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Outline of the stratigraphy and the geological history of the Suriname coastal plain

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Abstract

The stratigraphy and the geological history of the Suriname coastal plain are reviewed, using recently updated and new information.

The geological history covers an interval ranging from Late Cretaceous to Holocene. The various transgressive and regressive cycles during this time have been correlated with the global eustatic sea level movements.

Introduction

Recently (Wong, in prep.), the lithostratigraphy of the sediments in the coastal plain of Suriname has been updated and revised, following modern principles and directives of the International Stratigraphic Guide (Hedberg, 1976). In that study, much use had been made of unpublished data from oil exploration wells, which makes it a lengthy and rather descriptive contribution. It was therefore, I felt necessary, using the revised data, to write a more general and concise text that focuses on the geological history of the coastal plain. In this paper the stratigraphic correlations between wells (Figs 3 & 4) and the distribution of the Late Cretaceous and Palaeogene coastal plain deposits (Figs 5, 6 & 7) are given. These interpretations are largely based on the exploration wells. To enable future researchers to trace back the basic information, references to several unpublished 'key' reports are also included here.

Geological setting

Suriname is situated on the northern edge of the Precambrian Guiana Shield. This shield is exposed over approximately 80% of the country's surface and underlies the sediments of the coastal plain. The coastal plain of Suriname (Fig. 1), together with those of French Guiana and Guyana, forms the onshore part of the Guiana Basin. This basin originated in the Late Jurassic – Early Cretaceous with the opening of the Atlantic Ocean. This was accompanied by steep faulting in the coastal area which continued into the Early Tertiary (Wijmstra; 1971, Krook; 1979). Various authors (a.o. Krook, 1979) pointed to related faulting which created several grabens in the Atlantic off the Amazon River and the Takutu Graben in Guyana. After this initial rifting phase the history of the Guiana Basin has been governed by the gradual subsidence of a passive or trailing continental margin resulting in deposition typified by little tectonic activity and numerous periods of erosion (Hanou, 1981).

Progressively older sediments onlap the Pre-

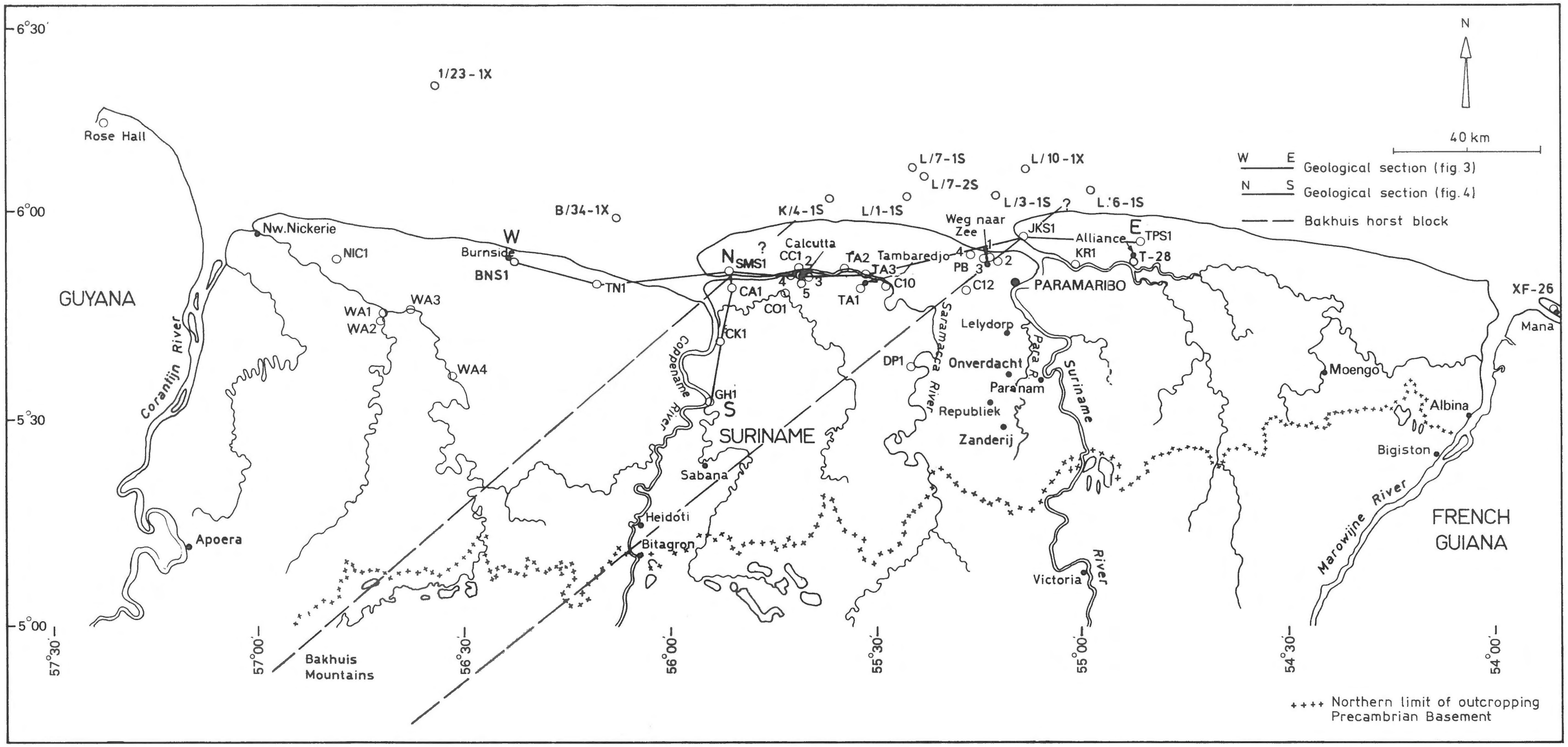

Fig. 1. Outline of the coastal area of Suriname with relevant drill-holes.

cambrian basement in a northern direction. The oldest sediments in the coastal plain (only encountered in drill-holes) are of Early Senonian (Late Cretaceous) age. The youngest sediments have a Holocene age. Only Pliocene, Pleistocene and Holocene sediments crop out in the coastal area, an exception being some Early Tertiary strata in the bauxite mining regions and south of Republiek in creek valleys. The coastal plain (sensu stricto) traditionally has been divided into two geomorphological units: the young coastal plain (in the north) with Holocene sediments and the old coastal plain (in the south), a dissected surface with predominantly Pleistocene sediments. Towards the south the coastal plain is bounded on another geomorphological unit of sedimentary origin. That unit is known as the Savannah Belt and comprises mainly Pliocene continental sediments and minor residual weathering deposits from the Precambrian basement. The rock units of the coastal plain have been grouped in the Corantijn Group (see Fig. 2). The Group consists of a monoclinically dipping (approx. 1°) section of predominantly clastic sediments. These sediments form a regular alternation of sands, clays, siltstones and minor shales. Locally marls, lignites (or peats) and gravels may be intercalated. The sediments were deposited under fluvial to marginal marine conditions. Several regressions and transgressions as well as major periods of non-deposition can be recognized. Correlation with similar global events has been attempted but proved to be difficult due to severe erosion and the lack of adequate biostratigraphic control.

The total thickness of the Group increases from south to north and from east to west. At the mouth of the Marowijne River the thickness is barely 200 m, but in the vicinity of Nieuw Nickerie at the mouth of the Corantijn River it is nearly 2000 m.

Geology and sedimentary history

Cretaceous

The Late Cretaceous (Early Senonian – Maastrichtian) sediments of the coastal plain, grouped in the Nickerie Formation, were deposited on the strongly weathered Precambrian erosional surface. The Nickerie Formation shows a uniform distribution throughout the whole area and is characterized by a regular alternation of numerous consolidated and unconsolidated poorly sorted, quartz sands with multicoloured claystones, siltstones and minor shales. Locally thin gravel beds may be intercalated in the basal part of the formation (see Fig. 5 for geographical distribution of the formation).

Discontinuous sandbodies which show general fining upward trends on the geophysical logs are particularly conspicuous in the lower part of the formation. This and the interbedded gravel probably characterize them as near source alluvial fans and braided river deposits. The clays represent extensive backswamps. This picture is supported by recent palynological research by Chen (1983) who added that tree ferns flourished in the swamps. A change in the log pattern higher in the sections suggests that in the course of time conditions changed to a meandering river system, resulting in pointbar, floodplain and backswamp deposits. The common pinkish and reddish brown quartz grains found in the sands may indicate that they are partly derived from the Precambrian Roraima Formation. This is in agreement with the findings of Kugler et al., (1944) about the provenance of the Cretaceous sediments in the Rose Hall well in Guyana.

The progressive north- and westward thickening of the formation suggests a relatively constant rate of subsidence during deposition whereby the deposition rate always exceeded the rate of basement subsidence. Chen (1983) presented data from which the relatively high sedimentation rate of 610 m per million years can be calculated. The regional thinning of the formation, as can be noted in the Saramacca – Weg naar zee area (Fig. 3), indicates that some differential movements occurred. This may be related to the Bakhuis horst (Fig. 1) and associated tectonic movements.

In the Cretaceous sections a few internal unconformities can be interpreted on the geophysical logs. There was, however, a major period of non-deposition at the end of the Cretaceous, when large areas were exposed to erosion and weathering. According to Noorthoorn van der Kruyff (1970)

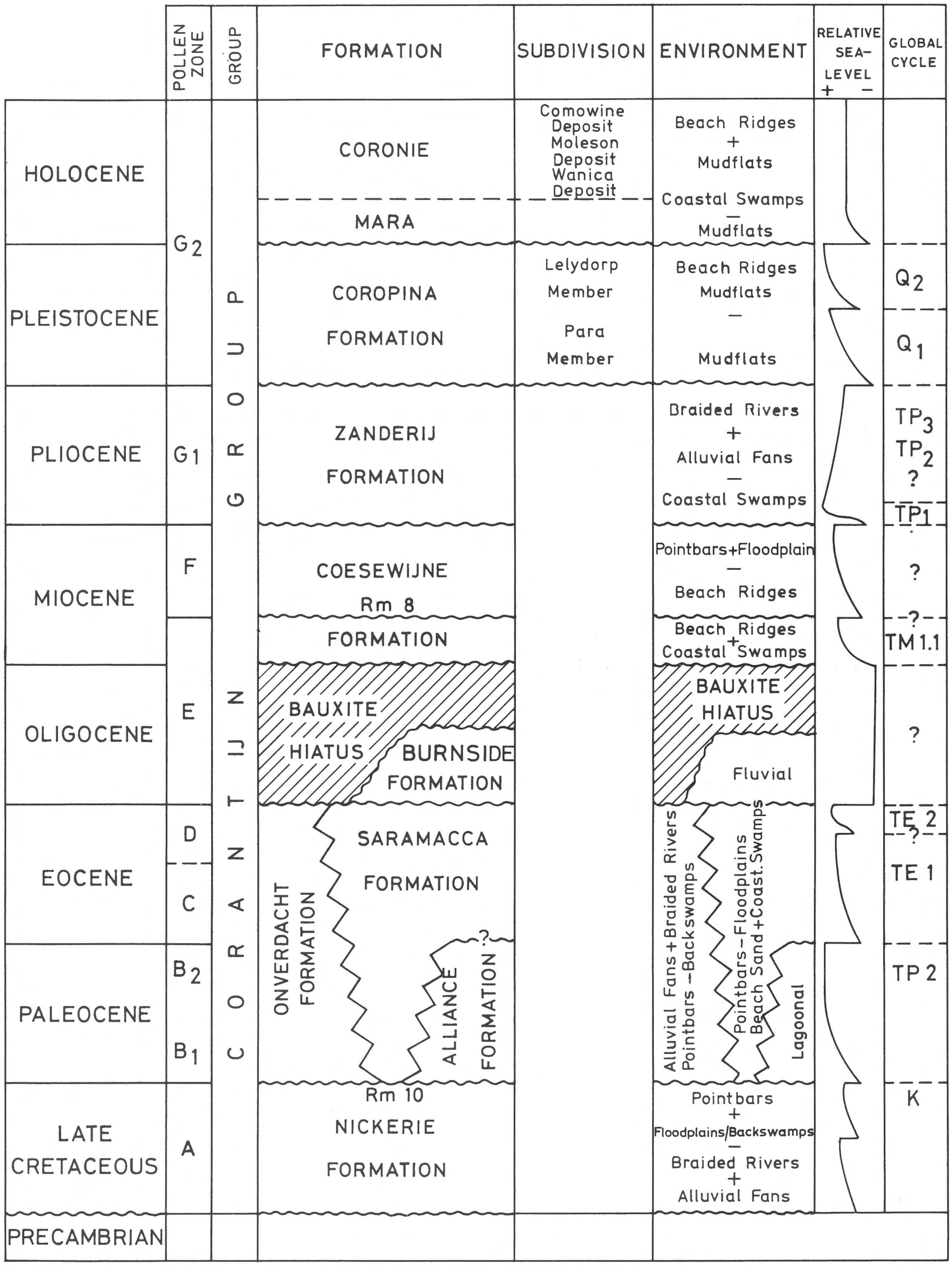

Fig. 2. Stratigraphic framework of the coastal plain of Suriname, modified after Dixon (1972), Hanou (1981), Krook (1979), Noorthoorn van der Kruyff (1970) and Wong (1984a & in prep.). Global cycles after Vail et al., (1977) and Vail & Mitchum (1979); + = rising sea level, − = falling sea level.

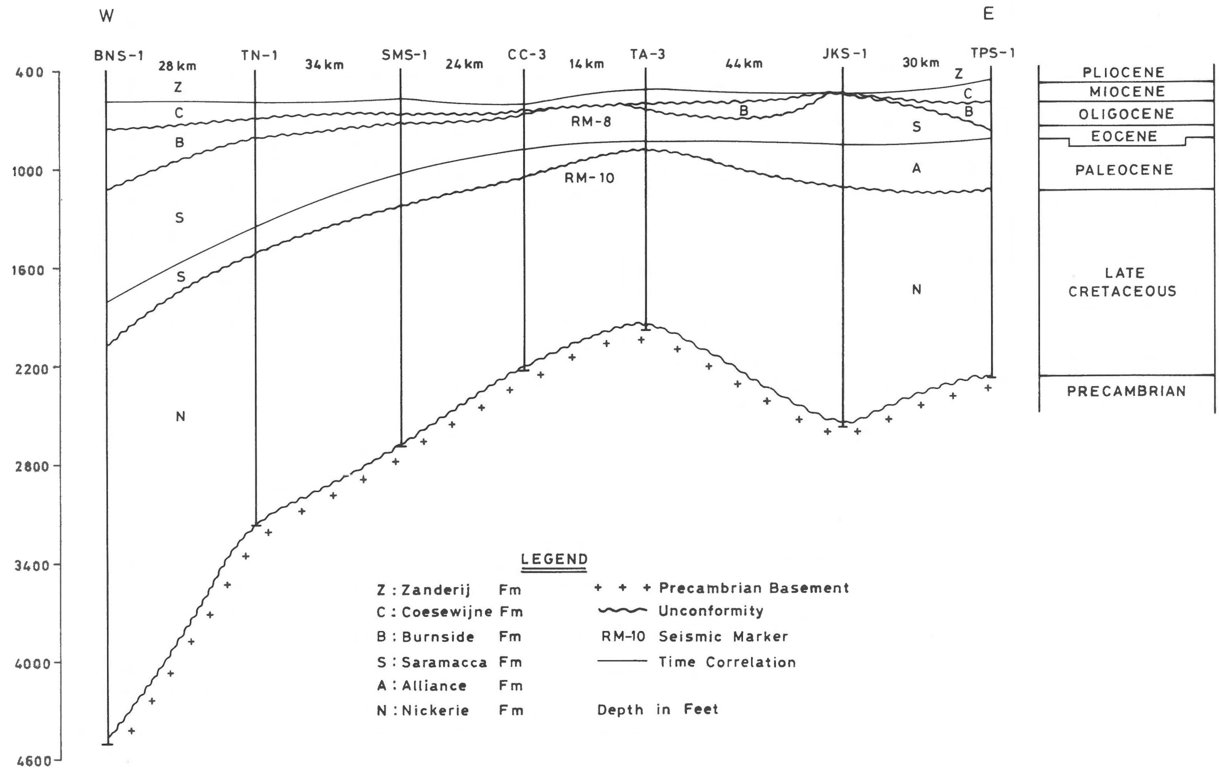

Fig. 3. E-W stratigraphical correlation through the coastal plain.

this was triggered by very gentle tectonic upheaval. The same author also stressed that with the extremely low relief of the coastal plain, even the gentlest movements would result in the emergence or inundation of large areas. From a modern point of view however, this upper Cretaceous unconformity corresponds with the global unconformity (Vail et al. 1977) that was caused by a eustatic fall in sea level at the end of cycle K.

Paleocene

The Paleocene section in the coastal plain begins with a transgression which reached farther south than the southern limit of the Cretaceous sediments (Fig. 4). In the central part of the coastal plain three different facies can be recognized from south to north, generally also reflecting the paleogeographical trend: a continental basin edge facies, a coastal-fluvial facies and a restricted, lagoonal, facies. The continental basin edge facies is represented by the kaolinized and bauxitized sediments grouped in the Onverdacht Formation with restricted occurrence in the so called Bauxite Belt in Suriname and Guyana. This is an arcuate belt more or less parallel to the zero contour of the basement. The sediments consist of coarse kaolinitic sands and varicoloured kaolinitic clays. The upper part of the formation may be altered into bauxite and laterite. Locally gravel layers are intercalated at the base of the formation. Similar sediments in Guyana belong to the Mombakka Formation (Van der Hammen & Wijmstra, 1964). Montagne (1964) and Aleva et al. (1969) recognized two sequences in Onverdacht sediments, ranging from coarse sand to kaolinitic clay. Various authors published detailed lithological data on the Onverdacht Formation, a.o.: Montagne (1964), Aleva (1965), Valeton et al. (1973) and Krook (1979). Among the observations they listed: poor sorting, graded bedding, layers of coarse-grained heavy minerals, slumping textures within the for-

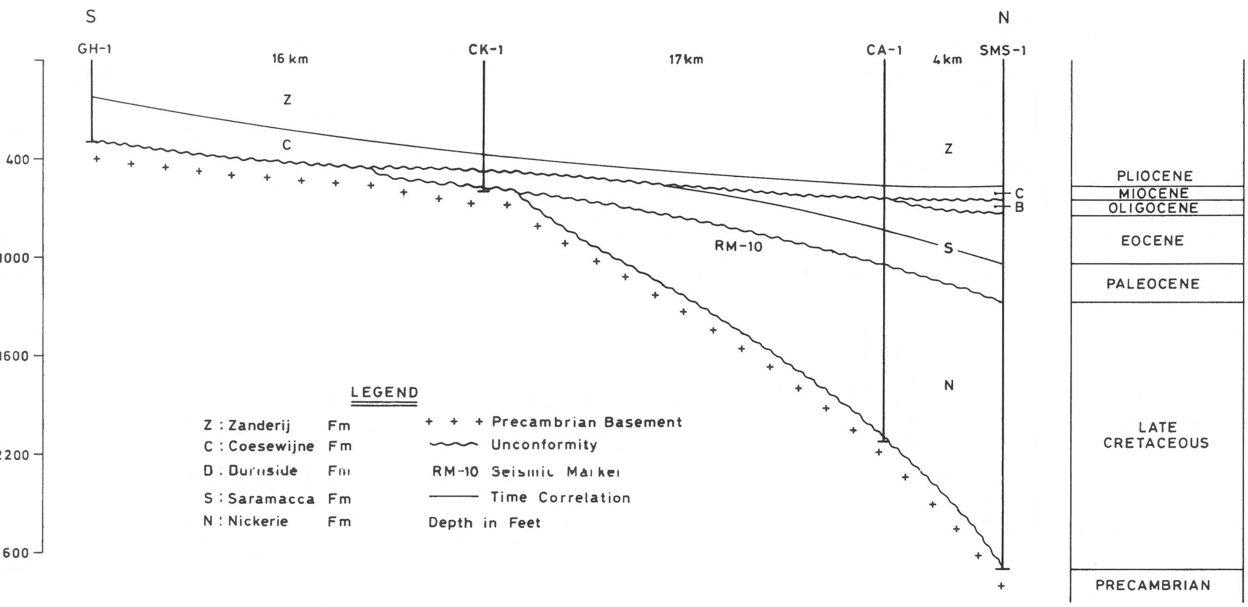

Fig. 4. N-S stratigraphical correlation through the coastal plain.

mation, transition and quick lateral changes of sedimentary units and the lenticular increase and decrease in talus cones. Biogenous fabrics in the bauxite and in the directly underlying sediments in the form of plant-root horizons and burrows, were described by Valeton (1971). From these data the following paleoenvironment can be reconstructed: in the immediate vicinity of the Precambrian hinterland, alluvial fans and braided rivers deposited sands and gravels near the edge of the basin, while the clays were formed in floodplains and swamps. A few, badly preserved, benthonic foraminifera and some well-rounded glauconite grains reported by Ter Meulen (1948) from Onverdacht clays near Paranam are probably reworked and do not necessarily point to marine conditions. Finer clastic sediments higher in the sections and palynological data (Wijmstra, 1971) may indicate that in the course of the Paleocene the braided rivers deposits and alluvial fans were replaced by rivers of the meandering type and that a more humid, tropical climate prevailed. The feldspars eroded from granitic basement rocks are thought to have formed arkosic to subarkosic sands which were altered into bauxites by weathering processes (Aleva, 1965, Krook 1969a, 1969b).

Towards the north in a different facies, the unconsolidated sands and clays of the Saramacca Formation accumulated. It seems likely that a lateral transition into the Onverdacht Formation existed but post Eocene erosion and most probably faulting, hampers a clear picture. Sediments, recently attributed to the Saramacca Formation by Wong (in prep.) have been reported by Dixon (1972) to occur at greater depth downfaulted (150 to 200 m in the east and 400 to 450 m in the west) from the Bauxite Belt. The sands consist of poorly sorted, translucent quartz grains which range from very fine to very coarse. Occasionally, shell fragments are found in the sands. The clays are white, grey to light green and black, kaolinitic, laminated, occasionally very silty and carbonaceous. The formation can be easily recognized on geophysical logs because it shows a distinct characteristic on the bulk density logs. Due to the greater degree of compaction of the clays in this formation, they have a higher bulk density than the sands. Hanou (1981) remarked that the bulk density may have been affected by the abundance of kaolin. The same author also noted that some of the thick (up to 40 m) sand units in the lower part of the formation are laterally extensive with a sheet-like appearance. Detailed lithological study of Wong (1984b) of the basal sand unit (oil-bearing in the

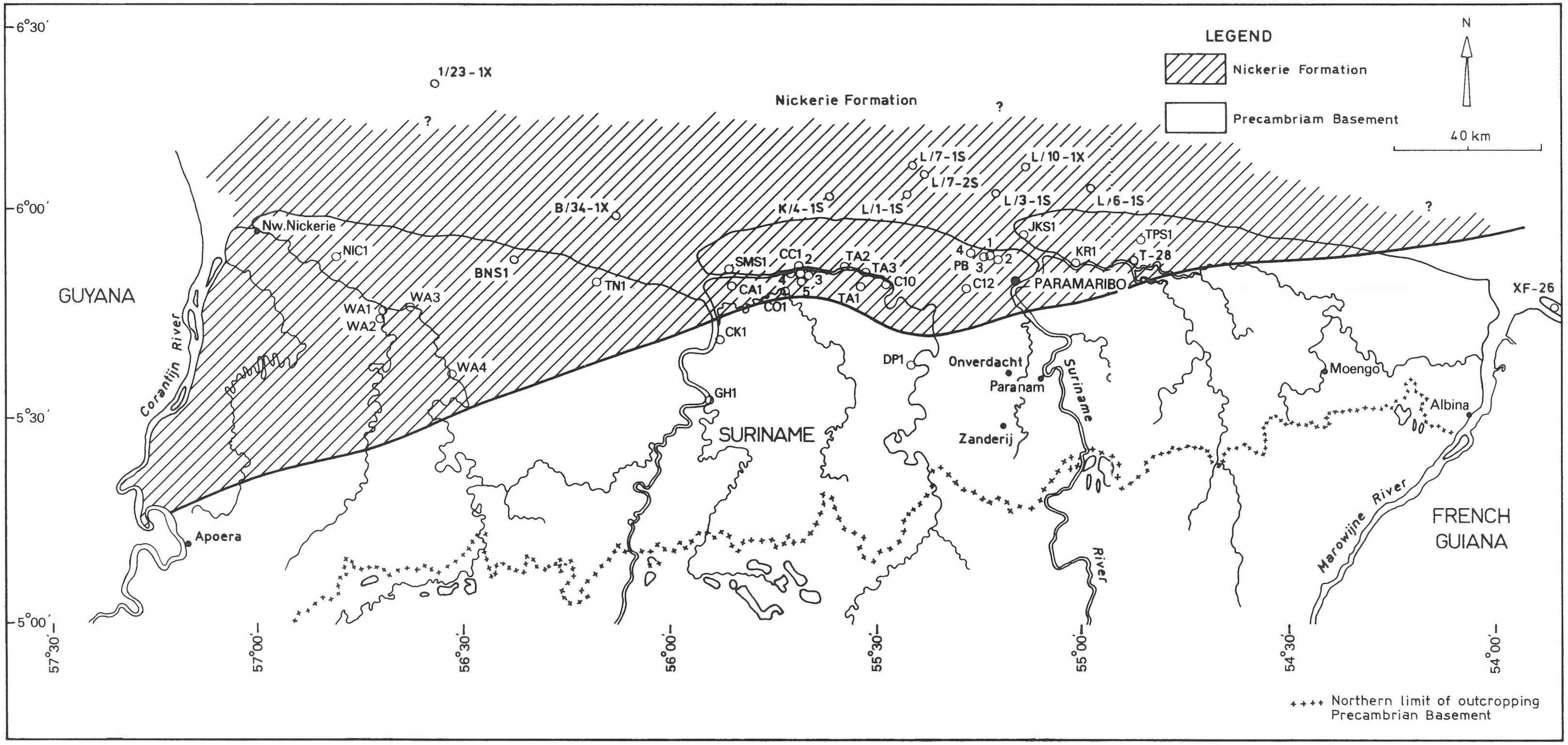

Fig. 5. Subsurface distribution of the Nickerie Formation.

Tambaredjo area) revealed that this sand is very well sorted and generally shows a fining upward sequence, grading from medium coarse to very fine grained. These sands were deposited in a complex of overlapping beach ridges and lenses that were reworked by wave action as the sea transgressed to the south. Wong (1984b) envisaged NE-SW running, undulating sand ridges which presumably originated under the influence of longshore currents. This configuration is comparable with the Pleistocene and Holocene ridge complex in the coastal plain. Within the basal sand a lateral change was observed from a shore face in the north to a backshore and even dune facies in the south. The clays were deposited in coastal swamps and mud flat environments. The Early Paleocene transgression may be correlated with the global sea level rise which took place at this time (cycle TP 1 of Vail et al., 1977). From the geophysical logs it can be concluded that in the course of the Paleocene the sand bodies become increasingly less continuous. According to Hanou (1981) the depositional conditions became transitional (various deltaic sands), ultimately culminating in a fluvial realm (pointbars and floodplains). This change was due more to progradation of non-marine sediments over marine sediments rather than subsidence and basin filling.

North of the Paleocene beach ridges the calcareous sediments of the Alliance Formation extend in a narrow strip between Mana (NW French Guiana) and Alliance under the coastal plain (see Fig. 6). They continue just north under the present day coastline west of Paramaribo, as revealed by recent drillings of Suriname Gulf Oil Co. The formation is composed of silty marls with intercalations of clays, claystones, sands (all more or less calcareous) and lignites. Foraminifera, Ostracoda, Bryozoa and oyster fragments occur throughout the entire section. The foraminifera belong exclusively to a Paleocene benthonic association described by Drooger (1960a, b), Van Voorthuysen (1969) and Wong (1976). The reconstruction of the depositional conditions, given by the latter, indicates a vegetated coastal lagoonal environment with fluctuating salinities.

Eocene

Lithologically there is no significant difference between the Paleocene and Eocene part of the Saramacca Formation. The base of the Eocene is characterized throughout the whole coastal plain by a thick (max. 45 m) clay unit. This basal clay was deposited during a rapid transgression which gave rise to an extensive coastal swamp. It is tempting to correlate this transgression with the global sea level rise during cycle TE 1.1 of Vail et al. (1977), but stratigraphic control is lacking. Decreasing marine conditions generated a cycle similar to the Paleocene development of the Saramacca Formation i.e. deltaic sands overlain by continental deposits. The depositional thickness of this section increases seaward, indicating that the basement was again subsiding at a rather constant rate (Hanou, 1981). In the Alliance area the calcareous lagoonal facies was replaced by the terrigeneous deposition of the Saramacca Formation. This regressive phase may be connected with the general uplift of the area at the beginning of the Middle Eocene. By the end of the Middle Eocene the coastal landscape was flat, but through the settling of clay the more sandy lenses protruded a few metres above the surrounding marshes and were thus in ideal position for lateritization (Aleva, 1984). According to King et al. (1964) the Paleocene – Eocene sediments formed a denudation surface known as the Early Tertiary planation period. A drainage pattern developed in the Late Eocene at the start of bauxitization (Aleva, 1965; Aleva et al., 1969). The elevated erosional remnants enhanced the formation of bauxite while the resulting hard caps protected the plateaus from being affected by further erosion. Palynological investigation (Wijmstra, 1971) revealed that the actual bauxitization took place during the Late Eocene and the Oligocene. It is generally accepted that the Precambrian rocks which were also part of the Late Tertiary I planation surface were also bauxitized during this period (i.e. Lely, Nassau, Browns, Wintiwaai and parts of the Bakhuis mountains). Valeton (1972) illustrated that, on a world-wide scale, the Eocene has been a major bauxitization period in which numerous economic deposits were formed.

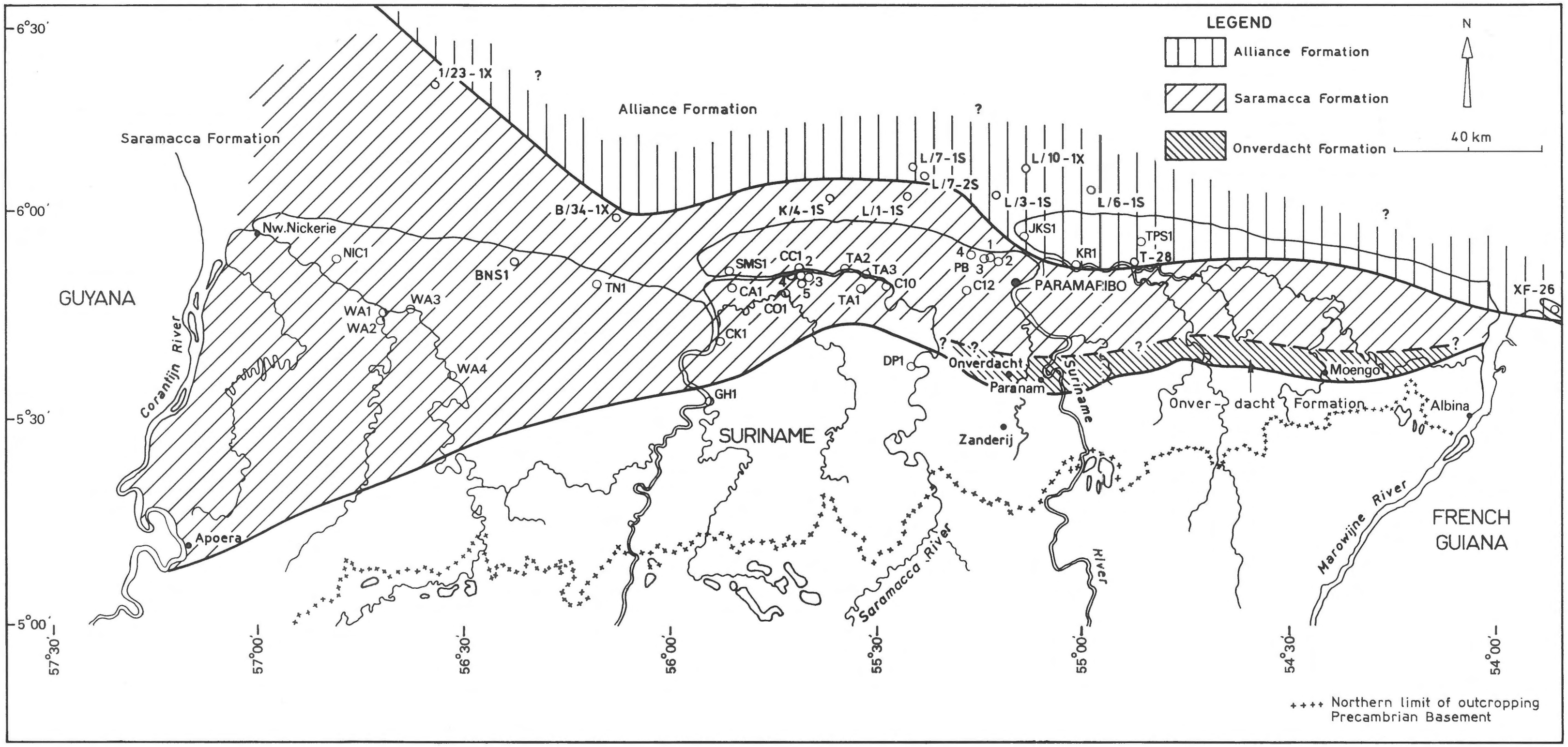

Fig. 6. Subsurface distribution of the Onverdacht, Saramacca and Alliance Formations.

Oligocene

The sediments formed during the Oligocene are mainly massive coarse sand units which are more or less kaolinitic with occasional thin interbedded, low density, clay layers. Wong (in prep.) proposed the new name Burnside Formation for these sediments. They were formerly known as the 'A sands', a name which originated from Guyana where Grantham & Noel-Patton (1937) introduced it. On the geophysical logs the Burnside Formation appears as a thick massive sand, a configuration which may be due to coalescing and stacking of numerous individual sand bodies. Correlation of several wells in the coastal plain shows that the formation is laterally not extensive or continuous (Fig. 3 & 7). It is very thin or even absent in the Tambaredjo-Calcutta area, thickens rapidly towards the west, while attaining a maximum of 80 m in the BNS-1 well.

The strong influx of arenaceous material during the so-called bauxite hiatus in the Oligocene (due to the increased erosion of the Early Tertiary sediments) may point to a change from a humid tropical climate (with a dense vegetation) to semi-arid conditions (with open savannahs). The presence of coastal savannah elements in the Oligocene pollen record of the off-shore well B/34–1x (Chen, 1983) supports this assumption. It is very likely that the pronounced global regressive phase at the end of cycle TO 1 of Vail & Mitchum (1979) is apparent here, but again sufficient stratigraphic data are lacking. The strong erosion created scarps, mesas and terraces, while weathering of the topographic highs continued. Sands eroded from the exposed sediments and most probably also from the crystalline shield, were redeposited in low areas as valley and channel fills (Dixon; 1972, Wong; 1984a). To the north, and stratigraphically higher, the valleys gave way to a plain with braided streams and meandering rivers (Hanou, 1981). The combined processes of erosion and sedimentation resulted in a broad, flat, regionally extensive surface, dominated by the bauxite-covered hills.

Miocene

In this paper the concept of Dixon (1972) and Wong (in prep.) is followed in which, based on lithological criteria, only Miocene sediments belong to the Coesewijne Formation. The formation consists of dark grey to black organic clays and sandy clays with interbedded sands. These medium to coarse, poorly sorted sands are deposited in small lenses.

According to Noorthoorn van der Kruyff (1970) the Oligocene hiatus extended into the basal part of the Miocene. Hereafter the sea transgressed over the coastal plain and deposition of the Coesewijne Formation commenced. During this transgression beach sands and swamp clays were deposited as far south as Lelydorp. Krook (1979) proposed beach drifting and he also tied the great amount of clay to the birth of the Amazon River, draining the Andes region. Wijmstra (1971) reported a great change in the vegetation of the coastal area during this transgression, of which the first appearance of mangrove elements (*Rhizopora*) is most conspicuous. After this short depositional cycle, which lasted till mid-Early Miocene, a gentle uplift caused the sea to recede (Noorthoorn van der Kruyff, 1970). The same author remarked that during the following denudation phase much of the Early Miocene and Early Tertiary sediments were eroded; among the latter possible bauxite deposits in western Suriname. The resulting unconformity can be traced over the entire coastal plain. This is seismic reflector RM 8 of Noorthoorn van der Kruyff (1970). Another planation level developed (the Late Tertiary-I level of King et al., 1964) and lateritization took place during this stage. During pollen Zone F (Middle Miocene) an extensive transgression reached as far south as Republiek (Krook, 1979). At this time deposition of the Coesewijne Formation terminated because the Late Miocene shows a return to regressive conditions. Both Noorthoorn van der Kruyff (1970) and Wijmstra (1971) had palynological evidence that a large part of the Late Miocene is missing. Large scale denudation produced the Late Tertiary II level (King et al., 1964). According to Krook (1979) this surface was intensively weathered and locally laterite was formed. Subsequently the laterite crusts were eroded and

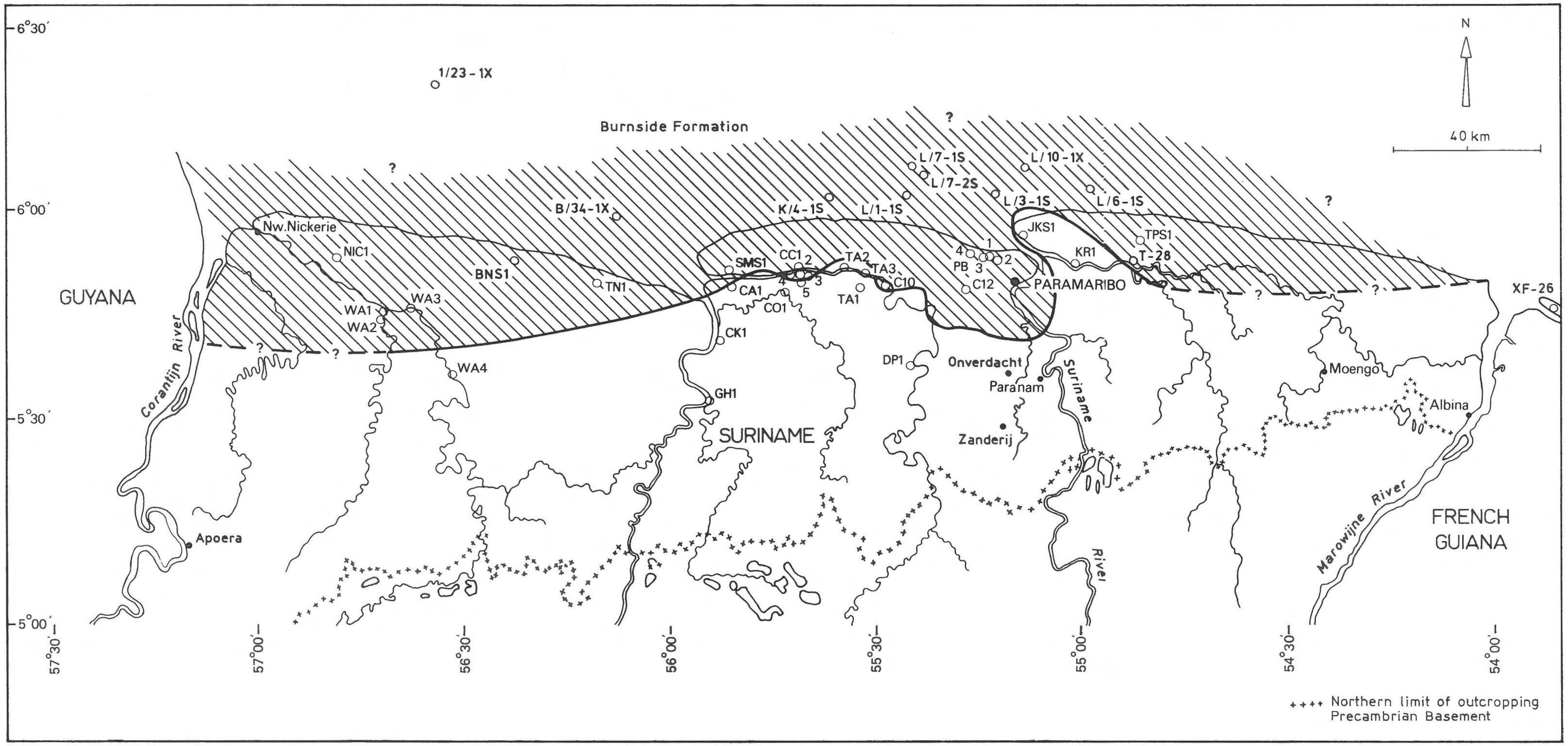

Fig. 7. Subsurface distribution of the Burnside Formation.

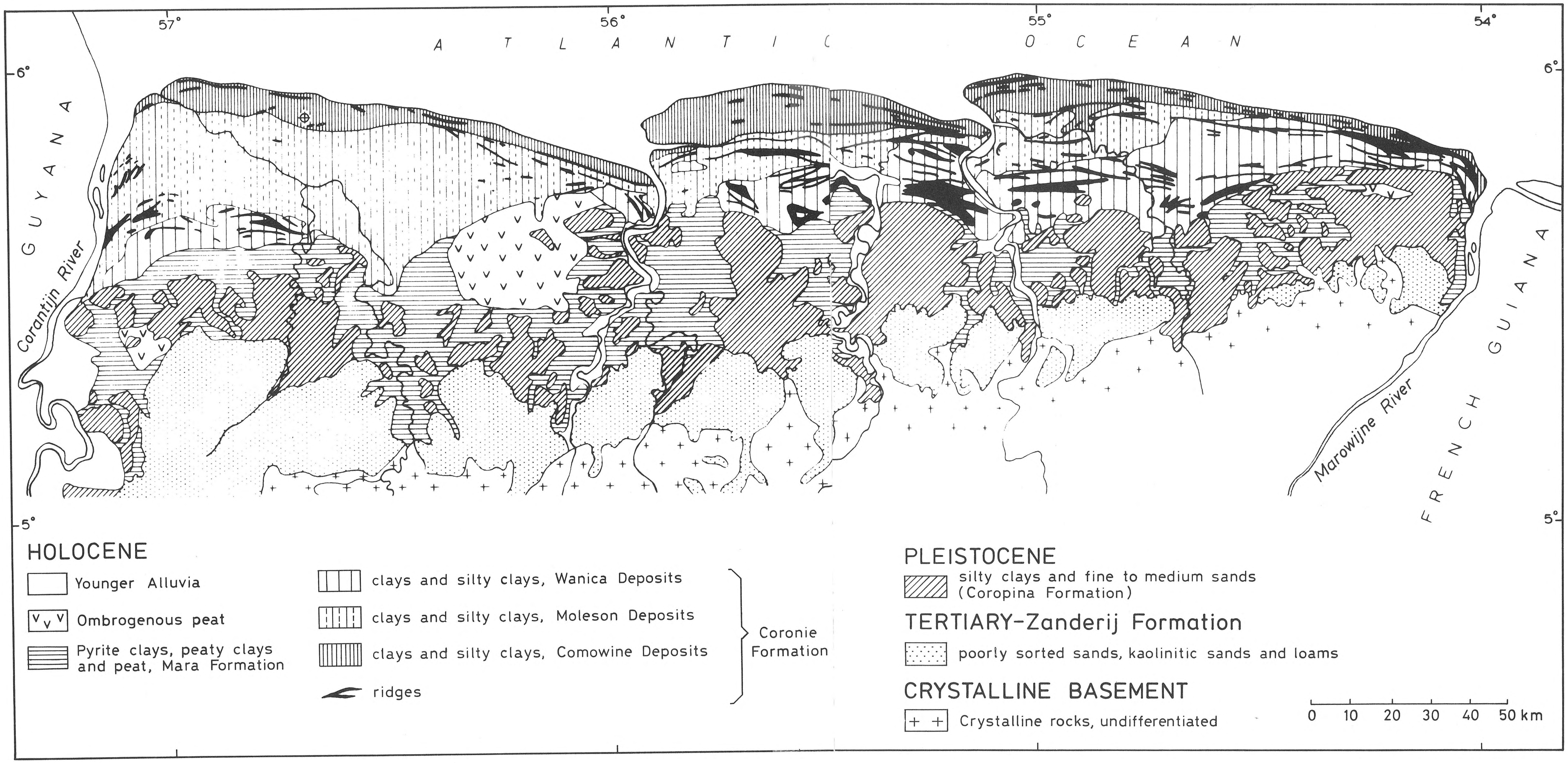

Fig. 8. Geological map of the coastal plain of Suriname (modified after Krook; 1979, Roeleveld & van Loon; 1979 and Wong; in prep.).

only a few remnants are left. Janssen (1979) suggested that throughout the country several non-commercial bauxite deposits were formed during this time. In the Moengo area I noticed several low grade bauxite plateaus which may have originated in the same period and which are situated at levels below the main commercial plateaus.

Pliocene

Pliocene sediments in the coastal plain are represented by the Zanderij Formation (cf. Dixon, 1972) which crops out mainly in the savannah belt (Fig. 8). The formation is characterized by white and brown quartz sands, more or less kaolinitic, with interbedded clays. Bosma et al. (1984) observed that in the savannah belt the boundary between brown and white sand is often sharp and that this is partly related to vegetation and topography; white sand being more common on the plateaus, and brown sand on the slopes. Based on well data Dixon (1972) distinguished two main facies: a lower clayey and an upper sandy facies. Locally, the base of the sandy unit is graveliferous as reported by Zonneveld (1955), Brinck (1956), Van der Eyk (1957), Krook & Mulders (1971) and Wong & Van Lissa (1978). This gravel forms the base of white sand terraces and plateaus which are situated along the southern margin of the Zanderij Formation in the vicinity of major rivers such as Marowijne, Suriname and Saramacca. In the savannah belt the Zanderij Formation may attain a maximum thickness of 20 m; in the coastal area the maxima range from 40 to 50 m (in the east) to approximately 165 m (in the west). Several deep wells in the coastal plain show that these massive sands are much more extensive than the Coesewijne sands. Similar deposits in Guyana and French Guiana are known as the 'White Sands' and the 'sables blancs' respectively.

According to Krook & Mulders (1971) and Krook (1979) sea level rose during the Early Pliocene and the coast moved far to the south (to near Zanderij and Sabana). Wong (1984a) suggested that clays, deposited during this transgression, accumulated in extensive coastal swamps in which reducing conditions favoured the preservation of organic matter but on the other hand prevented the existence of a flourishing marine community. After deposition of this clayey facies the sea receded again and a period of severe erosion started. The climatological conditions gradually became semi-arid (Krook, 1969a) and relatively extensive savannahs came into existence (Wijmstra, 1971). Coarse clastics were transported by braided rivers and, eventually by ephemeral streams which formed alluvial fans. These protostreams of many present day rivers deposited gravels and coarse sands in several channels cut in the underlying formations. A terrestrial origin is also suggested for contemporaneous deposits as far north as Alliance by Van Voorthuysen (1969). He stated that the recorded high salinity and the presence of gypsum in these sediments are indicative of strong evaporation during this time.

Pleistocene

Most of the sediments deposited during this period comprise the Coropina Formation. The formation consists of a lower Member (Para Member) characterized by stiff, grey and brown clays and an upper Member (Lelydorp Member) which is predominated by silts, silty clays and fine sands (cf. Bosma & Groeneweg, 1973 and Wong, 1984a). The formation crops out in the old coastal plain (Fig. 8). According to Dixon (1972) the Coropina Formation in the young coastal plain consists mainly of grey and yellow clays with interbedded sands and sandy clays. Based on this observation Wong (1984a) remarked that in the young coastal plain the two Members can no longer be distinguished. This agrees with Krook (1979) who did not want to use the name Coropina Formation for contemporaneous sediments from the drillholes in the young coastal plain. Wong (in prep.) suggested that the Para and Lelydorp Members, as known from the old coastal plain, grade to the north into other (unnamed) lithological variations. The spatial relationship between the two Members in the old coastal plain has been elaborately studied and illustrated by Veen (1970). According to the original definition (Montagne, 1964) the Para Member in the Onverdacht area consists of heavy, finely laminated, stiff grey, purple, red and brown clays with films of fine sands and with lenses of coarse sand, mainly near the base. These clay layers attain thicknesses up to 10 m. Brinkman & Pons (1968) reported that the clays of the Para Member display a purple, red and brownish mottling near the top. This member mainly crops out near the northern limit of the savannah belt where it forms a strongly dissected surface which continues into Guyana and French Guiana. The Member unconformably overlies both the Zanderij Formation and weathered basement rocks. To the north it is covered by sediments of the Lelydorp Member and the Mara Formation (the latter in erosional gullies).

The Lelydorp Member is characterized by fine sorted sands, silts and silty clays (the so called 'stofzanden' of the old coastal plain). Montagne (1964) described a sandy facies, recognizable as lenticular sand bodies and a clay facies, now red-mottled and stiff, resting on Para clays. According to Brinkman & Pons (1968) the Lelydorp clays show two different facies:

1) In the south: a dark grey, pyritic clay rich in organic matter the colour of which is now grey and red mottled (known as the Onoribo phase).

2) In the north: a yellowish red and brown mottled clay with only traces of pyrite (known as the Santigron phase). Krook (1979) found these two phases on top of each other in an outcrop along the Coppename River NE of Heidoti. Wong (in prep.) emphasized the pedological significance of these lithological varations, but they were thought too minor to include them in a lithostratigraphical subdivision. According to Brinkman and Pons (1968) the Lelydorp sand ridges are each more extensive and coarser textured going east, comparable to the sand ridges of the Holocene deposits. The Lelydorp Member occurs north of the outcrops of the Para Member in the old coastal plain east of Coronie and continues into French Guiana (Brinkman & Pons, 1968).

Brinkman & Pons (1968) included still another lithological unit in the Coropina Formation namely, sandy to clayey river deposits, that are locally underlain by gravel layers. They are found in terraces at elevations between 4 and 30 m above the mean local river level. The width of these terraces is usually less than 2 km, but may occasionally reach 5 km. Several terrace levels have been recognized and described by De Boer (1972). The sandy to clayey deposits have thicknesses varying from 1 to 6 m. The gravel beds are 2–3 m thick. They rest on weathered basement and locally crop out at the surface. These terraces have been found along the Marowijne River (near Albina and Bigiston), along the Suriname River (Victoria and Babocnhol; Mulders, 1971) and along the Coppename River (Heidoti, Sabaroe, Tjakka Tjakka Ston and Bitagron). At Tjakka Tjakka Ston the gravel beds are more than 6 m thick and overlie older Pleistocene deposits. Based on their elevation in the terrain a Pleistocene age had been assigned to them. On the recently published map of Suriname (Bosma et al, 1984) they are mapped as a separate unit under (8): Sand, clayey sand and gravel. To stress their separate status in relation to the Coropina Formation and to facilitate future references, Wong (in prep.) proposed to introduce the name 'older alluvium' for these terrace deposits. This name may also distinguish them from the younger Holocene alluvial deposits for which I proposed the name 'younger alluvium'.

The sedimentary history of the Pleistocene Coropina Formation which constitutes the old coastal plain, has been described in detail by several soil scientists, a.o. Brinkman & Pons (1968) and Veen (1970). The sediments were deposited during several stages of high sea level corresponding to interglacial periods in the Pleistocene, whereas regressions took place during the glacial periods.

According to Brinkman & Pons (1968) the sediments of the Para Member were deposited during a transgression in the Mindel-Riss or Early Riss-Würm Interglacial period. The sea abraded the older exposed formations and this predominantly coarse material was deposited on top of the basement (Montagne, 1964; Veen, 1970). These sands represent various backbars, probably formed by beach drifting. The clays were deposisted in extensive mud flats. After this episode the sea withdrew and weathering and soil formation occurred in the Riss glacial period or perhaps during a temporarily lower sea level in the last interglacial. Veen (1970) suggested that the soil formation took place in a flat, mostly water-logged plain, possibly with a marsh vegetation.

As Brinkman & Pons (1968) pointed out, deposition of the Lelydorp Member started during a renewed rise in sea level, possibly during part of the last interglacial period (Eemian). During this transgression the dark Onoribo clays, rich in organic matter (*Rhizopora*) and pyrite, were deposited in a brackish environment. Next, under relatively deep, normal marine conditions the sediments of the Santigron phase were deposited. The paleogeography of this episode shows offshore sandbars near the coast and extensive mud flats to landward. Similar to the present situation mud was supplied by westward flowing longshore currents (the Guiana Current) whilst the sand was transported by beach drifting. With the onset of the Würm glacial period a major regression started that exposed the sediments to weathering and soil formation. Sea level fell about 90 m (Nota, 1969). This and the much drier climate with heavy periodical rains at that time, caused an intensive dissection of the flat topography by the incision of numerous gullies.

The several terraces along the Suriname, Marowijne and Coppename Rivers also reflect the successive climatological changes in the Pleistocene. During glacial periods, semi-arid and regressive conditions prevailed whereby severe erosion took place. Much eroded material was transported by braided rivers and occasionally alluvial fans were formed (Krook, 1970). Wong (1979) suggested that the Marowijnse gravels in the 'older alluvium' are reworked gravels from the Zanderij Formation.

Holocene

Traditionally, the widely differing units of the young coastal plain have been grouped in the Demerara Formation. Wong (in prep.) proposed to abandon this name and to attach a formational status to the units originally defined by Brinkman & Pons (1968) as Mara and Coronie deposits.

The Mara Formation consists of soft, grey, unmottled to hardly mottled peaty clays and clayey peats with high pyrite contents. According to Brinkman & Pons (1968) the Mara clays contain relatively little pyrite and organic matter north of the Lelydorp ridges whereas the clays between the Lelydorp erosion remnants and those towards the east and the south have relatively high organic matter and pyrite content. Towards the north the sand content increases. Montagne (1964) reported shell remnants of *Ostrea* sp. in the Mara clays together with a predominance of *Rhizopora* pollen grains. High percentages (up to 100%) of *Rhizopora* pollen grains have also been recorded by Roeleveld (1969) from two sections drilled in Mara sediments in gullies south of Lelydorp. In Suriname the formation is far less extensive than in Guyana, but has a wider distribution than in French Guiana. Much of the Mara sediments in Suriname occur in the erosion gullies in the Coropina Formation (Fig. 8). In the Onverdacht-Lelydorp bauxite mining area soft Mara clays in the overburden of the bauxite, locally caused several mining problems. The formation is exposed in the southernmost part of the young coastal plain, but also underlies sediments of the Coronie Formation.

The Coronie Formation consists of clays that are low in pyrite and organic matter and of numerous lenticular coarse and fine sand units (ridges) which may contain shells. Generally the sands east of the Suriname River are very fine grained and well sorted. In many cases the individual sand units coalesce and form wide sand flats. Brinkman & Pons (1968) recognized three morpho-stratigraphic units within the Coronie Formation e.g. Wanica, Moleson and Comowine deposits. These units are separated from each other and locally also from the Mara Formation by erosional coastlines, in many cases with shell or sand ridges (Fig. 8). The criteria to define these Recent to Sub-Recent units are generally based on morphological and soil characteristics. For more details the reader is referred to Brinkman & Pons (1968).

There are two other lithologies, traditionally also grouped in the former Demerara Formation. They are designated on the recent geological map of Suriname (Bosma et al., 1984) as (1) Alluvial clay and sand and (2) Peat. Following Wong (in prep) the alluvial deposits are referred to as 'younger alluvium'. The sediments of this unit have been deposited in natural levees and backswamps reaching thicknesses of maximum 6 m. They usually overlie peat, sediments of the Mara and Coronie Formations or the 'older alluvium'. The natural levee deposits are mainly grey silty clays with occasionally sandy clays, clayey sands and sands. The clays differ from the Coronie clays by their higher silt content and a slightly higher elevation (better drainage). Hence, they show a deeper and more intense soil formation with a strong orange mottling. The swamp deposits are heavy clays, usually covered with a thin layer of peat. All lithological data are from Brinkman & Pons (1968).

To the south the alluvial deposits gradually thin out and become confined to narrow zones and isolated patches in present river valleys, at heights ranging from 1–4 m above mean level, covering mainly Precambrian bedrock (Bosma et al., 1984). The Holocene age has been determined by radio carbon analysis of intercalated peat layers (Brinkman & Pons, 1968).

The ombrogenous peat occurrences on the map of Bosma et al. (1984) represent four large freshwater swamps with poor drainage. They are domeshaped and have a characteristic radial drainage pattern. A maximum peat thickness of 7 m is known from the Nanni swamp. Wong (in prep) proposed to treat this unit as a separate unit called 'Peat'.

The following sedimentary history of the Holocene is principally based on data provided by Brinkman & Pons (1968) and Roeleveld & Van Loon (1979). During the first transgression in the Holocene, under conditions of continuously rising sea level, the gullies of the dissected Pleistocene landscape were filled with Mara clays. Mud accumulated in extensive brackish coastal swamps with an almost pure mangrove vegetation. In these swamps reducing conditions prevailed, favouring the formation of pyrite and the preservation of organic material. Under these conditions of contin-

Table 1. Diagram of the lithostratigraphical units in the coastal plain, showing the main characteristics, thicknesses and the geometry of the units. Dashed line shows grain size.

Formation or Member	Sand coarse fine	silt	clay	Thickness	Geometry
Coronie Fm	- - - - - - - - - - - - - ridges with and without shells		- - - - - - gy, With brn, ol, yel brn, yel mot	0–5 m	Flat lenticular sandbodies
Mara Fm			- - - - - - gy, carb mod-abnt pyr	max 8 m?	Flat also as gully infillings
Coropina Fm Lelydorp Mbr	- - - - - - - - - - - - - f, srtd bleached or unbleached	- - - - - - rd and yel mot	- - - - - - sdy, rd and yel mot	max 5 m?	sheet to discontinuous lenticular sandbodies
Para Mbr	- - - - - - - - - - - - - lenses of crse, sd. occ cross bedd. layers of vff srtd sd		- - - - - - hvy, lam rd, brn yel purp mot occ lam	max 10 m?	sheet to discontinuous lenticular sandbodies
Zanderij Fm	occ grdg to gvl - - - - - - - - - - - - -		frm, sdy kaol - - - - - -	variable max 165 m	Massive continuous
Coesewijne Fm	prly srtd - - - - - - - - - - - - -		Dk gy-blk, carb - - - - - -	variable max 180 m	sheet to discontinuous
Burnside Fm	ang gr. - - - - - - - - - - - - -		frm, gy - - - - - -	variable max 80 m	Massive continuous
Onverdacht Fm	occ grad to gvl unsrtd, kaol - - - - - - - - - - - - -		frm, gy wh, pk, purp - - - - - -	variable max 40–50 m	sheet often bauxite or laterite capped plateaus
Saramacca Fm	occ grdg to gvl prly srtd-w srtd - - - - - - - - - - - - -		wh, gy, lt gn, blk kaol - - - - - -	variable up to 300 m	Massive sheet continuous, but also lenticular sandbodies
Alliance Fm	 - - - - - - - - - - - - -	gy - - - - - -	calc, bcmg mrl - - - - - -	variable up to 60 m	Massive continuous
Nickerie Fm	occ grdg to gvl prly srtd, subang- subrnd. orng, rd-brn qtz gr - - - - - - - - - - - - -	wh, gn, orng-brn - - - - - -	wh, gn, orng-brn - - - - - -	variable up to 700 m	Massive discontinuous wedge to sheet

uously rising sea level the build up of the coastal area was generally vertical with a constant to receding shore line. Sea level attained its present position about 6000 years B.P. and the lateral accretion of the young coastal plain, alternating with erosional phases, started. Increasing amounts of terrigeneous sediments from the Amazon were deposited under more or less constant sea level conditions. The sediments of the Wanica deposits accumulated from 6000 to 3000 years B.P., while sea level at that time stood possibly slightly above its present position. The sand ridges (cheniers) represent numerous beach sands that were deposited by longshore currents. The large supply of terrigeneous material deflected the smaller rivers which drain the Guiana Shield to the west forcing them to flow parallel to the coast. Marine clays of the Moleson deposits accumulated between 2500 and 2000–1350 years B.P. Clay and sand ridges were formed under similar conditions as those of the Wanica deposits. The shell ridges represent old shell beaches that were cut off from the sea by mud accumulations. Sedimentation of the Comowine deposits began about 2000–1300 years B.P. and is still continuing. The majority of these sediments were deposited at or near mean sea level in intertidal, subtidal and at times supratidal environments (Ginsburg & Missimer, 1976). The intertidal areas near the coastline are presently mangrove swamps with *Avicennia* predominating in the outer zone and *Rhizopora* as the dominant floral element in the inner zone. The shoreline and nearshore subtidal areas undergo rapid changes. Contemporary deposition along the Guiana coast is cyclic, with an average period of 30 years, representing alternating times of intense erosion and times of rapid deposition forming wide intertidal mudflats. Under influence of the Guiana Current and wind-generated waves and currents, the mudbanks (in the form of 'slingmud') and the erosional areas move gradually westward. Since the volume of sediment that accumulates during the depositional phases is generally greater than the volume removed during an erosional phase, the result is a net progradation of the shoreline.

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