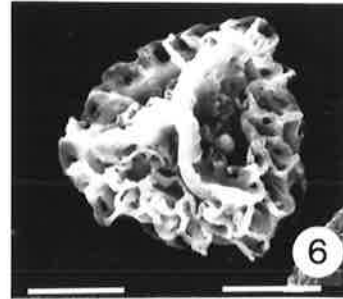
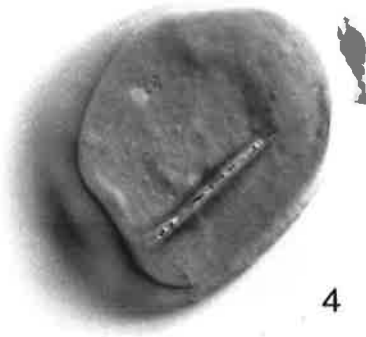
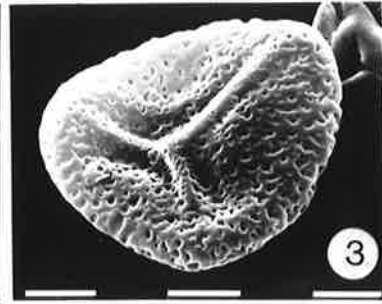
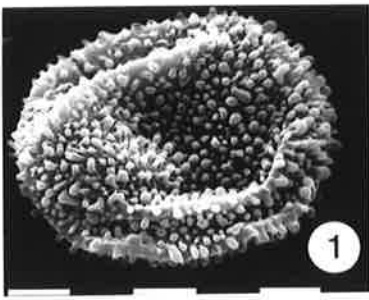


PLATE 3

Figures 1-3 *Magnastriatites grandiosus* Kedves & Porta emend. Dueñas 1980. Figure 1: Slide FP10108, M34/0, SEM 652, oblique proximal view showing well developed ribs and trilete mark. Figure 2: Slide FP10108, Q29/0, SEM 653, oblique distal view showing well developed ribs. Figure 3: Slide FP101B, Q31/4, LM 10233, equatorial view similar to Figure 2.

Figure 4 *Polypodiisporites pohangensis* Takahashi 1979. Slide FP103A1, Q34/0, LM 10505, equatorial view showing evenly verrucate sculpture.

Figure 5 *Polypodiisporites alienus* Potonié emend. Khan & Martin 1971. Slide LP11201, P21/2, SEM 1069, oblique proximal view showing well developed monolete mark and verrucae.

Figure 6 *Polypodiisporites usmensis* Hammen emend. Khan & Martin 1971. Slide MM10602, P21/4, SEM 1208, equatorial view showing well developed baculate sculpture.

Figures 7 & 8 *Rugulatisporites quintus* Pflug & Thomson in Thomson & Pflug 1953. Figures 7 & 8 are the same spore, slide KP126SS1, F33/4, SEM 383 & 384, proximal view showing well developed trilete mark and rugulate sculpture at different magnifications, scale bar of Figure 8 is 1 μ m.

Figures 9-11 *Undulatisporites unduliradius* Takahashi in Takahashi & Shimono 1982. Figures 9-11 are the same spore, slide LP117S1, M9/2. Figures 9 & 10: SEM 065 & 066, proximal view showing undulating sculpture and well developed trilete mark at different magnifications, scale bar of Figure 10 is 1 μ m. Figure 11: LM 11128A, showing comparative morphology under LM.

PLATE 3

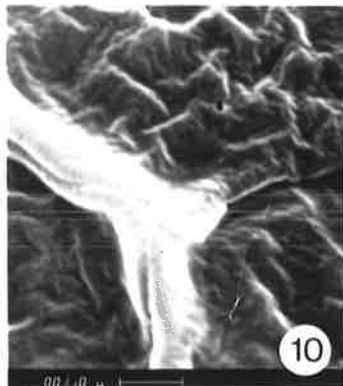
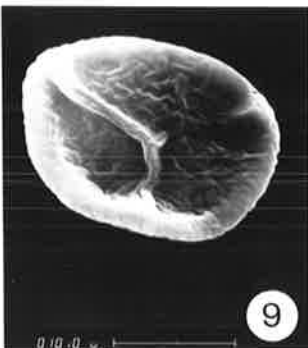
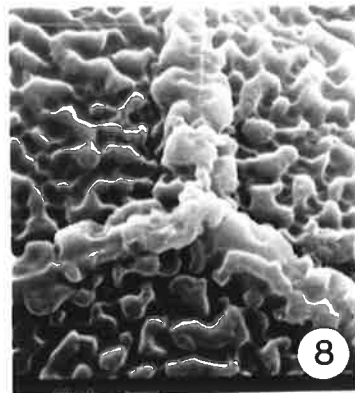
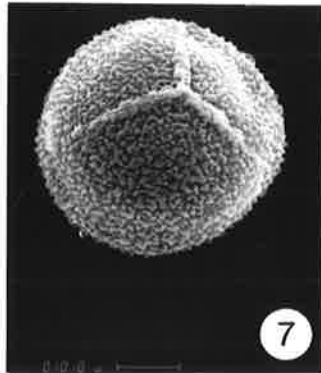
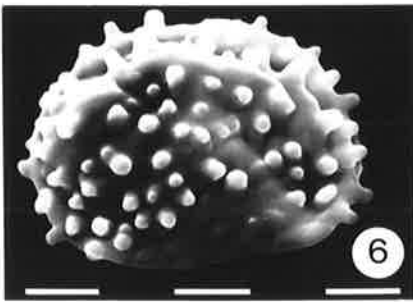
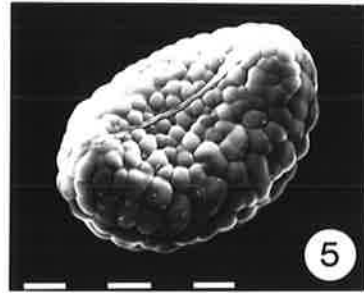
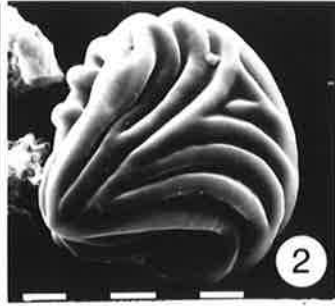


PLATE 4

Figures 1-3 *Dacrydiumpollenites florinii* Cookson & Pike ex Harris 1965. Figures 1-3 are the same pollen grain, slide MM12201, P24/0. Figure 1: SEM 1284, distal view showing variation of rugulate sculpture between sacchi and corpus. Figures 2 & 3: LM 11719 & 11718, proximal views at different foci showing corpus exine thickness.

Figures 4-6 *Inaperturopollenites dubius* Potonié & Venitz ex Thomson & Pflug 1953. Figures 4 & 5 are the same pollen grain, slide LP10601, L31/1. Figure 4: SEM 715, showing scattered tubercula over densely verrucate surface. Figure 5: LM 11809, showing comparative morphology under LM. Figure 6: SEM 731, is similar to Figure 4 and grain is often split.

Figures 7-9 *Piceapollenites alatus* Potonié 1931. Figures 7-9 are the same pollen grain, slide MM13501, M21/2. Figure 7: SEM 1301, distal view showing smooth sacchi with microperforations and distal furrow. Figures 8 & 9: LM 11712 & 11713, proximal views at different foci showing comparative morphologies under LM and internal reticulate structure of sacchi.

Figure 10 *Podocarpidites ellipticus* Cookson ex Couper 1953. Slide M68401, O24/3, SEM 1581, equatorial view showing smooth sculpture.

Figures 11 & 12 *Pinuspollenites* sp. 1436. Figure 11: Slide KP12001, N24/2, SEM 1436, showing smooth sacchi and microscabrate corpus. Figure 12: Slide LP11301, M26/2, SEM 1096, a broken saccus showing internal reticulate structure, scale bar of Figure 12a is 5 μm ., and 12b = 2 X 12a.

Figure 13 *Pinus* sp., Recent, SEM 050, distal view showing smooth sacchi and microscabrate corpus.

Figures 14-16 *Tsugaepollenites igniculus* Potonié ex Potonié 1958. Figures 14-16 are the same pollen grain, slide LP10501, K31/0. Figures 14 & 15: SEM 1021 & 1022, showing microechinae on verrucate surface at different magnifications, scale bar of Figure 14 is 100 μm . Figure 16: LM 11714 & 11715, showing comparative morphologies under LM at different foci, 635X magnification.

PLATE 4

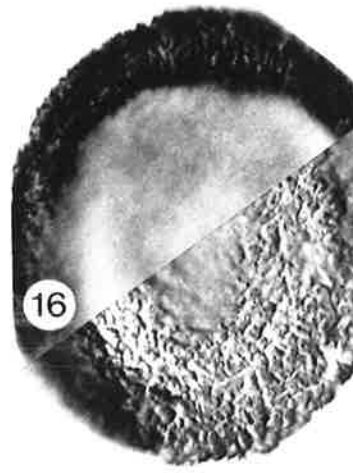
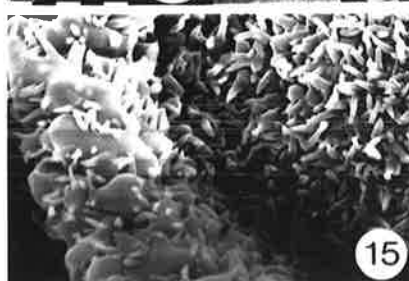
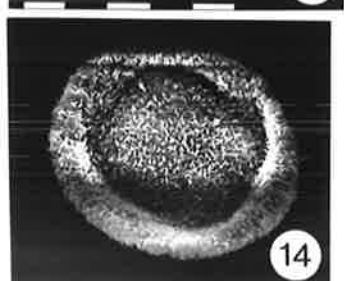
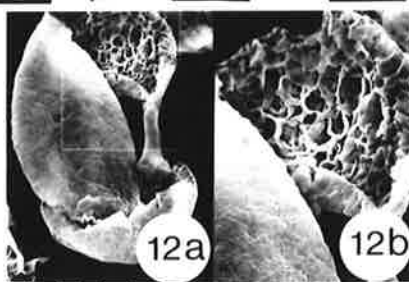
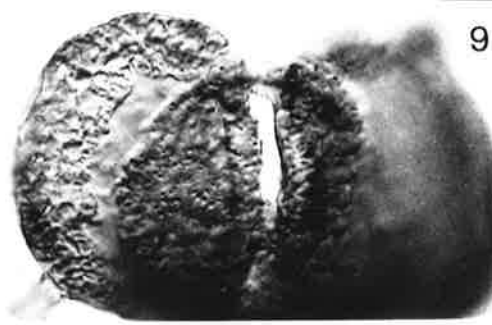
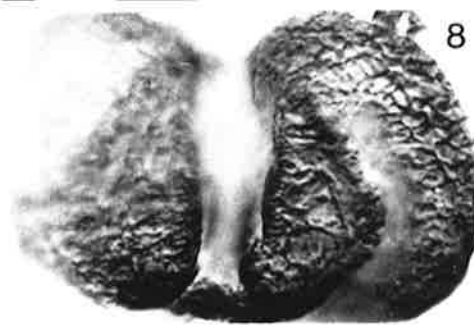
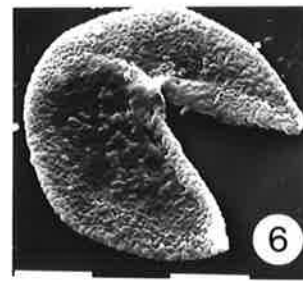
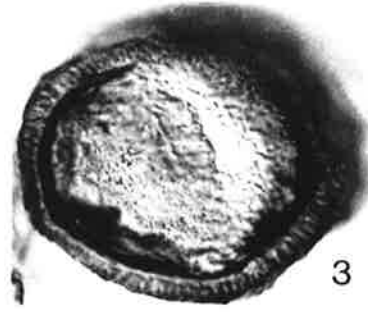
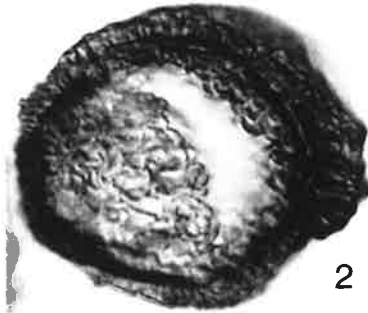
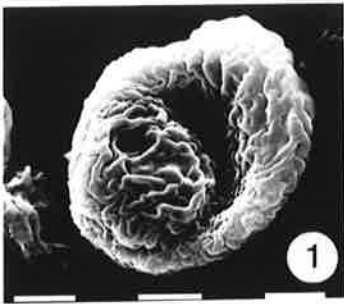


PLATE 5

Figures 1-3 *Aceripollis* sp. 727. Figures 1-3 are the same pollen grain, slide LP10601, K27/0. Figures 1 & 2: SEM 727 & 728, equatorial view showing striate sculpture at different magnifications, scale bar of Figure 2 is 1 μ m. Figure 3: LM 11717 showing exine structure.

Figures 4 & 5 *Aceripollis* sp. 842. Figures 4 & 5 are the same pollen grain, slide MM12701, O29/0. Figure 4: SEM 842 & 843, equatorial view showing striate sculpture at different magnifications, scale bar of Figure 4 is 1 μ m.

Figure 6 *Aceripollis* sp. 853. Slide MM12701, S26/0, SEM 853, equatorial view showing well developed striate sculpture.

Figures 7 & 8 *Aceripollis* sp. 1175. Figures 7 & 8 are the same pollen grain, slide MM10902, H27/0. Figure 7: SEM 1175, equatorial view showing weakly developed striate sculpture. Figure 8: LM 11822, equatorial view showing stratified exine.

Figures 9 & 10 *Alnipollenites verus* Potonié 1931. Figure 9: Slide LP10603, M29/0, SEM 742, polar view showing well developed arci and microgranulate sculpture, some microgranulae join together to become an elongate ridge. Figure 10: slide FP101B, F25/0, LM 10319, polar view showing well developed arci.

Figures 11 & 12 *Alnus firma* Sieb. & Succ., Recent. Specimen origin: Japan. Voucher reference: South Australia State Herbarium AD 97713226. Figure 12: SEM 1389, polar view showing well developed arci and microgranulate sculpture. Figure 13: SEM 1390, oblique equatorial view showing annulate pore.

Figures 13-15 *Ammania* sp. 382. Figures 13-15 are the same pollen grain, slide KP126SS1, N26/2. Figures 13 & 14: SEM 382 381, equatorial view showing pseudocolpi and striate sculpture at different magnifications, scale bar of Figures 13 & 14 are 1 μ m. Figure 15: LM 11907, showing comparative morphology under LM.

PLATE 5

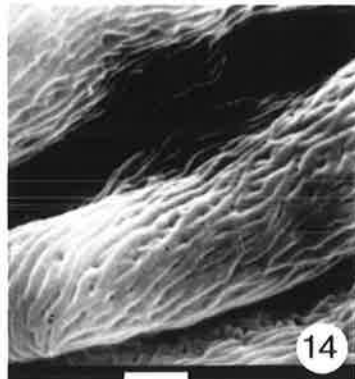
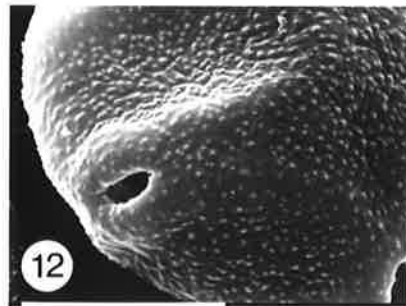
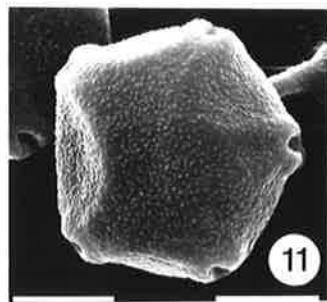
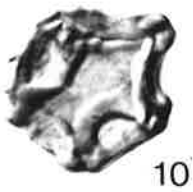
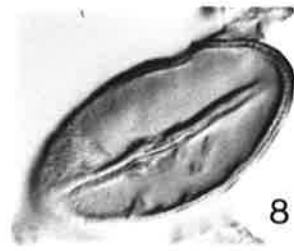
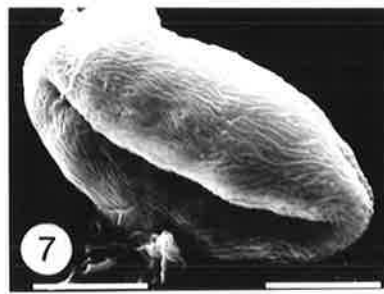
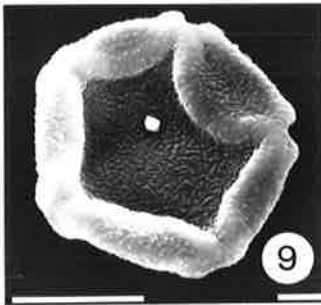
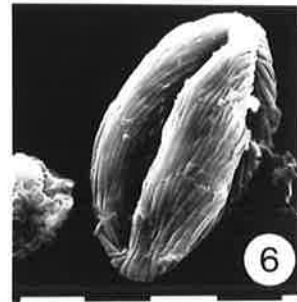
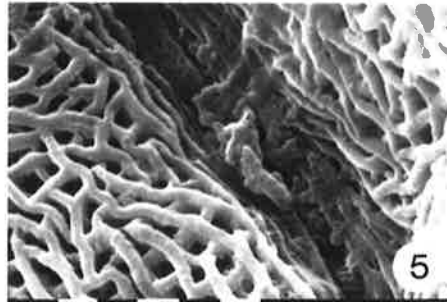
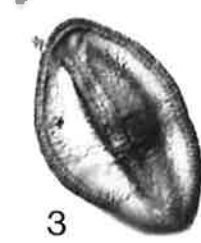
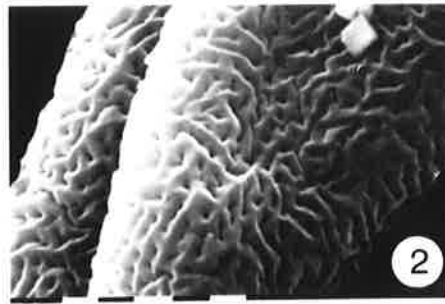
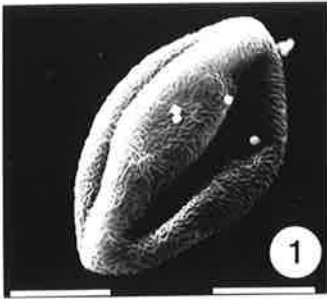


PLATE 6

Figures 1-3 *Avicennia* sp. 1492. Figures 1 & 2 are the same pollen grain, slide AP10105, L28/2. Figure 1: SEM 1492, equatorial view showing microreticulate sculpture. Figure 2: LM 11815, equatorial view showing exine structure. Figure 3: Slide AP10105, Q19/2, SEM 1506, polar view showing microreticulate sculpture varying slightly from Figure 1, and polar area.

Figures 4 & 5 *Bombacacidites annae* Hammen ex Leidelmeyer 1966. Figure 4: Slide MM129S2, this pollen grain is mounted in double coverslip and located with microgrid at 1K1, SEM 189, polar view showing variable reticulate sculpture. Figure 5: Slide MM116A8, LM 11101A, polar view showing exine structure.

Figure 6 *Bursera* sp. 1427. Slide KP12001, J26/2, SEM 1427, oblique equatorial view showing protruding pore.

Figures 7-11 *Caryapollenites simplex* Potonié 1960. Figure 7: Slide KP12002, N26/1, SEM 1470, polar view showing microgranulate sculpture and pores. Figure 8: Slide FP10302, S28/1, SEM 667, polar view similar to Figure 7. Figure 9: Slide FP103A1, K34/4, LM 10923, polar view showing smooth sculpture. Figures 10 & 11: Slide FP102A, O36/0, LM 10732 & 10733, polar view showing smooth sculpture at different foci.

Figures 12 & 13 *Cardamine* sp. 323. Figures 12 & 13 are the same pollen grain, slide MM129S11, K26/2. Figures 12 & 13: SEM 323 & 324, equatorial view showing reticulate sculpture at different magnifications, scale bar of Figure 13 is 1 μm .

Figures 14 & 15 *Cephalomappa* sp. 590. Figures 14 & 15 are the same pollen grain, slide E27004, R24/0. Figures 14 & 15: SEM 590 & 591, oblique equatorial view showing echinate sculpture and protruding pores at different magnifications.

PLATE 6

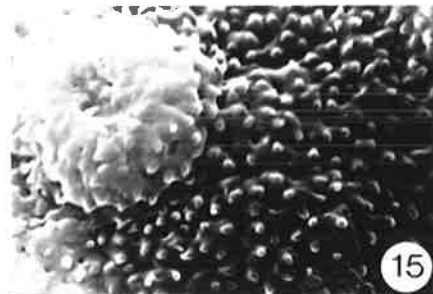
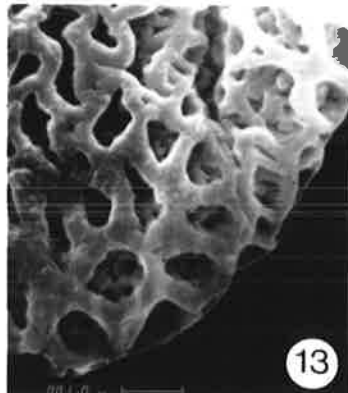
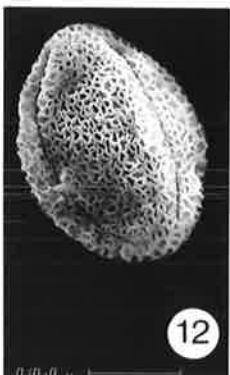
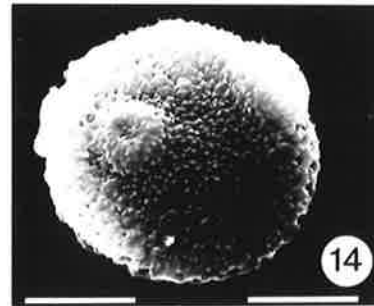
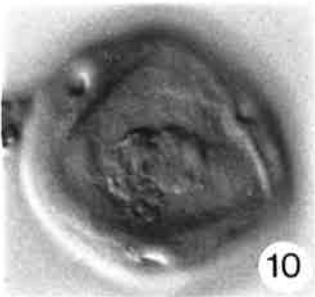
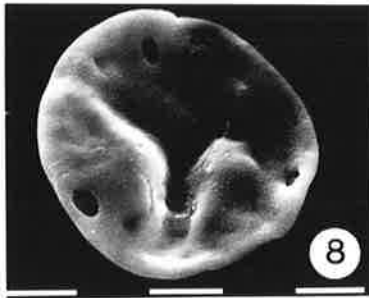
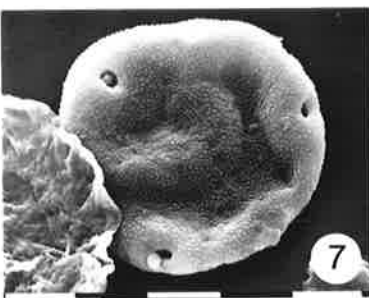
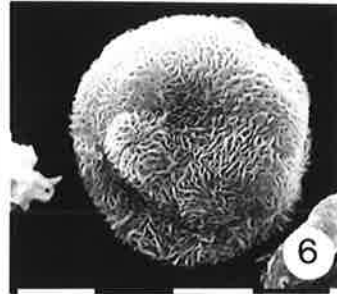
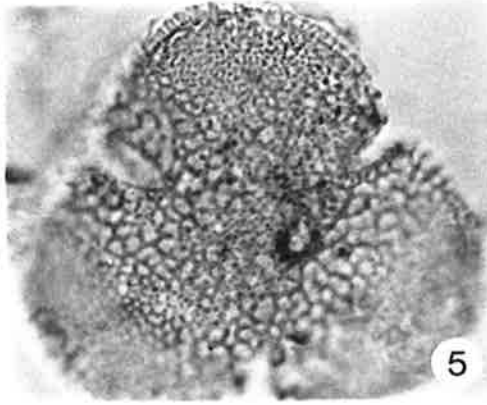
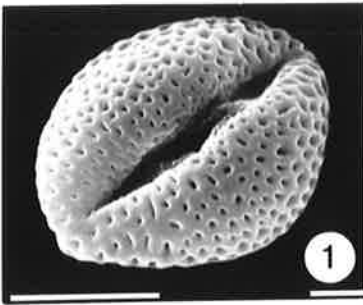


PLATE 7

Figures 1-3 *Cupuliferoipollenites pusillus* Potonié ex Potonié 1960. Figures 1-3 are the same pollen grain, slide LP10505, M20/4. Figure 1: SEM 1046, equatorial view showing microrugulate ridges. Figures 2 & 3: LM 11709 & 11710, equatorial views at different foci showing comparative morphologies under LM.

Figures 4 & 5 *Castanea crenata* Sieb. & Succ., Recent. Specimen origin: Japan. Voucher reference: South Australia State Herbarium AD 98663346. Figures 4 & 5 are the same pollen grain, SEM 527 & 528, equatorial view showing microrugulate ridges at different magnifications, scale bar of Figures 4 & 5 are 1 μm .

Figure 6 *Castanopsis hainanensis* Merr., Recent. Voucher reference: South Australia State Herbarium AD 98709461, SEM 513, equatorial view showing microrugulate ridges, 1 μm scale bar.

Figure 7 *Cyperaceaepollis neogenicus* Krutzsch 1970. Figure 7: Slide MM11301, N20/0, SEM 1342, equatorial view showing microperforate sculpture and lacunae.

Figures 8 & 9 *Dipterocarpus* sp. 780. Figures 8 & 9 are the same pollen grain, slide MM11801, Q30/2. Figure 8: SEM 780, oblique polar view showing convoluted ridges separated by fossulate depressions. Figure 9: LM 11700, oblique polar view showing undulating sculpture and exine structure.

Figures 10 & 11 *Dicolpopollis kalewensis* Potonié ex Potonié 1966. Figures 10 & 11 are the same pollen grain, slide E27004, Q24/4, SEM 592 & 593, oblique polar view showing microperforate sculpture at different magnifications.

Figures 12 & 13 *Excoecaria* sp. 1404. Figures 12 & 13 are the same pollen grain, slide KP12801, N17/3, SEM 1404 & 1405, equatorial view showing reticulate sculpture at different magnifications, scale bar of Figure 13 is 1 μm .

Figures 14-16 *Echiperiporites* cf. *E. estelae* Germeraad *et al.* 1968. Figures 14 & 15 are the same pollen grain, slide P252S1, M20/4, SEM 481 & 482, showing microscabrate sculpture with spines at different magnifications, scale bar of Figure 15 is 1 μm . Figure 16: Slide FP103A1, J34/3, LM 10921, showing comparative morphology under LM.

PLATE 7

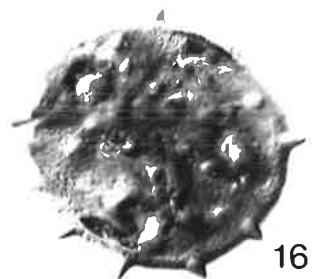
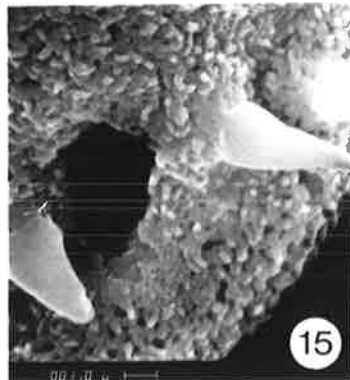
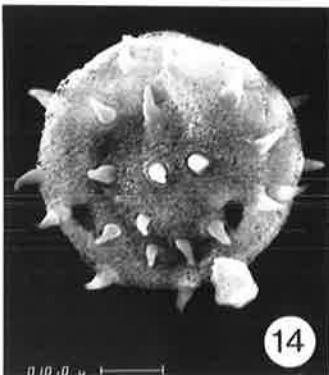
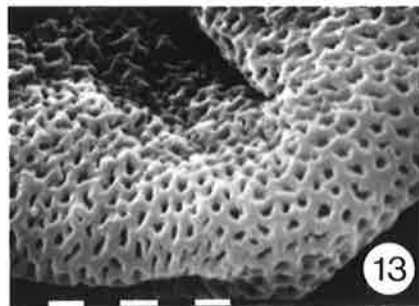
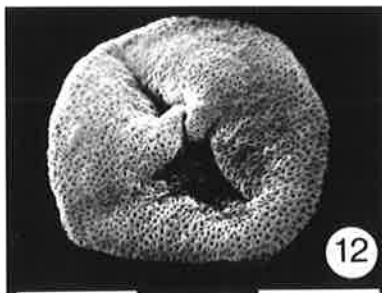
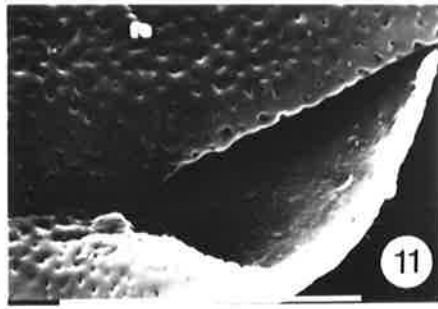
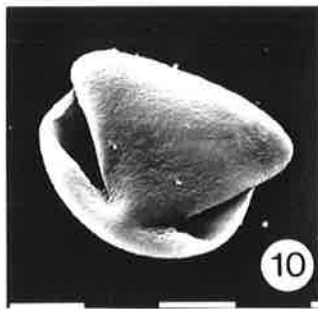
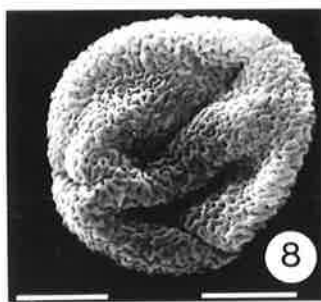
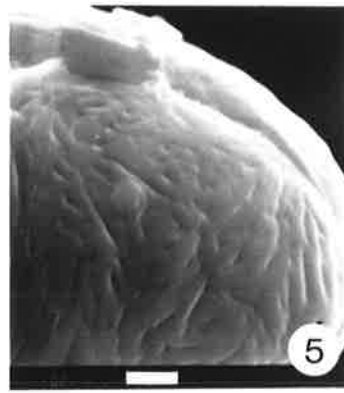
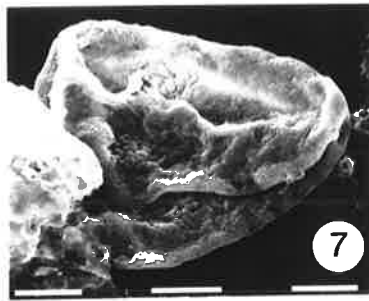
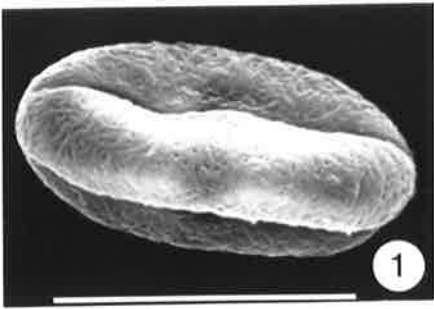


PLATE 8

Figures 1 & 2 *Faguspollenites* sp. 845. Figures 1 & 2 are the same pollen grain, slide MM12701, P28/3, SEM 845 & 846, equatorial view showing microscabrate sculpture at different magnifications, scale bar of Figure 2 is 1 μm .

Figure 3 *Fagus crenata* Blume, Recent. Specimen origin: Japan. Voucher reference: South Australia State Herbarium AD 98137091, SEM 1382, oblique equatorial view showing microscabrate sculpture.

Figure 4 *Florschuetzia trilobata* Germeraad *et al.* 1968. Slide M97301, G20/4, SEM 1611, equatorial view showing smooth sculpture and well developed meridional ridges.

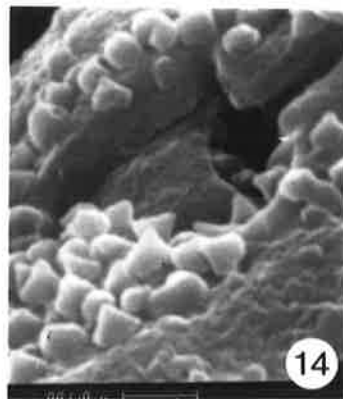
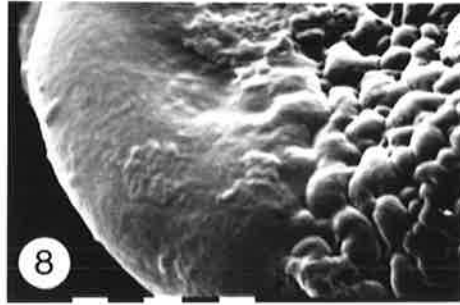
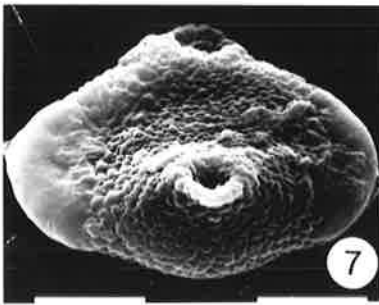
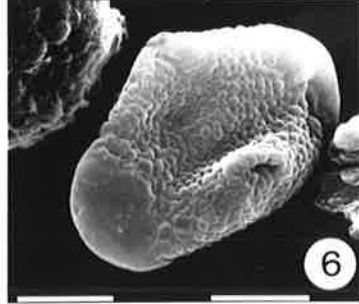
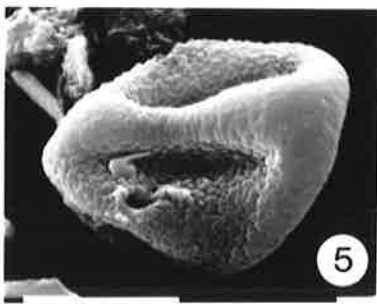
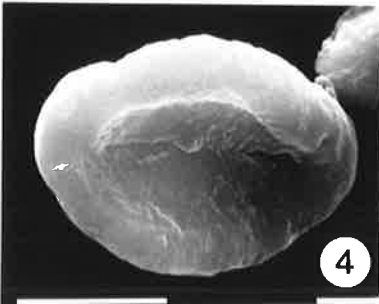
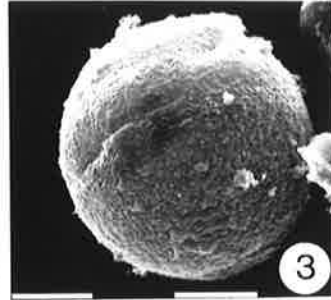
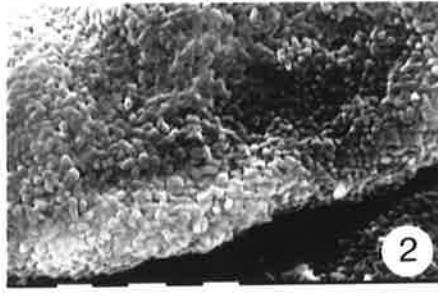
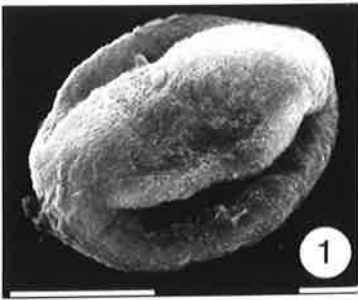
Figure 5 *Florschuetzia semilobata* Germeraad *et al.* 1968. Slide AP10105, R25/0, SEM 1498, oblique equatorial view showing smooth meridional ridges and dense verrucae around porate areas.

Figures 6-9 *Florschuetzia levipoli* Germeraad *et al.* 1968. Figure 6: Slide P42001, N26/1, SEM 1531, oblique equatorial view showing smooth polar areas and dense verrucae around equatorial area. Figures 7-9 are the same pollen grain, slide P42001, N19/4. Figures 7 & 8: SEM 1532 & 1533 equatorial view similar to Figure 6 at different magnifications, scale bar of Figure 8 is 1 μm . Figure 9: LM 11914, equatorial view showing exine thickness.

Figures 10 & 11 *Florschuetzia meridionalis* Germeraad *et al.* 1968. Figures 10 & 11 are the same pollen grain, slide M79201, G21/3. Figure 10: SEM 1617, equatorial view showing smooth polar caps and dense variable verrucae around porate areas and meridional ridges. Figure 11: LM 11917, equatorial view showing difference of exine structure between porate and equatorial areas.

Figures 12-15 *Florschuetzia* sp. 647. Figures 12 & 13 are the same pollen grain, slide FP10108, M26/1, SEM 647 & 648, equatorial view showing verrucae around porate areas and striate meridional ridges at different magnifications. Figure 14: SEM 031, pollen grain was not preserved, equatorial view showing exine thickness. Figure 15: Slide FP101A, L35/2, LM 10712, equatorial view showing comparative morphology under LM.

PLATE 8



11

15

PLATE 9

Figures 1-4 *Hopea* sp. 1299. Figures 1 & 2 are the same pollen grain, slide MM13502, O24/1. Figure 1: SEM 1299, equatorial view showing finely reticulate sculpture. Figure 2: LM 11704, equatorial view showing pores and exine thickness. Figures 3 & 4 are the same pollen grain, slide MM10901, P18/1, SEM 1145 & 1146, equatorial view showing finely reticulate sculpture at different magnifications, scale bar of Figure 4 is 1 μ m.

Figures 5-8 *Lagerstroemia* sp. 325. Figures 5-7 are the same pollen grain, slide MM136S3, P23/0. Figures 5 & 6: SEM 325 & 326, equatorial view showing rugu-verrucate sculpture at different magnifications, scale bar of Figure 6 is 1 μ m. Figure 7: LM 11811, showing stratified exine and pores. Figure 8: Slide MM10604, Q23/4, SEM 1240, equatorial view similar to Figure 5.

Figure 9 *Juglanspollenites verus* Raatz 1939. Slide SP10502, L20/3, SEM 1667, polar view showing pores and microgranulate sculpture.

Figures 10-12 *Ilexpollenites iliacus* Potonié 1960. Figure 10: Slide MM12702, S24/2, SEM 883, equatorial view showing variably clavate sculpture. Figures 11 & 12 are the same pollen grain, slide FP103A1, Q32/4, LM 10514 & 10515, equatorial view showing comparative morphologies under LM at different foci.

Figures 13 & 15 *Lanagiopollis nanggulanensis* Morley 1982. Figures 13 & 14 are the same pollen grain, slide MM129S9, T22/1. Figure 13: SEM 343, polar view showing reticulate-rugulate sculpture. Figure 14: SEM 344, polar view showing stratified exine around porate area. Figure 15: Slide MM116A8, V27/4, LM 11104A, polar view showing stratified exine.

PLATE 9

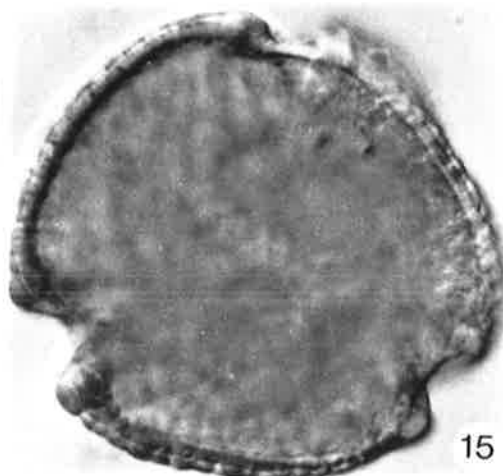
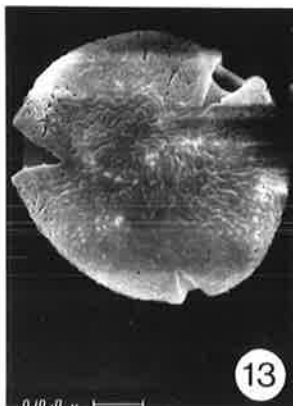
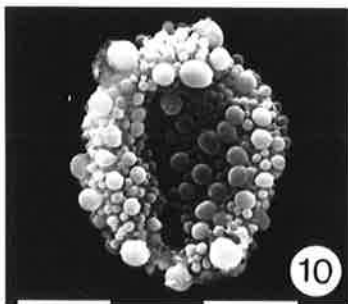
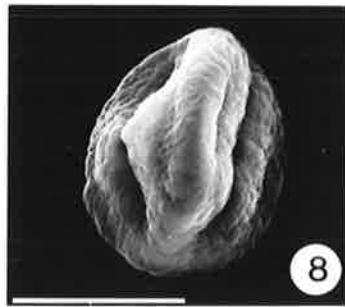
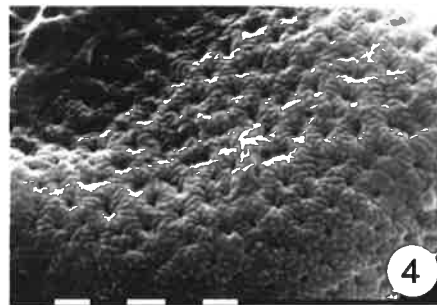
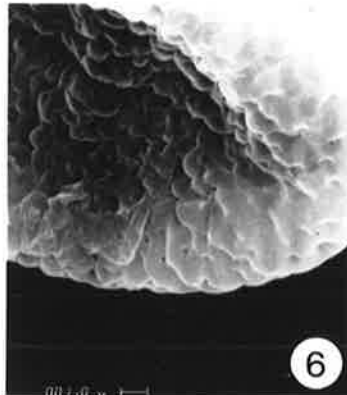
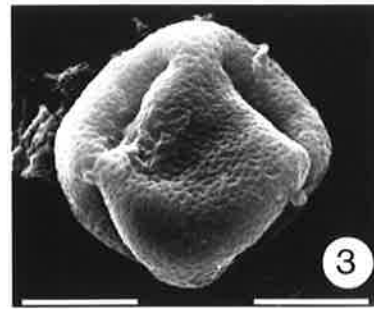


PLATE 10

Figures 1-4 *Margocolporites vanwijhei* Germeraad *et al.* 1968. Figures 1 & 2 are the same pollen grain at different magnifications, slide MM12702, K30/3, SEM 896 & 897, polar view showing two different reticulate sculptures between colpate and intercolpate areas. Figure 3: Slide MM12201, P25/1, SEM 1283, oblique equatorial view similar to Figure 1. Figure 4: Slide FP112A, O36/2, LM 10821, polar view showing comparative morphology under LM.

Figures 5 & 6 *Momipites coryloides* Wodehouse 1933. Figures 5 & 6 are the same pollen grain, slide LP10702, K22/0. Figure 5: SEM 1066, equatorial view showing evenly microgranulate sculpture. Figure 6: LM 11920, equatorial view showing unclearly stratified exine.

Figures 7 & 8 *Myrtaceidites mesonesus* Cookson & Pike 1954. Figure 7: Slide FP10110, R20/0, SEM 967, polar view showing syncolpate and smooth sculpture. Figure 8: Slide FP101C, D25/3, LM 10424, polar view showing comparative morphology under LM.

Figure 9 *Myricipites dubius* Wodehouse 1933. Slide M79201, H23/4, SEM 1616, oblique polar view showing evenly microgranulate sculpture.

Figure 10 *Monoporopollenites gramineoides* Meyer 1956. Slide MM10604, Q22/4, SEM 1239, polar view showing evenly microgranulate sculpture.

Figures 11 & 12 *Pandaniidites texus* Elsik 1968. Figures 11 & 12 are the same pollen grain at different magnifications, slide MM12702, L32/3, SEM 903 & 904, polar view showing smooth sculpture with spines, scale bar of Figure 12 is 1 μ m.

Figures 13 & 14 *Periporopollenites stigmosus* Potonié ex Thomson & Pflug 1953. Figures 13 & 14 are the same pollen grain at different magnifications, slide FP10302, R28/3, SEM 668 & 669, showing finely reticulate sculpture and granules inside porate areas.

Figure 15 *Polyadopollenites myriosporites* Cookson ex Partridge in Stover & Partridge 1973. Slide MM12702, L30/0, SEM 905, showing microperforate sculpture.

PLATE 10

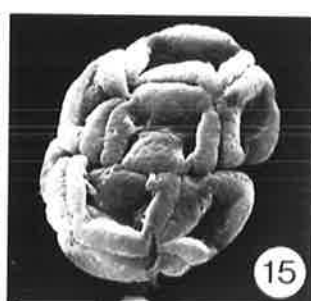
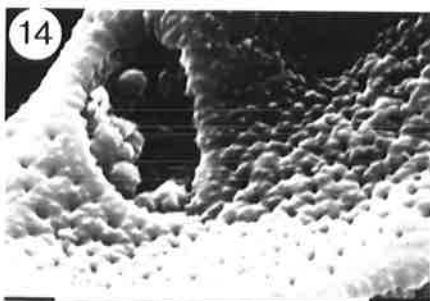
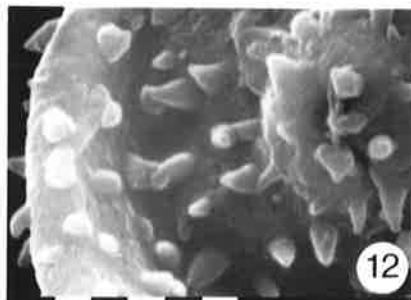
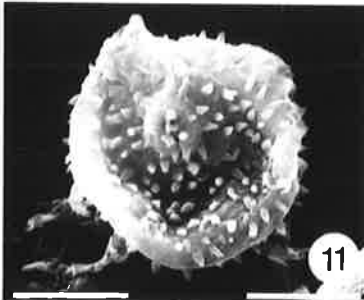
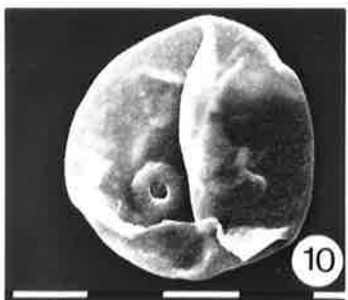
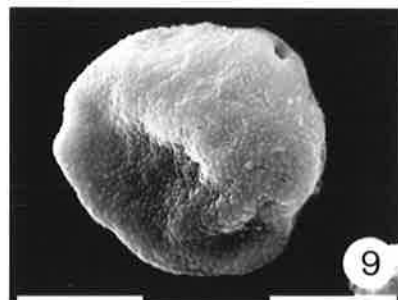
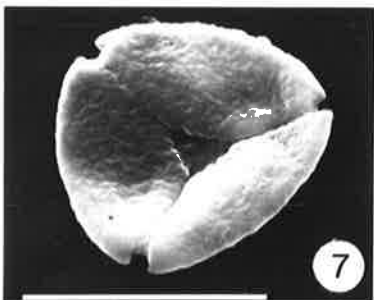
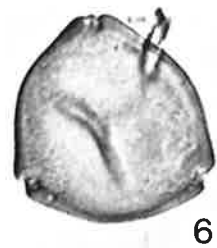
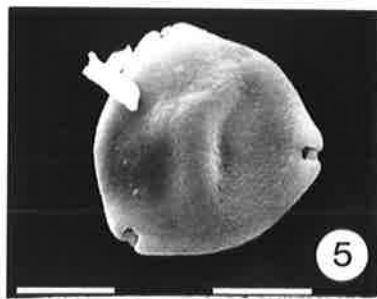
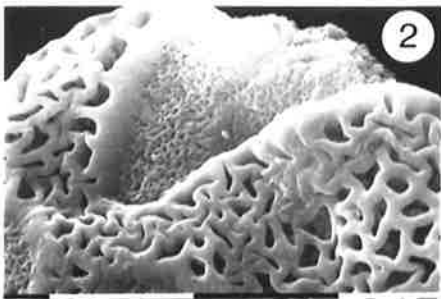
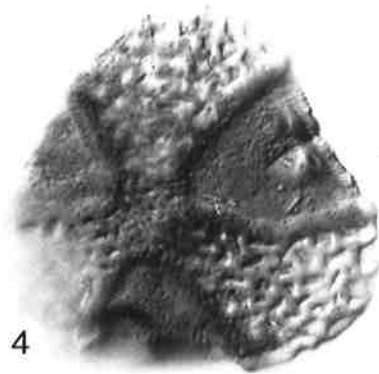
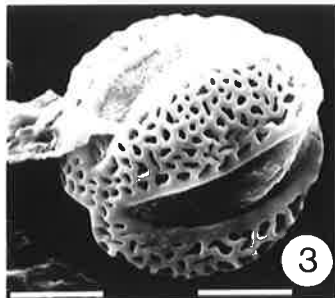
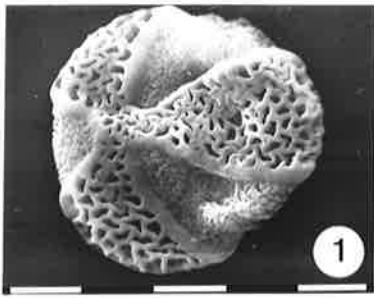


PLATE 11

Figures 1 & 2 *Psilatricolporites operculatus* Hammen & Wymstra 1964. Figures 1 & 2 are the same pollen grain at different magnifications, slide MM11802, P25/1, SEM 783 & 784, polar view showing scabrate sculpture.

Figure 3 *Polyatriopollenites stellatus* Potonié & Venitz ex Pflug 1953. Slide SP10501, O19/0, SEM 1640, polar view showing microgranulate sculpture.

Figures 4-7 *Quercoidites* sp. 777. Figures 4 & 5 are the same pollen grain at different magnifications, slide MM11801, O28/0, SEM 777 & 807, equatorial view showing weakly verrucate sculpture, scale bar of Figure 5 is 1 μm . Figure 6: Slide LP10601, L25/2, SEM 724, polar view showing variably verrucate sculpture. Figure 7: Slide FP10307, Q28/0, SEM 704, polar view also showing variably microscabrate-verrucate sculpture.

Figure 8 *Quercus helferina* A. DC., Recent. Specimen origin: Thailand. SEM 1139, equatorial view showing microscabrate sculpture.

Figure 9 *Quercus phillyraeoides* Gray, Recent. Specimen origin: Japan. Voucher reference: South Australia State Herbarium AD 98663303, SEM 541, oblique equatorial view showing verrucate sculpture.

Figures 10 & 11 *Quercus serrata* Thumb, Recent. Specimen origin: Japan. Voucher reference: South Australia State Herbarium AD 97941265, SEM 531 & 532, oblique equatorial and polar views showing verrucate sculpture.

Figure 12 *Radermachera* sp. 1546. Slide T76002, M25/1, SEM 1546, oblique polar view showing reticulate sculpture.

Figures 13-15 *Rhoipites* sp. 1263. Figures 13 & 14 are the same pollen grain, slide MM11803, J27/0. Figure 13: SEM 1263, equatorial view showing perforate sculpture. Figure 14: LM 11904, equatorial view showing circular pores. Figure 15: Slide MM11803, K18/0, SEM 1264, equatorial view showing also perforate sculpture.

PLATE 11

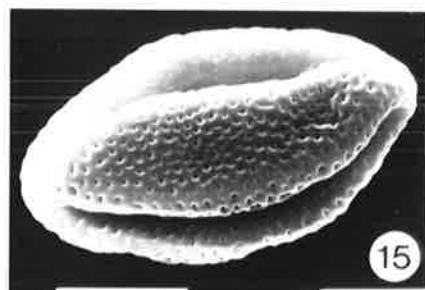
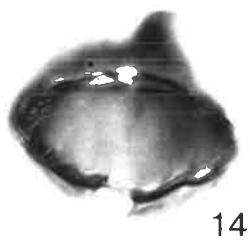
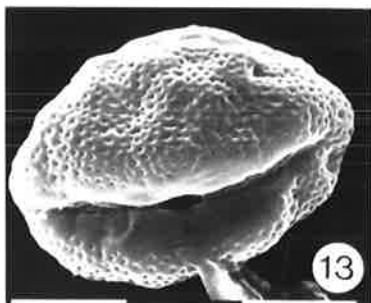
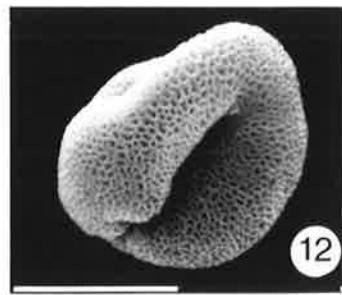
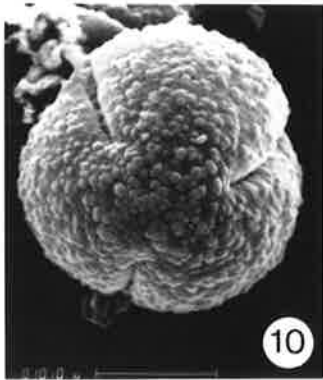
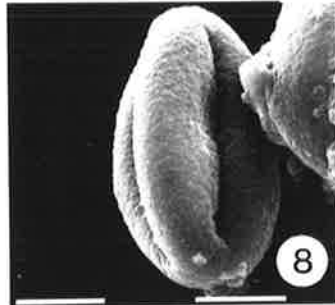
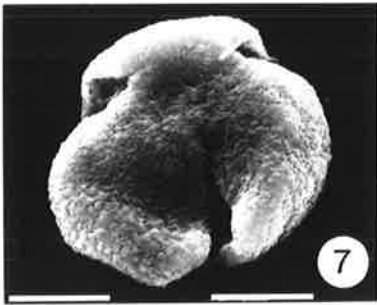
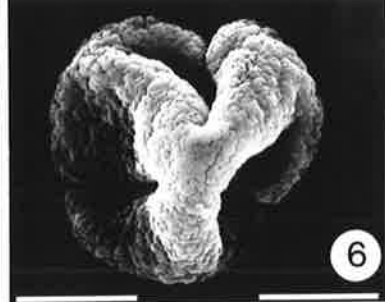
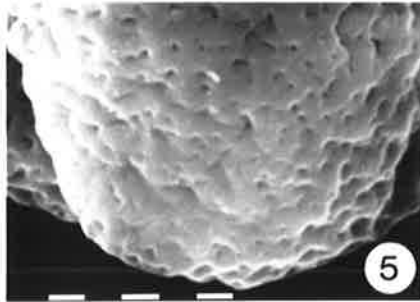
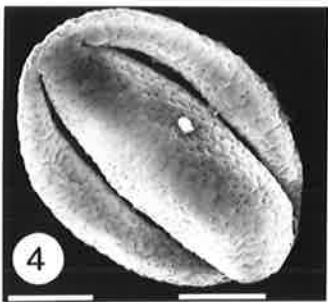
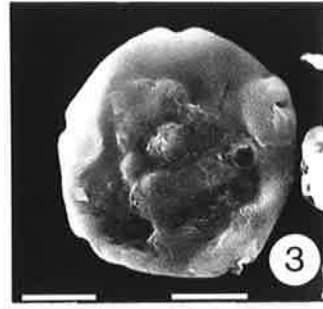
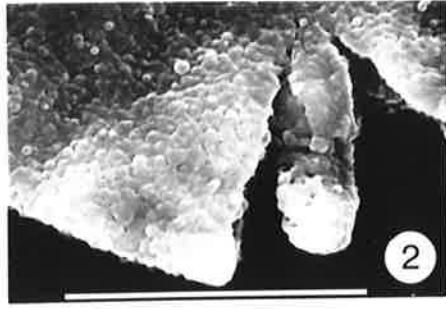
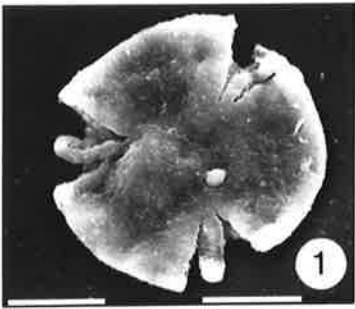


PLATE 12

Figures 1-5 *Retitricolpites* sp. 258. Figures 1-3 are the same pollen grain at different magnifications, slide MM143S5, this pollen grain is mounted in double coverslip and located with microgrid at 2G5, SEM 258, 259 & 260, polar view showing reticulate sculpture and stratified exine, 1 μm scale bar for Figures 2 & 3. Figures 4 & 5 are the same pollen grain at different foci, slide FP103A1, N33/3, LM 10510 & 10511, oblique polar view showing reticulate sculpture.

Figures 6-10 *Rhoipites* cf. *R. retiformis* Pocknall & Mildenhall 1984. Figures 6-8 are the same pollen grain, slide FP103S3, this pollen grain is mounted in double coverslip and located with microgrid at 1F6. Figures 6 & 7: SEM 130, 131, equatorial view showing reticulate sculpture at different magnifications, scale bar of Figure 7 is 1 μm . Figure 8: LM 11127A, equatorial view showing comparative morphology under LM. Figure 9: Slide FP10110, H24/0, SEM 1010, equatorial view similar to Figure 6. Figure 10: Slide FP10110, Q20/4, SEM 968, equatorial view similar to Figure 6.

Figures 11 & 12 *Rhoipites* sp. 847. Figures 11 & 12 are the same pollen grain at different magnifications, slide MM12701, P28/0, SEM 847 & 848, equatorial view showing reticulate sculpture, scale bar of Figure 12 is 1 μm .

Figures 13-15 *Rhoipites* sp. 1267. Figures 13-15 are the same pollen grain, slide MM11803, O20/1. Figures 13 & 14: SEM 1267, 1268 equatorial view showing reticulate sculpture at different magnifications, scale bar of Figure 14 is 1 μm . Figure 15: LM 11901, equatorial view showing pores.

PLATE 12

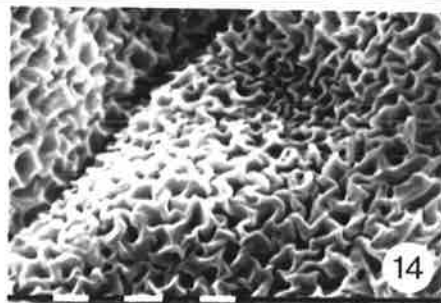
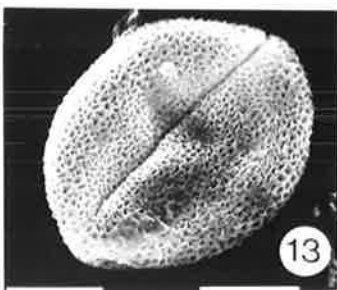
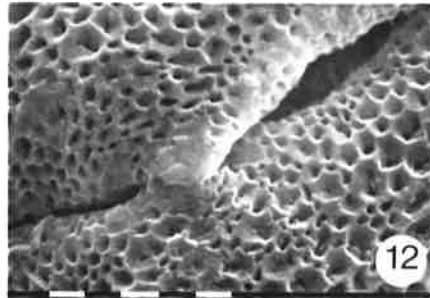
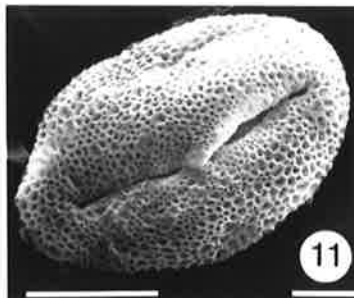
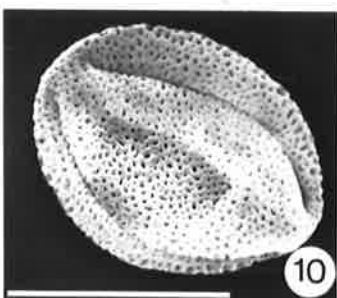
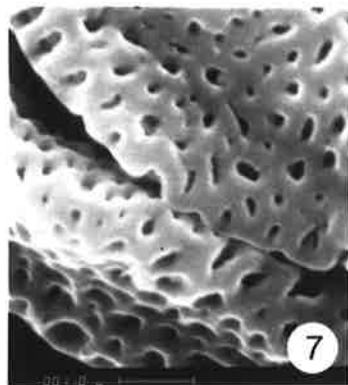
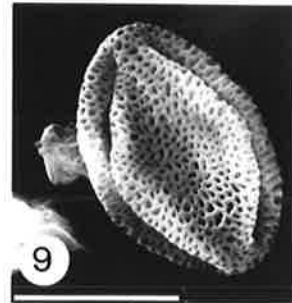
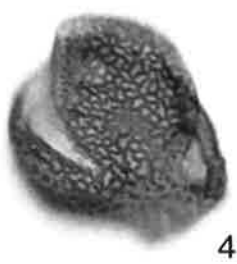
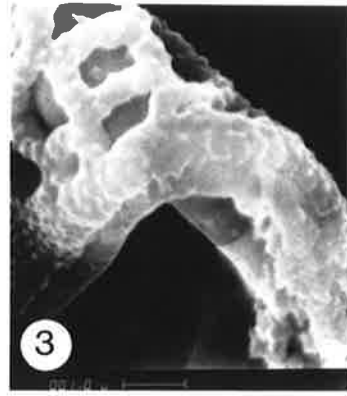
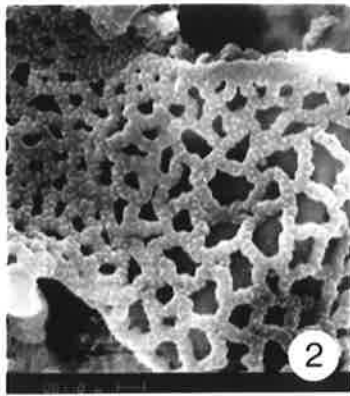


PLATE 13

Figures 1 & 2 *Rhoipites* sp. 1345. Figures 1 & 2 are the same pollen grain at different magnifications, slide MM11301, K19/1, SEM 1345 & 1346, polar view showing well developed reticulate sculpture, scale bar of Figure 2 is 1 μ m.

Figures 3 & 4 *Rhoipites* sp. 1207. Figures 3 & 4 are the same pollen grain, slide MM10903, L25/1, SEM 1207, equatorial view showing variably reticulate sculpture. Figure 4: LM 11703, equatorial view showing comparative morphology under LM.

Figures 5 & 6 *Salixipollenites* cf. *S. discoloripites* Srivastava 1966. Figure 5: Slide FP10110, K23/1, SEM 996, equatorial view showing reticulate sculpture. Figure 6: Slide FP10110, R22/2, SEM 972, equatorial view showing smaller reticulate sculpture adjacent to colpi.

Figures 7 & 8 *Tetracolporopollenites sapotoides* Pflug & Thomson in Thomson & Pflug 1953. Figures 7 & 8 are the same pollen grain, slide MM13501, K29/1, SEM 1311, equatorial view showing perforate sculpture. Figure 4: LM 11819, equatorial view showing circular pores.

Figure 9 *Spinizonocolpites prominatus* (McIntyre) Stover & Evans 1973. Slide AP10106, N20/1, SEM 1501, showing reticulate sculpture with spines and clearly stratified exine.

Figures 10-12 *Tiliaepollenites* cf. *T. indubitabilis* Potonié 1931. Figures 10-12 are the same pollen grain, slide MM11802, L27/2. Figures 10 & 11: SEM 796 & 797, polar view showing reticulate sculpture at different magnifications, scale bar of Figures 11 is 1 μ m. Figure 12: LM 12032, polar view showing exine thickness and stratified exine.

Figures 13-15 *Tricolpites* sp. 854. Figure 13: Slide MM12701, R23/7, SEM 854, polar view showing microgranulate sculpture. Figure 14: Slide MM11802, H26/1, SEM 798, oblique polar view similar to Figure 13. Figure 15: Slide MM11802, P25/0, SEM 787, equatorial view similar to Figure 13.

PLATE 13

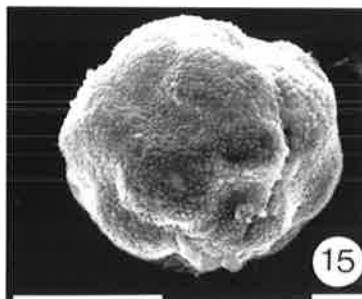
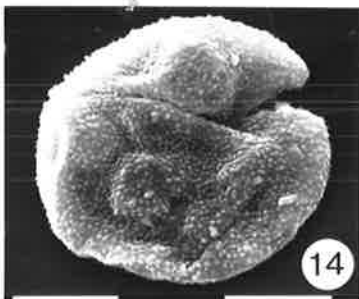
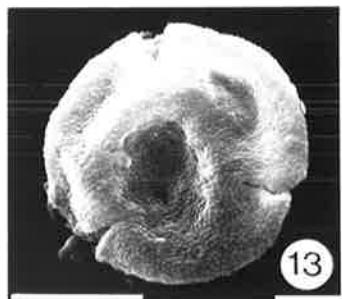
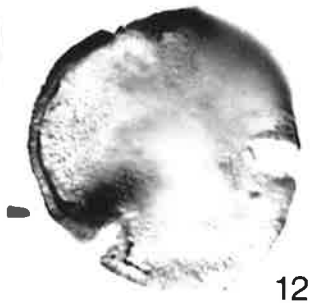
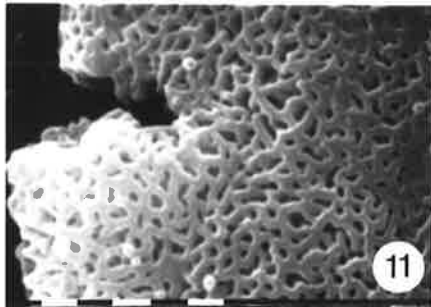
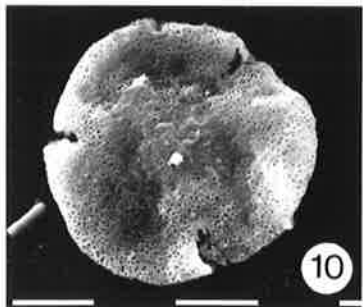
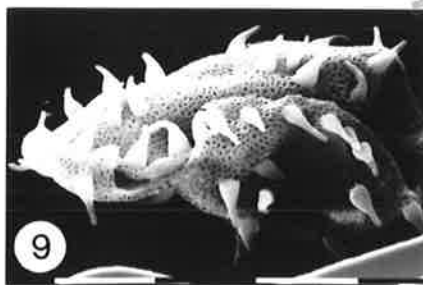
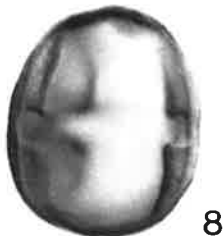
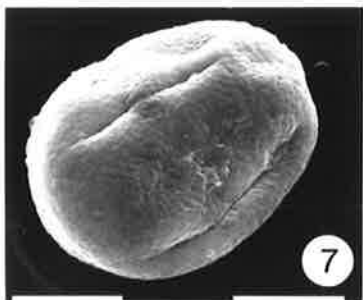
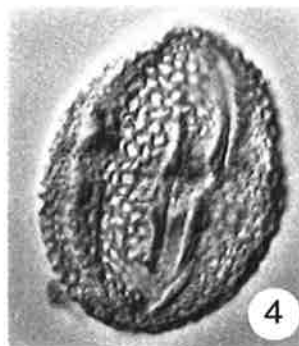
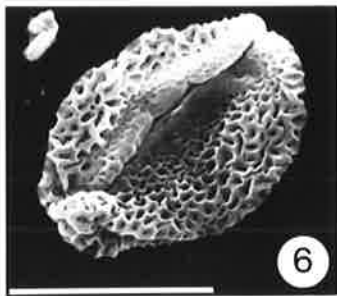
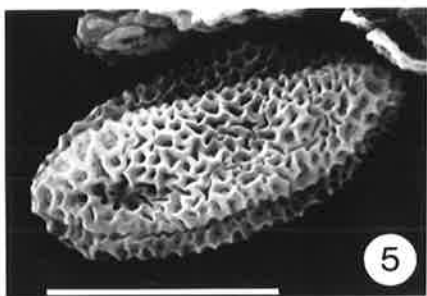
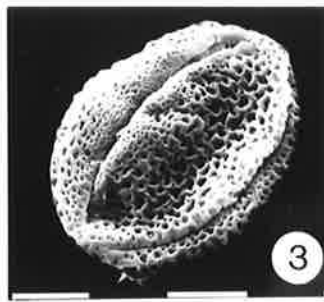
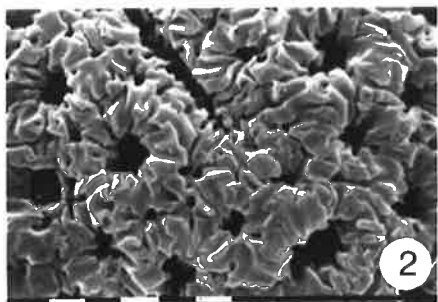
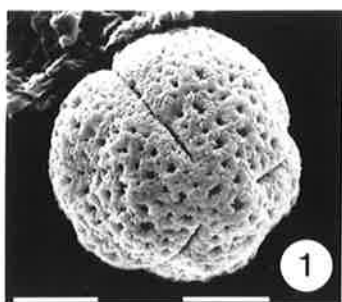


PLATE 14

Figures 1-3 *Tricolporites* cf. *T. valvatus* Harris 1972. Figures 1-3 are the same pollen grain, slide FP10203, M25/2. Figures 1 & 2: SEM 664 & 665, equatorial view showing finely striate sculpture at different magnifications, scale bar of Figure 2 is 1 μ m. Figure 3: LM12005, equatorial view showing comparative morphology under LM.

Figures 4 & 5 *Tricolporopollenites* sp. 810. Figure 4: Slide MM13301, N32/0, SEM 810, equatorial view showing striate-granulate sculpture. Figure 5: Slide MM11801, L25/3, SEM 760, equatorial view similar to Figure 4.

Figures 6 & 7 *Tricolporopollenites* sp. 862. Figures 6 & 7 are the same pollen grain, slide MM12701, J29/4, SEM 862 & 863, equatorial view showing finely striate sculpture at different magnifications, scale bar of Figure 7 is 1 μ m.

Figures 8 & 9 *Tricolporopollenites* sp. 908. Figures 8 & 9 are the same pollen grain, slide MM12702, J28/0, SEM 908 & 909, polar view showing reticulate sculpture at different magnifications, scale bar of Figure 9 is 1 μ m.

Figure 10 *Tricolpites* sp. 1366. Slide MS37001, M22/1, SEM 1366, equatorial view showing finely reticulate sculpture.

Figures 11 & 12 *Triorites* sp. 1373. Figures 11 & 12 are the same pollen grain, slide MS38202, M21/1, SEM 1373 & 1374, polar view showing reticulate sculpture at different magnifications, scale bar of Figure 12 is 1 μ m.

PLATE 14

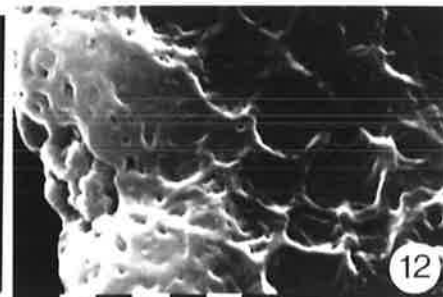
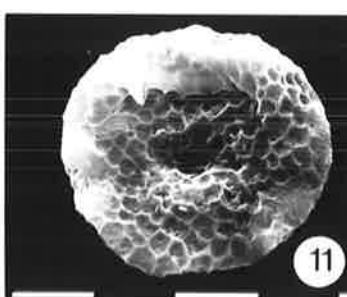
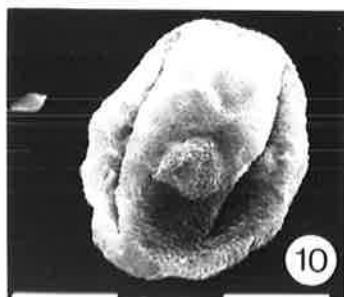
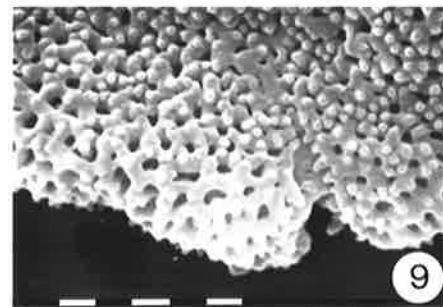
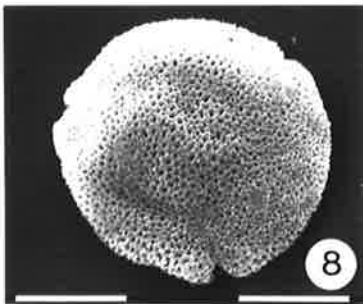
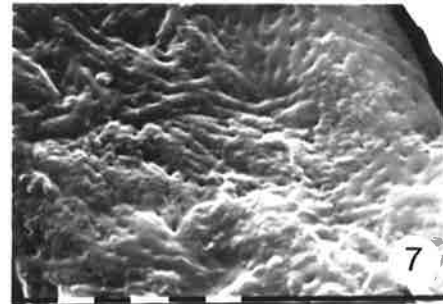
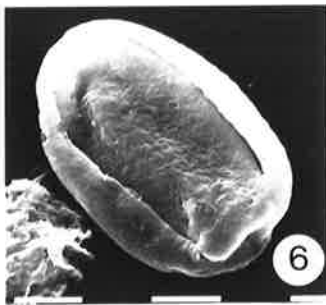
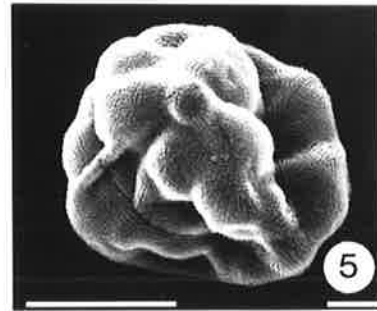
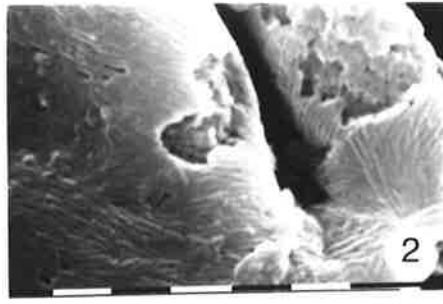
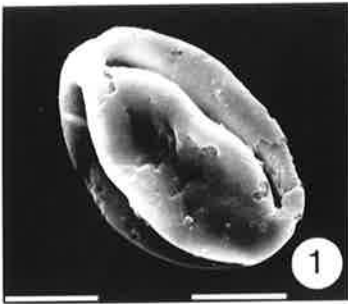


PLATE 15

Figures 1-3 *Triorites* sp. 788. Figures 1-3 are the same pollen grain, slide MM11802, P26/4. Figures 1 & 2: SEM 788 & 789, equatorial view showing reticulate sculpture and protruding pores at different magnifications, scale bar of Figure 2 is 1 μm . Figure 3: LM 12028, equatorial view showing protruding pore and stratified exine.

Figures 4 & 5 *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953. Figures 4 & 5 are the same pollen grain, slide MM12702, O30/2. Figure 4: SEM 887, polar view showing microgranules arranged in parallel ridges. Figure 5: LM 11832, polar view showing vestibulate pores.

Figure 6 *Betula pendula* Roth, Recent. Specimen origin: Europe. Voucher reference: South Australia State Herbarium AD 96325180, SEM 565, polar view showing microgranules arranged in parallel ridges.

Figures 7 & 8 *Carpinus japonica* Blume, Recent. Specimen origin: Japan. Voucher reference: South Australia State Herbarium AD 96619045, SEM 500 & 501, polar view at different magnifications showing microgranules arranged in parallel ridges, scale bar of Figure 8 is 1 μm .

Figure 9 *Tubulifloridites antipodica* Cookson ex Potonié 1960. Slide SP10501, N22/2, SEM 1649, polar view showing echinate sculpture.

Figures 10 & 11 *Xylocarpus* sp. 1526. Figures 10 & 11 are the same pollen grain, slide P22202, M24/1. Figure 10: SEM 1526, oblique equatorial view showing perforate sculpture and protruding pores. Figure 5: LM 11823, equatorial view showing protruding pores and stratified exine.

Figures 12-14 *Zonocostites ramonae* Germeraad *et al.* 1968. Figures 12 & 13 are the same pollen grain, slide AP101S4, F23/3. Figure 12: SEM 427, equatorial view showing finely reticulate sculpture. Figure 13: LM 12021, equatorial view showing lalongate pores. Figure 14: SEM 1483, oblique polar view similar to Figure 12.

PLATE 15

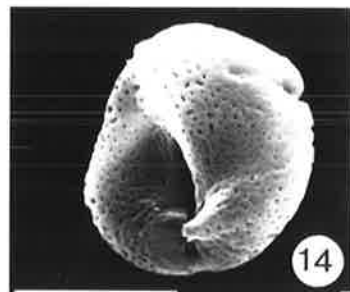
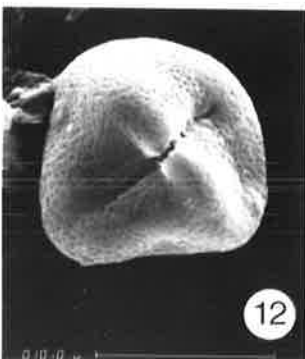
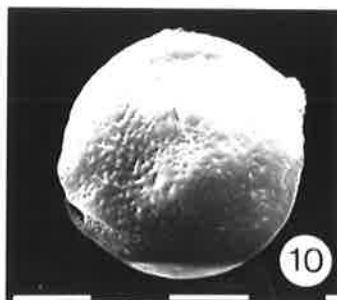
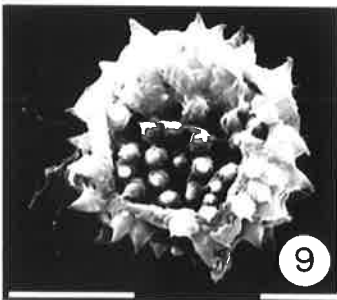
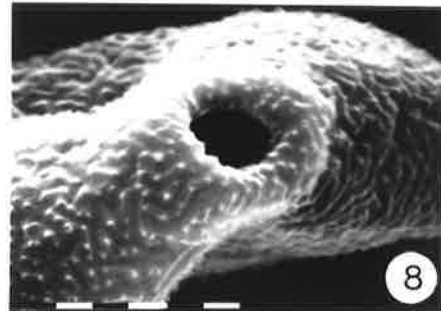
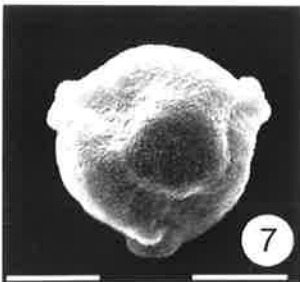
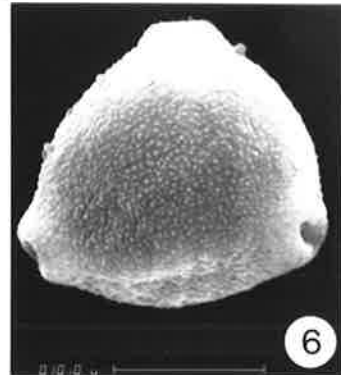
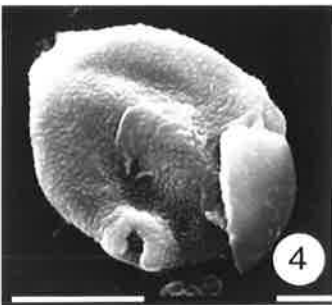
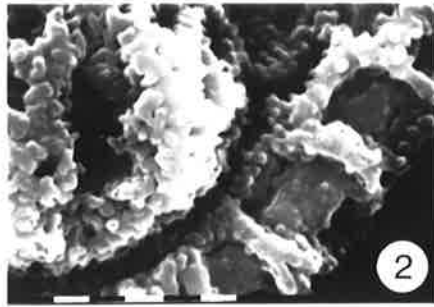
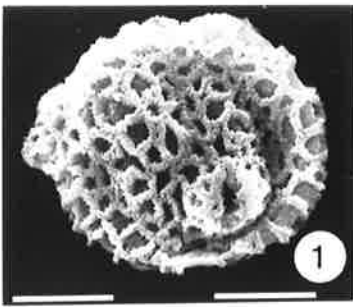


PLATE 16

MISCELLANEOUS PALYNOMORPHS

Figure 1 *Pediastrum kajaites* Wilson & Hoffmeister 1953. Slide FP10109, L24/0, SEM 656, 100 μ m scale bar.

Figure 2 *Pediastrum paleogeneites* Wilson & Hoffmeister 1953. Slide MM12701, P28/1, SEM 844.

Figure 3 *Pediastrum delicatites* Wilson & Hoffmeister 1953. Slide FP10107, O24/2, SEM 643.

Figure 4 Amorphous organic matter occurs abundantly from Mae Sot oil shale, SEM 924.

Figures 5 & 6 ?*Dapsilidinium* sp. Figures 5 & 6 are the same specimen, slide T656S1, N22/4, SEM 429 & 430.

Figures 7-9 *Operculodinium centrocarpum*. Figures 7 & 8 are the same specimen, slide T656S1, N22/4, SEM 429 & 430. Figure 9: Slide M68402, P22/3, SEM 1606.

Figures 10 & 11 *Spiniferites* sp. Figures 10 & 11 are the same specimen, slide M54001, L21/3, SEM 1570 & 1573.

Figure 12 ?*Lingulodinium maphacrophorum*. Slide T656S2, M22/0, SEM 435.

PLATE 16

