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Late Cenozoic Palynological Studies on Java

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on

Late Cenozoic Palynological Studies on Java

This study is based on palynological investigations at three sites in Java: Bandung Lake, Trinil and Bumiayu.

At Bandung Lake (Holocene) three cores were studied, while surface section samples were studied from Trinil in East Java (Middle Pleistocene) and Bumiayu in Central Java (Upper Pliocene). The Trinil site is well known for its hominid fossils.

The pollen flora at each site is fully described and illustrated while the pollen record at each location is used to reconstruct their vegetational, environmental and climatic histories. An attempt has also been made to determine whether palynology can be used to assist in dating these deposits. At all three sites, the character of the local vegetation is better reflected than that of the regional vegetation.

One of the Bandung sites (Rancaekek) was radiocarbon dated, suggesting deposition between 11,000 and 7,000 yr BP and represents a freshwater lake deposits. The lake gradually shallowed toward 7,000 yr BP, at which time it was drained.

The regional pollen component suggests climatic amelioration at about 8,000 yr BP, possibly reflecting the maximum incoming of solar radiation experienced in the Northern Hemisphere about 9,000 yr BP.

Studies at Trinil revealed a mosaic of forest and open vegetation growing on a lahar. The former climate at this locality was probably markedly seasonal, not unlike that of the present day. Palynology conclusively demonstrates that this sequence is Pleistocene rather than Pliocene in age.

The palynological record at Bumiayu reflects a regressive sequence with lagoonal and freshwater lacustrine environments (Kalibiuk Formation) followed by freshwater fluvial deposition (Kaliglagah Formation). The climate during the deposition of this sequence was markedly seasonal. The data support an Upper Pliocene age for the Bumiayu sequence.

Three taxa are shown to have become extinct in Java during the Plio-Pleistocene. These are *Stenochlaena laurifolia* and *S. areolaris*, which become extinct at the end of the Pliocene, and *Dacrydium*, which is thought to have become extinct during the Holocene.

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b.p.* = in back pocket

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Chapter 1

INTRODUCTION

1.1 The aims of the thesis

This study has three main aims:

The first aim is to establish the nature of lowland vegetation and climate of selected localities in the Late Cenozoic of Java. The second aim is to make a contribution to our knowledge of the palaeoenvironment of Late Cenozoic (Cainozoic) vertebrate and hominid fossil bearing formations. Thirdly, an attempt is made to differentiate between vertebrate fossil bearing sediments of different ages using palynology as a dating tool.

The geology and geomorphology of island Southeast Asia are extremely complex. In this region, the interaction of plate tectonic processes, changing climate and variations in sea level have had a profound effect on the distribution and migration of plants, animals and people (Ollier, 1985). It is clear that the geological background has a very direct effect on life and human activity in the region. Southeast Asia is divided into the mainland Sundaic and Insular sectors. Sundaic Southeast Asia has been markedly affected by rising and falling sea levels during and after the Pleistocene (Verstappen, 1975). It was formed by peneplanation of the land surface of the Sunda shelf land masses of the Malay peninsula, Sumatra, Kalimantan and smaller islands. It is thought that Java was created by the Indian Ocean plate under-riding the Sundaland arc (Katili, 1971). The Sunda shelf is a shallow sea, generally less than 100m deep and during glacial maxima would have been dry land. During the Mid-Holocene, sea levels reached about 4.5m above present mean sea level over a wide area (Tjia *et al*, 1984). During the Late Cenozoic, changes in sea level and also in climate, would have resulted in major changes of vegetation both within the mountains and within the lowlands. These changes would have had a significant effect on the stability and diversity of vegetation.

1.2 Evidence for vegetational and climatic change in the equatorial tropics.

While visiting the volcanic cone of Pangrango (Java) in 1861 and during his ascent of this mountain, Wallace (1869) saw the change from a tropical to a temperate flora with increasing altitude. He hypothesised that during the greatest severity of the glacial epoch, temperate plants would have extended to the confines of the tropics and, following climatic amelioration, would have retreated up these mountains, as well as northward to the plains and hills of Europe and Asia. He thus made one of the first inferences of vegetational changes in the equatorial tropics. Subsequently, few references were made to the changing pattern of vegetation within the equatorial tropics until the advent of palynological studies during the 1950s. Indeed, reference was generally made to the diversity and long term stability of equatorial vegetation (Ricklefs, 1973).

The first significant palynological evidence for equatorial vegetation change was from South America, where van der Hammen and his co-workers undertook extensive studies in the Andes of Colombia. Van der Hammen and Gonzalez (1960, 1964) presented a pollen diagram spanning the whole Pleistocene from the Sabana de Bogota (Colombia) (2,580m. a.s.l. 86°36′ E 5°58′ S), and also described the altitudinal zonation of Andean vegetation. They suggested that the main sequence of the Sabana de Bogota showed the progressive immigration of montane elements as well as palynomorph assemblage changes reflecting altitudinal shifts of vegetational zones in response to climatic changes during successive glacial/interglacial periods. In a subsequent study from a much drier area, van der Hammen and Gonzalez (1965) identified a moist Late Glacial forest which was followed by a high percentage of arid grassland elements in the Holocene of Cienaga del Visitador (3,300m. a.s.l.). They thus established that both temperature and humidity changes, which occurred with the climatic amelioration at the end of the last ice age, had a profound effect on Andean vegetation.

Other workers established similar vegetational changes in East Africa. Here van Zinderen Bakker (1962, 1964) published a pollen diagram from the Kaisungor swamp (2,900m. a.s.l.) in the Cherangani Hills (35°48′ E 1°24′ S), north-west Kenya. The present vegetation around this site is grassland formed by the clearance of dry montane forest. Van Zinderen Bakker (1962) interpreted a Late and post glacial correlation between East Africa and Europe based on information from this site. Coetzee (1967) noted the abundance of *Artemisia* as an indicator of dry conditions in Sacred Lake (2,400m. a.s.l.), a site on the slopes of Mount Kenya. She suggested that both temperature and moisture variations had again affected the montane vegetation. Later, Livingstone (1967) studied Mahoma Lake (2,960m. a.s.l.), a site from the Ruwenzori Hills, Uganda where he gave more emphasis to moisture changes. Morrison (1968) and Hamilton (1972) studied sequences from Uganda. These workers argued that both humidity and temperature fluctuations were important.

Similar studies were undertaken slightly later in Southeast Asia where Flenley (1972), Hope (1976) and Walker and Flenley (1979) showed that temperature changes were primarily responsible for montane vegetation change in Papua New Guinea.

Subsequently, evidence for worldwide climatic change was obtained from a different source, from the oceans. Planktonic foraminifera species show preferences for warm or cool waters. CLIMAP project members (1976) mapped the world climate for the last glacial maximum (18,000 yr B.P.) using as one source of evidence planktonic foraminifera. They illustrated that sea surface cooling during the glacial maximum affected the equatorial regions as well as higher latitudes, although to a lesser degree. Studies of glacial/interglacial cycles have also been made through the determination of changes in the ratio of the isotopes ^{18}O and ^{16}O within planktonic foraminifera and these studies have shown that many glacial/interglacial cycles occurred during the Pleistocene and previously during the Pliocene (CLIMAP project members, 1976).

Long records for vegetational change in terrestrial areas are few, especially within the tropics. However, Hooghiemstra (1984) has determined, in detail, temperature fluctuations from the Plio-Pleistocene of the Sabana de Bogota in Colombia (South America) and discovered that there, Pliocene temperature changes were as pronounced, if not more so, than those of the Pleistocene.

1.3 Evidence for vegetational and environmental changes in the Late Cenozoic of Southeast Asia.

1.3.1 Evidence for temperature changes

Palynological studies at high altitude localities (for example above 2000m a.s.l.) in Southeast Asia have mainly been undertaken in Papua New Guinea (143°36′ E 6°24′ S). Flenley (1972) studied Lake Inim (Figure 1.1) (2550m a.s.l.) and concluded that marked vegetational changes occurred which were related to temperature changes associated with Late Pleistocene and Holocene climatic amelioration. His diagram suggested clearly an open subalpine vegetation during the Late Pleistocene, with *Nothofagus* forest surrounding the locality during the Holocene. Subsequent studies by Hope (1976) established the effect of Late Pleistocene - Holocene climatic change on upper montane forests

Evidence for vegetational and environmental changes in the Late Cenozoic of Southeast Asia. Localities of sites studied for palynology in S E Asia.

1.Lake Inim
2.Mt.Wilhelm
3.Sirunki swamp
4.Alahan Panjang
5.Pea Sim-Sim
6.Danau Padang
7.Situ Gunung
8.Telaga Patengan
9.Situ Bayongbong

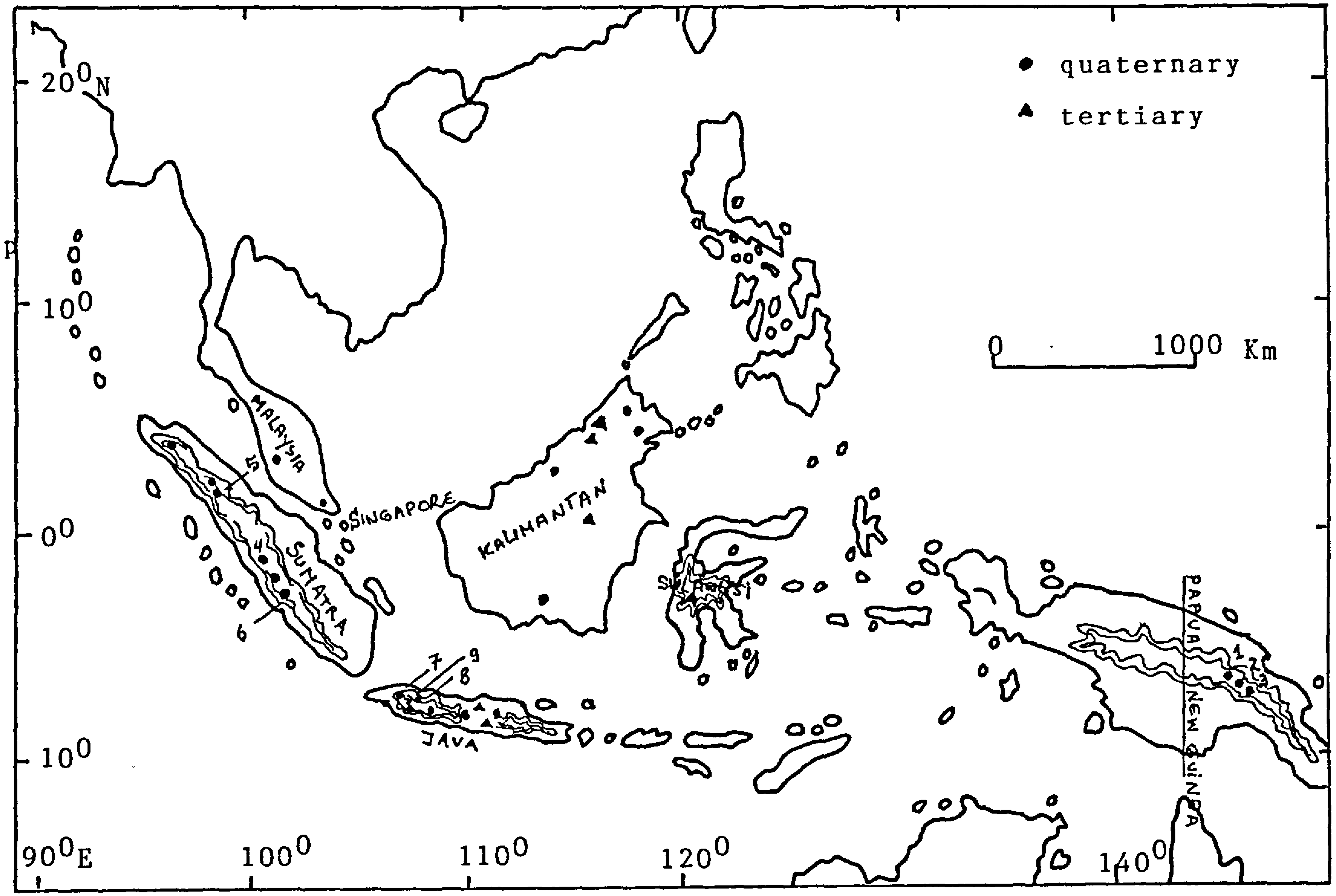


Figure 1.1

and tropicalpine vegetation between 3500 and 4500m a.s.l. on Mount Wilhelm (Papua New Guinea). Walker and Flenley (1979), following studies at Sirunki swamp (2500m a.s.l.), suggested that rather than vegetation zones shifting with changing temperatures, climatic changes resulted in plant formations being destroyed and subsequently reforming.

Studies at intermediate altitudes (1500 - 2000m a.s.l.) are predominantly from West Sumatra. Newsome (1985) and Newsome and Flenley (1988) examined the Late Quaternary vegetational history of the Alahan Panjang region (101°24′ E 1°48′ S). They suggested that during the Late Pleistocene, vegetation zones were depressed and a gymnosperm-rich rainforest, now found only above 1800m, surrounded Danau Di Atas (1500m a.s.l.). After ca 8200 B.P. there is evidence for disturbance of rainforests, possibly by man. Maloney (1980) describes a palynological sequence from Pea-Sim-Sim swamp (1,400m. a.s.l.) in the Batak highlands (98°48′ E 2°12′ S). A diagram was presented which may reflect Late Pleistocene cooling.

At lower altitudes, few sites have been studied which penetrate the Late Pleistocene. Morley (1981) interpreted a diagram from Danau Padang, Sumatra (950m. a.s.l.) which is close to the boundary between lowland and montane rainforest. He considered that the vegetational change from 10,000 to 8,600 yr B.P. relates to a general climatic amelioration. Most studies from low altitude locations relate wholly to the Holocene and primarily reflect local edaphic changes (for example Anderson and Muller, 1975; Haseldonckx, 1977; Morley, 1982). In general, studies at high altitudes show greater fluctuations than those at lower altitudes. Flenley (1984) interpreted this as indicative of steeper lapse rates during the last glacial maximum than at present.

1.3.2. Evidence from Java.

Polak (1933) made some early studies in Java on the pollen of peat soils of Rawa Lakbok, a coastal swamp, and Rawa Pening, an inland lake within Central Java, but little ecological research was undertaken. Van Zeist, *et al* (1979) drew two pollen diagrams from West Java (107°6' E 6°30' S). The pollen diagrams for Situ Gunung (1000m a.s.l.) and Telaga Patengan (1575m a.s.l.) suggested differences in the composition of the Holocene forest cover in both areas which are discussed below. Stuijts (1984) emphasised that during the Holocene, the forest cover of West Java underwent considerable changes. The effect of possible climatic changes on the vegetation was probably more pronounced in the mountains than in lowland areas. The vegetation appears to have been sensitive to small changes in the seasonality of precipitation.

There is also evidence for Tertiary temperature changes from foraminiferal data from Java.

According to Gorsel and Troelstra (1981), there is evidence for changes in the ratio of cold and warm water foraminifera from the Javan Mio-Pliocene in the Solo River area. A cold phase recorded here is believed to be equivalent to the Messinian which is thought to have been a cool and dry period elsewhere, especially in the Mediterranean and New Zealand (Morley and Flenley, 1987).

1.3.3. Evidence for changes of humidity.

Evidence for changes in humidity is far scarcer than that for changes in temperature. The geomorphologist Verstappen (1975) was convinced that there was evidence for former drier conditions at low altitudes in Indonesia and that dry periods alternated with more humid conditions. He stressed that there must have been a more pronounced dry season than that characterising the present day climate, in order to explain geomorphological features seen in a number of areas of Indonesia. During the upper Tertiary and the interglacial periods and also the Mid-Holocene climatic optimum, he suggested that the climate was probably more humid and about 1-2°C warmer than at present. He concluded that drier conditions, with lower precipitation values and a longer dry season, had occurred during the Pleistocene glacials. Van Steenis (1965) had also argued, from plant geographical evidence, that increasingly dry and seasonal climates occurred in Java during glacial periods. According to him, a small change in climate would cause a major shift of vegetation boundaries. Morley (1982) showed that the climate in South Kalimantan may have been more seasonal in the early Holocene, although he found no evidence of enhanced seasonality within the latest Pleistocene and Holocene in central Sumatra (Morley, 1981). From Australia, Kershaw (1976) produced striking evidence for vegetational change indicative of greater climatic seasonality in the Quaternary of Queensland (148°36′ E 22°24′ S).

The possibility of a savanna corridor through the Sunda shelf during the last glacial allowing the migration of Asian mammals into Java and Sulawesi, was proposed by Ashton (1972) and Sartono (1973). Medway (1972) also suggested that there was evidence in the Middle Pleistocene of open routes for the movement of forest-adapted mammals between continental southeast Asia and Sundaland. Morley and Flenley (1987) showed evidence for a period of seasonal climate within the Mid-Pleistocene of the Malay Peninsula. They examined a peat horizon near Kuala Lumpur, Malaysia and discovered an assemblage dominated by *Pinus* pollen. The assemblage clearly indicates a markedly seasonal climate and the authors suggested that in the Mid-Pleistocene ever-wet rain forests were pushed further south. They also suggested strongly seasonal climates within the Late Tertiary in the Malay Archipelago, based on geological evidence.

For the Late Tertiary, a more seasonal climate is indicated for the Late Miocene and Pliocene of Brunei according to Muller (1972) and for the Natuna sea according to Morley (1978) from the presence there of pollen of *Aegialites* (Plumbagincaceae). The genus *Aegialites* currently exhibits a markedly disjunct distribution and occurs in Indo-China and Australia (Soepraptohardjo and Driessden, 1976).

1.3.4. Evidence for changes of sea level.

Sea levels are thought to have varied throughout the Quaternary. These changes are reviewed for Southeast Asia by Morley and Flenley (1987). Low sea levels would have predominated during glacial periods as large volumes of water were locked up in ice sheets at high and mid latitudes. During glacial periods, much of the Sunda shelf would have been dry land, and the total land area of the Sunda region would have been much greater than at present. Consequently, the region may have experienced a more continental climate. Sea levels slightly above present are recorded for the Mid-Holocene by Tjia *et al* (1984). Polhaupessy (1982) examined the Quaternary vegetational history of Batujaya (West Java) which indicated local, recent littoral estuarine vegetation well above current sea levels, indicating former higher sea levels.

1.3.5. Effects of mankind.

From Draepi Swamp (1885m a.s.l.), within a highland valley in Papua New Guinea (145°18′ E 5°54′ S), Powell (1970) produced pollen diagrams strongly suggesting that earlier forest-dominated vegetation gave way to an essentially deforested landscape by about 5000 yr B.P. Similarly, the pollen record from Danau Padang in central Sumatra was studied by Morley (1982) and he concluded that the expansion of regrowth communities around 4000 yr B.P. indicated forest clearance which substantiated archaeological evidence that man had been active in that area. Evidence for slightly earlier disturbance of vegetation by man comes from the Pea-Sim-Sim, site central Sumatra (Maloney, 1980). Here it appears that anthropogenic disturbance may have started as early as 7500 yr B.P. Subsequently, Newsome (1985) examined the Late Quaternary vegetational history of the Alahan Panjang region of west Sumatra. She provided evidence for the disturbance of rain forests, possibly by man, in Danau Di Atas at about 8200 yr B.P. In Java, van Zeist *et al* (1979) suggested that pollen diagrams from Situ Gunung (1000m a.s.l.) and Telaga Patengan (1575m a.s.l.) in west Java reflect a shift to a drier climate about 5000 yr B.P. Van Steenis (1975), however, suggested that the reduction in *Altingia excelsa* was due to selective felling by man and, therefore, an alternative explanation for this vegetation change relates to the impact of man in the area, not to climatic change.

1.4. Java man

Java is famous to paleoanthropologists for its hominoid fossils. The first discovery was of a skull and femur, made by Dubois (1894) in Trinil, which he named *Pithecanthropus erectus*. For some years, Dubois excavated in Sumatra and Java and the result was a magnificent collection of fossil vertebrate remains, making it possible to form a picture of the Pleistocene fauna of Java. Subsequently, scientists working in different areas of Java have found extensive evidence for human evolution, especially from the Sangiran area where a good lithostratigraphic succession is exposed. Many controversies arose when the subject of the genealogical position of the specimens was discussed. Von Koeningswald (1934, 1935) published a proposed biozonation for the mammal-bearing deposits of Java. He distinguished the faunas from oldest to youngest as: Ci Sande fauna, Ci Julang fauna, Kaliglagah fauna, Jetis fauna, Trinil fauna, Ngandong fauna and Sampung fauna. The faunas did not occur in a single profile and consequently, the succession of the different faunas was based partly on lithostratigraphical correlations. According to von Koeningswald's concept, "Guide fossils" were very important, especially for the correlation of Javanese faunas with those of the Siwaliks (in India) and China. It was later suggested by de Vos *et al* (1982) and Sondaar *et al* (1983) that in the study of Java man, lithostratigraphy, chronostratigraphy and biostratigraphy have often been confused, resulting

Table 1.1

Age	after Von Koeningswald 1934	after De Vos et al 1982 and Sondaar 1984		
			first* and last° occurrence of Proboscidians	Some localities with land vertebrates
Holocene	Recent	Recent		Recent
		Wajak		Wajak
Pleistocene	Sampung	Punung	*Elephas maximus**	Punung
	Ngandong	Ngandong	*Stegodon trigonocephalus*° *Elephas hysudrindicus*°	Ngandong Sidorejo
	Trinil	Kedung Brubus	*Stegodon hypsilophus*°* *Elephas hysudrindicus**	Kedung Brubus Jetis, upper part of the so called Kabuh Formation of Sangiran area
?	Jetis	Trinil H.K. – – – – Cisaat	*Stegodon trigonocephalus**	"Grenzbank" in Sangiran area Trinil , H.K. Cisaat , Ci Julang?
	Kali Glagah	Satir	*Mastodon bumiajuensis*°*	"Black clays" in Sangiran area (loc.1.4) , Satir
Pliocene	Ci Julang			No land vertebrate localities found so far
	Ci Sande			

Faunal succession of mammals on Java.

in a misleading history of faunal succession and evolution.

De Vos and Sondaar (1982) and De Vos (1982) studied Dubois collections in the Leiden Museum and reinterpreted the succession based on the Trinil and Kedung Brubus faunas. They proposed a new biozonation for the mammal bearing deposits of Java using different concepts from those of von Koeningswald (Table 1.1). Sondaar (1984) examined the literature, field data and collections of fossil mammals from Java and has recently revised the faunal evolution and mammal biostratigraphy of the island. He distinguished seven faunal units for the Pleistocene. Sondaar's concept of these faunas, starting with the oldest, is as follows: the Satir fauna, Cisaat fauna, Trinil Haupt - Knochenschiecht (Trinil H.K.) fauna, Kedung Brubus fauna, Ngandong fauna, Punung fauna, Wajak fauna and recent. Sondaar (1984) places particular emphasis on fossil localities, faunal evolution and the palaeogeography of Java. Based on the absolute dates of the hominid bearing deposits of Java, Leinders *et al* (1985) considered the age for the various faunas as: Satir fauna 1.5Ma, Cisaat fauna 1.2Ma, Trinil fauna 1.0Ma and Kedung Brubus fauna 0.8Ma . Nevertheless, Sondaar's scheme needs to be further tested by sedimentological and other geological field work before it can be fully confirmed.

1.5 Evidence of the vegetational setting of the Java man sites

Palaeobotanical studies were initially undertaken by Schuster (1911) who studied leaf floras. The fossils frequently show drip-tips, supporting a rain forest origin for the floral assemblage from the Trinil area (Flenley, 1979). More recently, Semah (1982, 1984) has studied Java man sites using palynology. Semah (1982) has drawn a preliminary pollen diagram from Sangiran, Central Java, which illustrates the local vegetational changes and provides some evidence for the environment in which *Homo erectus* lived. She showed the appearance of mangrove forest followed by continental formations which was related to a regression of the shoreline.

Subsequently Semah (1984) described the changes in vegetational environment of the Solo area during the Lower and Middle Pleistocene. The sea level fall at the end of the Pliocene resulted in the development of more continental vegetation in this area. During the Lower Pleistocene, within the Pucangan Formation, she suggested the presence of rainforest and, moving into the overlying Kabuh formation, suggested a less humid vegetation. She attempted to reconstruct the palaeoenvironment of the Trinil area with only a single isolated polleniferous spectrum. This was wholly inadequate for making satisfactory interpretations of palaeovegetation from this important vertebrate locality.

1.6. The use of palynology as a dating tool in the Southeast Asian Late Cenozoic

The value of palynology as a dating tool in the tropics was first illustrated in Kuyl, *et al* (1955) applying the method in South America, West Africa and New Guinea. Generalised zonation schemes for South America, West Africa and Brunei were later introduced by Germeraad, *et al* (1968) who divided the Southeast Asian Neogene into three zones on the basis of the evolutionary variation within pollen of the genus *Sonneratia* (form genus *Florschuetzia*).

Anderson and Muller (1975), however, have shown that coastal vegetational associations in the Indonesian area have changed very little in composition during the Late Cenozoic.

Morley (1978) devised a zonation scheme for the Indonesian Late Cenozoic involving seven zones, based on a combination of the *Florschuetzia* lineage, spores attributed to the genus

Coastal depositional environments interpreted from palynological studies.

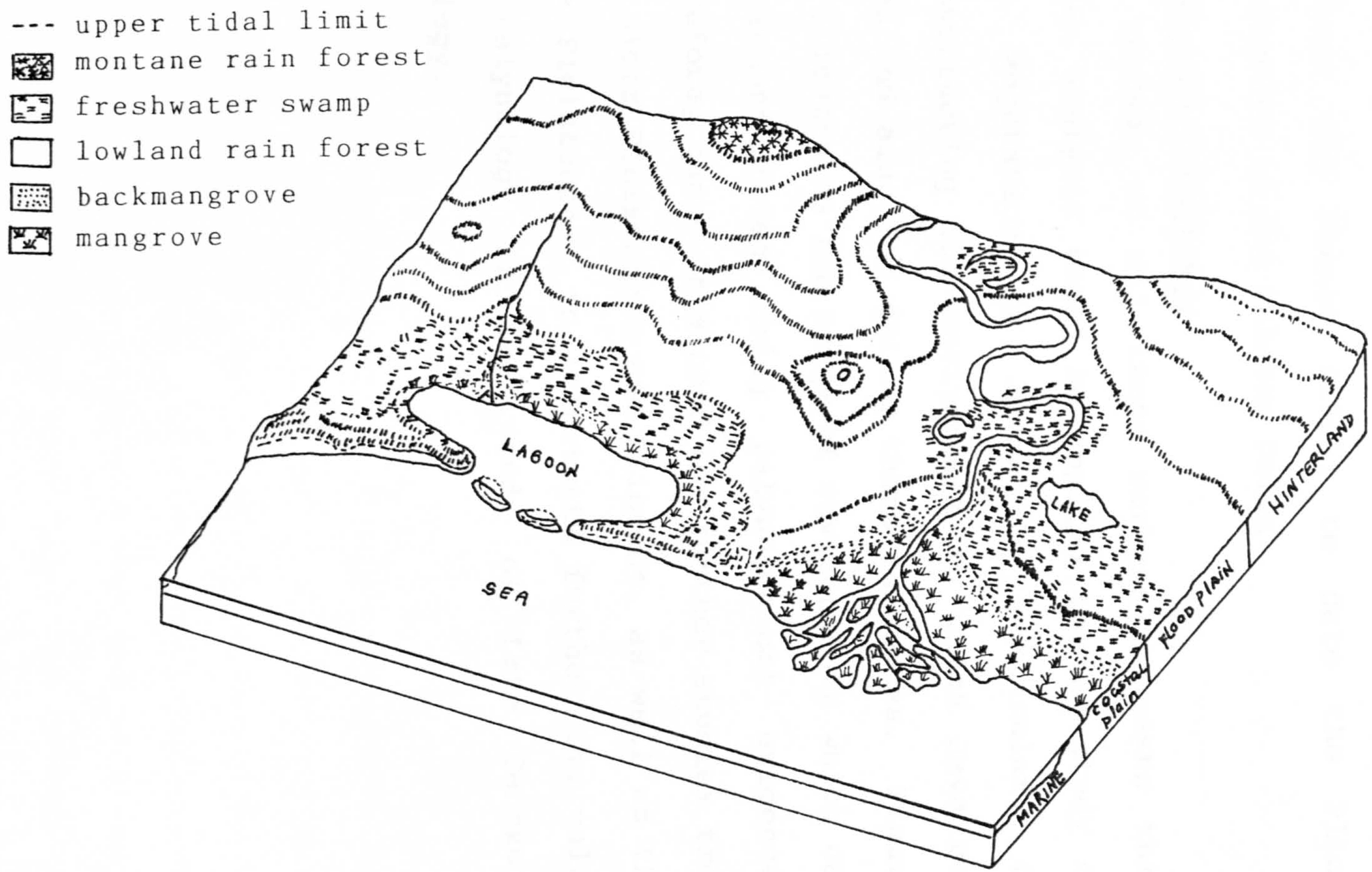


Figure 1.2

Stenochlaena and pollen of the gymnosperms *Podocarpus imbricatus* and *Phyllocladus*. Morley's (1978) scheme was subsequently used successfully by Caratini and Tissot (1985) to date the Plio-Pleistocene in the Mahakam Delta.

1.7 The successes of Palynology

The success of all these workers suggests that pollen analysis could be applied to the study of past vegetation in Java, in particular, to reconstructing the environment in which Java man lived and also for dating these sequences. Figure 1.2 illustrates the range of environments which can be reconstructed using palynological evidence. Therefore, there is a need for further studies from the older Pleistocene and Pliocene, as well as the Late Pleistocene, to illustrate further the value of palynology in the study of Late Cenozoic geology.

Chapter 2

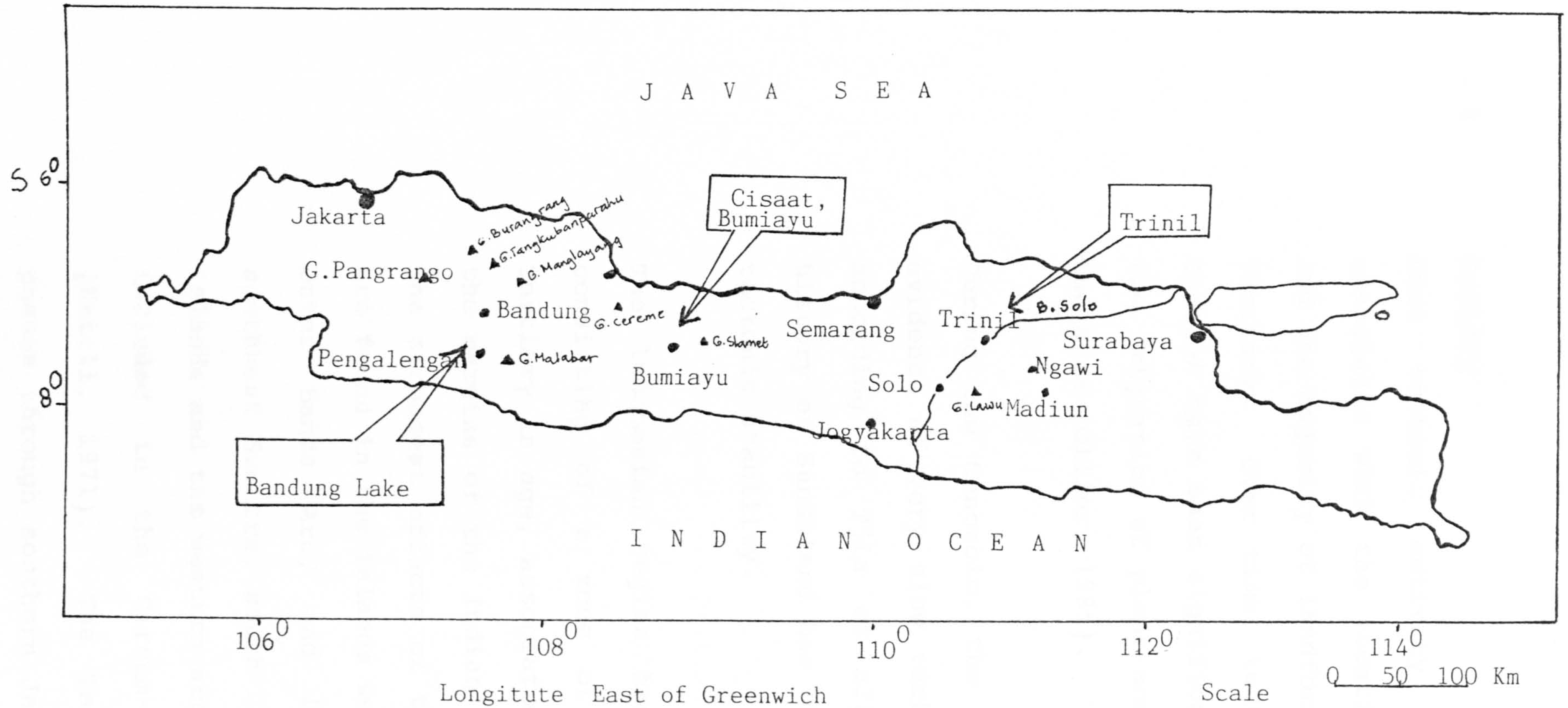
THE STUDY AREA

2.1. Location

Indonesia, with its thousands of islands spread out along the equator, is situated between the mainland of Asia and Australia and is bordered by the Pacific and Indian Oceans. Two-thirds of the total area of Indonesia is water, but the land area is rich in volcanoes and mountain ranges (Figure 1.1).

Java is an island in the Indonesian volcanic archipelago which is situated between 106°99' 35" East and 06°10'37" South. The island is about 1000Km long (E-W) and covers an area of 127,000 Km^2 (van Bemmelen, 1949).

Java is associated with the Sunda Shelf Sea and physiographically belongs to the central Sundaland (van Bemmelen, 1949). The landscape of Java (Figure 2.1) consists of mountainous country in the provinces of West and East Java, connected by a narrow stretch of low country in Central Java (van Steenis, 1965).



Index map of the study area,Java

▲ mountain peaks

● places

Figure 2.1

2.2. Geology

Most tectonic activity in the region is associated with the location of plate margins and the majority of landforms are not older than Tertiary. Over time, tectonism and sea level changes have been significant factors affecting the migration of plant and animal species into the area (Ollier, 1985).

During the Cenozoic, the Sunda platform shows evidence of very slow vertical movement, while according to Tjia *et al*(1984), the Cenozoic history of Sundaland has been one of increasing tectonic stability.

The Indonesian region has been portrayed as consisting of a zone of concentric folding, Tertiary in age, associated with activity along the margins of the Indian plate (Katili, 1971). The strongest effects of the Tertiary movements are found in the islands west of Sumatra and the outer Banda Arc, and in some portions of southwest Sumatra, south Java, the Lesser Sunda Islands and the western arc of Sulawesi. Java is included in the Circum-Asiatic fold system (Katili, 1971). The Tertiary orogenic belt passes through southern Java where it is marked by chains of mountains.

The island of Java, however, belongs entirely to the lower Tertiary mountain systems around the pre-Tertiary Sundaland which form the Sunda Mountain System (van Bemmelen, 1949).

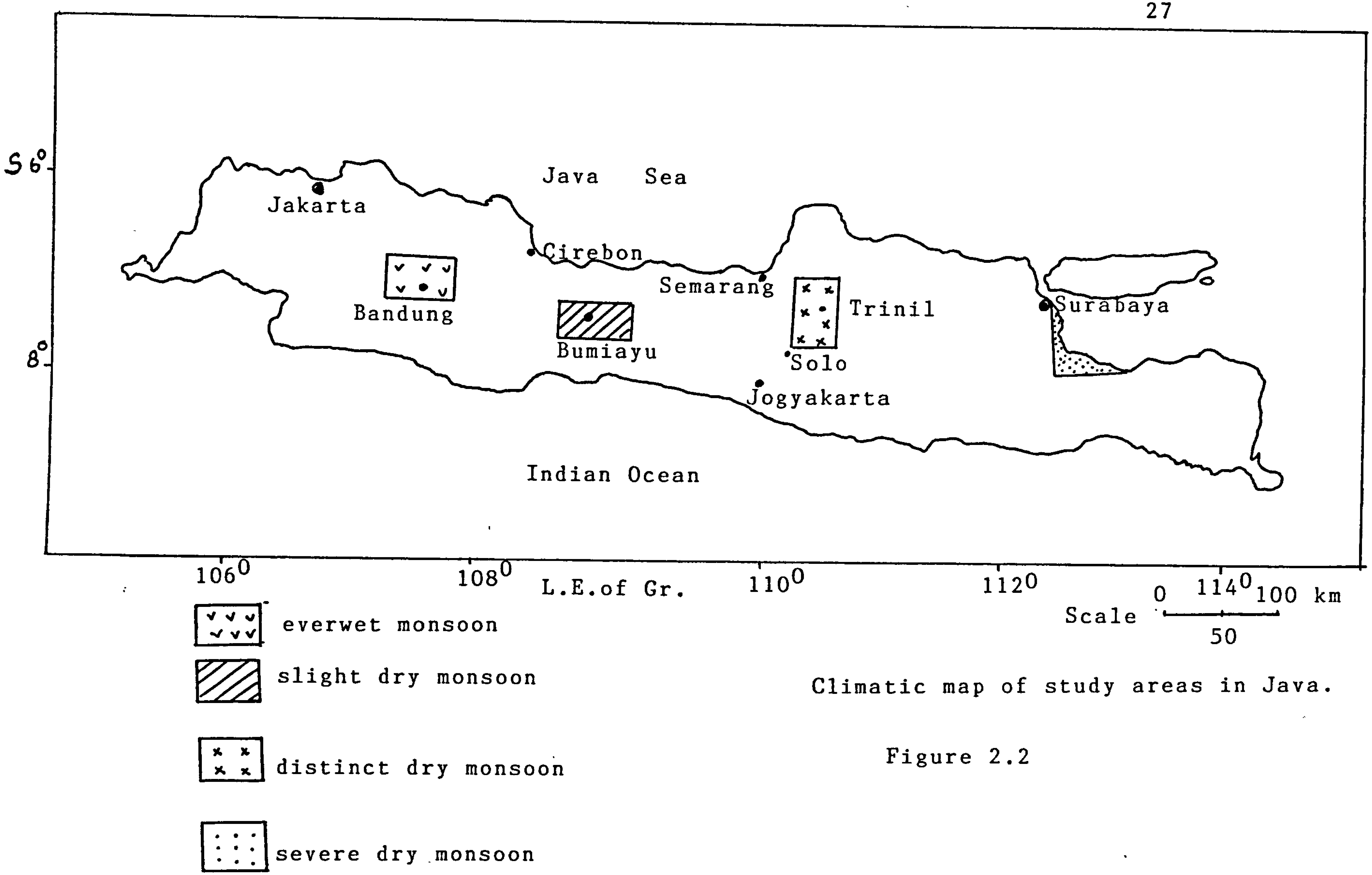
According to van Bemmelen (1949), the main structural elements of the island are the anticline of south Java, extending along the southern half of the island and the geosyncline of north Java, occupying its northern half. The crest of the anticline of Java has eroded, now being physiographically a depressed zone with island-like elevations of the former anticlinal crest. In the middle part of Java, the southern mountains have disappeared below sea level, so that here the median depression is bordered by the Indian Ocean.

2.3. Climate

Due to the structure of the islands and their geographical location, the air over Indonesia is warm and humid. The climate is almost entirely controlled by the monsoon, especially in the southern part of the country (Sukanto, 1969).

In Indonesia, the convergence of air coming from the Northern Hemisphere with air from the Southern Hemisphere, plays an important role in determining climate. This region is known as the Intertropical Convergence Zone (ITCZ). In general, wet climates prevail in the areas north of the Convergence Zone and dry climates prevail south of it. Although the climate is called 'dry', this does not mean that there is no rain at all. In fact, there is no month without rainfall, although wet and dry seasons are distinguishable. The seasonality of direction of prevailing wind is the most distinctive feature of this region. In addition to precipitation along the ITCZ, the high humidity of the air may also cause heavy rain showers of long duration and accounts for the frequency of thunderstorms, which probably occur more frequently than anywhere else in the world (Sukanto, 1969).

Mean annual precipitation is a significant meteorological variable in Indonesia. In general, the amount of rainfall is more than 2,000 mm/year (Sukanto, 1969).



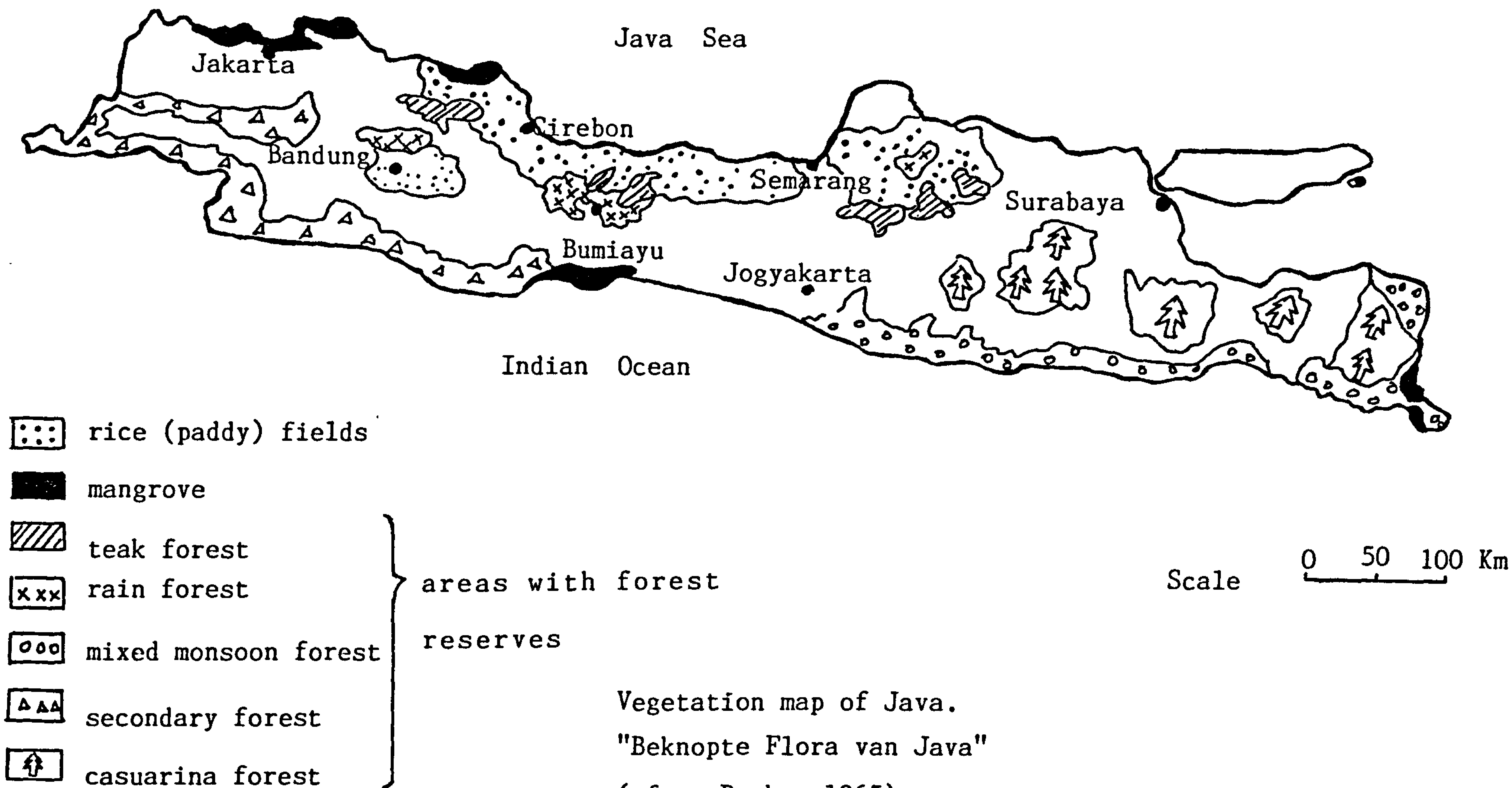
Climatic map of study areas in Java.

Figure 2.2

Mean air pressure over Indonesia does not show sharp contrasts across the region. Isobars are generally widely spaced and consequently winds are usually weak. Annual mean air pressure in Jakarta is ca. 1010.0 mb and in Padang (Sumatra) ca. 1010.9 mb. The mean relative humidity is ca. 76% in Jakarta and ca. 80% in Padang, Sumatra (Sukanto, 1969).

The wet season in Java (Figure 2.2) covers roughly the period December - January - February. This is associated with the westerly monsoon (Sukanto, 1969).
March, April and May comprise a transition period between the wet and the dry season, although the wind direction during this period remains quite constant.

The dry season in Java lasts from June to August when air currents from the southern hemisphere move over the equator towards the Asiatic continent. Winds from the south replace those from the west as the ITCZ is displaced polewards. This is the time of the easterly monsoon. Humidity remains high, but there is less precipitation.



Vegetation map of Java.
"Beknopte Flora van Java"
(after Backer,1965).
Figure 2.3

September, October and November are a transition period when the ITCZ is on its way back to the southern hemisphere.

Detailed climatic data are not easily available for all parts of the island.

2.4. Major vegetation types of Java

According to van Steenis (1938), the natural vegetation of Java is now almost entirely restricted to the forest reserves (Figure 2.3); there are eleven major vegetation associations, the most important of which are listed below:

2.4.1. Mangroves

Forest vegetation types on coastal mud, within the intertidal zone, are termed mangroves. They grow in salt or brackish water. They are characterised by the root-formations of the trees binding the mud together. The main components are trees of the genera *Rhizophora*, *Bruguiera*, *Ceriops*, *Sonneratia* and *Lumnitzera*. Some herbaceous plants and the mangrove fern *Acrostichum aureum* are also present.

2.4.2. Beach formations

These may be divided into three components:

2.4.2.1. <u>*Pescaprae* formation</u>

The *Pescaprae* formation is the low, largely herbaceous plant fringe growing from the drift zone on to beach ridges behind the sandy beach. *Ipomoea pescaprae* is dominant, with other *Ipomoeas* spp, *Canavalia* spp, *Vigna* spp, *Vitex trifolia*, *Spinifex littoreus*, *Thuarea involuta*, *Ischaemum muticum* and *Euphorbia atoto* also being characteristic. Some species are very rare, such as *Launaea sarmentosa* which is only found on accreting coasts (van Steenis, 1965).

2.4.2.2. <u>*Barringtonia* formation</u>

This formation is named after *Barringtonia asiatica*. Other characteristic species are *Guettarda speciosa*, *Calophyllum inophyllum*, *Pandanus tectorius*, *Desmodium umbellatum*, *Hibiscus tiliaceus*, *Cocos nucifera* and *Casuarina equisetifolia*. This formation occurs on beach ridges and on rocky coasts.

2.4.2.3. <u>Dunes</u>

Dunes are rarely well developed around Java, although the north coast of Madura has several dune complexes. The species of the dunes are those of the *Pescaprae* formation and the *Barringtonia* formation. *Spinifex* and

Pandanus are often dominant and *Ipomoea pescaprae* is one of the pioneers.

2.4.3. Lowland swamp forest

This is found behind the mangrove belt and is generally very poor in species. *Ficus retusa* may be dominant, occurring with *Nauclea orientalis*, rattans and the climbing fern *Stenochlaena palustris*.

2.4.4. Mixed lowland and hill rainforest of dry land

This is the formation occurring below 1000 - 1500m in areas of moist climate and is the climax vegetation type. It is the richest vegetation type of the equatorial belt with a high canopy and many strata in it (van Steenis, 1965). *Altingia excelsa*, for example, achieves its maximum growth in Sumatra at an elevation of 600 m within this vegetation type. These rain forests grow on a variety of soils including volcanic soils, which are sometimes of very poor quality, or on older Tertiary bedrock. The mixed lowland and hill rain forest includes epiphytes, Bamboo, *Pleomele* and Loranthaceae.

2.4.5. Montane everwet rainforest (1500 - 2400m)

The number of tree species is lower than in the mixed lowland and hill rainforests, while epiphytes, pteridophytes and moss are more richly developed. Many lowland families, such as Dipterocarpaceae, Sapotaceae, Ebenaceae, Annonaceae, Bombacaceae, Lecythidaceae etc., are no longer represented or have only a few stray representatives, and other more temperate families appear. The Lauraceae and Fagaceae are often abundant and hence, these forests are often termed the lauro-fagaceous zone, Theaceae, Hamamelidaceae, Magnoliaceae, *Helicia* spp, *Astronia* spp, *Vernonia arborea*, *Eugenia* spp, *Acer* spp, *Podocarpus* spp, *Morus macroura* and herbs are also characteristic. Other species present include *Rubus cyrtandra*, *Gunnera* spp, *Dichroa* spp, *Hydrangea* spp, *Astilbe* spp, *Viola* spp, *Lonicera* spp, *Lactuca* spp, *Gynura* spp, *Solanum* spp, *Lobelia* spp, *Nertera* spp, *Ophiorrhiza* spp, *Lysimachia* spp, *Begonia* spp, *Impatiens* spp, *Argostemma* spp etc. *Strobilanthes* spp are also present; this taxon flowers only once every seven years (van Steenis, 1972).

2.4.6. Mountain swamps and lakes

The vegetation here is very similar to that of lowland swamps, but includes more temperate species. All the lakes are eutrophic and occasionally *Sphagnum* develops (van Steenis, 1965).

2.4.7. Subalpine vegetation

This type is essentially temperate rainforest, but differs from that forest type in having one stratum composed of only small trees. The forest is poorer in species than the montane forest. Ericaceae *(Vaccinium* spp) predominate. Other trees present are species of *Rapanea*,spp *Symplocos* spp, *Eurya* spp, *Leptospermum flavescens*, *Myrica javanica*, *Schefflera* spp, *Albizia* spp, *Photinia* spp, *Polyosma* spp, etc. The temperate flora is represented by *Thalictrum* spp, *Boenninghausenia* spp, *Ranunculus* spp, *Berberis* spp, *Melissa* spp, and *Microtis* spp.

2.4.8. Monsoon forest

The Monsoon forest is the climax type of vegetation in areas with a marked annual dry season. The forest is mixed in character and is composed of trees, herbs and shrubs. It is found along the south coast of East Java but declines as one goes westward into the everwet

West Java. Some of the trees present are: *Tectona grandis*, *Tamarindus indica*, *Albizia lebbekioides*, *Acacia leucophloea*, *Schoutenia ovata* and *Phyllanthus emblica*. The major shrubs are *Capparis* spp and *Diplophractum auriculatum* and the herbs are species of Gramineae, Cyperaceae, Leguminosae, Malvaceae etc.

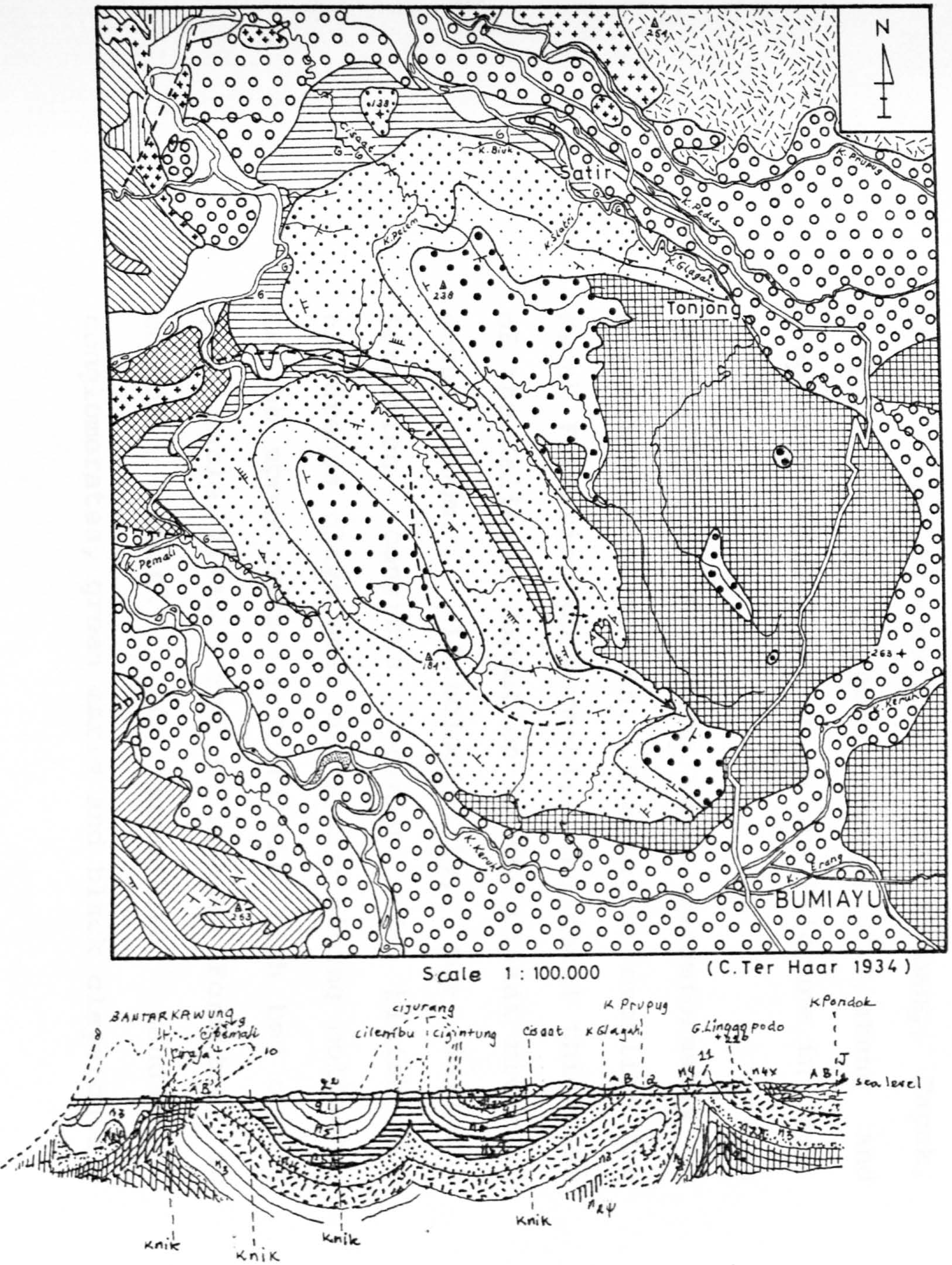
2.5. The Sampling Localities

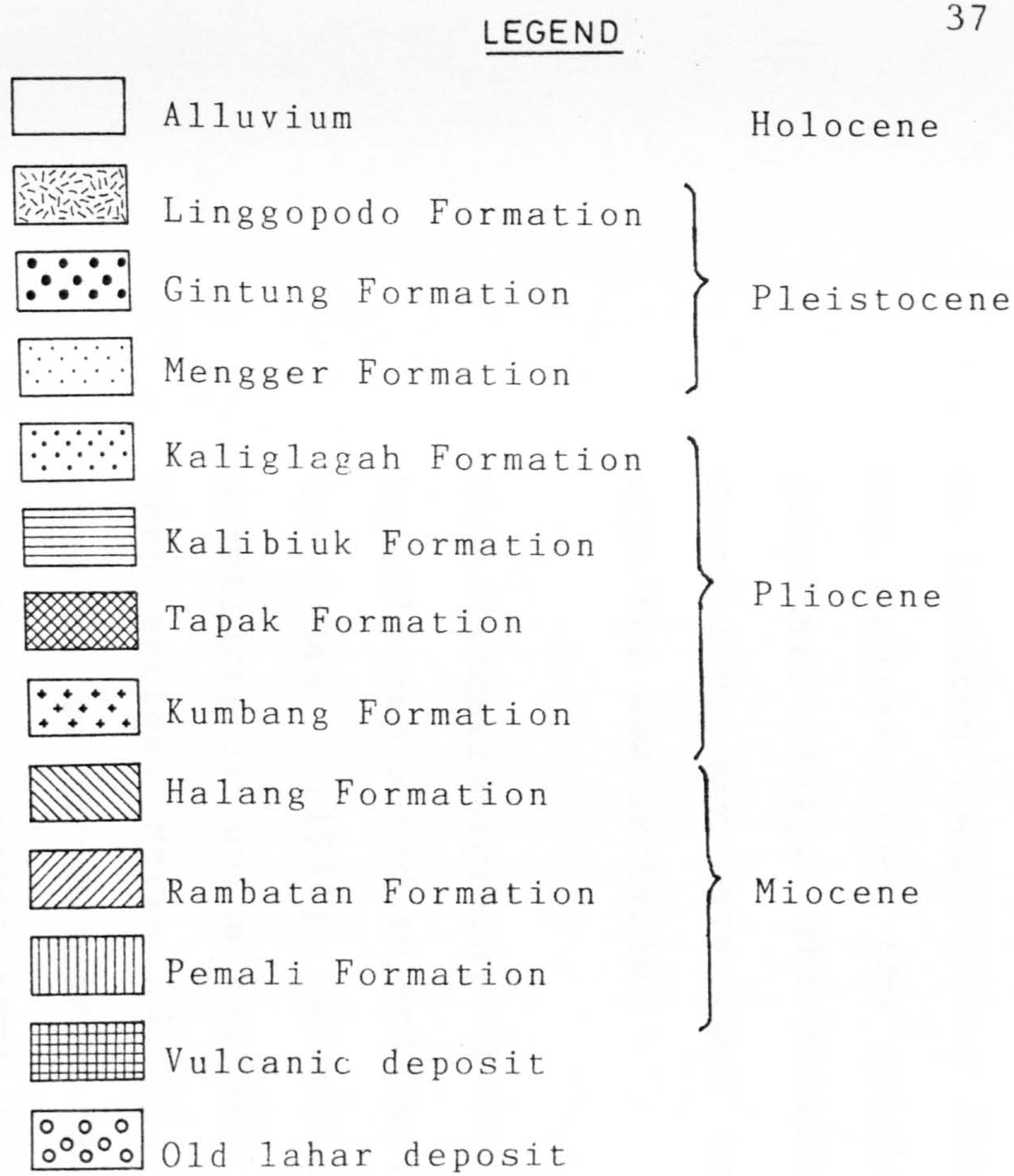
2.5.1. Cisaat, Bumiayu (108°55'27" to 108°59'27"E, 7°09' to 7°12'20"S)

2.5.1.1. Geology and Stratigraphy of Bumiayu.

The Bumiayu area lies more or less in the middle part of the island of Java (Figure 2.1), on the border between the provinces of West and Central Java. The area is interesting palaeontologically because of the presence of the Kaliglagah fauna (von Koeningswald, 1934). The first complete geology map for the Bumiayu area (scale 1 : 100,000) was published by ter Haar (1934). A couple of years prior to the publication of ter Haar's map, van der Maarel (1932) published a geological sketchmap of the area around the Cisaat and Glagah Rivers to accompany his report on the mammalian fauna of Java. In van der Maarel's sketch map, the sites of systematic excavations, which were the sources of important mammalian fossils, are indicated. The Kaliglagah fauna of von Koeningswald was based on fossil bones collected from these excavations, combined with the fossils which had already been discovered.

Sondaar (1984) found that the Kaliglagah fauna of von Koeningswald was actually a mixture of fossils from two different stratigraphic levels. He tried to clarify this problem and he proposed two different faunal groups from the Kaliglagah fauna *sensu* von Koeningswald. Under the new scheme, the older was called the Satir fauna and the younger the Cisaat fauna. The former is characterised by the presence of *Mastodon*, *Hexaprotodon* and cervids. The Satir fauna is, however, poor in mammalian species and this points to island conditions as migration was restricted. The Cisaat fauna, the younger one, is characterised by the occurrence of *Stegodon*, *Hexaprotodon* and Cervids. This fauna shows the recent arrival of *Stegodon* and felids and probably also a more advanced species of *Hexaprotodon*. The Cisaat fauna is also poor in mammalian species. This situation again points





Geological map of Bumiayu

Figure 2.4

to isolated conditions. The presence of felids may indicate that the mainland was not far off (Sondaar, 1984). The extinction of *Mastodon* and *Geochelone* may have been caused by competition with the new arrivals.

The lithostratigraphy of the Bumiayu area can be briefly explained as follows:-
ter Haar (1934) classified the different stratigraphic units exposed in the Bumiayu area into series. Marks (1957), however, considered them to be formations. These formations, from oldest to youngest are: the Pemali and Halang, which are Miocene, and the Kumbang, Tapak, Kalibiuk, Kaliglagah, Mengger, Gintung and Linggopodo Formations which are Pliocene in age.

The Kaliglagah Formation rests uncomformably on the Kalibiuk Formation. The latter overlies the Tapak Formation conformably. The total thickness of the Kalibiuk Formation in the Cisaat river is about 500m. Lithologically, the Kalibiuk Formation consists mainly of bluish-grey calcareous claystone, often containing mollusca. In the upper part, a *Turritella*-rich bed occurs (see Table 2.1). The Kaliglagah Formation is composed mainly of andesitic sandstone, conglomerates, green marls and black claystones.

The present palynological study of the Bumiayu area is concerned with the Pliocene Kalibiuk and Kaliglagah Formations that are exposed along the Cisaat river (Figure 2.4) where many mammalian fossils have been unearthed through excavation near Cisaat village. The fossil fauna coming from these excavations (sites 6, 11, 9, 13 of Van der Maarel, 1932) is included in the Cisaat fauna by Sondaar (1984). This fauna is characterised by *Stegodon*, *Hexaprotodon*, cervids and very few bovines.

Along the Cisaat River valley the Kalibiuk Formation passes upwards through a transitional zone into the typical Kaliglagah Formation. Here, the Kalibiuk Formation consists of a bluish-grey massive clay containing sandstone intercalations. Foraminifera and mollusca are found in this Formation (ter Haar, 1934). In the upper part of the Kalibuik, more marine sediments occur, with abundant *Turritella* (Table 2.1). Above this bed, a transitional zone, consisting of clay, lignite and sandstone beds, can be observed. Upward, the sediment becomes coarser to form the typical Kaliglagah Formation. Along this river, the Kaliglagah Formation is composed mainly of alternating clays (often silty), sandstones and conglomerates. The sandstones are commonly cross-bedded. The clays are generally rich in caliche (carbonate) nodules. This Formation contains abundant freshwater mollusca and a few reworked marine mollusca can also be found. Plant remains also occur in the Kaliglagah Formation (ter Haar, 1934). The Kaliglagah Formation in this Cisaat section, has yielded vertebrate fossils, which are included in the Kaliglagah fauna of von Koeningswald.

The remaining part of the Kaliglagah fauna, *sensu* von Koeningswald, is called the Satir Fauna by Sondaar (1984). The fossils forming this fauna come from excavations (sites 1-4 of van der Maarel, 1932) at Kaliglagah near Satir Village (see Figure 2.4).

The Kaliglagah fauna is older than the Cisaat fauna and comes from an horizon in the Kaliglagah Formation about 50m above its base. The upper part of the Kaliglagah Formation in this section is characterisic of the lower part of the younger lithostratigraphic unit.

For the purpose of this study, a transect map was made along the Cisaat river (Figure 2.5). Using this transect map as a guide, about 40 samples were collected for palynological study. The sampling regime will be discussed in the following Chapter 3.

Table 2.1

List of the mollusca from the Kaliglagah Formation, after Oostingh (in Ter Haar 1934).

+	*Turritella djadjariensis* Mart	R
	Thiara scabra (Mull)	
	Thiara tjemoroensis (Mart)	
	Melanoides tuberculata tuberculata (Mull)	R
	Melanoides tuberculata tegalensis Oostingh	
	Melanoides woodwardi (Mart)	
	Melanoides fennemai (Mart)	
	Melanaides junghuhni (Mart)	
	Melanoides madiunensis (Mart)	
	Melanoides tjariangensis (Mart)	
	Melanoides preangerensis (Mart)	
	Melanoides fallax Oostingh	
	Melanoides flavida (Dunker)	R
	Melanoides martini Oostingh	
	Brotia oppenoorthi Oostingh	
	Sulcospira testudinaria (Busch)	R
	Sulcospira foeda (Lea)	R
	Viviparus javanicus (Busch)	R

	Pila conica (Gray)	R
+	*Calyptraea renovata* (Crosse et Fisscher)	R
+	*Natica helvacea* Lam.	R
+	*Natica zebra* Lam.	R
+	*Finella pupoides* A. Ad.	R
+	*Siphonalia paradoxica crassicostata* (Mart)	
+	*Vexillum limiticum* Oostingh	
+	*Marginella ventricosa minor* (Mart)	
+	*Marginella tegalensis* Oostingh	
	Lymnaea javanica ((van Hasselt MS) Mouss)	R
	Gyraulus convexiusculus (Hutton)	R
	Isidora (Ameria ?) sp	
	Canesella martini Oostingh	
+	*Arca granosa* L	
+	*Area terhaari* Oostingh	R
	Elongaria orientalis (Lea)	
	Pseudodon vandervlerki Oostingh	
	Corbicula gerthi Oostingh	
	Corbicula pullata (Phil)	
+	*Joannisiella oblonga* ((Sow. MS) Desh)	
+	*Chione squamosa antiqua* Oostingh	
+	*Katelysia oppenoorthi* Oostingh	
+	*Paphia cheribonensis* Oostingh	
+	*Aloidis tjiguhanensis* (Mart)	

+ = marine mollusca R = Recent

2.5.1.2. Climate of Bumiayu

The climate of Bumiayu can be based on Boerema's (1928) observations. He measured the annual rainfall in the northern part of the central area of Bumiayu as 2319mm. This part of the area can be divided into two climatic regions based on the timing of the monsoon. In the western area, the west monsoon brings heavy rain during January and February, while the east monsoon results in a minimum of rainfall during August. The rainfall on the mountainous area in the western part of the region is 3600mm per annum. The rainfall in the southern corner of the Bumiayu area is 2938mm per annum. The maximum rainfall is in February and the minimum in July. The eastern part of the Bumiayu area also receives abundant rainfall under the influence of the west monsoon, while the minimum rainfall is in August. According to van Steenis (1965) the climate of the Bumiayu area may be classified as 'slight dry monsoon'.

2.5.1.3. Present Vegetation

The natural vegetation which covered the Bumiayu area in the recent past is known to have been poor in species in all ecological groups. According to van Steenis (1965), this area was covered by dry fields, with scattered areas of rain forest and teak forest.

2.5.2. Trinil (111°21'40" E, 7°22'30" S)

2.5.2.1. Geology and Stratigraphy of Trinil

Trinil became well known to palaeo-anthropologists with the discovery of a hominid skull (then known as *Pithecanthropus erectus*) on the east bank of the Solo river by Dubois (1894). Since then, it has been the subject of a number of studies. The first stratigraphical studies around this area were made by Carchaus (1901) and Dozy (1911), members of the Selenka expedition. This expedition, in an effort to find more *Pithecanthropus* specimens, carried out excavations on the same site as Dubois. Later, geological studies were made by van Es (1931), Dufyes (1936) and the Indonesian Japan Co-operation team on the CTA - 41 Project (Watanabe and Kadar Eds. 1985).

It was the stratigraphic subdivision of Dufyes (1936) which was followed by later investigators in discussing the stratigraphy of the area. The following is a brief explanation of the geology

Geological sketch map of the Trinil area (after Duyfjes,1936; simplified by Suradi et al, 1985).

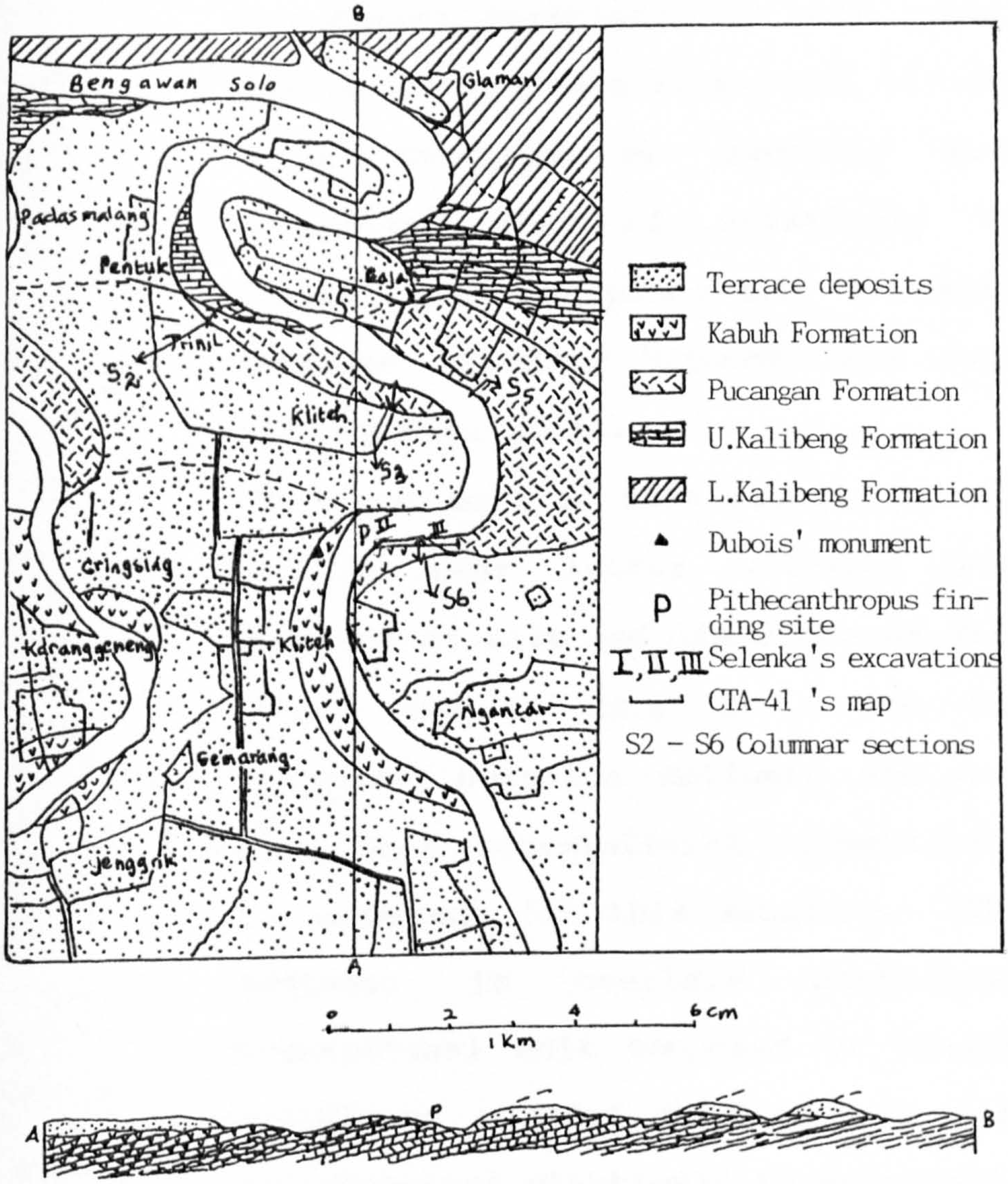


Figure 2 . 6

of the area, especially around the *Pithecanthropus* site (Figure 2.6).

The oldest stratigraphic unit exposed here is called the Kalibeng Formation, the lower part of which consists of massive, yellowish-grey calcareous clay of relatively deep marine origin, rich in planktonic foraminifera which indicate an early Pliocene age (classified as N19, by Blow 1969).
The upper part of this formation, which is well exposed near Pentuk village (Figure 2.6), consists of silt and limestone of shallow marine origin and is from 25 - 47m thick. The limestone contains mollusca and corals. The planktonic foraminiferal assemblage suggests a Pliocene age for this sequence. This Tertiary sediment is overlain conformably by a transitional unit composed of bluish-grey clay containing rounded fragments of limestone and allochthonous planktonic foraminifera (Suradi *et al*, 1985). The next youngest formation is the Pucangan Formation which overlies the older unit conformably. This formation is composed of a volcanic mudflow or lahar (also called breccia), sandstone, clay and silt. The Pucangan formation is about 28m thick and of freshwater origin. It is in turn overlain by the

fluviatile Kabuh Formation, which rests unconformably over the Pucangan Formation. The Kabuh Formation consists of conglomerate, sand, silt and clay.

The lower part of the Kabuh Formation, which consists of conglomerate, contains fossil bones and is believed to be similar to the so-called "Haupt Knochen Schicht" (de Vos *et al*, 1982). Haupt Knochen Schicht is a faunal assemblage with biostratigraphical significance from the Trinil area, named by von Koeningswald (1934) and reconsidered by de Vos *et al*,(1982) and Sondaar *et al*, (1983). It is from this bed that the Dubois' collection, including the *Pithecanthropus erectus* skull, has been unearthed. The total thickness of the formation is from 45 to 53 m.

The Notopuro Formation, which unconformably overlies the older Kabuh sediments, is composed of gravel and sandbeds, which very often contain pumice balls. The youngest sediment in the Trinil area is the terrace deposit, which consists of gravels and sands. It lies unconformably over the older sediment.

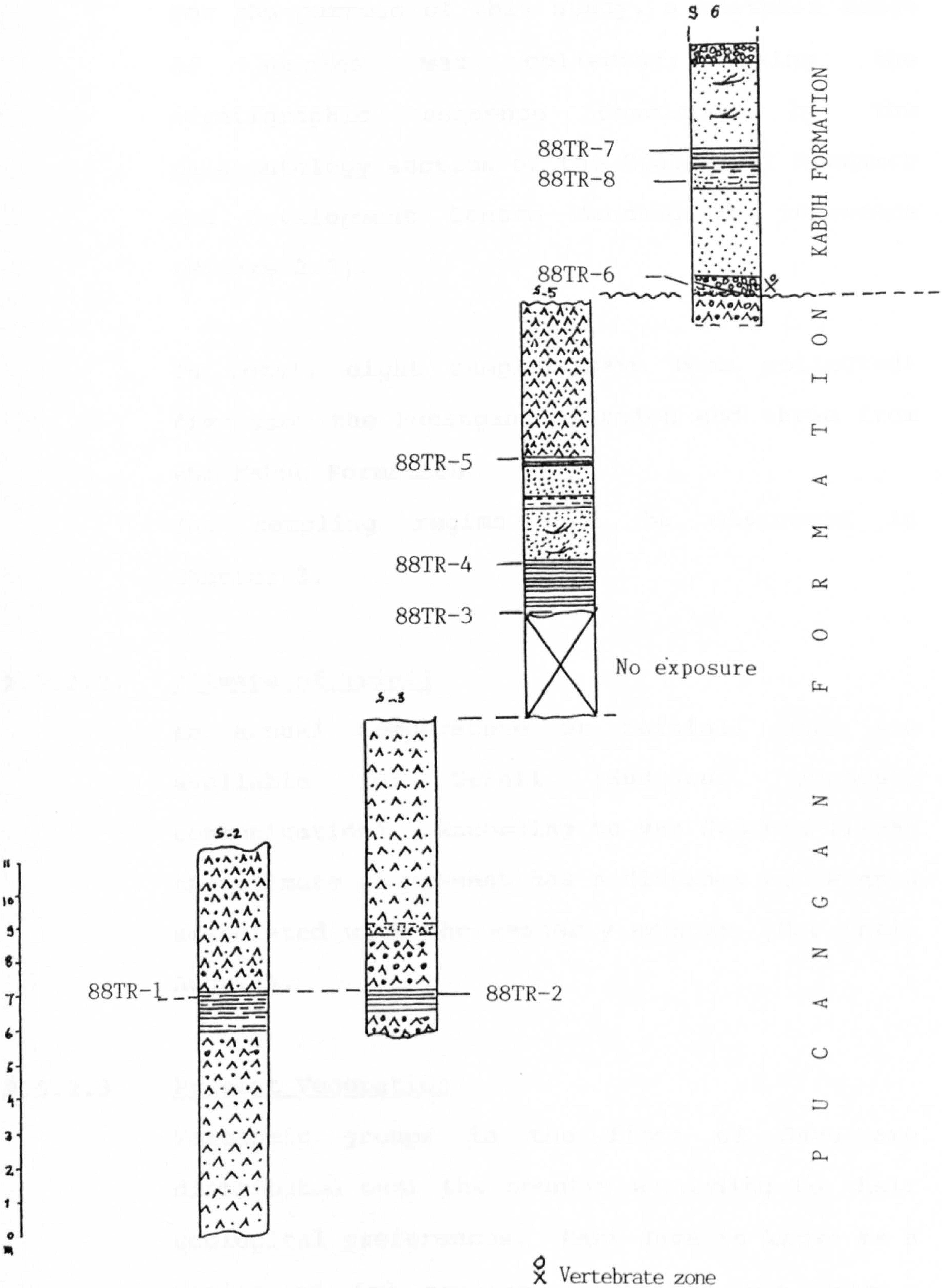
Structurally, the sedimentary and volcanic rocks form a homocline which is dipping toward the south (Suradi *et al*, 1985).

Since Dubois' discovery of the first *Pithecanthropus* (later *Homo*) skull in Java in 1894, there has been much controversy concerning the source, taxonomy and age of the *Pithecanthropus* specimens. Further discussion of this problem is beyond the scope of the present study.

The vertebrate fossils coming from the Kabuh Formation (Dubois' collection) have become the type collection for the Trinil HK Fauna of de Vos *et al* (1982). This fauna is different from that of von Koeningswald's. Although von Koeningswald uses the name Trinil Fauna for one of his faunal units in Java, he does not confine the fauna making up the unit to those coming from Trinil *sensu stricto*. He also includes fossils from other localities (for example Kedung Brubus) in this fauna. The Trinil HK Fauna contains *Acanthion brachyurus*, *Panthera trinilensis*, *Prionailurus bengalensis*, *Stegodon trigonocephalus* Martin, *Rhinoceros sondaicus Desmarest*, *Muntiacus* sp, *Axis lydekkeri* Martin, *Duboisia santeng* (Dubois), *Bubalus palaeokerabau*

Dubois, *Bibos palaesondaicus* Dubois, *Sus brachygnathus* Dubois, *Trachypithecus cristatus* Raffles, *Macaca* sp, *Meganthropus and Homo erectus* (Dubois). This fauna is relatively poor in species diversity and relatively low in numbers (de Vos, 1982). It contains some endemic taxa such as *Rattus trinilensis* Musser. These facts suggest that the palaeoenvironment of the Trinil HK fauna was an isolated island, with little faunal interchange with the Asiatic mainland. De Vos *et al* (1982) considered that the high number of large bovids indicated a relatively dry biotope, with open woodland. Such an interpretation corroborates the conclusion of Weesie (1982) who studied the avian fauna of the same area. De Vos *et al* (1982) also suggest that these conditions occurred during a global ice age.

Through the present study, the author wishes to analyse the problem of the age and environment of Trinil from the palynological point of view. This study is concerned with the Pleistocene (the Pucangan and Kabuh Formations) sediments only.



Columnar Section of the Trinil area
Figure 2.7

For the purpose of this study, a suitable range of samples was collected, using the stratigraphic sequence developed by the palaeontology section of the Geological Research and Development Centre Bandung as reference (Figure 2.7).

In total, eight samples have been collected: five from the Pucangan Formation and three from the Kabuh Formation.
The sampling regime will be discussed in Chapter 3.

2.5.2.2. Climate of Trinil

No annual temperature or rainfall data are available for Trinil (Sudijono, personal communication). According to van Steenis (1965) the climate at present has a distinct wet season associated with the easterly monsoon (May until August).

2.5.2.3. Present Vegetation

Taxonomic groups in the flora of Java are distributed over the country according to their ecological preferences. East Java is known as a region of low species diversity, but with a large number of grasses. Trinil (in East Java) is covered by scattered patches of rain forest, dry fields and teak forest.

2.5.3. Bandung Lake (107°29'27" and 107°45'27" E, 6° 55' and 7°0' S

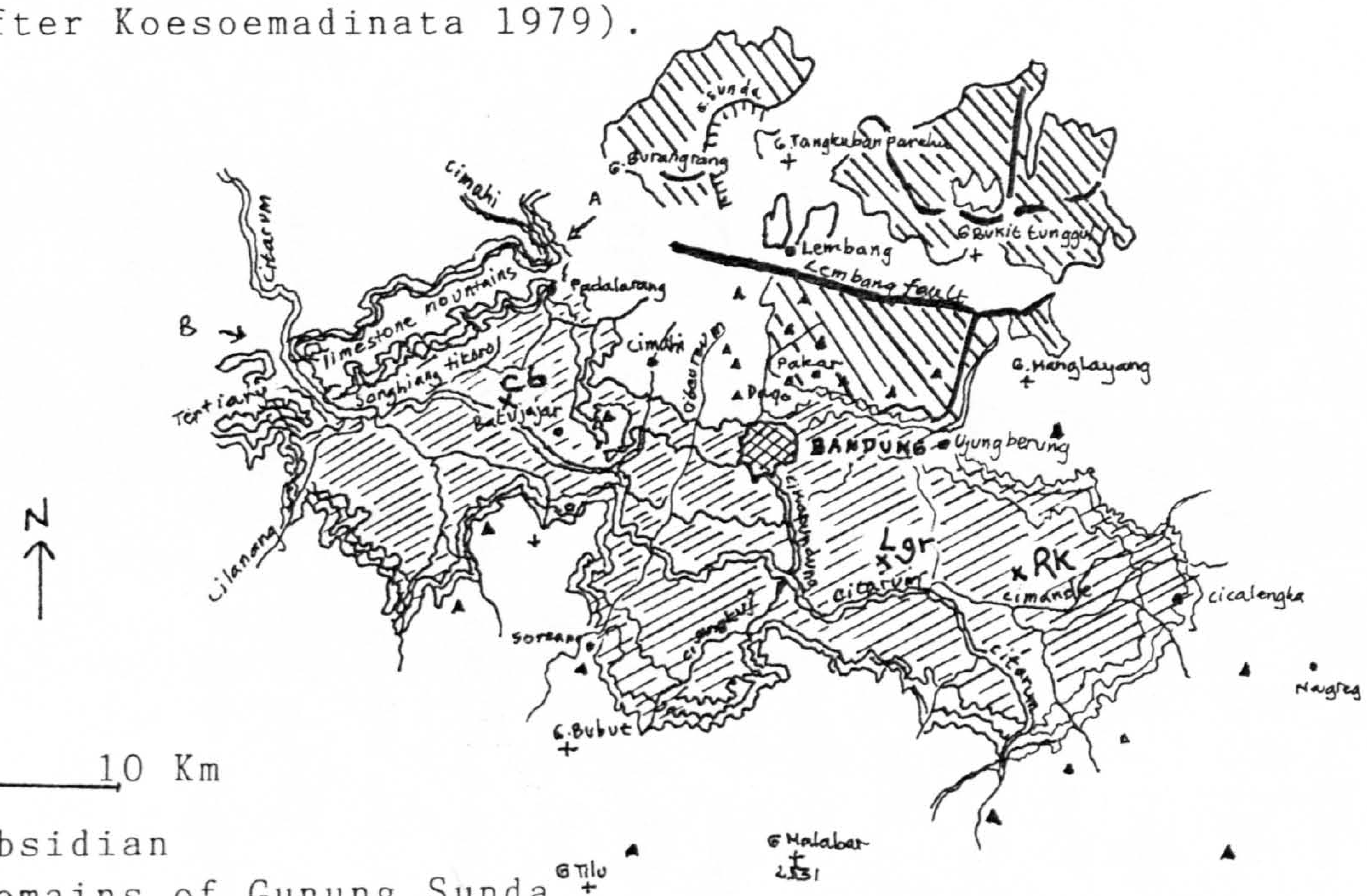
2.5.3.1. Geology and Stratigraphy of Bandung Lake

The geological evolution of Bandung can be briefly explained: the history of the lake is related to the development of the volcano Tangkubanparahu to the north of the basin (Figure 2.8). Twenty million years ago, during the Miocene, the northern part of modern Java was covered by sea. The coast was a little south of present day Pangalengan (see Figure 2.1). A chain of volcanoes was situated parallel to the coast and just offshore. The end of the Miocene was a time of major folding and mountain building that shifted the coast from the south of Pangalengan to the north of modern Bandung (Koesoemadinata, 1979).

Further major orogenic and tectonic activity occurred at the end of the Pliocene. The coast again shifted, further to the north.

There are a number of volcanoes around the Bandung basin which are still active. Their

Sketch map of ancient Bandung Lake
(after Koesoemadinata 1979).



0 10 Km

▲ Obsidian
Remains of Gunung Sunda
Ancient Bandung Lake
Lembang fault
A Outlet in prehistorical time
B Outlet after the catastrophe
725 m above sea level

Cibogo (Cb)borehole
Linggar (Lgr) borehole
Rancaekek(Rk)borehole

Figure 2.8

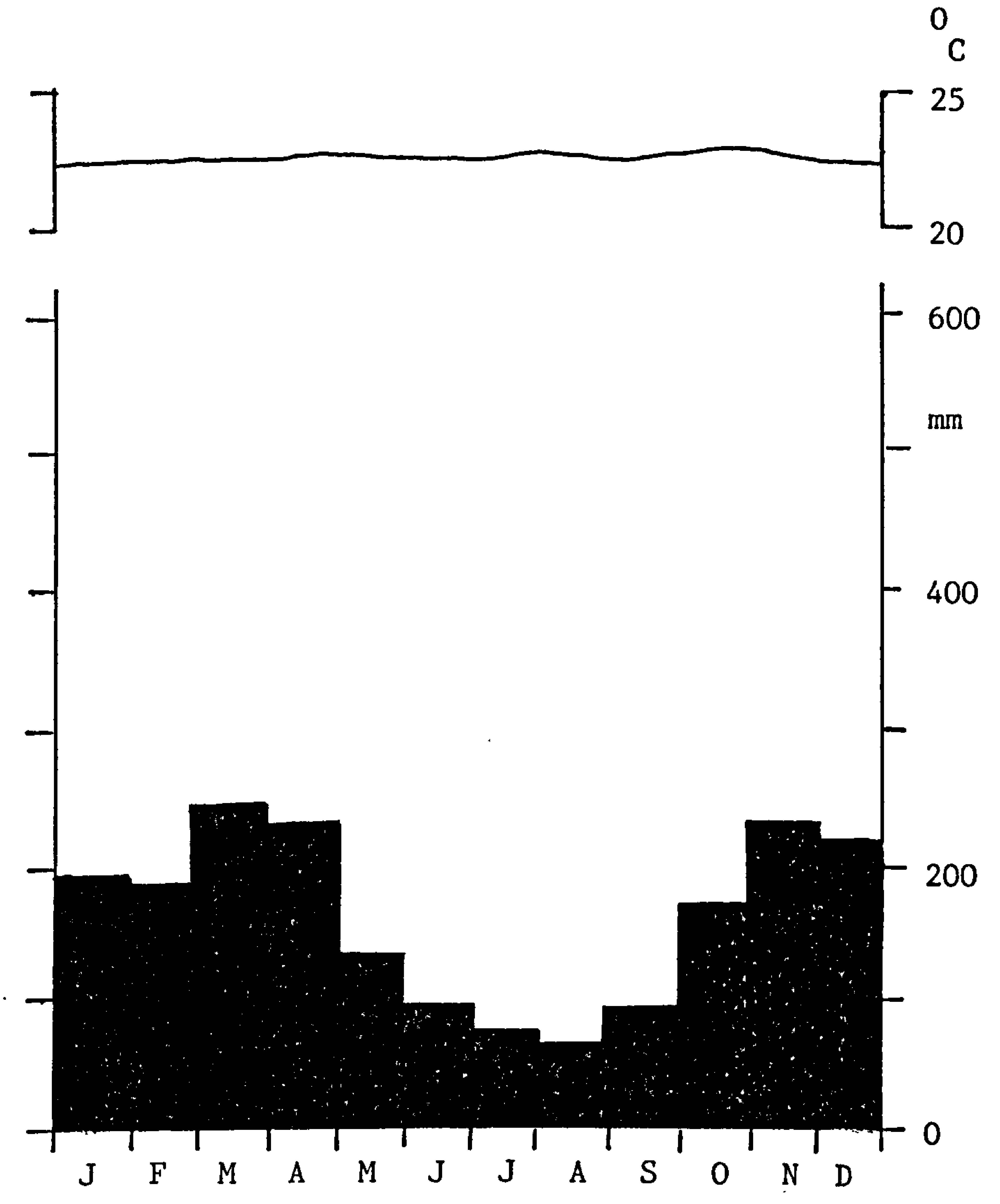
ejecta are distributed on the plains of Subang and Bandung. The age of the first eruption of the volcanic complex is Early Pleistocene, while according to Stehn and Umbgrove (1929), typical Early Pleistocene mammalian bones were found in the lahars and tuffs. The Lembang fault was formed at this time, running in an East-West direction (Figure 2.8), with the upthrow to the south of the fault. The lava flows from Tangkubanparahu were cut off by this fault. The rivers running down the slopes of the volcano were also cut off by the fault, so that they eroded a canyon through the fault wall. An example of this can be found at Maribaya. It appears that the fault reached the magma chamber of the volcano and in the caldera of Gunung Sunda, the embryo of the Gunung Tangkubanparahu was formed. The ejecta of the new volcano were distributed to the north as well as to the south, filling up the depression north of the Lembang fault.

Towards Bandung, the flows of lava resulting from the creation of the Tangkubanparahu had to follow the river courses in order to get through the Lembang fault ridge. The depression of Bandung was filled up, in particular its western part, where the fault line can no longer be seen due to a covering of volcanic debris. Hence, the lava flows could move freely across the former fault line to Cimahi. At one stage, the activity of this volcanic complex was even stronger, so that the course of the Citarum River was blocked entirely by lava. Material erupted during this period of activity can be seen particularly clearly in a tunnel at Dago, to the north of Bandung (Figure 2.8).

When the course of the Citarum was blocked, the water was not able to cut through the dam of lava. The volume of water trapped in the Bandung plain increased and the water level rose. It was in this way that the Bandung Lake was formed (Koesoemadinata, 1979). During the time of the existence of Bandung Lake, human beings occupied the basin, as is indicated by the presence of obsidian tools which have been found in caves, or at open sites by rivers, or by the palaeolake shore (Subagus, 1979). The tools found were for use in hunting and food gathering. Sites where obsidian tools were found, were generally situated at about 725m above sea level (von Koeningswald, 1935). This height presumably marks a maximum for the level of Bandung Lake, about 25m above the present basin floor.

Koesoemadinata and Hartono (1981) subdivided the Pleistocene to Recent stratigraphy of the Bandung area (from oldest to youngest), into: the Cikapundung Formation, the Cibeureum Formation, the Kosambi Formation, the Cikidang Formation and River deposits. The Cikapundung and the Cibeureum Formations represent Early and Late Pleistocene volcanic deposits which are separated from each other by an erosional surface. The Kosambi Formation consists of the deposits of the former Bandung Lake and rests conformably on the Cibeureum Formation. The Kosambi interfingers with the upper part of the Cibeureum Formation. The Cikidang Formation may represent sub-recent volcanic activity (Pleistocene). The youngest deposits in the Bandung area (Pleistocene/Holocene) are fluvial in origin.

The present study is concerned with the uppermost part of the Kosambi Formation (lake sediments) which has a maximum thickness of 80m (Koesoemadinata and Hartono, 1981). Samples for study were collected using a hand operated coring device. The maximum depth reached by this coring operation was 16 m. The coring sites are Linggar (Lgr), Cibogo (Cb) and Rancaekek (Rk) (See Figure 6.1).



Climatic diagram for Bandung station.
(after Nieuwolt,1977). Figure.2.9

The upper part of the Kosambi Formation in the areas studied, consists of clays and sands. In total 84 samples were analysed and are described in the present work.

Well logs and summary pollen diagrams for these bore holes are shown on Figures 4.1 - 4.3; 4.6 - 4.8.

2.5.3.2. Climate of Bandung Lake

The climate of Bandung Lake was described by Szemian (1934). The annual rainfall is between 2000 mm to 3000 mm (Dept. of Information Republic of Indonesia, 1988). The northern part of Bandung receives abundant rainfall between February and April. According to Nieuwolt (1977), from February to April the monthly rainfall at Bandung is 250mm (Figure 2.9). The major dry period is in August. The annual average temperature of Bandung is 22.1°C with an absolute maximum of 34.2°C and an absolute minimum of 11.2°C. The daily average range temperature is between 9.3°C and 17.9°C. Average monthly humidity at Bandung is 75 to 86%, with an absolute minimum of 23% (Szemian, 1934).

2.5.3.3. Present Vegetation

In West Java, the everwet ecological conditions allow the development of a richer and more varied flora than elsewhere in the country. The main vegetation types comprise mixed lowland and hill rain forest, and montane everwet rain forest. In the environs of Bandung, several ornamental plants have been introduced by private gardeners and flower firms. In the mountains, agricultural and fodder crops, as well as tea and cinchona estates, have been developed (Dit. Jen. Agraria Dept. dalam negeri, 1971). However, paddy fields, open fields, rain forest and estates have been built over during the 20th century.

The sampling regime will be discussed in Chapter 3. Methods of pollen analysis used in this study and descriptions of the pollen grains which were recorded will be described in the two following Chapters, 3 and 4.

Chapter 3.

METHODS OF ANALYSIS AND INTERPRETATION.

Sampling for palaeontological studies yielded a set of stratified samples within which variations in pollen assemblages could provide information on vegetational and environmental changes. The collection of samples for pollen studies was based on the observed stratigraphy.

In this study, lake sediment cores from Bandung Lake and clay units of outcrops or river cuts, exposed in the Trinil and Bumiayu areas, were sampled. Sequences from these three sites yielded records covering different time periods.

The field work had to be carried out with the greatest care in order to obtain uncontaminated samples of the deposits.

3.1. Field methods

3.1.1. Stratified sampling of Trinil and Bumiayu exposures.

The sampling method was based on palaeontological criteria. The sampling procedure was to collect single samples from each stratum which was considered likely to be polleniferous in order to obtain a set of stratified samples. Coarse sediments were considered unlikely to be polleniferous. According to Krumbein (1965), systematically selected samples are likely to give reliable estimates of population variances and might be particularly applicable for the detection of ecological gradients.

3.1.2. Sampling of the Bandung Lake deposits.

Lake deposits are considered to be ideal for palynology in many ways, especially since they are little affected by oxidation (Moore and Webb, 1978).
The principal object of the use of lake sediment cores is to secure samples for pollen analysis that are pure and free from contamination. Ideally, a complete stratigraphic survey should be undertaken first, but in the present case this was impossible because of the size of the basin. Only three cores, taken near the edges of the basin, were available and therefore, all three have been analysed, since it was not clear which was likely to be the oldest or the most complete. Continuous cores were obtained from three localities Cibogo (Cb), Linggar (Lgr) and Rancaekek (RK). The lengths of these cores were: 12.00m, 15.75m and 14.05m respectively (Figures 4.6 - 4.8).

3.1.3. Equipment.

For the stratigraphic samples from exposures, a lightweight trimming hammer, which is suitable for collecting soft rock samples, and a clean knife were used. After every use, the hammer or knife was cleaned with a wet cloth to reduce aerial pollen contamination. For sampling the Bandung Lake sediment, a Dachnowsky sampler was used initially (Faegri and Iversen, 1964). This type of sampler has the great advantage of being lightweight and simple to operate and maintain. It can be pushed by hand only through soft sediments, but not through more compacted sediments. In the case of Bandung Lake, it could not penetrate deeply because of the sticky and hard clay sediments. On other occasions, the piston could not easily be retracted because the friction of the sediment was not sufficient for it to be retained within the tube. The sampling of Bandung Lake was, therefore, carried out with a shallow hand corer, type DR 90 USA, which penetrated the deposits to a maximum of 16m. The individual core sections were 31cm long, with a diameter of 4cm. The three continuous borehole profiles were taken with this instrument. After taking each core segment, the sampler was washed with a wet cloth to prevent pollen contamination.

3.1.4. Care of samples

Outcrop samples were immediately placed, with great care, into air-tight plastic bags which were already labelled with the sample data. For subsequent transport, all these samples were placed into a second, cotton sample bag with the same code and number. Lake sediments were also wrapped immediately after retrieval using a thin layer of plastic and fastened with adhesive tape. A plastic bag, which was already marked with the code and number, was used as a second layer to protect the sample from fungi and bacteria and to maintain high humidity. Aluminium foil was used for further protection and the core segments were placed in a suitable box for later transport to the laboratory.

3.2. Laboratory methods

There is no single method for recovering plant microfossils from sediments which represent a variety of compositions and a variety of depositional environments. The use of the correct technique for the separation of mineral and organic fractions is absolutely essential. The techniques used in this study are described below.

3.2.1. Sample preparation - fossil pollen

3.2.1.1. Sample characteristics

In this study, both outcrop samples and lake samples were mainly from clay lithologies. The samples were dried in an oven for some hours before crushing with a mortar and pestle. After crushing, the mortar and pestle were cleaned with a brush and an abrasive cleaner and dried. The dispersal chemicals did not behave in the same manner with all sample suspensions. Some worked with one sediment, but not with another which needed heating to disperse a specific matrix, so different concentrations were necessary with different matrices.

3.2.1.2. Sample preparation

In this study, the standard method for pollen sample preparation is based on Faegri and Iversen (1975), with some modifications.

1. The clay samples were cleaned and only the centre part was used.

2. From the centre of the outcrop samples or core segments, $2cm^3$ of sample were taken. These were oven dried at 150^oC and then crushed with a mortar and pestle and sieved.

3. The sieved clay sample was disaggregated by boiling in 10% hydrochloric acid (HCl) in a water bath for 10 minutes and boiled in 40% hydrofluoric acid (HF) for 30 minutes. (Polyethylene containers were used).

4. The sample was washed with distilled water three times.

5. All the residue was treated with 10% potassium hydroxide (KOH) and heated for ten minutes in a boiling water bath.

6. The sample was thoroughly washed with distilled water until the residue became clean.

7. Heavy liquid separation was carried out in a zinc chloride ($ZnCl_2$) solution with a specific gravity of 2.2. This mixture was added to the test tubes and they were centrifuged for 30 minutes at 2000 r.p.m.

8. A few drops of acetone ($(CH_3)_2CO$) were added and again centrifuging was continued for 10 minutes.

9. All the floating part was collected, leaving behind the heavy minerals.

10. The residue was washed three times with distilled water, and then the floating part collected.

11. After preparing a fresh acetolysis mixture (nine parts of acetic anhydride ($(CH_3CO)_2O$) to one part of concentrated sulphuric acid (H_2SO_4), the test tube was primed first with glacial acetic acid and then with acetolysis mixture and was boiled for 10 minutes in a water bath being stirred occasionally.

12. After cooling, all the test tubes were filled again with glacial acetic acid (CH_3COOH)and centrifuged for 10 minutes.

13. The residue was decanted and washed with distilled water three times.

14. After adding a few drops of 10% potassium hydroxide (KOH) the sample was again centrifuged for 10 minutes.

15. The residue was again washed with distilled water three times.

16. For staining fossil pollen and spores, some drops of safranine were added to the residue, which needed to be boiled for 3 minutes in a water bath. Staining assists in detecting small or thin walled palynomorphs which otherwise may be overlooked (Faegri, 1936).

17. Again the residue was washed with distilled water until it was clean.

18. Mounting was in glycerine jelly because of its favourable refractive index, 1.43 (Andersen, 1965; Traverse, 1988). Clean slides were kept on a hot plate with a drop of glycerine jelly on the surface. One drop of residue was mixed with the glycerine jelly. To avoid air bubbles, the coverslip was put on top of the drop very carefully.

19. After the slides had cooled down, the cover slip edges were cleaned with wet cotton wool, sealed with nail varnish to prevent dislodging or drying out and the slides were labelled.

3.2.1.3.Mounting method

In pollen analysis, proper mounting techniques and mounting media are very important. The mounting medium also effects the size of pollen grains, which is an important taxonomic measure.

3.2.1.4.Modern pollen preparation

A modern pollen and spore collection is an essential tool for the palynologist working on Late Cenozoic sediments (Traverse, 1965).

To achieve this, it is essential that modern pollen and spore types are compared with fossil pollen and spores, thus allowing taxonomic and phylogenetic relationships to be determined. Knowledge of pollen and spores of recent plants can be helpful in interpreting features of fossil specimens.

The herbarium is the best source of pollen and spores for reference collections. Use was made of the extensive pollen reference collection in the Department of Geography at Hull University. This collection was augmented with Javanese material collected in the Botanical Garden, Bogor which was processed as follows:

In the case of large flowers a few anthers were carefully placed in a small marked envelope. In the case of smaller flowers, the whole flower was collected or even the whole inflorescence. These samples were then prepared using the Erdtman (1960) acetolysis technique, with some modifications:

1. The test tubes were filled with flower anthers and fresh acetolysis mixture (add nine volumes of acetic anhydride ($(CH_3CO)_2O$) to one volume of concentrated sulphuric acid (H_2SO_4). Acetolysis mixture was added very slowly, while keeping the solution moving to prevent the build up of hot spots.

2. All the samples needed to be boiled for 15 minutes in a water bath and stirred occasionally.

3. After cooling, glacial acetic acid (CH_3COOH) was added until the tubes were full.

4. To remove the acetolysis mixture, samples were centrifuged and decanted.

5. The residue was washed three times with distilled water.

6. Ten percent potassium hydroxide (KOH) was used and boiled for 10 minutes on a water bath.

7. Samples were washed again with distilled water until clean.

8. A few drops of safranine were dropped onto the residue and the sample heated in a water bath for one minute with occasional stirring.

9. The residue was washed until the excess stain was removed.

10. Slides were prepared on a hot plate with one drop of glycerine jelly. After melting, one drop of modern pollen was mixed in. Slides were covered with a coverslip and left overnight for even spreading.

11. For dark grains, bleaching was carried out using 10% hydrochloric acid.

12. The coverslip edges were cleaned with wet cotton wool and sealed with nail varnish.

13. The remaining pollen residue was then stored in a small vial with glycerine jelly and covered with a clean cork.

3.2.2.Pollen and Spore identification

3.2.2.1.Pollen and spore identification

Pollen grains are always difficult to identify, whether from illustrations or from a key. Various scientific laboratories operate their own systems. In the Geological Research and Development Centre Bandung, a very simple perforated card system is used in the construction of ordinary keys, as the cards can be shuffled around until a maximum number of notches coincide. The pollen grains found in the sediment cores of Bandung lake and in the stratified samples from Bumiayu, Central Java and Trinil, East Java were primarily identified by comparison with slides of modern reference pollen. Apart from the modern pollen slides, drawings and photographs of tropical pollen taxa shown in publications were consulted. The most useful publications were:

1) Erdtman, G. (1952). *Pollen Morphology and Plant Taxonomy - Angiosperm.* (An Introduction to Palynology I) Hafner Publishing Company, New York and London 533 pp.

2) Erdtman, G. (1957). *Pollen and Spores morphology/plant taxonomy - Gymnospermae, Pteridophyta, Bryophyta* (illustr.). (An Introduction to Palynology II) Almqvist and Wiksell, Stockholm 151 pp.

3) Faegri, K and Iversen, J. (1975). *Textbook of Pollen Analysis*. Blackwell, Oxford 295 pp.

4) Huang Tseng Chieng. (1972). *Pollen Flora of Taiwan*. National Taiwan University Botany Department Press 297 pp.

5) Kremp, G.D. and Kawasaki, T. (1972). *The Spores of the Pteridophytes*. Hirokawa Publishing Company, Tokyo 390 pp.

6) Punt, W. (1962). Pollen morphology of the Euphorbiaceae with special reference to taxonomy. *Wentia* 7, 1-116.

7) Thanikaimoni, G. (1970). Les Palmiers Palynologie et Systematique. *Inst. fr. Pondichery, Trav. Sect. Sci. Techn.* tome XI, 286 pp.

In general, the identifications had to remain confined to the generic level. Fern spore identification is even more uncertain than that of pollen grains because tropical ferns are poorly represented in reference collections.

3.2.2.2.Pollen counting

Faegri and Iversen (1964) noted that a minimum pollen count of 150 grains is required for analysis of samples from temperate regions. Most tropical plant communities are, however, floristically very rich. In the tropics, a greater diversity of species is present than in temperate areas and so a larger pollen count is often necessary, particularly if a representative count is to be obtained for those taxa recorded at low percentages. Morley (1976) demonstrated in a pollen trapping study in hill dipterocarp forest at Ulu Gombak, Malaysia that while common taxa were well represented with counts of 150 grains, the percentages of rare types did not stabilize until 300-500 grains had been counted. Hamilton (1972) suggested that 500 grains would have to be counted to give accurate frequencies for rarer pollen types.

In view of these results, a minimum of 300 pollen grains, excluding aquatic and pteridophytes spores, were counted for all samples where possible. This pollen sum was termed "total dryland pollen." In some instances, however, this number could not be reached, particularly for some of the surface samples, but also for a small number of fossil pollen samples from Bandung Lake. The results of the counts are presented as percentage diagrams. The preparation of absolute pollen diagrams was not felt to be necessary in view of the large count size used.

Diversity is a very important aspect of tropical forest ecology. According to Morley (1976) diversity of pollen types derived from dryland environments show a linear relationship with altitude: diversity decreasing with increasing elevation.

In lakes, especially in large water bodies, currents may arise which destroy and redeposit the sediments, thus resulting in difficulties of interpretation (Faegri and Iversen, 1975).

Thus, the range of pollen types from dryland environments found in lake sediment samples, may give an indication of the altitudinal zonation of vegetation around the site (Morley, 1982).

3.2.2.3.Modern pollen rain

Wright *et al* (1967) emphasised the importance of surface pollen samples for the interpretation of Quaternary pollen assemblages. Surface samples taken from representative localities over a wide area and studied by pollen analysis can be used to determine the relationship between the pollen rain and the modern vegetation (Birks and Birks, 1980). The natural pollen traps which have been used by previous authors include upper surfaces of lake sediments (Davis, 1967), soil surfaces (Tauber, 1967) and moss polsters (James, 1983).

In this study, no surface samples or moss polsters were used because of the disturbance of the rain forest in the study areas, which had been destroyed for agricultural purposes. Also, there was no time or finance available to carry out a modern vegetation study, without which a modern pollen rain study is of limited value. Consequently, surface sample studies from elsewhere in Indonesia were utilised (Flenley, 1973; Morley, 1976; Newsome, 1985).

3.2.2.4.Charcoal analysis

Charcoal which is formed as a result of incomplete combustion is a commonly found microscopic material in the Bandung lake sediments.Charcoal comprises elemental carbon and is indestructible by micro-organisms or other diagenetic processes. Microfragments of charcoal are often preserved in lake and swamp sediments and their representation has previously been used to illustrate the history of the burning of vegetation (Singh *et al*, 1981; Clark, 1982).

In this study, point count estimation of charcoal in pollen preparations was performed on samples from the Cibogo (Cb) core according to the method of Clark (1982).

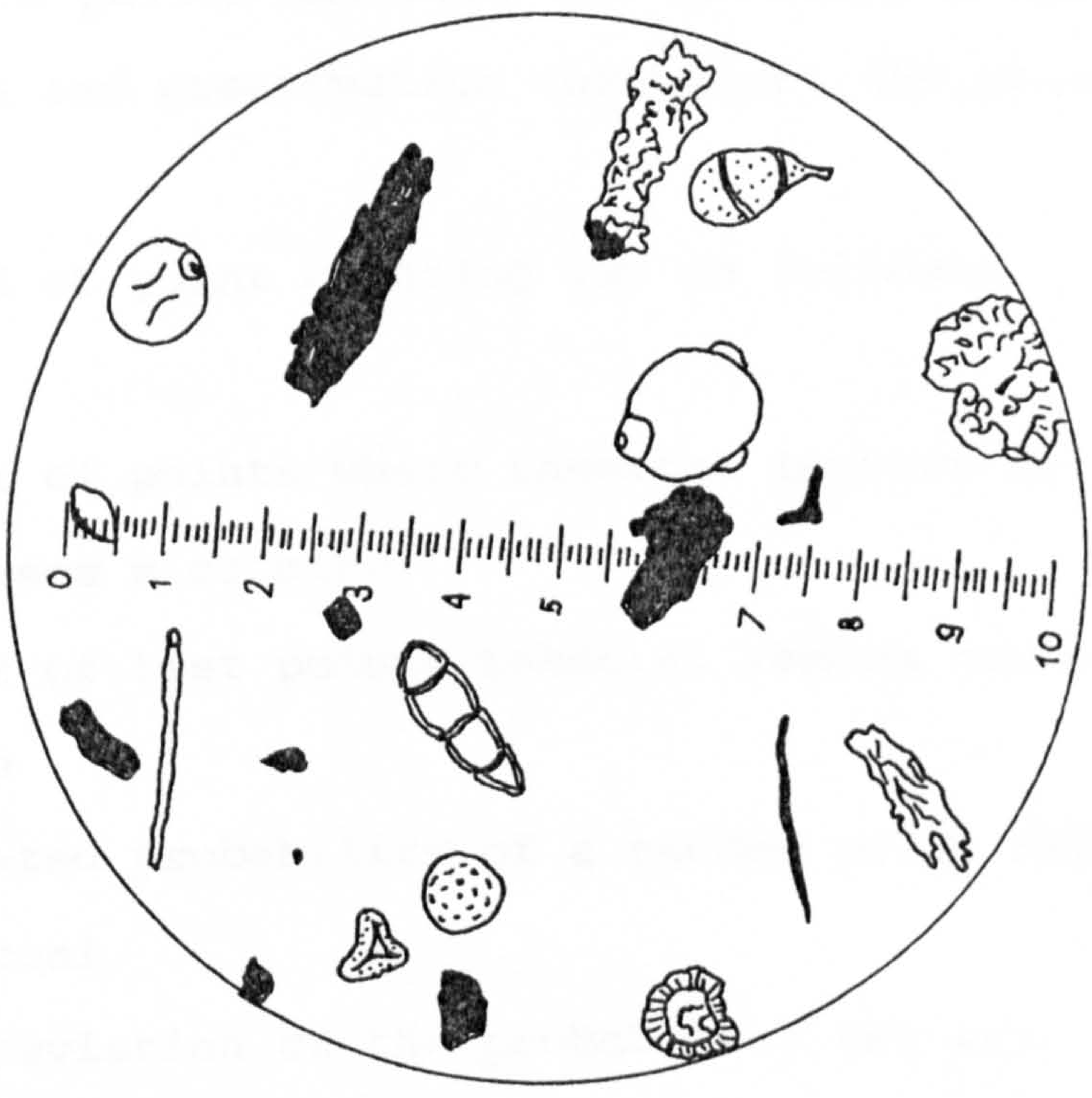


Figure 3.1

A field of view in a pollen preparation with a standard eyepiece mi - crometer.Of the eleven points defined by the upper ends of lines nearest the numbers, only one touches charcoal (after Clark ,1982).

This method of estimating charcoal is relatively straight-forward, takes little time to obtain results and provides an indication of the area of the slide covered by charcoal remains (Figure 3.1). Iversen (1964) also used a point counting procedure, similar to that of Clark (1982), for which the results are given in percentages relative to pollen amounts, but assuming constant pollen deposition and preservation throughout the sequence.

The method of point counting was as follows:

C = number of points where charcoal appears to touch the eyepiece micrometer

N = number of test points taken at random across the slide

P = estimated probability of a random point falling on charcoal

standard deviation of the probability (P) is:

$$S_p = \sqrt{P\ (1-P)/N}$$

Recommended procedure:

1) Count one or more transects

2) Calculate a first estimate of P, $P = C/N$

3) Select relative error

4) Calculate necessary N for given relative error

$$N = (1-P) / P \, (Sp/P)^2$$

5) Count to N as many points as possible

6) Calculate $P = C/N$

7) Estimate area of charcoal on slide

$$A = P.A_p$$

A_p = surface of cover glass

8) Percentage of charcoal on slide will be

$$P \times A_p \times 100\% = ----\%$$

3.2.2.5. Fungal spore analysis

According to Elsik (1976), some Cenozoic fungal spores are potentially useful for stratigraphy, but pose a difficult nomenclature problem because of their great variability in form (Wijmstra *et al*, 1971).

Wijmstra *et al* (1971) noted that fungal spore spectra show characteristic fluctuations which may be used to interpret ecological relationships. To test the value of fungi for ecological interpretation in Java, studies were performed on a single site from Bandung lake (Rancaekek, Rk). According to Clark (1982) the point count technique for the estimation of charcoal can also be used for other constituents of the sediments such as diatoms, fungal spores or mineral grains. The same point count estimation was, therefore, used for the fungal spore analysis in this study.

3.2.2.6. Chemical analysis

The chemical analysis of the lake sediments of Linggar (Lgr) was carried out by the Directorate of Mineral Resources, Chemical Mineral section, Bandung (Certificate No 73 - 88/PS/88). No details of the methods used are available. The result of these analyses is a chemical component diagram. Details are given in Table 3.1.

Chemical analysis of Linggar   Table 3.1

Analysis numbers		Depth of samples	C % Total	H %	N %	CO_2 %	Cl^- ppm	P ppm
73/PS/88	Lgr83	0.00m	1.88	1.51	0.15	0.03	88.6	393.2
74/PS/88	Lgr83	1.00m	1.21	1.45	0.13	0.03	59.1	674.0
75/PS/88	Lgr83	2.00m	1.16	1.32	0.11	0.01	73.87	739.4
76/PS/88	Lgr83	3.00m	0.92	1.55	0.09	0.03	59.1	421.3
77/PS/88	Lgr83	4.00m	0.34	1.54	0.2	0.01	88.7	411.9
78/PS/88	Lgr83	5.00m	0.41	1.58	0.05	0.04	88.7	580.4
79/PS/88	Lgr83	6.00m	1.22	1.43	0.08	0.05	44.3	505.5
80/PS/88	Lgr83	7.00m	1.67	1.68	0.08	0.04	59.1	627.2
81/PS/88	Lgr83	8.00m	1.94	1.73	0.17	0.01	59.1	748.9
82/PS/88	Lgr83	9.00m	1.47	1.69	0.13	0.06	44.3	823.8
83/PS/88	Lgr83	10.00m	1.96	1.82	0.15	0.01	59.1	823.8
84/PS/88	Lgr83	11.00m	2.26	1.55	0.22	0.03	59.1	655.3
85/PS/88	Lgr83	12.00m	1.52	1.66	0.15	0.04	59.1	823.8
86/PS/88	Lgr83	13.00m	1.08	1.50	0.07	0.05	59.1	748.9
87/PS/88	Lgr83	14.00m	1.01	1.48	0.08	0.30	73.9	823.8
88/PS/88	Lgr83	15.00m	0.78	1.35	0.04	0.08	59.1	748.9

3.2.2.7.Radiocarbon dating

Radiocarbon dating of four samples from Rancaekek (eastern part of the Bandung lake bed) was accepted as desirable by the NERC Radiocarbon Steering Committee. The depths of these samples were as follows:- 2.7m - 3.0m; 7.2m; 12.0m and 13.0m.

However, as the samples contained very little carbon (C 1-3% dry weight) it was not feasible for them to be dated at the NERC laboratory of the Scottish Universities Research and Reactor Centre, by the conventional method. Instead, the samples were submitted by the NERC Committee to the Accelerator Dating Laboratory at Oxford (see Table 3.2).

Results from the bottom sample (13.0m) produced a very strange date. It was assumed that this was most likely to be either disturbed or contaminated by biocides used to prevent fungal growth. All dates were measured on two fractions, the humic fraction and a residual carbon fraction. A measurement of the residual carbon fraction yielded dates of 10,950 ± 120 yr BP at a depth of 12.0m, 8820 ± 90 yr BP at a depth of 7.2m and 7810 ± 100 yr BP at a depth of 3.0m. On this basis, the Rancaekek sediments span a period from the terminal Pleistocene in to the Holocene (see Chapter 6 for discussion).

Table 3.2

Radiocarbon dates obtained for Rancaekek samples:

OXA	Depth	Fraction	Date + Error (^{14}C yr BP)	OXA	Fraction	Date + Error (^{14}C yr BP)	^{13}C
1959	2.7-3.0	residual carbon	7810 ± 100	-	humics	no date	(-20%)
1960	7.2	residual carbon	8820 ± 90	1969	humics	8840 ± 110	-23.1
1961	12.0	residual carbon	10950 ± 120	1970	humics	10480 ±	-16.7
1962	13.0	residual carbon	235.6% mod	1971	humics	494% modern	-19.4

3.3 Factors affecting palynological interpretation

The composition of a fossil flora in a soil deposit depends on several different factors: the nature of the source area in terms of pollen production, pollen dispersion, sedimentation by infiltration into the soil and preservation. These factors are discussed in more detail below.

3.3.1. Pollen production

An appreciation of the different mechanisms of pollination is of great importance in the evaluation of pollen analytical data.

A few aquatic taxa are pollinated under water and unfortunately these pollen grains are not recognisable because of their extremely thin exine and they can not be traced in pollen analysis. The small group of the obligate autogamous plants is heavily under-represented because the flowers never open and no pollen is exposed (Müller, 1947). For ordinary autogamous plants, a few species do flower and some pollen is produced which is transported by the wind. For the entomophilous group, in which the pollen is carried from the anther of one flower to the stigma of another by insects, there is little chance of pollen grains being preserved as fossils in ordinary deposits due to the low percentage of the pollen production going in to the pollen rain (Faegri and Iversen, 1975). By contrast, wind pollinated flowers produce large quantities of pollen which is released into the air and is spread over a wide area as pollen rain.

In a forest region, flowering and pollen production is highly variable. Tall trees are freely exposed but young specimens produce practically no pollen (Faegri and Iversen, 1975). The flowering of shrubs and forest floor herbs is usually not profuse, as many of them are insect pollinated. This may well have a major effect on the species found in the pollen rain. The explanation for the absence of many taxa from the record is that many may be entomophilous. In addition, many tropical taxa are irregular in their production of flowers and pollen from year to year (McClure, 1966). Thus, levels of pollen production and the manner of pollination of different plant groups, must be considered when interpreting fossil pollen assemblages.

3.3.2. Pollen dispersal

Transport of pollen over long distances in the direction of the prevailing wind, is a factor to be taken into account. Water is also a very powerful dispersal agent (Muller, 1959). The buoyancy of the pollen may play a part. If there is a differential rate of sinking, this may influence the pollen record, as the more buoyant pollen may be transported away from the depositional site (Flenley, 1973; Faegri and Iversen, 1975). McAndrews and Power (1973) established that rivers, coming from different vegetation regions into a lake, will bring in pollen loads of different compositions which will lead to differences in the pollen flora of sediments in different parts of the lake.

The mechanisms of pollen dispersal were studied by Janssen (1966) and a tentative model, illustrating pollen transfer in West Malaysia was developed by Morley (1976) based on this work. These studies provide a basis on which the various components of pollen transport in a tropical environment can be constructed (Figure 3.2). Janssen (1966) suggested three categories of pollen source regions i.e. local, extra-local and regional. The different pollen sources for the study site are discussed in detail in Chapter 6. The representation of various dryland pollen components

Pollen dispersal Figure 3.2

(after Morley,1976)

u large girth trees pollen

m medium girth trees pollen

l small girth trees pollen

nl non-local pollen

dry-land forest canopy pollen

dry-land forest trunk space pollen

arboreal swamp pollen

herbaceous swamp pollen

aquatics pollen

Pollen dispersal

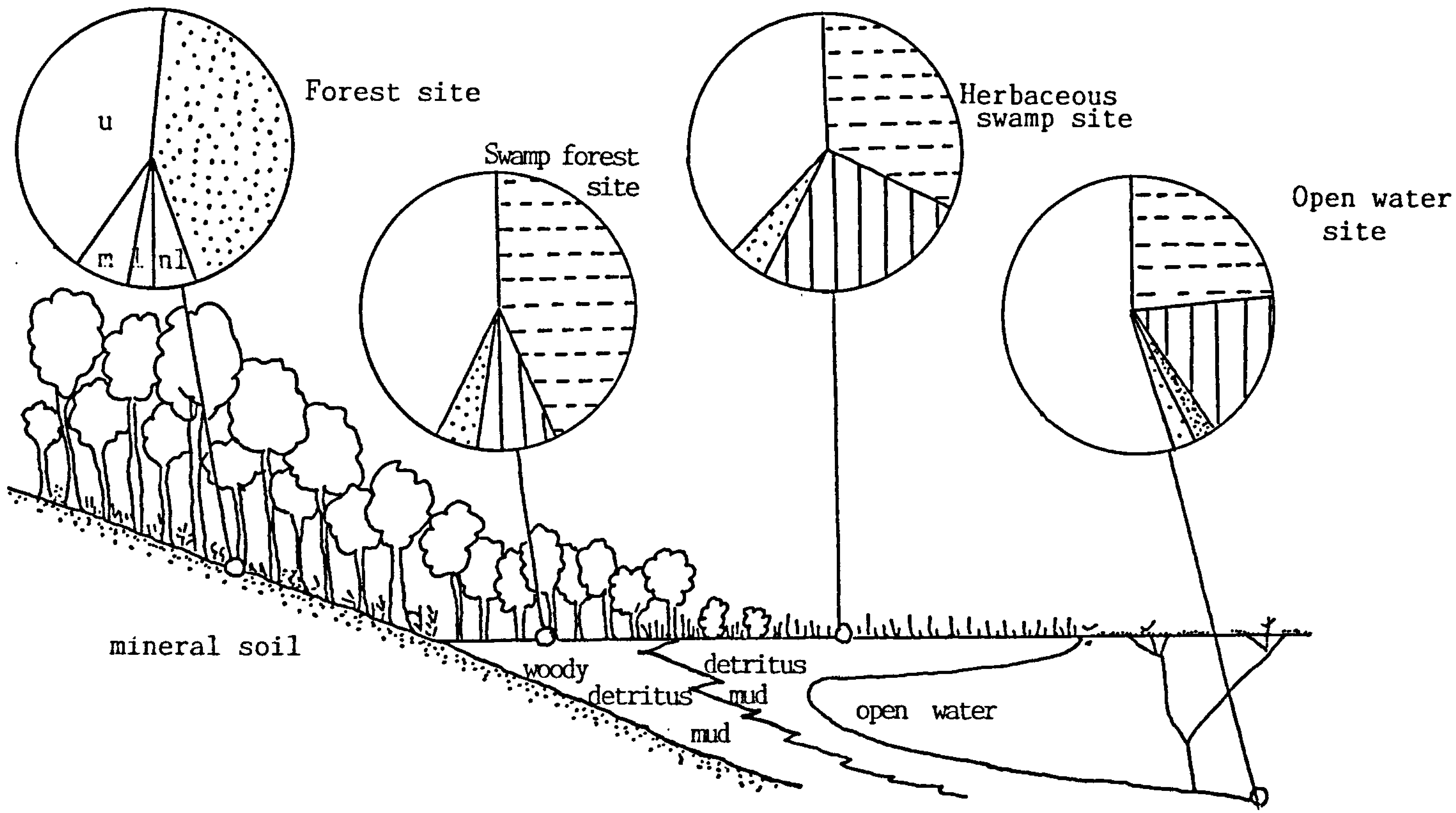


Figure 3.2

shows a relationship between pollen transfer within a forest and within a swamp environment. The dryland taxa are largely dependent upon the area of the local vegetation.

The regional component is provided by pollen from upland trees growing beyond the confines of the basin itself. Pollen from the taller trees in these upland forests dominates the regional scale, wind-transported pollen assemblages, and provides a simplified picture of the forest community from which it is derived. Local pollen rain comes from plants that grow very close to the sampling point. Extra-local pollen rain is derived largely from trees that grow on the slopes adjacent to the sample site, but which do not occur extensively over larger areas.

3.3.3. Pollen sedimentation

Depth of sedimentation is related to age, while peat deposits are like lake sediments which develop in a stratified sequence. Different types of lake sediments accumulate at different rates (Cushing, 1967).

With radiocarbon dating it is possible to work out sedimentation rates and from measurements of pollen concentration, the rate of pollen sedimentation per unit surface area can be determined (Flenley, 1973).In order to do this, a number of processes affecting sedimentation need to be considered. Water turbulence is one of the features which results in the mixing of the surface layers of sediments. An additional complication is caused by the fact that erosion of the surface sediments tends to be greatest in shallow water, near the lake margin, but re-deposition takes place evenly over the whole basin (Davis, 1968). This results in the actual accretion rate of sediment being lower in shallow water than in deep water. Streams entering a lake bring with them a load of material eroded from the surrounding watershed and deposition of this material, especially the large particles, will occur near the point of entry. Scouring by entry and exit streams, on the other hand, may remove lake sediment, producing an hiatus in the stratigraphic profile (Cushing, 1967). The rate of sedimentation and the density of pollen within the sediment, usually have to be expressed in relative terms, as a percentage of tree pollen, total pollen or some other appropriate proportion. In terms of potential as a record of vegetational change, each has certain advantages, or otherwise, which can be decided in relation to the actual problems under consideration. According to Davis (1967) trapping is unexpectedly consistent within each lake. These factors must be considered carefully in the interpretation of the data obtained from such an investigation.

3.3.4. The size of site

Lakes that have filled in and become swamps are especially favourable for palynological study because their sediments can be cored easily when the surface is firm enough to support equipment and personnel. According to Faegri and Iversen (1965), the ideal size of lake for sampling the sediments is an area of approximately $5000m^2$. Bandung lake is too large to be ideal, with an area of c. $50{,}000m^2$. In the lowland tropics, however, small lakes tend to be ephemeral because the ecological conditions favour high biological productivity and, as a result, rapidly infill (Morley, *et al*, 1973). The choice of a large lake was, therefore, unavoidable if a reasonable sequence of sediments, of a substantial age, were to be obtained.

3.3.5. Pollen preservation

Havinga (1964, 1967) tested the differential corrosion susceptibility of pollen grains under natural conditions. He demonstrated that oxidized pollen, as well as corroded but non-oxidized pollen, is attacked by bacteria and certain yeasts.

According to Havinga (1964) oxidation in soil attacks pollen. Havinga (1967) assumed that different types of soils would have different effects on pollen corrosion.

The fungus, Phycomycetes, is known to attack pollen grains and its presence in a soil would be likely to lead to poor pollen preservation. According to Moore and Webb (1978) soil pH is also significant and the best level of preservation is achieved in soil with pH of less than 5. Published evidence clearly demonstrates that accurate interpretation of pollen spectra may be hindered if the effects of differential pollen destruction are not taken into account. Havinga (1964) noted that when interpreting pollen diagrams of mineral deposits, it should never be overlooked that there is a possibility of the pollen composition having been changed by selective corrosion.

3.3.6. Summary of effects on interpretation

Possible problems which might effect the interpretation of past vegetation assemblages based on pollen in lake or soil deposits are related to variations in pollen source region, pollen production, pollen dispersion, pollen sedimentation, size of site and pollen preservation. All these factors need to be considered.

Using the methods of preparation outlined above, all pollen fossils were examined on a Carl Zeiss camera ultraphot with 1000x magnification. The fossil pollen types encountered are described in the following chapter (Chapter 4).

Chapter 4

PRESENTATION OF RESULTS AND DETERMINATION OF POLLEN AND SPORES

4.1 Introductory remarks

Because of the similarity between Tertiary and Quaternary palynofloras in many parts of the world, Zagwijn (1960) and Muller (1964) proposed the use of modern nomenclature for fossil pollen grains from these periods. In this study, many pollen grains remain unidentified due to a combination of lack of reference material, especially for small psilate tricolporate grains (less than 15 μm) and poorly preserved grains. Not all the pollen grains encountered could be identified with the same degree of certainty. In order to distinguish the accuracy of determination, the system outlined by Benninghoff and Kapp (1962) was used as follows. The suffix "sim" is used when the palynomorphs have a strong similarity to the identified taxon, but differ slightly from the named taxon. The suffix "comp" is used when the fossil grains compare with the modern taxon and are exactly alike, but the type originates from more than one taxon or some doubt exists about the conclusiveness of the identification. Where no suffix is given, the identification is certain.

Description of the palynomorphs is given in as much detail as possible and accompanied by photographs of the specimens at x 1000 magnification (see plates 1-16). The taxa are grouped according to their type following the terminology of Faegri and Iversen (1964). Within these groupings they are described by their generic or family names for ease of reference. The groupings also provide a basic ecological classification for the taxa e.g. primary forest, mangrove etc. A note is given of the pollination mechanism of the source taxa, as this may affect the quantity of dispersed pollen. Sometimes, however, the spectrum may also include derived pollen and the possibility of the transport of pollen downwards through the profile must also be considered (Faegri and Iversen, 1975). The majority of taxa for which the pollination mechanism is not discussed are probably entomophilous. Other factors affecting pollen dispersal are mentioned where appropriate. Apart from pollen, a great variety of microscopic plant debris may appear in preparations made for pollen analysis, like fungal and moss spores, fragments of tissues, charcoal, hairs, etc. More work has to be done on these; few of them can be used diagnostically.

4.2 Presentation of the results

The results of the palynological examinations are presented in the form of pollen diagrams, five of which are included in this study (Figures 4.1, 4.2, 4.3, 4.4 4.5, in back pocket). They are those from Cibogo, Linggar, Rancaekek, Cisaat (Bumiayu) and Trinil respectively. The first three are from ancient Bandung Lake. Pollen frequencies of all taxa are expressed as percentages of the sum of the total arboreal pollen types (ΣAP). For Cisaat (Bumiayu), the ratio between the percentages for total tree pollen (ΣAP) total herbaceous pollen (ΣNAP) and total spores (ΣFeS) are shown on the right-hand side of the diagram. In addition, for the Bandung Lake, Cisaat (Bumiayu) and Trinil diagrams, the percentages of primary and secondary arboreal pollen are also shown. In all the pollen diagrams, the pollen assemblage zones are indicated, having been characterised by their own pollen floristic composition. They are, therefore, biozones, in the sense of West (1968). This zonation was made subjectively, without the use of a computer zonation program (Gordon and Birks, 1972).

4.3 Pollen and spore descriptions

A. Type vesiculate

(1) *Dacrydium* (Podocarpaceae)

Plate 3 No 1

Description : Grains with two vesicles, length including sacci 35-57 um. Spherical body with diameter of 28-45 um and reticulate or rugulate sculpture. Vesicles extend almost laterally from the body and are often joined on the proximal side. Vesicles provided with an elongate to striate pattern (Erdtman 1957).

Remarks : Present in Bandung Lake and Cisaat (Bumiayu), at low percentages.

Source ecology : *Dacrydium* occurs commonly on high mountains in the Malay Peninsula. In Sumatra it is present in the Toba area and in the Kalimantan lowlands on Kerangas soils and in peat swamp forest. *Dacrydium* does not occur in Java today(Backer, 1965).

(2) *Podocarpus (=Dacrycarpus) imbricatus* (Podocarpaceae)

Plate 3 No 2

Description : Grains three-vesiculate, length (body and sacci) 50-80 um, vesicles irregularly coarse pseudo - reticulate, but body finely reticulate (Erdtman, 1957).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil (See Appendix 2).

Source ecology : Large forest trees, usually occurring above 1000m a.s.l. although they can occur in areas as low as 170m a.s.l. (van Steenis, 1972). They are often dominant in montane forest above 1500m a.s.l. such as on Gunung Pangrango and Gunung Gede in West Java. *Podocarpus imbricatus* is also a good pollen producer and pollination is by wind. They are also characteristic as emergent trees in West, Central and East Java. For fossil *Podocarpus* pollen, Cookson and Pike (1953) decided to include all the *Dacrycarpus* type in one generalised sporomorph *Dacrycarpites australiensis*. Muller (1966) suggested that *Dacrycarpus* is common in the lower montane forest above 1000 m a.s.l. and the present day geographical distribution of *Dacrycarpus* includes Indochina, Kalimantan, Java and New Guinea.

(3) *Podocarpus neriifolius* comp (Podocarpaceae)

Plate 3 No 3

Description : Grains with two vesiculate, length (body and sacci) 60-90 um. Body spherical to ellipsoidal, diameter 30 um, psilate, scabrate or indistinctly reticulate. Vesicles very large, regularly or irregularly psuedo-reticulate (Erdtman, 1957).

Remarks : This type of grain corresponds closely to *Podocarpus neriifolius*.but is also found in other species. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil (See Appendix 2).

Source ecology : Large forest trees occurring in hill forest above 200m (Keng, 1972) in Sumatra. They can occur at sea-level, but are abundant at 1400m in forest on mountains in Java (van Steenis, 1972). This species is probably a large pollen producer and anemophilous. It is cultivated as an ornamental tree.

(4) *Pinus* (Pinaceae)

Plate 3 No 4

Description : Grains with two vesicles. Length of body 30-39 µm and vesicles 26-34 µm. Body spherical, exine psilate with slightly scabrate to reticulate processes.

Remarks : Present in Bandung Lake and Trinil in very low percentages.

Source ecology : Native in mainland South-East Asia, Philippines and Sumatra but cultivated in Java. This type of grain might originate at long distances from the site of collection.

B. Type Inaperturate

(5) *Agathis* (Araucariaceae)

Plate 3 No 5

Description : Spherical with a diameter of 28-38 µm. Exine thick, scabrate to slightly verrucate.

Remarks : Present only in Cisaat, Bumiayu in low percentages.

Source ecology : This taxon occurs in Sumatra, Kalimantan and Eastern Indonesia, while in West Java it is frequently cultivated (Backer, 1965).

(6) Araceae (undifferentiated)

Plate 3 No 6

Description : Grains spherical, diameter 15-20 μm. Exine mostly scabrate to irregularly rugulate. This type is slightly different from *Arisaema* but could have originated from the same group of araceous taxa.

Remarks : Present only in Cisaat (Bumiayu), in low percentages.

Source ecology : Araceae occur particularly as herbs along riverbanks or in swamp forest (Backer, 1965).

(7) *Blyxa* (Hydrocharitaceae)

Plate 3 No 7

Description : Grains spherical, diameter 26-41 μm, exine finely and regularly echinate. Echinae are 1.5-2 μm in height, grains sometimes folded but are in a good state of preservation.

Remarks : Present in Bandung Lake and Cisaat (Bumiayu).

Source ecology : *Blyxa spp* occur as aquatic herbs, commonly along riverbanks, in pools, ditches or flooded rice fields, often coated with algae, mud or iron-compounds (Backer, 1965).

(8) *Cyrtospermum* comp (Araceae)

Plate 3 No 9

Description : Grains spherical, diameter 21-24 µm. Exine scabrate to irregularly rugulate. This type could have originated from a variety of araceous taxa.

Remarks : Present only in Trinil.

Source ecology : *Cyrtospermum spp* are marsh plants, sometimes occurring in swamp forests and often along riverbanks, in this case of *C. merkusii* (Backer, 1965).

C. Type Monoporate

(9) Cyperaceae (undifferentiated)

Plate 3 No 10-14

Description : Grains spherical, frequently folded, diameter 20-50 µm. Exine scabrate and very thin. Aperture mostly indistinct without an annulus.

Remarks : Cyperaceae pollen have been described by several authors and are often sub-divided into smaller taxonomic groups. No attempt was made to differentiate them here due to poor preservation. Anderson and Muller (1975) described Cyperaceae pollen from peat swamps in Marudi. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil in moderate to high percentages. (See Chapter 5, Introductory remarks).

Source ecology : Mainly as swamp herbs, in rice fields, in open, wet localities, near coasts and in cultivated fields. Also found in subalpine regions or in alpine vegetation. Wind pollinated.

(10) Gramineae (undifferentiated)

Plate 4 No 1-5

Description : Grains spherical to oblate, diameter 20-50 µm, although some are bigger. Exine psilate to scabrate, sometimes covered with punctae, very thin and sometimes folded. Pore with distinct annulus. All Gramineae have been grouped in the main pollen diagrams, but different size categories have been presented for the Trinil diagram (Figure 4.4).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil in moderate to high percentages.

Source ecology : Gramineae occur mainly as an herbaceous family in various environments, but are especially dominant in savannahs in the seasonally dry tropics, in secondary communities and in swamps. Pollination is by wind and most are self-pollinating (Erdtman, 1952). The same pollen type is produced by bamboo.

(11) *Pandanus* (Pandanaceae)

Plate 4 No 6

Description : Grains spherical to oblate, diameter 12-20 µm. Exine minutely echinate, echinae less than 1 µm in height. Pore without annulus, often indistinct (Erdtman, 1971).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil in low to moderate percentages.

Source ecology : Shrubs or trees of palm habit with prop roots or aerial roots. They occur near the beach, in littoral scrub, in swampy localities and occasionally in mountain forests in Java up to 1000 m a.s.l. Some are cultivated as ornamentals.

(12) *Typha* (Typhaceae)

Plate 4 No 8-10

Description : grains more or less spherical, diameter 25-30 µm. Exine finely but distinctly reticulate, with clear columella visible in optical section. No annulus around the pore (Erdtman, 1952).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Typha angustifolia* is a tall herb of fresh or brackish swamps. It has creeping rhizomes. Cultivated as an ornamental in Java (Backer, 1965).

D. Type Diporate

(13) *Ficus* (Moraceae)

Plate 4 No 11

Description : Grains peroblate or oblate in equatorial views. Diameter 12-14 µm. Exine thin, psilate. Pores without annuli.

Remarks : Present only in Bandung Lake at low to moderate percentages.

Source ecology : *Ficus spp* occur as trees, shrubs or herbs in forest or non-forest. According to Muller (1972, 1975) the peculiar occurrence of *Ficus* pollen must be due to its incorporation into sediment from fallen inflorescences, which break up in water then releasing the pollen.

E. <u>Type Triporate</u>

(14) *Canthium* (Rubiaceae)

Plate 4 No 12

<u>Description</u> : Grains oblate, circular in polar view, diameter 21-35 µm. Exine thick but finely reticulate, slight annuli present around pores.

<u>Remarks</u> : Present in Cisaat (Bumiayu) and Trinil in low percentages.

<u>Source ecology</u> : As trees or shrubs, along streams or throughout forests. Often found in back-mangrove environments (Backer, 1965).

(15) *Casuarina* (Casuarinaceae)

Plate 4 No13-14

<u>Description</u> : Grains oblate, semi-angular to circular in polar view. Diameter 24-36 µm. Exine fine scabrate but often rugulate. Pores circular and protruding.

<u>Remarks</u> : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil. This type includes *C. junghuhniana* and *C. equisetifolia*.

Source ecology : *C. equisetifolia* commonly occurs near the sea, usually cultivated in Java. *C. junghuhniana* occurs widely on volcanic peaks in East Java (van Steenis, 1972).

(16) *Celtis* (Ulmaceae)

Plate 4 No 15-16

Description : Grains oblate, circular in polar view, diameter 18-21 um. Exine scabrate, pores circular with annuli (Erdtman, 1952).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil in low percentages.

Source ecology : *Celtis spp* occur as tall canopy trees in lowland and submontane forest, often as unarmed or spiny erect shrubs or trees. Occur throughout Javan forests (Backer, 1965).

(17) *Durio zibethinus* comp (Bombacaceae)

Plate 4 No 17

Description : Grains oblate, circular in polar view, diameter 30-50 um, exine psilate. Pores circular (Huang, 1972).

Remarks : Present only in Cisaat (Bumiayu) in low percentages.

Source ecology : This type corresponds well with the cultivated durian, *Durio zibethinus*, planted as a fruit tree and occurs in secondary forest in Java (Backer, 1965). *Durio carinatus* is a common tree of swamp forests.

(18) *Engelhardia* (Juglandaceae)

Plate 4 No 18-20

Description : Grains with three pores, oblate, circular in polar view, diameter 15-21 um, exine psilate, very thin, often folded. Circular pores, slightly protruding without annuli.

Remarks : Present in Bandung lake and Cisaat (Bumiayu) in low percentages.

Source ecology : Tall trees of montane humid forest, in Java occur only rarely, in the West. High pollen producer and pollination is by wind (Backer, 1965).

(19) *Florscheutzia semilobata* (Sonneratiaceae)

Plate 4 No 21

Description : Grain radially symetrical, prolate in polar view, lobate, pores circular, tectum ± 1 um thick, areolate to verrucate. Sculpture coarser on meridional ridges, finer on porate fields on the poles showing a transition to a psilate polar cap. Grain diameter 23-24 µm, variable.

<u>Remarks</u> : Present only in Cisaat (Bumiayu).
F. semilobata enters the palynological record during the Lower Miocene. Although transitional specimens are scarce, it is thought to have been derived from *F. trilobata*, by morphological change from a continuous tectum to a discontinuous one, resulting in a verrucate sculpture, equally distributed over the whole grain. This species has a much more restricted distribution than *F. trilobata* and becomes extinct within the Lower Miocene. It cannot be closely matched with the pollen of any living species of Sonneratiaceae or Lythraceae, although there is a certain resemblance to the pollen of *Sonneratia griffithii* (Germeraad *et al.*, 1968).

(20) *Helicia* (Proteaceae)
Plate 4 No 22

<u>Description</u> : Grain oblate or apiculate, triangular in polar view, diameter 15-20 µm, pores without annuli. Exine psilate, slightly granulate.

<u>Remarks</u> : Present in Bandung Lake and Trinil.

<u>Source ecology</u> : In Java occurs as tall trees in mixed montane forest (Backer, 1965).

(21) *Myrica* (Myricaceae)

Plate 4 No 23-25

Description : Grains oblate, polar view semi-angular to circular, diameter 18-23 µm. Exine finely scabrate, pores circular and protruding with distinct vestibulae (Huang, 1972).

Remarks : This type is comparable to *M. esculenta* and *M. javanica*. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *M. esculenta* is common as a small tree in West and Central Java. It occurs in primary or secondary forest. The genus *Myrica* is a characteristic element of the vegetation of active craters (van Zeist *et al.*, 1979). *M. javanica* is common as a small tree throughout Java in open forest and it is often cultivated for reafforestation purposes (Backer, 1965). This species was considered by van Steenis (1965) as a climatic indicator of everwet conditions. *Myrica* is wind pollinated (Corner, 1940), producing pollen in prolific quantities.

(22) *Pometia* (Sapindaceae)

Plate 5 No 1-3

Description : Grains oblate to spheroidal with a triangular to rounded equatorial outline, diameter 19-28 µm. Exine distinctly reticulate, lumina 1 µm in diameter, columellae small but distinct. Pores protruding, provided with vestibulae (Muller, 1981).

Remarks : Protrusion of pores is often variable. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : In Java, *Pometia pinnata* occurs as large trees in lowland or submontane forest and often along streams.

(23) *Sonneratia caseolaris* (Sonneratiaceae)

Plate 5 No 4

Description : Grains prolate, circular to rounded triangular in polar view, sometimes bulging at the equator, length 26-44 µm. Exine psilate at poles, broken into a verrucate to areolate pattern in the equatorial region. Columellae visible in the equatorial exine, but absent from the polar exine. Exine generally thicker on the poles than in the equatorial area. Protruding pores, circular, 3-7 µm in diameter. The transition from the ornamented equatorial belt to the psilate polar caps is very variable. The change may be marked, or the ornament may fade out gradually. This type of grain can be distinguished from *S. alba* by the absence of meridional ridges. Variability in shape, thickness of tectum at the poles and coarseness of sculpture on the equatorial belt occurs very often. Muller (1964) describes *S. caseolaris* in detail and Germeraad *et al* (1968) point out that this species is equivalent to the fossil pollen type *Florschuetzia levipoli* which first appears in the Lower Miocene in Kalimantan.

Remarks : Present only in Cisaat, Bumiayu.

Source ecology : As a mangrove species, a pioneer tree, common near brackish waters in areas less saline than those occupied by *S. alba* (see below). Pollinated by bats.

(24) *Sonneratia alba* (Sonneratiaceae)
Plate 5 No 5

Description : Grains prolate, rounded, triangular in polar view, length 28-44 μm. The exine with distinctive intra-areolate pattern and becomes verrucate in porate fields. Meridional ridges run between the pores parallel to the polar axis. Collumellae are visible in both polar and equatorial exine. Characterised by exine thickness at the poles, sculpture coarseness and meridional ridges. Variable in shape.

Remarks : Present only in Cisaat (Bumiayu).
Germeraad *et al* (1968) described this species under its fossil name *Florschuetzia meridionalis*. This fossil occurs from the Middle Miocene in Indonesia.

Source ecology : *S. alba* is a pioneer mangrove species commonly forming a belt parallel to the coast. Pollination is by bats.

(25) *Symplocos* (Symplocaceae)

Plate 5 No 6

Description : Grains oblate, rounded, triangular in polar view, diameter 24 µm. Exine scabrate to finely reticulate. Small circular pores, protruding slightly (Huang, 1972).

Remarks : Present in Bandung Lake and Cisaat (Bumiayu).

Source ecology : Common as trees or shrubs in montane humid forests in West Java (Backer, 1965).

(26) *Trema* (Ulmaceae)

Plate 5 No 7-8

Description : Grains oblate, diameter 15-24 µm. Exine scabrate to finely reticulate. Pores circular with distinct annuli (Huang, 1972).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : Common as small trees or shrubs, occurring in primary and secondary mixed forests (Backer, 1965), but especially common in secondary forest.

F. Type Periporate

(27) *Altingia excelsa* (Hamamelidaceae)

Plate 5 No 9

Description : Grains are prolate to suboblate, diameter 25-35 µm, circular in polar view, exine reticulate to slightly scabrate with 10-14 pores.

Remarks : Present only in Bandung Lake in low percentages.

Source ecology : *Altingia excelsa* occurs as tall trees in montane forest, often cultivated as wayside trees or for reafforestation purposes.

(28) Chenopodiaceae (undifferentiated)

Plate 5 No 10-12

Description : Grains spherical or oblate, diameter 17-30 µm, more than 40 circular pores.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : McAndrews (1967) measured the distance between 2 poles (C) and the diameter of the grain (D); he found that the ratio of chord to diameter is a character of taxonomic significance and has been used in this study. He measured 35 species of *Chenopodium*. They are annual or perennial shrubs or small trees of open areas, and occur on road-sides, waste land, rice fields, gardens and are often cultivated as a vegetable oil producer in West and East Java (Backer, 1965).

(29) *Hibiscus* comp (Malvaceae)

Plate 5 No 13-14

Description : Grains spherical, with diameter of 36-58 µm, spines conical, blunt ended, 4-9 µm long, 2-3 µm thick at the base, 6-10 µm apart. Body exine scabrate to finely reticulate, thickened at roots of echinae. Pores slightly annulate, with a diameter of 4 µm. Variation in size, coarseness of wall structure and spines, density of spines and number of pores.

Remarks : Pollen grains of this type are very similar to *H. tiliaceus* and to *Thespesia spp* and other Malvaceae. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *H. tiliaceus* occurs in coastal areas on the banks of tidal rivers (Watson 1928). *Thespesia spp* are more typical of beach forest. These trees are pollinated by birds.

(30) *Polygonum* (Polygonaceae)
Plate 5 No 16-17

Description : Grains spheroidal, 33-45 µm, circular in polar view. Exine with baculate to slightly verrucate processes. Muri with clavae are irregularly distributed.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : Very common as herbs, occurring in open localities, forest borders, humid or soggy agricultural fields, dried up pools, near water (Backer, 1965).

G. Type Stephanoporate

(31) *Austrobuxus nitidus* (Euphorbiaceae)
Plate 5 No 15

Description : *Longetia nitida* was described by Punt (1962) under the *Austogeitonia* subtype. It is synonymous with *Austrobuxus nitidus* which was described by Erdtman (1952) and van Steenis (1964). Muller and Anderson (1975) found *Austrobuxus nitidus* pollen in very low percentages in the Marudi peat swamp. Grains spherical, exine echinate, diameter 25-31 µm (excluding spines), echinae 6-7 µm long and 2-3 µm wide at base. Body psilate to scabrate. Circular pores of 5 µm in diameter, annular thickening around pores which are positioned around the equator, often obscured by echinae.

Remarks : Present only in Cisaat (Bumiayu) in moderate percentages.

Source ecology : Common as trees in peat swamp forest, coasts and drylands (Backer 1965).

(32) *Strobilanthes* (Acanthaceae)

Plate 5 No 18-20

Description : Grain spheroidal (39-62 µm wide), 4-5 pores. Circular in polar view, exine granulate with LO pattern,(L = light O = obscuritas or darkness (Erdtman, 1952)). and characteristic 'ladder-like' features. LO analysis elucidated sexine details in sporoderm seen in optical section.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : Forest shrub, frequently flowering gregariously at intervals of 5-9 years. All or most specimens in the same region often flower during a few weeks, at about the same time and are then very conspicuous, commonly forming a dense undergrowth. Mostly occur in the montane forest (van Steenis 1972).

H. Type Monocolpate

(33) *Arenga* (Palmae)

Plate 6 No 1

Description : Grains plano-convex in equatorial view, oval in polar view, length 21-29 µm, exine echinate, echinae 1-2 µm in height. Becoming smaller and closely packed towards the colpus.

Remarks : Present in Cisaat (Bumiayu).

Source ecology : Tree palms, very rare in swamp forest but common in lowland forest (Backer, 1965).

(34) Liliaceae (undifferentiated)

Description : Grains subspheroidal or triangular to lobate, 12-60 µm in length. Exine scabrate to slightly verrucate.

Remarks : Present only in Bandung Lake.

Source ecology : The Liliaceae family occurs as herbs no taller than 1 m. New individual develops on stolons in humid forest and in shaded places (Backer, 1965).

(35) *Nuphar* (Nymphaeaceae)
Plate 6 No 5-6

Description : Grains subprolate to spheroidal, circular in polar view. Exine psilate with echinate processes. Length of grain 25-35 µm.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : These perennial freshwater plants are mostly floating or raised above the water. *Nuphar spp* are commonly cultivated.

(36) *Nypa* (Palmae)
Plate 6 No 4

Description : Grains suboblate to spherical, length 28-50 µm. Exine finely reticulate with scattered echinae. Echinae 3-5 µm long. The grains are distinguished by a continuous equatorial colpus.

Remarks : This pollen has been described by Muller (1964) and Thanikaimoni (1970). The equivalent form species is *Spinizonocolpites echinatus*, according to Muller (1968) and Germeraad *et al* (1968), which occurs from the upper Cretaceous. Present only in Cisaat (Bumiayu).

Source ecology : *Nypa fruticans* is at present restricted to swampy saline soils along sea shores and rarely occurs beyond the littoral zone.

(37) *Oncosperma* (Palmae)
Plate 6 No 7

Description : Grains plano-convex in equatorial view, oval in polar view, length 26-29 µm. Exine clavate to baculate. Elements 2-3 µm high and 1 µm thick, scattered over the surface. Meridinosulcate colpus extending the length of the grain (Haseldonckx, 1977).

Remarks : Present only in Cisaat (Bumiayu).

Source ecology : Very common in back-mangroves, where the water is still saline but with an influence of fresh water (Wyatt-Smith, 1963).

(38) Palmae (undifferentiated)
Plate 6 No 8

Description : Grain elliptical in polar view, length 66 µm, width 52 µm. Exine psilate or finely distinctive as reticulate to rugulate.

Remarks : Present only in Cisaat (Bumiayu).

Source ecology : Probably forest palm trees (Thanikaimoni, 1970).

(39) *Avicennia* (Verbenaceae)

Plate 6 No 9

Description : Grains prolate to spherical, diameter 24-28 µm. Circular in polar view, exine reticulate with slightly verrucate processes.

Remarks : Present in moderate abundance in Cisaat (Bumiayu).

Source ecology : *Avicennia* spp commonly occur in mangrove swamps, along riverbanks and more saline areas and along the banks of tidal streams (Muller, 1964).

I. Type Tricolpate

(40) *Dipterocarpus* (Dipterocarpaceae)

Plate 6 No 10-12

Description : Grains oblate, circular in polar view, diameter 35-54 µm. Exine distinctly reticulate with lumina ca. 1 µm in diameter.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : Tall trees of lowland forest, occasionally found up to 1000m a.s.l. (Backer 1965). The Dipterocarpaceae are an important family which dominate lowland forest or drylands and sometimes peat swamps. They are low pollen producers. Important genera are *Dryobalanops*, *Dipterocarpus*, *Shorea*, *Vatica* and *Hopea*. *Dryobalanops* and *Dipterocarpus*, can be separated from *Vatica*, *Hopea* and *Shorea* on the basis of size. Muller (1975) described that *Dipterocarpus* is the largest in size (30-60µm, Morley, 1976), *Dryobalanops* intermediate in size (50 µm) and *Shorea* and other genera small (25 µm).

(41) *Dryobalanops* (Dipterocarpaceae)
Plate 6 No 13

Description : Grains spherical to prolate, length 26-29 µm. Exine finely reticulate with columellae.

Remarks : Present only in Cisaat (Bumiayu).

Source ecology : Occur as large trees in lowland forest particularly along riverbanks (Backer, 1965). *Dryobalanops rappa* is the only species of the genus found in peat swamps in Marudi (Muller 1975).

(42) *Geranium* (Geraniaceae)

Plate 6 No 14

Description : Grains are prolate to spheroidal of 50-105 µm diameter and circular in polar view. Exine reticulate with clavate processes.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : Known as annual to perennial herbs which occur in montane forests, on old walls, rocks or roadsides (Backer, 1965).

(43) *Ilex* (Aquifoliaceae)

Plate 6 No 15-16

Description : Grains oblate to spherical, diameter 17-30 µm. Exine thick, gemmate or short baculate processes, showing considerable size range (height 2-3 µm common); long colpi.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : Occur as trees, shrubs or epiphytes on trunks in montane forest of West Java (Backer, 1965). Occasionally growing in gullies, it also frequents swamps and secondary communities (Wyatt-Smith, 1964).

(44) Plumbaginaceae (undifferentiated)

Plate 6 No 17

Description : Grains oblate to spherical, diameter 48-67 µm, exine thick with scabrate processes, long colpi, circular in equatorial view.

Remarks : Present only in Cisaat (Bumiayu). This type is close to *Plumbago*.

Source ecology : Occur as under shrub or herbs, very frequently cultivated in Java as an ornamental. Native in continental Asia. Locally occurring as an escape, in *Imperata* fields, in brushwood or on village graves (Backer, 1965). Practically the whole Southeast Asia region during the Tertiary shows humid tropical conditions with the occurrence of a number of mangrove species such as *Rhizophora*, *Sonneratia*, *Avicennia* and Plumbaginaceae (*Aegialites*) which points to the presence of seashore conditions (Bande and Prakash, 1986).

(45) *Quercus* (Fagaceae)

Plate 6 No 18-19

Description : Grains spherical to prolate, length 18-32 µm in polar view sometimes trilobed. Exine scabrate, colpi long and thin.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Quercus spp* are widespread in occurrence as monoecious shrubs or trees, particularly in humid or mixed forest (Backer, 1965).

(46) *Shorea* (Dipterocarpaceae)

Plate 6 No 20

Description : Grains oblate to spherical, diameter 18-40 μm. Exine scabrate to finely reticulate. Long and narrow colpi with a small polar area index.

Remarks : Present only in Cisaat (Bumiayu).

Source ecology : In Sumatra and Java, *Shorea spp* are tall trees of lowland to submontane forest up to 1500m (van Steenis, 1934).

J. Type Syncolpate

(47) *Barringtonia* (Lecythidaceae)

Plate 6 No 21

Description : Grains prolate, length 28-54 um, exine psilate or finely reticulate, colpi crassimarginate, prominently reticulate along thickened colpi margins (Kubitzki 1965; Venkatachala and Kar, 1968; Payens, 1967).

Remarks : This type of grain is close to *B. spicata*.

Source ecology : Occur as tall trees, particularly of coastal and riparian vegetation. Common in secondary forest, pollination possibly by bats (Whitmore, 1973).

(48) *Eugenia* comp 1 (Myrtaceae)
Plate 7 No 1-3

Description : Grains oblate, triangular to circular in polar view. Diameter 13-15 um, exine psilate. Apocolpium and colpi distinct.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Eugenia spp*, *Syzygium spp* and *Tristanea spp* occur as shrubs or trees in swamp or dryland areas. Also common in upper montane forest.

(49) *Eugenia* comp 2 (Myrtaceae)

Plate 7 No 4

Description : Grains oblate to suboblate, diameter 20-26 µm. Semiangular in polar view, exine psilate to slightly granulate.

Remarks : Present only in Trinil in moderate percentages.

Source ecology : This grain is close to *Syzygium* spp, which occur as trees in forest at lower altitudes (Backer, 1965).

K. Type Stephanocolpate

(50) *Acrocephalus* (Labiatae)

Plate 7 No 5

Description : Grains spheroidal to subprolate 22-24 µm. Circular in polar view, diameter 25-30 µm, exine finely reticulate to scabrate.

Remarks : Present only in Trinil.

Source ecology : Occurs as herbs in agricultural fields and along roadsides.

L. <u>Type Tricolporate</u>

(51) *Ageratum* comp (Compositae)

Plate 7 No 6

<u>Description</u> : Grains oblate to subspheroidal, circular or inter-semi-angular in polar view. Exine psilate with echinate of 2 μm in height. Diameter 15-18 μm.

<u>Remarks</u> : Present in Trinil.

<u>Source ecology</u> : Occur as herbs, smell of cumarine, mostly at high altitudes in fields, plantations, near water and along roadsides (Backer, 1965).

(52) *Alangium* (Alangiaceae)

Plate 7 No 7

<u>Description</u> : Grains oblate, circular to subangular in polar view, diameter 40-52 μm. Exine reti-rugulate often with warty elements, ectoapertures of moderate length widest at equator. Endoapertures pori, lalongate 10 μm in diameter with thickened costae.

<u>Remarks</u> : This grain is close to *A. ebenaceus* and its form agrees with the fossil species *Lanagiopollis nanggulanensis* which is described in detail by Morley (1982) and is common in the Middle - Late Eocene of the

Nanggulan Beds, Central Java. In Java *A. rotundifolium* occurs as trees in montane forest. Present in Cisaat (Bumiayu).

Source ecology : According to Morley (1982), *A. ebenaceus* frequently occurs in coastal or riparian habitats; he points out that *Alangium* is a low pollen producer. *Alangium havilandii* was described by Reitsma (1970) as a species from the peat swamp.

(53) *Bischofia* (Euphorbiaceae)

Plate 7 No 8-10

Description : Grains spheroidal to subprolate, 20-25 µm long, circular in polar view. Exine scabrate to slightly/finely reticulate.

Remarks : Present in Trinil in low percentages.

Source ecology : This tall tree commonly occurs in montane mixed forest or teak forest (Backer 1965).

(54) *Bombax* sim (Bombacaceae)

Plate 7 No 11

Description : Grains oblate, diameter 25-48 µm, circular to subangular in polar view, exine thick, scabrate to finely reticulate, short colpi (Van der Hammen, 1954).

Remarks : Present in Cisaat (Bumiayu). The first occurrence of the genus *Bombax* can be dated as Paleocene in the Carribean area and Paleocene - Eocene in Nigeria. *Bombax ceiba* becomes rare during the Eocene in Nigeria (Germeraad *et al* 1968). According to Davis (1967) the grain size of dry *Bombax* is 32.8-65.2 µm. Fuchs (1967) identified the palynomorphological characteristics to distinguish the family Bombacaceae. He examined a number of genera which he decided should be transferred to the families Sterculiaceae, Malvaceae and Tiliaceae. The family Bombacaceae now seems to be one of the palynomorphologically best known families. The Bombacaceae family is one of the important components of stratigraphic palynology. It was widely distributed during the Tertiary. For their importance in the investigation of stratigraphic palynology in the tropics, Tsukada (1964) studied modern and fossil pollen of Bombacaceae. The time span of its geological distribution was from Lower Paleocene to Pleistocene.

Source ecology : *Bombax spp* are mostly cultivated as ornamental trees in Java (Backer, 1965). In Kalimantan, *Bombax valetonii* occurs commonly in primary or secondary forest.

(55) *Brugueria* comp (Rhizophoraceae)

Plate 7 No 12

Description : Grains oblate to spherical, diameter 13-19 µm, semiangular to circular in polar view, vestibulae aperture and transversal colpus. Exine psilate to finely reticulate (Kubitzki, 1965).

Remarks : Present in Cisaat (Bumiayu) in low percentages.

Source ecology : *Brugueria spp* are mostly tall trees along coastal fish ponds in Java or occurring in mangrove forest (Backer,1965).

(56) *Buchanania* (Anacardiaceae)

Plate 7 No 13

Description : Grains prolate to subprolate, 23-35 µm diameter. Circular or semi-circular in polar view, pore or aperture drop type. Exine scabrate with striato-reticulate processes (Huang, 1972).

Remarks : Present in Bandung Lake.

Source ecology : *Buchanania spp* occur as trees in open forest, along forest borders or along riverbanks.

(57) *Calophyllum* (Clusiaceae)

Plate 7 No 14-15

Description : Grains suboblate to spheroidal with diameter 23-45 μm, circular or semi-angular in polar view. Exine scabrate to finely reticulate.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : *Calophyllum spp* occur as large trees in forests, especially around the margins. Common in peat swamp and beach forests, and also cultivated as shade trees or as ornamental trees in Java.

(58) *Castanopsis* comp (Fagaceae)

Plate 7 No 16-18

Description : Grains prolate, length 21 μm, width 12-15 μm. Exine psilate, but at high power a slight reticulum can be observed at the poles. Long and thin colpi with small pores, extended in an equatorial direction (Muller, 1964, Flenley, 1967).

Remarks : This type is most similar to *Lithocarpus spp* present in Bandung Lake and Cisaat (Bumiayu).

Source ecology : Common trees of lowland and montane forest, usually in primary forest (Backer, 1965).

(59) Compositae/Tubuliflorae (undifferentiated)

Plate 7 No 19-23

Description : Grains spherical, diameter 28 µm (including spines). Echinae regularly spaced over exine surface, echinae 3-5 µm high, colpi obscured by echinae.

Remarks : Present in Bandung Lake and Cisaat (Bumiayu).

Source ecology : Probably herbs or trees of open areas. This family is widely distributed in Java and sometimes cultivated as ornamentals (Backer, 1965).

(60) Cruciferae (undifferentiated)

Plate 7 No 24

Description : Grains prolate to suboblate, diameter 14-32 µm. Circular-oblate or intersemilobate in polar view, colpi mostly long. Exine reticulate or scabrate with baculate or clavate processes.

Remarks : Present in Bandung lake.

Source ecology : Annual or perennial, terrestrial or aquatic herbs often with watery sap. Very commonly cultivated in Java as vegetables or as ornamental plants (Backer, 1965).

(61) *Desmodium* comp (Leguminosae)

Plate 7 No 25

Description : Grains prolate to oblate, 19-42 µm long. Circular to semi-angular in polar view. Exine with scabrate to reticulate processes.

Remarks : Present in Trinil.

Source ecology : Occur as shrubs in dry grassy fields, periodically in teak forest, in secondary forest on dry clay and sometimes along roadsides (Backer, 1965).

(62) *Dodonaea* (Sapindaceae)

Plate 7 No 26

Description : Grains prolate to spheroidal, circular in polar view, pores drop type (Huang, 1972), exine psilate, slightly granulate and 26-33 µm in diameter.

Remarks : Present in low percentages.

Source ecology : *Dodonaea* occur as erect shrubs in open forest, in montane forest and sometimes on sandy or rocky beaches (Backer, 1965). In Uganda, *Dodonaea viscosa* has great powers of withstanding fire even in dry rocky localities (Eggeling and Dale, 1951).

An excellent hedge can be made from *Dodonaea* and the genus is especially useful for this purpose in dry regions, where other species do not thrive.

(63) Euphorbiaceae (undifferentiated)

Plate 8 No 3

Description : Grains oblate, diameter 32-56 µm, circular to sub-angular in polar view, variation of colpi in length and thickness of margin. Exine psilate to scabrate.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu).

Source ecology : This type of grain is usually produced by herbs, shrubs or trees in forest and is close to *Antidesma spp* (Punt 1962).

(64) Euphorbiaceae type 1

Plate 8 No 1

Description : Grains spherical to prolate, diameter 39-45 µm, circular in polar view, exine psilate to slightly scabrate with short baculae.

Remarks : Present in Trinil, in low percentages.

Source ecology : This grain is similar to *Codiaeum spp* and usually occurs in common forest (Punt, 1962).

(65) Euphorbiaceae type 2

Plate 8 No 2

Description : Grains spherical to prolate, diameter 33-46 µm, circular in polar view, exine thick with coarse reticulum and long spines.

Remarks : Present in Trinil in very low percentages.

Source ecology : This grain is similar to *Amanoa spp* and usually occurs in common forest (Punt, 1962).

(66) *Garcinia* comp (Clusiaceae)

Plate 8 No 6

Description : Grains prolate to spheroidal, circular in polar view, exine scabrate to granulate, with a diameter of 20-26 µm.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : *Garcinia spp* commonly occur as large trees in forests, mixed teak forest and open forest. Occasionally cultivated in Java below 500m a.s.l.

(67) *Grewia* (Tiliaceae)

Plate 8 No 7-8

Description : Grains spherical to prolate, length 38-57 µm. Exine coarsely reticulate with thick walls. Colpi long and thin with large circular lalongate pores which are characteristic of this type of pollen (Huang, 1972).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Grewia spp* are common as trees, shrubs or climbers and occur in open mixed forest in dry areas. Particularly common in the secondary forests of Java (Backer, 1965).

(68) *Ixora* (Rubiaceae)

Plate 8 No 9-10

Description : Grains oblate to prolate, diameter 19-25 µm, circular to semi-angular in polar view. Colpi crassimarginate. Exine verrucate and finely reticulate with regular luminae.

Remarks : Present in Trinil.

Source ecology : *Ixora spp* occur as small trees in forests; as shrubs they are often cultivated as ornamentals.

(69) *Justicia* comp (Acanthaceae)

Plate 8 No 11-13

Description : Grains prolate to subprolate 25-34 µm long, circular in polar view. Exine scabrate, areoles studded along the colpi.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : *Justicia spp* occur as erect shrubs, but related genera producing the same pollen type are herbs. Characteristic of wetland environments but also cultivated in Java as hedges (Backer, 1965). The form species for *Justicia spp* is *Multiareolites formosus*. This fossil occurs in the Upper Miocene and Pliocene of the Indo-Malesian region (Germeraad *et al*, 1968).

(70) Leguminosae (undifferentiated)

Plate 8 No 14

Description : Grains oblate, diameter 25-35 µm, circular to semi-angular in polar view. Exine psilate to scabrate (Huang, 1972).

Remarks : Present in Bandung Lake and Cisaat (Bumiayu). Leguminosae are also discussed by Germeraad *et al* (1968). Some species, from genera such as *Crudia*, are locally common in swampy areas, but not in peat swamps (Whitmore, 1972).

Source ecology : This pollen has not been positively determined to generic level. Many types are forest trees and many of the Leguminosae are cultivated (Backer,1965).

(71) *Macaranga* (Euphorbiaceae)

Plate 8 No 15

Description : Grains oblate to spherical, diameter 12-22 µm. Exine psilate to scabrate. Colpi narrow, colpi transversales very long, almost zonate (Punt, 1962).

Remarks : Present in Cisaat (Bumiayu) and Trinil.

Source ecology : *Macaranga spp* are trees which occur in non-forest vegetation and in swamp forest. Often at the margins of these habitat types (Backer, 1965).

(72) *Mangifera* (Anacardiaceae)

Plate 8 No 16

<u>Description</u> : grains prolate, circular in polar view, exine thickly scabrate to finely reticulate. Diameter 26-35 µm (Huang, 1972).

<u>Remarks</u> : Present in Cisaat (Bumiayu).

<u>Source ecology</u> : Trees, occurring in forests, sometimes in swamp forest and often cultivated as a fruit tree (Backer, 1965).

(73) *Myrsine* (Myrsinaceae)

Plate 8 No 17

<u>Description</u> : Grains prolate to spheroidal, circular in polar view, diameter 22-25 µm. Exine psilate to fine reticulate.

<u>Remarks</u> : Present in Bandung lake.

<u>Source ecology</u> : Mostly occur as trees in montane forest.

(74) *Neesia* (Bombacaceae)

Description : Grains oblate, circular to triangular in polar view, diameter 42-54 μm. Comparable with *Durio* in aperture structure, but differ in having a finely reticulate ornament (Muller, 1964).

Remarks : Present in Cisaat (Bumiayu).

Source ecology : Mostly found in lowland swamp forest in Java. This type of grain is close to that of *N. altissima* which occurs in moist forest (Backer, 1965).

(75) *Neonauclea* comp (Rubiaceae)
Plate 8 No 19-20

Description : Grains suboblate to prolate, diameter 13-19 μm. Exine fine scabrate to reticulate, circular to semi-angular in polar view.

Remarks : Present in Trinil.

Source ecology : *Neonauclea spp* and related genera occur as trees in lowland and montane humid forest or teak forest and in regrowth vegetation, especially in primary forest. They are sometimes cultivated for reafforestation in Java (Backer, 1965).

(76) *Pluchea* comp (Compositae)

Plate 8 No 21

Description : Grains subspheroidal, 19-30 µm in diameter, exine psilate-echinate with 2-2.5 µm high spines.

Remarks : Present in Trinil.

Source ecology : *Pluchea spp* occur as erect shrubs along the coast of Java. Often near salt springs or shaded localities. In lowland areas mostly cultivated as medicinal plants or as hedge plants.

(77) *Randia* (Rubiaceae)

Plate 8 No 22

Description : Grains spheroidal to suboblate 13-34 µm in diameter, circular to semi-angular in polar view, pores circular, 2 µm diameter. Exine scabrate to finely reticulate.

Remarks : Present in Bandung Lake.

Source ecology : *Randia spp* occur as trees, climbing or erect shrubs in mixed forest, on rocky soils and limestones. In Java, also cultivated as an ornamental (Backer, 1965).

(78) *Rhizophora* (Rhizophoraceae)

Plate 8 No 23

Description : Grains prolate to spherical, length 20-26 μm. Exine psilate to scabrate very often the poles are coarser than the equatorial region. Medium length of colpi, colpi transversales characteristically zonate with distinct costae.

Remarks : Present in Cisaat (Bumiayu). Muller, (1964); Kubitzki, (1965) and Muller and Caratini (1975) described this type of grain in detail.

Source ecology : The characteristic trees of mangrove tropical coasts are *Rhizophora* . The optimum development of this taxon can be found in deltas and riverbanks or on unconsolidated clayey to sandy soils in marine to brackish environments. *Rhizophora spp* pollen can be transported in a seaward direction by water and also carried by wind. However, they are usually conserved in fine grained marine sediments.

(79) Rosaceae (undifferentiated)

Description : Grains prolate to oblate, diameter 16-35 μm. Circular or semi-angular in polar view. Exine scabrate or striato-reticulate.

<u>Remarks</u> : Present in Trinil.

<u>Source ecology</u> : Rosaceae occur as creeping or climbing, annual or perennial shrubs or trees in open forest, at forest edges and in mountain regions. Also cultivated as fruit trees (Backer, 1965).

(80) Rubiaceae (undifferentiated)

Plate 8 No 18, 24

<u>Description</u> : Grains oblate to prolate, diameter 40-50 µm. Circular to semi-angular in polar view. Exine psilate to scabrate. Sexine reticulate or granulate (Huang, 1972).

<u>Remarks</u> : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

<u>Source ecology</u> : Rubiaceae occur as terrestrial epiphytic, climbing herbaceous or woody plants. Common trees in lowland and submontane forest (Backer, 1965).

(81) *Schefflera* (Araliaceae)

Plate 9 No 1

<u>Description</u> : Grains spherical to prolate, length 17-28 µm. Exine scabrate to finely reticulate. Colpi distinct, narrow and long. Colpi transversales thicker than colpus,

long (18-27µm x 8-12µm) with costae polar edges and diffuse ends. Polar area index small (Huang, 1972).

Remarks : Present in Cisaat (Bumiayu).

Source ecology : Very common in swamp forest (Backer, 1965).

(82) *Schoutenia* (Tiliaceae)

Plate 9 No 2

Description : Grains oblate, circular in polar view, diameter 32 µm. Exine echinate, echinae small, height of echinae greater than basal width and sparsely distributed. Body finely reticulate to scabrate between spines. Annuli present around pores. Colpi nearly as long as pore axes.

Remarks : Present in Trinil.

Source ecology : Common trees of lowland forest, often occurring gregariously by streams.

(83) Theaceae (undifferentiated)

Plate 9 No 3, 7

Description : Grains prolate, diameter 16-56 µm, circular to semi-angular in polar view. Exine psilate to scabrate.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : In Java this family occur as trees or shrubs in humid forest, sometimes cultivated in grassy jungles, on volcanic soils, near craters, often in secondary forest and subalpine situations (Backer, 1965).

(84) Umbelliferae (undifferentiated)
Plate 9 No 4-5

Description : Grains oblate to spherical, diameter 14-27 µm, circular in polar view. Exine scabrate to finely verrucate.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : Members of this family are mostly cultivated as aromatic herbs in kitchen gardens, occur commonly in mountain regions and around pools (Backer, 1965).

(85) *Uncaria* (Rubiaceae)
Plate 9 No 6

Description : Grains spherical to subprolate, trilobed in polar view, diameter 18-20 µm. Exine scabrate, colpi medium length, curving toward the poles. Colpi transversales are short and indistinct.

Remarks : Present in Cisaat (Bumiayu).

Source ecology : *Uncaria spp* are very common as climbing herbs of open areas and in swamp forest (Backer, 1965).

M. Type Stephanocolporate

(86) *Lasianthus* (Euphorbiaceae)

Description : Grains prolate to spheroidal, 55-75 µm diameter, circular to semi-angular in polar view. Exine verrucate to reticulate.

Remarks : Present in Bandung Lake.

Source ecology : *Lasianthus spp* occur as small trees in montane forest or in secondary forest (Backer, 1965).

(87) Meliaceae (undifferentiated)
Plate 9 No 8

Description : Grains subprolate to suboblate, 13-48 µm diameter, exine psilate to finely reticulate.

Remarks : Present in Bandung lake.

Source ecology : The family Meliaceae occur as trees in montane and lowland forest, sometimes cultivated in the lowlands or planted as shade trees.

(88) *Melastoma* (Melastomataceae)

Description : Grains oblate to spheroidal, 20-24 µm in diameter, exine psilate to slightly scabrate.

Remarks : Present in Bandung Lake.

Source ecology : *Melastoma spp* occur as shrubs and trees in montane forest, sometimes near solfataras (Backer, 1965), and in secondary vegetation.

(89) *Memecylon* comp (Melastomataceae)

Plate 9 No 9

Description : Grains oblate to subprolate, diameter 15-18 µm, circular in polar view, exine psilate, six thin colpi.

Remarks : Present in Cisaat (Bumiayu).

Source ecology : Trees or shrubs which occur in shady forest, sometimes open forest or young forest (Backer, 1965). This genus, *Memecylon*, (from the family Melastomataceae), occurs in freshwater swamp forest as *M. monchyanum* (Backer, 1965).

(90) *Palaquium* comp (Sapotaceae)
Plate 9 No 10

Description : Four colporate grains with a subprolate outline in equatorial view, length 25-40 µm. These grains have straight sides with rounded poles. The exine is thick, psilate, scabrate or faintly reticulate. Colpi are thin and of medium length, ellipsoidal colpi transversales.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Palaquium* comp are tall trees of swamp, coastal and lowland rain forest extending to mountain forest up to 1800m a.s.l. (Backer, 1965).
Anderson and Muller (1975) described this taxon as a common swamp genus.

(91) *Phyllanthus* (Euphorbiaceae)
Plate 9 No 11

Description : Grains prolate to spheroidal, circular in polar view. Exine with scabrate to finely reticulate processes, diameter 10-12 µm (Punt, 1967).

Remarks : Present in Bandung Lake and Trinil.

Source ecology : *Phyllanthus spp* occur as shrubs in shady primary forest and also in secondary teak forest. In Java, members of the genus are cultivated as fruit trees (Backer, 1965).

N. Type Pericolporate

(92) *Polygala* (Polygalaceae)

Description : Grains spheroidal to prolate, diameter 28-36 µm, exine psilate to slightly granulate 10-12 furrows.

Remarks : Present in Trinil.

Source ecology : *Polygala spp* occur as erect shrubs or herbs in forests, along earth walls and roadsides and in Java mostly cultivated for oleiferous seeds (under the fancy name of *P. oleifera)*.

O. Type Tetrads

(93) *Vaccinium* (Ericaceae)
Plate 9 No 12-13

Description : Grains united in tetrahedral tetrads, diameter 17-27 µm. Individual grains are very closely united, imparting a semi-angular shape to the tetrad.

Exine psilate. Each grain has tricolporate apertures with annular thickenings around pores.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Vaccinium spp* are very common as shrubs and often occur as epiphytes in dryland and swamp environments (Backer, 1965).

(94) *Gardenia* (Rubiaceae)

Plate 9 No 14

Description : Tetrad grains, 32-48 µm in diameter, individual grains triporate, circular in polar view, circular annulate pores. Exine psilate to slightly granulate.

Remarks : Present in Bandung Lake.

Source ecology : *Gardenia spp* occur as erect shrubs or small trees. Native from New Guinea, Malay peninsula, Sumatra and Kalimantan, but in Java now cultivated as an ornamental tree in gardens (Backer, 1965).

P. Type Polyads

(95) *Acacia* comp (Leguminosae)

Plate 9 No 15

Description : Grains commonly united in groups of sixteen, with diameter 32-35 µm. Apertures of individual grains are porate but are generally not clearly visible (Huang 1972).

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil. Pollination is by insects.

Source ecology : Occur as lianas, shrubs or trees in forest, often cultivated.

(96) *Albizia* comp (Leguminosae, Huang 1972 or Mimosaceae, Backer 1965)

Plate 9 No 16

Description : Grains with 16 united cells, diameter 87 µm, exine psilate to slightly granulate.

Remarks : Present in Trinil.

Source ecology : *Albizia spp* occur in secondary open forest. Frequently cultivated for reafforestation, shade trees or wood supply (Backer, 1965).

Q. Type Monolete

(97) *Cyclosorus*

Plate 10 No 1

Description : Spores plano-convex in lateral view, length 27-34 um. Surface distributed with echinae (Nayar and Devi, 1964).

Remarks : Spores were present in Cisaat (Bumiayu).

Source ecology : *Cyclosorus spp* are common terrestrial ferns in the ground cover of swamp forest.

(98) *Davallia*

Plate 10 No 2-4

Description : Spores plano to concavo - convex in lateral view, length 22-57 um. Exine areolate, areolae variable in size.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Davallia spp* occur as epiphytic ferns in swamp forest and dry land rain forest.

(99) *Filices areolate*

Plate 10 No 5-6

Description : spores plano-convex in lateral view, length 23-47 um, exine areolate. Areolae very large, producing irregular outline of grain. Most of this group are areolate because they have lost their exosporum.

Remarks : Present in Cisaat (Bumiayu).

Source ecology : This genus occurs in practically every ecological niche. It is, however, most likely that the majority of fossil spores in this group originate from terrestrial swamp ferns or epiphytes.

100) Undifferentiated Monolete spores

Plate 11 No 1-10, 12

Description : This monolete spores group included those with clavate, short echinate, verrucate, scabrate, and grossly or finely echinate ornaments. Spores plano-convex in lateral view, length varying between 17-45 um.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : Common epiphytic ferns of swamp and dryland forest.

101) *Sphenomeris* comp

Plate 10 No 8

Description : Spores plano-convex in lateral view, length 30-58 um. Exine psilate, scabrate to rugulate with a regular psilate thickened flange (4-7 um wide).

Remarks : Present in Cisaat (Bumiayu).

Source ecology : *Sphenomeris spp* are local swamp or forest ferns (Holttum, 1954).

102) *Stenochlaena areolaris* (Dennstaedtiaceae)

Description : Spores plano-convex in lateral view, length 35-60 um, exine thin, psilate to scabrate with discrete echinate projections. Average length of spines is less than 10 um. The processes occur in various shapes: blunt, acute, bifurcate and digitate. Laesura accompanied by lip-like exinal folds and tapering with rounded ends.

Remarks : Muller (1972) observed *Stenochlaena areolaris* in Pliocene sediments from Sarawak. *S. areolaris* was common in Kalimantan in the Miocene and disappeared during the Pliocene. Playford (1982) described *S. areolaris* as *Scolocyamus magnus*. Present in Cisaat (Bumiayu).

<u>Source ecology</u> : *Stenochlaena areolaris* is currently restricted to the Philippines and Eastern Indonesia and grows in the uplands on *Pandanus spp* and is an epiphytic fern.

103) *Stenochlaena laurifolia* (Dennstaedtiaceae)

Plate 10 No 10

<u>Description</u> : Spores concave-convex in lateral view (Nayar and Devi, 1964), length 35-47 um. Exine verrucate, verrucae arranged uniserially to form knobbly ridges running parallel to the convex outline of the spore. Variability exists in size and coarseness of the sculpture.

<u>Remarks</u> : The spore *S. laurifolia* is equivalent to the form species *Stenochlaenidites papuanus* (Khan, 1976a). In Java *S. laurifolia* appears in the Upper Miocene and disappears by the Quaternary (Morley 1978). Present in Cisaat (Bumiayu).

<u>Source ecology</u> : *S. laurifolia* is at present a fern of "alluvium" forest extant in the Philippines and New Guinea, but extinct in the Sunda region.

104) *Stenochlaena palustris* (Dennstaedtiaceae)

Plate 10 No 7, 9, 11

Description : Spores plano-convex in lateral view or slightly concave in proximal outline and length 24-45 um. Exine verrucate, often cone-like and randomly distributed on surface.

Remarks : *S. palustris* is equivalent to the fossil form species *Verrucatosporites usmensis* which is described by Germeraad *et al* (1968). The authors report it in Kalimantan from the middle to upper Eocene onwards. *S. palustris* is present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *S. palustris* is a climbing fern of secondary forest, common in disturbed forest or open areas. Anderson and Muller (1975) note that this type of fern is abundant on the margins of peat swamps, especially on shallow coastal peat.

R. Type Trilete

105) *Acrostichum*

Plate 12 No 2

Description : Very large spores with a convex - triangular outline in polar view, diameter 69 um. Exine psilate to scabrate, mostly found in a good state of preservation. Laesurae are short, not reaching the apices. This grain is similar to *A. aureum* (Anderson and Muller, 1975).

Remarks : Present in Cisaat (Bumiayu) and Trinil.

Source ecology : This species is characteristic of the mangrove environment.

106) *Ceratopteris*

Plate 12 No 7

Description : Rounded, triangular, trilete and striate spore (Kremp and Kawasaki, 1972). Large spore with thin perine, the outer most granular layer and a thick exine faintly subdivided into c.f. sexine (parallel ridges separated by U shaped valleys) and c.f. nexine of equal thickness throughout. The sexine has a fine granular structure (Erdtman 1957).

Remarks : Present in Cisaat (Bumiayu).

Source ecology : *Ceratopteris thalictroides* is a small fern which grows in aquatic habitats.

107) *Cyathea* comp

Plate 12 No3-6

Description : Spores triangular, generally with straight or concave sides, rarely with convex borders. Diameter 29-48 um. Exine psilate, laesura long, attaining the equatorial margin and with flange-like or lip-like margo.

Remarks : Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *Cyathea spp* are tree ferns common in forest and non-forest, but predominating in montane vegetation (Johnson, 1960; Holttum, 1963).

108) *Lycopodium*

Description : Spores rounded, triangular to circular in polar view, diameter 21-26 um. Exine psilate on proximal face and rugulate on distal face. Laesura medium length.

Remarks : Present in Bandung lake, Cisaat (Bumiayu) and Trinil.

Source ecology : This type is close to *L. cernuum* which is common as a herb of non-forest and swamps (Johnson, 1960).

109) *Lycopodium phlegmaria*

Plate 12 No 8

Description : Spores rounded, triangular in polar view, diameter 28-50 um. Exine sparsely foveolate. Laesura long.

Remarks : Both *L. phlegmaria* and *L. pinifolium* produce this spore type. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : *L. phlegmaria* is a common epiphyte growing on swamp or dry land forest trees. Anderson and Muller (1975) record this type from their phasic community I.

110) Undifferentiated Trilete spores

Plate 15 No 1-13

Description : This trilete spore group includes spores with psilate, verrucate and echinate processes. Spores rounded, triangular in polar view, diameter variable.

Remarks : Present in Bandung Lake and Cisaat (Bumiayu).

Source ecology : Probably climbing ferns which may also be present in local herbaceous vegetation.

111) *Lygodium*

Plate 12 No 9-10

Description : Spore rounded, triangular in polar view, convexo-convex in lateral view, with a diameter of 50 um (Nayar *et al*, 1964). Exine coarsely striate, becoming elongate on the proximal face and up to 5 um long. Exine are very thick, laesura are long, almost reaching apices.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : These species are common climbing ferns of swamp communities. They may also be present in herbaceous and regrowth vegetation.

112) *Pteris spp*

Plate 13 No 1-12

14 No 2-5

Description : In general *Pteris* spores are rounded, triangular or circular, of diameter 35-50 um.

Remarks : Nayar and Devi (1966) determined *Pteris* spores to species level. Because of the absence of a comprehensive reference collection of Pteridophyte spores, however, determination was impossible here. Present in Bandung Lake, Cisaat (Bumiayu) and Trinil.

Source ecology : This taxon shows a wide ecological distribution but is usually found occupying well drained and forest areas. Generally, *Pteris spp* are abundant in disturbed areas, especially on old walls and on rocks (Holttum, 1968). According to Morley (1980), however, *Pteris longipinnula* occurs in forest in the Kerinci area.

113) *Selaginella*

Description : Spores rounded, triangular to circular in polar view and a diameter of 22 um. Exine clavate, clavae of variable size, reaching up to 4 um high.

Remarks : Present in Bandung Lake and Trinil.

Source ecology : This fern type, *Selaginella spp* is common to swamp and lowland montane forest (Johnson, 1960).

4.4 Description of Dinoflagellates

The Dinoflagellates were poorly preserved in the samples, making generic identification impossible.

The environmental implications of the occurrence of this group, however, warrants a brief description of the types found. Their presence (particularly the spinose variety) is generally indicative of shallow, offshore marine environments, however, they can occur in brackish water estuarine and lagoonal sediments and even freshwater swamps, though in small numbers (Cranwell, 1964). The dinoflagellates found in this study can be classified under the genus *Spiniferites*.

<u>Type 1</u>

114) Plate 16 No 17

Body spherical, diameter 25-38 µm. Tabulate processes, 7-13 µm long, with bifurcate tips and closed wide - flair bases. Body ornament psilate. An apical archeopyle is indistinguishable in the specimens. This type could be tentatively classified as *Spiniferits* sp. Five specimens only were recorded in sample P36 of Cisaat (Bumiayu). Three specimens of dinoflagellate cysts were found in sample P20.

4.5 Description of Fungal material and Charcoal.

Various types of fungal spores and filaments were distinguished in the samples, some of which are illustrated in Plate 16, No 1-16. Due to problems concerning classification, however, no further identification has been attempted. Fungal material occurred consistently in most of the samples from Rancaekek, while charcoal was common in Cibogo. The analysis of the fungal material and charcoal was carried out following the techniques of Clark (1982) (See Sections 3.2.d and e). These data can be used to provide additional ecological information. Five summary pollen diagrams combined with the results of fungal spores, charcoal and chemical component analysis are given in this chapter (Figure 4.6, 4.7, 4.8, 4.9, 4.10).

The Palynomorph taxa

A summary of the occurrence of palynomorph taxa which have been recorded in this study is presented in Table 4.1.Working with Cenozoic microfloras, it is instructive to compare fossil pollen spectra with pollen rain from modern communities of plants. Such comparisons aid in interpreting the results of the analysis, by providing some basis for understanding what the relative frequencies of fossil pollen may mean in terms of the abundance of parent plants.

In the zonation section (Chapter 5), knowledge of the ecology of the various plant taxa of which pollen is identified, is needed for the ecological interpretation of pollen assemblage zones. Wright *et al* 1967, suggested that if modern pollen rain is known, then it can be compared with extant vegetation. This may then provide the basis for interpreting fossil pollen assemblages.

In this study, there was insufficient time to study pollen rain from present day plant associations from Indonesia, and hence published data were utilised in this respect (see Chapter 3). However, the Bandung Lake cores sampled from the Kosambi Formation of Holocene age (Koesoemadinata and Hartono, 1981) could beneficially be used as a Holocene analogue on which to base reconstructions of the ecology and sedimentation patterns of the Trinil and Bumiayu sections. Because the Holocene site will be used as an analogue, the descriptions of the studied profiles will be presented youngest to oldest, not in the traditional geological manner of progressing from oldest to youngest.

The principles underlying the pollen zonation and the description of the pollen assemblages from Bandung Lake, Trinil and Cisaat (Bumiayu) will be outlined and discussed in Chapter 5.

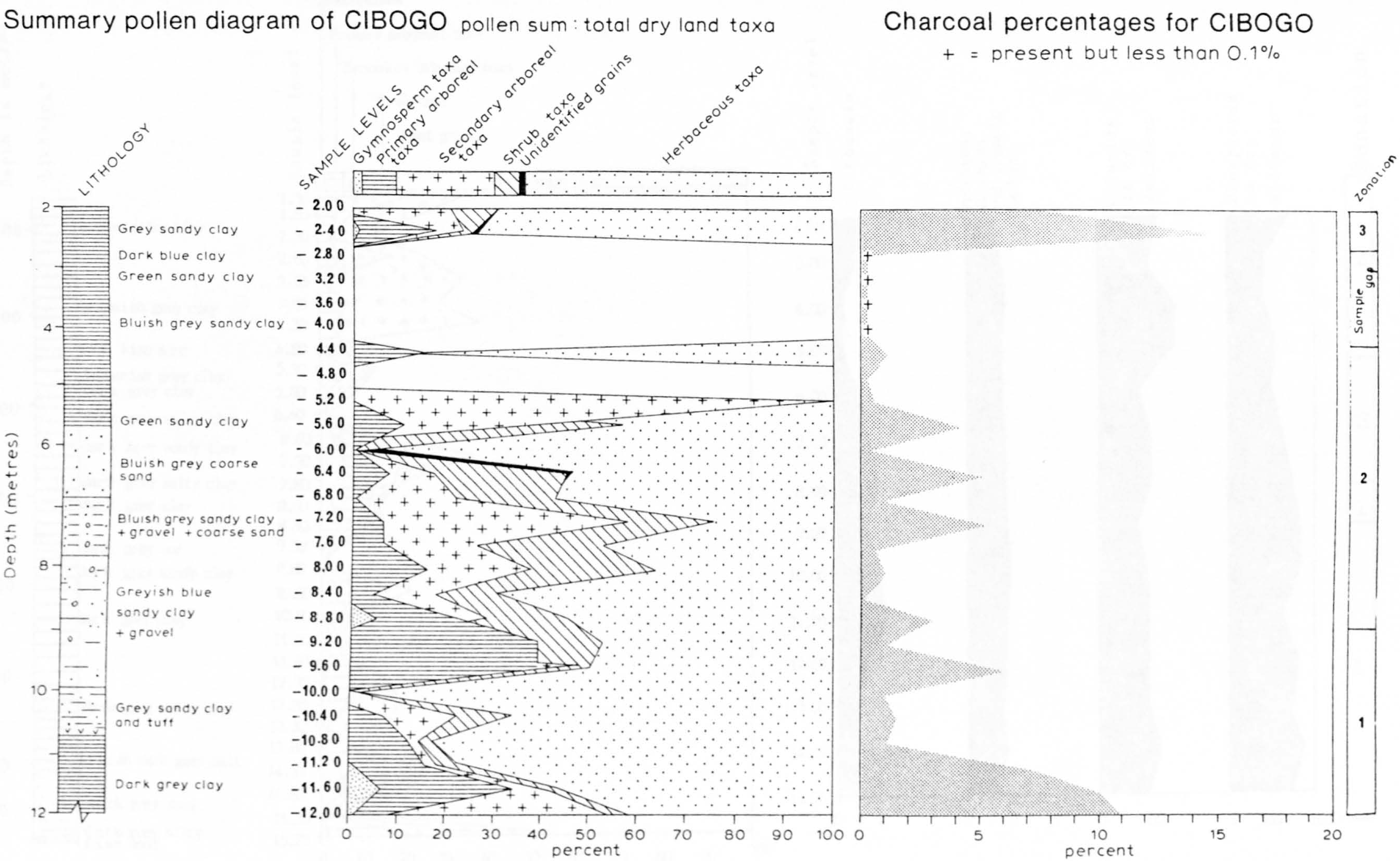
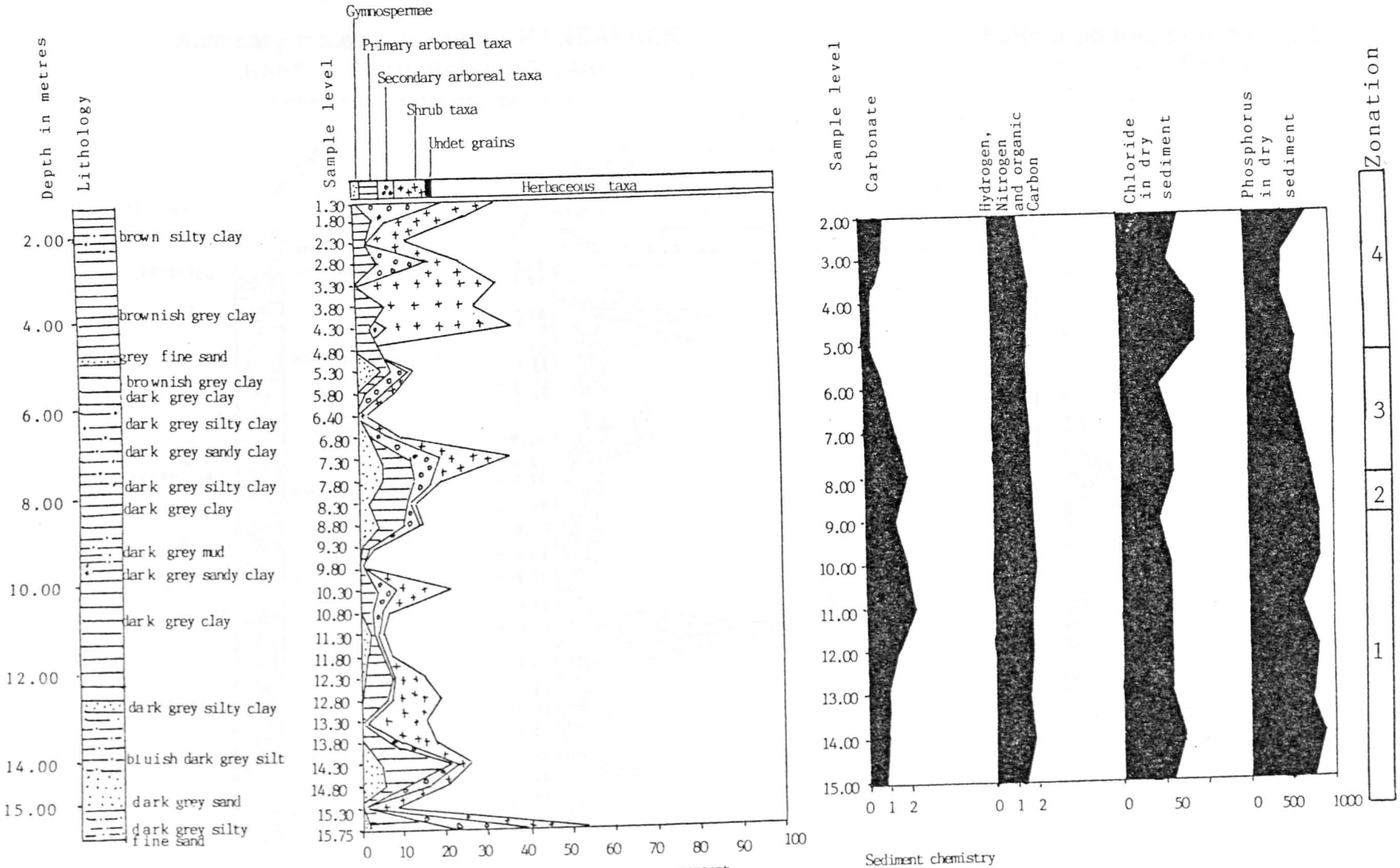

Summary pollen diagram of CIBOGO pollen sum : total dry land taxa
Charcoal percentages for CIBOGO
+ = present but less than 0.1%
LITHOLOGY
SAMPLE LEVELS
Gymnosperm taxa
Primary arboreal taxa
Secondary arboreal taxa
Shrub taxa
Unidentified grains
Herbaceous taxa
Zonation
Depth (metres)
Grey sandy clay
Dark blue clay
Green sandy clay
Bluish grey sandy clay
Green sandy clay
Bluish grey coarse sand
Bluish grey sandy clay + gravel + coarse sand
Greyish blue sandy clay + gravel
Grey sandy clay and tuff
Dark grey clay
2.00
2.40
2.80
3.20
3.60
4.00
4.40
4.80
5.20
5.60
6.00
6.40
6.80
7.20
7.60
8.00
8.40
8.80
9.20
9.60
10.00
10.40
10.80
11.20
11.60
12.00
percent
Sample gap
3
2
1

Figure 4.6



Summary pollen diagram of Linggar
Pollen sum : total dry taxa

Sediment chemistry
Scale for C,H,N and CO_2 is percentage.
Scale for Cl^- and P is ppm.

Figure 4.7

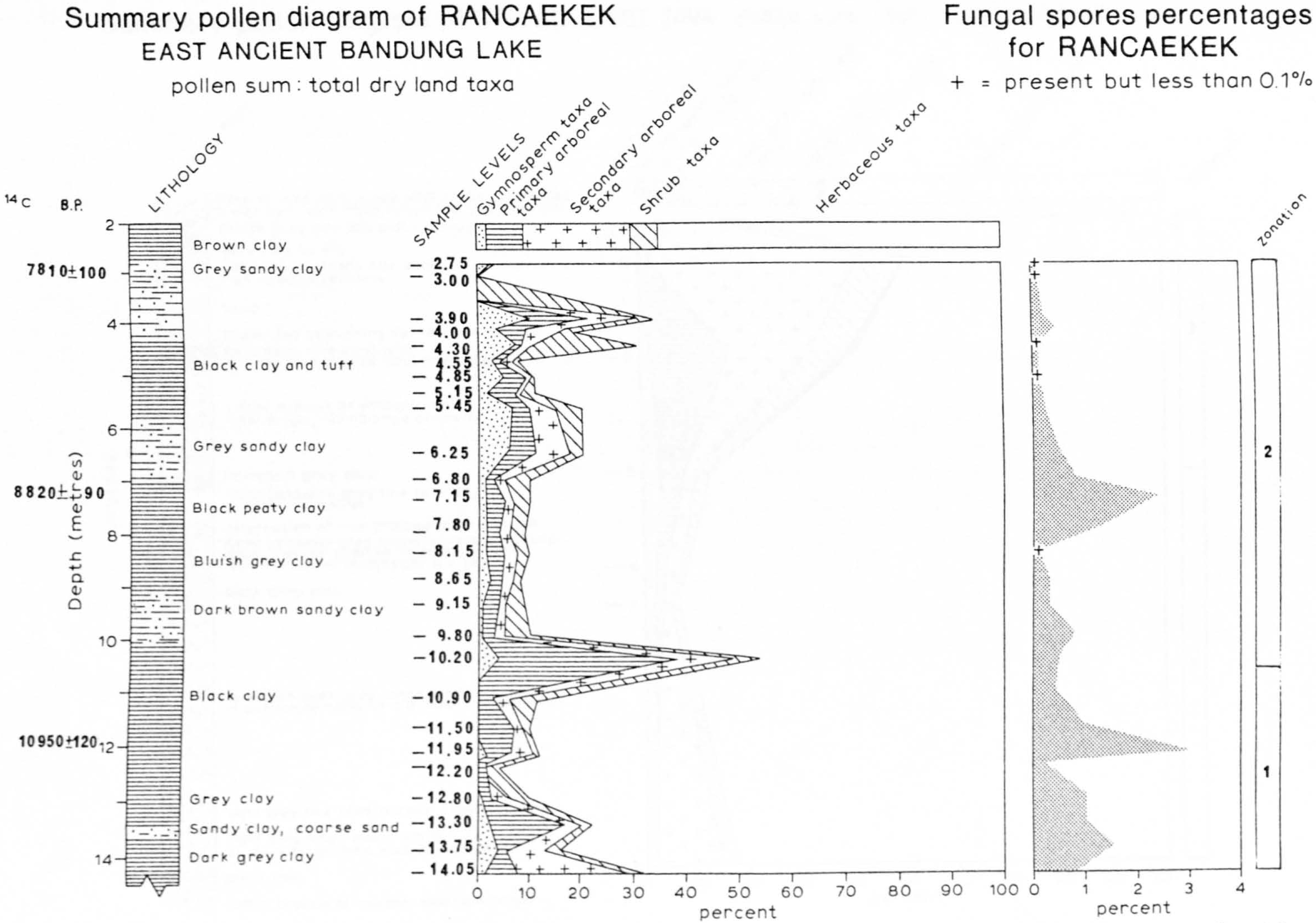

Summary pollen diagram of RANCAEKEK
EAST ANCIENT BANDUNG LAKE
pollen sum: total dry land taxa
Fungal spores percentages
for RANCAEKEK
+ = present but less than 0.1%
14C B.P.
7810±100
8820±90
10950±120
Depth (metres)
LITHOLOGY
Brown clay
Grey sandy clay
Black clay and tuff
Grey sandy clay
Black peaty clay
Bluish grey clay
Dark brown sandy clay
Black clay
Grey clay
Sandy clay, coarse sand
Dark grey clay
SAMPLE LEVELS
2.75
3.00
3.90
4.00
4.30
4.55
4.85
5.15
5.45
6.25
6.80
7.15
7.80
8.15
8.65
9.15
9.80
10.20
10.90
11.50
11.95
12.20
12.80
13.30
13.75
14.05
Gymnosperm taxa
Primary arboreal taxa
Secondary arboreal taxa
Shrub taxa
Herbaceous taxa
percent
Zonation
2
1

Figure 4.8

Summary pollen diagram of TRINIL, EAST JAVA pollen sum : total dry land taxa

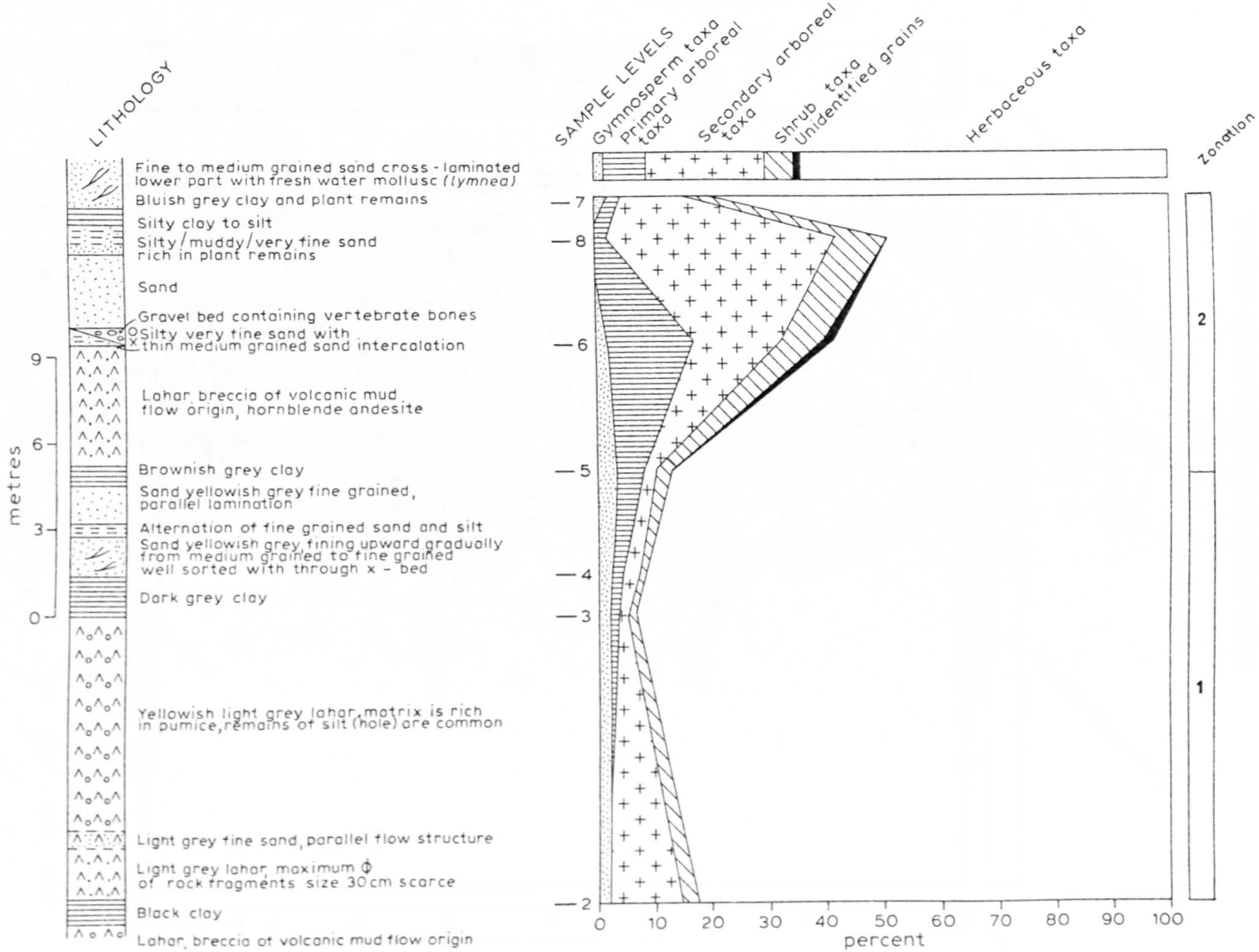


Figure 4.9

Summary pollen diagram of CISAAT, BUMIAYU

pollen sum : total dry land taxa

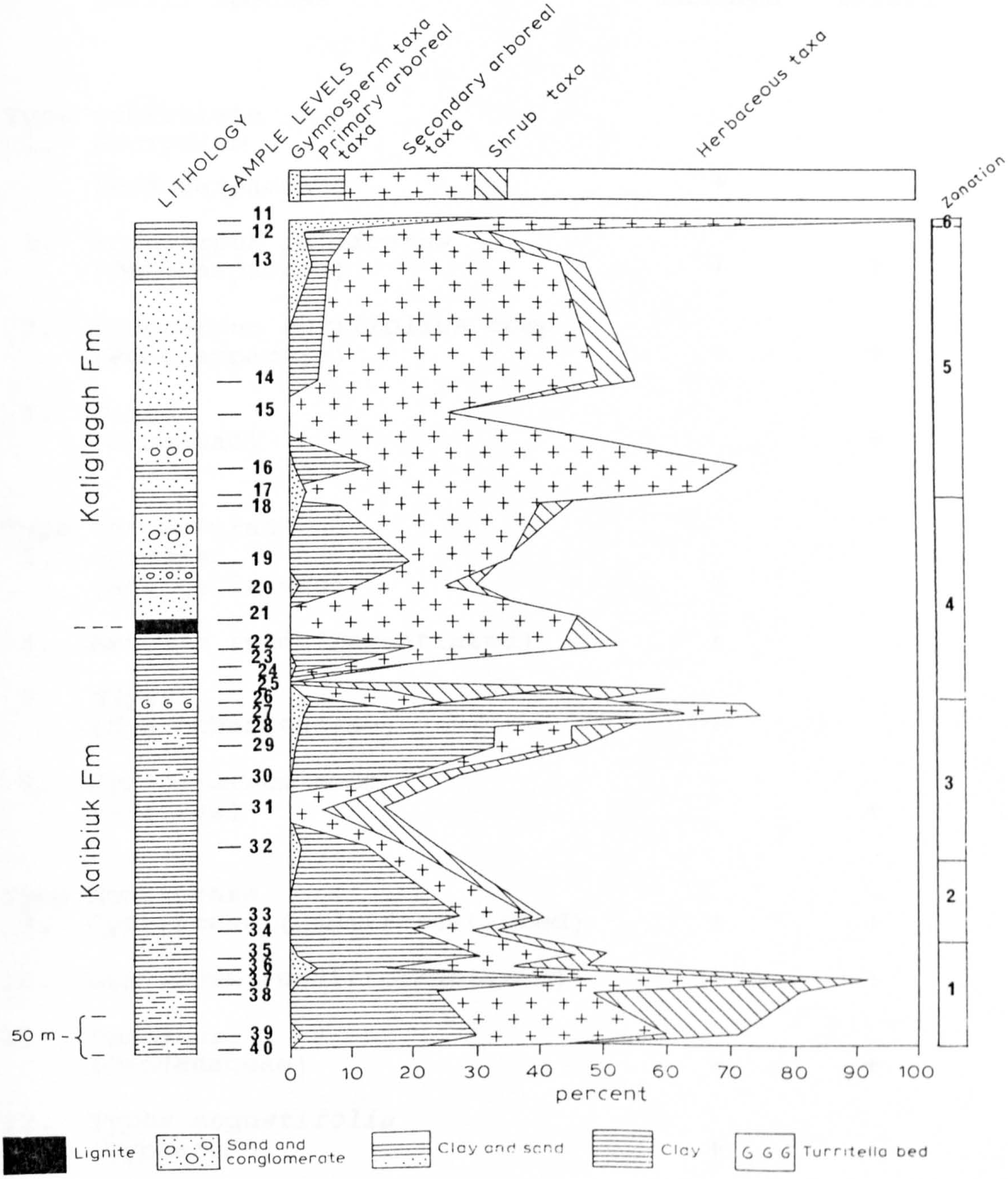


Figure 4.10

Table 4.1

Summary of occurrence of palynomorph taxa recorded in this study

Botanical affiliation and fossil species	Locality: Bumiayu	Trinil	Bandung Lake
Type vesiculate			
1. *Dacrydium* (Podocarpaceae)	+		+
2. *Podocarpus imbricatus* (Podocarpaceae)	+	+	+
3. *Podocarpus neriifolius comp* (Podocarpaceae)	+	+	+
4. *Pinus* (Pinaceae)		+	+
Type Inaperturate			
5. *Agathis* (Araucariaceae)	+		
6. Araceae (undifferentiated)	+		
7. *Blyxa* (Hydrocharitaceae)	+		+
8. *Cyrtospermum* comp (Araceae)		+	
Type Monoporate			
9. Cyperaceae (undifferentiated)	+	+	+
10. Gramineae (undifferentiated)	+	+	+
11. *Pandanus* (Pandanaceae)	+	+	+
12. *Typha angustifolia* (Typhaceae)	+	+	+
Type Diporate			
13. *Ficus* (Moraceae)			+

Botanical affiliation and fossil species	Bumiayu	Locality Trinil	Bandung Lake
Type Triporate			
14. *Canthium* (Rubiaceae)	+	+	
15. *Casuarina* (Casuarinaceae)	+	+	+
16. *Celtis* (Ulmaceae)	+	+	+
17. *Durio zibethinus comp* (Bombacaceae)	+		
18. *Engelhardia* (Juglandaceae)	+		+
19. *Florscheutzia semilobata* (Sonneratiaceae)	+		
20. *Helicia* (Proteaceae)		+	
21. *Myrica javanica* (Myricaceae)	+	+	+
22. *Pometia* (Sapindaceae)	+	+	+
23. *Sonneratia caseolaris* (Sonneratiaceae)	+		
24. *Sonneratia alba* (Sonneratiaceae)	+		
25. *Symplocos* (Symplocaceae)	+		+
26. *Trema* (Ulmaceae)	+	+	+
Type Periporate			
27. *Altingia excelsa* (Hamamelidaceae)			+
28. Chenopodiaceae (undiff.)	+	+	+

Botanical affiliation and fossil species	Locality: Bumiayu	Trinil	Bandung Lake
29. *Hibiscus comp* (Malvaceae)	+	+	+
30. *Polygonum* (Polygonaceae)		+	+
Type Stephanoporate			
31. *Austrobuxus nitidus* (Euphorbiaceae)	+		
32. *Strobilanthes* (Acanthaceae)		+	+
Type Monocolpate			
33. *Arenga* (Palmae)	+		
34. Liliaceae (undifferentiated)			+
35. *Nuphar* (Nymphaeaceae)		+	+
36. *Nypa* (Palmae)	+		
37. *Oncosperma* (Palmae)	+		
38. Palmae (undifferentiated)	+		
Type Tricolpate			
39. *Avicennia* (Verbenaceae)	+		
40. *Dipterocarpus* (Dipterocarpaceae)	+	+	+
41. *Dryobalanops* (Dipterocarpaceae)	+		
42. *Geranium* (Geraniaceae)		+	+

Botanical affiliation and fossil species	Locality: Bumiayu	Trinil	Bandung Lake
43. *Ilex* (Aquifoliaceae)	+	+	+
44. Plumbaginaceae (undiff.)	+		
45. *Quercus* (Fagaceae)	+	+	+
46. *Shorea* (Dipterocarpaceae)	+		
Type Syncolpate			
47. *Barringtonia* (Lecythidaceae)	+		
48. *Eugenia* comp 1 (Myrtaceae)	+	+	+
49. *Eugenia* comp 2 (Myrtaceae)		+	
Type Stephanocolpate			
50. *Acrocephalus* (Labiatae)		+	
Type Tricolporate			
51. *Ageratum* comp (Compositae)		+	
52. *Alangium* (Alangiaceae)	+		
53. *Bischofia* (Euphorbiaceae)		+	
54. *Bombax* sim (Bombacaceae)	+		
55. *Brugueria* comp (Rhizophoraceae)	+		
56. *Buchanania* (Anacardiaceae)			+

Botanical affiliation and fossil species	Locality Bumiayu	Trinil	Bandung Lake
57. *Calophyllum* (Clusiaceae)		+	+
58. *Castanopsis* comp (Fagaceae)	+		+
59. Compositae/Tubuliflorae (undiff)	+		+
60. Cruciferae (undiff.)			+
61. *Desmodium* comp (Leguminosae)		+	
62. *Dodonea* (Sapindaceae)		+	
63. Euphorbiaceae (undiff.)		+	+
64. Euphorbiaceae type 1		+	
65. Euphorbiaceae type 2		+	
66. *Garcinia* comp (Clusiaceae)		+	+
67. *Grewia* (Tiliaceae)	+	+	+
68. *Ixora* (Rubiaceae)		+	
69. *Justicia* comp (Acanthaceae)		+	+
70. Leguminosae (undifferentiated)	+		+
71. *Macaranga* (Euphorbiaceae)	+	+	
72. *Mangifera* (Anacardiaceae)	+		
73. *Myrsine* (Myrsinaceae)	+		+
74. *Neesia* (Bombacaceae)	+		

Botanical affiliation and fossil species	Locality: Bumiayu	Trinil	Bandung Lake
75. *Neocauclea* comp (Rubiaceae)		+	
76. *Pluchea* comp (Compositae)		+	
77. *Randia* (Rubiaceae)			+
78. *Rhizophora* (Rhizophoraceae)	+		
79. Rosaceae (undifferentiated)		+	
80. Rubiaceae (undifferentiated)	+		
81. *Schefflera* (Araliaceae)	+		
82. *Schoutenia* (Tiliaceae)		+	
83. Theaceae (undifferentiated)	+	+	+
84. Umbelliferae (undiff.)	+	+	+
85. *Uncaria* (Rubiaceae)	+		
Type Stephanocolporate			
86. *Lasianthus* (Euphorbiaceae)			+
87. Meliaceae (undifferentiated)			+
88. *Melastoma* (Melastomataceae)			+
89. *Memecylon* comp (Melastomataceae)	+		
90. *Palaquium* comp (Sapotaceae)	+	+	+
91. *Phyllanthus* (Euphorbiaceae)		+	+

Botanical affiliation and fossil species	Locality: Bumiayu	Trinil	Bandung Lake
Type Pericolporate			
92. *Polygala* (Polygalaceae)		+	
Type Tetrads			
93. *Vaccinium* (Ericaceae)	+	+	+
94. *Gardenia* (Rubiaceae)			+
Type Polyads			
95. *Acacia* comp (Leguminosae)	+	+	+
96. *Albizia* comp (Mimosaceae)		+	
Type Monolete			
97. *Cyclosorus* (Polypodiaceae)	+		
98. *Davallia* (Dennstaedtiaceae)	+	+	+
99. *Filices areolate* (Polypodiaceae)	+		
100. Undifferentiated Monolete spores	+	+	+
101. *Sphenomeris* (Dennstaedtiaceae)	+		
102. *Stenochlaena areolaris* (Dennstaedtiaceae)	+		
103. *Stenochlaena laurifolia* (Dennstaedtiaceae)	+		
104. *Stenochlaena palustris* (Dennstaedtiaceae)	+	+	+

Botanical affiliation and fossil species	Bumiayu	Locality Trinil	Bandung Lake
Type Trilete			
105. *Acrostichum aureum* (Dennstaedtiaceae)	+	+	
106. *Ceratopteris* (Adiantaceae)	+		
107. *Cyathea* comp (Cyatheaceae)	+	+	+
108. *Lycopodium cernuum* (Lycopodiaceae)	+		
109. *Lycopodium phlegmaria* (Lycopodiaceae)		+	+
110. *Undifferentiated Trilete spores*		+	
111. *Lygodium* (Schizaeceae)		+	
112. *Pteris* spp (Dennstaedtiaceae)	+	+	+
113. *Selaginella* (Selaginellaceae)		+	+
114. *Spiniferites* sp	+		
115. Dinoflagellate (Undiff.)	+		
116. Fungal spores			+
117. Charcoal			+

CHAPTER 5

ZONATION AND DESCRIPTION OF POLLEN ASSEMBLAGES FROM BANDUNG LAKE, TRINIL AND CISAAT (BUMIAYU)

Introductory remarks

Pollen diagrams from the study sites have been divided into pollen assemblage zones for ease of discussion (see Chapter 4 Section 2) and the composition of each assemblage zone is described below.

Percentages of each taxon were classified as follows:

5% = low, up to 10% - 20% = moderate, 20-30% = high, more than 30% = abundant.

In this Chapter, a mention of a plant name without additional qualification makes reference to a pollen type and not to the parent plant.

5.1. Pollen diagrams from Bandung Lake

Three pollen diagrams were drawn from the Bandung Lake cores: Cibogo pollen diagram (Cb) from the western part of the lake; Linggar pollen diagram (Lgr) from the central part of the lake and Rancaekek pollen diagram (Rk) from the eastern part of the lake (See Figure 6.1).

5.1.1. Pollen diagram of Cibogo (Cb)

This pollen diagram (Figure 4.1) has been divided into three zones which are distinguished and characterised by their pollen composition. Between zones 2 and 3 there is a gap, since no pollen occurred in samples Cb 2.80m, Cb 3.20m. Cb 3.60m and Cb 4.00m.

5.1.1.1. Pollen zone 1, spectra 12.00m - 8.80m

This zone is characterised by high percentages of Cyperaceae, *Typha* and *Nuphar*, while Gramineae are abundant. The gymnosperms *Podocarpus imbricatus* and *P. neriifolius* are present in low percentages. *Castanopsis* comp, *Eugenia* comp 1, *Myrica* and *Quercus* occur in low percentages. Chenopodiaceae, Polygonum and Umbelliferae also occur in low percentages.

5.1.1.2. Pollen zone 2, spectra 8.80m - 4.00m

Grasses and *Pandanus* are present in high percentages in this zone, while pollen of some forest trees such as *Calophyllum*, *Castanopsis* comp, *Dipterocarpus*, *Eugenia* comp 1 and *Quercus* occur in moderate frequencies. Theaceae occur in high percentages, while Compositae and Umbelliferae occur moderately.

5.1.1.3. Pollen zone 3, spectra 2.80m - 2.00m

Cyperaceae and Gramineae are abundant in this zone but *Typha* and *Nuphar* occur in low percentages. *Podocarpus neriifolius*, *Quercus* and *Eugenia* comp 1 are present in low percentages but *Castanopsis* and *Calophyllum* are represented in moderate percentages. Chenopodiaceae and Umbelliferae are rare.

5.1.2. Pollen diagram of Linggar (Lgr)

This pollen diagram (Figure 4.2) has been divided into four zones which are distinguished and characterised by their pollen composition as follows.

5.1.2.1. Pollen zone 1, spectra 15.75m - 9.30m

Cyperaceae, Gramineae and fern spores, which represent the swamp vegetation bordering the lake, are abundantly present in this zone. Chenopodiaceae, Cruciferae and Umbelliferae are present in moderate frequencies. The upland taxon *Castanopsis* comp occurs in high percentages, with *Myrica* and the gymnosperms *Podocarpus imbricatus* and *P neriifolius* present in low percentages.

5.1.2.2. Pollen zone 2, spectra 9.30m - 8.30m

This zone is characterised by the presence of high percentages of Umbelliferae (22%), while the swamp grasses such as Cyperaceae and ferns are in moderate percentages.

5.1.2.3. Pollen zone 3, spectra 8.30m - 4.80m

This zone is also characterised by the presence of fern spores and grasses in high percentages, while *Castanopsis* comp, *Myrica*, *Podocarpus imbricatus* and *P neriifolius* are present in moderate frequencies.

5.1.2.4. Pollen zone 4, spectra 4.80m - 1.00m

Nuphar, Grasses and Cyperaceae are dominant in this zone. *Pandanus* occurs regularly in moderate percentages. *Engelhardia* occur in low percentages while *Calophyllum* occurs in low to moderate frequencies.

5.1.3. Pollen diagram of Rancaekek (Rk)

The third pollen diagram from Bandung Lake (Figure 4.3) has been divided into two zones as follows:

5.1.3.1. Pollen zone 1, spectra 14.00m - 10.20m

In this zone, *Castanopsis* comp occurs in very high frequencies (33%)at 10.20m but is present in moderate percentages elsewhere. Among the upland taxa, *Quercus* is moderately represented, while *Altingia*, *Calophyllum*, *Myrsine*, *Podocarpus imbricatus*, *P neriifolius* and *Dacrydium* occur in low percentages. Umbelliferae are present regularly in low to moderate percentages, but

Gramineae, Cyperaceae and fern spores occur abundantly.

5.1.3.2. Pollen zone 2, spectra 10.20m - 2.00m

This zone is distinguished by the irregular presence of *Castanopsis* comp, occurring in lower percentages than in Zone 1 and by high pollen taxon diversity. *Podocarpus imbricatus* and *P.neriifolius* comp are present in moderate percentages, while *Dacrydium* and *Pinus* occur in low percentages.

Myrica and *Eugenia* Comp 1 are moderately represented but *Calophyllum*, *Dipterocarpus*, *Palaquium* comp and *Quercus* occur in low percentages.

Umbelliferae are commonly present at low to moderate percentages where Gramineae, Cyperaceae and fern spores are dominant.

5.2. Pollen diagram of Trinil

The stratigraphic section in this area was sampled by the palaeontology section of the Geological Research and Development Centre Bandung and used as reference in this study. Eight samples were collected from isolated spot clay sediment units in the Trinil area and the diagram was built up based on this columnar section (see Figure 2.4). The Trinil pollen diagram (Figure 4.4) has been divided into two zones which are distinguished and characterised by their pollen composition as follows:

5.2.1. Pollen zone 1, spectra 2 - 5

Montane gymnosperms, such as *Pinus* spp and *Podocarpus neriifolius*, which reflect long distance dispersal are present in low percentages in this zone. Upland taxa such as *Eugenia* comp 1, *Eugenia* comp 2, *Myrica* and *Quercus* are present in low percentages. Pollen of *Garcinia* comp occur in moderate frequencies, whereas *Ilex* occurs in low percentages. Zone I shows a very low diversity of pollen of terrestial taxa. Chenopodiaceae are present in low percentages in the upper and lower part of the zone.

The marsh taxon *Cyrtospermum* is present in moderate abundance, while the Compositae group such as *Pluchea* and *Ageratum* occur in low frequencies. Grasses occur abundantly, at a variety of sizes such as smaller than 20um, 24um, 30um, 36um, 39um, 45um, 48um, 54um and 69um. The size categories were used to try to distinguish wild grass pollen from cultivated grass pollen (Wodehouse, 1935). Cyperaceae are reasonably uncommon in this zone (See Figure 4.4 in back pocket).

The aquatic taxa, *Typha* and *Nuphar*, are present in low percentages. *Stenochlaena palustris* and other fern spores are commonly represented.

The overall palynomorph assemblage from this zone is of very low diversity. None of the mangrove pollen types are present in this zone.

5.2.2. Pollen zone 2, spectra 5 - 7

The gymnosperms are represented by *Podocarpus neriifolius* which occurs throughout the zone. In Sample 6, however, *Podocarpus imbricatus* was also recorded and both of these *Podocarpus* taxa were present in low percentages.

Eugenia comp 1, *Eugenia* comp 2, *Myrica* and *Quercus* are from upland environments and present in low percentages. This zone is characterised by a high diversity of pollen of terrestrial taxa such as that of *Albizia* comp, *Bischofia*, *Calophyllum*, *Casuarina*, *Celtis*, *Desmodium* comp, *Dipterocarpus*, *Dodonea*, *Euphorbiaceae*, *Grewia*, *Helicia*, *Macaranga* spp, *Palaquium* comp, *Phyllanthus* and *Schoutenia*, all present in low percentages. Rubiaceae, represented by *Canthium*, *Neonauclea* and *Ixora*, are also present in low percentages. Pollen of the riverside taxon *Pometia* occurs in moderate percentages. The upland shrubs such as *Vaccinium* and Theaceae are present in low percentages. The terrestrial herbs such as Chenopodiaceae, Acanthaceae, *Pluchea* and *Ageratum are* present in the middle of this zone and occur in low percentages. The swamp herbs and shrubs such as *Pandanus*, *Acrocephalus*, *Cyrtospermum* comp and Cyperaceae occur in variable percentages, whereas the aquatic taxa *Typha* and *Nuphar* are present in low percentages.

Stenochlaena palustris and spores of the brackish water fern *Acrostichum* are very common.

5.3. Pollen diagram of Cisaat, Bumiayu

Forty isolated spot clay samples which represented the Kalibiuk and Kaliglagah Formations,were collected along the Cisaat river. The pollen diagram has been built up with thirty samples based on the stratigraphy (Figure 2.3) which was drawn up by the Palaeontology Section of the Geological Research and Development Centre in Bandung.

The pollen diagram from Cisaat (Figure 4.5 in back pocket) has been divided into six zones which are distinguished and characterised by their pollen composition.

5.3.1. Pollen zone 1, spectra P40 - P34

This zone is characterised by moderate percentages of *Rhizophora* and low percentages of *Sonneratia caseolaris* and *Avicennia* comp as mangrove elements. *Podocarpus neriifolius, P. imbricatus* and *Dacrydium* are present in low percentages and may reflect long distance dispersal. *Myrica, Ilex,* and *Quercus,* from upland environments and pollen of the riverside taxon *Pometia* is present in moderate percentages.

In this zone, a high diversity of pollen of terrestrial taxa, such as that of *Alangium, Celtis, Canthium, Dryobalanops, Dipterocarpus, Shorea, Agathis, Casuarina, Palaquium* comp, and *Symplocos* are also represented. Pollen of *Eugenia* comp 1, *Grewia, Durio zibethinus* and *Bombax* are present in moderate percentages in this zone. *Nypa* and *Oncosperma* (back mangrove) occur in moderate percentages. In this zone, pollen of Gramineae is present in low to moderate frequencies. Cyperaceae and spores of *Sphenomeris* occur in high percentages, with *Typha* and *Pandanus* present in moderate percentages. Five specimens of the dinoflagellate cyst *Spiniferites* sp were recorded in sample P36 (See Figure 4.5).

5.3.2. Pollen zone 2, spectra P34 - P32

The overall palynomorph assemblage from this zone is of very low diversity. In this zone the mangrove pollen type *Rhizophora* occurs in low percentages, while pollen of *Bruguiera* comp and *Avicennia* comp are variably present. Pollen of *Sonneratia caseolaris* and *Nypa* is moderately represented. The upland taxon *Quercus* occurs in low percentages, *Neesia* (fresh water swamp) is present in low percentages and *Alangium* is moderately represented. Gramineae pollen is extremely abundant, Cyperaceae is present in low percentages, while *Stenochlaena palustris* and *Sphenomeris* spores are very common.

5.3.3. Pollen zone 3, spectra P32 - P24

Pollen of mangrove elements such as *Rhizophora* and *Bruguiera* comp are present in high percentages in this zone, while *Sonneratia caseolaris* and *Avicennia* comp are moderately represented.

Pollen of *Podocarpus neriifolius* comp and *P. imbricatus* from montane areas is present in low percentages. There is also a high diversity of upland taxa in this zone, such as *Myrica*, *Quercus*, *Eugenia* comp 1, *Trema*, *Grewia* and Plumbaginaceae. These types are present in moderate percentages, especially in the upper part of the zone. Swamp elements such as *Durio zibethinus*, *Pandanus* and

Neesia are moderately represented in the upper part of the zone, whereas Chenopodiaceae pollen is common in the lower part. Grass pollen is abundantly present in this zone, especially in the lower part, whereas in the upper part high percentages of Cyperaceae occur. Spores of *Stenochlaena palustris* and *Sphenomeris* are present throughout.

5.3.4. Pollen zone 4, spectra P24 - P18

This zone is characterised by the presence of pollen of mangrove elements in low percentages. Types present include *Rhizophora*, *Sonneratia caseolaris*, *Bruguiera* comp and *Avicennia* comp. *Florschuetzia semilobata* is presumed to be reworked from Lower Miocene deposits. Pollen of *Podocarpus neriifolius* occurs in low percentages. This zone shows low upland taxon diversity; pollen of *Quercus* occurs in high percentages while *Myrica* and *Grewia* are present in low percentages. The palm group in this zone is represented by undifferentiated Palmae pollen, *Oncosperma* and *Nypa* occur in low percentages. Gramineae pollen, *Sphenomeris* and *Stenochlaena palustris* spores are abundantly present, while Cyperaceae pollen locally occurs in high percentages. Pollen of the swamp taxa *Pandanus* and *Typha* occur rarely, whereas *Ilex* is common. Three specimens of dinoflagellate cysts are also found in P20 (See Figure 4.5).

5.3.5. Pollen zone 5, spectra P18 - P12

In this zone, pollen of the montane gymnosperm *Podocarpus neriifolius* comp is present in low frequencies, whereas that of the upland taxa *Myrica, Quercus* and *Castanopsis* comp occur in variable frequencies. Mangrove pollen is absent. Pollen of undifferentiated Palmae and *Arenga* occurs irregularly. Gramineae pollen, *Sphenomeris, Pteris* and *Davallia* spores occur abundantly. Cyperaceae are rare, while *Stenochlaena palustris* spores occur in low percentages. Spores of *Stenochlaena areolaris* occur throughout the zone, whereas *Stenochlaena laurifolia* is recorded in sample P24. Both of these spore taxa are currently extinct in Java.

5.3.6. Pollen zone 6, spectra P12 - P11

This zone is characterised by the presence of pollen of the mangrove taxa *Rhizophora* and *Sonneratia alba* in very low percentages. Pollen of the montane elements *Podocarpus neriifolius* and *P. imbricatus* occur consistently, whereas that of the upland forms *Myrica, Quercus, Castanopsis* comp, *Eugenia* comp 1, *Shorea, Trema* and *Engelhardia* are present in low percentages.

Durio zibethinus pollen occurs rarely, whereas undifferentiated Palmae, *Pandanus* pollen and *Stenochlaena areolaris* spores occur in moderate percentages. Gramineae and Cyperaceae pollen are present in very high percentages, whereas *Sphenomeris* spores show variable representation.

Concluding Remarks

Using the above zonation and description of pollen assemblages from the three sequencies of Bandung Lake and from Trinil and Cisaat (Bumiayu), the discussion and interpretation of the palaeoenvironment will be presented in the following Chapter 6.

Chapter 6

DISCUSSION AND INTERPRETATION

Introductory remarks.

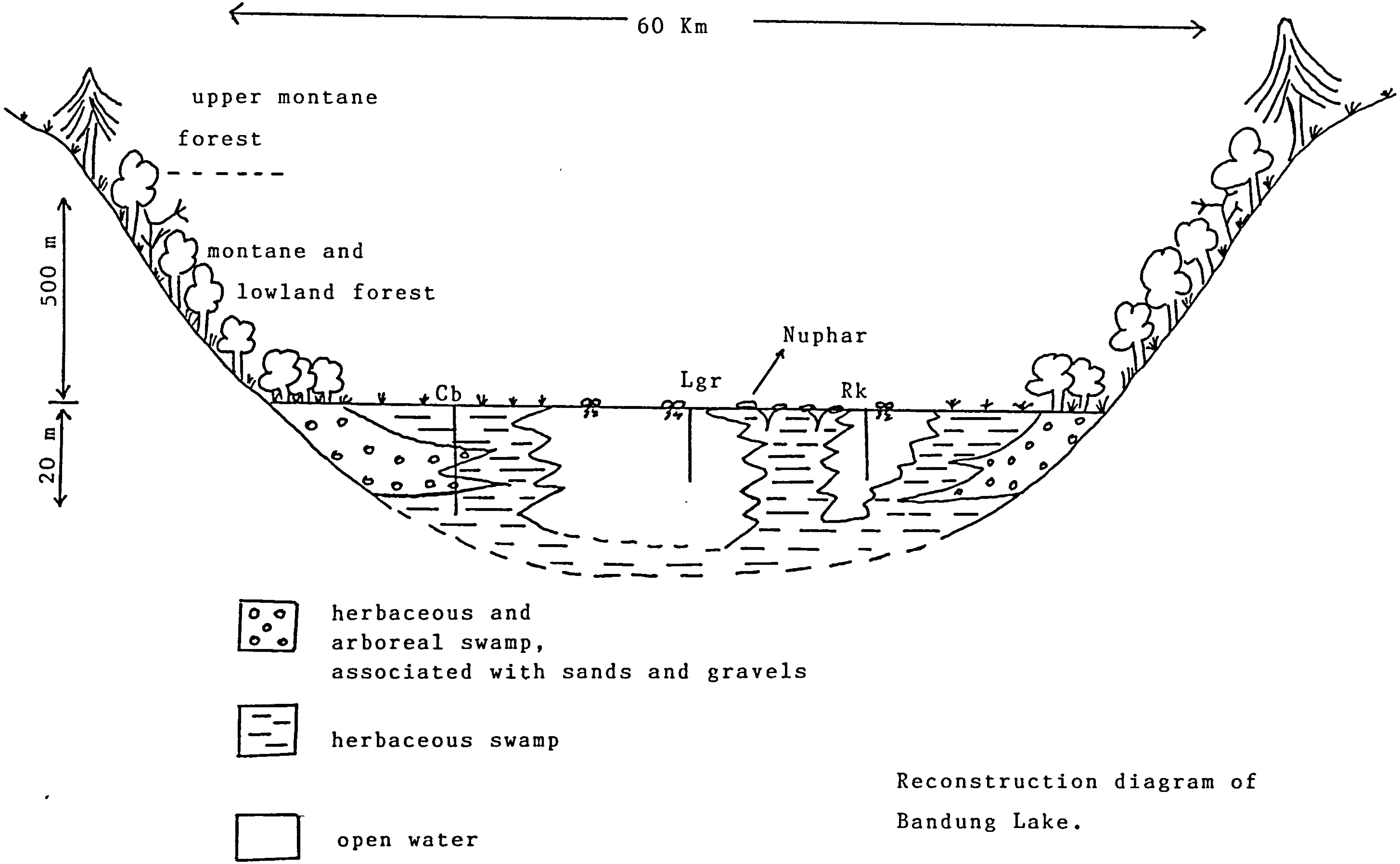
Palaeoecological data derived from all the fossil groups studied, but with particular reference to the pollen and spores, are summarised below for the three sites under investigation.

Ecological studies of present vegetation provide keys to interpreting the representation of former plant communities by fossil assemblages.

6.1 Bandung Lake

Introductory remarks.

Three cores were collected from Bandung Lake: Cibogo (Cb) in the western part of the Lake; Linggar (Lgr) in the central part of the Lake and Rancaekek (Rk) in the eastern part of the Lake (Figure 6.1). One of the three core sites, Rancaekek (Rk) has been dated with radiocarbon dating and an age of 10,980 ± 120 yr B.P. was obtained from a depth of 12.00m . An intersite correlation with Linggar (Lgr) core was attempted on the basis of the date obtained from the



Reconstruction diagram of Bandung Lake.

Figure 6.1

Rancaekek (Rk) core. It is suggested that a Holocene age could apply for the sedimentary sequence at Linggar.

6.1.1. Pollen diagram of Cibogo (Cb) Figure 4.1

Pollen assemblage zones are based on the palynofloral composition, presented in Chapter 5.

6.1.1.1 Pollen zone 1, spectra 12.00m - 8.80m.

This zone is characterised by the presence of aquatic taxa *Nuphar* and *Typha* together with Cyperaceae and *Polygonum*. The gymnosperms are *Podocarpus imbricatus* and *P. neriifolius*, see Chapter 4. The arboreal taxa are represented by *Myrica*, *Quercus*, *Castanopsis* or *Lithocarpus* and *Eugenia*.

6.1.1.2 Interpretation of palaeoenvironment

This zone reflects a lacustrine setting, with shallow water and the presence of the rooted open water aquatic *Nuphar*, together with Cyperaceae, *Polygonum* and *Typha*, which may have been growing in a marginal, possibly floating, herbaceous marsh. The clay and sand sediments in this zone are possibly due to the inwashing of sediment from the catchment.

Gymnosperms present are *Podocarpus imbricatus* and *P. neriifolius* which probably grew at high altitudes on mountain slopes surrounding the lake. Other upland tree taxa such as *Myrica*, *Quercus*, *Castanopsis* or *Lithocarpus* and possibly, *Eugenia*, may have been growing on the surrounding uplands. No specific taxa are found to indicate arboreal swamp species in this zone.

6.1.1.3 Pollen zone 2, spectra 8.80m - 4.40m

Obligate aquatic taxa are notably missing in this zone, while herbaceous swamp taxa occur as grasses, sedges; Umbelliferae and Compositae. *Pandanus*, *Celtis*, Euphorbiaceae, *Symplocos* and Myrtaceae are the arboreal swamp taxa. Montane conifer pollen is rare.

6.1.1.4. Interpretation of palaeoenvironment

1 Pollen and spores in this part of the sequence indicate a covering of herbaceous swamp with a dominance of grasses, sedges, Umbelliferae (for example *Hydrocotyle* and *Oenanthe* (see Backer, 1965)), and possibly Compositae. Sand and silty clay sediments in this zone indicate the establishment of the lake. Open water areas were reduced or absent compared with zone I, since *Nuphar* and other aquatic taxa were missing. Arboreal swamp taxa occurred extensively in the

region, possibly in peripheral areas surrounding the lake and included the common development of *Pandanus*, and might also have included *Celtis* and Euphorbiaceae.

2 The evidence for montane vegetation within this pollen zone is sparse. Montane conifer pollen, for instance, is poorly represented. This is thought to be due to the swamping of regional pollen by locally derived pollen during this interval. Based on intensive studies (counts of about 900 grains) it is possible to say that the decline in regional pollen is apparent, not real, and has been caused by an increased abundance of pollen from locally occurring taxa. This increase was probably as a result of the development of arboreal swamp in the vicinity, producing large quantities of locally derived pollen, thus masking the representation of regional pollen rain.

3 Taxa such as *Symplocos* and Myrtaceae (for example *Eugenia*) were most probably represented within arboreal swamp vegetation, since the representation of regional pollen rain within this sequence is restricted.

6.1.1.5. Spectra 4.40m - 2.40m (unzoned)

Clay samples in this part of the core do not contain pollen and spores. Charcoal analysis did, however, reveal low percentages of charcoal.

Perhaps these spectra are barren because of bacterial oxidation during a period of drying out or possibly as a result of burning by man. Under such conditions, leaching of the soil may have taken place.

6.1.1.6. Pollen zone 3, spectra 2.40m - 2.00m

Grasses, sedges, Umbelliferae, *Typha*, Compositae and Chenopodiaceae are present in this zone. The grasses are abundant while *Typha* is very rare and *Nuphar* is absent. Upland taxa occur such as *Quercus*, *Eugenia*, *Castanopsis* and *Calophyllum*. *Podocarpus neriifolius* abundance is very low.

6.1.1.7. Interpretation of palaeoenvironment

Herbaceous swamp conditions are indicated by zone 3, which includes pollen from grasses, sedges, Umbelliferae, *Typha*, Compositae and Chenopodiaceae. Swamp grasses are abundant but *Typha* is very rare and *Nuphar* is absent. Arboreal swamp vegetation was probably much reduced during this interval since *Pandanus* is absent and other possible arboreal swamp taxa are much reduced. This arboreal swamp vegetation may have been destroyed as a result of the activities of man (see below). The upland taxa are represented by *Quercus*, *Eugenia*, *Castanopsis* or *Lithocarpus* and *Calophyllum*. The presence of montane conifers and oaks in the surrounding upland is again clearly reflected. Clay sediments in this zone indicate the presence of a lake.

6.1.1.8. Charcoal analysis

Charcoal analysis shows that the upper part of the diagram, spectra 2.80m - 2.00m, contain the highest percentages of charcoal (Figure 4.6). This can be interpreted as being due either to man disturbing the area by clearing the vegetation for agricultural purposes, or to natural fires (Clark, 1988).

The lower part of the diagram (12.00m - 8.80m) may also reflect either some anthropogenic disturbance or natural fires and volcanic activity within the catchment.

6.1.1.9. Summary of the Cibogo sequence

Pollen zone 1 (spectra 12.00m - 8.80m) reflects shallow, open water conditions at the site with aquatic taxa. Zone 2 (spectra 8.80m - 4.40m) shows more herbaceous and arboreal swamp taxa which produce more local pollen than in zone 1. Spectra 4.40m - 2.40m (unzoned) contains no pollen at all, presumably because of oxidation and possibly erosion during a drying phase. The sandy sediments are possibly due to inwash of sediments from the catchment.

Zone 3 (spectra 2.40m - 2.00m) after drying out, swamp vegetation returned while charcoal is present in high percentages. The charcoal values observed in the blue clay sediments, can be considered to be due either to natural fires or to the burning of swamp vegetation and dryland vegetation by man.

6.1.2. Pollen diagram of Linggar (Lgr) Figure 4.2

6.1.2.1. Pollen zone 1, spectra 15.75m - 9.30m

Herbaceous swamp is represented by Gramineae, Cyperaceae, *Typha*, fern spores, Cruciferae, Chenopodiaceae, Umbelliferae and *Nuphar*.

Marginal swamp taxa such as *Ilex* and Myrtaceae occur, while *Castanopsis* or *Lithocarpus*, *Myrica*, *Podocarpus imbricatus* and *P. neriifolius* represent montane rain forests.

6.1.2.2. Interpretation of palaeoenvironment

Abundant Gramineae, Cyperaceae, *Typha* pollen and fern spores within this zone reflect the development of an extensive herbaceous swamp bordering the lake. The change from sand to clay sediments indicates the establishment of lacustrine conditions. Cruciferae, Chenopodiaceae and Umbelliferae are the shrubs and herbs which may have grown on this herbaceous swamp. The low representation of *Nuphar* within this zone suggests that local water depths were probably too great to permit the growth of rooted aquatics, whereas the common representation of *Ilex* and Myrtaceae may reflect marginal swamp forest development. The presence of montane rain forest bordering the lake is reflected by the regional pollen component. *Castanopsis* or *Lithocarpus*, *Myrica*, *Podocarpus imbricatus* and *P. neriifolius* were well represented within these forests which clearly did not differ greatly from the present day upper montane forests surrounding Bandung Lake (Backer, 1965).

6.1.2.3. Pollen zone 2, spectra 9.30m - 8.30m.

Umbelliferae and fern spores are abundant in this zone.

6.1.2.4. Interpretation of palaeoenvironment

Within this zone conditions were very similar to those recorded in zone 1, although ferns and Umbelliferae were a much more significant component of the herbaceous swamp communities. Umbelliferae are almost certainly derived from *Oenanthe* or *Hydrocotyle* which are known to be swamp herbs in Java (Backer, 1965).

6.1.2.5. Pollen zone 3, spectra 8.30m - 4.80m

This zone is characterised by Gramineae, Cyperaceae and fern spores from swamp vegetation while Castanopsis or *Lithocarpus*, *Myrica*, *Podocarpus imbricatus* and *P. neriifolius*, from the montane rain forest are represented in low numbers.

6.1.2.6. Interpretation of palaeoenvironment

This pollen zone reflects a similar swamp vegetation to the underlying zone 2, with Gramineae and Cyperaceae and ferns abundant, probably from a fringing band of swamp vegetation. The surrounding forests comprise montane rain forest with *Castanopsis* or *Lithocarpus*, *Myrica*, *Podocarpus imbricatus* and *P. neriifolius*. The reduced representation of montane forest taxa within this zone, compared to previous zones, may either be due to the restricted occurrence of this vegetation type in the area, or to the swamping effect of locally derived pollen.

6.1.2.7. Pollen zone 4, spectra 4.80m - 1.00m

Cyperaceae, *Nuphar* and *Pandanus* are abundant in this zone. The upland taxa present include *Engelhardia*, *Calophyllum* and *Trema*.

6.1.2.8. Interpretation of palaeoenvironment

With the dominance of Cyperaceae and *Nuphar*, this pollen zone suggests a shallowing of the lake at the coring site to 2-3m, at which depth *Nuphar* will grow well. *Nuphar* tends to grow toward the centre of lakes where open water exists. This pollen zone shows that the lake was rapidly infilling, since the regional component is virtually absent despite very large pollen counts being made (i.e. 2,000 pollen grains). *Nuphar* and Cyperaceae were definitely growing at the depositional site. Swamp forest with *Pandanus* is characteristic of this zone and probably bordered the lake. It is likely that Engelhardia and *Calophyllum* grew in upland sites. The upland component is again much reduced within this zone, which may reflect either the swamping effect of local pollen, or the reduced representation of upper montane forests within the area. The increased representation of *Trema* in the top sample may reflect the growth of secondary forest, possibly due to anthropogenic influence.

6.1.2.9. Chemical analysis

The results of selected chemical analyses of the Linggar sediments (Figure 4.7) show little change.

According to Birks and Birks (1980), high amounts of carbonate and chloride may be present in deposits during dry conditions when evaporation exceeds precipitation. In this study, carbonate declines and chloride increases between zones 3 and 4 which seem to represent periods of lower water level.

6.1.2.10. Summary of the Linggar sequence

Pollen zones 1, 2 and 3 show the development of swampy conditions and pollen zone 4 reflects a shallowing in water depth at the core site to a depth of 2-3m, with the lake rapidly infilling. Pollen zone 1 shows different sediments and is more sandy than the other zones. Fine sand occurred in zones 3 and 4 which was presumably washed in from the catchment. The Linggar core is believed to cover the period of the Holocene.

When considering the changes in stratigraphy at the site, the possibility of reworking and redeposition of the sediments due to fluctuating water levels, must be considered.

It seems likely that the changes in conditions recorded in the sequence may be attributed to relatively minor fluctuations in the climate. However, in this geological context, the possible impact of tectonism must also be considered.

Van Steenis (1965) suggested that the Holocene climate in this area had been everwet throughout the period. Evidence presented here, indicates that the climate may have been more variable than he suspected.

6.1.3 Pollen diagram of Rancaekek (Rk) Figure 4.3

6.1.3.1. Pollen zone 1, spectra 14.00m - 10.20m

Herbaceous swamp are represented in this zone by Umbelliferae, Gramineae, Cyperaceae, *Typha* and fern spores.

This zone is characterised by the abundant occurrence of the upland taxa *Castanopsis* or *Lithocarpus*, while the other upland taxa are *Quercus*, *Altingia*, *Myrsine* and *Calophyllum*.

Gymnosperms are *represented by Dacrydium, Podocarpus imbricatus* and *P. neriifolius*.

6.1.3.2 <u>Interpretation of palaeoenvironment</u>

This zone is interpreted as reflecting open water conditions with a marginal herbaceous swamp including Gramineae, Cyperaceae, *Typha* and ferns.

Swamp forest is probably of restricted occurrence within this zone. The upland rainforest flora includes *Castanopsis* or *Lithocarpus, Quercus, Altingia, Myrsine and Calophyllum,* together with gymnosperms such as *Dacrydium, Podocarpus imbricatus* and *P. neriifolius* from surrounding upper montane forest. Swamp herbs of Umbelliferae grew regularly around the lake. The alternating bands of sand and clay in this zone indicate the initial establishment of the lake.

Castanopsis comp pollen reaches its maximum percentages (33%) from spectrum 12.20m to spectrum 10.20m. The subsequent decline in *Castanopsis* comp values probably reflect the reduced influx of the upland rain forest component of *Castanopsis* into the area.

6.1.3.3. Pollen zone 2, spectra 10.20m - 2.00m

This zone is characterised by herbaceous swamp taxa such as Gramineae, Cyperaceae, *Typha* and ferns. Upland taxa are *Myrica*, *Eugenia*, *Quercus*, *Dipterocarpus*, *Calophyllum* and *Palaquium*. *Castanopsis* or *Lithocarpus* in this zone occur in very low abundances. Gymnosperms are *Pinus*, *Dacrydium*, *Podocarpus imbricatus* and *P. neriifolius*.

6.1.3.4 Interpretation of palaeoenvironment

Pollen and spores in zone 2 also reflect open water because of the dominance of Gramineae, Cyperaceae, *Typha* and ferns which are derived from a marginal herbaceous swamp. The alternating bands of sandy clay and clay may be due to fluctuations in water depth. The most common Gramineae in Java are *Oryza sativa*, wild grasses and bamboo. According to van Zeist (1984), cultivated rice pollen cannot yet be distinguished by size and structure of the pollen wall from the wild grass pollen, but most pollen recorded here is thought to be from wild grasses and bamboo.

The upland taxa are *Myrica*, *Eugenia*, *Quercus*, *Castanopsis* or *Lithocarpus*, *Dipterocarpus*, *Calophyllum* and *Palaquium* which would have grown on the higher ground surrounding this eastern part of the Bandung Lake.

The regional pollen component reflects the surrounding upland vegetation, which would have included *Podocarpus imbricatus*, *P. neriifolius*, *Dacrydium* and rare specimens of *Pinus*. It was thought that *Dacrydium* was a taxon transported a long distance from Sumatra. *Pinus* may also have been transported in this manner; *Dacrydium* occurs widely in peat swamps and Kerangas (heath vegetation) in Kalimantan, and also occurs in the highlands of Sumatra and the Malay peninsula (van Steenis, 1972). The persistent representation of *Dacrydium* throughout the Rancaekek and Linggar sites, however, argues for an origin in Java. This would indicate that *Dacrydium* has disappeared from the island of Java, possibly as a result of human or volcanic activity, since approximately 7000 yr B.P.

6.1.3.5 Fungal spores

The fungal spore analysis used the same method as the charcoal analysis (Clark, 1982). The spores always show a quite low percentage, not more than three percent (Figure 4.8). The decline of Gramineae, Cyperaceae, *Nuphar* and *Typha* contrasted

with an increase in the numbers of fungal spores, which supports the inference of reduced local humidity.
According to Wijmstra (1971) the percentages of fungal spores are high when local conditions are relatively dry and low when local conditions are relatively wet.

In this study the high values of fungal spores are at 13.80m, 12.00m and 6.80m which show relatively dry local conditions, while the decline of fungal spores is during the relatively wet conditions recorded in the clay deposits of Rancaekek (Figure 4.8). This suggests that the fungal spore curve could be an indicator of certain soil moisture changes in contrast with the representation of the regional pollen in this sequence.

Age of the Rancaekek sequence

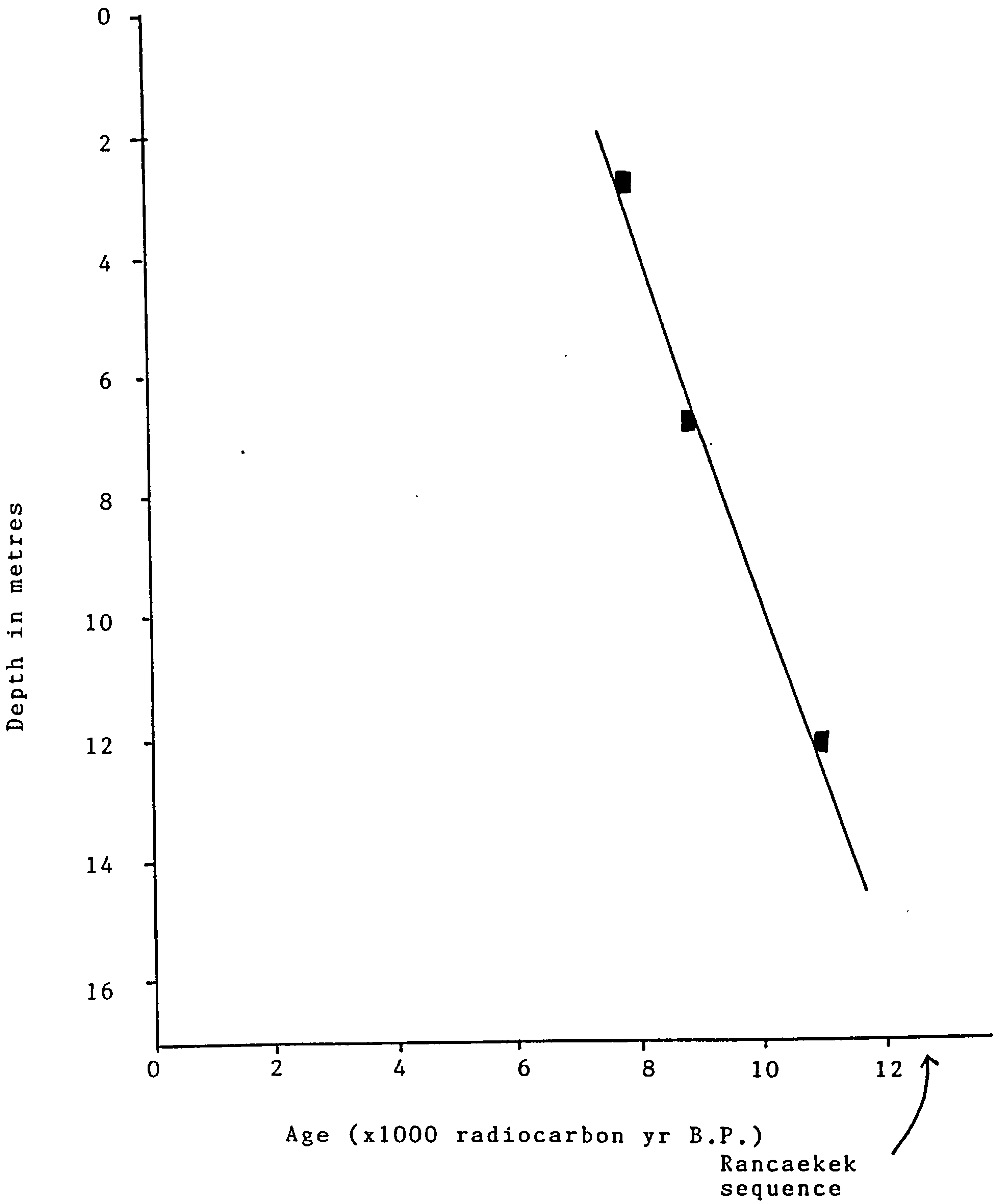


Figure 6.2

6.1.3.6 Radiocarbon dating

The radiocarbon dating procedure is described in Chapter 3, section 3.2.g. and the results shown in Table 3.2. The age-depth curve for the Rancaekek sediments is shown in Figure 6.2.

It might be possible to use a modified version of Figure 6.2 for the Linggar core sediments, which may have accumulated at the same rate as the Rancaekek sequence (see Figure 6.1). The similarity in stratigraphy of the Rancaekek (Figure 4.8) and Linggar (Figure 4.7) cores may provide some support for this approach. In Figure 6.2 the apparent marked reduction in the rate of sedimentation after 7,800 yr B.P. (at 2.7-3.0m) is probably caused by deflation of the top sediments, possibly with sediment shrinkage associated with drying of the lake. The draining of the lake by the Cibeureum River at this time may have played a significant part.

6.1.3.7 Summary of the Rancaekek sequence

Pollen zone 1 (spectra 14.00m - 10.20m) shows open water with marginal herbaceous swamp at the site. The upland pollen rain shows the rain forest component of the surrounding highlands with maximum percentages of *Castanopsis* or *Lithocarpus*. A ^{14}C date of 10,950 $\pm$ 120 yr B.P. was obtained at

12m. Zone 2 (spectra 10.20m - 2.00m) reflects open water with marginal herbaceous swamp at the site. The stratigraphy of Rancaekek shows a thin layer of tuff at a depth of 4.80m. This appears to have had little effect on pollen assemblages incorporated into this site. The upland pollen rain also shows the rain forest in characterised by Castanopsis or *Lithocarpus*. A decline in *Castanopsis* or *Lithocarpus* occurred between 10,950 ± 120 and 8,820 ± 90 yr B.P. based on the bracketting ^{14}C dates. This *Castanopsis* or *Lithocarpus* value reflects either human impact by clearance of the vegetation or volcanic activity reflected by the presence of ash layers.

The climate of the two pollen zones appears to have been everwet.

6.1.4 Discussion, age and summary of Bandung Lake

Using the three cores from Bandung Lake (Figure 6.1) plant palaeocommunities and the history of the lake can be reconstructed. The Cibogo (Cb) core comes from the western part of Bandung Lake, close to the edge, and is undated. Initially, the pollen represents a lacustrine setting with shallow water, and with a marginal floating herbaceous marsh growing in the vicinity. This was succeeded by herbaceous swamp, with arboreal swamp probably being extensive within the peripheral areas. The sequence contains sands and gravels which were washed in, and may reflect a pronounced drying phase at this time. Subsequent to this the lake appears to have dried out, or reverted to herbaceous swamp. Evidence of montane vegetation is sparce; the pollen assemblage zones for the Cibogo pollen diagram suggest that the pollen rain at this deposition site is mainly local in origin, derived from plants that grew very close to the sampling point.

The Linggar core (Lgr) is from the southwestern part of Bandung Lake closer to the centre of the basin. The Linggar pollen diagram reflects an overall more open water lacustrine setting compared to Cibogo. A more extensive herbaceous swamp than that suggested for the Cibogo site is also indicated. In the upper part, the Linggar core reflects a shallowing to possibly 2-3m depth. The Linggar pollen assemblages include a higher representation of regional pollen rain from plants common far beyond the immediate basin slopes. This regional pollen differs little in composition from that in the Cibogo and Rancaekek cores.

The Rancaekek core (Rk) was collected from the eastern part of Bandung Lake and the pollen diagram again reflects open water conditions with marginal herbaceous swamps. The presence of upland rainforest and upper montane forest surrounding the basin, is indicated. The pollen zones in the Rancaekek pollen diagram suggest more extra-local pollen rain than Linggar. Some of this extra-local pollen rain might be from plants which grew on the highlands surrounding the depositional site. In this core, few marginal arboreal swamp taxa are found. Radiocarbon dates from this core indicate that sediment began accumulating at the site before 10,980 ± 120 years B.P. Extrapolation of accumulation rates (Figure 6.2) suggests that the sequence studied extends from about 11,000 yr B.P. to 7,000 yr B.P. and therefore, spans the Pleistocene-Holocene boundary. A number of tree pollen taxa disappeared in the upper part of the diagram between 8,820 and 7,810 years B.P. The disappearance of *Dacrydium* at this point is interesting because it is not found in Java today (van Steenis, 1972 and Backer, 1965).

Dacrydium is present in very low percentages (between 4m-6m depth), and may either reflect long distance transport, from Kalimantan or Sumatra, or more probably, its early Holocene occurrence in Java, with a subsequent extinction before 7,000 yr B.P., as a result of climatic changes, volcanic activity or, possibly, man.

Some climatic changes, possibly on small scale, effecting lake levels and local stratigraphy seem to be recorded in the three Bandung cores. There is, though, no clear evidence for the effect of climatic variation on regional vegetation. It is noteworthy, however, that within the Rancaekek core, which has been radiocarbon dated, upland gymnosperms show a reduction in abundance at about 8,000 yr B.P. A similar decline is seen at about 7m depth in the Linggar core. The decline in gymnosperm pollen seen in the Rancaekek core corresponds closely with the end of the early Holocene climatic amelioration interpreted by Morley (1982) from Danau Padang in Sumatra for the period 10,000 to 8,600 yr BP. It is possible, therefore, that the decline in gymnosperm pollen observed here may relate to the end of the same climatic amelioration. Additional work is necessary to confirm this. The timing of this early Holocene warming is consistent with an increase in summer insolation to the northern hemisphere tropics due to orbital parameter changes. The possible effects of such changes in insolation on monsoon climates have been described by Kutzbach and Guetter (1983).

The effects of human disturbance may be recorded within the final phases of the three sequences, but there are no major changes in the regional pollen rain which can be associated with anthropogenic forest clearance. Taking into account the radiocarbon dates obtained from the Rancaekek core, the sequence studied is probably too old to reflect significant human influence in the area, which probably occurred from the Neolithic period (Subagus, 1979).

Variations in stratigraphy, with alternating bands of clay to silt and sand may be due to fluctuations in water depth, which may relate either to variations in water level or to changes in sediment input from the catchment. Such variations might be due to tectonics or volcanicity, or possibly to climatic fluctuations.

6.2. Trinil

Samples were collected from polleniferous clay units in exposed sections along the Solo river, East Java between Karanggeneng-Kliteh villages and the site where the *Pithecanthropus* fossil had been found (Figure 2.4).

The clay samples were analysed based on the geological section of Trinil area (Figure 2.5) and provide the Trinil pollen diagram (Figure 4.4 in back pocket). This study area is considered to be Middle-Pleistocene in age (Hooijer, 1956, Sartono, 1969).

6.2.1. Pollen diagram from Trinil

This diagram indicates considerable variations in the composition of the Middle-Pleistocene vegetation cover of the Trinil area.

The floristic diagram shows the presence of extensive lowland rainforest and provides evidence for the occurrence of montane vegetation in the vicinity.

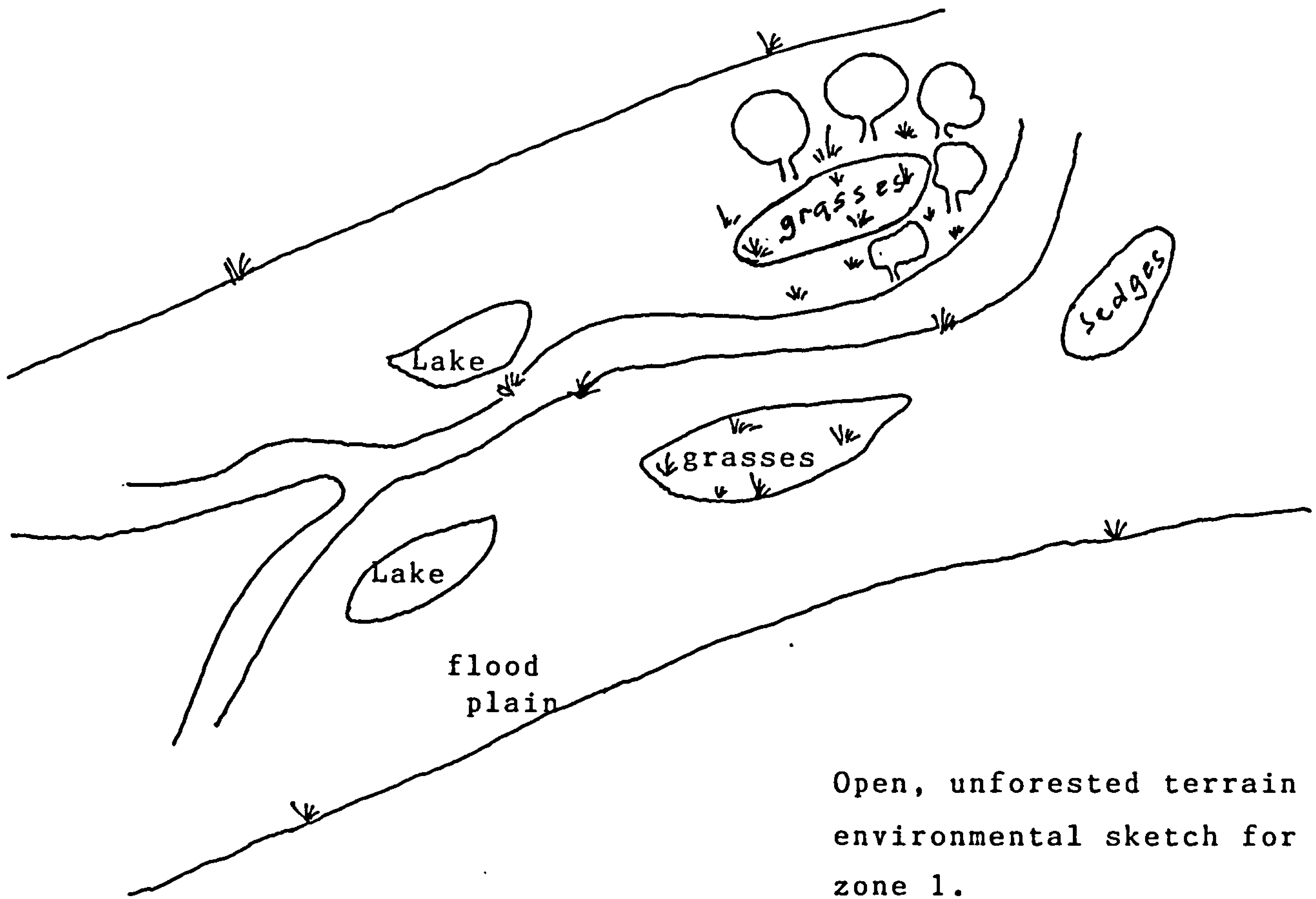
6.2.2. Pollen zone 1, spectra 2-5

The terrestrial taxa present include *Eugenia*, *Garcinia*, *Ilex*, Chenopodiaceae, *Cyrtospermum* and Compositae, such as *Pluchea* and *Ageratum* while Gramineae also occur in abundance in this zone (see Figure 4.4). *Eugenia spp* are mostly abundant in lowland rainforest and swamp forest. *Myrica* and *Quercus* are derived from the upland vegetation, while *Pinus spp* and *Podocarpus neriifolius* are representative of montane vegetation, their pollen being brought in by wind or streams. The taxa *Typha* and *Nuphar* indicate the presence of aquatic vegetation in this area. *Stenochlaena palustris* and a few other ferns might also have grown in open vegetation associated with aquatic or hydroseral plant communities.

6.2.3. Interpretation of palaeoenvironment

This pollen zone reflects the presence of open, unforested terrain with a few terrestrial taxa such as *Garcinia*, *Ilex*, Chenopodiaceae, *Cyrtospermum* and Compositae, and an abundance of Gramineae within close proximity to the depositional site (Figure 6.3). The presence of common grasses, freshwater taxa and ferns indicates small freshwater lakes in the area. These lakes were probably surrounded by grassy swamps with ferns and with aquatic taxa in open areas. Unforested terrain occupied much of the flood plain, although a mosaic of forested and unforested terrain could have been present (c.f. Figure 6.3). The occurrence of freshwater grassy swamp may have been due to a seasonal rainfall regime in this area similar to that experienced at present.

Lowland rain forest, possibly together with grass, may have been present on well-drained soils bordering the depositional site, but it is poorly recorded in the pollen record, possibly due to low pollen productivity of rain forest plants. The



Open, unforested terrain generalised environmental sketch for pollen zone 1.

Figure 6.3

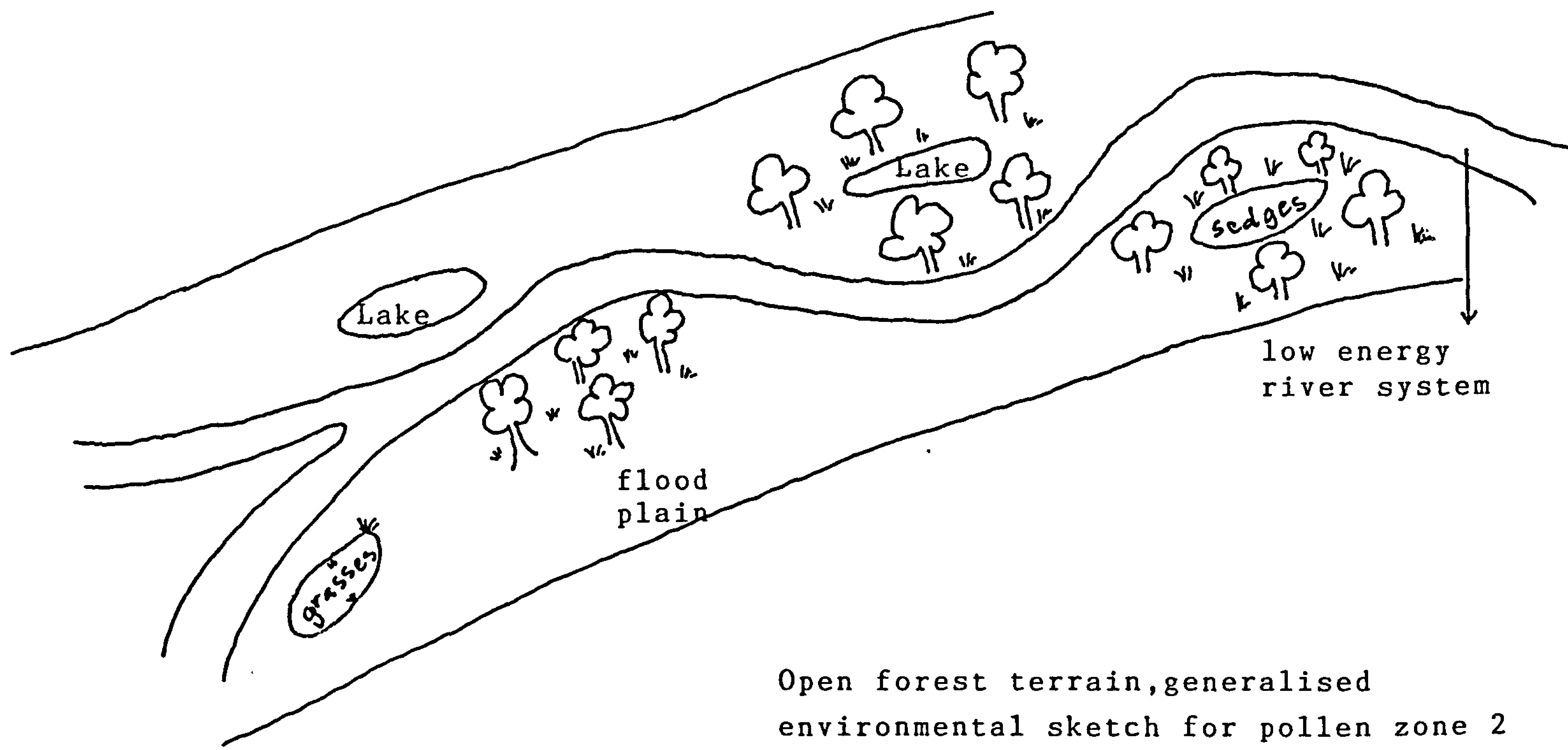
montane taxa recorded within this zone presumably represent montane vegetation on adjacent high mountains.

6.2.4. Pollen zone 2, spectra 5-7

More woody vegetation dominate this zone; it is characterised by arboreal species of the genera *Albizia*, *Bischofia*, *Casuarina*, *Celtis*, *Calophyllum*, *Dipterocarpus*, *Desmodium*, *Dodonaea*, Euphorbiaceae, *Helicia*, *Ixora*, *Macaranga*, *Neonauclea*, *Phyllanthus*, *Palaquium* and *Grewia*. Riverside or riparian vegetation present in the vicinity may have included *Pometia* and *Schoutenia* and possibly *Pandanus*. Herbaceous swamp vegetation, with Gramineae, Cyperaceae, small herbs such as *Pluchea*, *Ageratum*, Chenopodiaceae, *Acrocephalus* (Labiateae), *Cyrtospermum* (Araceae) and ferns, was probably extensive. Montane forest with *Podocarpus spp*, *Vaccinium* and Theaceae was present within the general region.

6.2.5. <u>Interpretation of palaeoenvironment</u>

As in zone 1, zone 2 also reflects open vegetation in the vicinity of the site, with highly diverse rainforest surrounding the area and riverine forest bordering rivers draining the region (Figure 6.4). Tree numbers increase in zone 2 which indicate the occurrence of locally wet conditions, where the



Open forest terrain,generalised
environmental sketch for pollen zone 2

Figure 6.4

arboreal taxa could grow prolifically close to the site of deposition.

Grasses and ferns dominated swamps, which were extensive, while aquatic vegetation occurred within freshwater lakes in this area.

Evidence for the vegetation of well-drained areas away from the depositional site is sparce, but open vegetation and rain forest may have occurred at low altitudes, and montane forest, with *Podocarpus*, *Vaccinium* and *Theaceae* growing on nearby high mountains.

The presence of extensive, low altitude, grass-dominated swamps probably reflects a seasonal precipitation regime at this site. The occurrence of *Dodonaea*, *Acacia/Albizia* and *Desmodium* within the terrestrial vegetation, may reflect a slightly drier climate than at present (van Steenis, 1965).

6.2.6. Discussion and age of Trinil

Hooijer (1956) stated that the Trinil fauna were of Middle Pleistocene age,but this was not accepted by von Koeningswald (1956) who considered the sequence to be of Pleistocene age. Subsequent to both authors debate about the age of the Trinil fauna, Orchiston and Siesser (1982) studied the

Plio-Pleistocene fossil hominids of Java and assumed that the Trinil fauna should be of Middle Pleistocene age.

A Middle Pleistocene age for the *Homo erectus* of Trinil has been supported by Hadiwisastra (1984) and Pope (1985). Sondaar (1984) reports that no hominids were found in the lower part of this sequence probably due to an environment too open for their liking. This is corroborated by the scarcity of arboreal taxa indicated by the pollen assemblages in zone 1. The hominids might have occurred in the upper part of the sequence (zone 2) (Matsu'ura, 1982), where trees occur in greater abundance (Sondaar, 1984).

According to Morley (1978) the presence of *Podocarpus imbricatus* without *Stenochlaena laurifolia (Stenochlaenidites papuanus*, Khan 1976) may indicate an undifferentiated Pleistocene age for this sequence.

In this study, the occurrence of only *Podocarpus imbricatus (Dacrycarpus imbricatus)* without *Stenochlaena laurifolia* argues for a Pleistocene age for the sequence. At the present time, palynological evidence is insufficient to make a

Summary for Trinil

Pollen assemblage zones	Lithology and local positional setting	Surrounding dry-land vegetation and areas	Vegetation in upland areas	Faunal age
2	Clays deposited within the flood plain. Open vegetation with rain forest and riverine forest surrounding the area. Few small freshwater lakes.	Rainforest, riverine forest. Extensive grasses. Seasonal climate	Podocarpus neriifolius Podocarpus imbricatus growing in montane forest.	Middle Pleistocene
1	Clays deposited within the flood plain. Few small freshwater lakes.	Some terrestrial taxa and grasses. Seasonal climate.	Podocarpus neriifolius and Pinus spp as long distance transported taxa. (See Chapter 4)	

Table 6.1

more detailed zonation of the Pleistocene in this area.

A variety of methods have been used in attempts to date the Plio-Pleistocene hominid - bearing Formations of Central and East Java. Hominids from the Trinil site were thought to be *Homo erectus*, of Middle-Pleistocene age, inhabiting dry, open woodland during glacial phases (de Vos, 1985). Based on the present study, Java man may have lived in dry, open forested terrain in the Trinil area, as recorded in pollen zone 2. (Table 6.1).

A summary of palaeoenvironmental data for the Trinil area is presented in Table 6.1.

6.3 Bumiayu

Polleniferous clay samples were collected from sections along the Cisaat river, Bumiayu (Central Java). They were analysed and provide a pollen diagram for Cisaat (Figure 4.5 in back pocket). The sediments analysed are considered to be Upper Pliocene in age based on vertebrate and molluscan assemblages. (See Chapter 2).

6.3.1. Pollen diagram of Cisaat, Bumiayu

Six pollen zones have been identified based on species diversity and relative abundance. These are shown in Figure 4.5 (in back pocket).

6.3.2. Pollen zone 1, spectra 40-34

The occurrence of pollen of *Rhizophora*, *Sonneratia caseolaris*, *Nypa*, *Oncosperma* and *Avicennia* reflects the presence of brackish mangrove or back mangrove swamp in the area. The occurrence of the marine dynocyst *Spiniferites* sp supports this interpretation of brackish conditions. The abundance of pollen of Gramineae, Cyperaceae, *Sphenomeris*, *Pandanus* and *Typha* is thought to reflect herbaceous swamp vegetation, around small lakes or along slow moving rivers close to the site. The freshwater swamps or small lakes were probably formed immediately behind the back mangrove (see Figure 6.5). Freshwater swamp forest, including *Pometia*, *Durio* and *Bombax*, probably also grew nearby. The presence of pollen of *Podocarpus neriifolius*, *P. imbricatus* and *Dacrydium* reflects the character of the montane vegetation and represents a regional or long distance component in the pollen rain. *Myrica* and *Quercus* pollen may reflect upland vegetation surrounding the depositional area.

Depositional environments represented within palynological zone 1. Representing a brackish, coastal plain depositional setting.

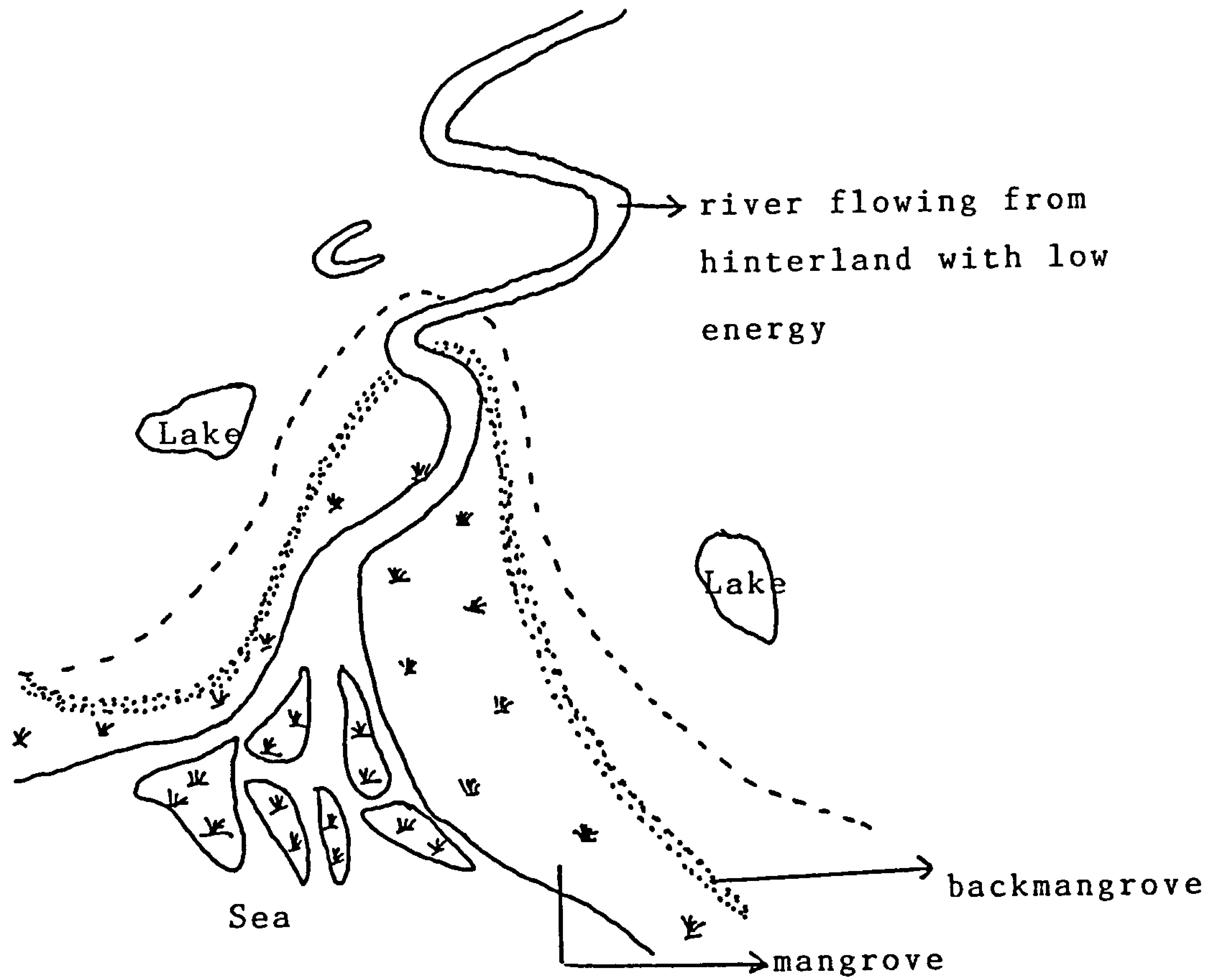


Figure 6.5

6.3.3. Interpretation of palaeoenvironment

Deposition within a brackish, coastal plain setting is suggested by the presence of mangrove and back mangrove plant communities (Figure 6.5). The area was also characterised by the presence of slow moving rivers depositing clay, but very little sand. The rivers were lined with swamp forest and possibly herbaceous swamp, which probably also occurred around small freshwater lakes within the flood plain. The hinterland region includes mountains over 1000m high which were, presumably, the source of the pollen of *Podocarpus imbricatus*. Currently in Indonesia, grass-dominated swamp vegetation develops only on high altitude swamps, for example Bandung Lake (700m a.s.l.) and Danau Bento in Sumatra (Morley *et al*, 1973) or at low altitudes under a seasonal climate (Morley, 1982). Since deposition at Cisaat occurred at sea level, a seasonal climate seems indicated by the fossil pollen assemblages.

6.3.4. Pollen zone 2, spectra 34-32

In this zone the presence of *Bruguiera*, *Sonneratia caseolaris* and *Avicennia* again indicate the development of mangrove swamps in the area. *Rhizophora* is absent from this zone. *Avicennia* is a pioneer in mangrove forest; the genus is known as a low pollen producer (Muller, 1964).

Depositional environments reflected in pollen zone 2, representing an open water lagoonal, coastal plain setting.

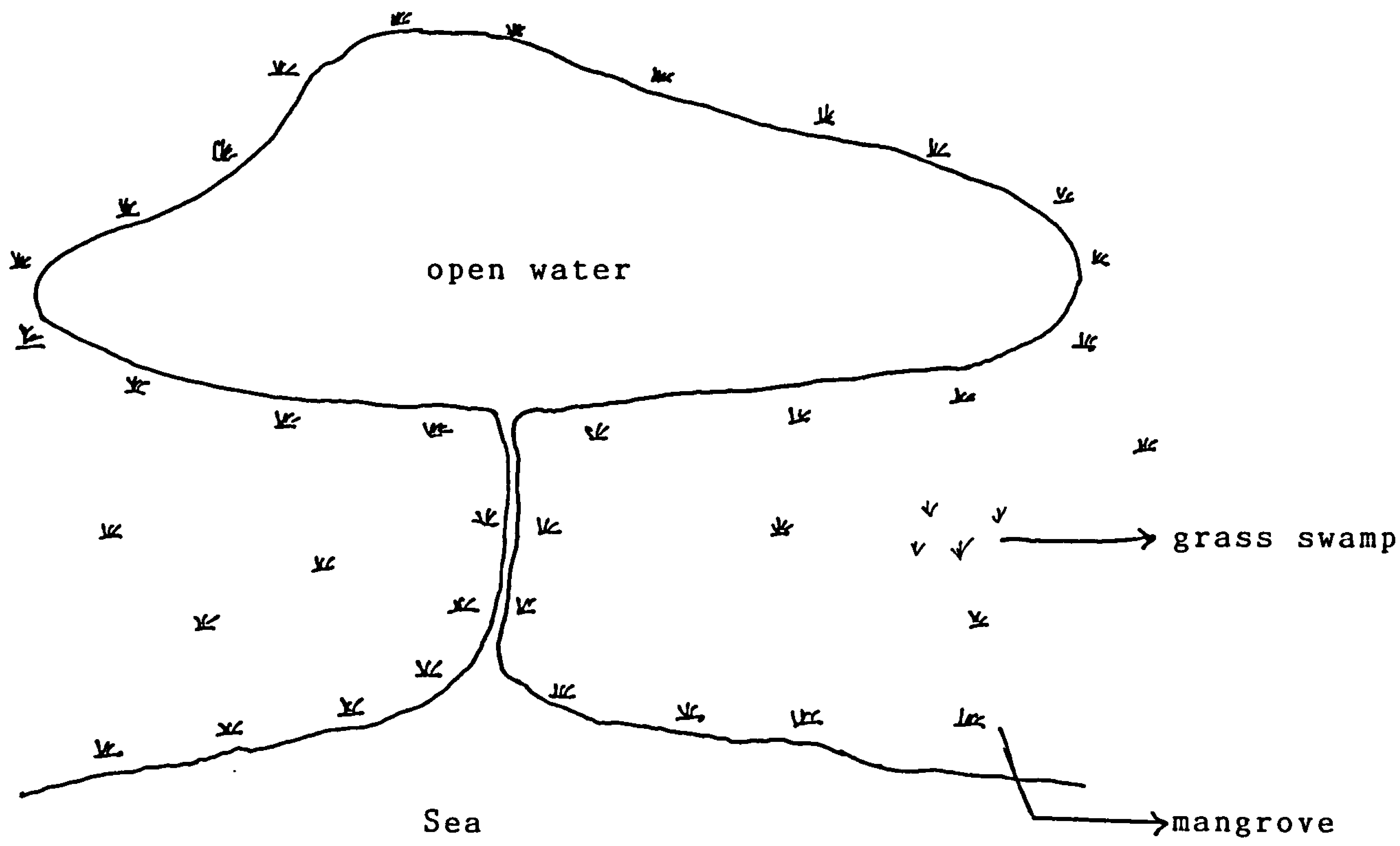


Figure 6.6

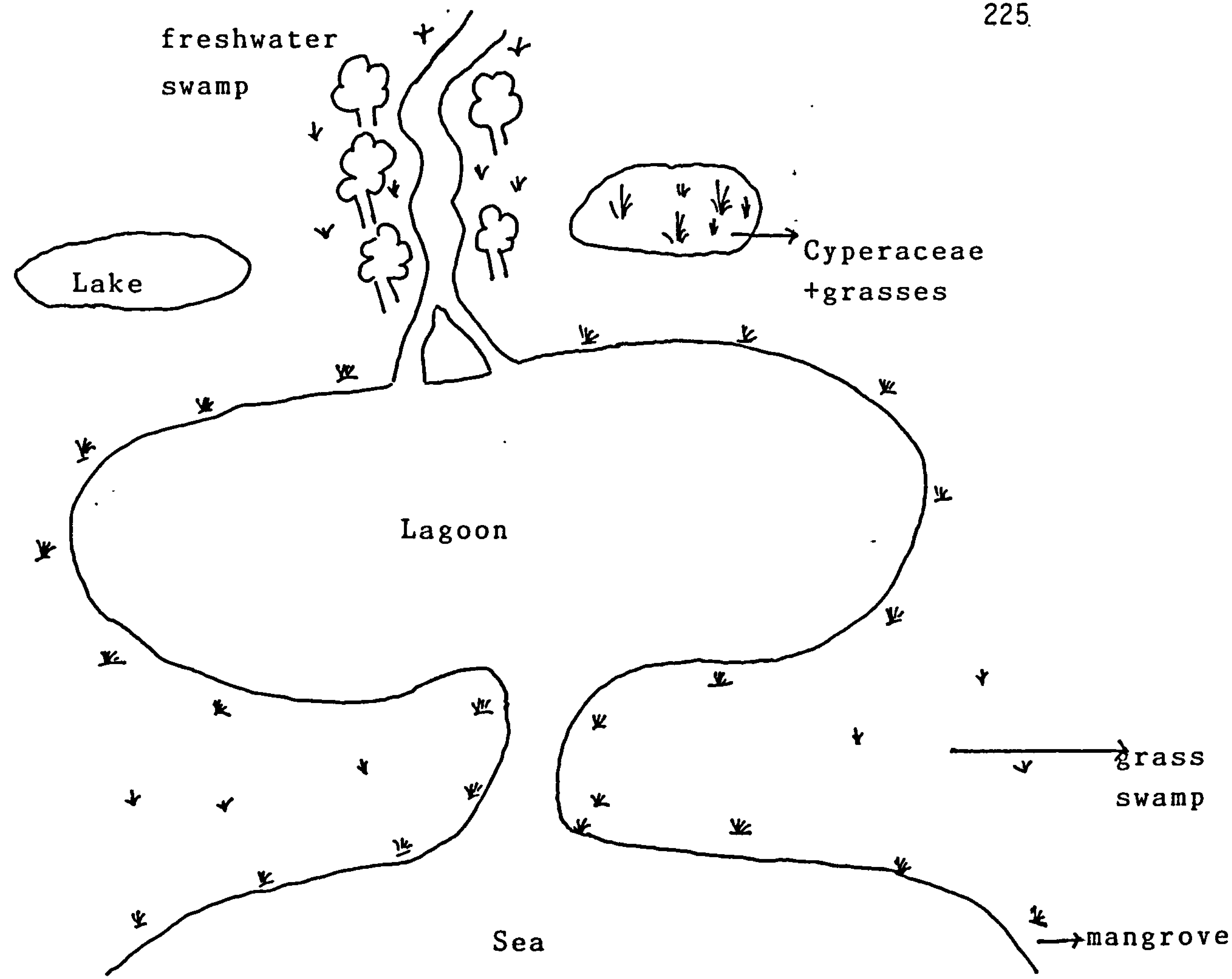
In recent, or fossil samples, *Avicennia* type pollen is rarely dominant and usually about equally as abundant as *Nypa*, which is also a low pollen producer. In this zone *Avicennia* pollen occurs more abundantly than *Nypa* (*Avicennia* up to ca 30 per cent) and consequently *Avicennia* may have formed a significant component of the vegetation. According to van der Hammen (1974), the occurrence of high percentages of *Avicennia* pollen must reflect the growth of the mangrove in the immediate vicinity.

The diversity of the upland pollen flora in this zone is very low. Pollen of upland taxa, such as that of *Podocarpus* and *Quercus* is rare, suggesting that transport of pollen from hinterland areas was minimal over the time period represented by this zone .

Grass pollen is extremely abundant throughout this sequence and is probably derived from grasses growing in a freshwater swamp, probably in association with ferns, such as *Sphenomeris* and *Stenochlaena palustris*.

6.3.5 <u>Interpretation of palaeoenvironment</u>

The presence of mangrove vegetation in the area again indicates deposition in brackish water within



Depositional environments reflected in pollen zone 3,representing deposition in a lagoonal, coastal plain setting.

Figure 6.7

a coastal plain setting (Figure 6.6). The absence of pollen transported from upland areas argues for deposition in a setting where local pollen deposition has totally overwhelmed the regional pollen component. The presence of extensive, grass dominated swamps, with minimal freshwater swamp forest, together with the rarity of upland pollen and the clayey nature of the sediments themselves, would be explained by deposition in an extensive freshwater to brackish lake or lagoon, surrounded by grass and mangrove swamps. As with zone 1, the presence of abundant grass swamps in a low altitude setting suggests a seasonal climatic regime.

6.3.6. Pollen zone 3, spectra 32-24

The occurrence of mangrove elements in this pollen zone, such as *Rhizophora*, *Bruguiera*, *Sonneratia caseolaris* and *Avicennia* again reflects a back mangrove vegetation. In this zone, only *Podocarpus imbricatus* and *P. neriifolius* amongst the gymnosperms, express montane vegetation which was growing in the upland surrounding the depositional area. These types represent long distance pollen transport.

Freshwater swamps were widespread in the surrounding area and were characterised by *Durio*, *Pandanus*, *Neesia* and Chenopodiaceae, and an abundance of grasses, Cyperaceae, *Stenochlaena palustris* and *Sphenomeris* ferns.

6.3.7 <u>Interpretation of palaeoenvironment</u>

Brackish back mangrove swamps on the coastal plain generally occur in the lower reaches of major streams or within a lagoonal setting. A lagoonal setting within the flood plain, with slow moving inflowing rivers, depositing clay but little sand, is indicated (Figure 6.7).

The rivers were probably lined with swamp forest and herbaceous swamp, which also occurred around the lagoon. The shell bed of *Turritella*, represented by sample 27, may reflect a period of reduced water level or emergence, since this sample accumulated within a mangrove swamp dominated by *Bruguiera spp* rather than the more salt tolerant *Rhizophora spp*.

The high diversity of plant debris will probably be due to fluvial erosion and redeposition and is associated with sandy sediments.

The abundance of grasses and ferns and the presence of small lakes at a low altitude in a coastal setting, suggests a continued seasonal climate.

Depositional environments reflected in pollen zone 4, representing deposition in a high energy, brackish to freshwater fluvial setting.

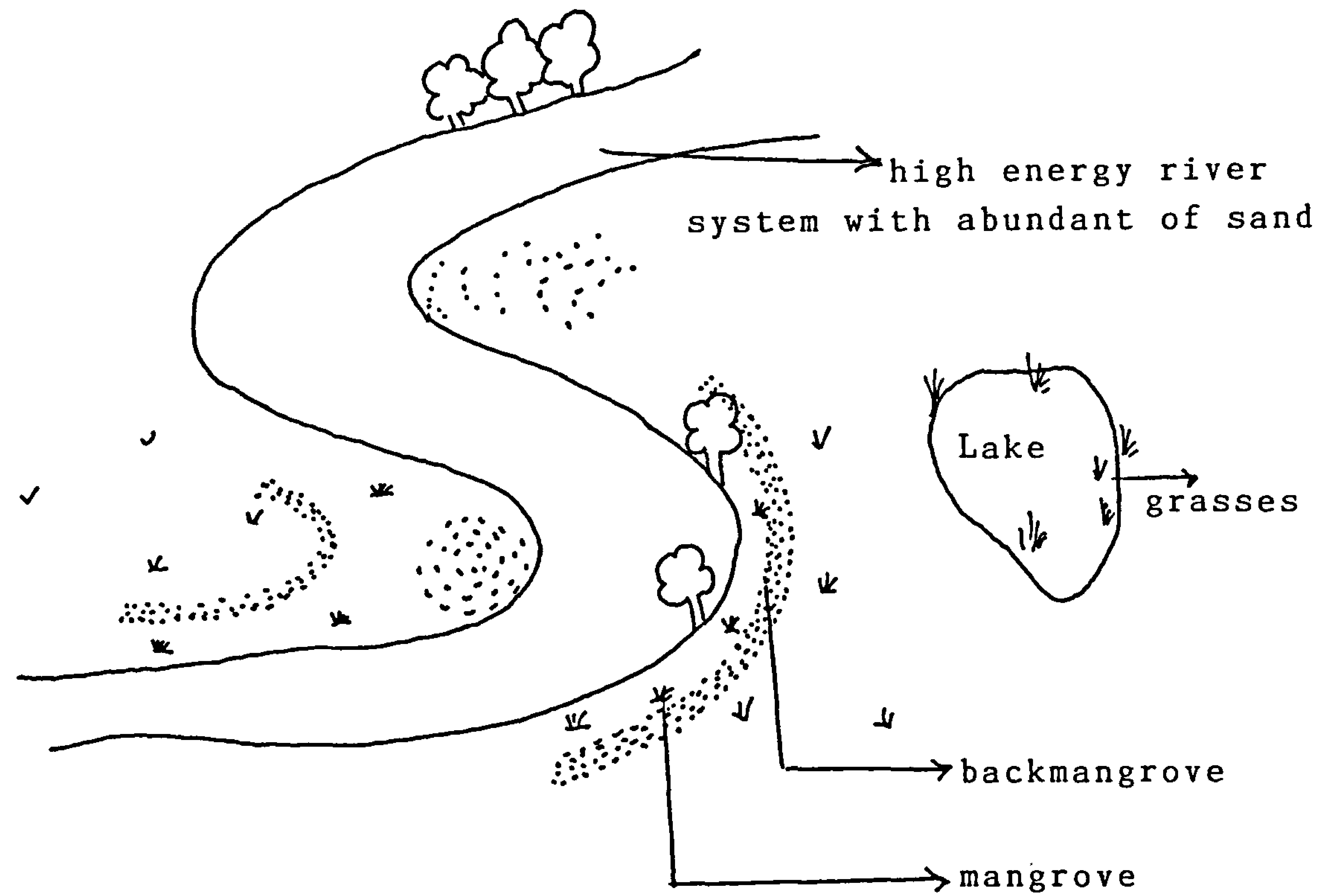


Figure 6.8

6.3.8. Zone 4, spectra 24-18

This pollen zone again reflects the presence of back mangrove vegetation in the vicinity, characterised by *Rhizophora*, *Sonneratia caseolaris*, *Bruguiera* and *Avicennia*, although in reduced abundance. The palms, *Oncosperma* and *Nypa* probably also occurred in this back mangrove vegetation.

In this zone the regional pollen component is reduced and long distance transport of pollen along river systems is of minor importance.

Grasses indicate small lakes, or small freshwater swamps, which were almost covered by grasses, ferns and a few water plants. Spectrum 21 came from a thin peat bed and, therefore, provides a fairly accurate reconstruction of the plant associations growing in herbaceous swamp environments within this area. These were dominated solely by Cyperaceae.

6.3.9 Interpretation of palaeoenvironment

Zone 4 represents deposition in a high energy, brackish to freshwater fluvial setting (Figure 6.8). The brackish coastal swamp includes relatively few species, which suggests a decreasing influence of the tides. The major brackish swamp taxa suggest the occurrence of brackish mud flats, and the dominance of grasses and sedges the occurrence of herbaceous vegetation bordering small lakes. Subsequently, this zone reflects the infilling of the brackish lagoon interpreted during zones 2 and 3.

Rivers were probably lined with freshwater swamp forests and possibly herbaceous swamp. Grass and sedges dominated herbaceous swamp which probably occurred around small lakes within the flood plain. The thin peat bed represents preservation of a Cyperaceae - dominated herbaceous swamp. Montane forests occurred in upland areas above 1,000m a.s.l.

It is suggested, again, that the climate of the area was seasonal in nature due to the extensive representation of grass dominated swamps in a coastal plain setting. The presence of abundant Caliche (carbonate) nodules (ter Haar, 1934), which develop only under markedly seasonal climates (Morley and Flenley, 1987), provides evidence for a relatively strongly seasonal climate during this and subsequent zones.

6.3.10 Zone 5, spectra 18-12

Few upland taxa are present in this zone such as *Myrica*, Theaceae, *Quercus*, *Lithocarpus* . Swamp forest is represented by the abundance of Euphorbiaceae, *Austrobuxus*, *Macaranga*, *Memecylon*, *Eugenia*, *Grewia*, Plumbaginaceae and *Shorea*. The palms are undifferentiated Palmae and *Arenga*.

Cyperaceae shows a decrease in percentages within the zone, but Gramineae are abundant.

Herbaceous swamp communities are represented by Cyperaceae, Gramineae, *Stenochlaena palustris*, *Stenochlaena areolaris*, *Sphenomeris* and other Lycopodiaceae and Polypodiaceae.

6.3.11 Interpretation of palaeoenvironment

Fluvial deposits are not very suitable for palynological investigation except in back swamp environments, because of the amount of sand and coarse silt in the sediment and the fact that the deposits are likely to have been exposed to oxidation during their formation (Hillen, 1984).

Flood plain sediments, including river deposits, are generally like lake sediments i.e. consisting of clays and silts (see Bandung Lake, which was used as the "modern" analogue in this study). Major high energy streams, however, will deposit more abundant sand-sized material.

Depositional environments reflected
in pollen zone 5, representing deposition
in a fresh-water flood plain setting.

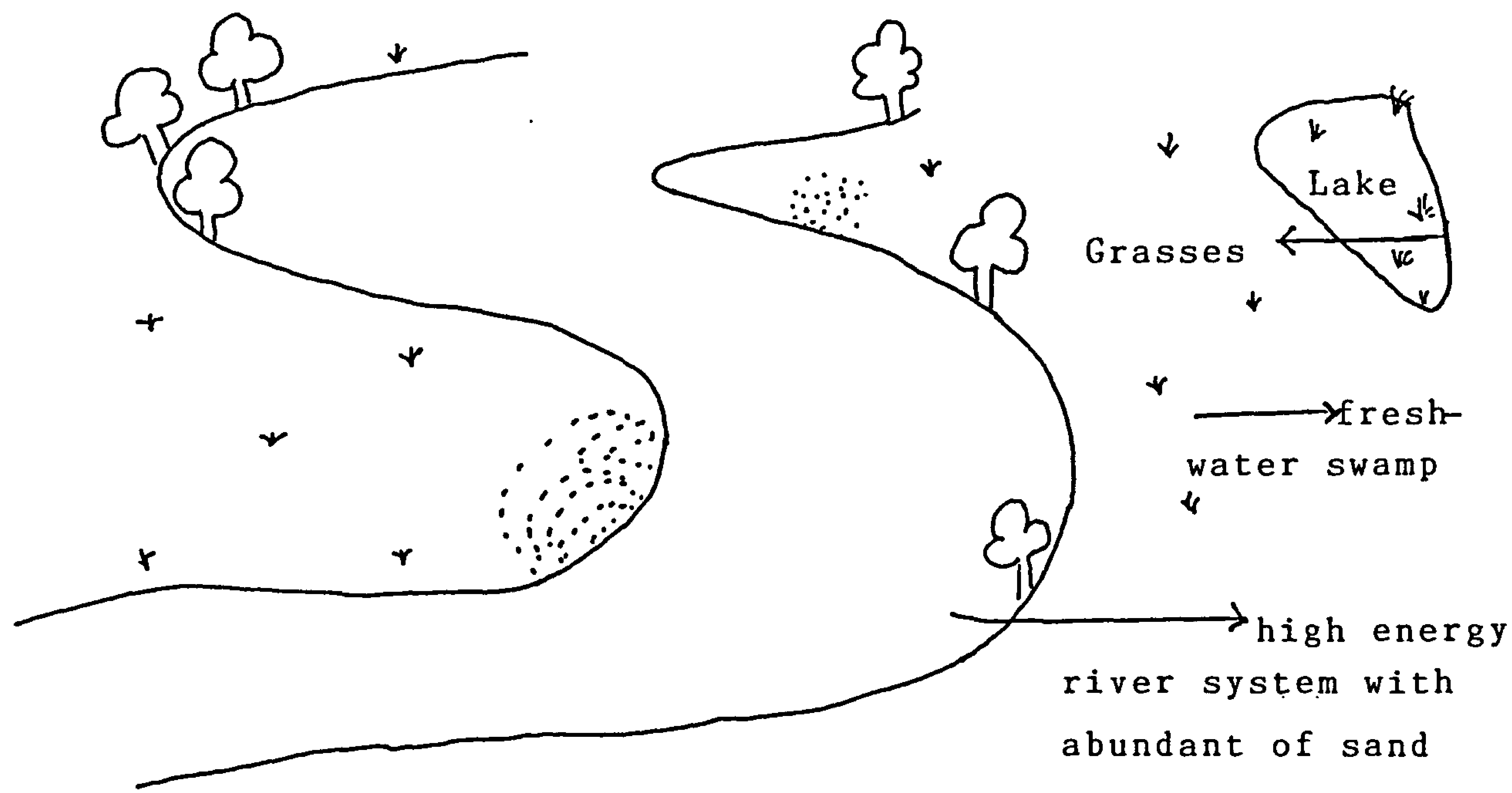


Figure 6.9

As indicated earlier, this sequence probably reflects a high energy, freshwater flood plain setting, resulting in predominantly sand deposition (Figure 6.9).

Palynomorph assemblages reflect locally derived swamp forest vegetation, with single species dominance in several samples (for example samples 14 and 16).

Grasses present may be derived from herbaceous swamps or, in this zone, possibly from terrestrial areas. The assemblages of pollen taxa in this pollen zone are more terrestrial than zone 4. *Sonneratia caseolaris*, however, occurs in very low abundance, and indicates that some brackish influence still occurred.

The occurrence of the common grasses in this zone reflects a seasonal precipitation regime at this site. Such an interpretation is supported by the continuing occurrence of caliche nodules.

6.3.12 Zone 6, spectra 12-11

The presence of *Rhizophora*, *Sonneratia alba* and various palms in this zone, reflects mangrove vegetation at the site. *Podocarpus neriifolius* and *P. imbricatus* are from montane forests, probably

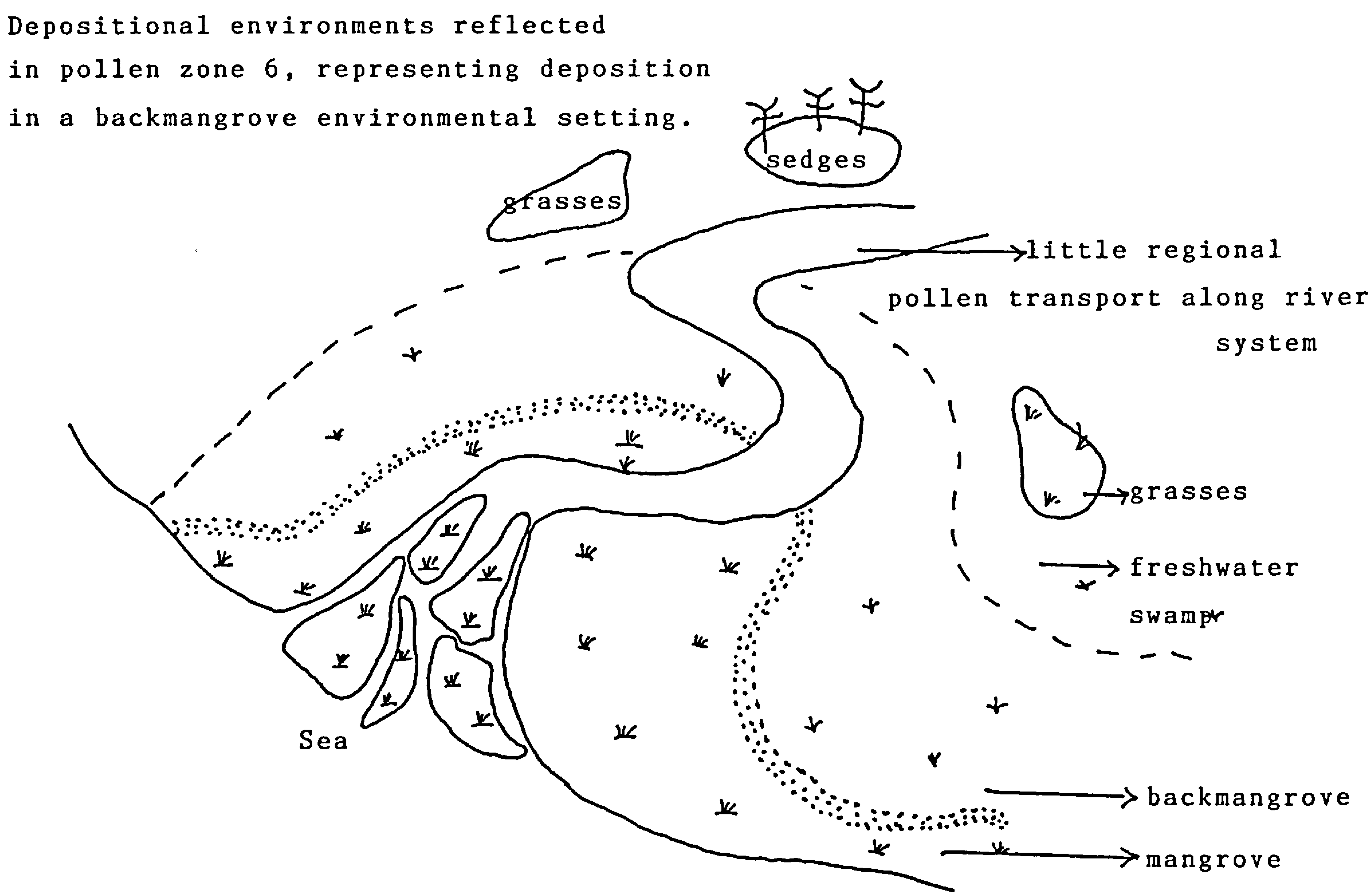

Depositional environments reflected
in pollen zone 6, representing deposition
in a backmangrove environmental setting.
grasses
sedges
little regional
pollen transport along river
system
grasses
freshwater
swamp
backmangrove
mangrove
Sea

Figure 6.10

distant from the site of deposition, since the pollen of upland taxa occurs in very low values. Freshwater swamp forest is probably of restricted representation and diversity. The common presence of grasses again indicates the extensive occurrence of herbaceous swamp communities in the area. These might form floating mats of vegetation over open water.

6.3.13 Interpretation of palaeoenvironment

This zone reflects a back mangrove depositional setting (Figure 6.10) with the presence of *Rhizophora* and palms which are usually found along river distributaries today.

The presence of *Sonneratia alba* pollen within this sequence may reflect the close proximity of more normal salinity mangrove swamps. *S. alba* usually occurs only in the vicinity of river mouths or along the seaward edges of mangrove swamps, where salinities are high. This back mangrove area was characterised by slow moving brackish rivers, with the deposition of very little sand. Swamp grasses, sedges and ferns possibly occurred around small lakes within the flood plain and may have been present on floating mats of herbaceous vegetation. The occurrence of grass dominated swamps on the coastal plain, and the rarity of peat accumulation again reflects deposition under a seasonal climatic regime.

6.3.14 Discussion and age of Cisaat, Bumiayu

According to ter Haar (1934) Molluscan assemblages from the *Turritella* bed show that the Kalibiuk formation is a marine lagoonal facies.

The interpretation of pollen analysis showed that zones 1, 2, 3 and 4 reflect brackish mangrove, back mangrove and freshwater lacustrine and lagoonal low energy deposition, thus essentially confirming the interpretations of ter Haar (1934). Zones 5 and 6 reflect high energy freshwater flood plain and normal salinity mangrove swamp respectively.

Morley (1978) used the biostratigraphical zonation of pollen and spores in Kalimantan for the zonation of Tertiary and Quaternary sediments in Indonesia. Comparison with his stratigraphical scheme for Kalimantan is also useful for the southern Sunda shelf and Java due to its proximity. Thus, using this scheme the age of the Kalibiuk formation in the Cisaat section can be interpreted.

According to Morley (1978) the spores of *Stenochlaena laurifolia (Stenochlaenidites*

papuanus), occur in the Upper Miocene to Upper Pliocene, whereas, west of Wallace's line,* (see end of Chapter) pollen of the montane conifer *Podocarpus imbricatus* appears in the Upper Pliocene and Pleistocene. Based on the presence of both taxa, the age of the Kalibiuk Formation is concluded to be Upper Pliocene, thus confirming the interpretation of von Koeningswald (1934).
According to von Koeningswald (in ter Haar, 1934) the Kaliglagah Formation was deposited conformably on the Kalibuik Formation and the two are of about the same age (Upper Pliocene).

Muller (1966, 1972) determined that *Podocarpus imbricatus* migrated into the Sunda region from Eastern Indonesia following the Late Neogene collision of the Australian and Asian plates. This provides further support for the ages of the Kalibiuk Formation suggested above.

A summary for Cisaat, Bumiayu is presented in Table 6.2.

The data on which the interpretation of the environment of deposition in this study are based include pollen, spores and dinoflagellates, lithologies and published data concerning faunal remains. Interpreting the sedimentary environment requires a knowledge of the palaeogeographical distribution of species and a careful assessment of ecological studies of the present day vegetation. Conclusions based on the interpretations made in this study will be described in the following Chapter 7.

*Wallace discovered the dramatic change in fauna and drew a red line which occurs in the middle of the Malay archipelago. He provides an historical understanding of palaeogeography and biogeography of the region (George, 1981).

Table 6.2

Summary for Cisaat, Bumiayu

Pollen assemblage zones	Lithology and local depositional setting	Surrounding dry-land vegetation and climate	Vegetation in upland areas	Faunal age
6	Clays deposited in close proximity to more normal salinity mangrove swamps. Inflowing rivers with minor swamp forest.	No information	Podocarpus growing in montane forest	Upper Pliocene
5	Sands deposited in a high energy fluvial freshwater flood plain setting, with swamp forests and herbaceous swamp dominated by Gramineae Caliche nodules reflect strongly seasonal climatic setting.	Grasses could provide a component of terrestrial vegetation e.g. seasonal climate.	Podocarpus spp growing in montane	
4	Transitional sequence, sands, muds and peats deposited in brackish to fluvial setting. Caliche nodules reflect strongly seasonal climatic setting.	No information	Poor information, Podocarpus growing in montane forest.	

Pollen assemblage zones	Lithology and local depositional setting	Surrounding dry-land vegetation and climate	Vegetation in upland areas	Faunal age
3	Clays deposited in brackish lagoonal setting surrounded by mangrove swamps and with herbaceous swamp dominated by grasses. Slow moving river flow into the lagoon. Shell bed reflects sudden fall in sea level with dominance of Bruguiera swamps.	No information	Podocarpus spp growing in montane forest.	Upper Pliocene
2	Clays deposited in extensive freshwater to brackish lakes or lagoons bearing extensive grass dominated herbaceous swamp and with extensive by mangrove swamps in the vicinity.	No information	No information	
1	Clays deposited in low energy brackish, coastal plain setting with mangrove swamps traversed by slow moving rivers, lined with swamp forest, small lakes bearing grass dominated swamp within the flood plain.	No information	Podocarpus spp growing in montane forest.	

CONCLUSIONS

Chapter 7

7.1 The purpose of the present study is to determine the history of depositional environment and vegetation, climate and ages of different stratigraphic sequences from the Plio-Pleistocene of Java. The youngest (Holocene) sequence (from Bandung Lake) was used as an analogue from which the processes of palynomorph transport and deposition in to a depositional system could be studied. The two older sections, Trinil from the Middle Pleistocene of East Java and Bumiayu of Upper Pliocene age from Central Java, were then interpreted with respect to depositional processes observed within the Bandung Lake sequences and other comparable depositional systems which have been described in the literature. All of these initial aims of this study were realised. The major conclusions reached for each of the three sites may be summarised as follows:-

1. The major part of the palynomorph assemblages deposited at each site was primarily derived from local hydrophytic vegetation. This readily permitted the interpretation of local hydroseral vegetation and when combined with lithological and other data, a detailed reconstruction of the palaeoenvironment at each site could be made.

2. Regionally derived pollen provided a much smaller proportion of the palynomorph assemblages at each site and correspondingly, the reconstruction of the regional vegetation history were less precise. Nevertheless, sufficient data was obtained within the regional pollen component to assess the major vegetational changes which are thought to have taken place around the study sites.

3. Radiocarbon dating of one of the three cores taken from Bandung Lake (Rancaekek) indicated that the sequence spanned the Holocene (11,000 yr BP - 7,000 yr BP, see Chapter 6, section 1.3). Throughout this period the area was occupied by an extensive lake, which gradually shallowed within the upper part, finally drying up at about 7,000 yr BP.

   Freshwater swamp forest, herbaceous swamp and floating aquatic plant communities were important constituents of the hydrosere of the lake.

4. The regional pollen component reveals a reduction of montane pollen by about 8,000 yr BP which may represent the effect of the maximum of incoming solar radiation in the Northern Hemisphere centred around 9,000 yr BP and brought about by orbital variations (Kutzbach, 1983). Upper montane everwet rain forest was initially

extensive around the site, being replaced at this time by lower montane to rain forests.

5. No positive evidence for the activities of man was identified from the Bandung Lake cores. This probably relates to the age of the deposits. The youngest dated sediments studied within the cores yielded an age of 7810 $\pm$ 100 yr BP and probably reflect deposition at a time prior to that at which man had a significant effect on the vegetation of the Bandung region.

6. Studies at Trinil (see Chapter 2, section 2b) indicated the depositional sequence represented by the Kabuh Formation consisting of gravel, silt, clay and sand. The area is now vegetated by an open patchwork of forest, herbaceous and aquatic plant communities and appears to have been similar in the past.

7. Palynological data demonstrate that the Trinil sequence is Pleistocene in age; a more precise age estimate cannot be made at present on the basis of palynology.

8. The sequence studied at Bumiayu, consisting of the Kaliglagah and Kalibiuk Formations, is interpreted as having accumulated in regressive lagoonal, lacustrine and freshwater fluvial environments. The pollen sequence in the present study at Bumiayu has been

divided into six pollen zones (see Chapter 5) which can be interpreted as representing six different depositional environments from coastal plain to freshwater fluvial:

Zone 1 (spectra 40 - 34) representing a brackish coastal plain depositional setting.

Zone 2 (spectra 34 - 32) indicating an open water lagoonal coastal plain setting.

Zone 3 (spectra 32 - 24) shows a lagoonal coastal plain setting.

Zone 4 (spectra 24 - 18) reflects a high energy, brackish freshwater fluvial setting.

Zone 5 (spectra 18 - 12) represents a freshwater flood plain setting.

Zone 6 (spectra 12 - 11) reflects a back mangrove environmental setting.

9. Both palynological and lithological evidence from the Kaliglagah and Kalibiuk Formations indicates that this sequence accumulated under a more strongly seasonal climate than experienced in the area at present.

10. Palynological data support other lines of evidence that the Kaliglagah and Kalibiuk Formations studied at Bumiayu are of Upper Pliocene age.

11. This study demonstrates that three plant taxa have become extinct during the Plio-Pleistocene in Java. The ferns *Stenochlaena laurifolia* and *S. areolaris* became extinct within the Pliocene, whereas the genus *Dacrydium* possibly became extinct during the Holocene.

7.2 General climatic picture of Java

The Late Cenozoic vegetational and environmental changes in Java recorded by this study provide additional information on the nature of lowland vegetation and climate in the region. Modern vegetational studies have revealed the distinctive distribution of species characteristic of equatorial rain forest and of drought resistant plants (associated with tropical climates with a pronounced dry seasons) in Southeast Asia (Verstappen, 1975). Changes in the pattern of distribution of these species in the past, are believed to be climatically significant. In the last 100 years an increase of about 1^{o}C in annual average temperature has been recorded at most equatorial stations, while in the Sumatran highlands, the mean annual temperature seems to have increased by about 2^{o}C (Morley, 1982). In this study no significant changes in increased temperature are recorded. This is in keeping with previous work from West Java, which V. Zeist (1984) suggested was similar to Sumatra, in recording a stable temperature regime based on the broad outline vegetation history.

In terms of water balance, studies of past vegetation suggest that drier conditions have been the exception and that humid tropical conditions are thought to be more "normal" in Southeast Asia.

It was long believed that variations in the atmospheric and oceanic circulations which lead to the ice ages of the temperates regions, had not significantly affected the vegetation of equatorial regions (Verstappen, 1975). In lowland tropical Southeast Asia, the temperature depressions of the glacial periods do not appear to have been major, but in the mountain areas there is evidence for a marked fall in annual average temperature (Flenley, 1979).

During and after the last ice age, various climatic regimes have prevailed in the area because of changes in temperature, precipitation and vapour pressure. Palynological studies of Pleistocene deposits enable the effects of climate changes to be seen more clearly. Data on climatic change in the humid tropics during the Late Cenozoic remain limited, particularly with respect to Southeast Asia.

The evidence available for this part of the world, especially for Java, has been reviewed in this thesis. In general, the climate in Java did not differ greatly from the present day. The variations experienced might have been the result of slight changes in the geomorphological contexts of the sites as well as through sea level fluctuations. The impact of small scale variations in precipitation seasonality is also evident in the records from Bandung Lake and Bumiayu.

In Southeast Asia, palynological reasearch in New Guinea, Sumatra and Java has provided evidence for vertical movements of vegetation belts which are mainly due to enhanced reductions in temperature with increasing elevation under steeper lapse rate conditions in the glacial periods. In New Guinea, we have evidence from above 1,900m for vertical movement of the upper forest limit, while for Sumatra and Java we have evidence from lower altitudes (900 -1,600m) (Morley, 1982).

Studies of pollen sequences from Java have shown that the climates of East and West Java were distinctive (as at present), but that there has been little variation in temperature. Precipitation appears to be the sensitive variable. Sumatra and Kalimantan, the western part of Southeast Asian area, is characterised by an everwet climate, while the Lesser Sunda Islands experience a more pronounced dry season. Java lies in the transitional zone between everwet and monsoonal climate, with West Java having an everwet climate and East Java a distinct dry season associated with seasonal changes in wind direction (monsoon). A shift in the boundary between the two climatic regions should result in changes in the regional vegetation reflecting the marked differences in the natural vegetation of the various climatic zones at present. In the transitional zone, an east-west shift of minor extent would be marked by small local changes in the regional vegetation pattern of island Java. This study provides palynological evidence of such a minor east-west shift in the Holocene period (from Bandung Lake). Such a shift supports the findings of Stuijts (1984).

The position of the Intertropical Convergence Zone (ITCZ) is not exactly over the equator but is affected by the distribution of land and sea. Over Southeast Asia, the seasonal shifts in the position of the ITCZ are particularly large.

The exact position of the ITCZ in a given year depends on the relative strengths of the Asiatic and Australian anticyclones in the northern hemisphere winter and summer respectively. The simultaneity of the ice ages in the northern and southern hemispheres suggests that during the Pleistocene, the fluctuations of the Asiatic and Australian anti-cylclones were also in phase.

The climatic changes resulting from these seasonal variations in the position of the ITCZ are most important in Southeast Asia. During the glacial periods, the ITCZ was generally located south of its present position. As a result, southern Indonesia would have had less precipitation, its position relative to the ITCZ being like that of northern Indonesia today.

A greater length and intensity of dry season tends to be associated with such a decrease in precipitation, resulting in a shift in the climatic zones covering the region. Climatic conditions in Java were characterised by lower precipitation and temperature during these glacial periods which is significant in this study.

7.3 Factors affecting the climate

Temperature

Temperature changes were associated with the glacial-interglacial alternations that characterised the Pleistocene period. The extent of these changes of temperature in equatorial regions have tended to be underestimated. Global estimates indicate a decrease in mean temperature of 3 - 9^{o}C during the last glaciation, while sea surface temperatures were depressed by about 5^{o}C (Verstappen, 1975). An increased lapse rate seems to have prevailed during Glacial periods in Southeast Asia (Walker and Flenley, 1979). The present mean annual temperature of West Java is like that of Sumatra with a similar increase of 2^{o}C during the Holocene.

Precipitation

There is evidence, from different types of sources, for changes in the seasonal distribution of precipitation over Java. Changes in total precipitation and its seasonal distribution within the Late Cenozoic in Southeast Asia are believed to be indicated by the migration of particular mammals from Thailand into Java and Sulawesi during the Upper Cenozoic (Sartono, 1973). Caliche (carbonate) nodules have been found in the Cisaat, Bumiayu section. These nodules form only under dry climates, which combined with the pollen evidence from the site, indicates increasing seasonality in precipitation.

Hydrology

Lake-level

Sites which reflect local hydrological variation, such as minor lake-level changes in the Bandung Lake, depend on the changing balance between precipitation and evaporation and, presumably, on the geomorphology of the basin.

Sea-level

During the Pleistocene, the glacio-eustatic variations in sea-level associated with ice ages were felt in the Southeast Asian region. Local tectonic events, however, have resulted in complex sea-level histories for different parts of the Southeast Asian region. In this study, the sequence at Bumiayu (between the Kaliglagah and Kalibiuk formations) shows emergence, but due to volcanic activity, not to changing sea-level.

Due to the great extension of shallow shelf areas (Sunda and Sahul shelfs) in Southeast Asia, the amount of land exposed during glacial times was much larger than at present.

The effect of the post-glacial rise in sea-level is also recorded. Tjia *et al* (1984) suggest that during the Middle Holocene, sea-level reached about 4.5m above its present day position over a wide area of Indonesia, while Haile (1975) concluded that evidence of Quaternary shorelines in Peninsular Malaysia reveals a rise greater than 6m, this is likely to be related to local diastrophism.

Human impact on the environment

Pollen analysis of the Trinil sequence suggests that the Java man remains found here are of Middle Pleistocene age, where the hominid existed in an environment of open rain forest. The present day natural vegetation of the Trinil area is of teak forest, under a monsoonal climate. Consquently it seems that, at the time of deposition of the vertebrate bone-bed at Trinil, the area experienced a climate transitional between wet and monsoonal, with a dry season rather more marked than at present.

In Southeast Asia we still have to learn to distinguish clearly between anthropogenic disturbance of the vegetation and those changes caused by natural factors. However, one may be confident that Southeast Asia will yield pollen records useful for reconstructing both the vegetation history and human impact in the region.

Palynological studies have proven to be of value in providing further evidence for the palaeoecology of Java man (*Homo erectus*) which will help to establish the depositional setting and age of the site in respect of the Southeast Asian region.

7.4 Hominid fossil bearing sediments in Java

Indonesia has played an important role in palaeoanthropology due to Dubois discovery and the Java man site at Trinil. Since these finds, further work has been published with a debate based on controversies over phylogeny, taxonomy, chronology and artefactual associations. The historical site of Trinil, which has been established in the so-called Kabuh Formation, is related to the fossiliferous and hominid-bearing formation of early - Middle Pleistocene age (Orchiston and Siesser, 1982). The Indonesian hominid sites were placed into a stratigraphic sequence by Sondaar (1984).

The site at Trinil yielded *Homo erectus* who perhaps inhabited dry, open woodland during glacial phases. The Trinil HK fauna are relatively poor in species which points to an isolated position. The environment is considered to have been one of open woodland. This might also point to a glacial interval.

The taxonomy, archaeology and palaeoenvironmental contexts of the earliest known Asian hominids have helped to provide a palaeoecological setting for human evolution Southeast Asia. More information is available concerning the early Asian hominids than there is for similar types of finds in Africa and Eurasia. This probably reflects different methods of palaeoanthropological study in different parts of the world.

Pope (1985) suggested that studying the fossil faunas of island Southeast Asia it became immediately apparent that open grassland - dwelling forms are consistently absent and that this negative evidence is meaningful. As a result, a fairly heavily forested environment during the Southeast Asian Mid-Pleistocene is suggested.

Palaeoenvironmental reconstruction allows the undisturbed lowland and mountain rainforest areas of Southeast Asia to be identified.

The environment which these hominids occupied was quite different from that of Africa or South Asia. It was a much more forested environment, and this has been illustrated by the present study of the Trinil area. Concerning the *Homo erectus* groups we have indicated several local vegetational changes, sea-level changes and climatic variations which might be of palaeoenvironmental significance. All these palaeoenvironmental pictures contribute to our knowledge of the Javanese *Pithecanthropus* environments.

Closing Statements

A variety of micropalaeontological approaches have been used to try and solve the problem of dating the Plio-Pleistocene boundary in Java. In this study, palynology was used and seems quite a promising tool.

Palynological studies undertaken here, have conclusively demonstrated that palynology has a major role to play in helping to unravel the palaeonvironmental and palaeoclimatic history of the Javanese Pliocene and Pleistocene, and also in dating these sequences. In particular, it must be emphasised that these studies may assist in further determining the environment in which Java man evolved within the Pleistocene.

The effect of modern man on the Holocene vegetation of Java is another area of great potential for palynological studies.

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PLATES

All magnifications x 1,000

unless otherwise specified

PLATE 1

Vesiculate

Podocarpus neriifolius (from Linggar and Rancaekek)

1. distal face, body of 32 um
2. distal face, slightly lower focus, body of 32 um
3. proximal face, body of 45 um
4. distal face, body of 60 um
5. distal face, body of 72 um
6. sacci, with distal invagination
7. sacci, with distal invagination

PLATE 1

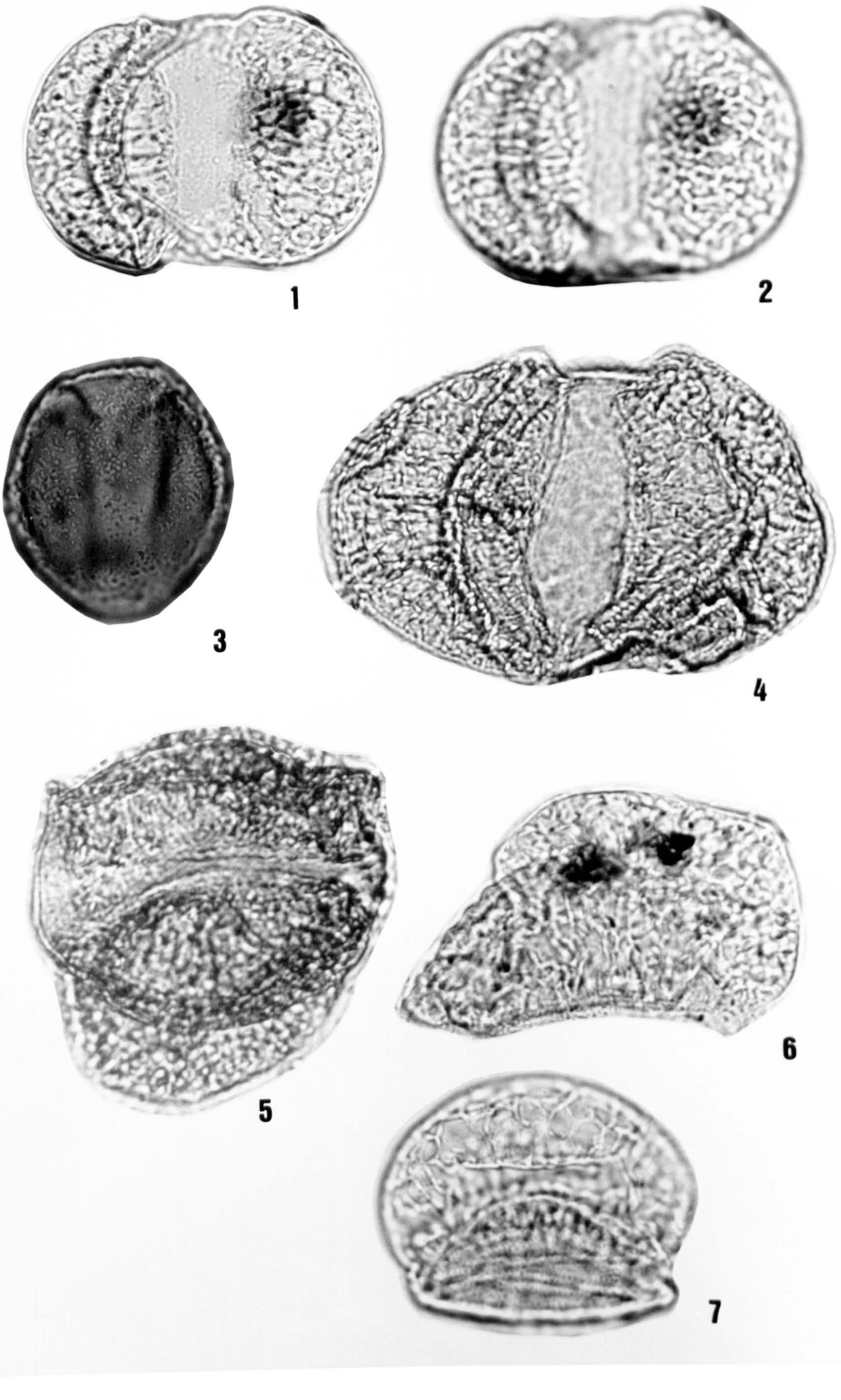


PLATE 2

Podocarpus imbricatus (from Linggar and Rancaekek)

1. distal face, body of 48 um
2. distal face, body of 54 um
3. distal face,slightly lower focus, body of 54 um
4. part of proximal face, body of 48 um
5. part of proximal face, body of 48 um
6. body of 36 um
7. body of 36 um
8. body of 42 um
9. body of 48 um
10. body of 54 um
11. sacci with distal invagination

PLATE 2

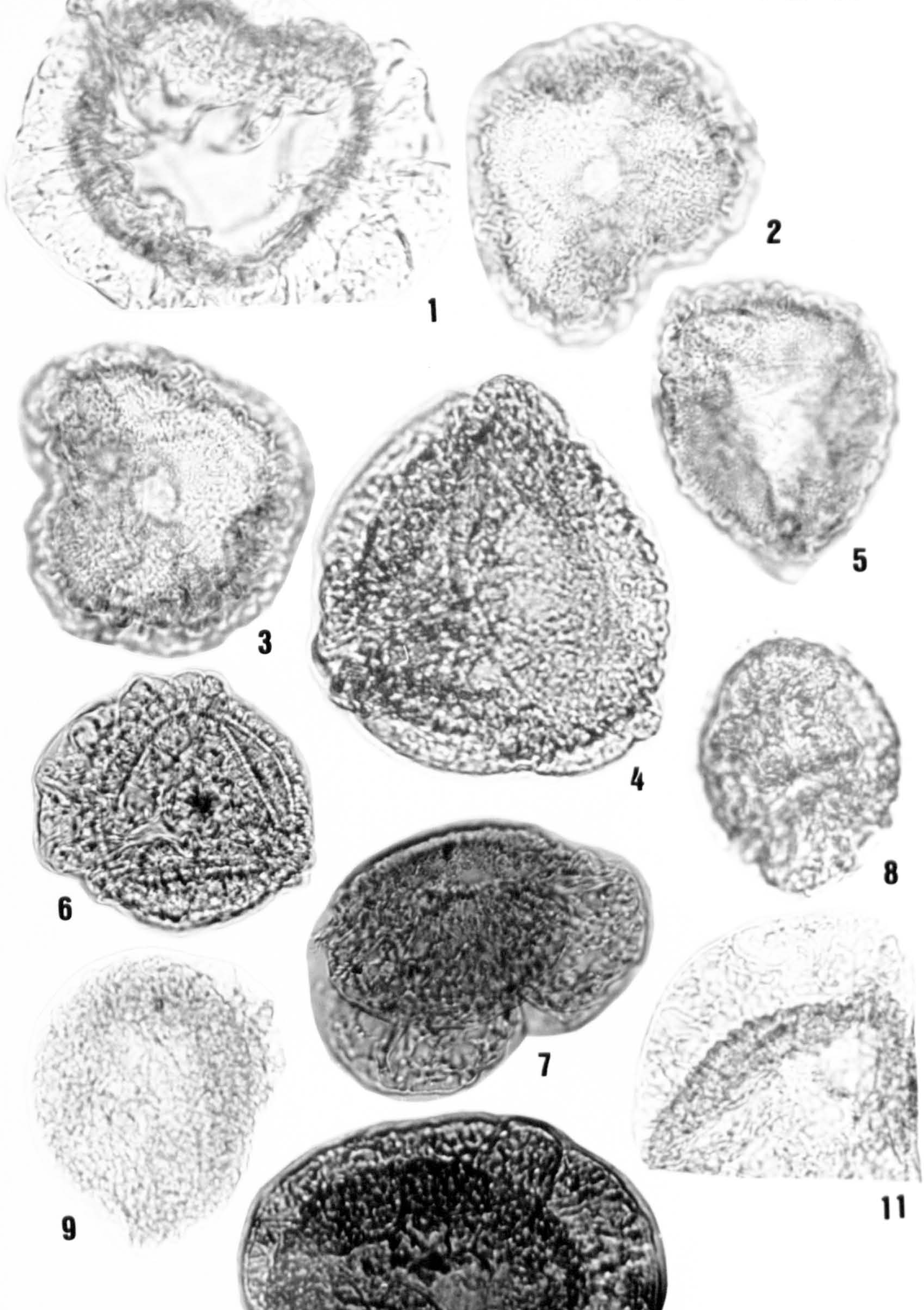


PLATE 3

Vesiculate

1. *Dacrydium* (from Bumiayu)
2. *Podocarpus imbricatus* (from Bumiayu)
3. *Podocarpus neriifolius* (from Bumiayu)
4. *Pinus* (from Trinil)

Inaperturate

5. *Agathis* (from Bumiayu)
6. Araceae (from Bumiayu)
7. *Blyxa* (from Trinil)
8. *Blyxa* (from Cibogo)
9. *Cyrtospermum* (from Trinil)

Monoporate

10. Cyperaceae (from Cibogo)
11. Cyperaceae (from Trinil)
12. Cyperaceae (from Linggar)
13. Cyperaceae (from Rancaekek)
14. Cyperaceae (from Bumiayu)

PLATE 3

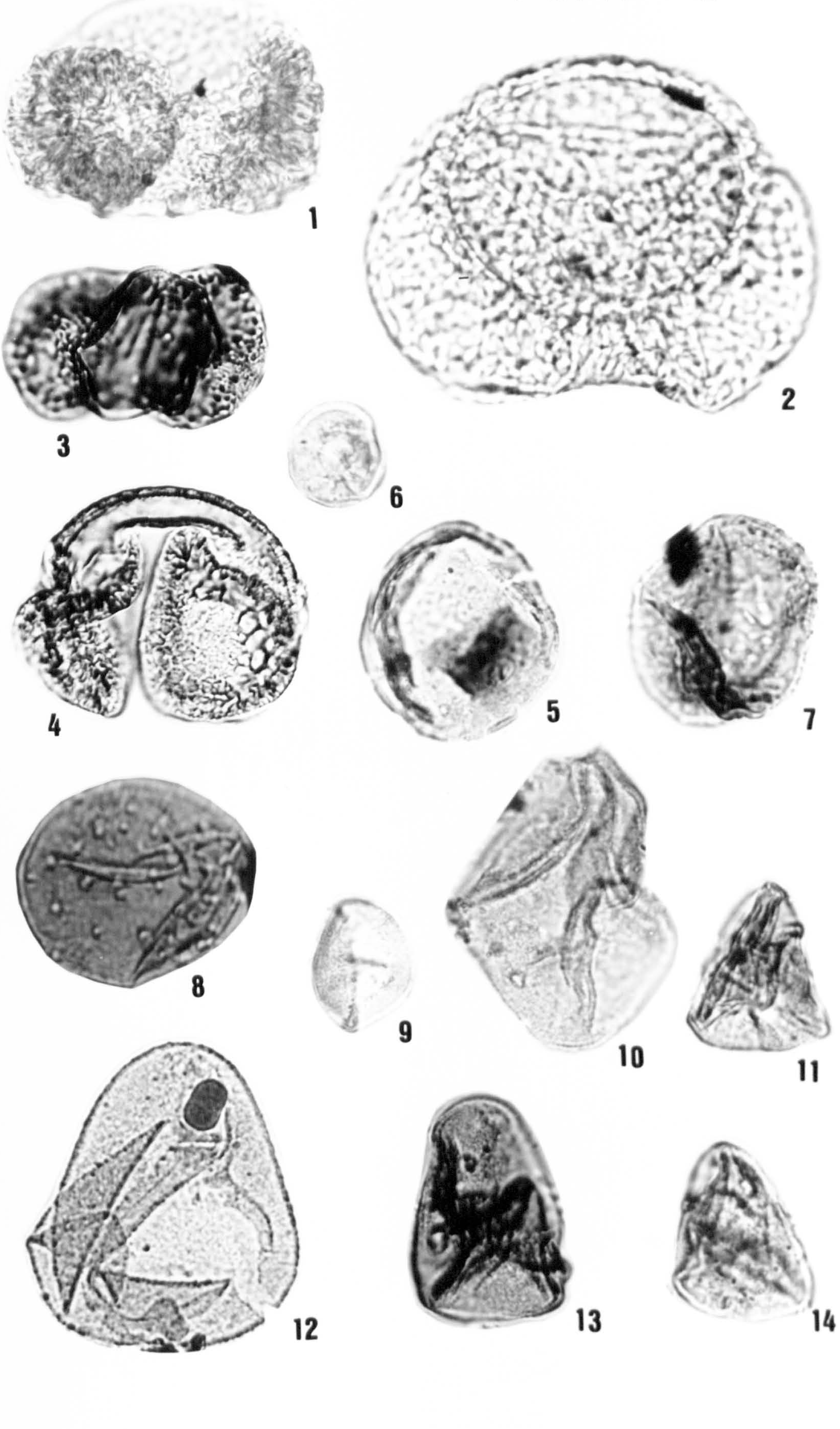


PLATE 4

1. Gramineae (from Bumiayu)
2. Gramineae (from Trinil)
3. Gramineae (from Cibogo)
4. Gramineae (from Rancaekek)
5. Gramineae (from Linggar)
6. *Pandanus* (from Trinil
7. *Pandanus* (from Cibogo)
8. *Typha angustifolia* (from Rancaekek)
9. *Typha angustifolia* (from Cibogo)
10. *Typha angustifolia* (from Trinil)

Diporate

11. *Ficus* (from Linggar)

Triporate

12. *Canthium* (from Bumiayu)
13. *Casuarina* (from Trinil)
14. *Casuarina* (from Bumiayu)
15. *Celtis* (from Cibogo)
16. *Celtis* (from Rancaekek)
17. *Durio zibethinus* (from Bumiayu)
18. *Engelhardia* (from Cibogo)
19. *Engelhardia* (from Bumiayu)
20. *Engelhardia* (from Trinil
21. *Florscheutzia semilobata* (from Bumiayu)
22. *Helicia* (from Trinil)
23. *Myrica* (from Bumiayu)
24. *Myrica javanica* (from Linggar)
25. *Myrica javanica* (from Trinil)

PLATE 4

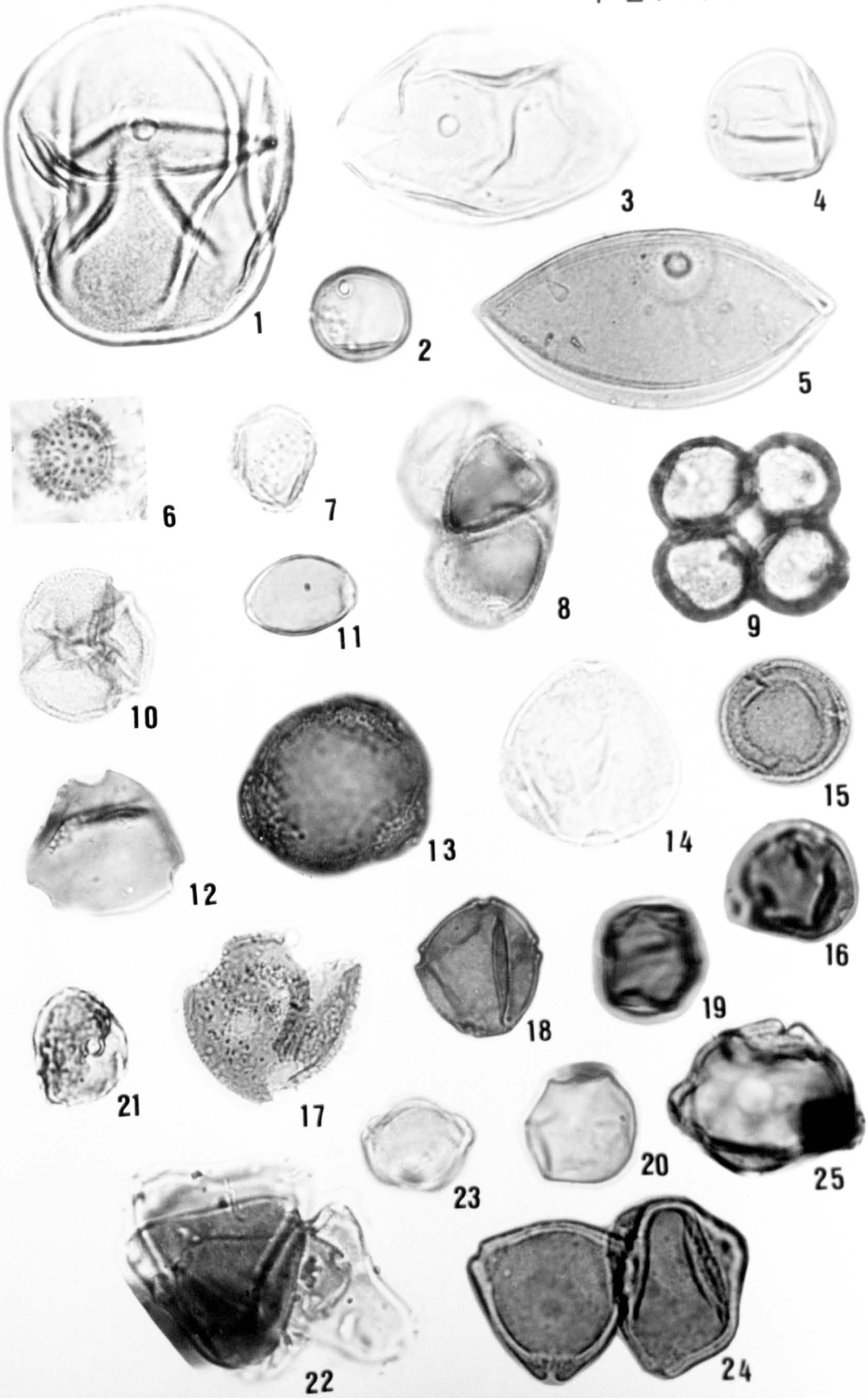


PLATE 5

1. *Pometia* (from Cibogo)
2. *Pometia* (from Trinil)
3. *Pometia* (from Bumiayu)
4. *Sonneratia caseolaris* (from Bumiayu)
5. *Sonneratia alba* (from Bumiayu)
6. *Symplocos* (from Bumiayu)
7. *Trema* (from Cibogo)
8. *Trema* (from Trinil)

Periporate

9. *Altingia excelsa* (from Rancaekek)
10. Chenopodiaceae (from Bumiayu)
11. Chenopodiaceae (from Trinil)
12. Chenopodiaceae (from Trinil)
13. *Hibiscus* (from Bumiayu)
14. *Hibiscus* (from Trinil)
16. *Polygonum* (from Cibogo)
17. *Polygonum* (from Bumiayu)

Stephanoporate

15. *Austrobuxus nitidus* (from Bumiayu)
18. *Strobilanthes* (from Rancaekek)
19. *Strobilanthes* (from Rancaekek)
20. *Strobilanthes* (from Trinil)

PLATE 5

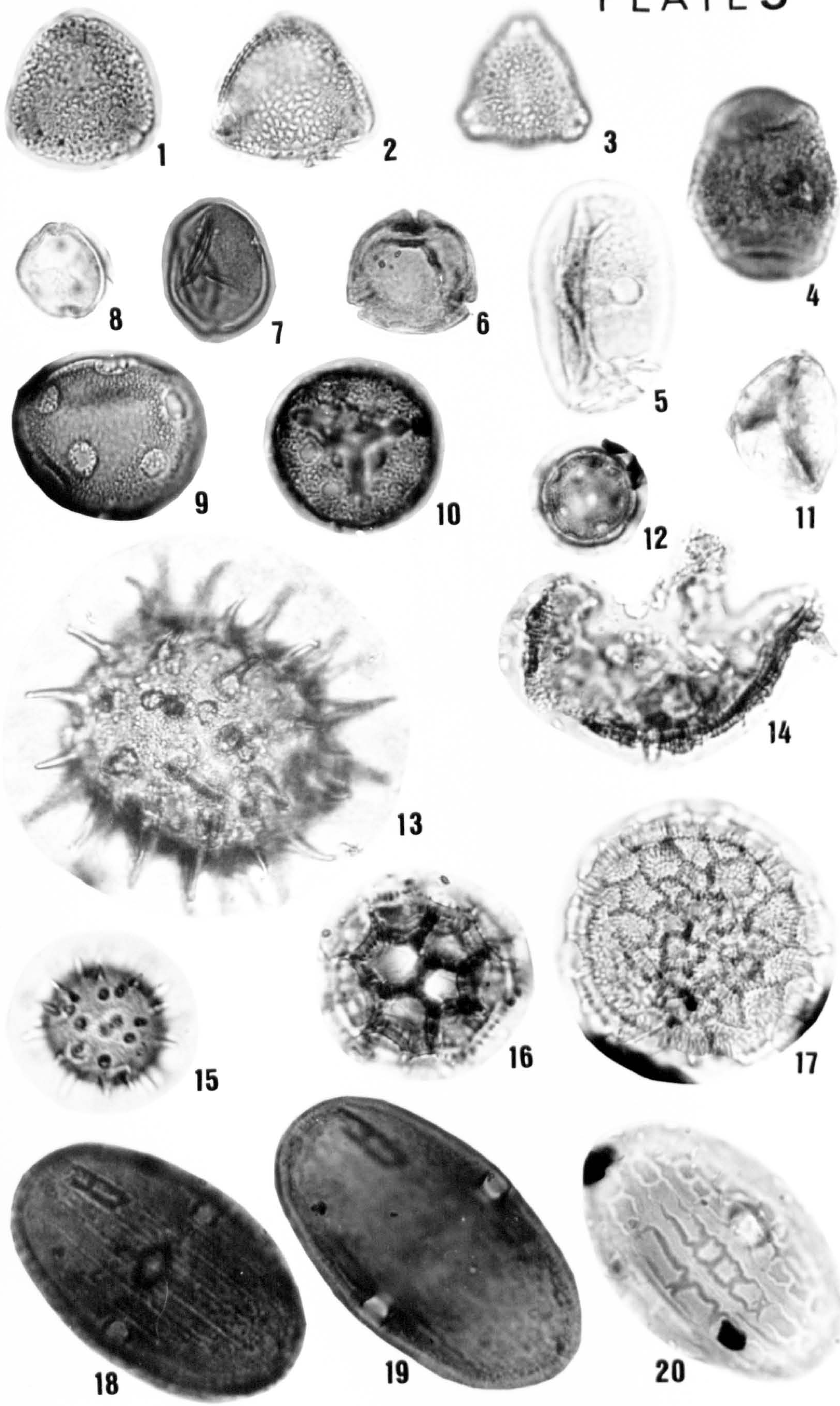


PLATE 6

Monocolpate

1. *Arenga* (from Bumiayu)
2. Liliaceae (from Cibogo)
3. Liliaceae (from Cibogo)
4. *Nypa* (from Bumiayu), magnification x 500
5. *Nuphar* (from Cibogo)
6. *Nuphar* (from Cibogo)
7. *Oncosperma* (from Bumiayu)
8. Palmae (undiff.) (from Bumiayu)

Tricolpate

9. *Avicennia* (from Bumiayu)
10. *Shorea* comp (from Bumiayu)
11. *Shorea* comp (from Trinil)
12. *Dipterocarpus* (from Linggar)
13. *Dryobalanops* (from Bumiayu)
14. *Geranium* (from Trinil)
15. *Ilex* (from Cibogo)
16. *Ilex* (from Bumiayu)
17. Plumbaginaceae (from Bumiayu)
18. *Quercus* (from Trinil)
19. *Quercus* (from Cibogo)
20. *Shorea* comp (from Bumiayu)

Syncolpate

21. *Barringtonia* (from Bumiayu)

PLATE 6

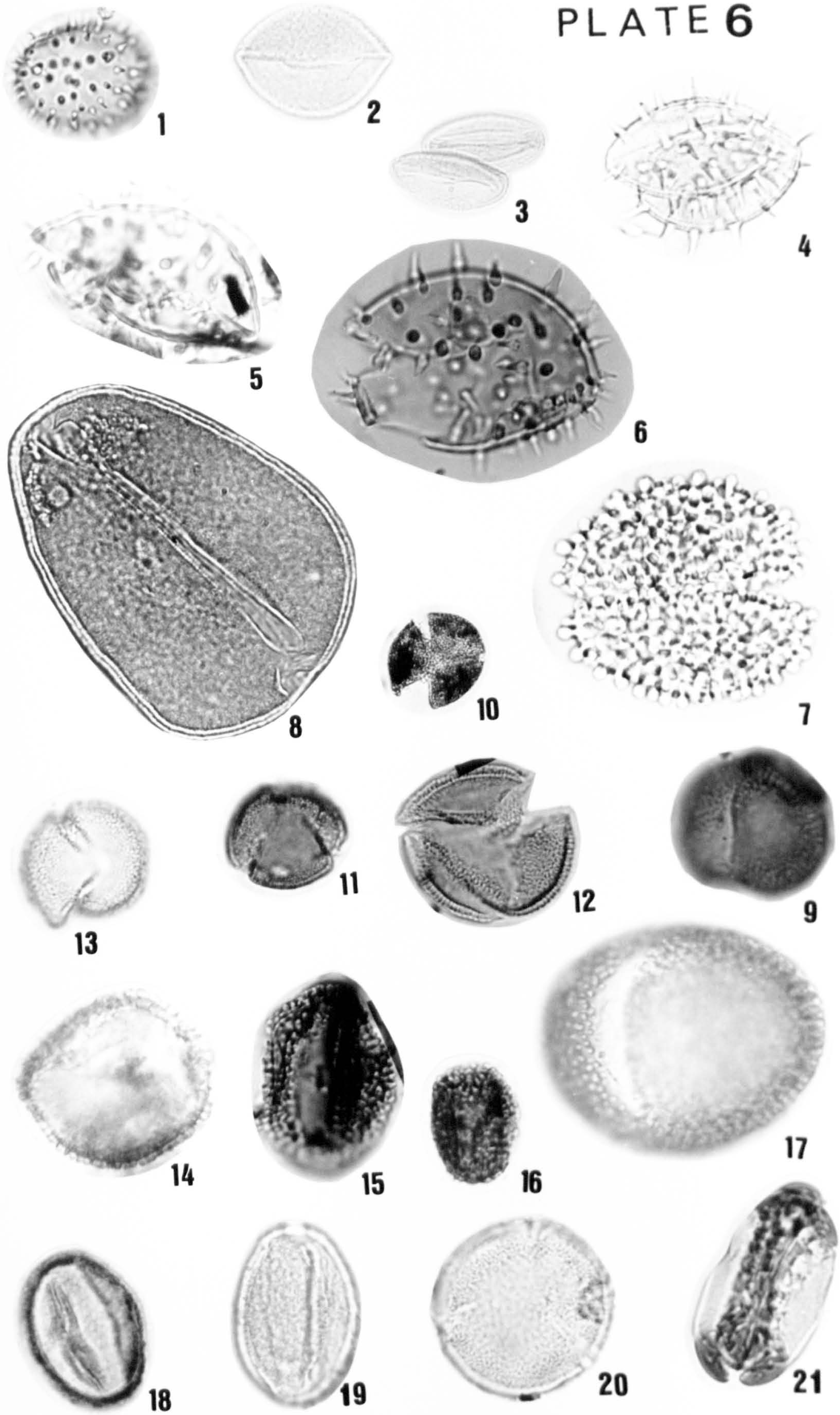


PLATE 7

1. *Eugenia* comp 1 (from Bumiayu)
2. *Eugenia* comp 1 (from Trinil)
3. *Eugenia* comp 1 (from Rancaekek)
4. *Eugenia* comp 2 (from Trinil)

Stephanocolpate

5. *Acrocephalus* spp (from Trinil)

Tricolporate

6. *Ageratum* comp (from Trinil)
7. *Alangium* (from Bumiayu)
8. *Bischofia* (from Trinil
9. *Bischofia* (from Trinil)
10. *Bischofia* (from Trinil)
11. *Bombax* sim (from Bumiayu)
12. *Brugueria* comp (From Bumiayu)
13. Buchanania (from Rancaekek)
14. Calophyllum (from Cibogo)
15. *Calophyllum* comp (from Trinil)
16. *Castanopsis* comp (from Bumiayu)
17. *Castanopsis* comp(from Cibogo)
18. *Castanopsis* comp (from Rancaekek)
19. Compositae (Tubuliflorae) (from Bumiayu)
20. Compositae (Tubuliflorae) (from Linggar)
21. Compositae (Tubuliflorae) (from Linggar)
22. Compositae (Tubuliflorae) (from Rancaekek)
23. Compositae (Tubuliflorae) (from Rancaekek)
24. Cruciferae (from Linggar)
25. *Desmodium* comp (from Trinil)
26. *Dodonaea* (from Rancaekek)

PLATE 7

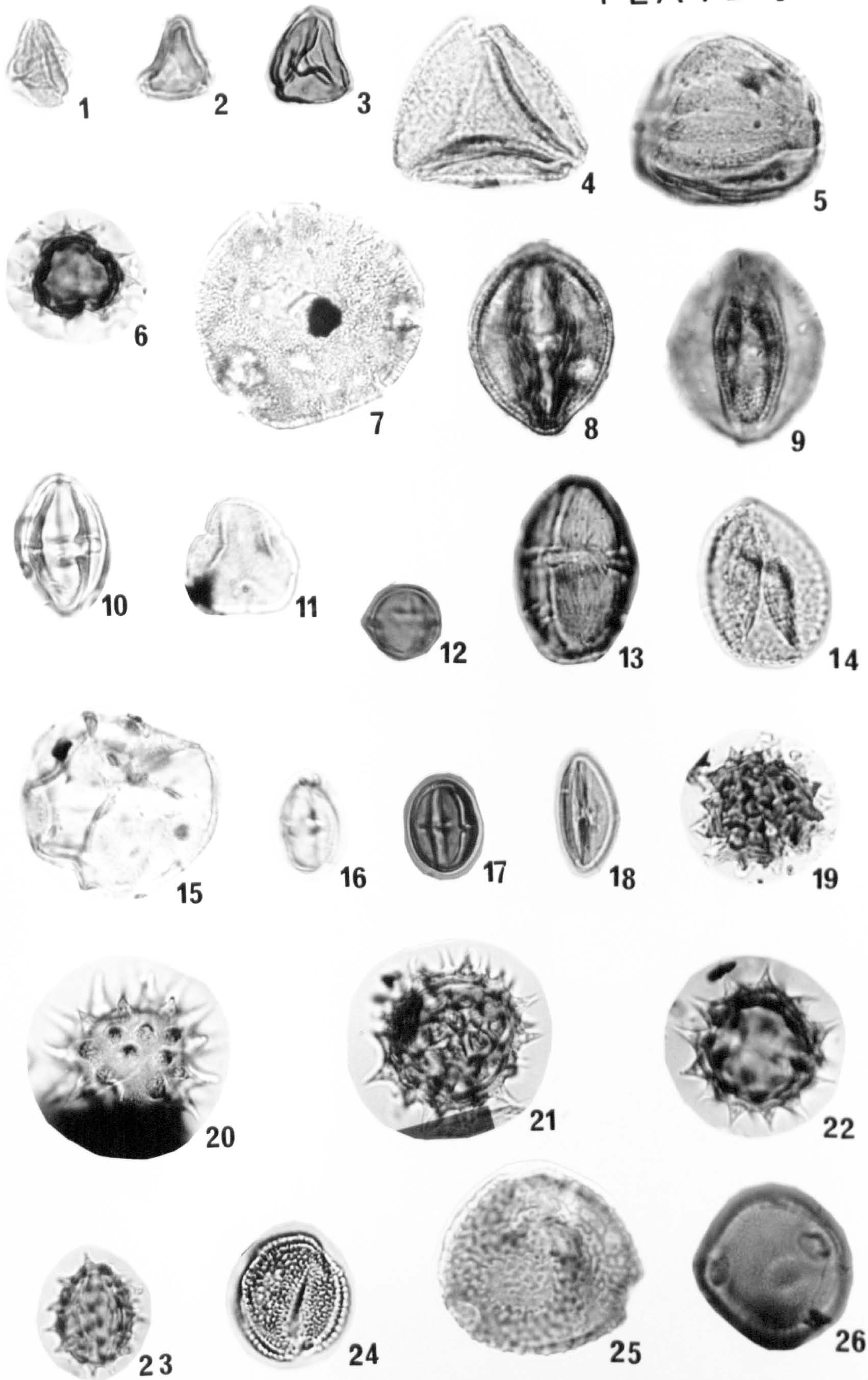


PLATE 8

1. Euphorbiaceae Type 1 (from Trinil)
2. Euphorbiaceae Type 2 (from Trinil
3. Euphorbiaceae (from Bumiayu)
4. Euphorbiaceae (from Trinil)
5. Euphorbiaceae (from Trinil)
6. *Garcinia* comp (from Trinil)
7. *Grewia* (from Bumiayu)
8. *Grewia* (from Bumiayu)
9. *Ixora* (from Trinil)
10. *Ixora* (from Trinil)
11. *Justicia* comp (from Trinil)
12. *Justicia* comp (from Trinil)
13. *Justicia* comp (from Cibogo)
14. Leguminosae (from Bumiayu)
15. *Macaranga* (from Trinil)
16. *Mangifera* (from Bumiayu)
17. *Myrsine* comp (from Rancaekek)
19. *Neonauclea* comp (from Trinil)
20. *Neonauclea* comp (from Trinil)
21. *Pluchea* (from Trinil)
22. *Randia* (from Rancaekek)
23. *Rhizophora* (from Bumiayu)
18. Rubiaceae (undiff.) (from Bumiayu)
24. Rubiaceae (undiff.) (from Trinil)

PLATE 8

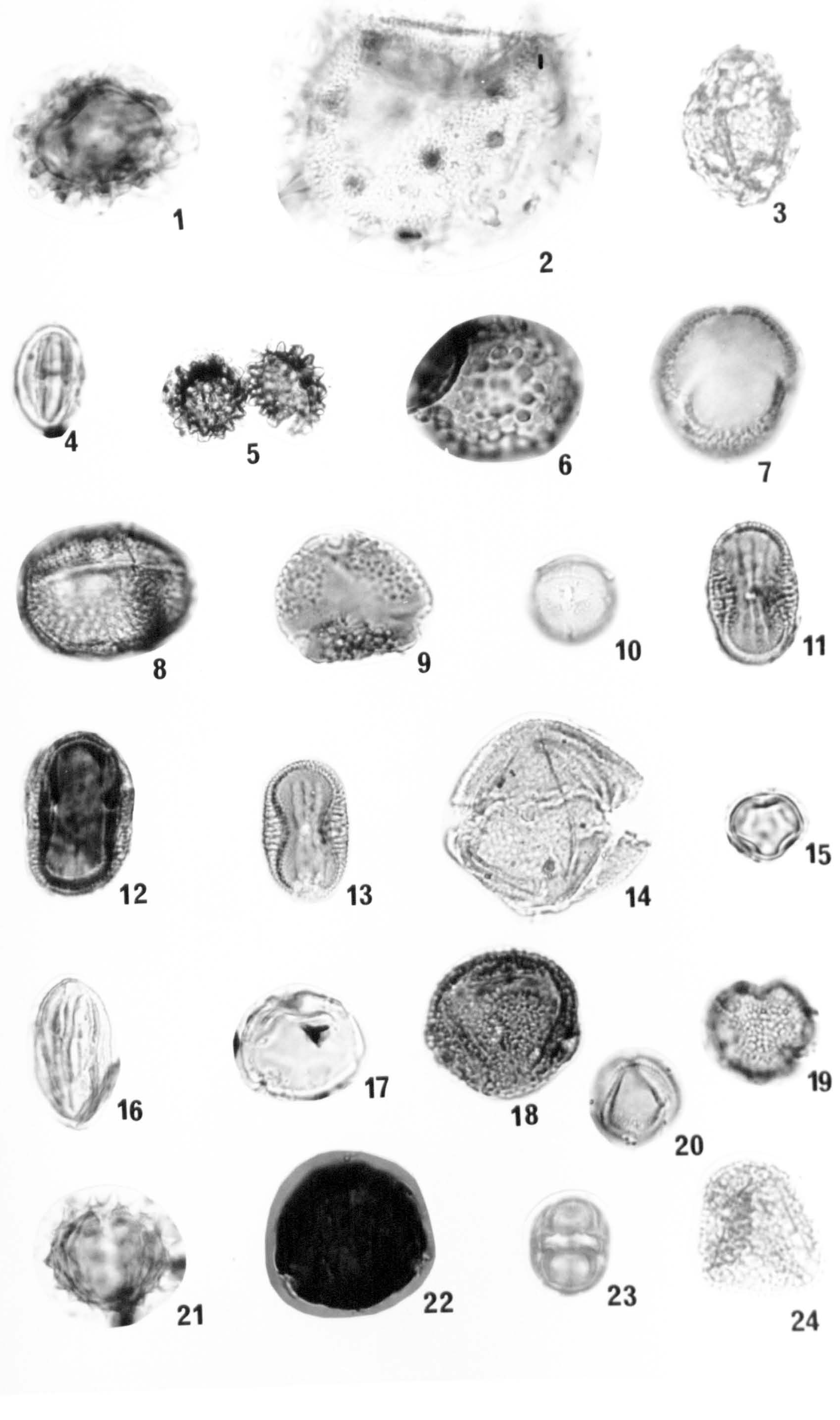


PLATE 9

1. *Schefflera* (from Bumiayu)
2. *Schoutenia* (from Linggar)
3. Theaceae (undiff.) (from Rancaekek)
7. Theaceae (undiff.) (from Bumiayu)
4. Umbelliferae (from Bumiayu)
5. Umbelliferae (from Rancaekek)
6. *Uncaria* (from Bumiayu)

Stephanocolporate

8. Meliaceae (from Linggar)
9. *Memecylon* comp (from Bumiayu)
10. *Palaquium* comp (from Bumiayu)
11. *Phyllanthus* (from Trinil)

Tetrads

12. *Vaccinium* (from Trinil)
13. *Vaccinium* (from Bumiayu)
14. *Gardenia* (from Trinil)

Polyads

15. *Acacia* comp (from Trinil)
16. *Albizia* comp (from Trinil)

PLATE 9

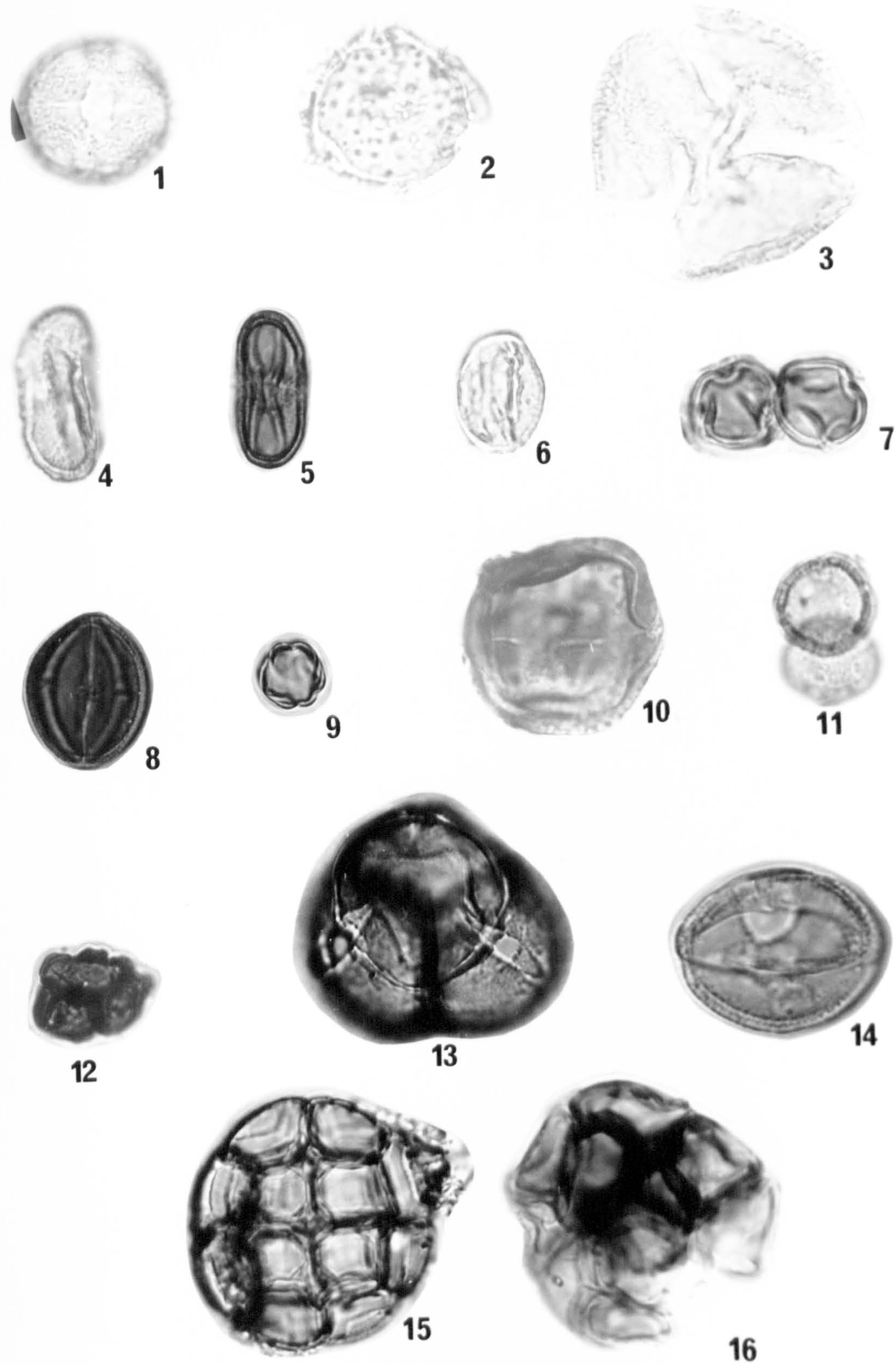


PLATE 10

Monolete

1. *Cyclosorus* (from Bumiayu)
2. *Davallia* (from Bumiayu)
3. *Davallia* (from Rancaekek)
4. *Davallia* (from Linggar)
5. *Filices areolate* (from Rancaekek)
6. *Filices areolate* (from Bumiayu)
8. *Sphenomeris* (from Bumiayu)
7. *Stenochlaena palustris* (from Bumiayu)
10. *Stenochlaena laurifolia* (from Bumiayu)
9. *Stenochlaena palustris* (from Trinil)
11. *Stenochlaena palustris* (from Bumiayu)

PLATE 10

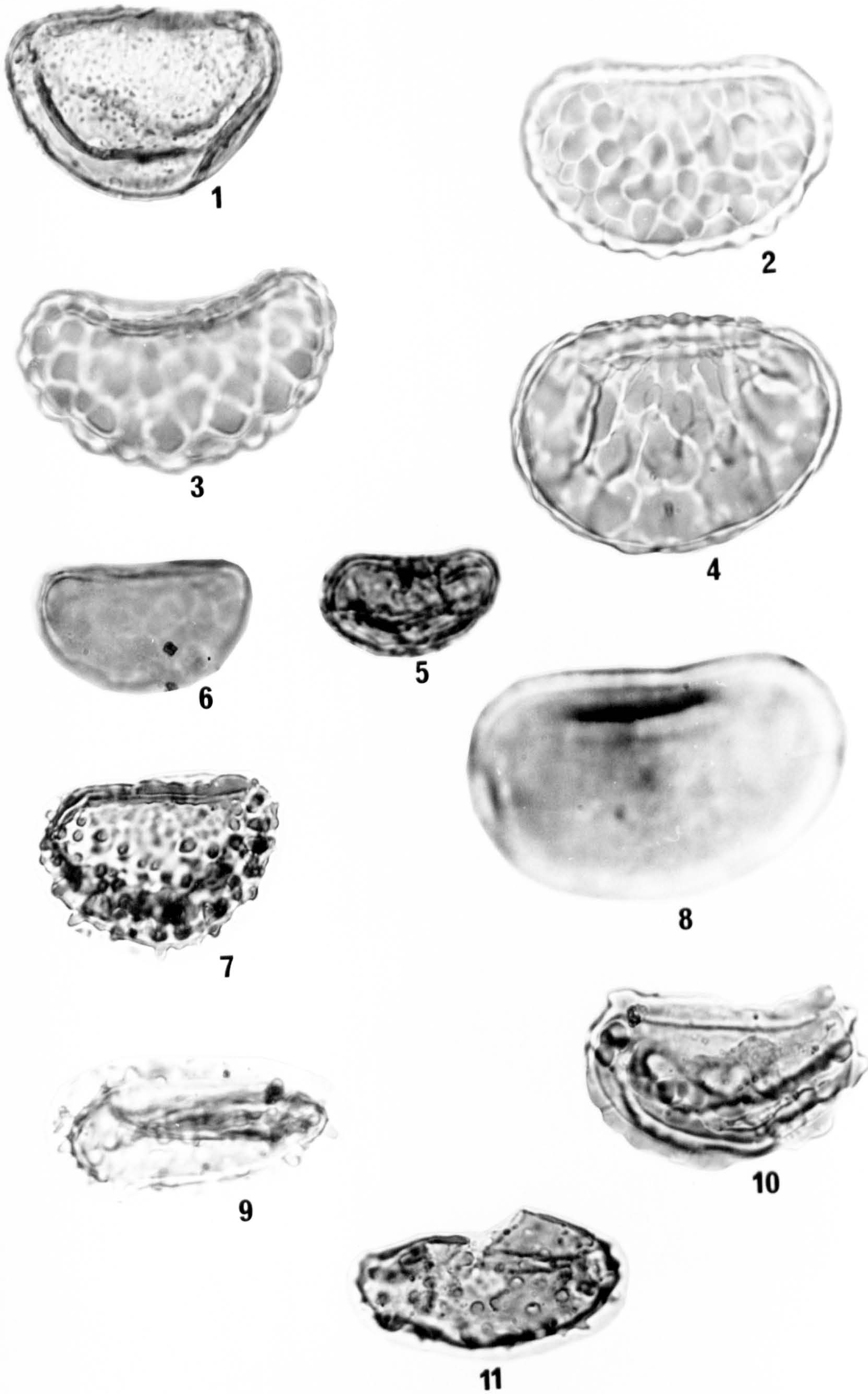


PLATE 11

Monolete spores/Polypodiaceae

1. Monolete psilate (from Rancaekek)
2. Monolete reticulate (from Linggar)
3. Monolete reticulate (from Trinil)
4. Monolete reticulate (from Linggar)
5. Monolete reticulate (from Bumiayu)
7. Monolete with thick exine (from Bumiayu)
8. Monolete gemmate (from Trinil)
6. Monolete verucate (from Bumiayu)
9. Monolete clavate, echinate (from Rancaekek)
10. Monolete baculate (from Bumiayu)
12. Monolete echinate (from Cibogo)
13. Monolete echinate (from Rancaekek)
14. Monolete echinate (from Linggar)
15. Monolete echinate (from Cibogo)
16. Monolete echinate (from Rancaekek)
11. *Asplenium* (from Cibogo)

PLATE 11

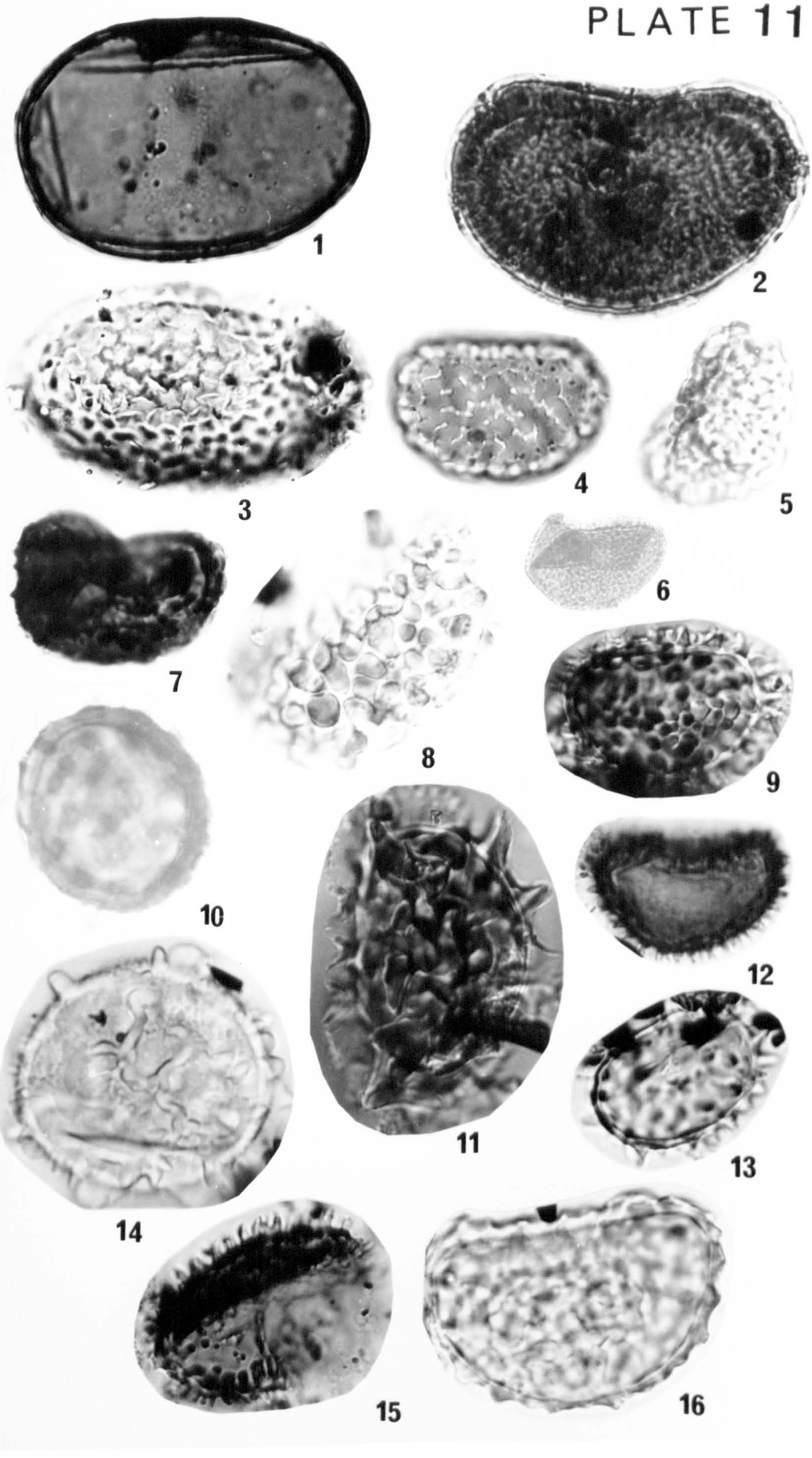


PLATE 12

Trilete

1. *Trilete psilate spore* (from Trinil)
2. *Acrostichum aureum* (from Bumiayu)
7. *Ceratopteris* (from Bumiayu)
3. *Cyathea* comp (from Bumiayu)
4. *Cyathea* comp (from Trinil)
5. *Cyathea* comp (from Linggar)
6. *Cyathea* comp (from Cibogo)
8. *Lycopodium phlegmaria* (from Trinil)
9. *Lygodium* (from Linggar)
10. *Lygodium* (from Rancaekek), magnification x 500
11. Trilete echinate spore (from Rancaekek)

PLATE 12

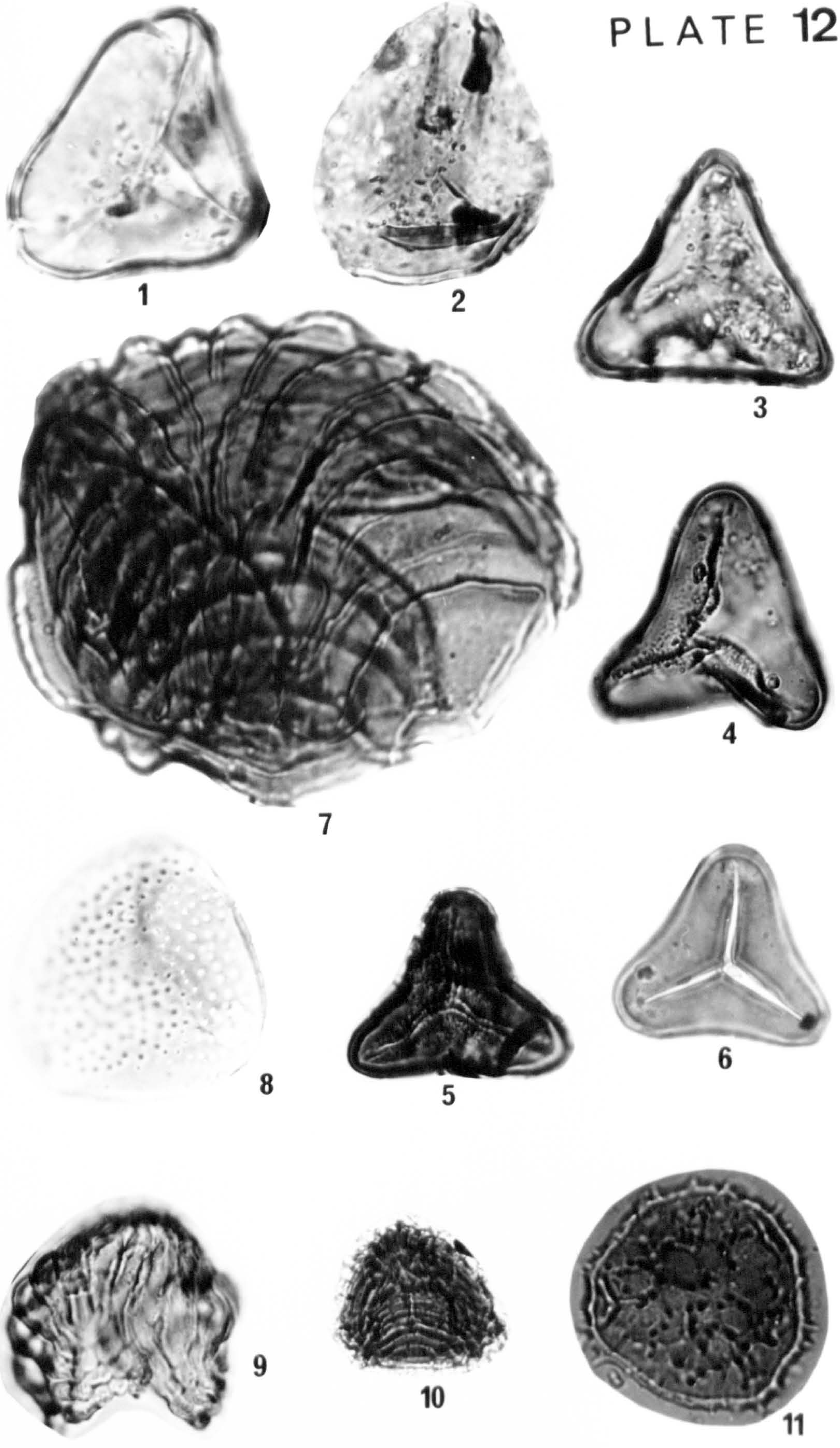


PLATE 13

Pteris

1. *Pteris* undiff. (from Bumiayu)
2. *Pteris* undiff. (from Bumiayu)
3. *Pteris* undiff. (from Bumiayu)
4. *Pteris* undiff. (from Bumiayu)
5. *Pteris* undiff. (from Bumiayu)
6. *Pteris* undiff. (from Bumiayu)
7. *Pteris* undiff. (from Trinil)
8. *Pteris* undiff. (from Trinil)
9. *Pteris* undiff. (from Trinil)
10. *Pteris* undiff. (from Linggar)
11. *Pteris* undiff. (from Linggar)
12. *Pteris* undiff. (from Linggar)

PLATE 13

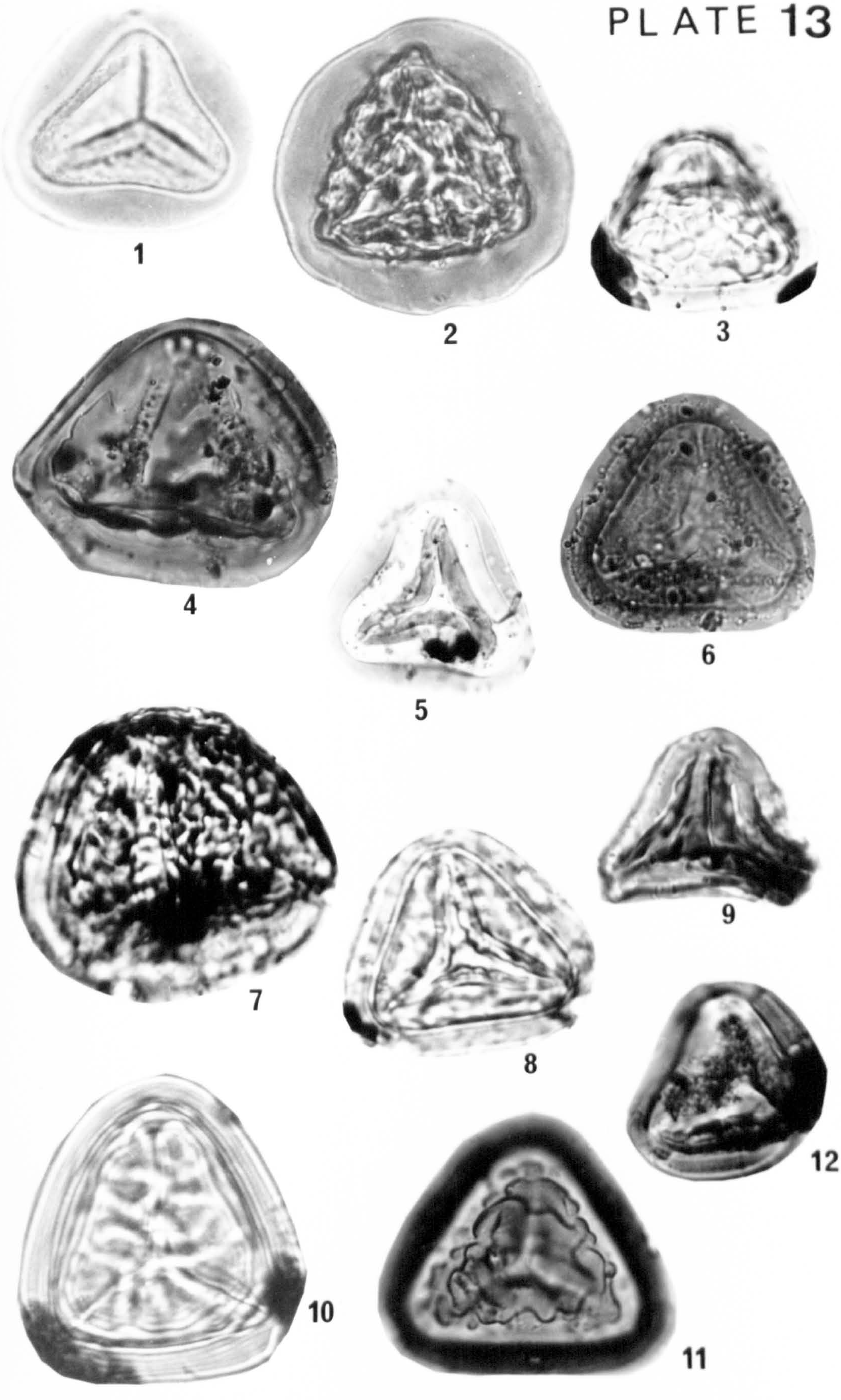


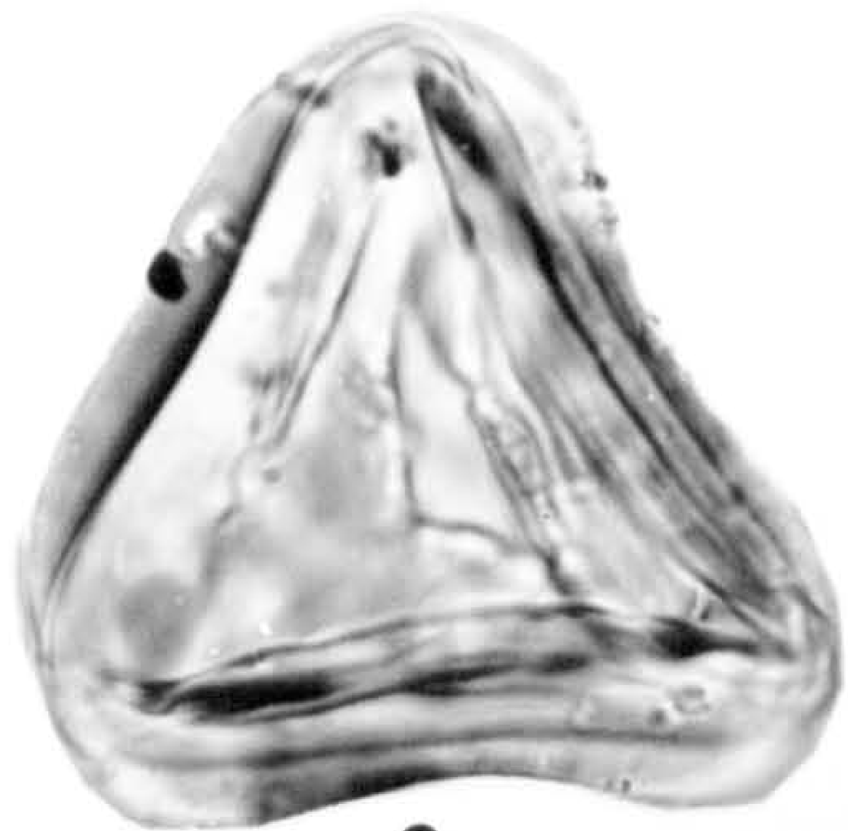
PLATE 14

Pteris and Trilete spores

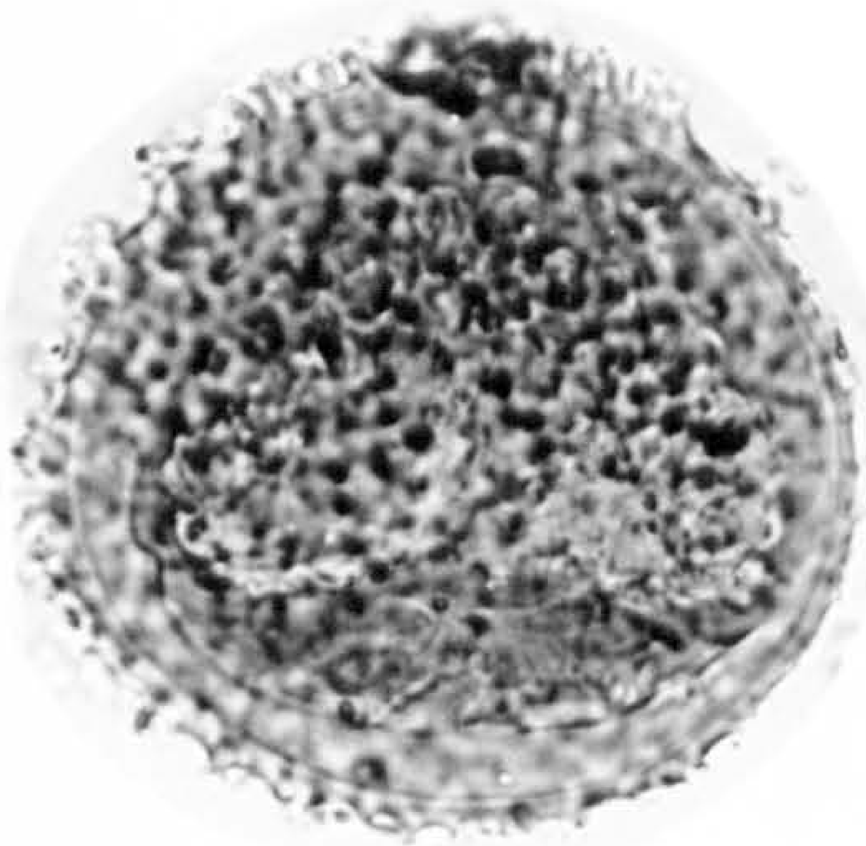
1. Trilete, psilate spore (from Linggar)
2. *Pteris* undiff. (from Linggar)
3. *Pteris* undiff. (from Linggar)
4. *Pteris* undiff. (from Linggar)
5. *Pteris* undiff. (from Linggar)
6. Trilete psilate spore (from Linggar)
7. Trilete scabrate spore (from Linggar)
8. Trilete, reticulate spore (from Cibogo)

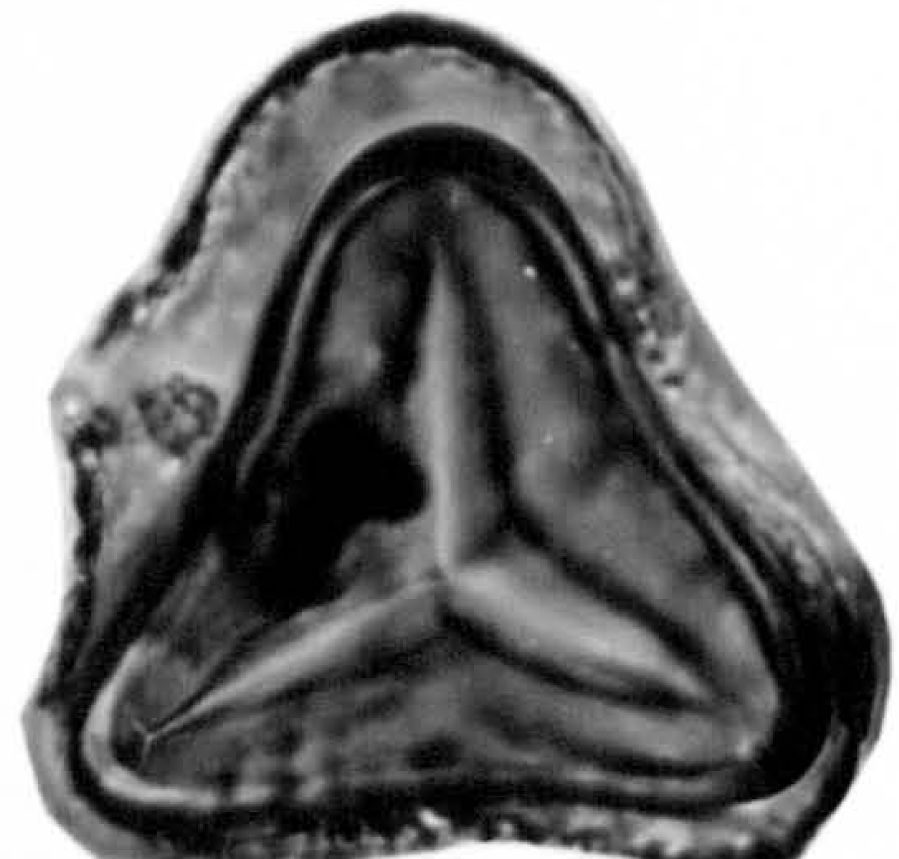
PLATE 14

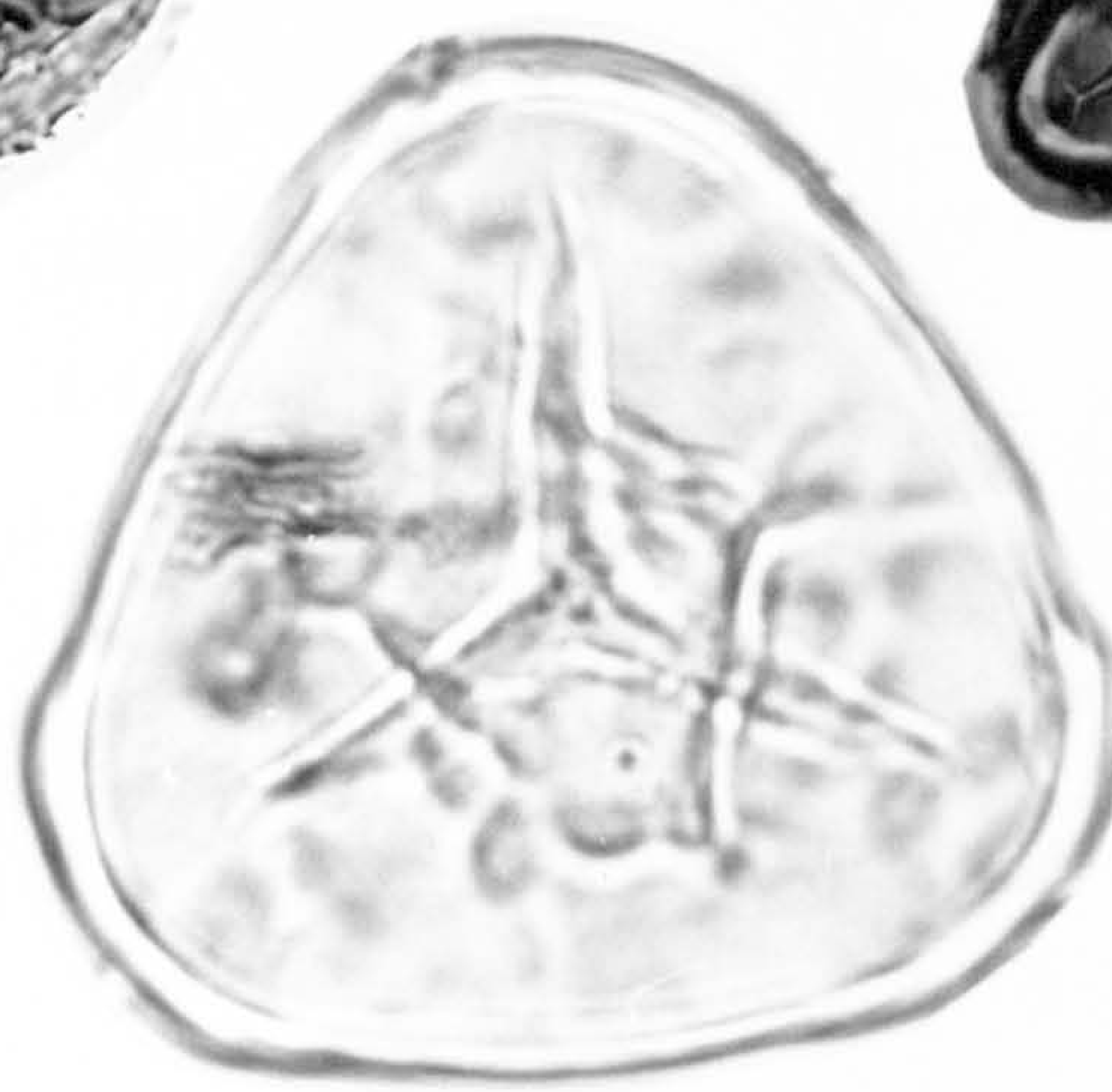

1

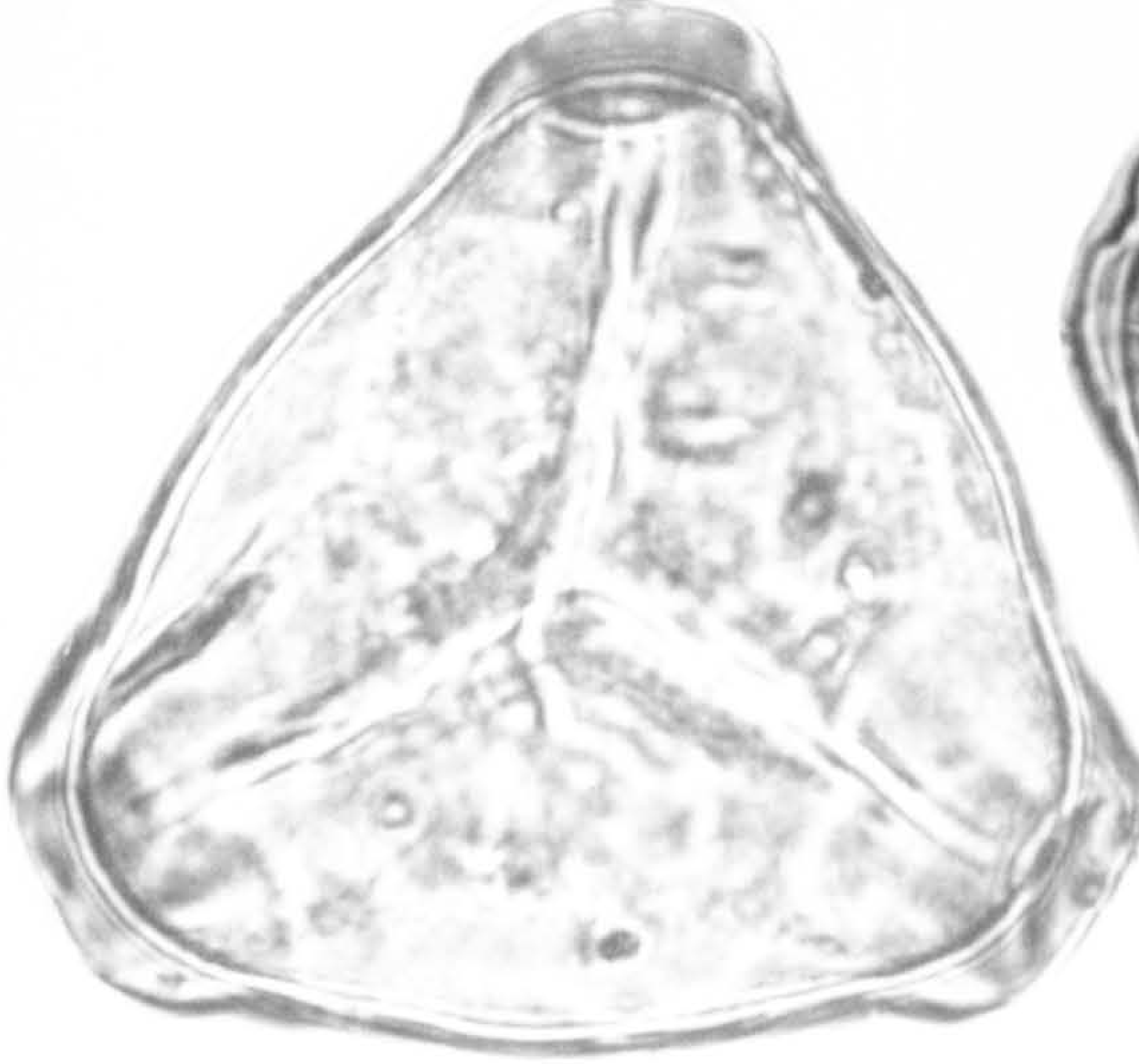

2


3


4


5


6


7

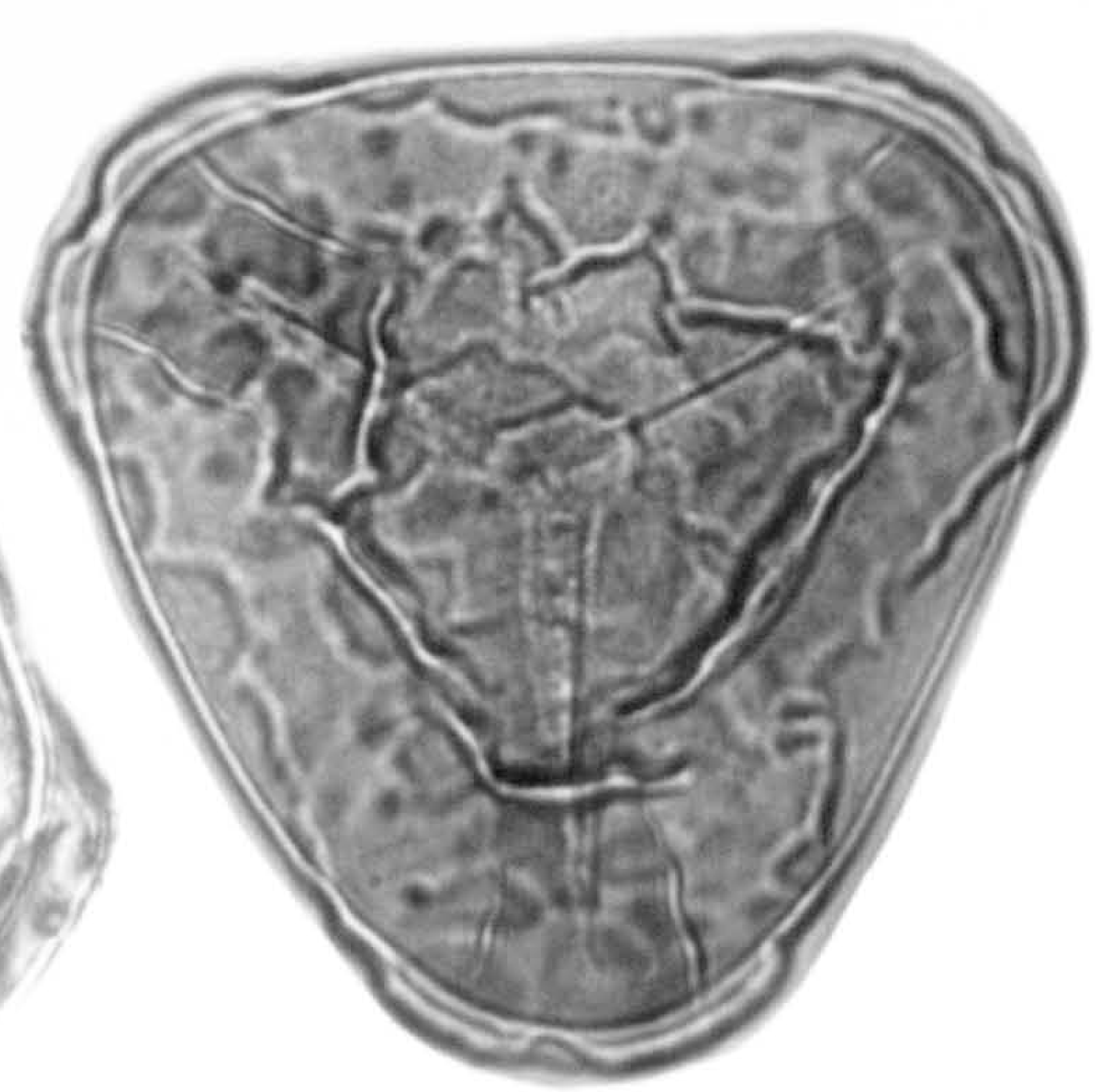

8

PLATE 15

Trilete spores/Lycopodiaceae

1. Triangular, trilete, psilate (from Cibogo)
2. Triangular, trilete, psilate (from Cibogo)
3. Triangular, trilete, psilate (from Rancaekek)
4. Triangular, trilete, reticulate (from Cibogo)
5. Triangular, trilete, reticulate (from Linggar)
6. Triangular, trilete, reticulate (from Rancaekek)
7. Rounded triangular, trilete, scabrate (from Linggar)
8. Rounded triangular, trilete, echinate (from Rancaekek)
9. Rounded triangular, trilete, verrucate (from Rancaekek)
10. Rounded triangular, trilete, gemmate (from Rancaekek)
11. Rounded triangular, trilete, echinate (from Linggar)
12. Rounded triangular, trilete, echinate (from Linggar)
13. Rounded triangular, trilete, echinate (from Rancaekek)

PLATE 15

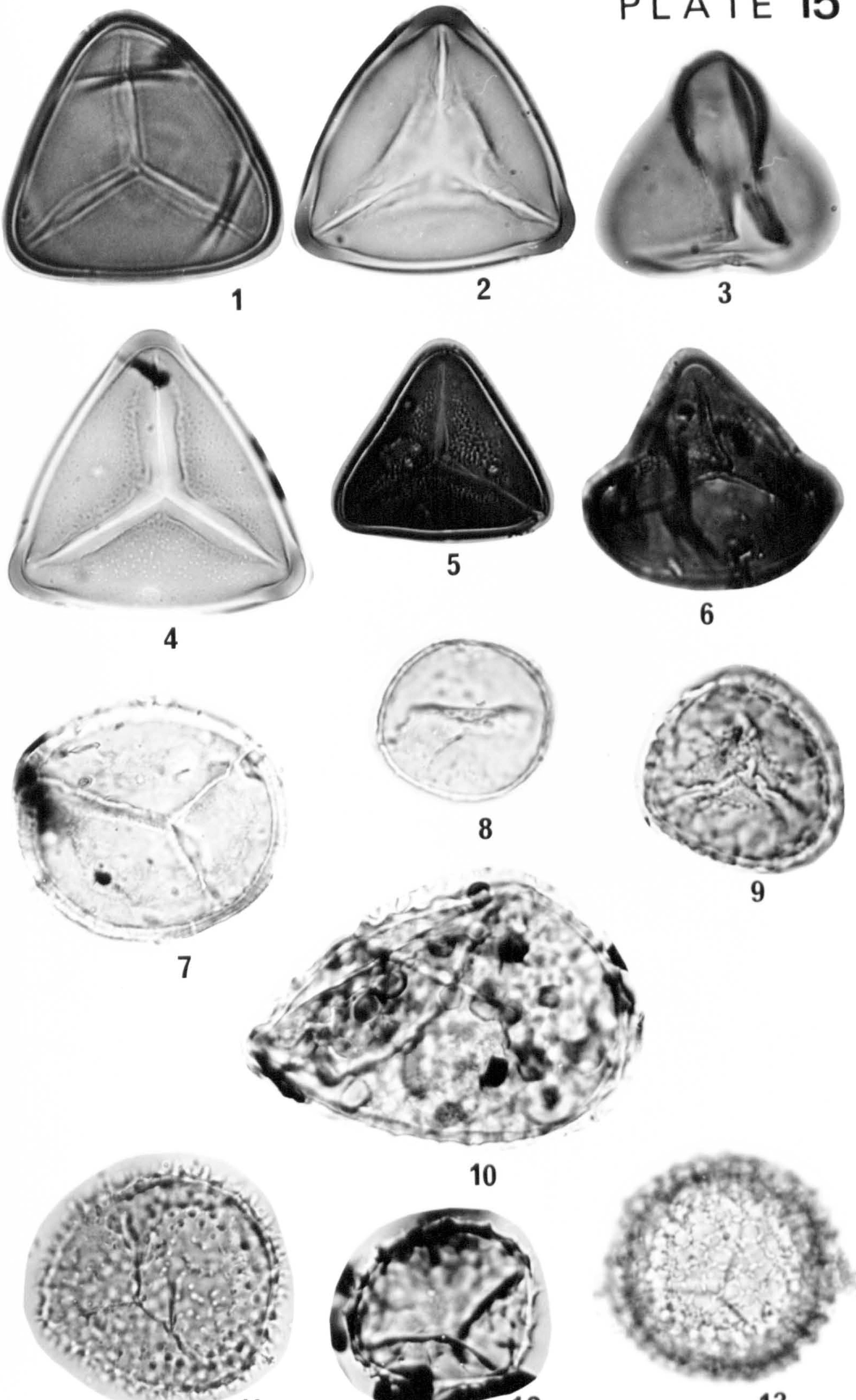


PLATE 16

Fungal spores and fungal filaments from Rancaekek

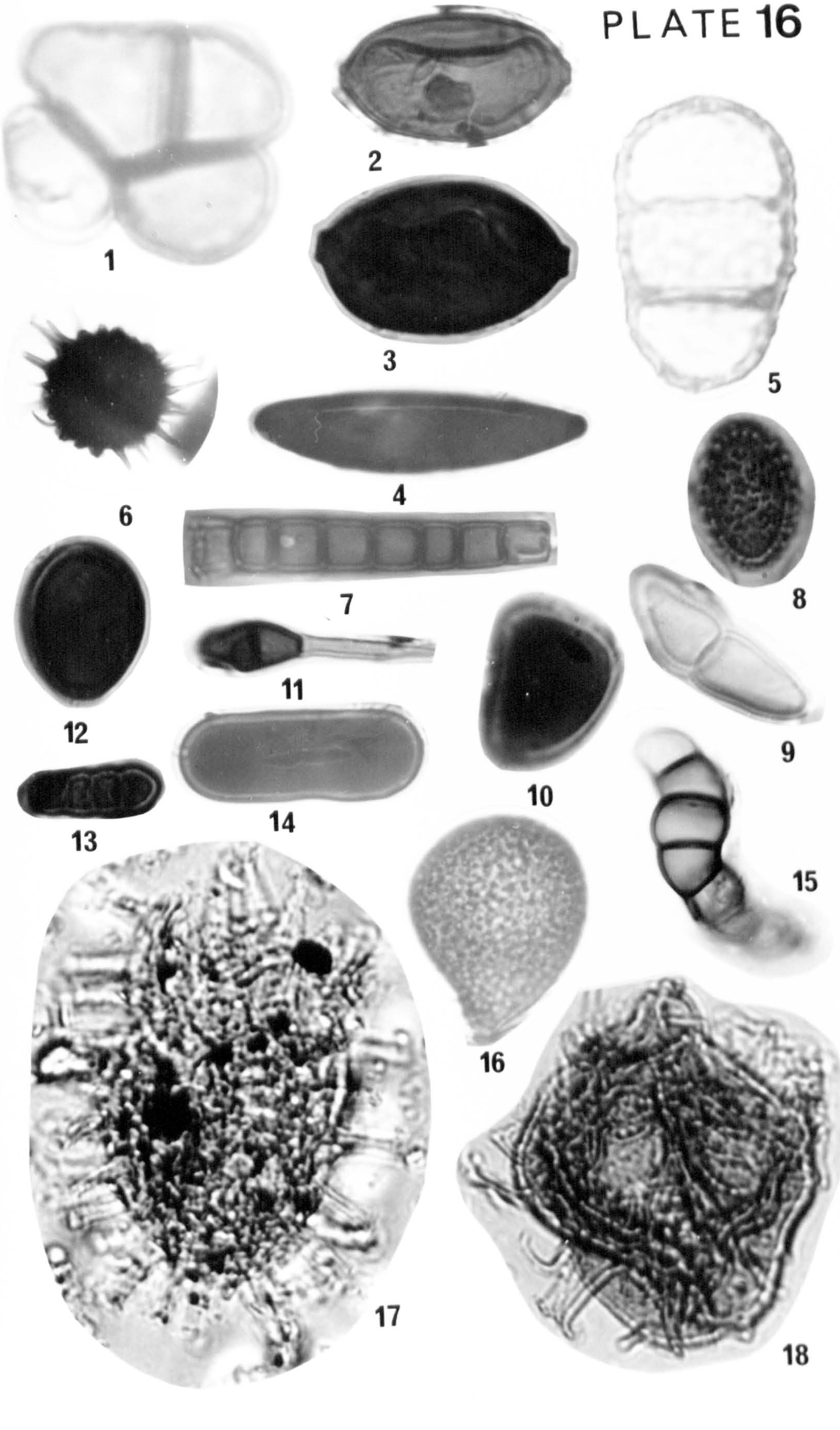
No 1-16

Dinoflagellates

17. Spiniferites (Hystricosporites) from Bumiayu

18. Dinoflagellate type 1, from Bumiayu

PLATE 16



Appendix 1

The following tables present details of the pollen counts of each sample examined for this study.

For convenience, each pollen or spore type has been given a code number under which it is described in Table 4.1

Appendix 1a

Cisaat, Bumiayu (P) Pollen and spores actual counts

Sample Number / Pollen & Spores	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23
78		4						3	15	7		9	4
55										2			
23		1						2		2			
24		1											
19												3	6
39									10	1			
47										1		2	8
3	1	3	1				1			1			2
2		1											
1													
21		5				1			3	1		1	
63		1				15		3	3	5	1	8	5
31			1	1									
80													
71	1	3	3	3	1								
72													1
88			3				2						
82		1	1	2			3	1					2
43							18	10	4	3	1	6	4
45		1		13		4		3	2	6	3		
58		3	2	1									
48		4		1			4	4	8	2			
79		6							8				

Sample Number / Pollen & Spores	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23
26		1											
67			1			2	1					1	2
44			1										
22													
17		1											
74													4
54													
18		2											
29									1				
85										1			
52													
93								1					
16													
14													
41													
40												1	
46		1							1				
7													
5										1			

Sample Number / Pollen & Spores	P 24	P 25	P 26	P 27	P 28	P 29	P 30	P 31	P 32	P 33	P 34	P 35	P 36
78		48	5		13	33	7		11		5	12	9
55				63	17	4				7	7		
23		4					3		2	1		2	
24													
19													
39		13	2	4	5	2	5		4	7	9	8	3
47				2									
3			1	2	2		1		2		2	1	1
2				1		1			1				
1				5		1							
21			1	7	2	4						3	3
63		7			2		3		5	7	7	8	11
31													
80					1								
71			3										
72					2						1		
88			1										
82													
43		2	3		1	2							
45		1			1	1	1	2	3		2	1	2
58													
48		2	3		4	2	1						
79		4		1	3	3							2
26				3		3					1		1
67		6	1	2							2		1
44			1	1									
22		2	2	4		1						1	1
17		4		2	1	1	1				1		

Sample Number / Pollen & Spores	P 24	P 25	P 26	P 27	P 28	P 29	P 30	P 31	P 32	P 33	P 34	P 35	P 36
74		3				3			2			4	1
54													
18													
29													
85													
52										1	3	1	
93													1
16					3							1	2
14					1								
41													
40													
46													
7													
5												1	2

Sample Number / Pollen & Spores	P 37	P 38	P 39	P 40
78	52	15	15	1
55				
23	2		2	1
24				
19				
39			2	1
47				
3	2		1	
2			1	
1	12	6	6	4
21		6	1	9
63				
31				
80			1	
71	1		1	
72	1			
88				1
82				
43	5	1	4	
45	3		8	2
58	1			
48	4	2	2	2
79		2	3	
26				
67	1	1		1
44				
22	15	7	6	2
17	5			

Sample Number / Pollen & Spores	P 37	P 38	P 39	P 40
74				
54				1
18				
29				
85				
52				
93				
16				
14	5	1		
41	8			5
40	9			
46				
7	1			
5	1		1	

Sample Number / Pollen & Spores	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23
27													
15													
90													
25													
38													
33				3									
36												1	
37										3		3	
38		3	1									1	
28										1		2	12
84				3			3	1		2			
Undit													
70				1	1		1						
6													
63													
95	1	1											
59		1								1		1	5
11		5		1				1		4		6	3
12							1		6				
10	1	115	16	18	6	14	13	35	106	102	6	41	226
9		86	4			1				27		80	11
104		1	1	3			2	2	13	13	1	1	15
102		4	3	2		4		2	2	6		11	1
103													
101	29	18	13	38	5	12	30	35	82	82	9	62	32
112	6	2	11	9	2	1	8	17	7	10		2	3
98	9	20	14	1	2		12	11	17	11	2	5	11
100	1		2	7			8	9	6		2		1

Sample Number / Pollen & Spores	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23
107		1	2						1				
108		1	1									1	
106													
105	1		1										
110		80		4	1	1	8	1	12	5	3	6	
99													
97													
114													

Sample Number / Pollen & Spores	P 24	P 25	P 26	P 27	P 28	P 29	P 30	P 31	P 32	P 33	P 34	P 35	P 36
27													
15		1										2	
90													
25													
33													
36									1				
37													
38		1		1									1
28								4	8		1		
84													
Undit													
70													
6													
63													
95												1	
59										1			1
11		8	6	5	2	2	7				3	3	5
12			1								9	2	12
10	6	71	29	43	57	69	71	35	131	36	91	51	51
9		18	14	39	20				9				4
104		29	4	11		12	15	2	20	4	5	4	10
102				8	6						1		
103		1											
101		45	31	49	15	17	28	11	46	14	29	26	38
112		16	2	6	2	5	1	4	7	2	3	6	3
98	2	18		12	4	14	4	1	1	1	6	11	11

Sample Number / Pollen & Spores	P 24	P 25	P 26	P 27	P 28	P 29	P 30	P 31	P 32	P 33	P 34	P 35	P 36
100	1	11	3	4	10	5	4			2		1	2
107			3	4	1		4	2			1	1	2
108				1							1	1	
106						1							
105									8			2	
110			1	3	8	4	6		6		5	4	8
99			1										
97													
114													5

Sample Number Pollen & Spores	P 37	P 38	P 39	P 40
27			1	
15				
90			1	3
25		1	2	
38				
33				
36	1	2		4
37	5	2		1
38			5	
28		3	1	1
84				
Undit				
70				
6		9		1
63			3	
95				
59			1	
11	15	13	2	5
12		1		
10	13	9	26	51
9	10	16		55
104	20	10		2
102	3	1		
103				
101	108	76	29	39
112	3	1	2	1
98	20	22	7	4

Sample Number	P 37	P 38	P 39	P 40
Pollen & Spores				
100	3	1	1	3
107	5	6	3	
103		1		
106		2		
105	5	7	4	
110	3		2	11
99		1		
97		1	2	10
114				

Appendix 1b

Trinil (Tr) Pollen and spores actual counts

Sample Number / Pollen & Spores	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Tr 8
2						1		
3		2	1	3	2	8	6	
4			1					
15			1			5		
20						7		
21			1			23		1
45		1			1	7	7	2
67						1	4	2
82								1
40						12		
22						7		8
62						10		
90						2		
26						10	1	13
16						3		
48				1		23	1	1
49							52	
57						11		
66		21						
95		1						
96						2		1
61								2
64		1				36		1

Sample Number / Pollen & Spores	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Tr 8
65						23		
53						10		
91						5		
71					1	21		
80						6		
14			1					
75				3	3	45	6	2
68				7		1	2	
29						1		
43		2	1			6		
Undit						18		
79							15	
32						4		1
69		1				27	4	3
92						6		
30						3		
84			1			13	1	
93						3		
83			2			34		2

Sample Number / Pollen & Spores	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Tr 8
28		3		1	2	13	3	2
50						15		
8			37			28		
76				3		44		
51			4	2		20		2
42				1	1			1
11		2				2		
10		170	178	275	116	697	469	50
9		18		169	24	339	726	42
12					4	71		
35			1			15		
104			11	13	9	98	4	8
105				4	10	16	2	1
112			2	8	7	24		
98						25		7
100		43	63	85	95	291	31	43
107						34		
111			1	1		3		
113			5		2	3		
108		5	1	1				
109		1				1		1
110		7	11	27	34	111	9	15

Appendix 1 C Cibago (Cb) Pollen and Spores actual counts

Sample Number / Pollen & Spores	Cb 2.00 m	Cb 2.40 m	Cb 2.80 m	Cb 3.20 m	Cb 3.60 m	Cb 4.00 m	Cb 4.40 m	Cb 4.80 m	Cb 5.20 m	Cb 5.60 m	Cb 6.00 m	Cb 6.40 m	Cb 6.80 m
2													
3		1											
27													
21		1											
45		3											
58		14								1			
48		3							2				
26		2											
16	2								8	5			5
63									5				
13													
57		15					1			2		6	
25													
67													
94										3		4	
22												3	
83										6		17	4
40										1			
93												3	
29													
43										1			
Unid		1										1	
69													
32													

Sample Number Pollen & Spores	Cb 2.00 m	Cb 2.40 m	Cb 2.80 m	Cb 3.20 m	Cb 3.60 m	Cb 4.00 m	Cb 4.40 m	Cb 4.80 m	Cb 5.20 m	Cb 5.60 m	Cb 6.00 m	Cb 6.40 m	Cb 6.80 m
30													
42		2											
84		7								2		5	4
28	1												
59		1								1		2	1
11										1			
10	7	114					6	1		15		40	10
9	18	29					3		8			7	4
12		8								1			
35													
104		2								1			
105													
111		11									1	1	1
98		4								3		2	2
100	3	51						4	4	43	5	40	29
107													
109													
110	2	16						1		5	1	12	3

Sample Number Pollen & Spores	Cb 7.20 m	Cb 7.60 m	Cb 8.00 m	Cb 8.40 m	Cb 8.80 m	Cb 9.20 m	Cb 9.60 m	Cb 10.00 m	Cb 10.40 m	Cb 10.80 m	Cb 11.20 m	Cb 11.60 m	Cb 12.00 m
2												4	1
3					3						1	14	1
27											1		
21							1			1	5	6	
45		2		1	1		1					10	17
58	2								1		2		17
48					1		1					1	5
26	8								1				39
16	2	2	5								4	5	
63	7								1				16
13			4										
57		2	4		13	2	9			14	116	76	
25	4		1						2				
67													2
94		2	1		1								
22							1			3	3	1	
83	1	6	4		6	1	2					2	
40			2	3					1	4		16	
93													
29												1	
43	1				1				2		19		20
Unid											1	1	
69									1				4
32											1		

Sample Number Pollen & Spores	Cb 7.20 m	Cb 7.60 m	Cb 8.00 m	Cb 8.40 m	Cb 8.80 m	Cb 9.20 m	Cb 9.60 m	Cb 10.00 m	Cb 10.40 m	Cb 10.80 m	Cb 11.20 m	Cb 11.60 m	Cb 12.00 m
30										4	58	6	
42													
84		1	1	1	1		2	1		2	17	16	2
28							2			1	6		2
59	1		4	2	4					3	22	3	
11		2	2	1	1							1	
10	9	14	13	15	29	4	16	19	19	123	580		92
9	3		1		8	4	8	19	87	47	277	125	78
12		1	1		6			2		13	47	56	5
35					3		7		1			1	3
104											1		
105	1												
111	1	1		1	1				4		7		3
98		5	4	8	19	4				1	3		5
100	27	40	39	28	71	6	2	36	305	132	104		907
107	1								2				
109										3			2
110	7	10	6	2	15		3	2	12	5	36		17

Appendix 1d

Linggar (Lgr) Pollen & Spores actual counts

Sample Number Pollen & Spores	Lgr 1.30 m	Lgr 1.80 m	Lgr 2.30 m	Lgr 2.80 m	Lgr 3.30 m	Lgr 3.80 m	Lgr 4.30 m	Lgr 4.80 m	Lgr 5.30 m	Lgr 5.75 m	Lgr 6.40 m	Lgr 6.80 m	Lgr 7.30 m
1													
2									8			17	23
3									21				
27													
21							1		11			1	54
45										1			3
58													2
40													
22												2	
18			1	1								2	
90													
26	1						1					4	16
16		1		4					12			12	
13													
48		1							1	1			12
73													
57		4		1		1		1		1		1	
82													
95													
86	1												
43	5								5			5	21
Undit													135

Sample Number Pollen & Spores	Lgr 1.30 m	Lgr 1.80 m	Lgr 2.30 m	Lgr 2.80 m	Lgr 3.30 m	Lgr 3.80 m	Lgr 4.30 m	Lgr 4.80 m	Lgr 5.30 m	Lgr 5.75 m	Lgr 6.40 m	Lgr 6.80 m	Lgr 7.30 m
69	1												3
30												1	
84		2	3						1	2			1
83	1		1	1			1					5	
34									8	6		23	
28	2	7					2		3	1	1	3	8
60													
59	1	14	2	3					2		1	4	6
42		1											
11		9	2	2	4	1	8				3		
10	19	52	26	24	8	10	19	16	403	36	223	369	523
9	27	79	19	6	6	8	23	3	131	27	59	93	259
12									11	1		2	3
35	64	125	40	16	6	6	12	6	1	4	3		
7										8]			
104													17
105	2												2
112	1	1	2	2	1	1		3	8			6	10
98	2	6	1	1	1	1			28	5	1	13	31
100	18	50	23	10	8	7	17	20	90	19	15	165	573

Sample Number / Pollen & Spores	Lgr 1.30 m	Lgr 1.80 m	Lgr 2.30 m	Lgr 2.80 m	Lgr 3.30 m	Lgr 3.80 m	Lgr 4.30 m	Lgr 4.80 m	Lgr 5.30 m	Lgr 5.75 m	Lgr 6.40 m	Lgr 6.80 m	Lgr 7.30 m
107									14			8	23
106													
108													
109							1						
110	10	14	3	1		1		1	264	28	24	210	290

Sample Number Pollen & Spores	Lgr 7.80 m	Lgr 8.30 m	Lgr 8.80 m	Lgr 9.30 m	Lgr 9.80 m	Lgr 10.30 m	Lgr 10.80 m	Lgr 11.30 m	Lgr 11.80 m	Lgr 12.30 m	Lgr 12.80 m	Lgr 13.30 m	Lgr 13.80 m
1			31			1							
2	15	2	26					15	26	5	7		3
3	28	11	21	1			1	27	42	16	3		
27	1		1					1					
21	22	25	35			7		1	10	10	17		4
45	1					3							
58	25	12	37			2	8		11	7	2		13
40									16				
22			4										
18			5										
90													
26								2					
16			26			2	4	1					
13									1				
48	5	1	3			3	3		2	1		1	2
73								1					
57	8		15	1	2		8		32	81	28	3	5
82										1			
95													
86													
43	28		17	1		1	3	6	16	3	7		
Undit	5							13					
69													
30		1							43	19			5
84	32	19	381	29	6	3	10		80	20	1	6	13
83	1		1						9		1		

Sample Number Pollen & Spores	Lgr 7.80 m	Lgr 8.30 m	Lgr 8.80 m	Lgr 9.30 m	Lgr 9.80 m	Lgr 10.30 m	Lgr 10.80 m	Lgr 11.30 m	Lgr 11.80 m	Lgr 12.30 m	Lgr 12.80 m	Lgr 13.30 m	Lgr 13.80 m
34	13	15	31	3	2	1	42		40	5	11		
28		1	3			25	4	1	5	71	85	38	21
60	5		2						23		2	2	5
59	8	4	8				3	3	32	26	8	2	8
42													
11	3		3			5		1	2				1
10	545	336	987	85	122	177	551	1300	2330	1382	672	243	252
9	77	43	117	10	1	10	13	197	350	301	110	44	64
12		9	21			1	5		42	19	7		3
35		3	8					1	1		1		1
7									5				
104	40	23	36		1		3	5	26	9	6	1	4
105													
112	33	18	38		2	3	1	4	10	11	10	4	3
98	11	22	13				5	10	13	2	6	1	5
100	331	331	445	6	9	31	37	238	368	135	106	31	60
107	24	18	42	1				1	3		2		
105	1												
108											9		
109		4	14	1			1						
110	549	334	585		2	5	9	43	169	31	92	12	27

Sample Number Pollen & Spores	Lgr 14.30 m	Lgr 14.80 m	Lgr 15.30 m	Lgr 15.75 m
1				
2	9	4		1
3	3	10		2
27				
21	3	9		
45		1		
58	24			23
40				
22		1		
18		2		
90				2
26				10
16		1		
13				
48	1	4		
73				
57	10	1		
82				
95		1		
86				1
43		3		9
Undit				6
69				4
30	1	1		
84		22		
83		5	1	5
34				

Sample Number Pollen & Spores	Lgr 14.30 m	Lgr 14.80 m	Lgr 15.30 m	Lgr 15.75 m
28	10	2		
60			4	
59	14	2		3
42				
11		1		
10	224	150	8	56
9	49	89	9	63
12	10			
35				
7				
104	3			
105				2
112	3	5		6
98	1	2		1
100	24	48	3	45
107	1	9		6
106	1			
108				
109				
110	30	86	3	36

Appendix 1e

Rancaekek (Rk) Pollen and spores , actual counts

Sample Number Pollen & Spores	Rk 2.75 m	Rk 3.00 m	Rk 3.90 m	Rk 4.00 m	Rk 4.30 m	Rk 4.55 m	Rk 4.85 m	Rk 5.15 m	Rk 5.45 m	Rk 6.25 m	Rk 6.80 m	Rk 7.15 m	Rk 7.80 m
1						9	9	7	23		16		
2			7	1	9	8	35	9	12	25	74	22	7
3	2		1	4	16	16	15	6	34	22	54	10	3
4						1					1		
15												1	
27				1			1			3			
87				1					6	1			
88											5		
20							2						
21			4		1	6	36	9	22	23	34	4	11
45					1		1	1		8	14	4	2
58			5	5		2	5	11	10	16	55	38	1
56													
40				2						3			
22						1					8	4	
62										19			
90			1										
26				2	6				14	6	22		
16			2	2				2	1	2			
13				1								4	
48			3	3	3	1	3		4		7	5	2
73										5			
57								53				2	

Sample Number Pollen & Spores	Rk 2.75 m	Rk 3.00 m	Rk 3.90 m	Rk 4.00 m	Rk 4.30 m	Rk 4.55 m	Rk 4.85 m	Rk 5.15 m	Rk 5.45 m	Rk 6.25 m	Rk 6.80 m	Rk 7.15 m	Rk 7.80 m
66													
18							3		1			16	
95										3			
70											12		
63												1	
91													
94											1		
77					60	2	1	4	20	9	45	2	
80									1				
43	1		1	2		1	2	2	5	11	7		1
Unid	1												
25										5			
32					1							3	
69											13	4	
84			1	7	4	21	18	24	42	24	240	48	23
30							4				50	22	2
83			3	1			3		3	7			
28					3		1	1	1	6	18	1	1
34			5			17	18	8	19			5	

Sample Number Pollen & Spores	Rk 8.15 m	Rk 8.65 m	Rk 9.15 m	Rk 9.80 m	Rk 10.20 m	Rk 10.90 m	Rk 11.50 m	Rk 11.95 m	Rk 12.30 m	Rk 12.80 m	Rk 13.30 m	Rk 13.75 m	Rk 14.05 m
1	4		1					2				1	
2	2	2	7	2				4		2		16	1
3	4	6			8			6			5	5	4
4													
15										1			
22	1		1							3		6	5
87													
88													
20													
21	1	3	8	5	6	1	1	10		2	1	1	1
45					6			7			2	16	27
58	5		9		66		10	17	5	3	19	12	14
56					1								
40				1									
22			1	1				1		1			1
62													
90													
26							1				2		3
16	8												7
13													
48		3		7	2		1	7		1	1	16	1
73													4
57	12					2	2	1			7		
66	1												
18			11										
95		1				1							5

Sample Number Pollen & Spores	Rk 8.15 m	Rk 8.65 m	Rk 9.15 m	Rk 9.80 m	Rk 10.20 m	Rk 10.90 m	Rk 11.50 m	Rk 11.95 m	Rk 12.30 m	Rk 12.80 m	Rk 13.30 m	Rk 13.75 m	Rk 14.05 m
70			1										
63													
91	3												
94													
77	1												3
80								3					
43	1	2	2	3	11	3		6		1		7	12
Inid													
25	3				1								
32													
69			4	1				1		2			
84	18	43	20	34	2	4	3	86	3	10	2	24	3
30		2	4	1				1		1			
83				3	8	4		6		7		20	3
28	2		3	2	5	1		1		3	1		
34	3		63				3		1		5		1

Sample Number Pollen & Spores	Rk 2.75 m	Rk 3.00 m	Rk 3.90 m	Rk 4.00 m	Rk 4.30 m	Rk 4.55 m	Rk 4.85 m	Rk 5.15 m	Rk 5.45 m	Rk 6.25 m	Rk 6.80 m	Rk 7.15 m	Rk 7.80 m
60			2		1			3	2	9	2		
59					5	3	11	2	8	38	7	6	
42						1				7			
11				1		2				3		1	
10	107	18	46	117	219	1208	1052	1422	829	654	5864	2034	603
9	11	1	11	4		63	5	205	66	203	325	156	33
12			1	4		1		16		22	856	329	110
35			1							4			
104		1	3	2	4	17	28	7	18	44	60	15	
105		4		21		2	21		13		28	7	1
112	24	7		9	14	13	20	8	30	14	111	9	4
98	1	3	4	10	28	15	17	23	20	5	27	6	5
107	7	5		5	36	14	36	7	35	63	19	6	5
106										1	3		
113	1											4	
108						7	3	1		5			
109								2	4		6	4	2
110			62	29	241	196	326	238	376	268	472	98	72
100	19	36	76	63	109	155	277	205	353	232	411	172	80

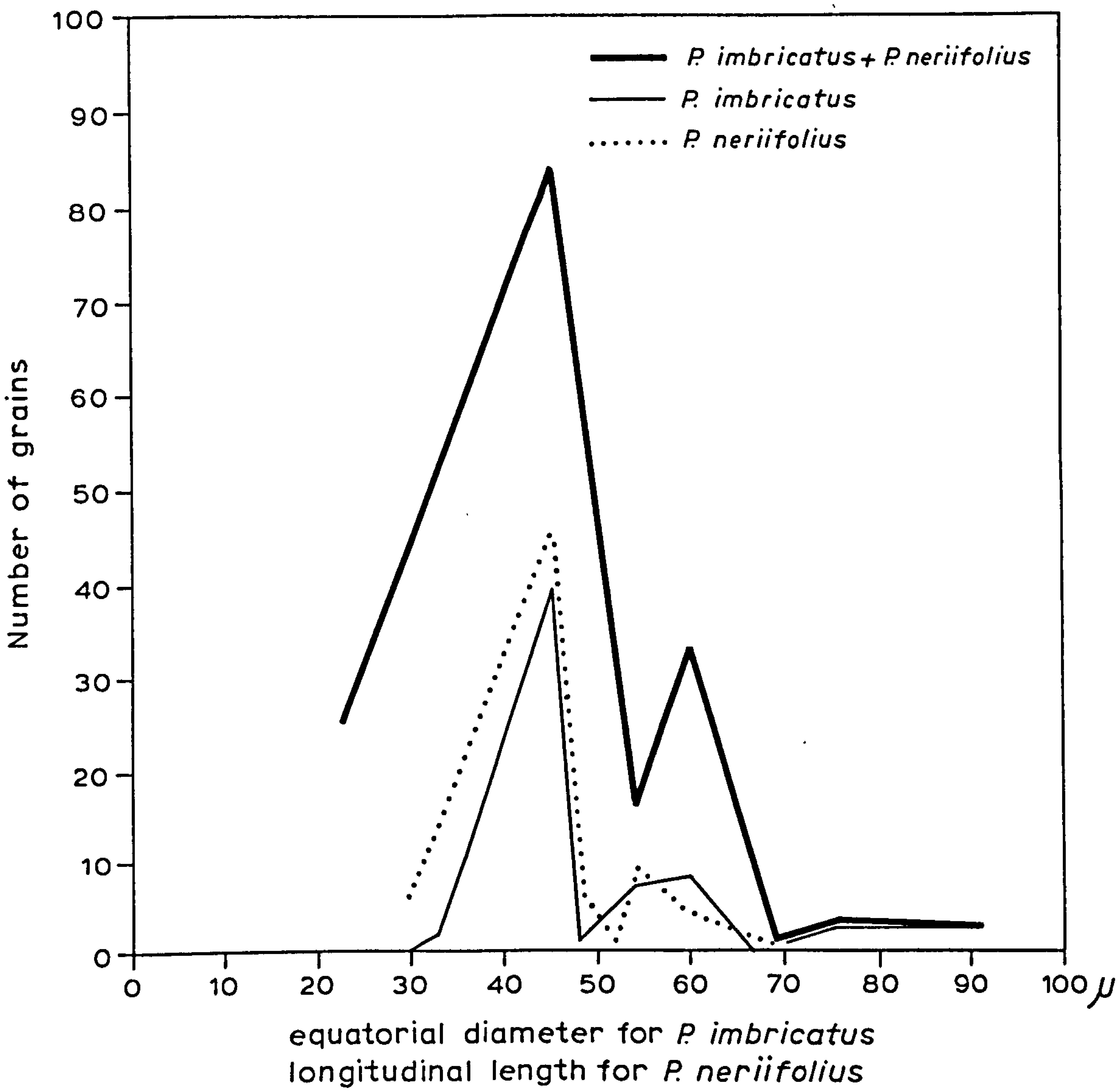
Sample Number Pollen & Spores	Rk 8.15 m	Rk 8.65 m	Rk 9.15 m	Rk 9.30 m	Rk 10.20 m	Rk 10.90 m	Rk 11.50 m	Rk 11.95 m	Rk 12.20 m	Rk 12.80 m	Rk 13.30 m	Rk 13.75 m	Rk 14.05 m
60	1							2	1				1
59	1	3	10	4				3	1	3	1	6	2
42													1
11			2										3
10	539	255	813	452	98	84	159	479	228	226	147	484	208
9	19	16	193	76	2	2	12	34	4	12	22	81	1
12	15	10	8	12				6		9	16	42	
35	1		2										1
104	19		41	3			1	11		5	8	13	
105		2	28				1	8		3	3	2	
112	15	5	19	2	26			7	5	3	4	9	13
98	12	9	10	4			1	4	1		1	1	
107	5	12	34	3						3	1	3	
106								2					
113	2		8										
108											3		
109	11	2	11	2				2		1		1	
110	259	137	388	69	28	1	17	74	8	24	28	99	10
100	167	322	358	101	57	26	32	71	17	33	47	116	26

Appendix 2

Size variations of *Podocarpus* may be due to generic, ecological and physiological factors.

Martin, (1959) found considerable variability in *Podocarpus* pollen size and in pollen proportions between populations of single species. (See A.R.H. Martin, (1959). South African palynological studies, I. *Grana Palynologica* 2 : 1 40-68).

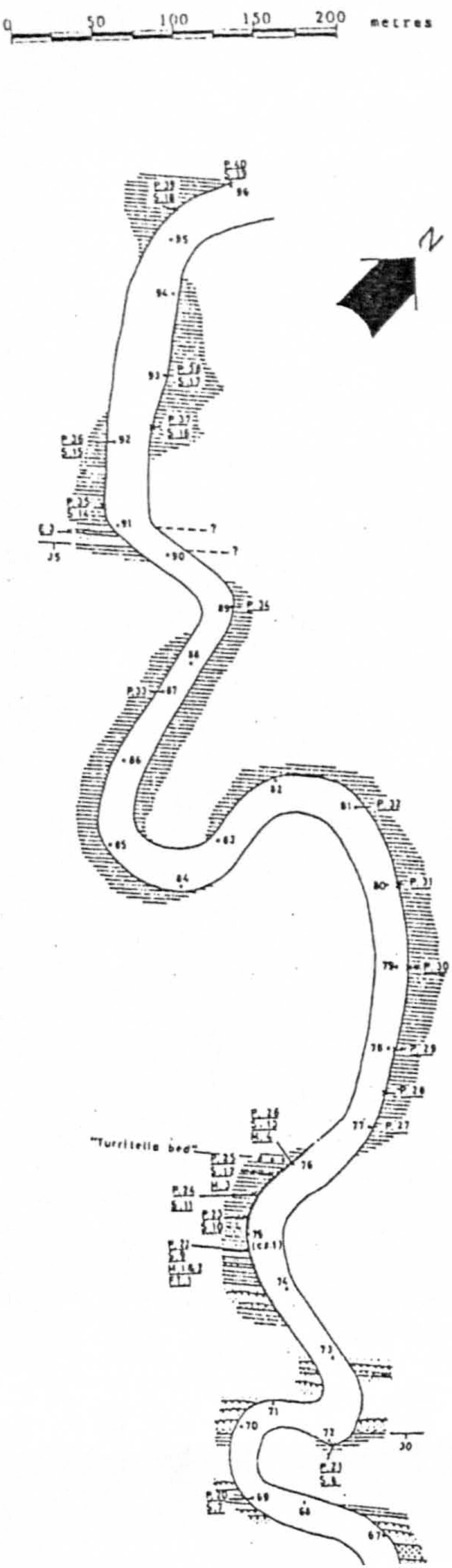
Size ranges of *Podocarpus imbricatus* and *Podocarpus neriifolius* based upon 200 grains from LINGGAR and RANCAEKEK, ANCIENT BANDUNG LAKE



CONTAINS PULLOUTS

GEOLOGICAL TRANSECT MAP

CISAAT , BUMIAYU.




K. Pelem

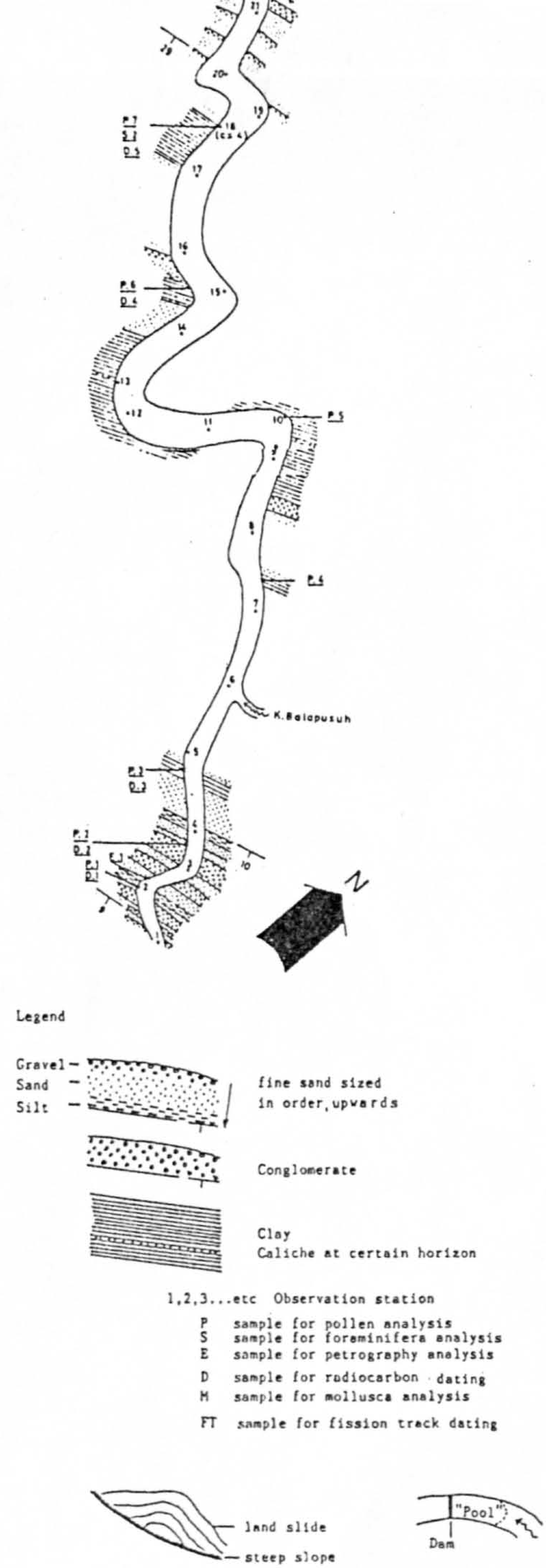
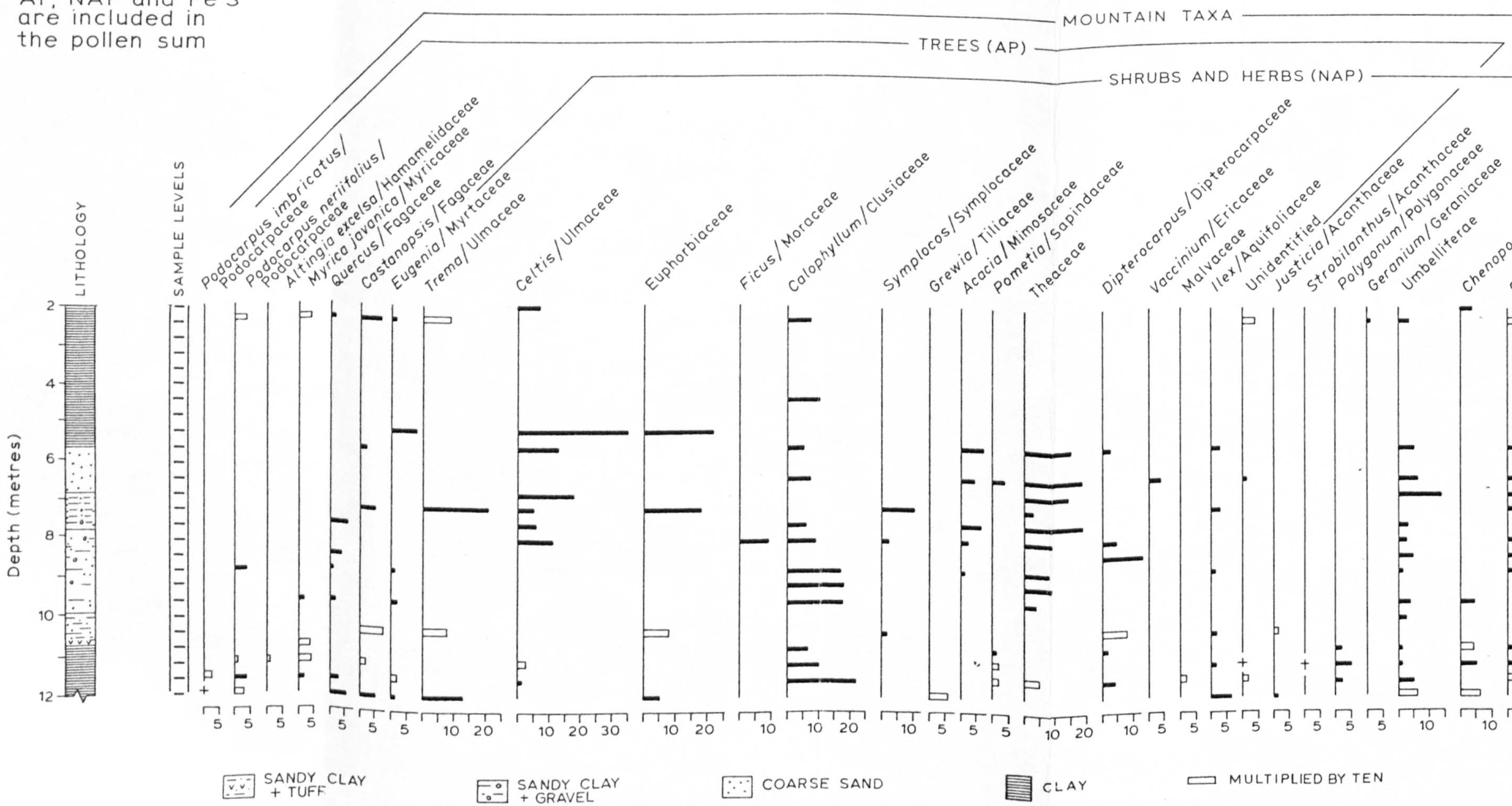
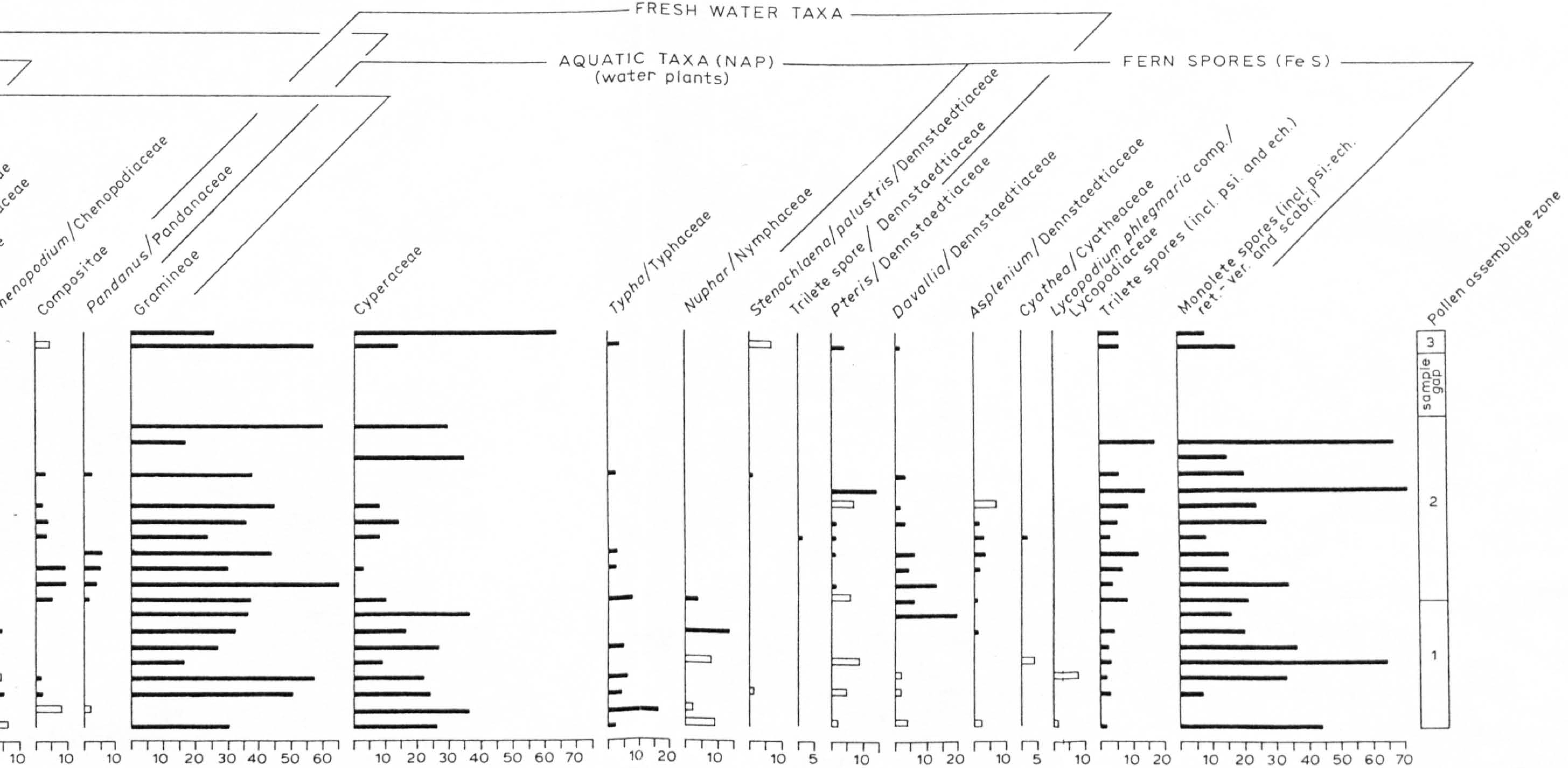

K.Balapusuh
N
Legend
Gravel
Sand
Silt
fine sand sized
in order, upwards
Conglomerate
Clay
Caliche at certain horizon
1,2,3...etc Observation station
P sample for pollen analysis
S sample for foreminifera analysis
E sample for petrography analysis
D sample for radiocarbon dating
M sample for mollusca analysis
FT sample for fission track dating
land slide
steep slope
"Pool"
Dam

Figure 2.5

Cibogo (Cb), West of Bandung Lake

AP, NAP and Fe S are included in the pollen sum



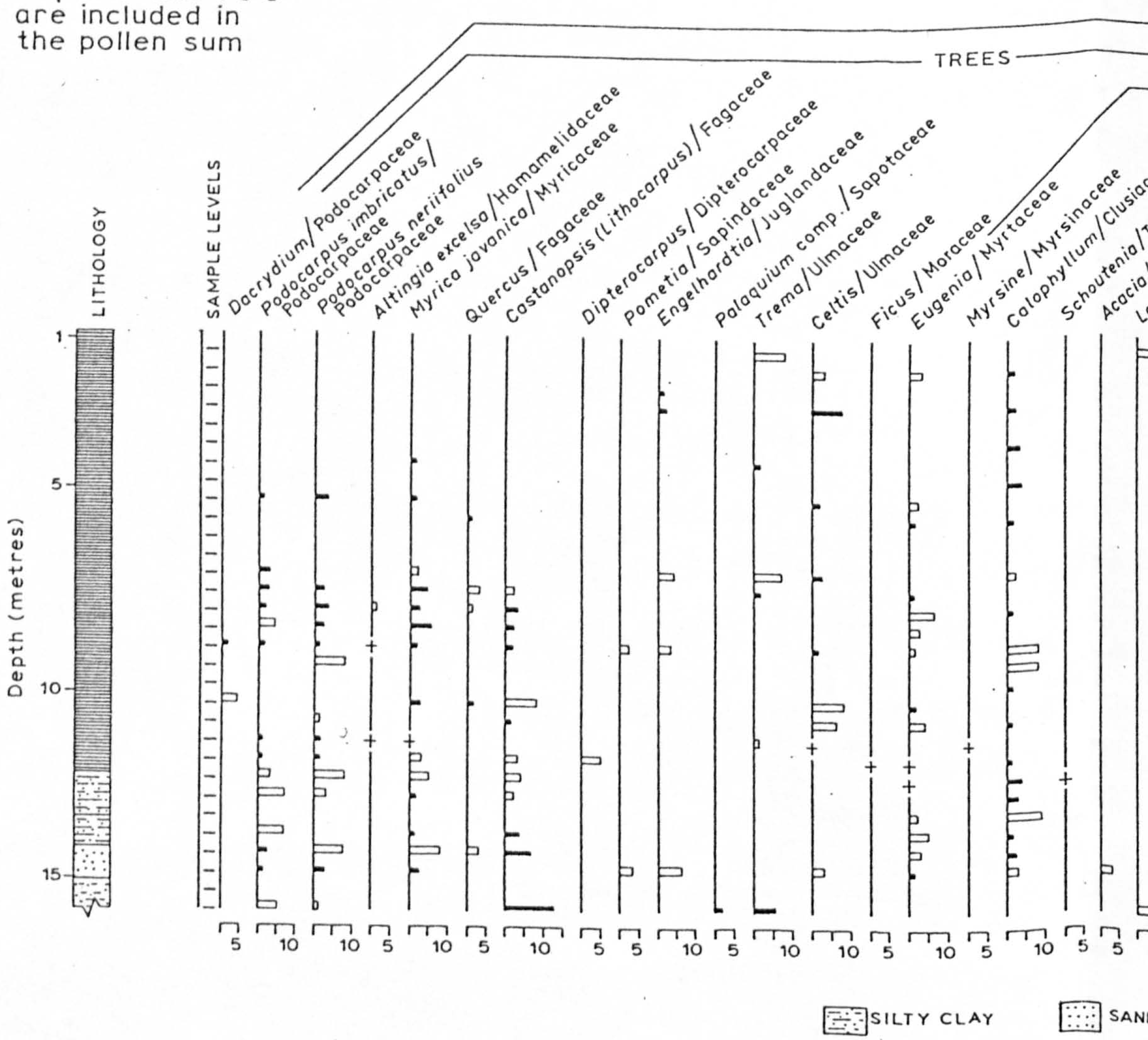


+ INDICATES PRESENT LESS THAN 0.1 PERCENT

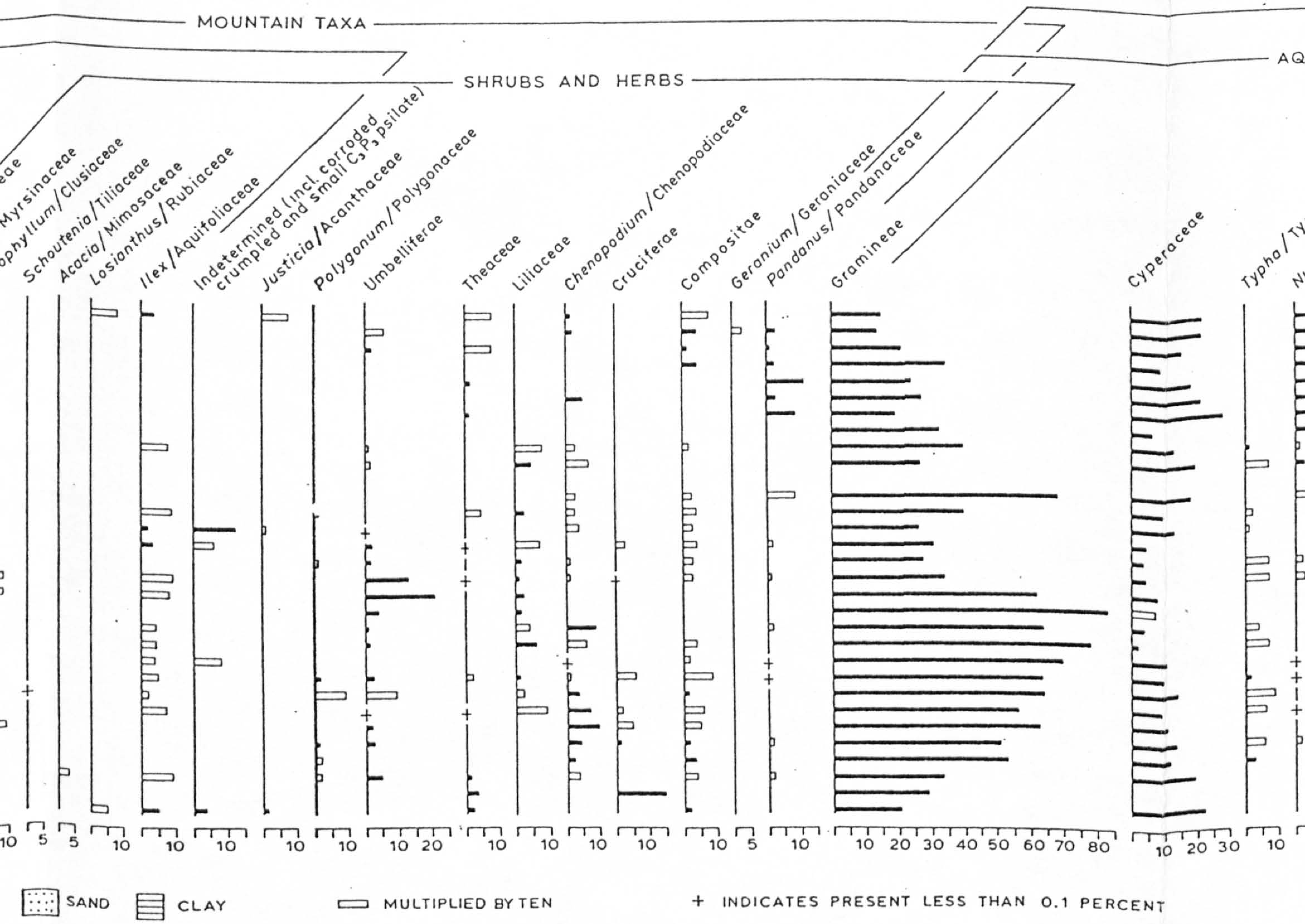
Figure 4.1

Linggar (Lgr) South West of Bandung Lake

AP, NAP and Fe S
are included in
the pollen sum



ke


MOUNTAIN TAXA
SHRUBS AND HERBS
AQ
Myrsinaceae
Schoutenia/Tiliaceae
Acacia/Mimosaceae
Lasianthus/Rubiaceae
Ilex/Aquifoliaceae
Indetermined (incl. corroded crumpled and small C3P3 psilate)
Justicia/Acanthaceae
Polygonum/Polygonaceae
Umbelliferae
Theaceae
Liliaceae
Chenopodium/Chenopodiaceae
Cruciferae
Compositae
Geranium/Geraniaceae
Pandanus/Pandanaceae
Gramineae
Cyperaceae
Typha/Ty
10 20 30 40 50 60 70 80
SAND
CLAY
MULTIPLIED BY TEN
+ INDICATES PRESENT LESS THAN 0.1 PERCENT

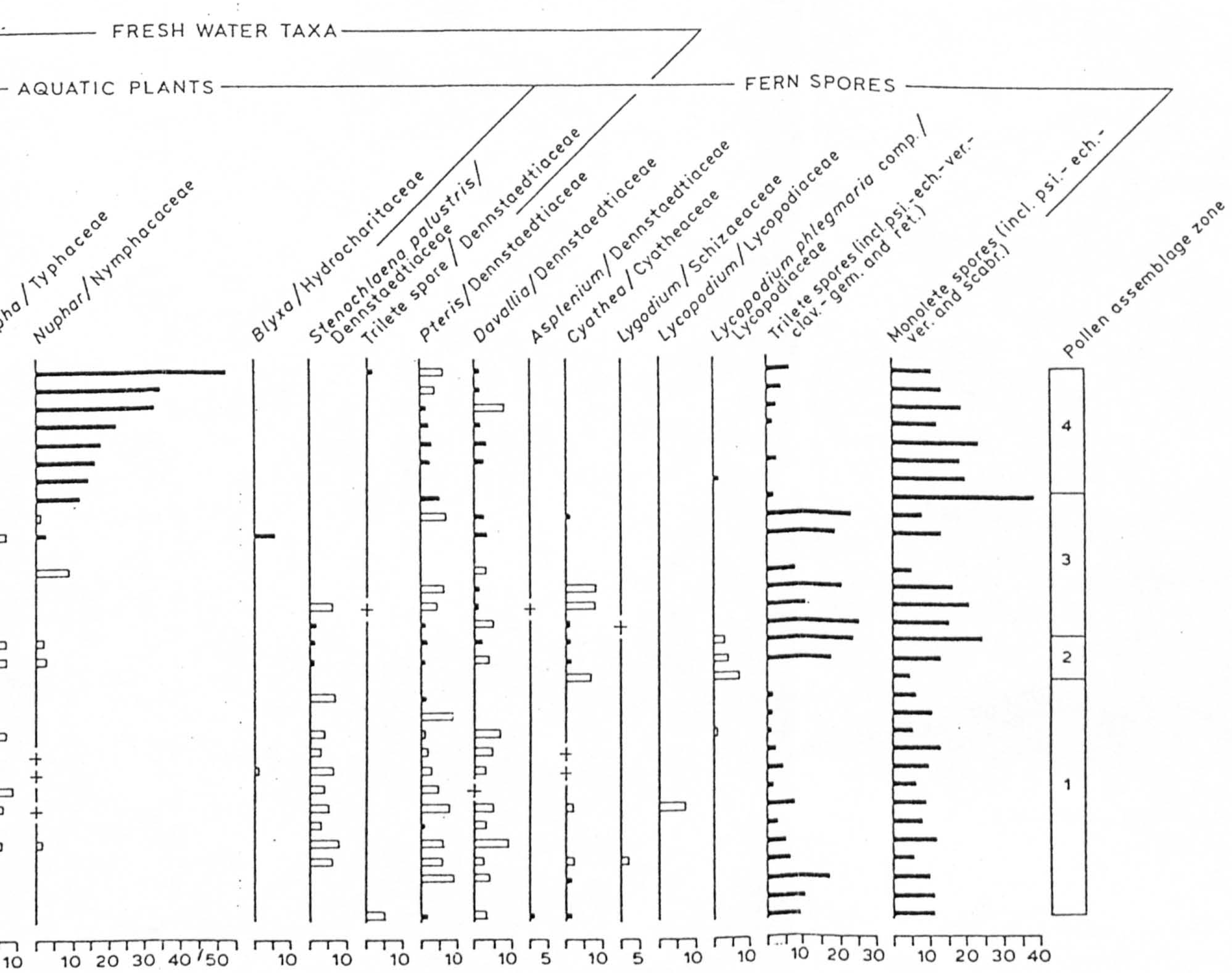
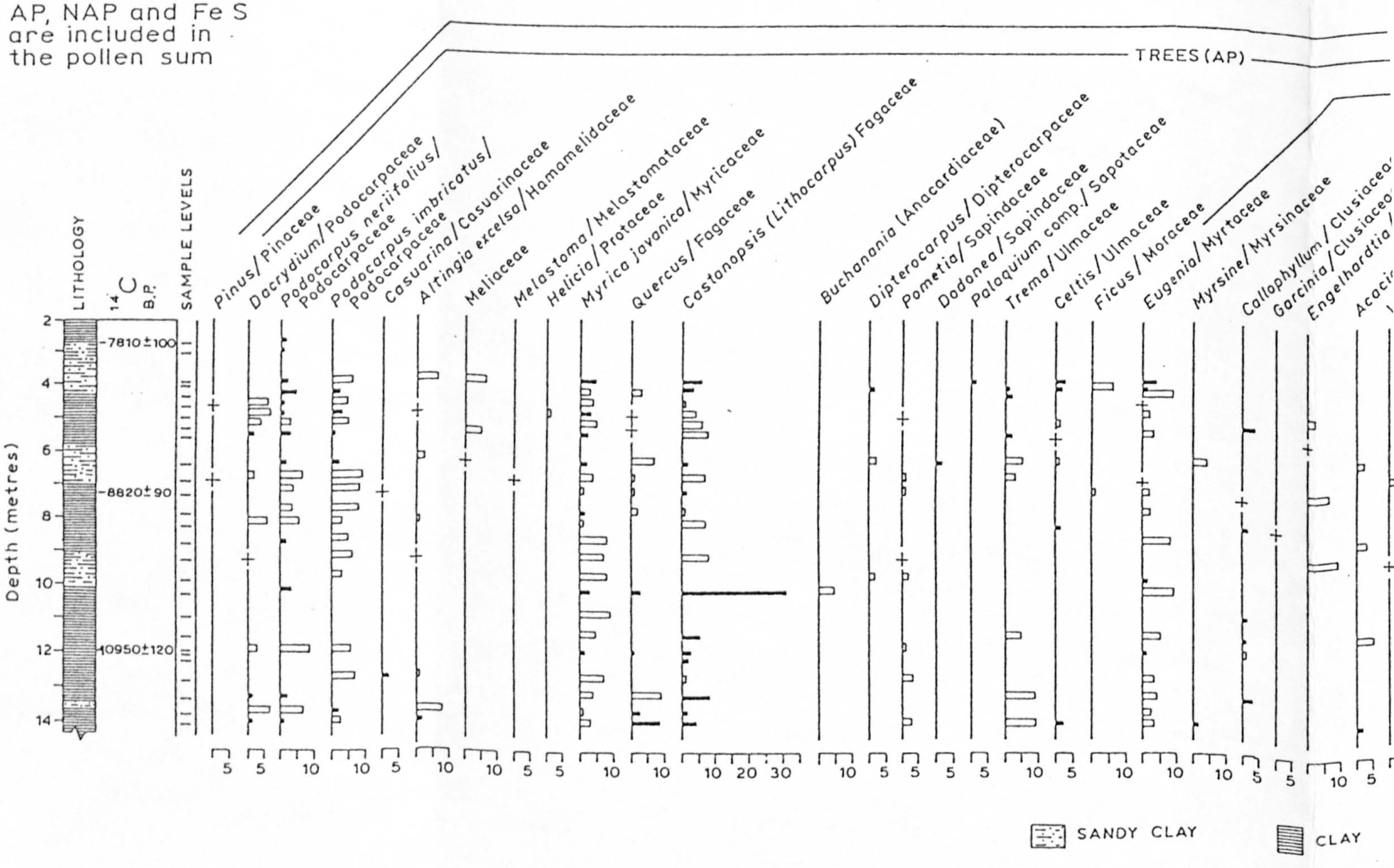


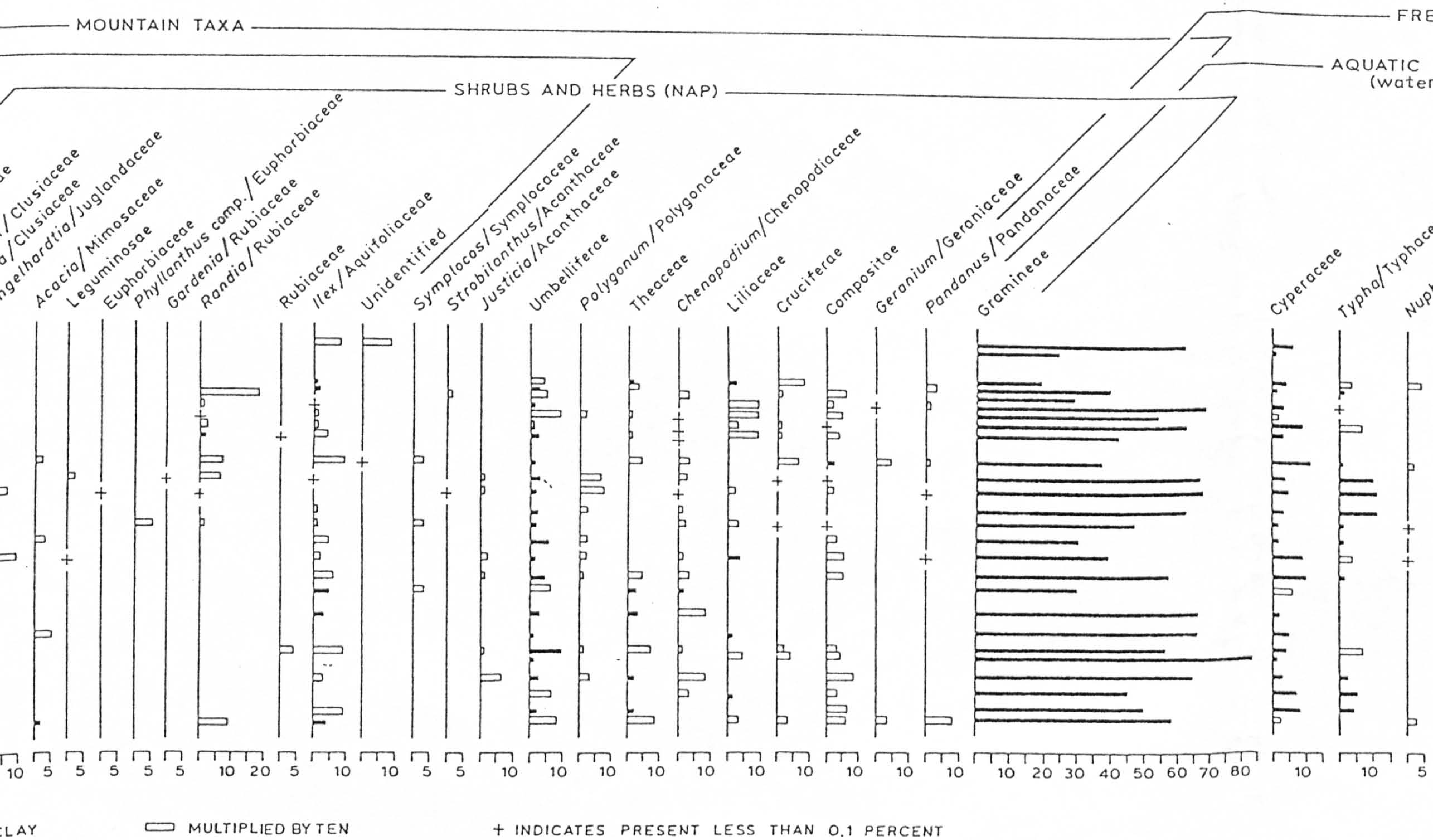
Figure 4.2

1990 Ph.D P7

Rancaekek (Rk) East of Bandung Lake

AP, NAP and Fe S are included in the pollen sum




MOUNTAIN TAXA
SHRUBS AND HERBS (NAP)
AQUATIC
Acacia/Mimosaceae
Leguminosae
Euphorbiaceae
Phyllanthus comp./Euphorbiaceae
Gardenia/Rubiaceae
Randia/Rubiaceae
Rubiaceae
Ilex/Aquifoliaceae
Unidentified
Symplocos/Symplocaceae
Strobilanthus/Acanthaceae
Justicia/Acanthaceae
Umbelliferae
Polygonum/Polygonaceae
Theaceae
Chenopodium/Chenopodiaceae
Liliaceae
Cruciferae
Compositae
Geranium/Geraniaceae
Pandanus/Pandanaceae
Gramineae
Cyperaceae
10 5 5 5 5 5 10 20 5 10 10 5 5 10 10 10 10 10 10 10 10 10 10 20 30 40 50 60 70 80 10 10 5
MULTIPLIED BY TEN
+ INDICATES PRESENT LESS THAN 0.1 PERCENT

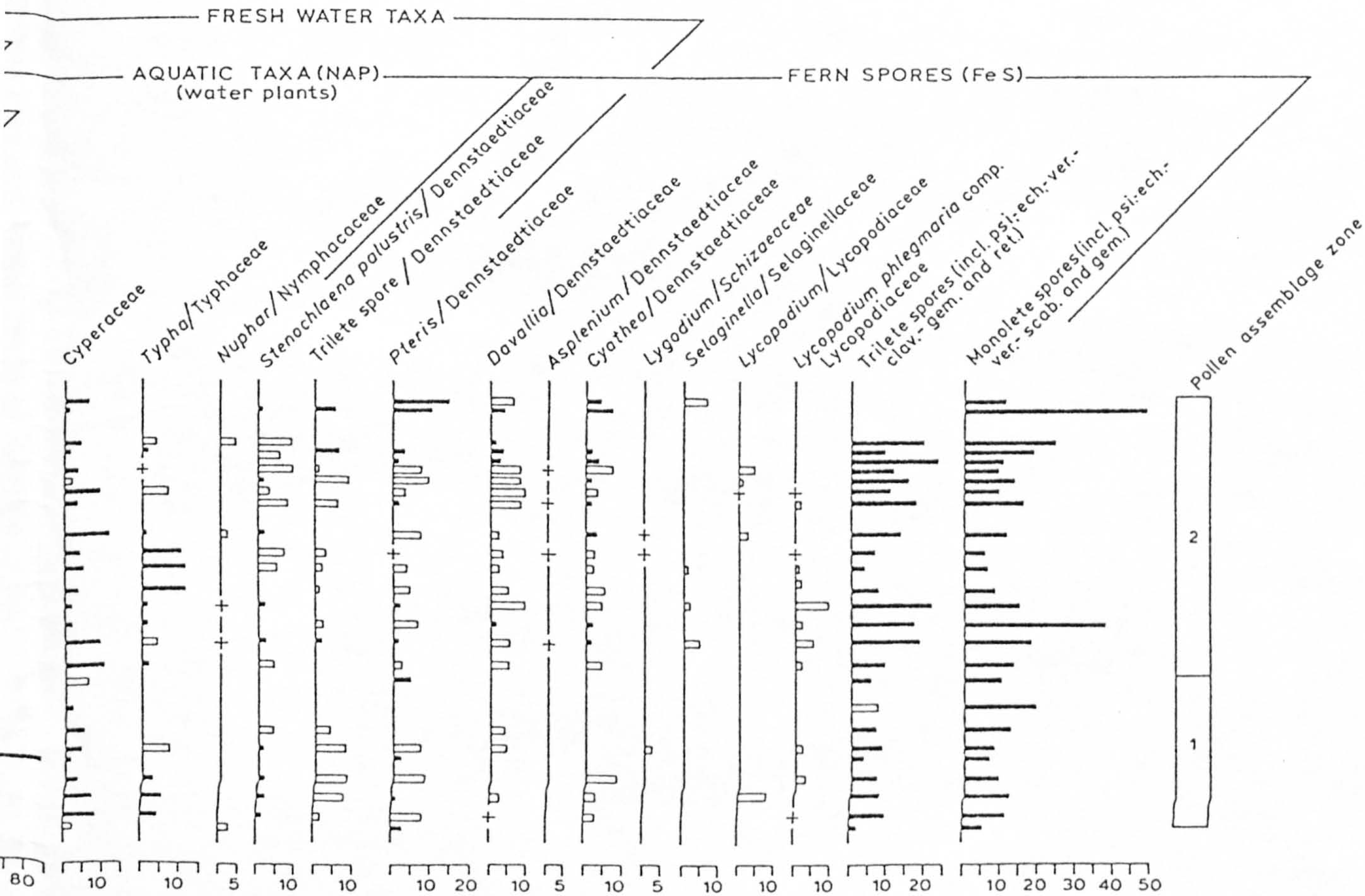
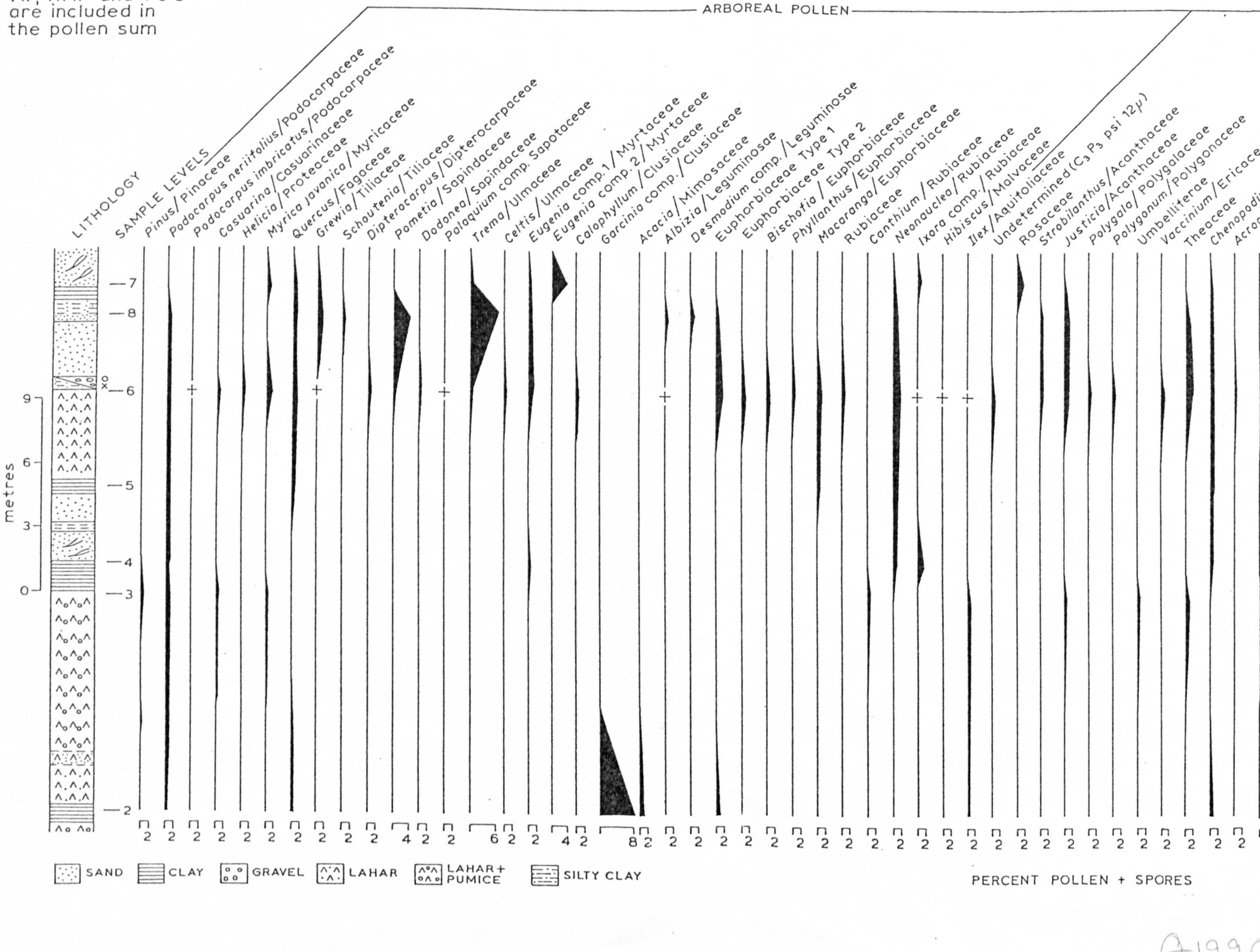
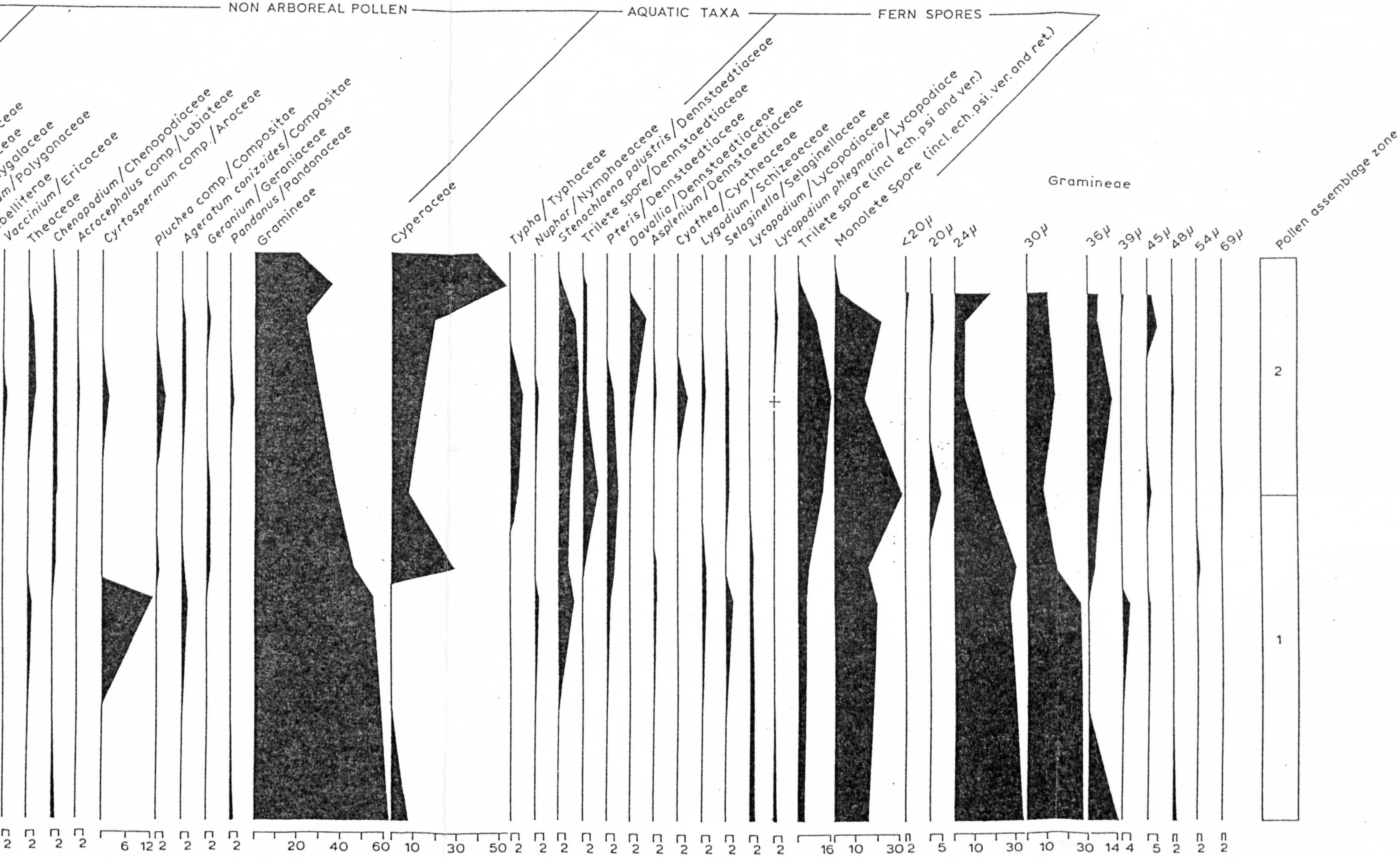

FRESH WATER TAXA
AQUATIC TAXA (NAP)
(water plants)
FERN SPORES (Fe S)
Cyperaceae
Typha/Typhaceae
Nuphar/Nymphacaceae
Stenochlaena palustris/Dennstaedtiaceae
Trilete spore / Dennstaedtiaceae
Pteris/Dennstaedtiaceae
Davallia/Dennstaedtiaceae
Asplenium/Dennstaedtiaceae
Cyathea/Dennstaedtiaceae
Lygodium/Schizaeaceae
Selaginella/Selaginellaceae
Lycopodium/Lycopodiaceae
Lycopodium phlegmaria comp. Lycopodiaceae
Trilete spores (incl. psi.-ech.-ver.-clav.-gem. and ret.)
Monolete spores (incl. psi.-ech.-ver.-scab. and gem.)
Pollen assemblage zone
2
1
80
10
10
5
10
10
10 20
10
5
10
5
10
10
10
10 20
10 20 30 40 50

Figure 4.3

Trinil, East Java

AP, NAP and Fe S are included in the pollen sum

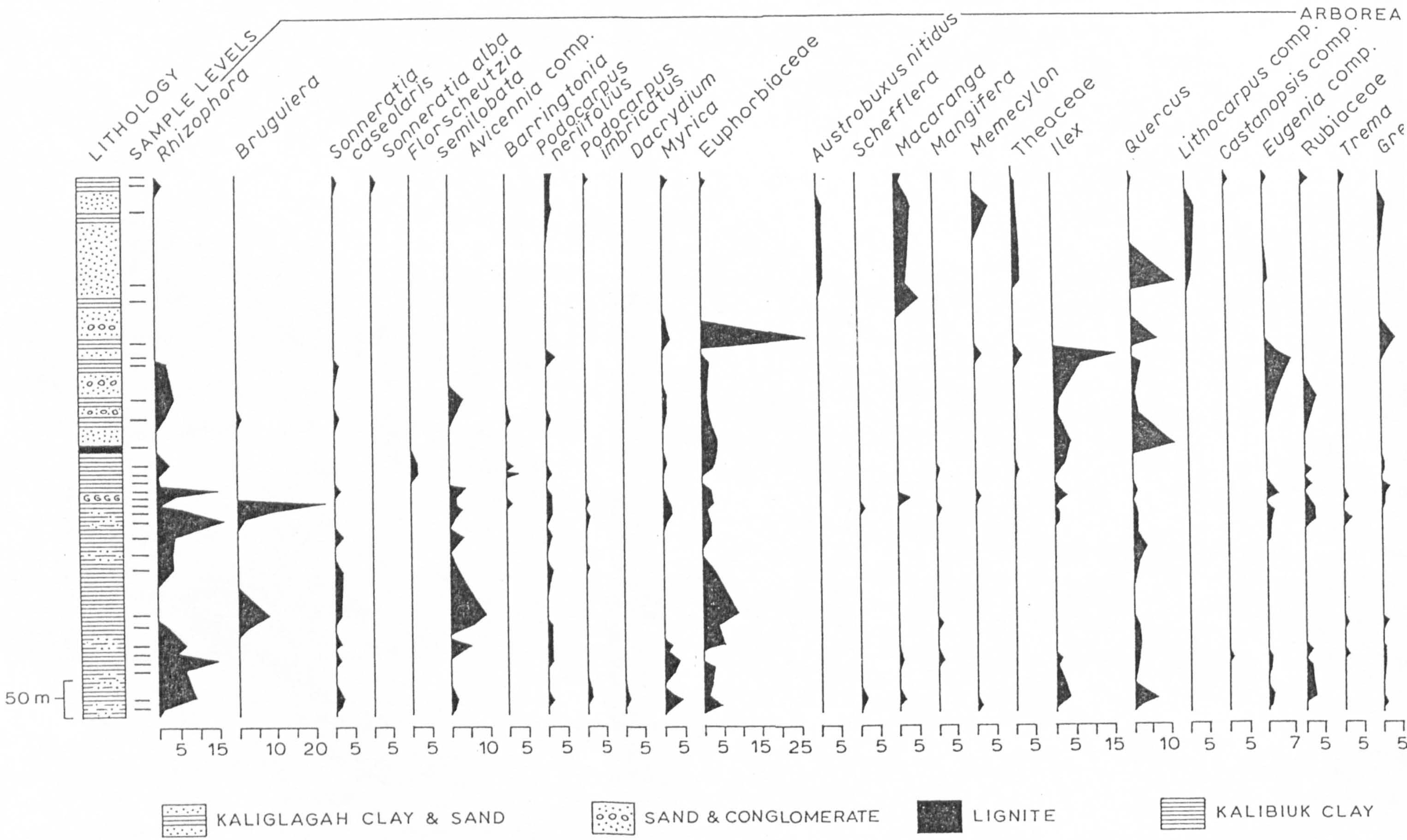


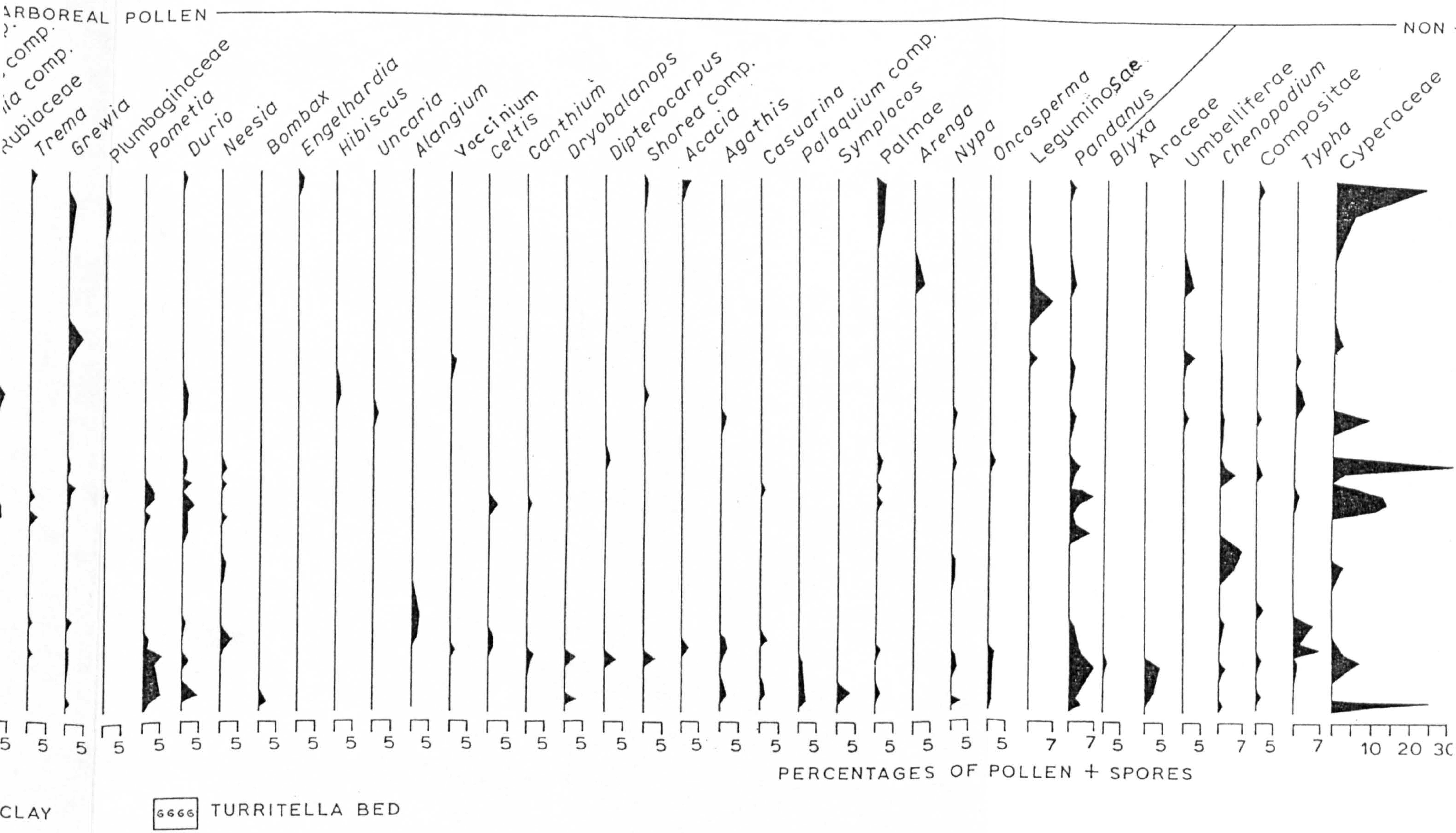


ORES + INDICATES PRESENT LESS THAN 0.1 PERCENT

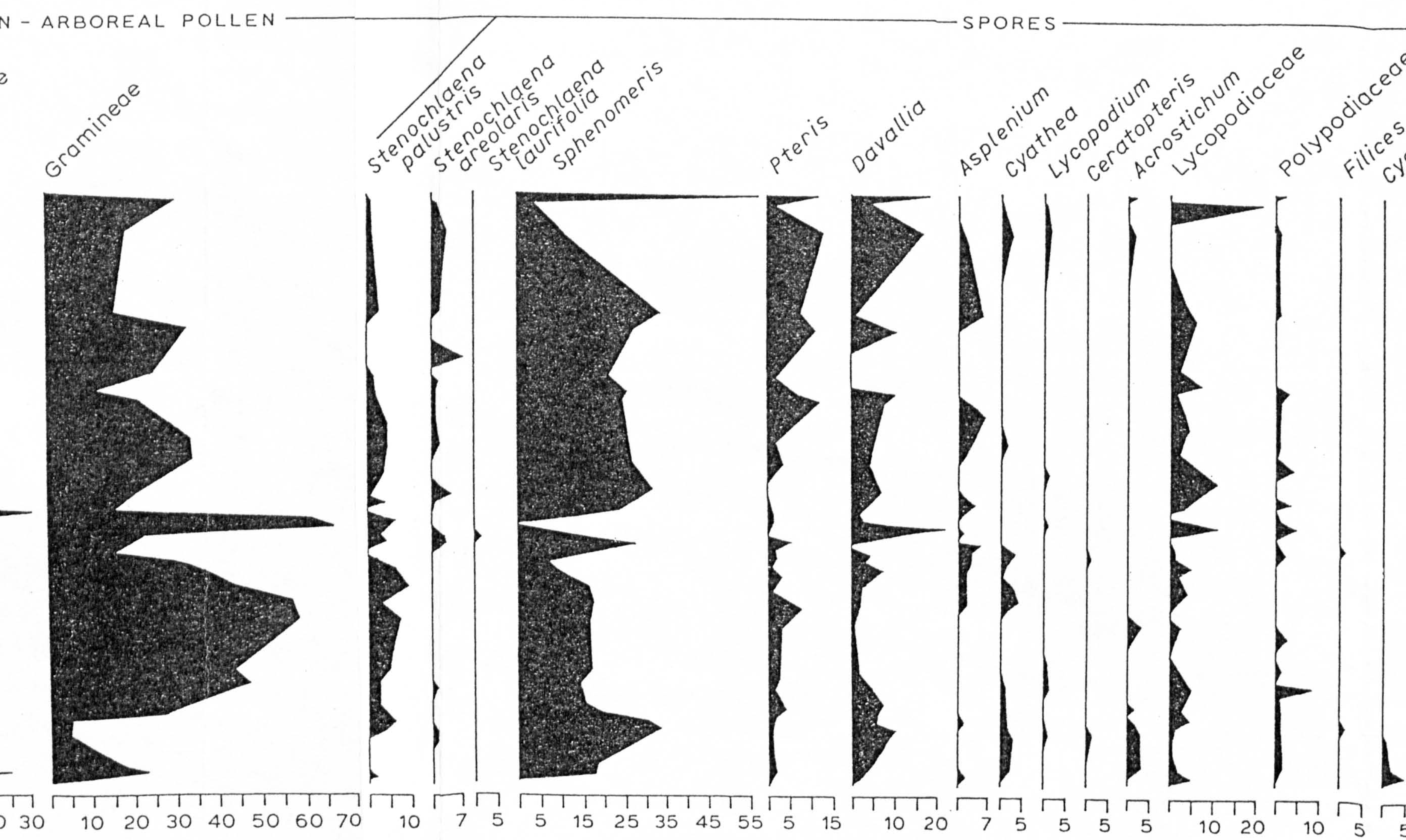
Figure 4.4

CISAAT, Bumiayu

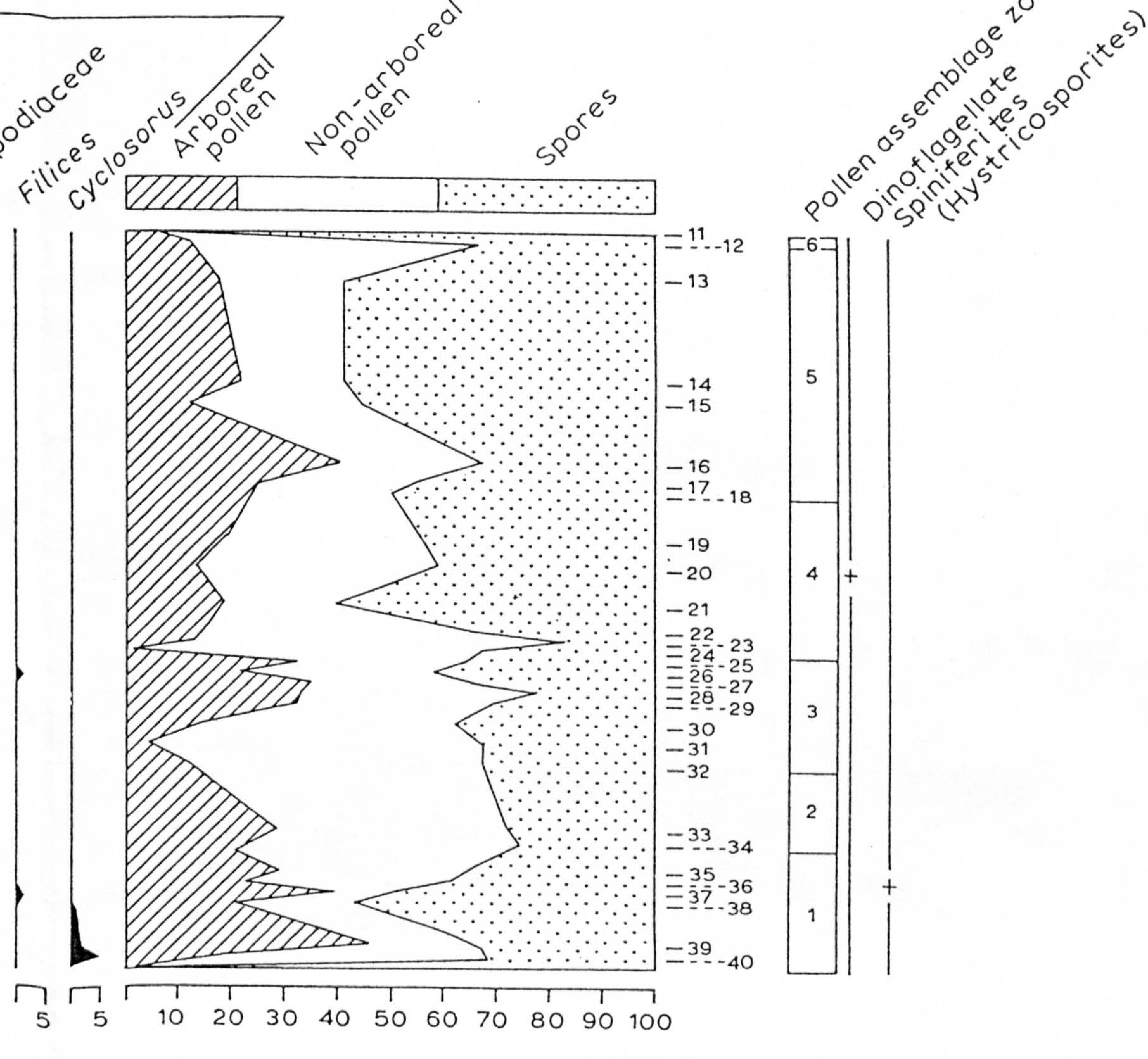




ARBOREAL POLLEN
NON
comp.
ia comp.
Rubiaceae
Trema
Grewia
Plumbaginaceae
Pometia
Durio
Neesia
Bombax
Engelhardia
Hibiscus
Uncaria
Alangium
Vaccinium
Celtis
Canthium
Dryobalanops
Dipterocarpus
Shorea comp.
Acacia
Agathis
Casuarina
Palaquium comp.
Symplocos
Palmae
Arenga
Nypa
Oncosperma
Leguminosae
Pandanus
Blyxa
Araceae
Umbelliferae
Chenopodium
Compositae
Typha
Cyperaceae
10 20 30
PERCENTAGES OF POLLEN + SPORES
CLAY
TURRITELLA BED



N - ARBOREAL POLLEN
SPORES
Gramineae
Stenochlaena palustris
Stenochlaena areolaris
Stenochlaena laurifolia
Sphenomeris
Pteris
Davallia
Asplenium
Cyathea
Lycopodium
Ceratopteris
Acrostichum
Lycopodiaceae
Polypodiaceae
Filices



podiaceae
Filices
Cyclosorus
Arboreal pollen
Non-arboreal pollen
Spores
Pollen assemblage zone
Dinoflagellate
Spiniferites (Hystricosporites)
11
12
13
14
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16
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37
38
39
40
6
5
4
3
2
1
5
5
10 20 30 40 50 60 70 80 90 100

Figure 4·5