Coastal progradation in response to variations in sediment supply, wave energy and tidal range: examples from Sierra Leone, West Africa

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Abstract: *The coast of Sierra Leone, in West Africa, shows various types of shorelines with varying degrees of progradation. The mode and extent of recent progradation have been examined with reference to variations in sediment supply, wave energy and tidal range. Mangrove-colonized tidal flats have developed in sectors where a shallow, irregular inner shelf has resulted in frictional dissipation of wave energy and in tidal range amplification, thus allowing coastal deposition of abundant, upland-derived fine-grained sediments reworked by tidal currents. Local wave reworking of estuarine shoal sands in areas of fine-grained sedimentation has led to chenier formation. Sand barriers and simple beach ridges occupy coastal sectors exposed to higher wave energy and exhibit marked variations in progradation. They include minor beach-ridge deposits trapped in small embayments downdrift of now stable soft cliff outcrops, stationary barriers in small bedrock embayments between headlands fed solely from offshore and showing little progradation, and finally, massively prograded beach-ridge plains exhibiting complex plan-view patterns related to variations in wave refraction, and fed by both fluvial and nearshore sources. The coast of Sierra Leone stands out as one of transition in West Africa between muddy progradation to the north and sandy progradation to the south.*

Key words: Coastal progradation - Tidal flats - Cheniers - Sand barriers - Beach-ridges - Sediment supply - Waves - Tidal range - Sierra Leone - West Africa.

Résumé : Progradation côtière en réponse à des variations d'apports sédimentaires, d'énergie de la houle et de marnage : le cas du littoral de la Sierra Leone, Afrique de l'Ouest. *Le littoral sierra leonais en Afrique de l'Ouest montre des variations spatiales marquées en matière de mode et de degré de progradation récente, en liaison avec des variations d'apports de sédiments, d'énergie de la houle et de marnage. Des vasières à mangroves se sont amplement développées en marge des secteurs où un plateau continental interne peu profond provoque une dissipation quasi totale de la houle tout en entraînant une amplification du marnage. Cela favorise le dépôt et le remaniement, par les courants de marée, de vases continentales apportées par des fleuves. Très localement, le remaniement de ces vases par la houle donne lieu à la formation de cheniers de sables. Des cordons et autres barrières sableuses se sont développés dans des secteurs plus exposés à la houle et montrent des degrés de progradation très variables. Ces dépôts vont de simples cordons sableux piégés en aval de falaises tendres aujourd'hui stables à de véritables plaines de cordons, nourris par des fleuves et l'avant-côte, représentant une progradation massive et compliquée, en passant par de petites barrières de poche entre caps rocheux, très peu progradées et formées uniquement de sables provenant du proche plateau continental. La Sierra Leone fournit un littoral de transition à l'échelle de l'Afrique de l'Ouest entre une progradation sableuse au sud et vaseuse au nord.*

Mots clés : Progradation littorale - Vasières - Cheniers - Barrières sableuses - Cordons littoraux - Apports sédimentaires - Houles - Marnage - Sierra Leone - Afrique de l'Ouest.

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INTRODUCTION

A striking feature of the coast of Sierra Leone, in West Africa (Fig. 1), is the marked variability of Holocene to Modern open-coast deposits related to wave and tidal processes. These deposits range from massively prograded tidal flats, associated with fine-grained sedimentation and locally exhibiting cheniers (ANTHONY, 1989a), to extensive sand beach-ridge plains (ANTHONY, 1991), with very variable degrees of progradation. Such variability over a relatively short spatial distance provides a good opportunity for explaining contrasting modes of coastal progradation in response to various geological and dynamic variables. This paper reviews the environmental setting of this alluvial coast and highlights in particular the way in which inherited coastal and inner continental shelf morphology and lithology have affected incident wave energy, tidal range and sediment supply, three variables particularly sensitive over short space and time scales, and which have induced in turn sharp longshore and shore-normal variations in both modes and rates of progradation. At a time when concern is increasing over the response of coastal sediments to environmental change, especially sea level rise, the study of space and time variations and the geological and dynamic factors responsible for such variations is not only a major approach in its own right in understanding coastal deposits (DAVIES, 1980) but is also a necessary preliminary step in gaining some insight into the still elusive responses of alluvial coasts to any future environmental change.

Much of the work synthesized here was carried out over a period of several years and has involved extensive field surveys and sampling, shallow coring and consultation of bore-hole logs, maps and aerial photographs, and various sedimentological and chemical analyses on hundreds of samples. The full study design and complete results are reported in ANTHONY (1990).

GENERAL SETTING AND GEOLOGICAL HERITAGE

The study area stretches between approximately 7° N and 9° N and experiences a hot, humid seasonal climate. Annual rainfall, virtually totally concentrated between May and November, varies from 3,000 mm to 5,000 mm, depending on topography, latitude and exposure to the rain-bearing southwesterly winds. Mean monthly temperatures range from a minimum of 24 °C in August to a maximum of 28 °C in March. The seasonal rainfall regime is paralleled by river flow regime, marked by heavy discharge and sediment supply to the coastal zone in the wet season months.

The coast is dominated by a sedimentary plain ranging in height from sea level to 40 m. This plain shows more or less constant width north of Sherbro Island before narrowing down southwards. The constituent *Bullom Group* sediments (Fig. 2) range in age from Tertiary to late Pleistocene, are overlain along much of their seaward margin by Holocene to Modern clastic deposits and overlie a basement consisting of gneisses, granulites and mylonites that form the rim to the West African Archaean Craton (WILLIAMS and WILLIAMS, 1976). Locally referred to as the *Kasila Group*, these basement rocks outcrop landward of the coastal sediments as low dissected hills. In the central part of the study area, the coast is punctuated by the bold mountain range of the *Freetown Basic Complex* (Fig. 2) which rises up to 880 m practically out of the sea. The constituent rocks are Mesozoic gabbros and norites emplaced during the early opening of the Atlantic.

The general coastline orientation is NW-SE and has been largely determined by lineaments of Pan-African age (550 Ma) along which rifting of the West African margin occurred during the Mesozoic (JONES and MGBATOGU, 1982). The continental shelf

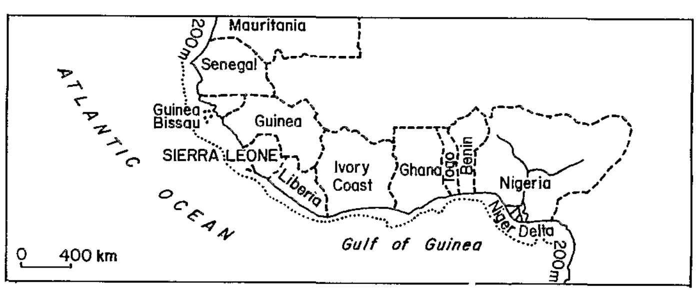


Fig. 1. — General map of study area.
Localisation de la zone d'étude.

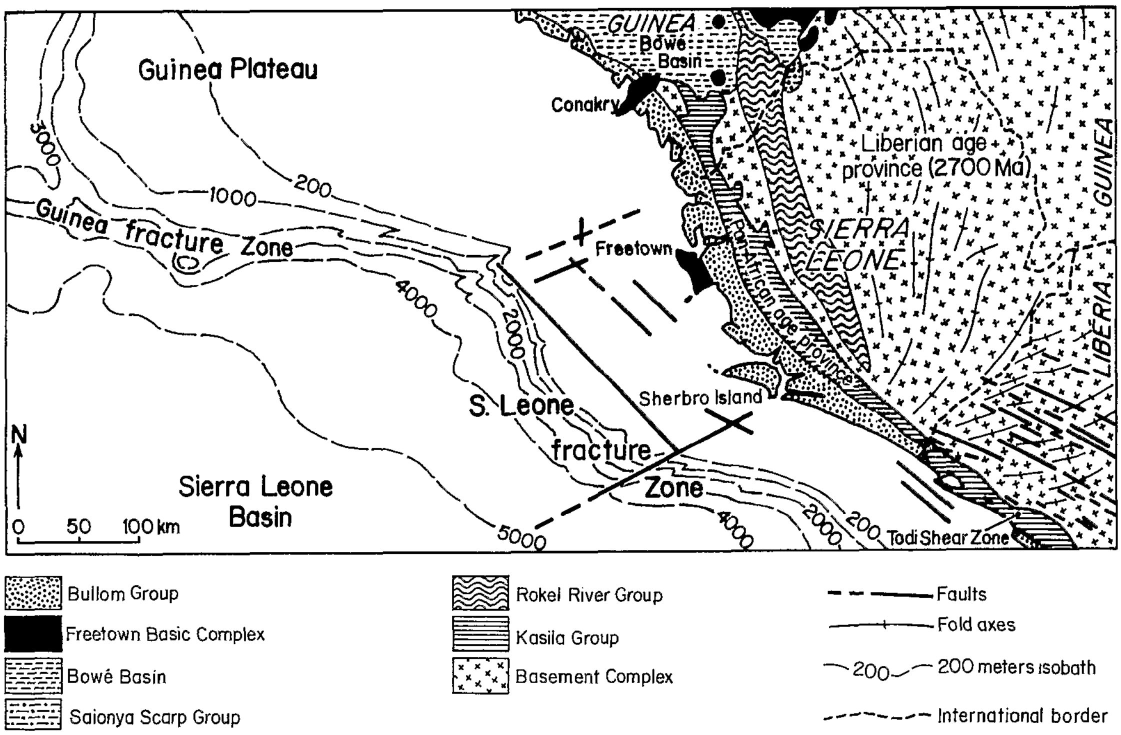


Fig. 2. — The continental margin and major geological units in Sierra Leone.
La marge continentale et les principales unités géologiques de la Sierra Leone.

(Fig. 3) shows marked spatial variations that are important in explaining coastal morphology. In the south, this shelf is uniformly narrow, nowhere exceeding 50 km in width. It is also relatively deep, 50 % of its surface having a depth of over 50 m. The nearshore profile is relatively steep. This southern shelf surface shows a discontinuous sediment cover in certain localities, with basement subcropping (McMASTER *et al.*, 1975). Geomorphic features include remnant barrier islands and a massive nearshore shoal representing a late Pleistocene barrier-spit complex (McMASTER *et al.*, 1970; VOGEL, 1982). Shelf width increases sharply to 120 km off Sherbro Island. A further sharp increase in width occurs off the Sierra Leone/Guinea border where the shelf widens to 200 km. These increases in width are related to left-lateral offsetting by two major fracture zones (Fig. 2), the Sierra Leone and Guinea fracture zones (JACOBI and HAYES, 1982). North of Sherbro Island, 75 to 90 % of the shelf is less than 50 m deep and its surface is marked by remnant barrier spits, barrier island-lagoon complexes and sea cliffs as well as major drowned deltas north of the Sierra Leone/Guinea border where extreme progradation of the shelf edge has resulted in masking of the continental slope (McMASTER *et al.*, 1970). The nearshore profile of this northern shelf is relatively shallow and rather irregular.

Shelf surface characteristics are in part an outgrowth of the recent sea-level history of this region, deduced from the regional late Pleistocene and Holocene sea level trends. Sea level rose rapidly in West Africa from a lowest stand of ca. - 110 m at 19,000 B.P. (McMASTER *et al.*, 1970) to attain a highest stand of + 1 to + 2 m at ca. 5,500 B.P. (MICHEL, 1977; GIRESSE, 1987). The sea-level history following this period is not clear. Collation of data from various areas of the West African coast suggests a fluctuating trend within an overall net drop in level not exceeding 2 m (ANTHONY, 1991). Because of the major differences in shelf geometry and morphology, the shoreface regime during the Post-Glacial Marine Transgression has been different from the south to the north (ANTHONY, 1989b). The southern sector, from Sherbro Island southwards, experienced a slow, moderately ener-

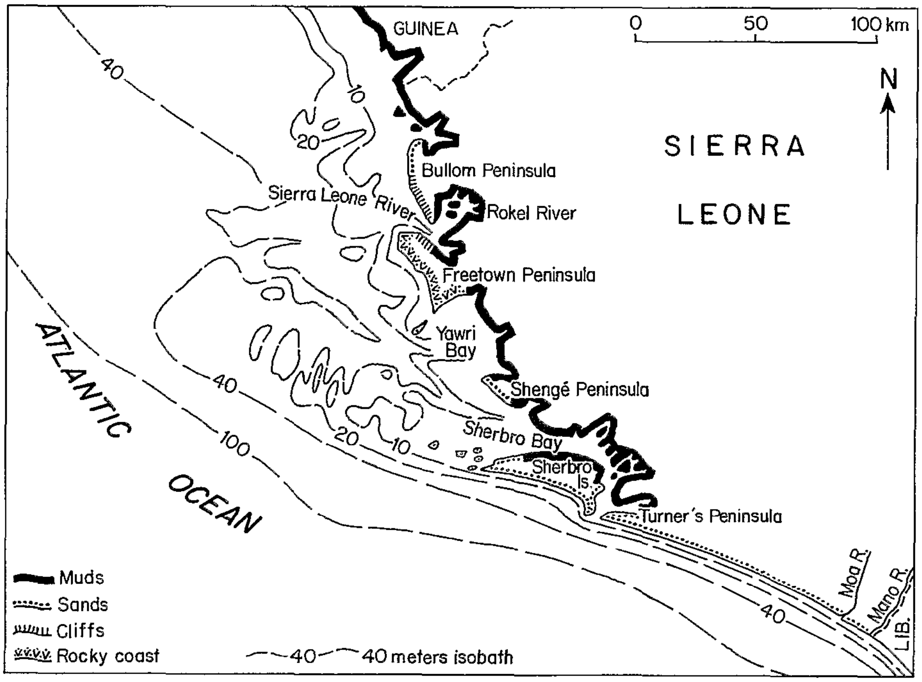


Fig. 3. — The gross relationship between shelf characteristics and coastal lithology. The inner shelf, as discussed in the text, has influenced coastal development via wave energy and tidal variations as well as sediment supply.

Relations grossières entre la bathymétrie du plateau continental et la lithologie côtière. Le plateau continental interne a, comme il a été démontré dans le texte, influé sur le développement de la côte par le biais des variations d'énergie de la houle, du marnage et des apports sédimentaires.

getic transgression under environmental conditions of low sediment influx as a result of a much drier climate than that prevailing today (THOMAS and THORP, 1980, 1985). Available evidence from the shelf suggests shoreface erosion and regularization followed by sedimentation of Holocene and modern silts and clays on the middle shelf (McMASTER *et al.*, 1975; McGRAIL, 1982; VOGEL, 1982). The final stages of the transgression appeared to have been associated with shoreface aggradation from the erosion of a poorly consolidated late Pleistocene coastal terrace cut into the Bullom Group coastal plain substrate. North of Sherbro Island, coastal translation during the transgression was extremely rapid and characterized by low wave energy conditions and a mesotidal regime as a result of shelf geometry. These conditions may have been enhanced by subsidence. Greater morphological diversity prior to the transgression and limited reworking of the shelf and shoreface are expressed by various drowned features and by a complex relict surface sediment cover on the middle and outer shelf (McMASTER *et al.*, 1970, 1971).

SEDIMENT SOURCES AND SUPPLY

The various sedimentological analyses carried out on representative samples throughout the study area (ANTHONY, 1990) show the overwhelming importance of terrigenous inputs, represented by fine to coarse quartz sands, quartz silts and a clay fraction dominated by kaolinite. Immediate sediment sources have not been, however, always directly continental, as the nearshore zone has, in certain sectors, been a significant sand source, as suggested by both the analysis of coastal sediment transport cells and a consideration of coastline morphological characteristics (ANTHONY, 1990, 1991). Such nearshore sands were initially emplaced as sheetwash deposits and coastal sediment bodies during lower sea level stands, or, as the Post-Glacial Marine Transgression, close to the present shoreline in its final stages, eroded pre-existing clastic deposits, leading to nearshore aggradation.

Direct sediment supply from upland has depended on factors such as river catchment size and the capacity of aggraded river mouths to supply excess sediment to the open coast. This capacity has in turn depended on both inherited river valley morphology and subsequent coastal progradational trends. While some rivers such as the Scarcies in northern Sierra Leone and the Moa in southern Sierra Leone have rapidly filled their mouths to evolve into deltaic systems that inject sediments onto the open coast (Fig. 4), major and still deep structural or geomorphic bays such as the Rokel River and Sherbro Bay, into which drain several rivers, still actively trap incoming sediment, including sands from the nearby shelf (ANTHONY and MARIUS, 1985).

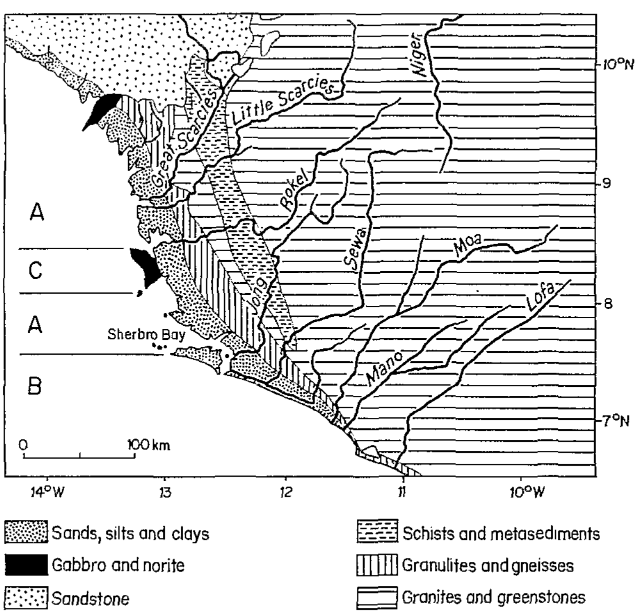


Fig. 4. — Lithology of catchments and sediment sources for coastal progradation. Sediment sources: A. Rivers and coastal cliffs; B. Rivers and nearshore zone; C. Nearshore zone.

Lithologie des bassins versants et des formations sédimentaires ayant alimenté la progradation des dépôts côtiers. Sources : A. fleuves et falaises côtières; B. fleuves et proche plateau continental (avant-côte); C. proche plateau continental (avant-côte).

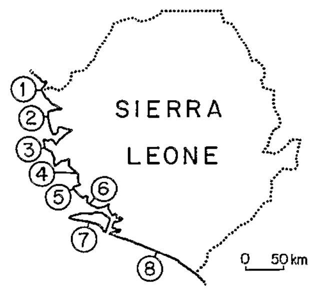
Sediment supply from the nearshore zone has essentially depended on shallow water wave energy levels which affect wave dissipation and refraction as well as on sediment mobilization shorewards and alongshore. Sediment redistribution alongshore from both point sources such as river mouths and line sources such as the nearshore zone has occurred in response to longshore drift currents generated by incident waves. The transport patterns associated with both shore-normal and longshore sediment movements are expressed by the plan-view morphology of coastal deposits as sediment cells (ANTHONY, 1991). In addition to wave processes, sediment redistribution has also been carried out by tidal currents and wind-generated circulations in the coastal zone. Finally, the location and texture of coastal deposits reflect wave energy levels as well as inherited shoreline morphology which determines in part the existence of sediment traps.

WAVES AND TIDES

The variations in marine processes along the coast are hinged on the relative contributions of wave energy and tidal currents. The wave climate consists of two components. North of Sherbro Island, the coast is exposed year-round to a mixture of long period swells ($T = 7\text{-}16$ s) and seas ($T < 5$ s) from the northwest. Wave energy is low to moderate with deep-water heights less than 1.2 m occurring 72 % of the time (ANONYMOUS, 1980). Between June and October, moderate to high energy (1.5-4 m) waves from the south are superimposed on the northwesterly waves and may even become dominant for short periods of time. The coast south of the Freetown Peninsula is exposed throughout the year to low to moderate energy ($H = 0.5\text{-}1.5$ m), long period ($T = 8\text{-}16$ s) swells from the southwest. Swell energy increases from June to October.

In spite of the fairly identical nature of the deepwater wave regime, characterized essentially by low to moderate energy swell, nearshore wave energy levels vary spatially as a function of nearshelf geometry (Fig. 5). This variation illustrates the important control exerted by inner shelf characteristics, including antecedent geomorphology, on wave parameters and, thereupon, patterns of coastal progradation.

Tides are semi-diurnal and tidal range shows spatial variations (Fig. 6) which may be explained by the variations in shelf geometry noted above. The coast between the Turtle Islands and Guinea experiences a spring-tide range that increases from 2 m in the South to 3 m in southern Guinea, the increase being hinged on increase in shelf width and decrease in gradient. From Sherbro Island southwards, the coast, fronted by a narrow shelf, has a spring-tide range that does not exceed 1.3 m. Tidal dominance of coastal processes is apparent in sectors exhibiting a mesotidal range in association with extreme wave energy dissipation, as discussed later.



Profiles	Sector	Hb (m)
1	Sallatouk Point	<0.25
2	Bullom Peninsula	0.25-0.5
3	Freetown Peninsula	0.5-1
4	Yawri Bay	<0.25
5	Shengé Peninsula	0.25-0.5
6	Sherbro Bay	<0.25
7	St Ann's Peninsula	0.5-1
8	Turner's Peninsula	0.5-1

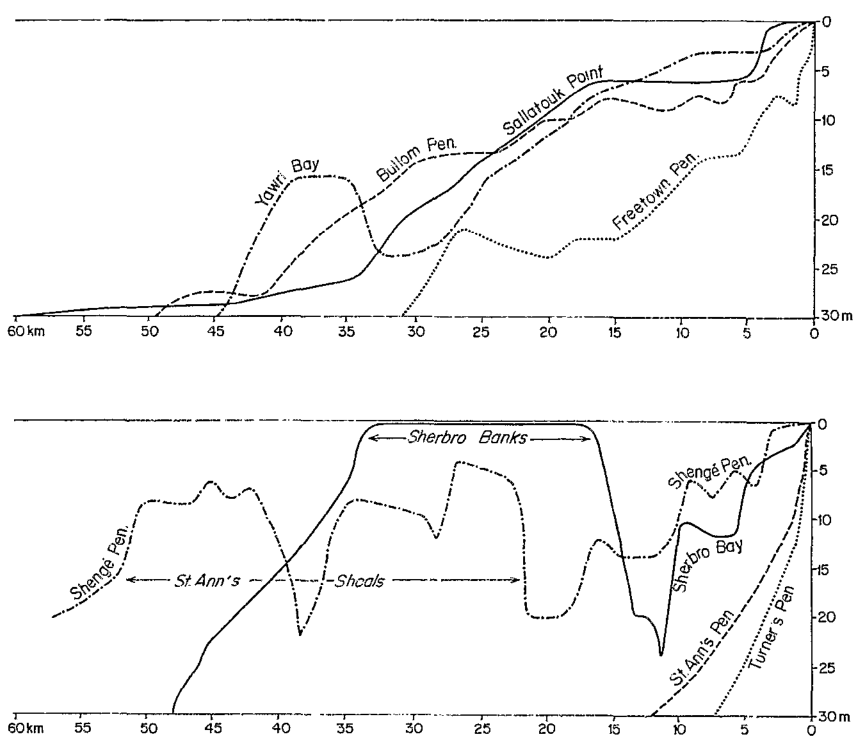


Fig. 5. — Nearshore shelf profiles and estimates of modal breaking wave heights for various sectors of the study area. The more irregular or shallower the profile, the greater the amount of wave energy dissipation, hence the marked spatial variations in wave height and energy in spite of a fairly homogeneous deepwater wave climate.

Profils de l'avant-côte et estimations de la hauteur de la houle au déferlement pour divers secteurs de la région étudiée. Plus le profil est irrégulier et de faible pente, plus la dissipation d'énergie est importante, d'où les variations spatiales très marquées de l'énergie de la houle au niveau du déferlement.

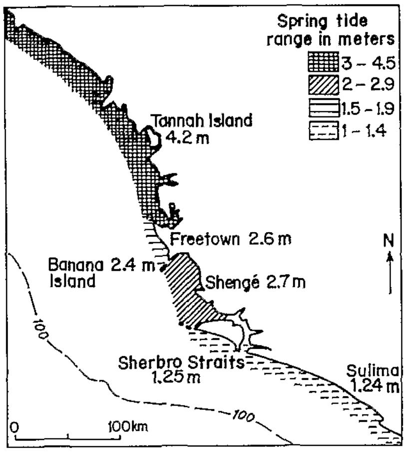


Fig. 6. — Variations in spring tidal range from southern Sierra Leone to southern Guinea. Continental shelf widening and shallowing from south to north leads to a concomitant increase in range.
Évolution du marnage de vive-eau le long des côtes sierra léonaises et sud-guinéennes. Cette évolution suit la largeur et la pente du plateau continental, diminuant lorsque la largeur diminue et la pente s'accentue.

MODES OF COASTAL PROGRADATION

The two contrasting modes of progradation may be summarized in terms of predominantly muddy and predominantly sandy coasts (Fig. 3). The constituent deposits range from tidal flats to beach-ridge barriers (Fig. 7). These modes of progradation are discussed below.

Muddy progradation

Muddy progradation is expressed essentially by open coast fine-grained tidal flats colonized by mangroves. These have developed in low-energy sectors where a wide, shallow and irregular inner shelf and nearshore zone have resulted in considerable dissipation of wave energy while favouring tidal range amplification. These hydrodynamic conditions have favoured the development of open estuaries and extensive tidal channel networks while precluding the formation of beach-ridge barriers, lagoons and freshwater floodplains which could trap fluvial sediments (Fig. 7). The open nature of the estuaries allows for direct supply of mud and sand to the littoral zone while the prevailing low wave energy conditions have favoured mud accumulation. These flats consist of muds made up of kaolinitic clays and quartzitic silts as well as a significant proportion (up to 10 %) of organic matter. The tidal flats are fronted by a muddy-sandy foreshore whose gradient ranges between 1:500 and 1:1000.

Muddy progradation has been most important adjacent to the more important estuarine deltas in northern Sierra Leone and neighbouring southern Guinea (Fig. 8). This stretch of coast is fronted by a shallow and irregular nearshore zone (Fig. 3) which, under conditions of sustained mud supply, has been conducive to rapid rates of aggradation and progradation since the Middle Holocene. South of the Scarcies estuarine delta, tidal flats are best developed in embayments sheltered behind beach ridges barriers such as Sherbro Bay or protected from swell by nearshore shoals or bay-mouth shoals such as Yawri Bay. Muddy progradational coasts show little spatial contiguity (Fig. 7) as a result of marked variations in incident wave energy dissipation. Sand barriers occur landward of deeper, higher-energy bathymetric "windows" that allow for efficient wave energy transmission. These barriers alternate with open-coast muddy deposits protected by offshore shoals (Fig. 9). The nearshore shelf has not been a source of sediment for the progradation of muddy coasts which thrive essentially on fine-grained fluvial sediments that accumulate under low wave energy conditions.

The progradation of muddy coasts appears to have been strongly affected by changes in tidal dynamics related to natural and mangrove-enhanced accretion. Mangrove colonization has resulted in the progressive constitution of organic muds, especially in inner areas where flood-dominated currents may have favoured initial preferential accretion. As tidal flats have accreted, ebb currents have tended to become dominant, leading to net export of incoming mud onto bare fringing tidal slopes which show rapid

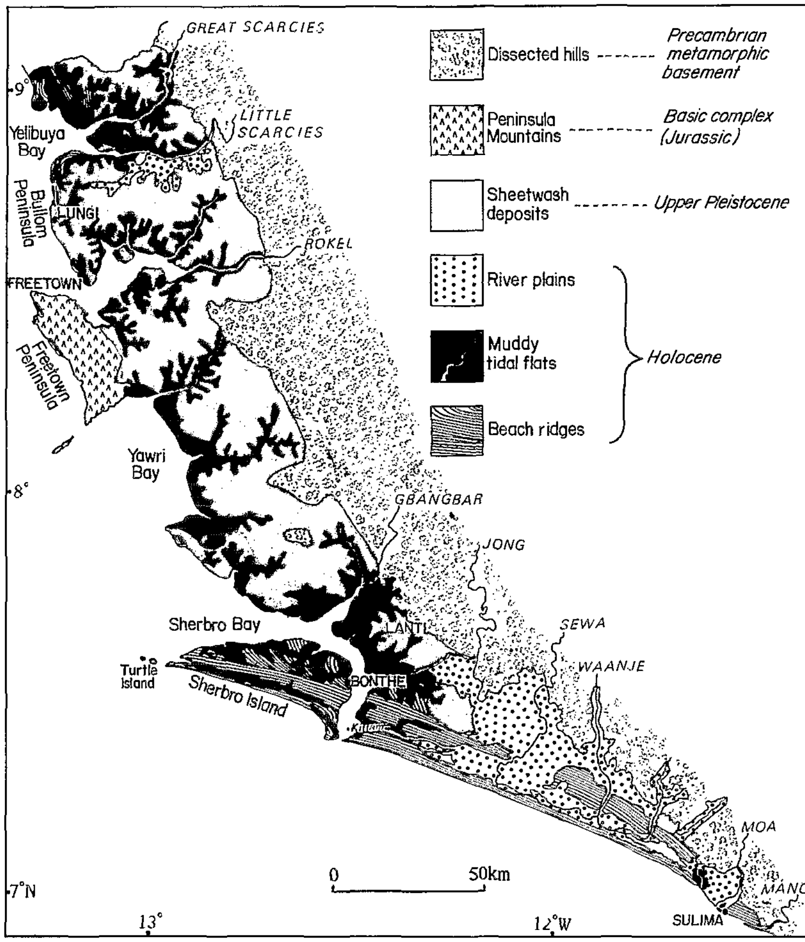


Fig. 7. — Coastal geomorphic units in Sierra Leone, incorporating sandy and muddy progradational deposits.
Contrastes géomorphologiques le long du littoral de la Sierra Leone, incorporant des dépôts de progradation sableuse et vaseuse.

progradation in some areas. Such ebb export also results in the constitution of turbidity plumes both in sheltered areas and open-coast sectors where muds in suspension are trapped inshore by moderate breezes and coastal currents, a feature that becomes even more pronounced along the Guinea and Guinea-Bissau coasts (RUE, 1989; DIOP, 1990). Tidal flat evolution also appears to have been affected by tidal creek migration which has led to slow recycling of muds and concomitant homogenization of accretion rates across the flats.

Within the low-energy, essentially muddy environment of northern Sierra Leone and Guinea, wave reworking of estuarine and subtidal sands into cheniers has occurred in a number of favourable localities between the Scarcies and the Mellacoree estuaries (ANTHONY, 1989a). The cheniers occur in clusters and their formation appears to have depended essentially on the local geomorphic framework, although past alternations between muddy progradation and the elaboration of chenier clusters may have been enhanced by a probable conjunction of several factors, including climatically induced changes in mud supply, and relative sea-level oscillations since the middle Holocene (ANTHONY, 1989a). The initial phases of muddy progradation were punctuated by frequent phases of chenier formation, apparently under conditions of efficient wave action over deeper, less filled estuaries associated with reduced muddy sedimen-

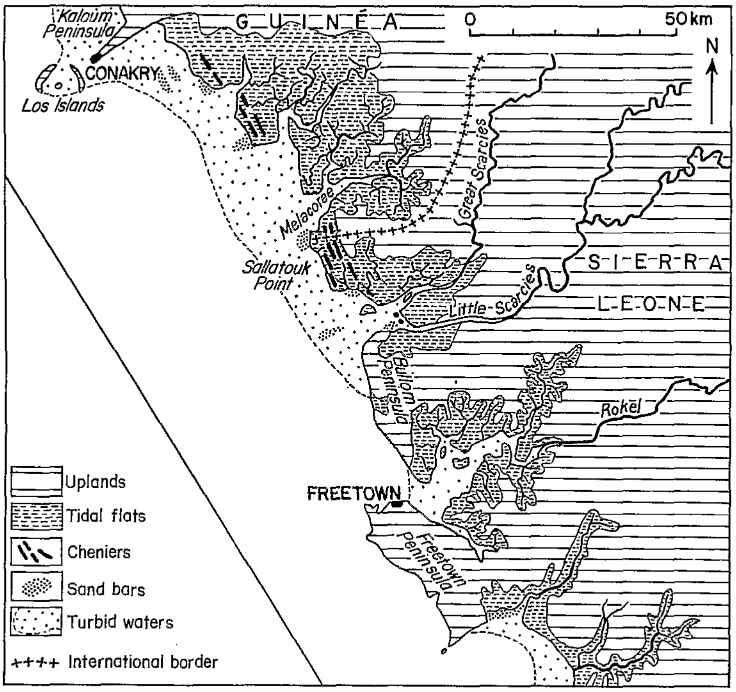


Fig. 8. — The extensive sea-front tidal flats and locally associated cheniers in northern Sierra Leone and southern Guinea.
Les vasières très étendues de front de mer et leurs cheniers le long des côtes septentrionales de la Sierra Leone et méridionales de la Guinée.

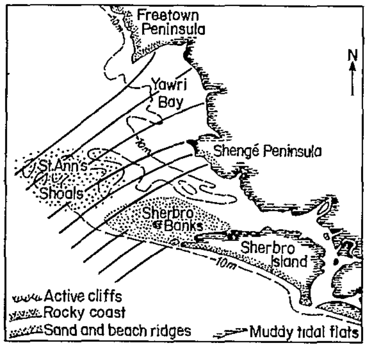


Fig. 9. — Schematic representation of marked spatial variations in wave refraction and frictional dissipation related to both nearshore sand shoal bodies and coastal configuration, and corresponding modes of coastal development.

Représentation schématique des variations marquées de la réfraction et la dissipation des houles en fonction de la présence de bancs sableux au large et de la configuration du trait de côte. Noter la correspondance entre ces variations et le mode d'évolution du rivage.

tation. These cheniers peter out seaward (Fig. 10), probably in response to several factors, including attenuated wave action as a result of energy capture by accreted estuarine shoals, an increase in mud supply from the upland and a negative sea-level pulse resulting in higher rates of mud export from accreted inner tidal flats and increased muddy sedimentation over a shallower nearshore zone. At present, both muddy progradation and chenier formation proceed simultaneously. The loci of present chenier formation occur just shoreward of narrow bathymetric "windows" which allow for localized efficient wave energy transmission (Fig. 10). This illustrates the importance of nearshore morphology on present, and most likely, past chenier plain development.

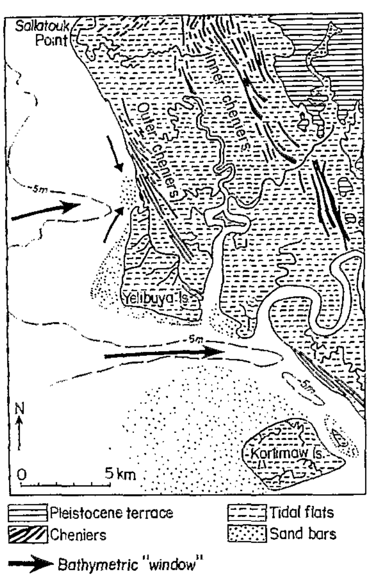


Fig. 10. — Relationship between cheniers and narrow bathymetric "windows" through which occurs efficient transmission of wave energy for chenier formation. These cheniers have been formed from sands reworked from subtidal and intertidal estuarine bar deposits.

Relation entre l'emplacement des cheniers et des « fenêtres » bathymétriques permettant une transmission efficace de l'énergie des houles nécessaire pour la formation des cheniers. Ceux-ci sont constitués de sables remaniés à partir de bancs estuariens subtidaux et intertidaux.

Sandy progradation

More exposed areas affected by moderate wave energy are characterized by the development of various types of sand barriers exhibiting distinct morpho-stratigraphic patterns (ANTHONY, 1990, 1991). These deposits consist virtually entirely of quartz sands and lack suitable datable carbonate material. They have been considered as Holocene (post-middle Holocene) deposits on the basis of distant correlation with partly dated similar barriers elsewhere in West Africa which share a common climatic and dynamic setting and show similar morphological (including the common occurrence of a dual barrier system), stratigraphic and soil development patterns (ANTHONY, 1985). Patterns of barrier development vary markedly, depending on geomorphic setting, sediment availability and wave/sediment cell dynamics.

Along the central and northern coasts of Sierra Leone, faced by a wide, irregular shelf, minor barriers have developed only in areas fronted by a fairly deep shoreface. Much of this coast has not prograded or shows very little progradation. The Bullom and Shenge Peninsulas, two of the three peninsulas that punctuate these sectors of coast, exhibit soft Bullom Group cliff outcrops downdrift of which have formed simple beach-ridge barriers in small embayment traps (Fig. 7). These deposits rest directly on the Late Pleistocène Bullom Group substrate. Most cliffed sectors are now stable, fossilized or only slightly recessive. Apparently, phases of Holocene cliff recession and toe accumulation, augmented by subaerial processes of cliff failure, have led to rates of inshore and nearshore accretion that have outstripped the capacity of waves and longshore currents to disperse this material offshore or downdrift, especially as sea level stabilized. These conditions have led to a slow-down in both wave-induced cliff retreat and sediment supply downdrift for beach-ridge formation. The development of these peninsulas has thus involved a slow change from active cliff retreat and efficient wave action necessary for beach-ridge formation downdrift, to quasi-stability associated with toe accumulation and shoreface shallowing (ANTHONY, 1990).

The Freetown Peninsula, an important outcrop of basic intrusive rocks, shows a series of bedrock embayments in which have developed narrow beach barriers exhibiting very little or no progradation. These barriers show a transgressive relationship vis-à-vis lagoonal muds which they partly overlie, form tombolos in some cases, and are capped by a low fore-dune. The morphological and dynamic context, together with textural, mineralogical and scanning electron microscope analyses of these barrier deposits show that they were formed from shoreward drift of sands from the nearshore zone, and their medium to fine texture and iron-free surface also recall nearby sand bodies on the shelf reported by McMASTER *et al.* (1971). The limited progradation of these essentially pocket barriers apparently reflects both the "closed" nature of the beaches as far as external sediment sources other than the nearshore zone are concerned, as well as the rather deep and sediment deficient nature of this nearshore zone, inherited from the morphological framework predating and subsequent to the Post Glacial Marine Transgression. The remarkable historical stability exhibited by these beaches (ANTHONY, 1987) and their limited progradation are probably due to the fact that the bedrock embayments were infilled by nearshore-derived sand at a rather early stage to an equilibrium configuration whose maintenance has probably been favoured by stability of the wave climate and by relative sea-level stability. This equilibrium is threatened by illicit quarrying of sand from some of these beaches.

The most important sector of sandy progradation is the coast of southern Sierra Leone where massive beach-ridge plains stretch from Sherbro Island to Liberia as complex prograded double barriers 60 to 120 km long, separated by fluvio-lagoonal deposits on both Sherbro Island and the mainland (Fig. 7). Each barrier consists of several dozens of beach-ridges and exhibits complex plan-view patterns (Fig. 11). These barriers were formed in a major coastal embayment that stretched from Liberia to the Shenge Peninsula.

Mineralogical and sedimentological analyses and plan-view beach-ridge patterns show that these barriers were formed from both regressive near-shore sands and longshore drift inputs from river-mouths and associated shoals. Additionally, the initial stages of progradation were also fed by erosion of cliff outcrops that have been fossilized by the prograded barriers. Redistribution of these sands in the prograding coastal zone occurred under the influence of longshore currents generated by spatial differences in refraction. This drift redistribution process can be diagnosed from the complex beach-ridge patterns exhibited by these barriers (ANTHONY, 1991).

These predominantly regressive barrier sands, over 15 m thick on their seaward flank, thin landwards at the inner edges of the earliest barriers where they show a transgressive relationship vis-à-vis fluvio-lagoonal muds. Progradation since the middle Holocene ranges from 5 to 18 km and has varied spatially as a function of coastal morphology and shelf geometry. Progradation has been greatest in

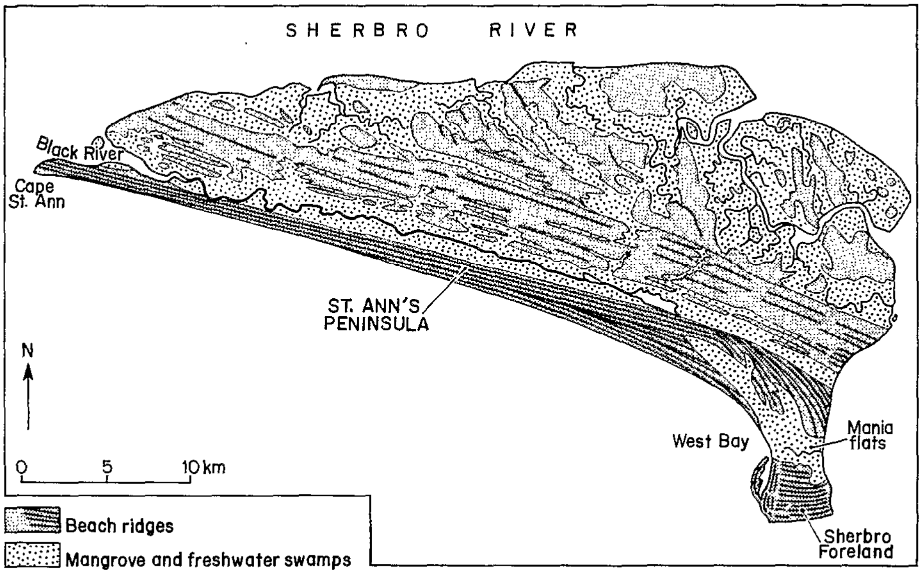


Fig. 11. — Complex beach-ridge patterns on Sherbro Island, a major prograded sand barrier complex in southern Sierra Leone, reflecting changing sediment drift cells and corresponding transport patterns.

Dispositions de cordons sableux de l'Ile Sherbro. Ces cordons montrent un dispositif de progradation importante et complexe, marqué par des cellules de dérive sédimentaire changeantes.

the Sherbro Island area and diminishes southwards as orientation of the beach-ridge plain becomes parallel to that of the shelf. A wider nearshore shelf in the Sherbro Island area prior to beach-ridge formation and a slight re-entrant of the coast created conditions for the development of a massive salient trap in a drift terminus situation adjacent to Sherbro Bay. The occurrence of double barriers separated by lagoonal arms on both Sherbro Island and the mainland is not very clear, but the most plausible explanation is probably that of a mutual adjustment between nearshore slope and river-mouth discharge within the context of a rapid sea-level oscillation. Such oscillations have been identified by various workers throughout West Africa (POMEL, 1979; TASTET, 1979; MICHEL, 1980; LANG and PARADIS, 1984), including from the Freetown Peninsula in Sierra Leone (LABOREL and DELIBRIAS, 1976). They seem to be confirmed by differences in height between beach-ridge sets on the exposed, eroding eastern flank of Sherbro Island (ANTHONY, 1990, 1991).

SUMMARY AND CONCLUSION

In terms of recent sedimentation, the coast of Sierra Leone comes out as a major junction coast between a predominantly muddy mode of sedimentation in Guinea and Guinea-Bissau to the north and a sandy mode in Liberia and the rest of the West African coast to the south. This large-scale variation reflects a fundamental change in coastal margin structure and orientation whose repercussions are expressed as changes in shelf characteristics and coastal lithology. The fore-going analysis has insisted on the occurrence of finer-scale variations in the nature and degree of progradation of Holocene to Modern coastal deposits, embedded within this regional scale transition. The two basic modes of clastic sedimentation in this area are tide-dominated and wave-dominated, and embrace deposits ranging, over relatively short distances, from simple muddy tidal flats locally exhibiting cheniers, to simple barriers, and complex sand beach-ridge plains. This diversity has provided a good occasion for qualitatively assessing the effects of spatial variations in sediment supply, wave energy and tidal range on progradation. The gradation from muddy to sandy sedimentation, expressed by distinct morphologies and stratigraphic relationships, is paralleled respectively by an increase in breaker wave energy and by a fall in tidal range, schematized in figure 12. Although environments pass from wave-dominated in Liberia and southern Sierra Leone to tide-dominated in northern Sierra Leone and Guinea, this dynamic transition is not spatially regular. This is because of the way marked spatial variations in inner shelf and nearshore morphology (Fig. 3), related in part to late Pleistocene and Holocene sedimentary history and geomorphic development, have exerted a dominant control on shoreface and littoral sedimentation by strongly affecting the marine processes responsible for redistribution and organization of available sediments. Apart from such variations in the distribution of nearshore and breaker-wave energy and tidal range (Fig. 5 et 6), rates of progradation have also depended on both net sediment influx (Fig. 4) from inland and on the capacity of wave-induced and tidal currents to transport sediment alongshore from point sources or from the shoreface, in the case of waves, and alongshore as well as from inner areas of tidal flats, in the case of tidal currents.

At a finer scale, the organization of incoming sediments by wave and tidal current processes has also depended on local shoreline morphology and on spatiotemporal changes in coastal and nearshore dynamics, including the development of wave/

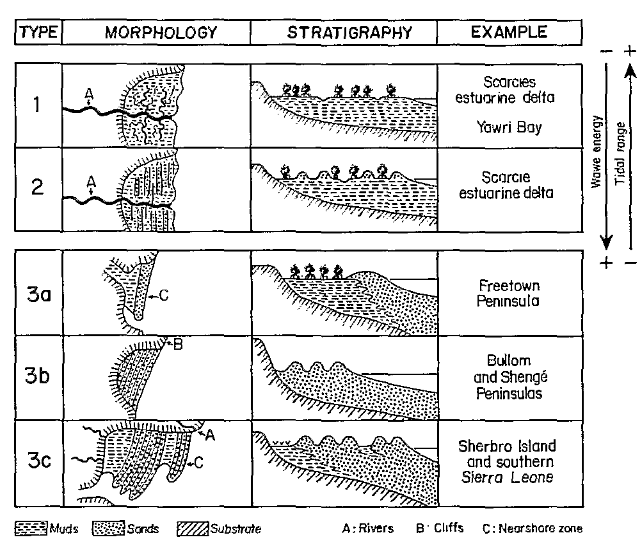


Fig. 12. — Schematic morphology and stratigraphy of muddy and sandy stationary to progradational coastal deposits in Sierra Leone. The figure shows matching schematic variations in wave energy and tidal range as well as the various sources that have fed progradation.

Morphologie et stratigraphie schématiques des dépôts vaseux et sableux stationnaires à progradants en Sierra Leone. La figure schématise également les variations d'énergie de la houle et de marnage correspondantes ainsi que les sources sédimentaires ayant alimenté la progradation.

sediment cells expressed by complex beach-ridge patterns (Fig. 11). The overall sea level context since the middle Holocene appears to have favoured forced regressive sedimentation in certain sectors, leading to thick accumulations of sand. Within the framework of the coastal and nearshore morphology, the sediment input conditions and the wave and tidal conditions outlined in the foregoing sections, the role of sea level since the end of the Post-Glacial Marine Transgression would appear to have been most marked on sediment mobility. The relatively stable to slightly regressive nature of sea level would have been such as to favour progradation under certain conditions. In muddy sectors, this would have occurred through shallowing of the nearshore sediment sink, thus accelerating rates of progradation. In sandy sectors, as a result of the regressive lowering of wave base, landward transfer of sands from the nearshore source to beach-ridges would have occurred in areas where the nearshore zone was shallow enough and where breaker wave energy has been high enough to drive these sands landwards. While the role of spatial variations in sediment supply, wave energy and tidal range appear clear, there is an urgent need to unravel the sea-level history of this coast and to assess more distinctly its effect on these three parameters within the post-middle Holocene time frame.

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