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A PEDO-GEOMORPHOLOGICAL CLASSIFICATION AND MAP OF THE HOLOCENE SEDIMENTS IN THE COASTAL PLAIN OF THE THREE GUIANAS

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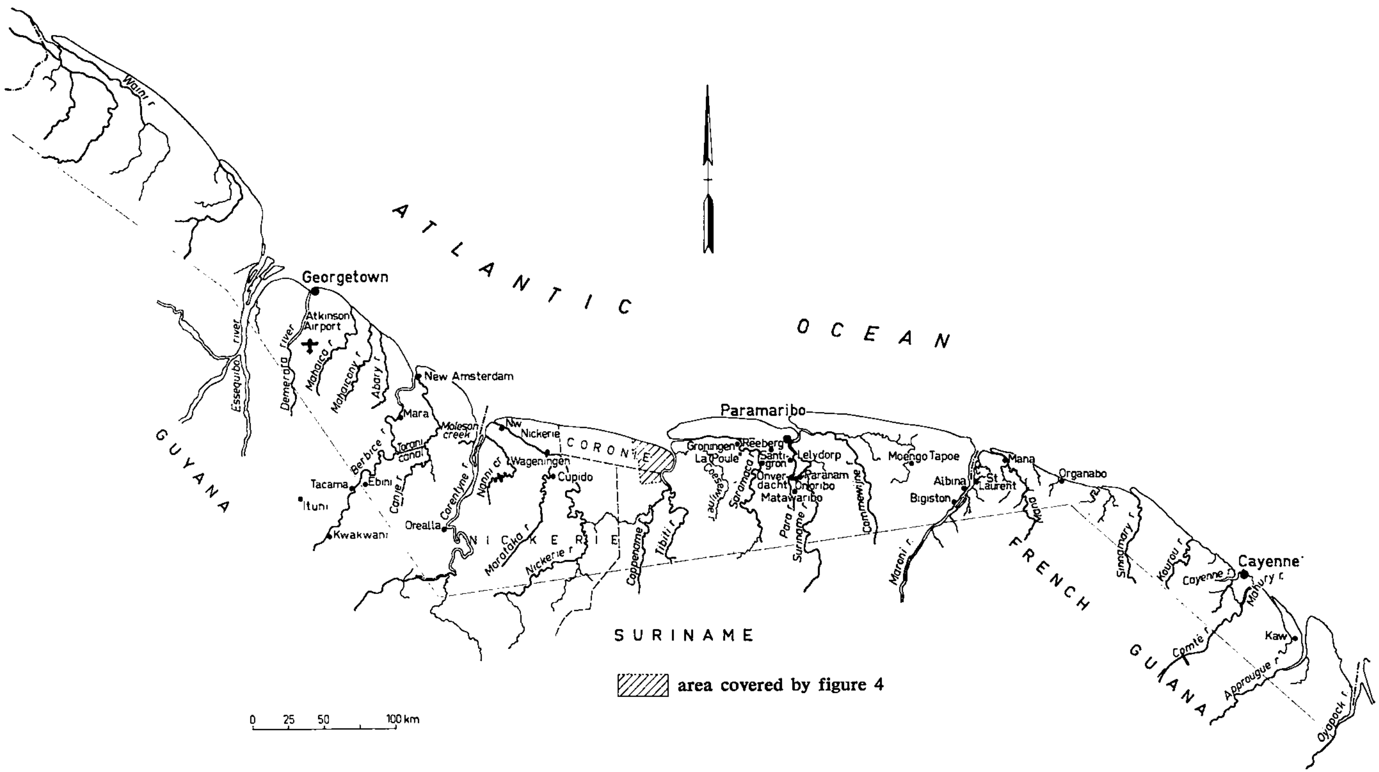


Fig. 1. Location map

1. SUMMARY

In this paper an attempt is made to classify the sediments in the coastal plain of the three Guianas on the basis of age, facies, geomorphology and pedological characteristics. A pedo-geomorphological sediment map of the area is included (separate). All geographical names referred to in the text are indicated on a location map (figure 1).

Some remarks are made about two typical facies of clay sedimentation: one with a *stable sea level* and one with a *rising sea level*. The former is characterized by rapid lateral sedimentation of clays low in organic matter and pyrite, and a subsequent vegetation of mainly Avicennia nitida (figure 2A). In the latter, vertical sedimentation prevails under an actively growing vegetation, almost purely Rhizophora spp., which accumulates much pyrite and organic matter (figure 2B and C).

The relative age of the sediments is determined by stratigraphical contacts, geomorphology, facies, depth of erosion and depth and intensity of soil formation. Their absolute age is estimated from a number of C^{14} data and by comparison with dated sedimentation sequences from other parts of the world.

The classification pertains to the surface sediments only; we made use, however, of age data derived from studies of deeper layers. For a better understanding of the Holocene (Demerara) sedimentation sequence a short discussion of Pleistocene sediments (Coropina Series) is included. The Para clay deposits, strongly mottled and firm to very great depths are probably of middle Pleistocene age. The Lelydorp deposits, the clayey as well as the sandy soils, also show a fairly strong soil development and are considered as a coastal landscape of young Pleistocene age. For the Holocene deposits as a whole we use the customary name Demerara Series. The old Holocene deposits are named Mara deposits: up to the present it has not been possible to subdivide them into phases. Three young Holocene sedimentation phases: Wanica, Moleson and Comowine were recognized and indicated on the separate map. Together they are referred to as Coronie deposits. These sediment phases correlate with transgressive phases known from other parts of the world.

The three phases of young Holocene deposits as well as the older Holocene ones all show very characteristic soil development. They can be distinguished on the basis of different depth and colours of ripening, oxidation, mottles, consistency, depth of desalinization, base saturation, degree of development of the Bt horizon, etc.

Absolute age determinations together with relative ones show that the Lelydorp deposits are of Eemian age. We have to consider the Mara deposits as older than 6000 years. The Wanica phase probably lasted from (6000 or) 5500 to 3500 (or 3000) years B.P. (before present). The datings of the Moleson and Comowine phases are respectively 2500 to 1300 B.P. and 1000 B.P. to present time.

From a comparison of the levels of several sediments along the Guiana coast we infer that the area between Cayenne and the Commewijne river shows a small uplift in the Holocene period. The areas between Paramaribo and Coronie and between New Amsterdam and Georgetown are considered to be more or less stable. The coastal area northwest of the Demerara river must be subsiding rapidly. We also found indications of slight subsidence in the area southeast of Cayenne and near the mouth of the Corentyne river.

2. INTRODUCTION

In the coastal plain of the three Guianas the main geomorphological elements are the following (see also figures 2, 3, 4 and 5):

A. *Beach ridges.* Along deep parts of the coast narrow elongated ridges of sand or shells are formed. Their tops reach to highest wave level which is two to four metres above mean sea level (MSL). When the coast is eroded during their formation only one or two ridges are formed on the edge of the clay flat. Under accretive conditions broad bundles of deep-rooted ridges are formed. Along the Gulf Coast their maximum height is about $3^1/_2$ metres and abandoned ridges are called cheniers (BERNARD and LEBLANC, 1965).

B. *Marine tidal clay flats and marshes.* They develop during accretion from uncovered mudbanks before the coast to brackish and salt Rhizophora and Avicennia marshes. After being cut off from sea water and subsequent desalinization, they change into clay marshes with fresh water forests or grass swamps covered with a thin "pegasse" (peat) layer.

C. *Natural levees of the rivers and estuaries.* These occur in broad to narrow bands parallel to the rivers, have mainly silty clay textures, are silted up to above mean high tide level (MHL) and carry an evergreen seasonal forest.

D. *Peat swamps.* In back swamps eustatic peat is formed on top of tidal clay flats under the conditions prevailing during a relative rise of the sea level. Very poor drainage conditions in large areas lead to the formation of ombrogeneous peats with swamp vegetation. A complete "geomorphological landscape" includes each of the four elements described above. Due to incomplete development or partial erosion sometimes poorly developed elements or remnants only may be found. The coastal plain of the three Guianas consists of a series of such geomorphological landscapes, sometimes incomplete. These landscapes each with their own characteristic pattern of elements, show differences in development and lie one behind the other along the coast. Sometimes as a result of erosion one or more of the landscapes are lacking.

According to age two to four main landscapes have been distinguished in the coastal plain of the three Guianas by many authors: CHOUBERT (1952), BOYÉ (1959), LÉVÊQUE (1962) in French Guiana; BAKKER and LANJOUW (1949), BAKKER (1949), SCHOLS and COHEN (1953), BROUWER (1953), VAN DER VOORDE (1957), VAN DER EYK (1957), DOST (1963a and b) in Suriname; BLEACKLEY (1957), MCCONNEL and DIXON (1960) in Guyana. We summarize their main divisions below.

All authors divide the coastal plain into a young coastal plain and an older one. The soils of these plains are formed on Demerara and Coropina (French: Coswine) sediments, of Holocene and Pleistocene ages respectively. The soils of the old coastal plain or Coropina landscape are described as deeply developed, sticky, intensely red-mottled clays. In contrast the soils of the young coastal plain are shallow, physically hardly ripened clays with reduced, soft subsoils. Where Demerara clays rest on sticky, mottled Coropina soils the profiles show a prominent unconformity which is also reported from the Gulf Coast by BERNARD and LEBLANC (1965).

The Holocene in French Guiana is divided into Recent and Demerara: the former comprising the saline soils, the latter the desalinized soils which have undergone some soil formation and partly lie at elevations up to 2 metres higher than the recent soils (BOYÉ). A similar difference in level was observed in eastern Suriname (BROUWER, corrected by VAN DER EYK). In the area east of Cayenne, a distinction was made between normal marine clays and pyrite clays (LÉVÊQUE) roughly coinciding with the distinction of a younger and older Demerara coastal plain (DOST) in Suriname and with the distinction between peats and Demerara clays on the geological map of Guyana (MCCONNELL and DIXON).

The Pleistocene in French Guiana is divided into Coswine supérieur and inférieur, coinciding with the division of the Coropina in Suriname into the (higher) Lelydorp and the (lower) Para landscapes. In Guyana, only the lower Coropina was recognized, so no subdivision was necessary. BOYÉ states that only higher and no lower Coropina (= Para) was observed at the surface between Cayenne and Organabo, but mentions possible occurrences (terrace remnants at a level of about 4 metres on bicolored, i.e. grey and strongly red-mottled clay) west of Organabo, while LÉVÊQUE describes soils on emerged sedimentary material east of Cayenne which strongly resemble the Para clays of Suriname. MONTAGNE (1964) found a clear stratigraphic discontinuity between Lelydorp and Para deposits in the Billiton bauxite mine near Onverdacht, Suriname. In his opinion both deposits are of Pleistocene age. He was the first to point out that the Lelydorp deposits include two synchronous marine facies, an upper sandy one forming the sand ridges of the Lelydorp landscape and a lower clayey one consisting of the original swamp clays between and under the sand ridges, most of which are now red-mottled due to soil formation. These Lelydorp clays together with the underlying Para clays form one thick complex of red-mottled clays in which the boundary between Lelydorp and Para clays can only be distinguished in long profiles.

For the present study we have made use of the papers by the authors mentioned above. In addition we used data and maps by DERTING and GROSS-BRAUN (1964), APPLEWHITE (1964) and BRINKMAN (1964a and b) for Guyana; DOST (1962, 1963a and 1964a and b) and unpublished soil surveys by the Department of Soil Survey for Suriname; BARRUOL (1959), CHOUBERT (1961), LÉVÊQUE (1962), PONS (1964b) and MARIUS et SOURDAT (1964) for French Guiana; and our own field data.

3. SEA LEVEL MOVEMENTS, MARINE SEDIMENTATION, SOIL FORMATION AND EROSION

3.1. The sediments

The sediments of the Guiana coastal plain are mainly very heavy clays, nearly all noncalcareous, formed as extensive clay flats and tidal marshes, mainly turned into broad swamps. REYNE (1961) considers the Amazone to be the source of these clay sediments, the material being transported by the Guiana stream to the Guiana coast. At present the rivers supply virtually no clay. Sand only occurs in very small areas, mostly as ridges. The source of the sand is to be found in the rivers but in recent times only the Maroni, Corentyne and Essequibo rivers transport sand to the sea. Natural levees in the estuaries are also heavy clays. They are rich in silt, also carried downstream by the rivers.

Shells are transported from the shallow ocean bottom to the coast and form a minor part of the coarse sediments from which the ridges are built.

3.2. The sea level movements

The geomorphology and soil formation which result from the several kinds of sedimentation and vegetation are highly influenced by the movements of the sea level. In great lines sedimentation is dominant over soil formation when the sea level rises but when it drops soil formation prevails. With a constant sea level both processes, geogenesis and pedogenesis are in operation simultaneously.

At every point of the coast the relative sea level movement is a function of the movement of the earth's crust, local settling of the land and the absolute sea level movement. For our purpose the relatively rising and the stationary sea levels are the most important features, settling only plays a minor role.

The absolute sea level movement during the Holocene appears to be a regular but rapid rise to the present level which was reached about 6000 years ago. After that time no important movements took place. Neither in Holland (JELGERSMA, 1961) nor along the Gulf Coast (BERNARD and LEBLANC, 1965) nor in other places where modern investigations have been carried out could corroboration be found for an absolute maximum sea level of 3 m above the present one about 6000 years B.P. as suggested by FAIRBRIDGE (1961). Neither can we agree with him in assuming oscillations of several metres during the last 6000 years. Neither in Holland, nor along the Guiana coast are there any phenomena to support this thesis.

In our opinion, the region of Paramaribo has to be considered as a nearly stable section of the coast. Moreover, as subsidence is thought to be very small in this area, we may substitute the curve for the relative sea level by that of the absolute movement. Figure 7 gives the curve of the relative (= absolute) sea level movement near Paramaribo. The general trend is in agreement with the curve of FAIRBRIDGE (1961) except for the maximum of 3 m and the oscillations.

C^{14} age determinations of eustatic peat layers support the course shown for the rising part of the curve (VAN DER HAMMEN, 1963). They were made of peaty clay at a depth of 20 m near Georgetown: 8590 ± 65 B.P. (GRN 3058); peaty clay at a depth of 4.50 m in a gully at Matawaribo: 7240 ± 100 B.P. (GRN 4847, ROELEVELD, 1968); peat at a depth of about 2.50 m west of Nickerie: 6720 ± 70 (GRN 4519) and peat at a depth of 1.50 m, ibid.: 6360 ± 70 (GRN 4517).

The curve shows two main parts: a rapid rise to about 6000 years B.P. and a stable part from 6000 years B.P. up to the present.

For some areas along the Guiana coast we must assume differential movements of the earth's crust. Between the Commewijne river and Cayenne there must have been a slight uplift. East of Cayenne towards the Brasilian border there is evidence of slight subsidence. In northwestern Guyana, there is strong subsidence increasing towards the Venezuelan border. In this area the relative rise of the sea level has continued up to present times.

3.3. **Clay sedimentation and initial soil formation at a constant sea level**

At a constant sea level deposition takes place in a lateral direction only (figure 2A). A narrow coastal strip is quickly transformed from sea to land, about 1 to 2 metres above mean sea level, while the landward parts of the plain which were deposited earlier, rapidly change into fresh-water swamps with a thin layer of peat (pegasse). With sufficient sediment, this process may take place over vast distances with a lateral speed of accretion exceeding 100 metres per year (REYNE, 1961). The narrow coastal strip is covered by Avicennia (with very few Rhizophora in places), which produces only very small quantities of organic matter. Beyond this strip a grass and sedge swamp forms the transition to the forested fresh-water swamps.

These clayey sediments are characterized by a low organic matter content and a small amount of pyrite, accumulated by Avicennia roots (PONS, 1963, 1964a), which is formed by reduction processes from sulphates in saline or brackish water in the presence of recently dead organic matter. The Avicennia coastal clays show this phenomenon only in vertical root holes.

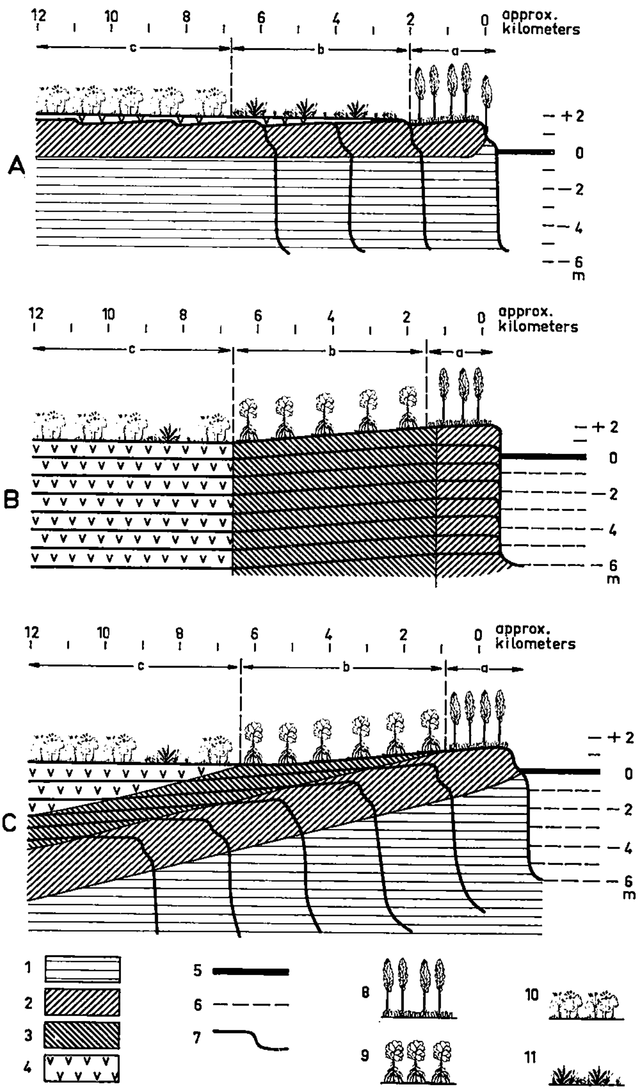
The soils formed from this sediment have a high base saturation, which may drop to moderate with age by production of some acid, by leaching and possibly by repeated reduction-oxidation processes after desalinization. These soils are partially oxidized (mottled) and relatively firm to a depth of about 0.5 to 1.5 metres. In the lowest parts of the marine clay plain, where sedimentation has only gone to about mean sea level, these processes of "initial soil formation" may not have penetrated beyond the first few centimetres of the soil profile. After deposition thin layers of peat accumulate on the surface of the sediment, to about 1.5 m above mean sea level.

Thus, with a constant sea level "normal" sea clays are formed (figure 2A) with only few and small incidental areas where layers of "pyrite clay" occur, mostly with moderate to low pyrite percentages.

3.4. **Clay sedimentation during a rise in sea level**

When the sea level rises during deposition a very different kind of sediment is formed (figures 2B and 2C). While the surface of the land continuously sinks below mean sea level, the sediment-laden water penetrates far inland over the previous sediments through the growing vegetation. This vegetation is adapted to the brackish water and to the strongly reducing conditions caused by the low position of the land. It is in fact an almost pure Rhizophora vegetation, extending inland for several kilometres between a narrow Avicennia fringe on the coast and a growing peat swamp beyond the reach of the sediment.

Under these conditions a very soft and reduced clay is formed, high in organic matter, especially Rhizophora roots, and very high in accumulated, so-called secondary



LEGEND

1. Marine mud flat clay, very soft to soft, very low in organic matter, without root channels, mostly fine-laminated with silt layers
2. Marine coastal clay, moderately firm to soft, low in organic matter, top layers homogenized, lower layers with vertical root channels of Avicennia nitida
3. Brackish-water pyrite clay, humous to peaty, very soft with many remains of fine Rhizophora roots, wood and other organic material, with much secondary pyrite
4. Eustatic peat, soft, sometimes with minor clayey peat layers, with remains of small ferns, Rhizophora roots, Carex roots, different kinds of wood and many other kinds of organic material
5. Present mean sea level
6. Former sea levels in periods of rising sea
7. Successive sedimentation surfaces
8. Avicennia nitida
9. Rhizophora spp.
10. Trees of fresh water swamp forests (Pterocarpus officinalis, Euterpe oleracea, Symphonia globulifera, Virola surinamensis, Tabebuia insignis, Mauritia flexuosa and others)
11. Plants of fresh and brackish grass swamps; grasses, ferns (Blechnum spp.), sedges and others

Fig. 2. Cross sections of marine sediment types developed under different coastal conditions (in all cases without ridges)
A. Stable sea level, growing coast; B. Rising sea level, stable coast; C. Rising sea level, growing coast

pyrite (PONS, 1963, 1964a). In all cases, whether the coast is receding, stationary (figure 2B) or advancing (figure 2C) most of the surface sediment consists of "pyrite clay", which would change into so-called "cat-clay" or "acid sulphate clay" upon drainage and oxidation. In contrast to "normal" marine clays, these "pyrite" clays show hardly any mottling, oxidation or loss of water (no "initial soil formation" or "ripening"), as long as the water level does not drop. In fact, during the rise in sea level no real soil formation takes place. Their position with regard to the sea level is low, and relatively thick eustatic "pyrite peat and peaty clay" layers accumulate landward of the sediment.

An example was described by ROELEVELD (1968) from an erosion gully, relatively far inland, filled with this kind of peaty pyrite clay. It contains more than 95 % Rhizophora pollen (figure 6). The clayey sediments with the same amount of Rhizophora pollen, described by VAN DER HAMMEN (1963), have in our opinion also been deposited under these conditions.

When sedimentation stops a layer of eustatic freshwater peat (pegasse) is formed on top of the clay. It normally contains no pyrite and grows to an elevation of about 1.5 metres above mean sea level.

In a temperate climate, for example in Holland, the same kind of pyrite clay is formed under conditions of a relatively rising sea level, but with a different kind of vegetation (Phragmites communis) accumulating secondary pyrite. At a relatively constant sea level, marine clays low in pyrite and organic matter are deposited in a temperate climate as well as in the tropics (EDELMAN, personal communication, 1958; PONS, 1960; PONS and WIGGERS, 1959 and 1960).

3.5. Erosion and ridge formation

At a constant sea level and with little or no clayey sediment, lateral abrasion of the coast may take place with a speed comparable to the speed of accretion: sometimes more than 100 metres per year (REYNE, 1961).

When sandy or shell material is available for sedimentation the edge of the abraded coast may be covered by a narrow sandy ridge. With much coarse sediment, a wider ridge is thrown up landward over the clay and seaward beyond the abrasion edge. With little sandy material the abrasion of the coast continues, while the sandy ridge is shifted inward and remains at the edge of the clay. The level of the ridges may vary between 1 and 3 metres above the clay (2 to 4 metres above mean sea level) depending on the orientation of the coast and the height of the prevailing waves.

With erosion of the coast, shallow tidal creeks may develop in the clay surface. After a drop in sea level deeper gullies are eroded in the clay, but direct erosion of the coast by the sea is less.

3.6. Initial and progressive soil formation after a drop in sea level

After a drop in sea level the initial soil forming processes such as desalinization, oxidation, mottling and water loss all occur to a greater depth. In places with deep drainage progressive soil formation soon follows, which may be shown by laterite formation (iron concretions), very strong mottling, formation of textural B horizons, compaction leading to impermeability and groundwater podzolization. Pyrite clays, after water loss under reduced conditions, may develop upon oxidation into very firm, strongly mottled "pseudo ground-water laterites" (BRINKMAN et al., 1964c, unpublished). In less extreme cases soils with a strongly red- and yellow-mottled horizon are formed. Base saturation becomes very low, since the large excess of acids formed from the pyrite effectively leaches the bases from the profile. "Normal" sea clays with low organic matter and pyrite contents develop into moderately firm, deeply yellowish red- and yellowish brown-mottled soils with a moderate base saturation. Any horizon in which the groundwater level fluctuates becomes slowly cemented by redistribution of iron oxides and is also subject to compaction. These phenomena may be observed, too, in clayey sediments which are originally deposited at a higher level than the large marine clay swamps, e.g. estuary ridges.

Table 1. Stratigraphy of the sediments in the coastal plain of the three Guianas

Main kind of sediment	Phase	Deposits	Series
1. Peat growing above sea level	*uncorrelated* (probably Wanica through Comowine)		
2a. Saline to brackish marine clay without or with vague mottles	Comowine	Coronie	Demerara *(Holocene)*
2b. Ditto with brown mottles			
3a. Marine clay with high base saturation and olive or yellowish brown mottles	Moleson		
3b. Ditto in thin layers on older sediments			
4. Sandy ridges with or without shells, seldom podzolized	Comowine and Moleson		
5. Marine clay with medium to low base saturation and yellow mottles	Wanica		
6. Sandy ridges without shells, partly podzolized			
7. Soft brackish water clay with much pyrite and organic matter, covered with peat of varying depth, mostly unmottled	—	Mara	
8. Estuarine and riverain clays and loams	—	*uncorrelated*	
9. Firm red- and yellow-mottled clay to loamy fine sand, sometimes to coarse sand; sands mainly podzolized		Lelydorp	Coropina *(Pleistocene)*
10. Sandy and loamy ridges, mainly podzolized			
11. Sandy to clayey river terraces			
12. Firm red-mottled clay with silty top		Para	
13a. Older sediments (White Sands)			Berbice *(Pliocene)*
13b. Residual			Crystalline basement

3.7. **Soil formation in riverain and estuarine deposits**

The riverain and estuarine levee deposits occur at slightly higher elevations than the purely marine clays, so that even in rather young soils "ripening" and mottling may go to a greater depth than in the marine soils. In addition, the water from which they are deposited is generally less saline, so that desalinization and leaching may go faster. Thus, the observable differences between levee soils of different ages are much smaller than in the marine soils. For that reason the levee soils of the Coronie deposits have not been subdivided into phases on the map.

4. COROPINA SERIES

The Pleistocene Coropina series is devided into the older Para deposits and the younger Lelydorp deposits. These occur in the southern part of the coastal plain, south of the Holocene sediments. In northwestern Guyana and east of the Commewijne river the southern boundary of the coastal plain is formed by the residual soils of the crystalline basement (no. 13b on the separate map). The sandy deposits (Berbice series) of the Zanderij landscape (13a), remnants of the big Plio-Pleistocene delta of some old Corentyne valley — recently described by MONTAGNE (1964) and VAN DER HAMMEN and WIJMSTRA (1964) — form the boundary in the central part of the three Guianas.

4.1. **Para deposits**

The Para deposits (unit no. 12 on the separate map) mainly occur near the southern limit of the Guiana coastal plain. They are erosion remnants of an old depositional landscape, generally consisting of silt loams to silty clays.

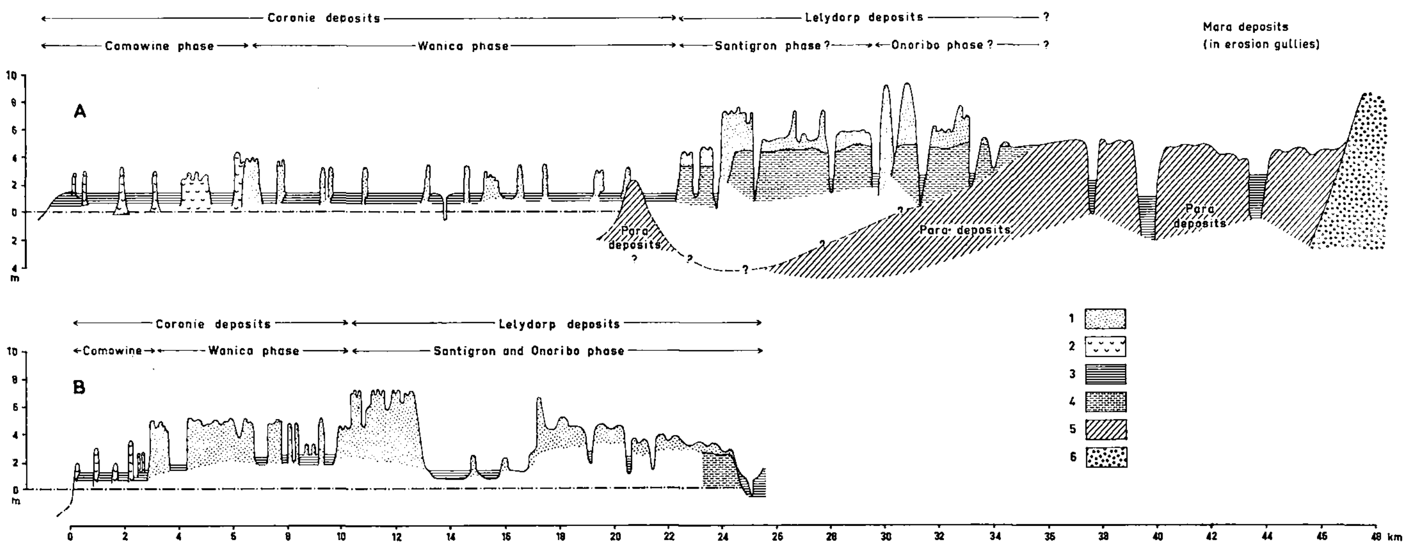
In the bauxite mines near Onverdacht, Suriname, clay layers of maximal 10 metres, partly underlain by coarse unsorted sands, also belonging to the Para deposits, have been described by MONTAGNE (1964).

These interglacial sediments were subject to intensive ripening to considerable depth (at least 10 or more metres) and strong soil development during the Würm period with its low sea level. They now consist of thick stiff clay layers, very strongly acid, strongly red- and purple-mottled and finely laminated to a great depth. We consider them to be of middle Pleistocene age, probably Mindel-Riss interglacial, since they are much more weathered than the Eemian Lelydorp clays. Their present surface lies at about 2 to 7 metres above sea level. Buried parts of the Para deposits have also been observed in borings underneath younger deposits, at depths from 2 metres above to 30 and more metres below sea level.

At present the surface lies much too low for middle Pleistocene interglacial deposits. Differences in tectonic movements along the Guiana coast, however, should be responsible for the reported differences in surface levels. About the original surface layers much is uncertain. Probably top layers of unknown thickness may have disappeared owing to erosion (MONTAGNE, 1964). A second reason for uncertainty about the original surface elevation is found in younger clay covers of unknown thickness and of the same facies. Where these covers were laid down after erosion of the topsoil of the Para clay and have developed into the same kind of red- and purple-mottled clay they are not distinguishable from the actual Para clays.

From available data we constructed two rough cross sections of the whole coastal plain, which are shown in figure 3. Profile A, situated near Paramaribo, shows in its southern part the Para deposits. Because most of them are strongly eroded, the determination of their original level is difficult. In Guyana the highest elevations known to us are about 5 metres above mean sea level, in Suriname about 7 metres, both near the edge of still older sediments. Even where the Para deposits occur at great depths, the upper metres are strongly mottled, indicating soil formation at a still lower sea level.

The area indicated on the map includes other formations, e.g. Holocene deposits in the erosion channels, etc. Especially in the north of each area of Para deposits, areas of Lelydorp clay deposits, covering or replacing Para deposits, may occur. Sufficient field data are not available at present to delineate the southern border of the Lelydorp clays accurately, because of difficulties in distinguishing between mottled Para and



LEGEND

1. Fine sand and loamy fine sand
2. Shells or fragments of shells mixed with varying quantities of fine sand
3. Clay, soft to friable, unmottled or with fine mottles
4. Sandy clay and clay, compact, with red and yellow mottles or unmottled
5. Silty clay, very compact, with red and violet mottles
6. Coarse sand or loamy coarse sand

? Boundaries or correlations uncertain

Fig. 3 *. Rough cross sections of Holocene and Pleistocene sediments. A. Near Paramaribo; B. Near Moengo Tapoe

* Modified from VAN DER VOORDE (1957), BROUWER (1953) and LINDEMAN (1953)

mottled Lelydorp clays. The area of Para deposits (unit no. 12 on the separate map) may include some Lelydorp clays, especially south of Cayenne, between St. Laurent and Organabo, in the Nickerie area and the Canje river area.

4.2. **Lelydorp deposits**

These young Pleistocene deposits, probably from the Eemian interglacial (no. 9 and no. 10 on the separate map) occur north of the outcrops of the Para series, in French Guiana from Cayenne to Organabo and in Suriname east of Coronie. MONTAGNE (1964) describes a sandy facies forming sand ridges and a clay facies — originally swamp clays — now red-mottled and stiff and resting on Para clays.

According to our own observations the Lelydorp clays themselves show two distinct facies. In the southern part of the landscape the fine sandy ridges (no. 9) are underlain and surrounded by originally dark grey pyrite clays, rich in organic matter, which upon oxidation have developed into grey, strongly red-mottled (Munsell notation 5 YR and 7.5 YR highest chromas, 2.5 YR medium and high chromas, 10 R, all chromas) clays with very low base saturation (no. 10) wherever they occur at depths less than the Holocene soil formation (about three metres). This rising sea level facies of the marine coastal clay sediments (sections 3.4 and 3.6) was observed in the bauxite mine Onoribo IV of the Suriname Aluminium Company, near Paranam on the Suriname river (BRINKMAN *et al.*, 1964c, unpublished). In the northern part of the landscape the ridges are underlain and surrounded mainly by yellowish red- and brown-mottled clay, with only traces of pyrite clay or the associated red-mottled clay (no. 10). This stable sea level facies (sections 3.3 and 3.6) has been described in detail in the soil survey of Santigron (BRUIN, 1964). These two clay facies have developed into two different phases of the Lelydorp deposits: the Onoribo and Santigron phases (figure 3).

The Lelydorp deposits in their original state were a coastal sand ridge and clay landscape (VAN DER VOORDE, 1957; MONTAGNE, 1964) comparable with the landscape of the young coastal plain. The Lelydorp sand ridge-complexes e.g. are each more extensive and coarser textured toward the east, just like the sand ridge-complexes of the young Holocene deposits. Lelydorp deposits which are mainly sandy occur directly west of the Maroni river just like the Holocene ridges further north. In French Guiana the Lelydorp deposits between Cayenne and Organabo even consist nearly entirely of sand, locally even coarse sand.

Two rough cross sections (figures 3A and 3B) show the situation of the Lelydorp deposits and their morphology. By subsequent sheet erosion of the high sand ridges and colluviation following and during soil formation most of the low lying clays were covered with loamy and sandy material. In the broad sandy Lelydorp complexes of French Guiana, where clayey subsoils are nearly absent, this colluviation has led to very broad flat sandy areas with strong podzolization caused by poor drainage (wet podzols).

Erosion gullies were formed as far as about 7 metres below surface. West of the Commewijne river, the surface of the clay is about 3 metres above present mean sea level. The surface elevation of the ridge sands varies between 4 and 8 metres. In eastern Suriname the level of the ridges varies between 6 and 10 to 12 metres (BROUWER, 1953; LINDEMAN, 1953). In French Guiana they reach levels between 5 and 12 metres (BOYÉ, 1959, CHOUBERT, 1952). In French Guiana no Lelydorp clay areas have been recognized. BOYÉ, however, describes "Coropina terraces" between Cayenne and Organabo immediately south of Lelydorp sand ridges, and near St. Laurent behind the river terraces described below, at about 4 to 5 metres above mean sea level, which might be Lelydorp clays. In Guyana, neither Lelydorp clays nor ridges have been recognized. The clay levels of the Lelydorp deposits indicate a relative sea level during deposition of about 3 metres above the present near the Suriname river (figure 3) and of about 5 metres above the present in French Guiana, west of Cayenne.

The ridge levels vary, but are 4 to 5 metres above the clay levels at the most, depending on exposure of the coast and intensity of wave action, as well as on total amount and grain size of the sandy sediment. Thus, the Lelydorp ridges are deposited at sea levels of 3 to 4 metres near the Suriname river (figure 3A), 4 to 6 metres in eastern Suriname (figure 3B) and 5 to 7 metres in French Guiana, all above present sea level.

At a depth of 3 to 5 metres below the surface these Lelydorp deposits are in a reduced condition: soil formation is much shallower than in the Para deposits. The erosion gullies in this landscape, too, have depths of less than 7 metres below surface. This suggests a relatively great distance from the sea during the period of very low sea level in the Würm glaciation and a very slowly permeable sediment.

In soil surveys in the upper Commewijne river near the contact with the residual material of the Guiana Shield (unit no. 13b on the separate map), two kinds of peaty "deep black soils" have been observed. The lower one occurs at the level of recent swamps, and is probably the most landward part of the "Mara deposits" (see below). The other one occurs as small terrace remnants, a few metres higher than the swamp level, in gully heads in Para deposits. These are probably the continental swamp edge of the marine Lelydorp clay deposits.

We presume, also on geomorphological grounds, that the two facies: Onoribo and Santigron, represent two sedimentation phases in the Lelydorp deposits. Sufficient field evidence to prove this is not available, however. On the map, the Lelydorp ridges could be indicated only approximately (no. 10), because colluviation and erosion make it sometimes difficult to identify individual ridges.

The marine Lelydorp clays south of the area where the Lelydorp ridges occur together with these clays (no. 9), are included on the map with the Para deposits and shown as no. 12, because these clays — both originating from pyrite clays — are both strongly red-mottled when oxidized, and have not been distinguished from each other in the field so far. The very great oxidation depths of the Para clays and the 3 to 5 m depth of oxidation of the marine Lelydorp clays may serve as a basis for field mapping in some cases.

For Guyana we used the soil maps of the joint British Guiana – U.N. Special Fund soil survey. Here Lelydorp clay was not recognized separately.

For Suriname we used the maps of VAN DER EYK (1957) and VAN DER VOORDE (1957), and the new soil map of northern Suriname by DOST (in preparation). According to our field observations Lelydorp deposits are lacking in Suriname west of Coronie.

For French Guiana we modified the Geological Map of French Guiana 1 : 500,000 using the detailed geological maps and the soil map by LÉVÊQUE (1962) and MARIUS et SOURDAT (1964) and our own observations during an excursion (PONS, 1964b).

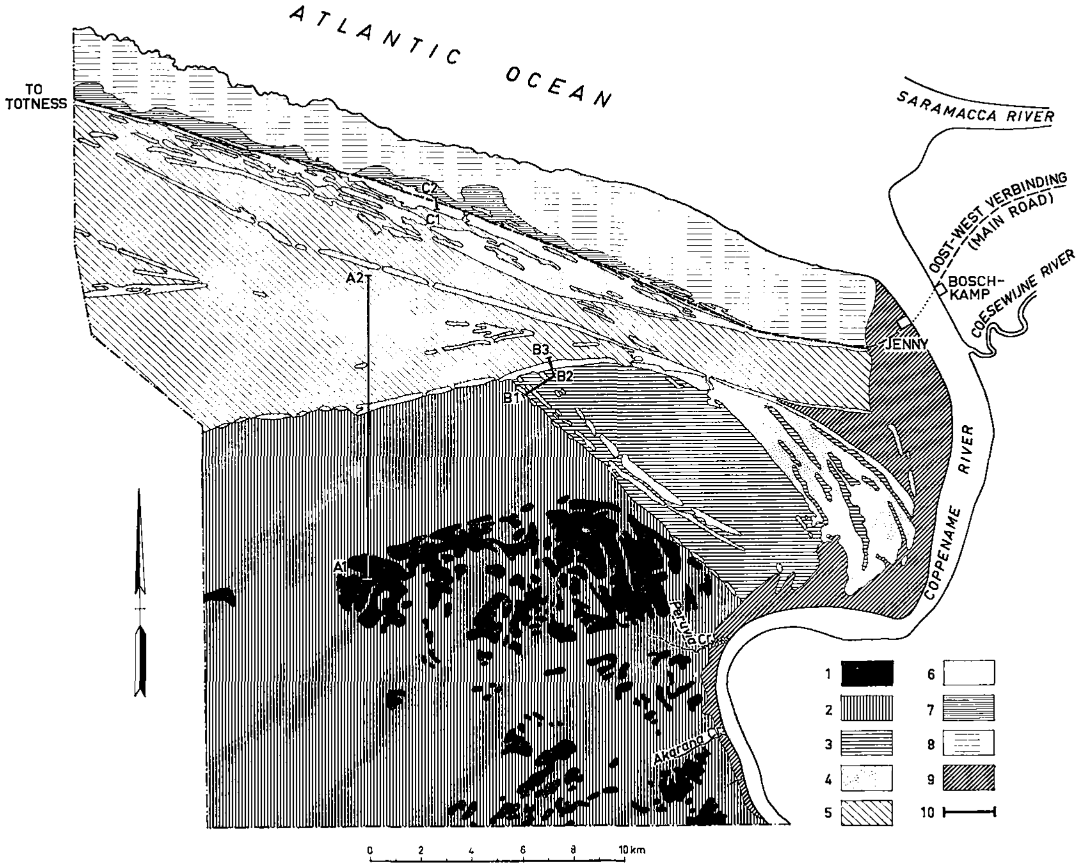
A large area with mainly fine sands between Organabo and Cayenne we indicated as no. 10 on the separate map, since the older continental sediments all apparently contain a coarse or medium sand fraction. Due to colluviation the original ridges are scarcely visible and have as far as possible been sketched in as no. 9. The latest soil map of MARIUS et SOURDAT (1964) shows many podzols on fine sands in this area.

The red-mottled clays near and southeast of Cayenne bear more resemblance to Para deposits and have been mapped as no. 12. This is also suggested by the description given by LÉVÊQUE (1962). We assume that any Lelydorp deposits in this area would be much more sandy.

4.3. **Riverain and estuarine terraces**

Along the Maroni river, both in Suriname (near Albina and near Bigiston) and in French Guiana (near St. Laurent) there are sandy river terraces, at maximum elevations of 5 to 7 metres above present mean sea level. On the map we have indicated these as no. 11: sandy to clayey Lelydorp river terraces. They consist of loamy coarse sand to coarse sandy clay loam, with clay occurring in the basins. Especially the sandier parts show strong soil formation. One of us found soft, laminated, reduced marine clay under a sandy terrace, about 8 metres below surface (BRINKMAN, 1960b). The clay-mineral composition of this sample was identical to that of the Coronie deposits of the coastal plain and different from that of the Para deposits. In a seaward dirrection the Lelydorp terraces disappear due to strong erosion. The boundary between units 11 and 12 near St. Laurent is difficult to trace because part of unit 12 mapped in that vicinity is possibly Lelydorp (10).

Along the Suriname river similar terrace remnants have been observed, occurring at elevations similar to those along the Maroni river. A few small silty terrace remnants at about the same level were observed on the Berbice river e.g. near Tacama. So little soil formation had taken place here that they were included with the silty alluvial soils in the soil survey of the Ebini-Ituni-Kwakwani area (BRINKMAN, 1964b).



LEGEND

Pedological units

1. Fine sands, loamy sands and clays; more or less eroded and colluviated old coastal ridges and eroded marine clays, both with very strong soil development, Lelydorp deposits
2. Peat and pegasse (recent organic litter), more than 1 m thick on soft, mostly reduced clays; recent organic layers on Rhizophora clays of Mara deposits
3. Clays with strong soil development; yellow mottled; marine Avicennia clays of Wanica phase, Coronie deposits
4. Fine sands or loamy fine sands with strong soil development; coastal ridges of Wanica phase, Coronie deposits
5. Clays with moderately weak soil development; olive mottled; marine Avicennia clays of Moleson phase, Coronie deposits
6. Shells or calcareous fine sands with moderate to weak soil development; coastal ridges of Moleson and Comowine phases; Coronie deposits
7. Clays with weak soil development; brown mottled; marine Avicennia clays of Comowine phase, Coronie deposits
8. Clays with very weak soil development; dun mottled; marine Avicennia clays of Comowine phase, Coronie deposits
9. Clays and silty clays with strong soil development; red, yellow and brown mottled; riverain and estuarine clays of several phases of Coronie deposits
10. Location of cross sections of figure 5

Geomorphological units

Beach ridges: numbers 1, 4 and 6
Clay flats: numbers 3, 5, 7 and 8
River and estuary levees: number 9
Peat swamps: number 2

Fig. 4 *. Pedo-geomorphological sediment map of the eastern part of Coronie district (location shown in figure 1)

* Modified from Pons and Parsan (1964)

5. DEMERARA SERIES

These Holocene sediments are partly riverain and estuarine and partly marine. They occur as infillings of erosion gullies in the older landscapes, and as large areas of swamps and flats more to the north. The marine clays generally lie a little below present mean high tide level, about 1 metre above mean sea level.

The marine part of the Demerara Series consists of two kinds of deposits, the *Mara deposits* and the *Coronie deposits*. The sedimentation of the former occurred during a rise in sea level, whereas the latter were deposited while the sea level was constant. Three phases: *Wanica, Moleson* and *Comowine,* have been recognized within the Coronie deposits. They are separated from each other and locally also from the Mara deposits by erosion coast lines, in many cases with sand or shell ridges.

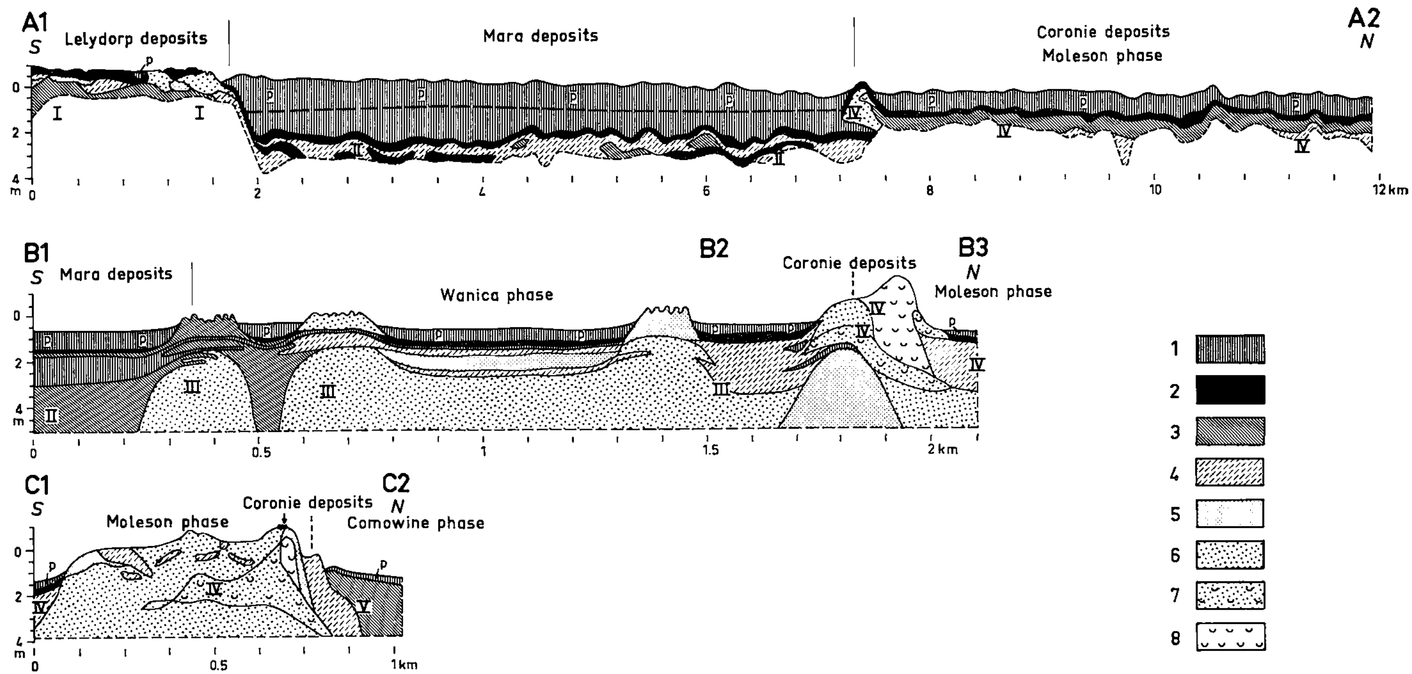
Only in one place in the three Guianas, west of the Coppename river, has the complete Holocene sequence been observed. We shall first deal with the Mara deposits and the three phases of the Coronie deposits in the three Guianas and consider their location in the Coronie area. The sediment map of this area (figure 4) is based partly on the soil survey of Coronie (PONS and PARSAN, 1964) and partly on later field observations of the second author.

The map shows an eroded Lelydorp landscape in the south (figure 4 no. 1). The individual ridges are not shown, because erosion and colluviation together with soil development have wiped out the contours. Nevertheless there are ridges in the northern part of this area, as is shown on profile A of figure 5. More to the south there is an eroded Lelydorp clay deposit (so-called "schollen" landscape). In the whole area of Lelydorp clay and sand deposits a fossil soil development has gone down to depths of 3 to 5 metres.

There is a clay sediment at an elevation of about 1.5 m below mean sea level and covered by peat (figure 4 no. 2, see also figure 5A and B) around the Lelydorp erosion remnants. This clay represents the Mara phase. North of the Lelydorp ridges it contains relatively little pyrite and organic matter. Between the Lelydorp sand and clay erosion remnants and to the east and the south the clays have relatively high organic matter and pyrite contents. To the north the sand content increases. Soil development is only very weak in the northern part of the Mara deposits and partly even absent in the central and southern parts (figure 5A). The Mara clay was partly eroded from the northeast, before the Wanica phase was deposited.

Figure 5B shows that the oldest Wanica ridges are underlain by peat on clay and sandy clay. Originally the Wanica deposits (figure 4 no. 3 and 4) must have been very extensive in the northern part of the area shown in figure 4. At the same time there was a large area of Mara clays with peat cover in the northwestern part. This peat growth proceeded during the sedimentation of the Wanica deposits (figure 5A). Soil development in clays and sand ridges of the Wanica phase is fairly deep. In a later stage large areas of the Wanica clay with related fine sand ridges and also of the Mara clay with peat were eroded and replaced by clays and related sand and shell ridges of the Moleson phase.

Figure 5A shows the Moleson ridges, characterized by abundant shells and underlain by peat on Mara clay; figure 5B shows the same ridges underlain by Wanica clay and sandy clay with thin peat layers. The Moleson marine clays (figure 4 no. 5) and the Moleson coastal sand and shell ridges filled the area in the northern part of Coronie district (figure 4). A cross section of a complicated Moleson ridge system, consisting of



LEGEND

I. Lelydorp deposits; II. Mara deposits; III. Coronie deposits, Wanica phase; IV. Coronie deposits, Moleson phase; V. Coronie deposits, Comowine phase

1. Peat and very recent peat or pegasse (p)
2. Peaty clays, peaty fine sandy clays and clayey peats
3. Clay
4. Fine sandy clay
5. Fine sandy loam
6. Fine sand and loamy fine sand
7. Fine sand and loamy fine sand with varying quantities of shell fragments
8. Pure shells or shell fragments with some sand

↓ Oost-West Verbinding (main road)

The 0-level indicates only the approximate water level in the swamp during the survey, which varies between 1.5 and 3.0 m above mean sea level

Fig. 5 *. Cross sections of the eastern part of Coronie district (locations shown in figure 4)

* Modified from PONS and PARSAN (1964)

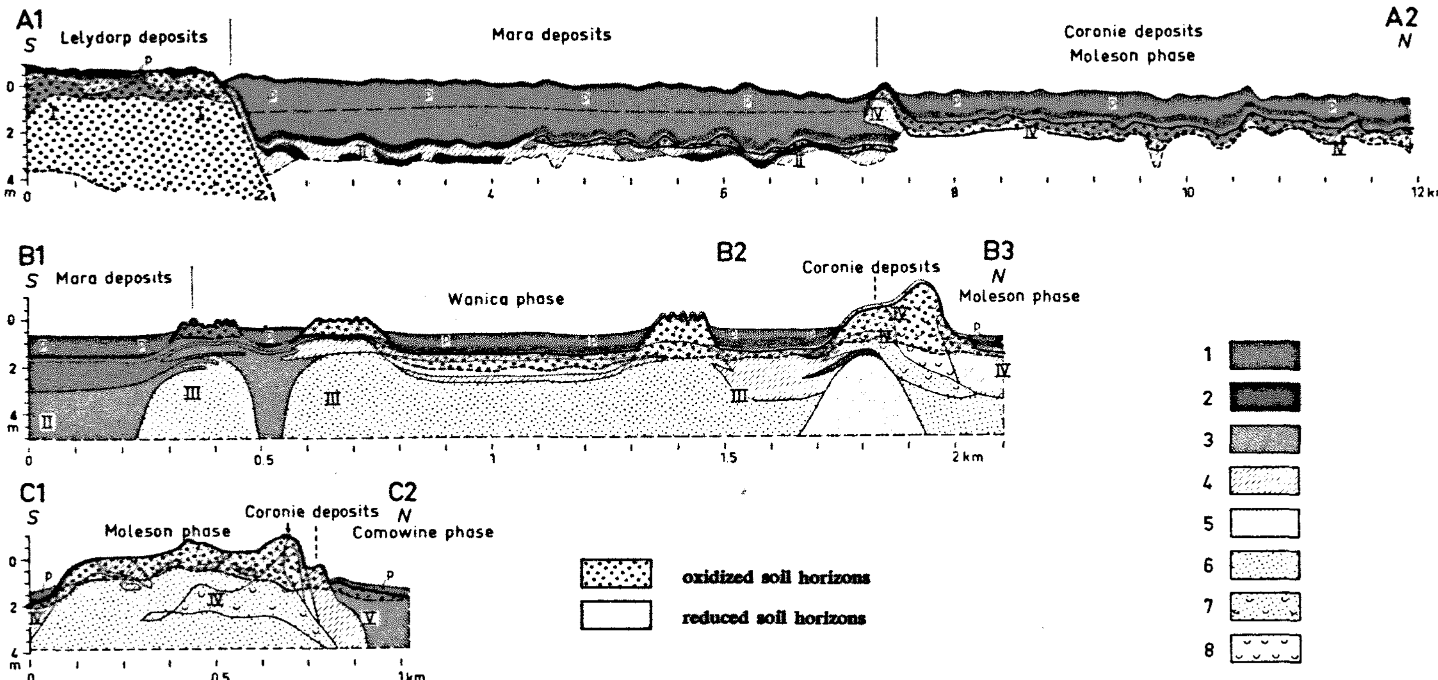


Fig. 5a. Transparency showing oxidized and reduced soil horizons

LEGEND

I. Lelydorp deposits; II. Mara deposits; III. Coronie deposits, Wanica phase; IV. Coronie deposits, Moleson phase; V. Coronie deposits, Comowine phase

1. Peat and very recent peat or pegasse (p)
2. Peaty clays, peaty fine sandy clays and clayey peats
3. Clay
4. Fine sandy clay
5. Fine sandy loam
6. Fine sand and loamy fine sand
7. Fine sand and loamy fine sand with varying quantities of shell fragments
8. Pure shells or shell fragments with some sand

↓ Oost-West Verbinding (main road)

The 0-level indicates only the approximate water level in the swamp during the survey, which varies between 1.5 and 3.0 m above mean sea level

Fig. 5 *. Cross sections of the eastern part of Coronie district (locations shown in figure 4)

* Modified from PONS and PARSAN (1964)

fine sand with varying amounts of shell fragments and some individual ridges of pure shells, is given in figure 5C.

After the Moleson sedimentation phase, clay of the Comowine phase (figure 4 no. 7 and 8) without or nearly without ridges was deposited in this area. Along the Coppename river riverain and estuarine clays (fig. 4 no. 9) were deposited on the peat overlying the Mara clays during the Wanica, Moleson and Comowine phases.

It is not possible to distinguish the several phases with certainty in all cases throughout the coastal plain of the three Guianas. Some areas only show one or two of the possible differentiating characteristics (depths of oxidation, colour of mottles, depths of desalinization, correlating ridges, C^{14} data, etc.). This is partly due to different soil development than is normal for the clays of each phase because of the specific geographical situation of certain sediment areas. Also parts of the original sediments may have different properties and for that reason show other soil characteristics. We always used, however, at least two differentiating characteristics.

The dating of the Mara deposits and the different phases of the Coronie deposits will be dealt with in chapter 7: dating of the sedimentation sequence. The age estimates are given without comment in this chapter.

5.1. Mara deposits (6000 years or older)

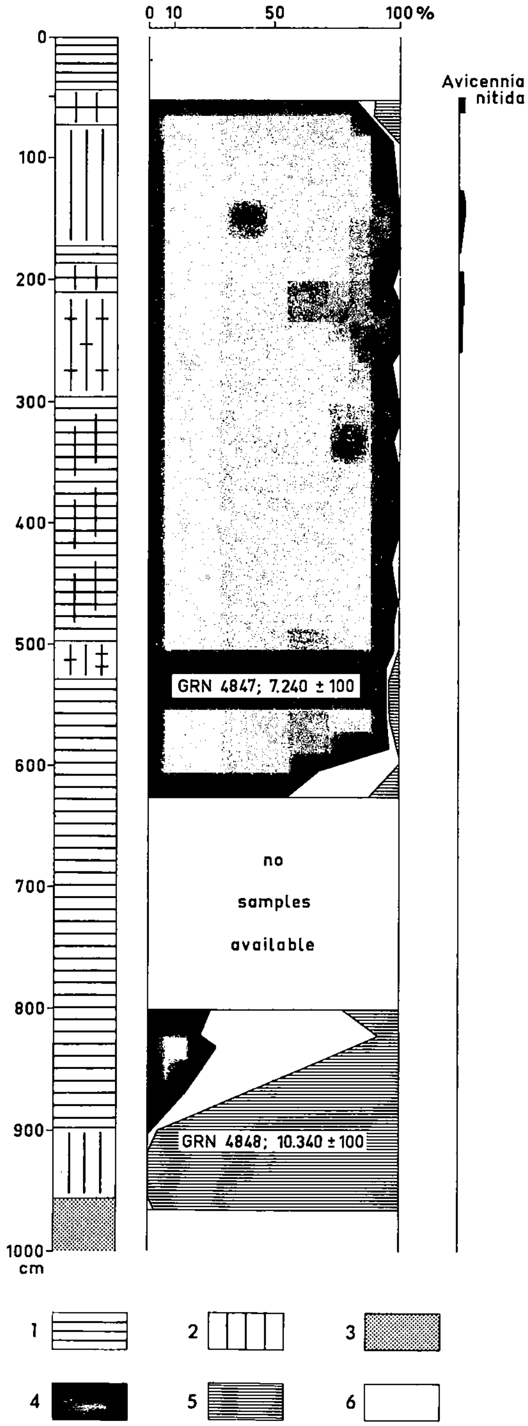
The clays of the Mara deposits occur in Coronie (figures 4 and 5) south of the oldest Coronie ridges. On the separate map the clays of this phase are shown as no. 7. They occur in large areas, mainly west of the Canje river, between the Corentyne and the Commewijne rivers and in western and eastern French Guiana. In southern direction the sediments penetrate into the erosion gullies of the older landscapes.

They were deposited during the early Holocene rise in sea level immediately before the Wanica phase with about constant sea level. Because of the rising sea level during deposition, a relatively large part of the material consists of soft, grey, unmottled to hardly mottled "pyrite clay" (argile à sulfure), high in pyrite and organic matter, which would give rise to "cat clay" or "acid sulphate clay" upon drainage and oxidation.

Mara deposits, especially in the southern parts and the fillings in the older erosion gullies, are often developed as soft peaty clays and eustatic clayey peats with high contents of pyrite. They are former brackish Rhizophora swamp forests with a small supply of clay because of the great distance to the sea. ROELEVELD (1968) made a pollen-analysis of two profiles with respectively 8.5 and 4 m soft peaty clay and peat. The greater part of these soft clays and peats may be considered as Mara deposits, because nearly 100 % of the pollen are Rhizophora and they contain much pyrite.

For a small part the Mara clays, especially along the northern edge of the area, have medium pyrite content and show some mottles probably because of deposition close to the sea or on estuary levees with some oxidation during accretion. At present, most of these sediments are buried under varying depths of peat and/or younger clays, due to their low elevations. West of the Essequibo river, the mineral surface under the peat lies very deep (4 to 7 metres). This may be due to accretion of the coast during sedimentation (see section 3.4). The absence of Pleistocene surface sediments in the area suggests a considerable subsidence.

Due to this continued tectonic subsidence, pyrite clay and peat deposits indistinguishable from those of the Mara phase have accumulated west of the Essequibo river long after the transition to sedimentation at constant sea level elsewhere in the Guianas. The pyrite clay and peat are bordered and locally overlain by sediments of the Comowine phase, without evidence of the intervening phases and may still accumulate in places.



LEGEND

Sediments

1. Clay
2. Peat
3. Sand

Pollen

4. Rhizophora spp.
5. Other trees
6. Grasses

Fig. 6 *. Pollen-analytical profile Matawaribo

* Simplified from Matawaribo I, ROELEVELD (1968)

In most places the original coast-line belonging to this deposit seems to have been eroded, while the present edge is covered by younger clayey or sandy sediments. The estuary levees occurring east and west of the Berbice river, about 30 to 50 kilometres from the present coast, and between the Mahaicony and Mahaica rivers (no. 14 on the separate map), appear to belong to the Mara phase.

The soft, reduced pyrite clays with associated mottled estuary levees have been described by RAMDIN (1961) in his soil survey of the Mara Backlands. Later, large areas were mapped in the soil surveys of the Mahaica-Mahaicony-Abary and Canje areas (APPLEWHITE, 1964; BRINKMAN, 1964a).

In Suriname this sediment is far less known than in Guyana. Besides in Coronie (figures 4 and 5A and B) it was found on both sides of the Nickerie river, covered by 2 metres of peat and riverain clays — where we investigated the pyrite content microscopically (PONS, 1964a) — and also near the Marataka, the Coppename and other rivers.

Much of the Mara clay occurs in the erosion gullies of the Para deposits and the Lelydorp deposits, as shown in Coronie district (figures 4 and 5) and as described by ROELEVELD (1968) from Matawaribo near Paramaribo (figure 6).

In Guyana VAN DER HAMMEN (1963) mentions clayey peat horizons, in gullies in Para (or Lelydorp?) sediments, comparable with rising sea level deposits or pyrite clays or Rhizophora clays, because they have the same 95 % Rhizophora pollen content as found by ROELEVELD (1958). These Mara deposits have C^{14} datings of about 6450 and 6150 years B.P. (GRN 3109: 6470 $\pm$ 85 and GRN 3136: 6140 $\pm$ 75 years B.P.) but are situated about 3 metres above present mean sea level. The mottled clays — probably Wanica clays — on top of these clayey peats extend to about 4 metres above the present floodplain (Corentyne) and about 4 metres above present mean sea level (Canje). These high elevations of Mara and Wanica clay can only be explained by recent local uplifts in southeastern Guyana.

In French Guiana these deposits are described as a separate sediment by BOYÉ (1959) and mapped by LÉVÊQUE (1962) as the greater part of his "argiles à sulfure". Near Mana we saw profiles of typical Mara clays.

5.2. **Coronie deposits**

5.2.1. **Wanica phase** (Coronie I; 6000 or 5500 to 3500 or 3000 years B.P.). The deposits of the Wanica phase (a small part of which in Coronie district is shown in figure 4) occur in large semi-continuous areas between the Corentyne river and the Maroni river and in a narrow strip between the Sinnamary and Kourou rivers. The marine clays and sandy ridges are indicated as no. 5 and 6 respectively on the separate map.

Near the Suriname river they extend from Paramaribo in the north to Lelydorp village in the south (figure 3). These two places are connected by a road called "Path of Wanica". It is along this road that they were first studied (VAN DER VOORDE, 1957; DOST *et al.*, unpublished reports, Dept. of Soil Survey, Paramaribo). The clays are a "normal" marine facies, low in pyrite and organic matter, deposited at a constant sea level (see section 3.3). West of the Commewijne river, the clays and ridges of this phase occur at the same level as the most recent deposits. (Schematic profile in figure 3A, modified from VAN DER VOORDE, 1957.) The Wanica clays and ridges east of the Cottica river (figure 3B, modified from BROUWER, 1953 and LINDEMAN, 1953) occur at elevations of about 1 to 2 metres above equivalent recent sediments.

The situation in French Guiana is about the same as in eastern Suriname. The clays and ridges there are also on a higher level than the younger part of the coastal plain. When we made an excursion there they appeared to be typical yellow-mottled Wanica sediments. From these elevation data it is probable that the coastal areas of eastern Suriname and western and central French Guiana are more or less uplifted, whereas the land west of the Commewijne river is considered to be stable. As mentioned in section 5.1, a few patches of high-lying Wanica clays in southeastern Guyana also point to a local uplift.

The clay soils of this phase (no. 5 on the map) generally have a rather low, locally medium base saturation, they are desalinized to at least 2.5 metres, and show evidence of initial soil formation (firm consistence, yellow [1]) or yellow with some yellowish red [2]) mottling) to depths of 1.0-1.5 metres. The corresponding ridges (no. 6) are very characteristic and always consist of noncalcareous loamy, fine to very fine sand without or with very few shells or shell fragments, in contrast to the ridges of other phases. They characteristically occur in broad bundles. Very shallow erosion gullies have been observed in this sediment west of the Commewijne river, deeper and broader gullies to the east.

On the map the sediments are shown in Suriname and French Guiana. For Suriname we have shown part of the yellow-mottled clays from the soil map of northern Suriname, and have made use of the detailed soil map of an area along the Nickerie river (SCHELTEMA, 1965). Although the separate map shows no Wanica sediments near the Marataka river, the ridge of Cupido in the vicinity has been recognized as Wanica phase by the nature and degree of soil development in the ridge and in the associated, very narrow band of marine clay. This strip of Wanica age separating the older (Mara phase) peat and clay to the south from the younger clay of Moleson age in the north is of importance for this study because the absolute age of the underlying peat is known.

For French Guiana we delineated the area using the detailed geological maps and the observations during our excursion (PONS, 1964b). Probably there are only very small areas of the sediments of this phase in Guyana. The yellowish-brown-mottled clays of the Abary plain have a higher base saturation and less deep mottling than the Wanica clays in the other countries, so that we tentatively included them in the next (Moleson) phase. C^{14} datings of carbon from the Amerindian settlements in the Abary plain described by MEGGERS and EVANS (1955) might determine whether this is correct.

5.2.2. **Moleson phase** (Coronie II; 2500 to 1300 B.P.). The marine clays of this phase are indicated on the separate map as no. 3 and 3a, the sand and shell ridges — together with the sand and shell ridges of the Comowine phase — as no. 4. They occur in a large triangle between the mouths of the Berbice and Coppename rivers, the eastern edge of which is shown in greater detail in figure 4. The apex lies about 60 kilometres from the mouth of the Corentyne river. A smaller area occurs between the Oyapock and the Mahury rivers east of Cayenne, and a very small area west of Paramaribo. Probably a triangular area east and west of the Abary river also belongs to this phase (see below).

The sediments occur mostly at about present high tide level, but parts are as much as one metre lower. Most of the marine clays of this phase have a high base saturation,

1) Munsell notation: 2½Y 6/4-6/5-6/6-7/5-7/6-7/7; 10YR 6/4-6/5-6/6-6/7; 7½YR 7/5-7/6-7/7.
2) Munsell notation: 7½YR 5/7-5/8-6/6-6/7-6/8; 5YR all chromas, etc.

olive, olive brown [1]) and sometimes yellowish brown [2]) mottles and a relatively soft consistence. Desalinization has not gone deeper than 1 to 1.5 metres. The lowest parts of this sediment are unmottled, are very soft and have probably never been dry since their deposition. The clay is interrupted by ridges, partly single, partly in bundles, consisting of sand to sandy loam frequently mixed with shell fragments and locally consisting of pure whole shell material. As a type locality we chose the UN-BG Soil Survey of the Moleson-Jackson area, Corentyne, British Guiana, by SMITH (1961).

No erosion of the surface has been observed in this phase, which indicates that after deposition the sea level must have remained essentially constant. The ridge pattern in a few places strongly suggests appreciable lateral marine erosion of the coast, however.

On the separate map the area of Moleson sediments west of the Corentyne river in Guyana is adapted from DERTING and GROSS-BRAUN, 1964. In parts of the Canje area, estuarine sediments are overlain by thin layers of marine clay of the Moleson phase. These are indicated as no. 3a on the map. In Suriname we modified the soil map of northern Suriname (DOST, 1964b) according to our new ideas, new observations and soil surveys near Wageningen (Nickerie) (PONS and VAN DEN BROEK, 1964). The narrow area immediately south of the Saramacca river and west of Paramaribo is also included because of the occurrence of yellowish brown-mottled clays with fairly frequent shell ridges, which are absent in the Wanica phase. In French Guiana we followed the soil map of LÉVÊQUE (1962) and correlated clay soils southeast of Cayenne with the Moleson phase during our excursion. The correlation of the area east and west of the Abary river into this phase is somewhat doubtful. This part is slightly better drained, the soils have yellowish brown mottles and are firmer than in the other areas, but they have a relatively high base saturation, they are not underlain by sandy horizons, and sand ridges are rare, in contrast to the sediments of the Wanica phase. In addition, the size of the estuary levee remnant west of the Mahaicony river suggests that this may have been the Wanica coast line. The reason for the greater apparent age of the sediments of this area may be the better drainage as a result of a recent shift in the course of the Abary river, which now cuts through the area with hardly any levees.

5.2.3. **Comowine phase** [3]) (Coronie III; later than 1000 B.P. to present). The marine clays of the Comowine phase (no. 2 on the separate map) occur in a band along nearly the whole Guiana coast, in contrast to the preceding phase of sediments, which filled in a few estuaries going many miles inland. This narrow coastal strip is also evident in figure 4.

Their surface lies at about high tide level. The sediments are strongly saline in most or part of the soil profile and either have brown or reddish brown [4]) mottles when superficially desalinized, or have vague [5]) mottles or no mottles when saline. The original pyrite content is normally low to medium, but locally some thin layers of pyrite clay occur in this phase, usually as depression fills in sediments of this or the preceding phase.

1) Munsell notation: 5Y 4/3-5/3-4/4-5/4-5/5; 2½Y 4/3-4/4-5/3-5/4-5/5; 10YR 5/3 (-5/4).
2) Munsell notation: 10YR 5/4-5/5-5/6; 2½YR 5/6.
3) We prefer the simpler, older name Comowine for these deposits to Commewijne, the present Dutch name for the river.
4) Munsell notation: 10YR 4/4-5/4; 7½YR 4/3-4/4-5/4-5/5-5/6.
5) Munsell notation: 2½Y and 10 YR with chroma 2 or slightly higher.

In the plantation Maasstroom on the north bank of the Commewijne river both authors recognized these clays as an independent sediment unit, present in Guyana as well as in Suriname. The youngest clay deposits in French Guiana also belong to this phase as is clear from the descriptions of LÉVÊQUE (1962), who also reports small areas of pyrite clays of the same age east of Cayenne (a small part of his "argiles à sulfure").

In all three Guianas the clay deposits of the Comowine phase alternate with ridges, mainly consisting of fine to coarse sand, and a few with shells or shell fragments. The ridges are indicated on the map as no. 4 together with the ridges of the Moleson phase.

The separate map and figure 4 show the marine clays of the Comowine phase in two legend units: the brown-mottled clays (no. 2b) and the saline clays with vague or no mottling (no. 2a). Along the coast of the northwest district of Guyana only the latter and younger occur. The central and eastern parts of the Guyana coast have the two types together with some bundles of loamy fine sandy ridges. The data are partly derived from the UN-BG Soil Survey (DERTING and GROSS-BRAUN, 1964; APPLEWHITE, 1964; BRINKMAN, 1964a), and partly from SIMONSON (1958). Along the coast in Suriname between the Corentyne and Coppename rivers, a narrow strip of saline clays occurs with only a very narrow strip of brown-mottled clays in Coronie (figure 4). Along the central and eastern Suriname coast a broad band of brown-mottled clays, and towards the sea a broad band of saline clays occur. The data are derived from the soil map of Suriname (DOST, 1964b). In western and eastern French Guiana both types are also present, in central French Guiana only a very narrow strip. Data were derived from the geological map (LÉVÊQUE, 1962) and from our own observations.

5.2.4. **Riverain and estuarine Coronie deposits.** The soils in the river and estuary levee deposits of the young coastal plain, indicated as no. 8 on the map, show much less differences in depth and intensity of soil formation than the corresponding marine clays.

On the map, no subdivision could be made between the estuarine and riverain Coronie deposits, so we included them all in one legend unit (no. 8). Soil formation in these clays differs from that in marine clays, because the chemical composition of the water during sedimentation and the ripening conditions were different, because drainage was better, leaching somewhat faster and salt content lower. Further reasons were a different vegetation and, especially more to the south, admixture of varying amounts of continental material. This results in more intensive and deeper soil formation of even the youngest phases. Soils with yellowish brown and some red mottles are common, as well as moderately and well developed B horizons. Systems of different ages have been recognized stratigraphically, however.

The oldest parts of the Berbice levee system, indicated as estuary levees (no. 14), occurring as narrow strips immediately along the swamps of pyrite clay under peat (Mara deposits, no. 7) and situated some distance east and west of the Berbice river, about 30-50 kilometres from the sea, may have been deposited at the same time as the last Mara deposits. The same holds for the estuary levee (no. 14) between the Mahaica and Mahaicony rivers. This levee, however, is so wide and high that its formation may well extend into the Wanica phase.

An erosion scarp, indicated as no. 15, which changes to the north into a silty ridge (probably consisting of reworked Para and/or Lelydorp deposits) runs from near Orealla on the Corentyne river to near New Amsterdam on the Berbice river. This was probably the coast line in the beginning of the Wanica phase.

In fact both legend units, no. 14 and 15, dealt with above, are geomorphological peculiarities; they belong, however, to no. 8, representing the oldest part of this unit and are as old as the marine Mara deposits and the Wanica phase.

The vast area of estuarine sediments to the east of the erosion scarp in the Corentyne estuary (no. 8) is probably synchronous with the younger part of the Wanica phase and with the Moleson phase. It contains depressions which are filled by thin (0.5-1.5 m) layers of marine clay of the Moleson phase, shown separately on the map as no. 3a.

The levees of the Demerara river between Georgetown and Atkinson appear to be very recent, probably of Comowine age, as well as the Essequibo islands and the estuary levees east and west of the Essequibo mouth, which have a clear stratigraphical connection with marine clays of the Comowine phase.

Northwest of the Essequibo river most of the rivers scarcely have any levees, and these are very young, as are the marine clays along the coast.

In Suriname, too, riverain and estuarine deposits of all Coronie phases are present. The sandy ridges east of the Corentyne are derived from the Corentyne river debouching to the northeast and are of Moleson age. Along the Nickerie river, there are some narrow, straight estuary levees which are shown on the map as no. 15. They consist of clay and belong to the Moleson phase. They are connected with some shell ridges and have elevations of more than 1 metre above the surrounding marine clay.

The levees along the present courses of the Marataka, Nickerie, Tibiti and Coppename rivers are young and rest on a thick peat layer overlying pyrite clay. Many abandoned levee systems connect the middle courses of these rivers. Some of these are as old as the Mara deposits. These older levees occur especially in the hardly explored swamps north of the Tibiti and east of the Coppename river.

The Coesewijne and Saramacca rivers too, have often changed their courses to the east, already in the early part of the Wanica phase, so their abandoned levee systems are relatively old. The Suriname river has mainly young levees and a few older remnants.

The history of the Commewijne, Perica and Cottica rivers is very complicated. In the early part of the Wanica phase they were almost totally blocked by ridges. The marine clays of the Wanica phase are dissected by these rivers whose lower courses are very young.

We know very little about this subject as far as French Guiana is concerned. East of Cayenne the map by LÉVÊQUE (1962) shows levees on peat, which indicates that these, too, may be young and may belong to the Moleson and Comowine phases.

6. PEAT GROWING ABOVE SEA LEVEL

Besides the large areas of eustatic peat of varying thickness covering especially the Mara deposits (no. 7) and growing up to sea level, there are a few vast swamps where drainage is so slow that the peat grows up above sea level. Thus, a vast low mound of peat is formed which grows up until the increase in runoff from the slope balances the excess precipitation. On the aerial photographs, these areas of "ombrogenous peat" are recognized by their characteristic radial drainage pattern. They are indicated on the map as no. 1.

Because of the enormous difficulty of access, no soil survey work was done as yet in these areas. Only southeast of Coronie (see figure 4, southwestern part) we touched the edge of this ombrogenous peat. In the southern part of the profile A of figure 5 an increasing depth of peat and pegasse overlying horizontally deposited clay is visible to the south.

Because of the location of these areas in the landscape we assume that this peat growth started during the Moleson or Wanica sedimentation phases. At present, growth still continues.

The map shows three areas of ombrogenous peats: one south of Nickerie (the Nanni conservancy), one south of Coronie, and one north of Montagne de Kaw. The Nanni and Kaw areas are characterized by small open lakes near the centre.

A peat thickness of 4 metres was reported to occur in the centre of the Nanni area. The lower 1.5 metres may be eustatic peat, so that the peat surface might be about 2.5 metres above mean sea level.

7. DATING OF THE SEDIMENTATION SEQUENCE

A number of C^{14} analyses are now available which enable us to assign tentative absolute ages to most of the sedimentation phases in the Guiana coastal plain.

7.1. Source of age data

FAIRBRIDGE (1961) collected a large number of C^{14} age determinations of sea levels from stable parts of the world's coasts and constructed a C^{14}-controlled sea level curve for the Holocene. (The age data used by him are uncorrected, and might be 200 to 250 years too young.) The C^{14}-controlled sea level curve for the coast of the Netherlands by JELGERSMA (1961) was also used as well as the new data of PONS *et al.* (1963). VAN DER HAMMEN (1963) mentions C^{14} age determinations of old Holocene sea levels for former British Guiana in his palynological studies. GEYSKES (1961a and b) quotes C^{14} analyses for two Amerindian settlements: one on the "Hertenrits" sediments of the Moleson phase and partly covered by Comowine sediments, the other on Comowine sediments. LAEYENDECKER-ROOSENBURG (1966) published a new C^{14} age determination together with palynological investigations of the Hertenrits. DELANEY (1966) published sixteen C^{14} age determinations of shells collected in 1955 from several ridges in the Saramacca and Suriname districts and from the present coast of Suriname. We also used two C^{14} analyses of layers from Holocene Rhizophora peat and peaty clay deposits filling an erosion gully in the Lelydorp and/or Para deposits, investigated by ROELEVELD (1968).

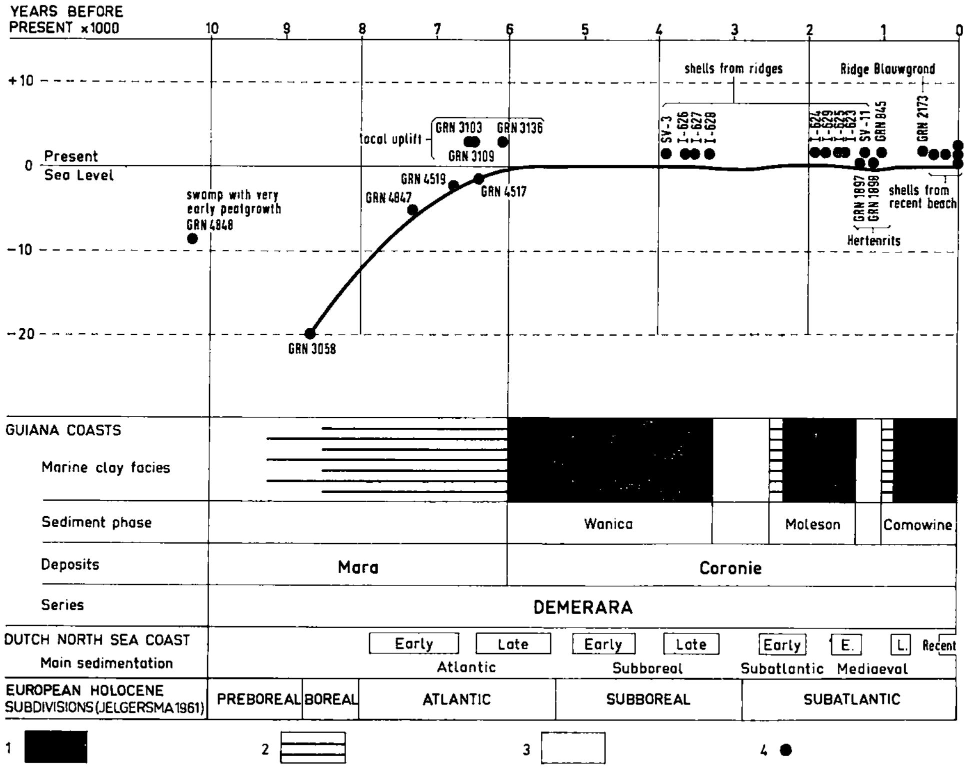
Recently some C^{14} analyses have been completed by the Physics Laboratory of the State University at Groningen, Holland. All available local data have been included in figure 7, as well as the derived sea level curve, the depositional phases and facies in the Guianas, and the subdivision of the Holocene in Holland.

7.2. Magnitude of errors

In 1955 DELANEY (1966) collected a number of shell samples in northern Suriname. Of 16 of these samples C^{14} age determinations were made and represented in his article. Five of these are of shells from the recent coast between the Maroni and Suriname rivers. The ages of these shells were determined as $\leqslant$ 100, 210 $\pm$ 75, $\leqslant$ 140, $\leqslant$ 100 and 350 $\pm$ 140 years (respectively from the samples: SV-6, SV-5, SV-13, SV-10 and SV-12).

From these data it is clear that normally only recent shells are moved to the coast and, as a consequence, that the age of shells in subrecent ridges may be used as an age estimate for the ridges. However, DELANEY's data show that the ages of the two samples of broken shells (SV-1: crushed shells of Van Brussel, Kwatta and SV-4: broken shells from Charlesburg shell ridge) do not correspond with their situation in the coastal plain. Therefore we shall only use the determinations of complete shells in order to avoid as much as possible the chance of shells lying in a secondary position.

Another source of errors will be caused by soil formation during which a very strong decalcification takes place with leaching of $CaCO_3$ from the surface layers of the soil profile and precipitation in the subsoil. During this process recent CO_2 can take part in the formation of $Ca(HCO_3)_2$ in the leaching liquid and may be incorporated in the precipitating $CaCO_3$ which then shows a younger age than the sediment. Samples I-627



LEGEND

1. Deposition of "normal" sea clays at constant sea level
2. Deposition of pyrite clays at rising sea level
3. Erosion
4. C^{14} age determinations (see table 2)

Fig. 7. Holocene sea level curve of the Guiana coast near Paramaribo, C^{14} datings and sedimentation phases

and I-628 from the same pit, respectively 30 cm and 60 cm deep, and with ages of respectively 3500 ± 150 and 3200 ± 150 years, show that this process probably has not influenced the determined ages of whole shells to any great extent.

7.3. Para and Lelydorp deposits

The Para deposits are much more weathered than the Lelydorp deposits. They are always oxidized to a considerable depth (figure 5a). Locally in gullies the thickness of these sediments is more than 8 metres, and we never saw reduced Para deposits.

Since Lelydorp deposits are oxidized to depths between 3 and 5 m we consider the time interval between the Para and Lelydorp deposits greater than that between Lelydorp and Demerara deposits. Detailed investigations by MONTAGNE (1964) have also shown that Lelydorp and Para deposits are sediments of very different ages. Therefore, if the Lelydorp deposits are young Pleistocene (see below), the age of the Para deposits should be middle Pleistocene, probably Mindel-Riss interglacial. The strong soil formation even in parts of the Para deposits which are now deeply buried would then have taken place at the very low sea levels during the Riss and the Würm glaciations. The level of the Para deposits which originally must have been some 20 or 30 m above present sea level has since changed to different other elevations by tectonic movements and erosion.

The Lelydorp deposits, both the clays and the related sandy ridges, were generally considered as young Pleistocene marine sediments. This is now confirmed by the C^{14} age determination of a Rhizophora stump found within the never-oxidized pyrite clay in the Onoribo bauxite mine in Suriname at a depth of about 5 m below surface. Its age was determined to be more than 48.000 years (GRN 4718). The surface of the Lelydorp deposits is about 4-7 m above present mean sea level. These data suggest a young Pleistocene age of the older (Onoribo) phase of the Lelydorp deposits, and probably also for the younger (Santigron) phase, which is closely similar, both in degree of soil development and landscape. The landscape is rather strongly eroded due to the low sea level in the Würm glaciation. Soil formation is remarkably shallow, generally to depths not exceeding three metres. In many places permanently reduced pyrite clay occurs, never oxidized since its deposition, from a depth of about 3 metres down to the contact with the underlying strongly oxidized Para deposits.

Part of the riverain and estuarine terrace deposits, situated some metres above recent river flood plains and at about the same elevation as the Lelydorp deposits, are considered to be of the same age. Unfortunately, no age data are available for the river terraces in Suriname.

7.4. **Mara deposits**

Near Kwakwani on the Berbice river, the apparently similar riverain and estuarine terrace deposits were shown by VAN DER HAMMEN (1963) to be less than 6500 years old (GRN 3103: 6490 ± 80 years B.P.) Related gully fillings in Coropina terraces along the Canje and Corentyne rivers have similar ages (GRN 3136: 6140 ± 75 years and GRN 3190: 6470 ± 85 years B.P. respectively). These three figures were found by analysis of thin brackish eustatic peat layers covered by thin layers of clay. The peat was undoubtedly formed at or near sea level. It now occurs some three metres above present sea level, slightly below the surface of the local Coropina deposits. Based on these data VAN DER HAMMEN (1963) accepted a maximum relative sea level at about 6000 B.P. of 3 metres above present sea level. Ages of 6500-6000 years B.P. (GRN 4519: 6720 ± B.P., GRN 4517: 6360 ± 70 B.P.) have, however, been determined for the eustatic peat layers investigated by the authors, which occur at depths of respectively 2½ and 1½ metres below present sea level in Suriname, in an area which does not show any evidence of subsidence.

These peat layers occur along the Marataka river in the district Nickerie, very near to the Corentyne river. Although these data are very limited we suggest that the small patches of high-lying peat for which similar ages are quoted above, may indicate a very recent tectonic uplift of the region west of the Corentyne river. We consider that the old Holocene unmottled pyrite clays (the Mara deposits) were formed at a rising sea level under Rhizophora vegetation. On the basis of FAIRBRIDGE'S (1961) and our own data we assume a Holocene rise of sea level with a maximum at about 6000 B.P., so that the age of the Mara deposits is 6000 years or older. The data of ROELEVELD (1968) fit in very well with this idea. The top of the Mara deposits is found at several levels from below to slightly above mean sea level. Probably the Mara deposits comprise several phases, and the top of Mara deposits in different areas may represent a different phase and age. Further investigations would have to be carried out for more detailed classification. But also a minor uplift or subsidence may have changed the elevation of the Mara deposits.

In the region of the Torani canal and Canje river there are large areas of Mara clay approximately at present swamp level (slightly above sea level). We suppose this is related with the above mentioned recent uplift of this region. Careful measurements of the relative elevations of the Mara clay areas and the patches of "elevated peat" and some absolute age determinations on Mara clays might clarify this point.

In the northwestern part of the coastal area the top of the Mara clays is at 5 to 7 m below mean sea level and overgrown with thick eustatic peat layers. Other phenomena too, indicate that this area has subsided in recent times.

7.5. **Coronie deposits**

The Coronie deposits, sedimented at constant sea level are subdivided into three phases: Wanica, Moleson and Comowine, as indicated on the separate map. Their ages are discussed below.

7.5.1. **Wanica phase.** The sand and shell ridge of Cupido in the Nickerie district may be considered as the beginning of the Wanica phase. This ridge is formed between 6360 and 5130 years B.P. The first date is the age of the deepest part of a peat layer, 1 m thick, beginning at a depth of 1.50 m below mean sea level and resting directly upon the Coropina clay (Lelydorp or Para deposits). This peat layer is overlain by the ridge consisting of four metres of sand with shells. The ridge, therefore, must be younger than 6360 years B.P. The second date is the age of the top of the peat, at 90 cm below surface of a clay-on-peat profile, about 200 metres north of the Cupido ridge. The whole peat layer, 60 cm thick, of this clay-on-peat profile was developed after the formation of the Cupido ridge. Taking into account the physiographic situation we estimate the age of the Cupido ridge at about 6000 to 5500 years B.P.

The clay layer overlying the peat of the above-mentioned profile, also belongs to the Wanica phase. It is dated at about 5000 years B.P. and belongs to the older part of the Wanica phase.

For the age determination of younger ridges of the Wanica phase we can use four samples: I-626, I-627, I-628 and SV-3. Sample SV-3 (shell in older Saramacca sand ridge) is from the Wanica ridge complex between La Poule and Groningen, in the middle part of the Wanica phase, and has an age of 3850 ± 150 years B.P. The three other samples are situated at the northern edge of the Wanica ridge complexes in the Saramacca district. Their ages, respectively 3500 ± 150, 3200 ± 150 and 3560 ± 175 determine the age of the youngest part of the Wanica phase at about 3500 B.P. On geomorphological grounds we believe that in Saramacca the youngest part of the Wanica phase has been eroded, so the Wanica phase ended sometime after 3500 B.P.

Summarizing we consider the beginning of the Wanica phase to have been at about (6000 to) 5500 years B.P. and the end at about 3500 (to 3000) years B.P.

7.5.2. **Moleson phase.** The age of the Moleson phase can be estimated with the help of five C^{14} analyses of shells and from the age determination of the Hertenrits and surroundings. The samples I-624 and I-629 (Delaney, 1966) are situated in original, not reworked Moleson shell ridges. Their ages are 1850 ± 170 and 1675 ± 140 years B.P. respectively. This dates the middle part of the Moleson deposits at about 2000-1500 B.P.

In our opinion the older part of the Moleson deposits is not present in Saramacca, but well represented in Nickerie from where we have no C^{14} determinations. From data in other countries (comparison with Holland and East Pakistan, below) we estimate the beginning of the Moleson phase to have been some time after 2800 years B.P.

The interval between the Moleson and the Comowine sedimentation phases could be dated with much more certainty. GEYSKES (1961a and 1962) described the "Hertenrits", an Amerindian settlement mound north of Wageningen (Nickerie), and quoted radiocarbon analyses for material found in the lowest and lower parts of the mound, indicating a period of habitation beginning at about 1265 and continuing to much later than 1130 years B.P. (GRN 1897: 1265 ± 60 years and GRN 1898: 1130 ± 45 years). Our own field observations established that the "Hertenrits" mound as well as a similar mound some 10 km more to the east, was built on top of sediments of the Moleson phase and that the lower parts of the mound were covered by sediments of the Comowine phase. A preliminary estimate for the end of the Moleson phase was given by PONS (1966) as 1000 years B.P.

Recently more detailed pollen-analytical investigations together with one new C^{14} age determination of the Hertenrits were published by LAEYENDECKER-ROOSENBURG (1966). The pollen diagrams of four profiles (one in the Hertenrits itself, one adjacent to the mound, one at some distance and the fourth next to a raised bed used for agriculture) show four pollen zones. The oldest zone (A), present in the subsoil of all profiles, has high Rhizophora pollen percentages together with medium Avicennia percentages and represents Moleson phase sediments under mangrove vegetation. Zone B, only a thin layer, also present in each profile, shows herbaceous swamp elements and slow sedimentation of brackish to fresh-water clay. Zone C, only present in the surrounding profiles but not in the profile of the mound itself, shows a sudden rise of the Avicennia curve, indicating a new transgression of the sea with marine sediments, correlating with the Comowine phase. Zone D comprises the recent pegasse layer with high percentages of herbaceous swamp elements.

The area was first inhabited during deposition of the upper part of zone B. The two C^{14} analyses quoted by GEYSKES were of samples taken from the upper part of this zone. LAEYENDECKER-ROOSENBURG believes that the first habitation was possible because of the relatively dry and freshwater conditions at the end of the clay sedimentation of zone A. People first settled directly on the clay near a creek, which silted up in the following period. This means that some time previous to 1265 B.P. the deposition of the Moleson sediments ended and conditions became favourable for man to settle in the coastal area.

The C^{14} determinations of shell material (DELANEY, 1966) of the youngest Moleson ridges support these datings. The samples I-625 and I-623 are from young shell ridges at the northern edge of the Moleson deposits (in the Saramacca district). They show ages of respectively 1525 ± 150 and 1500 ± 150 years B.P. The age of the sample SV-11 of DELANEY (only indicated as "younger shell ridge Saramacca") is 1120 ± 110 years B.P. and may also belong to the Moleson phase.

Summarizing we can date the beginning of the Moleson phase at about 2500 B.P.; the middle part at about 2000 to 1500 B.P. and the end at about 1300 B.P.

7.5.3. **Comowine phase.** According to LAEYENDECKER-ROOSENBURG (1966) a new transgression caused inundations and sedimentation of a marine clay layer (Zone C, see above) which can be correlated with the Comowine sediments. From our own field observations as well as from figure 3 of LAEYENDECKER-ROOSENBURG it was clear that the Comowine sediments covered the foot of the mound. We therefore believe that the

Table 2. C^{14} determinations

Number of sample	Age, years before present	Location, short description	Source
GRN-2173	480 ± 50	Amerindian settlement on a Comowine sand ridge, Blauwgrond, north of Paramaribo, in Comowine phase.	GEYSKES (1961b)
GRN-1898	1130 ± 45	Base of Hertenrits, an Amerindian raised settlement between Moleson and Comowine phases.	GEYSKES (1961a and 1962)
GRN-1897	1265 ± 60	do.	
GRN-845	1055 ± 60	Hertenrits. Organic layer (incorrectly described as pegasse) in raised layers of the settlement mound.	LAEYENDECKER-ROOSENBURG (1966)
GRN-4847	7240 ± 100	Matawaribo. Erosion gully filled with peat and clay. Peaty clay layer at a depth of 5.25-5.55 m.	ROELEVELD (1968)
GRN-4848	10340 ± 100	do. Peat layer at the bottom of the gully, from a depth of 9.00-9.30 m, i.e. about 8.50 m below present sea level.	
GRN-4518	5130 ± 70	Cupido near Marataka river. Youngest peat of a clay-on-peat profile just north of the oldest Wanica ridge. About present sea level.	Unpublished
GRN-4517	6360 ± 70	do. Peat just above Coropina clay. Peat profile covered by oldest Wanica ridge. About 1½ metres below sea level.	
GRN-4519	6720 ± 70	do. Peat profile south of Wanica ridge, peat about 2½ metres below present sea level.	
GRN-3136	6140 ± 75	Torani canal, Canje river. Peat layer in gully in Coropina sediments, some metres above present sea level, accumulated during 'regression'.	VAN DER HAMMEN (1963)
GRN-3109	6470 ± 85	Orealla, Corentyne river. Base of peat layer in gully in Coropina sediments, some metres above present sea level, accumulated during transgression.	
GRN-3103	6490 ± 80	Kwakwani, Berbice river. Base of peaty clay under river terrace, some metres above present sea level.	
GRN-3058	8590 ± 65	Ogle Bridge near Georgetown. Borehole, peaty clay at a depth of 20 metres overlying mottled firm clay.	VAN DER HAMMEN (1963)

Table 2 *(continued)*

Number of sample	Age, years before present	Location, short description	Source
GRN-3506	> 45000	do. Hard peaty clay at a depth of 29 metres, below mottled firm clay.	
GRN-4718	> 48000	Onoribo mine. Autochthonous Rhizophora stump at a depth of 4 metres, in reduced pyrite clay of Lelydorp deposits, overlying Para clays.	Unpublished
SV-6	< 100	Biggi Santi — Suriname coast between Maroni and Suriname rivers. Recent shell (Ostrea equestris).	DELANEY (1966)
SV-5	210 ± 75	Box creek. do. (Ostrea spp.).	,,
SV-13	< 140	Biggi Santi. do. (Anomia simplex).	,,
SV-10	< 100	Halet Kamp. do. (Chione subrostrata).	,,
SV-12	350 ± 140	Coronie. do. (Trachicardium muricatum).	,,
SV-11	1120 ± 110	Saramacca. Younger shell ridge (Anomia simplex).	,,
I-625	1525 ± 150	do. Pit Km 86.7, shells.	,,
I-624	1850 ± 170	do. Pit Km 72.5, shells.	,,
I-629	1675 ± 140	do. do. shells.	,,
I-623	1500 ± 150	do. Pit Km 59.2, shells.	,,
I-626	3560 ± 175	do. Shell ridge, shells.	,,
I-627	3500 ± 150	do. Pit Km 43, 30 cm deep, shells.	,,
I-628	3200 ± 150	do. do. 60 cm deep, shells.	,,
SV-3	3850 ± 150	do. In older sand ridge, shell. (Mulinia cleriama).	,,
GRN-4938	2790 ± 50	Near Dacca, East Pakistan. Infilled gully in Pleistocene terrace; middle vegetation layer.	BRAMMER and BRINKMAN (unpublished)
GRN-4937	5030 ± 70	do. Top of lower vegetation layer.	,,
GRN-4939	5280 ± 60	do. Stump below top of lower vegetation layer.	,,

inhabitants built their mound or the main part of it before these Comowine sediments were laid down. Organic layers (incorrectly referred to as "pegasse layers") in the upper parts of the mound show an age of 1055 ± 60 years B.P. (GRN-845). This means that the beginning of the Comowine transgression must be dated at shortly after 1055 B.P. The Amerindians were forced to leave the Hertenrits and similar wet places shortly after 1055 B.P. They probably moved to the ridges, where after that time habitation must have been intensive.

GEYSKES (1961b) quotes a radiocarbon age of 480 ± 50 years B.P. (GRN 2173) for material from an Amerindian settlement at Blauwgrond, north of Paramaribo, on a ridge approximately in the centre of the belt of Comowine sediments.

Maps from the first half of the seventeenth century show a much shorter distance from Paramaribo to the sea than at present. REYNE (1961) demonstrated by a map that accretion of the coast near Coronie continued until 1914. At present, sections of accretion and erosion alternate along the coast of the Guianas, with perhaps a small balance in favour of sedimentation. The Comowine sedimentation phase has therefore continued until present times.

7.6. **Comparison of the phases of the Demerara Series with the main North Sea deposits**

In figure 7, the Mara deposits and the phases of Coronie deposits can be compared with the main Holocene marine deposits along the Netherlands North Sea coast (JELGERSMA, 1961, and PONS *et al.*, 1963).

The Mara deposits are probably equivalent to the early Atlantic marine deposits, but cover also the early stages of the late Atlantic marine deposits.

The Wanica phase appears to be contemporary to the early and late Subboreal marine deposits and perhaps the youngest part of the late Atlantic.

It is very probable that the Moleson phase is synchronous with the early Subatlantic (1st and 2nd pre-Roman) deposits together with the late Roman and early Mediaeval deposits.

The beginning of the Comowine phase fits in very well with the beginning of the late Mediaeval deposits. Both are still going on at present.

7.7. **Comparison with some East Pakistan data**

It is very tempting to compare the sedimentation sequence described above with a few recent data from the Brahmaputra delta in East Pakistan (BRAMMER and BRINKMAN, unpublished). There, the Madhupur jungle tract, a Pleistocene terrace landform surrounded by Holocene river floodplains, extends from Dacca to the north. It is elevated above the level of the floodplain and bounded by a set of fault scarps on its western edge, but dips under the younger sediments in the southeast and east (MORGAN and MCINTIRE, 1959). On this side the deep valleys, eroded in the terrace, have been completely filled in by younger floodplain material. From the surface downwards, this consists of three layers of clayey sediments low in organic matter, each underlain by a more humous, darker or more mucky or peaty vegetation layer. The upper one of these vegetation layers is only a few inches thick and, although still distinguishable by its darker colour, has lost most of its presumed originally high organic matter content. The second, equally thin, is very dark grey and mucky. The bottom one is much thicker, very dark grey or black, mucky or peaty and continues downward as a mucky clay to clay deposit with many tree stumps in places. The stumps appear to be of a coastal swamp tree, locally called sundri (a mangrove), but have not been identified yet. They occur in their original position in the sediment. In a few excavations this was observed to overlie the mottled, stiff Pleistocene material dissected by the valley. The three vegetation layers may occur at variable depths, but generally they are about $1^1/_2$, $2^1/_2$ and 4 metres below present floodplain surface respectively. In shallow valley heads, the lower one or two may be lacking. Radiocarbon ages for wood from a tree stump, for the top of the lower and for the middle vegetation layer are 5280, 5030 and 2790 years B.P. respectively (GRN 4939: 5280 ± 60; GRN 4937: 5030 ± 70; and GRN 4938: 2790 ± 50 years B.P.). The upper layer has not yet been dated.

If one assumes a seaward movement of the Bengal coastline due to accumulation of sediment, and gradual burial of older coastal sediments by younger river deposits, possibly accompanied by a slight subsidence, this sequence is directly comparable with the Holocene sequence found in the Guianas. The lower vegetation layer with tree stumps overlying the Pleistocene valley bottom could be the Mara phase, which is also suggested by the strikingly similar radiocarbon ages. The three layers low in organic matter could represent the Wanica, Moleson and Comowine phases, here lying one on top of the other and separated by vegetation layers, instead of one before the other separated laterally by erosional coast lines as found in the Guianas. On the basis of the data from Pakistan we may guess that the Wanica-Moleson transition in the Guianas occurred about 2800 years B.P. (Subboreal-Subatlantic transition in the Netherlands: 2700 B.P.). Conversely, the radiocarbon data from the Guianas for the Moleson-Comowine transition would suggest that the youngest vegetation layer in the Pakistan sequence may be between 1250 and 1150 years old. This would be in accordance with historical data indicating that most of the floodplain in East Pakistan became habitable about 1000 years ago.*

* Added in proof: youngest vegetation layer 1430 ± 70 B.P. (GRN 5077, preliminary result subject to revision).

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Brinkman & Pons

PEDO-GEOMORPHOLOGICAL MAP OF THE SEDIMENTS IN THE COASTAL PLAIN OF THE THREE GUIANAS

LEGEND

Symbol	Main kind of sediment	Phase	Deposits	Series
1	Peat growing above sea level	uncorrelated probably Wanica through Comowine		
2a	Saline to brackish marine clay without or with vague mottles, or with brown mottles	Comowine	Coronie	Demerara (Holocene)
2b	ditto with brown mottles			
3	Marine clay with high base saturation and olive or yellowish brown mottles	Moleson		
3a	ditto in thin layers on older sediments			
4	Sandy ridges with or without shells, seldom podzolized	Comowine and Moleson		
5	Marine clay with medium to low base saturation and yellow mottles	Wanica		
6	Sandy ridges without shells, partly podzolized			
7	Soft brackish water clay with much pyrite and organic matter, covered with peat of varying depth, mostly unmottled		Mara	
8	Estuarine and riverain clays and loams		uncorrelated	
9	Firm red and yellow mottled clay to loamy fine sand, (unknown area included in Para) sometimes to coarse sand; sands mainly podzolized		Lelydorp	Coropina (Pleistocene)
10	Sandy and loamy, mostly indistinct ridges, mainly podzolized			
11	Sandy to clayey river terraces			
12	Firm red mottled clay with silty top		Para	
13a	Older sediments (White Sands)			Berbice (Tertiairy)
13b	Residual			Crystalline basement

14 Estuary levees

15 Erosion scarp and silty ridge

SCALE 1 : 1 000 000

0 10 20 50 100 kilometres
0 10 20 30 40 50 miles

Soil Survey Institute
Wageningen