Southeast Asian Studies, Vol. 24, No. 2, September 1986

Problem Soils in Southeast Asia

A Study of Floral Composition of Peat Soil in the Lower Batang Hari River Basin of Jambi, Sumatra

SUPIANDI Sabiham* and FURUKAWA Hisao**

Abstract

Pollen diagrams have been prepared of three sections of peat soil deposits from different localities on the coastal swampy land of Jambi in order to study the vegetational change from the basal clay to the present-day forest. The age of peat soil deposits was determined by ^{14}C dating of peat layers.

The existence of arboreal and non-arboreal pollen types in the main portion of the peat soil deposits in the study area indicates the change from fern association in the bottom layer to the swamp forest in the upper layer. However, the floral composition of these soils indicates a difference in environment between the center zone and the zone transitional to the coastal zone. In the center zone of the Kumpeh area, the peat swamp was inundated by fresh water in all layers, which are characterized by an abundance of ferns in the bottom layer, by many kinds of arboreal pollen types in the upper layer, and by a uniform pollen type between these layers. In the center zone of the Tanjung area, the peat swamp was inundated by fresh water in the upper layer and brackish water in the bottom layer. In the zone transitional to the coastal zone the peat swamp was inundated by brackish water in all layers. The floral composition of peat soil inundated by brackish water is mostly derived from mangrove vegetation.

Peat accumulation in the study area is thought to be related to water inundation during the transgression period.

Introduction

The coastal swampy lands of the lower Batang Hari river basin of Jambi cover more than 12,400 sq. km and comprise 23.2 percent of the land surface of this part of Jambi Province. The soils in this area consist generally of alluvial soil and peat soil.

Since 1974, the first author has been involved in research into the development of tidal swamp lands of Jambi and South Sumatra Provinces to study the ecology of coastal swampy areas. In 1983, he researched peat soil deposits in the Kumpeh, Tanjung and Berbak Delta areas of Jambi, and the results were submitted as a M. S. thesis to Kyoto University [Supiandi 1985]. Now the authors are

* Faculty of Agriculture, Bogor Agricultural University, Indonesia; Faculty of Agriculture, Kyoto University, Kitashirakawa, Sakyo-ku, Kyoto 606, Japan

** 古川久雄, The Center for Southeast Asian Studies, Kyoto University

interested in the pollen content of peat soil deposits in connection with their research into the floral composition of peat soil in the lower Batang Hari river basin of Jambi, Sumatra. The location of the study area is presented in Fig. 1.

Peat swamps in this area are mostly of the woody-peat type, having acid reaction and a wide range from eutrophic to oligotrophic peats [*ibid.*]. These peat soils have been deposited since the terrestrial soils on the Pleistocene terrace were trans formed into fluviatile swampy soils. Soepraptohardjo and Driessen [1976] suggested that the swampy area located between the vaguely defined river levees became successively covered with mangrove and swamp forest vegetation, which built up thick, dome-shaped formations of ombrogenous lowland peat.

The objective of this paper is to describe the vegetational change from the basal clay to the present-day forest of the study area on the basis of pollen analysis. The stratigraphy and geomorphology of the study area are also presented in order to distinguish the peat accumulations.

Materials and Methods

Field Study

The planned study area was plotted on the sheet of Series 1501 (G) Jambi-Sumatra map (1 : 250,000) in order to decide the location of transects through distinct vegetation types and to plan soil borings along the transects of up to six meters in depth. The study area consists geographically of the Kumpeh, Tanjung, and Berbak Delta areas. These areas were surveyed by the authors from October 9 to November 22, 1983 with the assistance of 10 laborers. Observations and measurements on soil properties were made at intervals of 0.5 to 2.0 km along the transects in order to study the stratigraphy and geomorphology of these areas.

To study the fossil pollen in connection with the history of plant communities, samples were collected from layers at several observation points using the sub-sampling method, for which two-centimeter-thick samples were taken from each soil

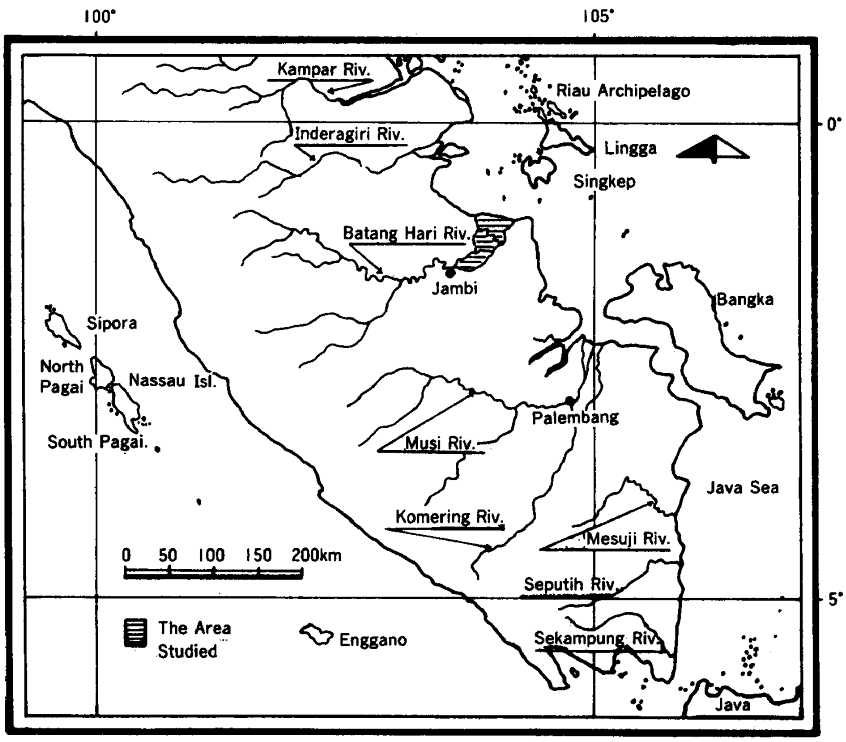


Fig. 1 Location of the Area Studied (after Supiandi [1985])

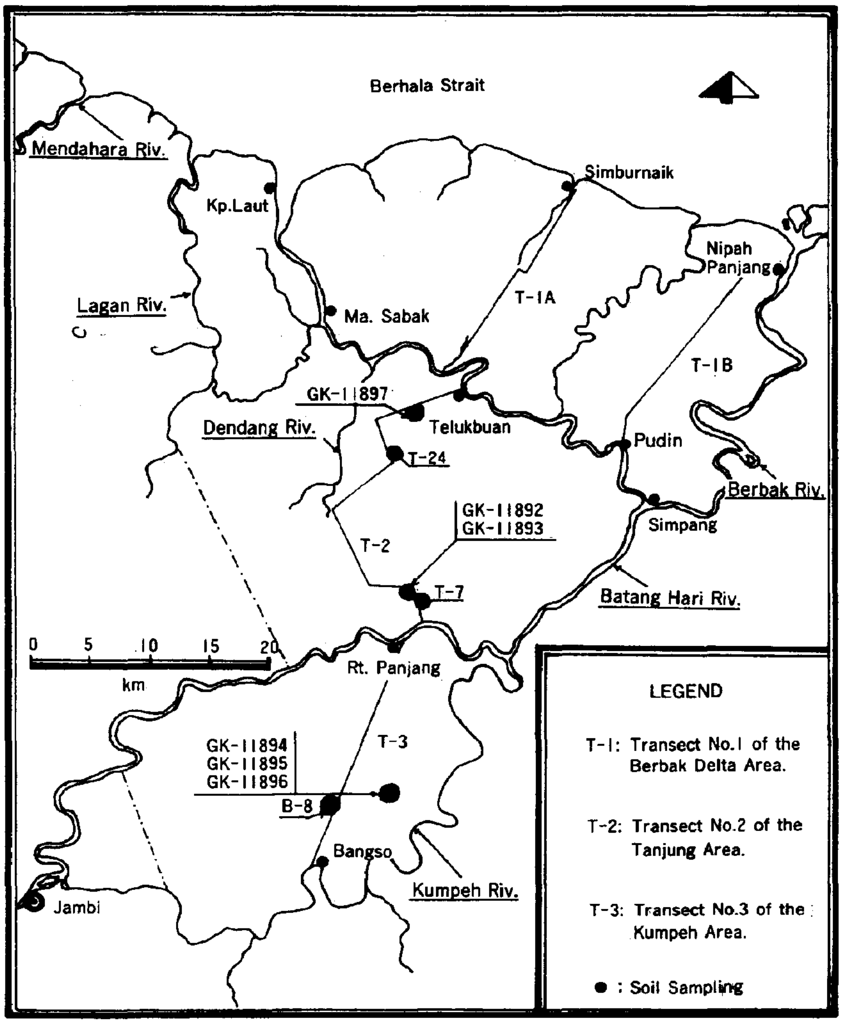


Fig. 2 The Location of the Transects and Soil Sampling for Pollen Analysis and Carbon Dating

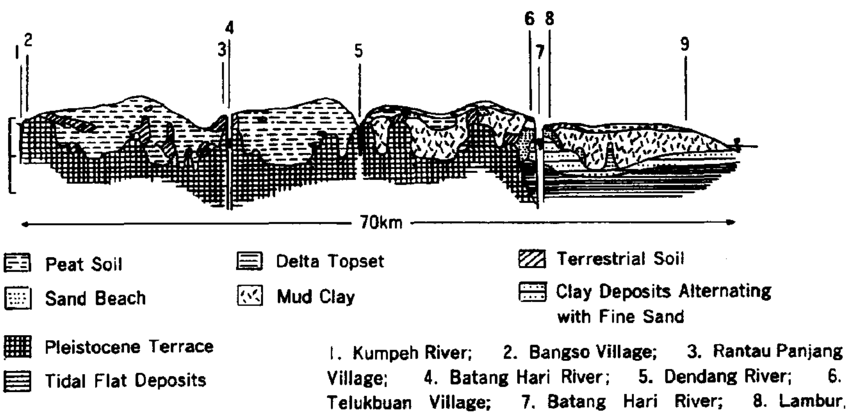


Fig. 3 The Stratigraphy and Geomorphology of the Study Area in Cross-section from Bangso to Simburnaik (after Furukawa and Supiandi [1985])

sample in plastic pipes at 10-centimeter levels in vertical sequence. To study the age of peat soil deposits, samples were collected from layers at different observation points. Fig. 2 shows the soil sampling sites.

Laboratory Experiment

The fossil pollen grains and spores in the soil samples were investigated by pollen analysis in order to reconstruct the floral composition. The Erdtman method [Brown 1960], which was modified by Takeoka (Kyoto Prefectural University), was used for extraction of fossil pollen in the soil samples. For reference, modern pollen samples were collected from the Herbarium Bogoriense. The modern pollen was extracted by the Jimbo method [*ibid.*]. For this study, we also used the other references of pollen and spore types described by Anderson and Muller [1975], Huang [1972] and Kremp and Kawasaki [1972].

General Description of the Study Area

Stratigraphy and Geomorphology

The area under investigation is situated in eastern Jambi, Sumatra and is bounded on the north by the Berhala Strait, on the west by the Batang Hari and Dendang rivers, and on the east and south by the Batang Berbak, Batang Hari and Kumpeh rivers (Fig. 2). This area forms part of the eastern coastal plain of Sumatra, which was previously located on a Pleistocene terrace. The stratigraphy and geomorphology of the study area in a cross-section from Bangso village (near to the Kumpeh river) to Simburnaik village (near to the sea) were described by Furukawa and Supiandi [1985] (Fig. 3). The five zones and 15 stratigraphic types distributed successively from inland to the coast in this area were as follows below.

1. Zone transitional to the middle reaches. Terrestrial soils have developed on the (1) low terrace, (2) meandering scars, and (3) natural levee along the Kumpeh river.
2. Central zone covered by swamp forest. This area is mostly (4) peat-capped terrace. During the post-Glacial period, when the sea level rose, the terrace surface with terrestrial soils is supposed to have been transformed into fluviatile swampy lands. Ombrogenous peat plains were then developed, sometimes exceeding six meters. The periphery contains an admixture of fluvial deposits from the meandering river course. (5) Natural levees are less developed along the Batang Hari river, consisting of imperfectly drained clay soils which are generally derived from terrestrial soil.
3. Zone transitional to coastal zone. (6) Successive terrestrial soils have developed from fluvial deposits on the terrace surface. (7) Mangrove deposits directly covering the terrace surface are most widely distributed. (8) Another sedimentary phase indicates mangrove to have intruded much later on the peat-capped terrace. (9) The natural levees have developed along the streams which flow through former mangrove deposits. (10) Former beach ridges often outcrop.
4. Coastal zone with fish-bone channel networks. This area has been exploited by local people. (11) Thick sand ridges are advancing offshore, and (12) mangrove deposits have developed on tidal flat. The present surface is covered by humiferous clay and sometimes thin peat soil. (13) A narrow mangrove belt covers the present coastline.
5. Remnant hill isolated from the middle reaches. This was an island during the period of high sea level in the past. (14) Hillslopes are covered by brush, rubber gardens and fruit trees. (15) Shallow valley bottoms are utilized for bush-fallow cultivation of wet rice in the rainy season.

The Present Vegetation

The vegetation of an area is a reflection of the interaction of several environmental factors. Vegetation types have to be determined since they are directly related to the soil. Thus, the characteristics of the dominant species can be used to predict

Table 1 List of Species Found in the Study Area*

Genus No.	Name of Species	Location
	Tree Species	
1.	*Actinodaphne macrophylla*	Center zone of Kumpeh area
	A. sphaerocarpa	Center zone of Kumpeh area
2.	*Aglaia argentea*	Center zone of Kumpeh area
	A. trimera	Center zone of Kumpeh area
3.	*Alseodaphne insignis*	Center zone of Kumpeh area
4.	*Alstonia pneumatophora*	Zone transitional to coastal zone
5.	*Antidesma spicatum*	Zone transitional to coastal zone
6.	*Barringtonia* sp.	Center zone of Kumpeh area
7.	*Callophyllum* sp.	Center zone of Kumpeh area
8.	*Commersonia bartramia*	Center zone of Kumpeh area
9.	*Cratoxyllum* sp.	Center zone of Kumpeh area
10.	*Cryptocarya bicolor*	Center zone of Kumpeh area
11.	*Cynometra ramiflora*	Zone transitional to coastal zone
12.	*Dacryodes rugosa*	Center zone of Kumpeh area
13.	*Diospyros argentea*	Center zone of Kumpeh area
	D. buxifolia	Center zone of Kumpeh area
	D. malabarica	Center zone of Kumpeh area
	D. polyalthioides	Center zone of Kumpeh area
	D. rigida	Center zone of Kumpeh area
	D. sub-rhomboidea	Center zone of Kumpeh area
	D. sumatrana	Center zone of Kumpeh area
14.	*Elaeocarpus* cf. *paniculatus*	Center zone of Kumpeh area
	E. glaber	Center zone of Kumpeh area
15.	*Eucalyptus* sp.	Center zone of Kumpeh area
16.	*Eugenia* sp.	Center zone of Kumpeh area
	E. acuminatissima	Center zone of Kumpeh area
	E. clavamyrtus	Center zone of Kumpeh area
	E. claviflora	Center zone of Kumpeh area
	E. curranii	Zone transitional to coastal zone
	E. jamboloides	Zone transitional to coastal zone
	E. laxiflora	Center zone of Kumpeh area
	E. zippeliana	Zone transitional to coastal zone
17.	*Euphoria* cf. *chinensis*	Zone transitional to coastal zone
18.	*Garcinia gandichandii*	Center zone of Kumpeh area
19.	*Knema conferta*	Zone transitional to coastal zone
	K. tomentella	Center zone of Kumpeh area
20.	*Lepisanthes amoena*	Center zone of Kumpeh area
	L. tetraphylla	Center zone of Kumpeh area
21.	*Macaranga* sp.	Center zone of Kumpeh area
22.	*Myristica maxima*	Center zone of Kumpeh area
23.	*Nephelium* sp.	Center zone of Kumpeh area
24.	*Phaenanthus sumatranus*	Center zone of Kumpeh area

Genus No.	Name of Species	Location
25.	*Polyalthia lateriflora*	Center zone of Kumpeh area
	P. longifolia	Center zone of Kumpeh area
	P. subcordata	Center zone of Kumpeh area
	P. sumatrana	Center zone of Kumpeh area
26.	*Pometia pinnata*	Center zone of Kumpeh area
27.	*Pternandra caerulescens*	Center zone of Kumpeh area
	P. rostrata	Center zone of Kumpeh area
28.	*Pterospermum cordifolium*	Center zone of Kumpeh area
29.	*Quassia* sp.	Center zone of Kumpeh area
30.	*Santiria laevigata*	Zone transitional to coastal zone
	S. oblangifolia	Center zone of Kumpeh area
	S. tomentosa	Center zone of Kumpeh area
31.	*Scaphium macropodum*	Zone transitional to coastal zone
32.	*Shorea* sp.	Center zone of Kumpeh area
	S. ovalis	Center zone of Kumpeh area
33.	*Timonius* sp.	Center zone of Kumpeh area
34.	*Xanthophyllum eurhychum*	Center zone of Kumpeh area
35.	*Xylopia mayana*	Center zone of Kumpeh area
36.	*Zizyphus elegans*	Center zone of Kumpeh area
	Grasses	
37.	*Cyperus platystylia*	Zone transitional to coastal zone
38.	*Panicum incomtum*	Zone transitional to coastal zone
	Shrubs	
39.	*Connarus semicondrus*	Zone transitional to coastal zone
40.	*Lasianthus constrictus*	Center zone of Kumpeh area
41.	*Lucinaea montana*	Center zone of Kumpeh area
42.	*Tarenna fragrans*	Center zone of Kumpeh area
	Herbs	
43.	*Blumea balsamifera*	Zone transitional to coastal zone
44.	*Fimbristylis quinquangularis*	Zone transitional to coastal zone
45.	*Justicia maritiana*	Zone transitional to coastal zone
46.	*Labisia pumila*	Center zone of Kumpeh area
	Fern	
47.	*Acrostichum aureum*	Zone transitional to coastal zone

* Collected by H. Furukawa and Erizal.
The specimens were identified by staff members of Herbarium Bogoriense.

which environmental factors are important in the area.

The vegetation types in the study area consist of swamp forest vegetation characterized by evergreen seasonal forest, of mangrove forest, and of herbaceous swamp.

Mangrove Forest

In some places in the study area, the mangrove forest is rarely or not developed because the inhabitants farmed the lands, especially for paddy and coconut. These areas are characterized by the existence of fish-bone-like channel networks. However, in the area along the river estuaries on and behind the levees, where the soil is characterized by soft mud clay which never dries out completely, *Rhizophora* sp. normally dominates. At the margin or where the forest is a little more open, the fern *Acrostichum* sp. may occur in the undergrowth.

In the area near to sea, *Avicennia* sp. grows well on more clayey and settled soil. In general, this area is mostly inundated during high tides.

In the area along the Batang Hari river, from the Dendang river mouth towards the lower course of Batang Hari river, we found *Sonneratia* sp., sometimes with *Nipa* sp. The presence of this vegetation demonstrates that the area frequently influenced by tidal action.

Swamp Forest Vegetation

In the swamp forest of the study area, many important species were found in the center zone. Many kinds of trees and shrubs grow well, making this swamp forest evergreen, tall and profusely-leaved. The zone transitional to the coastal zone was also been covered by swamp forest until recently, and is now being opened by the government.

In some places, the original vegetation of the swamp forest has been cut by local people for logs, so that the vegetation in these spots is now in the process of formation of remainder swamp forest. This situation is characterized by the growth of new species, such as *Paspalum commersonii*, *Stenochlaena palustris*, *Cyperus diffusus* and *Imperata cylindrica*.

In the area covered by dense forest, many trees species grow well, including *Koompassia malaccensis*, *Durio carinatus*, *Jackia ornata*, *Tetrameristra glabra*, *Shorea* sp., and *Dyera* sp. On the peat soil deposits, besides these species, *Licuala acutifida* may occur in the undergrowth.

The other species found in the swamp forest of the study area are presented in Table 1.

Table 2 The Location of Peat Soil Samples for ^{14}C Dating

Sample No.	Depth (cm)	Material and Locality	Present Position from MSL* (Approx. in m)
		Center Zone of Kumpeh Area	
GaK-11894	200–250	Woody peat; 7 km Northeast of Pulau Mentaro	4.0 to 4.5
GaK-11895	400–450	Charred wood; 7 km Northeast of Pulau Mentaro	2.0 to 2.5
GaK-11896	700–750	Charred wood; 7 km Northeast of Pulau Mentaro	−1.5 to −1.0
		Center Zone of Tanjung Area	
GaK-11892	200–250	Woody peat; 3 km North of Rantau Panjang	4.0 to 4.5
GaK-11893	400–430	Woody peat; 3 km North of Rantau Panjang	2.0 to 2.5
		Zone Transitional to Coastal Zone	
GaK-11897	335–390	Charcoal; SK-8 Unit II Dendang I	2.0 to 2.5

* Mean Sea Level.

Table 3 The Results of ^{14}C Dating of Peat Soil from the Center Zone and the Zone Transitional to the Coastal Zone

Sample No.	Depth (Av. in cm)	Age (Years BP)	Depth of Soil Sample (cm)	Calculated Rate of Peat Accumulation (cm/100 yr)
		Center Zone of Kumpeh Area		
GaK–11894	0–225	4040±180	200–250	6
GaK–11895	225–425	4360±130	400–450	63
GaK–11896	425–725	5710±130	700–750	22
		Center Zone of Tanjung Area		
GaK–11892	0–225	5890±190	200–250	4
GaK–11893	225–425	6830±180	400–430	21
		Zone Transitional to Coastal Zone		
GaK–11897	0–365	5980±180	335–390	6

The Age of Peat Soil Deposits in the Study Area

To study the age of peat soil deposits in the study area, several peat soil samples from three profiles were sent for dating by Prof. Kunihiko Kigoshi, Faculty of Science, Gakushuin University, Tokyo. The samples collected from the center zone and the zone transitional to the coastal zone (Table 2) are expected, together with the study of fossil pollen from each layer of peat soil deposits, to yield information on the beginning of peat soil deposition.

The results of ^{14}C dating of these peat soil layers at various depths shown in the Table 3 indicate that peat soil deposits started to accumulate during the Holocene period. When the sea level rose, the fluviatile swamps in the study area were formed covering the Pleistocene terrace. It was the organic matter deposited in the bottom layers of these areas that commonly formed the basis of peat swamps.

The deposition of peat soils in the study area appears to indicate that the rates of peat accumulation (Table 3) are more rapid in bottom layers than in surface layers. The decrease in the rate of peat accumulation in surface layers may be the result of the subsidence process of peat soil, which increases the degree of decomposition of the soil. Supiandi [1985] reported that the humification in surface layers is more rapid than in bottom layers. He also mentioned that peat soil in bottom layers is very soft due to a high water content, which may hamper the organic matter decomposition.

Floral Composition of Peat Soil Deposits in the Study Area

To study the floral composition of peat soil deposits it is necessary to analyse the fossil pollen sedimentation in each layer of soil. The most important feature of peat soil deposits to emerge from the study of fossil pollen is that they develop in a stratified sequence. As the vegetation continues to grow, the pollen types become buried by further deposits of organic matter and are thus stratified into horizons within the developing peat profile.

Peat soil deposits in the study area were formed under the influences of water inundation and a marine environment. These raise several problems in the interpretation of the results of pollen analysis, because some of the fossil pollen types buried in peat soil deposits may have been brought in by the main rivers or the air. Several places in the study area were inundated by river water overflowing onto the soil surface, and these various pollen types were transported by surface water. Pollen transportation by air into the study area is also possible. These grains may cause considerable confusion because they will be of fossil pollen and will possibly have been derived from quite different vegetation.

We nevertheless carried out a pollen analysis because we believed that the fossil pollen buried by organic matter deposits would elucidate the former situation of the environment. It was found that during the accumulation of organic matter, the vegetation has changed gradually in composition until the present-day.

Discussion of Diagrams

Table 4 represents the total of arboreal and non-arboreal pollen types from all sub-samples of profiles B–8 and T–7 (center zone) and T–24 (zone transitional to coastal zone). The results of pollen observation are presented in Figs. 4, 5 and 6a, which are composed in the same way. Microphotographs are given of the most important fossil pollen types (see Plates 1 to 6).

Based on the boring data and fossil-grain observations, peat soil deposits consist of several layers which are characteristic of different environments. This clearly demonstrates the vegetational change from the basal clay to the present-day forest. These layers are described below.

Table 4 The Total of Arboreal and Non-arboreal Pollen Types from All Sub-samples of Profiles B–8, T–7 and T–24

Depth (cm)	Total Grains	Pollen Types (%)		Unknown (%)
		Arboreal Pollen	Non-arboreal Pollen	
		*Profile B–8**		
0–138	2512	86	13	1
138–162	700	87	12	1
162–347	4290	92	6	2
347–418	1723	31	54	15
		Profile T–7		
0–120	2107	80	18	2
120–220	2069	83	14	3
220–400	1807	33	65	2
400–420	424	59	38	3
420–470	320	27	71	2
		Profile T–24		
80–100	361	78	19	3
100–150	911	89	9	2
150–227	968	83	14	3
227–263	126	79	15	6

* After Supiandi [1985].

Center Zone

Fig. 4 shows the floral composition of a peat soil from profile B–8 of the center zone of the Kumpeh area. The layer at the depth of 347 to 418 cm is categorized as a transition layer between the basal clay and peat soil deposits. This layer represents the first peaty sediment deposited on the terrestrial soil. It is dominated by non-arboreal types and characterized by an abundance of such spore grains as *Alsophylla*, *Nephrolepis* and *Asplenium*. This clearly demonstrates the presence of vegetation with

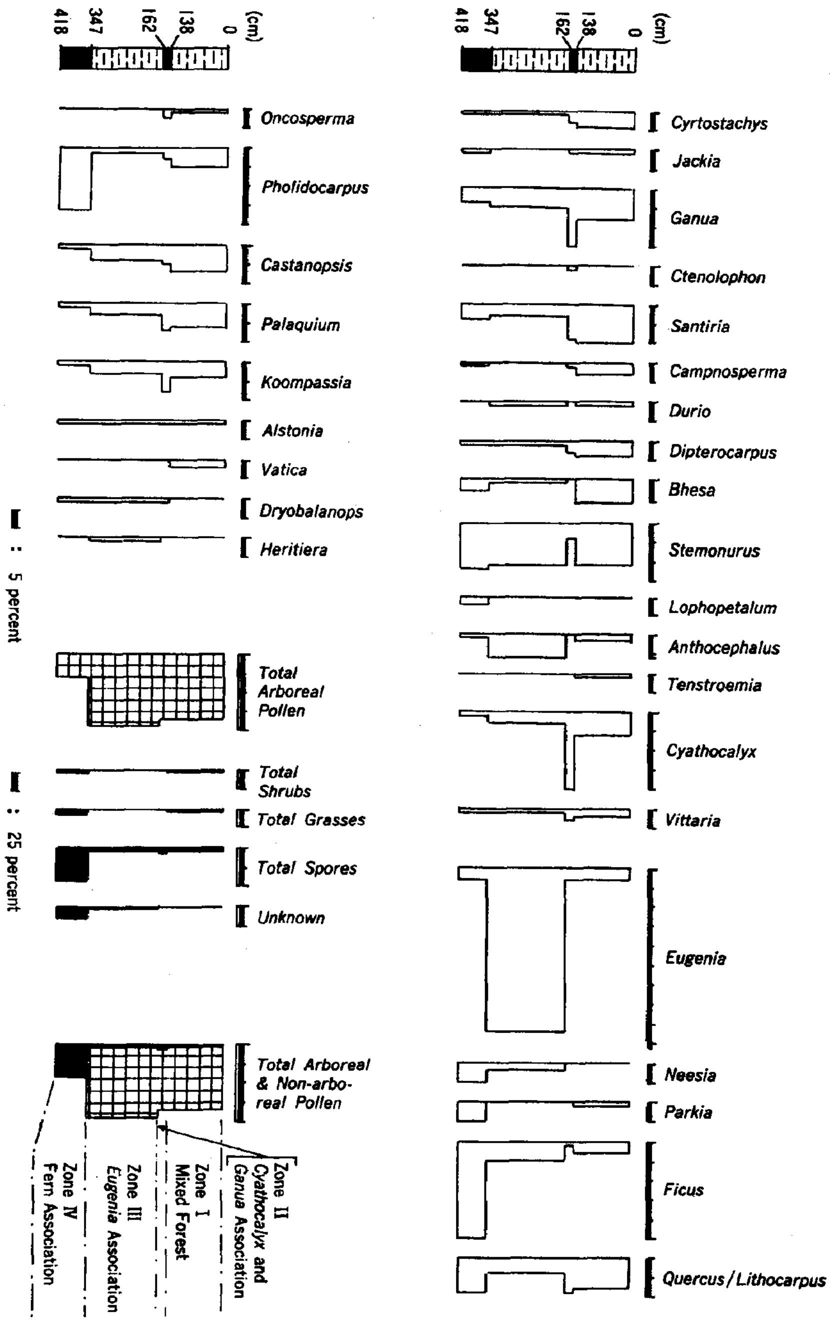


Fig. 4 The Pollen Diagram of Profile B–8

fern association. The results of ^{14}C dating indicate that the lowest peat deposits with fern association probably started to form about 5,700 years ago. *Ficus* and *Pholidocarpus* are more prominent in the arboreal pollen types. This indicates that before the transgression period the vegetation types on the Pleistocene terrace were probably dominated by *Ficus* and fern types. However, after the Pleistocene terrace had been transformed into fluviatile swamp by the rise in sea level during the transgression period, the tree species became dominated by *Pholidocarpus*. Ridley [1924] reported that the habitats of *Ficus* spp. in the Malay Peninsula are mostly in the upland areas; and in 1925 he reported that the habitats of *Pholidocarpus* spp. are mostly in swampy areas.

The layer at the depth of 162 to 347 cm is categorized as peat soil deposits with small amounts of mineral material contents. Samples from this layer show a decrease in the fossil grains of spores, *Pholidocarpus* and *Ficus*, and an increase in arboreal pollen types, which are dominated by *Eugenia*. This clearly demonstrates a succession from fern association to swamp forest, which probably started approximately 4,300 years ago. We believe that the environment of this layer was a swampy area, because Ridley [1922] reported that some species of *Eugenia* grow well in

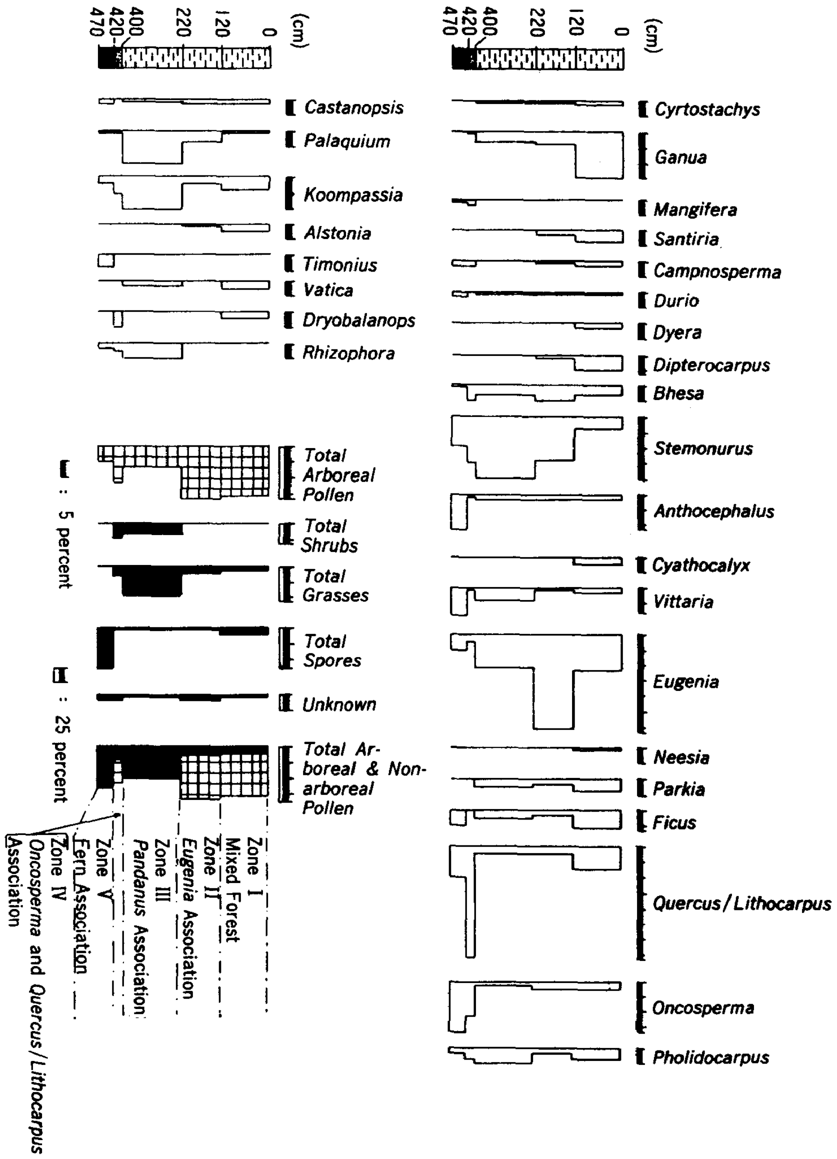
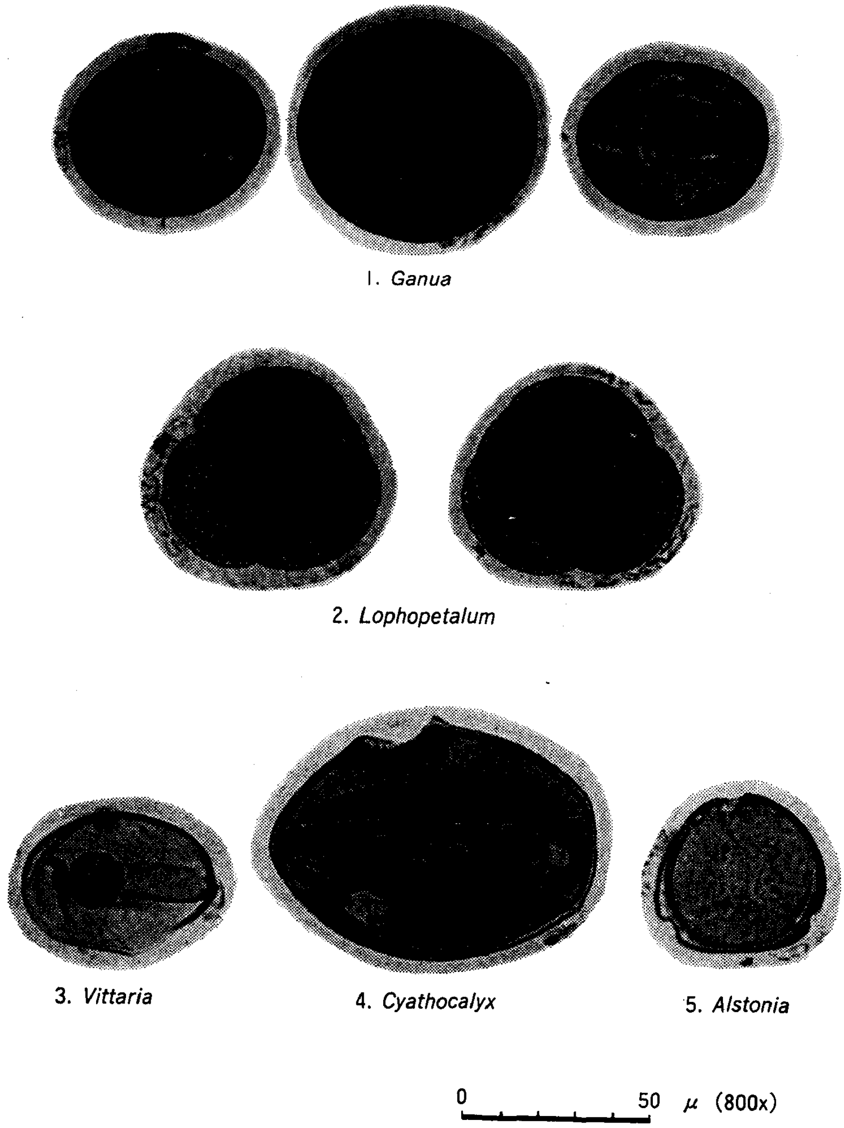


Fig. 5 The Pollen Diagram of Profile T-7

swampy areas. This layer also demonstrates a decrease in the fossil pollen types of *Parkia* and *Neesia*. The fossil pollen of oak trees is also represented in the soil samples of this layer, but some of this fossil pollen is presently difficult to identify correctly. Some species of *Quercus* were reclassified by Soepadmo [1972] into the genus *Lithocarpus*. For this reason these species are not listed individually here. However, we believe the oak tree fossil pollen in each layer of this area to be that of tropical oak trees, like the Malayan oak trees reported by Corner [1940]. To name these species correctly, the fossil pollen of oak trees should be investigated in more detail.

The layer at the depth of 138 to 162 cm is characterized by clay deposits derived from terrestrial soils. The clay deposits were mixed with small amounts of dull yellow orange (10YR 6/3) organic matter. In this layer, the samples show a decrease of *Eugenia* and an increase of other arboreal pollen types, especially *Ganua* and *Cyathocalyx*. The existence of *Cyathocalyx* in this layer indicates that the mineral soil deposited here is a terrestrial soil, because *C. virgatus* King grows mostly in upland areas [Ridley 1922]. Thus the fossil pollen of *Cyathocalyx* was probably transported by water together with the terrestrial soil from the upper part of Jambi. The existence of *Ganua* indicates that this layer was previously a swampy area. Smythies [1965] reported that the species *Ganua motleyana* (de Vriese) Pierre ex Dubard in Sarawak is locally frequent in mixed peat swamp forest on shallow peat soil deposits, and



1. *Ganua*

2. *Lophopetalum*

3. *Vittaria*　4. *Cyathocalyx*　5. *Alstonia*

0 — 50 μ (800x)

Plate 1

the other species (*G. coriacea* Pierre ex Dubard) is frequent to rare in mixed peat swamp forest throughout Sarawak.

The layer between 0 and 138 cm is characterized by peat soil deposits. In this layer, many kind of arboreal pollen types were found. However, the fossil grains of *Ganua*, *Santiria* and *Stemonurus* were more prominent than other fossil grains. This clearly represents the first of the successive stages in the formation of the mixed forest.

The floral composition of peat soil deposits from profile T–7 of the center zone of the Tanjung area, shown in Fig. 5, indicates that in the depth of 420 to 470 cm, *Lycopodium*, *Stenochlaena* and *Nephrolepis* dominate the fossil grains. The existence of these spores indicates the presence of vegetation with fern association. This vegetation grows on the Pleistocene terrace, of which the surface is supposed to have been transformed into fluviatile swampy lands during the post-Glacial period. In this layer *Oncosperma* is prominent in the arboreal pollen types, which indicates inundation by brackish water during the transgression period. Anderson and Muller [1975] mentioned that the existence of *Oncosperma* represents a zone lying inland of mangrove vegetation, subject to periodic, non-diurnal inundation and where saline influence is less strong.

The layer at the depth of 400 to 420 cm is categorized as a transition layer between the basal clay and peat soil deposits. It is characterized by a decrease in spore grains and an increase in the number of arboreal pollen types, especially the fossil pollen of oak trees (*Quercus* or *Lithocarpus*)

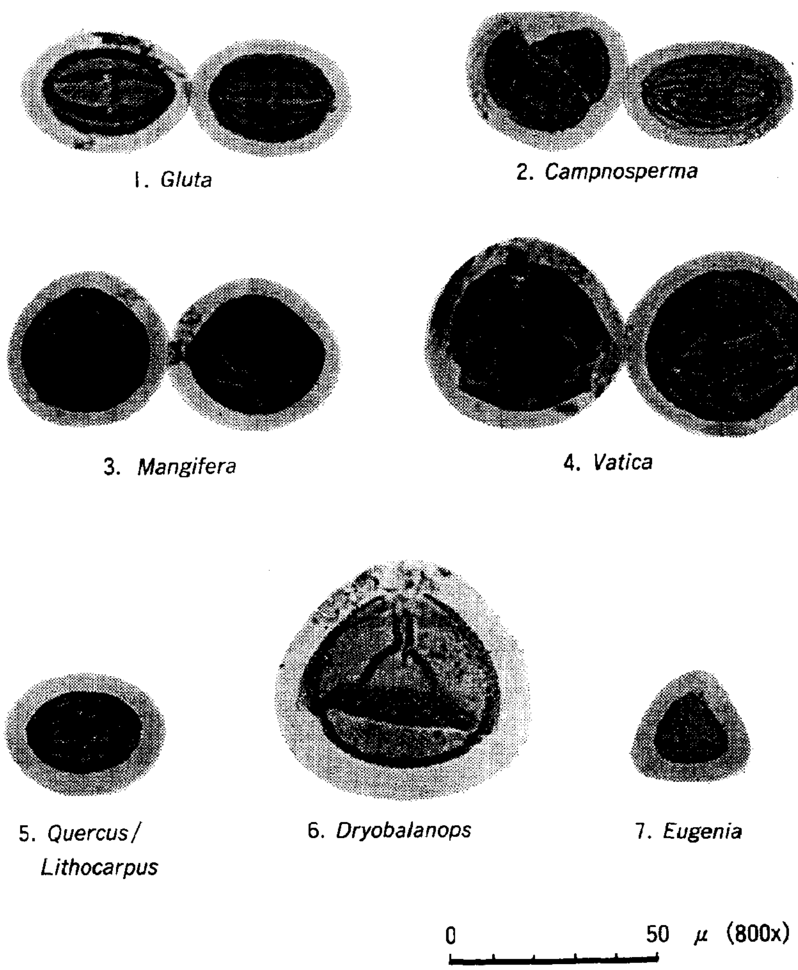


Plate 2

and *Stemonurus*. Soepadmo [1972] reported that *Quercus* is confined to ever-wet conditions; the genus occurs from sea level to 3,350 m, with a preference for the region between 600 and 1,500 m, in various sorts of primary forest, namely, lowland mixed *Dipterocarp* forest and swamp forest (with fluctuating water level). He also mentioned finding *Quercus subsericea* on rocky seashores in Cave Rachado near Port Dickson (Negeri Sembilan, Malaya) at 0–10 m, facing the mangrove. Other species, such as *Lithocarpus cooperatus* Blanco (*Quercus fernandesii* Vidal, *Q. reflexa* King, *Q. boholensis* Merr, *Q. cooperata* Blanco) and *L. nieuwenhuisii* (von Seemen) A. Camus (*Q. clementis* Merr, *Q. ochracea* (Schottky) Merr, *Q. nieuwenhuisii* von Seemen) were found in peat swamp and/or heath forests. An other scientist [Corner 1940] reported that *Quercus bennettii* Bennett and *Q. grandifrons* Lat. were found in the lowland swampy forest of Malaya, and that *Q. hystrix* grows in swampy forest. In this layer (at the depth of 400 to 420 cm), the fossil pollen of *Stemonurus* are also more prominent than the other arboreal pollen types. *Stemonurus secundiflorus* Bl. Bijdr reported by Ridley [1922] grows mostly on river-banks and in low swampy woods. The existence of *Stemonurus* and *Quercus* or *Lithocarpus* thus indicates that the area was previously swampy, and this played an important role in the first deposition of peat soils on the terrace surface, which is probably started approximately 6,800 years ago. In this layer, however, the fossil pollen of *Oncosperma* decreases due to a change of environment to the one with decreased saline influence.

The layer at the depth of 220 to 400 cm is categorized as peat soil deposits. The samples from this layer show a decrease in the *Lithocarpus* or *Quercus* and an increase

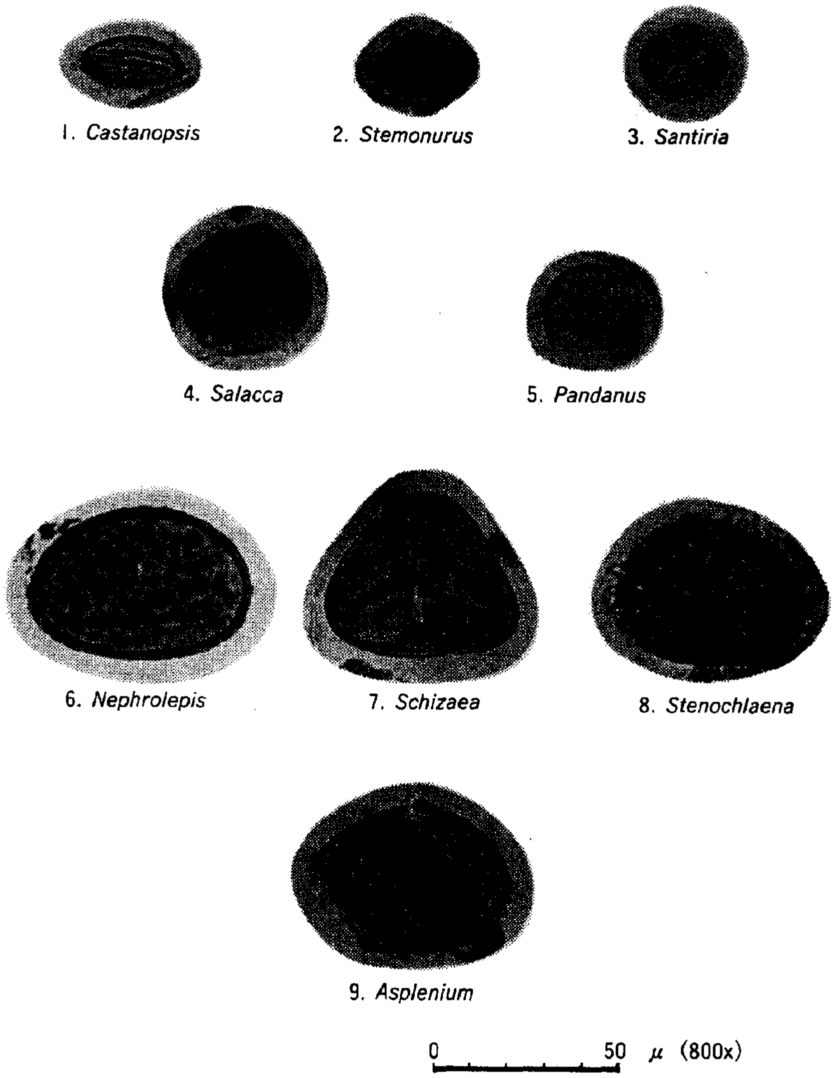


Plate 3

of the *Stemonurus* and other arboreal pollen types. Non-arboreal pollen types also increase and are characterized by an abundance of the *Pandanus*. Anderson and Muller [1975] reported that three *Pandanus* species, namely, *P. andersonii*, *P. ridleyi* and *P. sigmoidues*, occur in the peat swamp forest of NW Borneo. This clearly represents a different situation from that in the center zone of Kumpeh area. This layer also demonstrates an increase of *Eugenia*, *Palaquium* and *Koompassia* pollen types.

The peat soil deposit at the depth of 120 to 220 cm shows a decrease in the *Pandanus* and *Stemonurus* pollen types and an increase of *Eugenia*. This appears to indicate a succession from grasses to swamp forest, which probably started approximately 5,800 years ago. The existence of *Eugenia* indicates that, at that time, the area was swampy. This layer also demonstrates a decrease in the *Palaquium* and *Koompassia* pollen types.

The samples from the depth of 0 to 120 cm show a fairly heterogenous pollen content. There is a decrease of *Eugenia* and an increase in the number of arboreal pollen types, indicating the initial stage in the formation of mixed forest.

Zone Transitional to Coastal Zone

The floral composition of peat soil deposits from profile T–24 of the zone transitional to the coastal zone of the Tanjung area is shown in Fig. 6a. Fig. 6b is a supplement to Fig. 6a which shows in more detail some of the most important fossil pollen, in order to distinguish the floral composition from each horizon of profile T–24.

The soil surface of the area around

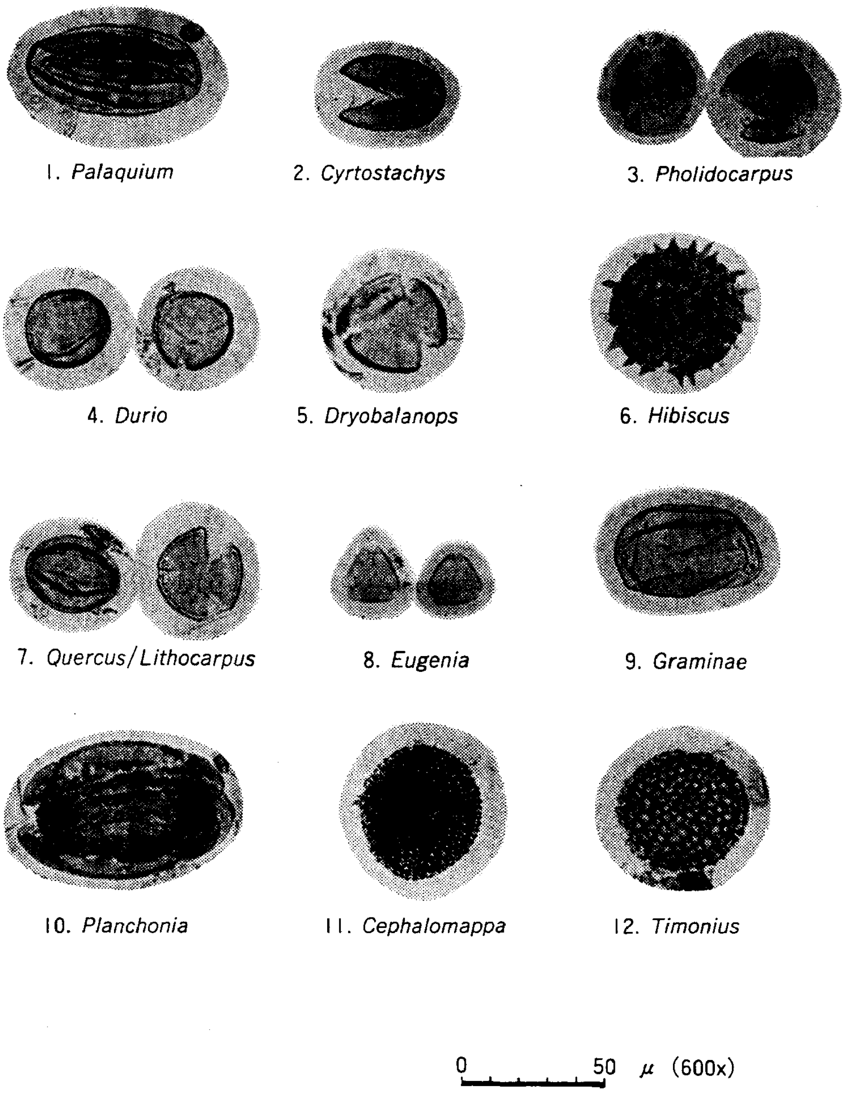


Plate 4

profile T–24 was covered by mineral materials during excavation of the canal. In fact, the soil surface is about 80 cm below the present covering, so that the soil samples for fossil pollen study were collected from 80 to 263 cm depth.

The layer at the depth of 227 to 263 cm is characterized by clay deposits with small amounts of plant remains, being gray (7.5Y 6/1) in color and light clay in texture. In this layer, *Pholidocarpus*, *Oncosperma* and *Sonneratia* dominate the fossil grains. The existence of these pollen types indicates that the area was once probably covered by mangrove vegetation. These clay deposits are successively terrestrial soils which developed from fluvial deposits on the terrace during the transgression period, so that this area was previously inundated by brackish water.

A peat soil mixed with small amounts of mineral materials at the depth of 150 to 227 cm shows a decrease in the arboreal pollen types of *Sonneratia*, *Oncosperma* and *Pholidocarpus* and an increase of *Nipa*, *Rhizophora* and *Lithocarpus* or *Quercus* pollen types. The existence of *Nipa* and *Rhizophora* pollen types appears to indicate a succession of this area towards a marine environment.

The layer between 100 to 150 cm is characterized by the dominance of *Rhizophora*. In this layer, *Sonneratia* and *Oncosperma* again increase, but *Nipa* and *Quercus* or *Lithocarpus* decrease. This clearly demonstrates that the area was then still inundated by brackish water.

The floral composition at the depth of 80 to 100 cm, which is characterized by the dominance of *Nipa*, that the area was influenced by tidal action. However,

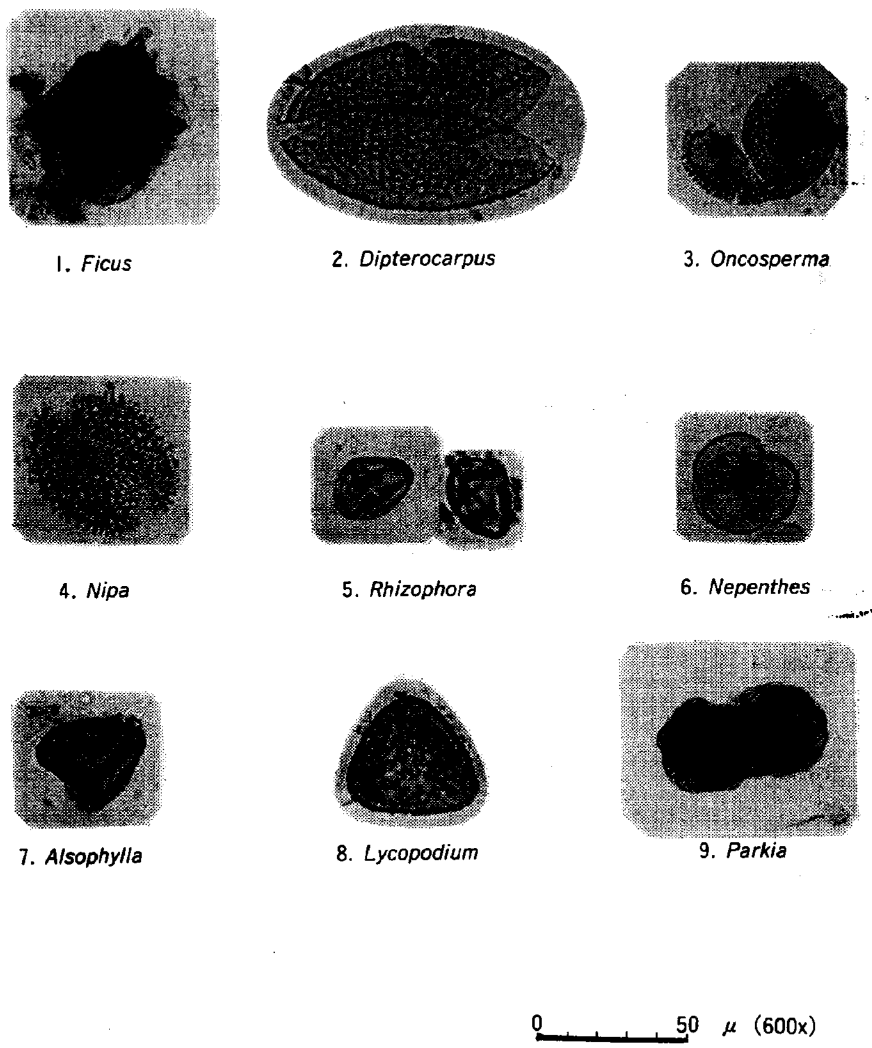


Plate 5

Rhizophora and *Sonneratia* are decreased. When the sea level changed to a few meters lower than at present during the period 3,000 to 1,500 yr BP [Fuji, Lin and Tjia 1971], the marine environment was also changed to the present one, and the *Rhizophora* and *Sonneratia* almost completely disappeared.

Conclusion

Peat soil deposits in the study area can be divided into several layers (zones) according to the results of pollen analysis from profiles B–8 and T–7 (center zone) and T–24 (zone transitional to coastal zone), which are described below.

Center Zone of Kumpeh Area (Profile B–8)

1. Zone I: peat soil deposit derived from mixed forest; the samples from this layer show a fairly heterogenous pollen content.
2. Zone II: mineral soil deposit derived from terrestrial soil. *Cyathocalyx* and *Ganua* pollen types were more prominent than other arboreal pollen types.
3. Zone III: peat soil deposit consisting mostly of a uniform pollen type, and characterized by the dominance of *Eugenia* pollen type.
4. Zone IV: mineral soil deposit characterized by the dominance of non-arboreal pollen types with fern association.

Based on the fossil pollen content, all of these layers are categorized as being formed in a swampy area inundated by fresh water.

Center Zone of Tanjung Area (Profile T–7)

1. Zone I: peat soil deposit derived from mixed forest; in this layer many kinds of arboreal pollen types were found.

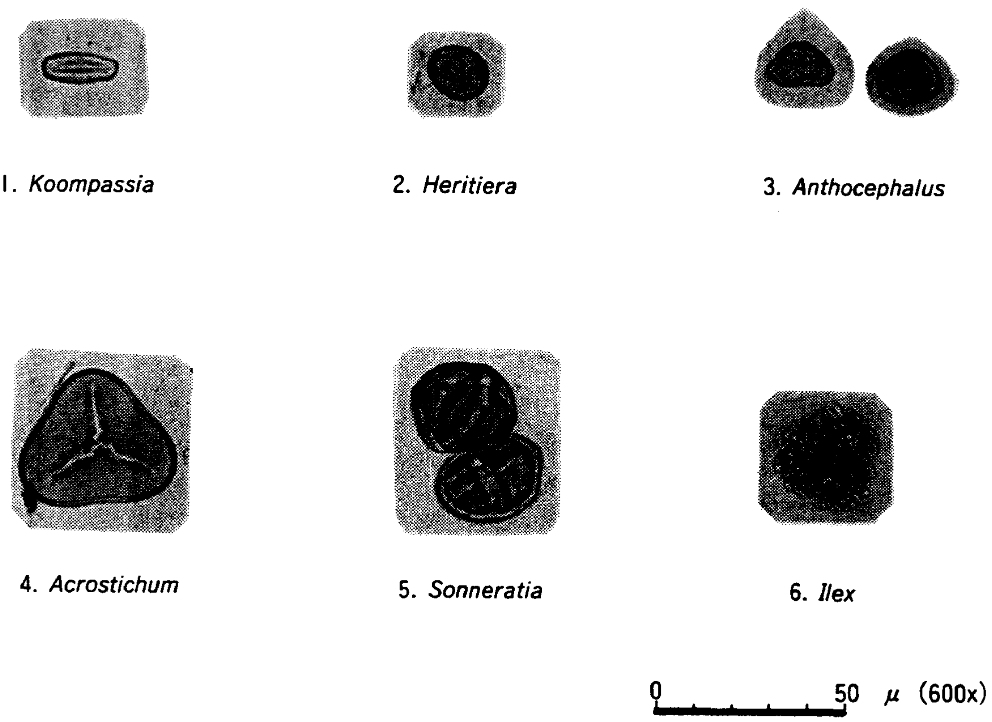


Plate 6

2. Zone II: peat soil deposit consisting mostly of a uniform pollen type, characterized by the dominance of *Eugenia* pollen type.
3. Zone III: peat soil deposit mostly derived from non-arboreal pollen types, and characterized by the abundance of *Pandanus*.
4. Zone IV: peaty mineral deposit containing mostly *Stemonurus* and *Lithocarpus* or *Quercus* pollen types.
5. Zone V: clay deposit containing non-arboreal pollen types, characterized by an abundance of fern association. In this layer, *Oncosperma* is more prominent in the arboreal pollen types.

Based on the fossil pollen content, all of these layers are categorized as being formed in a swampy area. Zone V was previously inundated by brackish water, and Zones I, II, III and IV by fresh water.

Zone Transitional to Coastal Zone (Profile T–24)

1. Zone I: peat soil deposit derived from coastal swamp forest, characterized by an abundance of *Nipa* pollen type.
2. Zone II: peaty mineral deposit, also derived from coastal swamp forest, but characterized by the dominance of *Rhizophora* and *Sonneratia* pollen types.
3. Zone III: mangrove deposit containing mostly *Rhizophora*, *Nipa* and *Lithocarpus* or *Quercus* pollen types.
4. Zone IV: also a mangrove deposit.

Based on the fossil pollen content, all of these layers are categorized as being formed in a swampy area previously inundated by brackish water.

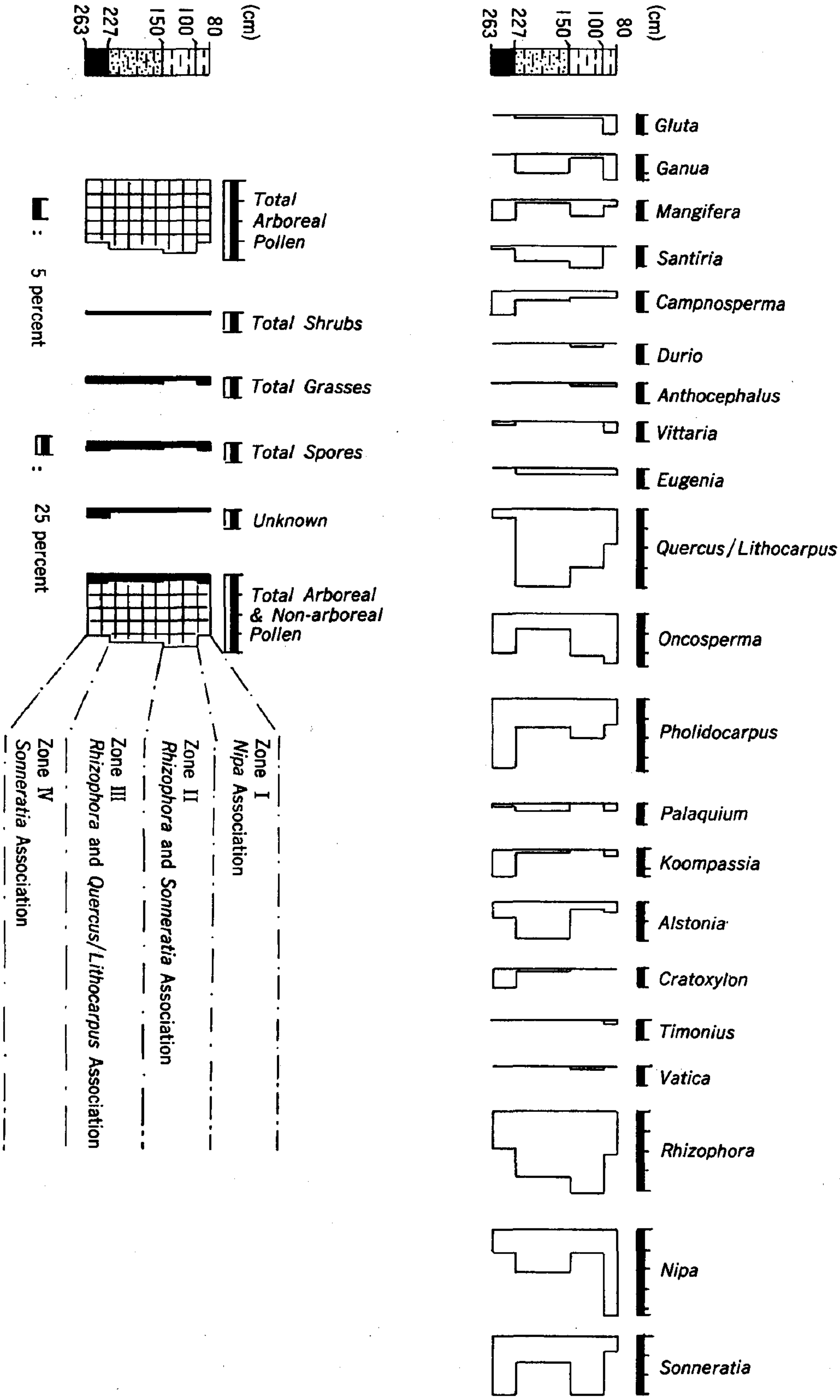


Fig. 6a The Pollen Diagram of Profile T-24

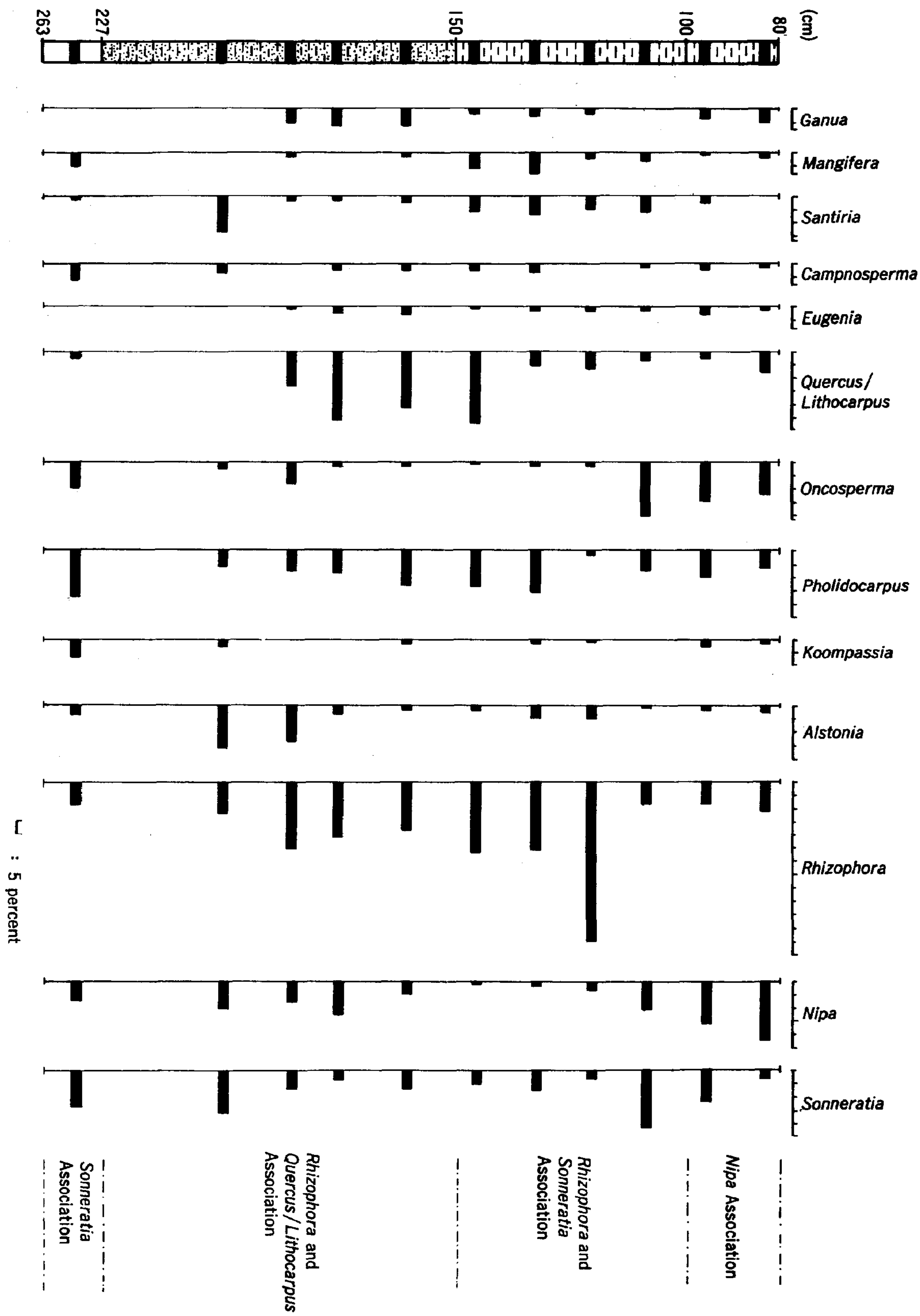


Fig. 6b The Pollen Diagram of Profile T-24

Acknowledgements

The authors wish to thank Prof. Dr. M. Takeoka of Faculty of Agriculture, Kyoto Prefectural University for his kind guidance and suggestions throughout the course of this research. They are grateful to Dr. Kuswata and Dr. Soedarsono Riswan of Herbarium Bogoriense for their help in collecting many modern pollen samples for reference.

References

Anderson, J. A. R.; and Muller, J. 1975. Palynological Study of a Holocene Peat and a Miocene Coal Deposit from NW Borneo. *Review of Paleobotany and Palynology* 19: 291–351.

Brown, C. A. 1960. *Palynological Techniques.* Library of Congress Catalog Card Number. 60–14297. Baton Rouge, La.

Corner, E. J. H. 1940. *Wayside Trees of Malaya.* Vol. I. Singapore: Government Printing Office. pp. 293–305.

Fuji, S.; Lin, C. C.; and Tjia, H. D. 1971. Sea Level Changes in Asia during the Past 11,000 Years. *Quaternary* 14: 211–216.

Furukawa, H.; and Supiandi, S. 1985. Batan Hari Gawa Ryuiki Teishicchi no Nogyo Keikan. Sono 1. Chikei to Taisekisojo [Agricultural Landscape in the Lower Batang Hari, Sumatra. Part One: Stratigraphy and Geomorphology of Coastal Swampy Lands]. *Tonan Ajia Kenkyu* [Southeast Asian Studies] 23(1): 3–37.

Huang, T. C. 1972. *Pollen Flora of Taiwan* (Including 177 Plates). National Taiwan University. Botany Department Press. 297 pp.

Kremp, G. O. W.; and Kawasaki, T. 1972. *The Spores of the Pteridophytes.* Tokyo: Hirokawa Publishing Company, Inc. 398 pp.

Ridley, H. N. 1922. *The Flora of Malay Peninsula.* Vol. I. London: L. Reeve & Co., Ltd.

————. 1924. *The Flora of Malay Peninsula.* Vol. III. London: L. Reeve & Co., Ltd.

————. 1925. *The Flora of Malay Peninsula.* Vol. V. London: L. Reeve & Co., Ltd.

Smythies, B. E. 1965. *Common Sarawak Trees.* Borneo Literature Bureau. 153 pp.

Soepadmo, E. 1972. Fagaceae. In *Flora Malesiana,* general ed. by C. G. G. J. van Steenis, Ser. I, Vol. 7(2), pp. 265–403. Leyden: Noordhoff International Publishing.

Soepraptohardjo, M.; and Driessen, P. M. 1976. The Lowland Peats of Indonesia, a Challenge for the Future. *Peat and Podzolic Soils and Their Potential for Agriculture in Indonesia* 3: 11–19.

Supiandi, S. 1985. A Geomorphological Study of Peat Soils in Jambi, Sumatra. M. S. Thesis. Division of Tropical Agriculture, Faculty of Agriculture, Kyoto University.