A PALYNOLOGICAL STUDY ON THE QUATERNARY OF BRITISH GUIANA

by

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SUMMARY

Pollen diagrams have been prepared of eight sections of Quaternary sediments from different localities on the coastal plain of British Guiana, and partly dated with the C 14 method. A Riss-Würm interglacial transgression, a Würm-glacial regression and a Holocene transgression have been established. The Würm-glacial vegetation on the place of the present coastal plain area was a poor grass-savanna type. The Holocene transgression at about 9500 B.P. is represented at 23 m. below present sea level and the maximum attained around 6500 B.P. when the relative sealevel was at least 2½ m. above that at present.

INTRODUCTION

The present study was sponsored by the Geological Survey of British Guiana with financial support by the Government of British Guiana. Further financial and other assistance was accorded by the Demerara Bauxite Co., the Reynolds Metals Co., Billiton Co. and Suralco. The C 14 analyses were paid by the Netherlands Foundation of Pure Scientific Research (Z.W.O.) and carried out by Dr. J. C. Vogel at the C 14 laboratory in Groningen.

The first initiative was taken by Dr. R. B. Mc.Connell, then Director of the Geological Survey, when he invited me to visit British Guiana in November 1958. At that time numerous samples were taken from the bauxite mines, from exposures along rivers and canals, and from stored borehole cores. During this fieldwork I was accompanied by Dr. D. Bleackley and benefitted considerably from his extensive knowledge of the geology of the coastal plain.

Subsequently a deep borehole was sunk by the Pure Water Supply Department in association with the Geological Survey at a site near Georgetown (Shelter Belt), from which undisturbed samples were taken from the surface to the basement and subjected to pollen analysis.

In Februari 1962 a second visit was made to British Guiana and on this occasion observations were extended to Surinam. Additional samples were taken, new data collected, and plans were made for a more intensive study of the whole Guiana basin.

The present paper deals with the results of palynological studies on Quaternary sediments.

A second publication, on the Tertiary and Cretaceous, is in course of preparation. It will be realized that the present study represents only a first attempt to solve the Quaternary problems of Guiana by means of pollen analysis and much more work will have to be done in the future.

I wish to express here my gratitude to the many institutions, companies, friends and collaborators who aided me in many ways, and particularly to Dr. R. B. Mc.-Connell, former director of the Geological Survey of British Guiana, Dr. P. H. A. Martin-Kaye, the present director, and Dr. David Bleackley, former geologist of the same institution, for their help and interest in all respects; to the government of British Guiana, the above mentioned bauxite companies and the Netherlands Foundation of pure Scientific Research Z.W.O., for the financial support; to Mr. P. Snijders, Mr. Baumgardner and Mr. Langenberg, company geologists of Demerara Bauxite Co. and Reynolds Metals Co. respectively, for their very valuable assistance in their particular mining regions.

My gratitude is also due to the Agricultural Department and the Department of Forestry of British Guiana, and the botanist Dr. Harrison for their help with the study of the vegetation and the providing of pollen-material from recent plants; to Prof. Dr. F. P. Jonker, Utrecht, for providing us with another number of pollen-samples from herbarium specimens; and to Dr. D. C. Geijskes and Dr. J. C. Lindeman, for helpful discussions on several problems. Dr. J. C. Vogel of the C 14 laboratory in Groningen carried out the C 14 analysis. The assistance of Mr. Juan Perico and Mrs. Riate van Mullem, who prepared the samples in the laboratory is greatly appreciated, Mrs. van Mullem also undertaking the statistical size-measurements of the *Rhizophora* pollen grains. Mr. T. A. Wymstra, who made some of the analyses (Shelter Belt) is now pursuing follow-up work in the Guianas.

And finally I wish to thank the many others I cannot mention here personally who helped me in one way or another to realize this study of the Quaternary of British Guiana.

THE COASTAL PLAIN

The stratigraphy of the coastal area of the three Guianas (British Guiana, Surinam and French Guiana) presents many problems of dating and correlation, mainly due to the scarcity or absence of good marine fossils. The sediments were laid down in a type of basin, the greatest thickness being found at the coast near the Berbice river. Here the belt of coastal sediments is widest, becoming narrower coastwards and westwards.

The southern limit and the floor of the sedimentary basin is mainly formed by the metamorphic or igneous Precambrian rocks of the Guayana Shield, which reach or come near to the coast in the North West of British Guiana and in French Guiana. The seaward extension of the basin goes probably to the edge of the shelf.

Several publications deal with the stratigraphy of the coastal plain of British Guiana and its problems, the latest being those of Bleackley (1956, 1957, 1962) and Mc.Connell (1957) to which reference should be made. Here it is necessary to mention a few of the more important data, and then give a correlation of the main stratigraphical units on the basis of the results of pollen studies.

Geomorphologically the belt of coastal sediments may be divided into three major units. They are, from South to North (see fig. 1):

1. The white sand depositional plain
2. The old coastal plain
3. The young coastal plain.

The white sand plateau rises from some 35 feet above sea level at its northern edge to about 450 feet at its highest southern limit. There is in general a more or less pronounced erosional scarp at its northern limit with the old coastal plain (fig. 9). Stratigraphically it consists of the White Sand Series: mainly coarse sands, with intercalated, white to cream, sometimes sandy, kaolinitic clays and some grey clays and lignitic beds. The presence of a bauxite horizon (and successive erosional phase) make it possible to distinguish locally two wellmarked sub-divisions of this series.

The old coastal plain has an elevation of 10 to 27 feet above main sea-level, and has been dissected, often markedly, by a younger erosion-phase. Stratigraphically it consists of the Coropina Formation, which is comprised of clays, silty clays and sands. A rather heavy soil-formation is frequently to be found at its surface.

The young coastal plain has an elevation of 0 to 8 feet above sea-level. It consists lithologically of soft, marine to brackish clays, the Demerara clay. Superficial sand-ridges may eventually be incorporated in this formation, and also the flood-plain deposits of the rivers into which it gradually passes, the latter reaching higher elevations southward (15 feet).

In the Mackenzie-area the uppermost part of the White Sand series consists of approximately 60—110 feet of coarse white and sometimes brown sands locally cross bedded and locally containing pebbles. It includes an intercalation of white sandy clays. This unit rests locally directly on the bauxite or, locally, on grey clays with lignitic beds. These grey clays lie on bauxite or occur in gullies between the bauxite bodies. The white sands with white sandy clay intercalations may be recognized in many places on the white-sand plateau. In general they apparently

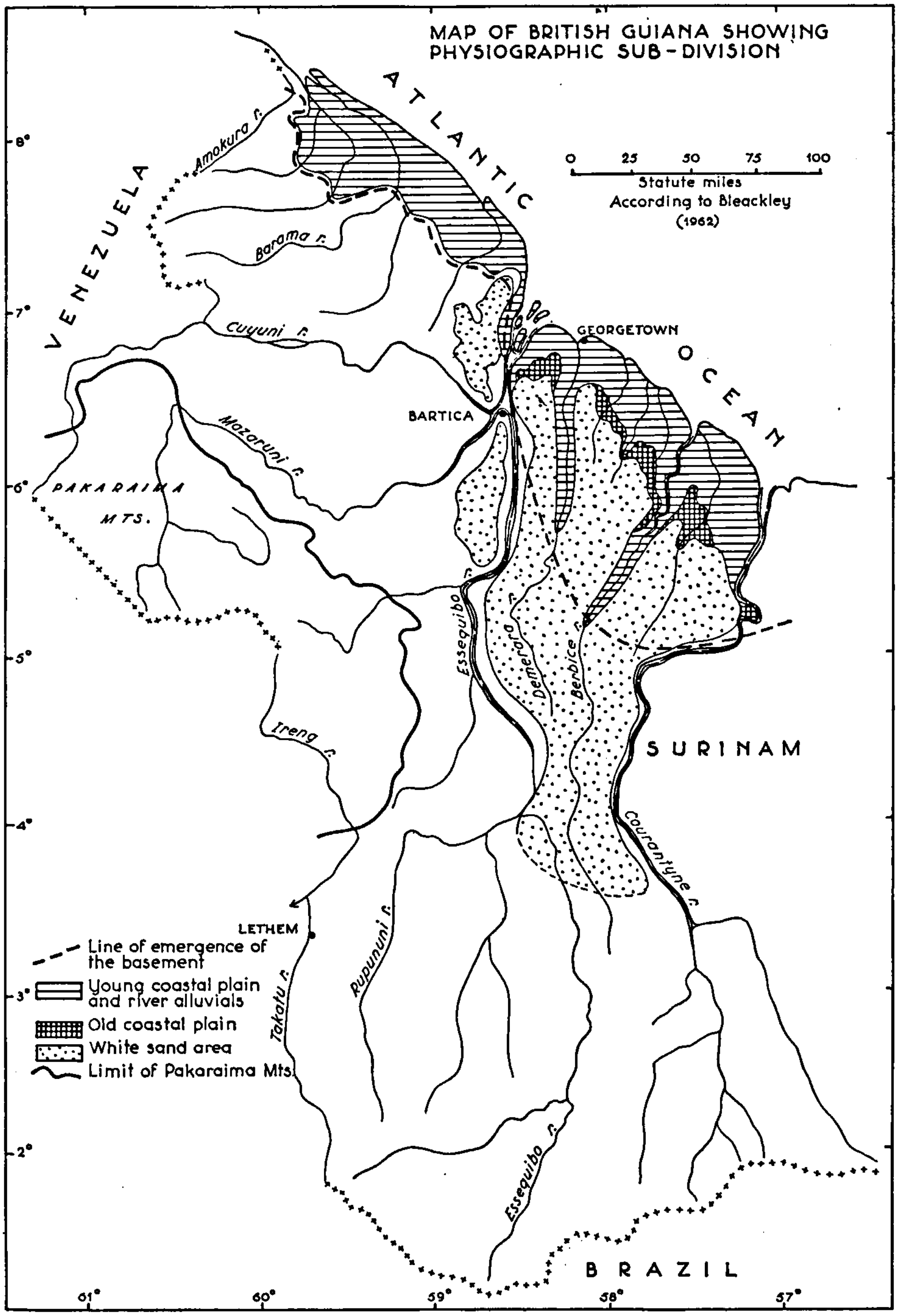


Fig. 1. Map of British Guiana showing physiographic subdivision.

form the upper and youngest portion of the sediments of the white sand depositional plain [1]. It is here designated *Mackenzie Formation*, as it is at Mackenzie where this formation is typically developed and well exposed in the mines of the Demerara Bauxite Company. The underlying grey clays and lignite beds form another unit, excellently exposed in the Montgomery- and Arrow-Cane mines of the Mackenzie area. This latter unit may be provisionally termed the *Montgomery Formation*. The thickness of the two formations together may vary from 100 to 300 feet. Below the bauxite lies another much older formation of the White Sand Series, which will not be discussed here.

Along the coast a great number of water wells have been drilled, and a stratigraphical nomenclature has been introduced to indicate the various more or less continuous lithological units. The Upper Clays extend from the surface to a depth of approximately 150 feet. The Upper Sands immediately below them, extend to

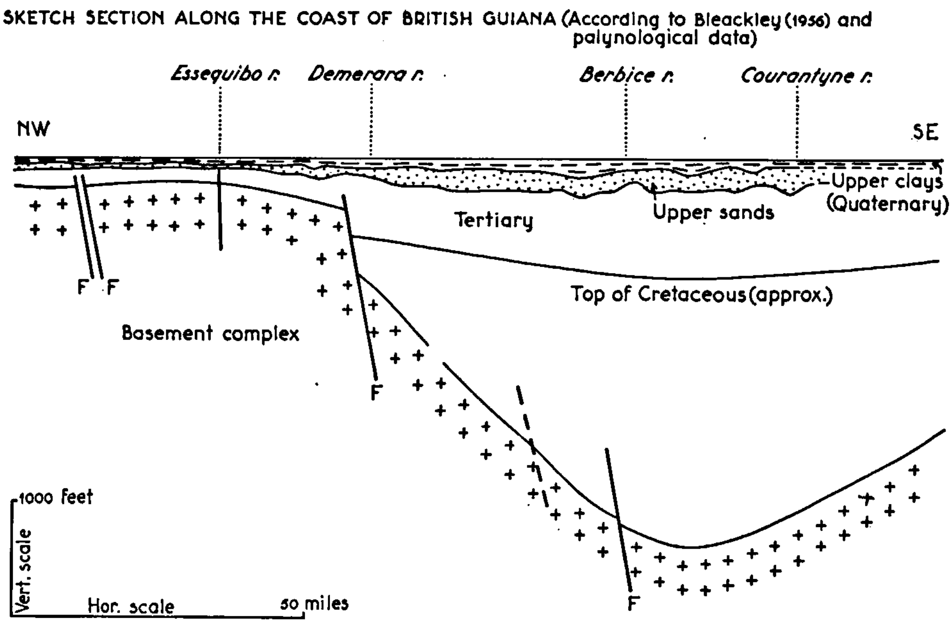


Fig. 2. Section along the coast of British Guiana.

a depth of 250—400 feet, then followed by the Intermediate Clays, A-Sands and "Alternating Sands and Clays". The base of the A-Sands lies at approximately 700—900 feet. The depth of the basement, the top of the Cretaceous (in the "Alternating Sands and Clays") and the position of the Upper Clays and Upper Sands in a section along the coast are shown in fig. 2.

In order to obtain a complete reference section for pollen analysis in addition to other purposes, a deep borehole was drilled to basement in the Georgetown area, near Shelter Belt. The palynological data so obtained opened the possibility of correlating on a firm basis the sediments of the white-sand plateau with the stratigraphy of the coastal wells and to establish the age. The complete results of these

[1] Superficial younger reworking and redeposition of the uppermost white sands on the plateau have probably taken place locally, but seem to be of little importance, and have not been taken into account.

studies will soon be published, but brief mention may be made here of those data which are of interest for this study on the Quaternary.

The Montgomery Formation corresponds palynologically to the Intermediate Clays (or at least to the upper part of them), which are approximately Miocene in age. The Mackenzie Formation corresponds to the Upper Sands, and there are several indications that their age is approximately Pliocene, although a Lower Pleistocene age cannot be excluded. No analysable assemblages were obtained from the clay-intercalations of the Upper Sands in the Shelter Belt well. Nevertheless, in several coastal wells elsewhere on the coast of British Guiana, intercalations of lignite and clay have been found although, unfortunately, samples of this material were no longer available. A borehole from the Surinam coast penetrated an apparent equivalent of the Upper Sands, but with important clay-intercalations. The samples are now being studied. They contain amongst others *Symphonia*, a Pliocene-Pleistocene species, whilst typical older species are lacking. For the present the base of the Quaternary is provisionally placed at the bottom of the Upper Clays, although the Upper Sands may eventually turn out to be Lower Pleistocene.

The Upper Clays correspond palynologically to the sediments of the Young and the Old Coastal plains, and are Quaternary in age.

THE PRESENT VEGETATION

A preliminary review of the vegetation-types of British Guiana was given by Fanshawe (1952), and of Northern Surinam by Lindeman & Moolenaar (1959). There is also a more detailed study of the coastal vegetation of Surinam by Lindeman (1953). For present purposes it is only necessary to mention a few data from the above mentioned publications, supplemented by a few unpublished field observations.

The climate of British Guiana is tropical with two wet and two dry seasons, and a high relative humidity. In the eastern district there is only one wet season and the relative humidity is lower. The main wet season is from May to August and the minor one in December-January. The rainfall in the coastal area is between 60 and 100 inches a year, increasing from East to West. The mean shade temperature in the same area is approximately 29 °C during the hottest month and 26 °C during the coldest month (Fanshawe, 1952).

For the classification of the climax vegetations we will follow the nomenclature of Beard (1944) slightly modified and adapted by Fanshawe (1952). The names of associations, descriptions of terms etc. are taken from Fanshawe and from Lindeman (1953).

In the North Eastern part of British Guiana, between the Essequibo and the Corentyne, Swamp forest, Marsh forest, Seasonal forest and some Dry evergreen forest are predominant. These names apply to "formation-series", and the Marsh forest series also includes savanna and the Swamp forest series herbaceous swamps. "Swamp" implies inundation or water-logged conditions where the soil rarely dries out completely. "Marsh" implies marked seasonal fluctuations in the moisture conditions of the soil ranging from water-logged to very dry, and is always related with impeded drainage (clay-pan etc.). Seasonal forest is found when there is a marked seasonal distribution in rainfall, combined with a good drainage of the soil. Dry evergreen forest occurs in areas with completely free drainage (Fanshawe, 1952). On the white-sand plateau formations of the Dry evergreen forest (Wallaba forest, Xeromorphic woodland, savanna of the dry type) and the Seasonal forest (Evergreen seasonal forest) occur.

Fig. 3. *Avicennia* forest, with the fern *Acrostichum aureum*. NW of Paramaribo.

Fig. 4. *Avicennia* as pioneer on silty beach and mudflats. Beterverwachting (B.G.).

The old coastal plain supports evergreen seasonal forest and sometimes wet savannas. On the young coastal plain (including the river flood-plains and lower parts between the Coropina islands) formations of the Swamp and Marsh forest occur, including mangrove forest, wet savannas and herbaceous swamps. These associations proved to be the most important for our studies, as in this environment or in the neighbourhood of these vegetation types the deposition of most of the analysed sediments took place. In general for the major part of the coastal sediments the plants for which high pollen frequencies are found belong to the Mangrove-forest. The sedimentation apparently took place for an important part in a shallow marine, lagunal or estuarine environment.

Rhizophora, *Avicennia* and *Laguncularia* are the three principal species of the Mangrove-forest. Although Fanshawe (1952) mentions one association only, it seems fairly clear that there are several (Lindeman, 1953). One association, the *Avicennia* forest, occurs on more silty and settled soil, in general only inundated during the rainy season and spring-tides (fig. 3).

In Surinam and in British Guiana this association occurs on the coast but also along the river estuaries on and behind the levees, in the latter case behind a front belt of *Rhizophora*. *Laguncularia* may occur in this association, but normally *Avicennia* dominates completely. At the margin or where the forest is a little more open, the fern *Acrostichum* may occur in the undergrowth (fig. 3). *Sesuvium*, *Iresine* and a few other herbs may be found under similar conditions. *Avicennia* is also a pioneer on mudflats at a growing coast (fig. 4) where these flats become higher than normal high tide (Lindeman, 1953). As may be seen both in British Guiana and Surinam under these circumstances the *Avicennia* forest is high and fully developed landwards and gradually lower towards the sea.

The second association is the *Rhizophora*-forest (fig. 5) which occurs as the outer vegetational belt along the river estuaries and rivers, on soft mud which never dries out completely. It may also occur under similar conditions directly exposed to the sea (Fanshawe, 1952). Lindeman does not mention this type of occurrence for Surinam, although *Rhizophora*-forest may be found on small sand ridges on the coast (personal communication). Along the rivers upstream from the estuaries the *Rhizophora* fringe seems usually to be very narrow. In the lagoons on the North Coast of Colombia, *Rhizophora*-forest may be an important element of the vegetation.

Rhizophora is in general the dominating tree in this association, but *Laguncularia* may occur. There are three species of *Rhizophora* in Guiana. *R. mangle* s.s. grows only seaward and along the coast. Upstream this species is replaced by *R. harrisonii* and *R. racemosa* (Lindeman & Moolenaar, 1959; Jonker, 1959).

Lindeman (1953) mentions still a third type of mangrove-forest, which may be another association. It lies above high-tide where there are frequent variations in salinity (sea water and river water) and consists of a mixed mangrove forest, with tall trees of both *Rhizophora* and *Avicennia.*

Geijskes (personal communication) made extensive observations on the occurrence of the mangrove species along the rivers as related to the salinity of the water and the distance from the mouth. He found that upstream from the coast *Laguncularia* disappears first, followed by *Avicennia*, and finally *Rhizophora.*

The *Rhizophora* limit corresponds approximately with the limit of salt water influence, although there are apparently (Lindeman, 1953) scattered occurrences in fresh water.

In the following enumeration of other vegetation-types, only a few of the more important species or genera are mentioned, mainly those which are found in the pollen samples. As the mangrove fringe along the river becomes discontinuous,

Fig. 5. *Rhizophora* forest at the mouth of the Demerara river, near Georgetown.

Fig. 6. Swamp forest, with *Mauritia* palms. Berbice river plain near Kwakwani.

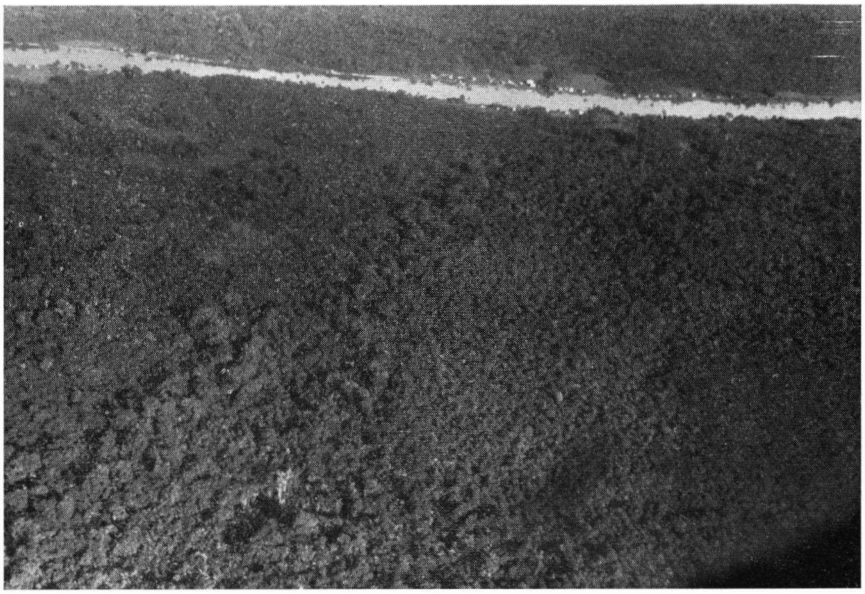


Fig. 7. Swamp and marsh forest on the Demerara river plain (note the palms on the lower middle part of the photo). Taken from the air.

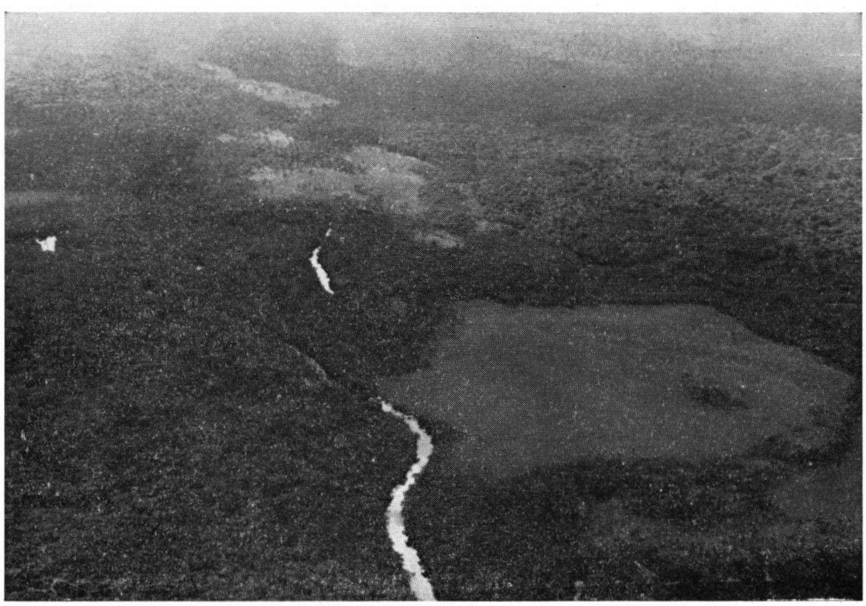


Fig. 8. Swamp and marsh forest and herbaceous swamps on the coastal plain SE of Georgetown. Taken from the air.

swamp woodland with *Bombax aquaticum*, *Pterocarpus* and a few other species, assert themselves. In the swamp forest (fig. 7 and 8) *Virola* and *Symphonia* are important, and such palms as *Jessenia* and *Euterpe* are common. *Mauritia* may occur where the forest is not too high (fig. 6). In herbaceous swamps (fig. 8) we find *Cyperus giganteus*, *Typha angustifolia*, *Sagittaria* and others. *Isoetes ovata* may also be present. In the semi-aquatic swamp vegetations *Utricularia*, *Eichhornia*, *Nymphaea*, *Polygonum*, *Cuphea*, *Jussiaea* and grasses may be found. These swamps have fresh or slightly brackish water.

The Palm marsh forest may be found on soils with or without pegasse. Important species are *Symphonia globulifera*, *Tabebuia insignis*, *Pterocarpus*, *Cassipourea*, *Eschweilera*, *Manilkara* and the palms *Euterpe*, *Manicaria* and *Maximiliana*. There may be a ground cover with *Rapatea paludosa* or other plants. In the marsh forest which is often found on pegasse *Iryanthora* and *Tabebuia* are important.

Fig. 9. Northern limit of white sand plateau, S of Georgetown. At bottom right the coastal plain. A small creek (with higher forest) cuts into the edge of the plateau. Low bush and grass cover partly the white sand surface. Taken from the air.

In the Palm marsh woodland *Clusia fockeana*, *Tabebuia* and *Ilex martiniana* are common species. *Mauritia* may be present. The Palm marsh seems to be represented by the "*Mauritia* savanna" where the ground cover consists of *Montrichardia*, *Typha*, sedges and grasses.

Savanna vegetations occur where a pronounced alternation exists of moisture and drought. During the rainy season large areas may be inundated whereas at other times of the year the soil is liable to dry up completely. The vegetation of these regions, which may possess a clay or iron pan, is dominated by grasses and sedges, sometimes with many flowering herbs, shrubs and low trees. The most typical trees are *Curatella americana* and *Byrsonima crassifolia*.

Fig. 9 gives an example of the dry bush and dry Savanna vegetation which partly covers the white sand surface.

This dry type of savanna is related to the wet type, but should belong to another formation series (Dry evergreen) in the system of Beard.

THE POLLEN TYPES

Since all the pollen grains belong to plant species, genera or families still living at the present day and which have been discussed by Fanshawe (1952) and Lindeman (1953) brief comments will be sufficient. Microphotographs are given of the most important pollen types (see plates I to X).

Rhizophora

This is the most frequent pollen type in the coastal sediments of Guiana. The tree is widespread in the recent mangrove-forest situated on soft mud along river estuaries and in tidal rivers approximately as far as the limit of salt-water influence. It also occurs along the sea-shore and in lagoons and brackish water swamps. The pollen of the three species *R. Mangle*, *R. racemosa* and *R. harrisonii* may be differentiated morphologically, although sometimes only with difficulty. This is important, as their ecological requirements are different, *R. mangle* being the most salt-tolerant species, occurring near the mouth of the rivers and estuaries.

Avicennia

Fairly frequent in the coastal sediments, and common in certain horizons, *Avicennia* occurs at present in Mangrove forest on silty soil along the coast, and behind the *Rhizophora* fringe on and behind levees along the rivers and estuaries. Upstream they disappear before *Rhizophora.* In fossil occurrences they are most abundant in the sections of quaternary sediments nearest to the present coast. In the Holocene they are especially notable in the upper and lower parts of the sections. In the sediments of the river-valleys *Avicennia* pollen grains are scarce but become a little more abundant during transgressive phases.

Ilex

Ilex grows recent in marsh forest (*I. martiniana*) and swampwood (*I. guianensis*). Fossil *Ilex* pollen grains are often frequent in those parts of the diagrams where *Rhizophora* shows lower percentages.

Symphonia

Recent in marsh and swamp forest. Fossil: see *Ilex*. Frequent in the Holocene, rarer in older sediments.

Palmae

There are different species recognizable, but here only a few partly morphological groups are differentiated.

1. Monocolpate (psil-retic-fov)
2. Trichotomocolpate
3. *Astrocaryum acaule* type
4. *Mauritia*

To the first group belong many important genera, like *Euterpe*, *Maximilliana* etc., often frequent in marsh and swamp forest. *Iriartea* was sometimes differentiated. Different species of *Astrocaryum* occur in marsh forest, rain forest and on sand ridges. *Mauritia* occurs in low parts of savannas, in swamps and on low river banks. It needs light, and dwells in places where it can reach above the crowns of the trees.

Fossil: see *Ilex*.

Myrtaceae

Mainly *Eugenia*. When there are two curves, for Myrtaceae and for *Eugenia*, the first includes other genera than *Eugenia*. All are "syncolporate". *Eugenia* occurs in rain forest and on ridges near the coast.

Malpighiaceae

There are several types, not differentiated here. The *Byrsonima*-type is not included. In swamps, mangrove scrub and different forest types. Fossil in *Rhizophora*-pollen-associations and forest pollen-associations, but more frequent in the last.

Melastomataceae

When there are two curves, for Melastomataceae and *Miconia*, the first comprises the pollen-grains larger than 19 μ and the second those smaller than 19 μ.
Recent: Many species, in different forest-types and savannas.

Bombacaceae

The following two groups are distinguished in the diagrams:
Catostemma
Bombacaceae (all different types).
Recent: *Catostemma* occurs in rain and marsh forest, Bombacaceae in general may occur under the same conditions, in swamp woodland along river banks, and also in savannas.
Fossil: not very frequent, the first principally in sections away from the present coast.

Alnus, *Podocarpus* and *Juglans*

Isolated finds. There is an almost continuous low curve for *Alnus* in the Upper Holocene of Ogle Bridge.
Recent in mountain forest.
The fossil grains must have been introduced by long-distance transportation by the air or by water (rivers and sea?).

Annonaceae, *Proteaceae type*, *Sapotaceae*, *Mimosaceae*, *Moraceae*, *Anacardiaceae*, *Caesalpiniaceae* and *Lecythidaceae-type*

Isolated finds or rather low percentages. Higher percentages of Mimosaceae only in one case (Berbice, Kwakwani). As far as data about recent occurrence are of importance, they will be mentioned in the description of the diagrams.

Cecropia

This genus is not included in the Moraceae-curve.
Recent rather common in the coastal region, on levees etc. It needs light, and is always found in open forest.
Fossil not very frequent, rarely higher percentages.

Virola

Recent: very common in marsh forest.
Fossil: see *Ilex*.

Gramineae and *Cyperaceae*

Recent: principally in savannas and in herbaceous and semi-aquatic swamp. *Spartina* is a pioneer on mudbanks on the coast. Fossil: in higher percentages in the sediments of Würm-age (Ogle Bridge) and locally in the Upper Holocene.

Amaranthaceae-Chenopodiaceae type

Recent: in more or less brackish herbaceous swamps (Amaranthaceae).
Fossil: associated with swamp and marsh and with *Rhizophora*-pollen associations. Apparently only in the Upper Quaternary.

Compositae (Tubuliflorae)

Recent: principally in swamps and in savannas. Fossil: higher frequencies in the Upper Quaternary only.

Umbelliferae, Nymphaeaceae, Polygonum, Typha, Pistia and *Jussiaea*

Recent: mostly in herbaceous or semi-aquatic swamps. Fossil: occasional finds and locally somewhat higher percentages.

Sagittaria

Recent: in herbaceous swamps, and as a pioneer on mudbanks in river estuaries. Fossil: in the Torani canal section at the regression stage.

Malvaceae

Recent in swamps and marsh forest, along rivers, in strand scrub and in mangrove along rivers. Fossil: see *Sagittaria.*

Little can be said at this moment of isolated finds of *Caryophyllaceae-type*, *Geranium-type* and *Polygalaceae.*

Hymenophyllum-type

Probably *Trichomanes.* Recent: in marsh forest, and other forest types. Fossil: in samples 4 and 5 of the Ogle Bridge section.

Acrostichum aureum

Recent: locally in *Avicennia*-forest, especially where this has been partly destroyed. Fossil especially in the Ogle Bridge section. Probably the spores easily lose the faint ornamentation, and the curve for "Trilete psil (large)" spores corresponds then also to *Acrostichum.* In that case the *Acrostichum* curve goes ± parallel to the *Avicennia*-curve in the section mentioned.

Monolete spores (psil., ver., fov.)

Probably all corresponding to genera of the Polypodiaceae.

Representatives of this family occur frequently in fresh water swamps, but are also found under slightly brackish conditions.

Trilete spores (psil, fov, ech.)

The psilate spores correspond possibly also to genera of the Polypodiaceae, and so may the foveolate. The first seem to be especially common in the middle part of the Shelter Belt diagram of the Quaternary.

Ceratopteris (Trilete str.)

Floating in fresh or slightly brackish swamps. Fossil occurrence occasional only.

Lycopodium

Both the reticulate and the pitted type were occasionally found. Recent: in savanna, including floating savanna in swamp (Lindeman, 1953).

Isoetes

Recent: in herbaceous swamp (*I. ovata*). Fossil occasional; a low but almost continuous curve in the Upper Holocene of the Ogle Bridge diagram.

Fungi-spores

There is a great variety of Fungi spores and many of them are locally very abundant. Only a total curve for all Fungi spores is given in the diagrams, but a few types are restricted to high *Rhizophora* percentages only and a few others to fresh-water conditions. The Fungi curve of the Ogle Bridge section shows some very interesting maxima. For a possible interpretation, see the discussion of the diagrams.

RECENT POLLEN SEDIMENTATION

For the correct interpretation of the pollen diagrams it is necessary to establish the relation of pollen sedimentation and vegetation in the region. Intensive investigation will be required in the future but it is already possible to draw certain important conclusions.

The first and main problem is that of pollen sedimentation and source in a marine environment. It seems that the valuable study of Muller (1959) on pollen sedimentation in the Orinoco delta and on the neighbouring shelf is relevant for Guiana conditions also. Muller found that pollen transportation by the air towards the sea must be very small, as a result of the prevailing wind-directions from the N.E. The highest pollen concentration in sea bottom samples was found near the shore (some 5000 grains per gram sediment), the concentration dropping seaward and reaches an approximately constant concentration of 500 grains per gram on the shelf. From this and from the fact that higher pollen concentrations occur in front of the principal river outlets, Muller concluded that pollen sedimentation on the sea bottom is principally due to transportation by water, the pollen being brought in by the main rivers and further moved by sea currents. He also found that the pollen percentages of *Rhizophora*, which are high in the coastal Mangrove zone, are 30—50 % in the bottom sediments immediately offshore and > 50 % farther offshore (corresponding approximately to the area with pollen densities of 500 per gram). In recent surface samples from behind the Mangrove belt and even rather far inland, *Rhizophora* was often represented by lower percentages, proving that this pollen was carried inland by the air (N.E. winds). The higher *Rhizophora*-pollen percentages farther offshore may perhaps be explained by the fact that this pollen is lighter than many other types, and is carried farther out by the water (Muller 1959).

The pollen-spectra we obtained from a few surface-samples from British Guiana give further information for the interpretation of the diagrams. The first sample is from the interior of an *Avicennia* forest at the shore near Beterverwachting (B.G.), and the second from a narrow fringe of *Rhizophora* forest at the coast near the mouth of the Demerara River, N.E. of Georgetown. The third sample is from a mud flat immediately in front of a silty ridge at Hope Beach, behind which an *Avicennia* forest has established.

These coastal samples may be compared with the uppermost samples taken almost at the surface farther inland from the Demerara river bank (Mackenzie), Berbice river bank (Kwakwani) and Atkinson field (pegasse). From all these data and taking Mullers observations into account the following conclusions may be drawn:

1. In a Mangrove forest the percentage of pollen of *Rhizophora* + *Avicennia* in the sediments may be between 45 and 95 %. If the Mangrove forest forms only a narrow fringe, the sediment tends to have lower percentages, as for instance 30.
2. Mud deposited in front of the coast-line, may have percentages of *Rhizophora* + *Avicennia* pollen of 30—50. Further offshore the percentage of *Rhizophora* pollen increases and may be up to 70 % or more.
3. Swamp forests immediately behind the Mangrove forest may have 45—10 % (or less) and Swamp forests farther inland may have 10—0 % Rhizophora pollen in the sediment.
4. The percentage of Avicennia pollen in surface sediments may be ± 25—40 % in extensive pure *Avicennia* forest. In mixed *Rhizophora-Avicennia* forest the values are lower, down to a few percent. In mud deposited in front of the coastline, percentages are in general very low (0—5 %), but may reach eventually 8 %. Farther offshore it becomes very rare.

	Avicennia forest Beterverwachting %		*Rhizophora* forest Georgetown %		Mud flat Hope Beach %	
Rhizophora	17,5	49,5 (Rhizophora + Avicennia)	25		30	38 (Rhizophora + Avicennia)
Avicennia	32		8		8	
Ilex	2		—		4	
Melastomataceae	2		—		—	
Virola	2		2		—	
Malpighiaceae	—	47 (Ilex to Other trees)	—	55 (Ilex to Other trees)	2	52 (Ilex to Other trees)
Bombacaceae	2		—		—	
Palmae	—		2		6	
Other trees	39		51		40	
Gramineae		3,5		12		10
	Total 100 %		Total 100 %		Total 100 %	
Cyperaceae	7		6		2	
Chenop.-Amaranthac. type	1		6		2	
Compositae (Tubulifl.)	—		2		2	
Nymphaeaceae	—		—		2	
Acrostichum aureum	—		10		6	
Monolete psil spores	7		2		12	
Monolete ver spores	—		4		—	
Trilete psil spores	2		2		—	

5. Heavy pollen grains like *Symphonia* rarely are found in sediments in front of the coast-line in any appreciable percentage. Lighter pollengrains are carried seawards more easily and may be sedimented at considerable distance from the shore.
6. The Fungi spore content is in general highest in the swamp and forest area behind the coast-line and ranges between 10 and 100 % of the pollensum, although both higher and lower values may occur (0—500 %). In the Mangrove belt the percentages are usually relatively low, ordinarily varying between 3 and 10 %. In a zone in front of the coast percentages are generally low (1—3 %) and spores of this type are not found farther offshore.

THE SIZE OF RHIZOPHORA POLLENGRAINS IN RELATION TO AGE

In the course of the analysis of the Shelter Belt material it was noted that the pollen grains of *Rhizophora* in the lower samples were smaller than those in the upper samples.

A provisional statistical analysis of the size of these pollen grains in a series of samples has been undertaken by Mrs. Riate van Mullem, the details of which, and the statistical problems involved, are to be the subject of a later publication. A few of the principal provisional results may be mentioned however. The length (Lg) of some 50 pollengrains of *Rhizophora racemosa* from each sample was measured, and the average calculated. These averages were then plotted against the depth of the samples (fig. 10), and a progressive decrease in size in depth demonstrated. Similar results were obtained for a few samples from Ogle Bridge (fig. 11) and provide

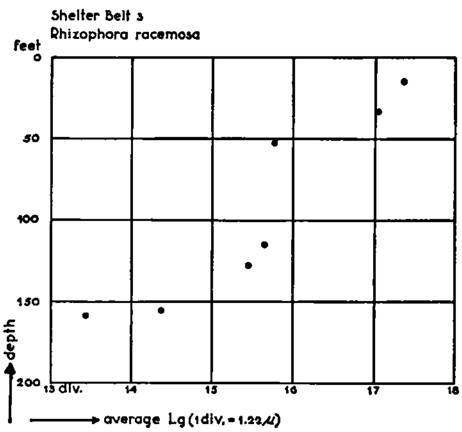


Fig. 10. Size-depth relation of *Rhizophora racemosa* pollen grains in the Shelter Belt section.

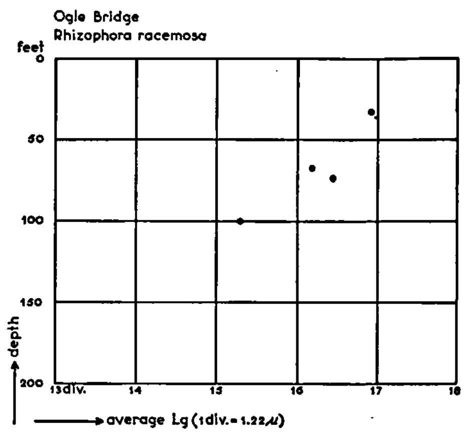


Fig. 11. Size-depth relation of *Rhizophora racemosa* pollen grains in the Ogle Bridge section.

additional evidence for the pollenanalytical and stratigraphical correlation of the two sections. Especially important is the correlation in size of *R. racemosa* at a depth of 100′ in Ogle Bridge, with those between 126—128′ in Shelter Belt. It seems that the same tendency holds for *R. harrisonii* for which the following measurements were obtained.

		Average Lg of *R. harrisonii* (1 unit is 1.22 u)
Demerara riverbank, Mackenzie,	sample 4 (9′)	18.08
Demerara riverbank, Mackenzie,	sample 42 (113′ 6″)	17.22
Oreala, Corentyne River, I,	sample 3	17.43
Torani Canal,	sample 7	17.30

It will be later seen that these results agree with the pollenanalytical and C 14 evidence. It would not be desirable to ascribe too much significance to these preliminary observations since much detailed work is required before the cause of this size change can be thoroughly established. But it is evident that if the decrease of size with age turns out to be a general phenomenon, it may prove the key to the solution of many yet unsolved correlation problems.

DISCUSSION OF DIAGRAMS AND C 14 DATES

All the diagrams have been composed and drawn in the same way. In the pollensum are included three groups of pollengrains:

Mangrove elements.
Gramineae (grasses).
Forest elements (trees) other than mangroves.

The first group is subdivided into *Avicennia* and *Rhizophora*, and the last group into determined and undetermined elements. All other pollen grains and spores are excluded from the sum. *Virola* was not recognized as such until the diagrams were already completed and is therefore amongst the not-included elements. To the right of the main diagram is the curve for the Fungi. Separate curves are provided for the elements included in the pollensum, and to the right of these the frequency of the not-included elements is indicated. In general 200 pollengrains were counted for each spectrum.

Most of the samples were treated in the same way, first boiling them briefly with KOH and when necessary using acetolysis (according to Erdtman). This was followed by gravitative separation in a bromoform-alcohol mixture, subjecting them first to an ultrasonic treatment.

The localities of the pollen-sections are indicated on the map of fig. 12.

Ogle Bridge (Diagram I)

The Ogle Bridge diagram is of considerable interest and rendered particularly so in that it is supported by C 14 datings. In the interpretation of the diagram it is of importance to note the high percentages of *Avicennia* in distinct zones, and the very high *Rhizophora* combined with very low Fungi percentages in the middle part (see the paragraph on recent pollen sedimentation). The first (left) part of the diagram has been published previously (van der Hammen, 1959 & 1961) before C 14 dates were available. Two C 14 dates confirm the interpretation then given. The dates are as follows:

GRN 3058 - Ogle Bridge, Borehole No. 39,
peaty clay at 67′ ———————————— 8590 (± 65) years B.P.
GRN 3506 - Ogle Bridge, Borehole No. 39,
hard peaty clay with woodfragments at 95′ ———— > 45000 years.

The average rate of sedimentation of the upper 67′ was thus 1 foot in about 130 years. If we use this figure, the early Holocene transgression at 74′ (about 73′ below present mean sealevel) took place approximately 9500 years ago. (If we take the begininng of the rise in *Avicennia* at 5000 BP (see below), then we find a rate of sedimentation of 1 foot in 90 years and 9200 BP for the transgression).

This time-depth relation agrees remarkably well with a date for the early Holocene transgression in the NW Netherlands (Jelgersma & Pannekoek, 1960): ± 9600 B.P. at about 23 meters [1]. In fact the peaty clay between 68′ and 74′ corresponds in certain respects with the lower peat of the Netherlands and similar horizons in other coastal regions.

The Fungi-curve shows several interesting maxima, which are not yet fully understood. They may indicate disturbance of equilibrium of the vegetation, as for instance the transition of a mangrove vegetation to fresh-water swamp vegetations, but might also simply be related to certain vegetation types.

Extremely interesting also is the section of the diagram between 74′ and 84′ which quite clearly represents the Würm-glacial. The vegetation was remarkably poor, consisting almost entirely of grasses. The few *Rhizophora* grains were probably brought in by wind from the coast much further north or have been reworked from older sediments.

[1] Corrected for Suess-effect.

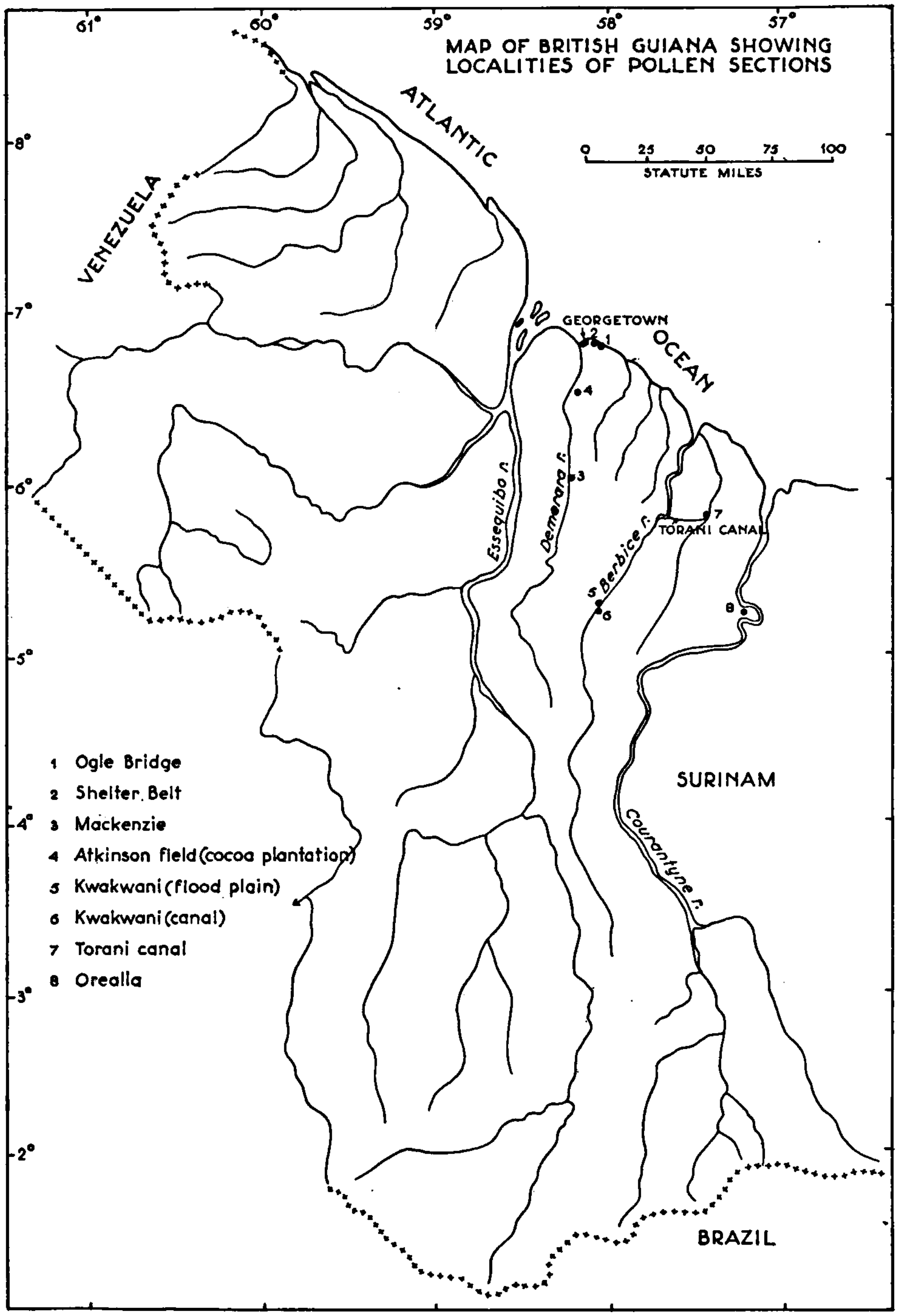


Fig. 12. Map of British Guiana showing the localities of the pollen sections. The numbers refer also to those of the corresponding diagrams.

The reason for such an impoverished flora remains uncertain (the possible influence of a lower temperature is discussed in the last paragraph). It developed over a clay surface, exposed by regression, and which would soon have become impermeable. The rainfall may have been heavier than at present causing prolonged inundation alternating with sharp dry seasons which dried out the soil completely. The presence of fine charcoal in this interval indicates that natural fires occurred. Such extreme conditions might produce this poor grass savanna.

Ogle Bridge Borehole

Depth below surface	Interpretation of the pollen-data	Age-interpretation
0—8′	Deposits near the shore-line. Open vegetation increased probably by human influence (fires, cultivation).	Holocene
8—30′	Deposits in or near open swamps, swamp forests and mangrove forests near the shore-line or not far behind it.	
30—74′	30—68′ Deposits in open sea or on tidal flats, rather far of the proper shoreline (or in a very big estuarium?). 68—74′ Deposits in mangrove swamp and immediately in front of the shore. ± 9500 B.P. early Holocene transgression (± 73′ below sealevel.	
74—84′	Poor open grass-savannas, far behind the shore-line.	Würm-glacial
84—94′	Deposits in open swamps and swamp forests not far behind the shore-line.	Early Würm-glacial or Late-Eemian
94—101′	Deposits immediately in front of the shore-line and in coastal mangrove swamp.	Riss-Würm Interglacial (Eemian)

Shelter Belt (Diagram II)

The diagram covers the upper 160′ of sediments from the borehole Shelter Belt 3 (near Georgetown). Undisturbed samples were taken at half foot intervals in the uppermost 40 feet, and at larger intervals in the lower part. The upper 160′ consist mainly of clays, and overlie ± 90′ of sands (the Upper Sands). This sand must correspond to the upper part of the white sands outcropping further south. The clays which underlie these white sands near Mackenzie (and overlie the bauxite) are upper Tertiary (see above in the paragraph on the coastal plain) according to palynological data, and correspond to the clays underlying the Upper Sands in the Shelter Belt borehole.

The age of the Upper Sands has not yet been established exactly, but may be Pliocene or Lower Pleistocene.

The diagram is composed in the same way as the others, but in addition, at the extreme right, another type of general diagram is given, with the spores included in the pollensum. This was done in view of the fact that in several intervals the pollen-content of the samples was very low, and insufficient grains could be counted to get reliable spectra. By including the spores interesting and significant changes of vegetation may be noted. In the same diagram (at the right) a few spectra are included based on less than 200 grains (between 50 and 100), but which nevertheless give important complementary data on the changes of vegetation.

The upper forty feet of the diagram may be directly compared and correlated with the diagram from the nearby Ogle Bridge borehole. The lowest part of this interval shows very high *Rhizophora* percentages, then the *Avicennia* curve rises considerably and the *Rhizophora* percentages decrease, to be replaced by other (swamp-) forest elements and some Gramineae. The uppermost spectrum shows a sudden change, the mangrove-elements drop to zero and the Gramineae increase, probably due to human influence on the vegetation. Both in the Ogle Bridge and in the Shelter Belt section, a sandy-silty horizon is present at the same depth below the surface, near the rise of the *Avicennia* curve. Shells were found in the lower part of this horizon in the Shelter Belt-hole.

Below 40′ the picture at Shelter Belt is a little different from Ogle Bridge. Between 40′ and 47′ there is an interval of tough grey mottled red and yellow clay, which does not contain pollen. The surface during this time was apparently above sea-level, and pollen were destroyed by oxidation (dry soil during the dry seasons).

From 47′—54′ there is a further grey clay with high *Rhizophora* percentages, but the interval from 54′—62′ consists of yellowish grey clay, with low pollen content. The diagram at the right shows high spore percentages at this interval, and no or very little mangrove elements.

From 61′—63′ there is some sand in the clay and a few shellfragments. At 63′ a series of red and yellow mottled clays (63′—114′) mainly without pollen begins, only the uppermost sample, at 63′ 6″ containing pollen grains.

The spectrum is drawn in the diagram at the right. This sample contained the following grains: 36 Gramineae, 26 Cyperaceae, 2 *Humiria* and 1 Monolete psilate spore.

The high Gramineae percentage suggests that this spectrum corresponds to those immediately below 74′ in the Ogle Bridge diagram. The age should therefore be Würm-glacial (top of Coropina formation). It thus appears that the old surface from the end of the Würm-glacial and which was inundated by the post-glacial rise of sea-level, was 11′ higher at Shelter Belt than at Ogle Bridge. It is apparently for this reason that the development in the lower Holocene was different here. While the surface at 74′ below actual sealevel was inundated immediately by the first rapid rise at the beginning of the Holocene, the surface at 63′ was not immediately and definitely covered. It must however have been very near the sea-level at that time, and possibly flooded by rivers or during springtides. The sediments were apparently laid down in a swamp or marsh very rich in ferns (probably including *Acrostichum*) and poor in trees. At approximately 54′ the sea-influence increased, but was interrupted by a short minor regression represented between 40′ and 47′. The soil was inundated again during the next transgression, the continuation of the sea-level rise.

Sterile mottled clay continues from 63′—114′. Red mottling mostly occurs in the upper and lower part, while yellow colours prevail between. The lower part is sometimes coloured dark brown, is locally sandy or silty, and near the base there is a thin intercalation of sand with fine gravel. Small charcoal fragments were noted in several slides of the samples from the whole sterile interval, just as in the interval between 74′ and 84′ at Ogle Bridge, to which it probably corresponds.

The next interval, from 114—133′ clearly shows influence of marine conditions in the upper and lower parts, and a probably minor regression (high spore percentages, yellow (-red) mottled clay) in between. The size of *Rhizophora racemosa* grains (samples 115′ 6″ and 127′, see fig. 10), are very near to those of the 100′ level of Ogle Bridge, and although to judge from their depth the first must be a little older than the latter, they belong probably to the same interglacial, i.c. the Eemian (Riss-Würm interglacial). Red mottling occurs again in the thin sterile interval around 135′.

The dark grey clays below this interval to the sands at 160′ contain abundant pollen, with relatively high percentages of *Rhizophora* and *Avicennia*. Unfortunately no samples were available from the middle part of this interval, and little may be said about its precise age. The samples do not contain Tertiary species but the size of the grains of *Rhizophora racemosa* is considerably smaller in the samples from 155′ and 157′ 6″.

We believe that at least this lower part belongs to one (or several) older interglacials but nothing more precise can be said about it, until a number of similar sections have been studied palynologically.

The interpretation of the Shelter Belt diagram may be summarized now as follows:

0—63′ - Holocene
63′—114′ - Würm-glacial
114′—133′ (or more?) - Riss-Würm interglacial
137′—160 - probably older interglacial(s) (at least the lowermost part).

The base of the Würm-glacial sediments at Shelter Belt lies some 30 feet lower than at Ogle Bridge. This seems to indicate that they were deposited in an early Würm-glacial stream valley, eroded in the Riss-Würm interglacial sediments. This view is supported by the fact that the top of the Riss-Würm interglacial is not represented in the Shelter Belt diagram, and by the fact that here sand and fine gravel is present at the very base of the Würm-glacial sediments. The bulk of the Würm-sediments may then have been deposited in this valley during interstadial phases of the Würm.

An attempt was made to obtain other support for the general interpretation (on the basis of palynological and other data) of the Shelter Belt section. Van Gijzel (1961) discovered a certain relation between the fluorescence of pollen grains in ultra violet light and their age. He was so kind to make a provisional study of a number of samples from the Shelter Belt borehole, and to communicate us his opinion. He believes that the samples down to 61′ are Holocene, and those from 61′ to 160′ are Pleistocene.

Demerara river bank, Mackenzie (Diagram III)

A series of samples from their borehole no. 110 situated near the Demerara River at Mackenzie were received from the Demerara Bauxite Co. The flood plain of the river here has an elevation of 12—13 feet above sea-level. The borehole penetrated 130′ in mainly soft sediments; at approximately 124′ it reached stiff grey clay, without pollen grains, probably representing the older sediments (or residual material) below the bauxite.

The diagram may be subdivided into two zones:

0—20 or 35′ - Upwards increasing percentages of (swamp- and marsh) forest elements, and decreasing percentage of *Rhizophora*.
20 or 35′—124′ - *Rhizophora* dominates almost completely: the Demerara river valley must have been something like an estuarium.

Only the two uppermost spectra (upper foot of sediment) are laid down under conditions of no or almost no influence of brackish water. The high percentage of Gramineae (grasses) in the uppermost sample indicates recent human influence (destruction of the forest on the flood plain). It is an interesting fact that the salt-water influence starts to decrease at almost the same depth below sea level as at Ogle Bridge. Comparison of the two diagrams leaves no doubt that the whole Mackenzie section is in the wide sense post-glacial. The fact that the"post-glacial" sediments start here at a far greater depth than at Ogle, and rest immediately on much older sediments, shows that important vertical erosion must have taken place during the time of low sea level of the Würm-glacial during which time sediments of the former Interglacial period must have been removed. During the Late- to Post-glacial rise of sea level, the deep valley must have been inundated during an earlier phase than the land-surface of that time at Ogle. It seems most probable therefore that the sediments between 90 and 124′ are of Late-glacial age, or at least very early Holocene.

It is an astonishing fact that the influence of the vegetation of the near white-sand plateau is not noticeable. The local production of pollen grains in the swamps and marshes bordering the estuarium or river seems to be the principal or only source of pollen in these sediments. The bulk of the pollen grains of *Rhizophora* is of *R. harrisonii*, suggesting that the site was not very near the mouth of the "estuarium".

Atkinson Field (*cocoa plantation*) (Diagram IV)

This section was sampled by auger (Bleackley) in a swamp forest on "pegasse" behind the Cocoa-Plantation not far from Atkinson Field. It is situated in one of the creeks eroded in the white sand "erosional scarp", and belonging to the Demerara river system. The diagram may be subdivided into two parts:

0—7′ Increasing percentage of fresh water (swamp) forest elements upwards
7—30′ *Rhizophora* dominates almost completely.

The diagram is directly comparable with those of Mackenzie and Ogle Bridge, and represents the Upper Holocene. In the upper part a succession is reflected from *Rhizophora* mangrove-forest via a swamp forest rich in *Symphonia*, to a swamp forest rich in *Ilex* and palms.

Kwakwani, Berbice river plain (Diagram V)

This section was also sampled by auger (Bleackley) in the floodplain of the Berbice River near Kwakwani. The river height there is 17 feet above main sea level, and the flood plain may be 1 or 2 feet higher. The section is 13′ thick, and represents only the uppermost part of the soft sediments.

The diagram shows an interesting succession. The lowermost part of the analysed sediments was deposited under brackish water conditions in or near a Mangrove (*Rhizophora*) swamp. Then follow fresh-water swamp forests with *Ilex* and Melastomataceae, which are replaced again (probably caused by a slight relative rise of the sea level) by Mangrove forest (with some *Avicennia*). Thereafter brackish-water influence on the vegetation decreases, and the mangrove forest is replaced by a *Mauritia*-swamp, followed by vegetations in which Mimosaceae, *Cecropia* and Palms play an important part.

The diagram doubtlessly represents the upper part of the Holocene. It is not impossible that the lowest Mangrove-zone of the diagram corresponds to the "Atlantic" transgression of the nearby site at the loading canal of Kwakwani (see below), but the exact age of the different zones cannot yet be established with certainty. It may eventually be possible to correlate this diagram with that of the Torani-canal (C 14 dated) as is discussed below.

Kwakwani canal (Diagram VI)

The small loading-canal near Kwakwani (fig. 13) cuts through a terracelike body of clay, silt and sand, which gently slopes towards the river and rises some 8—10 feet above the water level. The river here is about 17 feet above mean sea level. A peaty layer is intercalated in the upper clayey sediments and also slopes towards the river,

Fig. 13. Berbice River and loading canal near Kwakwani. Taken from the air.

descending from a height of about 7 feet down to the water level (fig. 14 and 15). The clay on top of the peaty layer is iron-mottled and contains pollen only in its lowest part. Below the peat the clay is silty, becomes whitish when it dries, contains very small charcoal fragments, and includes pollen only in its uppermost part.

The diagram shows three clearly defined zones. In the clay below the peat the Gramineae (grasses) dominate, in the peaty clay *Rhizophora* is the principal pollen type, and in the clay above the peat other forest elements dominate completely. There is no doubt therefore that the peat layer corresponds to a transgressive phase. This transgression apparently took place here over a higher surface of already somewhat eroded older sediments, which must correspond in age to the Coropina formation (Würm-glacial surface; see discussion of Ogle Bridge diagram). During the transgressive phase, the Berbice River became a much broader stream, with a more "estuarine" character and distinct brackish-water influence. The water level

Fig. 14. Section with peat layer, exposed in bank of loading canal near Kwakwani.

Fig. 15. Peat layer exposed in bank of loading canal near Kwakwani, (detail).

at the time became at least as high as some 7 feet above the present (24′ above sea level). After that, fresh water flood-plain sediments were deposited up to an elevation of some 8—10 feet above the present flood plain. From these facts it will be clear that the relative sea level at that time must have been more than 7—8′ higher than today. The following C 14 analysis from the lowermost part of the peaty clay, dates the beginning of the "transgression" at this place:

GRN-3103 - Peaty clay, corresponding to samples 7a and 8 of the pollen section.
Canal, Kwakwani ———————— 6490 ± 80 years B.P.

Torani-canal (Diagram VII)

The Torani canal diagram deals with a section on the North bank of the canal between Berbice- and Canje-Rivers. At this point, between the recent flood-plain sediments of both rivers, it cuts through a higher remnant of the Old Coastal plain of the "Coropina-formation" (fig. 16). The waterlevel of the canal is 2 feet above main sea level. The exposure rising 10 feet above the high-water level, consists of iron-mottled clay resting on grey clay with brown silty clay-bands. In a sort of former gully in the upper mottled clay at the Canje side a peatlayer is found, again covered with mottled clay. The peat layer rises from some 2½ feet to 7½ feet above the high-water level. The pollen section was taken at this point, and is indicated on fig. 16. The mottled clay below the peat was formed, according to the diagram, in or near a *Rhizophora* mangrove swamp, and the peat itself was formed at the beginning of a "regression". The mottled clay above the peat shows higher percentages of fresh-water swamp-forest elements, and the *Rhizophora* percentage is very low, although it shows a second smaller maximum. The diagram seems to be comparable with that of the Berbice flood plain near Kwakwani (diagram V).

There is an interesting succession immediately after the "regression". First several open-swamp elements show somewhat higher percentages (Amaranthaceae, *Sagittaria*, *Typha*, Gramineae). Then follow successively an *Ilex* maximum, a *Mauritia* maximum and a Melastomataceae maximum. In the uppermost sample the Palmae seem to reach a maximum, but the quantity of pollen grains which could be counted was not sufficient to be sure.

A C 14 analysis was made of the peat, with the following result.

GRN-3136 - Peat, corresponding to sample 7 of pollen section I.
Torani Canal ———————— 6140 (± 75) years B.P.

This cipher corresponds consequently to the moment of sudden "regression" (or cessation of brackish-water influence) registered in the diagram. If the correlation of the *Rhizophora* maxima with those of the section of the Berbice flood plain near Kwakwani is correct, then the same date would correspond to the 12-feet level of this latter section.

A second section was taken in the North bank of the Torani Canal, nearer the Berbice and passed through the older clays with silty bands, but none of the samples contained sufficient pollen grains.

It seems to be clear that the results indicate that the water level during the formation of the peat rose at least 7′ higher than todays highwater level; the tidal, flood-plain or river deposits from shortly before or after that time reached as high as 10 feet, and were spred over older Coropina sediments. These ciphers agree remarkably well with those from the canal section near Kwakwani.

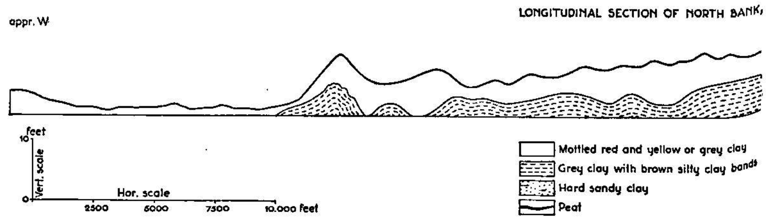


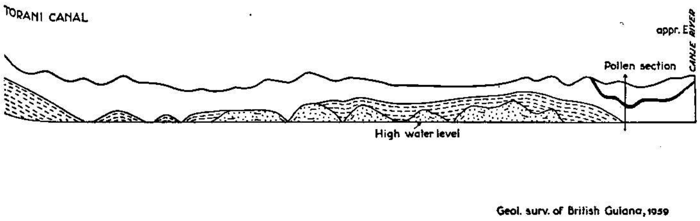
Fig. 16. Longitudinal section of the North bank of the Torani canal. The

Oreala, Corentyne River (Diagram VIII)

Near Oreala is a small remnant of an elevated plain, 15—25′ above main sea level, mapped by Bleackley (1957) as Coropina Formation (fig. 17). The white sand surface near that place is 40—45′ M.S.L. (fig. 18), and the floodplain of the Corentyne River 10—15′ M.S.L. The Coropina remnant is at one side eroded and visible in the high bank of the Corentyne River (fig. 19 and 20). Fig. 21 gives a sketch of the section exposed, and the locality where the pollen samples were taken. A peat layer slopes down from at least 7 feet to some two feet above the present river level and was apparently deposited in a gully eroded into older silty clay and silt. The gully was then filled up with clay, locally containing very thin silt layers, giving it a laminated appearance. As far as can be seen in the exposure the same clay also seems to cover the older sediments beside the gully. The height of the "cliff" is approximately 14 feet.

The diagram of pollen section I is directly comparable with that from the canal near Kwakwani. The lowest sample shows high Gramineae percentages, then

Fig. 17. "Coropina" surface (savanna) near Oreala (Corentyne river). White-sand plateau in the background.



Place of the pollen section (with peat horizon) is indicated at right.

the Mangrove elements come to dominate completely. In the upper part they decrease again and other forest elements increase. The upper part of the sediments are probably flood-plain deposits. An interesting feature is the high Fungi maximum just at the beginning of the "transgression" in both the Kwakwani canal and the Oreala diagrams.

The samples from section II (see fig. 21), from the older sediments below the peat, contained in general so little pollen that no diagram could be made. Only the uppermost sample (II-10) contained sufficient material.

Sample II-10

Rhizophora 2 % — Other trees 29 % — Gramineae 69 % (*Mauritia* 1 %, Cyperaceae 2 %, Trilete spores 1 %, Fungi 15 %)

The chronological position of this sample must be immediately below sample 2 of section I.

In the next deeper samples the following numbers of grains were found.

Sample II-9 (20 cm. below II-10)

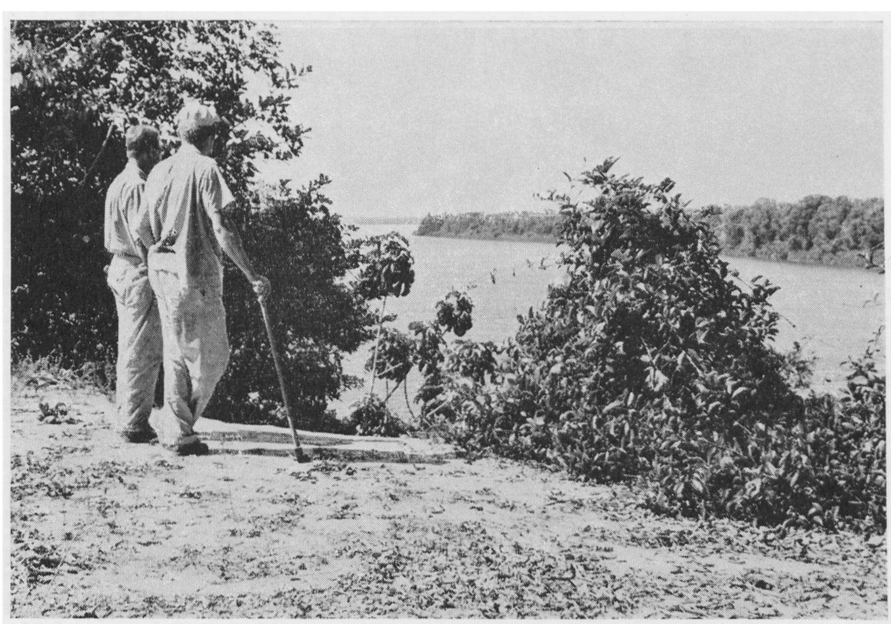


Fig. 18. View from the white sand plateau near Oreala over the Corentyne river.

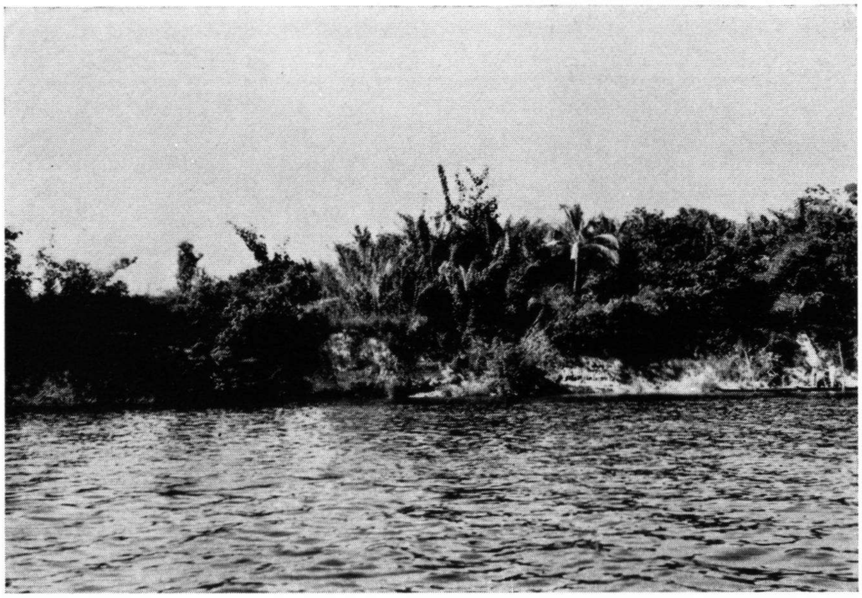


Fig. 19. Bank of the Corentyne river near Oreala ("Coropina formation" and Holocene peat and clay).

Fig. 20. Bank of the Corentyne river near Oreala. Detail of fig. 19.

Rhizophora 0 — Other trees 17 — Gramineae 6 — Cyperaceae 1 — *Alnus* 1 — Trilete 1.

Sample II-8 (40 cm. below II-10)
Rhizophora 3 — Other trees 13 — Gramineae 3
(*Spathiphyllum* type 3 — Monolete 2 — Fungi 9).

The "transgression" could be again dated here with a C 14 analysis from the base of the peat:

GRN 3109 - Base of peat layer in gully in Coropina clay. It corresponds to sample 4 of pollen section I. Oreala, high bank of Corentyne-River
———————————— 6470 (± 85) years B.P.

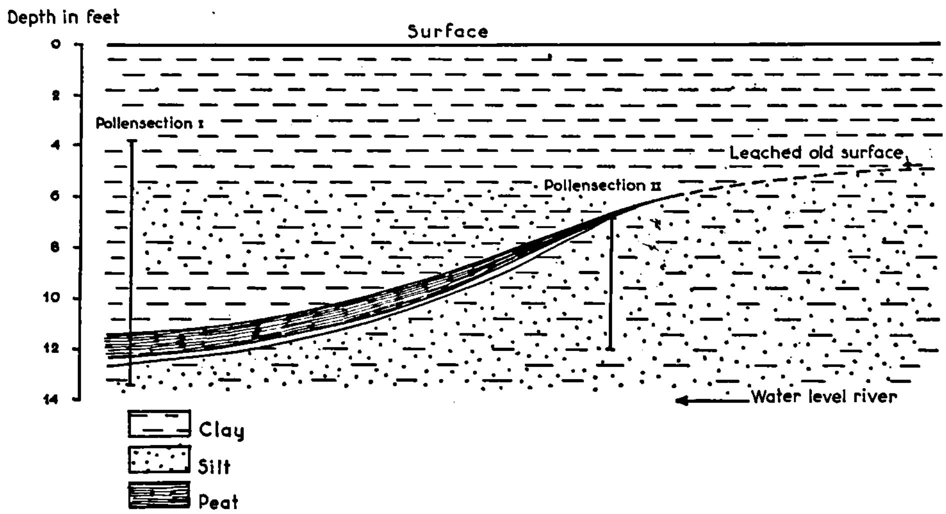


Fig. 21. Sketch of section in the bank of the Corentyne river near Oreala.

This date differs only in 20 years (much less than the possible statistical error) from the date of the base of the peat in the bank of the canal near Kwakwani. According to the maximum height of the peat layer, the water level at the time of the peat formation must have been at least 7 feet above the present, and the maximum height of the Holocene flood-plain deposits on top of the Coropina was approximately 14 feet higher than the actual low-tide level (probably some 12 feet above the actual flood plain).

It would be important to know how long the sedimentation of Holocene sediments on top of the Coropina continued. The lamination of the clay in the gully (between 6′ and 9′, see fig. 21) is probably seasonal. If this is true, then the number of units may give an idea of the time involved in the sedimentation of the whole ± 12 feet of sediments on top of the peat. Each unit (clayey and silty part) is about 3 mm thick ($\frac{1}{8}''$) (this cipher agrees very well with the average rate of sedimentation of the Holocene of Ogle Bridge, which is approximately 2,5 mm per year). The deposition of the whole 12 feet would then have taken place in some 1100 years, and the date for the end of sedimentation on top of the Coropina would then be approximately 5400 B.P., a cipher very near to that of the Atlantic-Subboreal boundary in Europe.

GEOLOGICAL (AND VEGETATIONAL) HISTORY

The age of the Upper Sands is not yet precisely known, but should be Pliocene or Lower Pleistocene, according to palynological data. They correspond to the Mackenzie Formation of the white-sand plain. They were probably deposited in a ± deltaic or fluvial environment and mainly above the sea level of that time. Comparison with the kind of sediments of the Upper Quaternary in the coastal area shows that the conditions must have been considerably different. Nota (1958) mentions Würm-glacial deposition of sandy sediments by braided rivers behind the Würm-glacial coast line, on the present shelf. It may be that the Upper Sands (Mackenzie formation) were deposited under such conditions during the Lower Pleistocene, but it seems that it also could be related to tectonic movements in the "hinterland" during the Pliocene (and eventually Lower Pleistocene), related with the great Andean orogenetic movements.

The deposition of these sands was followed by an erosional phase, during which valleys were cut in the original surface (see fig. 2). The coastal area was then subjected to the successive transgressions and regressions of various interglacials and glacials during the Pleistocene, and to subsidence. During the glacial regressions, valleys were cut into the sediments, and some red and yellow mottled clay was deposited, probably in valleys during moderately low positions of the sea level. During the interglacial transgressions vast areas were inundated and principally grey, dark grey or blue clays were deposited in the coastal area and far in the river valleys. Much of the older sediments must have been removed, and a true picture of the several successive drowned and covered old land surfaces would probably be rather complicated. A great number of boreholes will have to be studied palynologically if it is to be properly understood and if the age of the remnants of sediments of older interglacials is to be determined.

From the data available at present, we may deduce that the bulk of the material now found above the Upper Sands, was deposited during the Riss-Würm interglacial, the Würm-glacial and the Holocene. From these same data we may now deduce also an approximate rate of subsidence, since all the sediments with abundant *Rhizophora*, *Avicennia* and *swamp forest elements* were laid down not far above or below the sea level at that time. If we take the original top of the Riss-Würm interglacial sediments near Georgetown at maximal 85′ below the present sea level, and the length of time since the end of this interglacial as 75.000 years, then the average rate of subsidence would be a *maximal* 3.5 cm per 100 years. It is interesting to note that Jelgersma (1961) calculated values between 1.5 and 3.5 cm per 100 years for the Dutch coast during the same lapse of time.

During the Riss-Würm interglacial the sea invaded the present coastal area, up to the border (scarp) of the present white-sand plain, and entered the river valleys, deeply eroded during the preceding glacial (fig. 22). The present scarp, which forms the northern limit of the white sand plain, must have been formed by the retrogressive erosion of rivers and creeks during the glacials, and was possibly accentuated by wave-action along an abrading coast during the times of highest interglacial sea level.

During the present studies minor fluctuations of sea level have been registered pollen-analytically, but as a whole the sedimentation, principally of clays and some silt, had a near-coast character, and the coastal vegetations did not differ very much from those today. Towards the beginning of the Würm glacial, the sea began to recede, and erosion of the interglacial sediments started. These were almost completely removed from the river valleys, and only remnants remained. The Demerara river valley near Mackenzie was eroded 120′ deeper than the present river level. Between the main river valleys the sediments were dissected by erosion of smaller

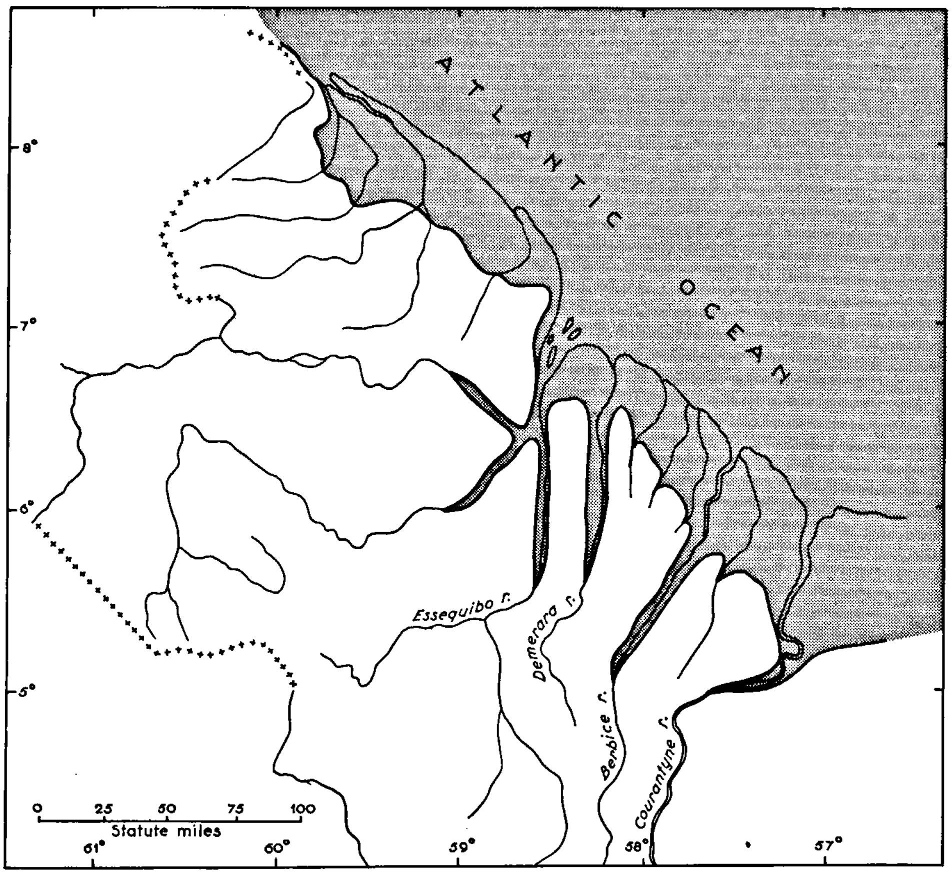


Fig. 22. Extension of the sea in British Guiana during the Riss-Würm Interglacial. The situation during the highest holocene sea level was almost the same.

creeks, leaving the higher "old coastal plain" divided into "islands" of what we now call "Coropina Formation". During the Würmglacial maxima of the northern latitudes, the sea level fell considerably, probably more than 70 meters, but during longer interstadial intervals, the sea level must have been considerably higher, and mottled clays and silts could be deposited locally.

Soil formation was strong in the clays well above sea level. Pollen were often destroyed or damaged in the upper part of the exposed interglacial clays and in the sediments of Würm age.

Nota (1958) discovered a former coastline at approximately 30—40 fathom depth (± 180—240′ or ± 55—73 metres) on the Western Guiana shelf, and indications of still lower positions of the sea level. Reef-like features, related to the former position of the sea level, were, shown by C 14 dating (Nota, 1958) to be between 17550 ± 110 and 11560 ± 240 years B.P. From this may be deduced that the rise of sea level from this shore line started approximately at the beginning of the Late glacial Alleröd-interstadial. Nota mentions another important fact for the reconstruction of the situation during the Würm glacial. He found very sandy fluvial braided-river deposits of Pleistocene age on the shelf, directly behind the drowned coast line. He supposes that the provenance of this sand may be in the white sand area of British Guiana, eroded and transported by the big Guianese rivers, at the time of the lowered sea level. This agrees very well with the important Würm glacial incision of the Guianese rivers that has been noted.

The vegetation during the Würm glacial cannot yet be fully interpreted, but the pollenanalysis already gives some important information. Along the coast and the river mouths there was doubtless a Mangrove zone with swamp and marshes directly behind. Müller (1959) gives a pollen spectrum from a sample at 1 m below the bottom surface on the shelf East of Trinidad, which has a corresponding C 14 age of 17820 ± 600 years. The water depth in that area is approximately 40 metres. The very high pollen and Fungi content shows that the material was deposited very near the shore. Analysis showed 27 % of *Rhizophora*, 2 % *Terminalia*, 1 % *Malpighiaceae*, 1 % *Anacardium*, 3 % *Acrostichum* and 66 % Varia.

On the clay soil of the present mainland of British Guiana, dissected by erosion gullies and valleys and high above the sea level, extensive grass savannas developed, apparently extremely poor in species. Gramineae (and sometimes Cyperaceae) were the predominating element. In one case a few *Humiria* grains were found. Although no definite conclusions can be drawn from the data yet available, it seems that a pluvial climate with one or two dry stations may have prevailed.

The peculiar circumstance of a clay soil high above sea level may have been the result of long inundation during the wet seasons and complete and deep drying out of the soil during the dry seasons.

On sloping plains soil material apparently washed down and accumulated in gullies and minor valleys. Oxidation during the drying out of the soil often destroyed the pollen grains. Little can be said of the vegetation of this time on the white-sand plains which must have been considerably influenced by the greater permeability of the soil.

The effect of the lower temperature on the tropical vegetation is still a very important question to be resolved.

In central America a poor type of savanna with Guianese species is known, at relatively high elevations (Lötschert, 1959). This type recalls the poor savanna from the Würm glacial at Ogle. If future more detailed studies should prove this supposed relationship to be true, then we would perhaps have found a suggestion of lower Würm glacial temperatures in British Guiana. It is also probable that by comparison of the pollen analysis of a great number of samples from the Würm-glacial coastal sediments from the shelf with those of the present coast, other important data would come to light.

A tentative reconstruction of northern British Guiana during the Würm glacial is given in fig. 23.

When the late glacial ("postglacial") rise of sea level started, the Würm glacial land surface was rapidly and progressively covered by the sea, which first entered the deep valleys and later covered higher parts. The Demerara river valley was, for instance, already flooded, at least as far up as Mackenzie, when the sea level had risen to some 120′ (36 metres) below the present. This must have been between ± 11.500 and ± 8600 B.P. (when the surface at Ogle Bridge was already flooded), and most probably at the very beginning of the Holocene or towards the end of the Late glacial. There was apparently a short interruption in the rise when 72′ (22 metres) level below the present was reached (12 fathom level of Nota, 1958). This depth corresponds almost exactly with the top of the Würm surface near Ogle Bridge, which was flooded earlier than 8600 B.P. (possibly around 9500 B.P.).

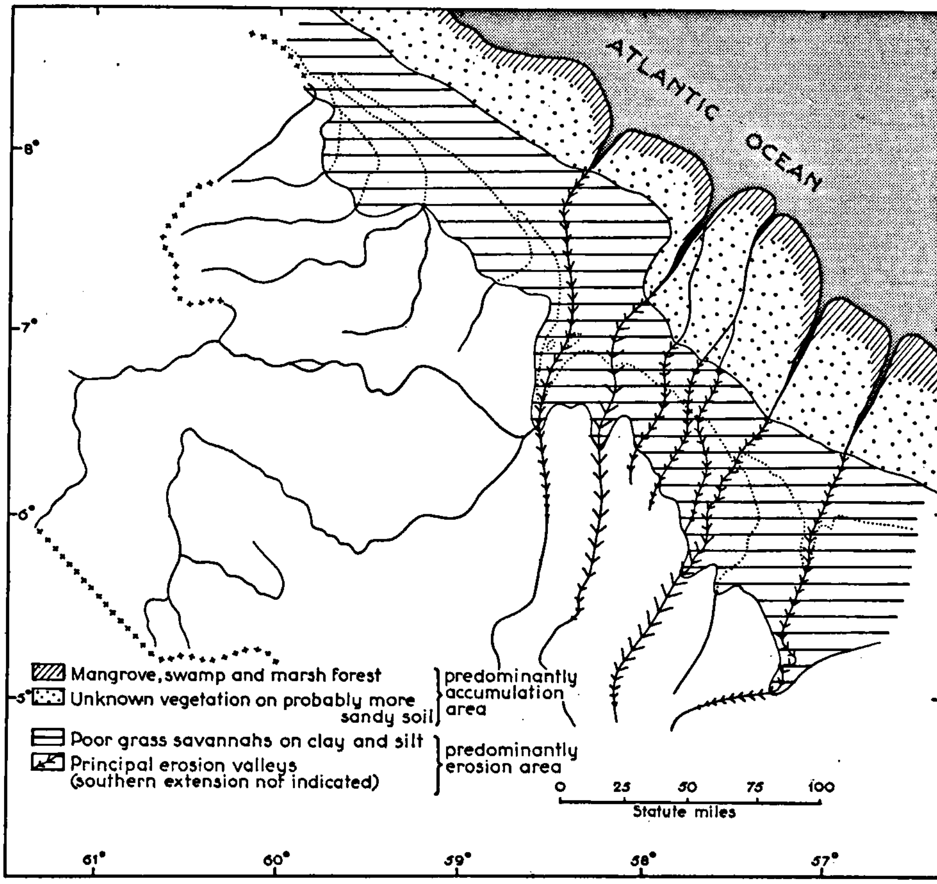


Fig. 23. Tentative reconstruction of northern British Guiana during the Würm-glacial. The course of the rivers over the present shelf is guessed, and the extension of vegetational areas is principally tentative.

If we take into consideration moreover the fact that some subsidence must have taken place since that time in our area, a date of ± 8000 as proposed by Nota for the 12 fathom level seems to be a little too young. A date nearer to the Late-glacial-Holocene boundary would now seem to fit better. The Holocene transgression culminated about 6500 B.P., flooding Coropina areas at least 7′—8′ above present water level (the situation was almost like the Riss-Würm interglacial, fig. 22). The salt water influence high up in the actual river valleys then diminished around 6000 B.P. But flood-plain sediments were deposited up to at least 10′ above the present flood plains, until a date very near to 5000 B.P.

It transpires that a considerable part of the Old Coastal plain was inundated during the late "Atlantic" transgression, leaving a younger cover of Holocene clays and silts on top of the Coropina formation. We may conclude that there was in British Guiana a late "Atlantic" transgression, with a relative sea level of at least 8′ (2,5 m) higher than today, followed by a minor regression around 5000 B.P. (early "Subboreal" regression).

In the coastal diagrams the early "Subboreal" regression may correspond to the sandy layer (base 28—26′ below the actual surface), which perhaps indicates the onset of near-coast conditions (pollen associations). After this regression, the relative rise of sealevel must have started again, and, although probably with several minor fluctuations, has apparently continued until the present time.

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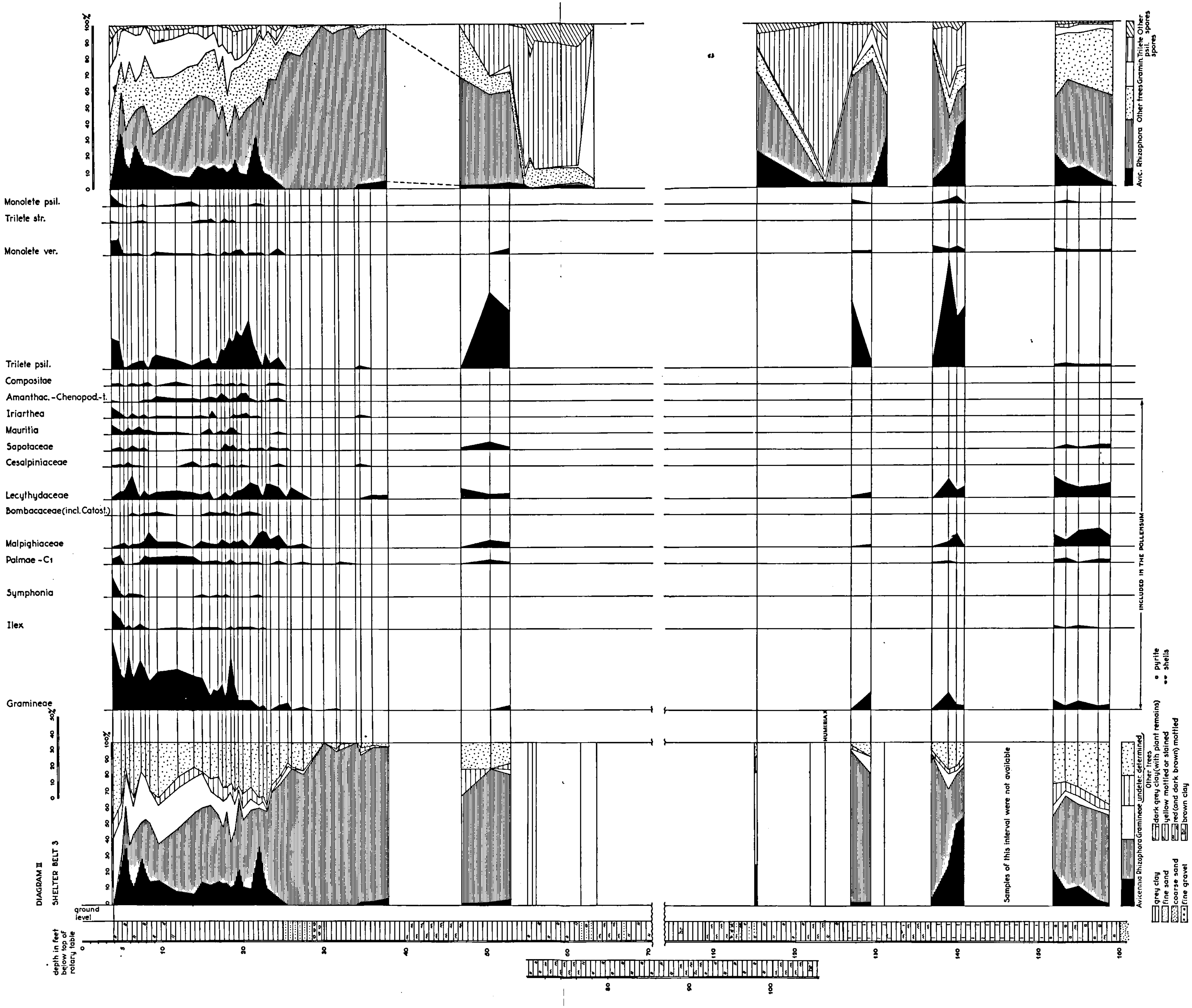


Monolete psil.
Trilete str.
Monolete ver.
Trilete psil.
Compositae
Amanthac.-Chenopod.-t.
Iriarthea
Mauritia
Sapotaceae
Cesalpiniaceae
Lecythydaceae
Bombacaceae(incl.Catost.)
Malpighiaceae
Palmae - C1
Symphonia
Ilex
Gramineae
Avic. Rhizophora Other trees Gramin. Trilete psil. Other spores
INCLUDED IN THE POLLENSUM
pyrite
shells
HUMIRIA X
Samples of this interval were not available
Avicennia Rhizophora Gramineae undeter. determined Other trees
DIAGRAM II
SHELTER BELT 3
ground level
depth in feet below top of rotary table
grey clay
fine sand
coarse sand
fine gravel
dark grey clay (with plant remains)
yellow mottled or stained
red (and dark brown) mottled
brown clay

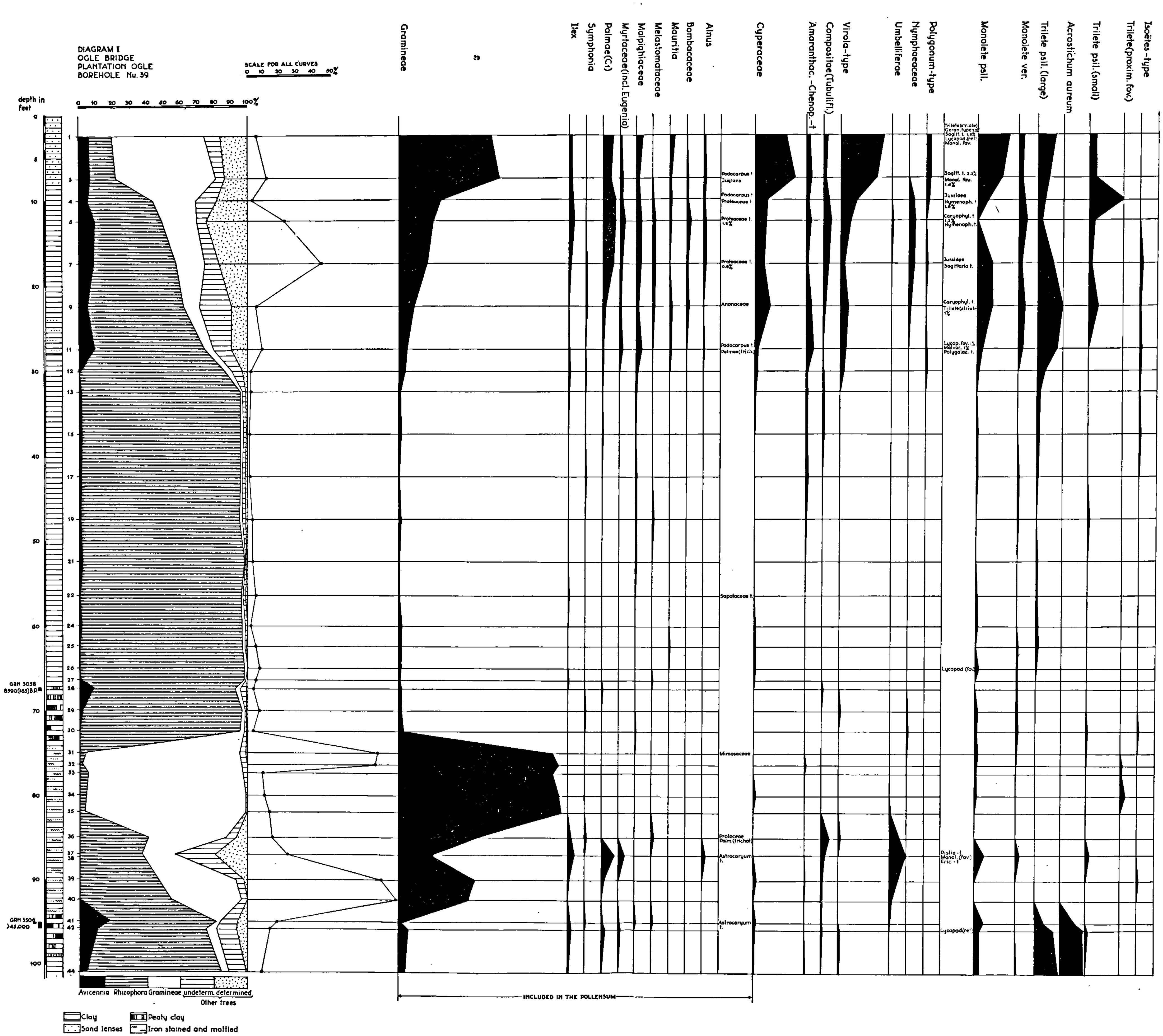


DIAGRAM I
OGLE BRIDGE
PLANTATION OGLE
BOREHOLE Nu. 39
SCALE FOR ALL CURVES
0 10 20 30 40 50%
depth in feet
0 10 20 30 40 50 60 70 80 90 100%
Gramineae
Ilex
Symphonia
Palmae(C.t)
Myrtaceae(incl. Eugenia)
Malpighiaceae
Melastomataceae
Mauritia
Bombacaceae
Alnus
Cyperaceae
Amaranthac.-Chenop.-t
Compositae(Tubulifl.)
Virola-type
Umbelliferae
Nymphaeaceae
Polygonum-type
Monolete psil.
Monolete ver.
Trilete psil. (large)
Acrostichum aureum
Trilete psil. (small)
Trilete(proxim. fov.)
Isoëtes-type
GRN 3058
8590(±65) B.P.
GRN 3506
>45,000
Avicennia
Rhizophora
Gramineae
undeterm.
determined
Other trees
Clay
Sand lenses
Peaty clay
Iron stained and mottled
INCLUDED IN THE POLLENSUM
Podocarpus t.
Juglans
Proteaceae t.
Anonaceae
Palmae(trich.)
Sapotaceae t.
Mimosaceae
Astrocaryum t.
Lycopod.(fov.)
Lycopod.(ret.)
Jussiaea
Sagittaria t.
Caryophyl. t.
Hymenoph. t.
Trilete(striate)
Pistia-t
Eric.-t

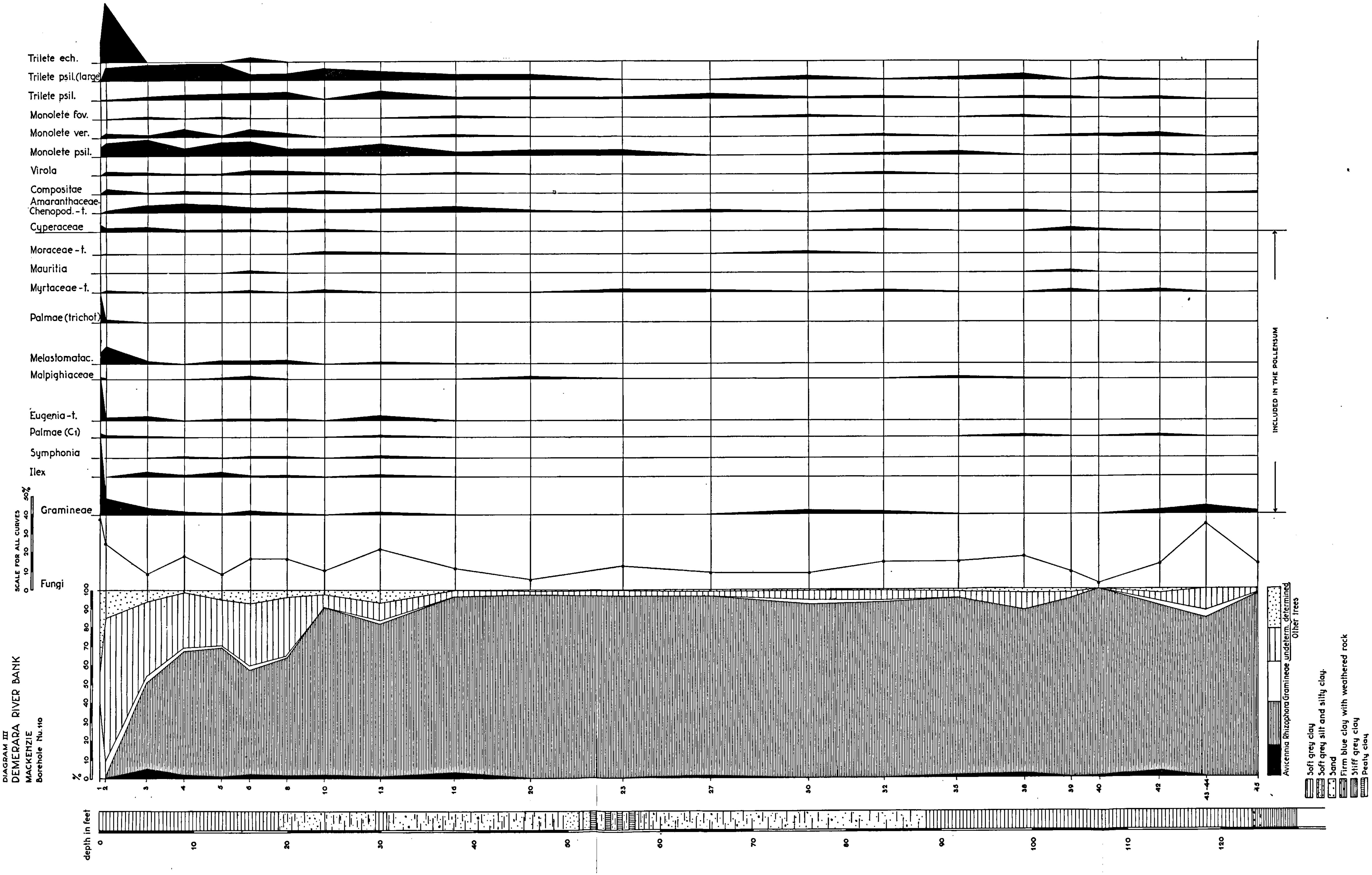


DIAGRAM III
DEMERARA RIVER BANK
MACKENZIE
Borehole No. 110
Trilete ech.
Trilete psil. (large)
Trilete psil.
Monolete fov.
Monolete ver.
Monolete psil.
Virola
Compositae
Amaranthaceae-Chenopod.-t.
Cyperaceae
Moraceae-t.
Mauritia
Myrtaceae-t.
Palmae (trichot)
Melastomatac.
Malpighiaceae
Eugenia-t.
Palmae (C1)
Symphonia
Ilex
Gramineae
Fungi
SCALE FOR ALL CURVES
INCLUDED IN THE POLLENSUM
Avicennia
Rhizophora
Gramineae
undeterm.
determined
Other trees
Soft grey clay
Soft grey silt and silty clay.
Sand
Firm blue clay with weathered rock
Stiff grey clay
Peaty clay
depth in feet

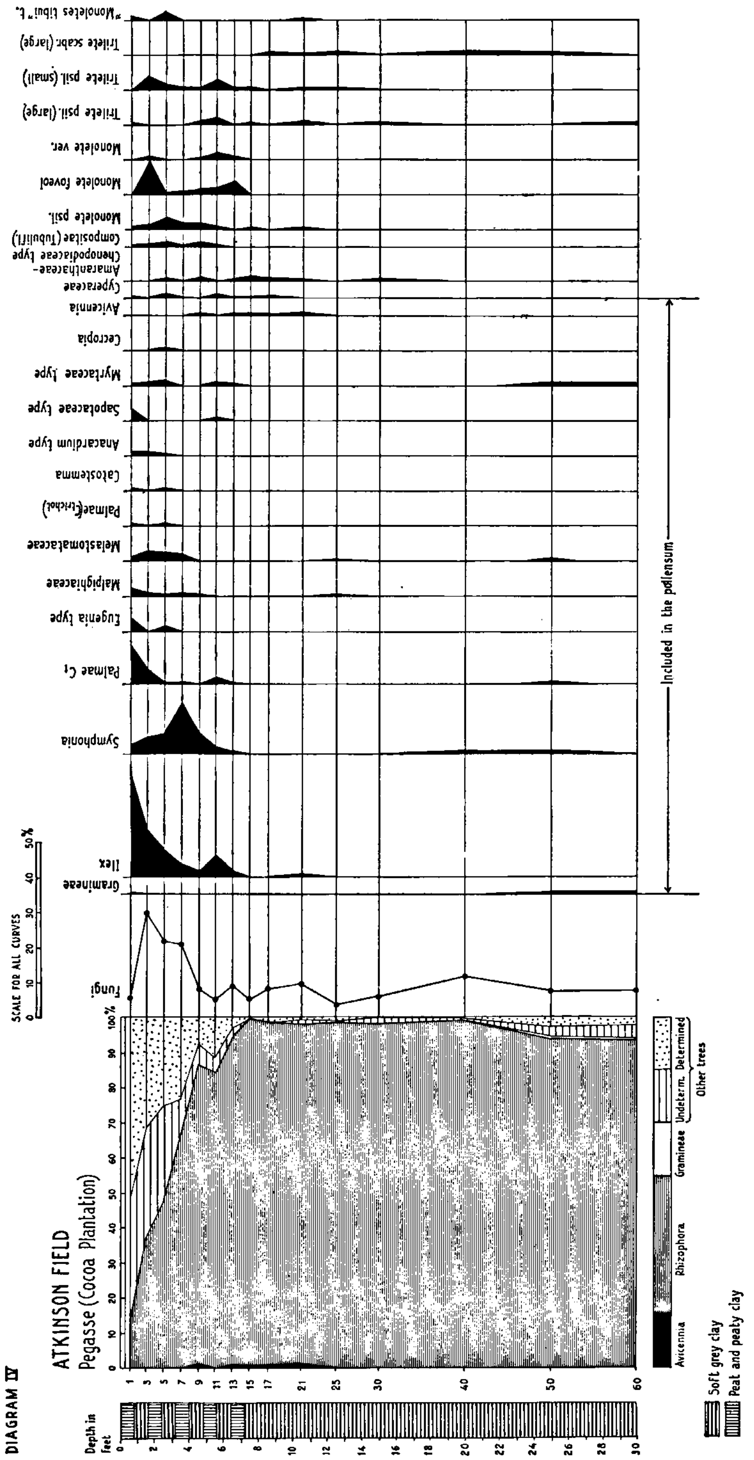
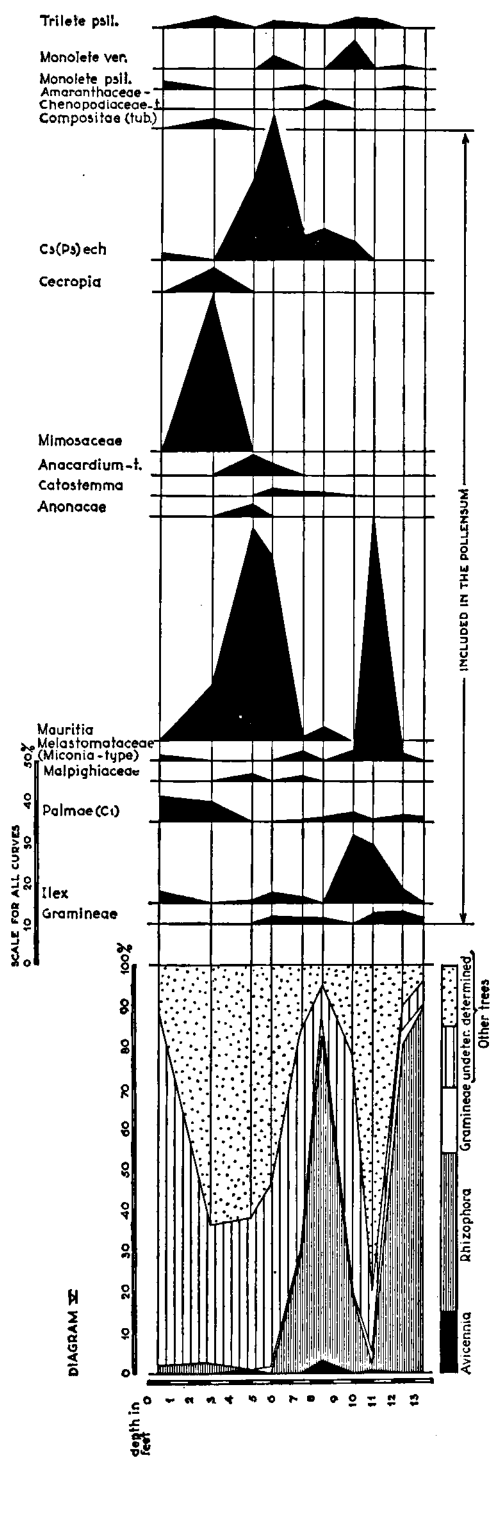
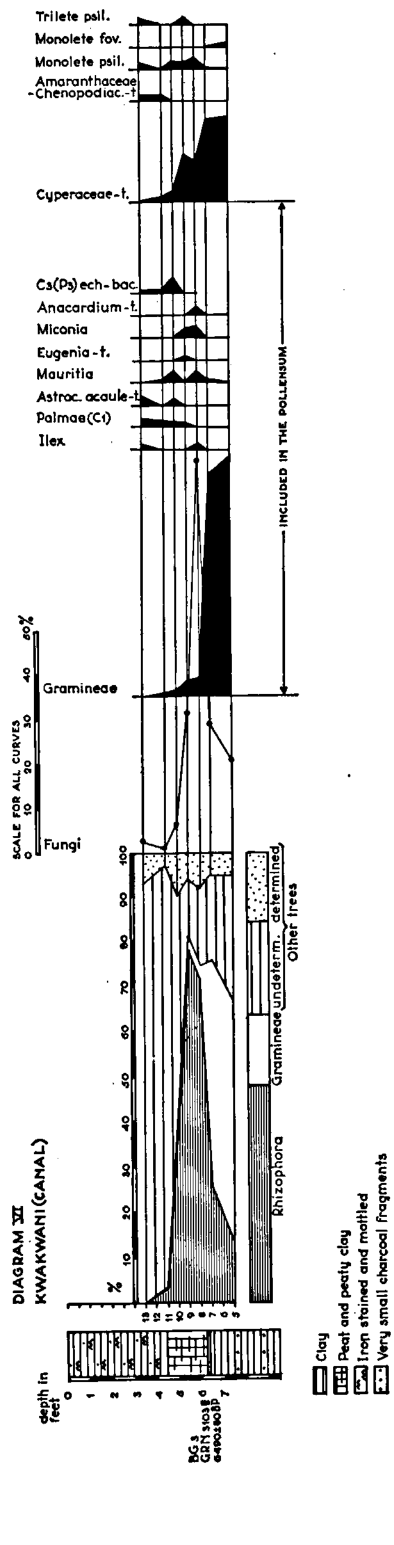
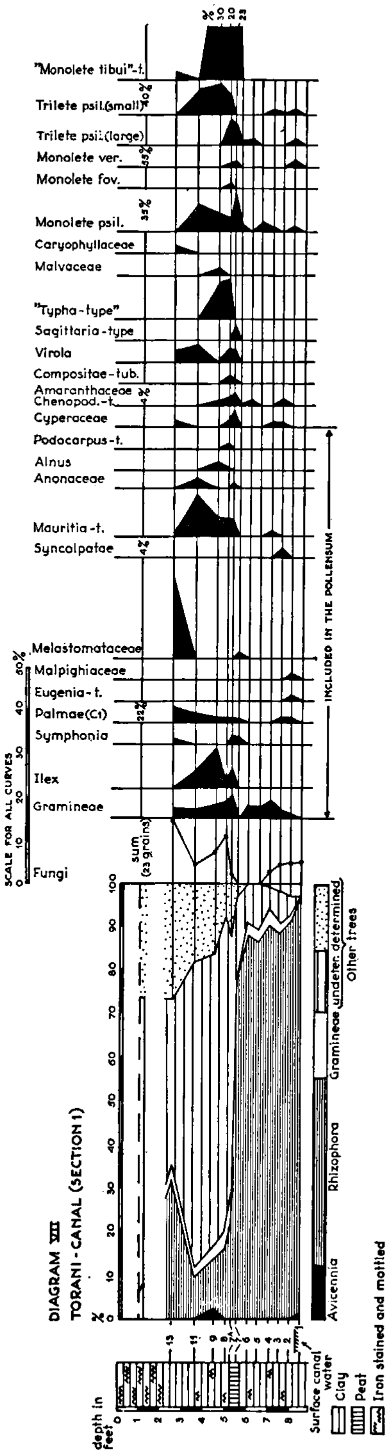
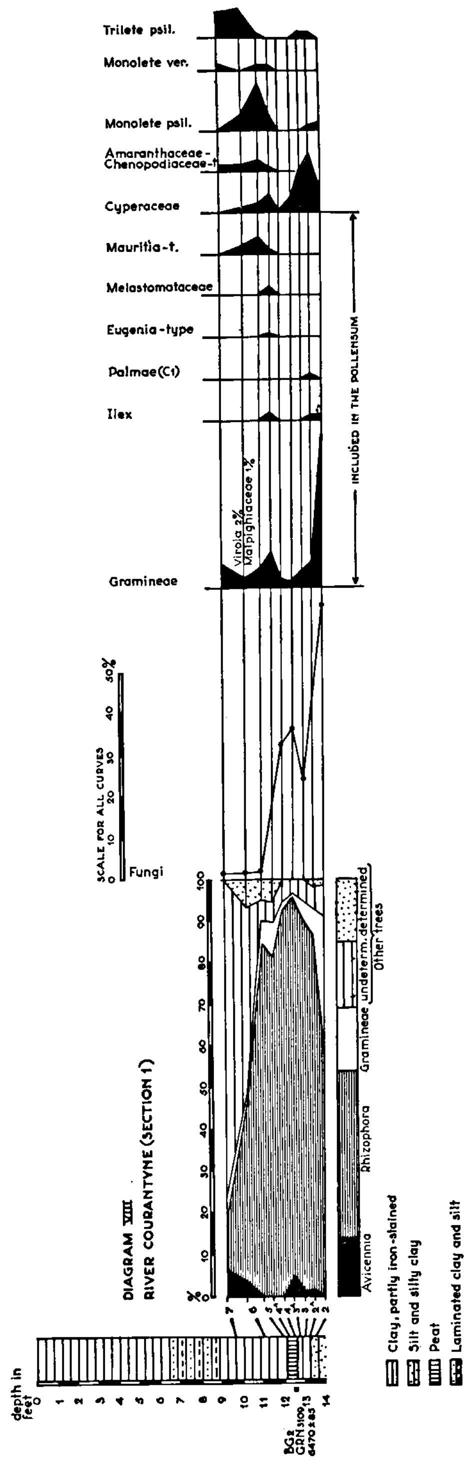

ATKINSON FIELD
Pegasse (Cocoa Plantation)
Depth in feet
SCALE FOR ALL CURVES
Fungi
Gramineae
Ilex
Symphonia
Palmae C1
Eugenia type
Malpighiaceae
Melastomataceae
Palmae (trichot.)
Catostemma
Anacardium type
Sapotaceae type
Myrtaceae type
Cecropia
Avicennia
Cyperaceae
Amaranthaceae-Chenopodiaceae type
Compositae (Tubuliff.)
Monolete psil.
Monolete foveol
Monolete ver.
Trilete psil. (large)
Trilete psil. (small)
Trilete scabr. (large)
"Monoletes tibui" L.
Included in the pollensum
Avicennia
Rhizophora
Gramineae
Undeterm.
Determined
Other trees
Soft grey clay
Peat and peaty clay

DIAGRAM IV


Trilete psil.
Monolete ver.
Monolete psil.
Amaranthaceae - Chenopodiaceae-t.
Compositae (tub.)
Cs(Ps) ech
Cecropia
Mimosaceae
Anacardium-t.
Catostemma
Anonacae
Mauritia
Melastomataceae (Miconia-type)
Malpighiaceae
Palmae (C1)
Ilex
Gramineae
INCLUDED IN THE POLLENSUM
SCALE FOR ALL CURVES
Avicennia
Rhizophora
Gramineae
undeter. determined
Other trees
DIAGRAM V
depth in feet


Trilete psil.
Monolete fov.
Monolete psil.
Amaranthaceae -Chenopodiac.-t
Cyperaceae-t.
Cs(Ps) ech-bac.
Anacardium-t.
Miconia
Eugenia-t.
Mauritia
Astroc. acaule-t.
Palmae (C1)
Ilex
Gramineae
Fungi
INCLUDED IN THE POLLENSUM
SCALE FOR ALL CURVES
Rhizophora
Gramineae
undeterm. determined
Other trees
DIAGRAM VI
KWAKWANI (CANAL)
depth in feet
Clay
Peat and peaty clay
Iron stained and mottled
Very small charcoal fragments


"Monolete tibui"-t.
Trilete psil.(small)
Trilete psil.(large)
Monolete ver.
Monolete fov.
Monolete psil.
Caryophyllaceae
Malvaceae
"Typha-type"
Sagittaria-type
Virola
Compositae-tub.
Amaranthaceae Chenopod.-t.
Cyperaceae
Podocarpus-t.
Alnus
Anonaceae
Mauritia-t.
Syncolpatae
Melastomataceae
Malpighiaceae
Eugenia-t.
Palmae(C1)
Symphonia
Ilex
Gramineae
Fungi
SCALE FOR ALL CURVES
INCLUDED IN THE POLLENSUM
sum (23 grains)
Avicennia
Rhizophora
Gramineae
undeter. determined
Other trees
DIAGRAM VII
TORANI-CANAL (SECTION 1)
depth in feet
Surface canal water
Clay
Peat
Iron stained and mottled


Trilete psil.
Monolete ver.
Monolete psil.
Amaranthaceae - Chenopodiaceae-t.
Cyperaceae
Mauritia-t.
Melastomataceae
Eugenia-type
Palmae(C1)
Ilex
Virola 2%
Malpighiaceae 1%
Gramineae
INCLUDED IN THE POLLENSUM
SCALE FOR ALL CURVES
Fungi
Avicennia
Rhizophora
Gramineae
undeterm. determined
Other trees
DIAGRAM VIII
RIVER COURANTYNE (SECTION 1)
depth in feet
Clay, partly iron-stained
Silt and silty clay
Peat
Laminated clay and silt

PLATES

PLATE I

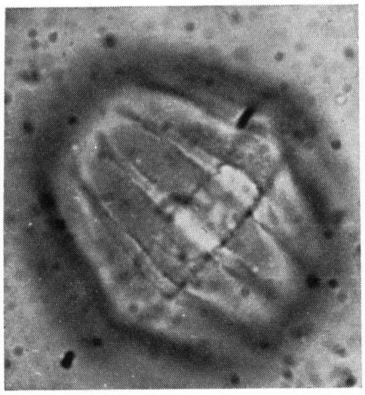
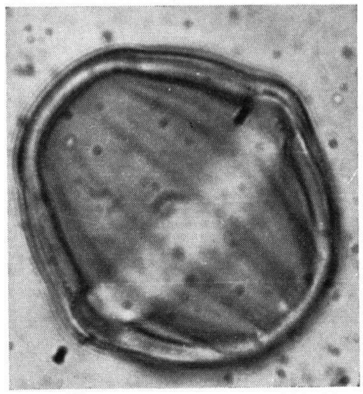



Fig. 1 Fig. 2

Polygala

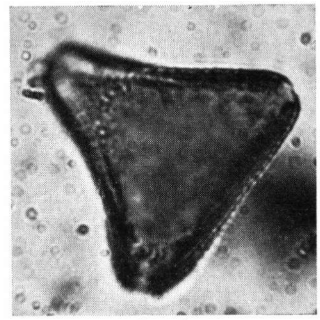


Fig. 3

Proteaceae

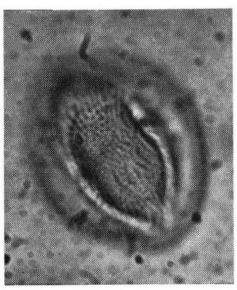
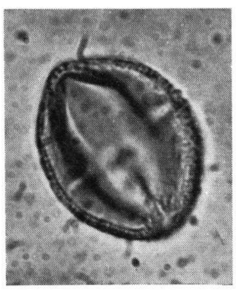



Fig. 4 Fig. 5

Anacardiaceae (500 ×)

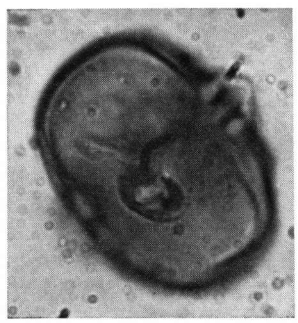
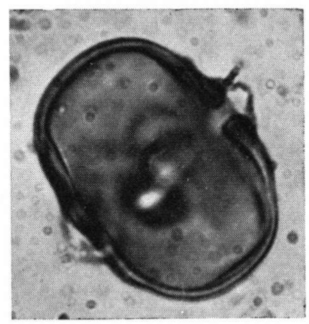



Fig. 6 Fig. 7

Caesalpiniaceae

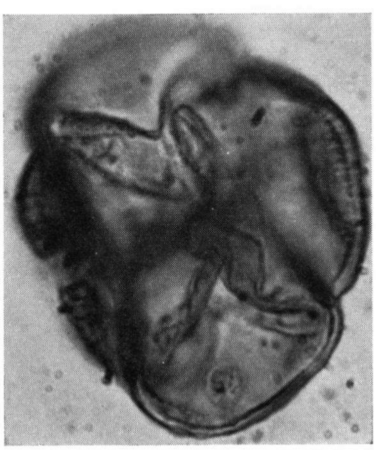


Fig. 8

Mimosaceae

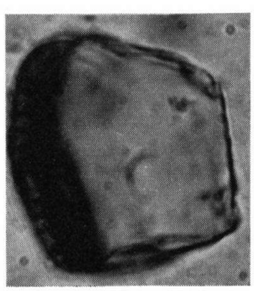


Fig. 9

Mimosaceae

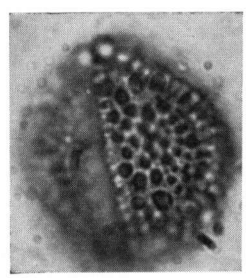
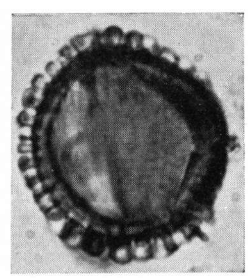



Fig. 10 Fig. 11

Ilex

1000 ×

PLATE II

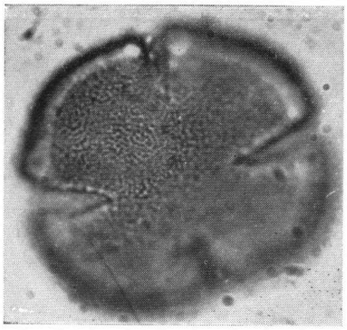


Fig. 1

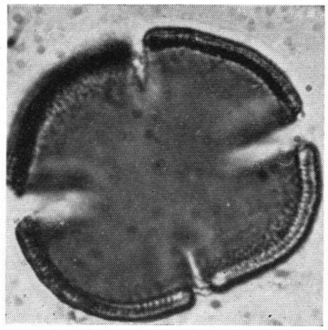


Fig. 2

Catostemma

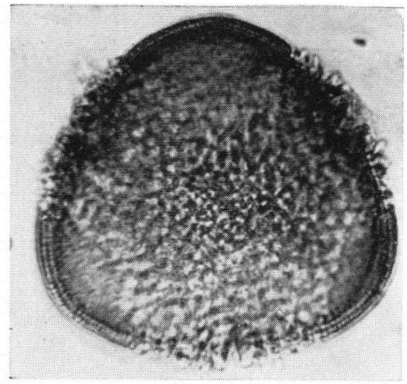


Fig. 3
Bombax

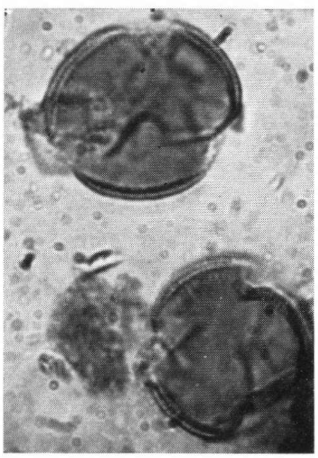


Fig. 4
Lecythidaceae

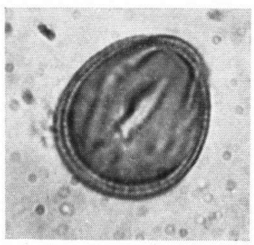


Fig. 5
Lecythidaceae

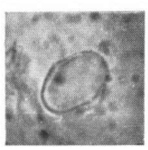


Fig. 6
Cecropia

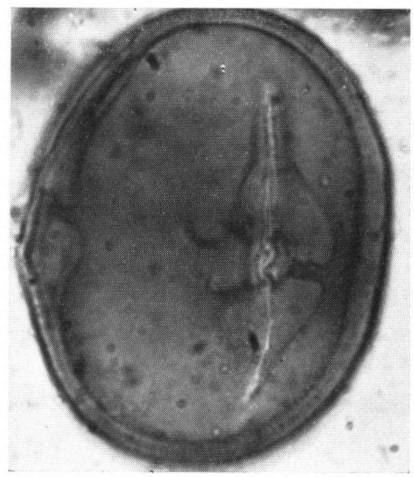


Fig. 7
Sapotaceae

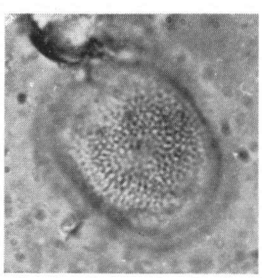


Fig. 8

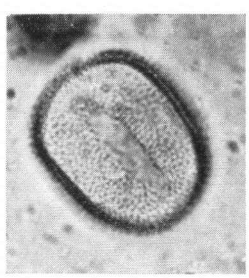


Fig. 9

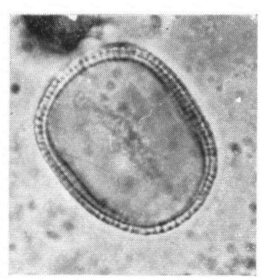


Fig. 10

Virola

1000 ×

PLATE III

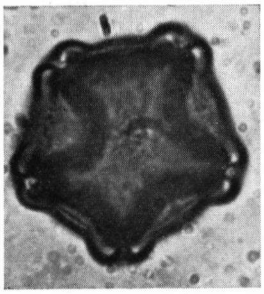
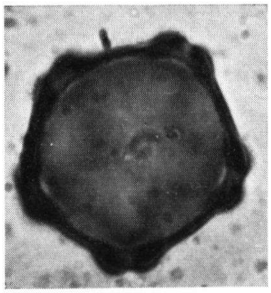



Fig. 1 Fig. 2
Alnus

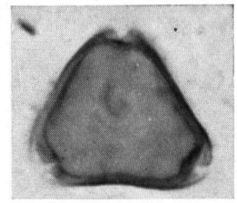



Fig. 3 Fig. 4
Myrtaceae

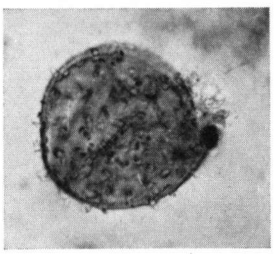
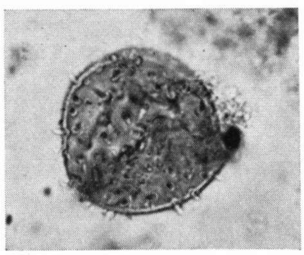



Fig. 5 Fig. 6
Mauritia (500 ×)

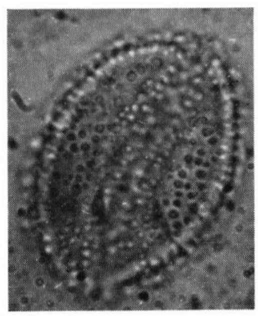
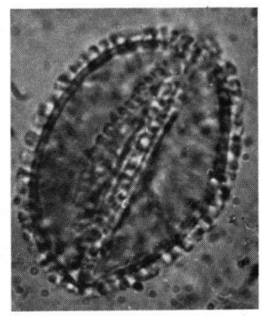



Fig. 7 Fig. 8
Iriartea

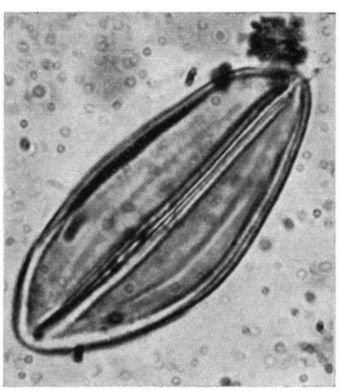


Fig. 9
Palmae

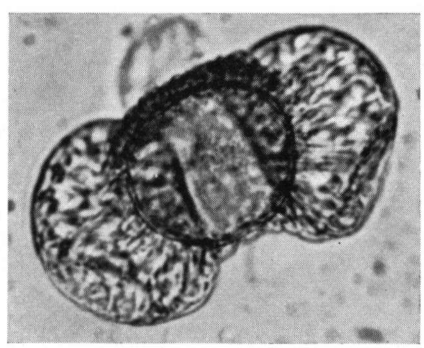


Fig. 10
Podocarpus

1000 ×

PLATE IV

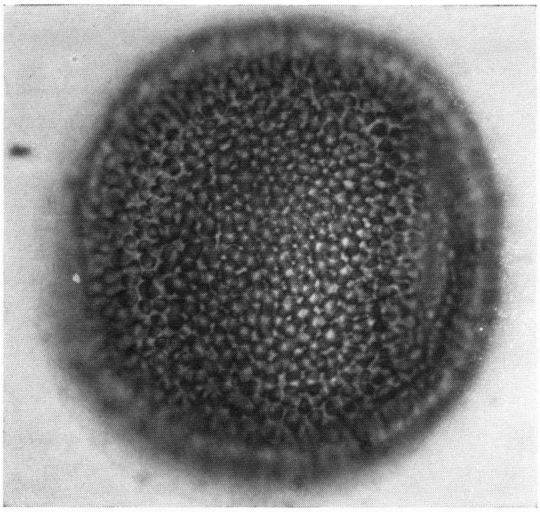


Fig. 1

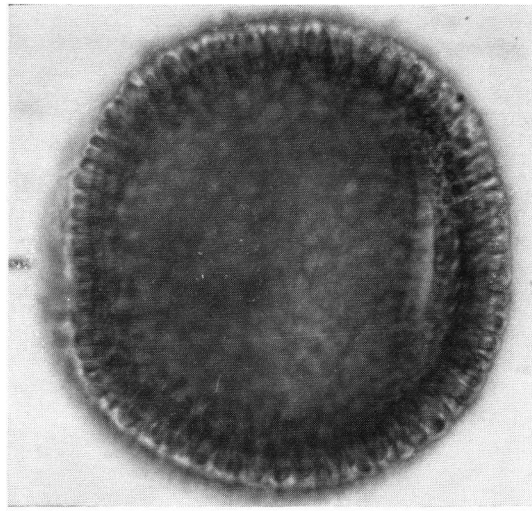


Fig. 2

Geranium

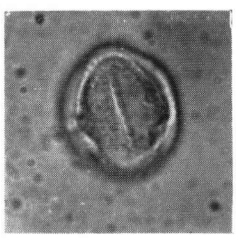


Fig. 3

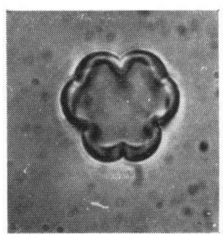


Fig. 4

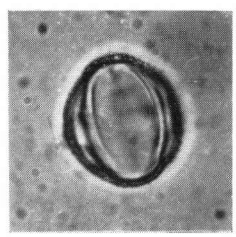


Fig. 5

Melastomataceae

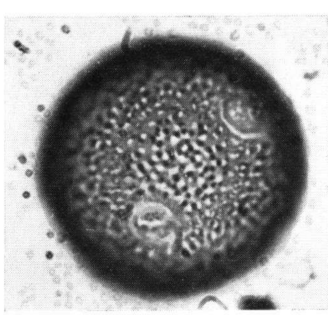


Fig. 6

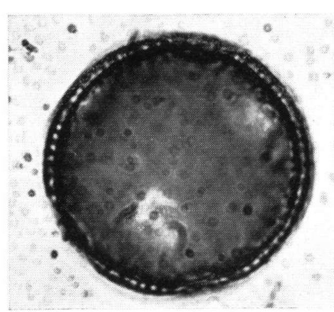


Fig. 7

Caryophyllaceae

1000 ×

PLATE V

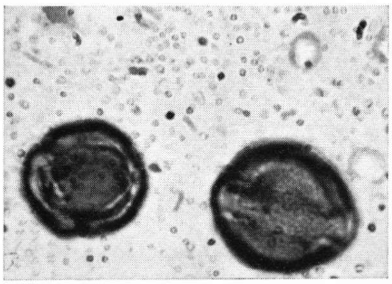


Fig. 1

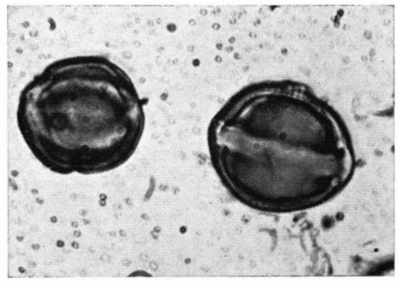


Fig. 2

Rhizophora harrisonii

Fig. 3

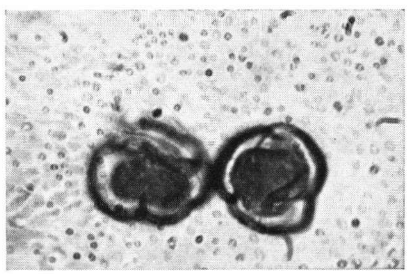


Fig. 4

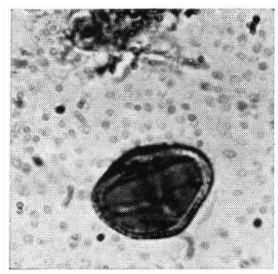


Fig. 5

Rhizophora mangle

Fig. 6

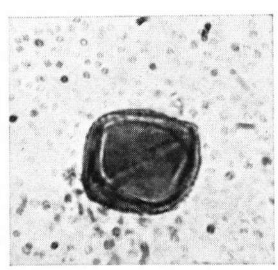


Fig. 7

Rhizophora racemosa

1000 ×

PLATE VI


Fig. 1

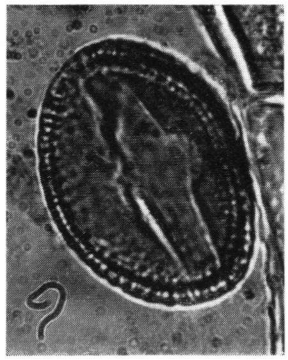


Fig. 2

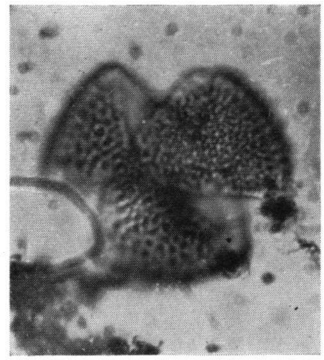


Fig. 3

Avicennia

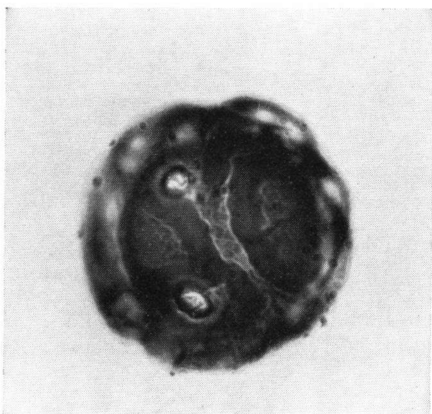


Fig. 4

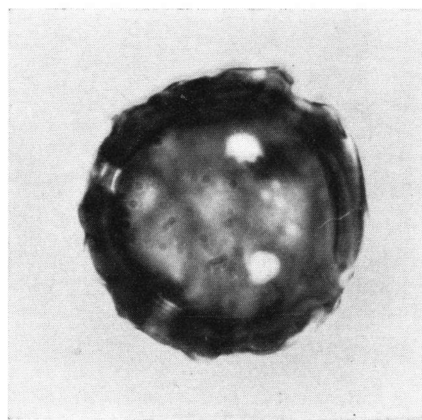


Fig. 5

Malpighiaceae

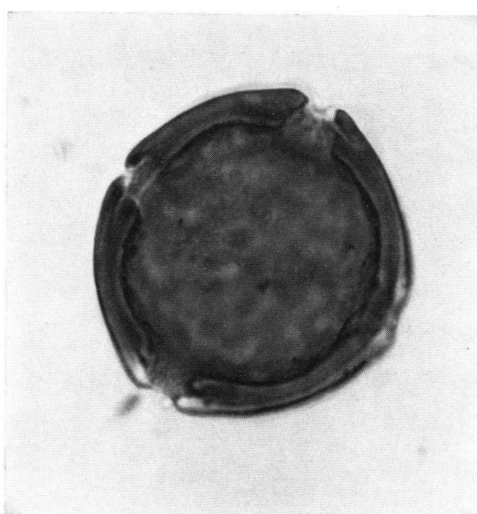


Fig. 6
Symphonia

1000 ×

PLATE VII

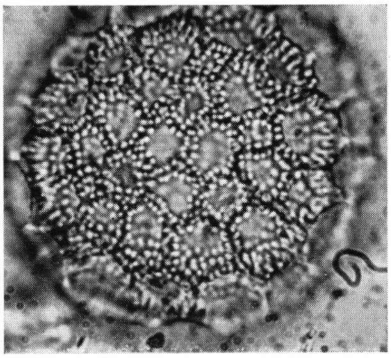


Fig. 1

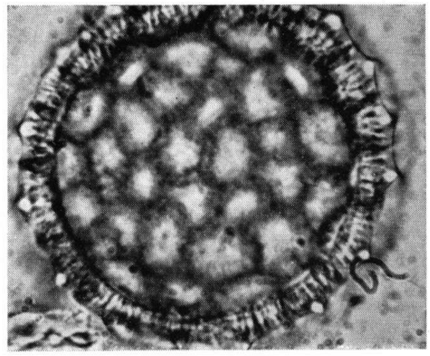


Fig. 2

Polygonum persicaria-type

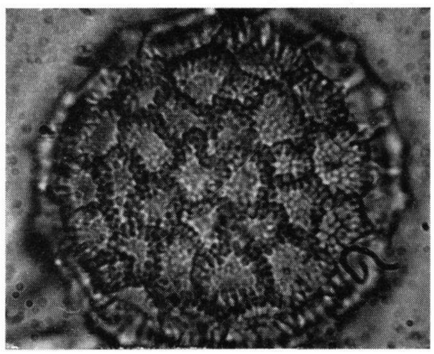


Fig. 3

Polygonum persicaria-type

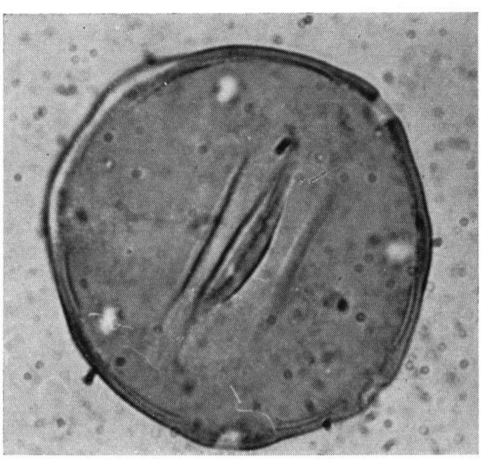


Fig. 4

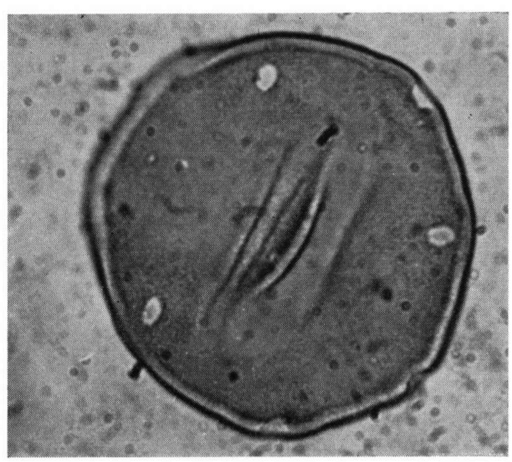


Fig. 5

Juglans

1000 ×

PLATE VIII

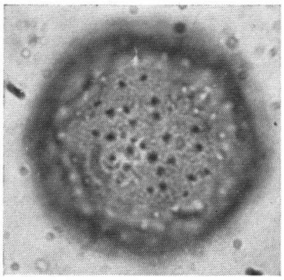
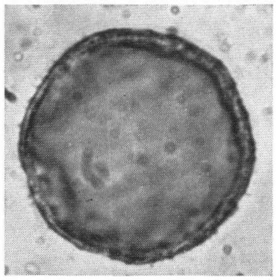



Fig. 1 Fig. 2
Sagittaria

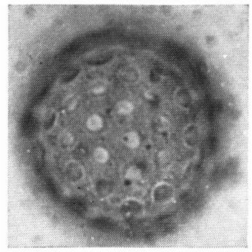
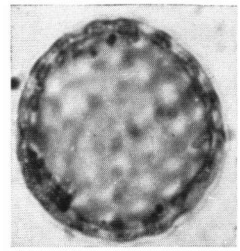



Fig. 3 Fig. 4
Chenopodiaceae - Amaranthus type

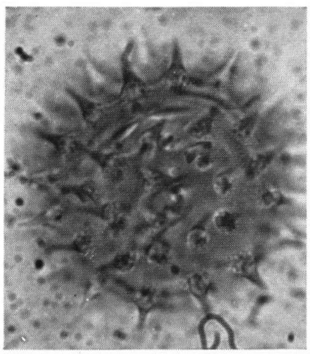
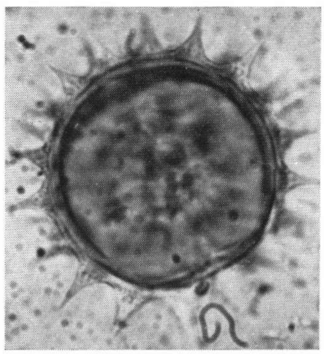



Fig. 5 Fig. 6
Compositae - Tubuliflorae type

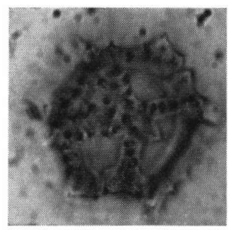
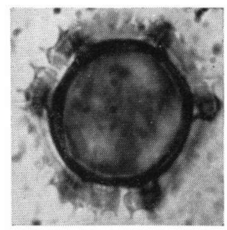



Fig. 7 Fig. 8
Compositae - Liguliflorae type

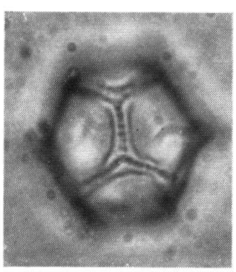
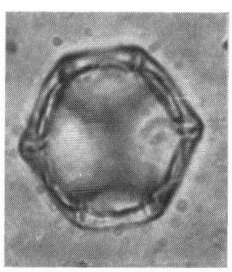



Fig. 9 Fig. 10
Amaranthaceae - Alternanthera type

Fig. 11
Gramineae

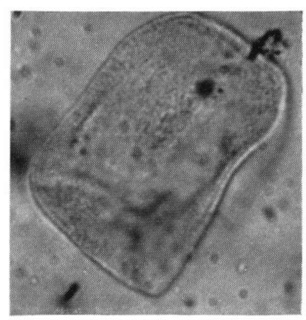


Fig. 12
Cyperaceae

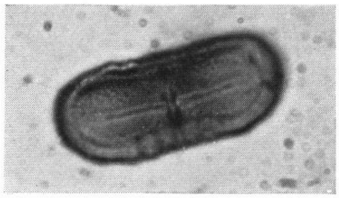
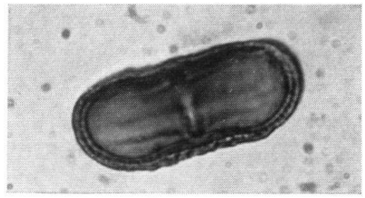



Fig. 13 Fig. 14
Umbelliferae

1000 ×

PLATE IX

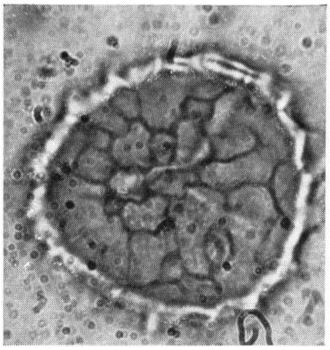


Fig. 1

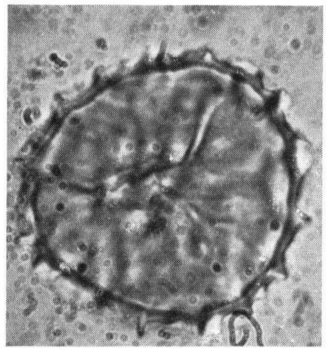


Fig. 2

Lycopodium

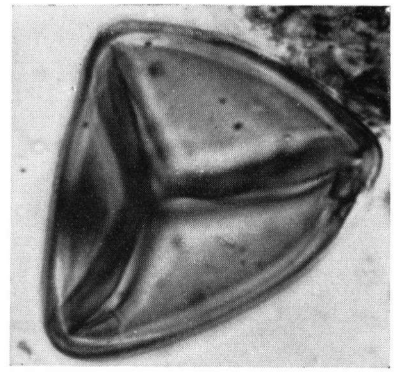


Fig. 3
Cyatheaceae type

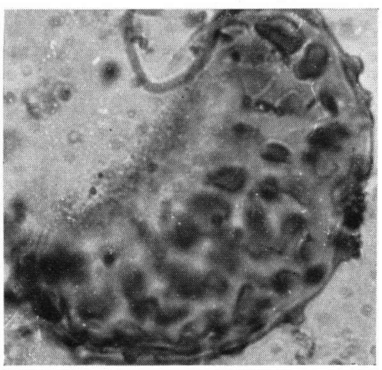


Fig. 4
Monolete ver. spore

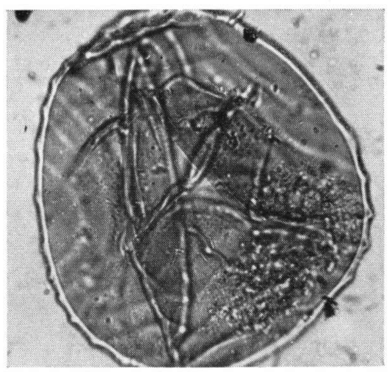


Fig. 5
Ceratopteris

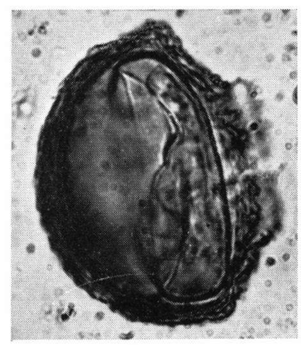


Fig. 6
Isoetes

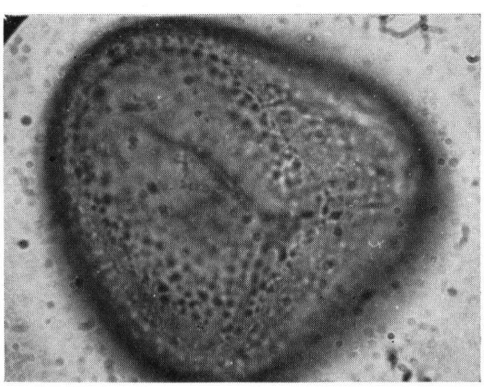


Fig. 7

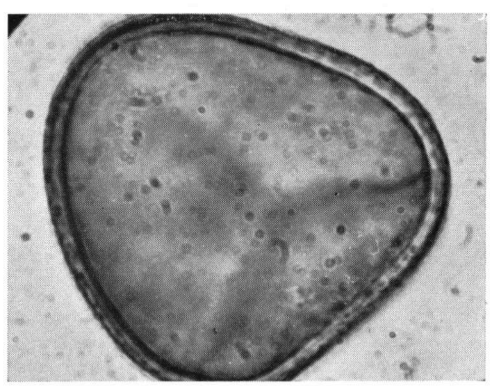


Fig. 8

Acrostichum aureum

1000 ×

PLATE X

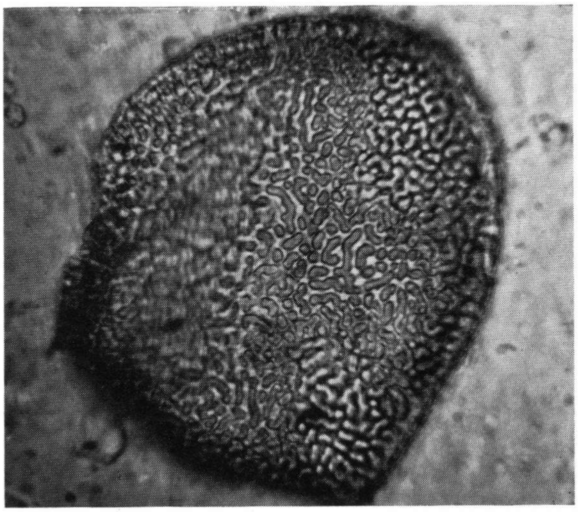


Fig. 1

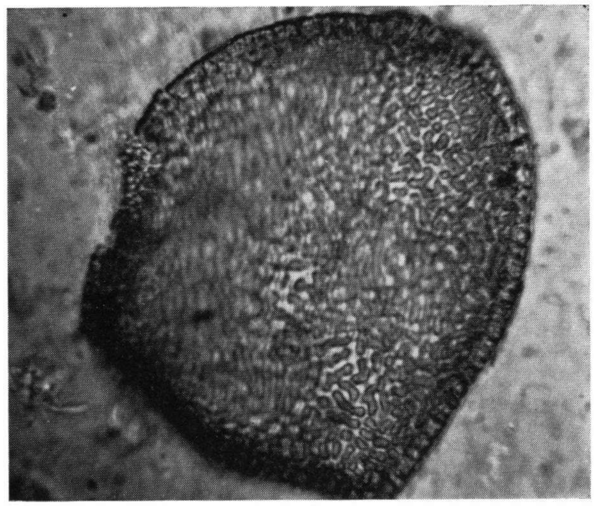


Fig. 2

Annonaceae

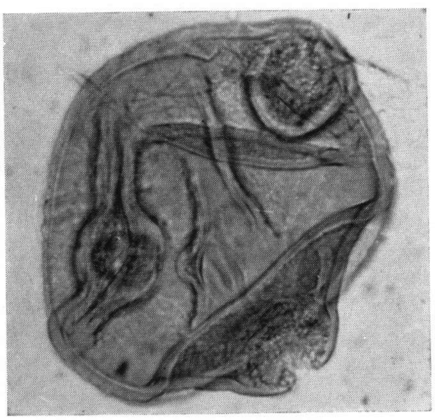


Fig. 3
Jussiaea

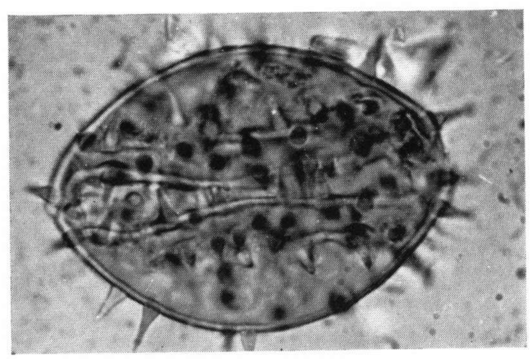


Fig. 4
Nymphaeaceae

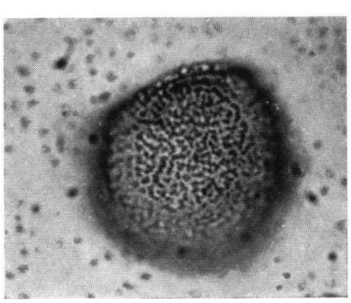


Fig. 5

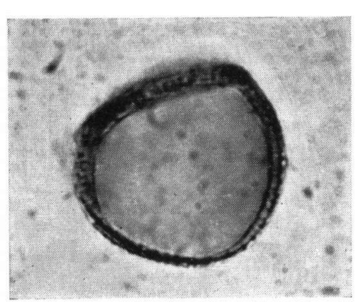


Fig. 6

Typha

1000 ×