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Palynology of the lowland Seberang Prai and Kuala Kurau areas North -West Peninsular Malaysia

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Abstract: Palynological analyses were carried out on thirty-six samples from boreholes A13, E15 and L7 in the lowland Seberang Prai and Kuala Kurau areas of North-West Peninsular Malaysia. More than seventy pollen types and a total of thirty-one fern spores were identified and differentiated. Pollen diagrams were constructed from selected taxa which are ecologically significant or when the occurrence is representative in the profiles.

The depositional sedimentary environments recognised from the ecological assemblages in the pollen and spores include mangrove, back mangrove and open swamp conditions. The mottled clay layers representing the pollen zones 0 and VII were interpreted to be deposited in a period of low sea level before the last transgression.

The significance of palynology in the Quaternary stratigraphy of the area is well demonstrated. The Gula and probable Simpang Formations are delineated in all the boreholes. The Beruas Formation constituted the uppermost layer in core A13 while the basal horizon in L7 is inferred as the Kempadang Formation.

INTRODUCTION

Quaternary deposits cover 20% of the total land surface in Peninsular Malaysia. Until recently little geological work has been done, and it is the aim of this study to demonstrate how palynology can be applied in establishing stratigraphic horizons in lowland sediments.

In related work, Hillen (1984) conducted an investigation in the Lower Perak area, which lies to the south of this study site. He summarized various sedimentary environments from the pollen contents of the Late Quaternary deposits. Other palynological work in Peninsular Malaysia are quite scarce (Haseldonckx 1977a, b; Chow, 1977). Haseldonckx (1977a) stressed the potential of palynology for the creation of a zonation scheme for the Quaternary deposits in the region. Van Zeist (1984) pointed to the potentials of palynological research in this part of the world in recognizing changes in vegetation brought about by climatic changes and the impact of man on the vegetation.

THE SEBERANG PRAI AND KUALA KURAU AREA

The area discussed in this report is situated in northwest of Peninsular Malaysia adjacent to Penang Island (Figure 1). They are well-drained by rivers from the east, flowing to the Strait of Malacca. The eastern hills form the backbone of the country (the Main Range) trending approximately north-south and reaching more than 2000 metres high. It is a Mesozoic granite intrusion (for the most part).

In Seberang Prai, Holocene ridges (*permatang*) form an interesting geomorphological feature in the area. These ridges stretch for kilometres trending approximately north-south and generally less than 200 metres wide, on which are situated the roads and houses. The sand ridges are an indication of higher sea levels during the last 5000 years (Tjia *et al.*, 1977).

The area is cultivated mainly with rice (on the flatland), oil-palm plantations (*Elaeis quineensis*), and rubber estates (*Hevea brasiliensis*) on higher areas. Along the coast and the river inlets, especially near Kuala Kurau, mangrove swamps form the natural vegetation cover. Natural plant life is found in most of the hills and the higher mountain ranges.

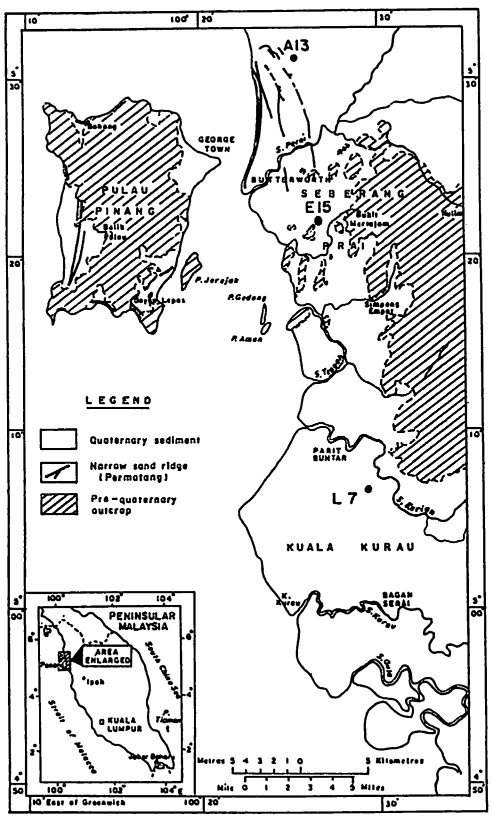

Figure 1 : Sampling localities of cores A13, E15 and L7 in the Seberang Prai and Kuala Kurau area, northwest Peninsular Malaysia (From sheets 28 and 39 of the Directorate of National Mapping Malaysia)

FIELD AND LABORATORY METHODS

The sampling localities A13, E15, and L7 define on area bounded by longitudes 100° 25' E and 100° 30' E and latitudes of 5° 31'N, 5° 22' N and 5° 09' N. They are located 5 to 8 km from the nearest shoreline. Coring was done with gauge (guts) corers having a diameter of 3 cm and lenght of 1 metre. The samples collected were placed in 1 metre PVC tubes (which had already been cut into two-halves lengthwise) and wrapped in plastic sheets in the field. The A13 profile, 8 m long, adjacent to a beach-ridge is from the northern most part of the area. Core E15, 8.50 m long, was sampled about 1.5 km from a small granite hill approximately 65 metres high. L7, 13 m long, from the southernmost site of the area, is located approximately 1.5 km from the bank of Sungai Kerian.

The samples were processed and analysed at the Biologisch - Archaeologisch Instituut, Groningen. About 1 to 2 cm^3 was cut from the inner part of the core and the treatment that ensued is according to Faegri and Iversen (1975). In all preparations the samples underwent heavy liquid separation using a bromoform-alcohol mixture (S.G. = 2.0), hydrofluoric acid (30%) treatment to dissolve the remaining silicate minerals, acetolysis to remove the cellulose using a mixture of 9 parts anhydric acetic acid with 1 part conc. sulphuric acid, and finally the sample was treated with safranine (normally less than 5 drops) for staining. The mounting medium used is silicone oil (AK 2000) which has the advantage that it does not cause a swelling of the pollen grains (Moore & Webb 1978).

THE SECTIONS

Descriptions of the sediment from the three profiles were made in the field. The standard equipment referred to includes grain size comparator, eye lens (about 10x magnification) and the Munsell's Colour Chart.

Core A13

The borehole is situated near Kg. Permatang Manggis, at 1.60 m above mean sea level.

0	-	0.20 m	disturbed
0.20	-	1.60 m	silt, clayey, moderately sandy (medium); light grey, yellow-orange mottling, slightly humic.
1.60	-	2.60 m	sand (medium), silty; dark greenish grey, very humic, moderate amount of plant fragments.
2.60	-	3.35 m	peat; brownish black
3.35	-	7.10 m	clay, silty; greenish grey, slightly humic, small amount of plant fragments; from 7.60m, yeloworange mottling; from 8.10 to 8.20m,

very gravelly, slightly sandy (moderately coarse).

Core E15

The borehole is located near Kg. Permatang Batu and 0.42m above mean sea level.

0	-	0.90 m	peat
0.90	-	8.05 m	clay, silty; yellowish grey, very humic; from 2.00 m, greenish grey.
8.05	-	8.50 m	clay, silty; greenish grey, very humic, thin (about 1 cm) fine sand layers.

Core L7

Situated at Ladang Dennistown and 1.59 m above mean sea level.

0	-	0.50 m	disturbed
0.50	-	9.30 m	clay, silty; slightly sandy (coarse); dull yel lowish brown, very humic, abundant plant fragments; from 1.40 m, greenish grey, slightly humic; from 6.00 m to 8.30 m, mod. amount of shell fragments; from 8.10 to 8.30 m, small amount of clay concretions.
9.30	-	11.50 m	clay; light grey, moderate amount of red and yellow-brown mottling.
11.50	-	13.00 m	clay; light greenish grey, sparse plant fragments; from 12.10 to 12.40 m, peaty.

INDENTIFICATION OF POLLEN AND SPORES

Slides were made and diluted with silicone oil to the required microfossil concentration. Generally, the concentration of pollen and spores at one particular view (400 x) does not exceed 5 grains. When detailed examination of a particular grain is needed the oil immersion objective with magnification of 1000x is used. For every sample, at least 200 pollen grains were counted whenever possible. Counting is carried out along regular traverses of the microscope slide.

For the identification of pollen grains a pollen reference collection (of more than 500 species) of the Southeast Asian plant taxa was available . References from various other sources included Huang (1972), Anderson and Muller (1975) and Morley (1976) were also consulted. Whenever possible the species concerned was ascertained. However, it is often difficult and identification is thus at the genus level, e.g. *Quercus, Eugenia*. When the pollen or spore examined is morphologically identical to a genus concerned but some doubts exist about the conclusiveness of the identification, the name is followed by the suffix *type,* e.g. *Macaranga*-type, and this is also applied when differentiation between two genera is difficult, e.g. *Castanopsis / Lithocarpus*-type. Grouping into family is made when sparse pollen grains of different genera are found. For example, Sapotaceae generally include *Madhuca, Palaquium* and/or *Payena* (refer to appendix 2). The grouping of Moraceae/Urticaceae undifferentiated shows the difficulty of separating between the two families, but *Ficus* is separated since it is a distinct pollen type (refer to appendix 1). In case of scattered occurrences and low frequencies, grouping into families is made for easier representation in the pollen graph.

The numbers of unidentified pollen grains which include 'unknown' and 'undetermined' grains are quite large. The undetermined grains constitute those which are folded, torn, hidden, crumpled or corroded. Tricolporate grains form the majority of the unknown types.

Although the spore collection is rather limited, at least six genera frequently encountered were determined : *Acrostichum, Davallia, Lycopodium, Microsorium, Selaginella* and *Stenochlaena palustris.* The unidentified spores are grouped into monolete and trilete types.

PRESENTATION OF THE RESULTS

The results of the palynological examination of the three cores Al3, El5 and L7 are presented in pollen diagrams (Figs. 2, 3 & 4). The percentages are calculated on the sum of arboreal, non-arboreal and unidentified pollen grains. The spore values are based on this pollen sum. Where necessary, ten times exaggeration is shown (unshaded) in each individual spectrum for a better clarification.

The five spectra on the left of the diagrams show arboreal pollen from the upland vegetation and lowland forests. *Pinus*, a conifer which is not indigenous in Peninsular Malaysia (Corner, 1951) but occurs in all the cores analysed, generally less than 2%, is envisaged to be transported from long distance, presumably from Sumatra, since it is a wind-pollinated tree, and pollen dispersal and deposition over great distance is not uncommon (Birks & Birks, 1980, p. 180).

The *Rhizophora* pollen type is important in the study area and is well represented in all the three cores. It is differentiated from the family Rhizophoraceae. The pollen type includes *R. mucronata* and *R. apiculata* which are characteristic of a mangrove environment, with tolerance to a higher degree of salinity shown by the former (Muller & Caratini, 1977).

The Arecaceae and *Pandanus* pollen types are classed as belonging to back mangroves. The term 'back mangrove' is loosely applied to denote the zone between the mangrove belt and the lowland forests, or the gradual transition from the mangrove area to peat swamp forests which is presently found at many localities on the west coast of the Peninsula.

Pollen curves further to the right of the diagrams represent trees, herbs and shrubs from various ecological habitats. No environmental differentation is made, but it should be mentioned here that they represent montane communities, lowland or swamp forests and riparian fringes. To cite a few: *Campnosperma, Eugenia, Ilex* and Cyperaceae are types common in the swamp forests; *Melastoma,* Meliaceae and Sapotaceae generally form part of the lowland forest; *Dillenia, Pometia, Saurauia* are abundant along river banks; *Macaranga* and Gramineae are dominant in open and cleared lowland area; *Celtis* represents the submontane habitat; *Garcinia* and some *Ficus* species are commonly found in the low montane and lowland forests.

Curves for unknown pollen grains and the undetermined are included since they are present in quite a proportion (up to about 15% unknown in A13) in all the samples. The pollen diagrams for E15 and L7 show curves for unknown type 1 (tricolporate, psilate, costae colpi, 10 to 12 um) which is absent in the A13 samples.

The composite diagram on the extreme right of the pollen diagrams is constructed from the total pollen spores counted and distinction is made between mangrove types including Rhizophoraceae, *Sonneratia* and *Acrostichum*; back mangrove types; other identified pollen; the unidentified pollen; and the spores.

The pollen assemblage zones reflect the main component of the local vegetation at a particular period of the sediment accumulation.

THE POLLEN DIAGRAMS

The pollen assemblage zones distinguished in the pollen diagrams are referred to in discussing the profile of each core studied. Eight zones are delineated, but the zonations achieved are strictly of local character.

Core A13 (figure 2)

Zone 0, spectrum 1

Pollen is absent in sample 1, prepared at the level just above the mottling zone. A hiatus in pollen deposition and preservation is inferred.

Light grey clayey silt made up the sediment layer.

Zone I, spectra 2-4.

Among the mangrove pollen types *Rhizophora* is predominant, occurring as much as 70%, while *Sonneratia* and *Acrostichum* are present in less than 5%. *Quercus,* Dipterocarpaceae, *Stenochlaena palustris* are also important.

The sediment corresponding to this interval is greenish grey silty clay.

Zone II, spectra 5-7

The pollen assemblage which constitutes this zone is subdivided into two intervals, IIa and IIb. A sharp decline in *Rhizophora* is noted and a corresponding decrease in *Sonneratia, Avicennia* and *Acrostichum*. A marked increase in back mangrove pollen types is shown by *Phoenix* and *Pandanus*. *Eugenia, Macaranga, Pometia, Rubiaceae, Solanum*, Gramineae and the unidentifieds are well represented. A great number of pollen types is present in this zone.

Subzone IIa shows a decrease in *Quercus* and an increase in *Castanopsia / Lithocarpus* - type. Dipterocarpaceae, *Dillenia, Garcinia, Ilex, Melastoma, Saurauia,* and Meliaceae are present in low quantities. In subzone IIb, Rhizophoraceae undifferentiated is the dominant pollen type but *Rhizophora* decreases in abundance. A slight increase in *Oncosperma filamentosa* and a higher value of *Quercus* are shown.

75cm peat occurs in the lower part of the interval, overlain by silty sand.

Zone III, spectrum 8

The disappearance of mangrove pollen types is particularly noted, while fern spores exhibit a dominance characterized by *Lycopodium, Stenochlaena palustris* and the unidentified monoletes and triletes. Arecaceae and *Pandanus* show low values, whereas *Ilex*, Sapotaceae, Rubiaceae, Moraceae/Urticaceae, Cyperaceae and the unknown pollen types increase significantly.

Core E15 (figure 3)

Zone IV, spectra 1-7

Rhizophora is very well represented ranging from 60% to 80%. *Quercus, Oncosperma filamentosa, Pandanus, Solanum*, Cyperaceae, Gramineae, *Stenochlaena palustris* are expressed satisfactorily.

Greenish-grey silty clay makes up the sediment; this clay normally stinks and monotonic.

Zone V, spectra 8-9

Although *Rhizophora* persists to be the major component, *Oncosperma filamentosa* increase markedly, while other pollen and spore types are comparatively unimportant.

Core L7 (figure 4)

Zone VI, spectra 1-3

Mangrove taxa of *Rhizophora and Acrostichum* display high values, while *Sonneratia* and *Avicennia* are present. *Quercus, Podocarpus* and Dipterocarpaceae show a considerable quantity, whereas very low frequencies of *Castonopsis / Lithocarpus* and *Celtis* are shown.

Pandanus, Campnosperma, Macaranga, Rubiaceae, Moraceae/Urticaceae and the unidentified exhibit their maximum values, and a diversity in pollen types occur here. *Stenochlaena palustris* and the unidentified spores are most abundant in this interval, but a slight decrease towards the upper level is observed.

Zone VII, Spectra 4-6

The samples prepared were devoid of pollen and spore.

The corresponding sediment is light grey clay with moderate amount of red and yellow-brown mottling. This indicate that oxidation had occurred and could well explain for the hiatus of the pollen record.

Zone VIII, spectra 7-16

The dominance of mangrove pollen types is clearly visible. Rhizophora accounts for more than 70% while *Sonneratia, Avicennia* and *Acrostichum* occur throughout the profile. Pollen types from other ecological sources are present in very low frequencies : *Pinus, Quercus*, Arecaceae, *Pandanus, Compnosperma, Macaranga, Solanum*, Cyperaceae and Graminaeae. *Stenochlaena palustris is* well represented in the section.

Silty clay characterizes the horizon and in the lower part shell fragments and clay concretions are found.

Zone IX, spectra 17-19

In this interval Rhizophoraceae undifferentiated and *Oncosperma filamentosa* form the dominant pollen types, the former probably being a back mangrove constituent. The rest of the pollen and spore types are present only in very low frequencies. The unknown, pollen type 1 shows a relatively high value.

A slight amount of coarse-grained sand is found in this silty clay horizon.

DISCUSSION AND INTERPRETATION

The pollen assemblages characteristic of each zone serve as criteria in interpreting the vegetation with regards to the environments of sediment deposition. The freedom of interpretation is limited by the lithologic properties of the sediment from which the pollen is extracted. An attempt is made to correlate the zones in the three pollen diagrams.

Zone O is correlated with zone VII, as evidenced from their lithological characteristics and the absence of pollen and spore in the intervals. The mottled horizons may be interpreted to have been deposited under a regime of fluctuating water levels. Sedimentation took place below the water surface, in a basically calm environment and thereafter the sediment was exposed to the air.

Another possible explanation is that it had formed below the water level, but later it became oxidised as a result of exposure to the air for a certain period. This is probably due to the fall in sea level or vertical upward movement at the site. Since Sunda Land has been stable during the last 6000 years (Tjia *et al.* 1984) the latter seems unlikely. In E15 the mottled sequence may be found at a greater depth than the section sampled.

The abundance of *Rhizophora* and the presence of *Avicennia*, *Sonneratia* and *Acrostichum* in zone I demonstrate mangrove vegetation in the vicinity. The presence of *Quercus* could be due to transportation by river from the highlands, although some *Quercus* spp. do occur in the lowland forests. The small amount of Dipterocarpaceae could be explained by the fact that this family is dominant in lowland forests of West Malaysia (Morley 1976). Similarly, the occurrence of *Stenochlaena palustris* is due to its commoness, thriving everywhere in the lowlands and open places (Holtum 1968). In a study on the relation between pollen deposition and vegetation in a mangrove environment, Chow (1977) recorded *Stenochlaena palustris* in all the samples constituting 1% to 7% of the total pollen.

The mangrove environment is interpreted to be developed along the coast in moderately sheltered location, probably at some distance from a river system which constantly feeds an influx of pollen from the lowland and mountain areas. The situation possibly resembles the condition which is presently existing, in the southern part of the area near Kuala Kurau.

Mangrove vegetation also prevails in zone IV and VIII. The pollen assemblages show trends similar to that in zone I, where mangrove taxa are typically dominant whereas pollen from other ecological background is of little importance. However, in the middle-upper level of zone IV the composite diagram shows quite a reduction in the mangrove taxa value. This could be due to local fluctuations in the pollen rain proportion from the mangrove community, or to the perpetual influx of pollen from the inland vegetation carried in by rivers, as is suggested by the slight rise in *Quercus* etc.

Zone II is interpreted to represent a back mangrove environment with strong mangrove and fluviatile influence. The sequence is represented by lower values of mangrove taxa and higher percentages of non-mangrove pollen types. *Phoenix* and *Pandanus* show their peaks in the interval. *Phoenix* is mentioned by Backer (1968) to occur along the coast and inland of West Java. It is in the saline condition of the mangrove environment, but it can also occur in the back mangrove or along rivers. *Pandanus* occurs in variety of habitats in lowland areas but it is also commonly found behind the mangrove proper and in peat swamp forests.

Subzone IIa represent an open swamp forest developed in a back mangrove environment. The maxima shown by *Macaranga* and Gramineae point to open condition. *Eugenia* which is common in secondary forest shows a peak value. The increase in *Castanopsis/Lithocarpus*, Dillenia, *Garcinia* and Rubiaceae indicate that these taxa are within close proximity. *Melastoma*, Meliaceae and *Solanum* are present. A rather high value of identified and the unidentified exemplified the diverseness of taxa occurring in swamp forest.

A decrease particularly in *Rhizophora* and the abundance of Rhizophoraceae undifferentiated suggest less saline conditions in subzone IIb. The latter pollen type could have been derived from the genera *Carallia* and *Gynotroches* which grow inland, in damp places and by the river (Corner 1951). The peak in *Pometia* supports the presence of river nearby. The interval probably has accumulated as a flood-bank deposit in the back mangrove.

Zone VI is ecologically correlated with subzone IIa, here the open swamp vegetation is within close proximity to the mangrove area and not far away from strand forest. *Macaranga,* Moraceae/Urticaceae and a high value in *Stenochlaena palustris* indicate open conditions. Pollen of arboreal taxa, such as *Quercus*, *Podocarpus* and Dipterocarpaceae, show their maxima suggesting an occurrence in the immediate vicinity. *Podocarpus* is common in montane vegetation but here *Podocarpus polystachyus* is envisaged, a conifer which is common on rocky and sandy coasts and in landward mangrove fringes (Corner 1951; Haseldonckx 1977b). *Pandanus, Campnosperma* and Sapotaceae are among the constituents in the area and the latter two are common on swamp forest. *Casuarina*, which in the three cores studied is found only in this interval strengthens the evidence of a location near the sea. The presence of *Altingia excelsa* is rather intriguing as it has not been reported for West Malaysia, but it is common in submontane forest in West Java (Backer 1968). The *Sagina* comp. referred to by Morley (1976) is probably *Altingia excelsa.*

Correlation of zone IX with subzone IIb is implied by the abundance in Rhizophoraceae. An increase in *Oncosperma filamentosa* values and the disappearance of typical mangrove constituents, such as *Rhizophora, Sonneratia* and *Avicennia,* support the evidence of less saline back mangrove conditions. A minor influence by the river is deduced from the slight amount of coarse-grained sand in the sediment.

Zone V is interpretated to be formed in a back mangrove environment comparable to that of zones IIb and IX. However, in this interval *Rhizophora* persists its dominance and Rhizophoraceae undiff. increase only slightly even though *Sonneratia* and *Avicennia* are absent and *Acrostichum* decreases. Local over-representation of *Rhizophora* is postulated as it is known to be a prolific pollen producer. The abundance of *Oncosperma filamentosa* in this horizon is in agreement with the similarity to zone IX. Maybe it is wise to say that

Oncosperma filamentosa is over-represented. But in the overall profile and in the other cores too, over-representation by *Oncosperma filamentosa* is not detected. Also it is commonly found in the landward side of mangrove swamps and in the riparian fringe. It is concluded that the horizon had accumulated in a back mangrove environment.

Zone III is distinct from the rest discussed. It shows a predominance of spores, particularly *Lycopodium, Stenochlaena palustris* and the unidentifieds, whereas mangrove taxa are almost absent. The former two are very common in open areas in secondary vegetation and in swamp forest. *Ilex*, Sapotaceae, Rubiaceae, Moraceae/Urticaceae and Cyperaceae stress the openness of the vegetation and swampy conditions. Accordingly, the vegetation in this interval is interpreted as a disturbed open swamp environment. It could mark the starting point of the disturbance by mankind on his surrounding. Correspondingly, the sediment is moderately sandy clayey silt, and the presence of yellow-orange mottling probably indicates the utilisation of the sediment. Today, the site studied, is mainly cultivated with rice.

As for the environment of deposition with respect to the prevailing surrounding vegetation the following can be remarked. In profile A13, mangrove sediment overlain the mottled clayey silt horizon. Open swamp forest and flood bank deposit respectively ensued in a back mangrove situation. A disturbed open swamp condition prevail until the present day.

Profile E15 had developed on a mangrove environment, succeeded by a back mangrove situation.

Profile L7 commenced in an open swamp vegetation close to mangrove area, not far away from strand forest. A hiatus in pollen deposition and/or preservation followed, the mode of sediment (mottled clay) deposition is as discussed. Subsequently, mangrove environment persisted until a later phase of back mangrove accumulation.

STRATIGRAPHY

With reference to the nomenclature of Quaternary stratigraphy in Peninsular Malaysia by Suntharalingam (1983), the stratigraphic position of the sediment visualised here from the pollen and spore content is introduced. The Pleistocene sediments are subdivided into Simpang Formation (mainly fluviatile deposit) and Kempadang Formation (salt and brackish water deposits). The Holocene sediments are the Beruas Formation (fluviatile and lacustrine deposits) and Gula Formation (salt and brackish water deposits).

The mottling horizons found in cores A13 and L7 represented by the pollen assemblages zones 0 and VII is interpreted to be an important stratigraphic marker. Although no dating has been done on any of the profiles studied, considering the accumulated sediment overlying the no pollen zones, it is inferred that this particular stratigraphic layer marked the Pleistocene boundary.

Correlation of pollen assemblage zones in the stratigraphical sequences for the three profiles studied is outlined in Table 1.

Table 1: Pollen assemblage zones with reference to the Quaternary stratigraphy in cores A13, E15 and L7

Core	Depth below the surface (in metres)	Pollen Assemblage Zone	Stratigraphy	
A13	0 – 1.60	II	Beruas Formation	
	1.60 – 3.35	II	Gula	(brackish water deposit)
	3.35 – 7.10	I	Formation	(salt water deposit)
	7.10 – 8.10	0	Simpang Formation	
E15	0 – 0.90	V	Gula	(brackish water deposit)
	0.90 – 8.50	IV	Formation	(salt water deposit)
L7	0 – 1.40	IX	Gula	(brackish water deposit)
	1.40 – 9.30	VIII	Formation	(salt water deposit)
	9.30 – 11.50	VII	Simpang Formation	
	11.50 – 13.00	VI	Kempadang Formation?	

COMPARISON WITH A SIMILAR STUDY

In comparing the results obtained by Hillen (1984) with that of the Seberang Prai and Kuala Kurau Area, the similarity in the pollen diagrams from the mangrove environments is noted. Characteristic is the predominance of Rhizophoraceae, whereas pollen of taxa from other ecological zones is of little importance. The transitional environment mentioned in Hillen's B10 area corresponds particularly to our zone IX, the back mangrove environment, in which *Oncosperma filamentosa* exhibits abundance. A diversity of pollen types is mentioned for the fresh/brackish water swamp sequences, which is similarly found in our zones II and VI, but in the area studied the disappearance of Rhizophoraceae is not dramatic indicating development within mangrove vicinity.

CONCLUSIONS

It is concluded that in a mangrove environment pollen and spore types of mangrove taxa usually constitute more than half of the species present. The three profiles A13, E15, L7 investigated show that mangrove environment was prevalent in all the sites, although the thickness of mangrove sediment varies in each core. Since mangrove vegetation is commonly found along the coasts, it implies that shorelines were formerly situated near these localities.

Mottling horizon below the mangrove sediment in A13 and L7 provide an important stratigraphic marker, delineating the Pleistocene from the Holocene units. Their presence probably indicate the last major low in sea level before subsequent rise as suggested by development of the mangrove communities.

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Manuscript received 12th January 1988

Appendix I

The percentages of pollen grains and fern spores not included in the pollen diagrams are listed below:

Cores A13:

spectrum 2: *Caesalpinia nuga* 0.3, *Mallotus* 1.4, *Pentace* 0.3, *Schuurmansia* 0.6, *Trewia* 0.8, Euphorbiaceae 0.6, *Cyathea* 0.8, *Lygodium microphyllum-type* 0.6;

spectrum 3: *Elaeocarpus* 0.3, *Pentace* 0.6, *Reevesia*-type 0.3, Malvaceae 0.3, *Blechnum* 1.0, *Cyathea* 1.0, *Gleichenia* 0.6, *Lomariopsis spectabilis* 0.3;

spectrum 4: *Eleagnus* 0.3, *Ficus* 0.3, *Pentace* 0.7, *Sterculia* 0.3; spectrum 5: *Caesaria* 0.5, *Ficus* 0.3, *Helicia* 0.3, *Mallotus* 0.3, *Schefflera* 2.1, *Sterculia* 2.6, *Tetracera* 0.8, *Dilleniaceae* 1.0, Euphorbiaceae 0.5;

spectrum 6: *Buchanania* 0.5, *Caesaria* 3.6, *Circaea* 1.9, *Erioglossum* 0.5, *Ficus* 0.7, *Helicia* 1.0, *Tetracera* 0.5, Dilleniaceae 0.2, Euphorbiaceae 1.0, Sapindaceae 1.0, *Lindsaea* 1.0;

spectrum 7: *Eleagnus* 0.6, *Pentace* 0.3, Compositae 0.2, Flacourtiaceae 0.2, Menispermaceae 1.5, Rhamnaceae 0.2, *Lygodium microphyllum* 0.5; spectrum 8: *Matricaria* 1.0, *Matthiola* 0.5, *Pentace* 2.9, *Blechnum* 0.5, *Lindsaea* 3.9, *Lomariopsis spectabilis* 1.5, *Lygodium microphyllum* 39.2, *Lygodium* 1.0.

Core E15:

spectrum 1: Rosaceae 0.4;

spectrum 2: Sterculiaceae 0.3, *Blechnum* 0.3, *Lygodium* 0.3, *Onychium* 0.3;

spectrum 3: *Elaeocarpus* 0.3;

spectrum 4: *Antidesma* 0.5, *Maesa* 0.9;

spectrum 5: *Antidesma* 0.5, *Mallotus* l15, Liliaceae 0.3,

Sapindaceae 0.5, Symplocaceae 0.3, *Lindsaea* 0.5, *Ophioglossum* 0.3;

spectrum 6: *Pentace* 1,0, Oleaceae 1.4, Polygonaceae 0.3, *Nephrolepis* l.0;

spectrum 7: *Phanera* 0.3, *Schuurmansia* 0.9, Araliaceae 0.9, Caprifoliaceae 0.3, Dilleniaceae 0.3, Euphorbiaceae 0.3,

Liliaceae 0.6, *Ophioglossum* 0.3, *Taenitis* 0.3;

spectrum 8: *Begonia* 0.2, *Clerodendron* 0.2, *Myrica* 0.2, *Tetrameles* 1.0, *Trema* 0.2, Euphorbiaceae 0.3, Polygonaceae 0.2, Sterculiaceae 0.3, Symplocaceae 0.2, *Ctenopteris* 0.2, *Dryopteris* 0.2;

spectrum 9: *Acanthus* 0.2, *Decaspermum* 0.2, *Salix*-type 0.3, *Tetrameles* 1.2, *Vitis*-type 0.2, Leguminosae 0.2.

Core L7:

spectrum l: *Nepenthes* 0.6, Amaranthaceae/Chenopodiaceae 1.2, Caryophyllaceae 1.8, Euphorbiaceae 2.4, Leguminosae 0.6, *Diplazium* 0.6, *Lygodium* 0.6, *Polypodium* 1.2;

spectrum 2: *Alstonia spatula* 0.3, *Altingia excelsa* 3.2, *Nepenthes* 0.6, *Pentace* 0.6, *Reevesia* 0.6, *Viburnum* 1.0, Dilleniaceae 1.0, Euphorbiaceae 0.6, *Ceratopteris* 1.3, Dryopteris *0.6*;

spectrum 3: *Alstonia spatula* 0.2, *Blechnum* 0.2, *Casuarina* 1.6, *Linociera* 0.7, *Mallotus* 2.5, *Olea* 0.5, *Pentace* 0.5, *Pterospermum javanicum* 0.2, *Salix*-type 0.2, *Sterculia* 0.2, *Tinomiscium* 2.2, *Trema* 0.20, Flacourtiaceae 0.2, Polygonaceae 0.2, *Anogramma leptophylla* 0.2, *Cyathea* 0.5, *Cyclosorus* 0.2, *Gleichenia* 1.6, *Lygodium microphyllum* 0.5;

spectrum 7: *Altingia excelsa* 1.3, *Myrica javanica* 0.5, *Ochna* 0.8, *Sterculia* 0.3, *Tinomiscium* 1.1, Compositae 0.3, Euphorbiaceae 0.3, *Anogramma* leptophylla 0.3, *Blechnum* 1.1, *Cyathea* 0.3, *Gleichenia* 0.8, *Lygodium microphyllum* 0.3;

spectrum 8: *Clerodendran* 0.9, *Duabanga* 0.2, *Ficus* 0.2, *Mallotus* 0.2, *Phyllanthus* 0.5, Amaranthaceae/Chenopodiaceae 0.2, Meliaceae/Sapotaceae 0.5, *Blechnum* 0.2, *Cyclosorus* 0.2, *Pteris* 0.2, *Vittaria* 1.3;

spectrum 9: *Clerodendron* 0.9, *Duabanga* 0.3, *Ficus* 0.3, *Schefflera*-type 0.7, Liliaceae 0.3, *Cyathea* 1.3, *Dryopteris* 0.7;

spectrum 10: *Callicarpa* 0.6, *Cleidion* 1.2, *Omalanthus* 0.3, *Pentace* 0.6, Euphorbiaceae 0.3, *Asplenium* 0.3, *Lindsaea* 0.9;

spectrum 11: *Clerodendron* 0.2, *Elaeocarpus* 0.2, *Mallotus* 0.9, *Pentace* 0.2, Liliaceae 0.2, *Cyathea* 0.7, *Gleichenia* 0.5, *Lygodium* 0.2, *Vittaria* 0.5;

spectrum 12: *Altingia excelsa* 0.2, *Linociera* 1.0, Leguminosae 2.1, *Cyathea* 0.8, *Coniogramma* 0.4, *Gleichenia* 1.0;

spectrum 13: *Benettiodendron* 0.6, *Elaeocarpus* 0.9, *Mallotus* 0.3, *Pentace* 0.3, *Reevesia* 0.3, Compositae 0.3, *Lindsaea* 0.3;

spectrum 14: *Mallotus* 0.3, Euphorbiaceae 0.3, *Cyclosorus* 0.3, *Polypodium* 0.3;

spectrum 15: *Lygodium* 0.4;

spectrum 16: *Alstonia spatula* 0.3, *Ficus* 0.8, *Salix*-type 0.3, *Viburnum* 2.0, Compositae 0.3, Flacourtiaceae 0.3, Malvaceae 0.3;

spectrum 17: *Alstonia spatula* 0.03, *Myrica* 0.02, *Pentace* 0.1, *Salix*-type 0.02, Menispermaceae 0.1;

spectrum 18: Cruciferae/Icacinaceae 0.4, Dilleniaceae 0.1, Verbenaceae 0.4, *Lygodium* 0.2, *Taenitis* 0.1;

spectrum 19: *Alstonia spatula* 0.1, *Ranunculus* 0.2, *Salix*-type 0.6, Euphorbiaceae 3.1.

Appendix 2

This is a list to present the various pollen types that occur sporadically but occasionally quite common which are grouped into families in the pollen diagrams.

Terms used in the pollen diagrams	Types identified
Arecaceae (others)	*Chamaerops,Deamonorops melanochaetes, Daemonorops sparsiflorus, Daemonorops, Metroxylon, Nypa fruticans*
Dipterocarpaceae	*Hopea, Shorea hypochra, Shorea, Vatica--type*

Meliaceae	*Aglaia, Dysoxylum, Lansium, Melia, Sandoricum, Xylocarpus*
Rhizophoraceae	*Bruguiera, Carallia, Gynotroches, Kandelia*
Rubiaceae	*Antocephalus, Coptosapelta, Diplospora, Galium, Hedyotis, Hymenodiction, Ixora salicifolia, Ixora, Knoxia, Nauclea, Randia, Tarenna, Tysanospermum, Timonius celebium, Uncaria*
Sapotaceae	*Madhuca, Palaquinum, Payena.*

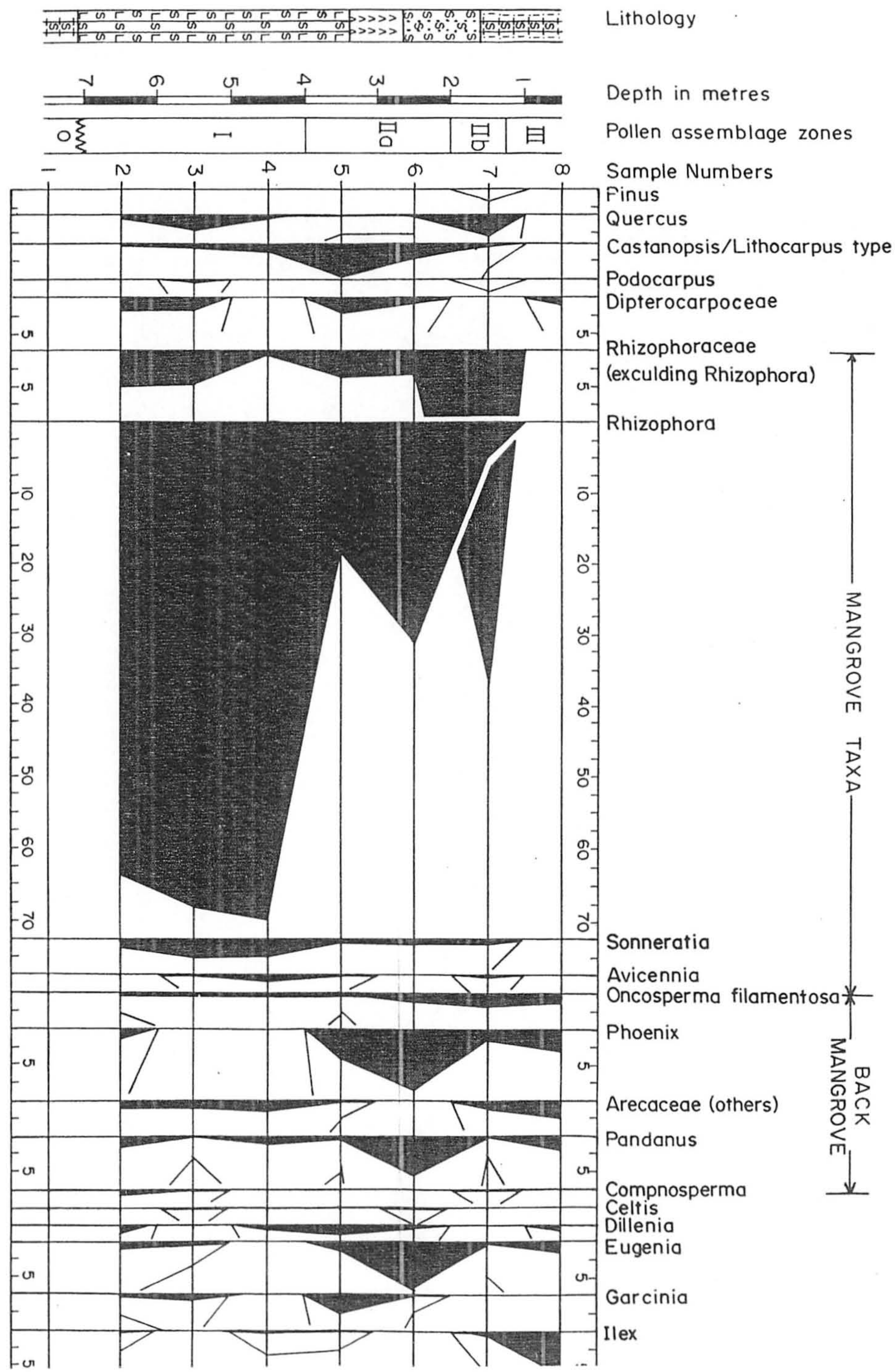

Lithology
Depth in metres
Pollen assemblage zones
Sample Numbers
Pinus
Quercus
Castanopsis/Lithocarpus type
Podocarpus
Dipterocarpoceae
Rhizophoraceae
(exculding Rhizophora)
Rhizophora
Sonneratia
Avicennia
Oncosperma filamentosa
Phoenix
Arecaceae (others)
Pandanus
Compnosperma
Celtis
Dillenia
Eugenia
Garcinia
Ilex
MANGROVE TAXA
BACK MANGROVE

Figure 2: 1/3

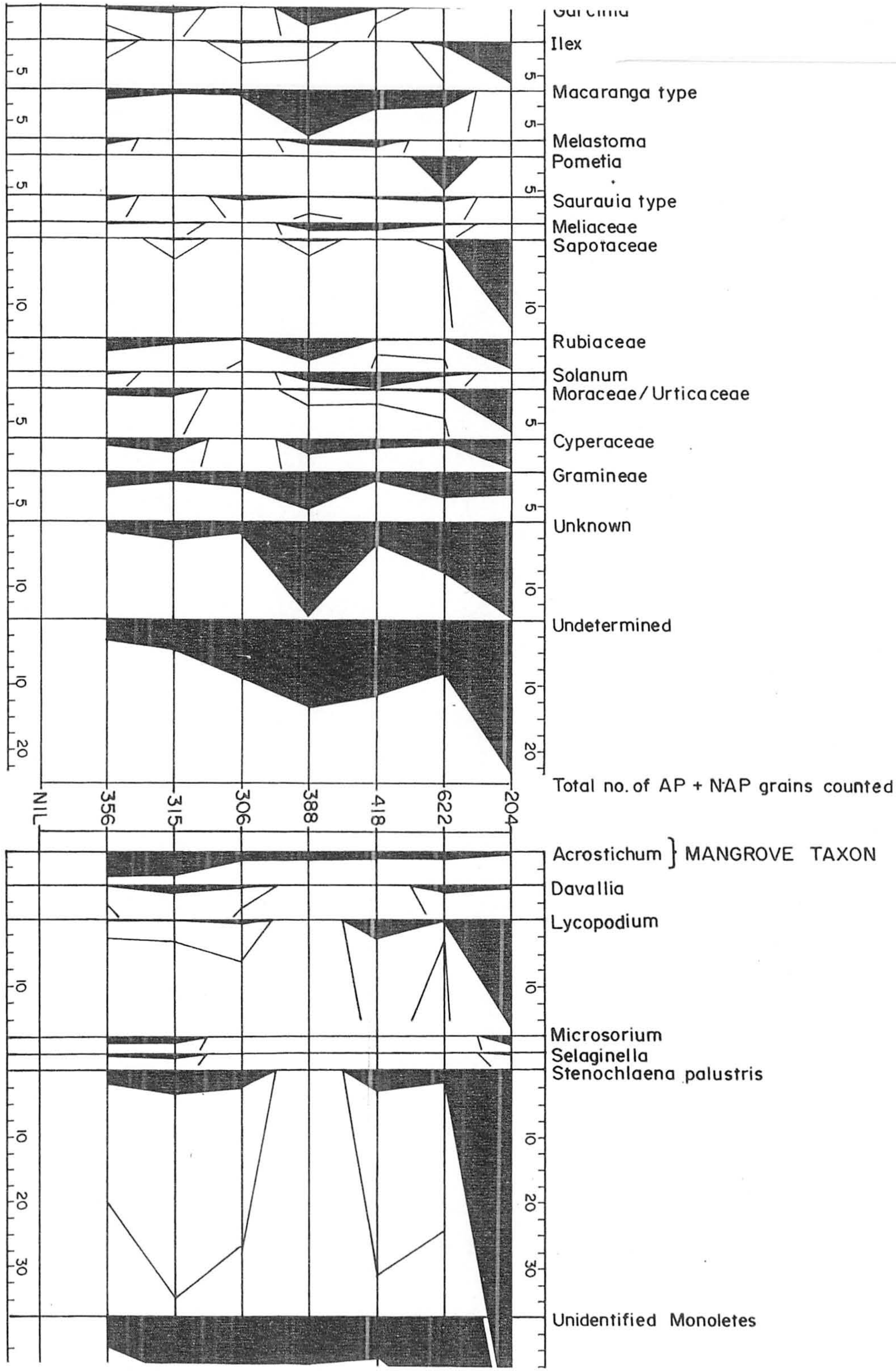
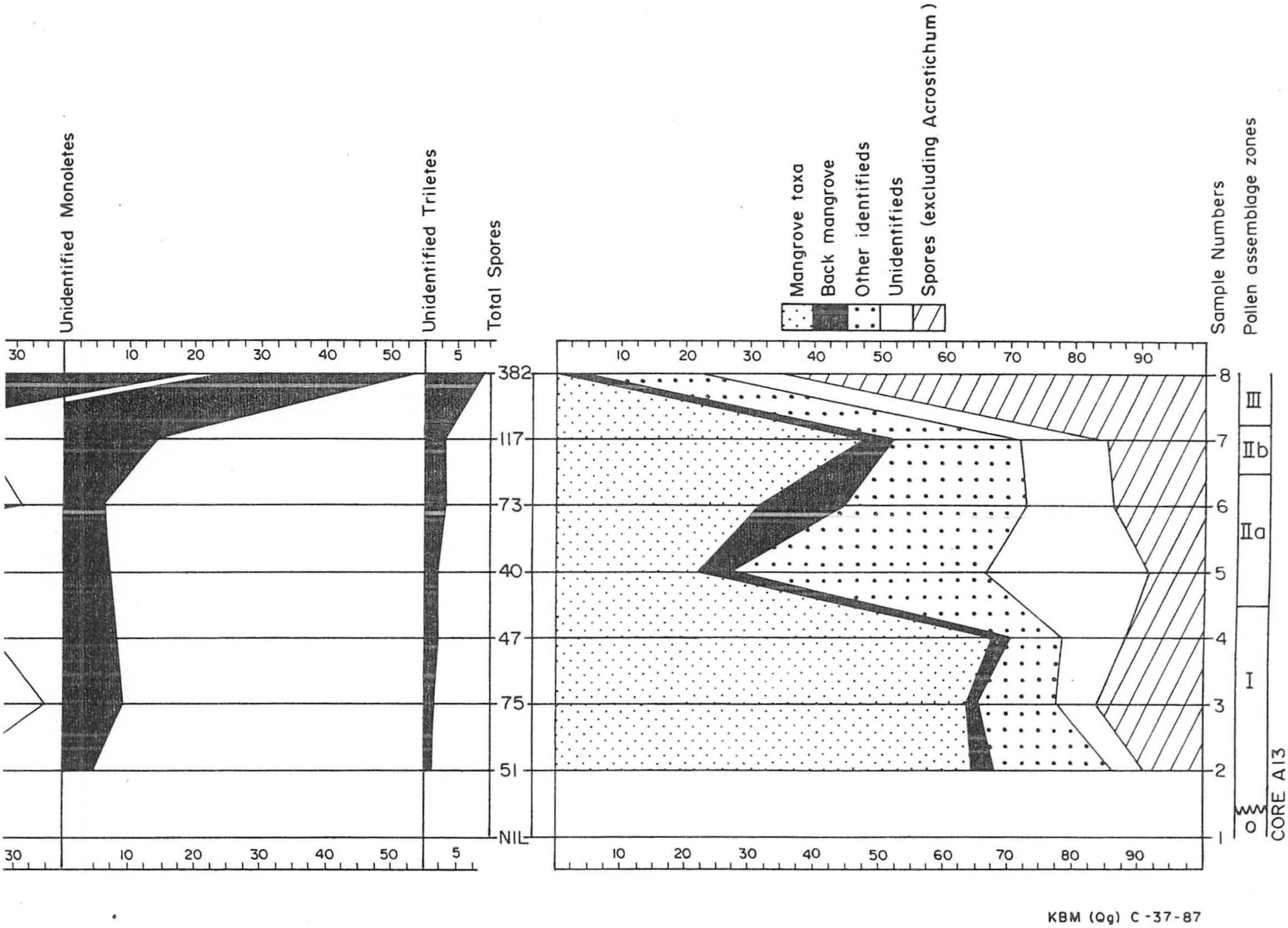


Figure 2: Pollen Diagram of core A13

Figure 2: 2/3



Unidentified Monoletes
Unidentified Triletes
Total Spores
Mangrove taxa
Back mangrove
Other identifieds
Unidentifieds
Spores (excluding Acrostichum)
Sample Numbers
Pollen assemblage zones
382
117
73
40
47
75
51
NIL
III
IIb
IIa
I
0
CORE A13
KBM (Qg) C-37-87

Figure 2:3/3

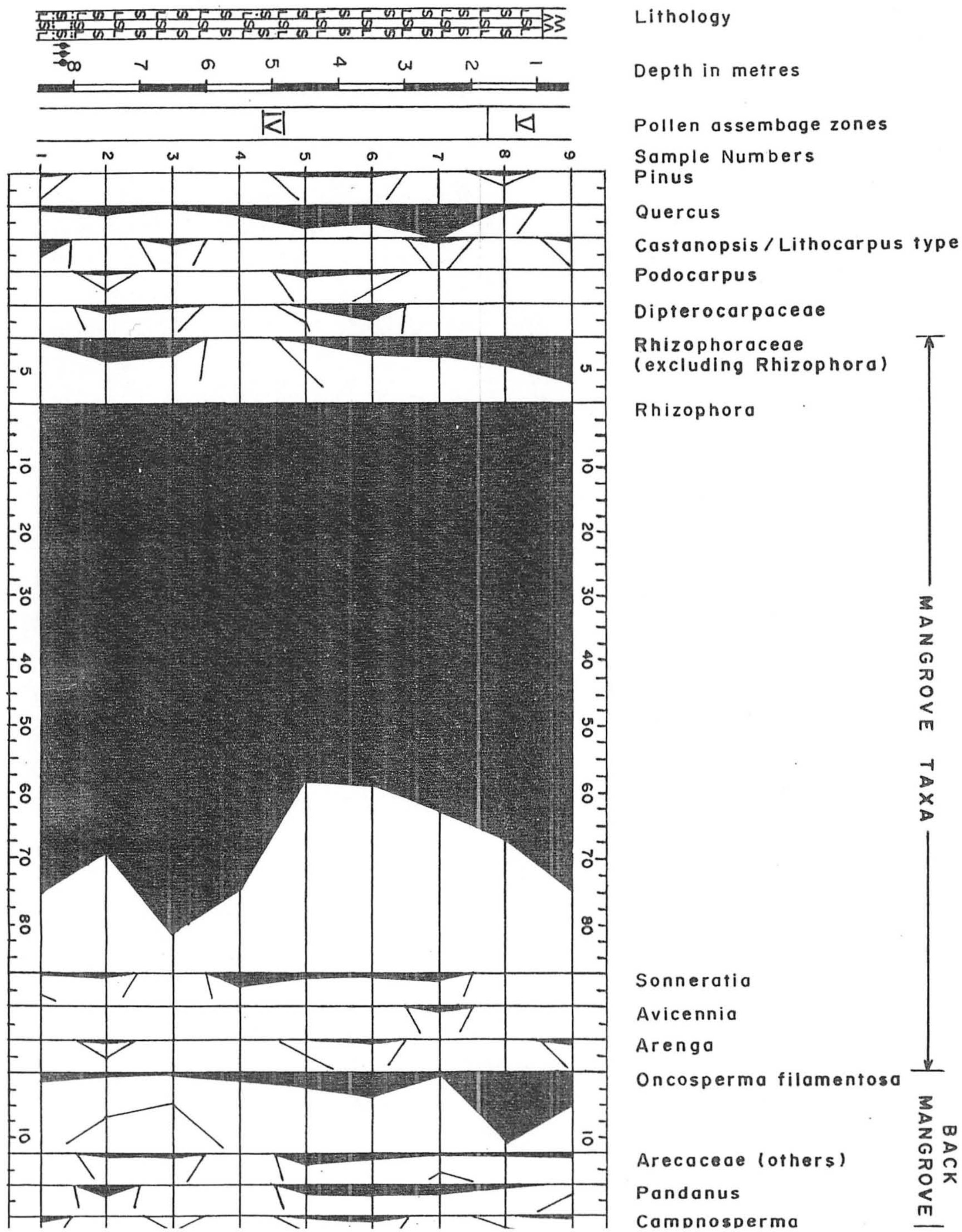


Figure 3: core E15 : 1/3

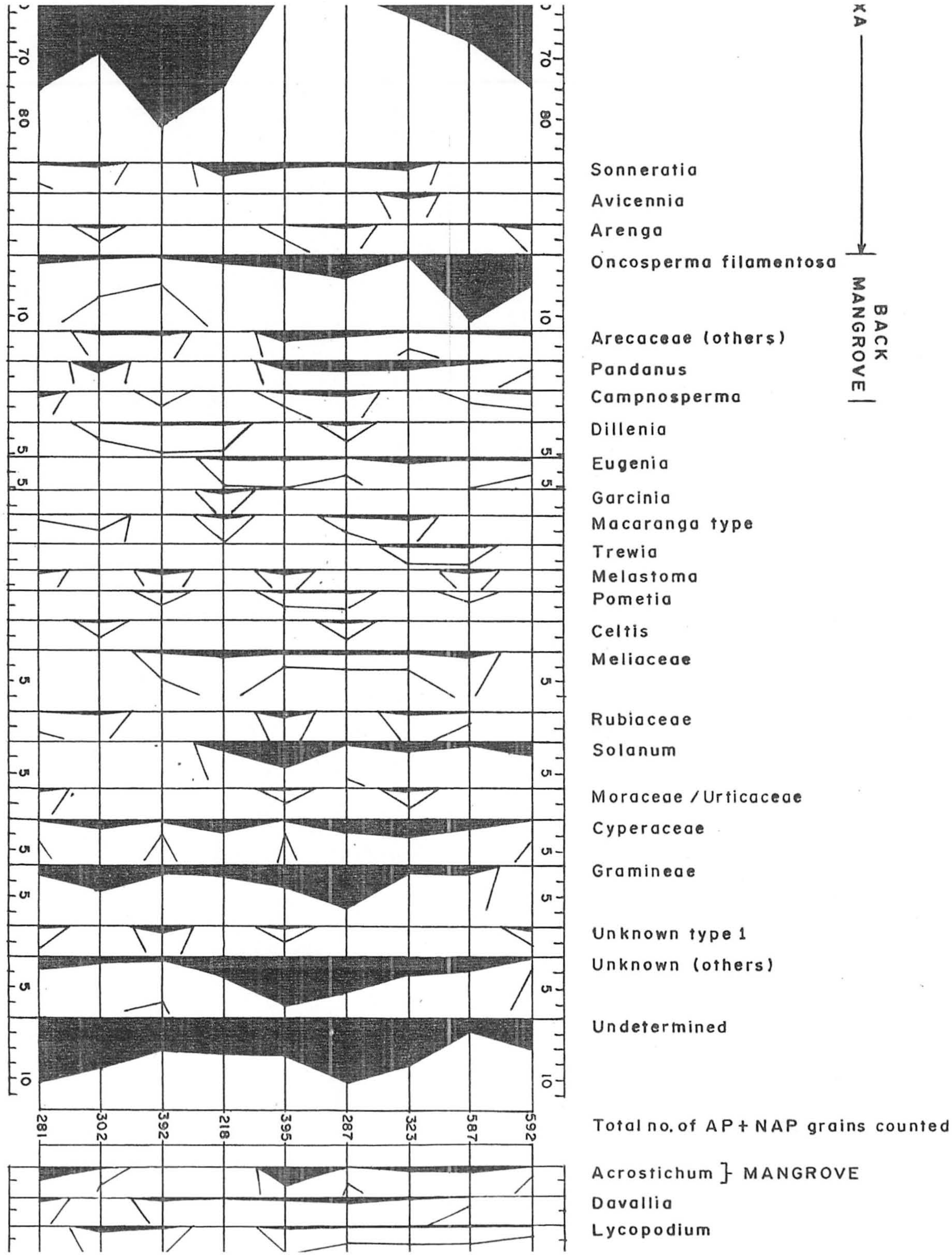


Figure 3: Pollen diagram of core E 15

Figure 3: core E15: 2/3

core E 15

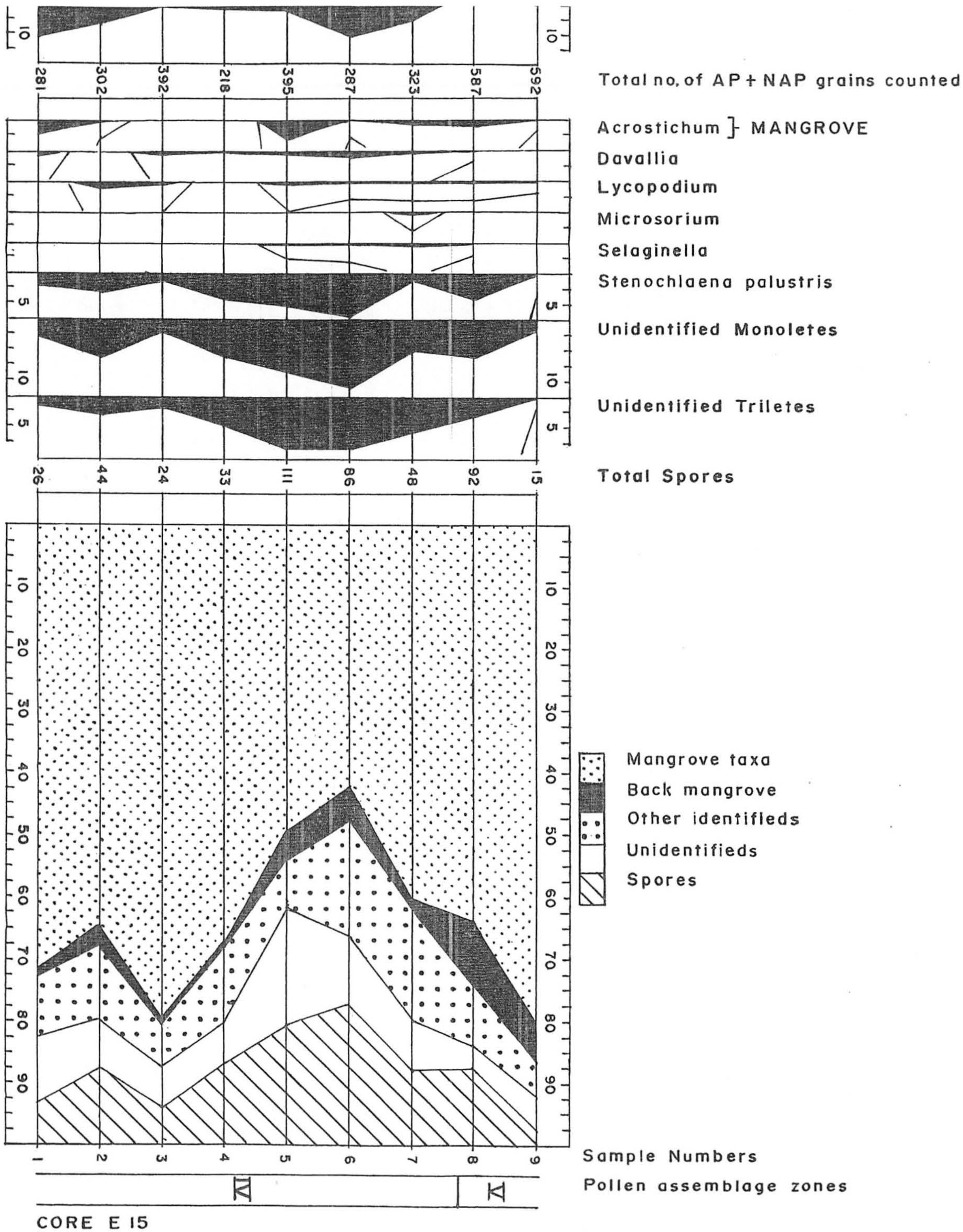
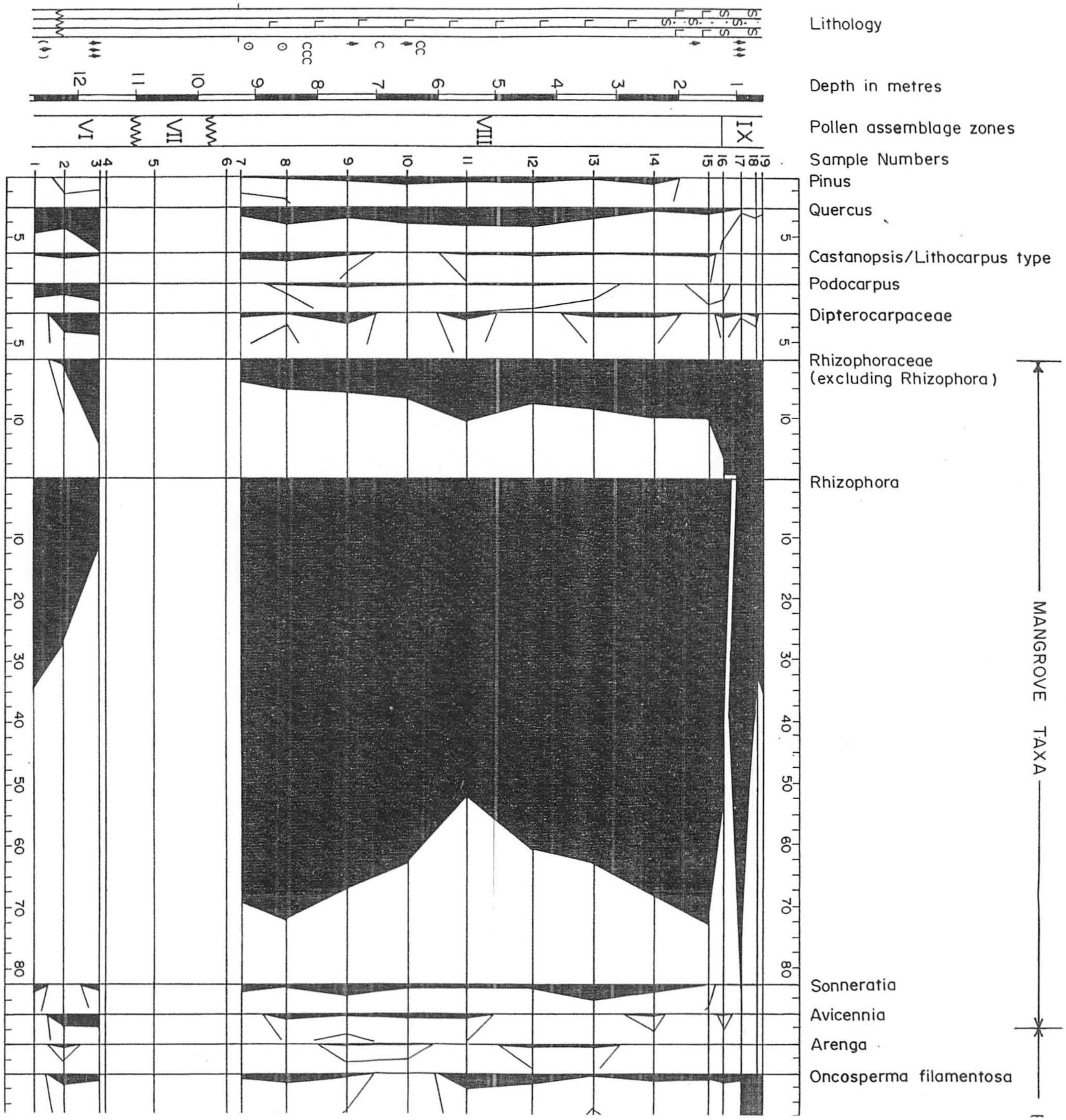


Figure 3: core E15: 3/3

KBM.(Qg) C-38-87.

Figure 4 : 1/4


Lithology
Depth in metres
Pollen assemblage zones
VI
VII
VIII
IX
Sample Numbers
Pinus
Quercus
Castanopsis/Lithocarpus type
Podocarpus
Dipterocarpaceae
Rhizophoraceae
(excluding Rhizophora)
Rhizophora
Sonneratia
Avicennia
Arenga
Oncosperma filamentosa
MANGROVE TAXA

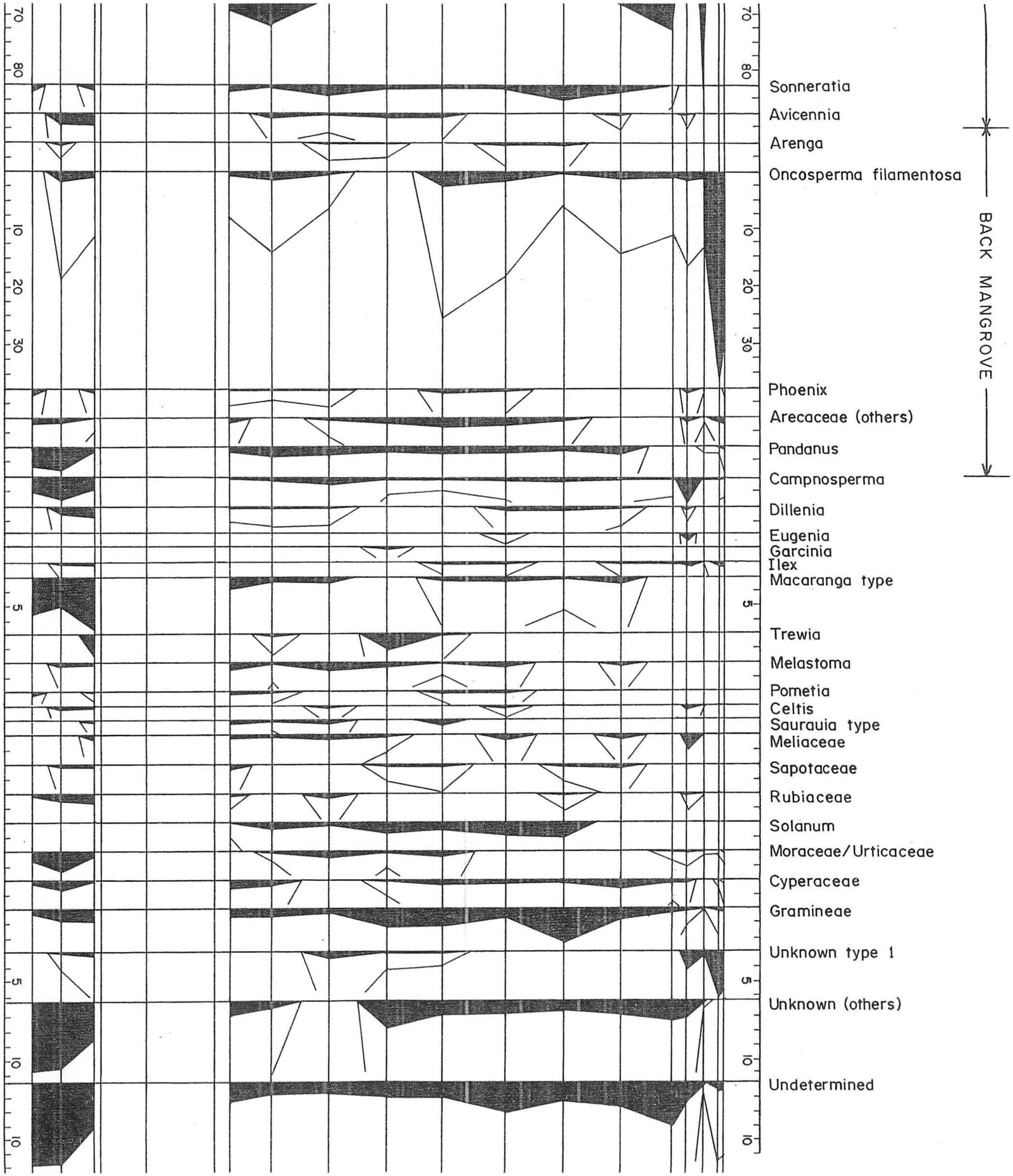
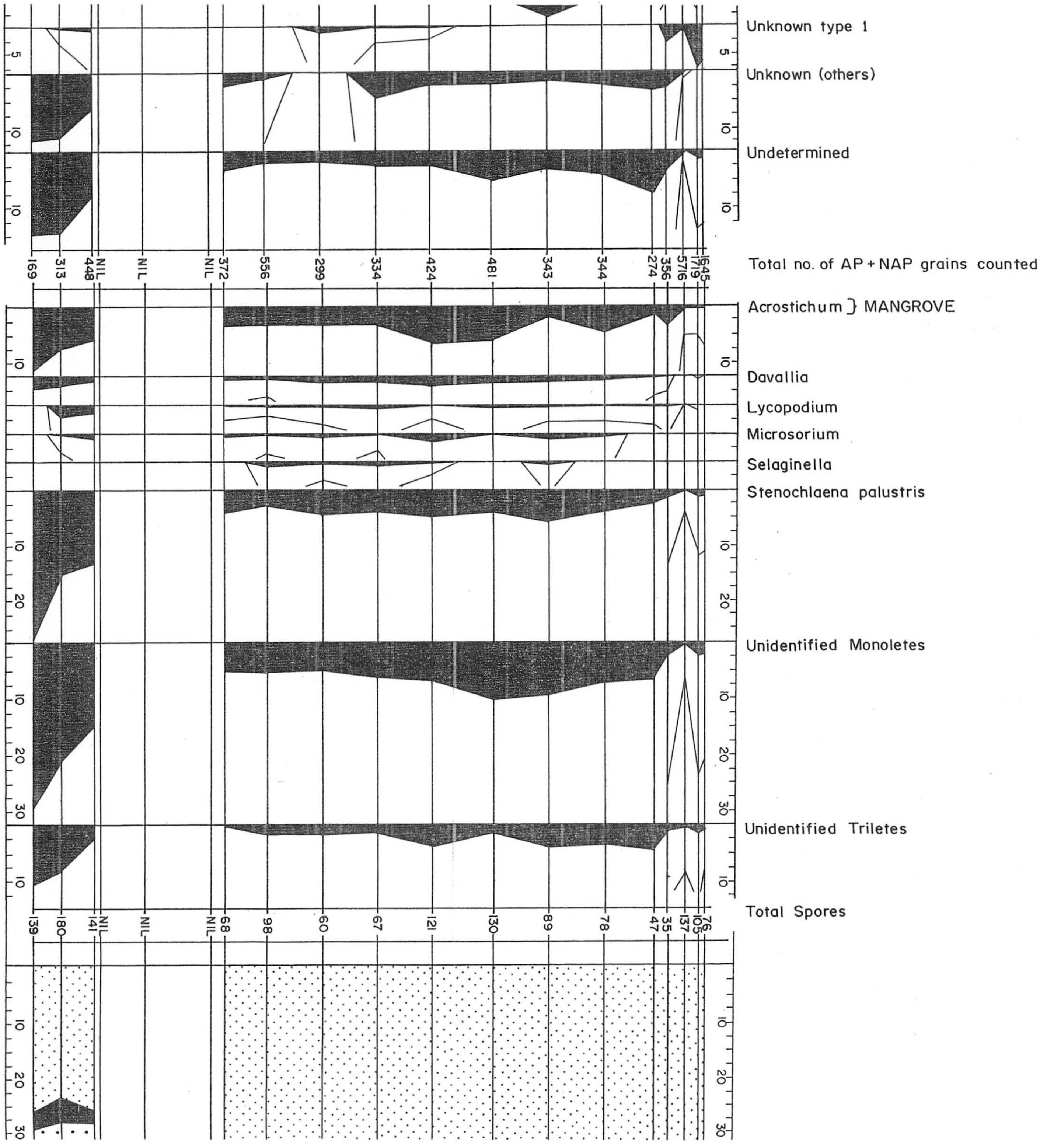


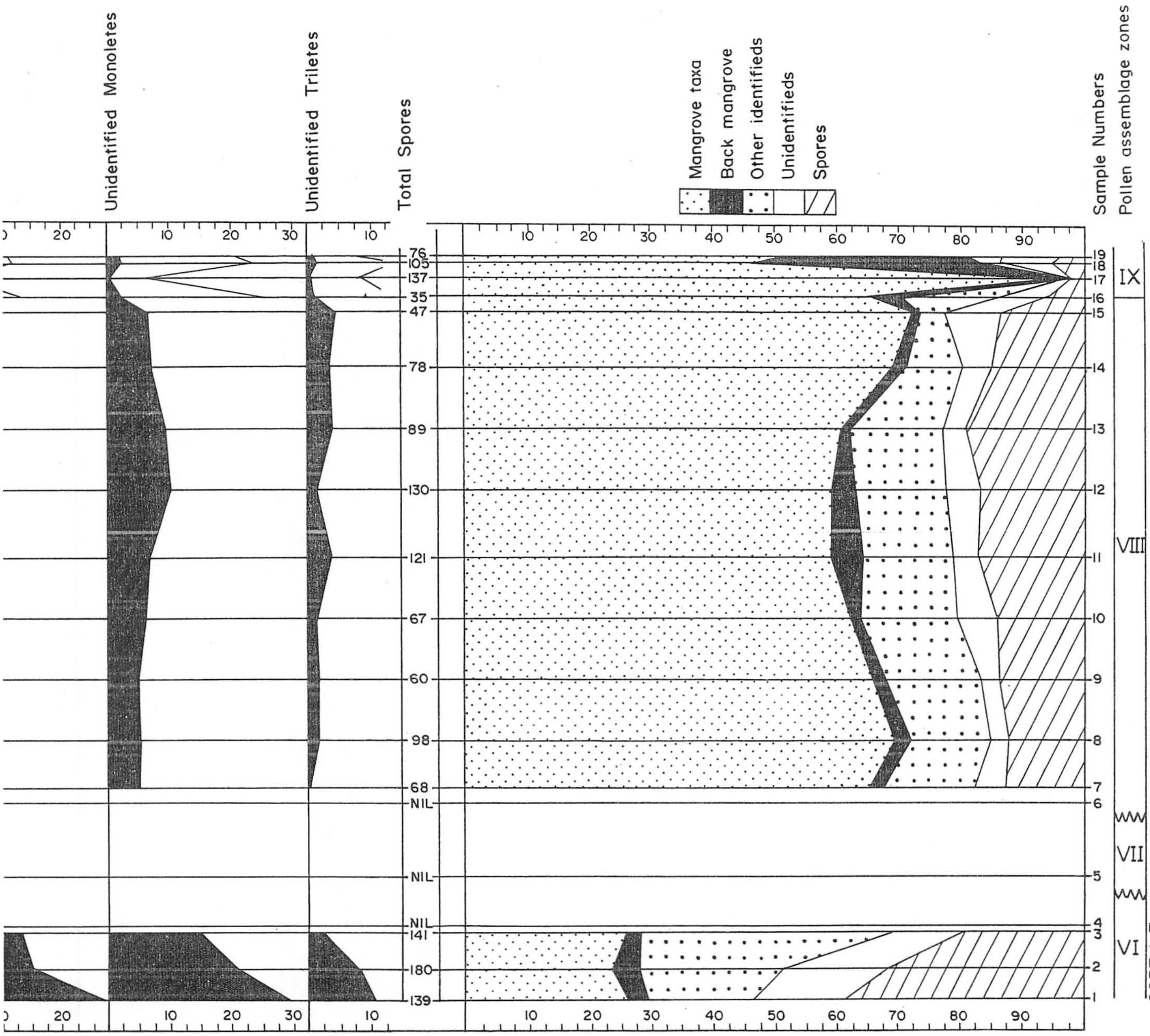
Figure 4 : 2/4

Figure 4 : Pollen diagram of core L7

ram of core L7

Figure 4: 3/4





KBM (Qg) C-39-87

Figure 4: 4/4