

ACTUAL DEVELOPMENT OF THE CHENIER COAST OF SURINAME (SOUTH AMERICA)

PIETER G.E.F. AUGUSTINUS

Department of Physical Geography, State University, Utrecht (The Netherlands)

(Received August 20, 1979)

ABSTRACT

Augustinus, P.G.E.F., 1980. Actual development of the chenier coast of Suriname (South America). *Sediment. Geol.*, 26: 91–113.

The Holocene coastal plain of Suriname is a chenier plain. Its actual sedimentological development has been studied during three field-work periods (1966, 1967/1968, 1972). Clay is the predominant sediment in this low- to medium-energy environment. It accumulates in extensive shoreface-attached mudflats (sometimes considered as giant mudwaves), which migrate continuously to the west due to deposition of slingmud at their west side and simultaneous erosion of the east side. In between the mudflats cheniers may develop.

Thin-section analysis of the clay deposits revealed that they are built up of an alternation of thick clayey laminae and thin laminae of silt and fine sand. The clayey laminae chiefly show a unistrial plasmic fabric. Disturbances in the upper zone are caused by bioturbation.

Two types of cheniers can be distinguished. One type contains fine sand which has been winnowed out of the pelite deposits. Since this sand is brought from the shelf the chenier formation begins at approximately mean low-water level. Longshore bars are formed and these are driven shoreward by wave action. The other type is built up of medium to coarse sand supplied by a local river. It is transported westward by beachdrift in a narrow zone around the mean high-water line. These cheniers develop therefore at or just above the mean high-tide level.

The sedimentary structures of both types of cheniers have many characteristics in common. However, each type also has its own distinct features.

INTRODUCTION

The Holocene coastal plain of the Republic of Suriname, one of the Guiana States along the north coast of South America (Fig. 1), is a belted marsh-and-plain ridge. It may be referred to as a chenier plain.

A chenier plain is characterized by 'shallow based, perched sandy ridges, which rest on clay along a marshy or swampy, seaward facing tidal shore, with other beach ridges stranded in the marsh behind' (Price, 1955). The ridges are called cheniers. They mark former coastlines. On a map they all look the same (Fig. 2). In detail, however, a large difference appears to exist

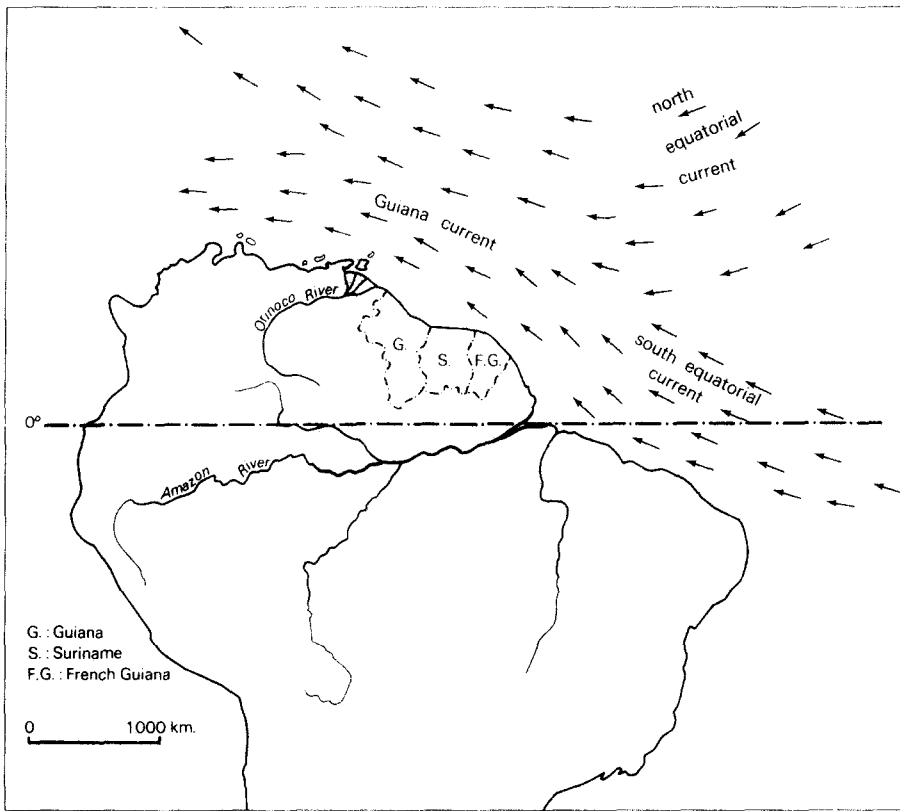


Fig. 1. Sketchmap of the northern part of South America. The most important sea currents are indicated by arrows.

between the cheniers in east and west Suriname. This is closely related to the difference in origin of the sandy sediments in both areas.

In east Suriname — and the adjacent western part of the coast of French Guiana — medium to coarse sand is supplied by local rivers. The very fine sand in the west Surinam cheniers is winnowed from the pelitic sediments which cover the nearshore part of the shelf. Both pelite and fine sandy admixture originate from the Amazon River. Computations reveal that about $0.1 \cdot 10^9$ tons per year of Amazon-borne sediments are transported along the Surinam coast (Nedeco, 1968; Allersma, 1968).

The Guiana Current transports the pelitic sediments along the north coast of Brazil up to French Guiana. In this area the current deviates from the westward deflecting shoreline in a northwestern direction (Fig. 1). The sediment transport, however, due to shoreward flowing bottom currents (Eisma, 1967; Gibbs, 1975), continues in a narrow zone along the shore up to the mouth of the Orinoco River. In the shallow coastal waters the waves,

generated by the prevailing NE trade-winds, take an increasingly greater part in the pelite transport as they approach the shore.

The transport of the enormous quantities of pelitic material takes place in suspension as well as by the migration of large, shoreface-attached mudflats, the higher parts of which are overgrown with mangroves. The migration of these mudflats is caused by the combined action of waves and currents. This results in deposition at the west side and simultaneous erosion of the east side (Fig. 3). Cheniers usually develop between the mudflats.

Genetically a chenier plain is an accumulation plain, built up on a relatively stable coast, generally subjected to moderate wave energy. Pelitic sediment is supplied by slow but persistent marine currents (Price, 1955). These specific conditions result in a limited occurrence of chenier plains. When Price published the first description of the chenier plain in 1955, only two examples could be given: the Mississippi River plain (Louisiana and Texas) and the Para-Amazon-Orinoco River plain (Brazil to Venezuela), which includes the Surinam coast. Since then cheniers have been recognized in other parts of the world: Essex, Great Britain (Greensmith and Tucker, 1969), Broad Sound, Queensland (Cook and Polach, 1973), Groningen, The Netherlands (Roeleveld, 1974), West-Malaysia (Diemont and Van Wijngaarden, 1975), Western Australia (Thom, 1975), and along the Gulf of Carpentaria, Queensland (Rhodes, pers. comm., 1978). These, however, are not fully comparable to the 'open ocean' chenier plains mentioned above, since they developed in more or less sheltered parts of sounds or gulfs.

Most of the studies dealing with the 'open ocean' chenier plains apply to the geomorphological description, the origin and dispersion of the sediments, local stratigraphy and general coastal oceanography. The reader is referred to Augustinus (1978, p. 9, 10) for a review of the literature concerning the chenier plain of Suriname. Since the early 1960s there is a growing interest in the transport and sedimentation of muddy sediments, particularly with regard to the so-called slimgud. The Delft Hydraulics Laboratory (1962) defines slimgud as a mixture of pelite and water with a concentration exceeding 5,000 mg/l. It is also referred to as soft silt or fluid mud. Wells (1977, pp. 3–6) treats the literature concerned.

The aim of this paper is to discuss the development of the Surinam coastal plain as a chenier plain. During three field-work periods (1966, 1967/1968, 1972) attention was paid to the rapidly changing shoreline, where the active development of the chenier plain takes place. The development of the clay deposits and the overlying cheniers will be treated in the following paragraphs and a description of the sedimentary structures will be given.

METHOD OF INVESTIGATION

The Surinam shoreline is about 350 km long and therefore fifteen key areas were chosen for detailed field study. They were chosen in order to represent the three distinguished major types of sedimentary environment:

the mud accretionary coast, the sand accretionary coast and the erosional coast (Augustinus and Slager, 1971; Augustinus, 1978).

A general impression of the processes in these coastal waters has been given in literature (e.g., Delft Hydraulics Laboratory, 1962; Nedeco, 1968; Allersma, 1968). In this investigation additional measurements have been made in order to reach a better understanding of the different sedimentary environments. At twenty-eight stations, distributed over eight key areas, nearshore oceanographic measurements were taken during a 24-h period for each one. Depth, current velocity and direction were measured, wave height was visually estimated and the wave period and direction of propagation were determined. Water samples were taken to determine suspension load and salinity. The results have only been applied qualitatively and are therefore not treated in detail.

The "on-land" survey was concentrated mainly on sedimentological, geomorphological, hydrological, and biological observations and measurements. The sedimentary structures in the chenier deposits were studied in trenches, in directions parallel and perpendicular to the cheniers. The structures in the clayey sediments of the mudflats were studied in large thin sections (Jongerius and Heintzberger, 1975). The grain-size of more than 500 samples was analysed, using a combined sieve-pipette method.

Relief measurements were carried out with a theodolite. Additionally, data concerning the evolution of the intertidal low-water drainage systems, and the heights of the (ground)water levels landward of the cheniers were collected. Biological observations were directed mainly to the colonizing vegetation, and to the fauna that lives, at least temporarily, in the sediments.

THE SEDIMENTARY ENVIRONMENT

The coast of Suriname can be classified as a low-to moderate-energy coast (Augustinus, 1978). Low waves, generated by the NE trade-winds, propagate over a smooth shelf. The shallow part of the shelf is covered by a thick pelite deposit that wedges out from the coast toward the 20-m depth contour (Nota, 1967, 1971). The slope of this shallow part of the floor, measured in the approximate direction of wave propagation, ranges from 1 : 1600 to 1 : 3000. The tidal wave approaches the coast almost perpendicularly. The average tidal amplitude at spring tide is approximately 3 m and as a consequence an extensive intertidal area has developed.

The silt content of the coastal waters is very high (hundreds to thousands mg/l). Owing to the salinity of the water the suspended clay particles are in a flocculated state. When the silt concentration exceeds a threshold value the floccules no longer settle solitarily but they begin to agglomerate. A gel is formed and settles as a whole, while the water is expelled through the voids (Delft Hydraulics Laboratory, 1962; Diephuis, 1966; Migniot, 1968). This gel is referred to as slingmud. Its most important property is that it damps wave motion.

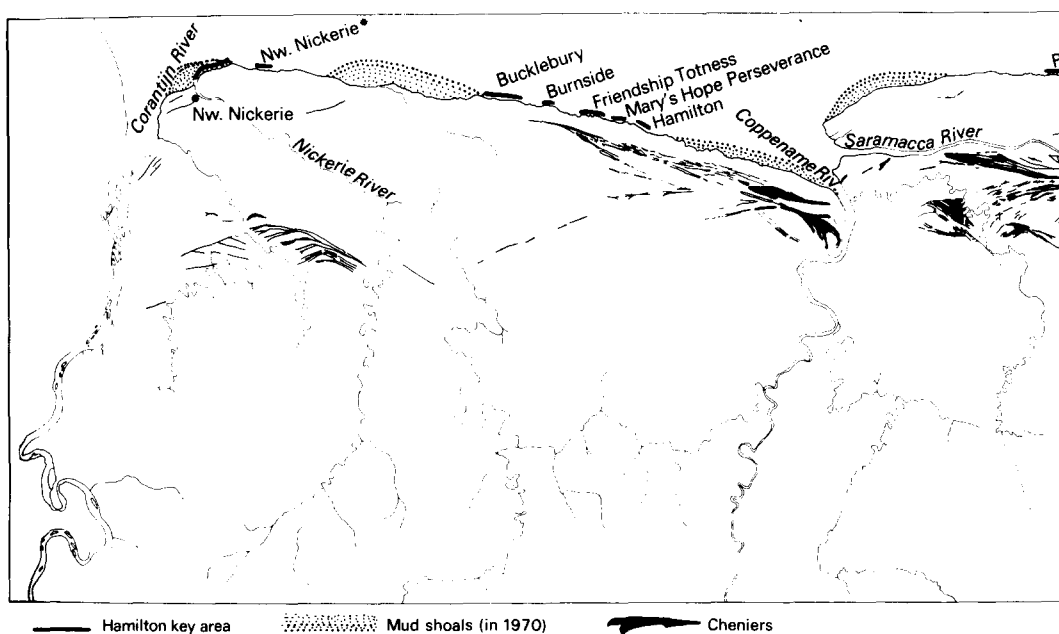


Fig. 2. The northern part of the Surinam coastal plain, showing the positions of the key areas. The

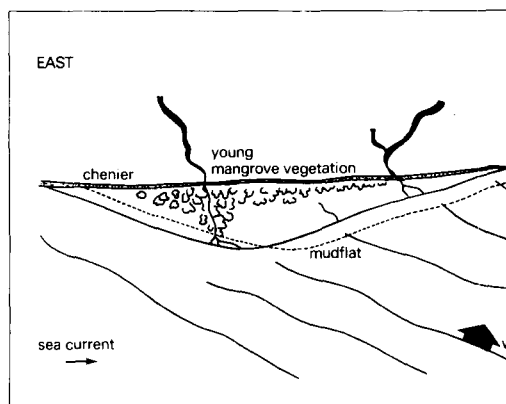
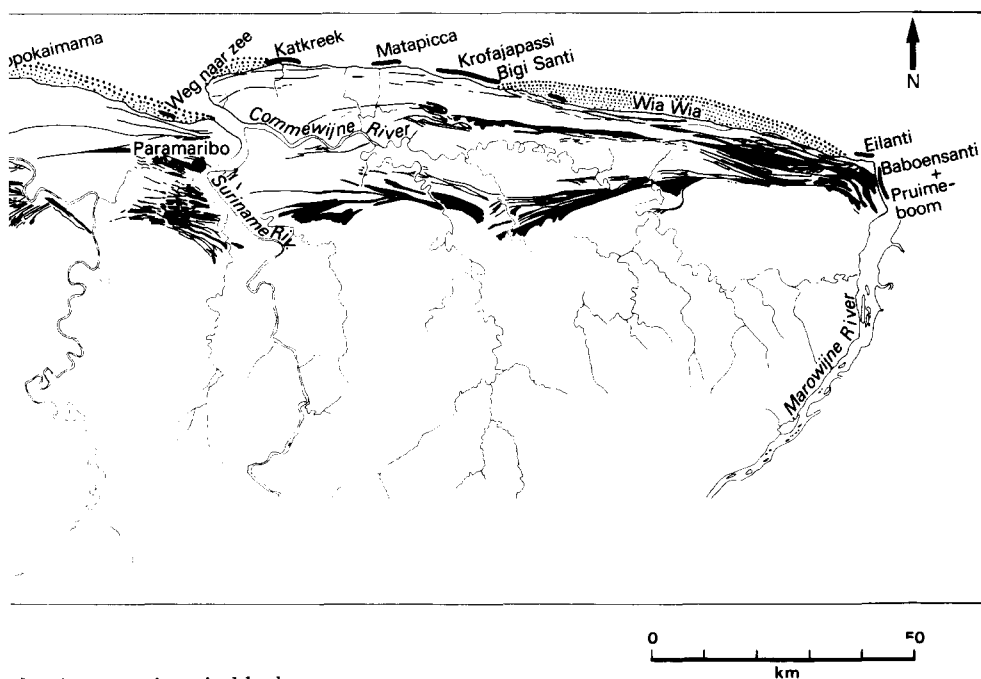
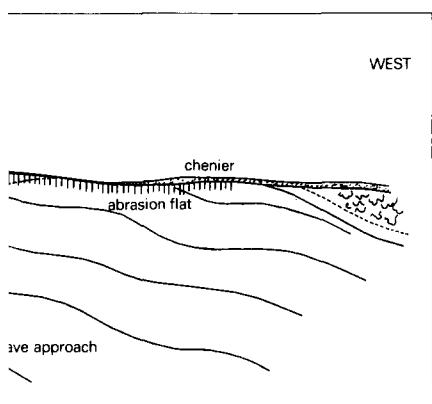


Fig. 3. Diagram showing the westward shifting landscapes and indicating current and wave mudflats is indicated by the broken lines.



cheniers are given in black.



; alternation of erosional and depositional direction. The westward migration of the

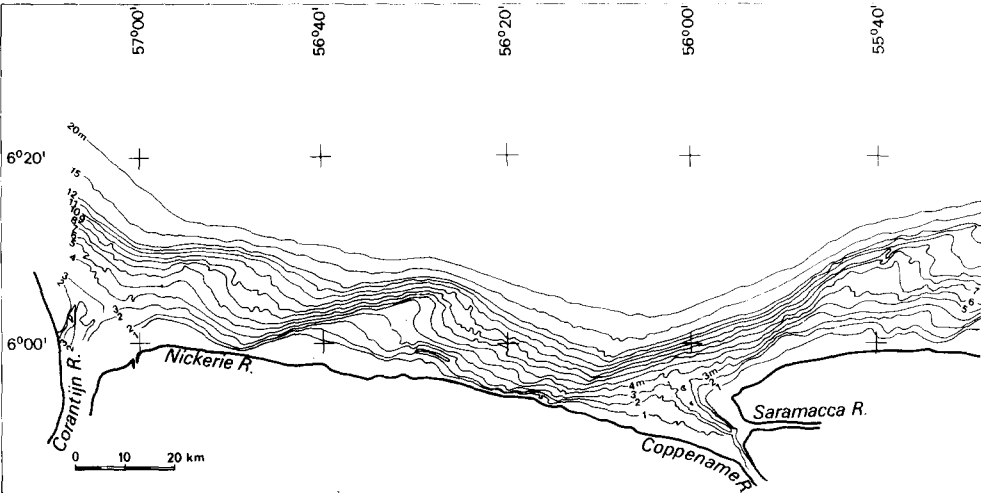


Fig. 4. Depth contours of the nearshore part of the Surinam shelf. (After data received from 'Luymes', 1966-1968).

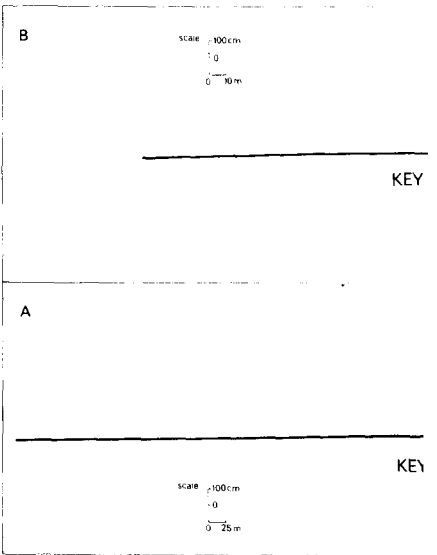
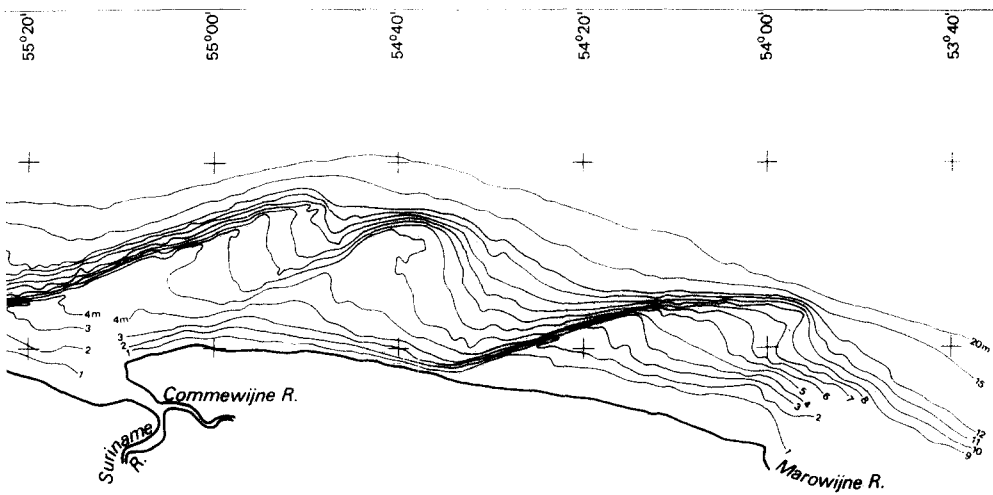
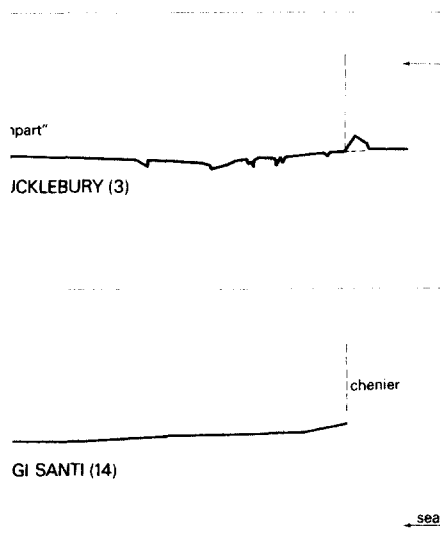


Fig. 5. Profiles of a mudflat.



ie Hydrographic Department of the Royal Netherlands Navy. Fair sheets H.N1.M.S. 'Snellius'



Along the Surinam coast a great deal of the pelite is (temporarily) stored in mudflats. These extensive mudshoals are attached to the coast (Fig. 3). They are separated by intermediate 'troughs' and their occurrence is so regular — as can be seen from the bathymetry (Fig. 4) — that they are sometimes considered to be giant mudwaves with an average wave length of approximately 45 km (Nedeco, 1968; Allersma, 1968). They migrate with an average celerity of 1.5 km/year. This indicates a period of 30 years.

The westward migration of the mudflats results from deposition of slingmud at the west side of the mudflats and simultaneous erosion on the east side, where in the mean time the sediment lost most of its wave-damping property due to consolidation. East of the mudflats the waves are therefore less attenuated and they may reach the shore and break. In this environment wave energy appears to be sufficiently high for the erosion of clay as well as for the transport of sand and shell clastics.

THE CLAY DEPOSITS

Clay is the predominant sediment in the Surinam chenier plain. It is deposited at the west side of the mudflats and eroded on the east side. Whether there is a net clay accretion or erosion in a certain period depends on the respective quantities concerned.

The accumulation of slingmud at the nose of a mudflat causes attenuation of the incoming waves and changes their form from sinusoidal to solitary-like (Wells, 1977; Wells and Coleman, 1978). However, the waves also affect the slingmud. Lhermite (1958) demonstrated in laboratory tests that the orbital motion of the water waves, although reduced by the viscosity of the mud, continues into the pelite deposit. He also found that the residual movement in the fluidized mud followed the direction of wave propagation. This indicates that slingmud may be transported in a fluidized state. Wells (1977) and Wells and Coleman (1978) consider solitary waves (which appear to be a common wave type above the Surinam mudflats) to be a dominant factor in the transport of fluid mud. Due to the direction of wave propagation (according to Nedeco, 1968, 93% of the waves approach the coast between N30°E and east) this transport has an important longshore component. The transport of slingmud should be sufficient to enable the westward propagation of the mudflats (Wells, 1977; Wells and Coleman, 1978).

The wave-damping property of the slingmud decreases with the increasing degree of consolidation of the sediment toward the east of each mudflat. Consequently the erodibility of the clay deposits with regard to the waves increases in that same direction, even though consolidated sediments are more difficult to erode.

The increasing erodibility of the clayey sediments of the mudflats toward the east is coupled to an increase in relief (Fig. 5). The west flank of each mudflat consists of slingmud and is therefore characterized by a smooth surface with a glassy appearance (Fig. 6), caused by a thin cover of expelled



Fig. 6. The surface of fresh deposited slingmud a few hours after emergence showing a glassy appearance. Key area Bigi Santi, 1972.

water (Wells, 1977). The drainage systems are very indistinct. The main channels usually run parallel to the slope and have a low sinuosity. The tributary channels generally show higher rates of sinuosity and meandering increases as they follow directions more perpendicular to the main channel. With the increasing consistency toward the east the smooth western nose grades into a pitted surface and the channels gain relief. The small and shallow irregular depressions are caused by local erosion (probably around spring tide). They have steep walls, owing to the cohesiveness of the clayey particles, reinforced by mucus of biological origin (e.g., gelatinous algae). The prevailing waves are generally low over the intertidal part of the mudflat. For this reason sedimentation normally dominates over abrasion and the depressions are slowly refilled with fresh sediment.

Above the well-consolidated clays at the eastern border of the mudflats, however, the waves are higher. They have propagated over 'trough' areas where the water is deeper and the gradient of the floor is steeper. Therefore, less wave energy is dissipated. Under these circumstances the small and shallow depressions are no longer refilled with fresh sediment. On the contrary, the depressions become deeper due to the scouring and whirling action of the water during periods of submergence. During exposure the steep walls desiccate, and shrinkage cracks appear parallel to the walls. During the next rising tide a thin layer may be eroded resulting in a widening



Fig. 7. A mud-bastion landscape, developed at the remnant of a mudflat in key area Katkreek, 1967.

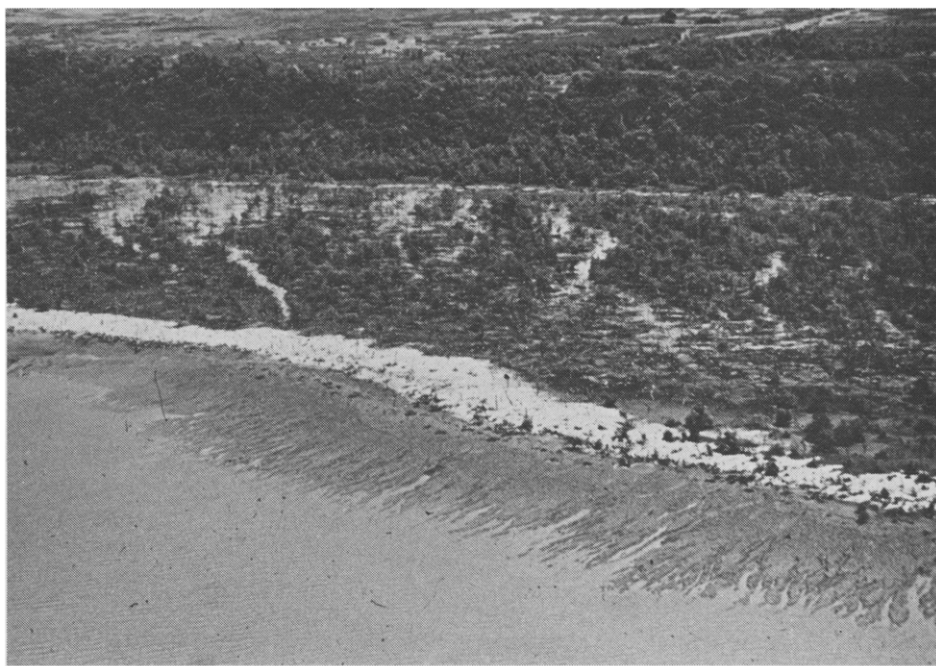


Fig. 8. Straight channels developed from local depressions in the mudflat which have merged together in the direction of wave attack. Key area Bigi Santi, 1972.

of the depression. When the width/depth ratio becomes too small (Bridges and Leeder, 1976, mention a critical value of 5) rotational slides develop, thus accelerating the widening process. An irregular pattern of depressions with sheer faces and more or less isolated flat-topped mud-bastions is formed (Fig. 7).

At this stage the drainage of the emerging mudflat is no longer concentrated in channels and is reduced considerably since most of the water is stored in the depressions (which have no drainage possibilities). The depressions tend to merge in the direction of wave attack, resulting in straight channels with flat bottoms and steep banks, ranging in height up to 1 m (Fig. 8). The sediment can then be removed more effectively by the channel flow and the lateral widening increases further. The abrasion covers an increasingly larger area and the seaward gradient becomes steeper. A low cliff (up to 1 m in height) usually indicates the temporary limit of landward-directed erosion around mean high-water.

SEDIMENTARY STRUCTURES OF THE MUDFLATS

Large thin sections (Jongerius and Heintzberger, 1975) were used for the examination of the clayey sediments. There was until recently very little available data concerning the sedimentary structures of the Surinam coastal pelite deposits. The reason for this is that collection of undisturbed samples and impregnation of the mud (average clay content ca 50%) with resin has been accompanied by many problems.

The thin sections were described according to the nomenclature proposed by Brewer (1964) even though this was actually intended for description of soils. The maximum length of the undisturbed cores, collected in the more or less consolidated sediment of the central and eastern parts of the mudflats, was approximately 80 cm.

The mudflat sediments are mainly composed of a clay matrix. Skeleton grains, predominantly silt-sized, occur in a random distribution pattern or are concentrated in laminae. Nota (1958) found that this lamination decreased in a seaward direction and attributed this decrease to the winnowing effect of the waves. The sandy laminae are usually very thin, ranging in thickness from a few tens of microns to some hundreds of microns. They mainly consist of grains in the size classes between 20 and 50 μm . Quartz, muscovite, feldspar and glauconite are the most common minerals. Organic remains also contribute to the coarse laminae. Elongated elements (plant remains, sponge needles) generally lie parallel to the bedding planes. The clayey laminae are usually thicker than the coarser ones, ranging from approximately 500 μm to a few centimeters.

Relatively thick laminae of clay-size material in similar deposits have been described by Slager et al. (1970). They concluded that these laminae were undisturbed and based this statement on the presence of a unistrial plasmic fabric. According to Brewer (1964) this is 'a plasmic fabric in which the

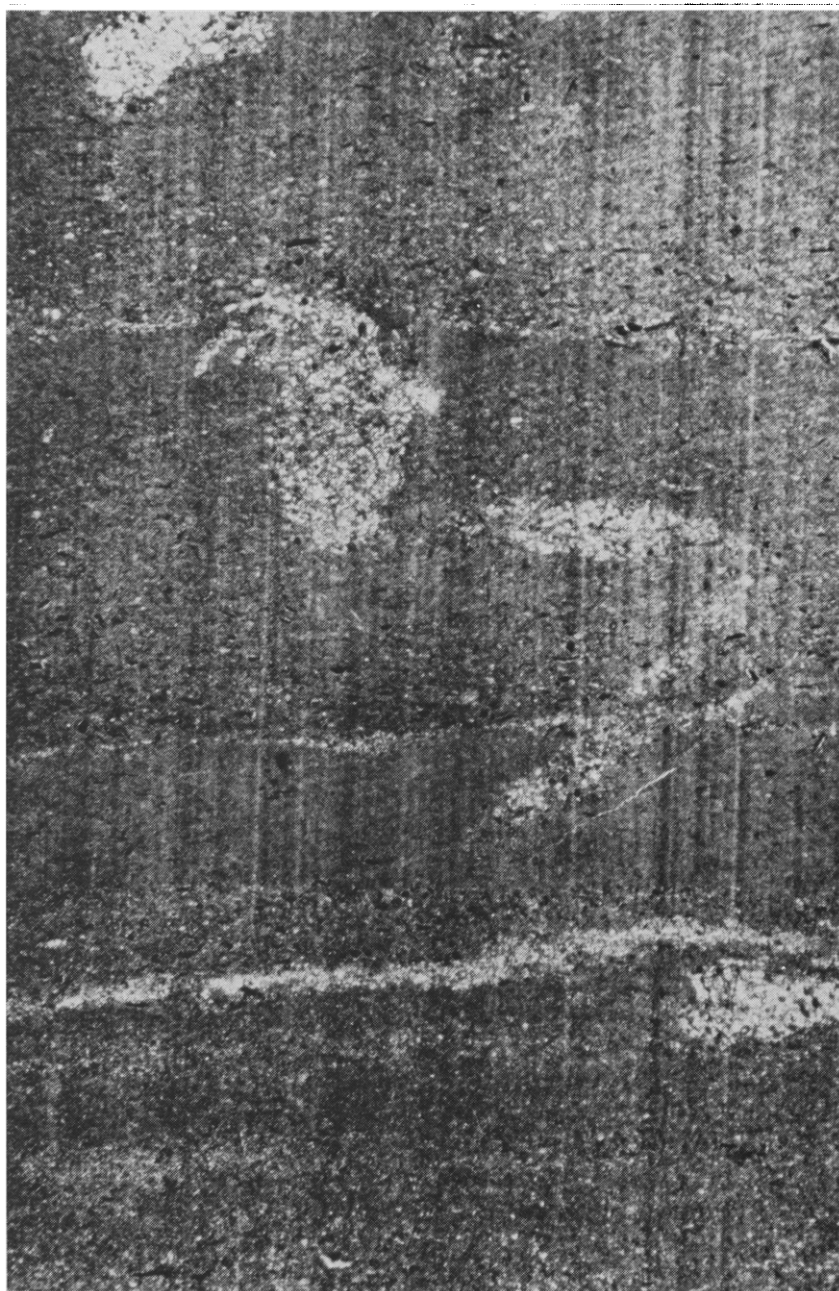


Fig. 9. A thin section of a core sample from the mudflat in key area Bigi Santi showing alternation of sandy and clayey laminae. The funnel-shaped disturbances are caused by bioturbation; $\times 22$.

plasma as a whole exhibits preferred parallel orientation, which gives the specimen as a whole a unidirectional striated extinction pattern'. This type of arrangement of the plasma is thought to be determined by the sedimentary process. Accordingly, this feature occurs predominantly in the undisturbed subsoil, whereas in the upper tens of centimeters — and increasingly toward the surface — a reorganisation of the plasma takes place (masepic, omnesepic, channel vosepic plasmic fabrics). In the same direction the unistrial plasmic fabric gradually disappears and finally is restricted to isolated irregular fields in the surface laminae.

Disturbances in the upper zone are caused by bioturbation. The degree of bioturbation varies between 0% (locally caused by the high rate of deposition) and 100%. Isotubules are the most common features. In vertical sections they are characterized by funnel-shaped depressions (Fig. 9).

A number of organisms may be held responsible for these burrows. Small fishes, e.g., *Gobionellus oceanicus* (Pallas) and also *Gobionellus boleosoma* (Yordan and Gilbert) are present in large numbers. When the mudflats are emerged these fishes take refuge in holes they make in the mud. Moreover, a great number of worms were found, usually at a few centimeters below the surface. When the deposit has accumulated to about mean high-tide level, large numbers of crustaceans appear.

Matrix faecal pellets (single as well as welded ones) with an asepic plasmic fabric have been found. They are 250–300 μm in diameter and possess a shell of parallel-oriented clay domains, a few microns thick. The faecal pellets were found in pedotubules as well as in layers. In the latter case they have been transported, probably together with the coarser mineral particles from the same layer.

Despite the zoning in faunal organisms and mangrove vegetation perpendicular to the coast no sequences in the pelitic sediment were found. This may be due to the narrowness of the zone (approx. 1 km wide) in which the samples were collected.

THE DEVELOPMENT OF THE CHENIERS

Between the mudflats the waves are not damped as severely as above the mudflats. They may therefore reach the shore. In these areas, which include the east sides of the mudflats, cheniers develop. In Suriname they consist of sand and/or shell clastics.

Shell clastics originate from animals living in different environments on the shelf. After death the shells are carried toward the coast by the combined action of waves and currents. This is possible because, due to their low specific gravity and their shape, shell clastics behave like solids with low hydraulic size in relation to their particle size.

Two types of sand can be distinguished: medium to coarse sand and very fine sand. Each one appears to be related to a characteristic chenier type. The medium to coarse textured cheniers are usually rather narrow (widths in

the order of magnitude of some tens of meters up to a hundred meters). The seaward slopes measured during the research range from 5° to 13° . The fine sandy cheniers are rather broad (hundreds of meters), and have very gentle seaward slopes ($0.5\text{--}2^{\circ}$). The formation of those two types of cheniers is essentially different.

MEDIUM TO COARSE TEXTURED CHENIERS

The medium to coarse sand is supplied by the Marowijne River and by the adjacent coast of French Guiana. The riverain supplied sand is not carried far outside the estuary. Since the high discharge of the Marowijne River (Nedeco, 1968, estimates $1,700\text{ m}^3/\text{s}$) prevents the settlement of slingmud in the estuary, the sand is deposited on more or less consolidated clay. It is moved from this source area toward the coast by constructive wave action, which appears to be very effective in the coastward transportation of sand in the low- to medium-energy environment of the Surinam coastal waters. This results in a concentration of sand just west of the Marowijne River in a narrow zone around high-water level. The grains are suspended by the turbulence of the breaking waves and transported by beachdrift.

During the rising tide (neap tide—spring tide cycle), when a beginning



Fig. 10. The very thin set of foreslope-parallel lamination of a severely eroded chenier, resting discordantly on landward-dipping backslope-parallel stratification. Key area Katkreek.

chenier is subjected to the influence of approaching breakers, sediment is stirred up at the seaside. Depending on the height of the crest, it is washed over toward the landward side or carried westward by beachdrift. During the period the sediment body is low, it moves gradually landward, due to the washover process. As the crest grows higher, beachdrift becomes dominant. At that point the chenier begins to extend westward due to alongshore-supplied sediment. If the sand supply is adequate and the seafloor does not change, the land should be protected by a continuous chenier at about mean high-tide level. The availability of longshore-transported sediments is, however, strongly affected by the mudflats. The chenier that has a westward moving mudflat in front is fixed. This occurs especially at the most western side of the mudshoal, where slingmud is normally present and wave action is damped. The cheniers west of the mudflats are therefore always cut off from their supply. This means that more sediment will be removed than is deposited. Consequently, the chenier crest will be lowered and the washover process becomes increasingly active again.

As far as the sedimentary structures are concerned the bidirectional lamination of the foreslope (seaward of the crest) and the backslope (landward of the crest) is a predominant feature (Fig. 10). The sedimentary struc-



Fig. 11. Small washover deltas at the lee-side of a chenier, built up during periods of stagnant water at the land side. Key area Nw. Nickerie, 1968.



Fig. 12. Cross-bedding of washover deltas dipping landward. The stages of deposition are marked by a 'pause plain' (see arrows). At the top delta cross-bedding is covered by gently inclined backslope-parallel lamination. Key area Popokaimama.

tures can be roughly divided into a narrow strip of seaward dipping foreslope laminae, whereas the landward dipping stratification forms the remaining chenier body. A similar description was given by Teichmüller and Teichmüller (in: Psuty, 1966) for the sedimentary structures in a beach ridge at Corsica (France). Seaward dipping parallel laminae at the foreslope are deposited from suspended-sand clouds produced by swash/backwash and surf action. When waves curl over the top of a chenier the water moves in a relatively thin sheet, such as a small-scale bore, in a landward direction over the backslope. A lamination similar to that of the foreslope results.

Cross-bedding is found intercalated in the evenly laminated sand and shell clastics of the backslope. This kind of structure depends on the water level in the mangrove swamps or in the salt pans landward of the chenier. When the water level is very low, or if there is no surface water at all, the sediment is deposited in parallel and almost horizontal laminae up to the very limit of the chenier. If the water level is sufficiently high so that part of the backslope is covered, small washover deltas develop at the landward side (Fig. 11). Accretion occurs due to the sudden slowing down where the running water moves into the stagnant water. Foresets raise themselves till the maximum angle of internal friction is reached. From that moment the well-developed lee-face is maintained by avalanching (Fig. 12).



Fig. 13. Asymmetric wave ripples at the foreshore of the fine sandy chenier in key area Bucklebury (1972). Lighter coloured particles (chiefly shell clastics) are washed into the troughs by the declining swash/backwash action. The chopping-knife has a length of about half a meter.

The formation of washover deltas is restricted to the periods in which water and sediment are washed over the backslope, i.e., usually around spring tide. After the spring tide has receded, the washover action diminishes and usually ends before neap tide. Topsets and corresponding foresets from this final stage in sedimentation are preserved. They contain finer material due to the lowered energy conditions and are therefore more compact. The outermost boundary of the whole sedimentation unit is called the 'pause plain' (Fig. 12).

During the next spring tide cycle, sedimentation may be reactivated, starting from this pause plain. When the landside of the backslope is still covered by water the washover delta will grow farther at a level corresponding with the stagnant water level. When the water landward of the chenier has disappeared (in the dry seasons, for instance), the steep backslope front is filled up and integrated with the smooth gradient of the upper surface.

The occurrence of large-scale cross-bedding at the landward side of the beach ridges is a well-known phenomenon. In the chenier backslope, however, the steep landward dipping foreset units are intercalated in gently inclined backslope lamination. This appears to be a characteristic feature for this type of Surinam cheniers. A schematic illustration of the salient sedimentary structures of these cheniers, shown in a cross-section, is given in Fig. 14.

FINE SANDY CHENIERS

The second type of chenier contains fine sand. The pelite originating from the Amazon River contains a small percentage of very fine sand ($M_z \approx 90 \mu\text{m} = 3.35\phi$). This fine sand appears to be winnowed out into the nearshore area chiefly at the erosive east side of the mudflats. There, clay is stirred up. The sediment is suspended and transported coastward by the combined action of waves and current. Closer to the coast where the water is more tranquil, the sand settles whereas the finer particles are transported farther. A thin sandy veneer is formed downcurrent of the location where the consolidated pelite was stirred up. An approaching mudflat may cover it for the next 30 years. Afterwards the whole process repeats itself until sufficient sand has been accumulated for the development of a chenier.

Since the sand is supplied from the seaside this chenier formation starts approximately at mean low-water level. Sand is suspended by breaker action and carried shoreward by the swash. A longshore bar develops, more or less parallel to the refracted waves.

The longshore bar moves obliquely landward and gathers volume and height. Once the east point of the ridge is attached to the coast it gives the impression of a spit, separated from the coast by a lagoon-like tidal flat. The growing chenier migrates farther landward over this protected 'tidal flat' and its deposits. The seaward slope of the fine sandy cheniers is extremely gentle, usually less than 1° . It is covered by water during a considerable part of the tidal cycle. After emergence the foreshore is covered by a regular pattern of long-crested, asymmetrical wave ripples. Wave lengths are up to 50 cm and the wave heights range from 3 to 5 cm. Lighter coloured particles, i.e., mainly fine shell clastics, are collected in the ripple troughs. These contrast sharply against the brownish colour of the quartz sand (Fig. 13).

The sedimentary structures fit the descriptions of longshore bars and beach ridges (Thompson, 1937; McKee and Sterrett, 1961; Hoyt, 1962; Reineck, 1963; Bigarella, 1965; Psuty, 1966; Wunderlich, 1972). The greater part of the chenier under study is built up of a thick bedset of gently seaward dipping laminae, with intercalated very thin beds of coarse shell clastics. Sometimes a small-scale cross-bedding has even been preserved. At the crest of the chenier, this complex is found to be more than 120 cm thick.

At the steeper landward side large-scale cross-stratification perpendicular to the chenier occurred. This is more regular here than in the medium to coarse sandy cheniers in east Suriname, since (due to the low position of the studied chenier) during high tide the backslope is always covered by water.

Immediately landward of the chenier the sediment of the lagoon-like tidal flat is characterized by interlayered sand/mud bedding. The sandy laminae are most pronounced and occur most frequently immediately behind the chenier. They gradually disappear in a landward direction. These coarse laminae probably originate from sand that has been washed over the chenier

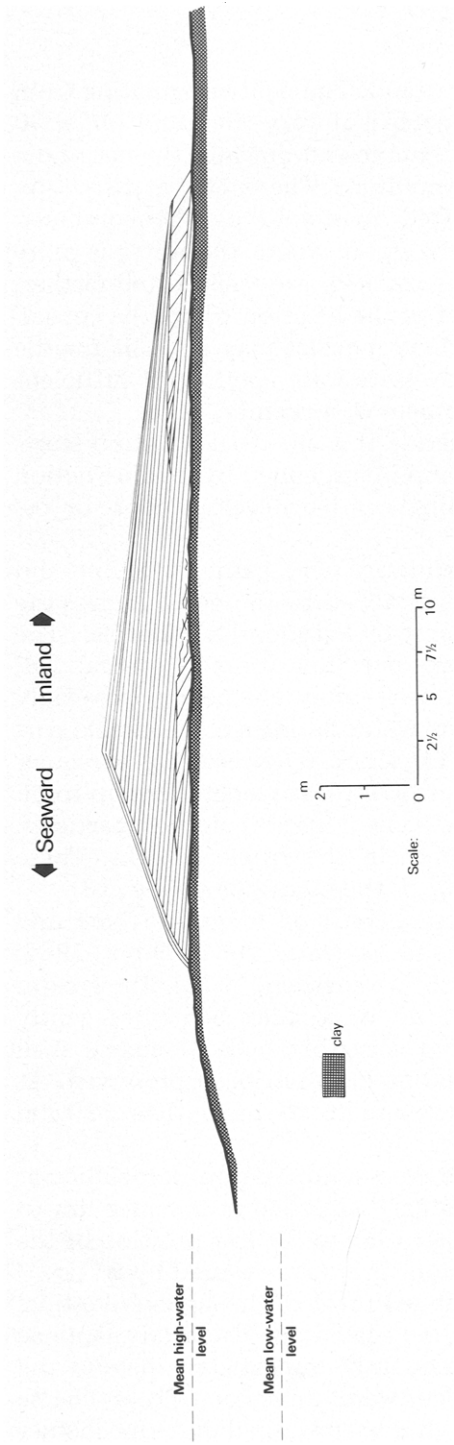


Fig. 14. Schematic representation of stratification within a medium to coarse sandy chenier.

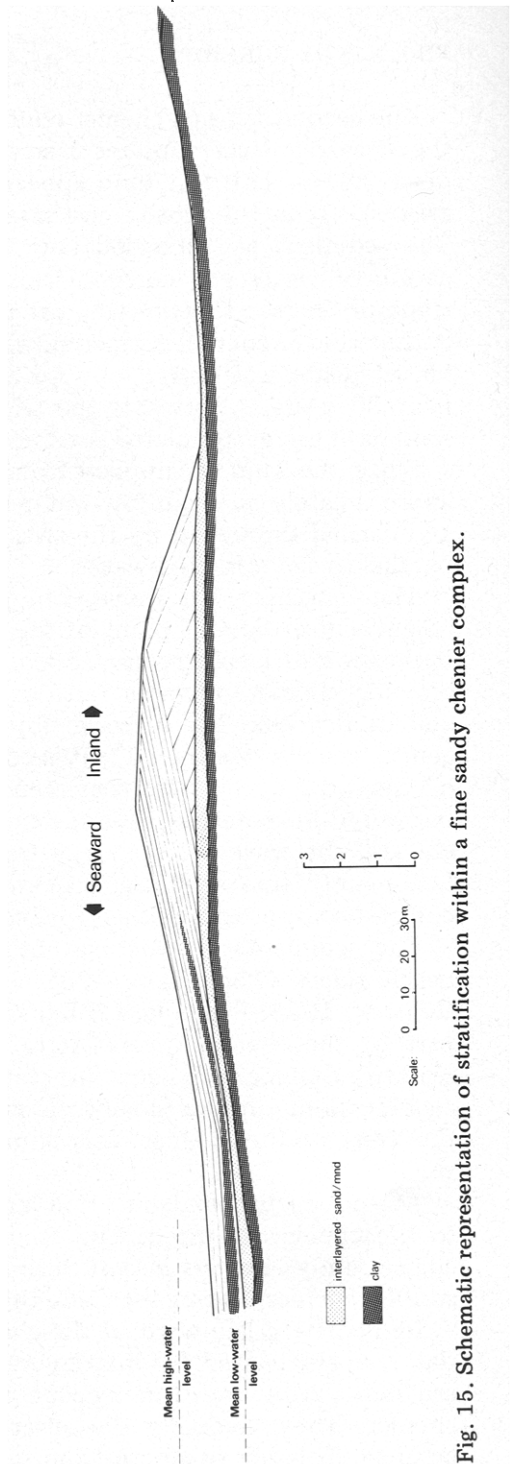


Fig. 15. Schematic representation of stratification within a fine sandy chenier complex.

during high tide when the protected area contains water. The thick clay layers have possibly settled as slingmud.

The rhythmic deposits will be overridden by the landward moving chenier. This has been observed several times and must be regarded as an important sedimentary characteristic of this type of chenier (Fig. 15).

Since small admixtures of fine sand are a general feature in the pelite deposits, fine sandy cheniers might be expected to occur along the whole Surinam coast. However, they are only found in west Suriname. The reason for this is that in east Suriname cheniers are built up from longshore-supplied medium to coarse sand. These protect the coast against erosion, at least to such an extent as to impede the winnowing of a quantity of fine sand adequate for the development of a fine sandy chenier. On the other hand, the medium to coarse sandy cheniers are restricted to the eastern part of the Surinam coast because they are fixed by the slingmud on their way to the west.

CONCLUSIONS

In this paper an attempt has been made toward a sedimentological analysis of the actual development of the Surinam chenier plain. The main conclusions can be summarized as follows:

(1) The clay deposits appear to be laminated at a micro scale. The clayey laminae usually have a unistrial plasmic fabric, increasingly disturbed toward the surface due to bioturbation of fishes, worms and crustaceans.

(2) Two types of cheniers develop, depending on the manner of sand supply. Medium to coarse sandy cheniers are built up from alongshore-supplied sand, by beachdrift and washover processes. They develop at or just above high-tide level. The formation of fine sandy cheniers starts at approximately mean low-tide level. The fine sand, winnowed out of the mud by wave action, is supplied from the shelf. In the very shallow nearshore water longshore bars are formed and these are driven shoreward by wave action.

(3) Although the sedimentary structures in both types of cheniers show much similarity, they also have distinctive characteristics. Steep landward-dipping foreset units intercalated in gently inclined backslope lamination appears to be a typical feature in the medium to coarse sandy cheniers. The occurrence of interlayered sand/mud bedding may be a decisive characteristic of the fine sandy cheniers.

ACKNOWLEDGEMENTS

The studies, part of which have been presented here, were supported by the Netherlands Foundation for the Advancement of Tropical Research. I thank Dr. J.H.J. Terwindt for his constructive criticism, Miss M.H. Tiemeyer for the preparation of the drawings and Mr. G.H. Huygen and Mr. T. Lekkerkerker for their assistance in the photographic work. I wish to thank Mrs.

E.Y. Kos-Jacobs and Drs. L. van der Maesen for the critical reading of the English text.

REFERENCES

- Allersma, E., 1968. Mud on the oceanic shelf off Guiana. Paper CICAR Symposium, Curaçao, 11 pp.
- Augustinus, P.G.E.F., 1978. The Changing Shoreline of Surinam. Thesis Univ. Utrecht, 232 pp. (Also in: Pub. Found. Sci. Res. Surinam, Netherlands Antilles, Utrecht, no. 95).
- Augustinus, P.G.E.F. and Slager, S., 1971. Soil formation in swamp soils of the coastal fringe of Surinam. *Geoderma*, 6: 203–211.
- Bigarella, J.J., 1965. Sand-ridge structures from Paraná coastal plain. *Mar. Geol.*, 3: 269–278.
- Brewer, R., 1964. *Fabric and Mineral Analysis of Soils*. Wiley, New York, N.Y., 470 pp.
- Bridges, P.H. and Leeder, M.R., 1976. Sedimentary model for intertidal mudflat channels with examples from the Solway Firth, Scotland. *Sedimentology*, 23: 533–552.
- Cook, P.J. and Polach, H.A., 1973. A chenier sequence at Broad Sound, Queensland, and evidence against a Holocene high sealevel. *Mar. Geol.*, 14: 253–268.
- Delft Hydraulics Laboratory, 1962. Demerara Coastal Investigation. Report on Siltation of Demerara Bar Channel and Coastal Erosion in British Guiana. Delft, 240 pp.
- Diemont, W.H. and Van Wijngaarden, W., 1975. Sedimentation patterns, soils, mangrove vegetation and land use in the tidal areas of West-Malaysia. *Proc. Int. Symp. Biol. Man. Mangroves*, Honolulu, 1974, 2: 513–528.
- Diephuis, J.G.H.R., 1966. The Guiana coast. *Tijdschr. K. Ned. Aardrijksk. Gen.*, 83: 145–152.
- Eisma, D., 1967. Oceanographic observations on the Surinam shelf. *Hydrogr. Newslett. R. Neth. Navy, Spec. Publ.*, 5: 21–53.
- Eisma, D. and Van der Marel, H.W., 1971. Marine muds along the Guiana Coast and their origin from the Amazon Basin. *Contrib. Mineral. Petrol.*, 31: 321–334.
- Gibbs, R.J., 1975. Distribution and transport of suspended particulate material of the Amazon River in the ocean. In: M. Wiley (Editor), *Estuarine Processes*, (2) Circulation, Sediments and Transfer of Material in the Estuary. Academic Press, New York, N.Y., pp. 35–47.
- Greensmith, J.T. and Tucker, E.V., 1969. The origin of Holocene shell deposits in the chenier plain facies of Essex (Great Britain). *Mar. Geol.*, 7: 403–425.
- Hoyt, J.H., 1962. High-angle beach stratification, Sapelo Island, Georgia. *J. Sediment. Petrol.*, 32: 309–311.
- Jongorius, A. and Heintzberger, G., 1975. Methods in soil micromorphology. A technique for the preparation of large thin sections. *Neth. Soil Surv. Inst., Wageningen, Soil Surv. Pap.*, 10: 4–48.
- Lhermite, P., 1958. Contribution à l'étude de la couche limite des houles monochromatiques. *Bull. Inf. C.O.E.C.*, 10: 263–284.
- McKee, E.D. and Sterrett, T.S., 1961. Laboratory experiments on form and structure of longshore bars and beaches. In: J.A. Peterson and J.C. Osmond (Editors), *Geometry of Sandstone Bodies*. AAPG, Tulsa, Okla., pp. 13–28.
- Migniot, C., 1968. Etude des propriétés physiques de différents sédiments très fins et de leur comportement sous des actions hydrodynamiques. *Houille Blanche*, 23: 591–620.
- Nedeco, 1968. Surinam Transportation Study: Report on Hydraulic Investigation. The Hague, 293 pp.
- Nota, D.J.G., 1958. Sediments of the Western Guiana Shelf. Thesis Univ. Utrecht, 98 pp.
- Nota, D.J.G., 1967. Geomorphology and sediments of the western Surinam shelf. A preliminary note. *Geol. Mijnbouw*, 48: 185–188.

- Nota, D.J.G., 1971. Morphology and sediments off the Marowijne river, eastern Surinam shelf. *Hydrogr. Newslett. R. Neth. Navy Spec. Publ.*, 6: 31—36.
- Price, W.A., 1955. Environment and formation of the chenier plain. *Quaternaria*, 2: 75—86.
- Psuty, N.P., 1966. The geomorphology of beach ridges in Tabasco, Mexico. *Coast. Stud. Inst., La. State Univ. Tech. Rep.*, 30: 51 pp.
- Reineck, H.E. 1963. Sedimentgefüge im Bereich der südlichen Nordsee. *Abh. Senckenb. Naturforsch. Ges.*, 505: 1—136.
- Roeleveld, W., 1974. The Groningen Coastal Area. Thesis Univ. Amsterdam, 252 pp.
- Slager, S., Jongmans, A.G. and Pons, L.J., 1970. Micromorphology of some tropical alluvial clay soils. *J. Soil Sci.*, 21: 233—241.
- Thom, B.G., 1975. Mangrove ecology from a geomorphic viewpoint. *Proc. Int. Symp. Biol. Man. Mangroves, Honolulu*, 1974, 2: 469—481.
- Thompson, W.O., 1937. Original structures of beaches, bars and dunes. *Bull. Geol. Soc. Am.*, 48: 723—751.
- Wells, J.T., 1977. Shallow-Water Waves and Fluid-Mud Dynamics, Coast of Surinam, South America. Thesis Louisiana State Univ., 99 pp.
- Wells, J.T. and Coleman, J.M., 1978. Longshore transport of mud by waves: northeastern coast of South America. *Geol. Mijnbouw*. 57: 353—359.
- Wunderlich, F., 1972. Georgia coastal region, Sapelo Island, U.S.A. Sedimentology and biology, 3. Beach dynamics and beach development. *Senckenbergiana Mar.*, 4: 47—79.