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A PALYNOLOGICAL STUDY ON THE TERTIARY AND UPPER CRETACEOUS OF BRITISH GUIANA

by

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SUMMARY

The pollen content of bore-hole samples and mine sections from the coast and from the bauxite belt of British Guiana has been studied. The pollen zonation is shown in fig. 6 and diagram IV. The description of the Upper Cretaceous and Tertiary pollen species is partly given in this article and partly in Van der Hammen, 1963; the Paleocene and Eocene species will be described in Leidelmeyer, 1965.

The general picture obtained for the Guiana Basin, is summarized in three sections, one along the coast (fig. 18), one parallel to the Demerara River (fig. 24) and one parallel to the Berbice (fig. 25).

The more detailed interpretation and correlation of the two deep coastal wells of Rose Hall and Shelter Belt is given in fig. 5. The situation in the bauxite areas is shown in fig. 17 and 20. The age of the bauxite (in the interval Lower Eocene to Lower Oligocene) corresponds to a hiatus in the coastal wells.

Surprising is the thick Upper Cretaceous (Maestrichtian) basal infill of the basin. The dating and correlation of the Cretaceous and Tertiary formations of British Guiana is summarized in a stratigraphical table (fig. 26).

INTRODUCTION

The present study forms the second part of a palynological study of the coastal sedimentary sequence of British Guiana. The first part dealt with the Quaternary (Van der Hammen, 1963) and gave a short description of the morphology and geology of the coastal plain, the present vegetation, recent pollen sedimentation and the principal Quaternary pollen types. Of the Tertiary pollen types, encountered in the present studies, only those not occurring in the Quaternary and not described in the previous paper have been described here.

Although the Paleocene is discussed here, the description of the rich Paleocene pollen flora is given in a separate study by Leidelmeyer ("A palynological study on the Paleocene of British Guiana", published in this same journal).

This work 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. and Reynolds Metals Co. Billiton Co. and Suralco also contributed to our last visit to the Guianas. We like to express to them our gratitude and equally to all the persons mentioned in the introduction of the article on the Quaternary, specially to Dr. P. H. A. Martin-Kaye, Director of the Geological Survey Dept. of British Guiana, and to Dr. David Bleackley, at one time a member of the Department.

GENERAL REMARKS ON THE GEOLOGY

The sediments of the Guiana basin increase in thickness towards the North (the sea) and towards the Berbice River, where the basin is deepest. The basement is formed by rocks of the Precambrian shield.

From bore-holes and geophysical research (Kugler c.s., 1942; Grantham &

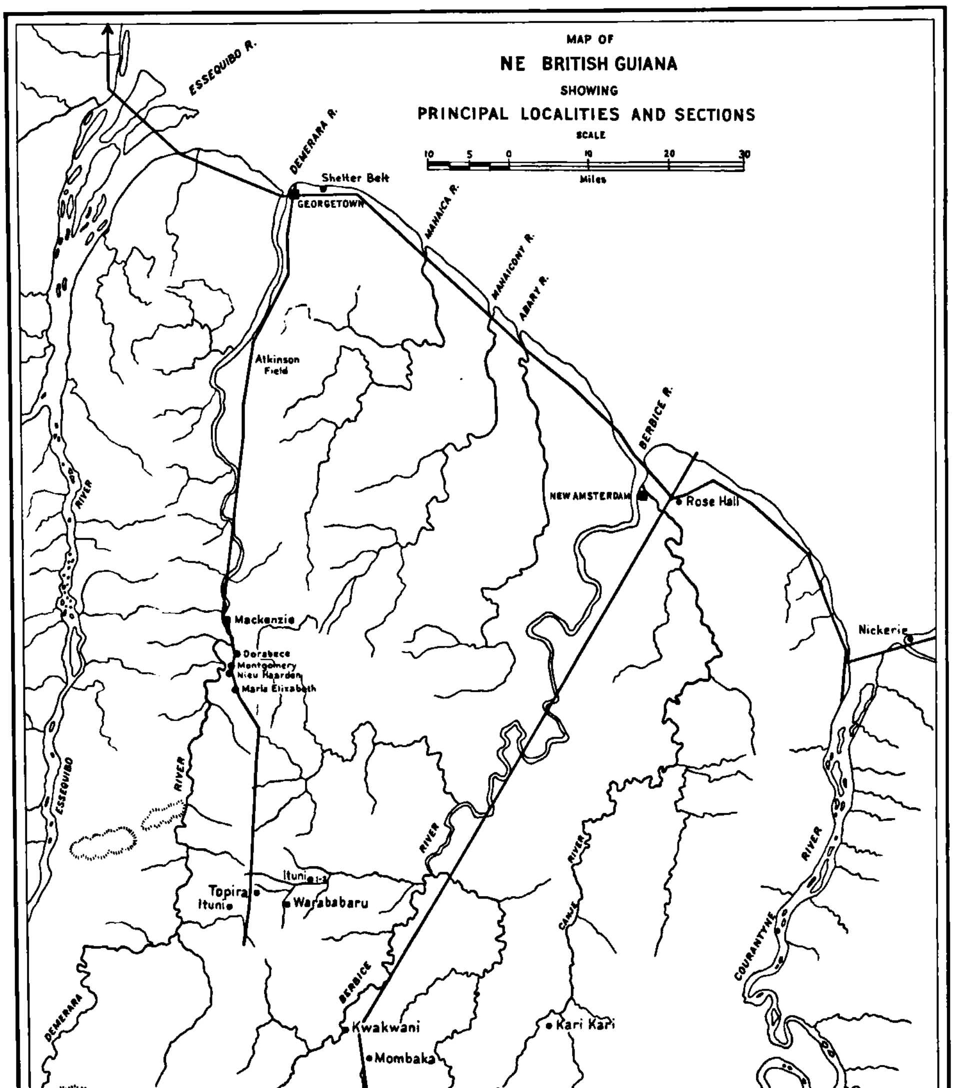

Fig. 1. Map of British Guiana showing the principal localities and sections.

Noel Paton, 1937; Bleackley, 1956 etc.) the depth of the top of the basement, the form of the basin and the thickness of the sediments is known approximately (fig. 2). Although no exact data are published, it is known from geophysical research that the basin continues on the shelf, becoming gradually deeper. The only tectonic deformations seem to be the general seaward slope of the strata and N.N.W. to N.W. aligned faults.

The age of the partially consolidated sediments has long been a matter of

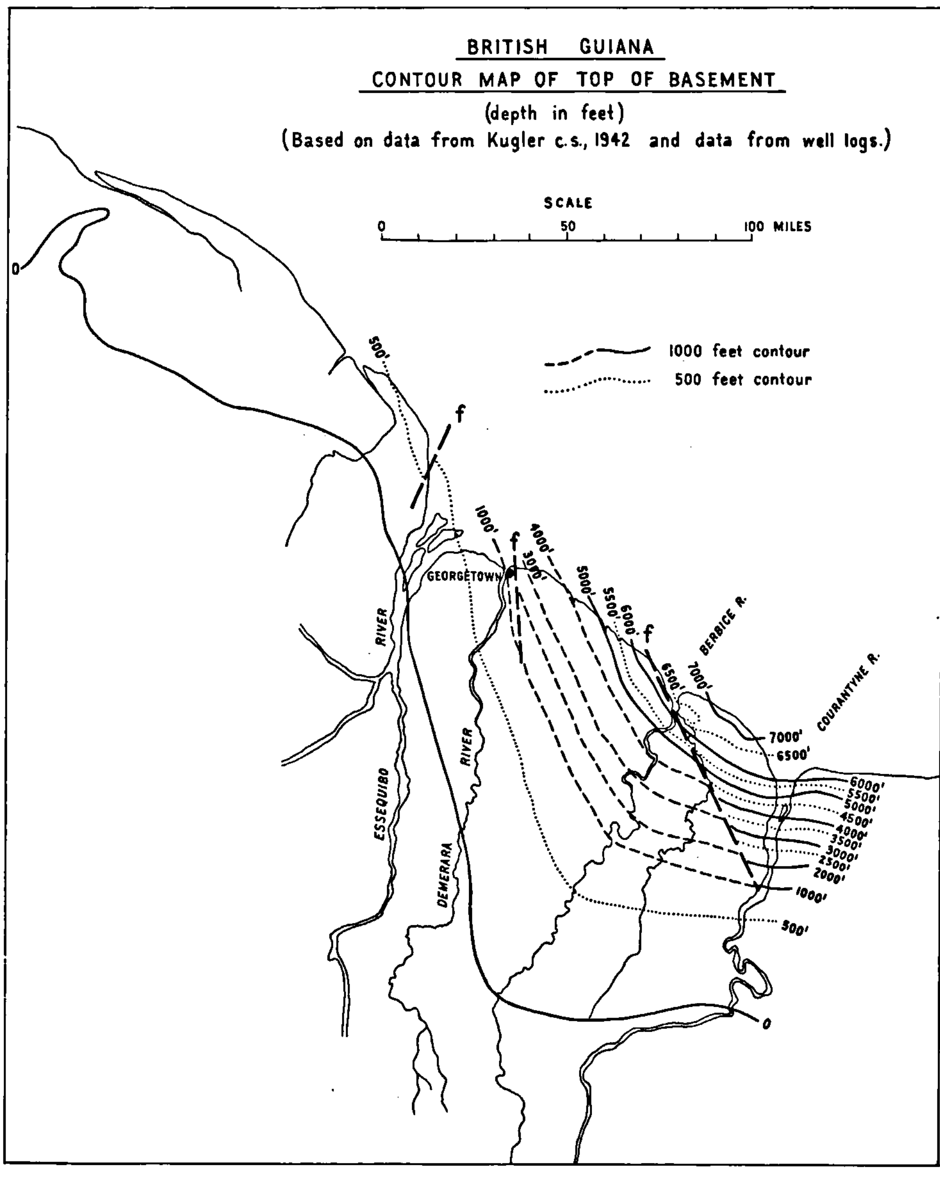

Fig. 2. Contour map of the top of the basement.

discussion, as marine fossils are absent or extremely scarce. Nevertheless, the series has mostly been regarded as Quaternary, including eventually Pliocene. It has however been proved recently that Paleocene sediments are present. Drooger determined a Paleocene fauna of foraminifera and ostracods in French Guiana (mentioned by Cruys in Boye & Cruys, 1961) and a Paleocene pollen flora was found in British Guiana and Surinam (Van der Hammen, Wymstra & Leidelmeyer, 1961). Later an Eocene pollen flora was also reported from British Guiana and Surinam (Wymstra & Van der Hammen, 1964). The presence of Cretaceous and Miocene sediments has already been mentioned in the first part of this study (Van der Hammen, 1963). The more important earlier data on the stratigraphy of the basin were published in Grantham & Noel Paton (1937), Kugler c.s. (1942) and Bleackley (1956).

Noel Paton compiled the data of a great number of coastal wells, giving the original logs and sections along the coast based on these logs (fig. 3). The subdivision he derived is as follows:

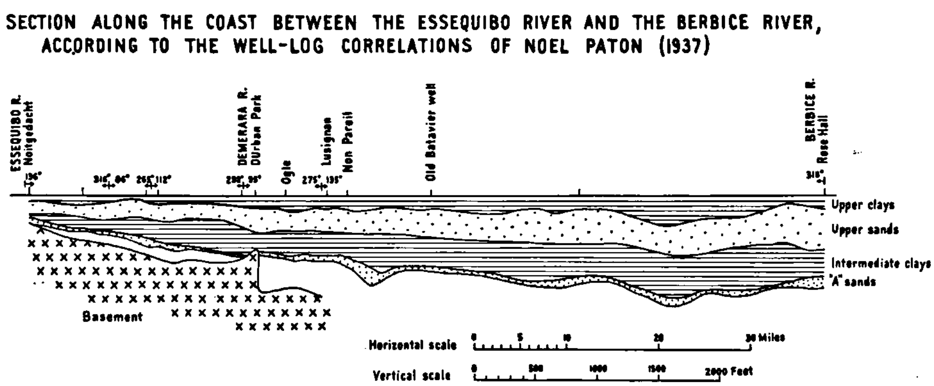

Fig. 3. Section along the coast between the Essequibo and the Berbice Rivers, drawn according to the well-log correlations of Noel Paton.

I. Upper Clay Series (with 1st Lignite zone).
II. Upper Sand Series (with 2nd Lignite zone).
III. Intermediate Clay Series (with lenticular sand bodies).
IV. The "A"-Sand.
V. Lower Clay Series.
VI. Lower Sand Series.

This subdivision is still in use for the coastal wells, at least I to IV. For the strata below IV the term "Alternating sands and clays" is also used. V and VI are then only the uppermost layers of this last mentioned unit. In the present paper these terms are used to indicate the lithostratigraphical units in the coastal region, as they are very useful.

Bleackley (1956) made a similar section along the coast (fig. 4) as Noel Paton. Although his correlations between the different wells closely resemble those of Noel Paton, they sometimes differ in a more or less important way. In the Shelter Belt section (fig. 5) Noel Paton would have called the interval 160—400': Upper Sands, the more clayey interval corresponding approximately to his "2nd lignite zone". On the other hand Bleackley would have called Upper Sands only the

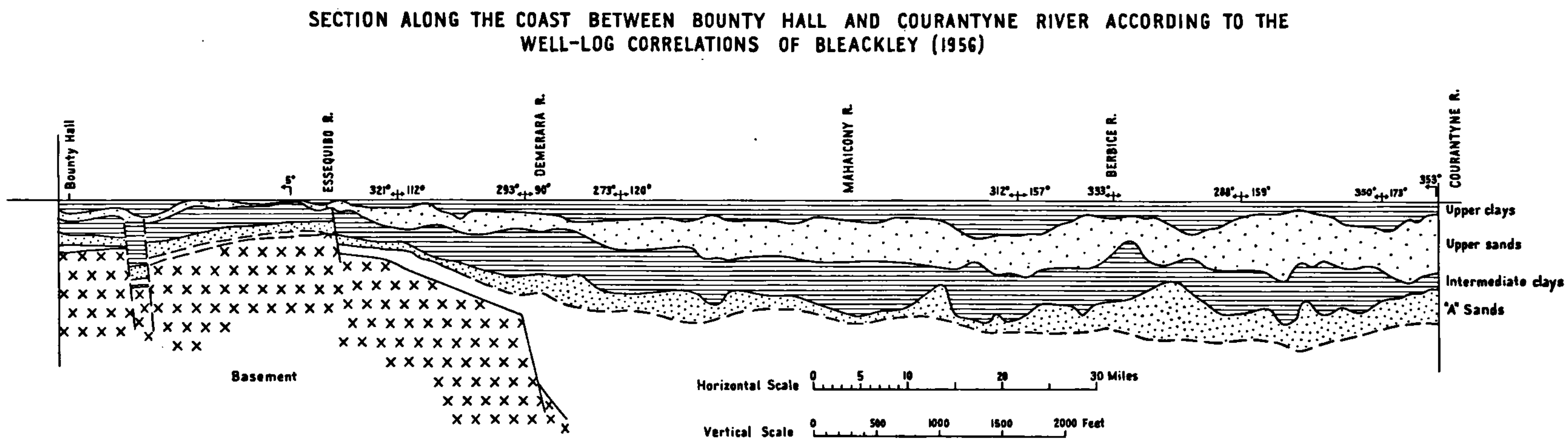

Fig. 4. Section along the coast between Bounty Hall and the Corentyne River, drawn according to the well-log correlations of Bleackley.

sand body between 160 and 252′, the strata below it belonging to the Intermediate Clay Series. Noel Paton and Bleackley agree in their interpretation and correlation of the Upper Sands in the main part of the coastal section, where it has a thickness of 400—500′.

They both show it thinning out towards the N.W. (see fig. 3 and 4), but Bleackley in a different way to Noel Paton. We will return to this problem later.

The report of Kugler c.s. (1942) results from oil exploration, including the deep bore-hole of Rose Hall and a geophysical survey. It gives a wealth of data on the 6300 feet of sediments near the axis of the basin in the lower Berbice. This whole series of sediments was at that time considered to be probably of Plio-Pleistocene age, as fossils were practically absent.

Fortunately we were able to collect some material from the original cores and cuttings of the well, in the Geological Laboratory of Trinidad Leaseholds Ltd. at Pointe-a Pierre (Trinidad), and by means of palynology the age of the series (ranging from Upper Cretaceous to Recent) could be established (see next chapter).

From the continuous use we could make of the data of Noel Paton and Kugler, it became clearer than ever to us, how important it is to publish uninterpreted raw data. They form a continuous source of information, independent of the changing ways of interpretation.

The most important data on the stratigraphy of the more landward part of the basin are in the files of the bauxite companies. Both the Demerara Bauxite Company and Reynolds Metals Cy kindly provided samples and the logs of a number of bore-holes, and permitted us to draw sections of mine-faces etc. Many data provided by the same companies are also mentioned in the (unpublished) thesis of Bleackley (1961), which includes a wealth of information.

It was commonly thought, that the bauxite was formed on residual clays, but since pollen-containing datable sediments (even lignites) were found below several of the deposits, it became clear that the majority of these bauxites were formed by alteration of the top of older sediments. These older sediments were shown to be of Paleocene (and Eocene) age by pollen studies (Van der Hammen, Wymstra & Leidelmeyer, 1961; Wymstra & Van der Hammen, 1964; for full documentation see the present article and Leidelmeyer, 1965).

The most important section studied was undoubtedly the Government Shelter Belt 3 bore-hole, which was specially sampled for the palynological studies and which provided our reference pollen diagram and the basis for our pollen zonation.

THE SHELTER BELT DIAGRAM AND THE POLLEN ZONES

In 1959 the Shelter Belt No. 3 well was drilled, not far from Georgetown. It was carefully sampled from undisturbed cores, for pollen analysis, so that the section could serve us for the elaboration of a reference pollen diagram and to establish a pollen zonation. In total 1935 feet of sediments were penetrated, before the basement was reached (see fig. 5).

The lithostratigraphic subdivision of the sediments of Shelter Belt No. 3 according to the terminology of Noel Paton and Bleackley would be as follows:

0—160′ - Upper Clays
160—400′ - Upper Sands (s. Noel Paton) or 160—252′ (s. Bleackley)
400—666′ - Intermediate Clays (resp. 252—666′)
666—780′ - A-Sand
780—820′ (975′) - Lower Clay + Lower Sand Series? } "Alternating sands
820 (975)—1935′ - no name } and clays".

We would like to use the name "Alternating sands and clays" and "Lower consolidated sands and clays" for respectively the intervals 820—1255′ and 1255—1935′. The result is then:

0—160′ - Upper Clays
160—400′ (252′) - Upper Sands
400 (252)—666′ - Intermediate Clays
666—780′ - A-Sand (s.l.)
780—1255′ - "Alternating sands and clays"
1255—1935′ - "Lower consolidated sands and clays"
1935′ - basement

Above the A-Sands is a sterile interval with kaolinitic clay (611—666′) and kaolinitic clays occur also in the 780—805′ interval below the A-Sand s.s. This is a fact with more than local importance, white kaolinitic clays occurring often immediately above and below the A-Sand (see the sections along the coast in the mentioned studies of Noel Paton and Bleackley).

Besides the Upper Sand and the A-Sand (incl. the kaolinitic clays above it), there are no major sterile intervals until ± 1260′. Below this level the sediments did not contain pollen grains, but a pollen-containing sample was found in the Lower consolidated series of the Rose Hall well (see next paragraph).

The diagram of the upper 820 feet of the Shelter Belt 3 (see Diagram III) consists of two parts. At the left is the general diagram, indicating the fluctuations of the percentages of the main groups of pollen grains. The two groups at the left are elements of the mangrove forest (*Avicennia* and *Rhizophora*), the other groups belong to the open grass-vegetation and to the freshwater swamp forests and other forests.

From the fluctuations of the first two groups, the history of trans-and regressions may be deduced. The uppermost part of the diagram (0—160′) is given in a much more detailed way in Van der Hammen (1963), and here only a selection of the analysed samples of this interval is given. To the right of the general diagram are the curves of relative abundance of the separate pollen-types and species.

Some of them are indicated by their natural botanical names, others by names in the artificial classification system. The description and illustration of the first-mentioned group was given in Van der Hammen (1963) and that of the last-mentioned group in the systematical part of the present article.

Finally, at the right of the separate curves, there is another general diagram, composed in a different way. The groups may be classified here as belonging to the Palms (left), other Angiosperms (middle) and spores (right) ("PAF-diagram"). This type of diagram was described in Van der Hammen (1957a) and was used with good results for correlation of Tertiary sediments in Colombia.

The lower part of the section (from 820 feet down) is presented in Diagram I. It was for the greater part elaborated by Leidelmeyer (1965), who described the rich flora from this interval. No *Rhizophora* is present in this part of the section, and the diagram is a PAF diagram.

The vertical distribution of species and types through the whole section is shown in Diagram IV, where the zonation based on this distribution is also indicated. No pollen were found in the lowest part of the section, from $\pm$ 1260′ down, but an older pollen association was found in the lower part of the Rose Hall well, and all the zones which may be distinguished are, with their type pollen associations, indicated in the table of fig. 6.

For the description and illustration of the pollen-species and types, we may, besides the systematical part of the present article, refer to the following publications:

Leidelmeyer (1965), Van der Hammen (1954, 1956b, 1963 and 1965). For a further explanation of the types of diagrams used, see Van der Hammen (1957a, 1957b and 1963).

Diagram IV

This diagram shows the vertical distribution of the more important pollen types found in the Shelter Belt section. They are arranged from left to right according to their first appearance. It should be kept in mind that this is the distribution in one well only, and that some species might have a longer range in other wells. This seems for instance to be the case with some of the species from the lower part of zone B_2, which elsewhere may occur also in the upper part of the same zone.

In general, however, the analysis of other sections and wells has confirmed the distribution of species here presented. Several marked changes in the qualitative composition of the flora are visible in the diagram, but one of them is very clear. It represents apparently a hiatus and lies at a depth of approximately 790—822 feet, in the kaolin-clays immediately below the base of the A-Sands. It is difficult to indicate the exact place of the hiatus, but it occurs most probably at the top or at the base of the sand from 810—822 feet. The two parts, below and above this hiatus, are so different that an additional different type of quantitative diagram is necessary for the upper part.

In the upper part the *Rhizophora* pollen plays an important role in the quantitative composition of the pollen flora (and may help us to detect fluctuations of sea-level), while this type is absent in the lower part.

The other, less important limits in the vertical distribution of species, were used to establish the pollen zones B, C, D, E, F and G, the palynological characteristics of which are clearly defined and incorporated in fig. 6. It may be seen from the diagram, that the two main sand-bodies of the represented part of the section, are sterile. This fact makes the interpretation as to which zone these bodies belong, difficult. This is especially the case with the upper sand-layer (160—252′) of the Upper Sands (in the sense of Noel Paton).

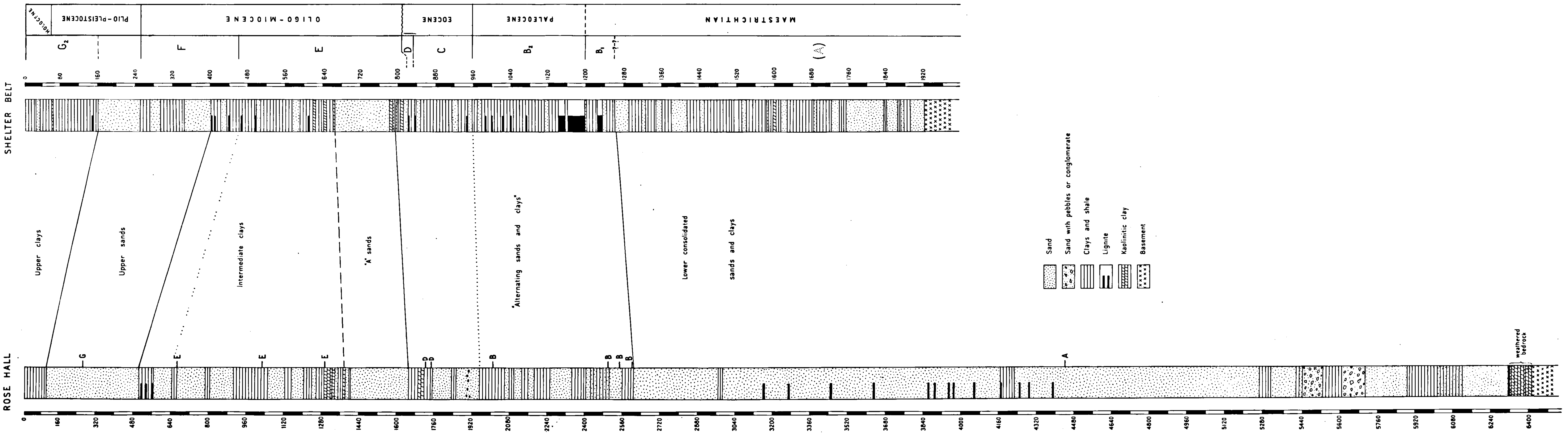

Fig. 5. Correlation of Shelter Belt and Rose Hall drill-holes, according to palynological data.

The sediments below this layer belong to zone F, those above it to zone G. The question of whether the sand belongs to zone F or G, cannot be solved by this Shelter Belt diagram, but will have to be solved by comparison and pollen analysis of other coastal wells. In the Rose Hall well the Upper Sands form one sand-body. In the upper part of this body, probably corresponding to our sandlayer between 160′ and 252′, a lignite occurs, from which some pollen could be isolated, indicating pollenzone G, although several of the more modern species are lacking (see fig. 5). In Surinam it also seems possible to subdivide zone G on the basis of pollen data from coastal wells into a lower and an upper part (G_1 and G_2) and it seems probable that our sand belongs to zone G_2. This interpretation needs direct confirmation.

The second problem is the A-Sands. Not only is the sand proper sterile, but also the kaolin-clays above it (620—666′). The interval 780—822′ (immediately below the A-Sands) contains sand below and in the upper part kaolin-clays, locally with lignitic streaks. The clay is sterile but the lignitic streaks, which occurred in two samples, contained pollen grains.

The sample at 786′ contained a rich pollen flora, with a comparatively high percentage of *Verrumonoletes* and *Striatriletes* (primitive *S. susannae* type), and a considerable number of species of zone E.

From the above it is clear, that the A-Sands should belong to this same pollen zone.

The second sample (789—801′) contained a poor pollen flora only. There is at least one species occurring in zone E, and some very small grains resembling *Rhizophora*. The most typical grains from zones C, D or E are not present, and most of the types are indifferent. A definite interpretation of this sample is therefore impossible; but taking into account the weak evidence and the fact that the sample is from only some 4′ below a sample with typical components of zone E, it seems logical to interpret it for the time being as belonging to zone E.

The next problem is zone D which is represented by one or two samples only. This is not really sufficient for the establishment of a zone, and it certainly needs a further definition; but the fact that comparable associations of pollen were found in the Rose Hall well, and probably also in Surinam, seems to justify it. At any rate there appears to be a relatively close relation between the zones C and D.

Another problem was the contamination of some of the lowermost samples of zone B_1. Species from zone C were found to be mixed with B_1 species in some samples of fine sand. Drilling mud or water saturated with clay from higher levels must have penetrated in those porous samples during the drilling and sampling.

These samples had therefore to be excluded, so that some samples below 1250 feet could not be included in the diagram.

Some uncertainty remained therefore, as we will see, on the exact age of zone B_1 and the sediments immediately below 1250′.

Diagram III

The diagram at the left shows the fluctuations of the Mangrove elements (*Rhizophora* and partly *Avicennia*) as related to the open grass-vegetation and the (mainly swamp-) forest elements. The relative fluctuations of sealevel are indicated by the fluctuations of the curves. The rise of the *Rhizophora*-curve indicates a rising relative sealevel, and the fall a falling relative sealevel. The maxima and minima of these curves should be good for a detailed well-log correlation, but this can only be worked out later, when more long sections have been analysed.

Zone E starts with a low relative sealevel, and the sterile A-Sands and the kaolin-clays above it must also have been deposited above sealevel during an important regression. Then follow a transgression, a regression, again a transgression and a regression and finally a transgression. Zone E can therefore be subdivided into three parts (each comprising a regression and a transgression). With the next regression starts zone F. This is an important event again, finally resulting in the deposition of a sterile sand at 400′ (the Upper Sands in the sense of Noel Paton), and one would be inclined to place the base of the Upper Sands a little lower, at the base of the sand at 440′, corresponding with the base of zone F.

After the basal regression of zone F follows a transgression interrupted by a slight regression, apparently related with the sand at 320′ which is followed by further transgression. A regression follows at the base of the sand at 290′, followed by a transgression. Finally there is an important regression again, at the very base of the sand at 252′ (Upper Sand in the sense of Bleackley). This regression and sand probably indicate the beginning of zone G.

For the upper 160′ of the sediments reference should be made to the former publication (Van der Hammen, 1963).

Of the PAF diagram may be said, that, as it includes the *Rhizophora* pollen, it will not give an ideal picture of the vegetational-climatic changes. But, as the *Rhizophora* pollen constitutes the bulk of the pollen in a greater part of the diagram, the counting of a sufficient quantity of other pollen grains could not be done in a reasonable time.

Nevertheless, there are a number of clear *Monocolpites medius* group maxima, partly coinciding with maxima of the *Echimonocolpites franciscoi* group (*Mauritia*-type) or of certain spore groups. There seems to be a certain coincidence between the regressive phases and these changes. This is the only conclusion which may be drawn from this PAF diagram which includes *Rhizophora*. Future analysis may make a better PAF diagram possible, so that the influence of the *Rhizophora* on this diagram (suppression of *M. medius*) may be excluded.

Both the pollen zones E and F (and probably also G) start with an important sand-layer deposited during an important regressive phase. Both zones may be subdivided into three, representing one re- and transgression each. The other two regressions of each zone seem to be less important than the first.

The PAF diagram (incl. *Rhizophora*) seems to indicate a coincidence of the regressions with certain vegetational changes in the forest, recognized as probably climatic in Colombian diagrams. This seems to confirm the climatic cycles recognized in Colombia and other places (Van der Hammen, 1957a and 1961), which lasted probably some 7 million years, and which are each subdivided into three more or less equal parts. A coincidence of the climatic cycles with cycles of re- and transgressions was there considered to be most probable.

Diagram I

This diagram at the left represents the lower part of the analysable section of the Shelter Belt well (820—1240′). It represents the part below the hiatus and above the sterile series of Lower consolidated sands and clays. This diagram was made by Leidelmeyer, with some additions by the authors. The complete diagram with the vertical distribution of the species will soon be published, together with full description and microphotographs of the species from this interval (Leidelmeyer, 1964). The diagram is a PAF diagram, and is made in exactly the same way as the diagrams of Lower Tertiary age from Colombia (Van der Hammen, 1957a and b).

The groups which are included in the pollen sum are from left to right the following:

Psilamonocolpites medius group.
Echimonocolpites franciscoi group.
Proxapertites operculatus group.
Angiosperms (others) group.
Psilatriletes group.

The percentage of one group is put on top of the other in each spectrum, from left to right, representing in the total width of the diagram the 100 % of the pollen sum. The pollen associations in the samples between ± 950′ and 1180′ correspond to those from the Paleocene of Colombia (see the species mentioned for zone B and specially B_2 in our table fig. 6, and Van der Hammen, 1957a and 1964).

The samples from the interval 820—950′ have pollen associations which resemble those from the Lower Eocene of Colombia, with which they have a number of species in common (see zones C and D of table 6, Van der Hammen, 1957a and a still unpublished study by Gonzalez).

The samples from the interval between 1180′ and 1240′ contain several species from the Maestrichtian of Colombia, but a few Paleocene species are already present in these samples. The fact that some of the samples from this interval were apparently contaminated by drilling mud, makes a definite interpretation based on the qualitative composition of this interval difficult, but it should at any rate be dated as near the Tertiary-Cretaceous boundary.

If we now compare the changes in the quantitative composition of the samples, that is to say the diagram proper, with the diagram from the same time interval of the Catatumbo and the Lebrija areas in Colombia (diagram I at right; see also Van der Hammen, 1957b), interesting facts come to light. Although there are differences in the percentages of the comparable groups, the course of the curves of several groups, especially of the *Psilamonocolpites medius* group, shows surprising similarities. If we take into account that climatic changes are probably the cause of these changes, a detailed correlation seems to be possible. The three subdivisions of the Colombian diagram (right) are easily recognizable in the diagram from Shelter Belt (left).

The shortest distance between the two places is at least 1600 km.

This correlation indicates that the Cretaceous-Tertiary boundary, as established in Colombia, should lie at ± 1180(—1190′), and the Paleocene-Eocene boundary at 950—960′. With the high *Psilamonocolpites medius* maximum at 835—840′ starts our zone D, which is followed by the hiatus at ± 800—822′. This zone D seems to correspond to the Colombian Lower Eocene B, but the data on the qualitative composition of zone D are too scarce to decide this definitely.

The age of the pollen zones for British Guiana

In fig. 6 the data on the qualitative characteristics of the pollen zones are brought together. It should be stressed that this zonation is based on these characteristics only. For that reason, zone B, although probably uppermost Cretaceous, is taken together with the Paleocene zone B_2 (and not with zone A of ± Maestrichtian age), because they have a number of typical, easily recognizable forms in common, like *Proxapertites*

POLLEN ZONATION FOR BRITISH GUIANA

Zones		Vertical distribution of guide-associaciations and -species		Age
G	2	Virola, Iriartea, Alnus (often high percentage of Avicennia)	Symphonia Avicennia Compositae	Quaternary to Pliocene
	1			
F			Psiladiporites minimus Retitricolporites irregularis	Lower Miocene to Oligocene
E		Psilatricolporites triangularis Clavainaperturites clavatus Retistephanocolporites quadriporus Retitricolporites guianensis	Verrutricolporites rotundiporus Psilatricolporites crassus	
D		Clavastephanocolpites crotonoides	Psiladiporites guianensis Retitricolporites mariposus	Eocene (mainly lower E.)
C		Psilastephanocolpites fissilis Psilatricolpites solus	Clavatricolpites annemariae Echistephanoporites alfonsi	
B	2	Polyplicadites vanegensis Retitricolporites annaeoides	Proxapertites operculatus Retimonocolpites proxaperturoides	Paleocene
	1	Retimonoporites tequendamae Psilatetradites umirensis Foveotriletes margaritae	Syncolporites lisamae Gemmastephanocolpites asteroformis Retidiporites magdalenensis	?
A		Retitricolporites reticulatus Retitricolporites florschützi Retitricolpites microreticulatus Psilatricolpites clarisimus Retitricolpites letitiae		Maestrichtian

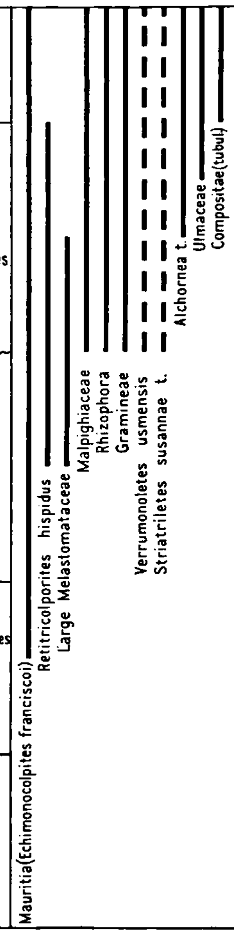

Fig. 6. Table of the pollen zones in British Guiana and their type associations.

operculatus. Zone A was established on the basis of a sample at ± 4435 feet in the Rose Hall well, at a level considerably lower than zone B_1.

At right the approximate age of the pollen zones is indicated. They are principally based on comparison with dated Colombian (and partly Venezuelan) pollen associations.

The association of species of zone A corresponds perfectly to the Maestrichtian pollen flora of Colombia (v. d. H., 1957a). It is therefore highly probable that the age of this zone is also Maestrichtian. Theoretically the same association might occur also in still older Senonian sediments, but we do not know pollen associations of such older Senonian sediments from Colombia. Most of the species occur in the Lower to Middle Maestrichtian, but two (*Retitricolporites reticulatus* and *Retitricolpites laetitiae*) were in Colombia not found in the basal Maestrichtian sediments.

We may conclude that zone A is of Maestrichtian age, and that there is only a slight possibility that it includes still some older Senonian.

We have seen that comparison of the diagrams and pollen associations of British Guiana and Colombia resulted in an uppermost Maestrichtian age (near the transition to the Paleocene) for pollen zone B_1 and a Paleocene age for zone B_2. This last mentioned age seems to be confirmed by the find of a fossiliferous horizon at 1000′ in the same Shelter Belt well, which was sent by Bleackley to Cruys, who reported that it could be correlated with his Paleocene material from French Guiana (see also Boye & Cruys, 1961).

Similar comparison with Colombia resulted, as we saw before, in a Lower Eocene age for zone C. The age of zone D is, as we have seen, not yet quite sure, but is at any rate Eocene, and probably also Lower Eocene (so that the whole succession in the Shelter Belt well between 1240 and 822′ is more or less continuous).

The age of zones E and F is also derived from comparison with Colombia, including some still unpublished data. The problem here is, that the Oligocene-Miocene boundary in marine successions in the Caribean is still in discussion, so that consequently this boundary cannot be sure in the pollen sections, which were dated correlating them by means of pollen with the marine sections. An important point is the beginning of the Tubuliflore Composites. These start at the base of the old Oligo-Miocene boundary, but if the boundary Oligo-Miocene has to be placed much lower, as has been proposed and which seems to be probable now, then the beginning of the Compositae in Sout America falls in the Middle of the Miocene. According to Eames c.s. (1962), the Oligocene would be even lacking completely in marine sequences of the Caribean, but it is not yet clear if the same holds for the fresh water deposits. In both zones E and F the Composites are completely lacking.

On the other hand, we see that at the base of zone E a relatively high percentage of *Verrumonoletes usmensis* occurs, together with an appreciable quantity of *Striatriletes* cf *susannae* (Shelter Belt). This, in comparison with the Colombian diagram (v. d. H., 1957a), indicates an age of "Oligocene" or younger. The same is indicated by several species, characteristic of these zones. Taking all these data together, we may conclude that the age of zones E and F belongs to somewhere in the "Oligocene" in the old sense or to somewhere in the Oligocene to Lower Miocene in the new sense.

Zone E contains several species (*Psilatricolporites triangularis, Clavainaperturites clavatus*) which were found in the "Oligocene" of Colombia, indicating that an Oligocene age for this zone is probable. It will be clear that we may at any rate safely assign an "Oligocene to Lower Miocene" age to zones E and F.

There seems to be a hiatus again between zones F and G, as zone G does not only contain Compositae, but also pollen grains (like *Symphonia*) which indicate at least a Pliocene to Quaternary age. The association of zone G_2 (G_1 is not proved in the Shelter Belt, but is probably represented in the Rose Hall well and certainly in Surinam) contains a number of species, which are probably Pleistocene. This is specially the case with *Alnus*, which entered South America in the Early Pleistocene (v. d. H., 1964b).

For the reasons mentioned above, a Pliocene to Quaternary age will have to be assigned to zone G. Zone G_2 probably is mainly Quaternary.

OTHER ANALYSED SECTIONS AND SAMPLES

We will now discuss the results of pollen analysis of a number of sections from drill-holes and mine-faces. A certain number of the mine-face sections, of which the samples were prepared, did not contain pollen. In all these cases the clays were white to cream kaolin-clay, sometimes sandy. We suppose that he pollen in this material has been destroyed (by oxidation) at the same time as the alteration of the clays took place (see next chapter). Sterile sections were found both in the Mackenzie-Ituni area (e.g. Topara mine) and in the Kwakwani-Mombaka area (e.g. Kwakwani mine, Mombaka mine, "White Cliff" on the Berbice). The section from the face of Montgomery mine (Mackenzie) contained lignite and grey clay, and contained abundant pollen grains. Further analysable material from the bauxite areas was found in drill-holes from the Kwakwani-Mombaka area and from the Canje area (Kari-Kari). One of the most important sections was certainly the well-known Rose Hall well, which will be discussed first.

The Rose Hall well (fig. 5)

This well was drilled in 1941 as a test-well for oil exploration, and reached a depth of 6456 feet (see Kugler, 1942). At this depth weathered basement was cored. No diagnostic fossils were found in the whole series of sediments, that was considered to be of Plio-Pleistocene age.

We got the permission, by intermediary of Dr. Kugler, to select samples for pollen analysis in the laboratory of Texaco Trinidad in Pointe-à-Pierre (Trinidad) from the remaining collection of cores and screen-samples of this well. The result was a rather small collection of suitable samples, but by comparison with the results obtained with the pollen analysis of the Shelter Belt well and in Colombia, it was possible to make for the first time a well-founded age-interpretation of the Rose Hall well.

The well-log is drawn in fig. 5, where it has been correlated with the Shelter Belt well.

From the samples, 11 gave a positive result. The place of these samples is indicated in the section; the letter indicates the pollen zone to which it belongs.

The results of the analysis are as follows:

R.H. 4429—39' (core)

Psilamonocolpites medius gr.	66 %	Age:
Psilatricolpites rubini	1.5 %	Pollen zone A
Retitricolpites reticulatus	3 %	
Retitricolpites microreticulatus	3 %	
Psilatricolpites clarissimus	3 %	
Retitricolpites letitiae	5.5 %	
Psilatricolporites florschutzi	3 %	
Other angiosperms	13.5 %	
Psilatriletes gr.	1.5 %	
Total	100 %	

RH 2597' (screen)

Psilamonocolpites medius gr.	12.5 %	Age:
Psilamonocolpites inornatus	41.5 %	Pollen zone B,
Retimonocolpites proxaperturoides	1.5 %	lower part
Echimonocolpites franciscoi	×	(probably B_1)
Polyplicadites cf *vanegensis*	×	
Other Angiosperms	37 %	
Triletes guaduensis group	7.5 %	
Total	100 %	

RH 2539—2549' (core)

Psilamonocolpites medius gr.	28 %	Age:
Psilamonocolpites inornatus	1 %	Pollen zone B
Retimonocolpites proxaperturoides	15.5 %	
Proxapertites operculatus	10.5 %	
cf *Echimonocolpites franciscoi*	1 %	
Retistephanocolpites cf *guaduensis*	1 %	
Stephanocolporites ambigens	4 %	
Echitriporites guianensis	2.5 %	
Scabratriporites suescae	2.5 %	
Retitricolporites annaeoides	1 %	
Gemmatricolporites divaricatus	2.5 %	
Other Angiosperms	14 %	
Retitriletes sp.	2.5 %	
Psilatriletes gr.	14 %	
Total	100 %	

RH 2490—2496' (core)

Psilamonocolpites medius gr.	39 %	Age:
Retimonocolpites proxaperturoides	8 %	Pollen zone B
Echimonocolpites franciscoi	1 %	
Proxapertites operculatus	3 %	
Polyplicadites vanegensis	2 %	
Retistephanocolpites angeli	3 %	
Gemmastephanocolpites asteroformis	×	
Echitriporites guianensis	1 %	
Retitriporites retibolus	1 %	
Retidiporites botulus	1 %	
Verrusyncolporites lisamae	4 %	
Retitricolpites cecryphalium	1 %	
Gemmatricolporites divaricatus	×	
Other Angiosperms	28 %	
Psilatriletes gr	8 %	
Total	100 %	

RH 2003—2011' (core)

Psilamonocolpites medius gr.	22 %	Age:
Retimonocolpites proxaperturoides	3 %	Pollen zone B
Echimonocolpites franciscoi	1 %	
Proxapertites operculatus	2 %	
Verrusyncolporites lisamae	2 %	
Echitriporites guianensis	5 %	
Foveostephanocolpites perfectus	1 %	
Clavatricolporites leticiae	1 %	
Retitricolporites annaeoides	1 %	
Other Angiosperms	50 %	
Psilatriletes gr.	12 %	
Total	100 %	

RH 1735—1745' (screen)

Psilamonocolpites medius gr.	7 %	Age:
Echimonocolpites franciscoi	5 %	Pollen zone D
Psilastephanocolpites fissilis	1 %	
Psilatricolpites solus	1 %	
Clavatricolpites annemariae	1 %	
Retitricolporites hispidus	3 %	
Other Angiosperms	82 %	
Total	100 %	

RH 1715—1725' (screen)

Psilamonocolpites medius gr.	20 %	Age:
Echimonocolpites franciscoi	1 %	Pollen zone D
Clavastephanocolpites crotonoides	1 %	
Retitricolporites hispidus	3 %	
Other Angiosperms	75 %	
Total	100 %	

RH 1290' (screen)

This sample was not counted. The following species were observed:

Psilatricolporites crassus	Age:
Large Melastomataceae	Pollen zone E
Palmae	
Psilatriletes	

RH 1025—1035' (screen)

Psilamonocolpites medius gr.	2 %	Age:
Echimonocolpites franciscoi gr. (*Mauritia* t.)	1 %	Pollen zone E
Rhizophora	88 %	
Psilatricolporites crassus	1 %	
Psilatricolporites triangularis	×	
Retitricolporites irregularis	2 %	
Other Angiosperms	5 %	
Verrumonoletes usmensis t.	1 %	
Total	100 %	

RH 659' (screen)

Psilamonocolpites medius gr.	14 %	Age:
Echimonocolpites franciscoi gr. (*Mauritia*)	14 %	Pollen zone E
Rhizophora	50 %	
Malpighiaceae	×	
Large Melastomataceae t.	1 %	
Ilex	1 %	
Malvaceae	1 %	
Catostemma t.	1 %	
Podocarpus	×	
Psiladiporites minimus	×	
Psilatricolporites crassus	1 %	
Psilatricolporites triangularis	×	
Verrutricolporites rotundiporus	×	
Retitricolporites irregularis	×	
Periporites akanthos	×	
Other Angiosperms	10 %	
Verrumonoletes usmensis t.	6 %	
Psilatriletes	1 %	
Total	100 %	

RH 240—320' (screen)

This sample was poor in pollen, and therefore it was not counted.

The following species were observed:

Avicennia	Age:
Symphonia	Pollen zone G
Ilex	
Bauhinia t.	
Mauritia	

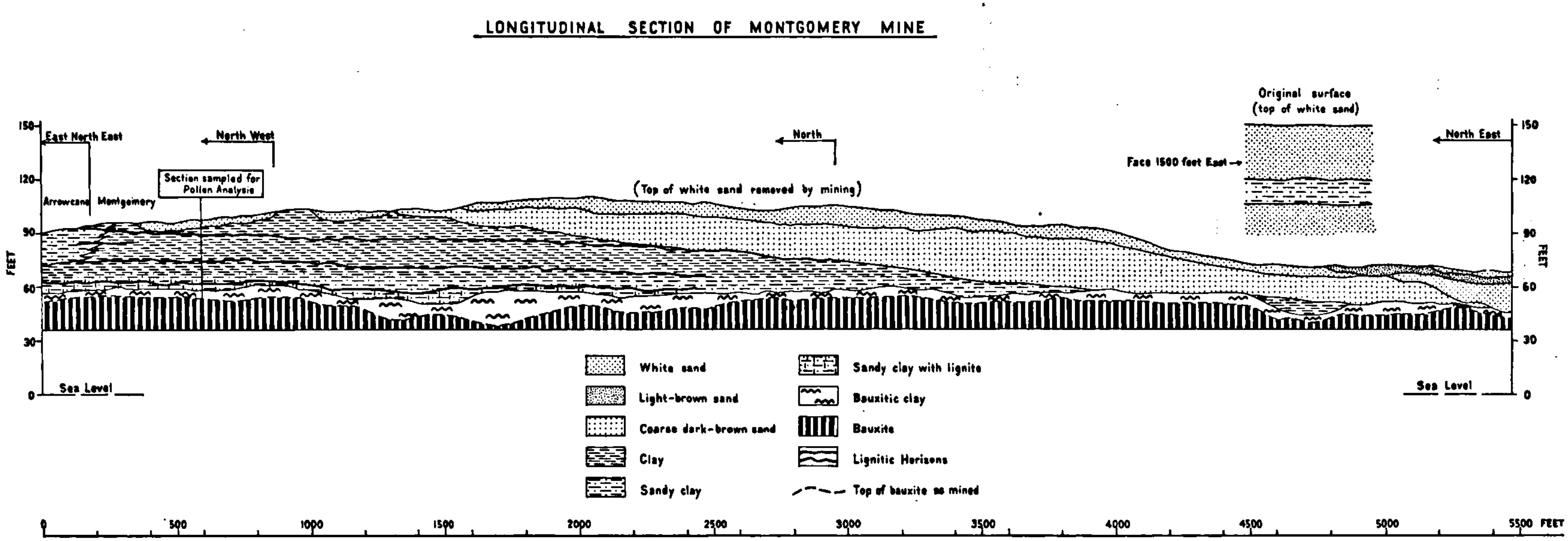

Fig. 7. Longitudinal section of Montgomery mine (Mackenzie area). (Geol. Surv. Section, with some additions).

The principal results may now be summarized as follows (based on the pollen analysis and the lithology).

1. The part of the section below 2600′ (or somewhat higher) is principally of Upper Cretaceous (Maestrichtian) age.
2. The part of the section between 1935′ and 2600′ is principally of Paleocene age.
3. From ± 1650′ (or somewhat lower) to ± 1935′ the sediments are of Eocene age.
4. From 500— ±1650′ the age of the sediments falls within the Oligocene to Lower Miocene. Part of the Upper Sands must also be of that age.
5. The uppermost part of the section (from approximately 280′ to the surface) must be of Pliocene-Quaternary age.
6. Comparison of the two dated wells (fig. 5) teaches us, that Noel Patons correlation of the Upper Sands was right, and that the lower part of this Upper Sand series corresponds principally to zone F and the Upper Sand member of this same series already to zone G.
7. The hiatus between zones D and E must lie between 1650 and 1700′.

The section from the Montgomery mine (Mackenzie) (diagram II)

The section and the diagram from this place are of great importance for the correlation of the stratigraphy of the bauxite area with that of the coastal wells. The exact location on the mine face of the sample series for pollen analysis is shown in fig. 7. The stratigraphic position is between the base of the "white sands" (the Mackenzie formation, fig. 11) and the top of the bauxite. It represents, at that place, the Montgomery formation (see also fig. 8, 9, 12 and 13).

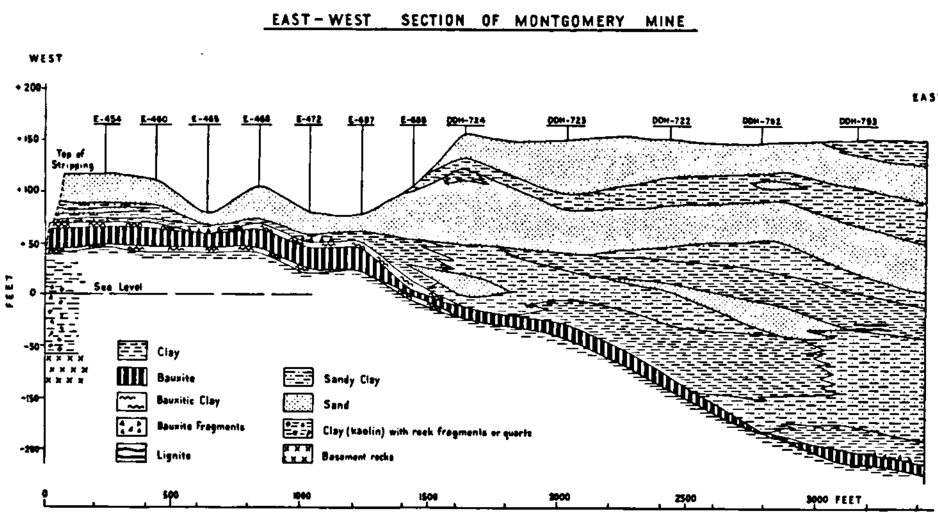

Fig. 8. East-West section of Montgomery mine (Mackenzie area). (Geol. Surv. Section according to drill-hole data of Demba by Bleackley, with some later additions).

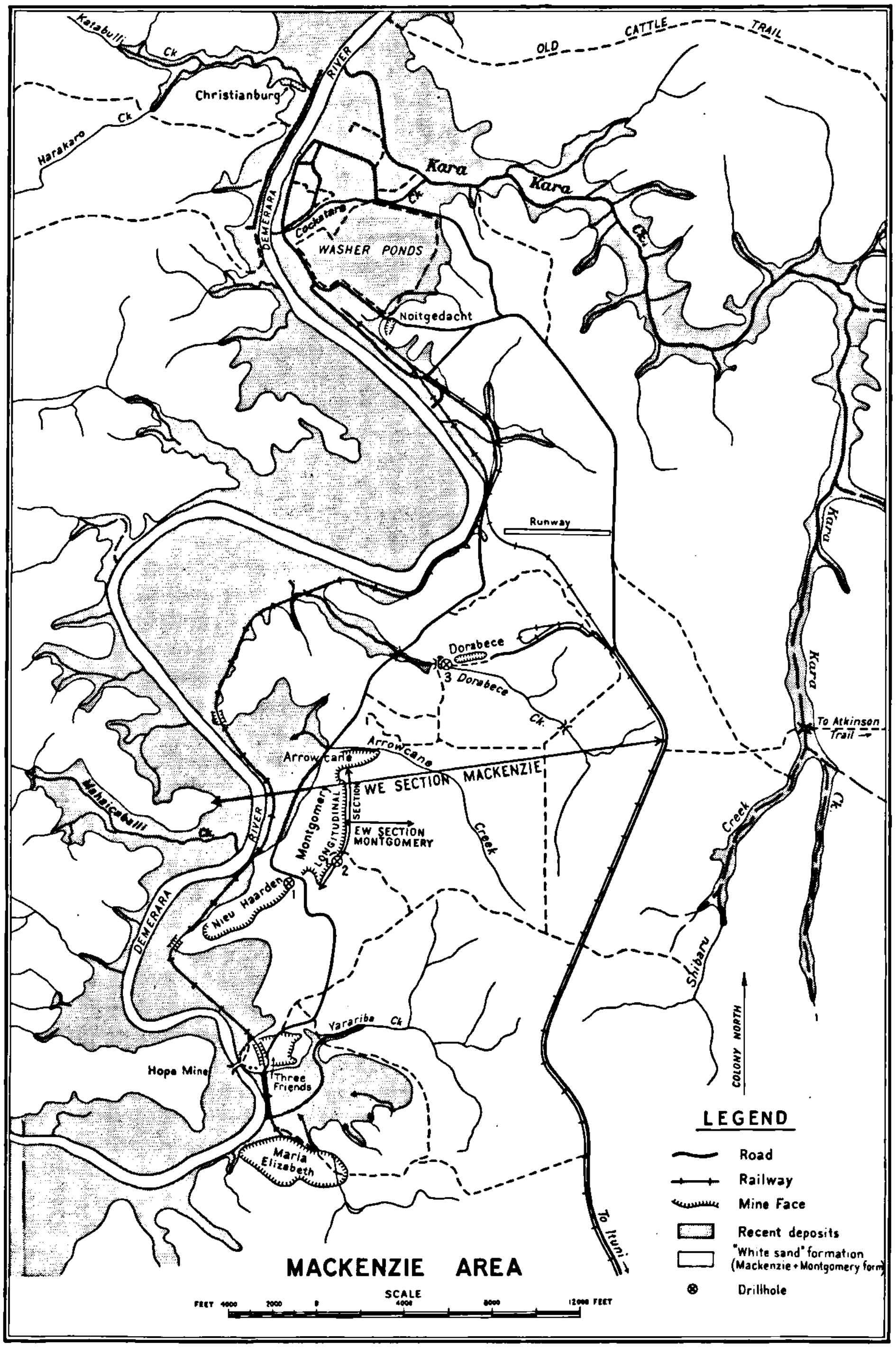

Fig. 9. Map of Mackenzie area, showing the position of the mines and of the sections (Map base supplied by Demba Cy).

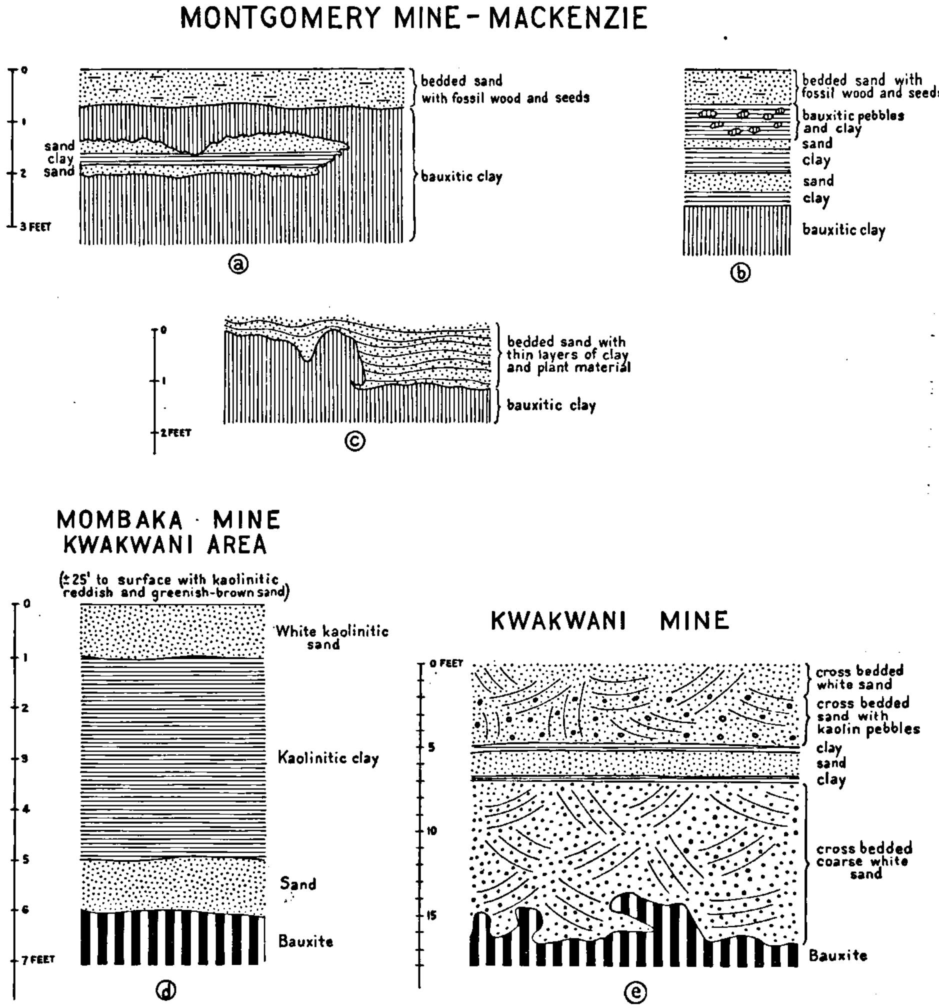

Fig. 10. Some details of mine faces in the Mackenzie and Kwakwani areas.

The diagram (II) is of the same type as diagram III: the fluctuations of the *Rhizophora* reflect the relative fluctuations of the sea-level.

The lowermost two spectra are from samples of $\pm$ grey clay taken from the bauxite itself. This clay must have entered along cracks, when the bauxite was submerged. These filled cracks, some of them running several meters into the bauxite, are visible at many places. It will be clear therefore that the age of the samples does not correspond to the age of the bauxite, but to the time of first submergence.

The two samples are poor, but the presence of *Psilatricolporites triangularis* indicates pollen zone E.

The next higher samples BC 1 and BC 2, were taken from a clear sedimentary intercalation in the upper part of the so-called bauxitic clay (fig. 10a). They have also a pollen association corresponding to that of pollen zone E. The geological

Fig. 11. Mackenzie formation, principally white sands, exposed in the higher part of the Montgomery mine (Mackenzie area).

Fig. 12. Montgomery formation, principally clays with intercalations of lignite. Montgomery mine (Mackenzie area).

implication of this fact is that at least the uppermost part of the bauxitic clay is formed later than the bauxite. This part may represent redeposited bauxite mixed with clay (see also fig. 10b). The fact that *Striatriletes* cf *susannae* occurs in the lower samples is interesting. The only sample of the Shelter Belt which contained this species was the basal sample of zone E, just below the A-Sands, and just above the hiatus.

It may be that this species is a facies indicator of beginning submergence. In Colombia it was often found at the beginning of a new pollen zone.

The samples no. 10 to no. 26, deposited like the former 2 samples in or near a swamp forest near the coast, belong also to pollen zone E (*Retitricolporites guianensis*). Then follows a sterile "varved" clay, overlain by a lignite forest bed with stumps and trunks (samples no. 33—35; fig. 14). Not a single grain of *Rhizophora* was found in this lignite bed, and it must have been deposited in a fresh water swamp rather far behind the coast. A very high maximum of the Palmae (*Psilamonocolpites medius* group) characterizes this interval.

After another sterile clay, the next lignite bed (samples 44—50) represents first a transgressive phase (high *Rhizophora* percentage), then a sudden regression, just below the base of the Mackenzie formation.

Fig. 13. Montgomery formation, Montgomery mine (Mackenzie area). The lignite horizons are clearly visible here. The top of the mine face corresponds to the base of the white sands of the Mackenzie formation. The lower part of the face corresponds to the bauxite. (This photograph was taken several years before the one of fig. 12, and was placed at our disposal by Ir. P. A. Snijders).

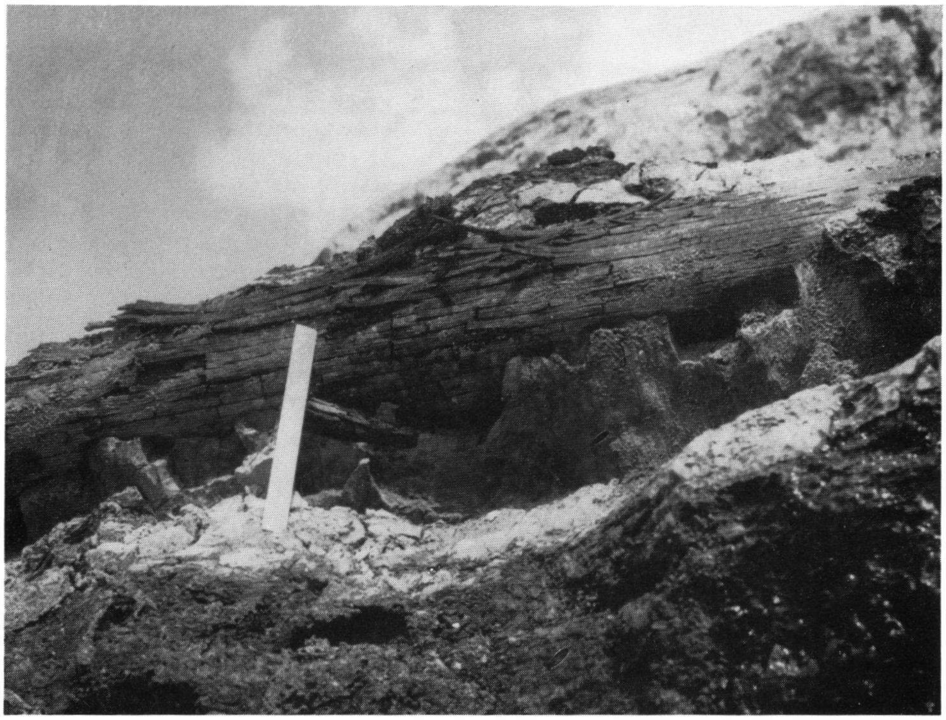

Fig. 14. Tree trunk from one of the lignite layers of the Montgomery formation, Montgomery mine (Photograph put at our disposal by Ir. P. A. Snijders).

The last mentioned lignites must belong to pollen zone F, and the high maximum of the Palmae (*Psilamonocolpites medius* group) in the lignite forest bed seems to indicate the limit between the two zones.

Mombaka (18—561 *A*) (fig. 15)

This drill-hole was made by Reynolds Cy in the Kwakwani area (fig. 15 and 16). It is one of the most important sections, as it represents the only place in British Guiana where datable sediments (lignites and clays containing abundant pollen) were found below the bauxite.

The scarcity of data from below the bauxite may be principally due to the fact that bore-holes penetrating to the basement at those places where bauxite is found, are rare. The fact that in Surinam such datable sediments were frequently found below the bauxite (Van der Hammen, Wymstra & Leidelmeyer, 1961; Wymstra & Van der Hammen, 1964) is in this respect revealing. A detailed study of the pollen content of the Mombaka samples is made by Leidelmeyer (1965), who gives a diagram.

We will represent here only the general pollen content of the interval. The depth of this interval with pollen is $\pm$ 125—150 feet below the surface (the bauxite lies between $\pm$ 40 and 60 feet below the surface, and the basement at $\pm$ 180 feet; see fig. 15).

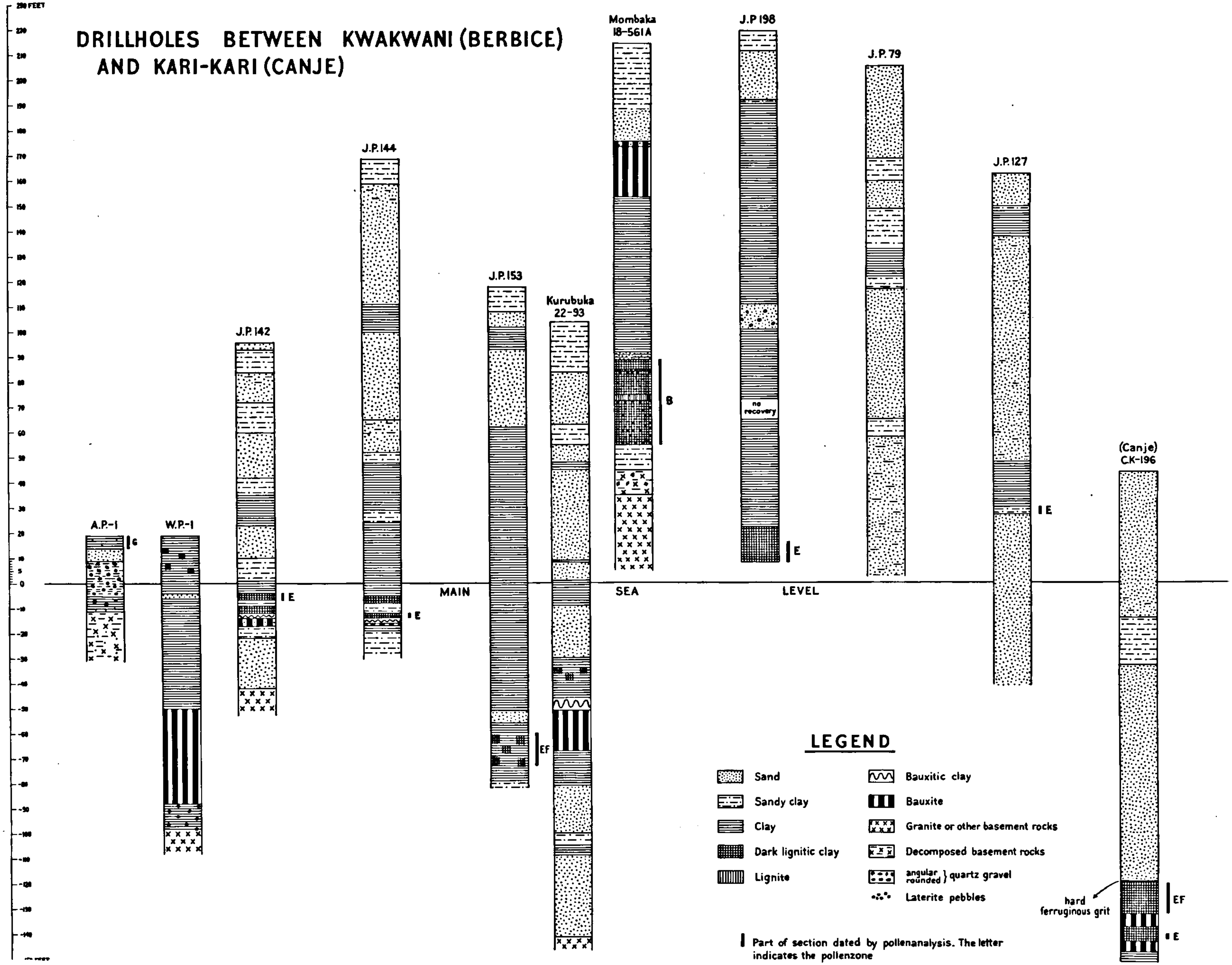

Fig. 15. Some drill-hole logs from the Kwakwani and Canje areas (Data supplied by the Geological Department of Reynolds Metals Cy at Kwakwani). Localization on fig. 16.

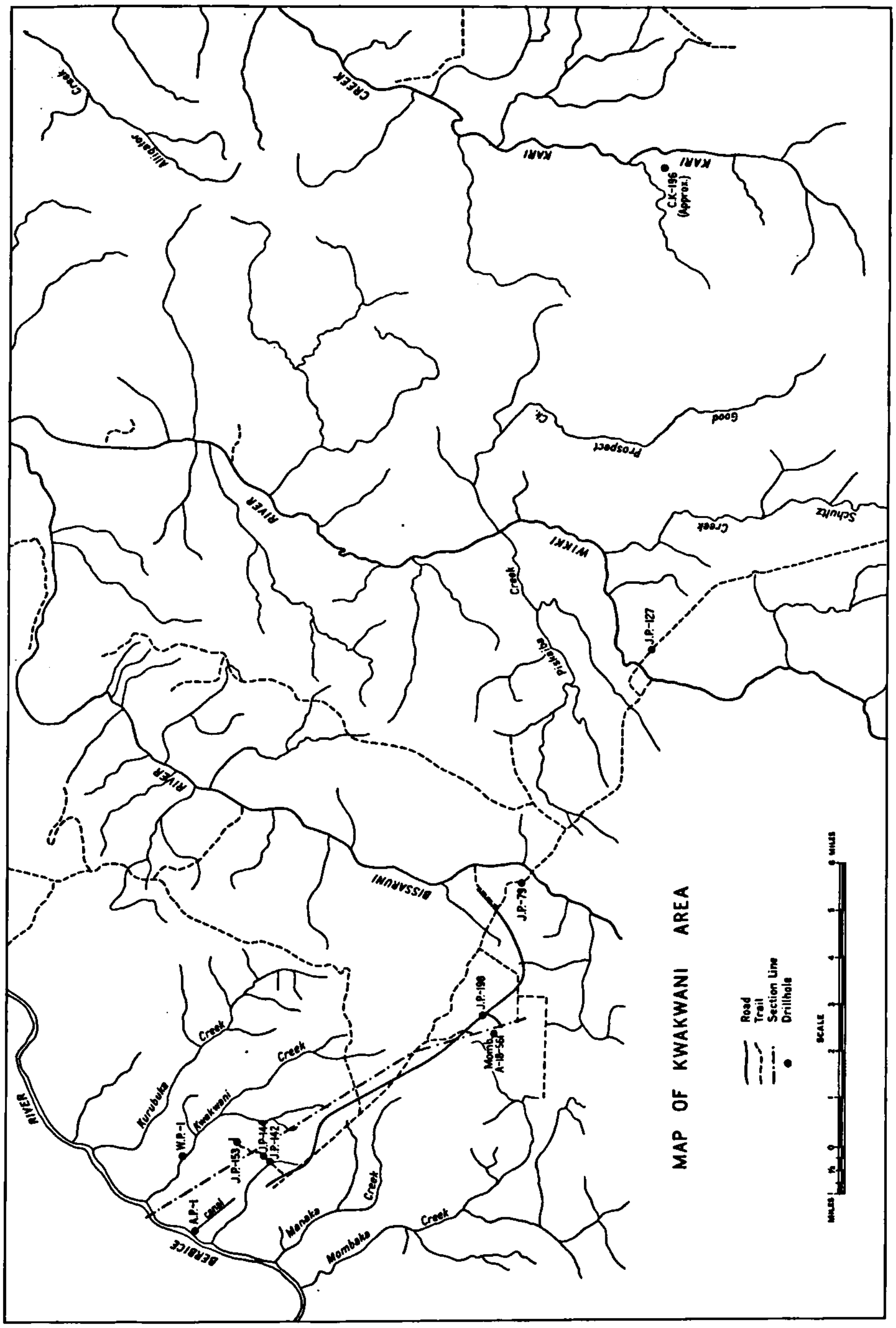

Fig. 16. Map of the Kwakwani area (and part of the Canje area), with the localities of the drill-holes of fig. 15 and the approximate location of section 17. Map-base supplied by Reynolds Metals Cy.

Pollen content of the samples between 125′ and 150′:

Psilamonocolpites medius gr.	40—60 % (one sample 17 %)
Echimonocolpites franciscoi gr.	1— 4 %
Proxapertites operculatus gr.	0— 1 %
Retimonocolpites proxaperturoides	0—30 %
Psilamonocolpites inornatus	0—12 %
Other Angiosperms	20—45 %
Retitriporites retibolus	
Retitricolpites cecryphalium	
Retitricolpites kwakwaniensis	
Retitricolpites analemae	
Retitricolpites cf *annaeoides*	
Verrusyncolporites cf *lisamae*	
Retidiporites magdalenensis	
Retidiporites botulus	
Polyplicadites vanegensis	
Psilatriletes sp.	

There is no doubt that this association belongs to the lower part of zone B_2. The fact that the lignite-horizon occurs just at the limit of a sand- (below) and a clay-series (above) in the area (see fig. 17), makes the comparison of this section with the Shelter Belt well very relevant.

A direct correlation between the Mombaka lignites and the lignites between 1140′ and 1195′ in the Shelter Belt is therefore possible.

Other drill-holes in the Kwakwani area (fig. 15)

Samples from a number of other drill-holes of Reynolds Cy in the Kwakwani area were analysed. The logs are presented in fig. 15, where the depth of the analysed samples is indicated. Fig. 16 gives the location of the same holes.

The samples that contained pollen grains consisted in general of grey or dark grey to lignitic clay. Purely white and cream kaolinitic clays were found to be sterile.

The following results were obtained:

Drill-hole JP-142. Depth 100—102′

Psilamonocolpites medius gr. (Palmae)	6 %	Age:
Echimonocolpites franciscoi gr. (*Mauritia*)	3 %	Pollen zone E
Myrtaceae	2 %	
Catostemma t.	8 %	
Melastomataceae	2 %	
Melastomataceae, large type	2 %	
Sapotaceae t.	6 %	
Araliaceae t.	1 %	
Echiperiporites akanthos	3 %	
Psilatricolporites triangularis	5 %	
Retitricolporites irregularis	28 %	
Retitricolporites squarrosus	3 %	
Other Angiosperms	29 %	
Verrumonoletes usmensis gr.	2 %	
Total	100 %	

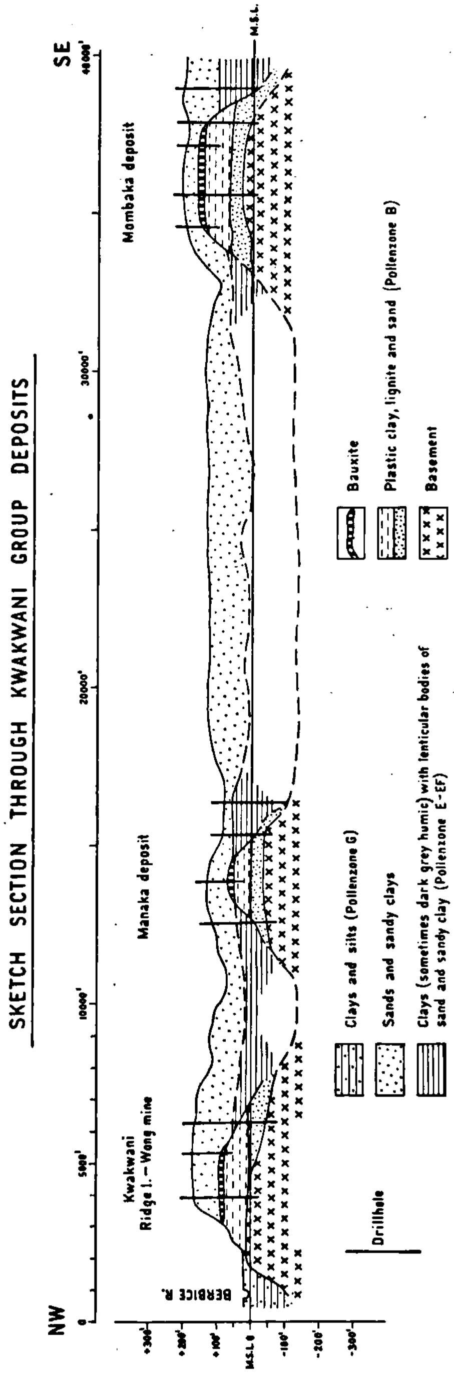

Fig. 17. NW-SE sketch section through deposits of the Kwakwani-group (see fig. 16). Based on drill-hole data (Reynolds Metals Cy) and palynological dating.

Drill-hole JP-144. Depth 181—183′

Monocolpites medius gr. (Palmae)	5.4 %	Age:
Rhizophora	1 %	Pollen zone E
Myrtaceae	4.3 %	
Catostemma	12 %	
Melastomataceae, large type	5.4 %	
Echiperiporites akanthos	3 %	
Psilatricolporites triangularis	1 %	
Retitricolporites irregularis	25 %	
Psilatricolporites rotundiporus	1 %	
Retitricolporites hispidus	4 %	
Clavainaperturites clavatus	9 %	
Other Angiosperms	28.9 %	
Total	100 %	

Drill-hole JP-153. Depth 178—191′

Monocolpites medius gr. (Palmae)	12 %	Age:
Echimonocolpites franciscoi gr. (*Mauritia*)	1 %	Pollen zone E or F
Rhizophora	13 %	
Gramineae	3 %	
Myrtaceae	1 %	
Melastomataceae	5 %	
Sapotaceae	5 %	
Malpighiaceae	1 %	
Anacardiaceae	1 %	
Retitricolporites guianensis	1 %	
Retitricolporites hispidus	1 %	
Retistephanocolporites quadriporus	1 %	
Retitricolporites squarrosus	1 %	
Other Angiosperms	40 %	
Psilatriletes	5 %	
Psilamonoletes	9 %	
Total	100 %	

Drill-hole JP-198. Depth 204—212′

Three samples were analysed from the cores of this interval, successively at 204′, 207′ and 208′.

Sample at *204′*

Rhizophora	85.7 %
Sapotaceae	1 %
Malpighiaceae	1 %
Retitricolporites guianensis	0.5 %
Psilatricolporites rotundiporus	7 %
Psilatricolporites crassus	0.5 %
Other Angiosperms	4.3 %
Total	100 %

Sample at *207'*

Rhizophora	85 %
Sapotaceae	2 %
Myrtaceae	0.5 %
Verrutricolporites rotundiporus	2.2 %
Psilatricolporites crassus	1 %
Psilatricolporites triangularis	1 %
Other Angiosperms	8.3 %
Total	100 %

Sample at *211'*

Psilamonocolpites medius gr. (Palmae)	1.5 %
Rhizophora	76.5 %
Myrtaceae	3.5 %
Malpighiaceae	0.5 %
Sapotaceae	0.5 %
Verrutricolporites rotundiporus	6 %
Retitricolporites guianensis	0.5 %
Psilatricolporites crassus	2.5 %
Psilatricolporites rotundiporus	4 %
Other Angiosperms	4.5 %
Total	100 %

The age of the three samples is pollen zone E.

Drill-hole JP-127. Depth 133—135'

Rhizophora	20.9 %	Age:
Myrtaceae	5.8 %	Pollen zone E
Catostemma	8 %	
Sapotaceae	17.4 %	
Anacardiaceae	6 %	
Melastomataceae, large type	3.4 %	
Malpighiaceae	3.4 %	
Retitricolporites guianensis	2 %	
Retitricolporites hispidus	2 %	
Psilatricolporites triangularis	1 %	
Psilatricolporites rotundiporus	7 %	
Other Angiosperms	18.1 %	
Striatriletes susannae type	2 %	
Verrumonoletes usmensis type	3 %	
Total	100 %	

From the data obtained from all these bore-holes, taking into consideration also the section of fig. 17, we may deduce that the old landsurface with the bauxite caps was submerged in the time corresponding to pollen zone E, and the valleys were filled up with sediments of that time. These sediments correspond lithologically, in stratigraphic position and in age with the Montgomery formation. The sands and sandy clays which cover the formation should correspond to the Mackenzie formation.

The upper part of the sediments of the bore-holes AP-1 and WP-1 belongs to the younger infill of the Berbice River system, and corresponds to the upper part of pollen zone G (Quaternary) (see also fig. 17 left, Van der Hammen (1963)), the diagrams Kwakwani-Canal (corresponding to the upper part of AP-1) and Berbice River plain-Kwakwani correspond to these sediments.

Kari Kari (*Canje*) *CK*-196 (fig. 15)

This drill-hole is situated in the Canje group deposits, in the area of the Kari Kari Creek. The log is presented in fig. 15 (right) and the approximate location on fig. 16.

The log shows two layers of bauxite, separated and covered by dark lignitic clay. The reason for this curious case must be the fact that the hole is situated near the edge of a deposit. Consequently there must have been erosion and redeposition at this locality during the submergence in the time of pollen zone E.

It seems therefore to be a similar (but more pronounced) case to the upper part of the bauxitic clay in the Montgomery mine (see above, and fig. 10a and b).

The age of both samples should indicate the first post-bauxite submergence.

The results of pollen analysis are as follows:

Depth 163—176'

Psilamonocolpites medius	Age:
Melastomataceae (large type)	Pollen zone E or F
Sapotaceae	
Psilatricolporites rotundiporus	
Psilatricolporites crassus	
Retitricolporites irregularis	
Echiperiporites akanthos	
Verrumonoletes usmensis t.	

Depth 185'

Rhizophora	78.5 %	Age:
Gramineae	1.5 %	Pollen zone E or F
Mauritia (*Echimonocolpites franciscoi* t.)	1 %	(probably E)
Malpighiaceae	0.5 %	
Catostemma	0.5 %	
Anacardium t.	0.5 %	
Sapotaceae type	5.5 %	
Malvaceae	0.5 %	
Psilatricolporites crassus	1 %	
Psilatricolporites operculatus	1.5 %	
Psilatricolporites rotundiporus	8.5 %	
Retitricolporites hispidus	0.5 %	
Echiperiporites akanthos	×	
Verrumonoletes usmensis t.	×	
Total	100 %	

The presence of *Echiperiporites akanthos*, which has up to the present only been found in zone E of the Montgomery section and the Rose Hall well, makes it probable that this sample belongs to zone E.

GEOLOGICAL CONCLUSIONS

The coastal area

In general it seems to be possible to recognize the main bodies of the lithological subdivisions according to Noel Paton, but in detail there are difficulties.

Pollen correlation between the Shelter Belt and Rose Hall wells showed clearly that in the former the Upper Sands are considerably thicker than originally thought (fig. 5), and it seems to be clear that the lower part of the Upper Sands and Noel Patons second lignite zone (middle less sandy part of the Upper Sands) correspond in age to pollen zone F.

Nevertheless, the data obtained so far from the pollen analysis of the Shelter Belt and Rose Hall wells, and the further lithological correlation of the coastal wells, (including the Nickerie well) give us now already a new general picture and interpretation (fig. 18).

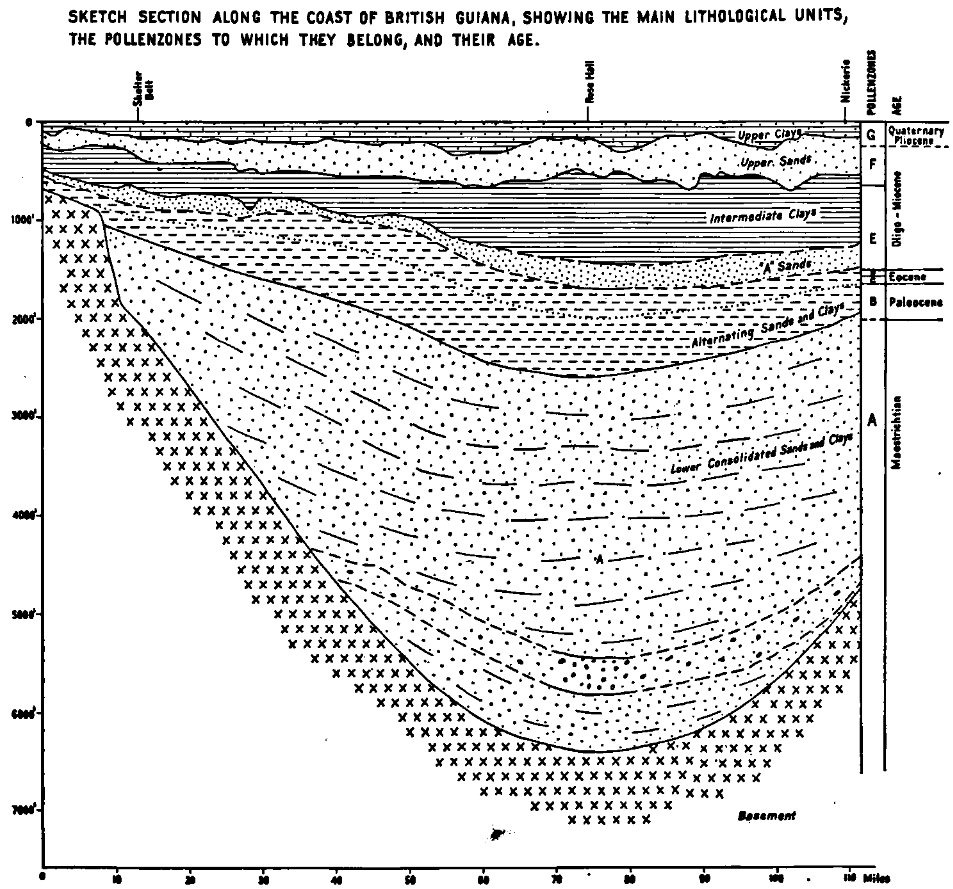

Fig. 18. Sketch section along the coast of British Guiana, showing the main lithological units, the pollen zones to which they belong, and their age.

On fig. 5 and fig. 18 the correlation of lithological units, pollen zones and age is indicated, and specially on the stratigraphical table for British Guiana, fig. 26.

The sketch-section of fig. 18 shows us that the basin contains a comparatively very large quantity of Upper Cretaceous sandy sediments. It is important to note that the limit "Lower consolidated sands and clays" — "Alternating sands and clays", which corresponds almost with the Cretaceous — Tertiary boundary, corresponds in the Rose Hall well with a rather important sediment-petrological change, as a granitic source is added to the reworking of pre-existing material (Kugler c.s., 1942). The section shows also that a hiatus between Eocene and Oligo-Miocene sediments is apparently present along the whole section, not far below the base of the A-Sands.

Both the A-Sand and the Upper Sands are remarkably constant horizons. A second hiatus may be present between zones F and G, probably at the base of the Upper Sand member (c) of the Upper Sands (see fig. 26).

The bauxite belt

The groups of bauxite deposits are all arranged along a belt (fig. 19) which is more or less parallel to the 0′ contour of the basement (fig. 2). It has been suggested by several authors that this line might be related to the coast-line in the time of bauxitisation.

In the Kwakwani area (fig. 15, 16 and 17 and the photograph fig. 22), the bauxite occurs principally on the higher parts of what seems to be an old buried land-surface with drainage-pattern. These higher parts are more or less flat-topped hills, which consist of plastic clay and sand (Mombaka formation), some 100′ thick, and resting on basement. The basement below these hills lies often higher than in the surroundings, so that we may say that the hills consist of basement rocks, capped by sediments (fig. 17). The bauxite occurs as flat caps on top of these hills, i.e. on top of the sediments. When the sediments are lacking, the bauxite may sometimes directly lie on weathered basement.

The age of the lignites occurring in Mombaka in the mentioned sediments has been established by pollen analysis as lower part of pollen zone B_2, that is to say Paleocene, but very near to the boundary with the Maestrichtian. As the lignites occur just above the lower sand member of the Mombaka formation, and in view of the position of lignites of the same age in the Shelter Belt well, a Maestrichtian age of this member seems to be probable, as we have shown here before (see also fig. 26).

The buried valleys between the hills were first filled with sediments corresponding to pollen zone E (Montgomery formation), and which were deposited very near the sea-shore (abundant *Rhizophora*).

The whole (both hills and filled-up valleys) was then covered by sands and sandy clays, which should correspond to the Mackenzie formation, but that do not contain pollen. This formation is lying with a clear limit on top of the bauxite in the mines of the region (fig. 22). The surface of the bauxite may be rather flat, but is often very irregular (fig. 10d and e).

Summarizing, we may say that from the bore-hole sections and the pollen dating the following seems to be evident:

a. There was a Late Cretaceous (basement) relief (land-surface).
b. This surface was submerged near the beginning of the Paleocene (deposition of Mombaka formation).

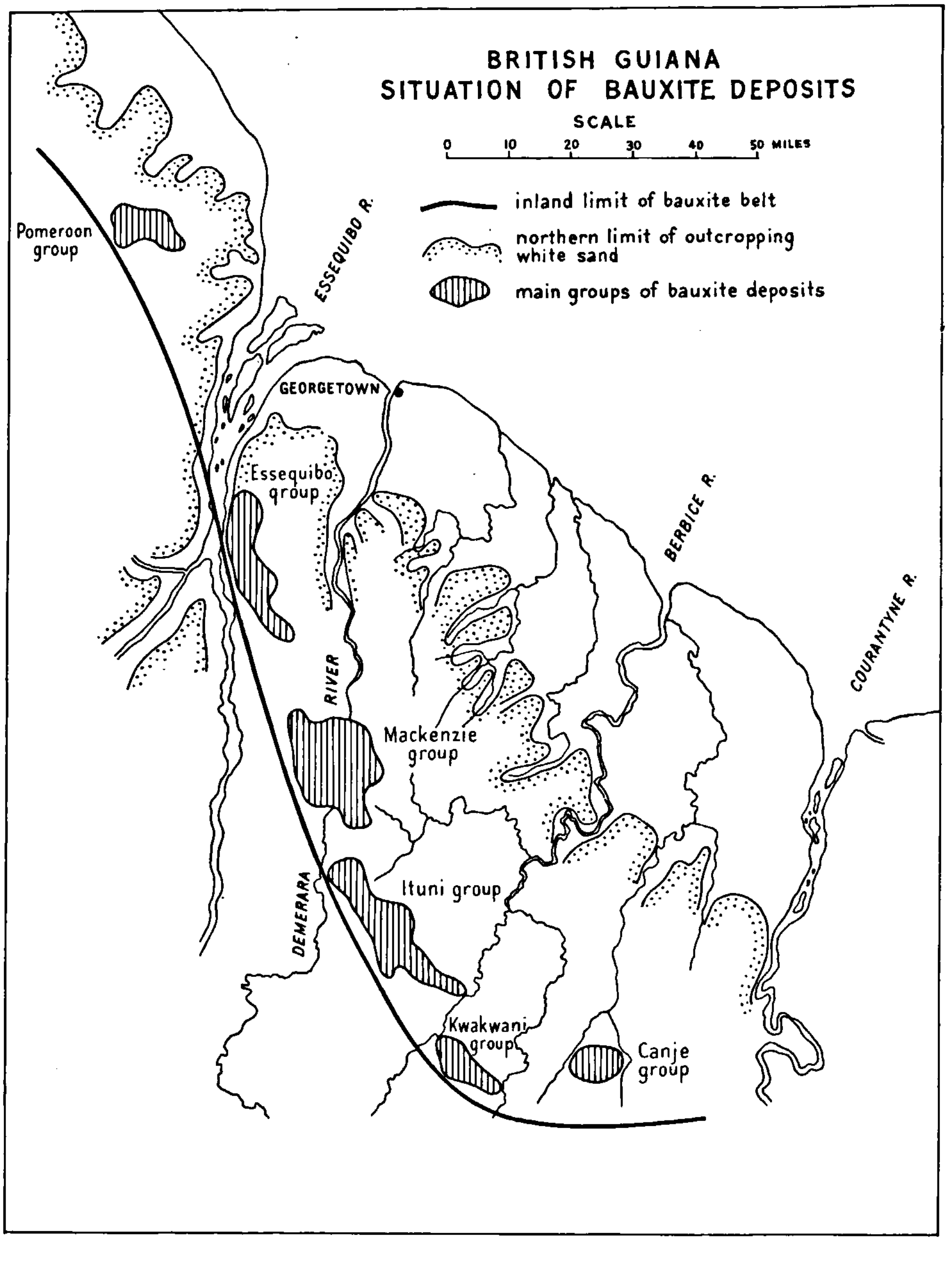

Fig. 19. Situation of the groups of bauxite deposits in British Guiana.

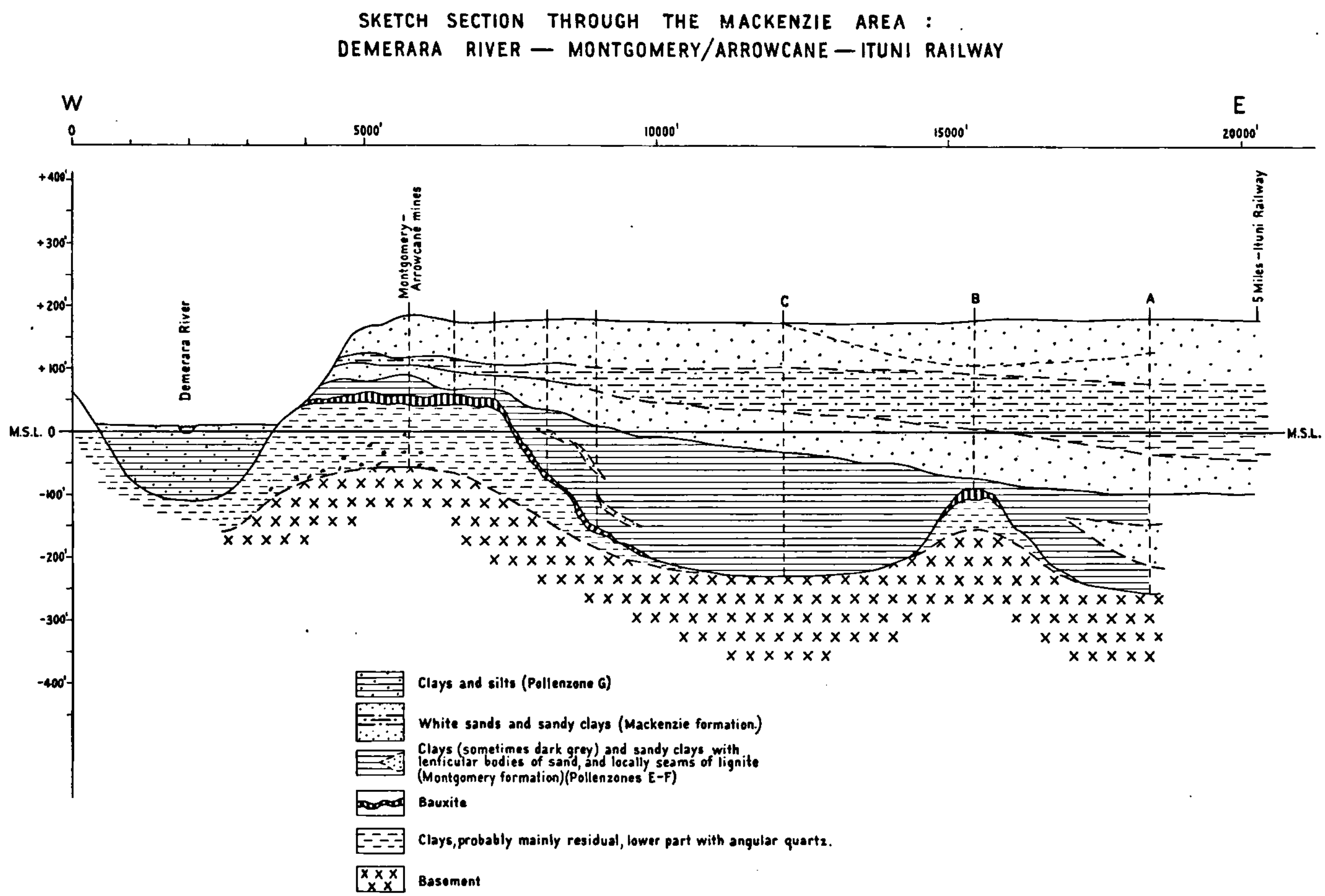

Fig. 20. West-East section through the Mackenzie area. (Compiled from drill-hole data of Demba Cy and other data from different sources).

c. Later the area was raised above sea-level again, and an old land-surface with drainage-pattern (following partly the old basement valleys) developed. Bauxitisation took place during this interval.
d. This land-surface was then for the greater part submerged during pollen zone E. The valleys were filled up with sediments of this age. The higher bauxite-capped hills must have been like islands in a swampy to estuarine environment.
e. During the deposition of the Mackenzie formation, the area may have been successively near and above sealevel, but finally became definitely above sea-level.
f. Erosion started and a drainage-pattern was formed, finally strongly deepened during the Pleistocene low glacial sea-levels and filled up now mainly with Holocene estuarine to fluviatile sediments.

The bauxite may sometimes be followed down the slope of the hills into the valleys. In these cases we find it often directly covered with a dark lignitic swamp-clay, representing the beginning of submergence at the very base of the Montgomery formation. This fact proves that the bauxite was already formed, when the transgression reached the area.

In the Mackenzie-Ituni area the conditions seem to be very similar (fig. 7, 8, 9, 20, 21 and the photographs fig. 11, 12, 13 and 14). The only important difference is, that possibly the clays below the bauxite are residual and not sedimentary. The three drill-holes that were made specially by the Demerara Cy below the bauxite to the basement (Nieu Haarden, Montgomery and Dorabece) did not find unquestionable sediments nor samples with pollen grains.

The upper part (in the Montgomery mine drill-hole) consists of clay, the lower part of clay with angular quartz. One is inclined to think that these clays are all residual. Because of the fact that the thickness is also ± 100′, like the Mombaka formation in the Kwakwani area, we think that the question is not yet solved, and that it is very possible that pollen-containing samples will be found below the bauxite. Comparing the sections from Kwakwani and Mackenzie, one must at least admit that the similarity is striking.

In the Montgomery mine some sediments of the age of pollen zone E were found on top of the bauxite. A layer of bauxitic clay is found here on top of the bauxite and below the Montgomery formation. This bauxitic clay sometimes shows a rather flat surface, but sometimes the top is irregular (fig. 10c), more or less like that of the bauxite in the Kwakwani area (fig. 10e). In the upper part of the bauxitic clay an intercalation of sediments was found (fig. 10a) and at another place similar sediments were found to be covered by a mixture of probably redeposited bauxitic pebbles and clay. The intercalated sediments of fig. 10a contain a pollen flora corresponding to zone E, as do samples from clay that penetrates through cracks in the bauxite. On top of the bauxitic clay layered sands, lignites and clays are normally found, these corresponding to pollen zones E and F. From all this it seems probable that the bauxitic clay belongs to the top of the bauxite proper, but that it has been redeposited and cemented, sometimes including (and partly "bauxitizing") younger sediments.

Sediments corresponding probably mainly to zone E (Montgomery formation) filled the valleys between the bauxite hills, like in the Mombaka area, the only difference being, as we just saw, that even some of the higher bauxite hills were completely submerged, so that we find locally the sediments of zone E also on top of these major bauxite deposits.

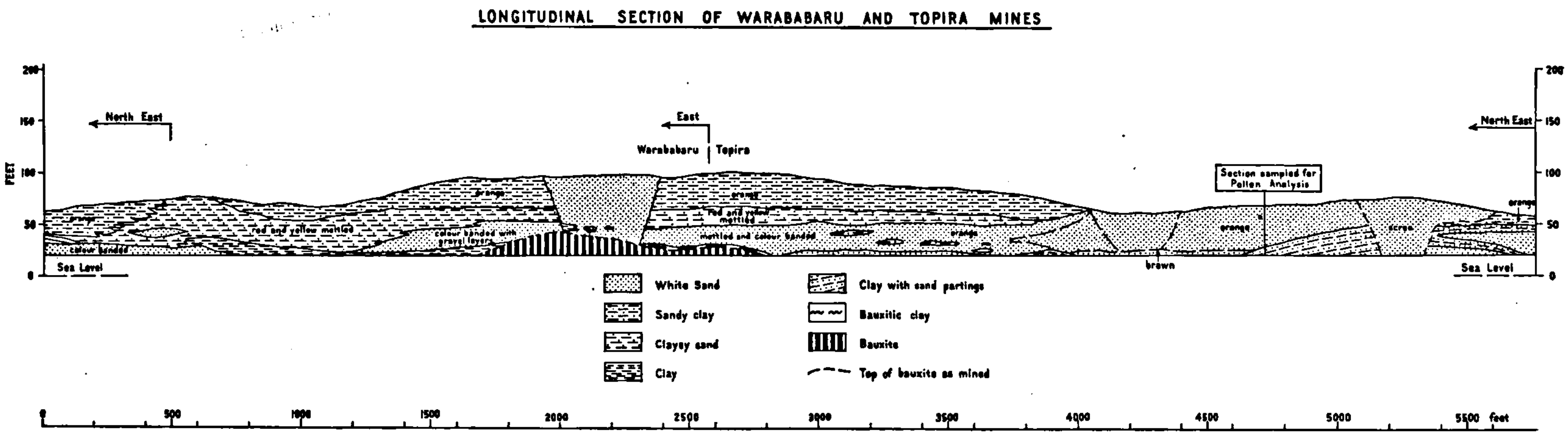

Fig. 21. Longitudinal section of the Warababaru and Topira mines, Ituni area (Geol. Surv. section).

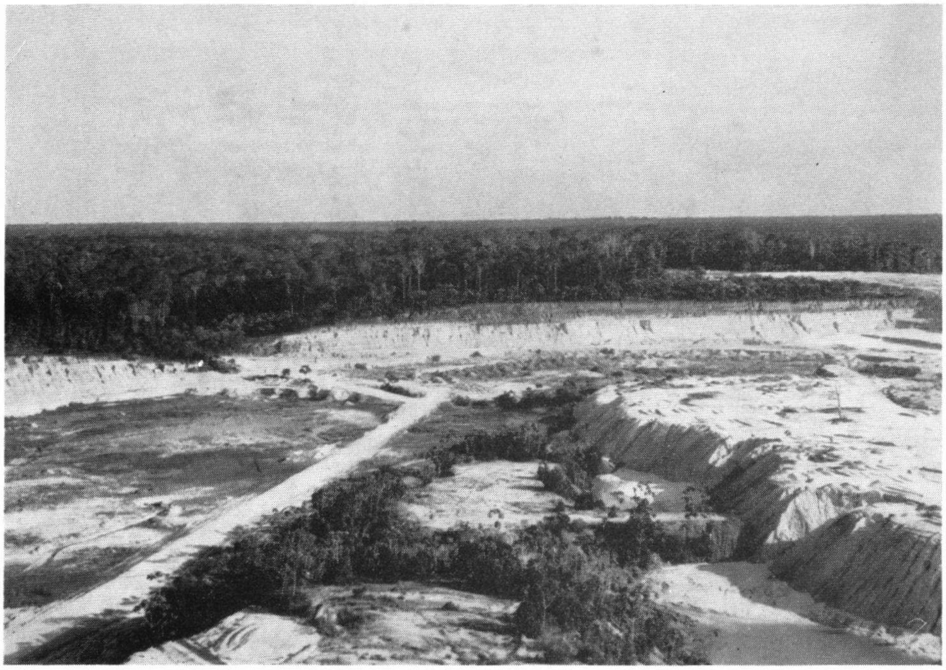

Fig. 22. Bauxite mine near Kwakwani. In the mine face the overlying sands of the Mackenzie formation are visible. (Photograph taken from the air).

But in other mines the situation is similar to that in the Kwakwani area, and the sands or sandy clays of the Mackenzie formation are found directly on top of the bauxite. This is the case at least in part of the Ituni area (Warababaru-Topira mines, fig. 21). Nevertheless "varved" clays are locally found in the NE part of the Topira mine, which resemble very closely those of the Montgomery formation in the Montgomery mine (see stratigraphic column of diagram II). A pollen section was taken at that place (fig. 21), but the samples did not contain pollen.

The Mackenzie formation can be clearly subdivided in the Mackenzie-Ituni area into three members: sands, sandy clays and sands. The clays immediately below the lower sand member may correspond to the beginning of pollen zone F (see diagram II and sections fig. 7, 8 and 20), but at many places the lower sand member seems to cut into the underlying sediments of zone E (see fig. 7) and appears to fill valleys cut into these sediments, partly following the old valleys (fig. 20).

One may conclude that, besides some minor differences due to local circumstances, the stratigraphical-geological picture of the Kwakwani-Mombaka area and of the Mackenzie-Ituni area is indeed very similar.

Considering now all the data from the bauxite belt, we may try to answer the question of the age of the bauxite. It must be stated first of all that there are no indications at all for the presence of more than one lowland bauxite (as suggested by Van Kersen, 1955), neither in British Guiana nor in Surinam. On the contrary, everything seems to point towards the conclusion that there is only one lowland bauxite in the Guiana Basin (see also Wymstra & Van der Hammen, 1964). According to the latter publication, Paleocene sediments are commonly found below the bauxite, but, moreover, sediments with an Eocene pollen flora (pollen zone C) were also found.

If we consider British Guiana only, the bauxite must have been formed in the interval between pollen zones B and E, that is to say most probably during the Eocene, although a "Lower Oligocene" age cannot be completely excluded. If we also consider the data from Surinam, then the interval can be still more restricted, because the pollen zone C must be of Lower Eocene age. From the data of the bauxite belt of the Guiana Basin, we may conclude therefore that the bauxite interval must lie somewhere between Lower Eocene and Lower Oligocene (see fig. 26). We will add some data on the eventual possibility of further restriction of the time of the bauxite interval in the following paragraphs.

The North-South sections (fig. 24 and 25)

When one tries to make North-South geological sections to connect the coastal area with the bauxite belt, serious difficulties are met. These difficulties result from the lack of data in the intervening area, borehole data being absent or extremely scarce and geophysical data on the depth of the top of the basement are only available for a section along the Berbice River.

Nevertheless we tried to make the sections, indicating for which intervals no drill-hole data were available.

The section along the Demerara River (fig. 24 and fig. 1) includes the Shelterbelt well, and was moreover compiled from a number of well-logs taken from Martin-Kaye and Bateson (1962), Bishop (1954), Bleackley and Noel Paton, or obtained directly from the Demerara Bauxite Cy; it includes also our own observations in the mines and, of course, those results of correlation and dating of the sediments by pollen analysis mentioned earlier in this article.

The section may be subdivided into a down warped coastal part and an inland part with a basement which slopes more gently towards the coast. The two parts are separated by an important fault. The strike of the fault is not precisely known, but may be NNW-SSE or NW-SE *. The coastal down warped basin contains a relatively thick Upper Cretaceous series, which seems to be lacking further inland.

The A-Sands are apparently still affected by movements along the fault, but may be located as far as Atkinson Field. Then we lose it, because of the lack of drill-hole data, and there are no signs of its presence in the Mackenzie-Ituni area.

The Upper Sands can be followed from the coast to Atkinson Field, where they come to the surface: pollen correlation showed that the Mackenzie formation (white sand) corresponds to the Upper Sands.

The base of pollen zone F lies just below the base of both these formations, which may moreover both be subdivided into three members (see the stratigraphic table of fig. 26).

The age and nature of the clays below the bauxite in the inland area is not known, as we have seen. They may be residual, but it is not excluded that there are Paleocene sediments among them (compare with the section along the Berbice, fig. 25.).

The clays with lenticular sands and sandy clays corresponding principally to pollen zone E are easily to be followed from the coastal region (Intermediate

* Recent seismic data put the existence of this fault in doubt.

Clays) to the buried "valleys" between the bauxite-deposits (Mackenzie formation).

In the section along the Berbice River (fig. 25 and fig. 1) the interval without drill-hole data is considerable, but here at least the position of the top of the basement is known, and it seems possible to connect more easily the coastal sections with those from the bauxite belt, as we know with certainty that the sediments below the bauxite are of Paleocene age. The section includes the Rose Hall well and data

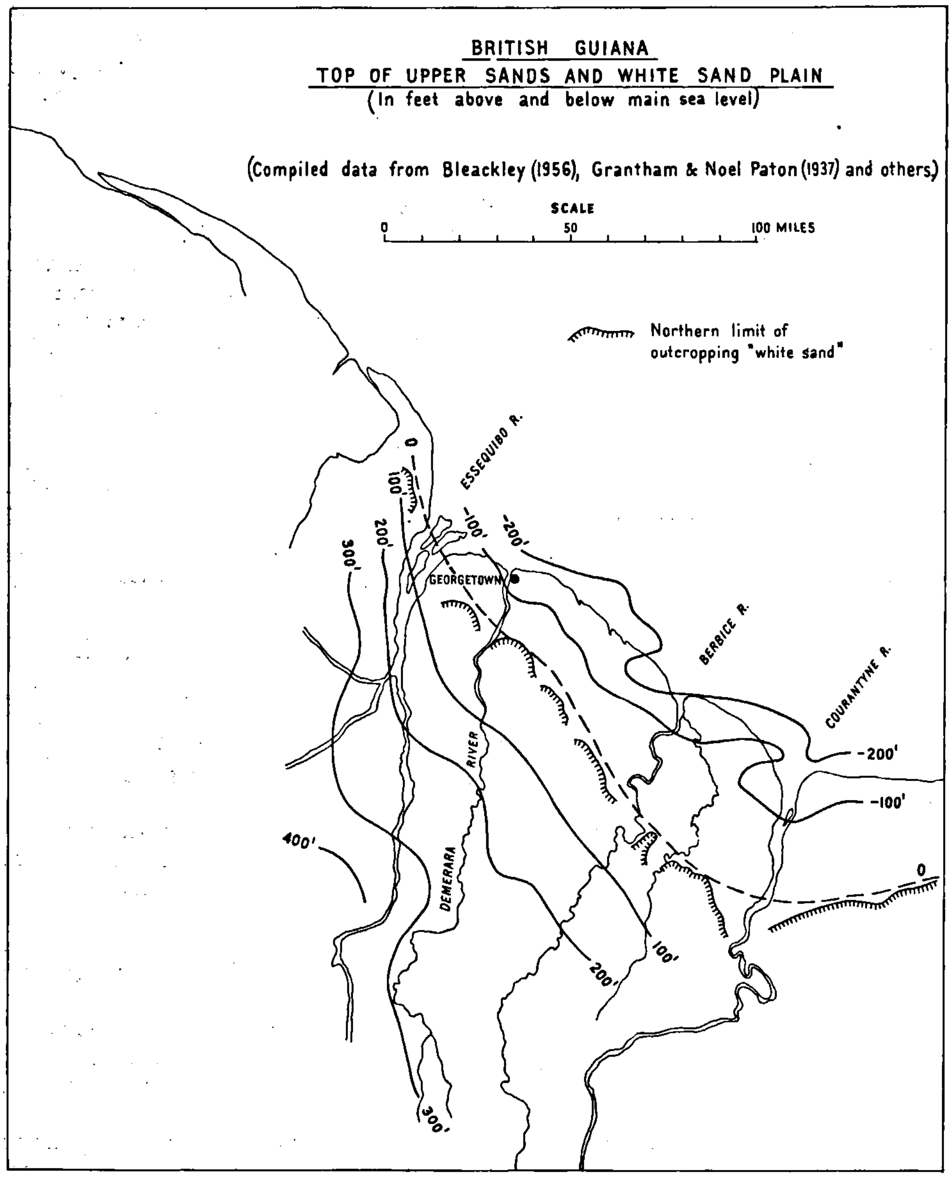

Fig. 23. Top of the Upper Sands and of the White Sand plain. (Compiled from different sources).

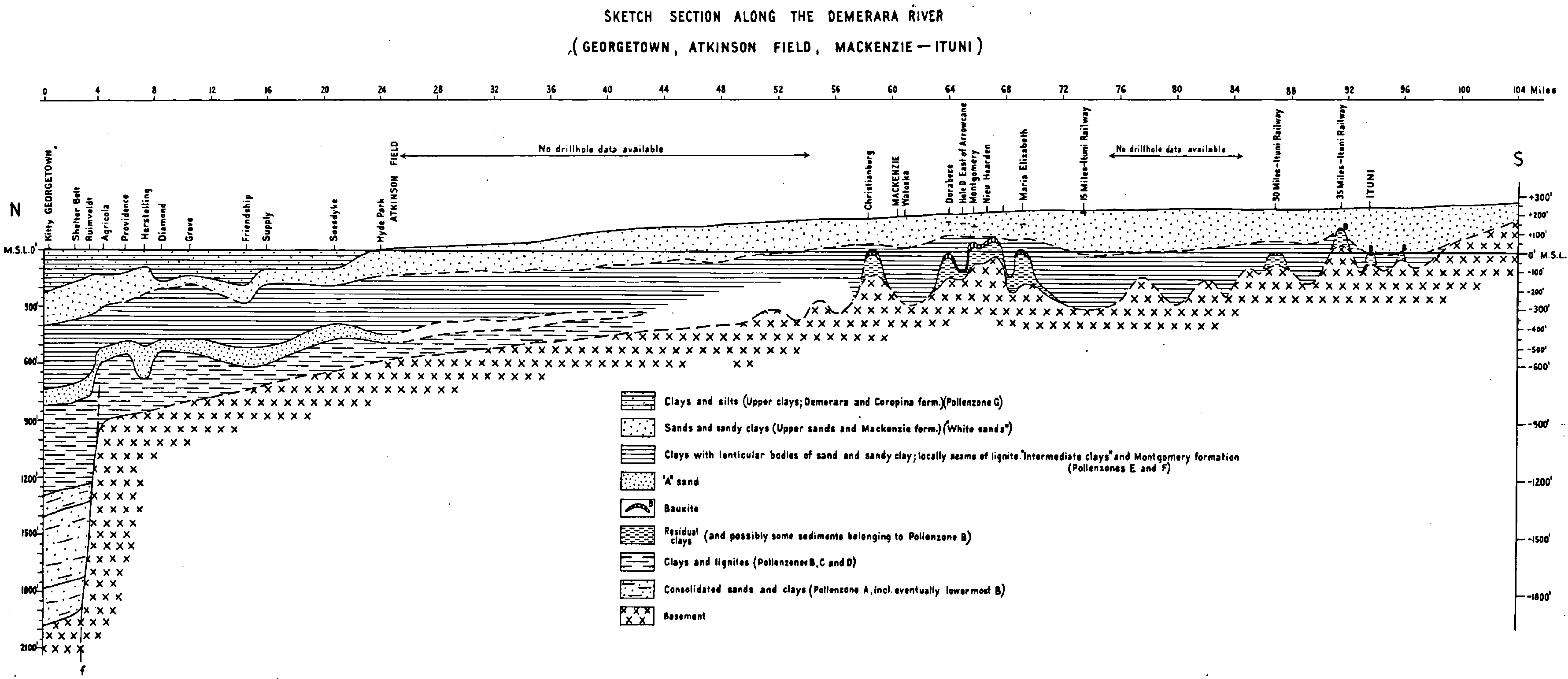

Fig. 24. Section along the Demerara River, from the coast via Mackenzie to the Ituni area.

from Noel Paton, and from drill-hole logs received directly from Reynolds Metals Cy. The geophysical data (depth of top of basement, see fig. 2) are from Kugler c.s. (1944).

In this section the coastal part has also been warped down along one or several faults. This part contains a very thick series of sediments of Upper Cretaceous age, followed by Paleo-Eocene sediments, which can partly be followed into the bauxite belt. The bauxite interval can also be followed until the hiatus between the sediments of pollen zones C-D and E in the coastal sediments. The A-Sands, little above this hiatus, cannot be traced into the bauxite belt, where they seem to be lacking, as in the Mackenzie-Ituni part of the Demerara section. The Upper Sands can be correlated just as in this last mentioned section, with the sands and sandy clays of the Mackenzie formation, outcropping in the inland part of the section. This pollen correlation in general, makes it possible to map the top of these sands (fig. 23).

As we can follow the hiatus of the bauxite interval into the coastal area, we may say that it is most probable that the coast at that time was still farther North than at present. If this is correct, then the association of the bauxite belt with a former coast-line of that time is impossible. As the drill-holes of the bauxite companies do not reach in general to depths below 200′, an eventual further coastward extension of the (deeper buried) bauxite belt is still unknown. But it is necessary to know the exact position of any extension of the bauxite belt if we are to determine its relation to a former coast-line. Deep drill-holes are therefore urgently needed between the known bauxite belt and the coast.

The present line of the belt might eventually indicate only the zone where bauxite lies within 200′ from the surface, and be related with the 0′ line of the basement instead of with a former coast.

We have seen that when the coast was near the bauxite belt, in the beginning of pollen zone E, the bauxite was already formed.

The Guiana Basin

The general picture we got in this article from the Guiana Basin, is summarized in three sections (fig. 1), one along the coast, and two more or less parallel to the rivers Demerara and Berbice (fig. 18, 24 and 25). A more detailed picture of interpreted coastal wells may be seen in the correlation of the Rose Hall and Shelter Belt wells (fig. 5), while the situation in two bauxite areas, Kwakwani and Mackenzie is sketched in fig. 17 and 20. The characterisation of the pollen zones is shown in fig. 6 and diagram IV, while the results of palynological dating and correlation of the formations of the coastal wells and the bauxite belt are summarized in the stratigraphical table of fig. 26.

The basin apparently subsided in its coastal part along steep faults, the strike of which is not known with certainty. The enormous infill of Upper Cretaceous sediments suggests that the movements (sinking of the coastal part of the basin along the faults) were strongest in that time. It seems that less important continued movement along the faults was still apparent after the time of deposition of the A-Sands (see the vertical displacement of this sand in fig. 24 left and fig. 4 left).

We have seen that there is an important hiatus in the stratigraphical succession of the basin, comprising at least the major part of the Middle and Upper Eocene, including eventually also Oligocene. The hiatus might very well represent a slight angular unconformity. A second hiatus comprises probably at least a major part of the Miocene.

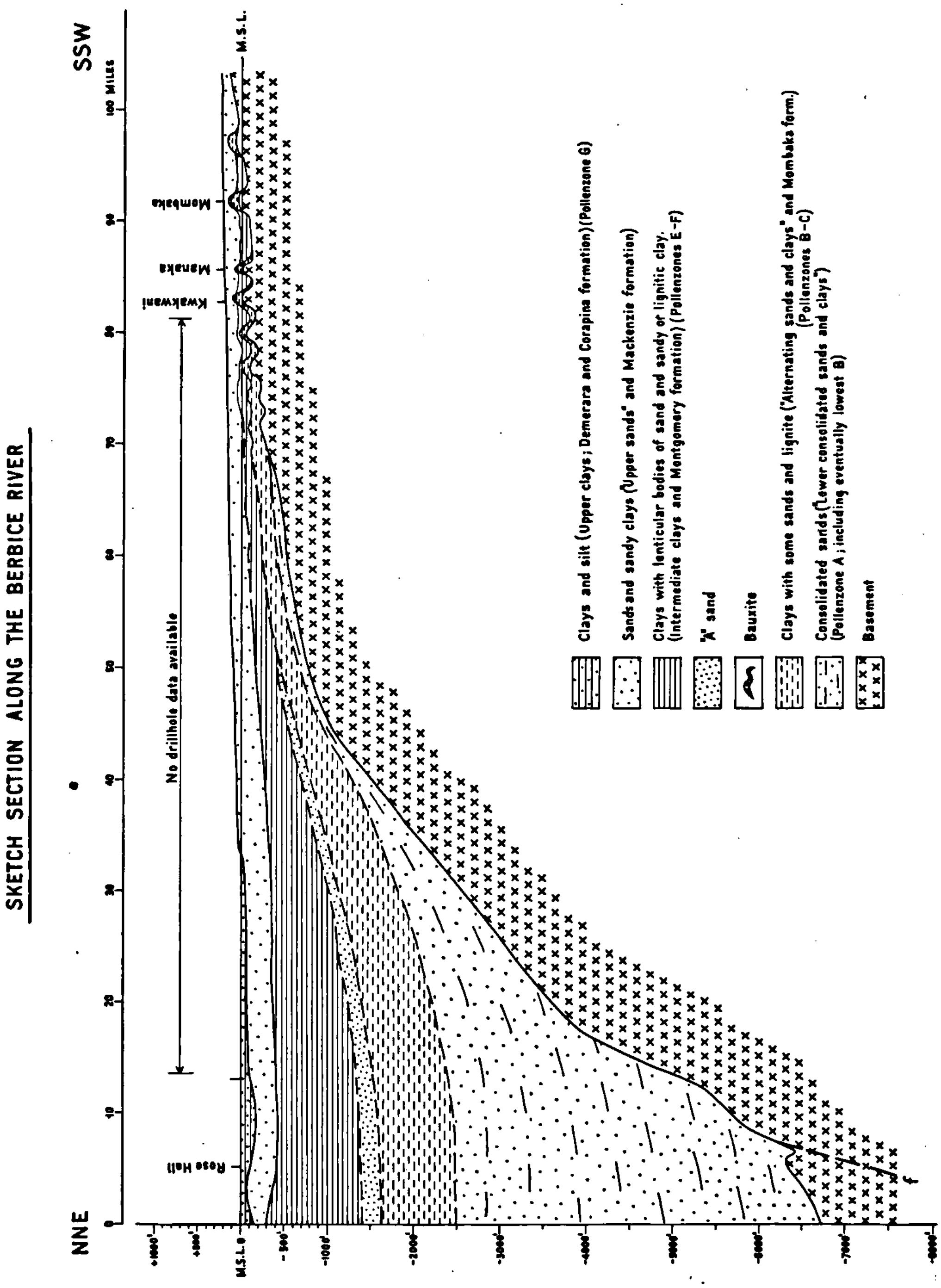

Fig. 25. Sketch section along the Berbice River, from the coast to the Kwakwani area.

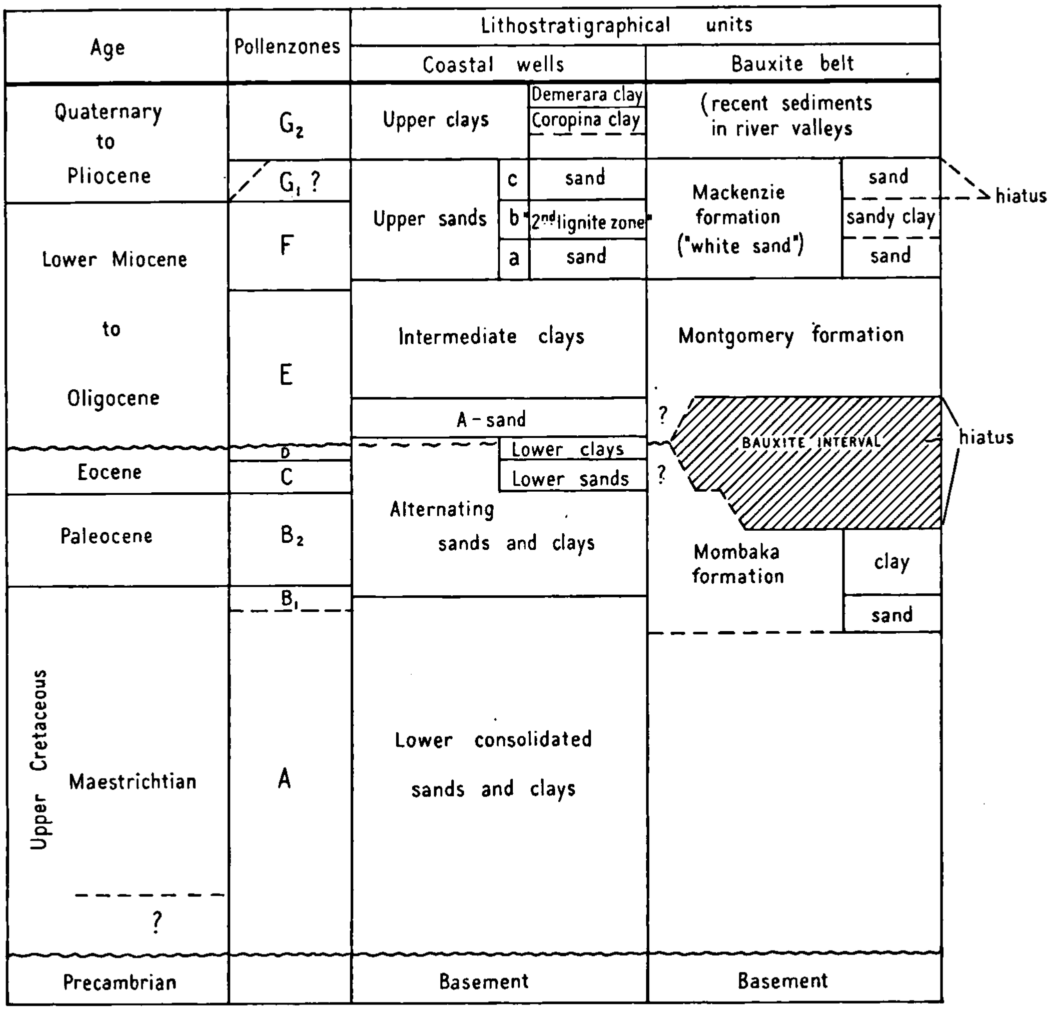

Fig. 26. Stratigraphical table for British Guiana (from Upper Cretaceous to Recent).

We will now try to compare these tectonic and stratigraphic conditions of the Guiana Basin with other areas.

Basins very similar to the Guiana Basin are found along the coast of Brasil (De Boer, 1963). We received from Petrobras a number of samples from bore-holes of the Marajo Basin (near the mouth of the Amazon), for palynological analysis.

The results showed that this basin, sunk along steep faults, contains a basal thick series of Upper Cretaceous (Maestrichtian) sandy sediments resting directly on basement, followed by Paleocene and some Eocene. The younger Oligo-Miocene part of the section begins with a sand which seems to be comparable with the A-Sands. Comparing the basins from the Guiana and Brasilian coast, one is inclined to relate it to a general rifting of the coast of South America, which in the North might have occurred in the Upper Cretaceous (see a.o. De Boer, 1963).

Comparison with the stratigraphy on the western edge of the Guiana shield in the Colombian Sierra de La Macarena (Paba & Van der Hammen, 1960), shows a thick Upper (to Middle?) Cretaceous sandstone series, resting on older Paleozoic and Precambrian basement. This sandstone is overlain by a series of reddish clays and clayey sands of 200 m thick, of Paleocene age. Then follow 300 m (Lower to Middle) Eocene sandstones and conglomerates.

In the upper part of this conglomerate series we found a (possibly 10 metres thick) layer of pisolitic bauxite. A Middle Eocene age of this bauxite is probable. The conglomerates are overlain by Upper Eocene to Lower Oligocene shales.

It is apparent that the stratigraphic position and age of the bauxite here corresponds very well with that in the Guiana Basin.

The stratigraphic succession in the Andes of Colombia shows also many parallels (Van der Hammen, 1960 and 1961). At the eastern edge of the geosyncline the Upper Cretaceous is developed as a sandstone series (El Morro), and the further succession is very similar to that in the Macarena, with the exception that there is no bauxite in the Eocene sandstones. Coals are present specially near the base of the Paleocene. Further to the West the facies of the Upper Cretaceous becomes more shaly. In the Upper Maestrichtian the marine facies changes into a paralic facies with coals. This continues in the Lower Paleocene. The facies of the Lower Eocene A is the continuation of that of the Upper Paleocene (exactly like in B.G.), but then the Lower Eocene conglomerates start, sometimes with a slight unconformity. They are often relatively thin. Still thinner or even lacking are the Middle Eocene conglomerates. They represent still clearer a phase of movements and local upheaval and some compression in the Andes. An unconformity of that age is recognizable in many places of the South American Andes.

The succession continues with shales and mudstones of Lower Eocene and Lower to Upper "Oligocene" age. The "Oligocene" starts with a marked sand layer. No sediments of (at least Middle to Upper) Miocene age are present in great areas of the proper Colombian Andes, they were deposited in the interandean graben-valleys.

Resuming the above we may indicate the following parallels. The important sinking of the Guiana Basin in the Maestrichtian coincides with the transition from marine to a continental-paralic facies in many parts of the Northern Andes.

Coals are specially frequent in the uppermost Maestrichtian and lowermost Paleocene, like the lignites in B.G. Sinking continued in B.G. in the Paleocene, and in the Andes the upheaval of Paleozoic massives, that probably started already in the Lower Maestrichtian, becomes pronounced in the beginning of the Paleocene. Tectonic-orogenetic movements during the Eocene resulted in the Andes in unconformities, the deposition of conglomerates and eventually a Middle Eocene hiatus ("Pre-andean" phase); on the western edge of the shield a bauxite layer was formed in that time. In B.G. in the same time a hiatus is present and bauxites were formed. In the Andes the new transgression starts partly in the Upper Eocene and more pronounced in the "Oligocene", that starts on many places with a marked basal sandstone. In B.G. the new transgression starts in the "Oligocene to Lower Miocene", and a marked basal sand (A-Sand) is developed. When the sedimentation in the proper Andes stops and is confined to the interandean graben-valleys, there seems to be also a hiatus (at least a part of the Miocene) in B.G.

There seems to be therefore considerable evidence that certain parallel important events are synchronous in great areas of Northern South America. Several of these events seem to be part of world-wide phenomena. There are for instance remarkable similarities with the coastal basin of Nigeria. Another example of a certain parallel development is the Dutch Peel region, where Upper Cretaceous (Senonian) lies directly on Paleozoic. This Senonian is overlain by Paleocene. Then follows a hiatus which represents the Eocene, and the sedimentation continues in the Middle Oligocene (Rapport Peelcommissie, 1963). We like to state therefore, that we believe that the formation of the bauxites in British Guiana is certainly not the result of a local phenomenon. It seems to be related with world-wide tectonic and possibly climatic phenomena.

SOME REMARKS ON THE PRACTICAL APPLICATION OF PALYNOLOGY IN BRITISH GUIANA

We have seen from the above that the application of Palynology for age determination and correlation of series of sediments has given us a considerably better picture of the geological history of our region, and one may conclude, that this knowledge and understanding is of general importance in the search for water, bauxite and oil.

But now the question arises, if Palynology in a more direct way may be applied with practical advantage during exploration.

Bauxite exploration

In principle, Palynology is certainly of value to bauxite exploration, because it is clear that once we find in a bore-hole pollen associations corresponding to zone A, B or C, we have passed the bauxite level and may stop drilling, and when we find E, F or G associations, we are still above the bauxite level. The sediments above the bauxite level (the Montgomery formation) frequently contain pollen, but the material below the bauxite may be often sterile or even residual, and this fact partly restricts the method. Bauxite exploration is rendered difficult in that the main deposits are bound to the higher parts of an old land-surface, to an old relief with drainage-pattern, which as such cannot be predicted. This can be clearly seen in the sections presented in this article (fig. 17, 20, 24 and 25), and has been definitely proved by the present pollen study. From the same sections it will be clear that the relief of this land-surface is often more or less congruent with a still older land-surface, represented by the top of the basement, and the main bauxite deposits lie often above a basement hill, even when Paleocene sediments are lying between bauxite and basement. Although it is not possible to prove this condition everywhere, it seems at least to be an unavoidable conclusion on some places where sufficient bore-hole data are available. The sedimentation of the Mackenzie formation seems again to follow approximately the same drainage-pattern, being thicker above the old filled-up valleys, and even the recent drainage-pattern seems to follow the same valleys. The cause of this phenomenon may be differential compaction (less thickness of sediments above the basement-hills than in the intermediate valleys). It will nevertheless be clear that it showed in each phase many exceptions, so that the total picture, notwithstanding a general congruency, is rather complicated. But one thing is clear, that in the "bauxite belt" (fig. 19) much of the exploitable bauxite is, in some way or another, related to higher parts of the basement relief.

The conclusion is quite simple: the first aim in bauxite exploration should be to obtain a map of the basement relief of the area under study. It seems to us, that it should be possible to find out a less expensive way than systematic drilling to obtain such a map. Some geophysical method (electrical, magnetic or seismic etc.) should be worked out, that may be employed with economic advantage.

Once such a map would be available, a few series of drill-holes could be made, which should be dated and correlated by means of the palynological method, so that sections through the area may be drawn.

We think that with the knowledge obtained in this way (map and sections), the localization of the individual bauxite deposits will take much less drilling than is at present the case. During this work of localization Palynology may give information on the correlation of the logs and consequently, in relation to map and sections, on how the drilling program should continue.

Special advantage may be taken from particular geological characteristics, of a given bauxite area. This can be best evaluated by the geologists who work in such an area, but an example may be given here.

In the Kwakwani area pollen-containing sediments of zones E-F were not found above the larger exploitable ore deposits, but are frequent in the "valleys" between the individual deposits. Finding of pollen-containing E-F sediments in a bore-hole would therefore indicate a stop-drilling in normal routine exploration borings. This situation does not hold in the Montgomery area (Mackenzie) but may eventually be found again in the Ituni area.

Water exploration

The use of Palynology in water exploration seems to be of great advantage. Doubts about the correlation of aquifers in coastal wells may be easily solved, and in general the correlation of well-logs. A special example is the "A-Sand": its position at the base of zone E makes it palynologically easily recognizable by means of the sediments immediately above and below it. Another example is the correlation of the "Upper Sands" in the Rose Hall and the Shelterbelt wells. Palynological correlation showed that amongst the possible different ways of correlation, the correlation of Noel Paton was the correct one. For a further knowledge on the distribution of aquifers in British Guiana, it seems to be highly recommendable that a few series of boreholes be made from the coast towards the South, approximately along the main rivers, as was proposed by Martin Kaye (1962), and correlate them by means of pollen studies.

Oil exploration

The advantage of Palynology in oil exploration has been sufficiently proved by the use of this method by most of the larger oil companies. In the Upper Cretaceous and Tertiary formations of northern South America it has been used with great success. One of the reasons of this success is, that pollen may be found equally in marine and terrestrial deposits, and therefore opens the possibility of direct correlation between sediments of widely differing facies where marine fossils fail.

For the oil prospects in British Guiana, the determination and recognition by means of palynological studies, of the presence of a considerable series of Upper Cretaceous and Tertiary sediments, seems to be of primary importance. It opens possibilities, which were considered to be small when the whole series was believed to be not older than Pliocene. Although no important deformations seem to be present, oil traps might for instance eventually be formed by the hiatus recognized below the base of the A-Sands, between the Eocene and Oligocene sediments. This hiatus (corresponding landwards with the bauxite interval) might very well represent a slight unconformity, and it seems to be most important to follow this level on the shelf, by geophysical methods.

Off-shore drilling is then necessary of course to prove the existence or non existence of oil accumulations.

In relation to the general possibilities for oil in British Guiana, the following might be of importance. In the coastal basins of Brasil we have been able to establish palynologically (near the mouth of the Amazon) the presence of a very similar series of sediments as in the Guiana basin. The series starts on the basement with a thick sandy series of Upper Cretaceous age, followed by sediments of Paleocene, Eocene, Oligo-Miocene and younger age. Oil exploration by Petrobras is now specially concentrated on these basins.

DESCRIPTION OF THE MORE IMPORTANT TERTIARY POLLEN TYPES

The pollen types of zones B and C are described in Leidelmeyer (1965) and partly in older publications (Van der Hammen, 1954b, 1956b, 1965). The pollen types of zone G may in general be compared with those of recent plant taxa, and are illustrated and shortly described in Van der Hammen, 1963. Those pollen types of the zones A, D, E and F which do not correspond to the known types of zone G or zones A and B, are described here. The micro-photographs of these types are found in Plates I—III.

It will be clear, that where a new genus is described in the system we use here, this will include automatically the differences with other related genera. An example is *Retistephanocolporites* nov. gen. The description is: stephanocolporate pollen grains with a reticulate sculpture. It differs from other related stephanocolporate genera, in having a reticulate sculpture, and for that reason we will not mention it separately.

The species are described according to the rules of Botanical nomenclature. As to the generic concept and names, we have principally followed the system published years ago (Van der Hammen 1954a and 1956a), based partly on the ideas of other authors in earlier publications. We will follow the proposal by Pierce (1961) and give the "subgenera" generic rank, as was also done by Varma & Rawat (1963), Ghosh & Banerjel (1963) and Van Hoeken-Klinkenberg (1964).

A few of these genera (or parts of them) may correspond to a generic name which has priority in the generic concept of Potonié (1956, 1958, 1960). In that case we have mentioned that name as an alternative. It is thought that this is the best way in the present state of pollen systematics, which, many will agree, is still very unsatisfactory.

As to the age, the pollen zone, or zones, are mentioned in which the species on the type locality was found.

For the approximate age of these zones, see the table of fig. 6. The range of these species, as far as known, is indicated in Diagram IV and fig. 6.

From *Striatriletes* (*Cicatricosisporites*) *susannae* type (Plate III, 3) and *Didimopanax* type (Plate II, 10) only a photograph is given here, but no further description. The first one is described in Van der Hammen (1956b) and the second one corresponds to a recent type.

In the following descriptions, most of the terms and symbols are according to the definitions of Iversen & Troels Smith (1950). All the slides are preserved in the collections of the Palynological Laboratory, Geological Institute, Leiden.

Diporates

Psiladiporites Varma & Rawat 1963.

Psiladiporites minimus nov. sp. Plate I, 10.
Holotype: slide Shelter Belt 455'—460', loc. 110.4 × 31.4 (micr. Po 40).
Pollen grain diporate, pore Pα1, Pβ2, Pγ3, sculpture type psilate. The thickness of the exine is $\leq 1\ \mu$; tectate, the columellae are very small and almost invisible. The size of the holotype is 10 μ. Variation of size from 8 to 14 μ, index pollinis 0.9, index exinae 0.1.

Age and locality: Pollen zone F of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: HCl and bromoform separation.

Tricolpates

Retitricolpites v. d. H. 1956a.

(Diagnosis: tricolpate pollen grains with a reticulate sculpture. The genotype, *R. ornatus* v. d. H., is a species based on a recent pollen grain. Potonié (1956—1960) thinks that this is not advisable. In the case that the foundation on a recent species should be proved not to be correct, which we do not believe, we would hold *Retitricolpites ovalis* as lectogenotype).

Retitricolpites ovalis nov. sp. Plate I, 5, 6.

Holotype: slide Shelter Belt 597'—604'a, 104.3 × 36 (micr. Po 40).

Pollen grain tricolpate, furrow Cα2, Cβ2, Cγ1, sculpture type reticulate with a maximum diameter of the lumina of $< 1\ \mu$. The polar area is very small. The thickness of the exine is $\pm 1.5\ \mu$; semitectate with clearly visible columellae of a diameter of about $0.5\ \mu$. The colpi have a typical undulating appearance. The muri are supported by a single row of columellae. The size of the holotype is $24\ \mu$. Size variation from 16—36 μ, index pollinis 2.1, index polaris 0.12, index exinae 0.01.

Age and locality: Pollen zone E of the bore-hole Shelter Belt near Gorgetown, British Guiana.

Preparation: HCl and bromoform separation.

Retitricolpites microreticulatus (v. d. H.) emend. Plate II, 1.

This species was described originally as *Tricolpites microreticulatus* from the Maestrichtian of Colombia (Van der Hammen 1954b). We give here a more complete description, according to the grain from slide R.H. 4429—39 no. 1. Loc. 101.6 × 35.5 (micr. Po 40).

Pollen grain tricolpate, furrow Cα1, Cβ2, Cγ1, sculpture type reticulate with a diameter of the lumina of $< 1\ \mu$; semitectate with columellae of a diameter of approximately $0.5\ \mu$. Size variation $\pm$ 20—30 μ. The size of the grain is $28\ \mu$. The grain is reticulate, but near the colpi this sculpture type becomes $\pm$ psilate. Index pollinis 1.9, index polaris 0.3, index exinae small.

Preparation: KOH and bromoform separation.

Retitricolpites reticulatus (v. d. H.) emend. Plate II, 7, 8.

This species was originally described as *Tricolpites reticulatus* from the Maestrichtian of Colombia (Van der Hammen 1954b). We give here a more complete description, according to the grain from slide R.H. 4429—39 no. 1. Loc. 106.5 × 28.1 (micr. Po 40).

Pollen grain tricolpate, furrow Cα1, Cβ1, Cγ1, sculpture type reticulate with a diameter of the lumina of approximately $0.5\ \mu$; semitectate, with a rather small polar area. The thickness of endexine and ectexine are almost equal. The size of the grain is $23\ \mu$. Variation from 20—36 μ, index pollinis 1.1, index polaris 0.13, index exinae 0.08.

Preparation: KOH and bromoform separation.

Psilatricolpites v. d. H. 1956a.

(Diagnosis: tricolpate pollen grains with a psilate sculpture. The genotype, *Psilatricolpites incomptus* v. d. H., is a species based on a recent pollen grain. Potonié (1956—1960) thinks that this is not advisable. In the case that the foundation on a recent species should be proved not to be correct, which we do not believe, we would hold *Psilatricolpites clarissimus* as lectogenotype.)

Psilatricolpites clarissimus (v. d. H.) emend. Plate II, 2.

This species was described originally as *Tricolpites clarissimus* from the Maestrichtian of Colombia (Van der Hammen 1954b). We give here a more complete description, according to the grain from slide R.H. 4429—39 no. 1, loc. 101.5 × 37 (99 × 35.6) (micr. Po 40), that seems to correspond to this species.

Pollen grain tricolpate, furrow Cα1, Cβ2, Cγ1, sculpture type psilate. Tectate with clearly visible columellae. The furrows have typical clearly marked edges. The size of the grain is ± 30 μ. Index pollinis 1.1, index polaris 0.2, index exinae small (to middle).

Preparation: KOH and bromoform separation.

Tricolporates

Retitricolporites v. d. H. 1956a.

(Diagnosis: tricolporate pollen grains with a reticulate sculpture. The genotype is *Retitricolporites normalis* v. d. H. Just incase, as stated by Potonié (1956—1960), the foundation on a recent species should not be correct, which we do not believe, we would hold *Retitricolporites guianensis* as lectogenotype.)

Retitricolporites guianensis nov. sp. Plate III, 1, 2.

Holotype: slide Monty 20a, loc. 101 × 35.5 (micr. Po 40).

Pollen grain tricolporate, furrow Cα1, Cβ2, Cγ2, pore Pαc, Pβ2, Pγ2; sculpture type reticulate with a diameter of the lumina of 4 μ. The polar area is small. The thickness of the exine is ± 2 μ, semitectate, the ectexine is thicker than the endexine. The muri are simplibaculate. The lumina are elongated and diminish towards the furrow. The size of the holotype is 33 μ, with a variation from 25—38 μ, index pollinis 1.3, index polaris 0.11, index exinae 0.08.

Age and locality: Pollen zone E of Montgomery mine Mackenzie, British Guiana.

Preparation: KOH and Bromoform separation.

Retitricolporites irregularis. nov. sp. Plate III, 9, 10.

Holotype: slide Shelter Belt 252′—252′ 6″a, loc. 110.4 × 42.1 (micr. Po 40).

Pollen grain tricolporate, some grains tricolpate, furrow Cα1, Cβ2, Cγ1, pore Pαb, Pβ2, Pγ2, sculpture type reticulate with a diameter of the lumina of 3 μ, the muri are simplibaculate, sometimes these elements are not fused, and then the grain is baculate. The polar area is rather small. The thickness of the exine (incl. reticulum-baculae) is 3—4.5 μ, the ectexine is thicker than the endexine; the grain is probably semitectate. The pore has costae pori and is always covered by ectexine elements: costae colpi are also present. The size of the holotype is 24 μ. Variation from 20—31 μ, index pollinis 1.08, index polaris 0.09, index exinae 0.18.

Age and locality: Pollen zone EF of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: NaOH and bromoform separation.

Retitricolporites hispidus. nov. sp. Plate I, 12.

Holotype: slide Shelter Belt 786—798B′, loc. 107.5 × 21 (micr. Po 40).

Pollen grain tricolporate, furrow Cα1, Cβ3, Cγ2, pore Pα1, Pβ3, Pγ3, sculpture type reticulate to foveolate with a maximum diameter of the lumina of 0.8 μ. The polar area is rather small, the thickness of the exine is 2 μ; semitectate to tectate.

The grain has very clearly marked costae colpi and costae pori. The pore is covered with ectexine elements. The size of the holotype is 25 μ. Variation of size from 21—32 μ, index pollinis 1.4, index polaris 0.2, index exinae ± 0.1.

Age and locality: Pollen zone EF of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: HCl and bromoform separation.

Retitricolporites crassicostatus nov. sp. Plate I, 7, 8.

Holotype: slide Monty 24a, location 110.2 × 48.7 (micr. Po 40).

Pollen grain tricolporate, furrow Cα1, Cβ3, Cγ1, pore Pαa, Pβ1, Pγ1, sculpture type reticulate to foveolate, with a maximum diameter of the lumina of the reticulum of 0.5 μ. The polar area is rather small. The thickness of the exine is 1.5—2 μ; semitectate with endexine and ectexine of the same thickness. The columellae are clearly visible and of about 0.5 μ diameter. The size of the holotype is 18 μ. Variation of size from 14—24 μ, index pollinis ± 1, index exinae ± 0.1.

Age and locality: Pollen zone E of the Montgomery mine Mackenzie, British Guiana.

Preparation: NaOH and bromoform separation.

Retitricolporites squarrosus. nov. sp. Plate III, 4, 5.

Holotype: slide Shelter Belt 786′—798′B, loc. 103.6 × 34.8 (micr. Po 40).

Pollen grain tricolporate, furrow Cα3, Cβ1, Cγ1, pore Pαc, Pβ1, Pγ2, sculpture type reticulate with a maximum diameter of the lumina of 0.7 μ. The polar area is rather small. The thickness of the exine is 2 μ. Semitectate. The columellae are clearly visible with a diameter of ± 0.5 μ. The ectexine is as thick as the endexine, along the colpi there are clearly marked costae colpi. The size of the holotype is 21 μ. Index pollinis ± 1, index polaris 0.1, index exinae ± 0.1.

Age and locality: Pollen zone E of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: KOH and bromoform separation.

Psilatricolporites v. d. H. 1956a.

(Diagnosis: tricolporate pollen grains with a psilate sculpture. The genotype, *Psilatricolporites inornatus* v. d. H., is a species based on a recent pollen grain. Potonié (1956—1960) thinks that this is not advisable. In the case that the foundation on a recent species should be proved not to be correct, which we do not believe, we would hold *Psilatricolporites operculatus* as lectogenotype.)

Psilatricolporites operculatus nov. sp. Plate I, 13.

Holotype: slide Shelter Belt 311′—307′Ab, loc. 108.3 × 31.2 (micr. Po 40).

Pollen grain tricolporate, furrow Cα2, Cβ1, Cγ2, pore Pαb, Pβ1, Pγ2, sculpture type psilate with ectexine thinner than endexine. The polar area is rather large. The thickness of the exine is 2 μ; tectate, in some grains costae colpi and costae pori are visible. The colpi have an operculum.

Natural relationship: This species resembles the *Alchornea* type of the Euphorbiaceae.

The size of the holotype is 17 μ. Variation from 12—28 μ, index pollinis 0.85, index exinae 0.1.

Age and locality: Pollenzone EF of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: NaClO and bromoform separation.

Psilatricolporites triangularis nov. sp. Plate III, 7, 8.

Holotype: slide JP 144a, 181′—183′, loc. 103.3—42.7 (micr. Po 40).

Pollen grain tricolporate, furrow Cα1, Cβ2, Cγ1, pore Pαb, Pβ2, Pγ1, sculpture type psilate. The polar area is rather large. The thickness of the exine is up to 2 μ; tectate, with the ectexine thinner than the endexine. The grain has heavy costae colpi and is of a triangular shape (in polar view); the columellae are not visible. Some of the grains have 4 colpi and 4 pori. The size of the holotype is 18 μ, index pollinis 0.5, index polaris 0.45, index exinae 0.1.

Age and locality: Pollen zone E of Mombaka area Kwakwani, British Guiana.

Preparation: NaOH and bromoform separation.

Psilatricolporites crassus nov. sp. Plate I, 1—4.

Holotype: slide Monty 47a, loc. 107.2 × 36.5 (micr. Po 40).

Pollen grain tricolporate, furrow Cα1, Cβ2a, Cγ2, pore Pαc, Pβ1, Pγ2, sculpture type ± psilate, perforate tectum, with a maximum diameter of the lumina of 1 μ. The polar area is rather large. The thickness of the exine is 2.5—4.5 μ; the endexine is ≧ the ectexine. The columellae are clearly visible and have a diameter from 0.5—1 μ. The pollen grain has clearly marked costae transversales which do not fuse at the ends. Some grains are completely tectate, in that case the exine shows more clearly a ± polygonal pattern. The size of the holotype is 55 μ. Variation of size from 40—65 μ, index pollinis 1.2, index polaris 0.4, index exinae 0.08.

Age and locality: Pollen zone EF of the Montgomery mine, Mackenzie, British Guiana.

Preparation: KOH and bromoform separation.

Psilatricolporites cyamus nov. sp. Plate III, 6.

Holotype: slide Shelter Belt 604′—612′B, loc. 111—29.8 (micr. Po 40).

Pollen grain is tricolporate, furrow Cα3, Cβ2, Cγ1, pore Pαb, Pβ1, Pγ1, sculpture type psilate (in some grains passing to reticulate with a diameter of the lumina of < 1 μ). The furrow is provided with a bridge in the middle. The thickness of the endexine and ectexine are almost the same. The grain is provided with costae colpi. Natural relationship: The grain resembles much some types in the family of the Guttiferae. The size of the holotype is 16 μ, index pollinis 1.1, index polaris 0.12, index exinae ± 0.1. Variation ± 15—20 μ, subsph-prol.

Age and locality: Pollen zone E of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: KOH and bromoform separation.

Verrutricolporites nov. f gen.

Diagnosis: tricolporate pollen grains with a verrucate sculpture. Genotype *Verrutricolporites rotundiporus* nov. sp.

Verrutricolporites rotundiporus nov. sp. Plate I, 14.

Holotype: slide Shelter Belt 311′—307′Aa, loc. 105.5 × 38.2 (micr. Po 40).

Pollen grain tricolporate, furrow Cα1, Cβ1, Cγ2, pore Pαb, Pβ2, Pγ1, 2, sculpture type verrucate (sometimes psilate) with verrucae 1—2 μ long and ± 0.5 μ high. The verrucae are of irregular shape. The polar area is rather large. The thickness of the exine is ± 1.5 μ; tectate, with clearly visible columellae of a diameter of < 0,5 μ. The furrow is covered with ectexine elements and not clearly defined. Sometimes there are also ectexine elements preserved in the perfectly circular pori. There are also grains where the verrucae are less clear, and there are grains which are psilate, but otherwise identical. These last mentioned grains may belong to another species (*Psilatricolporites rotundiporus*). The best characteristic of both types is the beautiful circular pore. The size of the holotype is 20 μ. Variation from 17—28 μ; index pollinis 1.1, index polaris 0.22, index exinae ± 0.08.

Age and locality: Pollen zone EF of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: NaClO and bromoform separation.

Foveotricolporites Pierce 1961.

Diagnosis: tricolporate pollen grains with a foveolate sculpture. Genotype *Foveotricolporites rhombohedralis* Pierce.

Foveotricolporites florschutzi (v. d. H.) emend. Plate II, 9.

This species was described originally as *Tricolporites florschützi* from the Maestrichtian of Colombia (Van der Hammen 1954b). We give here a more complete description, according to the grain from slide R.H. 4429—39 no. 1, loc. 105.2 × 32.5 (micr. Po 40), that seems to correspond to this species, although it is somewhat smaller than the holotype.

Pollen grain tricolporate, furrow Cα1, Cβ2, Cγ1, pore Pαc, Pβ2, Pγ1, sculpture type foveolate with diameter of the lumina of < 1 μ, sometimes the grain is reticulate, semitectate, with endexine thinner than the ectexine, and very indistinct columellae. The size of the grain is 18 μ. Variation of size is unknown, index pollinis 1.3, index polaris 0.16.

Stephanocolporates

Retistephanocolporites nov. fgen.

Diagnosis: stephanocolporate pollen grains with a reticulate sculpture. Genotype *Retistephanocolporites quadriporus* nov. sp.

Retistephanocolporites quadriporus nov. sp. Plate I, 9.

Holotype: slide Shelter Belt 510′—515′, loc. 110.7 × 36.6 (micr. Po 40).

Pollen grain stephanocolporate, furrow Cα1, Cβ2, Cγ3, pore Pγ1. Pollen grain has 4 pores and 4 colpi, sculpture type microreticulate with a maximum diameter of the lumina of < 1 μ. The polar area is large. The thickness of the exine is 1.5—2 μ; (semi-?)tectate, with clearly visible columellae of a diameter of ± 0.5 μ. The grain is provided with costae colpi-costae pori. The size of the holotype is 26 μ. Variation of size from ± 17—28 μ, index pollinis 1, index polaris 0.4, index exinae 0.08.

Age and locality: Pollen zone E of the bore-hole Shelter Belt near Georgetown, British Guiana.

Preparation: HCl and bromoform separation.

Stephanocolpates

Clavastephanocolpites nov. fgen.

Diagnosis: stephanocolpate pollen grains with a clavate sculpture. Genotype *Clavastephanocolpites crotonoides* nov. sp.

Clavastephanocolpites crotonoides nov. sp. Plate II, 3, 4.

Holotype: slide R.H. 1735'—45', loc. 99.8 × 38.5, micr. Po 40.

Pollen grain stephanocolpate, furrow Cα1, Cβ2, Cγ1. Pollen grain has 6 colpi apparently with costae colpi, sculpture type clavate, the height of the clavae is 3 μ, diameter at the base of the clavae $\pm$ 1.3 μ, at the top $\pm$ 1.7 μ. The thickness of the exine is 4 μ. The clavae are grouped in a croton pattern. The polar area is large. The size of the holotype is 38.5 μ, index polaris $\pm$ 0.6, index exinae 0.1.

Age and locality: Pollenzone C of the bore-hole Rose Hall, British Guiana.

Preparation: bromoform separation and acetolysis.

Periporates

Echiperiporites nov. fgen.

Diagnosis: periporate pollen grains with an echinate sculpture. Genotype *Echiperipcrites akanthos* nov. sp.

Echiperiporites akanthos nov. sp. Plate I, 11.

Holotype: slide Monty 24a, loc. 108.7 × 28.8 (micr. Po 40).

Pollen grain is periporate (sometimes apparently inaperturate), pore Pα1, Pβ3, Pγ1, sculpture type echinate. The base of the echinae is slightly thickened and somewhat intruding in the ectexine. The length of the spines is about 0.5—1 μ. The grain is tectate with clearly visible columellae of a diameter of $\pm$ 0.5 μ. The pore has a well developed margo. The size of the holotype is 22 μ; variation from 16—24 μ, index pollinis $\pm$ 1, index exinae 0.07.

Age and locality: Pollen zone E of the Montgomery mine, Mackenzie, British Guiana.

Preparation: NaOH and bromoform separation.

Inaperturates

Clavainaperturites nov. fgen.

Diagnosis: inaperturate pollen grains with a clavate sculpture. Genotype *Clavainaperturites clavatus* nov. sp.

Clavainaperturites clavatus nov. sp. Plate II, 5, 6.

Holotype: slide J.P., 100'—102'a, loc. 103.8 × 41.8 (micr. Po 40).

Pollen grain inaperturate, sculpture type clavate, the diameter of the rods is $\pm$ 0.5 μ, and of the clavae 1 μ, also there are some baculate elements. The thickness of the exine is $\pm$ 3—5 μ; intectate, with the endexine thinner than the "ectexine". The size of the holotype is 38 × 16 μ.

Age and locality: Pollen zone E of Mombaka area, Kwakwani, British Guiana.

Preparation: NaOH and bromoform separation.

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PLATE 1

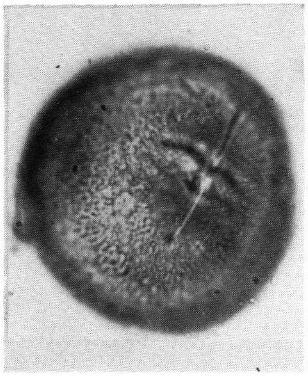


Fig. 1

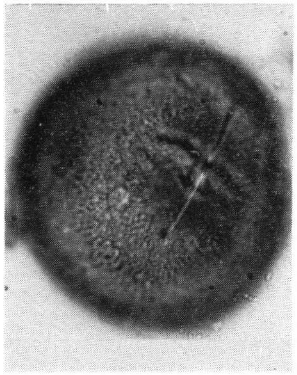


Fig. 2

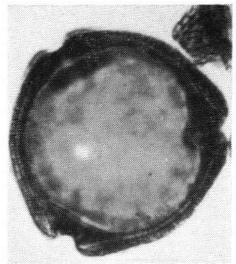


Fig. 3

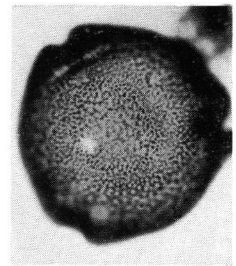


Fig. 4

Psilatricolporites crassus (±750 ×)

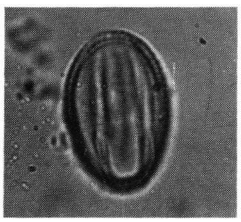


Fig. 5

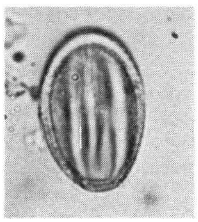


Fig. 6

Retitricolpites ovalis

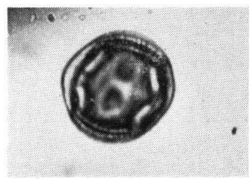


Fig. 7

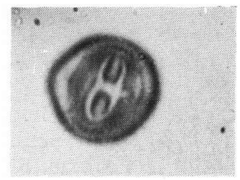


Fig. 8

Retitricolporites crassicostatus

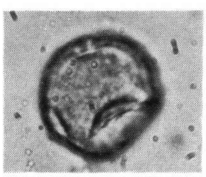


Fig. 9

Retistephanocolporites quadriporus (±750 ×)

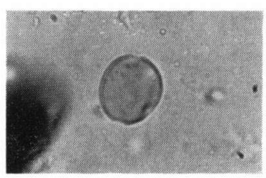


Fig. 10

Psiladiporites minimus

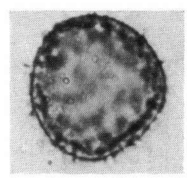


Fig. 11

Echiperiporites akanthos

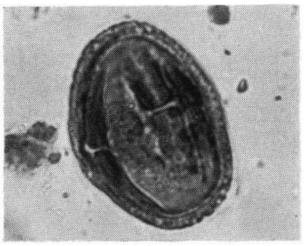


Fig. 12

Retitricolporites hispidus

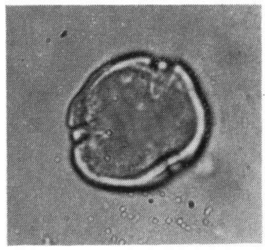


Fig. 13

Psilatricolporites operculatus

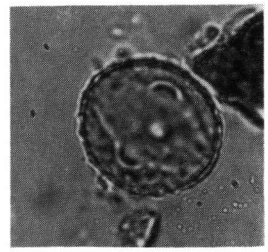


Fig. 14

Verrutricolporites rotundiporus

1000 ×

PLATE II

Fig. 1

Retitricolpites microreticulatus (1300 ×)

Fig. 2

Psilatricolpites clarissimus (1300 ×)

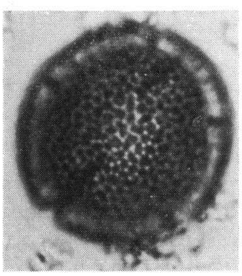


Fig. 3

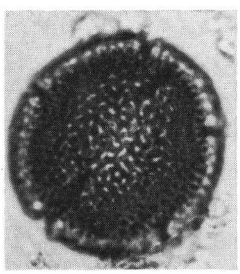


Fig. 4

Clavastephanocolpites crotonoides (750 ×)

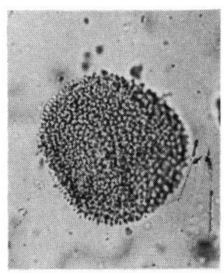


Fig. 5

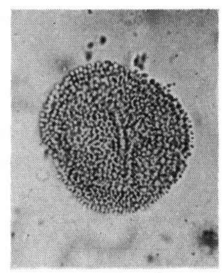


Fig. 6

Clavainaperturites clavatus (500 ×)

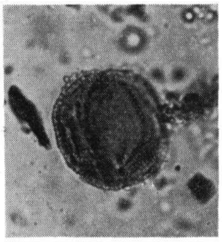


Fig. 7

Fig. 8

Retitricolpites reticulatus (700 ×)

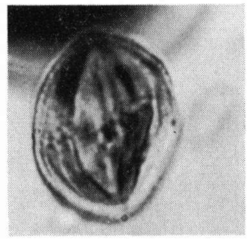


Fig. 9

Foveotricolporites florschützi (1300 ×)

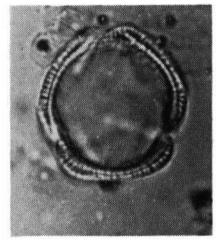


Fig. 10

Didimopanax type (1000 ×)

PLATE III

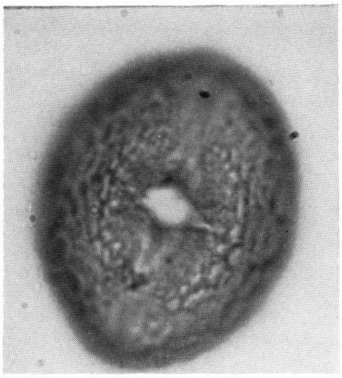


Fig. 1

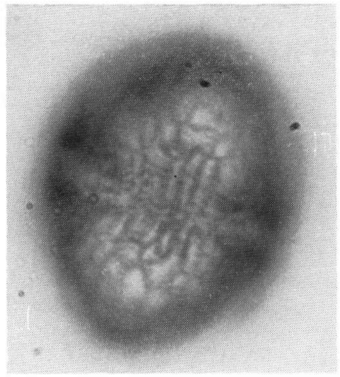


Fig. 2

Retitricolporites guianensis (1300 ×)


Fig. 3

Striatriletes (Cicatricosisporites) susannae type


Fig. 4


Fig. 5

Retitricolporites squarrosus

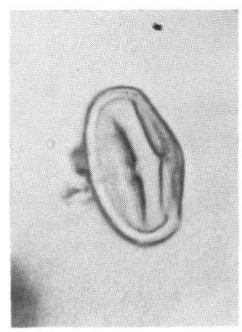


Fig. 6

Psilatricolporites cyamus

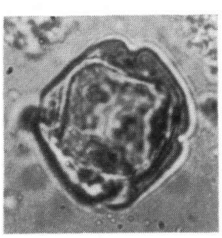


Fig. 7


Fig. 8

Psilatricolporites triangularis

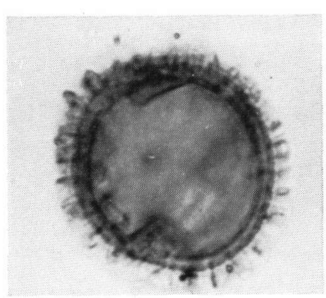


Fig. 9

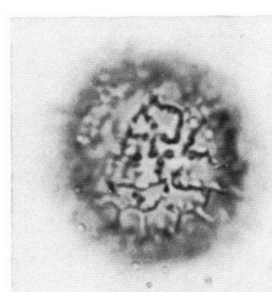


Fig. 10

Retitricolporites irregularis

1000 ×

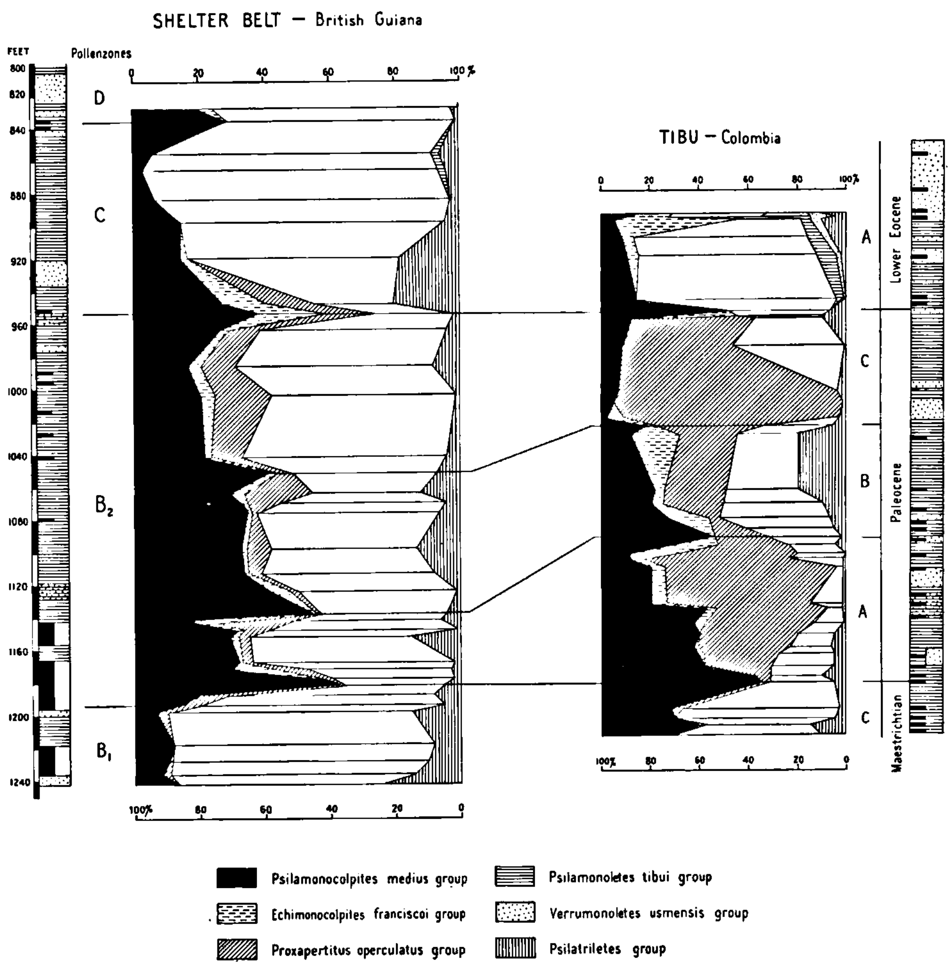
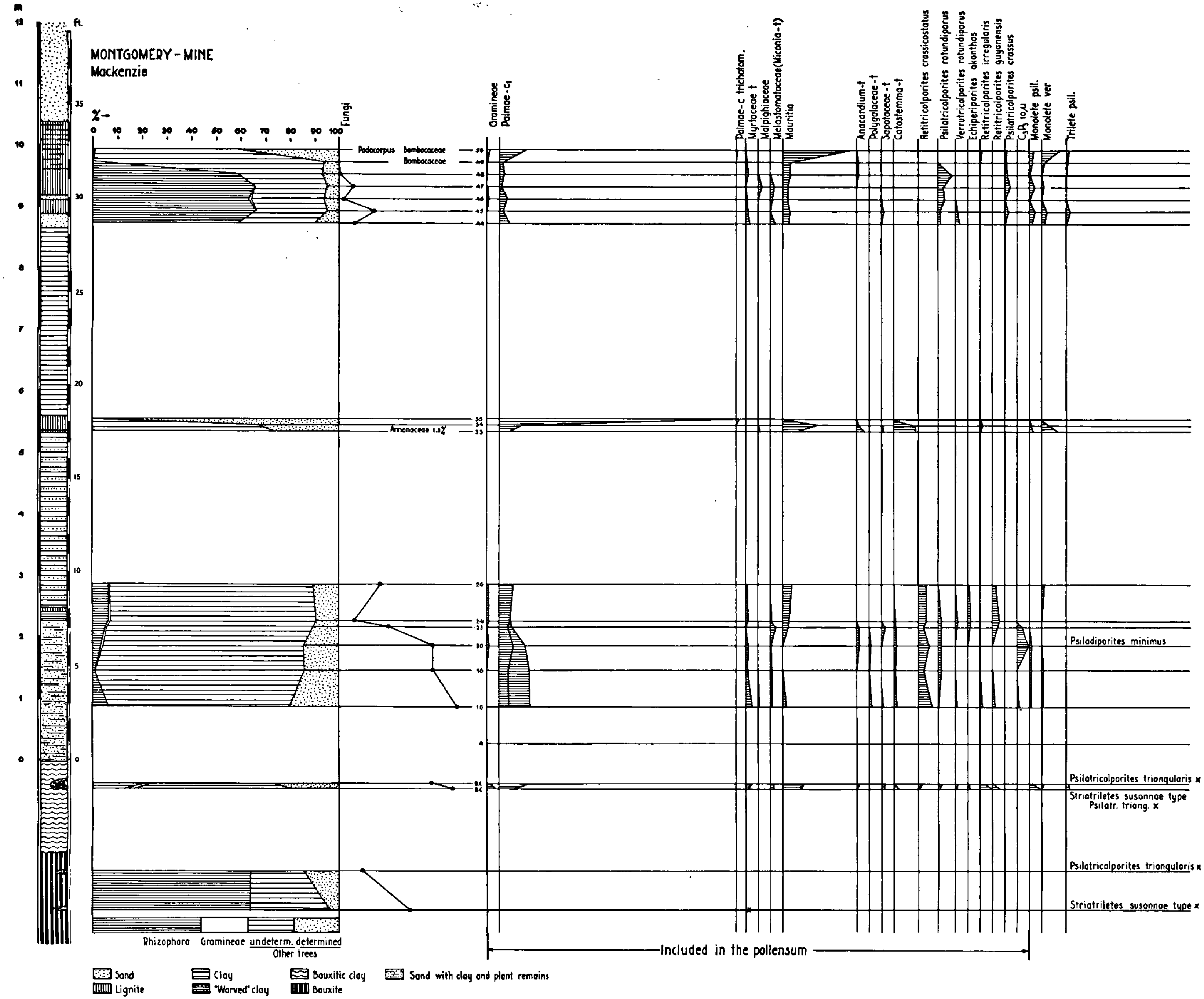


Diagram I. Pollen diagram of the Shelter Belt well, 820′—1260′ interval, compared with a diagram from Colombia (from Leidelmeyer, 1965 and Van der Hammen, 1957a, b).


MONTGOMERY - MINE
Mackenzie
m
ft.
%
Fungi
Podocarpus
Bombacaceae
Annonaceae 1.5%
Gramineae
Palmae-c1
Palmae-c trichotom.
Myrtaceae t
Malpighiaceae
Melastomataceae(Miconia-t)
Mauritia
Anacardium-t
Polygalaceae-t
Sapotaceae-t
Catostemma-t
Retitricolporites crassicostatus
Psilatricolporites rotundiporus
Verrutricolporites rotundiporus
Echiperiporites akanthos
Retitricolporites irregularis
Retitricolporites guyanensis
Psilatricolporites crassus
C3P3 10μ
Monolete psil.
Monolete ver
Trilete psil.
Psiladiporites minimus
Psilatricolporites triangularis x
Striatriletes susonnae type
Psilatr. triang. x
Psilatricolporites triangularis x
Striatriletes susonnae type x
Rhizophora
Gramineae
undeterm.
determined
Other trees
Included in the pollensum
Sand
Lignite
Clay
"Warved" clay
Bauxitic clay
Bauxite
Sand with clay and plant remains

SHELTER BELT 3

Vertical distribution of the more important species

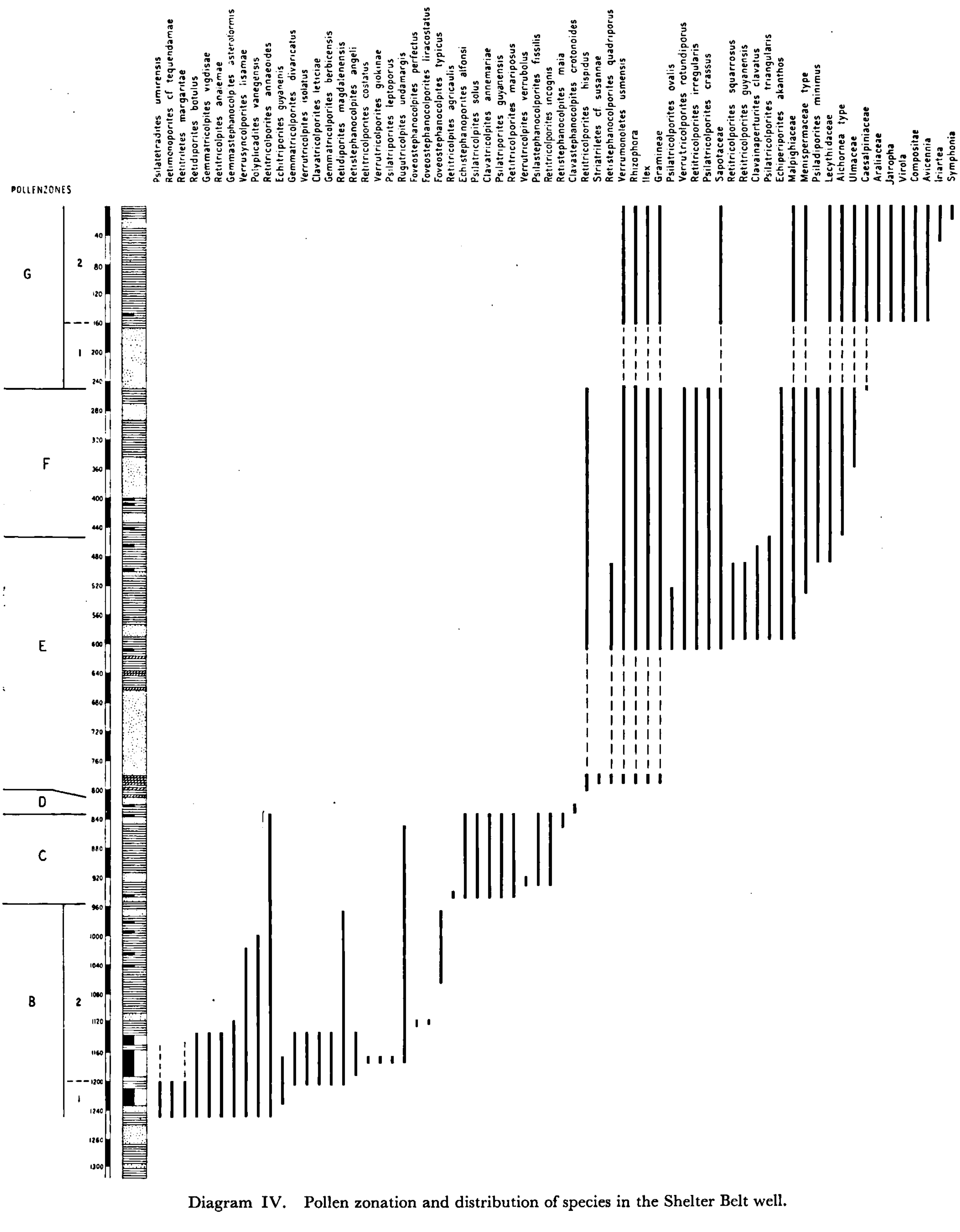


Diagram IV. Pollen zonation and distribution of species in the Shelter Belt well.

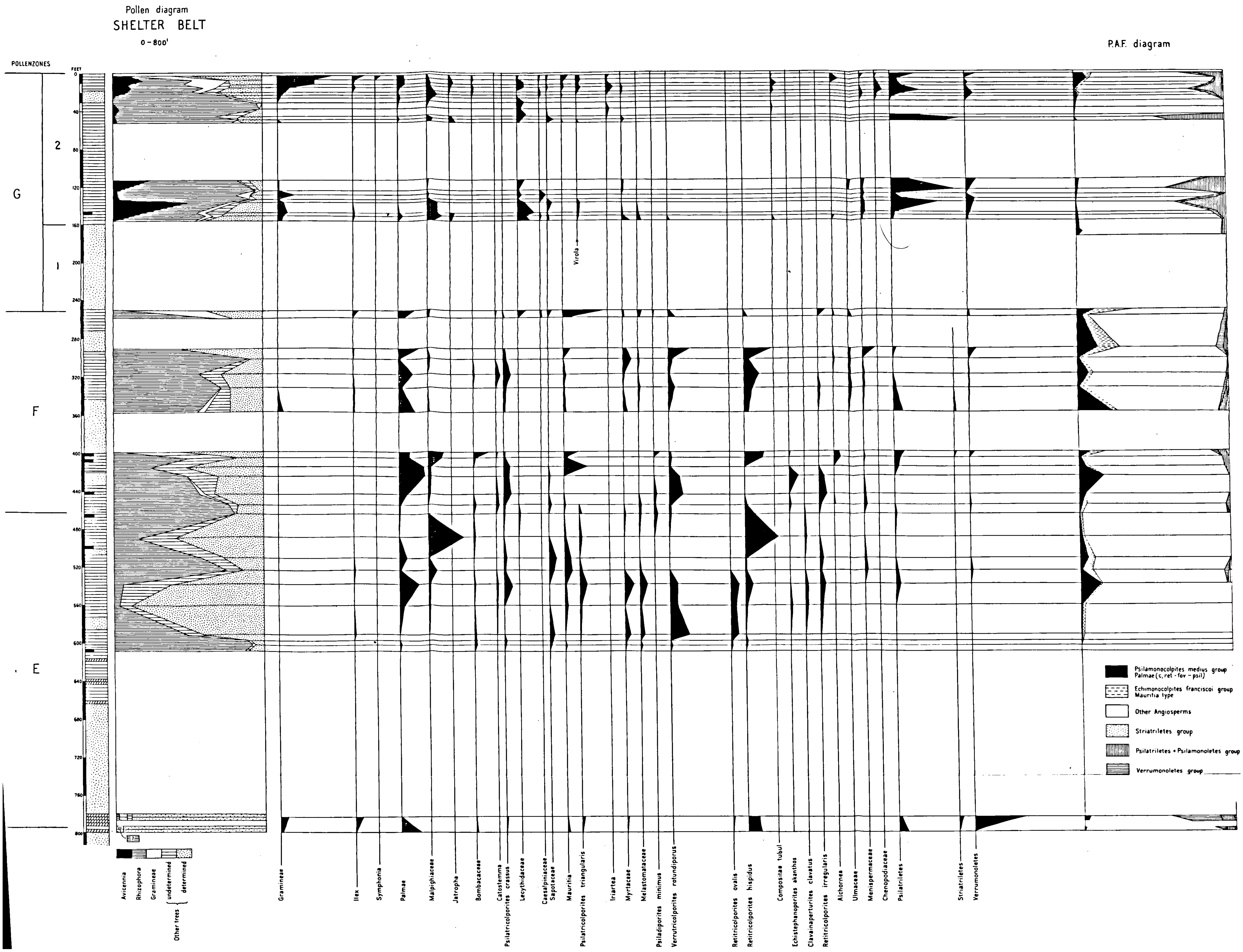


Diagram III. Pollen diagram of the Shelter Belt well, 0'—820' interval.