THE COASTAL ZONE OF LAGOS IN RELATION

TO

LAND RESOURCE DEVELOPMENT:

A study in Applied Geomorphology.

Thesis submitted to the Department of Geography of the University of Lagos in fulfilment of the requirements for the award of the Ph.D. Degree in Geography in June, 1975

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ABSTRACT

This thesis is written in two parts. Part one examines the environmental setting and the theoretical background to the evolution of the landforms in the coastal zone of Lagos, as well as the characteristics of the geomorphological problems in the area. Part two which covers chapters four to eight examines the techniques used in the study of land resource development in the coastal zone and elucidates the manner in which data were collected and the use of the data for land classification. Finally an appraisal of the significance of geomorphology to physical planning in general is made.

Chapter one consists of a critical examination of the environmental setting of the coastal zone of Lagos in relation to geology, past climatic and sea level fluctuations, vegetation and soil patterns and sequent occuppance; with a view to giving the work a sound geographical background. In continuation of the examination of the environmental setting of the area, Chapter two examines the genesis, the pattern of development and the spatial organization of landform units in the coastal zone. However, chapter three examines three geomorphological problems viz: 'land subsidence', beach erosion, poor drainage and flood hazards as part of the effect of man's interruption of natural land form processes.

With this background knowledge, chapter four describes in detail the various techniques used in the study of land resource development in the coastal zone such as sediment analysis, aerial photograph interpretation and geomorphological mapping. In chapter five, the details about the character of the sediments of the area are given while in chapter six the classification of the land in the coastal zone into units of distinct characteristics was carried out. The classification was further translated into a land classification map on a scale of 1/40.000 while a detailed geomorphological map of the western half of the coastal zone is presented at a scale of 1/20,000.

In chapter seven a brief examination of the relevance of geomorphology to physical planning in the Lagos Coastal zone is examined and proposals for how these problems can be avoided in the undeveloped areas are given as a conclusion to the Chapter. In chapter eight the conclusions drawn from the study are identified and summarised and specific recommendations are made with special emphasis on the necessity for geomorphological surveys to preceed the development of the land in the area.

The appendices are a collection of specialised techniques used in the gathering of data for this thesis.

Appendix one shows the list of statistical formulae used in the calculation of the grain size parameters of the sediments, while Appendix two shows the flow diagram used in the separation of the accessory minerals. The computer program used in the actual calculation of the units for determining the sediment characteristics is shown in Appendix three. The list of abbreviations used, areas of beach erosion along the Guinea coastlands, the explanation of the terminologies used in the thesis and a map of the various sediment groups in the coastal zone are shown in Appendixes four, five, six and seven respectively, while a list of texts read and used during the preparation of this thesis follows.

PREFACE

Most of the geomorphological studies carried out in Nigeria to-date, (Pugh 1956), Abegunde (1966) and Jeje (1971) emphasise the genesis and evolutionary history of some of the landforms. The few attempts made at the application of the deductions from geomorphological studies to the problems of land resource development in Nigeria include the works of Ofomata (1965) on soil erosion in Enugu area, Ologe (1969) on soil erosion in Zaria and Moss (1968) on soil resources (for agriculture) in parts of S. W. Nigeria. Except the latter, the other two works are unpublished thesis submitted for higher degrees in Universities outside Nigeria and hence they made no impact on land resource development programmes in Nigeria. The works of Moss (1965, 1968) associated particular soils to slopes and landforms, and his works are significant mainly to soil classification for agriculture (Pullan 1968). It is therefore, the primary objective of this thesis to examine not only the detailed evolutionary history, genesis and pattern of landform development in the coastal zone of Lagos, but also to apply the deductions from the character of the land to the problems of land resource development for settlement expansion in the area.

The study involves a detailed and critical analysis, and an interpretation of landform character, with a view to deciphering the attributes of the land such as the spatial organisation of landform units and the nature of subsurface drainage in the coastal zone of Lagos. The data relating to each of the attributes have been collected from sources varying from aerial photographs to field studies of the land-forms and detailed analysis of sediment characteristics of the area. The data on landforms and sediment character derived have been used to compile a detailed geomorphological map at a scale of 1/20,000.

The other aspect of the study is concerned with the application of data collected to the problems of land resource development in the Coastal zone and comprises the classification of the land into units of similar attributes; the translation of this classification into a land classification map on a scale of 1/40,000 for the whole study area and an examination of three geomorphological problems related to development in parts of the city of Lagos.

This aspect of the work involves the classification of the 'undeveloped' lands into land units based essentially on the 'convergence of evidence' derived from the analyses, viz: aerial photographs, sediments and landforms. The criteria for classification include landform, hydrography, sediment character and vegetation type.

Furthermore, the significance of the application of geomorphological principles to physical planning is considered in the light of the problems of the scarcity of good quality land and the deterioration in the quality of available land in the coastal zone of Lagos. Suggestions are made on how to prevent the recurrence of such problems in the undeveloped areas. The indispensability of the application of geomorphological principles to land resource development problems in the Lagos Coastal Zone is made manifest and cooperation between specialized disciplines interested in the development of land in Lagos is recommended.

It is hoped that the classification proposed as well as the map of the area compiled will provide the foundation for the development of a data-storage bank for the land in the coastal zone of Lagos, from which details concerning the character of each land unit can be derived, thereby enhancing the understanding of the character of the land before a comprehensive land resource development programme is planned and executed. A knowledge of the nature of the 'land problems' in the developed areas, it is hoped, would encourage future planners to take account of geomorphological factors so that such problems may not occur in the same dimensions again. With the detailed knowledge of the land elucidated by this thesis, it is hoped that suitable land areas would be allocated to fitting land use types and the use of land classification may have to be an indispensable prelude to land resource-development.

However, it is necessary to indicate here that sophisicated equipment were not available for my use during the preparation of this thesis. For example, I relied wholly on the pocket stereoscope for the study of aerial photographs; and the hand trowel for sampling sediments because they were the ones available. However, the deductions from available equipment proved satisfactory and used accordingly in this thesis.

At this point, I must acknowledge the efforts and assistance of the followisg persons and establishments to the success of the study. First, my gratitude and indebtedness go to my Supervisor, Dr. M. A. A. Abegunde, for his guidance and interest demonstrated many times by going out into the field with me. Even when he was away from the Campus for one session he continued the supervision effectively by post and has thus successfully brought the work to this stage. I owe a great deal of gratitude to him for his words of encouragement between 1973 and this date. I also acknowledge the interest shown in my work by the Acting Head of Department of Geography, Dr. I. A. Adalemo when he assumed office late in 1975. Furthermore, my gratitude goes to every member of staff of the Geography Department for their interest in my work and for coming to my aid at all times.

I am also grateful to members of staff of the Geology Department of the University of Ibadan, especially Professors Oyawoye, Burke and Dessavauggie and to Mrs. Bisi Durotoye and Dr. Dayo Adeleye who assisted me in the analysis of the sediments of the Coastal zone. My thanks go to Professor J. R. I. Allen of the Sedimentology Research Laboratory of Reading University and Dr. G. A. Stewart of the Land Research Division of the Commonwealth Scientific and Industrial Research Organisation, Australia, and the Military Engineering Experimental Establishment of Christchurch in Britain for making some rare documents on the field of study available to me on request.

I must not forget to express my gratitude to Dr. F. O. Ekogbulu of the Department of Computer Sciences and Dr. E. A. Adeboye of the Department of Mathematics both of the University of Lagos, who were co-graduate students and who gave me their companionship and encouragement; and to my daughter OLANREWAJU, whose arrival into this family at the time of study gave me a lot of inspiration, and to Patsy for her words of encouragement.

Lastly, my thanks goes to Mr. J. O. Ehiagwina of College of Education, Abraka who helped in the final typing and printing of this work.

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CHAPTER ONE

THE ENVIRONMENTAL SETTING OF THE COASTAL ZONE OF LAGOS

This chapter gives a general background analysis of the physical environment of the Lagos Coastal zone within Nigeria in particular and West Africa in general. The environmental factors analysed include, the spatial extent, the geological history, the effects of climate and sea-level changes on the evolution of the coastal zone, broad relief characteristics of the area delimited for study, the vegetation and soil patterns as well as aspects of the human occupance and its consequences. The examination of the factors enumerated above follows in the succeding paragraphs below.

1.1. THE SPATIAL EXTENT OF THE COASTAL ZONE

The coast of any place is defined by Bird (1968), as the area of land extending from the foreshore to the limit of marine influences inland and includes for example, old beaches, abandoned sea-cliffs, limit of salinity in the coastal waters, beach terraces and the limit of tidal movements along the margins of coastal rivers. This concept aptly describes the essential character of what should be regarded as the limits of any coastal zone, because most of the coastal zones of the world have changed over time either as a result of eustatic sea-level fluctuations or tectonic processes so that fossil beaches and cliffs may still form part of any coastal area delimited for study.

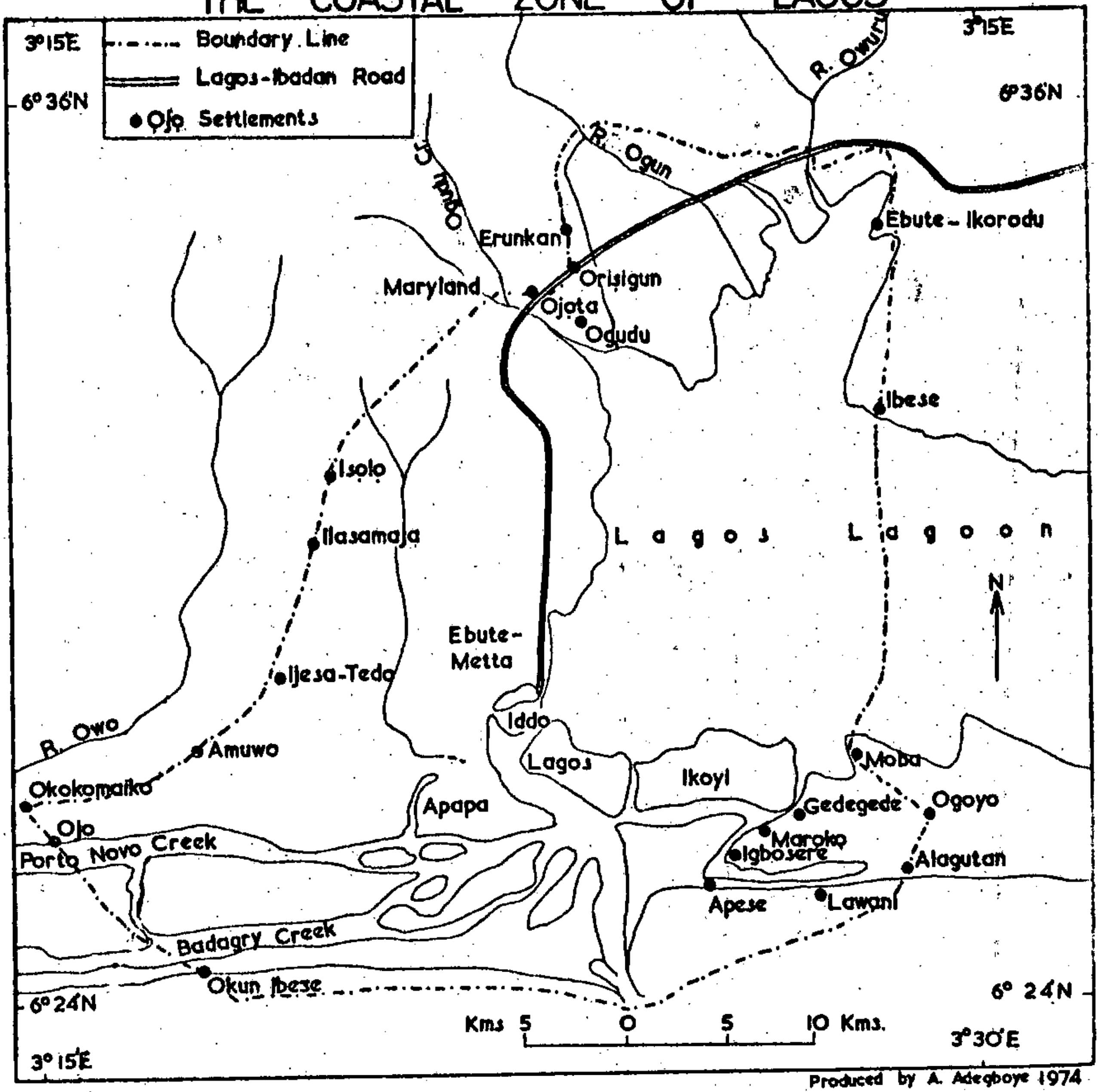
Moreover, these fossil marine features retain many coastal attributes such as high level of underground water, estuarine characteristics, marine sediments and evidences of marine processes and morphology. The distribution of salinity in coastal waters marks the limit of marine, brackish and fresh water environments, while the tidal flood is an efficient medium for salinity distribution. From the foregoing, it seems that a coastal zone can be reliably delimited by the application of this concept.

Apart from the suitability of the concept for the delimitation of the boundaries of most coastal zones of the world, it is also appropriate for the definition of the coastal zone of Lagos. For example, the foreshore areas extend for about twenty metres into the sea on the Atlantic coast beyond the active sandy-barrier formation. The limit of tidal movements has been found north of the bridges over rivers Ogun and Majidun on the Lagos-Ibadan road, and West of Kirikiri village near Port Novo creek in the West. It has also been encountered as far east as Moba and even beyond into the Epe channel, while the whole of the Lagos lagoon system is effectively covered by the tidal movements from the sea. Fossil marine features such as sandy-barrier formations occur in an east to west pattern in three successions, some six kilometres inland from the active sandy barrier on the Atlantic ocean beach; while the old post-glacial shore-line cut in the Coastal Plain Sands along the periphery of the Lagos lagoon marks the northern limit of the coast. (See Fig. 1.1)

The area referred to in this thesis as the coastal zone of Lagos extends from about Latitude 6°24'N to 6°36'N and Longitude 3°15'E to 3°30'E. It covers the area of land north of the wave-beaten active-sandy barrier between Okun Ibese in the west and Alagutan village in the East. The eastern boundary extends along a line passing through the villages of Alagutan, Ogoyo and Moba, across the Lagos lagoon through Ibese, to Ebute-Ikorodu in the North-east. The northern boundary is marked by the Lagos-Ibadan road to the Ogun river bridge where it extends along the river to the Ogun/Agboyi confluence at about latitude 6°36'N and longitude 3°22'E. This is further marked by a line from the Agboyi/Ogun confluence through Erunkan, Orisigun, Ojota, Maryland, Osodi, and Isolo. The Western boundary runs from Isolo, through Ilasamaja, Ijesa Tedo, Amuwo-Odofin, Okokomaiko, Ojo and to Okun Ibese on the Atlantic ocean. The area enclosed by this boundary is depicted by Fig. 1.1.

The area of study covers about 340 sq. km. of which over half is covered by open water, and one quarter already

FIG.1·1
THE COASTAL ZONE OF LAGOS



Produced by A. Adegboye 1974

developed and settled, while the remaining 100 sq.km. consist of undeveloped swamps, sandy-barrier formations and alluvial plains. Except for the area of land between Ogudu, Orisigun, Ojota and Isolo settlements in the northern parts where the deposits are mainly ferruginised sands of Plio-Pleistocene age, all other areas consist of Holocene deposits, resulting from fluvial, lagoonal and marine sedimentation. All over this area the generally low relief, loose sandy deposits and the occurence of a high level of underground water account for their common land-form characteristics.

Most of the terrestrial and marine deposits are arranged in linear east-west patterns in response to the direction of wave approach to the beach which is south-westerly and the longshore drift which is west to east. The characteristic complex net-work of lagoons and creeks in this area is related to the location of the mouths of rivers Ogun, Majidun, Afa and the Badagry creek within its boundaries, while the west-east orientation displayed by the lagoons reflects the processes involved in the formation of the sandy-barriers and ultimately an evidence for the phases of sea regression in this area.

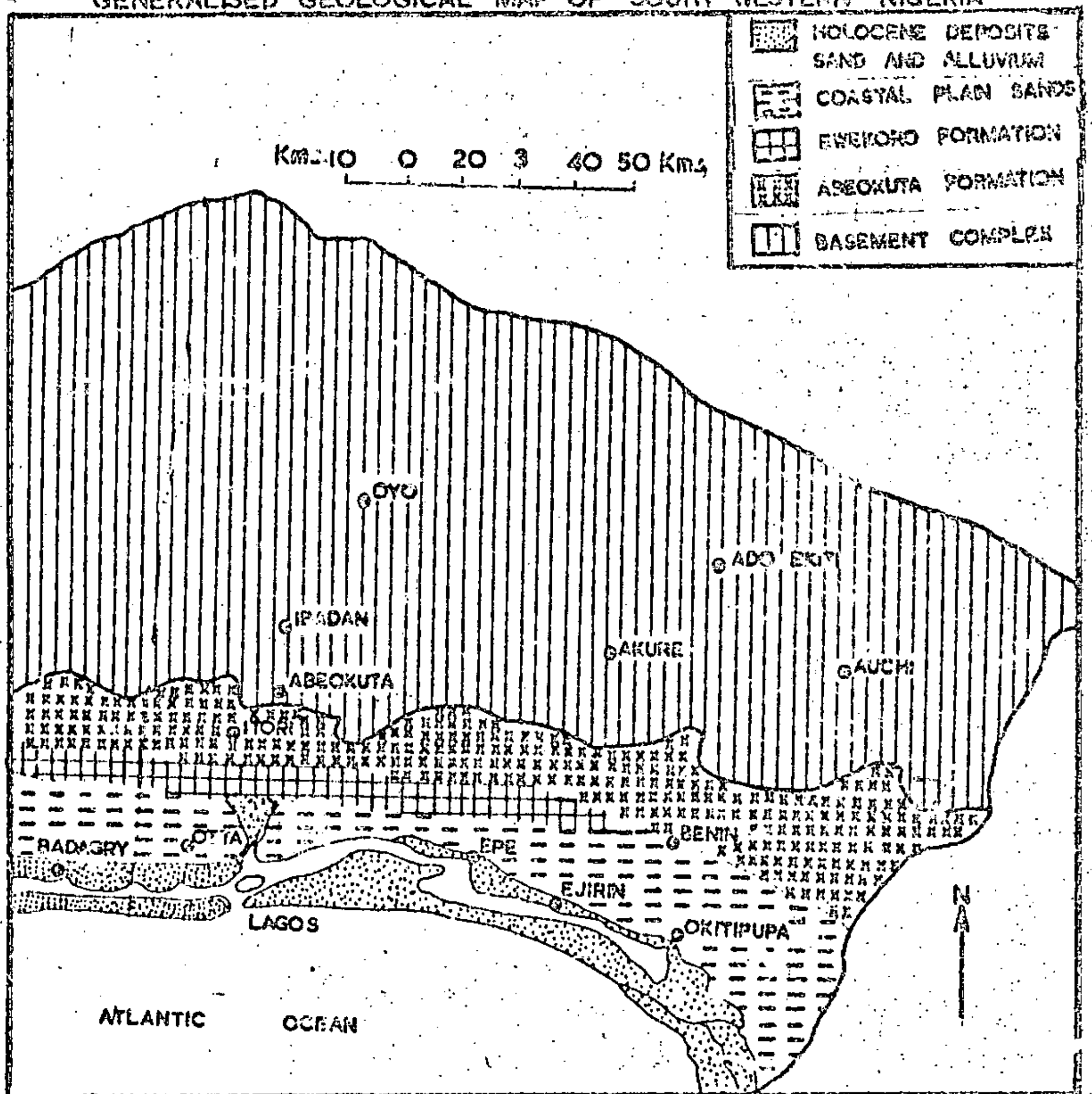
1.2 GEOLOGICAL HISTORY

The coastal zone of Lagos lies along the southern and most recent part of the sedimentary basin of south-western Nigeria, which extends westward to Dahomey. The sedimentary basin of south western Nigeria is clearly shown in the Geological map of the area depicted in Fig. 1.2. Geologic and Geophysical investigations made by Mobil Oil Nigeria Ltd. (1960) in the coastal zone, indicated that the subsurface strata consist of a great thickness of loose sediments which reached a depth of 2,100 metres through materials of Cretaceous, Tertiary and Quaternary ages. It has also been documented that sedimentation has continued in this area and the other lowlying areas of the Guinea coastlands since the Upper Cretaceous transgresion (Le Bourdiec 1958), (Jones and Hockey 1964).

Also, the Guinea coastlands including the Lagos Coastal zone witnessed a downwarping of the basement rocks at different times and rates. It has been reported that the gradual sinking of the Niger-Benue trough (Furon 1959), (Reyment 1964), was followed by a renewed down-warping of the Coastal margins of Nigeria in the Eocene period. (NEDECO 1959). It is thus most probable that this area has witnessed a gradual sinking of the bed-rock which, apart from regional down-warping, may be due to local flexure of the continental margin (Furon 1959), or subsidence due to sediment load and/or compaction. Similar explanations have been adduced for the sediments of the Niger delta. (NEDECO 1961), (Allen and Wells 1962).

Since the Holocene, about 10,000 years ago, the magnitude of sedimentation has been relatively low, as shown by the depth of recent deposits, which in their thickest parts were

FIG. 1·2
GENERALISED GEOLOGICAL MAP OF SOUTH WESTERN NIGERIA



Courtesy of Jones & Hockey '74

found to be about eighteen metres thick from the top layer of the Coastal Plain sands of the Ikeja Plains. (Abegunde 1966), Foundation Engineering 1971). The rate of subsidence west of the Niger has been reported to be very slow (Allen 1964b) as it is evident by the inability of the Ogun and Majidun rivers to fill their embayments. However, sediment accumulation continues in the lower Ogun embayment at a reduced rate as indicated by the existence of underwater deltas in the mouths of Ogun and Majidun rivers and the building of a two-kilometre peninsular into the Lagos lagoon. These features are illustrated in Fig. 1.10 on page 43. If the depths of sediments given above illustrate the intensity of sedimentation, the present rate seems to be relatively slower than that of the Holocene times.

Although there are three broad stratigraphical-units depicted in Fig. 1.3 on page 9, only two - the Plio-Pleistocene and Holocene deposits, lie within the area delimited for this study; while the third, the Eocene deposits, do not outcrop in any part of the area of study, but form the basal bed of the other deposits as shown in Fig. 1.4. The Coastal Plain sands, which are Plio-Pleistocene in age, (Furon 1959), (Jones and Hockey 1964) appear to rest on the Ilaro formation; probably unconformably since there existed some minor disconformities. (Jones and Hockey 1964). However, the boundary between the two stratigraphical units is marked by a change in the colour of

FIG 1.5

GENERALISED GEOLOGICAL MAP OF THE COASTAL ZONE.

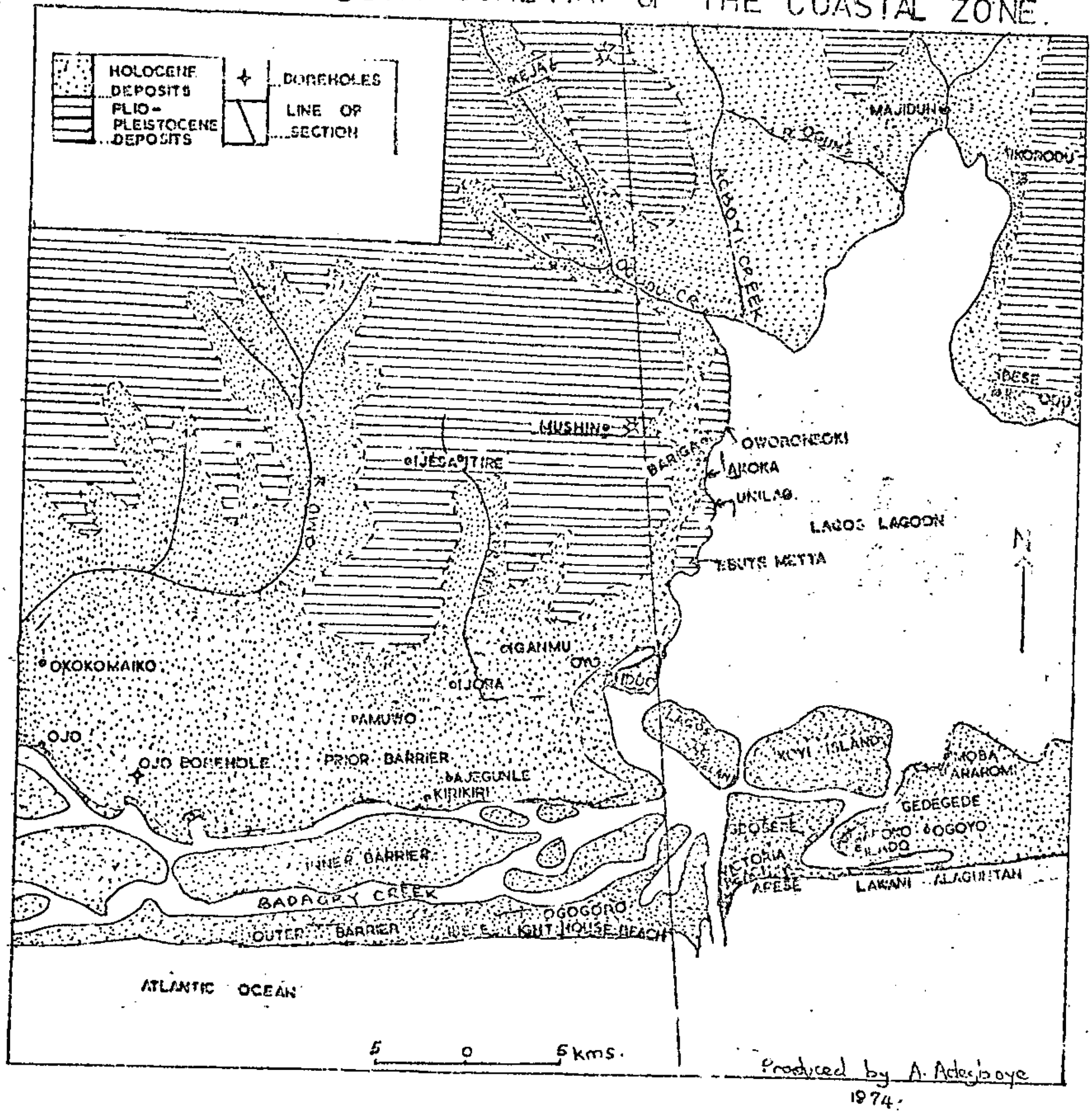
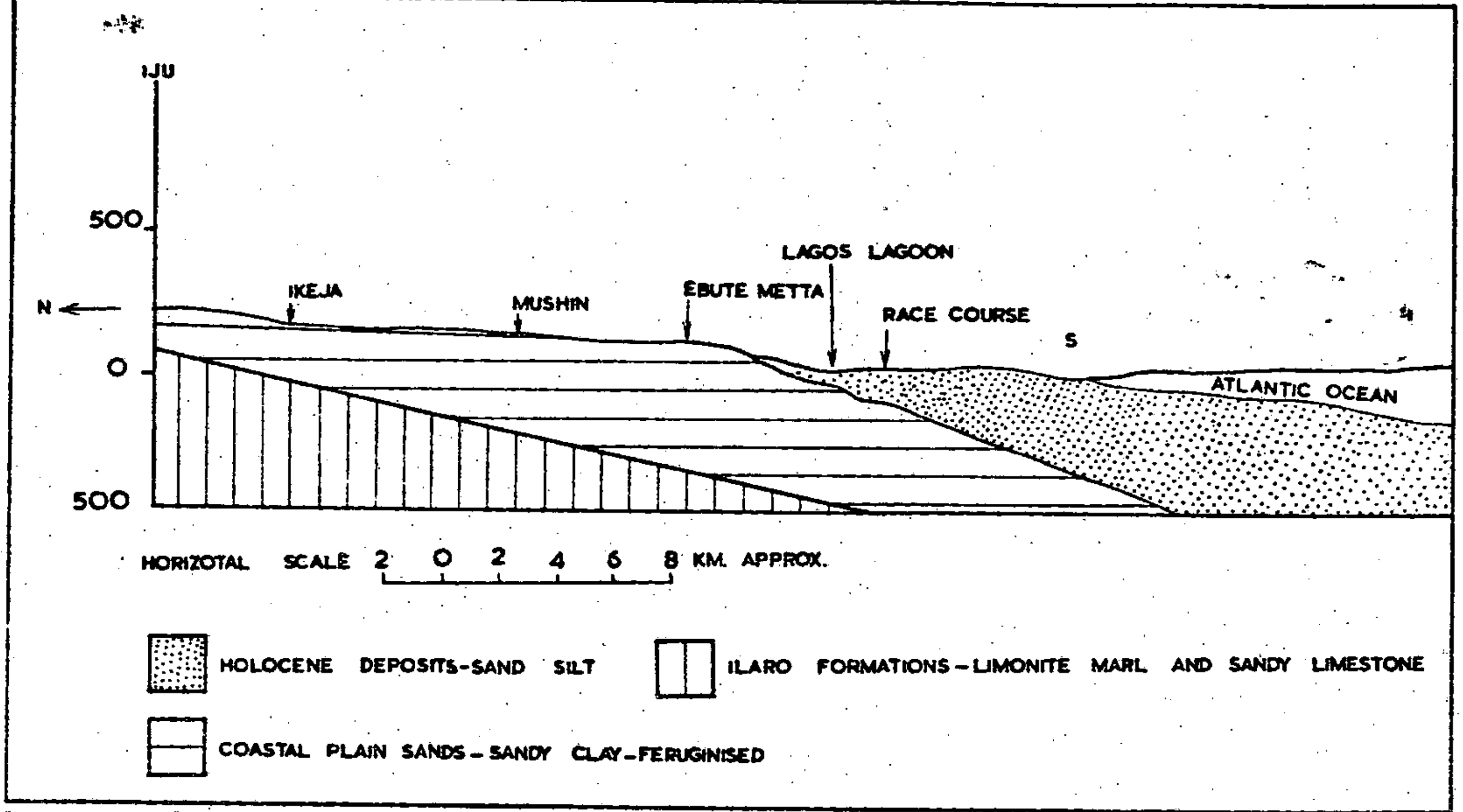


FIG. 1.4 GEOLOGICAL SECTION FROM IKEJA TO THE SEA IN LAGOS COAST



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the sediments from oxidised sands on top of the Ilaro formation to the coarse grained reddish sands of the Coastal Plain sands. Although the Ilaro formation is essentially of marine origin, the upper layers were sufficiently exposed to atmospheric weathering as to allow the oxidation of a depth of about four metres of soil before the deposition of the lower beds of the Coastal Plain sands.

From sedimentological and stratigraphical evidences it appears that the sediments of the Ikeja Plains of Plio-Pleistocene age were continental deposits, and were probably brought there by rivers. However, apart from colour changes, the occurence of marine derived micro-fossils such as Gastropoda, and Lamellibranchia species (Reyment 1964) in the Ilaro formation supports the concept of its marine origin. The dissected cliffs of the 'old shoreline' shown in Fig. 1.10 on page 43, mark the surface boundary of the Coastal Plain sands and that of the Holocene deposits. The depth of those deposits is illustrated by a borehole at Ikeja by the Nigeria Geogical Survey (1960) which went down through the Coastal Plain sands to a depth of about 105m. before encountering the deposits of Ilaro formation. (Jones and Hockey 1964). This Plio-Pleistocene sediments consist of angular quartz sands of about - 1Ø in diameter, and rounded pebbles of about - 3Ø in diameter, while the top 18m. are coarse, reddish in colour, and ferruginized. (Jones and Hockey 1964).

The Holocene deposits rest on a down-warped basin floor and are found to be thickest in the Ogun valley in the north, where the depth is about 18m. They comprise fluvial, lagoonal and marine deposits. On the old sandy-barrier formations, the characteristic loose sands is about 47m. at the Lagos Race Course, (Jones and Hockey 1964), 32m. on the Lagos Island (Foundation Engineering 1969), 24m. in the Ojo Borehole(Mobil Oil Nigeria Limited 1960). These contain alternating beds of sand, silt and clay which are combinations of marine and lagoon derived sediments. Also the differences in its thickness in the two locations indicate the greater degree of downwarping of the basement in the western than in the eastern part of the coastal zone.

It is difficult to build a detailed and reliable stratigraphy for this coastal zone now, because of the loose nature of the sediments, the paucity of borehole specimens and dating facilities. The account given in this thesis is basically to show the physical characteristics of the sediments. However, it is possible at this stage to establish that the sediments of the Lagos Coastal zone consist of loose sands alternating with clay, alluvium and peat. One may infer that the alternating thin beds of sand and silt characteristic of the edges of the lagoons may represent 'wash down' from the top of the sand-ridges during their early stages of development. The elucidation of the stratigraphical characteristics of this area helps in the understanding of the land character and may help in the classification of the land, because areas of thick beds of silt, peat or alluvium have been found to be prone to localised land-subsidence while areas of thick beds of sand are relatively stable.

The stability of any land area depends not only on the various sediment characteristics but also on the susceptibility of such an area to diastrophic forces, which may either be earth-quakes, faulting or vulcanicity. As far as the Coastal zone of Lagos is concerned - there has been no report of any vigorous diastrophic or tectonic activity from the available literature, nor are there field evidences to support its occurrence. However, there have been reports of tectonic activity in surrounding areas like the rupture of the Niger-Benue trough, the sharp flexures in the continental margin of the old basement rock in Dahomey (Furon 1959) and the continued subsidence in the Niger Delta (Allen and Wells 1962), which might have some marginal effects on the Lagos area. In other parts of West Africa, reports of faulting have been published, (Le Bourdiec 1958), (Burke 1969). The major earth movements along the existing coastal margin during the Palaeozoic and the Oligocene, which gently tilted the strata into the Atlantic Ocean, giving rise to very thick Cretaceous and Quaternary deposits (Allen 1964).

Recent investigations from all parts of West Africa support the concept of general earth-movements along the

Coastline for example Le Bourdiec (1958) reports "the southward sinking of the underlying shield" in Grand Bassam, Ivory Coast, while (Burke 1969) identified two faults in Dahomey and a considerable movement along the foot of the Akwapin hills in Ghana in the Quaternary. The great thickness of Tertiary and Quaternary sediments along the West African Coast put at 1,077 metres in Grand Bassam (Le Bourdiec 1958), 1,800m. in Dahomey (Furon 1959), 2,100m. near Ojo village west of Lagos in Nigeria (Mobil Oil Nigeria Limited 1960), and in the Niger Delta with a sediment thickness of about 10,500m. (Allen and Wells 1962); and the Accra earthquakes of 1939, point to a fact that the sinking may have continued up to the present time.

In the Lagos coastal zone the known form of earth movement is the gradual down-warping of the basement which is evidenced by thick mantle of sediments overlying the basement as illustrated by the depth of 2,100m of Tertiary and Quaternary sediments found in the Ojo borehole.

The influence of tectonic activities seem very neglible to be reckoned with as a factor in the evolution of the Lagos Coastal zone since about 20,000 years B.P., especially when the area west of Okitipupa has been classified as relatively stable when compared with the Niger Delta (Allen 1964b), and no visible field evidences of tectonic activities was encountered during the period of studying this area. It is therefore possible to disregard diastrophism as a criterion for land-form evolution and [illegible] a factor to be considered for land classification in the Coastal zone.

1.3. SEA LEVEL FLUCTUATIONS AND PAST CLIMATIC CHANGES

The background analysis of the Lagos Coastal zone will not be complete without a discussion on the sea-level movements and the changes in climate which together influenced the patterns of evolution of the coastal landforms. The sedimentary basin of Western Nigeria has witnessed a series of sea-level changes dateable from the invasion of the Upper Cretaceous sea in to the Southern area of the city of Abeokuta (Tattan 1943, Jones and Hockey 1964). Evidences of this transgression include the occurrence of alternating beds of sand and sandy-shales of Upper Cretaceous age, known as the Abeokuta formation. The details about the location of the geological formations are illustrated in Fig 1.2 above. The deposits of the Abeokuta formation rest conformably on the basement rock at Itori. South of this town, a borehole was sunk through the sediments to a depth of 270m, before encountering the basement rock (Nigeria Geological Survey 1960). These sediments have been identified as of the Danian age in Dahomey (Furon 1959).

Before the withdrawal of the sea from this area, large deposits of continental sediments were laid down in a 'shallow sea', probably due to fluvial deposition especially from the

Yewa, Ogun and Oni rivers. (See Fig. 1.2 for the location of these rivers.) These materials were later overlain by limestone and shale deposits known as Ewekoro formation and shown in Fig. 1.2 as a thin band sandwiched between the extensive Abeokuta formation to the North and Ilaro formation to the South. These were essentially shallow marine deposits, because they combine marine characteristics like glauconitic sediments and calcareous materials which developed into shales and shelly limestones now quarried for the manufacture of cement at Ewekoro.

The regression continued into the middle and upper Eocene periods, and was marked by the occurrence of coarse grained sands and phosphatic beds generally referred to as the Ilaro formation. (Jones and Hockey, 1964). The Oligocene and Miocene periods were probably marked by deep-sea and extensive sedimentation when the upper sediments of the Ilaro formation were laid down. A regressive phase followed this during the Pliocene, when continental deposits were laid down as the basal beds of the Coastal Plain sands.

Existing literature on sea-level changes along this coast refers only to the period between the Pliocene and the Upper Cretaceous. This may be due to the fact that no detailed study of the Holocene sediments has been carried out, and perhaps when this is done, more details would be available about the character of the Holocene deposits.

Attempts have been made in other parts of West Africa to reconstruct the sequence of sea-level changes in the Quaternary based on evidence from landform features like beach terraces, (Davies 1964) and sedimentary deposits and their structures, (Le Bourdiec 1958, Tricart 1962, Slansky 1962). Evidences from landform morphology are difficult to find in areas of loose sediments such as those in this study area, as the presence of river terraces may not be reliable in areas of evident downwarping of the basement such as in the Coastal zone of Lagos. The reconstruction of the sequence of sea-level changes in this study area is therefore derived from the origin of sediments. Where marine derived sediments are available in large quantities, such a period is 'tagged' a transgressive phase and when the majority of sediments are terrestrially derived, it is classified as regressive phase. Also, the succession of sandy-barrier formations has been used to reconstruct the sequence and pattern of sea-level fluctuations along the coastal zone in the Quaternary, because the emergence of sandy-barriers has been used to indicate periods of lower sea-level, as evident in the works of Johnson (1919), Shepard (1963), and Zenkovitch (1967).

The down-warping of the basement rock in the Palaeozoic and in the Oligocene, (Allen 1964) was probably responsible for the extensive sedimentation along the continental margin of South Western Nigeria, and the formation of the basin in to which the continental deposits of the Plio-Pliestocene periods were laid. The subsequent transgression probably initiated the indented edges of the southern margins of the Undulating plains. The withdrawal of the sea southwards from this point initiated the sandy-barrier fromations which consist of Holocene deposits.

Along the lower courses of the Ogun and other coastal rivers in this region, there are terraces on both sides of the valleys which might be the result of river incision during a dry climatic phase. In Senegal, Tricart (1960) correlated the periods of regressions and transgressions with dry and wet periods and Allen (1964) indentifies corresponding low sea-levels in the Niger delta with dry conditions. Also Burke and Durotoye (1971) stated that during the Pleistocene glacial-maxima, the Harmattan blew for much longer periods and the rejuvenation of river valleys occurred in South Western Nigeria. The likelihood of the coincidence of the downwarping of the basement with the fall of sea-level may not be ruled out, but has not been documented or proved.

Below the cliffs of the old shoreline, two terraces similar to those of the lower valleys of the coastal rivers and consisting of sands with shells of marine organisms such as molluscs and <u>anadara</u> species are found. (See Fig. 1.10 on page 43 for the location of these terraces.) The terraces seem to indicate phases of the fall of the sea-level, while the occurrence of shells of calcareous organisms in them confirms the extension of the transgression to the cliffs. The height of the cliffs which varies between 4.5 metres and 6 metres indicated the relative position of the sea-level, while the occurrence of valley re-entrants and inlets on them, illustrates the position of valleys which probably predated the marine incursions.

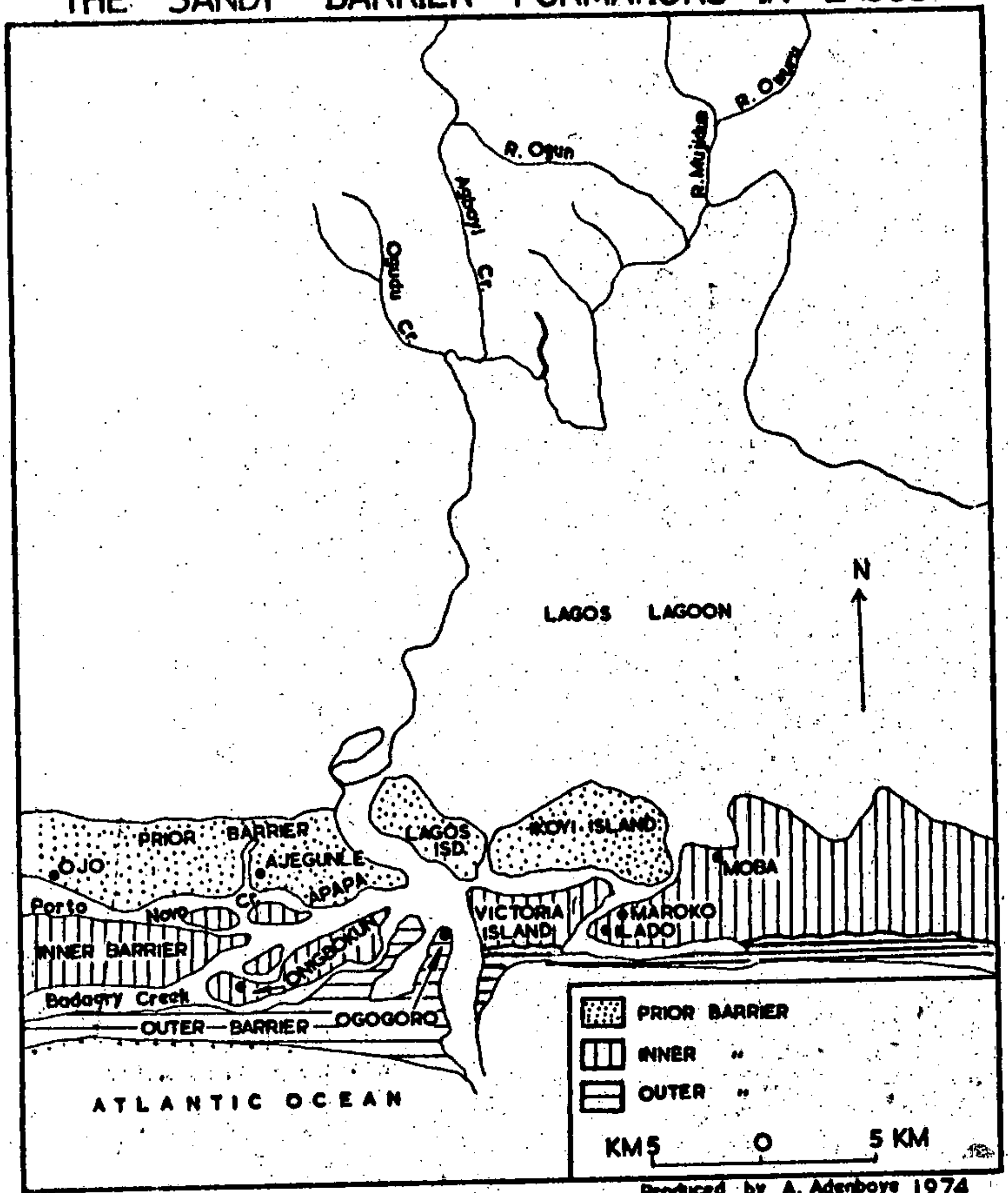
The role of sea waves during the high stand of the sea in modifying the re-entrants cannot be ruled out, hence the sea cannot be regarded as a causal factor but a modifying agency in their evolution. The widened re-entrants and the old-shoreline cliffs are not limited to the Lagos Coastal Zone alone, but have been found westwards through Ologo lagoon to Badagry, and eastwards to Epe and Ejinrin and have been documented in Okitipupa by Adegoke (1969) and West of the Niger (Allen 1964). If follows that the fluctuations of the sea-levels took place simultaneously throughout the South-western Nigeria sedimentary basin, as depicted by marine built landforms which are common through out the region. The location of the towns named above can be found in Fig. 1.2 on page 7.

Evidences of sea-level fluctuations can further be substantiated by the depths of Holocene deposits at various locations in West Africa. For example, the original bed of river Volta in Ghana is said to be 18 metres deep, Davies (1964); while the original bed of the Queme in Dahomey is put at 25 metres Furon (1959). Davies (1964), and Jones and Hockey (1964) drew a similarity between the depths of the original beds of the Queme and Ogun, while during a discussion with the site Engineer at the bridge over river Ogun in 1972, it was established that the depth of the alluvial materials at that point is over 18 metres. If the former beds of these rivers mark the former sea-level as contended by Pugh (1954a) and Slansky (1962), it follows that the sea-level has risen higher since that time in these places to have produced such a thickness of fluvially derived materials.

The existence of a Canyon off the coast of Lekki (Allen 1965), in the Western part of the Niger Delta outside the area of study, and the occurrence of a fossiliferous sandstone in the continental shelf off Accra in Ghana at a depth of 25 metres and identical with the present beach rock there, (Bruckner and Morgan 1965), are suggestive of former lower sea-levels along this coast. It is thus being established that the Pleistocene ended with a regressive phase due to glacio-eustatic fall of the sea-level, and was succeeded by a transgressive phase at the beginning of the Holocene.

The first retreat of the sea during the Holocene probably marked the emergence of the 'Prior' barrier. This sandy-barrier formation can be traced east-wards to Lagos and Ikoyi Islands and west-wards through Apapa, Ajegunle and Ojo village as shown in Fig. 1.5. Butzer (1964) and Zenkovitch (1967),

FIG.1·5
THE SANDY BARRIER FORMATIONS IN LAGOS



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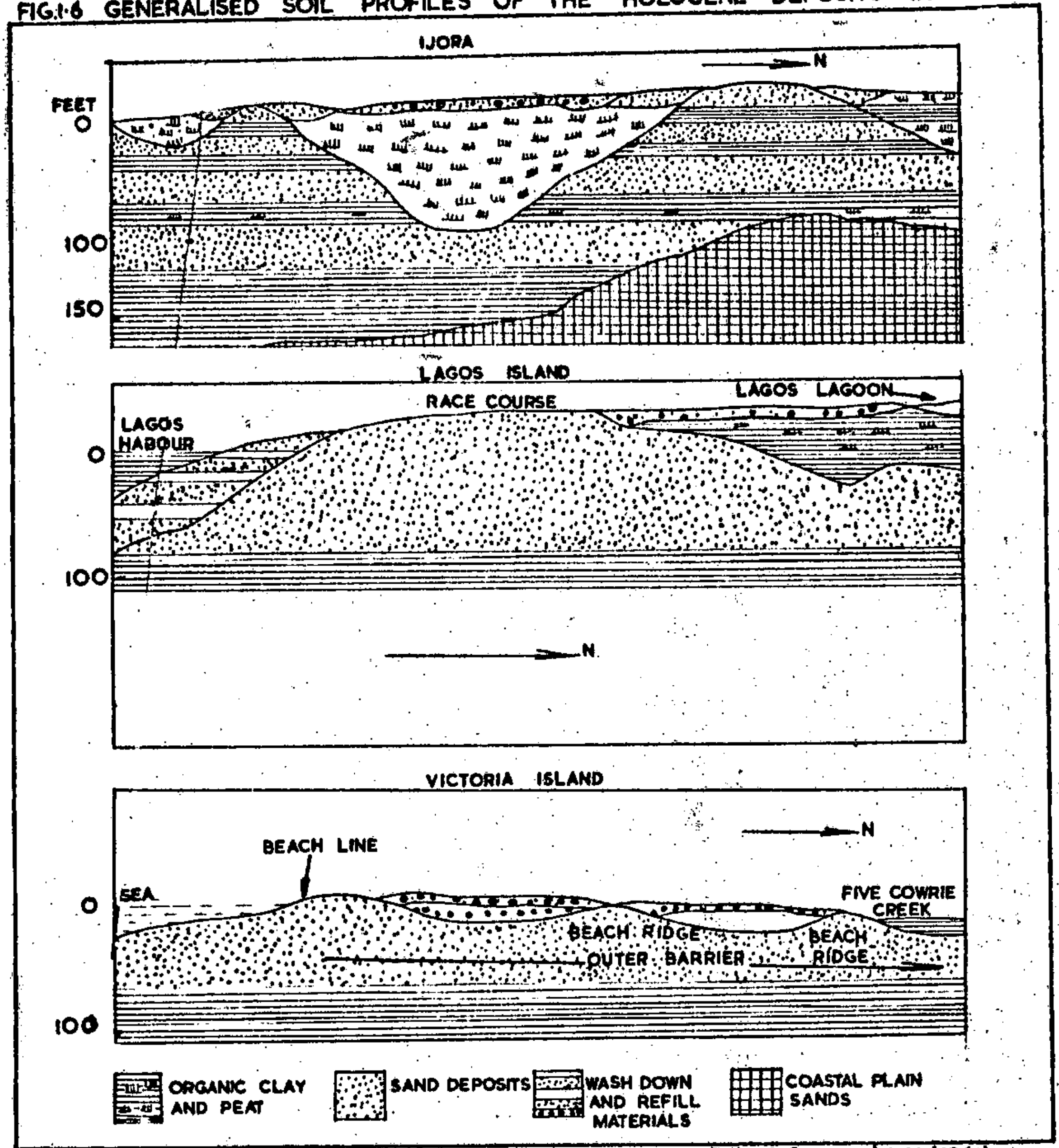
showed that barrier beaches and lagoons in the Quaternary could be associated with sea-level fluctuations. In fact Zuenner (1961) stated that former sea-levels in the case of bar and lagoon coasts lie somewhere between the level of the lagoon and the mean elevation of the bar. It follows that the former sea-levels probably lie somewhere between the level of the lagoons and the most adjacent beach ridges on this coast. Hence the succession of barriers along this coast has been used to illustrate the various phases of sea-level fluctuations. For example, if the Prior barrier represents a period of lower sea level, the Inner barrier; extending from Onigbokum, and Ogogoro villages in the west, breached by the Lagos harbour channel, and continuing through the Victoria Island, Maroko, Ilado and Moba as shown in Fig. 1.5., marks another phase of lower sea level, while the period of the formation of the present sea beach marked another low sea-level phase.

Evidences from vertical profiles in Fig. 1.6, which were cut through the sandy-barriers show a succession of sands, clays and peat. The sediments probably give indications of the various deposition environments in existence at that time, such as marine beds of deep sea environment and probably during transgressive phases, while the beds of clay and peat may represent the lagoonal deposits that usually follow the regressions after the sandy-barriers have 'emerged'.

FIG.1·6 GENERALISED SOIL PROFILES OF THE HOLOCENE DEPOSITS IN LAGOS



Courtesy of Federal Surveys Lagos (1961)

Table 1.1

SUGGESTED STRATIGRAPHICAL SUCCESSIONS IN THE COASTAL ZONE OF LAGOS

HOLOCENE DEPOSITS - LAGOS ISLAND

SEDIMENTARY STRATA	THICKNESS		PROBABLE AGE
Grey white sand	12	metres	Upper Holocene
Coarse grained sand	12	"	
Grey brown sands	3	"	
Variagated Coarse sands	10.5	"	
Carbonized black clay	3	"	Upper Holocene
Light grey and shelly silt	4	"	
Sand and clay	3	"	
Dark grew and shelly silt	1	"	
Limonitic sand stone	4	"	Upper Holocene
Black clay	1	"	

PLIO-PLEISTOCENE DEPOSITS - MUSHIN LAGOS MAINLAND

SEDIMENTARY STRATA	THICKNESS		AGE
Top 'soil'	0.6	metres	
Very sandy clay	10	"	Upper Pleistocene
Very coarse red sand	1	"	
Clayey sand	9	"	
Pink pebbles/sand	7	"	
Clay/fine grained sand	9	"	Lower Pleistocene
Silty clay	7	"	
Calcareous clay	14	"	Middle Pliocene
Silty clay	6	"	
Sandy clay	26	"	Pliocene (Lower)

Thus the systen of sandy-barrier formation can be used to determine the phases of sea-level fluctuations in the Quaternary, while the series of short term inundation and withdrawal can be demonstrated from their stratigraphic sequence.

The previous paragraphs tend to focus attention on sea-level changes in the past, without an examination of the characteristics in recent times. Although the pattern of sea level changes in the past can broaden the understanding of the land character, the knowledge of the recent trends would be a guide not only to the understanding of the land character, but to the planning for land use and conservation methods. That the sea level has risen in recent times is a well documented fact (Disney 1955), Fairbridge 1960 and 1961, Brunn 1962); and has been attributed to increased deglaciation in the Polar region (Miller 1964, Rusell 1964).

On the Lagos coast, there is evidence of a general sea-level rise derived from the records of the rate of beach erosion, put at a loss of about 600 metres of land to the sea between 1912 and 1968, (LEDB 1968) and about 2 metres a year since 1969, (KIO 1969), and the increasing occurence of wave-storms. Although beach erosion has been used as an index of sea level-rise (Brunn 1962, Swartz 1967), the erosion on the Lagos coast is not caused by sea level rise alone, but by a combination of complex hydrodynamic and geomorphological factors.

The most important of these is the prevention of the west-east littoral drift by the west mole in the Lagos Harbour mouth which has left the Victoria beach undernourished with sands. However, evidences of beach erosion exist on the accretive Light House beach as small sandy-cliffs cut in to the beach by waves. There are also reports of beach erosion from other parts of West Africa (Dei 1969, N.P.A. 1971) (See Appendix V). This universality of beach erosion in West Africa lends credence to Brunn's theory of eustatic rise of sea level as the cause of beach erosion in this parts.

The occurrence of wave-storms along this coast is rather seasonal that most of the beaches are eroded during the rainy season. There is no evidence from the tide records of a substantial rise in the sea level, but the general nature of erosion and the seasonal storms tend to confirm the theory of sea-level rise along this coast. Also the general increase in the volume of ocean water due to deglaciation in the ice caps might be a contributory factor to the eustatic rise in sea-level and the associated beach erosion.

A pattern of sea-level fluctuations in the Quaternary emerges from the analyses above, and has been pieced together in Table 1.2. There is no clear boundary recognised between transgressive and regressive phases, but conclusions were based on the convergence of evidences from two or three sources as shown in the tables.

Table 1.2

TENTATIVE CORRELLATION OF QUATERNARY SEA-LEVEL FLUCTUATIONS IN THE COASTAL ZONE OF LAGOS

AGE	MARINE LANDFORMS	SEDIMENT TYPE	TERRESTRIAL & FLUVIAL LANDFORMS	SEDIMENT TYPE	SEA LEVEL POSITION
RECENT	OUTER BARRIER	MARINE SANDS	ALLUVIAL Plains of Ogun/Majidun rivers	Sand/silt	Transgressive Regressive
UPPER HOLOCENE	Kuramo, Iru & Light House Creeks	Organic clays and peat.	-	Sand/silt peat and clay	Transgressive
MIDDLE HOLOCENE	INNER BARRIER	Marine Sands	-	Angular and Coarse sands	Regressive
	FIVE COWRIE AND BADAGRY CREEKS	Organic clay	-	Angular and Organic clay	Transgressive
	PRIOR BARRIER	Marine Sands	TERRACE III	Angular sands	Regressive
LOWER HOLOCENE	LAGOS LAGOON OLD SHORE LINE CLIFFS	Organic clay and peat.	-	Alluvium	Transgressive
20,000 years B.P. (PLIO-PLEISTOCENE	OLD BEACH TERRACE	Feruginised sands of the Coastal Plain Sands	TERRACE II	Angular and Coarse sands	Regressive
MIOCENE	IKEJA PLAINS	Weathered sand stones of Ilaro formation	TERRACE I	Clay/Silt fine sand	Transgressive

1.4 THE LAGOON COASTS OF WEST AFRICA

Nearly all the studies on the coast of West Africa are limited to the stretches that are accessible and proximate to coastal cities. Such studies include to works of Rougerie (1951), Tricart (1957), Le Bourdiec (1958), in the Ivory Coast, Pugh (1954b), Webb and Hill (1958), Webb (1960) and Allen (1962, 1964, 1965 & 1967) along the Niger delta coast, and Abegunde (1966) along the coast of Western Nigeria. None of these studies covers the whole of the coast from the Fresco lagoon in the Ivory Coast to the Niger delta in Nigeria. However, a comparative analysis of these works shows a sort of similarity and relationship in conclusions as to the pattern of distribution, characteristics and origin of the coastal lagoons.

Although two main lagoon systems have been identified in West Africa viz: the Ivory Coast Lagoon system extending from Fresco Lagoon to the mouth of the Bandama river; and a second system extending from the mouth of the Mono river in Togo to the Niger Delta in Nigeria, (Webb and Hill 1958), four main systems are identified on the Guinea Coast in this thesis. Apart from the two lagoon systems named above, others include the Aby lagoon on the mouth of River Tano in Eastern Ivory Coast and the Ada and Keta lagoons on the mouth of the River Volta in Ghana. The formation of the lagoons has been associated with the movement of beach-sands along the coast (Webb and Hill 1958).

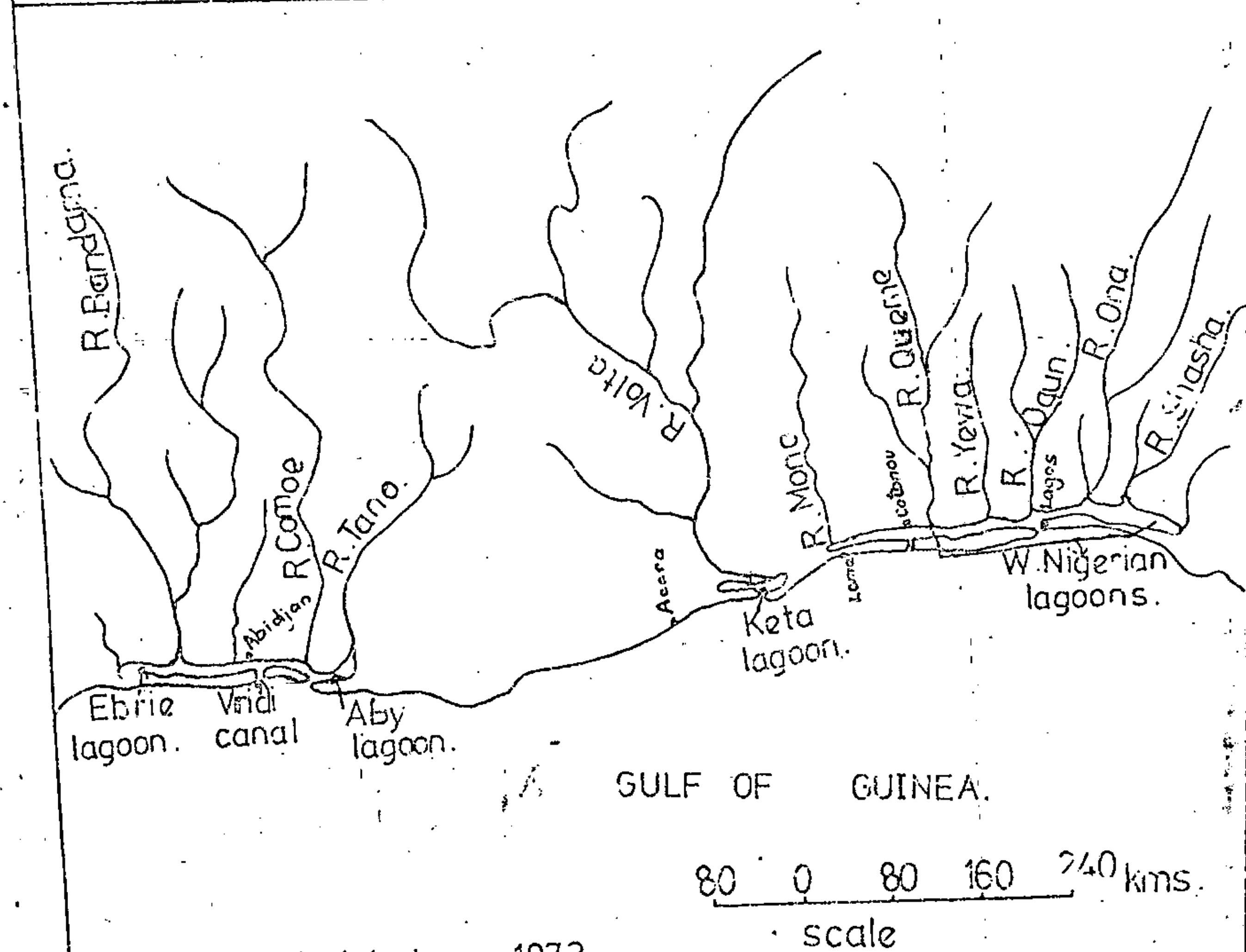
This has also been suggested by Kouriatchy (1934) and supported by Bernard (1939). However, the lagoons seemed to have developed in recent times during the oscillations of the sea-level resulting from glacio-eustatism.

The lagoons are associable with the sandy-barrier formations built across the mouths of coastal rivers thereby diverting their courses to directions parallel to the barriers. This is clearly illustrated in Fig. 1.7. This fact also explains the perpetuation of the lagoon, as they receive fresh supplies of water from the rivers. The complex nature of the lagoon system is illustrated as well in Fig. 1.7, and comprises the Fresco, Grand Lahou, Keta, Dahomey, Lagos and the Western Nigeria Lagoons. Of all these, the Western Nigeria lagoons system, including that of Lagos, extending from the Dahomey border in the west to the Niger delta in the east, forms the largest. It is within this system, and in the strategic position of the only outlet for the system into the sea, that the coastal zone of Lagos lies. It is therefore necessary to examine the physical characteristics of the Lagos lagoon system in as much as they affect the coastal zone in general and land resource development in particular.

THE LAGOS LAGOON SYSTEM

The most striking feature of the coastal zone of Lagos, is the net-work of lagoons and creeks of varying sizes and shapes. The distributional pattern of the lagoons and creeks

THE LAGOONS OF THE GUINEA COAST. Fig. 1.7



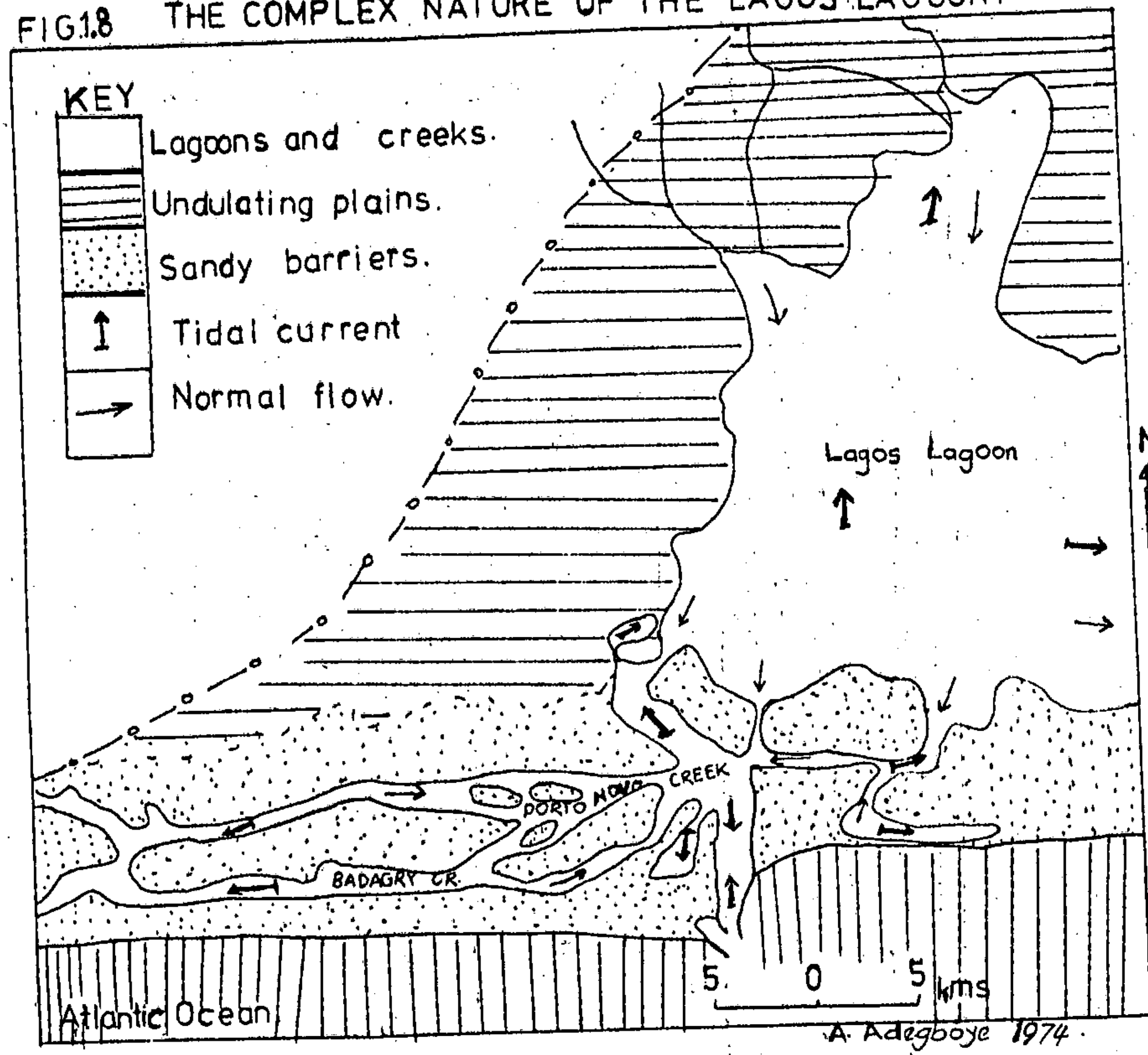
Produced by A. Adeghoye 1973.

is illustrated in Fog. 1.8. This system is obviously the largest and most complex of the lagoon systems along the west coast of Africa. It is unique in nature because of its natural outlet into the sea, whereas other south-western Nigeria lagoons, such as Lekki, and Ologe lagoons have no outlet .

The Cotonou canal in the Dahomey (see Fig. 1.7) was not completed until 1960, thus making the Lagos outlet the only permanent break along the 1500 km. coastline between the River Mono to the West and the Shasha river to the east. The Lagos lagoon also forms a natural outlet for the coastal rivers such as Queme, Yewa, Ogun, Ona and Shasha as shown in Fig. 1.7, draining an area of over 25,000 sq. km. (Webb 1960) (Mabogunjo 1961).

The chain of islands created by the Lagos system includes Lagos, Ikoyi, Iddo, the Victoria, Tin can and Powder Magazine Islands. The location of these islands is depicted in Fig. 1.13 and 2.11, respectively. The lagoon environment created the problem of isolated settlements, which has however been solved by the building of Carter bridge to link the mainland via Iddo Island with Lagos in 1931, the Five cowrie creek Bridge to link the Victoria Island with Lagos Island in 1960, the Eko bridge to link the mainland with Lagos Island in 1970; while a bridge is now proposed to link Maroko with Ikoyi Island across the Five Cowrie creek, and

FIG 1.8 THE COMPLEX NATURE OF THE LAGOS LAGOON.



third one east of Carter bridge to link Lagos Island with Okobaba in Ebute-Metta.

Another major character of the lagoon environment is the existence of tidal flats and marshes as well as Mangrove Swamps. These include the Ikoyi Point, Iganmu, Afa, Alaka, Maroko, Makoko and the Bariga swamps as shown in Fig. 2.10. Apart from being infested by mosquitoes and other pests, they form areas of settlement discontinuity within the metropolitan area and seem to constitute a barrier to settlement expansion. In an environment where land development is restricted by the hazards of swamps, flooding and occurrence of open water, and where there is a high demand for land for building and re-creation, it is pertinent to take an inventory of such land areas that are available, to define them on the basis of their physical and genetic characteristics and to evaluate them from the point of view of present and future land use requirements. If this is done, the land attributes would be known and a purposeful and meaningful planning programme will be easy to execute. This will lead to a rapid development and the opening up of "new lands".

1.5 CLIMATIC FLUCTUATIONS

A lot of documents exists on climatic fluctuations in West Africa. The works are generally based on inferences from the study of archaeological artefacts and pollen analysis some of the most important ones include those of Tricart (1961) in

Senegal and Davies (1964) in Ghana. Most of them disagree on the correlation of glacial periods with pluvial periods in Africa (Tricart 1961, Davies (1964); while some of them favour the contemporaneity of pluvial phases and sea level rise. Both Tricart and Cailleux (1961) and Davies (1964), used the term 'Pluvial' and 'interpluvial' to mean 'humid' and 'arid' conditions respectively without any precision. Although these scholars have been able to establish the occurrence of climatic fluctuations in West Africa, during the Quaternary, they have not been able to establish their detailed and sequential occurrences. The paucity of evidences which plagued their research is a problem yet to be solved, and its effects can be inferred from this thesis, because concrete evidence about the climates of the past is not available for use.

However, there is no doubt that the coastal zone of Lagos has experienced climatic changes in the past, but evidence has yet to be found to illustrate and establish a precise sequence of occurrence. Evidence from sedimentological sources, such as weathering, grain structures and lithology suggest the occurrence of alternating periods of dry and wet phases since the sediments were deposited. Hence much weight will be put on sedimentary properties such as grain structures, colour and soil profiles in explaining palaeoclimatic conditions in the coastal zone. This approach was adopted in the Coastal zone of the Ivory Coast in 1958 by Le Bourdiec and his findings were satisfactory.

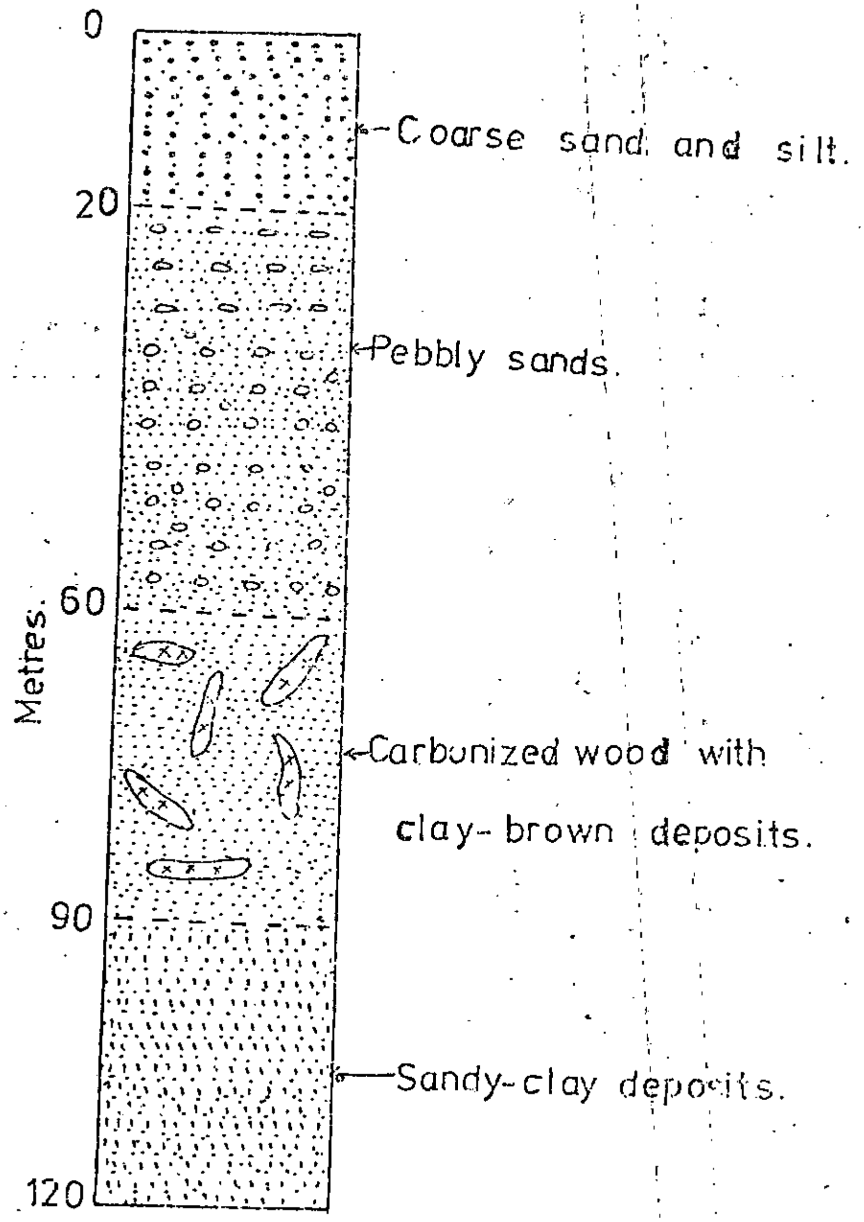
The lowest sediment stratum examined in the Coastal zone is the Coastal Plain sands which lies conformably on the older Ilaro formation. The bore hole through the Coastal Plain sands at Ikeja and Mushin, (see Fig. 1.3 for the borehole locations) by the Nigerian Geological Survey (1960), showed alternating beds of sandy-clay and clayey-sand in the lower 30 metres. The next 30 metres showed a bed of carbonized wood and clayey brown soils, while the upper 60 metres showed variations of coarse sand, silt and pebbly sand. (See Fig. 1.9 below). The lower bed of sandy-clay and clayey-sand is interpreted as belonging to a marine environment, because clays with microfossils especially ostrachoda are associated with marine and submarine environments (Reyment 1964). The layer of carbonized wood and clayey brown deposits illustrates periods of humid climate when thick vegetation grew over the marine deposits. The brownish colour of the sediments is a result of the precipitation of the iron and alluminium oxides in the deposits by acidulated rain water after exposure.

The pebbly sands found in the horizon between 20 and 60 metres in depth may be deposits of fluvially-derived sediments during a period of relatively dry climate. The upper 20 metres layer of ferruginised sand is generally associated with the last phases of the last glacial maxima, when climatic conditions were generally dry. Thus the sediments may be regarded as continentally derived, but the weathering and induration are evidences of post-depositional alternating humid and dry climatic conditions. The continental origin of the sediments of the upper horizon consisting of pebbly sands is further illustrated by the occurrence of angular grains of sand amounting to about 80%. This is evidence of very weak transport medium while the sorting coefficient of 1.40 and the low energy sorting environment could be an evidence of relative aridity when the most effective transporting agent was the rivers. This confirms the continental origin as well as the prevalence of dry conditions during the period of the deposition of the upper horizons of the Coastal Plain sands in the late Pleistocene period.

Tricart (1961) asserted that sea-level changes are contemporaneous with climatic fluctuations because of the rise in temperatures which is generally concomittant with deglaciation and subsequent increase in the volume of sea water and rise in sea level. Consequently he argued that a dry phase was equivalent to a regression and a wet phase to a transgression. This has been further supported along this coast by the occurrence of a dry-phase during the maximum Wisconsin or Wurm glaciation (Allen 1964) during which the pebbly deposits of the upper Ogun valley were deposited. (Durotoye and Burke 1971). Also during this dry phase, most of the coastal rivers rejuvenated their valleys and extended their mouths 'as canyons'

FIG 1·9

SKETCH SECTION OF THE COASTAL PLAIN SANDS AT IKEJA



courtesy of Geological Survey of Nigeria Ikeja borehole (1960) to the sea-level, which were then in the area of the present continental shelf. Allen (1964), Burke (1971). It is thus probable that the rejuvenation of the valley of river Ogun to a depth of 18 metres from its present flood plain, was carried out during this time.

On the basis of the association of the fall of sea-level with dry climatic phases (Tricart 1961) and illustrated in the coastal zone of Lagos as shown above, it is possible to establish that there were periods of marked climatic changes, between upper Pleistocene, through Holocene to the recent times in this area. This assertion is based on the evidence of the contemporaneity of the building of sandy-barriers and the occurrence of low sea-level as advocated by Zuenner (1961) Tricart (1961) and Shepard (1963), as well as the occurrence of rejuvenation in the valley of the coastal rivers. It is assumed that the growth of each sandy-barrier represents a period of marked dry phase, because sandy-barriers are associated with periods of low sea-level.

Since the period immediately following the end of the Pleistocene was marked by sea transgressions during which the indented old shore line cliffs formed in the marginal surface of Ikeja Plains and depicted in Fig. 1.10 page 43 were cut; this period could be regarded as a that of sea level rise when, according to Tricart (1961) high temperatures aided the deglaciation of the ice-caps in Europe and the volume of ocean water increased. This period has been referred to as a "wet phase"

Tricart (1961). The building of the Prior barrier shown in Fig. 1.5 page 21 might have resulted from the fall of the sea-level that succeeded the earlier rise which according to Tricart's classification was a 'dry climatic phase." The period between the emergence of the Prior barrier and the formation of the underwater bar of the Inner barrier which is a period of high sea-level might be regarded as another wet phase, while the emergence of the Inner barrier and the subsequent building of its berm might have occurred during another dry phase. If this pattern is carefully followed there would emerge at least two periods each of wet and dry climatic phases respectively in the coastal zone of Lagos from early Quaternary to the present time. The present time seems to be a humid period, as shown by the amount of annual precipitation from rain received in Lagos, the generally higher temperatures as well as the rising sea level illustrated by coastal erosion all over the world.

The sequence of climatic changes attempted above is not conclusive, because it relied mainly on evidence from land-form evolution, as the likelihood of a transgression submerging a previous barrier for example cannot be ruled out. A more reliable evidence can be deduced from the stratigraphy, fauna and flora, and the age of the deposits which unfortunately were unavailable during the course of writing this thesis. However, the sandy-barrier hypothesis and the rejuvenation of river-valleys in the coastal zone of Lagos are "observed evidences" of the climatic changes in the locality during the Quaternary. Until a dated classification is made this can however be used tentatively to illustrate the palaeoclimatic history of the area, with a view to ascertaining its effects on the evolution of its landforms.

Recorded data for the contemporary climate of the area exist from the beginning of the "colonial era", around 1860. The records illustrate the general humid nature of the climate since the beginning of the 20th century. There has been a generally high amount of rainfall with an average of about 1700-1800 mm. per year, and high temperatures averaging 30^{c}. The prevailing winds include the south-west monsoon, which is dominant mainly from April to November and the North East Trade Wind, which is dominant from December to March every year.

The southwest monsoon is maritime in origin and it is rainbearing while the north-easterly wind is continental in origin and is relatively cold and dry. The rainy months include May, June and July for the first maxima, while the second begins in September and ends in November. There is a short dry season in August every year. During the beginning of the rains, in the coastal area especially in the month of April the windforce is greatest, generally between Beaufort 6 and 8; while during the rains itself the force of the wind varies between Beaufort 4 and 5. The effect of the intensity of the wind is the extensive beach erosion which occurs along Victoria beach during this time, and the erosion of the beaches remain dominant during the heavy rains when the direction of the wind is both south-westerly and onshore; and heavy surfs break on the loose sands. However, during the period between December and March, the beaches are generally accretive, largely because the wind is offshore at this time. Thus, there seems to be a form of close relationship between the windsystem and beach dynamics. This will be further discussed in greater details in Chapter Two.

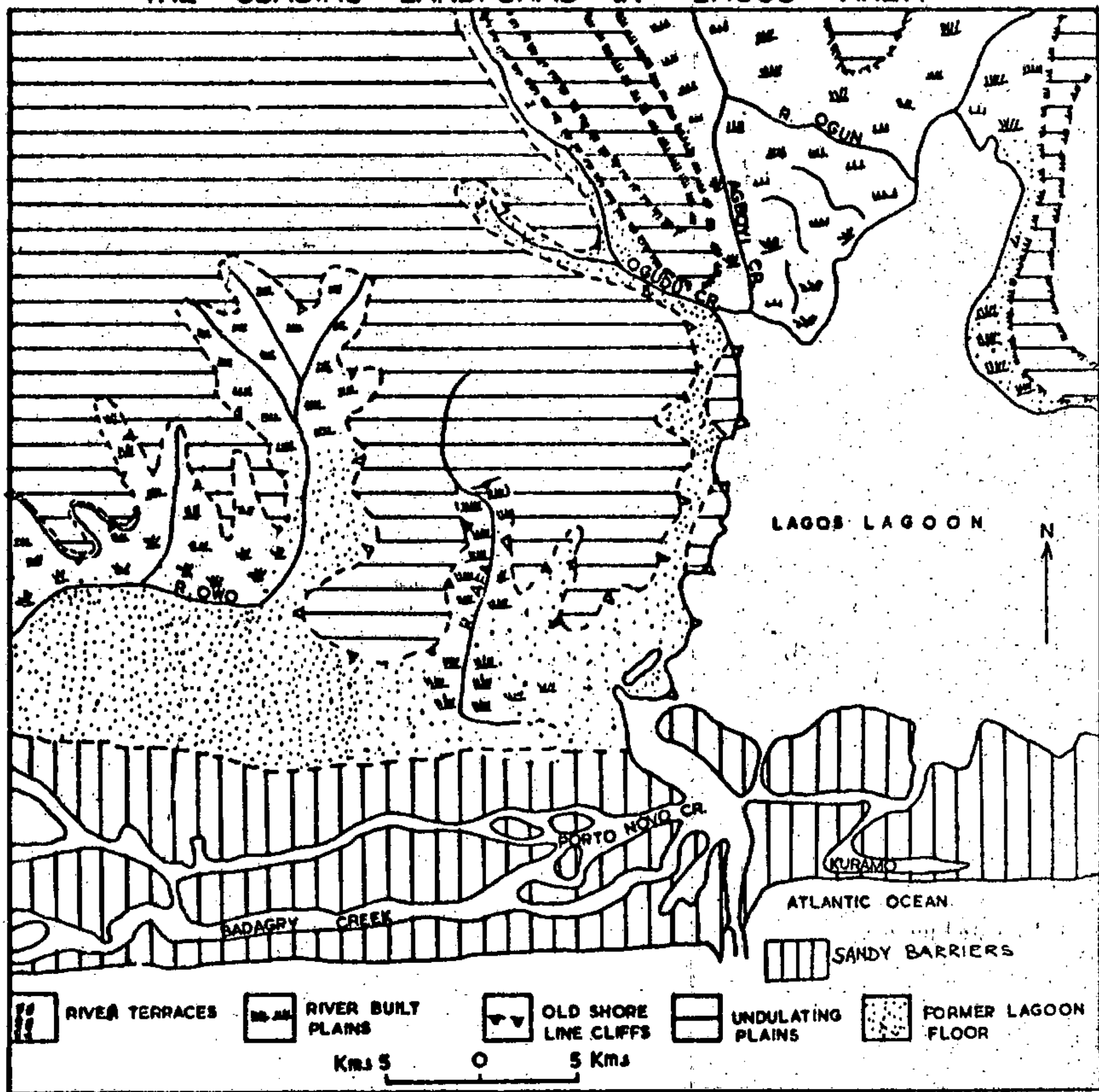
The effects of climate on the landforms and therefore on the character of the land include the characteristic deep weathering profiles, the increasing development of mineral aggregates such as concretions, and the dense vegetation cover associated with the development of relatively mature soil profiles. The humid climate provides a good habitat for crabs, worms, and bacterias etc, which aid the decomposition and aeration of the deposits. The torrential rains maintain a constantly high underground water level which accentuates the incidence of flooding in the lowlying parts of the coastal zone.

1.6 BROAD RELIEF CHARACTERISTICS OF THE AREA

The coastal zone of Lagos is a low-lying area with altitudes ranging between the sea-level on the coast to about 31 metres around Ikeja and Ojota in the north.

The relief features in this area cannot therefore be distinguished by their altidudinal differences as the area can be regarded as a gently sloping coastal plain. However, a variety of landforms can be found in the area as shown in Fig. 1.10 below. Parallel to the sea coast are three sandy-barrier formations separated by east-west flowing creeks. The height of the sandy-barriers varies between 1 metre near the present beach to about three metres on the oldest barrier in the north. North of the sandy-barrier formations, a low sandy plain exists in the areas west of Amuwo, Itire, Isolo and east of Okokomaiko, while the north-eastern part near Ojota, Orisigun, Erunkan, Ebute Ikorodu consists of north to south ridges separated by deep embayments occupied by short streams. Along the edges of the lagoons especially where the lagoons have retreated, swamps of varying dimensions and depth exist, such as at Bariga, University of Lagos, Ijora, Iganmu, Maroko, Ogun Valley, Tarkwabay and Makoko. Also, the edges of the swamps and occasionally the lagoon beaches are marked by near-vetical cliffs in two terraces which range between four and five metres in height. This line of cliffs is what has been previously described as the old shore-line, the origin of which had been explained earlier in this chapter. More details about the genesis and characteristics of these landforms will be discussed in chapter two as they are mentioned here merely as aspects of the relief features that resulted from the interaction of the various environmental factors hitherto discussed. Furthermore they represent the existing landforms in the coastal zone of

FIG.1·10
THE COASTAL LANDFORMS IN LAGOS AREA



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Lagos, whose detailed examination forms a part of this thesis.

The main rivers draining in to the area include the Owo, Afa, Ogun and Majidun (see Fig. 1.10). They flow from the highland areas of Western Nigeria north of the coastal zone. The orientation of the sandy-barrier system along this coast has largely aided the diversion of the rivers, such that they flow parallel to the coast as creeks for various distances before entering the sea in the Lagoon outlet near the Victoria beach. Such creeks include the Porto Novo and Badagry creeks and the Five cowrie creek; for the Owo and Ogun/Majidun drainage system respectively. More knowledge about the land in the Coastal zone can be acquired if an examination of the vegetation is among other things, an index of the soil character and the soil character to a greater extent is an evidence of the processes of evolution. The succeeding paragraphs describe the vegetation and soil patterns in this Coastal zone.

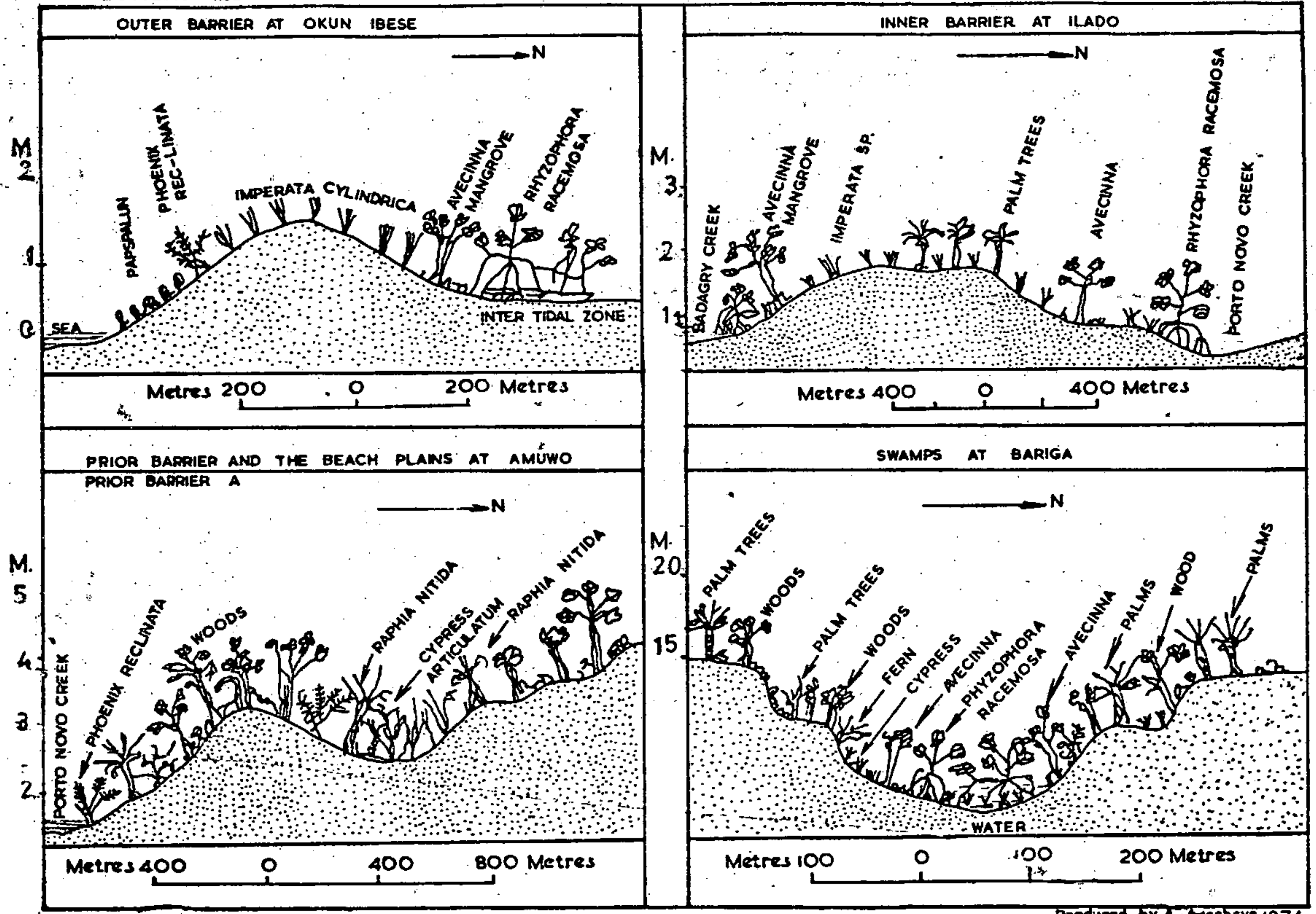
1.7 VEGETATION AND SOIL PATTERNS

Both the vegetation and soils in most parts of the coastal zone reflect the waterlogged nature of the environment, such that most of the soils are swampy and/or sandy as the case may be, while the species of plants that make up the vegetation are essentially aquatic in nature. This general pattern can be subdivided into a saline zone, comprising the outer-barrier formation adjacent to the sea, a brackish zone, comprising the land areas peripheral to the lagoons especially south of the Prior barrier, and a fresh water zone which consists of the Ogun/ Majidun flood plains and locations immediately south of them, as well as the flood plains of Afa, Owo and the Yewa rivers.

Each of the zones supports different but related types of vegetation which illustrate the plant-soil relationship in this area. For example, the most saline part, that is on the Outer-barrier formation, is generally colonised by creeping plants identified as Parspalum and Phoenix reclinata, while the less saline parts of the barrier formation are colonised by a low grass known as Imperata Cylindrica. In the brackish zone which consists of swamplands, Rhyzophora racemosa invades up to a depth of one metre of water in the edges of the lagoons, while Avecinna nitida occupies the intertidal zones. These species have an exemplary adaptability to this environment because of the net-work of pneumatophores which they develop for breathing purposes in the aquatic zone. Sketch sections across landform units showing vegetation successions are depicted in Fig. 1.11.

In the succeding beach plains behind the line of Avecinna; Hibiscus tillaceous, Phoenix reclinata, Raphia nitida and Ipomea Carica, grow in that order to the top of the drier beach ridges. Also in the fresh water environments, cypress articulatum occupies the intertidal or rather flooded areas, while narspalum vaginatum and ferns form the species of the succeding zone as shrubs and a mixture of palm trees and woods form the higher forest cover.

SECTIONS ILLUSTRATING THE DISTRIBUTION OF VEGETATION IN THE COAST OF LAGOS FIG. 1·11



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The succession of plant species seems to refelect the type of soil on which they grow rather than any other environmental factors. Apart from being an aquatic plant, the Mangrove species have been classified into salt-water and fresh-water species in other parts of the coast of Nigeria (Keay 1949), in Surinam; (Pons 1963) and in Australia, (Bird 1968). It seems that the dominant factors responsible for the occurrence of this type of vegetation are related to the soil conditions, because they have been found largely in saline and brackish soils and diminish considerably in fresh water environments. Also the succession of plant species from the lagoon beaches up to the top of the beach ridges as shown in Fig. 1.11 reflects the decrease in the salt content of the soil. A comparable pattern is that of succession of plant species from the sea-shore into the hinterland in a south-north axis. The existence of grasses of a variety of species and date palms with fibrous roots on the beach ridges seem to be an adaptation to the loose-sandy soil. Similar sandy soils have been known to carry grassland vegetation as in the Savannah zones of West Africa, (Adejuwon 1970), but the species of grasses is essentially an adaptation to the soil type. In general therefore, the distribution of vegetation in the coastal zone of Lagos, relates closely to the soil type.

However, in his analysis of the distribution of grassland vegetation in south western Nigeria Adejuwon (1970) discussed the existence of grassland vegetation on beach ridges and mangroves in the depressions. This also has been noted by Pugh (1954b) and was recognized during the course of the field work for this thesis. Thus, particular types of vegetation are associated with units of landforms, as illustrated by the occurrence of grassland vegetation on beach ridges and locations higher than the level of the highest tide, and by very thick clusters of Palm trees and Coconut trees which are cultivated on sandy beach-ridges. Areas that are peripheral to the lagoons display very thick vegetation cover, usually of Mangrove species and Palmetto palms and on the higher and more mature undulating plains in the north, low bushes grow. On aerial photographs, the tone of the photographs is generally lighter on the beach ridges and darker in the depressions, which illustrate the relationship between vegetation density and landform type in the area. Thus the relationship between vegetation and landform can further be demonstrated as due to land-form/soil character.

Soil formation processes in the sedimentary areas have been classified into 'geogenesis' and 'pedogenesis' (Pons 1963); geogenesis includes processes of physical sedimentation, which are essentially within the scope of geomorphology. Pedogenetic processes include both biological and chemical processes after the soil had been exposed to atmospheric weathering.

The role of vegetation can be recognised as assisting in the reclamation of swamps through the processes of colonisation of swamps and lagoon edges by mangroves, and in aiding the rapid rate of soil formation. The decayed organic matter from the vegetation encourages the weathering of the soil as well as the supply of humus colloids necessary for the development of soil aggregates.

However, the vegetation pattern is not only a reflection of the relief pattern but also of other environmental factors in the area. This is because the parameters influencing its pattern of distribution vary from direct relief influence to plant/soil relationships, and also to relief and soil relationship, so that the pattern can only be explained as ecological rather than due to a single factor. For the purposes of identification for land classification, the role of relief as a dominant and easily identifiable factor in this coastal zone is indispensable because, although plant varies with changes in the soil type locally, the general distributional pattern changes in relation to relief units.

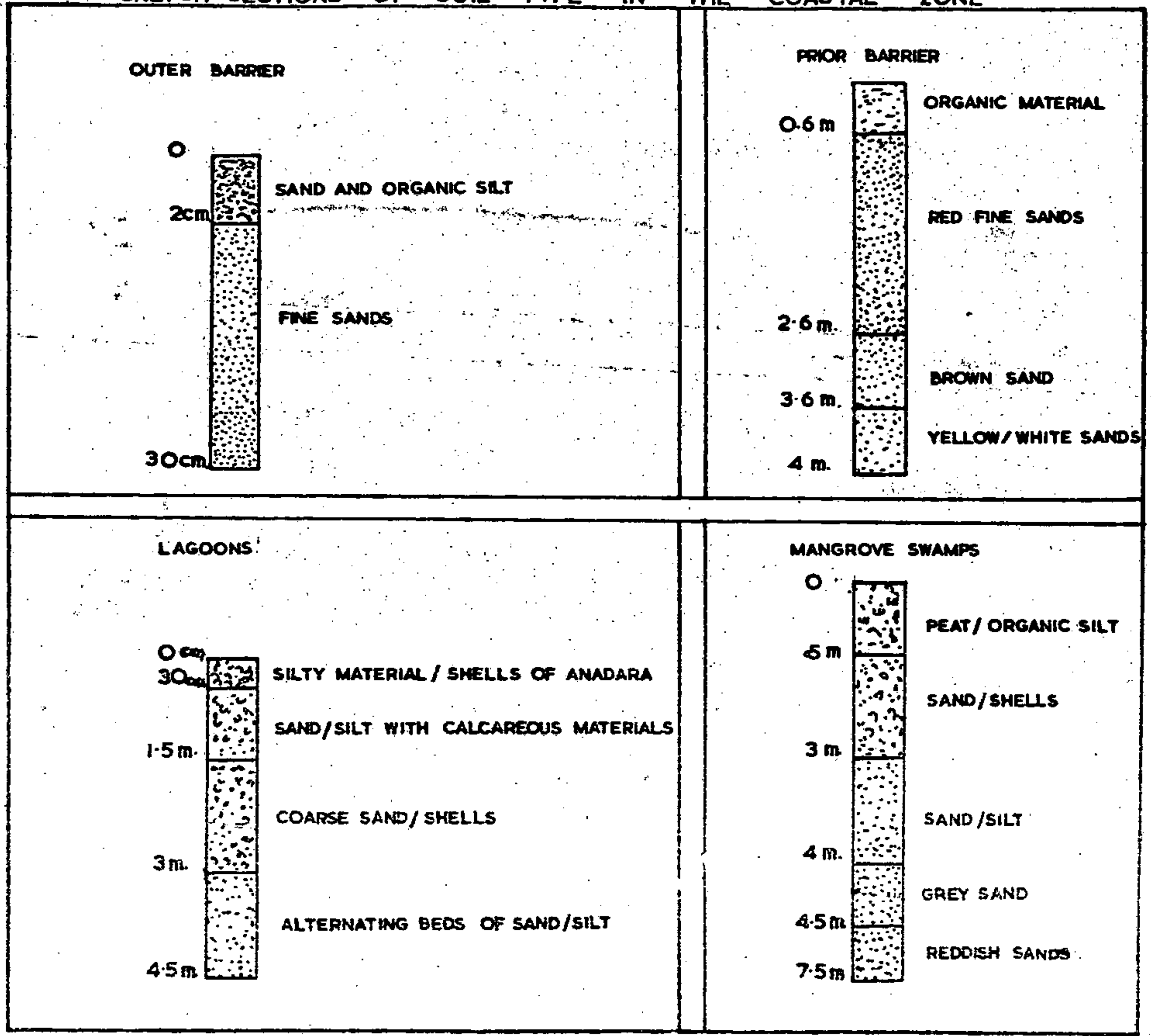
Most of the soils are immature because both the chemical and biological processes are in the early stages of development. They are either swampy, sandy or alluvial in nature. Since they are immature they are subject to changes in relation to environmental attributes such as movement of soil water, and in vegetation type. At present soil formation is a feature of the beach ridges where soil profile development has been operating, whereas in the depressions and on the beach plains, sedimentation is taking place as a result of annual or daily flooding by river and/or tidal floods. As the compressibility ratio of the soils is related to the water-content as well as soil texture, there is the likelihood that the alluvial and swampy tracts occupying the depressions, which hold a lot of water, would be more compressible than the loose coarse-grained sandy soils on top of the beach ridges and in the higher parts of the beach plains which are well-drained and more compact. Fig. 1.12 illustrates profile sections across some of the soils on the land form units.

Thus the identification and recognition of soil types would aid the identification of potentially compressible soils; but it is not enough to rely on the general outlook of the soil from the point of view of vegetation types or land-form units in classifying them, rather it is necessary to examine the characteristics of each soil-type to confirm or reject the hypothesis above. This is one of the problems to be examined in chapter five where the details of the sediment character of each of the landform units are analysed.

In general, therefore, both the soil and vegetation patterns can be said up to this stage to reflect the characteristics of the landform on which they exist. More recently formed beach ridges consisting of essentially loose sandy soil, are found to support grasses with stands of Palms, while the older Inner and Prior barrier formations support woody vegetation with thick undergrowth.

FIG. 1·12

SKETCH SECTIONS OF SOIL TYPE IN THE COASTAL ZONE



Courtesy of Foundation Eng. Ltd. 1972

The depressions support dense Mangrove vegetation and Palmetto Palms where the soil water is brackish or fresh, and the type of soil is either swampy or alluvial as in the areas around the Ogun/Majidun flood plain, Tarkwa bay-swamp and the Itirin lagoon swamp off Maroko. In the classification of the land units in chapter five the landform/vegetation pattern discussed above has been used as one of the criteria for the classification because distinct vegetation patterns grow on particular landform units.

In continuation of the examination of environmental factors of the coastal zone of Lagos, this thesis procedes with the analyses of the role of man as part of the factors of the environment which influence the course of landform evolution by modifying the existing ones and building a new landscape. The impact of man is considerably noticeable in the coastal zone that its detailed examination is necessary at this stage to round-off the chapter.

1.8 HUMAN OCCUPANCE AND ITS CONSEQUENCES

The activities of man form an essential part of his cultural landscape in as much as the modifications carried out by him give character to the environment. In order to understand the environment of the coastal zone of Lagos fully, a careful examination and analysis of the sequent occupance of the landscape becomes relevant. This includes the originally settled area, its pattern of expansion, types of environmental constraints met throughout the period and the present land use types and patterns.

The first settlement of Metropolitan Lagos has been dated variously at between 1630 and 1730, when emigrants were forced to flee from war-torn Yorubaland in to mainland Lagos (Lees 1879, Mabogunje 1961). The earlier date seemed to have gained a wide acceptance in the works of Payne (1896) and Losi (1914). Mabogunje (1961) however puts the date at early 17th Century, but the Portuguese account never referred to any settlement around Lagos Lagoon during this time except 'Geebu', an inland town which could mean the present Ijebu Ode. All these evidence, however, support the contention that the present coastal area of Lagos has seen at least three centuries of various human activities and associated land use types.

The first settled area was Ikorodu in the north, but within the metropolitan area itself, Ebute-Metta was first settled by the Aworis who came down from Egbado. Ebute-Metta was later abandoned for the islands where settlements such as Oto and Ijora sprang up. This move Mabogunje (1961) argues was due to the search for freedom from sporadic attacks from other settlers north of Iseri. (See Fig. 1.1) Thus insecurity on the mainland turned the attention of the early settlers to the islands for farming. Gradually farming sites such as Itolo, Idumagbo, Iga-Iduganran became camp sites and eventually settled areas.

From this time population concentration centred on the island and this was increased between 1800 and 1870 as a result of the abolition of the slave trade and the resettlement of freed slaves from Sierra Leone and Brazil. A substantial increase in population began at the beginning of the twentieth century when Lagos became not only a political capital but also the main port of trade for the whole country. Politico-economic developments favoured an increased population, from 32,000 in 1894 to 74,000 in 1911 and subsequently increased the rate of settlement expansion in Lagos.[11]

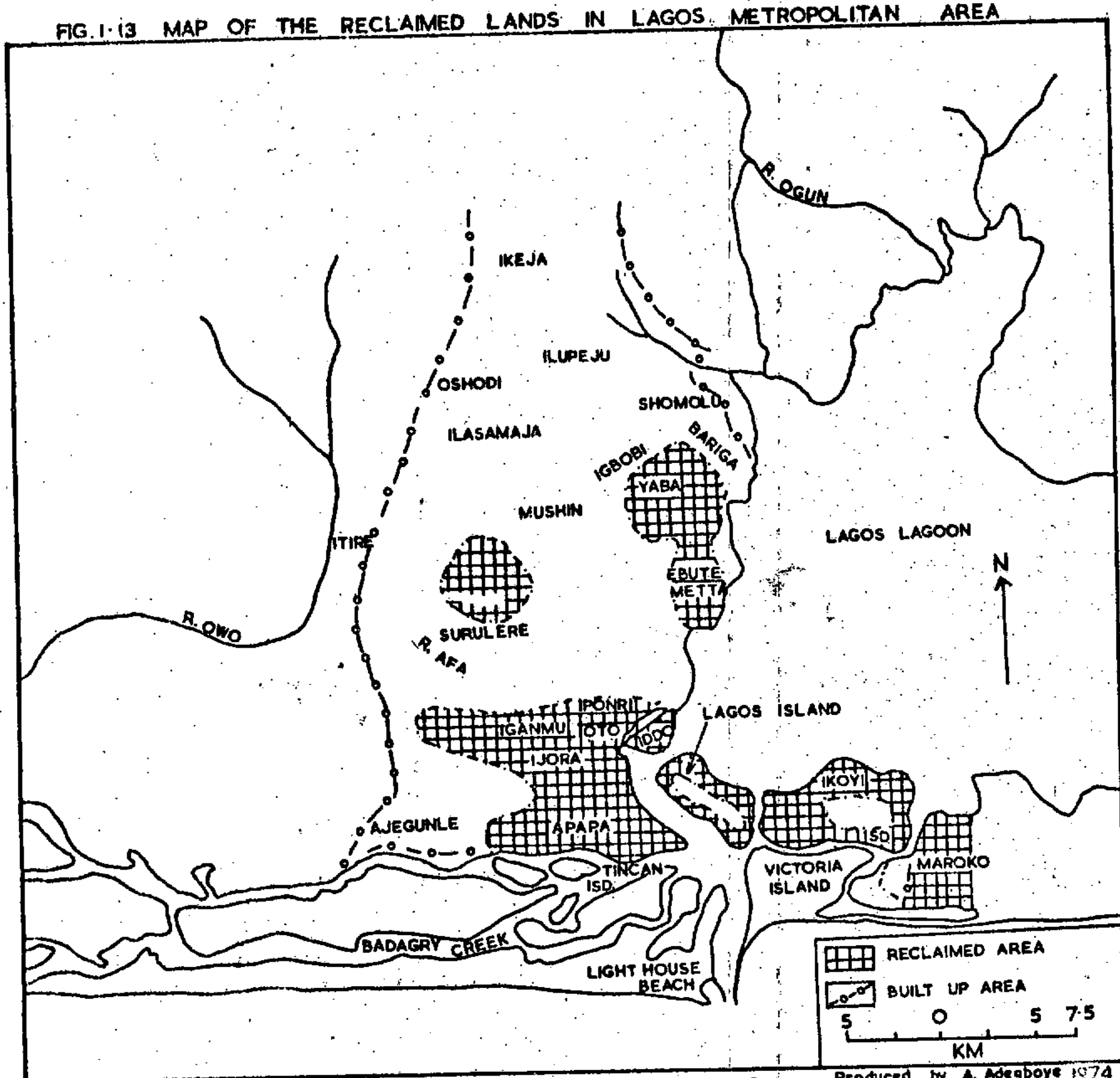
By 1900, for example, settlement extended to the Marina on the island and Ebute-Metta in the mainland. The swampy nature of the terrain at first restricted settlement to sand-ridges which were separated by marshlands and creeks. The need for more land for settlement expansion resulted in the draining of the Okokomaiko swamp in 1905 by Governor Macgregor (Mabogunje 1961) and the subsequent building of the Macgregor canal. In 1920, the Lagos Town Council took over the reclamation of land from the General Sanitary Board. Before its function were taken over by the Lagos Executive Development Board (L.E.D.B.) in 1929, the Town Council drained areas such as North-East Ikoyi, Okepa, Mekunwon, Okesuna, Elesin Igbo and Obalende. These locations are located on Lagos and Ikoyi Islands while Ijora and parts of Ebute-Metta and the Railway Reservation area are located in Ebute-Metta. The L.E.D.B. in its turn reclaimed Idumagbo lagoon in 1930, Isalegangan creek both on Lagos Island and New Yaba in 1933 and Apapa in 1946.

The areas are shown in Fig. 1.13 on page 56. Thus, hitherto a substantial part of the lands in the Lagos Island and mainland have been reclaimed for building purposes.

The merger of Lagos with the Old Western region in 1950 seemed to have reduced the problem of land for expansion since it could then extend to higher and well drained areas on the mainland without restriction by political boundaries. However, the reconstitution of Lagos into a Federal Territory in 1954, and its subsequent separation from Western Nigeria, reduced the extent of the land areas that could be settled by the Lagosians. This shortage of land was further aggravated by the era of industrial development when areas such as Iganmu, Apapa, Yaba and Ikeja sprang up as Industrial zones and resulted in the emigration of a very large number of people in to Lagos looking for employment opportunities. This phenomenon thus increased land, housing and space congestion and also land prices.

Some of the measures taken since settlement began in this area are summarised below. They include draindge works which were essentially executed to rid the swampy terrain of mosquitoes and other pests. Such schemes include the draining of the Okokomaiko, Maroko, Light House Creek, Tin Can Island and Makoko areas. Thus the reclamation of swamps usually comes first before the settlement on land in Lagos. Most of the areas shown in Fig. 1.13 have been reclaimed from swamps, while others which will feature in chapter three have not only been reclaimed

FIG. 1·13 MAP OF THE RECLAIMED LANDS IN LAGOS METROPOLITAN AREA



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and built up, but the areas have subsided due to 'failure' under static loading with buildings.

The clearing of slums in central Lagos began in the early 1960's because of the deplorable condition of living of the people especially, where houses were crowded together in floodable area such as Isale-Eko and Idumagbo. Consequently the Federal Government initiated the Surulere Resettlement Scheme, which has seen to the resettlement of over 50,000 people, and the development of Housing estates at Surulere, Apapa and Ilupeju.

Beach defence measures have been taken to arrest the loss of land to the sea on Victoria beach, but so far success has eluded the planners. The details about the measures taken along the beach will be discussed in chapter three. It is thus clear that the problem of land scarcity has been with the Lagosians for a long time, and is demonstrated by their efforts to develop land for settlement but unfortunately most of these areas have either been depressed and flooded or poorly drained.

The extent of man's impact on the land in the coastal zone of Lagos is obvious from the analysis above. Apart from the reclamation programmes and construction of settlements, roads and bridges, most of the drainage patterns have been perverted by interference and additional problems of flooding have emerged in most of the reclaimed areas. This aspect is described in detail in chapter three.

This chapter so far is a broad analysis of the character of the environment of the Lagos Coastal zone in the light of the geologic, geomorphologic, climatic and anthropogenic factors. It has been shown how each of these factors acts individually and interacts collectively to give character to the land area over time. The next chapter consists of a detailed examination of the characteristic landforms in the Coastal zone which are direct and indirect results of the combined effects of the environmental factors.

In continuation of the objective of this thesis, a detail analysis of the character of the various landform types is necessary at this stage in order to broaden the understanding of the land character. This aspect is carefully examined and laid out in chapter two below.

CHAPTER TWO

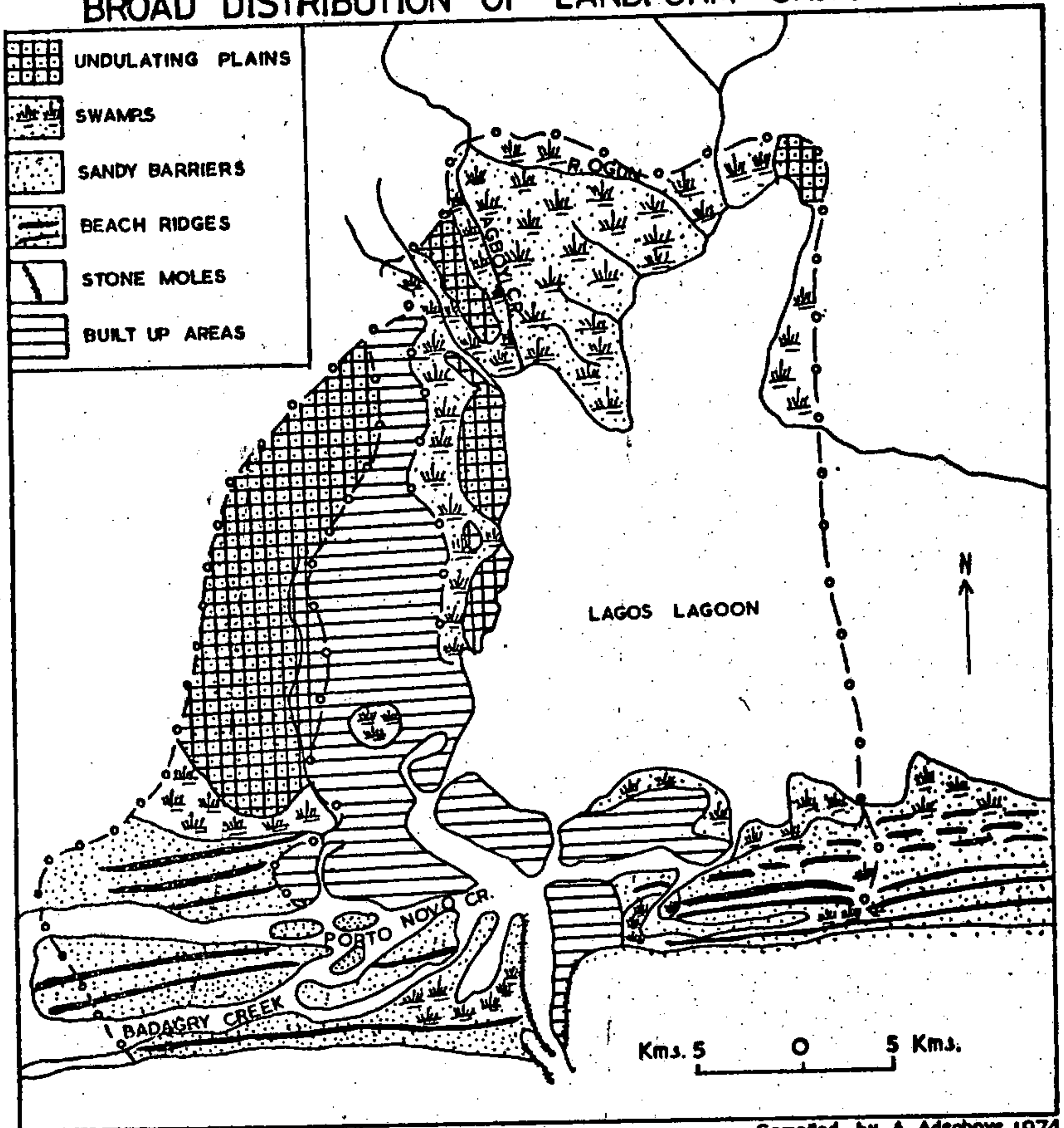
CHARACTERISTIC COASTAL LANDFORMS

2.1 GENERAL NOTIONS OF THEIR EVOLUTION

As in most parts of the coastal environment of Western Nigeria, the coastal zone of Lagos comprises both Pleistocene and Holocene accretionary landforms. The northern boundary of the area consists of ferruginised sandy surfaces of Pleistocene age, while the southern parts are made up of loose sands of lagoon, marine, as well as alluvial deposits of Holocene age. The deposition of these materials was largely effected during the alternating rise and fall of the sea-level from the late Pleistocene to Holocene age. The ferruginization of the Coastal Plain sands is evidence of humid and dry conditions that prevailed since the deposition. The details about the areal distribution of the landform units are shown in Fig. 2.1.

The Pleistocene deposits occupy the undulating plains and are marked by the interfluves and broad depressions of the short coastal streams, whose valleys were widened during periods of sea transgressions. An east-west line of forest covered low-cliffs separates them from the Holocene landforms which are essentially characterised by low sandy-plains, parallel and sub-parallel sandy-ridges on the barrier formations. These landform patterns have been identified along the coasts of Western Nigeria. (Pugh 1954), (Abegunde 1966). The west-east orientation of the

BROAD DISTRIBUTION OF LANDFORM UNITS FIG. 2·1



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sandy-barrier formations can be explained by the direction of the prevailing south-west wind, which ultimately controls the directions of both the waves and the littoral drift which supply the materials for the building of the sandy-barrier formations.

Three groups of sandy-barrier formations exist between the low cliffs of the 'old-shore line' and the present sea beach which have been designated as the 'Prior,' 'Inner' and 'Outer' barriers, according to the order of their evolution and spatial arrangement from north to south. The 'Outer barrier', which is the presently wave-beaten beach is the most recent. This is followed by the 'Inner barrier'; and nearest to the cliffs of the old shore line in the north is the 'Prior barrier'. A detailed examination and analysis of the genesis and character of the barrier formations is attempted below.

SANDY-BARRIER FORMATIONS

The characteristic assemblage of landforms in the coastal zone includes sandy-barrier formations and associated lagoon complexes. The compound word 'sandy-barrier formation' connotes a group of genetically derived landforms with marine sand as its major constituent material and which includes the beach-ridges and associated depressions, the beach plains, the breached-beach ridges, spits and mounds. A critical analysis of the concept of the evolution of sandy-barrier formations in general, might explain in part the pattern of evolution of the particular formationsin this area, but emphasis is also laid on the variants to this concept in this coastal zone where they occur.

CONCEPT OF THE EVOLUTION OF SANDY-BARRIER FORMATION

'Sandy-barriers' according to de Beaumont (1845) are built by the landward movement of material from offshore areas. In his own hypothesis, Gilbert (1885) attributed the formation of Sandy-barriers to a combination of longshore drift, with sediments derived from cliffs or other sources and built in the direction of the current as longshore spits. These two theories formed the basis of the hypothesis of Johnson (1919), in which he stated that the onshore movement of material and the formation of the 'bar', which later emerged to the surface to impound the sea water behind it and form lagoons; are the initial stages of sandy-barrier formation.

These theories tend to explain the initiation of the sandy-barrier formations as marine built landforms without adequately explaining the factors influencing the emergence of the sand 'bar' above the surface of the water, and the subsequent growth after exposure. However, they emphasised the role of waves and wave induced currents in the development of sandy-barrier formations, and that of the sub-marine and marine origin of the sediments used in building them.

Both Johnson (1919) and Shepard (1948) agreed that sandy-barrier formations are initiated first as a sand 'bar' submerged by water, but the emergence of the bar has been attributed to tectonic forces, (Johnson 1919) and/or eustatic fall of the sea-level. (Shepard 1963), (Zenko-vitch 1967). If at all, the emergence of the bar results from the uplift of the land, it is likely to be on a local scale, since there has been no record of simultaneous eustatic tectonic activities to explain the occurrence of sandy-barrier coasts of the world. The occurrence of sandy-barrier coasts is on a regional scale all over the world, e.g. the Gulf coasts of the United States of America. (Shepard 1960), the coasts of Ceylon, (Cooray 1960), the coasts of the black sea (Zenkovitch 1967), the coasts of Eastern Australia (Bird 1967), the coasts of the Mediterranean sea (King and Williams 1949); and the Guinea Coast of West Africa. It seems likely that the most significant factor of their 'emergence' must have been the eustatic fall of the sea-level. Although sea-level fluctuations are well marked all over the world since the Quaternary period, most of the sandy-barrier formations studied, have been dated post-glacial in origin, (Shepard 1963), (Bird 1963), (Allen 1964). If they are post-glacial, it is likely that they have been influenced by the sea-level changes that featured during this period as Zuenner (1961) went further to illustrate that former sea-levels in the case of bar and lagoon coasts, lie somewhere between the lagoon and the mean elevation of the bar.

When the bar eventually emerges above the sea-level a variety of processes occur in the subsequent development of the barrier-formation. One of the associated features of the sandy barrier-formation is the beach ridge, the formation of which Shepard (1963) attributed to the development of dunes on a prograding shoreline. This idea is supported by Hails and Hoyt (1967), when they suggested that most beach ridges originated as sand dunes. While this idea may not be totally rejected as a working hypothesis, it may be out of place to suggest a dune origin to all the beach ridges along all the coasts of the world, because as Jennings (1957) noted, it is rare to find sand dunes on the tropical coasts. This is explained by the fact that dune formation depends among other things, on the force of the wind, the width of the beach, the looseness and fineness of the sand grains. It is known that most of the tropical coasts are either lacking in effective wind-force, or in broad beaches, while the moist nature of the sand, and the vegetal cover especially parspalum, Imperata species and Mangroves, render the sands immovable by the prevailing winds. Hence it is unlikely that the formation of beach-ridges especially in the area of study can be explained by the processes of dune formation.

Perhaps the most likely explanation lies in the theory of 'cut and fill' which was measured on the coast of California by Shepard and La fond (1940), and Shepard (1948). It was established by these men that the height of the waves was the determining factor in 'cut and fill'. Also, Johnson (1949) correllated the cut and fill potential with wave steepness and then suggested that waves whose steepness exceeds 0.025 are responsible for filling, where wave steepness is calculated as H/L. This idea is also in agreement with the concept of constructive and destructive waves of Lewis (1931), while Davies (1957) attributed the formation of beach ridges to wave steepness and the supply of materials forming them. Also, Lewis (1931), noted that the waves of low steepness, by pushing materials up the beach are responsible for the building of a berm, which progrades sea wards for as long as these waves are in operation and until the incidence of steeper waves causes the berm to be cut back and possibly destroyed.

The summary of these theories shows that beach berms are essentially built by waves of lower amplitude and destroyed by waves of higher energy. Also, the availability of material is a pre-requisite for the building of ridges, so that the height of beach-ridges can be used to illustrate periods of abundant and constant supply of beach material as well as higher wave energy.

As has been noted in chapter one, the period of formation of the beach ridges can be associated with the period of a falling sea level when there would be the shallowing of the offshore areas and the sea-bed comes within the range of the wave base, so that materials would be easily scoured and transported shore-wards by the waves. As the beach-ridge was being built above the sea-level, some water is impounded behind it which later formed the lagoon. The lagoon is generally an ephemeral feature which may dry up as a result of seepage of its water in to the sea, evaporation and/or siltation. However, where the sandy-barrier formations seal off the mouths of rivers as in the Ninety mile beach in Australia, the Gulf Coasts of the U.S.A. as well as the Guinea Coasts of West Africa, the lagoons are generally permanent, because of the constant supply of water from the rivers and, from the sea through outlets.

The formation of sandy-barrier formations in general, can therefore be associated with wave deposition, littoral drift and abundant supply of beach materials during periods of sea-level fluctuation. The most recent periods of sea-level fluctuations had been associated with glacioeustatism; (Fair-bridge 1961), (Brunn 1962) which occurred sometime late in the Quaternary. With this background, a detailed examination, and analysis of the origin of the landforms in this coastal zone is given below.

2.2 STAGES IN THE EVOLUTION OF THE LANDFORMS

There are five major geomorphological units recognised in the coastal zone. These include (i) the undulating plains to the north (Phiocene) (ii) the low sandy plains, (Pleistocene), (iii) the marginal swamps of the lagoons and intertidal flats, (iv) the estuarine formations, and (v) the sandy-barriers (Holocene). The evolution of these landforms is closely related to the general pattern of evolution of sandy-barrier formation outlined above as some of the landforms, such as the lagoon depressions and the estuarine formations, develop after the formation of the sand-barriers. However, the undulating plains evolved from the deposited materials of fluvial origin, during a dry climatic phase. The details about the formation of the landforms are given below, with due emphasis being given to their genetic relationships.

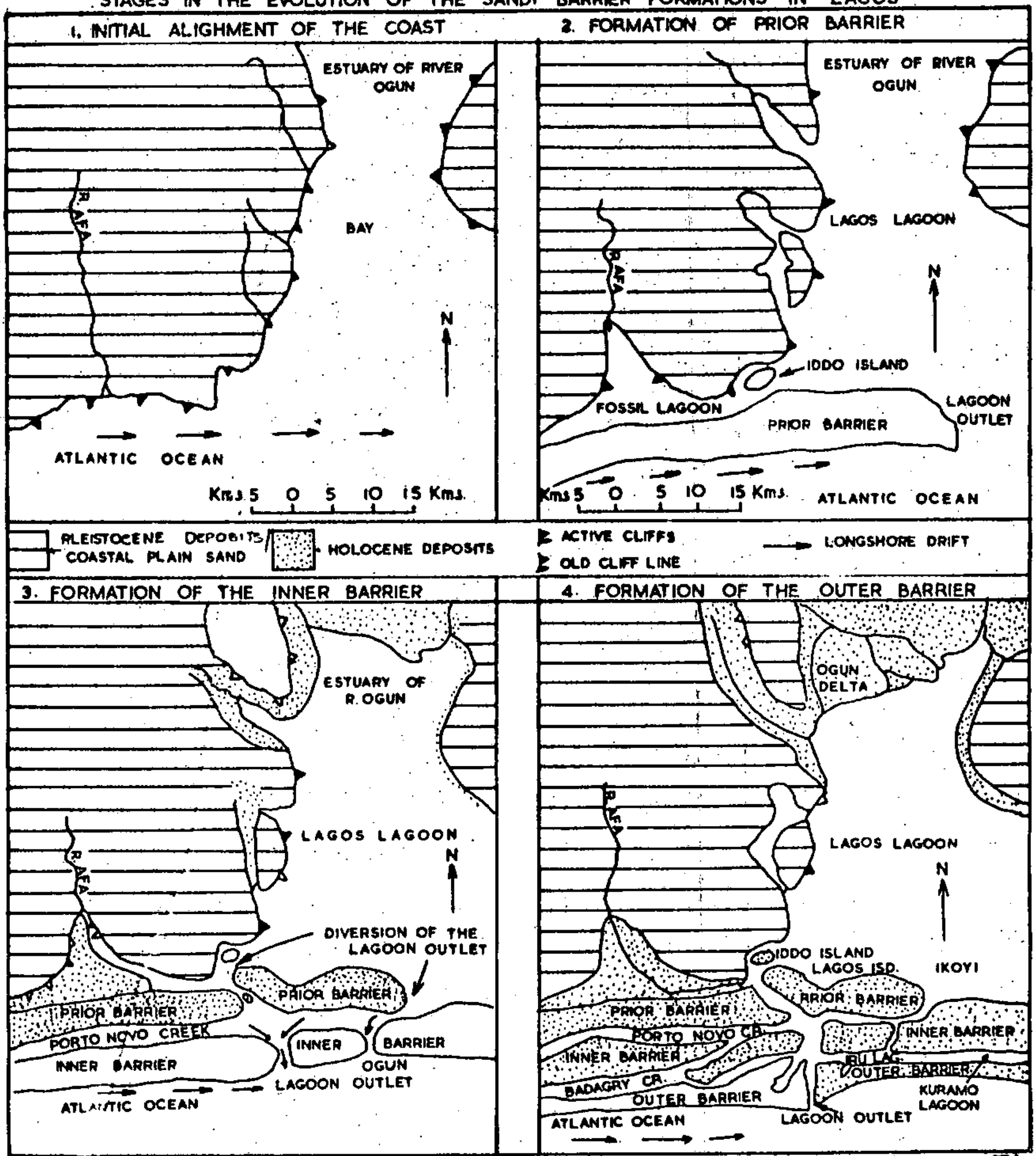
Three west-east orientated sandy-barrier formations designated Prior, Inner and Outer barriers shown in Fig. 2.1 have been identified in the coastal zone. The formation of the 'barriers' seemed to be associated with the various phases of sea-level changes characteristic of this part of Nigeria, (Jones and Hockey 1964) during the periods between late Pleistocene and the Holocene. The evolution of the landforms especially the undulating plains began during the Pleistocene when sea-level was low, and continental conditions prevailed over much of this area, (Burke and Durotoye 1970).

The evidences of a lower-sea level as have been established earlier in chapter one include the existence of the drowned-valleys of rivers Ogun, Majidun and Afa in this area, and the occurrence of Canyons at the mouths of some of the Nigerian rivers, off the continental shelf as identified by Allen (1965). Such rivers include the Niger, Cross, Ona, Shasa, and Yewa. The occurrence of a dry phase in the sub-saharan Africa around 20,000 years B.P. (Burke and Durotoye 1971) is an additional evidence to illustrate the probable occurrence of lower sea-level at this time in the Coastal Zone.

It is most likely that, it was at this time that the materials used in the building of subsequent sandy barriers were deposited by the rivers into the sea, from where they were gradually dragged shorewards by waves during subsequent sea transgression. Evidences - include the petrologic similarity of mineral accessories found in the marine sediments with those found in the present day water-sheds of the rivers - (Allen 1965).

During the last sea-level rise in Holocene, dated between 10,000 and 4,000 years B.P., with maximum rise by 7,000 years B.P. (Allen 1965), the sea probably advanced to the area designated 'old cliffline' in Fig. 2.2(1). This rise in sea-level flooded the lower courses of the short coastal streams and widened them, as shown in Fig. 2.2(1), perhaps as a result of bank-caving and undercutting of cliffs. The various broad depressions like the flood plains of the Ogun and Majidun, the Afa streams, and the various valley re-entrants and notches on the cliffs, mark the inlets during the transgression. The successive retreat of the sea which followed this transgression was likely

FIG. 2·2
STAGES IN THE EVOLUTION OF THE SANDY BARRIER FORMATIONS IN LAGOS



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The inner barrier is an example of the bread-ridging system of sandy-barrier formation -(Webb & Hill 1958), with a width of between one and three kilometers east of Victoria Island. This type of broad-ridging has been cited as a feature of periods of constant supply of sand from the sea (Webb & Hill 1958). However, it is possible to suggest also a combination of high wave energy which accounted for the raising of the height of the sand-ridges above three metres, and a period of gradual withdrawal of thesea which permitted such an extensive progradation, without any significant break in the supply of materials; that could have left a number of depressions sand-wiched inside the barrier, if there had been such breaks.

The sediment supply for the building of the Inner barrier is likely to have been derived from two sources, viz. marine and fluvial. This is because River Ogun as shown in Fig. 2.2 (ii) was probably supplying sediments through an outlet which might have existed east of Ikoyi Island during this time. It became sealed off by the barrier at a later stage and its waters diverted west wards into the outlet; while the sediments from the river probably nourished the northern part of the barrier. This is supported by the high percentage of ilmenite, an accessory mineral which occurs in large quantities in the drainage basin of river Ogun and in the northern part of the Inner barrier in the fossil outlet of the river (See Fig. 2.5 on page 75). The details about the sedimentological evidence are found in chapter five.

to have initiated the formation of the sandy-barrier formation referred to as the Prior barrier here and illustrated in Fig. 2.2(ii).

The indentations along the old-shore line were partially sealed off by an annual initial sandy-barrier formation, backed up by a shallow and slightly southward inclined off-shore zone. This shallow zone became occupied by a broad lagoon as the sea-margin continued to retreat further and a second phase of barrier formation was probably initiated. The fossil lagoon which was formed behind this barrier later shrank as a result of drainage leaving behind the Ebute-Metta lagoon and Iganmu swamps as relics. Also, the growth of the barrier caused the estuary of river Ogun to be pushed east-wards as the strong currents from the river probably prevented the eventual sealing off and further diversion of the mouth of the Ogun river.

The effect of the diverted currents of the Ogun river is probably illustrated by the southerly curvature of the Ikoyi Island where it should have continued east-wards. Thus, after the building of the Prior sandy-barrier formation, the outlet for the three coastal rivers in this area was east of Ikoyi, because the barrier was continuous stretch from the west up to this point, as the present harbour channel might have been a later development. This first phase of evolution of this barrier is shown in Fig. 2.2(3).

The building of the Inner barrier brought many changes in to the drainage pattern of the coastal zone. The 'emergence' of the barrier probably diverted parts of the waters of rivers Ogun and Majidun west-wards to initiate the Five cowrie creek. This same phenomenon resulted in the diversion of the waters of rivers Quene, Yewa and Owo which joined together to form the east-flowing Badagry and Port Novo Creeks as shown in Fig. 1.7. The convergence of these drainage systems in Lagos area, resulted in the 'breaching' of the Prior barrier between Apapa and Lagos Island, and ultimately initiated the present lagoon outlet south of it. The existence of Apapa shoal at this point of breaching and its east-west elongation seem to confirm it as the remnant of the breached barrier. This phase is illustrated in Fig. 2.2(ii).

Thus since the formation of the Inner barrier, the mouths of the coastal rivers except river Ogun, have essentially been directed towards the lagoon outlet. The area east of Ogoyo and Moba villages, was probably the former mouth of river Ogun before the formation of the Outer barrier, because there is no distinct beach-ridging in this area, and the areas west and east of it have beach ridges whose distal ends are diverted southwards. The most likely explanation of the curved 'tails' of the beach ridges and their broad depressions is the action of currents which may either be river currents or wave floods;

which might have prevented the growth of ridges or obliterated the sand-ridges as the case may be. At present the area is characterised by thick beds of mud and alluvium and covered with very woody vegetation, which is not characteristic of the sand ridges in this area. It can be inferred that the alluvial deposits shown in Fig. 2.3, were probably laid down by rivers entering the sea through this area; and these later developed into mature soil that support such a thick vegetation. If this is acceptable, then the alluvial deposits, the curved distal ends of ridges and the depression lying directly opposite the present mouth of river Ogun probably represented where the original mouth of the river must have stood before the Inner barrier was formed.

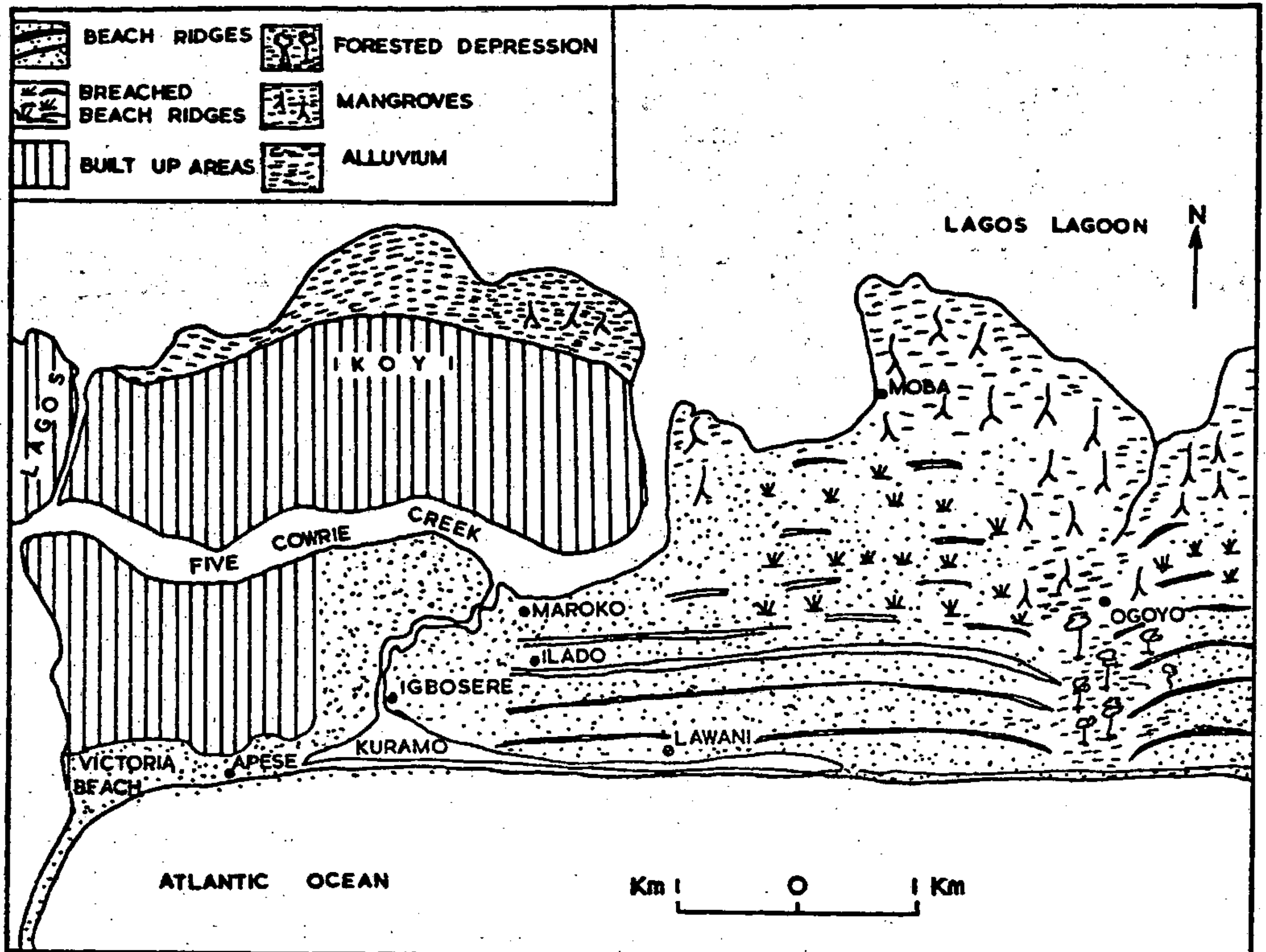
As shown in Fig. 2.2(ii) the Outer barrier developed in front of an east-west flowing creek, variously known as Iru and Kuramo lagoons east of the Lagos Harbour mouth. The Iru lagoon has been reclaimed, but the Kuramo lagoon still exists in the form of a Creek occupying a narrow depression between the Inner and Outer barriers.

From the outlet east-wards the barrier was built from an underwater bar "the Lagos bar" in the outlet. West of the outlet, the barrier continued unbreached into Dahomey territory. It is a broad-ridged barrier but has been substantially eroded in the east since the construction of the stone-moles along the Lagos Harbour Channel. Waves, deriving sediments from the sea bed, and the west-east littoral drift, are responsible for the building up of the Outer barrier.

As the sandy-barrier formations were built the depression separating them were occupied by lagoons. The formative stages of the lagoons are illustrated in Fig. 2.4. Some of the lagoons, such as those between the Prior barrier and the old shoreline cliffs in the West, the Itirin Lagoon and the eastern extension of Kuramo waters developed into marshes or swamps, probably because of either shrinkage due to evaporation, or seepage. The submergence of the Prior and Inner barriers between the present day Lagos Island and Apapa foreland might be responsible for the draining of the fossil lagoon between the Prior barrier and the old shoreline cliffs, which left behind a swamp into which river Afa deposits materials at present as can be seen from Fig. 2.4.

However, most of the lagoons are perpetuated, because they are fed by rivers whose courses have been diverted by the sandy-barrier formations, and by water from the sea, through the 400 metre-wide outlet. The sealing off, of the mouths of rivers Ogun and Majidun, and the subsequent diversion of their waters by the Inner barrier and the subsequent inundation of the lower courses of the rivers probably aided the creation of the extensive Lagos Lagoon, the Five cowrie creek and the Port Novo Creeks. Thus the formation of the sandy-barriers in part accounts for the evolution of the lagoon complexes, while the

FIG.2·3 ORIENTATION OF BEACH RIDGES SOUTH OE OGOYO



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sealing off of the mouth of rivers by these sandy barriers accounts for their perpetuation along this coast.

The Lagoon complexes thus differ from the classical lagoon system which is generally ephemeral, and are derived from the sealing off of sea water behind sandy-barrier formation as in the case of the fossil lagoon in Fig. 2.4. However, other lagoons in this sector are fed by both the sea and the rivers hence they differ and are perpetuated.

The Estuarine formations are derived from the sealing off of the debouchement of rivers, so that sediment accummulation takes place in the estuaries of the rivers and develop into a variety of land-forms such as broad flood plains, levees and abandoned river courses. At this stage, it is necessary to enumerate the details about the typical landforms in the coastal zone in general terms.

LANDFORM UNITS IN THE COASTAL ZONE

As had been earlier noted, there are four major landform complexes in the coastal zone of Lagos. The first group of landform complexes includes the Plains in the north-west and north-east of the area dominated by the low, monotonous and undulating hummocks composed of reddish sands. The second is made up of the Esturine formations which include, the lower and upper flood plains of rivers Ogun, Majidun and Afa. While the Lagoon complexes made up of the broad, submerged depressions of

FIG. 2·4a STAGES IN THE EVOLUTION IN THE LAGOS LAGOON SYSTEM

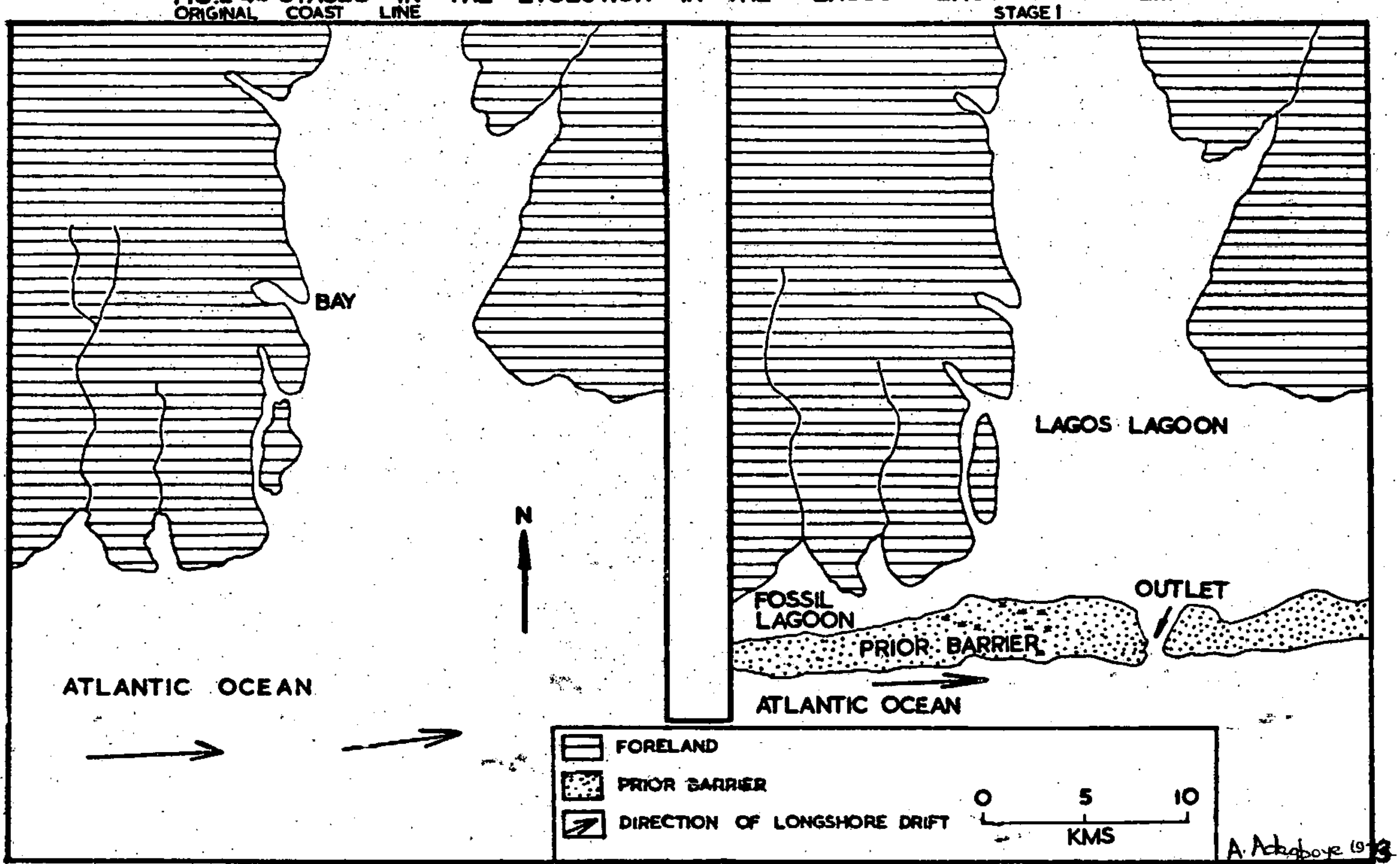
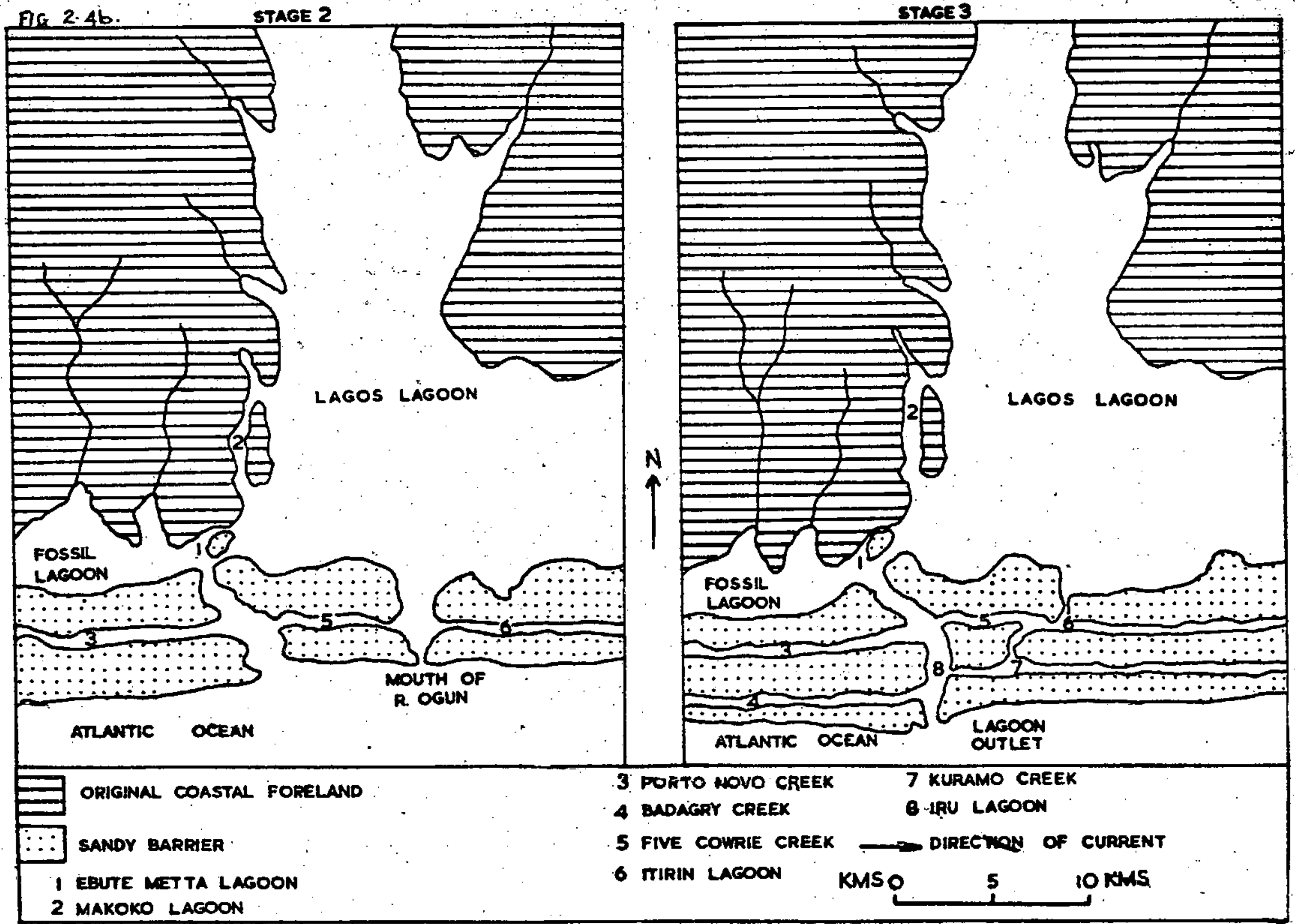


Fig. 2.4b.



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the Lagos Lagoon and the peripheral mangrove swamps and intertidal flats of the Badagry Porto Novo Creeks, constitute the third complex.. Finally the three sandy-barrier formations and their associated features such as the beach ridges, depressions, breached ridges and the beach plains, form the fourth group. The location of this variety of landforms is not contiguous, hence it is necessary here to examine their spatial distribution in relation to one another within the coastal zone. However, the broad distributional pattern of these landform complexes are shown in Fig. 2.1 and 2.5 respectively.

2.3 PARTICULAR FEATURES OF LANDFORM UNITS

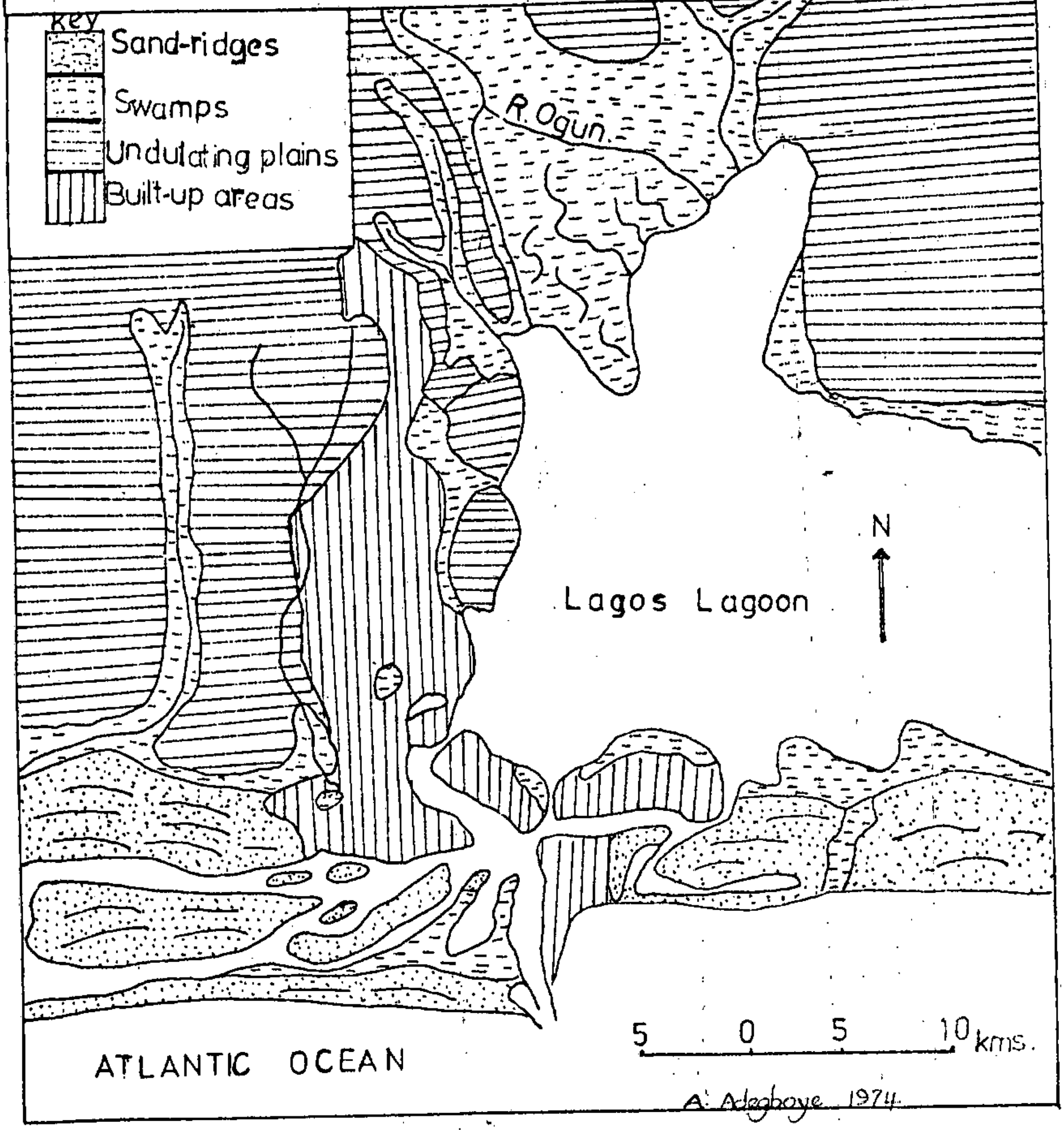
The detailed examination of the surface features of landforms help to establish the criteria for the differentiation and association of the various landform units for the purposes of classification into 'homogenous' units. Such a classification is intended for guidance in the future land use planning within the coastal area. Apart from this, the detailed character of each landform unit would be elucidated and a relationship between the character of the landforms and the processes could be established with a view to building up a comprehensive knowledge of the geomorphology of the area. The spatial distribution of the landform units is shown in Fig. 2.5 below.

THE UNDULATING PLAINS

From the edge of the lagoon depression at Oworonsoki the the undulating plains extend westwards through Shomolu, Mushin

FIG. 2.5

THE SPATIAL DISTRIBUTION OF THE COASTAL LANDFORMS.



and to Isolo. It is characterised by a longitudinal ridge and valley system, which surmounts the low sandy plains. This landform pattern results from the indentations made by the sea during the last transgression into the lower courses of the then coastal streams, which subsequently widened the valleys into a 'ria' pattern before the final retreat of the sea. The present ridges were the interfluves between the rivers and stand out relationvely higher above the depressions.

The height of the ridges varies between about 20 metres in the south and 31 metres above sea level in the north around Ojota while some of the depressions are about five metres lower than the top of the ridges. The depressions sometimes carry water, while in others, no surface drainage is visible. However, very thick beds of alluvial deposits ranging from two to three metres in depth, cover the bottom of the depressions. Most of the deposits are covered by a variety of vegetation, especially ferns and Raffia Palms. The sediments in the depressions comprise angular quartz grains, coarse silt and peat. However the ridges contain angular quartz grains of about - 1Ø in diameter and a matrix of weathered materials. These are essentially the ferruginised sediments of the Coastal Plain sands.

The ridges are well drained, such that no evidence of flooding was found on their surfaces during field work. This might be due in part to the generally gentle slope of the land, about 5° at Ojota, the effects of vegetal cover, the high degree of permeability of the weathered material and perhaps the existence of the depressions into which surface waters flow. Some of the ridges now carry sub urban settlements such as Ojota, Oworonsoki, Orisigun, Iseri. This is an added evidence of its freedom from flooding, because none of the depressions has been settled by man.

THE LOW SANDY PLAINS

These were built up from accumulations of Pleistocene deposits and are found conspicuously west of Surulere, Itire and Ijeshatedo settlements where they are surmounted by the undulating plains. (See Fig. 1.1). These low plains have faint slopes with an average gradient of between 2° and 4° at Ijesatedo and Itire respectively. The area is drained by very short streams into the Afa river flood-plain which lies to the south. Some of the low-lying parts are generally flooded during the rainy season as a result of the combined effects of heavy rainfall, flat terrain and high level of underground water. However, during the dry season the area is generally dry because of the rapid evaporation of the surface waters. The northern parts are well drained such that no standing water has been found on them even during the rains.

The sediment comprises loose sands with admixtures of silt which forms the matrix in the top fifteen centimetres, followed by oxidised sands to a depth of about sixty centimetres before encountering the level of underground water. The loose nature of the sediments permits active capillary action of water especially during the rainy season so that underground water rises rapidly to the surface. This in part explains the flooding that is characteristic of the southern periphery of this unit on which stands part of the Surulere Housing estate. Apart from the factor of faint relief and the climate, the nearness of the plains to the Lagos Lagoon aids the incidence of flooding. This unit is unique among other low-lying plains because of its older age, drainage and morphological characteristics which differ from any of the other land-form units in the area.

THE LAGOON DEPRESSIONS AND SHOALS

This land-form complex includes the marginal depressions,. tidal swamps and the shoals found in the lagoons; these are illustrated in Fig. 2.6. The origin of the lagoon system has been associated with the sandy-barrier formations that are characteristics of this coastal zone, but it is necessary here to examine the variants in the lagoon system from classical lagoon types.

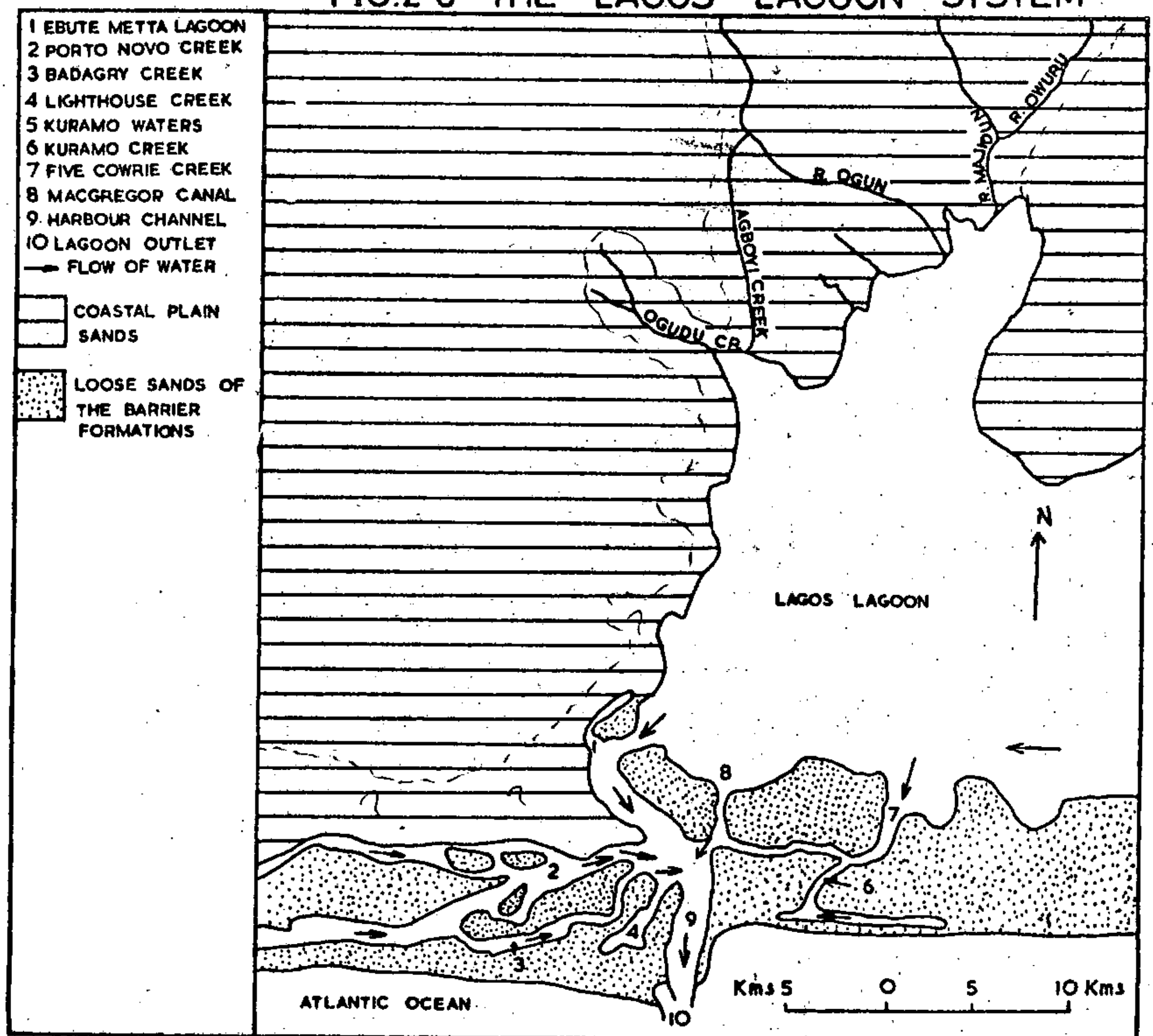
The lagoons as they are at present are essentially impounded sea water and diverted river courses which flow between sandy-barrier ridges, some of which have been breached by the lagoons in order to maintain a connection with the sea.

Thus the lagoon zone receives fresh water from rivers Ona, Majidun, Ogun and Ogudu in the east, and Owo, Yewa and Queme in the west, while it receives a great quantity of saline water from the sea during the flood tide through its four hundred metre wide outlet. (See Fig. 1.7). The mixture of the fresh and saline waters in the coastal zone especially during the rains, renders the marginal areas of the lagoons inundated to varied distances. Consequently areas marginal to the lagoons, especially where they are low-lying, are swampy and water-logged.

The brackish water creates a typical ecological environment where mangrove trees such as the Rhyzophora colonise the inter-tidal areas and contribute a great deal to the reduction in the size of the lagoon. The Rhyzophora recenosa mangroves, possess stilt roots with which they arrest and trap silt and build around themselves other organic and clay deposits. In this process some places like Moba, Sobo and Igbosere areas near the Five cowrie and Kuramo Creeks have been drained of the Lagoon water. Also, this process accounts for the rapid shrinkage of the Kuramo waters. Although the areas drained by this process are essentially water logged, and floodable, the process nevertheless forms the natural process of lagoon retreat along this coast.

The lagoon bed is essentially a zone of sedimentation since the last sea level rise, because evidences of rapid infilling of the embayment created by both river incision during the period

FIG.2·6 THE LAGOS LAGOON SYSTEM



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of low sea-level and the gradual downwarping along the coast of Lagos were indicated by Pugh (1954), Webb & Hill (1958). The primary source of sediment has been from the coastal rivers since the sealing off of their mouths from the sea by the building of the Inner barrier. Thus fluvial sediments were laid down in the lagoon ostensibly to fill the embayment, but rather they shoal the lagoon beds. As such one of the physical characteristics of the lagoon beds is the shoaling condition. The depths vary from one to two metres in most places, and up to four metres in the channels of rivers Ogun and Majidun, while in the southern parts especially in the Harbour, the depth is between ten and twelve metres. This great depth, results from the dredging for harbour operations.

The effect of 'shoaling conditions' is the accumulation of sediment mounds in the lagoons which are generally covered by water with a depth of less than one metre. These have been called 'shoals' because they are isolated shallow parts of the lagoons, (N.P.A. 1958) and examples include the Oworonsoki, Ereko, Moba, Apapa, Brugos, Bruce and Commander shoals, shown in Fig. 2.7. The lagoons have also been retreating as a result of active sediment accumulation, vegetation colonisation and perhaps evaporation. Such areas of retreat include the Itirin Lagoon east of Maroko, the eastern extension of the Light House Creek shown in Fig. 2.4 and the numerous swamps occupying the foot of the old shoreline in Bariga, University of Lagos, and

Makoko shown in Fig. 2.10 on page 95 which were evidently occupied by Lagoon waters in the past. The detailed description of these areas comes up under the descfiption of mangrove swamps below.

The lagoons display a peculiar hydrological character whereby their water level is affected by both the flood and ebbtide up to the Majidun bridge shown in Fig. 2.8 on the Lagos-Ibadan road, about thirty kilometers north of the sea beach. During the flood tide, most of the lagoon beaches are eroded especially between Ebute-Metta and Oworonsoki, where the cliffs of the old shore-line are beaten by the lagoon waves. The waves become very powerful when aided by the uprushing flood tide and the onshore south-westerly winds, so that a large area of land is eroded every year. The photograph on plate 4.1 below shows falling trees and palms resulting from erosion of the lagoon beaches metre by metre every year. This loss of land, the amount of which is not known, contributes in a way to the problem of land shortage in Lagos.

The lagoons occupy over half of the area of study, although they are not land areas to be developed, they form areas of substitute for other aspects of land use, such as recreation and water transport. Their examination is thus pertiment to the objectives of this thesis, especially the knowledge of the extent to which they influence the hydrological regime of the coastal zone. Thus very stringent and reliable precautionary

Fig. 2.7 SHOALS IN THE LAGOS LAGOON

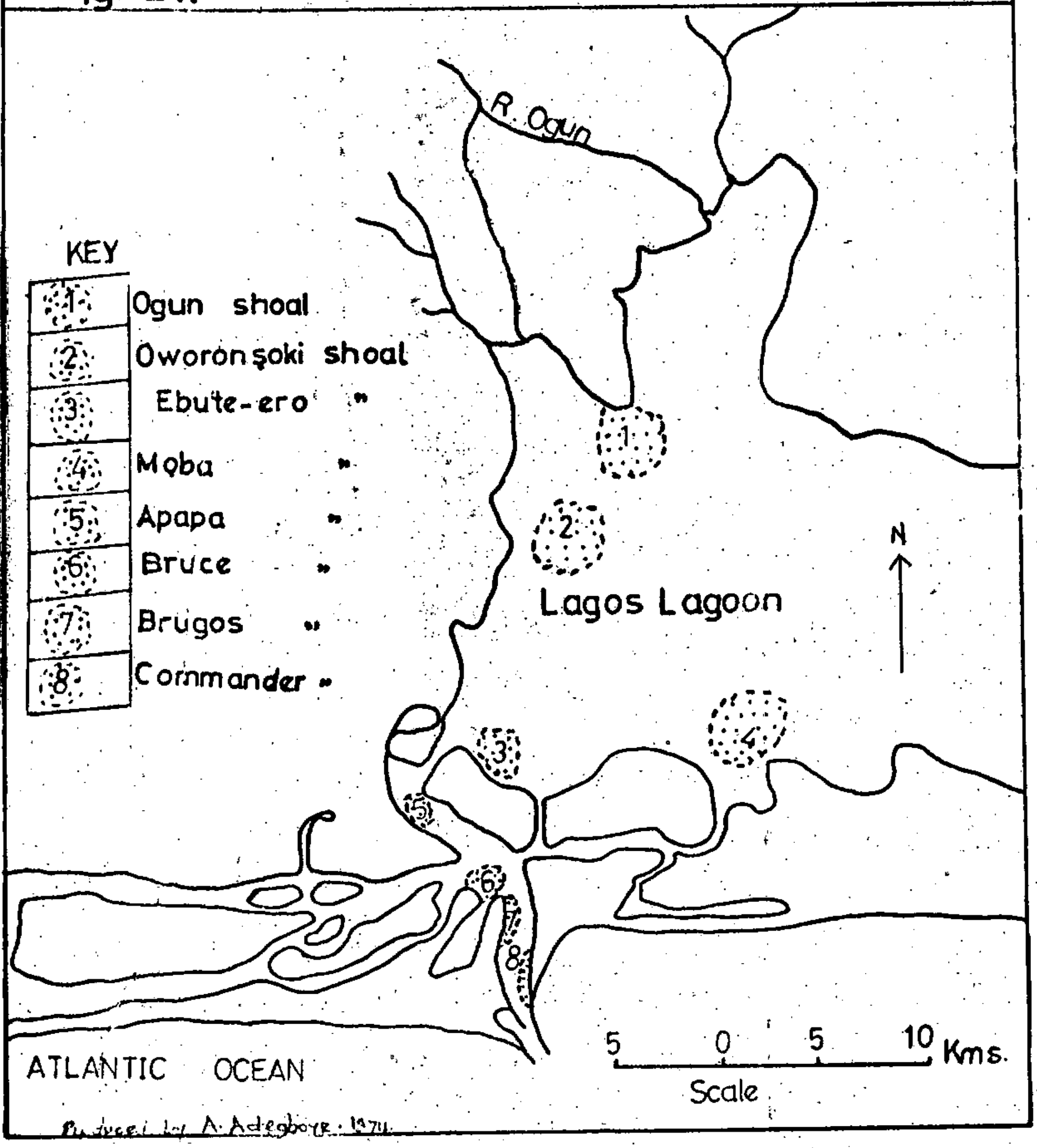

PLATE 2.1

ERODED TREES AND PALM TREES

measures should be taken in developing areas that are peripheral to the lagoons; to avoid problems such as flooding, sewage and drainage difficulties.

ESTUARINE FORMATION AND ALLUVIAL PLAINS

The areas classified as alluvial plains are those that are essentially within the lower river flood-plain areas and have been influenced by fluvial processes for a long time. These areas include, the flood plains of river Ogun and Majidun, shown in Fig. 2.8 which are about nine kilometers broad, and the Afa river flood plain east of Iganmu village to the south west, both shown as swamps in Fig. 2.10. The flood plain of the Ogun and Majidun shown in Fig. 2.8 occupies an infillied depression between Erunkan village in the west and Ikorodu in the east, it extends two kilometers south of the Lagos-Ibadan road into the northern end of the Lagos lagoon and tapers off towards the north. The area is essentially the depositional plain of rivers Ogun, Owuru-Majidun, and Ogudu which probably began to develop since the last Pleistocene sea level rise, when the drowned valleys of these rivers were invaded by the rising sea, and sediment accumulation ensued when the sea retreated. The estimated position of the initial mouths of these rivers lies somewhere between Agbowa in the East and Ebute-Metta in the west, because, these two points mark the original foreland, and under water channels have been traced from the mouths of the Ogun and

Majidun rivers up to a point on a straight line passing through these areas during field work.

The height of the cliff of the old shoreline cut into the Coastal Plain sand varies between fifteen metres and thirty metres above sea-level, but the floor of the depression of the alluvial plain is between three and five metres below the top of the cliffs. The depression has a complex drainage net-work built by the distributaries of the rivers. The magnitude of the number and size of the drainage net-work is evident on the Lagos-Ibadan road, where twenty eight-bridges of various sizes are built along the nine-kilometers of road length which traverses the depression.

Pugh (1954a) described the alluvial plains in the lower courses of the coastal rivers of south-western Nigeria, such as Yewa, Owo, Ogun, Majidun and Ona as depression or drowned estuaries later submerged by a transgressive sea, during which the infiling of the depression began. The evolution of the depression has been associated with both sea level changes and climatic fluctuations in this region during the Quaternary. Additional evidence of infilling includes the depth of Holocene deposits found to be 18 metres, and the building of two peninsulas into the Lagos lagoon as well as the existence of under water extensions of these paninsulas which were found during field work. Also, there is a great deal of similarity in the provenance of the sediments found in the upper and lower parts of the plain.

FIG.2·8
ALLUVIAL PLAINS OF RIVERS OGUN AND MAJIDUN

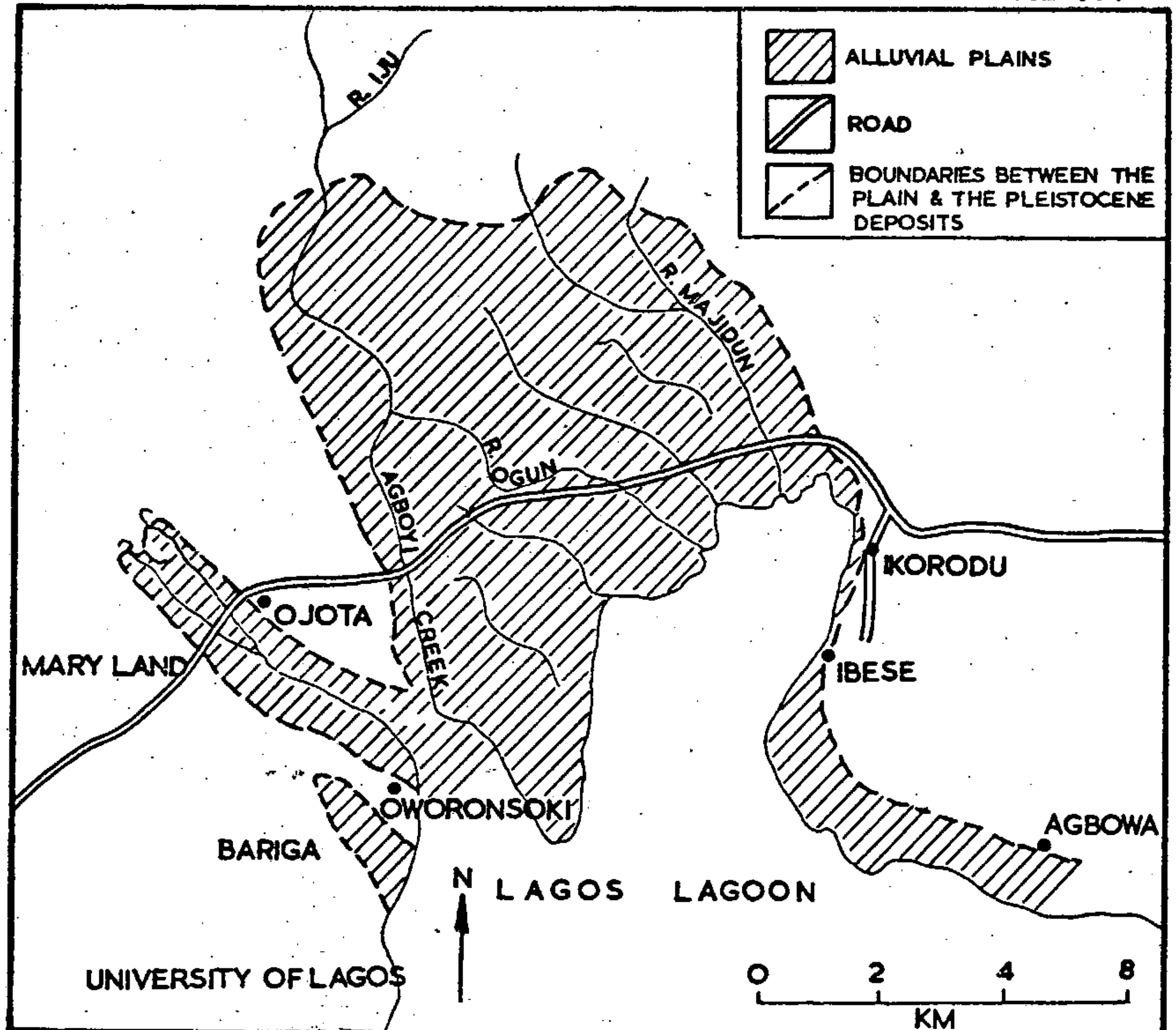

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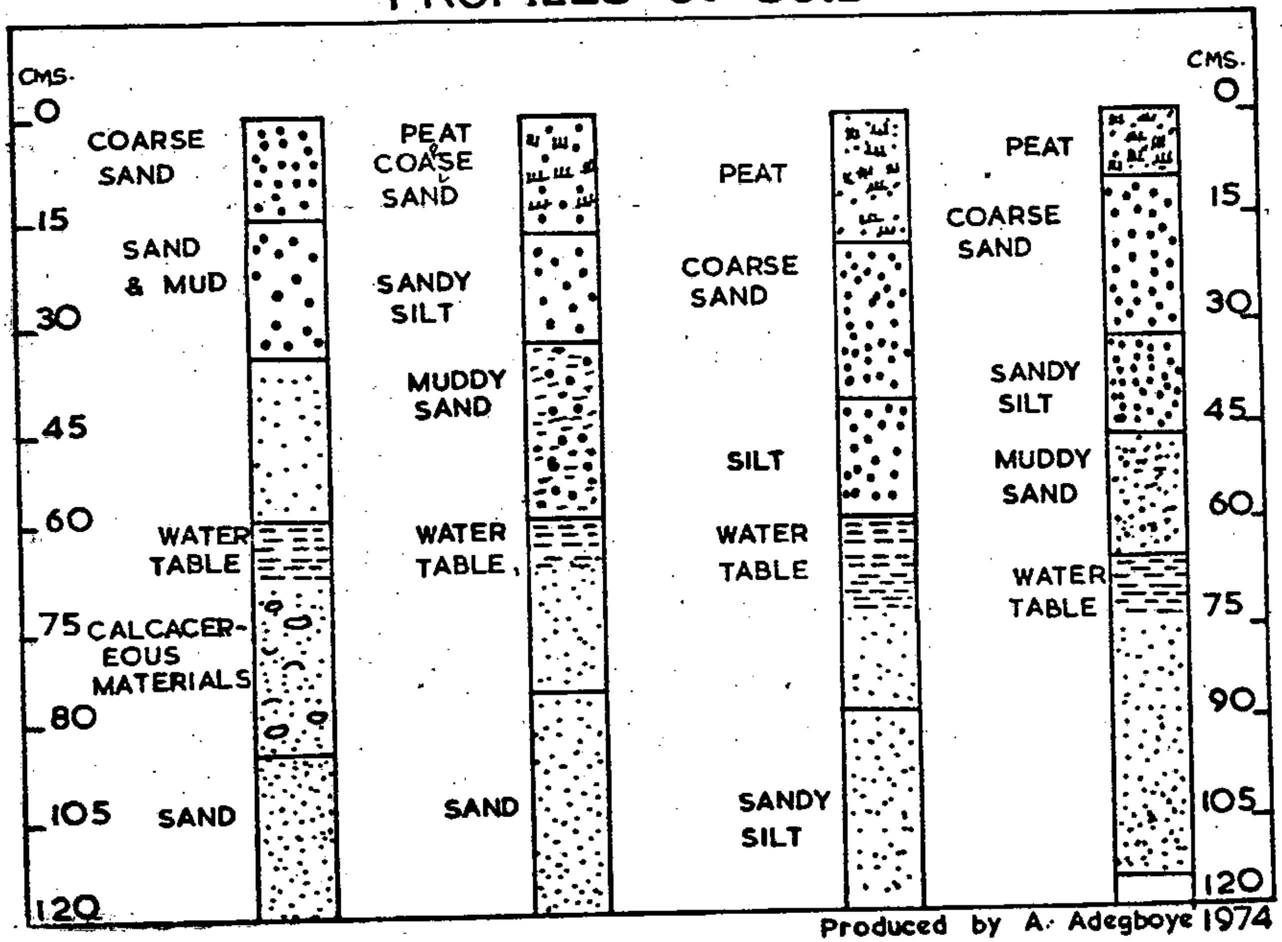
FIG. 2·9
PROFILES OF SOIL



The surface features are generally a combination of a flatish plain, with various abandoned river channels, meanders, and braided water courses. Evidence of changing river courses is found all over the area as shown by the remnants of abandoned channels as illustrated in Fig. 2.8.

The level of underground water varies from the foot of the marginal cliffs to the river banks and from season to season. The level is never below 30cm. at any time throughout the year, while during the rains, the depth of flood water reached about one metre in some places. The level of underground water is also controlled by the movement of the tide which has been observed on the two bridges crossing the Ogun and Majidun rivers during field work.

THE MANGROVE SWAMPS

There is a variety of swampy locations in the coastal zone; one class of swamps was described under the estuarine formations, the other group of swamps are those that are generally colonized by Mangrove trees. There are two major divisions of Mangrove swamps; the salt-water swamps and the fresh-water mangrove swamps. The former are found in locations very near the sea, like the Tarkwa bay Mangrove swamp, while the latter are found along the edges of the lagoons, or areas where lagoon water has retreated, like the Bariga, University of Lagos, Itirin lagoon and Kurano swamp shown in Fig. 2.10.

The basis of differentiation of the two groups derives

DISTRIBUTION OF SWAMPS IN THE COASTAL ZONE

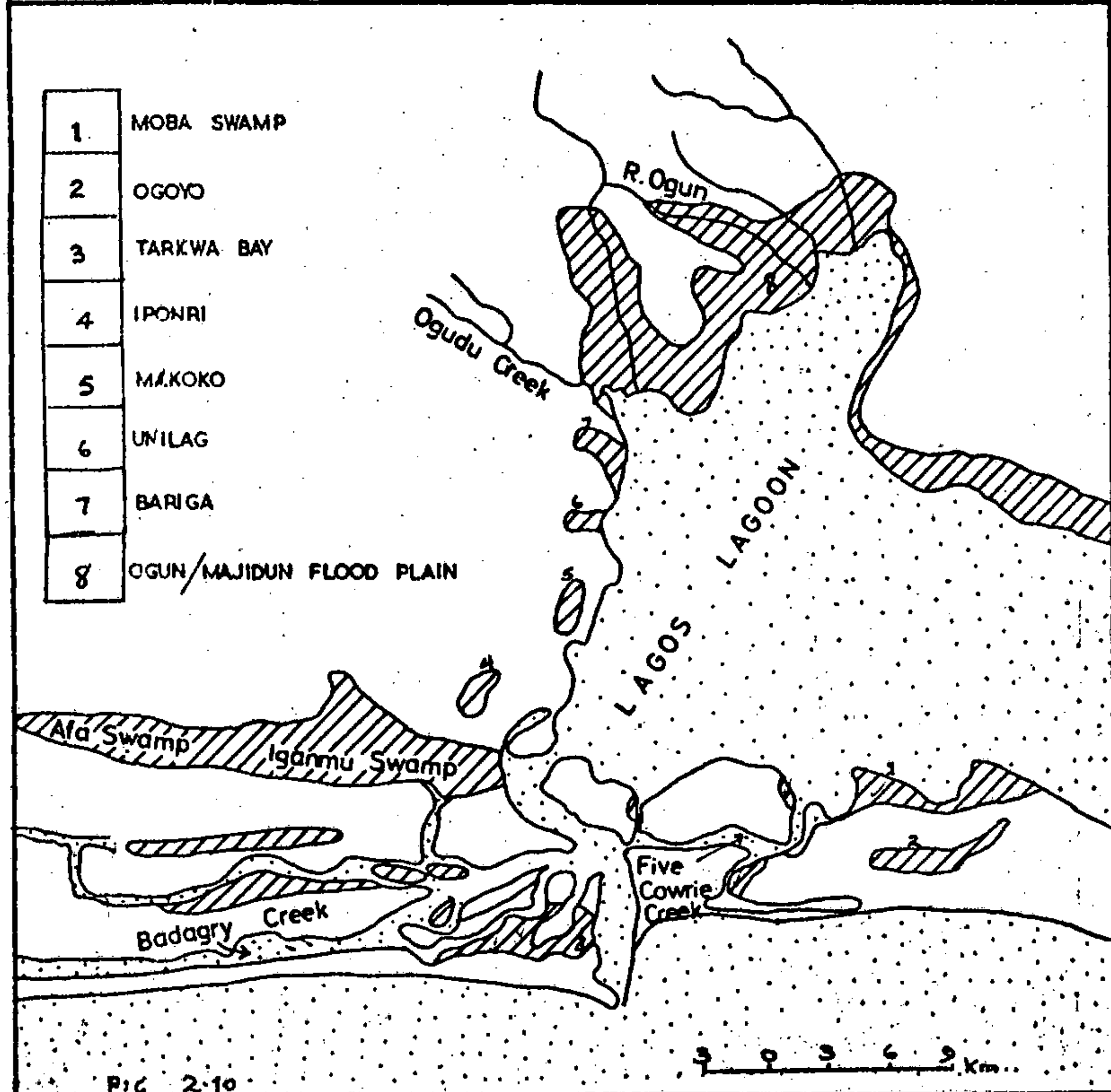


FIG 2.10
Adegboye 1972

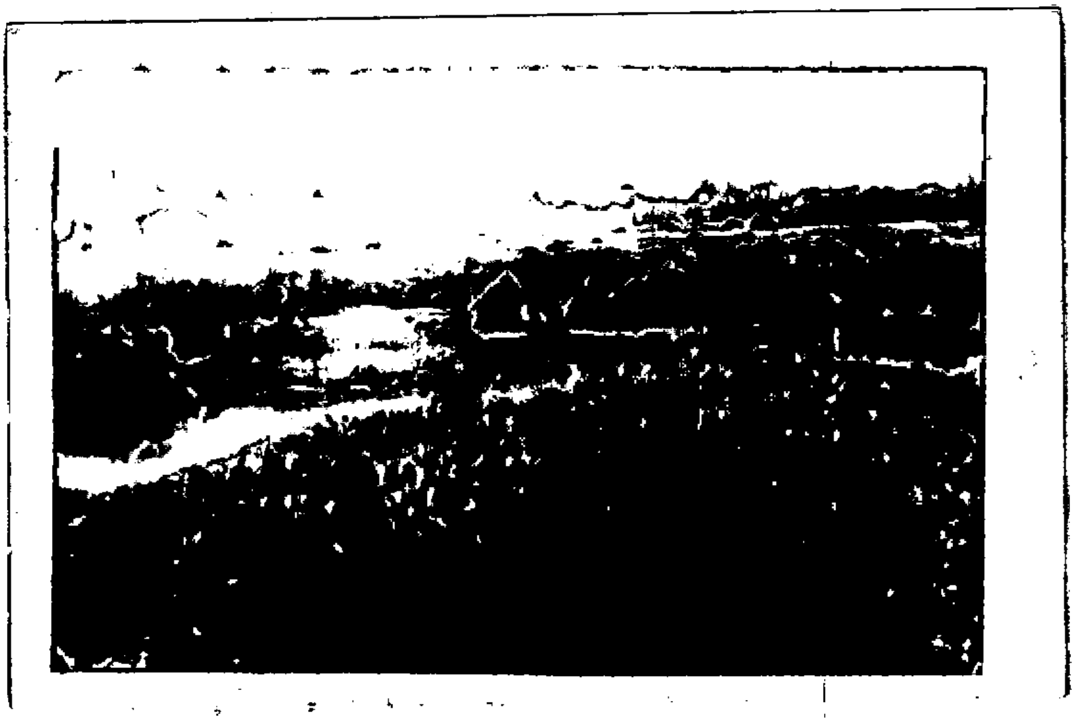
Compiled by A. Adegboye 1974

from the salt content of the soil as well as the species of Mangroves that colonize them. For example, the salt water mangrove swamps provide a good habitat for the Rhyzophora racemosa Mangrove while in the brackish water zone, the amount of salt has diminished considerably and the typical specie of Mangrove is the Avecinna nitida. However, in flooded and lower parts of the brackish water zone, the Rhyzophora thrives well.

Although the mangrove swamps are differentiated, they display indentical characteristics. The swamps occupy depressions of former lagoon beds in the locations named above, while some of them are found along the periphery of the lagoons, trapping silt and 'reclaiming' the lagoon bed. The swamps consist of peat, silt and admixtures of sand. The sand is generally coarse having a mean diameter of 2.1Ø but forms about 50 per cent of those already cut off from the lagoons which contain peat and silt of over 50% and are flooded.

Drainage in the swamps is poor in locations where they are cut off from the lagoon such as in the Bariga, University of Lagos and Makoko swamps where the drainage is centripetal, and the central parts are flooded throughout the year. Those along the lagoon beaches are submerged by the diurnal tide. The depth of the swampy deposits varies from location to location. In the University of Lagos swamp it was 3 metres, at Bariga 5 metres, at the Tarkwa Bay about 5 metres, and at Maroko about 4 metres deep, before encountering the underlying sand and

PLATE 2.2



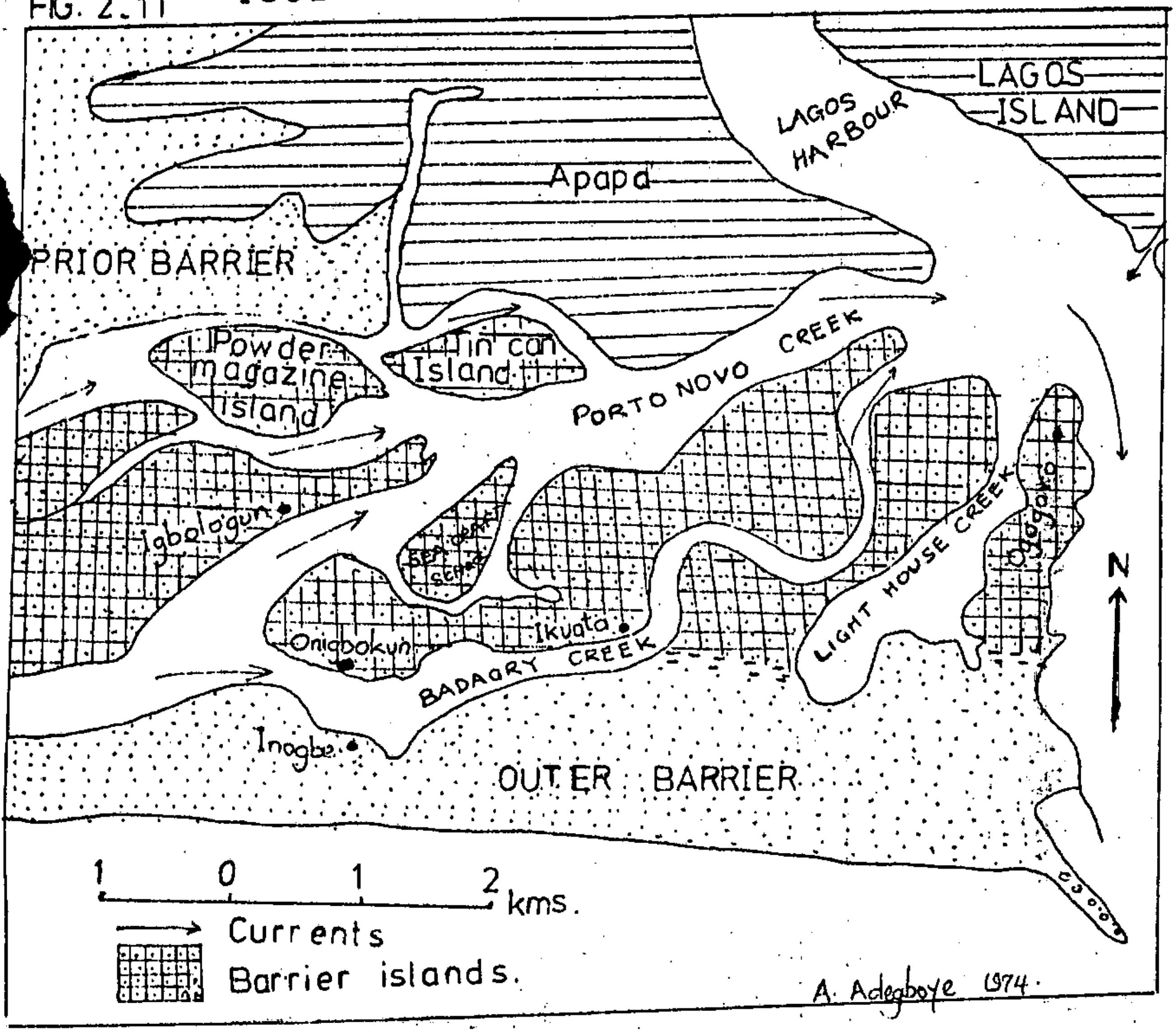
THE MANGROVE SWAMPS IN THE COASTAL ZONE

silt deposits. The swamps thus constitute a group of 'immature' and 'unstable' soils which have undergone only the processes called geogenesis by PONS (1963) and are still to undergo pedogenetic processes. The soils are highly acidic and plastic. The degree of compressibility of such soils with fine texture and high water content is generally high as they are fine textured and closer to their liquid limit. Even if they are drained, the muddy content will have to contract and subside, without being able to support any heavy weight of structures. The low degree of porosity characterstic of such soils, would impede the subsurface drainage, while the basin-like form of the swamps inhibits free surface drainage. As such the swamp-lands are potentially flood-ridden areas. The map in Fig. 2.10 shows the location of the swamps in the coastal zone, including those of the alluvial plains and the Mangroves while Plate 4.2 shows an example of a Mangrove swamp near the University of Lagos.

THE 'ISOLATED' BARRIER ISLANDS

The barrier islands are found along the lower courses of the Badagry Creek, between Onigbokun and Ogogoro village at the edge of the Lagos Harbour channel in the West. These islands developed from the anastomostic pattern put on by the Badagry Creek in this part, where it sub-divides into about four channels, each cutting through parts of the Inner sandy-

FIG. 2.11 ISOLATED BARRIER ISLANDS



barrier formation. The most important of these barrier islands include, Powder Magazine island, Sea-craft school island and Tin can island, which are well illustrated in Fig. 2.11.

The median diameter of the sediments found on the island varies between 2.5∅ and 2.8∅ and they look very similar in structural and textural properties, such as the degree of roundness and in micromorphology to those of the Inner barrier. Although recent sediments like silt and peat develop at the lower parts of edges of the islands, sediments in their central areas as well as in depth are quartz and display the size attributes mentioned above. It is thus possible to classify them as part of the sandy-barrier formation which were cut off by the braided channels of the Badagry Creek. Also, they display the characteristics of the sandy barriers, such as in sediment properties and their west to east elongated pattern. With these attributes they fall within the categories of the sandy-barrier groups despite their superficial alluvial cover and their marginal marshes.

THE BEACH RIDGES

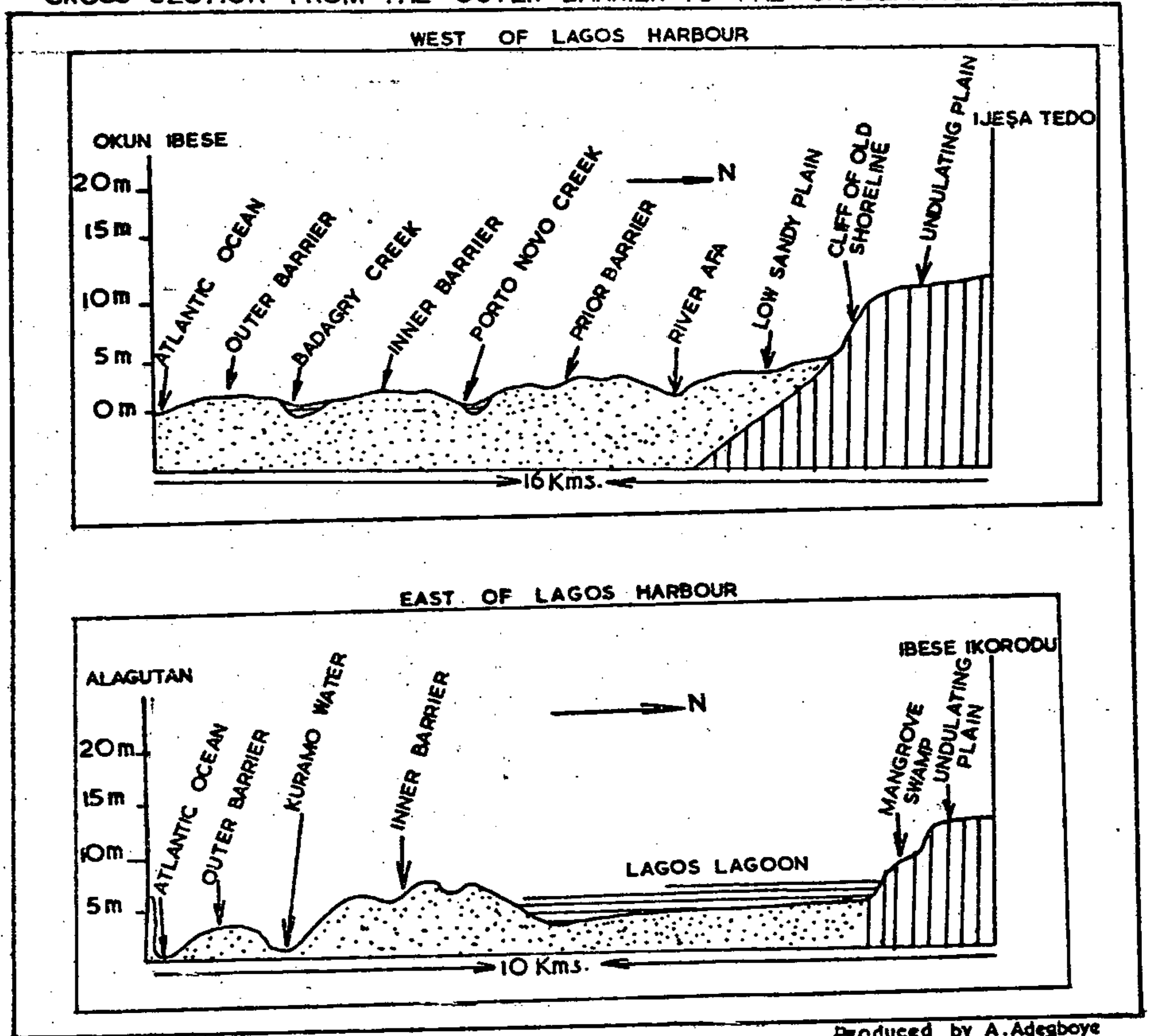
The beach ridges are well defined on the Prior barrier west of Ajegunle and on the Inner barrier east of Igbosere. They comprise the sandy-ridges, swales and breached ridges. On the Outer-barrier, there are only very few features that can be classified as micro-beach ridges west of the harbour. A cross section of the area of study between the sea beach in the south and undulating plains in the north illustrating the succession of sandy-barriers and associated beach ridges is shown in Fig. 2.12 below.

The beach ridges are orientated in a west to east direction roughly parallel to the coast, and in the same direction with the parallel and sub-parallel sandy-barrier formations upon which they are built. The orientation of the beach ridges is an evidence of a unidirectional littoral drift, wave attack on the coast and the wind system in the area. This in essence implies that since the last post-glacial sea-level rise when the first among the sandy-barriers was built, these processes have been constant along this coastal zone.

There are however, some variations in the character on the beach ridges such as the textural properties of the sediments, the maturity of the soil profile, and the spacing of the ridges. The variation in sediment size of the beach-ridges of the western and eastern side of the Lagos Harbour seems to be due to the effect of the provenance of the sediments. While the sediments of locations west of the harbour were derived from the sea, especially through the long-shore drift and sea waves over a very long fetch, these of the eastern side of the Harbour were not as worn because of the ineffectiveness of the long-shore drift in this area, and are thus coarse in texture. The variation in the spacing of beach ridges, seems to be the expression of the differences in the intensity of their

FIG. 2·12

CROSS SECTION FROM THE OUTER BARRIER TO THE UNDULATING PLAINS



Produced by A. Adegboye

formative processes such as sediment supply and period of wave deposition, at particular moments of operation. Thus widely spaced ridges such as these of the Prior barrier are indications of spasmodic but rigorous supply of sand for the building, and/or periods of the still stand of the sea-level that the height of the berm remained undeveloped as a result of the scarcity of beach material within the wave base.

By the virtue of the differences in their age of formation, the provenance of the sediments that make them up and the intensity of the various geomorphological processes that acted on them, the beach ridges exhibit a variety of contrasting forms notably in relief, sediment character and soil maturity. The beach ridges of the Prior barrier for example vary between three and four metres in height above sea-level. If after the occurence of a variety of post-depositional changes in them height the beach ridges were greater at the time of their evolution. On this basis, it is possible to suggest that a further reduction in their heights with time is likely. The variations in the height of the beach ridges on the two sandy-barrier formations, illustrate the disparity in the intensity of the forces that built them up. Hence the higher beach ridges can be used to illustrate higher wave energy environment, while the lower ones may illustrate the opposite.

The beach ridges are separated by depressions generally aligned in the same direction with the ridges and covered by a combination of silt and peat, being deposits left as a result of the flooding of some of them during the period of heavy rains. The higher beach ridges have relatively steep slopes of between 5^{o} and 7^{o} on the Prior barrier, while the lower beach ridges of the Inner barrier have low gradients of between 3^{o} and 5^{o}.

The characteristic sediment materials include quartz, weathered residue of iron and aluminium, silt, peat and clay. However, the quartz contents of the sediments of the Inner barrier vary between 80% and 85% without any significant per centage of either clay or peat, but, that of the Prior barrier contains almost fifty percent quartz, thirty percent ferromagnesian minerals and others such as silt, and peat total to about ten percent. The average median-diameter of the sediments on the beach ridges of the prior barrier is between 2.0Ø and 2.5Ø while that of the Inner barrier is about 1.6Ø, as shown in Table 5.1. The variation in the sizes of the grain derives from the age of deposition, and the rigor of transport, which on the Prior barrier has been earlier established to be vigorous, while on the Inner barrier, east of the Harbour channel, it has been found to be less vigorous, as shown by the variation in the height of the beach ridges. The higher per centage of admixtures of ferromagnesian minerals and silt to the sediments of the Prior barrier derives from the time that it has been exposed to atmospheric weathering and the subsequent break-down of the minerals, a situation which has not been well-marked on the beach ridges of the Inner barrier.

The depth of weathering in the beach ridges varies with location away from the present shoreline such that those of the Prior barrier are weathered to a depth of between two and four metres, while those of the Inner barrier vary between fifteen and thirty centimetres in depth and it is between one centimetre and five centimetres on the active outer barrier. This variation has earlier been attributed to the age of formation, but the density of vegetal cover seems to have aided the weathering of the beach ridges on the Prior barrier. In most cases, the top of the beach ridges of the Outer barrier is bare of vegetation or covered by the Cylindrical Imperata grasses, as illustrated in Fig. 1.11, as such, the addition of organic acids to weathering in this part is less significant. The wooded vegetation of the Prior barrier and the grassland vegetation of the Inner barrier may not be singularly regarded as the effect of differences in their ages but also of maturity of the soils on which they grew, because vegetation density in the coastal zone has been found to depend partly on soil maturity as demonstrated in chapter one. While there is a deep soil profile on the Prior barrier, no significant soil profile seemed to have developed in the Inner barrier as is illustrated in Fig. 2.9(A) on page 93

BREACHED RIDGES EAST OF VICTORIA BEACH

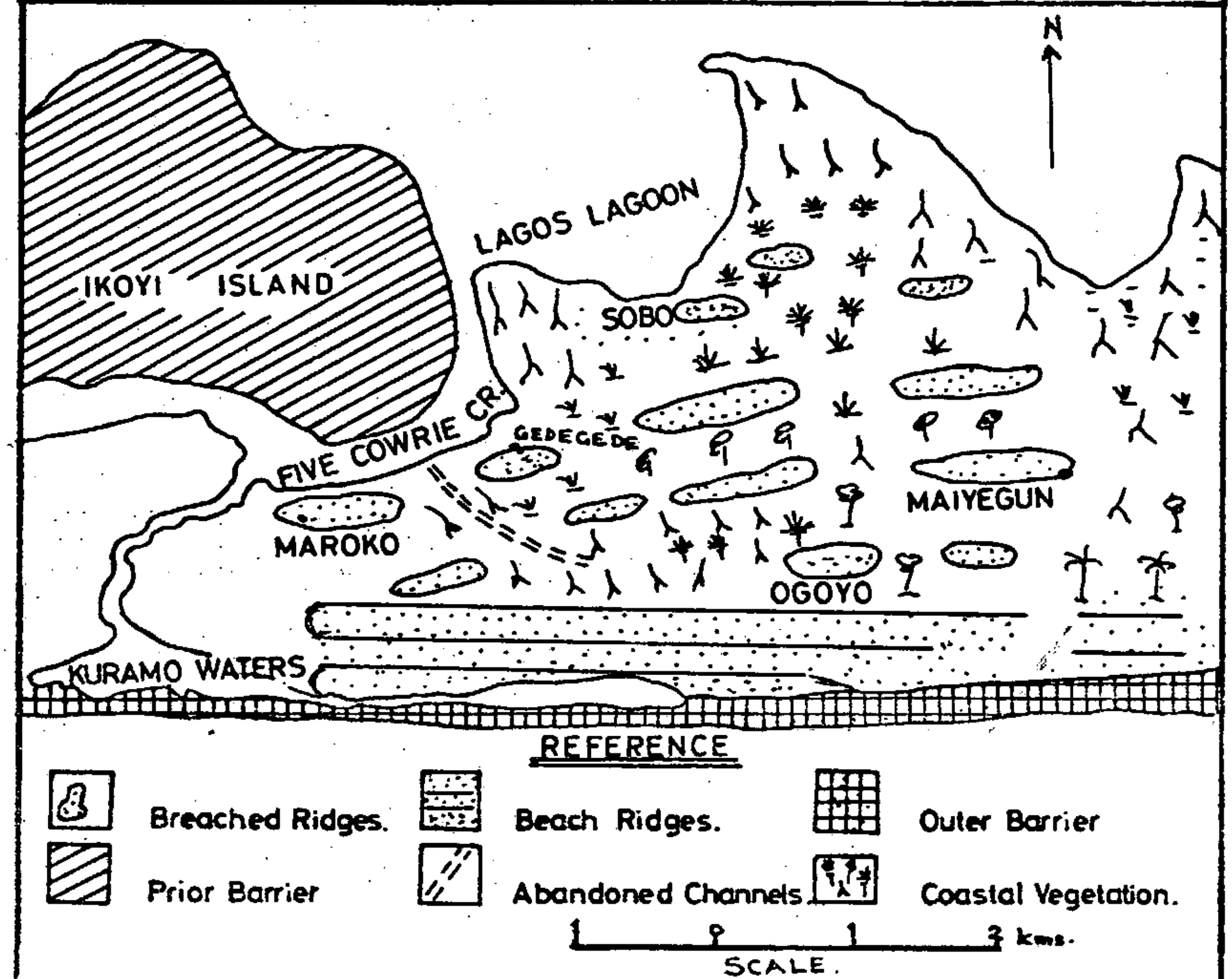


FIG 2.13

Compiled by A. Adagboye 1974

The problem of drainage is considerably taken care of by the positive relief of the beach ridges so that water concentrates in the depressions only during the rains and drains away as the level of the water-table falls. Both surface and underground drainage are unimpeded on the beach ridges, as the loose nature of sediments permits rapid percolation of water while the relatively steep slopes having an inclination of about 5^{o} drains off the overland flow. The movement of water is controlled mainly by the level of underground water which is highest in the depressions, and hence the occurrence of stagnant waters in them, but very low in the ridges.

On the Inner barrier, some of the beach-ridges have been breached by a post-depositional flooding. These are found east of Maroko village and west of Ogogoro village and illustrated in Fig. 2.13. They are elongated features arranged parallel to one another and separated by low-sandy plains. Although the pattern of evolution of both features is the same, the proceedure of development is slightly different. The floods that breached the ridges of the Inner barrier east of the harbour channel seem to be a result of a general rise in the level of the lagoon water which might be due to heavy rainfall, or a rise in the sea level which covered the beach ridges peripheral to the Five Cowrie Creek and breached them. The same phenomenon seems to be responsible for the breaching of the beach ridges west of the Lagoon outlet on the Inner barrier during the development of its braided channel. The details about this have been discussed under 'barrier islands'.

[illegible]

The remnants of the beach ridges are recognized both on the ground and in aerial photographs by the distinct vegetal cover of either coconut palms at the periphery of the lagoons or wooded vegetation and Palm trees in the higher parts as distinct from the monotonous grass cover of the surrounding grounds. This feature form the sites for villages such as Gedegede, Sobo, Araromi Moba and Ogoyo, east of the lagoon outlet, and Ogogoro, Onigbokun and Ikuata west of it.

They are closely related to the old beach ridges because they display an east-west linear pattern, and occur in rows parallel to the beach ridges and have identical sediment character with the old beach ridges. For example, while the median diameter of sand on the breached ridges is 1.7Ø, that of the old beach ridges is 1.8Ø, their coefficient of sorting is 0.7Ø respectively as can be seen in Table 5.1. The inference from these data is an almost identical processes of deposition of both sediments.

Both the old beach ridges and the breached ones form a zone of flood-free areas which can attract settlement. Infact most of the settlements such as Iganmu, Ajegunle, Amuwo and Ojo area built on the beach ridges of the Prior barrier and exhibit a linear pattern as the ridges (see Fig. 2.12); and of special significance in the newly constructed Lagos-Badagry highway which is built in parts on the sandy ridges. On the inner barrier, Maroko and Ilado are typical beach-ridge settlements, while a variety of fishing villages occupy the top of the remnants of the breached ridges along the Five Cowrie creek.

Despite the difference in their ages of formation and the intensity of sediment maturity the beach ridges of both sandy barrier formations, constitute a homogenous landform unit, with common characteristics of mode of origin, spatial organisation, sediment type and drainage patterns. Thus apart from being flood-free, they represent the most salient relief and "dryland" areas among the Holocene deposits of the coastal zone, and occupy a very large area on both barriers which extend much more beyond the area delimited for this study.

Another important surface feature of the sandy-barrier formation is the beach plains made up of an essentially broad-flatish surface, between the edge of the lagoon and the beach ridges east of Maroko and on the north-east of the beach ridges of the Prior barrier, between Ojo and Okokomaiko. These are located in Fig. 2.5 on page 80. The beach plain west of Ojo continues beyond the boundary of the area of study into the precints of Ologe lagoon about 20 kilometers westwards.

The common characteristics of the beach plains include the faint relief whose average altitude is about 6.2 metres, monotonous grass cover, very high level of underground water and annual flooding. The sediments are essentially depositional in origin, and wave built. The gentle rise of the Okokomaiko plain from the depression between the Prior barrier and the cliffs of the old shore line to the top of the ridge which extends over a distance of about four hundred metres suggest two major processes of formation. First, that the gradual rise depicts the gradual increase in the wave energy and sediment supply as the barrier was being built. Second, that the area was flattened by either wave floods or any form of flooding, after its formation. However, the Moba/Ogoyo plains are flattened beach ridges, as evident in the alignment of the remnants of the beach ridges which are parallel as shown in Fig. 2.13.

Although the beach plains display identical surface features of sediment type and altitude, they vary in depth of weathering. Deeper weathering profiles occur on the Okokomaiko plain of the Prior barrier as illustrated in the occurrence of reddish sand found up to the depth of one metre at the shallowwest point, whereas the profiles on the Moba/Ogoyo plain display little or no weathering profile as illustrated in Fig. 2.9c. The difference in the depth of weathering illustrates the age differentials in their formation as well as the influence of higher level of underground water arresting the weathering process in one part, and a lower level which aids it in the other.

THE OUTER-SANDY BARRIER FORMATION

The Outer barrier formation is the most recent of the sandy barrier formations in the coastal zone. It is variously known as Light House beach, west of the lagoon outlet, Victoria beach, immediately east of the outlet, and Alagutan beach further on eastwards up to the boundary of the area of study. The separate examination of this landform unit derives from its peculiar location on the sea coast and its unique characteristics such as rapid changes of form, beach material, and coastal processes which are of contemporary nature and afford a comparison with the infered processes and pattern of evolution of the older sandy-barrier formations. Also, the evidence of changes of form illustrated by differential erosion and accretion on the beach calls for detailed examination in this work, so that some of the objectives of this thesis might be fulfiled with respect to land conservation.

The Outer sandy-barrier formation shown in the Fig. 2.14 is breached by the 400 metre wide outlet of the lagoon system in this coast and creates a situation where the materials brought by the littoral drift in the west are considerably deflected into the sea by the currents of the lagoon outlet, and the beach east of this outlet becomes considerably under-nourished by the littoral drift. This seems to explain the

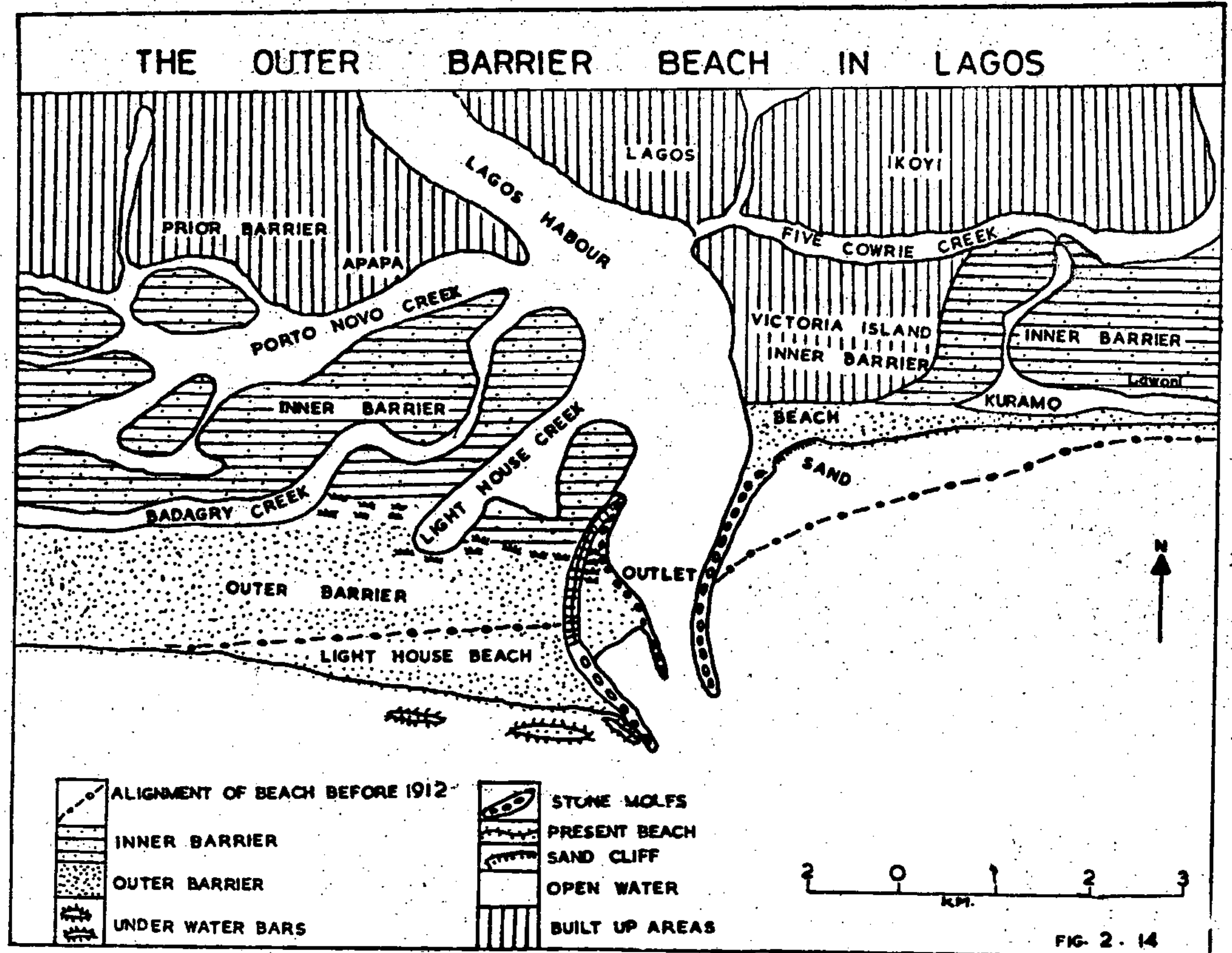


FIG. 2. 14

Drawn from Air photo 1/40000 of 1967

initial cause of the differential erosion on this beach, especially the fact that the Light House beach has been relatively an accreting or prograding beach while the Victoria beach has been erosive. The map in Fig. 2.15 showing the coastal zone in 1859 illustrates this fact; especially the protrusion of the Light House beach seawards and the small bay created into the Victoria beach by the sea.

The present configuration of the outer barrier was accentuated by the erection of the three stone moles which project into the sea and built to keep the entrance to the Lagos Harbour free from sediment accumulation, but which have temporarily prevented the west-east drift of material across the outlet from nourishing the beaches east of it. Hence, the persistent rate of rapid erosion between 1911, when the moles were completed, and 1957, when the documented measurement was made showed that the sea had penetrated into the beach for about 1,200 metres at the edge of the east mole and about 900 metres two kilometers eastwards (L.E.D.B. 1960).

Also, the relatively broad nature of the Light House beach, which is most cases exceeds 30 metres between the low water mark and the beach crest as shown in Fig. 2.14 can be explained by the steady rate of progradation which has been accentuated by the trapping of the west-east littoral drift behind the west mole as most of the waves break farther off-shore on the underwater 'bars'.

MAP OF THE LAGOS AREA IN 1859

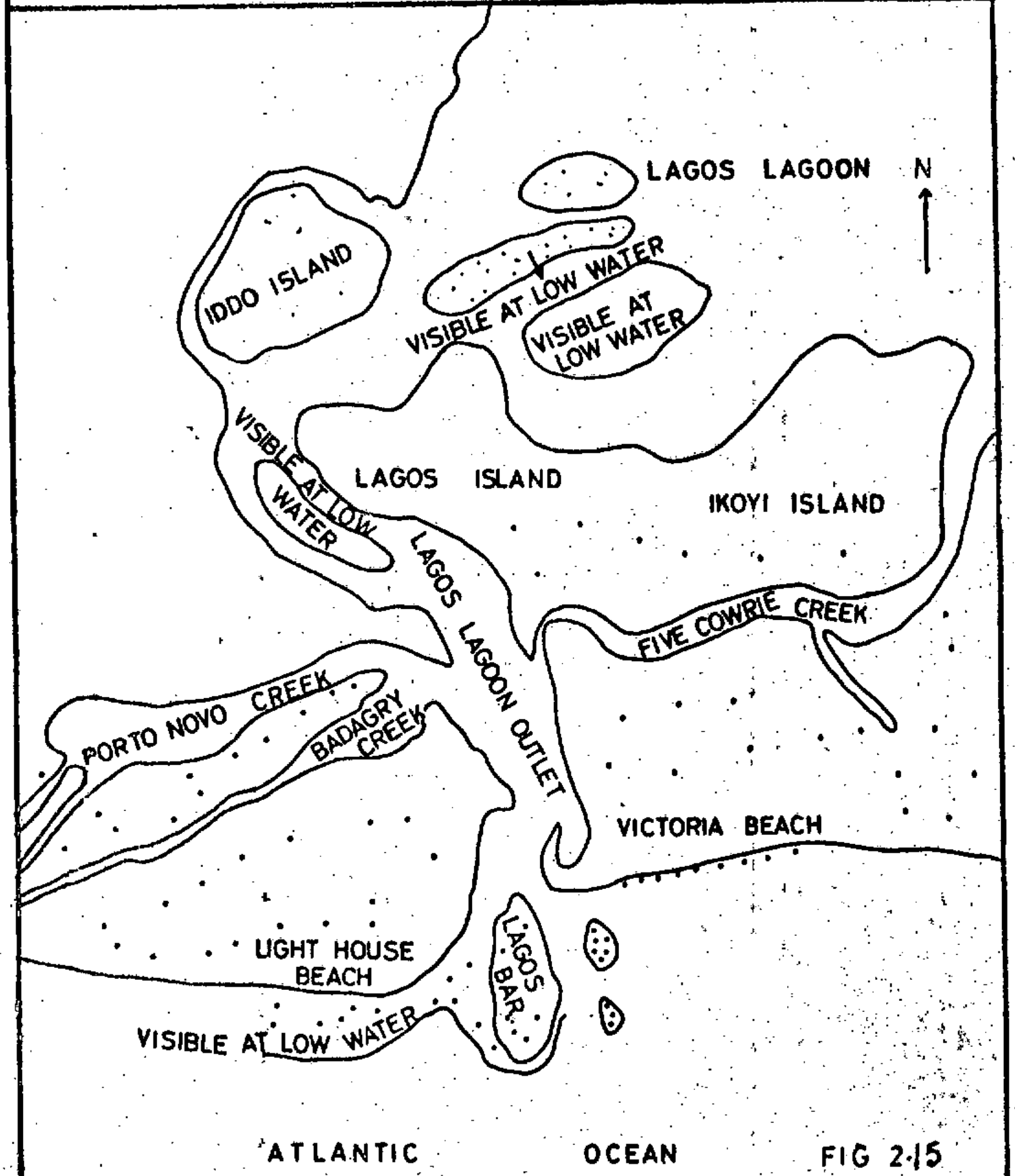


FIG 2·15

Adapted from Lagos River. Glover R.N. 1859.

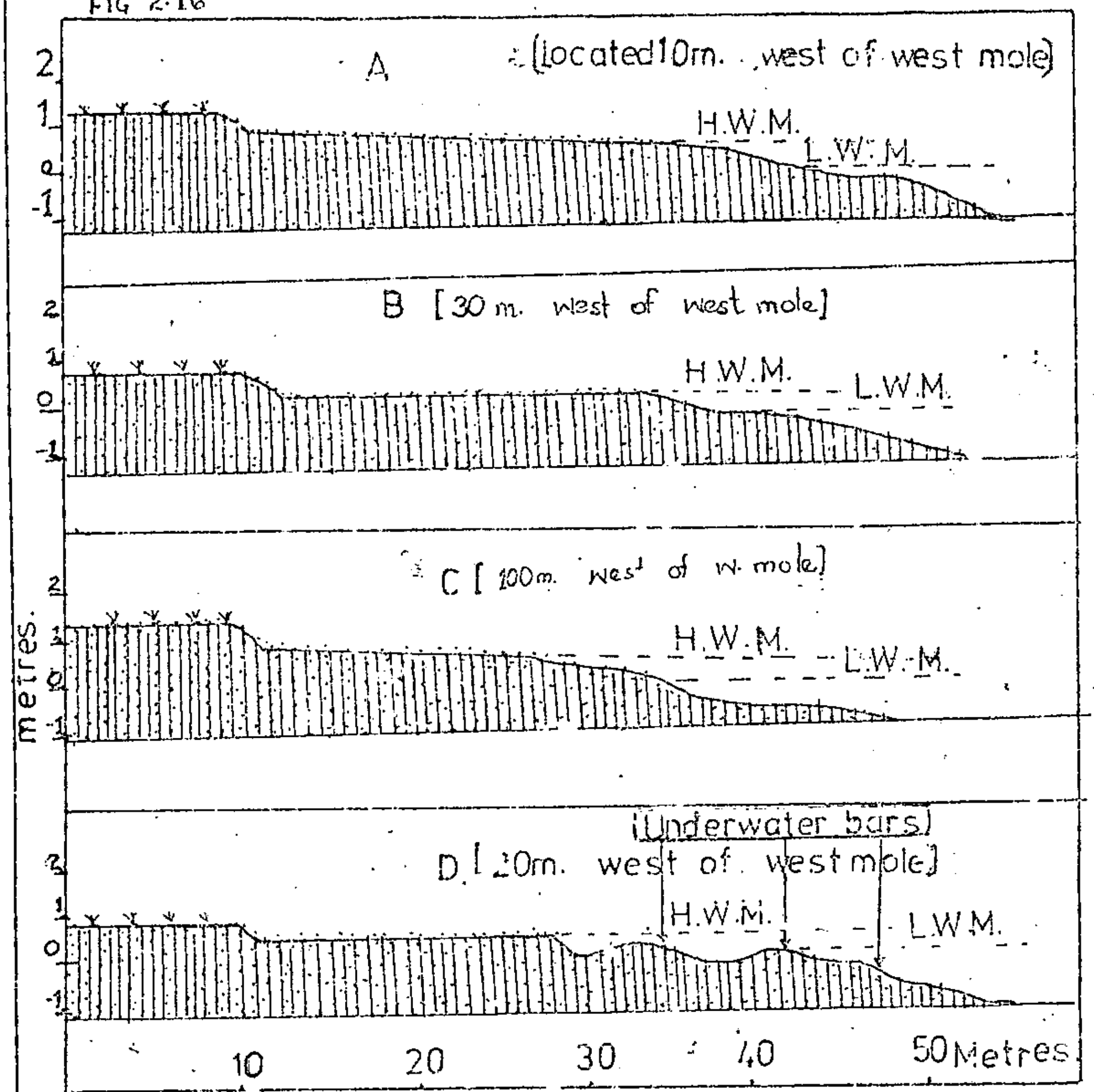
The breaking of waves offshore explains the low height and gradient of the beach which is about one metre and 2° respectively, because the energy of the waves has been refracted by the under-water bars, the positions of which are shown offshore in Fig. 2.15, this causes the back-wash to become very weak in transporting materials from the beach. Consequently, low beaches result and the angle of inclination is very low as illustrated in Fig. 2.16 showing the profiles of the beach.

However, on the Victoria beach, especially between the Eastern tip of the east mole and a distance of about 200 metres, which lies within the area of severest erosion; there is no beach berm development. This is likely to result from the deep water extending up to about six metres from the beach, which enhances waves with an amplitude of nearly four metres to break on the beach without being substantially refracted. As a result of the turbulence of these waves no under-water bar is visible from aerial photographs in the nearshore zone of this area, and hence the materials which should have been built up into a berm were transported down into the sea, leaving a two metre high sand-cliff cut into the beach. The sand-cliff is illustrated in Fig. 2.14 on page 112.

The localization of erosive activity and hence the development of sand-cliffs in this area can also be explained by the activities of waves which break on the beach for the first time in this area after their long journey from their

TYPICAL LIGHTHOUSE BEACH PROFILES.

FIG 2.16



Produced by A. Adegboye 1972.

zone of propagation; which might be thousands of kilometres away in the Atlantic Ocean. Also, those waves that break on the moles, develop some turbulent currents which have been seen to scour off the sands on which the moles rested and lead to the gradual collapse of the moles as shown in Fig. 2.17.

The coarse nature of the sediments in this area renders them vulnerable to wave erosion as the combination of coarseness and poor sorting make them easier to erode than sediments of relatively compact grain-packing like on the Light House beach. Thus the average median diameter of 1.2Ø on the Victoria beach is relatively coarser than that of the Light House beach which is about 2.5Ø in Median diameter, and hence the differential susceptibility rate to wave scouring. This has been confirmed by King (1953) on the Lincolnshire coast in England when she stated that the coarser the sand the greater the amount of seaward by storm waves (King 1959). It is therefore likely that therate of seaward removal of the Victoria beach sands is partly a function of the coarse nature of the sand grains, and partly of the turbulent nature of the sea waves as well as the steeper gradient of the beach.

After about 200 metres from the base of the east mole eastwards berm development on the beach becomes visible and there is a change in the beach configuation as shown in Fig. 2.14.

This change includes a broad beach, about six metre-wide at high water, terminating at the foot of the storm cliff on the beach crest, and the height of the beach varies between one and two metres. The immediate change in beach dynamics here to a relatively accretive process arises from the fact that the effect of the currents provoked by the deflection of the waves by the mole has diminished considerably leaving only direct wave action to act on the beaches.

Between Kuramo beach and Alagutan village east of the Victoria beach, the configuration again changed as depicted in the gradual bulging of the beach into the sea, as well as its attainment of height ranging from two to three metres, and a gradiant varying between five and six degrees. This change is an evidence of the reduction in the intensity of beach erosion, which has produced greater wave deposition and beach stability in these parts. It is likely that as this area lies between three to eight kilometers from the tip of the east mole where the severest erosion takes place, some of the materials removed are being deposited by the waves and the newly developed littoral drift. This becomes more evident by the fact that the dyed-sands used in determining the direction of transport of beach materials on the Victoria Beach were encountered first at the Kuramo beach, Lawani Village and in greater quantity along Alagutan beach. Also, the median size of the materials in this zone is not quite different or does not vary very much from that of the Victoria beach, while most of the sand grains are little worn. These suggest that most of the sand grains deposited on these beaches are derived from the angular sands dumped on the Victoria beach from the lagoon for beach replenishment and are drifted eastwards by wave currents. The average median size of the grain on the Victoria beach and at locations east of the beach is about 1.2Ø.

Although the intensity of beach erosion decreases eastwards from the Victoria beach, the limit of erosion is difficult to define, (Waterloopkundig 1961), hence the eastern stretch of the outer sandy barrier formation can be regarded as essentially erosive. The general cause of this erosion is likely to be related to the development of the west-east littoral drift of sediments to the east of the area of study. This phenomenon is likely to be related to the beach processes working along the coast, hence the analysis of the forces in action along the coast is necessary at this stage.

2.4 BEACH PROCESSES

The study of the processes of beach morphology along this coast is likely to illustrate their role in landform development and form the basis for predicting future trends and consequently be a guide for the planning and development of the beaches. The major processes of morphology include the sea waves and their associated currents and the influence of man. These broad headings can be further broken down into the type and pattern of waves, the littoral processes such as longshore currents, tidal currents, and other wave induced currents and storms, while the role of man includes the continuous interference with the natural processes in the cause of the pursuit of his daily duties e.g. the erection of permanent structures which are meant to modify the action of geomorphological processes along the coast.

WAVES

The average height of the significant wave (King 1959) as measured in the field is between one and two metres and may reach about four metres during storms. The long and low swells of between one and two metres in height are ocean waves which are constant throughout the year. Their energy varies with the position of the tide and they become erosive at high tide and at low tide they are depositional in most cases. But the high swells or "storm-waves" characteristic of the months of July and August every year are about four metres high and five metres in length. They both originate from a south - south-westerly direction and break at an angle of 210° on the coast (Webb 1960) (NEDECO 1970). The occurrence of strong waves during the rainy season in the Niger Delta, has been associated with the passage of line squalls, (NEDECO 1960). However the possibility of the passage of line squalls can not be totally ruled out since this has not been verified, but evidences of stronger wind force of up to Beaufort 8 in the month of August each year (Metereological Report 1970) might explain the cause of the steepness of the waves in this area during this period. Although erosion occurs throughout the year in the form of 'cut and fill' resulting in the development of the berm, the marks left by the erosion of July and August every year are found as low scarps on the accretive Light House beach and as sandy cliffs on the Victoria beach. Hence it is possible to associate the period of the greatest erosion with the period of heavy rains, when stormy winds develop.

WAVE CURRENTS

A variety of currents develop as a result of the angle at which the waves break on the beach; and they help in scouring beach materials and in transporting them along-shore or into the sea. The effectiveness of the swash and the back-wash is determined to a great extent by the beach gradient, hence these currents are more effective on the Victoria, Kuramo and Alagutan beaches with higher gradients than on the Light House beach in the removal of materials. However, the removal of materials from the beach is the major activity of the back-wash while deposition is the work of the swash. When the beach is steep, enough material would not get up to the beach crest whereas the backwash aided by the force of gravity removes a greater quantity of material sea-wards from the beach face. The currents developed as a result of the configuration of the coast especially of the outlet of the Lagos Harbour as shown in Fig. 2.17.

The complex nature of currents illustrates the pattern of sediment dispersal in this area. The waves of the Atlantic, beating on the West mole developed into a reversed current which transports material westwards between the low and high water marks whilst another moves parallel to the moles and transport sediments into the outlet. The latter currents seem to be responsible for the nourishment of the Lagos bar whose depth is put at below twelve metres (NEDECO 1970); and the position of which is shown on the map in Fig. 2.17.

The lagoon currents neutralise the effect of any west-east current at the outlet and divert the currents sea-wards, especially during the ebb-tide. However, the sea waves, which enter through the outlet seem to be responsible for the building of the Commander Shoal in the Western side of the east mole, while the Guinea Currents are in a distance offshore and make no effective impact on the beach dynamics. The consequences of these currents include the underscouring of the rock boulders of the West Mole which has led to the gradual collapse of many into the sea, the nourishment of the Lagos bar at depth, due to sands by-passing the West Mole (Waterloopkundig 1961) and the building of the Commander Shoal.

On the Victoria beach, almost similar currents develop as described above; these are shown in Fig. 2.18. The waves

WAVE CURRENTS ADJACENT TO THE LAGOON OUTLET

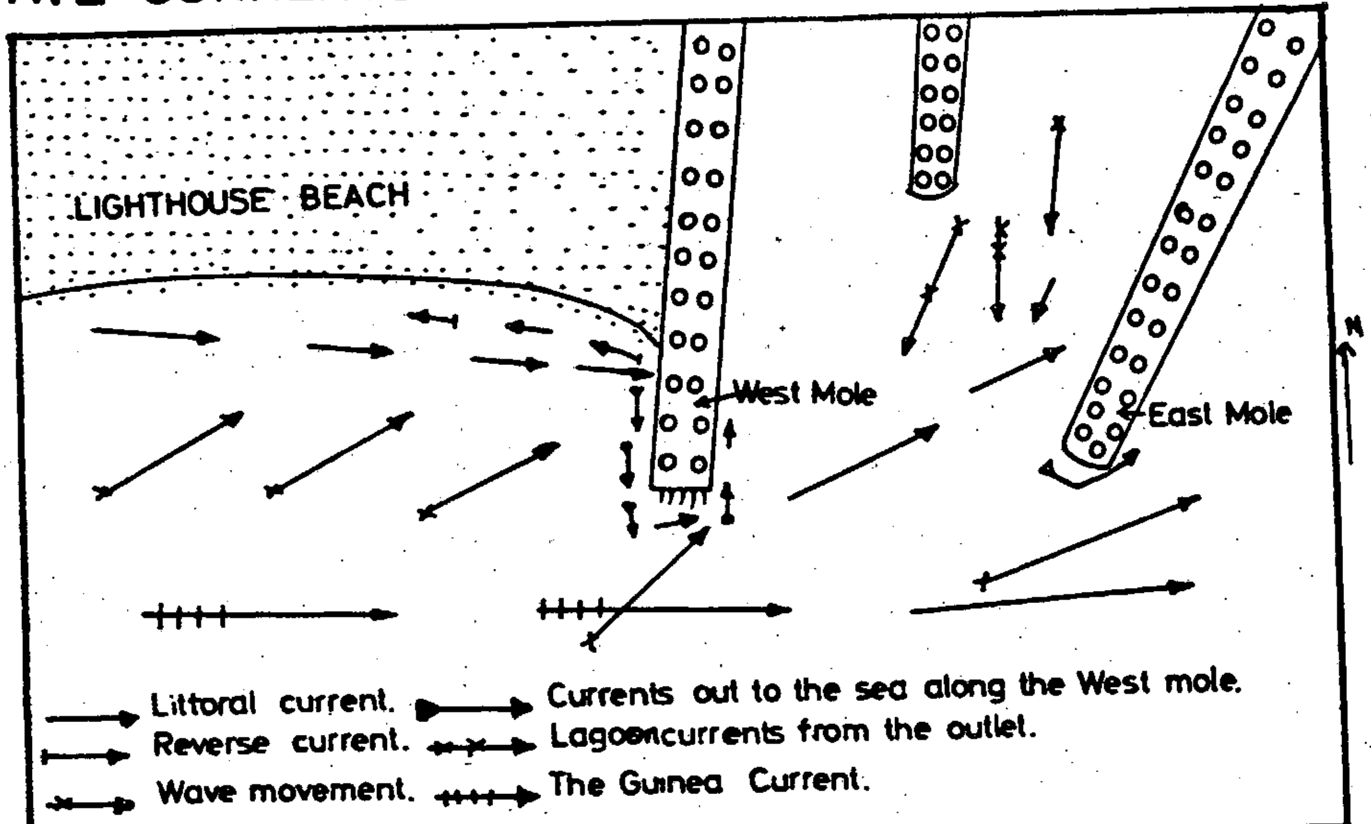


FIG. 2·17

BY ADEGBOYE 1974

breaking on the moles develop into a local turbulent current parallel to the moles and are responsible for underscouring the rock boulders and forcing them to collapse into the sea, and at the same time the currents combine with the wave currents at the tip of the East mole to initiate intensive scouring that aggravated the rate of erosion at the point. The wave currents develop into a west-east drift and transport material east wards.

The peculiarity of the beaches between Kurano and Alagutan is the development of rip currents, Shepard (1948). These currents develop at the depression between two cusps and can be seen over many metres as a body of water moving into the sea behind the breaker zone. This process is pronounced mainly during the high water period. It is localised to this part, because of the steeper gradients which initiated the concentration of water into the 'vales' of cusps, and which itself, is a feature of relatively steep beaches on this coast. The effect of the currents in general seems to be the accentuation of beach erosion and the removal of beach materials.

So far, a detailed examination of the character of the landform units in the coastal zone has been made above. Although, most of the landform units except the undulating and low sandy plains display certain genetic similarities they

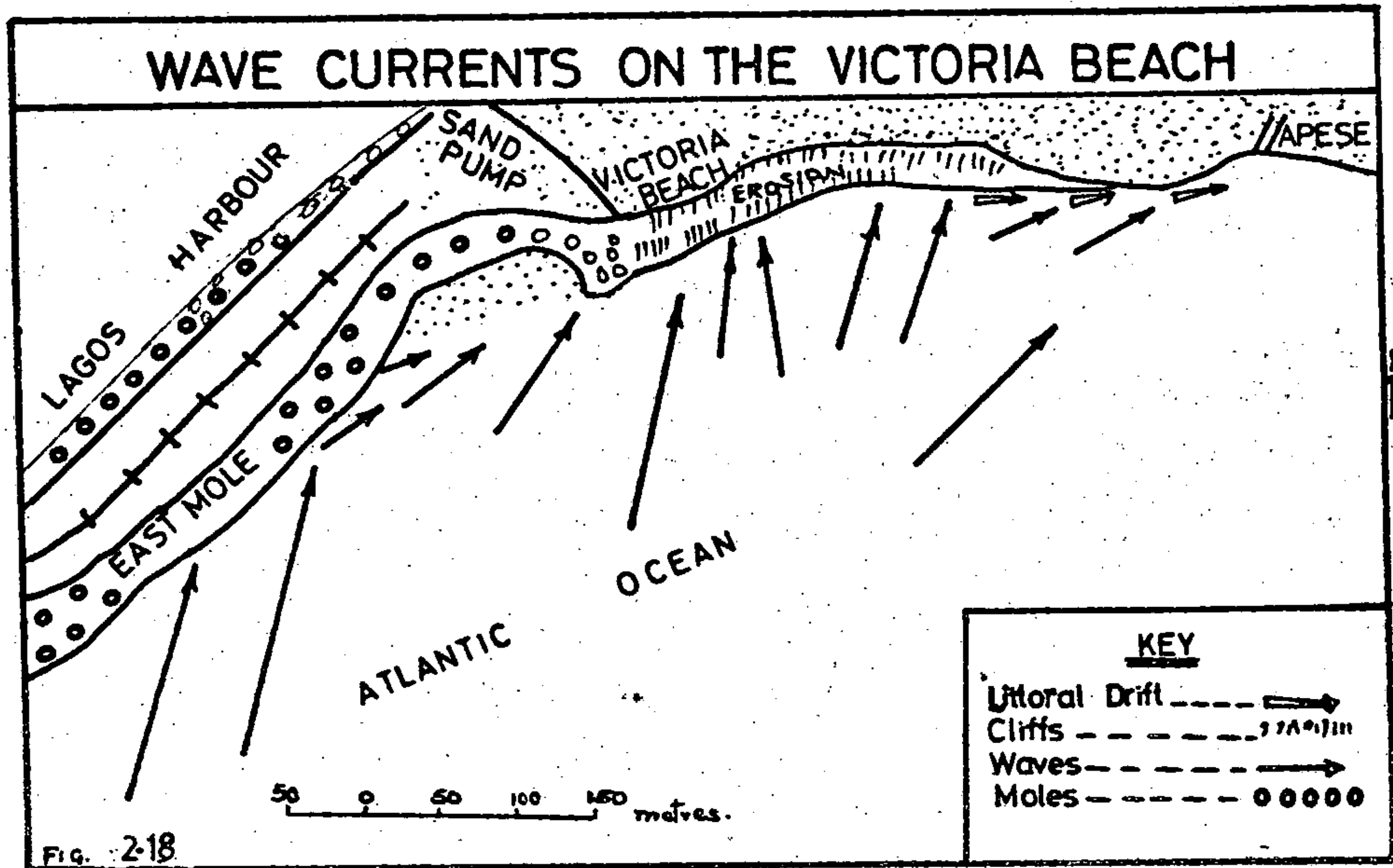


FIG. 2·18

BY A. Adegboye 1971.

also display distinct differences in their detailed character, which provide an appropriate framework for classifying them according to their land use potentialities. Also efforts have been made to relate the evolution of each landform unit to the environmental factors discussed in chapter one, as well as to elucidate the relationship of the contamporary geomorphological processes with landform characteristics. Thus, in chapters one and two, a sound background analysis of the physical environment of the Lagos Coastal Zone has been established. The next chapter gives a detailed account of some of the Geomorphological problems peculiar to this coast, which are relevant to the objectives of this thesis, and it draws a relationship between the problems and the geomorphological forces at work in the area.

CHAPTER THREE

CERTAIN GEOMORPHOLOGICAL PROBLEMS CONSIDERED IN THE COASTAL ZONE

As a result of the inter-action of the environmental factors discussed in chapters one and two on one part and the interplay of human activities on the other, a variety of geomorphological problems which have contributed to the over-all problem of land scarcity, exist side by side in the coastal zone of Lagos. The major problems, include localised-land subsidence, flood hazards, beach erosion and sediment accumulation in the Lagos Harbour mouth. The first three which have been identified as contributory to the problem of land scarcity in the area, are discussed exhaustively in this chapter.

The problems are examined in relation to the various environmental factors considered earlier in the thesis in the first part, while the second part analyses the background information about the problems as they affect the coastal zone, the measures taken to arrest them and the scope of success and failure in these attempts. The significance of geomorphological investigation to problems like these ones is given a critical appraisal and justified. Before this detailed analysis is begun, it is necessary at this stage to examine critically the details of the previous geomorphological and related investigations carried out in the coastal zone of

Lagos, with a view to understanding not only the character of the area but the depth of investigation of the problems better.

3.1 A REVIEW OF PREVIOUS STUDIES

The foremost pioneer geomorphological study carried out in the coastal zone of Lagos is the work of Pugh (1954a, b) which is a general description of sand-ridges west of the Lagos Harbour. His comments about the orientation of sand-ridges and the direction of the littoral drift on the Atlantic beach have been found to persist up till the present moment and have been quoted in the previous chapters. Apart from these, most of his assumptions about the evolution of the lagoon system, the ridge and swale concept, which he developed for the sandy barriers are found not to be totally correct. His failure to describe the character of the sediments in order to lend a support to his Aerial photograph analysis of the sandy ridges, accounted for his inability to give the much needed information on the textural and structural characteristics of the coastal sediments. However, his work was inspiring and was cited by other workers like Webb and Hill (1958) Webb (1960) etc. on the Coastal area of Lagos; in particular, his work offers a good source of reference to this thesis as well.

The works of Webb and Hill (1958) and Webb (1960) which are outline studies of the genesis of Sandy-barrier formations along the coast of Lagos relied heavily upon the findings of

Pugh along this coast. The work of Webb (1960) focussed attention on the retreating Victoria beach, and described the rapid rate of erosion as due to the erection of the stone moles at the Lagos Harbour entrance. As a Zoologist, he was ill-equipped to appreciate and understand fully the geomorphological character of the area he claimed to have studied. However some of his conclusions on the causes of erosion on the Victoria beach and the direction of movement of beach materials along the Guinea Coast are not only found to be true, but are quoted in this thesis. These two works are used as basic references for this thesis as their contents as well as conclusions are of very general character.

Perhaps, the most detailed geomorphological study of this area before now is the work of Abegunde (1966) in which he attempted a critical analysis of the processes of evolution of the landforms west and north of Lagos wherein relationships were brought out between the phenomena of landform evolution in the sedimentary basin and the littoral zone. He used air-photographs in association with landscape analysis and sedimentological techniques to derive his data. Although his work is largely theoretical in content, it gave a broad conceptual framework for the evolution of landforms and established a geomorphological map of the area at a scale of 1:50,000. Some of his conclusions have been used as a working hypothesis for the theoretical aspects of this thesis.

The work of Koennisberger et al. (1962) which examined, assessed and evaluated the question of Land scarcity in Metropolitan Lagos is perhaps the only work that attempts to touch slightly on problems of land resource development before this thesis. The work of Koennisberger et. al., was sponsored by the United Nations Technical Assistant Programme and its scope did not exceed the built-up parts of the metropolitan area. As this was not a geomorphological study in any form, its relevance to this thesis is confined to the call made in its report that a land use agency to take stock of new lands for development should be established by the Federal Government. The work did not in any form examine any geomorphological aspects of problems arising from the management of land around Lagos. Rather it based its conclusions on the amount of population, and the economic growth of the metropolis. In fact the work did not recognise any of the problems discussed in this thesis except that of land scarcity in general.

The call for the stock-taking of the land resource in Lagos area made by Koennisberger and his team in 1962 is yet to be fulfiled; and if any attempt is being made at all it is in the allocation of the existing land to various land users or the acquisition of unused land areas by government edicts without taking stock of the land. It is shown in this thesis that the call of Koennisberger et. al. (1962), should not only involve a survey of the unused lands around the metropolitan area of Lagos but the analysis of the character of the various landforms, and the classification and mapping of these according to their observed characteristics. In this way the classification and mapping would become useful in a practical way to planners of land-use in Lagos.

All other works on the Coastal zone are localised engineering investigations which did not take full cognisance of either the geologic and/or the geomorphological history of the area and as such, most of their recommendations where implemented have not succeeded. These include the works of Waterloopkundig laboratorium of 1951-1961 on Lagos Harbour as well as on the Victoria beach. The failure of the recommendations proposed shows certain misunderstanding of basic geomorphological factors of the Lagos area which arose from a consideration of Engineering methods per se without due regard to the geomorphic character of the area. This thesis draws attention to the fact that engineering activities must be based on a sound knowledge of the character of the land and the forces that modify it.

The previous geomorphological studies reviewed are of fundamental significance to the theoretical aspect of this thesis, while its applied aspect becomes innovative in the absence of any proto-type study.

3.2 LOCALISED LAND SUBSIDENCE

One of the geomorphological problems identified in the Coastal zone of Lagos and examined in this thesis is localised land subsidence. This results from the sinking or shrinkage of underlying sedimentary materials in particular locations especially in exposed and drained swamps and in areas which have been reclaimed with assorted refill materials. In the case of swamps drained by exposure to evaporation and rapid colonisation by vegetal cover, the underlying sedimentary layers contract as a result of the loss of water to evaporation and vegetation. As a result these areas shrink and form depressions generally filled by flood water throughout the year. Examples of such areas include the depression between Ijora, Iganmu and Oto villages, the north-south lagoon depression from Makoko to Oyingbo in Ebute-Metta and Okesuna swamp in the Lagos Island. These are located in Fig. 3.1 on page 137.

On the other hand, most of the reclaimed areas within the metropolitan area have shrunk to depths varying between - 50cm. and - 1 metre especially in the areas around Reclamation road, Oko Awo, Idumagbo, in Lagos island, south-west Ikoyi and parts of Odunfa street in Ebute-Metta, the Railway Compound, Makoko and Iwaya and parts of Surulere area on the Mainland. These areas are located in Fig. 3.1. The shrinkage of the refill materials has been found to result from the decomposition of these materials, the loss of water from the swamps as a result of the filling and the eventual compaction of the sediments and compaction and shrinkage due to artificial 'static loading' with buildings and 'dynamic loading' by vehicular traffic.

Sinking and collapsed houses have been observed in some parts of Lagos especially in Okesuna where a school which was built on reclaimed swamps completely sank; and in Ebute-Metta where a Health Centre built at the edge of a former north-south flowing creek have to be reinforced to prevent it from total collapse, and near it was the four storey building at 61, Odunfa Street, which collapsed in November, 1971. Some photographs illustrating some of the affected buildings are shown in Plate 3.1.

Most of the roads within the city are characterised by series of depressions, resulting from the shrinkage of the materials used in refilling them. Such depressions occur in former beds of creeks or swamps over which the roads are built. These depressions have been described as resulting from localised land subsidence, because of the size of areas affected which is generally less than 1000 sq. metres in the most affected parts of Idumagbo area. In most cases however, when there is any sign of the sinking of residential buildings they are abandoned or pulled down and reconstructed to avoid disaster.

Apart from the ultimate result of collapse of houses, most houses have sunk below the level of the street pavement, and flood waters invade the houses affected during the rains. Examples of this exist in Idumagbo, Reclamation road, Ebute-Metta

PLATE 3.1

COLLAPSED HOUSE AT NO 61 ODUNFA STREET, EBUTE-METTA AND OTHERS.

and Oko Awo. Some of the settled parts are isolated during the floods accompanying the heavy rains, while some of the streets become impassable because of the concentration of flood waters. Above all, with the occurrence of these problems, life does not seem to be safe in these and other uninvestigated parts of the settled areas of the metropolis. Land subsidence thus constitutes an environmental hazard to the people of metropolitan Lagos. The causes of land subsidence with respect to the areas mentioned above, is examined in the following paragraph.

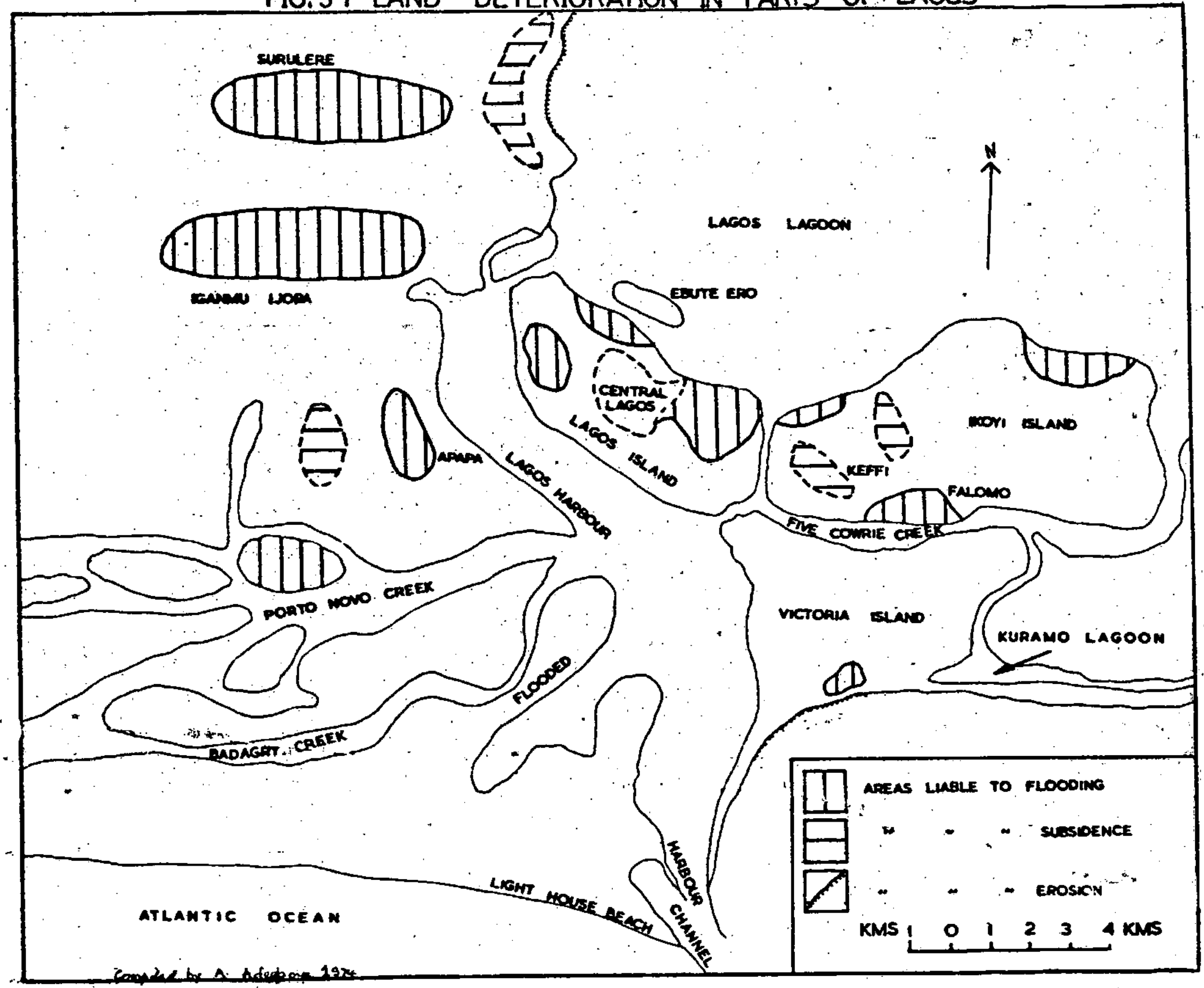
In the coastal zone of Lagos, land subsidence can be explained as resulting from de-watering and compression of the underlying sedimentary layers by the processes of drainage and reclamation. The geological build of Lagos and its environs is such that alternating strata of sediments were laid down. Most conspicuous among these is the alternating succession of sand or clay or silt which marks the phases of sedimentation described in chapter one. In some places the beds of former lagoons and creeks have also left very thick successions of silt deposits. All these occur in the reclaimed areas of Lagos shown in Fig. 3.1 and described below.

The exposure of the surface of these deposits to direct evaporation introduces the elements of mud-cracking, induration of minerals, and compaction to the sedimentary layers. This in effect produces the general lowering of these surfaces by the process of de-watering. However if the area is drained, by building dykes and pumping out water as in Maroko and Tin can Island, the rate of de-watering is accentuated and sediment compaction takes place more rapidly. Although these two methods of de-watering takes place in Lagos, they don't accellerate the rate of subsidence as the other aspect described below.

The problem is also closely related to the geological and geomorphological character of the land, and the method adopted by man in reclaiming the areas where the problem exists. It is shown in Fig. 3.1 and 3.2. respectively that the areas affected by subsidence are former marshlands and swamps. Although the main causes of the problem have been identified as due to de-watering of sediments, a further examination is necessary to ascertain the extent of the influence of the forces of nature and that of man in the creation and perpetuation of the problem. It is common knowledge, that the Coastal zone consists of alternate beds of sand, silt and clay, so that any land development programme should take cognisance of this fundamental aspect of land in relation to de-watering, compaction and subsidence. It seems as if this aspect of the land character was unknown to the private land developers, and was neglected by Government agencies, hence the occurrence of shrinkage, and subsidence all over the place.

In the quest for land for building purposes, the people of Lagos have depended on both private and Government financed land development projects. The private or communal developers

FIG. 3·1 LAND DETERIORATION IN PARTS OF LAGOS



are found in the first settled parts of Lagos Island who had developed their lands before the Government developed interest. The areas developed with public funds by the Government agencies include N. E. Ikoyi, Okesuna, Elesin, Idumagbo, Yaba layout, Apapa, parts of Iganmu, Victoria Island, Race Course and Itirin lagoon.

In the reclaimed areas the problem occurs because of a combination of factors such as methods of reclamation, materials used in refilling, and time allowed to natural de-watering processes after filling and before erecting blocks of houses on them. First, the methods of reclamation can be classified as (i) filling depressions or swamps with house-hold refuse as shown in Plate 3.2. (ii) filling swamps with ferrugunised sands dug from Ojota Quarry in the north-east of the area of study (iii) filling with lagoon sands pumped into the depression or swamps with sand-grouses and (iv) construction of ditches and encouraging vegetation growth as in the area between Moba and Ogoyo and the Tin Can Island.

One of the major criticisms of the methods of land reclamation in this area is the neglect of initial surveys of the depth of clay or silt in the swamps to be refilled, the estimation of the amount of materials to be used, the types of materials to be used to reduce the incidence of shrinkage and above all the non-recognition of the problem of land subsidence as an off-spring of the methods adopted in the reclamation procedure. Out of all

PLATE 3.2

RECLAMATION WITH REFUSE IN LAGOS

the areas reclaimed in Lagos up to 1962, records only show that there was a survey of the depth of depressions in the national stadium Surulere to determine the amount of refill materials necessary (LEDB report 1962), and sample cores on the Victoria Island show that the depth of mud and peat was about 7 metres (LEDB report 1962). Apart from these there is no indication of any preliminary survey of the area to be reclaimed within the Coastal zone. Most of the private developers do not bother about all those as their main concerns were just to fill up the swamps with any type of refuse, sand etc.

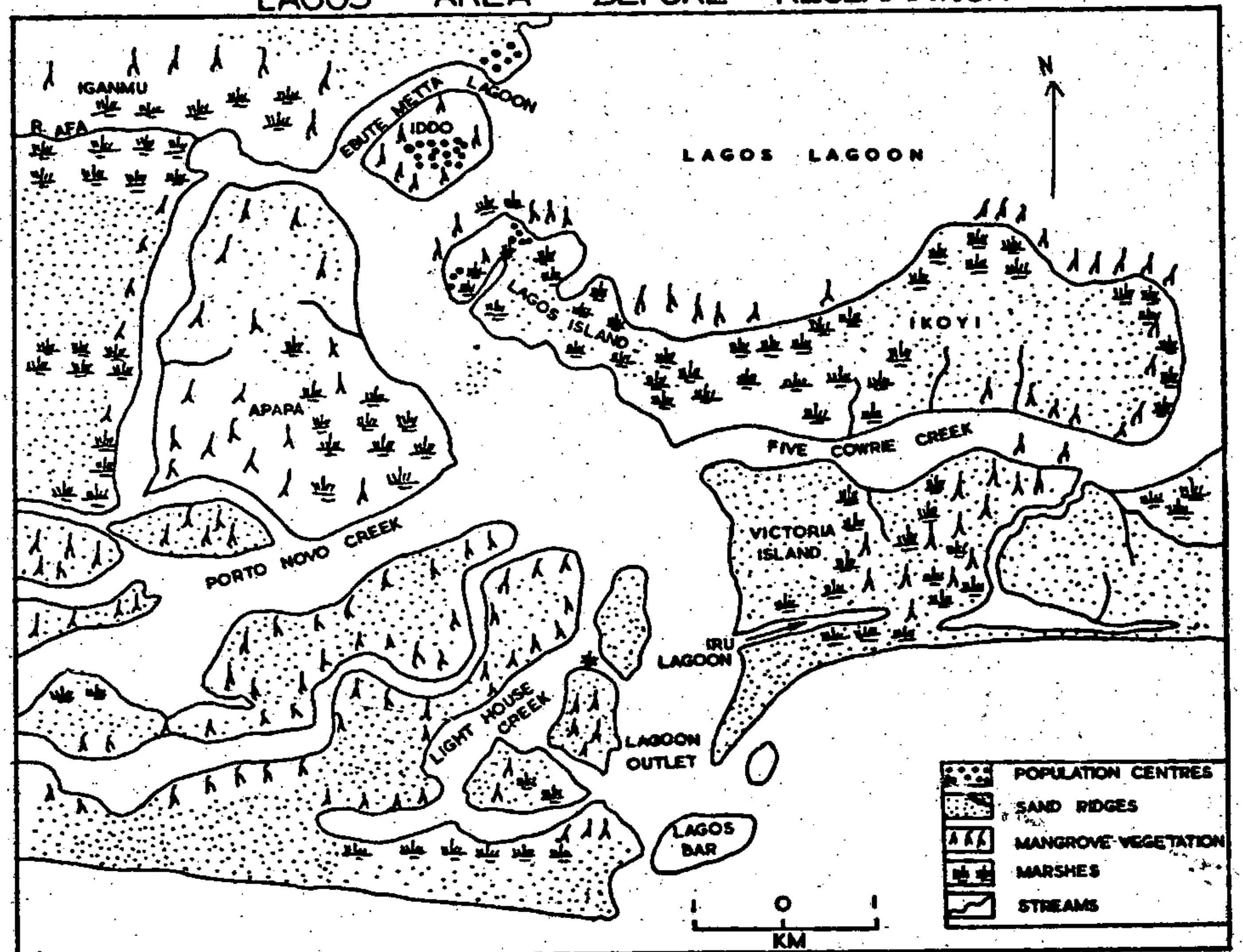
What can be considered to be the second weakness on the part of past developers is the rush in constructing buildings, roads etc. on newly reclaimed lands. This might be an index of the high demand for land for settlement expansion, it is also a way of contributing to the problem of land subsidence when heavy structures are 'loaded' on relatively 'unstable' materials. This high demand calls for a comprehensive inventory of the land in this area, so that problems of making use of lands that may readily deteriorate can be averted, especially in the case of private developers whose capital may not be enough to sink deep foundations.

The second criticism is about using house hold refuse in reclaiming swamps as shown in Plate 3.2 and carried out at present in Akoko, Surulere, Cemetery street Ebute-Metta, Ebute Elefun and parts of the Sand Grouse market in Lagos.

This method is encouraged by the Lagos City Council, as evident in the fleet of refuse carrying vehicles which discharge these refuses into the swamps. Apart from being a crude method, it is slow, unhygenic and gives very poor results. In fact, refuses decompose very slowly, while the organic acids liberated from them aid the weathering of any sandy materials below, so that rapid sediment communition and infact sediment compaction are aided by this process. Also the relative stability of the sediments cannot be guaranteed, especially when houses erected on areas reclaimed with refuse may collapse as exemplified by the four blocks of classroomsthat have been abandoned in St. Finbarrs College Akoka.

The most widely used material for private land development, and road building in Lagos is the ferruginised sands, quarried at Ojota on the Lagos-Ibadan road in the north-eastern part of the area of study. As it is shown in chapter four, Ojota sands are coarse textured with admixtures of ferrugunised sands. Although these materials give immediate results of relatively stable land, they shrink with time into the underlying layers of saturated clays or peat. This is because their chemical composition mainly of ferromagnessian minerals enhance renewed weathering of the grains into finer sizes, thus reducing the liquid limit as the sands become engulfed by the more humid layer of soil below. Some houses whose sites were reclaimed with this type of materials are not only sinking but have been

FIG.3·2
LAGOS AREA BEFORE RECLAMATION



From The Lagos River, Lt. Glover 1859

abandoned or rebuilt along Animasaun street, in Surulere, while roads such as Eric Moore-Apapa Road, Ijora-Apapa road, Animasaun street and Ajegunle-Malu road filled with these materials consist of horizontal depressions marking places where these materials have sunk into the underlying swamp. The quality of these materials for refilling is not condemned but the method of application. Thus rather than spreading the ferruginised sands on swampy horizons as it is the practice at present, efforts should be made to refill depressions from depth with these materials so that the incidence of rapid shrinkage will be reduced.

The most modern and highly technical method of reclamation used in the area, especially by contractors and Government sponsored agents is the sand-grouse for pumping lagoon sands into the area to be reclaimed. The quartz sands seem to be the sediment with the largest mean size and the largest in quantity in the coastal zone. It is neither lubricated by water (Casangrande 1932) nor easily deformable as other finer textured materials like clays or silt (Taylor 1947), but in this area, the quartz sand does not deform by itself, but sink into the muddy layer over which it is spread. Second, the lagoon sediments contain about 60% sand, 30% mud, and 10% calcareous materials (Sonuga and Puzanov 1968) as confirmed during laboratory analysis and shown in Table 5.2 on page 223, which are pumped to refill swamps. In essence, additional 30% of materials of finer texture are added to every swamp filled with lagoon sand, thus increasing the incidence of early shrinkage of the refill materials.

Apart from this, the lagoon sands are pumped with water jet, so that much water is added to already saturated swamps during this process and as such, it should take a longer time before the construction of buildings should start on such places. Although the sand pumping methods involve very large capital investiment, it is the fastest means of land reclamation in the Coastal zone and can be more effective if improvements are made in the whole system of land reclamation exercise throughout the coastal zone. Such improvements that can be made are described in the conclusion of the thesis.

The last method used is the draining of swamp lands by digging ditches to connect them to flowing rivers or creeks as is the case of the Moba-Ogoyo Plain, Tin Can Island, Makoko and National Stadium Swamps. This is perhaps the slowest method because it encourages the twin processes of draining surface and underground waters away. This process is aided by the exposure of the surfaces to evaporation as well as the growth of vegetation which leads to the eventual stabilization of the soils. As it is a very slow method, it is not recommended for areas of high demand for land as in Lagos, but can be an alternate measure or a preliminary measure to land development.

From the analysis above, it is clear that the problem of land subsidence resulting from loading is a common occurrence in areas of loose sedimentary formations but that of Lagos area has been accentuated by obvious mishandling of the reclamation projects due to the poor knowledge of the basic geological and geomorphological characteristics of the area. It is therefore necessary to build up an inventory of the land character in the area, so that land-development programme might be guided and be handled by those who understand the implications of the forces involved in the evolution of the land. Other problems exist side by side with this in the coastal zone and are examined below.

3.3 FLOOD HAZARDS

The problem of flood which, as has been described earlier is closely linked with that of land subsidence, because the flood waters concentrate in the depressions created over the deformed land surfaces.

The map on Fig. 3.1 shows the location of the areas hit by flood annually. Land subsidence is only a facilitating factor as far as flood hazard is concerned in the Coastal zone, especially since flooding is not limited to settled areas as land subsidence is, but to undeveloped areas as well. The whole of the area between Oto and Igammu village and the following places: Makoko, Ilaje, Animasaun, parts of Iponri, Bariga swamp on the mainland are permanently flooded, while the areas described as swamps in chapter two as well as the former mouth of river Ogun shown in Fig. 2.2 on page 69 are generally flooded during the rainy season.

The main causes of the problem of flood hazards are again both geological, geomorphological and anthropogenic. The lowying location of the coastal zone and the loose nature of its sediments give rise to free capillary movement between the sea and the adjacent land areas, the lagoons and coastal rivers; as shown by the rise and fall of the level of the stagnant water in Swamps such as at Tarkwa bay, Maroko, National Stadium and Ikoyi Point with the tides. Thus the geomorphological processes such as tidal movements, underground see-page and surface flow of water induce a compensatory flow of water from the sea to the land and vice-versa. This contributes to the high level of underground water characteristic of this coastal zone.

The heavy rainfall of about 1,800 mm. per annum distributed in the pattern described in chapter one contributes to the high level of underground water, the high rate of over land flow and the retention of the water in depressions for most of the year and in some cases permanently. The relief characteristics which are expressed in the low and monotonous plain with very gentle gradient between 2^{o} and 5^{o} in the steepest parts induce the incidence of stagnant pools of water and flooding in general, because the force of gravity as provided by the gradient is not sufficient to drain the water away, while the high level of underground water makes its percolation difficult. The only exception to this are the summit and sides of beach ridges, especially where they are salient as on the Prior barrier, and parts of the Inner barrier, and on the slopes of the old shore-line cliffs as well as the ridges of the undulating plains to the north-east.

Apart from these local phenomena, the existence of a complex drainage system, combining the waters from rivers Ogun Majidun and Afa directly in the lagoon, and those of Oni and Yewa indirectly through the creeks, and the volume of water from the 400 metres wide outlet of the lagoon as well as those in the net-work of the lagoons and creeks in the area contribute substantially to the high level of underground water and the incidence of floods in the coastal zone. From the analysis of this problem above, the magnitude and frequency of floods can be inferred and a knowledge of this is necessary in planning future land use patterns in the coastal zone whose developed parts are nearly all ridden by flood problems.

However, the human aspect of the problem can be found in the occurrence of flood in the developed parts of Lagos, isolating one part from the other during the rains and destroying homes and properties in other parts. One of the main causes is poor planning as shown by the poor alignment of streets, and orientation of drainage channels against the slope, indiscriminate reclamation of swamps, which formed the debouchements for the street drains. These are exemplified by the drains constructed in both Jankara and Sand Grouse market areas. Others include the direction and discharge of drainage channels into residential areas as illustrated by the drainage of Sabo areas of Yaba into Makoko village, those of western Mushin into Animasaun street in Surulere and those of Surulere into Iganmu area, while river Afa flows into the swamp west of Iganmu.

All these seem to reflect on the type of preliminary surveys carried out in those areas before development. For the Lagos Island, there seems to me none at all, but for that of Surulere, there seems to be little foresight in the planning, because areas regarded as out of reach of settlement expansion and used as debouchement of drainage channels are now inside the new estates going up at Iganmu and along the Badagry road, west of Iganmu. For a better and more reliable future planning it will be necessary to bring a larger area of land under consideration and an inventory of the character enumerated, so that a more rational planning can be achieved.

3.4 BEACH EROSION

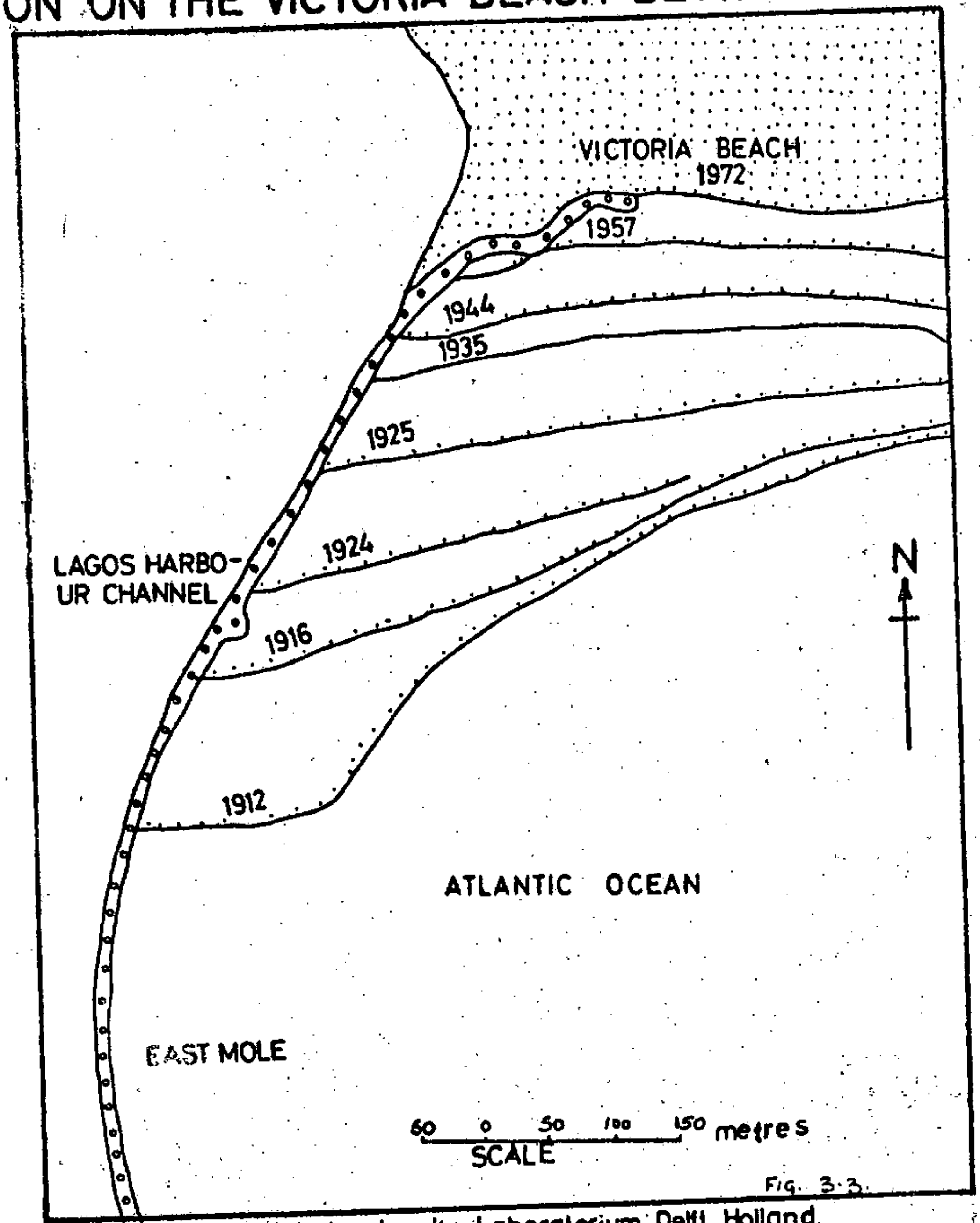
Beach erosion is common to all coasts of the world (Brunn 1962) but it has become a major threat to development along the Victoria Beach and island; it has also become connected with the development of floods in Lagos over Victoria and Ikoyi Islands, and parts of Apapa, should the sea breach the outer barrier formation anywhere on this particular beach. As a result of the continued erosion on the Victoria beach, a piece of land of about 600 metres in length between 1912 when the first mole was completed and 1968 when the last measurement was recorded (LEDB report 1968) had been washed away. The approximate rate of sea incursion into Victoria beach between this period is illustrated in Fig. 3.3. Beach erosion is also common on a smaller scale on the lagoon beaches especially on the western margins of the Lagos lagoon. The areas threatened by erosion in the coastal zone is shown in Fig. 3.1 on page 137.

The rate of loss of land through erosion of beaches calls for a comprehensive survey of the areas affected, the examination of the causes of erosion, as well as the suggestion of clues to this problem; as beach erosion aggravates the problem of land scarcity in this area. Erosion on the Victoria beach is seasonal and very well marked between the months of May, June, July, September and October; with a lull in August every year. This is the period of heavy rainfall along the coastal zone, while the month of August represents the short-break or dry period between the two periods of maximum rainfall in the area. Erosion is common on both the Light House and Victoria beaches during this period, but more rapid and marked on the latter. This process involves the removal of beach sands by very strong waves that develop in the sea during this period. The eroded beach sands are removed down to the near shore zone by the backwash and from there the finer part is transferred to quieter waters in the off-shore zone, while the coarser ones are partly left over for other waves to carry shoreward or are drifted eastwards by littoral currents.

The alignment of the Victoria and Light House beaches in 1859, illustrated in Fig. 2.15 on page 114 shows that beach erosion has been peculiar to the Victoria beach, before the interference by man, especially when a small bay developed on the Victoria beach foreshore, while a corresponding accumulation of sediments develops in the foreshore of the Light House beach. In recent times, the rate of beach recession on the Victoria beach has been phenomenal when compared with what obtains on the Light House beach. Field and laboratory investigations show that the accentuation of erosion on both beaches and in particular on the Victoria beach can be related to a complex interaction of the geological, geomorphological, and climatic forces which have interacted over time and are still dynamic in nature, and the impact of human influences on the modification of natural forces through the construction of moles at the lagoon outlet.

One of the fundamental causes of erosion on the Victoria

EROSION ON THE VICTORIA BEACH BETWEEN 1912 & 1972

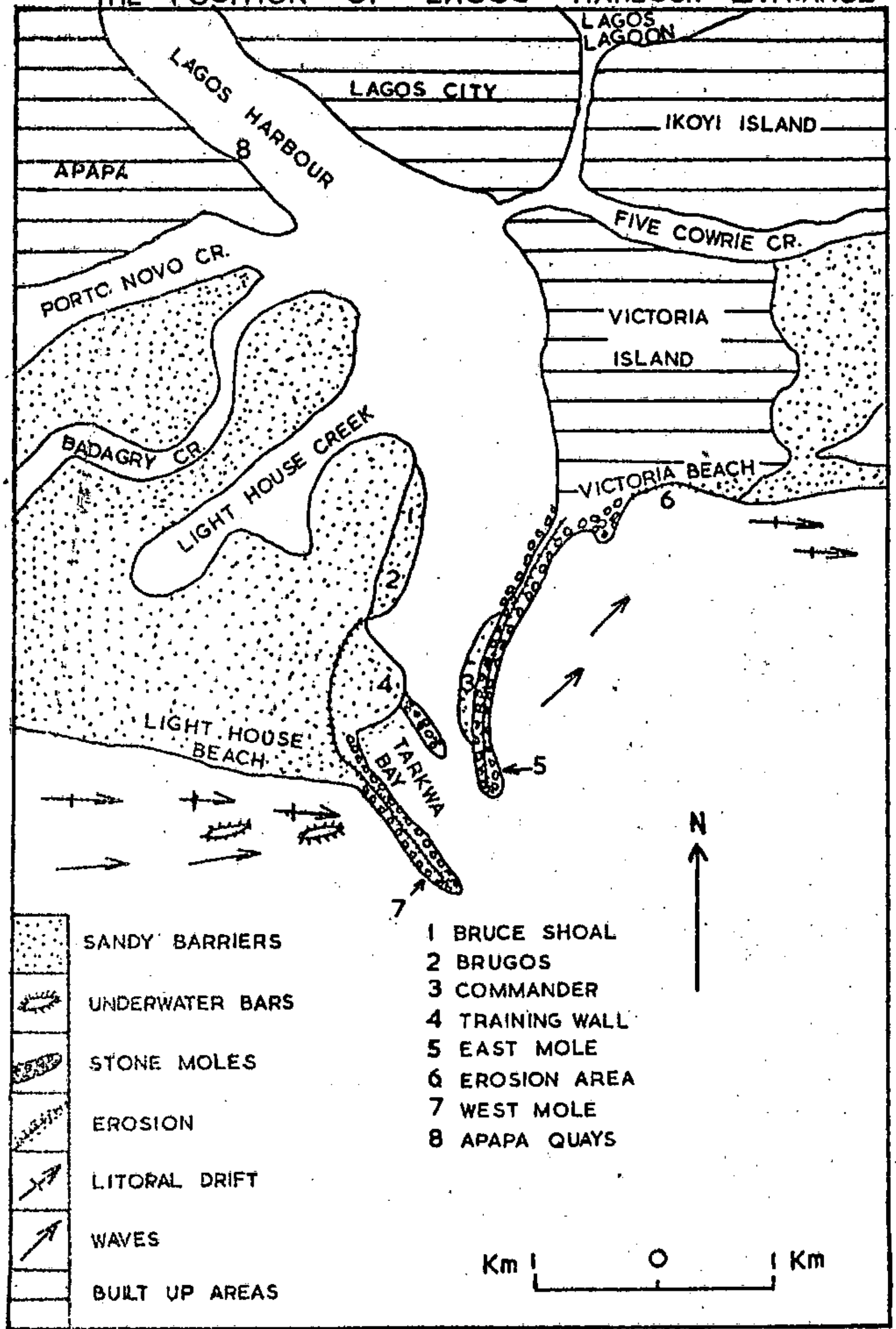


Adopted from Waterloopkundig Laboratorium: Delft Holland.

beach is its location in the eastern side of the lagoon outlet which coincidentally is in the leeward side of the west-east littoral drift that nourishes the beaches of the Guinea Coastlands with sands. Its location in the lee of littoral drift accounts for its bay-like shape in Fig. 2.15 cited above and with other factors account for the contemporary rapid rates of erosion on the beach. However, the under-nourishment of the beach became pronounced from the beginning of this century when three stone moles were erected in the outlet to stop the sand drift from the west from further shoaling of the Lagoon outlet and a training wall erected at the eastern part of the Tarkwa bay to confine any sand by passing the west mole into this bay, and the east mole, on the western edge of the Victoria beach, to concentrate the currents of the lagoon outlet into a smaller channel so that it could effectively scour the channel deep enough to enhance the free flow of shipping traffic into the Lagos Harbour. The location of these beaches and the moles is shown in Fig. 3.4 below.

As a result of this, the sand drift from the west accumulated behind the west mole, the 'Lagos bar' which was the submerged 'sand bar' that had prevented ships from entering the Lagos harbour was considerably undernourished and consequently disappeared into greater depths, while the

FIG. 3·4
THE POSITION OF LAGOS HARBOUR ENTRANCE



Compiled by A. Adegboye 1972

Victoria beach became completely undernourished. As the erection of the West mole stopped the sand-drift from the west, the east mole also stopped any material from the lagoon outlet from being deposited on the Victoria beach, while this beach became the origin of a new system of littoral drift to nourish the beaches east of it. These factors in combination with the occurrence of strong waves and the nature of beach materials seem to be responsible for the rapid rate of erosion on this beach.

The occurrence of strong waves in particular times of the year accounts for the actual removal of the beach materials. These waves, as have been described in chapter two, are not only of high amptitude, but induced by the South West winds over the Atlantic ocean, and are onshore.

The nearshore area of the Victoria beach is void of under-water bars that are sufficiently high to refract the high waves at the base, hence the waves break on the loose sands with great force and remove the sands seawards. The beach sands are perhaps the coarsest in the coastal zone with median ranging from .5Ø-1.7Ø and consist of no matrix or cement to make it more cohesive. Hence they become more vulnerable to beach erosion than the fine textured (Mdz. 2.5Ø - 2.8Ø) sand grains on the Light House beach. This goes further to support the assertion of King (1969), that beaches of Coarse materials are susceptible to storm waves.

Allied with the factors above is the development of local currents between the Lagoon outlet and the Victoria beach. The diagram illustrating this is shown in Fig. 2.17 on page 123 in chapter two. When the sea waves hit the east mole, some currents flow parallel to the moles and scour up the fundations, leading to the collapse of many of the rock boulders. On the Victoria beach, it has been found by experiment, that some of the sands eroded drift eastwards probably to nourish the beaches east of it as a continuation of the west-east littoral drift normal to the coast of the Gulf of Guinea. In the experiment, dyed sands were dumped into the point of the greatest erosion at the base of the east mole and were found the following evening to have been deposited in a small quantity on the beach at Apese village barely 1.6 km. away, and the following day some of the blue sands were at the Kuramo and Alagutan beaches respectively. From this experiment it was established that new processes of littoral drift develop on the Victoria beach and account for the excessive loss of sand peculiar to the base of the east mole.

The morphological character of the Outer sandy barrier formation in general and the Victoria beach in particular is marked by beaches of low altitude, generally lying between

30 centimetres and one metre above sea-level on the Light House beach and between 50 centimetres and 2 metres on the Victoria beach, with steep to near vertical gradients between the base of the East mole and Apese village in the east, and eastwards of this point the beach face has gradients ranging between 8° and 10° in most places. The Victoria beach is narrow, generally between ten and twenty metres broad and reduces to less than five metres broad at Lawani village in the east, whereas the Light House beach broadens to about one-hundred metres between the limit of erosion and the beach crest. These morphological characteristics aid the vulnerability of the Victoria beach to erosion because its height being generally lower than the high waves, causes it to be easily flooded, while the gradient being steep enough aids effective scouring and removal of beach sands by the backwash. In fact, rip currents (Shepard 1963) have been found between Kuramo and Alagutan beaches occupying the vales of the cusps built by waves at the foot of the steeper beaches in these parts.

Thus during the period of heavy rains when the south-west wind is most intense and generates waves of high amplitude over the Atlantic ocean, which beat on this coast, extensive erosion of the Victoria beach is carried out. The beach was planted with rows of Cassuarina trees to provide

PLATE 3.3.

THE LAST CASUARINA TREE ON VICTORIA BEACH, LAGOS shade for tourists who may visit it, but most of these trees have been washed away. The photograph on Plate 3.3 below shows the last of these trees when it was up-rooted by waves in 1971. Erosion is not limited to this beach alone, small scale erosion occurs on the Light House beach and the beaches west of it. Beach erosion was reported in Cape Coast in Ghana (Dei 1969) in the Coasts of Ivory Coast and Liberia (NPA 1972). This brings a new dimension to the occurrence of beach erosion which has been described as eustatic on all lowlying coasts of the world (Brunn 1962, Swartz 1967). Both Brunn (1962) and Swartz (1967) agreed that it might result from a general rise in the level of the sea all over the World, while Fairbridge (1961) explains this rise as due to the deglaciation taking place in the ice caps of the Polar regions. Scholl and Stuiver (1965) while agreeing with the scholars above added that sea level rose about 1.6 metres during the last 3,600 years. It is thus an acceptable fact that the sea level is rising all over the world, and the major effects can be found in beach erosion, but on this coast no measurement of the changes in the sea level have been taken and hence no data exist on this aspect. This thesis accepts the fact that eustatic sea level rise may be one of the causes of beach erosion in general all over the world, but each area has its own peculiar causes as in the case of Victoria beach in Lagos.

Erosion on Victoria beach has produced some staggering effects such as the loss of about 1.5 million cubic metres of sand per annum (Pugh 1954a) (LEDB report 1968). This figure has been put at 0.5 million cubic metres by NEDECO (1961) and Webb (1960). Whatever the exact amount of loss, it is very phenomenal for a beach with very little sand nourishment from natural sources. During the period between 1912 and 1968, the beach is reported to have lost a distance varying between 800 and 1200 metres to the sea (Stanley Consultants 1968), and 450 metres near the Kuramo beach. Another report gives the distance between Wilmont Point on Lagos lagoon and the sea on the Victoria beach in 1892 to be 2,250 metres (NPA 1964) but the same distance was less than 900 metres in 1972. The facts above demonstrate the pattern and magnitude of land loss on the Victoria beach since the erection of the stone moles at the outlet of the Lagonn.

The pattern of beach erosion threatens the existence of the beach itself and the high class residential area of Victoria Island in the event of a sea flooding which is not unlikely at this rate. Apart from the loss of land and the threat of flood hazard, most of the landforms such as beach ridges, sand banks visible in the area in 1859 have been destroyed, and the attempt of man to arrest the erosion by building sand banks, pumping sand, planting trees and erection of timber line on the beach had further complicated the geomorphological processes occurring in this area. It is the understanding of these processes in detail that can give a clue on how to arrest the land loss.

The problem of land loss seems to be of primary importance to the Engineers responsible for the arrest of the beach erosion on the Victoria beach and hence the employment of artificial sand nourishment methods, the extension of the mole eastwards by 600 metres, the erection of timberline on the beach and the building of sand banks lately. Although these methods have been employed, there has been no substantial gain of land over the sea, instead the reverse has been the case. The failure of the engineering solutions can be ascribed to the facts that no cognisance of the fundamental geomorphological forces at work on the Coast was taken before the erection of the stone moles and no consideration seems to be given to understanding the nature of the forces involved in the processes of erosion since it had started on the Victoria beach.

For example the surveys that were conducted before the erection of the moles were carried out in 1892 by Coode and Sons Ltd. of London, to determine the navigability of the Harbour channel (NPA 1964). In the report of the investigation, it was suggested that, to reduce the incidence of shoaling in the outlet, two stone moles should be built on either side of the lagoon outlet to prevent siltation by the littoral drift from the West and to concentrate the current of the lagoon into the channel to scour off the 'bar' (Coode and Sons 1893). As can be seen in the objective, no thought was given to the possible reaction of the geomorphological forces at work in the lagoon outlet and along the coast during the planning and execution of the stone mole project. Such has been the attitude of planners to landform processes along this coast that most of the projects executed, create greater problems of environmental deterioration.

Once the geomorphological problems described above are created, their existence contributes to the overall land-scarcity in the coastal zone, as most of the available 'good land' is being destroyed by erosion or endangered by floods etc. It is in recognition of this fact that the planners have organised some conservation measures for the arrest of the problems.

3.5 LAND - CONSERVATION METHODS IN PRACTICE

In the developed parts of the city of Lagos, very few attempts were made at rectifying the problem of land subsidence and collapse of houses. This includes the inspection of houses by the Town Engineer especially in the affected areas of central Lagos, and the pulling down of suspected houses or advising the occupants to abandon such houses. Examples are the abandoned church building along Reclamation Road and the Health Centre at Oko Awo. Apart from these no other efforts are made to reduce the incidence of 'land subsidence' in the city.

It is not even known whether any thorough investigation of the causes of this phenomenon is being carried out by the Town Planning department of the City Council to use it as a guide in planning for Urban expansion.

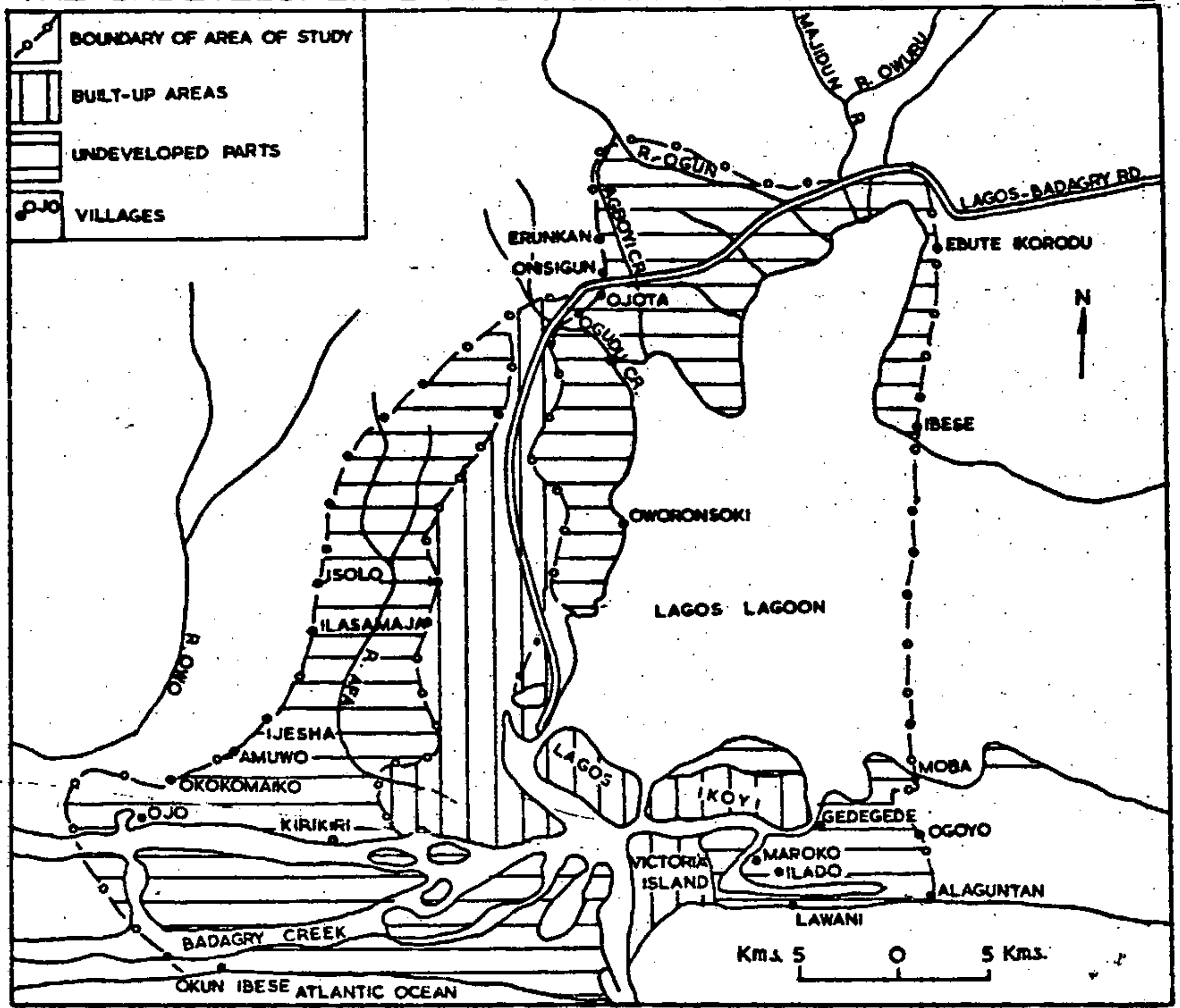
The problem of floods also remains unsolved mainly because it became difficult to realign the drainage channels or elevate the level of the depression in areas already settled such as Idumagbo, Reclamation Road, and Oko Awo areas of the city. One would think that the construction of ditches in the flooded parts of Maroko beach plain, Tin Can Island and Takwa bar swamp is an attempt to reduce flooding, but its aim is to concentrate the surface waters of these areas into channels and thereby expose solid land which eventually be developed. Thus the construction of ditches in this part is more to aid land reclamation than to reduce flooding, as the ditches are aligned against the inclination of the land and drainage in them does not only become stagnant but water overflows the ditches into beach plains during the rainy season and into some other parts during the high tide at Maroko. It follows that the problem of floods has not been considered seriously as to make the planner redeem the built up areas from flooding and prepare the undeveloped parts against it.

The problem of erosion on Victoria beach attracted both official and private interest because of the dangers inherent in an eventual breach of the outer sand barrier by the sea. The official interest is illustrated in the series of investigations carried out since 1951 by the Waterlookundig laboratorium (1951-1961) the surveys of the Ports Authority Engineers and the introduction of conservation measures such as the extension of the East mole to shield off parts of Victoria Island from waves, the introduction of sand re-plenishment programme from the lagoon, erection of zig-zag timber line on the beach face, and lastly the provision of 'sand banks' permanently on the beach for waves to erode.

While this thesis is not under-estimating the effect of the breaching of the beach by the sea on the coastal zone in general, a case is being made for the substantial loss of land to the sea on the Victoria beach especially when it inhibits settlement expansion and reduces space for re-creational activities. For example, the sea encroached upon a distance of 600 metres of land between 1931 and 1972 on the Victoria beach, while the horizontal distance of effective erosion is between the east mole and Kuramo beach covering a distance about two kilometers. Thus about 1200 hectares of land is lost to the sea. If this aspect of the problem is borne in mind, efforts could have been geared towards checking the erosion of the beach. Even, the various methods used and described below have not been successful because they have basically ignored the geomorphological forces at work. For example the extension of the east mole only shifted the point of erosion eastwards from the 'Signal station' to the end of the mole, while the lagoon sands used in replenishment are coarser than the characteristic beach sand found along this coast. The littoral drift sands have between 2.5Ø and 2.8Ø mz, while the lagoon sands have between 0.5Ø and 1.7Ø mz. The difference in size contributes to the differences in their relative resistance to erosion when attacked by waves. While the beach sands are free from silt and clay, the lagoon sands consist of about 32% silt and clay (Sonuga and Puzanov 1968). Thus only about 60-68% of the sands supplied from the lagoon can be utilized by the beach, while the finer ones are carried offshore by the backwash and rip currents.

The zig-zag timber line seems very vulnerable to the high waves during the rainy season, that they are under-mined

FIG.3·5
THE UNDEVELOPED LANDS WITHIN THE LAGOS COASTAL ZONE



Produced by A. Adegboye

and carried away into the sea. The method of stagnating the advance of beach erosion by building sand banks can only succeed for a season or two, because the stronger the waves the more vulnerable the sand banks become. It seems that for conservation measures to succeed, notice should be taken of the existence of a west-east littoral drift along the Victoria beach, the near shore deep zone which leaves the waves unrefracted and the texture and composition of sands used for replenishment.

It has been thus far illustrated that the three geomorphological problems considered, are either neglected or unrecognised and where recognized are treated as purely engineering problems. It has also been shown that the engineering solutions per se have not succeeded as the problems only tend to expand. This thesis is therefore suggesting geomorphological methods to the solution of the problems that would aid the work of the Engineers. These include the geomorphological survey of the 'undeveloped' lands around the metropolitan area and illustrated in Fig. 3.5 below, where urban land use may likely extend to in the future, and the elucidation of the character of the land in terms of the processes of evolution, the characteristics of their superficial deposits and their pattern of distribution. The data thus collected would be classified under units of similar attributes and would be mapped

PART TWO

CHAPTER FOUR

TECHNIQUES OF STUDY

In a comprehensive study like this, a series of techniques is bound to be employed from stage to stage in the acquisition, processing and interpretation of data. This second part of the thesis therefore describes the techniques used in the study of the coastal zone of Lagos. Among the most important techniques used are those of: (i) Aerial photographic analysis and interpretation of land-forms and processes (ii) sediment analysis: and (iii) Geomorphological mapping based on air-photo interpretation, field sampling and evidence from sediment characteristics. Neither micro-palacontological nor dating methods are used because of the absence of appropriate equipments; but some fossils have been collected and are used in illustration and for the correllation of sediment facies and landform units.

A brief examination and assessment of the suitability of these techniques to the study are given below.

4.1 AERIAL PHOTOGRAPH ANALYSIS AND INTERPRETATION

A reconnaissance survey of the area was carried out first by the study of aerial photographs to identify and recognise the position of accessible landforms, drainage patterns, mapping and sampling control points such as settlements and lines of communication. The relevance of this method derives from the fact that most of the area of study which is inaccessible during field work, comes under closer view under stereoscopic examination of the aerial photograph coverage. This opportunity enhanced the compilation of base-maps for the purposes of field survey, and the recognition of basic landform units and associations.

Some of the aerial photographs, especially those of sheet 279: 1/40,000 of 1967 were very useful in corroborating deductions concerning landform location and the shape of units, and unit associations recognised in the field. Also changes such as those produced by beach erosion, the pattern of reclamation and settlement expansion were also readily visible in the aerial photographs. One notable case is Victoria Island which in the 1949 photograph is seen to consist of swamps and pools of water and which has now been developed into a high class residential area as seen in the aerial photograph of 1967. The Western extension of the Kuramo Lagoon visible in the aerial photograph of 1949 and shown in Fig. 2.4 on pages 77 & 78 in this thesis, has disappeared under the ocean at the end of the east mole because of the rapid beach erosion here.

The boundaries of landforms such as beach ridges, swamps and plains were identified by changes in the vegetation tones and density, because the vegetation here is mostly edaphic climaxes as described in chapter one, which derive their character from soil/landform association. Thus beach ridges are distinguishable by their greyish grass cover, while the thick dark green vegetation corresponds to mangrove stands occupying depressions and/or swampy areas. From these aerial photographs the pattern of landform distribution becomes apparent even beyond the area of research.

A comparison of the aerial photographs taken in 1949, 1962, 1964 and 1967 depicted the variety and pattern of changes in the landforms along the coast. This is illustrated by the accretion on the Light House beach where sequential development of beaches from underwater bars to spits and eventually to beach berms becomes visible. The magnitude of beach erosion on the Lagos Lagoon is apparent from the rates of cliff retreat along the lagoon littoral in Ebute-Metta-East, where areas occupied by settlements in 1949 are now submerged by infiltrating lagoon water. This phenomenon is also found on Victoria beach, where some of the settlements had to be shifted inland, because old sites were engulfed by the sea. It is evident from the photographs that erosion either by lagoon or sea contributes substantially to the problem of land scarcity in Lagos, and also the photographs show the pattern of changes in the landscape in general, overtime.

The photo-mosaics provided a closer view of the metropolitan area without much coverage of the 'new lands' shown in Fig. 3.5 but, because of their large scale, some obscure features such as Iganmu swamp, Afa river valley and the extent of Okesuna swamp were observable. The photographs of sheet 279 and 65, scales 1/40,000 and 1/12,500, covering Lagos and environs respectively form the sources of information on the 'new lands' and areas beyond them. They show landforms clearly in their lateral extent and deductions regarding the effects of processes that followed their initiation (e.g. beach ridges, lagoons etc) for example an evidence of sheet wash, reclamation and mangrove colonization. Inferences from these analyses formed the basis of extrapolative studies in inaccessible areas of the coastal zone and beyond.

The West-east orientation of sandy ridges and barrier formations is distinctly seen on the cover Diagram No. 323 of Apapa and this has been found to be identical with orientation of the landforms in the field. This type of evidence - corroboration is an indication that deductions from aerial photographs are reliable to a great extent and can be relied upon in extrapolative studies.

Perhaps a major criticism of the use of aerial photographs might be their unsuitability for land classification mapping because available large scale photographs cover only the settled areas while the 'new lands', which are to be classified, have photographs available only at the smaller scales of 1/40,000. In these circumstances most of the landforms appear very small on the photographs and for this reason, the geomorphological map is compiled at a larger scale of 1/20,000 by combining information derived from them and from field-work data.

The scale of the map also makes it difficult to include minute details such as the dominant-waves' direction, orientation of micro-landforms such as breached ridges and barrier islands. Further more the photographs are not sufficiently clear even under the mirror sterescope, because some of them were taken under poor weather conditions.

The evolution of the settlement pattern is apparent from the study of the aerial photographs, in that most of the initially settled areas are on sand ridges and most of the present highways in the Lagos Island, especially Yakubu Gowon and Bamgbose streets are located on sand ridges. This observation is further illustrated in Figs. 4.1a & b. The other parts of the island which were swamps in 1949 such as southwest Ikoyi, Oke Arin, parts of Idumagbo, Moloney streets

FIG. 4·1a INITIAL RELIEF CHARACTER OF LAGOS AND IKOYI ISLANDS

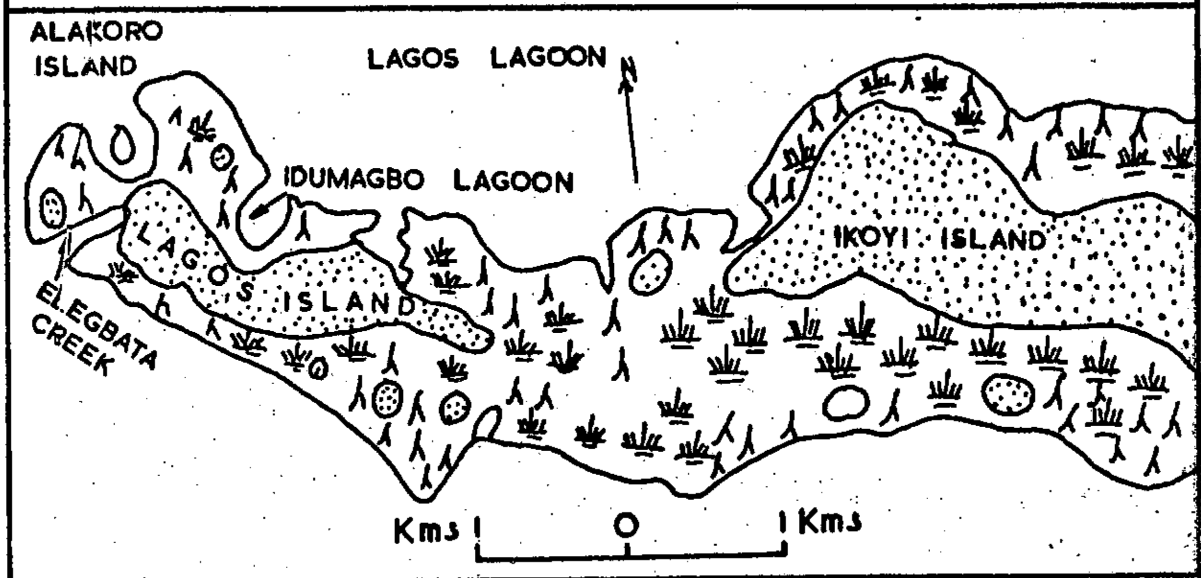
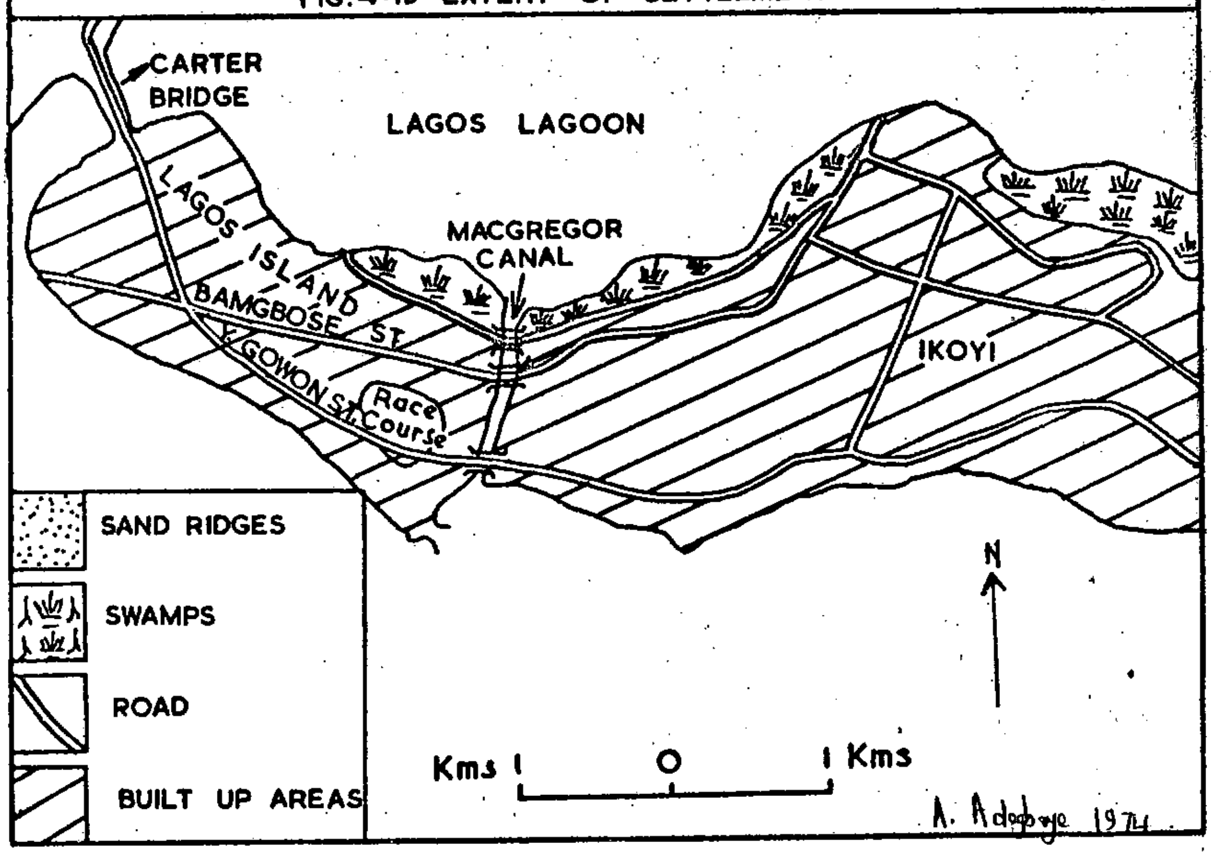


FIG. 4·1b EXTENT OF SETTLEMENT EXPANSION IN 1974



have been reclaimed and settled. These areas are also illustrated in Figs. 4.1a & b. It is these same areas that constitute the 'disaster' zones where subsidence and flooding form major problems as have been described in chapter three.

The aerial photographs used include the following:-

1. Victoria beach 1/12,500 coverage of 1949 by Federal Department of Survey Lagos.
2. Metropolitan Lagos, sheet 8,1/12,500 (1964) (Mosaic) Department of Survey Lagos.
3. Metropolitan Lagos, sheet 10,1/6,000 (1967) (Mosaic) Department of Survey Lagos.
4. Lagos and Environs: sheet 279; 1/40,000 (1967) Department of Survey Lagos.
5. Lagos and Environs: sheet 65: 1/12,500 (1962) Department of Survey Lagos.
6. Apapa and Environs: Cover diagram No. 323 1/12,500 (1954) Federal Department of Survey Lagos.

Some of these photographs are exceptional in some aspects of the study; for example, the aerial photograph of Victoria beach in 1949, on a scale of 1/12,500, that of Lagos environs in 1964 on the same scale and the Apapa Cover diagram of 1954 on a scale of 1/12,500, were of specific importance in the assessment and evaluation of the evolutionary development of the coastal landforms and settlements during the period 1949 to 1964. They depict the growth of settlements such as Ajegunle, Kirikiri and Agboju on sand-ridges. The initial surface drainage patterns in Apapa and

Iganmu is found to be flowing into Ebute-Metta lagoon and the Lagos lagoon at Ijora respectively; while currently they have been diverted into Porto Novo Creek via Apapa Canal during the reclamation processes. This aspect emphasised the role of man, mentioned in chapter three, in perverting the course of natural processes to suit his immediate needs and hence the birth of the various problems described in chapter three. This is illustrated in Figs. 4.2a & b, below.

On the whole, the use of aerial photographs enhanced the depth of knowledge acquired about the various stages of land development, because they were visible from photographs of different scales taken at different times. Evidence of processes are visible, indicating the rates of beach erosion and accretion, sediment accumulation; shrinkage in the 'new lands' also become known with the aid of the photographs.

4.2 FIELD SURVEY

A programme of intensive field survey was carried out from July 1970 to July 1971 and continued at a less vigorous rate throughout the remainder of the period of research. The surveys were carried out in phases: the first was a reconnaissance survey of routes and other control points such as settlements and landforms, while the second was the collection of spot samples of sediments, and the measurement and observation of landform features.

FIG. 4.2a IGANMU AREA IN 1949

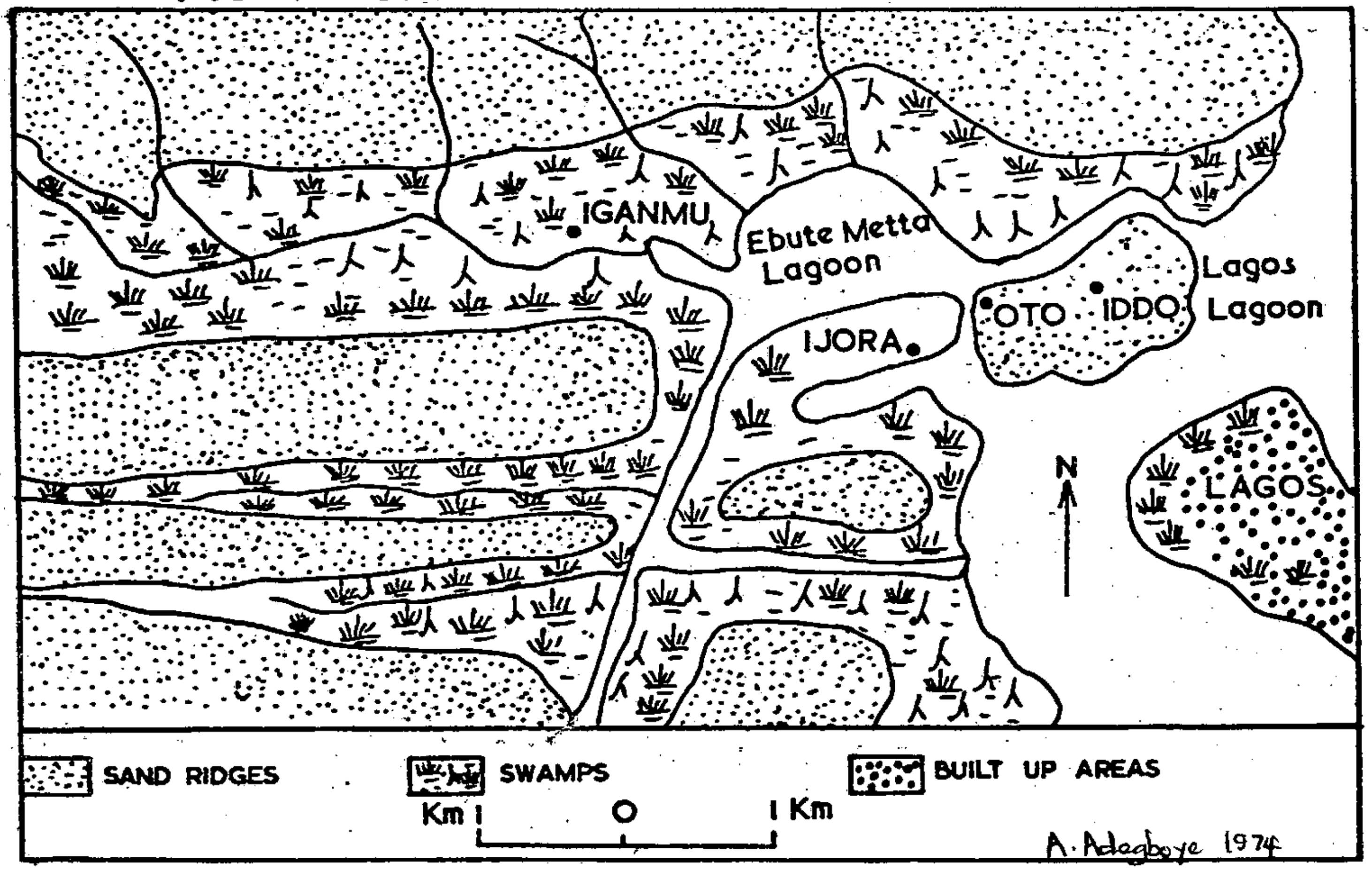
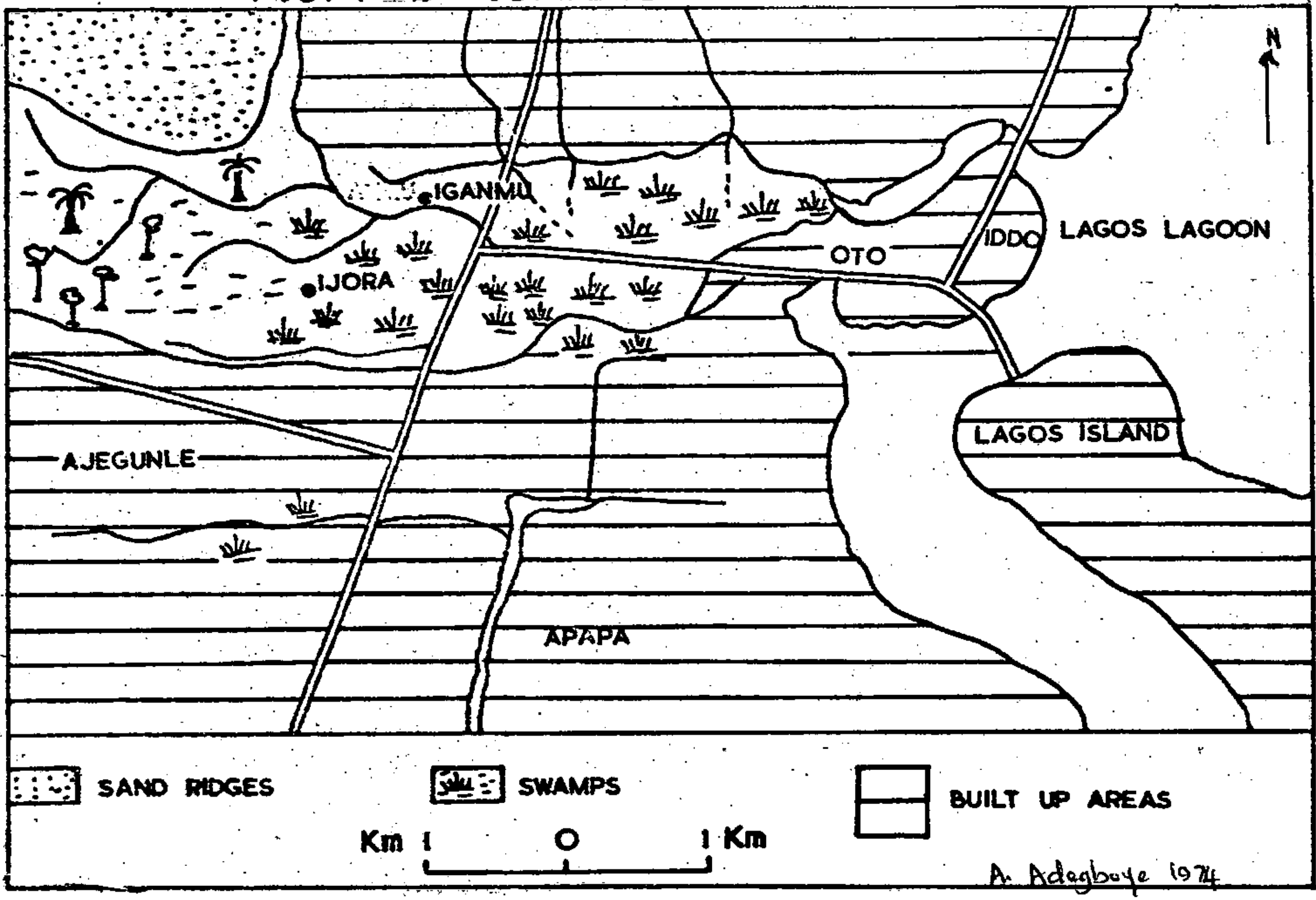


FIG. 4.2b IGANMU AREA IN 1972



A variety of techniques was used in the measurement of landform features. These include the use of levelling techniques to derive slope inclinations, pacing to obtain the relative horizontal distance of landforms and the use of measuring tapes to measure the relative heights of features such as the cliffs of the old shore-line, the sand cliffs on the Victoria beach and the depth of weathering along roadside cuttings on the Lagos-Badagry road and at the Quarry at Ojota.

Field mapping was carried out simultaneously during the field surveys but its accuracy was greatly impeded by factors such as swamps and open lagoon water which affected accessibility to some parts of the area of study, hence recourse was made to air photographs in mapping some of the landforms. Apart from this, maps were difficult to compile to scale in the field because of the difficulty of the terrain such as was enumerated above in this paragraph, hence only the location and orientation of landforms were obtained in the field and mapped accordingly, while the air photographs provided the information that determined the extent and sequence of landforms.

4.3 SEDIMENT SAMPLING

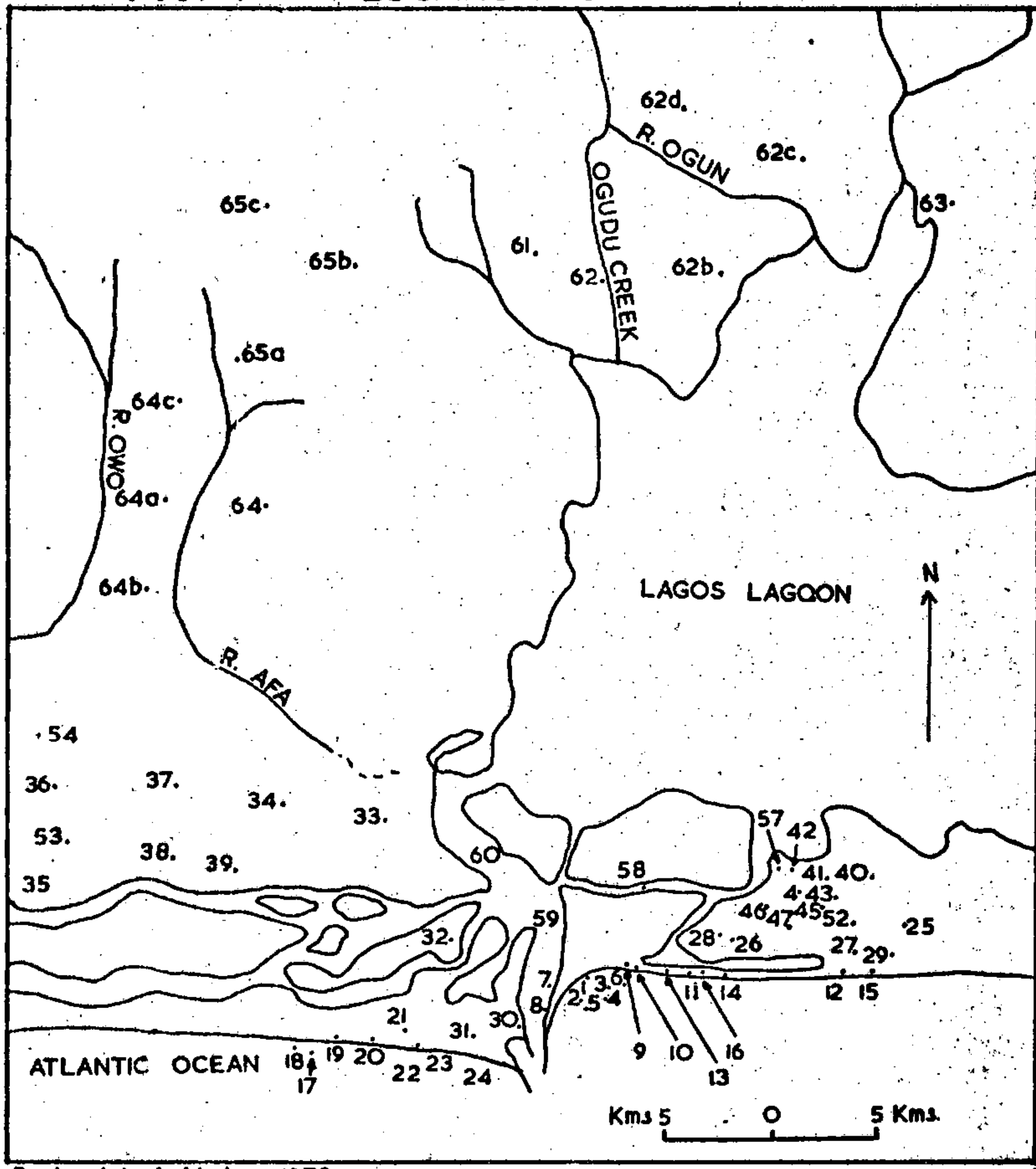
The surface materials of the land have been described as one of the fundamental attributes to be measured before a reliable land classification can be made (Christian 1968), and of the four land attributes used in Engineering land classification, (Brink et. al. 1966), gave precedence to surface materials, because they form the core of the information required for the engineering use of the land. It was the realization of the significance of surface materials to the understanding of land properties such as soil texture, soil structure, past and present morphological processes, that produced them, that formed the basis of sediment sampling programme of this research. Also, in order to establish a detailed classification of landform units, a thorough knowledge of the composition of surface materials is necessary because this is an area of very low relief where basic morphological properties of landforms such as slopes, and altitude are not distinct.

The location of sampling sites is shown in Fig. 4.3 below. The choice of sampling sites was guided by accessibility factors because of the difficulty of the terrain, the high level of under ground water which prevented sampling at greater depths and the alteration of the upper sediments by weathering which has changed the morphology of the grains. It was difficult also to take samples from the greater depths because of lack of suitable equipment. However, sixty five samples were taken from depths varying from 15 cm. to 60 cms. on the beach ridges, plains, Ogun flood plain and the undulating plains, and surface to about 15 cm. on the beach berms. Underwater samples were taken at depths varying from one to two metres in the sea and, one metre in the lagoons.

Depth samples were chosen because most of the upper horizons show evidences of weathering such as communition of grains, leaching of bases, and the precipitation of iron and alluminium oxides, and thus record the effects of surface weathering, whereas the depth of 45 cm. marks the lower limit of the permanent water table which is also the limit of weathering. It is arguable that materials at this level may not have undergone any serious weathering if conditions have remained the same with those currently existing. It has been demonstrated by the results of the analysis that most of the materials at the depth of 45 cm. to 60 cm. on the sandy barrier formations are similar in size, shape and mineraology to those of the present outer barrier beach which are more recent in origin.

The choice of sampling site on particular landforms was made by measuring the accessible part of the landform by pacing. The length of such landforms is divided into three parts and each part constitutes 'a sampling zone'. Within a sampling area, samples were taken from the most centrally located position. For example in the case of beach ridges,

FIG. 4·3 LOCATION OF SAMPLING SITES



Produced by A. Adegboye 1972

samples are taken from the top, where the incidence of modification is at a minimum, and not at the foot where the effect of accumulation through 'down-washing' of sediments is at a maximum. Initial profiles were dug into about three site in the 'sampling zone' to identify the colour, stratification and grain size generally by visualization and feeling with hand. If these attributes are identical, one of them would be sampled and put into labelled sample gags. If they are not identical, the contrasting ones are sampled and labelled as (a) (b) (c) for that sample site. These are first analysed in the laboratory to confirm their contrast; and if their properties are not too contrasting, one of them is chosen to represent that 'sampling zone', but if they maintain the contrast, after analysis, they are recorded and examined as such. An example of a sample zone with three different samples is in Maroko whose code numbers are Lag 71/47, 48, 49, in Table 5.1 on pages 212 - 215.

4.4 SEDIMENT ANALYSIS

The peoperties of superficial deposits used as part of the criteria for classification, include the grain size, shape, and mineraological characteristics of the sediments. Data relating to plasticity and permeability were also inferred from the properties enumerated above; and were selected because they are significant for the classification of sediments on the basis of their usability for settlement expansion and the rectification of problems of land subsidence, beach drifting and flood hazards. Special techniques have been used in deriving the character of each of the properties and they are briefly explained below.

GRAIN SIZE ANALYSIS:

Dry sieving methods were used and no attempt was made to use either the hydrometer and pipette techniques because the clay fraction in the sediments is always negligible. The British standard sieve Meshes, Nos. 7, 14, 25, 52, 100, and 200 or apperture sizes 8, 4, 2, 1, .5, .25, .13, .065 mm respectively were used since they were the only ones available. They were arranged in this order so that the results can give a geometric relationship which could be easily compiled especially when the logarithmic scale is used. Each sample was quartered down to 105 grains, using the coning method of Pettijohn (1957). One of the quarters was taken and disaggregated either using a pestle and mortar or using diluted Hcl at a ratio of 1:4 (Milner 1961) to disaggregate concretions and iron-coated grains. The residue was later put into a glass beaker and dried in an oven at a temperature of 37.5°C for about twenty minutes as recommended by Milner (1961). The weight was recorded at 100 grams and recorded in the 'analyses sheet' a copy of which is produced in Appendix VIII of this thesis. The sample was then transferred into the sieve already mounted in the 'automatic shaker' for a twenty minute shaking, so that every grain comes to rest at its own apperture grade. The materials left on each mesh were weighed and recorded on the Analysis sheet for the particular sample. This was converted into cumulative percentages and plotted on semi-logarithmic paper. These processes were carried out for each of the samples and the result is tabulated in Table 5.1 on pages 212 - 215. The determination of the moment measures measures was carried out by applying some statistical techniques w ich are described later in this chapter.

ANALYSIS OF GRAIN ROUNDNESS:

This exercise was carried out on some sand grains from selected samples which are representative of the various landforms in the area. It was difficult to calculate the grain shape parameter or sphericity because the majority of the sands are very fine in texture and standard equipment for the analysis of such grades of sand was not available for use. The method adopted was similar to that of Pettijohn (1957) when he classified sands into angular, sub-angular, sub-rounded, rounded and well-rounded grades, with pictures to illustrate them. A total of 100 grains of sand was taken from the sample, left in each sieve and observed under microscope at about 500 times exaggeration. The grains were compared visually with the pictures of the 'Pettijohn Grades' referred to above, and each was recorded against the identical picture. The percentage of each grade was computed and it was possible to establish areas with grains of high degree of roundness and a high degree of angularity. During the same observation, grain structures such as concretions, colouration, staining and pitting were recorded. These techniques form a basis for the identification of descriptive analogues where this proved valuable.

SEDIMENT CONTENT:

This included the determination of organic, clay, silt and sandy materials present in each sample. Some of the surface samples are treated with Hydrochloric acid to remove the organic compounds and the results are weighed and illustrated in Table 5.3 on page 230. The difference between the original weight and that of the residual material was recorded as the organic content by weight. The quantity of material which passes through the 200 B.S. mesh is regarded as within the silt and clay grades and was recorded as such. In fact the 200 B.S. mesh is used as the dividing line between the Coarse and fine-grained materials by the American Society of Civil Engineers. (Ladd et al 1969).

SEDIMENT STRUCTURE:

The bedding characteristics were only visible along a small portion of the beach where waves cut a cliff. In some places they have not been preserved or are not stable. Weathering has masked the bedding Planes in the upper horizons of the profiles cut, while the presence of underground water reduces the depth of visibility. However, a general bedding pattern has been identified from the bore-hole profiles of the Federal Surveys (1960) depicted in Fig. 1.6 on page 23. The short profiles cut during field-work have been described in chapter two of this thesis.

PLASTICITY:

The plastic limit for any sediment is the critical point where the soil becomes fluid under pressure. This is dependent on moisture content, grain sizes and the absorption capacity of the grain particles. Consequently clayey soils tend to retain more water than loose sandy soils, or in general fine-grained soils easily become more plastic than coarse-grained soils because of their high content of clayey materials. The determination of the degree of plasticity of the soils in the survey area is based on data from the laboratory analysis carried out by the Foundation Engineering Company Nig. Ltd. (1971) which, according to the Engineer in charge, reveals a high degree of plasticity for soils having large quantities of silt and clay, such as are found in the depressions and old lagoon beds, while areas of coarse sands display low plasticity.

It has also been established that the rate of compression of soils depend on the rate of absorption of water by the soil particles (Taylor 1947) and also that cohesive soils which are generally fine-grained retain water, while non-cohesive soils which are generally rich in quartz grains, do not retain or absorb water. Cohesive soils are therefore more easily compressible under static loading than loose soils. (Casangrande 1932). It follows that the degree of plasticity of soils can be inferred from their textural characteristics, hence the relative degree of plasticity of the soils in this study area is based on the textural characteristics of sediments.

This procedure is necessary in the classification of this area, because the plastic index is a basis for the determination of the stability of the soil, especially where construction work is envisaged. It has also been established in chapter three that the subsiding parts of Lagos Metropolitan area are reclaimed swamps and comprise about 70 per cent fine-grained materials which generally gave way under stress.

PERMEABILITY:

Permeability rate is increased by increase in grain size and improvement in sorting (Krumbein & Pettijohn 1938, Krumbein and Monk 1941). The degree of permeability of the sediments in this area was determined by inference from their grain-size and sorting characteristics based on the assumption described above. This exercise is important in determining potential flooding in the undeveloped areas, because the degree of permeability will determine the rate of infiltration of flood waters after a heavy rain. It is therefore an indispensable tool for the determination of floodable areas in this environment.

MINERAL CONTENT:

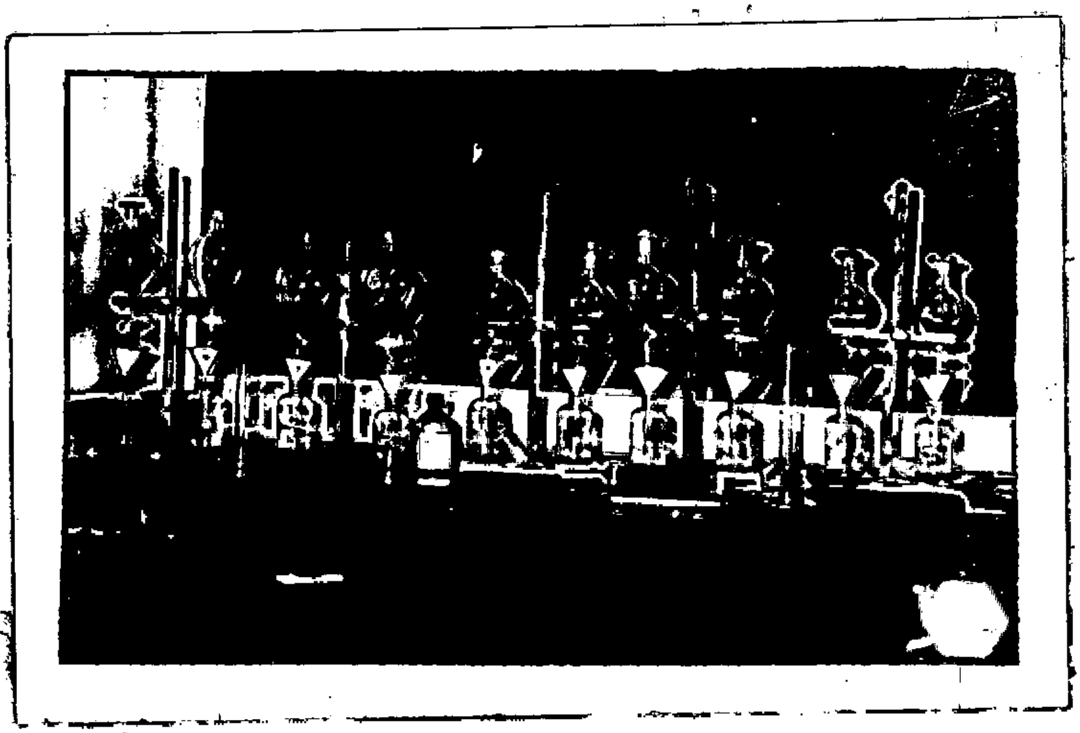
This was determined by a combination of chemical, visual and microscopical examination. A group of selected samples was subjected to chemical treatment to determine the mineral content of each sample as well as the heavy mineral residue. Those samples that pass through the B.S. 36 mesh were observed with a hand lens for shells of organisms and other organic materials. The quartered ones were each placed in hydrochloric acid in ratio 1:4 to wash away the authigenic materials so that the granular materials might be left behind. After washing, each residue was dried. A ten-funnel bromoform separation apparatus shown in Plate 4.1 was set up in the

Soil Mechanics laboratory of the Faculty of Engineering, University of Lagos; where the separation was carried out. A pair of funnels was used for each sample so that five samples were separated at a time. The first funnel was filled with a Bromoform-benzol solution having a specific gravity (S.G.) of 2.69 and 30 ml in quantity; and the sample was put into the funnel containing a filter paper and stirred for about twenty minutes to allow all 'heavier' materials to sink. These were released through the stop-cork into a container below from where it was poured into the second funnel where a pure-bromoform solution having S.G. 2.91 was put; it was again stirred and the heavier minerals sunk while the lighter ones floated.

Lighter materials such as quartz floated in the Bromoform-benzol solution while others sank. The floating grains were washed with diluted hydrochloric acid, dried, weighed and recorded as the relative weight of the typical mineral in the sample. In the pure bromoform solution, calcareous materials floated, and were washed, dried, weighed and recorded accordingly. The heavy mineral residues sank to the bottom of the stop-cork and were treated the same way as the samples above.

The essence of this exercise is to identify the variety of minerals present in the sediment, with a view to determining

PLATE 4.1



BROMOFORM-BENZOL SEPARATION PROCESS

their relative stability as a soil component especially under the humid tropical conditions, and to use them as a basis for making inference on the provennance of the sediments that constituted the materials of the landforms. The identification of the minerals was based on the scale of Milner (1961) where minerals with S.G. less than 2.69 are classified as quartz, those between S.G. 2.69 and S.G. 2.91, as Calcareous materials and those with S.G. above 2.91 as heavy minerals. The flow sheet used in this analysis is shown in Appendix II.

The heavy minerals found were identified under a polarized microscope using the following as marks of identification relief, pleochroism, symmetry and colour. Twenty four samples were observed and the results are recorded in Table 5.4 on pages 233 & 234. Other features of the heavy residues examined included the degree of etching, roundness and staining which helped to illuminate the geomorphic history of the sediments with regards to the sources of the sedimentary materials and their modes and directions of transport are illustrated in Fig. 5.6 and shown in Table 5.6 in chapter five.

The technique used in the mineraological analysis was similar to that of Milner (1961) but the results are generalised, because the minerals are separated into broad groups, so that a detailed analysis of the mineraological contents of the sediments cannot be embarked upon. However, the amount of details derived from this analysis gives a clue to some of the problems examined in this thesis as would be seen in chapter five.

4.5 MAPPING EXERCISES

Geomorphological mapping has been described as a "convenient and usable means of presenting varied land form data" (ECAFE 1963). This process embodies the cartographical representation of the character of the landforms such as the morphogenesis, the morphometric properties, the lithology of superficial deposits and the processes on a map, to enhance the understanding of the areal relationships of landforms over a large area. In order to present the landform data of the Coastal zone of Lagos in a comprehensive and practical manner, two types of maps are compiled. They are the detailed 1/20,000 geomorphological map shown as Fig. 6.7 in the map folder and the 1/40,000 land classification map shown as Fig. 6.2 in the map folder in this thesis. Both are essentially a visual and spatial representation of the detailed geomorphological data.

The geomorphological map illustrates the detailed character of the landforms in the area west of the Lagos Harbour such as the landform types, the various processes of morphology, and the character of the superficial deposits.

The land classification map illustrates the 'land units' in the Coastal zone of Lagos. More details about these can be obtained in chapter six.

The maps are based on the convergence of evidence from most of the following sources: sediment character, morphology of the landforms as deduced from aerial photographs and field-work. The legends used derive from the works of Klimazewski (1963), Vestappen (1970) and Demek (1972). Some symbols from the legends used in the International Training Centre in Delft were incorporated, while others were devised to conform to the features peculiar to this locality. (See Fig. 6.7). Such peculiar features include mangrove swamps and lagoon shoals. The maps are essentially the cartographic derivations of the theoretical analyses of the landforms, so that they may be understood in detail by Geomorphologists.

4.6 STATISTICAL ANALYSIS

All the data collected from sediment analysis were treated statistically using the sand-grade scale of Krumbein (1934, and 1936) and the formulae of Folk and Ward (1957) with their 1962 modifications by McCammon. The details of the procedure are given below.

The sieve meshes were arranged to coincide with the phi scale of Krumbein (1934) (1936). This method measures the volume of each size by weight, and the weight percent is calculated and plotted into cumulative frequency graphs, where weight percent is on the ordinate and the phi units on the abscisa axes respectively. Preference was given to this method because it is easy to convert the millimeter scale to Ø units; where Ø = $-\log_2$ of the diameter in millimeter. Furthermore, the logarithmic scale occurring from the Ø units provides for quicker and more accurate mathematical calculations, in that small fractions are not required for the finer particles, because they constitute positive Ø units. The frequency distributions are more symmetrical, and the parameters for calculating the moment measures are read off from the cumulative frequency curves, when plotted on a logarithmic paper.

Sixty-five samples were analysed, and their moment measures were computed using the Folk and Ward formulae (1957). This formulae adopts the percentile measures of Ø5, Ø16, Ø25, Ø50, Ø75, Ø84, and Ø95. This was preferred to the Inmans formulae (1952) which adopts only percentile Ø16 and Ø84 because it takes adequate cognisance of the coarsest and the finest tails of the distributions, which are essential in the determination of the character of the sediments in this environment.

The mean was adopted as a measure to describe the diameter of the sand grains because it gives the diameter of the 'centre of gravity' of the frequency distribution while the median divides the curves into two equal parts. The median is useful in a symmetrical distribution, as a measure of size, but not in most of these sediments, where the samples are skewed.

The Inclussive Graphic standard Deviation of Folk and Ward (1957) which has an efficiency of 79%, (McCammon 1962) is the best method known to me, in the calculation of the sorting of the sediments. The sorting creteria used are as follows:

Sorting Coefficient*	Interpretation
Under 0.35 ø	Very well sorted
0.35 - .5 ø	Well sorted
.5 - 1 ø	Moderately sorted
1 - 2 ø	Poorly sorted
2 - 4 ø	Very poorly sorted
over 4 ø	Extremely poorly sorted

KURTOSIS:

This is used in the identification of the type of energy environment of the sorting of sands, because a very high or a low Kurtosis value indicates a multi-stage sorting (Folk and Ward 1957). Skewness indicates the relative presence of coarser and finer materials in the sample. Both Kurtosis and Skewness are used in the determination of the palaeo-environments of the sediments, like the medium of sorting and changes. They are used in the establishment of the theoretical criteria for the genetic classification of the landforms.

*The value of the phi units is negative when it is coarser, and positive when finer. The conversion table below is used throughout this thesis and the formulae used in the computation are shown in Appendix I.

∅ units	-3	-2	-1	0	1	2	3	4	5
Millimeter Equivalent	8	4	2	1	.5	.25	.13	.065	0.03.

CHAPTER FIVE

CHARACTERISTICS OF THE SEDIMENTS

A widely used tool for reconstructing depositional environments is the physical properties of sediments, and this has been demonstrated by Pettijohn (1957) and Butzer (1964). A lot of deductions can also be made from the stratigraphy and mineraology of sediments with regards to their genesis and the identification of the post-depositional changes in them. For this study, the sediment properties which are made use of include the grain size, lithological and micro-morphological characteristics and minerao-logical composition. This is because the description and analyses of these sediment properties give clues to the sources and dispersal of sediments and to some extent the degree of maturity and hence the 'stability' of the landforms moulded from them. Grain-size characteristics in particular are significant because they form the basis for the classification and identification of the soil for engineering purposes (Ladd etal 1969) and they are also reliable indicators of the intensity of action of the processes which have moulded the various landforms.

In this thesis as well, especially where they form the index to engineering properties such as permeability and compressibility, grain-size characteristics have been made use of.

Some of the inferences in this work are based on the interpretation of the heavy-mineral content and the degree of roundness of sediments, because these form the indices for the identification of the origin of sediments and their direction of transport, as well as the transport history and the intensity of the geomorphological processes involved in the operation. The genesis of sediments has been deduced from the textural properties of sediments as exemplified by the works of Friedman in 1961, 1962 and 1967. Thus inferences from the sediment properties are indispensable to the understanding of the pattern and processes of evolution of the coastal landforms.

Furthermore, the detailed history of sediment transport and post-depositional changes are easily discernible from their micro-morphology, while the stratigraphical character of the sediments elucidates the evolutionary history of landforms. From the study of past processes from grain 'pathology', it is possible to reconstruct the different depositional phases as well as compare them with contemporary processes, with a view to postulating future trends of landform development which might aid the pattern of land-use development in this area.

The distribution of grain-sizes along the beaches may indicate areas prone to rapid erosion and areas of relatively minimal erosion, since the textural characteristics of sediments, such as grain sizes and degree of sorting, influence the rates of removal. It has been suggested elsewhere that 'storm waves' remove coarser materials more effectively than finer ones (King 1959) .

probably because of their loose nature. Thus the spatial distribution of these physical properties of sediments, e.g. grain size, structure and mineraology, may illustrate and aid the understanding of their pattern of arrangement along the beaches and become the basis of examination and analysis of beach dynamics such as erosion and accretion.

The coefficient of sorting of the sediments, especially on the Outer-sandy barrier and of depth materials elsewhere can be used to determine the intensity of the sorting media, and can be stretched further to include the approximation of the relative energy of the waves in that locality. For example the high degree of sorting displayed by the sediments may be indicative of the energy of the sorting media. With these, it is likely that areas of high energy waves and low energy waves can be deciphered, if for example, the sorting coefficient is found to be persistently high or low in particular localities.

The study of the morphoscopical aspects of the sediments may illustrate post-depositional changes in grain-texture, such as oxidation, development of concretions, silcretes and other aggregates. These changes may be examined further to establish the type of climatic influences, the hydrological conditions that might have provoked subsequent processes of grain morphology since the deposition of the sediments. A close study of the sediment types and fabrics might be used to explain the pattern of relief, especially when the relief is low-lying or faint and there is no evidence that tectonic forces modified the landforms. For example, the occurrence of sediment types such as clay, silt, and sand might be used to explain the distribution of landforms such as swamps, depressions and ridges. The examination of the sediment types might also explain the variations in moisture content, the amount of sand and silt, and can form the basis of prediction of soil compressibility; because soil compressibility according to Casangrade (1932) depends on the amount of material finer than .005mm.

Before describing the data collected from the analysis of sediments from the coastal zone, it is necessary that a broad-based examination of the sources of the sediments and the mode and direction of dispersal are examined. This would be done to identify the provenance of the sediments as well as their depositional environments.

5.2 SEDIMENT SUPPLY AND DISPERSAL

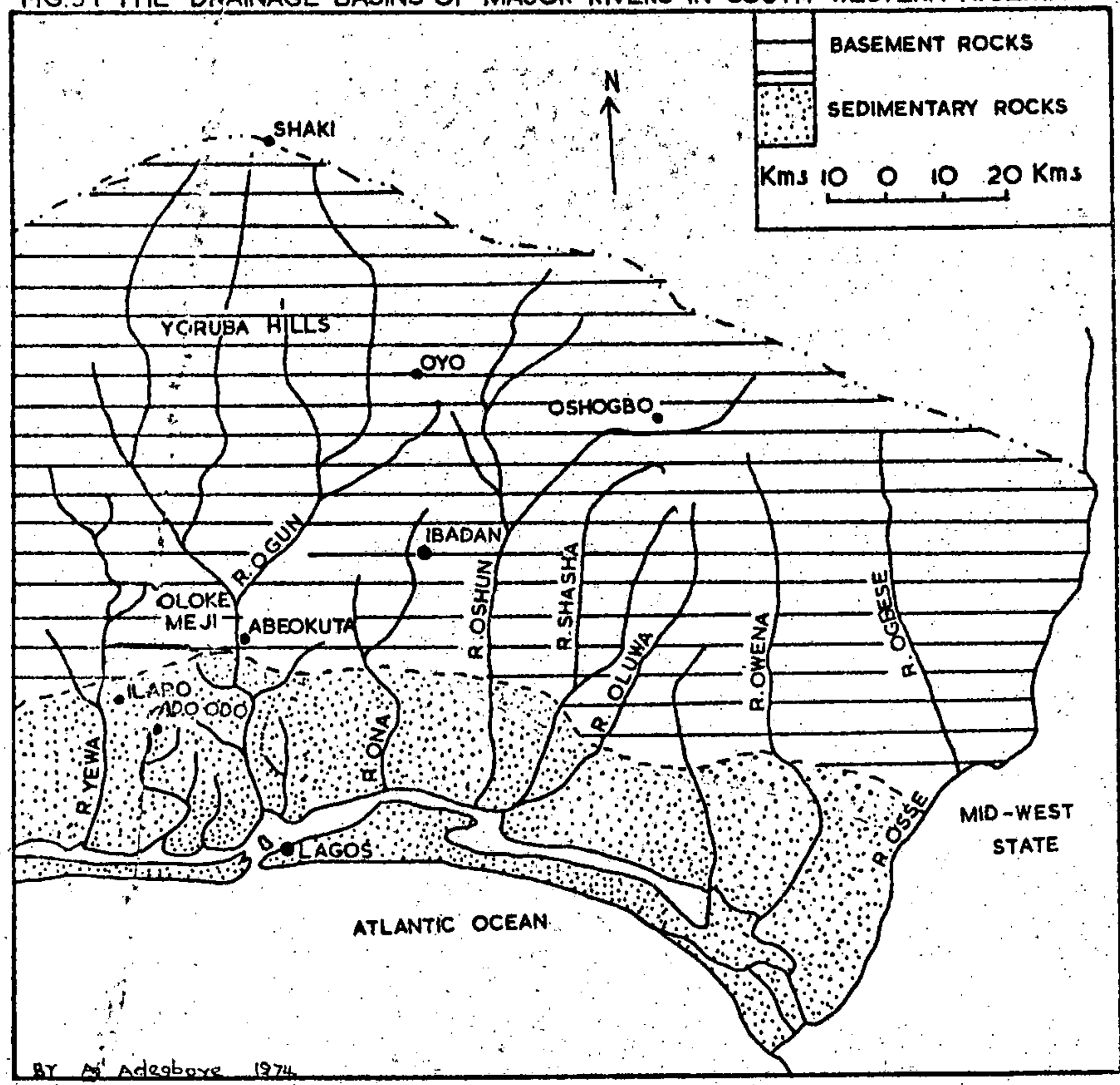
The sediments entering the coastal zone come from three independent sources. The first consists of the drainage basins of the coastal rivers like Ogun, Majidun, Owuru and Afa (illustrated in Fig. 1.7) whose debou-chements fall within this area of study as well as those rivers like Owo, Yewa, Queme and Mono shown also in Fig. 1.7, whose debouchements are outside the area, but contribute sediments through the Portonovo and Badagry creeks.

The second source is the sea bed, from where sediments are deposited on the beaches by waves or moved shore-ward by tidal currents or along-shore by the littoral drift. These two sources can be classified as terrestrial and marine. Third source is the organic materials which are produced by decayed vegetation and human waste used in reclamation or dumped into the Lagos lagoon. These three sources are illustrated in Fig. 5.6.

The terrestrial sources include the Quaternary and Tertiary sediments derived from the drainage basins of the coastal rivers named above which include the weathered rocks of the basement complex which outcrop in their upper reaches. For example, the rivers Mono and Queme drain the Acidic and basic gneiss areas of the Atacora range in Togo and Dahomey as well as the Tertiary sediments known as 'terre de barre' (Slansky 1962, Furon 1963), while the Yewa drains the southern foot hills of the gneiss and amphibolites, of Lanlate area, and the Ogun drains the pegmatite and migmatite rocks of Abeokuta area (Jones and Hockey 1964, Reyment 1964).

The fact that sediments from these sources get to the coastal zone is evident in the occurrence of heavy minerals such as hornblende, kyanite, staurolite and epidote which are derived from metamorphic rocks such as migmatites, pegmatite and amphibole; and ilmenite which is a heavy mineral derived from iron rich rocks. The distribution of the heavy mineral residue is shown in Table 5.6 below.

FIG.5·1 THE DRAINAGE BASINS OF MAJOR RIVERS IN SOUTH WESTERN NIGERIA



The medium of transportation is most likely to be the coastal rivers, especially the Majidun, Owuru, Ogun and Afa.

These rivers now seem to be responsible for the transportation and deposition of the finer materials such as clays and silt, which are carried down in suspension especially during floods in the rainy season and later deposited on the alluvial plains of the rivers. The broad alluvial plains near the debouchement of the rivers and the periphery of the lagoons adjacent to them carry thick veneers of these fine sediments. Examples of these are shown in Fig. 2.10 on page 95.

Apart from clay and silt, sediments brought by these rivers from terrestrial sources include sand and pebbles. The sands are generally coarse in texture because they have not been sufficiently worn by the rigour of river transport because of their relative petrological stability and relatively short time of transport: except for the stained quartz grains derived from the sedimentary deposits in the lower reaches of the rivers immediately north of the coastal zone.

Marine and submarine sources include sediments from the continental shelf which were initially terrestrial or fluvial sediments deposited when the sea level was lower than at present. There are also materials from the beaches and the suspended load from rivers which represent the finer grades of marine deposits. The media of transportation include sea waves, especially the high swells which agitate the sea floor and drag the materials shoreward for waves of lower amplitude to deposit them on the beaches, and the long-shore current which in this section is west to east in direction.

The type of sediments include the well - rounded sand and moderately coarse quartz grains and a few accessory minerals such as kyanite, zircon, horhblende, rutile and staurolite. Large quantities of Calcareous materials are also encountered. The marine origin of the sediments is illustrated by the high degree of roundness which they display, and is evidence of the intense action of marine processes operating in the area. The sediments possess admixtures of calcareous materials such as the shells of sea orchids and bi-valve 'animals' which are creatures of sub-marine environment. See Table 5.3 on page 219.

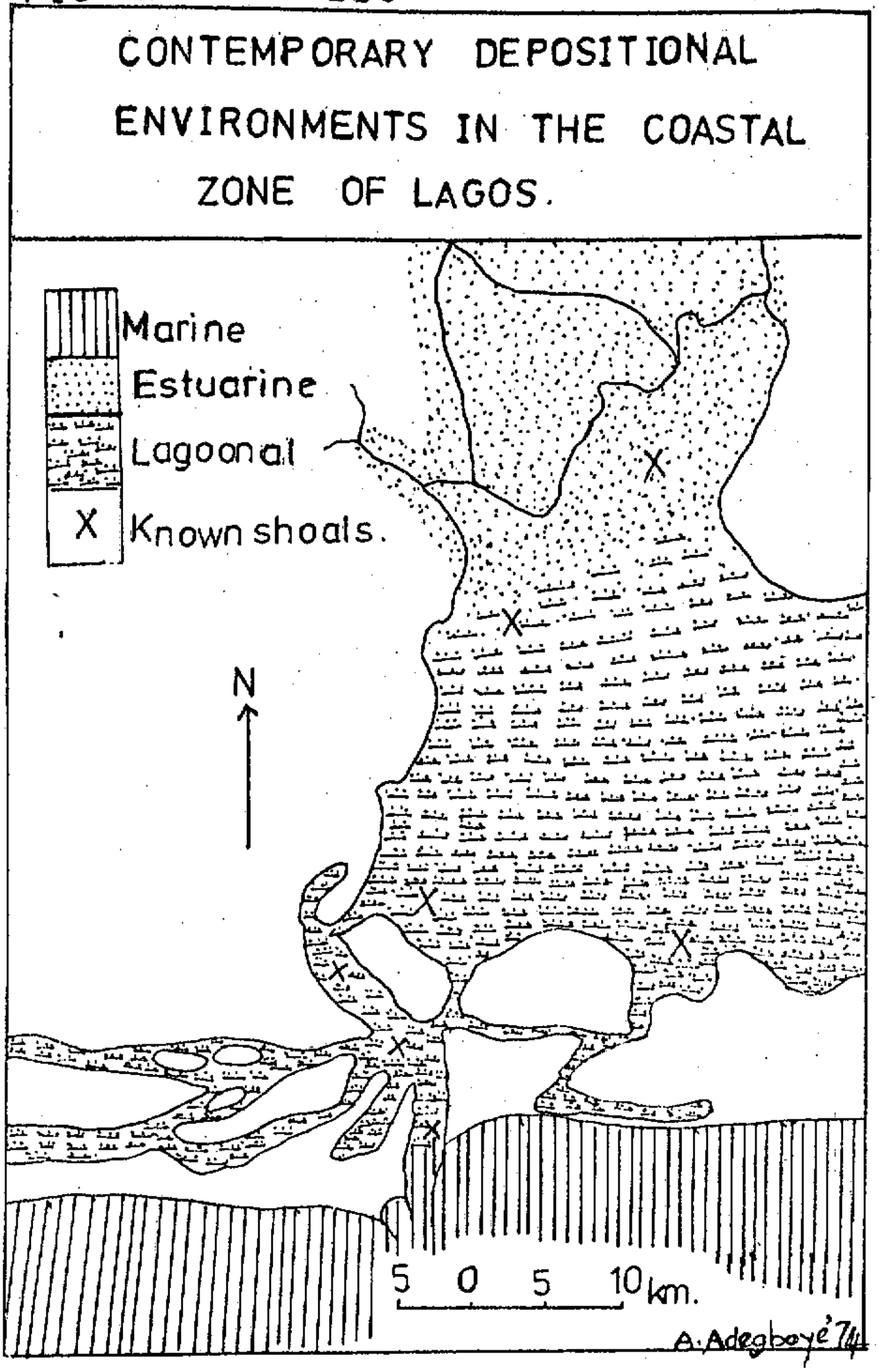
The Organic source includes the dumping of human faeces at Ebute Ero marked (♀) in Fig. 5.6, the disposal of refuse such as leaves and waste materials for reclamation of swamps in places such as Bariga, Apena, Itire and Okosuna, and the transfer of sand from the lagoon bed for reclamation purposes in general and for beach replenishment on the Victoria beach in particular.

Both the supply of sediments and their dispersal can be regarded as inter-woven to some extent because some of the sediments are in effect being dispersed as they are transported by the agents of supply. However, an attempt is made to examine the impact of the dispersal agents on sediment structure in the coastal zone. The most important agents of dispersal recognised are the sea waves and associated currents and the lagoon waves and their attendant currents.

Dispersal of sediments takes place from depositional zones such as lagoon beds, offshore areas and the alluvial plains of the coastal rivers in this area. From the offshore area, waves disperse sediments shoreward to the beach with the aid of the swash and may be re-distributed sea-wards with the aid of the rip currents and backwash. Thus the meeting point of both the in-coming waves and the back-wash may be readily recognised as the depositional zone in near shore areas. However the deposited materials are not permanent as they migrate shoreward and sea-ward following the movement of the tides and the character of the waves.

The lagoon beds consist of a great thickness of sediments derived from both the sea and land at varied times and thus constitute a depositional environment from where lagoon waves, especially during storms,disperse the materials along the beaches. The tide transports very large quantities of sediments in suspension into the sea during ebb-flow and associated waves agitate the bed of the lagoon during the flow, so that seaward movement of sediments is generally common during this period. Perhaps the most prominent agent of dispersal of sediments is the west to

FIG. 5.2


CONTEMPORARY DEPOSITIONAL ENVIRONMENTS IN THE COASTAL ZONE OF LAGOS.
Marine
Estuarine
Lagoonal
X Known shoals.
N
5 0 5 10 km.
A. Adegboye 74

east longshore - drift, characteristic of the Guinea Coast. The materials moved by this current are piled up behind the West mole at the Lagos Harbour mouth and reported to have prograded up to about 600 metres since 1912 and are likely to by-pass the tip of the west mole by 2030 A.D. at the growth-rate of 10 metres per annum (LEDB report 1968).

The same west-east current has been identified as responsible to some extent for the removal of sediments from Victoria beach. As sediments are transported along the coast, the materials in transit are essentially used for beach nourishment eastwards. A closer study of the dispersal and supply of sediments has led to a classification or grouping of depositional environments which are shown in Fig. 5.2.

The materials derived from the land and distributed by rivers are generally found in the flood plains and consist of alluvium, and peat. The materials deposited in the lagoons by rivers form peat and mud while those by the sea during transgressions consist of sand.

Although the map (Fig. 5.2) illustrates the contemporary patterns of sediment dispersal, it is possible to decipher the source and dispersal agents of the materials composing each sediment layer.

The detailed analysis of the deposits of each depositional environment follows. An analysis of sediment characteristics has been carried out, ranging from measures to moment; structural character, degree of roundness and heavy mineral content to mineraological composition. Details about these are shown in Tables 5.1, 5.2 and 5.3 respectively.

5.3 DETAILED ANALYSIS OF SEDIMENT CHARACTERISTICS

This analysis is made under two broad headings as follows:

i. textural characteristics which include the grain size distributions, degree of sorting (Table 5.1), and degree of roundness (Table 5.2).

ii. structural characteristics which include the grain pathology, concretionary development, mineral composition and bedding characteristics.

TEXTURAL CHARACTERISTICS

The textural characteristics of the sediments examined include the grain-size properties and the degree of roundness which are shown in Tables 5.1 and 5.2 below, but because of the complexities involved in the calculation of such sediment attributes as porosity and permeability, these characteristics were inferred from the size parameters. The analysis was limited to this range of tests because the necessary equipment was not available for use in the measurement of other properties such as the shear stress, but it is believed that the landform character can be well understood when such properties are defined. In fact grain-size characteristics have been used to derive soil properties such as permeability. (Krumbein and Monk 1942, Ladd etal 1969).

GRAIN SIZE: The result of the grain size analysis is shown in Table 5.1. The mean size (Mz) of the grains in this zone as shown in this table falls between - .3ø (LAG 71/07) for the coarsest and 3.6ø (LAG 71/18) for the finest. The lower limit of the grain sizes along this coastal zone is greater than the upper limit of the fine sand grade recommended by Ladd etal (1969) for the American Society of Civil Engineers, and coarser than the clay grade of Fried man (1961 and 1967). However a small proportion of the samples tapers towards the upper limits of the fine sand grade of Wentworth (1922) which he puts at 5ø as shown in Figs. 5.4, 5.5 and 5.6. Thus the sediments in the coastal zone can be classified as coarse in texture relative to the various standardizations enumerated above.

A closer view of the grain size character of the sediments displays a picture of varied mean-sizes between the Western and Eastern side of the Lagos Harbour. The mean diameters of sand grains west of the Lagos Harbour are as follows: Outer barrier 2.1ø - 3.6ø, Inner barrier 1.9ø - 2.4ø, and the Prior barrier 2.5ø - 3.4ø. But on the eastern side of the Harbour, the land-forms consist of coarser sediments especially, the Victoria beach, Kuramo beach and old beach ridges behind Alagutan village as demonstrated in Table 5.1, where their mean sizes vary between .8ø and 1.6ø; .8ø and 1.8ø respectively. (See LAG 71/01 - 06, 09 - 16, and 27 - 28) for the three landforms groups respectively. This is also shown in the frequency distribution curves in Figs. 5-3 to 5.5 where about 90% of the grains in the sediments from the west of the Lagos Harbour is finer than 2ø while over 80% of sediments from the Victoria beach, Kuramo beach and the old beach ridge at Alagutan village is coarser than 2ø. These distributions are shown in Figs. 5.3 and 5.5b for landforms west of the Harbour and 5.4a & b and 5.5a for those in the east of the Harbour.

Some samples in the eastern side of the Harbour especially those of the Beach plains LAG 71/47-52) Lagoons and Swamps (LAG 71/55-58) display a moderately finer texture than the other samples from landforms in the same areas described above. The mean size varies between 2.3ø and 2.5ø for beach plains and 2ø and 2.8ø for the Lagoons and Swamps, and over 75% of their sediments is finer than 2ø.

Sediment samples from the western side of the Lagos Harbour especially the Light House beach, the Inner and Prior barrier are fine textured because of the following reasons. Most of the sediments are marine derived and were deposited by waves which had travelled over a very long fetch over the Atlantic ocean and as such are considerably turbulent, so that the sediments have become well worn by these waves. Secondly, it has been established elsewhere (Pugh 1954b, Webb & Hill 1958, Webb 1960) and earlier in this thesis that most of the sediments in the western side of the Lagos

Harbour were drifted by littoral currents from the western parts of the Guinea Coastlands. It follows that the sediments have been considerably worn during the process of long transport along the coast of West Africa to this part of Lagos coastal zone. Apart from this, evidence of grain pulverization by waves beating against the rock boulders of the West mole exist as freshly broken and sharp edged sands are found immediately west of the mole as shown by the high percentage of angular grains in samples LAG 71/17, and 18 taken from this part. Sediments on the Prior and Inner barriers on this side of the Harbour are considerably finer probably because of the added effect of grain communition by weathering agents.

The relatively coarse texture of the sand-grains in the areas east of the Lagos Harbour might result from the "sheltering" effect of the Lagos lagoon outlet, whose currents prevented the direct transportation of the sands adrift from the west to Victoria beach and areas north of it. Also, the three stone-moles completely sealed off the littoral drift from reaching the Victoria beach. Thus, these two 'barriers' restricted the deposition of very fine sands to the Light House beach and exposed the Victoria beach side to sediments from the Lagoon outlet, which being fluvio-lagoonal in origin are, generally less worn than these from the sea bed.

Table 5.1 *GRAIN SIZE CHARACTERISTICS OF SEDIMENTS IN THE COASTAL ZONE

CODE NUMBER	SAMPLE LOCATION	SAMPLE DEPTH	Mz.	Md.	SORT	Sk	KURT
	ATLANTIC COAST						
LAG 71/01	Victoria beach - Opposite California Hotel	15cm.	1.3ϕ	1.4ϕ	0.6ϕ	-.5ϕ	.5ϕ
02	" " Sea beach encloased by East mole	Surface	0.8ϕ	0.9ϕ	0.9ϕ	-.3ϕ	1.5ϕ
03	" " Break point bar	Submerged	1.6ϕ	1.7ϕ	0.9ϕ	-.4ϕ	1.8ϕ
04	" " Breal point bar	"	1.1ϕ	1.2ϕ	0.7ϕ	-.9ϕ	0.9ϕ
05	" " Berm	Surface	1.5ϕ	1.6ϕ	0.5ϕ	-.8ϕ	0.4ϕ
06	" " End of East mole	"	1 ϕ	1.2ϕ	0.7ϕ	-.9ϕ	-0.9ϕ
07	Lagoon Outlet - Commander Shoal	Submerged	-0.3ϕ	0ϕ	0.4ϕ	0.3ϕ	0.2ϕ
08	" " Opposite Signal station	"	0.5ϕ	0.5ϕ	0.4ϕ	0.1ϕ	0.2ϕ
09	Apese village - Beach berm	Surface	1.5ϕ	1.7ϕ	0.6ϕ	-1ϕ	0.5ϕ
10	" " - " "	30cm.	1.8ϕ	1.7ϕ	0.9ϕ	1.5ϕ	1.3ϕ
11	Lawani village - Beach berm	Surface	1.2ϕ	1.5ϕ	0.7ϕ	-1.2ϕ	1ϕ
12	Alagutan village " "	"	1.3ϕ	1.3ϕ	0.5ϕ	0.2ϕ	0.4ϕ
13	Kuramo sea beach - Beach berm	15cm.	0.8ϕ	0.7ϕ	0.7ϕ	0.7ϕ	1ϕ
14	Lawani village - Break point bar	Submerged	0.8ϕ	0.7ϕ	0.9ϕ	1.8ϕ	1.4ϕ
15	Alagutan village - Break point bar	"	1ϕ	1.2ϕ	0.6ϕ	-0.2ϕ	0.8ϕ
16	Lawani village - Break point bar	"	1.1ϕ	1.2ϕ	0.5ϕ	-0.2ϕ	0.4ϕ
17	Light House beach - Beach berm	Surface	2.4ϕ	2.4ϕ	0.3ϕ	0.2ϕ	0.1ϕ
18	" " " - 400 metres of west of Mole	"	3.6ϕ	3.6ϕ	0.3ϕ	-.1ϕ	0.1ϕ
19	" " " - Break point bar	Submerged	2.3ϕ	2.3ϕ	0.5ϕ	0.2ϕ	0.3ϕ
20	" " " " " "	"	2.4ϕ	2.4ϕ	0.4ϕ	0.2ϕ	0.2ϕ
21	" " " Beach berm	15cm.	2.3ϕ	2.3ϕ	0.4ϕ	0.1ϕ	0.9ϕ
22	" " " " "	Surface	3ϕ	3.2ϕ	.2ϕ	-0.02ϕ	1ϕ

Table 5.1 Cont'd. *GRAIN SIZE CHARACTERISTICS OF SEDIMENTS IN THE COASTAL ZONE

CODE NUMBER	SAMPLE LOCATION	SAMPLE DEPTH	Mz.	Md.	SORT	Sk.	KURT
	ATLANTIC COAST						
LAG 71/23	Light House beach swash zone	Surface	2ϕ	2.1ϕ	.6ϕ	.1ϕ	.9ϕ
24	" " " Break point bar	Submerged	2.5ϕ	2.4ϕ	.7ϕ	1.5ϕ	0.9ϕ
	OLD BEACH RIDGES						
25	Ogoyo village - Inner barrier	45cm.	1.8ϕ	1.9ϕ	0.8ϕ	-0.14ϕ	1.1ϕ
26	Lawani " " "	45cm.	1.8ϕ	1.9ϕ	0.6ϕ	-0.8ϕ	0.7ϕ
27	Alagutan " " "	Surface	1.8ϕ	1.9ϕ	0.6ϕ	-1.1ϕ	0.8ϕ
28	Ilado village - " "	45cm.	1.7ϕ	1.8ϕ	0.9ϕ	-0.3ϕ	1.4ϕ
29	Alagutan " " "	45cm.	1.8ϕ	1.9ϕ	0.9ϕ	-.2ϕ	1.4ϕ
30	Tarkwa bay " "	30cm.	2.7ϕ	2.5ϕ	0.5ϕ	0.7ϕ	0.4ϕ
31	Light House beach " "	30cm.	2.7ϕ	2.5ϕ	0.5ϕ	0.7ϕ	0.4ϕ
32	Onigbokun Village " "	30cm.	2.5ϕ	2.5ϕ	0.4ϕ	0.2ϕ	1ϕ
33	Iganmu Village Prior barrier	4 metres	3.4ϕ	3.3ϕ	0.6ϕ	.3ϕ	.5ϕ
34	Amuwo " " "	3 "	3.1ϕ	3.3ϕ	0.4ϕ	-.4ϕ	.3ϕ
35	Ojo village " "	2 "	3.2ϕ	3.3ϕ	0.3ϕ	-0.3ϕ	.2ϕ
36	Okokomaiko " " "	1 "	3.2ϕ	3.3ϕ	0.4ϕ	-0.4	.2ϕ
37	Kirikiri village " "	50cms.	3ϕ	3.1ϕ	0.4ϕ	0ϕ	.1ϕ
38	Ijegun village " "	Surface	3.3ϕ	3.4ϕ	0.5ϕ	-0.3	.20
39	Agboju village " "	30cm.	3.2ϕ	3.3ϕ	0.6ϕ	-.4ϕ	.2ϕ
	BREACHED RIDGES						
40	Araromi village - Inner barrier	45cm.	1.6ϕ	1.6ϕ	0.6ϕ	-.25ϕ	.6ϕ
41	Moba " " "	60cm.	1.7ϕ	1.8ϕ	0.8ϕ	-.7ϕ	1.2ϕ
42	Gedegede (a) " " "	90cm.	1.7ϕ	1.7ϕ	0.8ϕ	-.7ϕ	1.4ϕ
43	Maroko (a) " " "	15cm.	1.6ϕ	1.7ϕ	0.9ϕ	-1.2ϕ	1.5ϕ

Table 5.1 Cont'd,

CODE NUMBER	SAMPLE LOCATION	SAMPLE DEPTH	* Mz.	* MD.	* SORT.	* SKEW	* KURT
LAG 71/44	Gedegede (b) Inner barrier	1.5cm.	1.4ϕ	1.5ϕ	-.7ϕ	-1.4ϕ	1ϕ
45	" " (c) " "	15.cm.	1.5ϕ	1.5ϕ	0.8ϕ	-0.3ϕ	1.2ϕ
46	Maroko (b) " "	15cm.	1.7ϕ	1.8ϕ	0.9ϕ	-0.3ϕ	1.4ϕ
	BEACH PLAINS						
47	Maroko village (a) Inner barrier	Surface	2.4ϕ	2.5ϕ	0.8ϕ	1.3ϕ	1ϕ
48	" " (b) " "	45cm.	2.3ϕ	2.5ϕ	0.8ϕ	1.8ϕ	1ϕ
49	" " (c) " "	60cm.	2.7ϕ	3ϕ	0.8ϕ	-0.3ϕ	1.1ϕ
50	Gedegede " (a) " "	30cm.	2.6ϕ	2.8ϕ	0.7ϕ	-2.7ϕ	.5ϕ
51	Ogoyo Village " "	45cm.	2.5ϕ	2.5ϕ	0.6ϕ	-0.5ϕ	-.5ϕ
52	Moba village " "	60cm.	2.5ϕ	2.5ϕ	0.6ϕ	-0.4ϕ	.6ϕ
53	Ojo village Prior barrier	30cm.	3.4ϕ	3.5ϕ	.7ϕ	-1ϕ	.7ϕ
54	Okokomaiko " "	60cm.	3.2ϕ	3.3ϕ	.8ϕ	-1.5ϕ	1ϕ
	LAGOONS AND SWAMPS						
55	Itirin lagoon (swamp)	20cm.	2ϕ	2.1ϕ	.8ϕ	-.9ϕ	1.3ϕ
56	Light House Creek (Lagoon sand	Submerged	2ϕ	2.1ϕ	.6ϕ	0.25ϕ	.6ϕ
57	Maroko Mangrove swamp	60cm.	2.2	2.3	.6ϕ	-.1	.5ϕ
58	Five Cowrie Creek (Moba Shoal	Submerged	2.1ϕ	2.1ϕ	.6ϕ	.3ϕ	.5ϕ
59	Badagry Creek (Bruce Shoal	Submerged	1.5ϕ	1.6ϕ	.5ϕ	.14ϕ	.3ϕ
60	Apapa Shoal Lagos Harbour	"	1.3ϕ	1.4ϕ	.6ϕ	.4ϕ	.2ϕ
	Undulating plains						
61	Ojota	20cm.	0ϕ	-.2ϕ	.9ϕ	.5ϕ	.3ϕ
62	Onisigun	20cm.	-.5ϕ	-.6ϕ	.8ϕ	.6ϕ	.2ϕ
63	Ikorodu	20cm.	-.1ϕ	-.8ϕ	.9ϕ	.5ϕ	.5ϕ

Table 5.1 Cont'd.

CODE NUMBER	SAMPLE LOCATION	SAMPLE DEPTH	*MZ.	*Md.	*SORT	*Sk.	*KUR.
LAG 71/ 64	Ijesha	20cm.	0ϕ	-.2ϕ	.7ϕ	.6ϕ	.1ϕ
65	Isolo	20cm.	.5ϕ	.6ϕ	.7ϕ	.4ϕ	.3ϕ

*Mz = Mean

*Md. = Md.

*Sort = Sorting (standard deviation)

*Sk. = Skewness

*Kurt = Kurtosis

*The method used in deriving these data are described in chapter four.

The coarse texture of the sand-grains is demonstrated in Table 5.1, where the finest mean sizes of materials are 1.8Ø on the Outer barrier, and the beach ridges of the Inner barrier and 1.7Ø on the breached ridges of the Inner barrier in this sector. (See Sample Nos. Lag 71/10, 25 - 27, and 42 respectively in Table 5.1).

Apart from the factors enumerated in the previous paragraphs, the coarse texture of the sand-grains especially of the Outer barrier in this sector has been found to be closely related to the type of sands used in replenishing the Victoria beach. It is common knowledge that sands are pumped from the dredged sands from the Lagos harbour whose sizes vary from .5Ø on the Brugos Shoal, -.3Ø on the Commander shoal and .5Ø on the Bruce Shoal (See Sample Nos. LAG 71/08, 07, and 59 respectively in Table 5.1).

In addition sands from the lagoon bed were brought to the beach in 1972 as stand-by sand-bank for beach replenishment. These lagoon sands vary in mean size from 2.1Ø in Moba Shoal to 1.3Ø in Apapa Shoal where the sands were dug up (See Sample Nos Lag 71/58 and 60 in Table 5.1). It follows that the Coarse texture of the sand-grains in this sectors derives from the "stranger" sands.

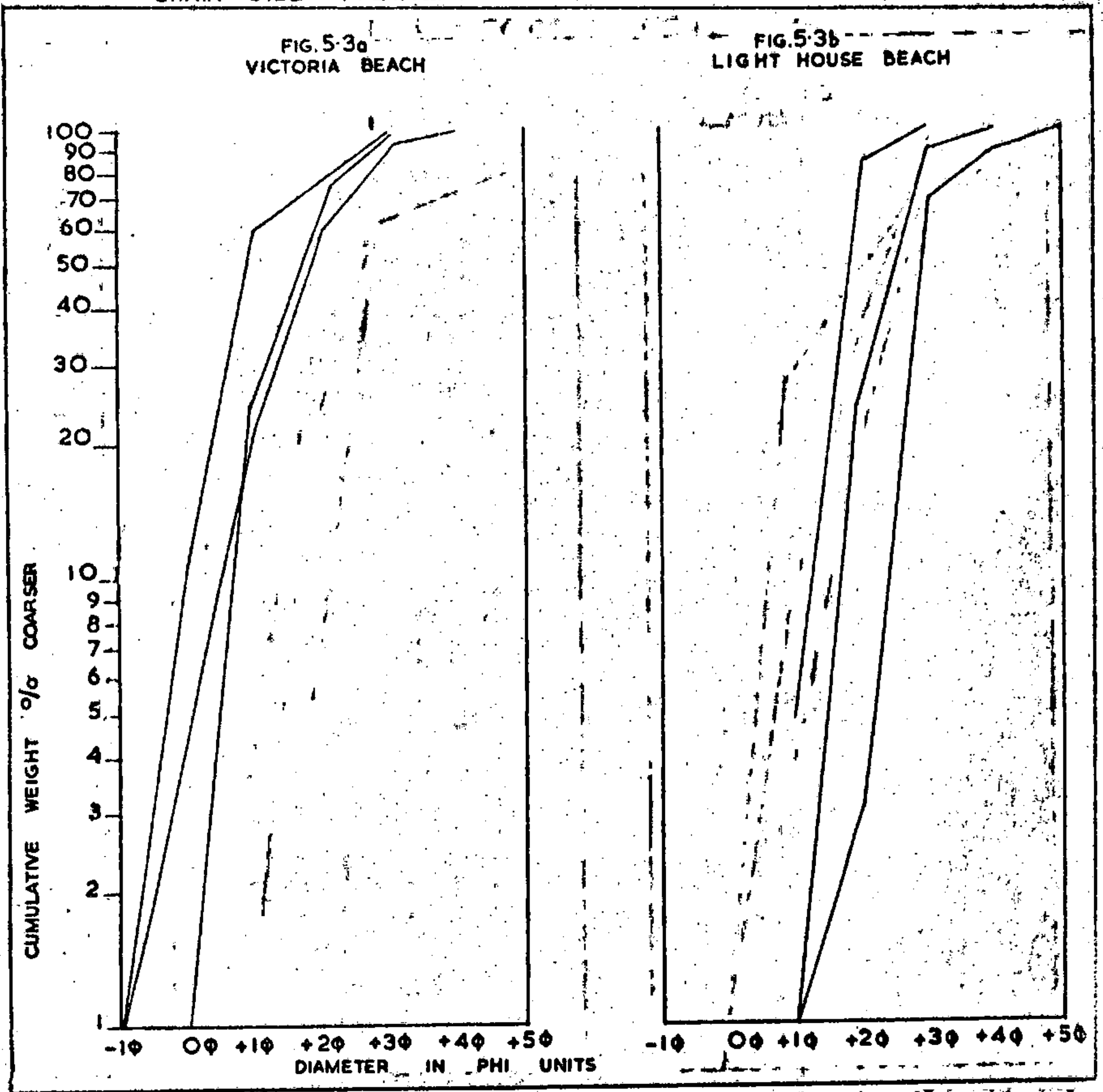
On the beach plains of the Inner barrier, east of the Lagos Harbour, the texture of the sediments is generally finer than on the adjacent beach ridges. This might be due to the effect of comminution by weathering and soil formation processes rather than those of the rigour of transport, especially when the sediments here display etched and pitted surfaces during morphoscopic analysis as shown in Fig. 5.2 (LAG 71/48, 49 and 50).

The coarse nature of the sediments in general derives from the inability of weathering processes to complete the total break-down of sand grains after they have been exposed to subaerial weathering. This is due to some extent to the high level of underground water, which prevent the penetration of air to effect rapid decomposition of sand grains; the relative stability of quartz minerals to weathering and the relatively 'recent' time of exposure of the landforms to subaerial weathering. The coefficient of sorting of the sediments varies between .2ø for the very well-sorted group found on the Light House beach and 0.9ø for the moderately sorted groups found scattered amongst the samples but more persistent on older landforms. The relatively high-degree of sorting of the sediments in the coastal zone whose upper limits fall within the moderately sorted grade of McCammon (1962) is derived from the high energy environment prevailing in this area. The most efficient sorting medium in this coastal zone is the sea waves as demonstrated by the high degree of sorting of materials taken from beach berms and areas adjacent to the beach of the Outer barrier. Where, for example, the sorting coefficient is high as in samples LAG 71/17, 18 and 22 at the beach berm they are found to be where the energy of the oncoming waves is dissipated on the beach.

The coefficient of sorting varies with particular landforms as can be seen from Table 5.1. Although Victoria beach is a wave-beaten beach, the coefficient of sorting there is relatigely lower than that on Light House beach. This seems to derive from the fact that only the waves constitute the sorting medium here, because the littoral drifts have stopped tentatively behind the West mole. Secondly the addition of sands from the lagoon used for beach nourishment might have reduced the coefficient of sorting of the sediments on Victoria beach.

On older landforms, such as beach ridges, breached ridges and beach plains sorting is relatively poorer, because of the re-arrangement of grains and cements by the agencies of weathering, and in some cases such as in the swamps and lagoon bed, the addition of sands washed down by rainwash from the top of ridges is a cause for the reduction in the degree of sorting. In general the sorting of the sediments reflects the rigour of the depositional media along this coast. However, the effectiveness of the coefficient of sorting as an index of the energy of the depositional media diminishes with time, because as sediments are

GRAIN SIZE FREQUENCY DISTRIBUTION CURVES



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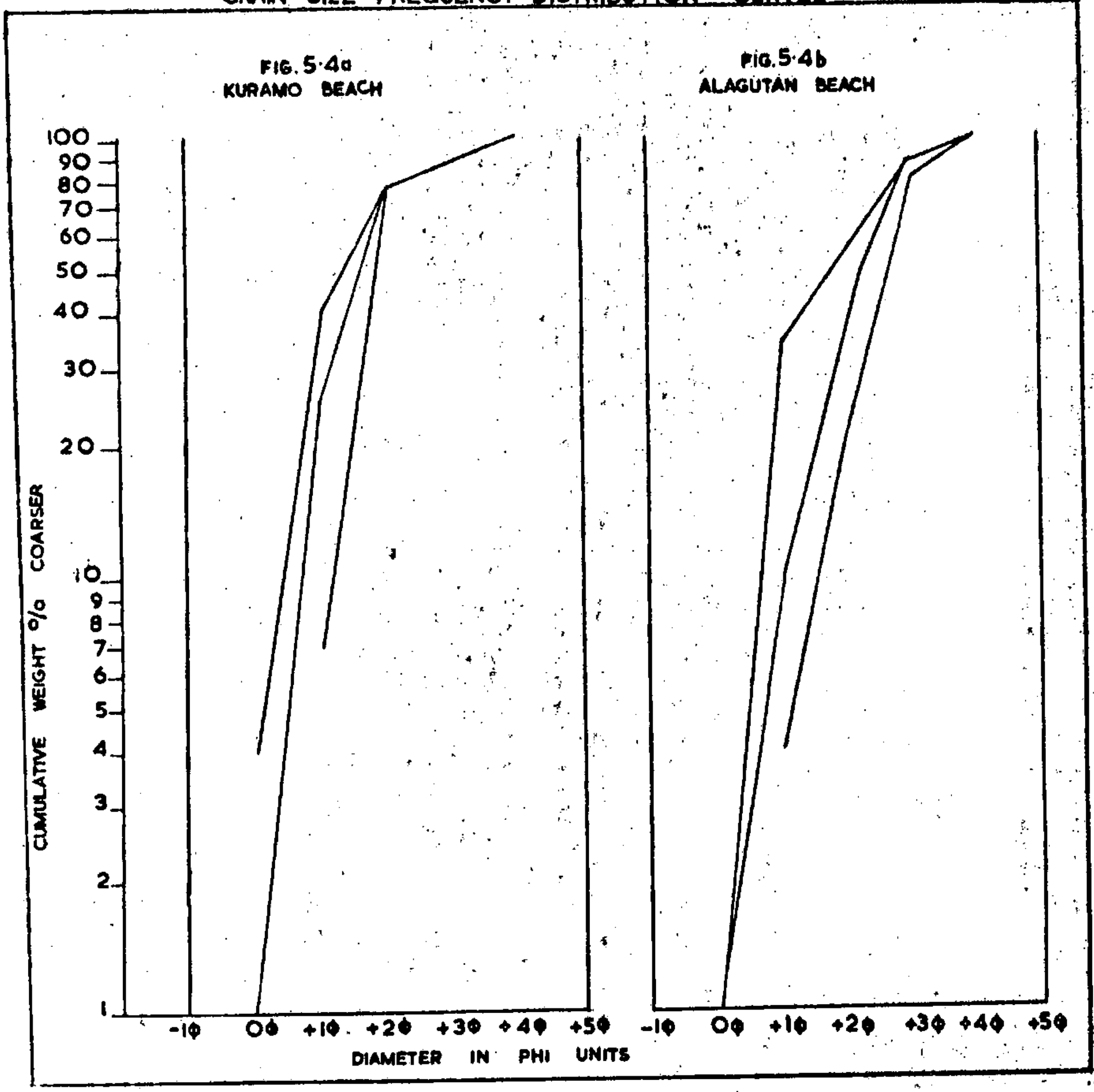

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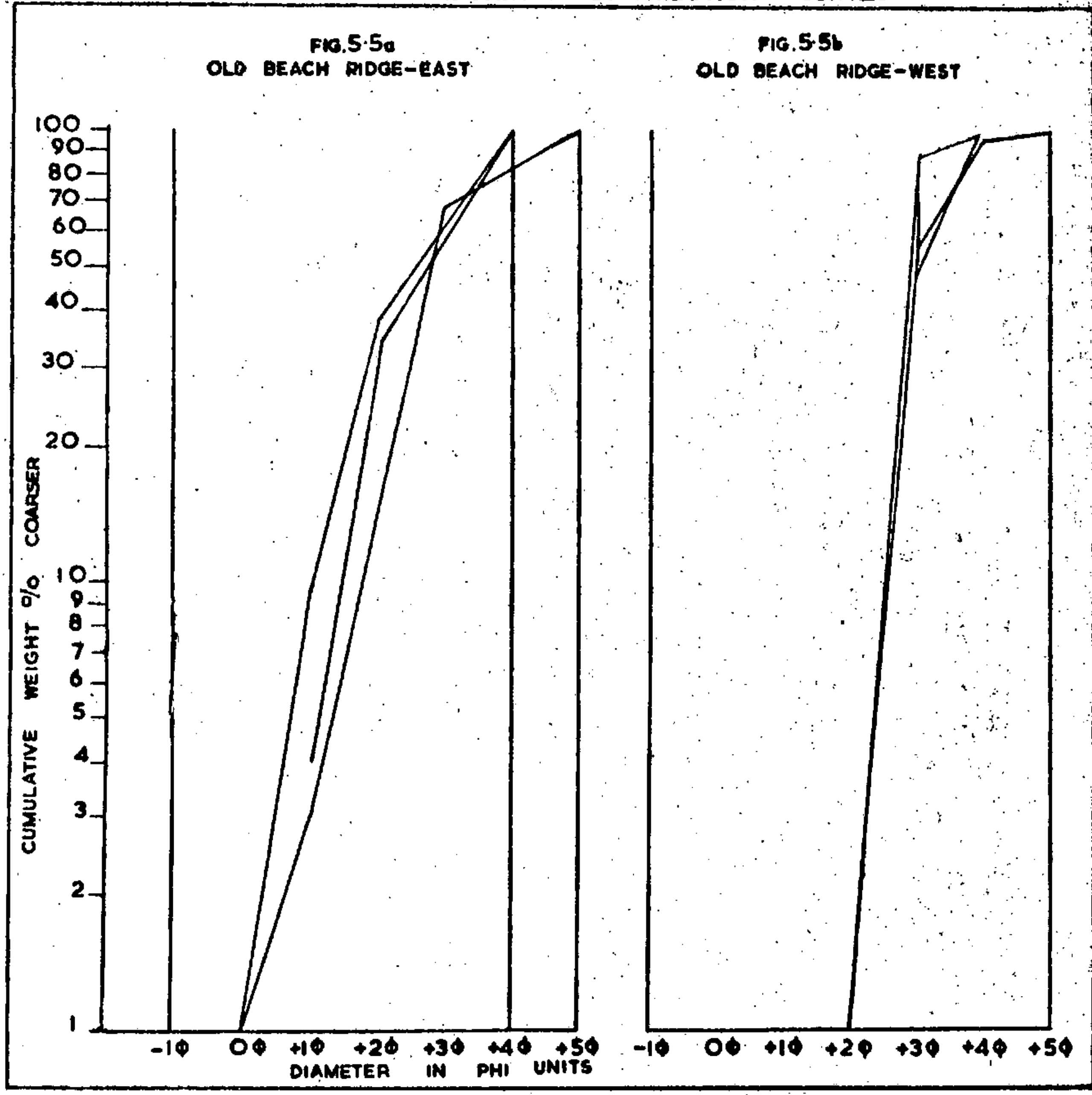


exposed to subaerial agencies, the processes of diagenesis and lithification develop, which alter the packing and arrangement of the sand grains.

It is however observable from Table 5.1 (LAG 71/17-23) that fine-grained sediments are better sorted than the coarser ones as demonstrated in samples LAG 71/01-06, 09-016, and 047-034 in Table 5.1. Even in the sediments from older landforms better sorting occurs on fine-grained sediments as in LAG 71/33-39 compared with samples from LAG 71/40-46 in the same tabulation. It follows that, finer sediments possess better degree of sorting than coarse ones and since the rate of permeability is a function of size and sorting amongst others (Krumbein & Monk 1941), it is possible to identify areas of high and low rates of permeability on the basis of these two factors.

DEGREE OF ROUNDNESS: The analysis of the degree of roundness of the sediments is shown in Table 5.2 below. It is observable from this table that angular and sub-angular grades occur in greater percentage in the samples from the undulating plains, Lagos lagoon outlet, and Light House and Victoria beaches. The occurrence of the angular grades in the undulating plains derives from the genesis of its sediments which is essentially fluviatile in origin, because they comprise the Coastal Plain sands which apart from being continental in origin, were deposited in a dry phase by rivers - (Jones and Hockey 1964). Thus the occurrence

TABLE 5.2

DEGREE OF ROUNDNESS AND STRUCTURAL CHARACTERISTICS OF SEDIMENTS IN THE COAST OF LAGOS

Serial No.	LANDFORM UNIT	Sample Number LAG 71/	% Angular	% Sub Angular	% Sub Rounded	% Rounded	% Well Rounded	Structural Pattern
1.	UNDULATING PLAINS	61	12	80	8	-	-	Large quantities of Clay materials
2.		62	58	28	14	-	-	Reddish Coating
3.		63	12	20	72	4	-	Concretionary
4.	SWAMPS	55	-	-	12	54	34	Stained red - fungal growth
5.		57	-	-	16.6	58	25	
6.		66	-	-	-	48	52	Crystal growth
7.		67	-	-	38	37	25	Darkish stains
8.		68	88	12	-	-	-	Admixtures of shells
9.	BEACH PLAINS	47	-	-	4.4	66.6	28.8	Admixtures of shell and sand
10.		48	-	-	7.8	53.8	38.4	Crystal growth and pitting
11.		49	-	-	6.6	73.3	20	Darkish Coatings
12.		50	-	-	25	42.1	32.8	Coatings
13.		51	-	-	17.3	58.2	23.9	Reddish Stains
14.	BREACHED RIDGES	40	-	-	42.6	32	25.3	Reddish Stains
15.		41	-	-	20	50	30	Red coatings but polished
16.		45	-	-	41.1	40	18.8	Etching and pitting
17.	OLD BEACH RIDGES	27	-	16.6	44.4	38.8	-	Concretions
18.		29	-	-	43	57	-	Iron coating, etched
19.		30	-	-	25	54.2	10.8	Grains
20.	CONTEMPORARY BEACHES							
21.		17	52	48	-	-	-	Sharp edged grains, very fine and clean
22.		18	80	20	-	-	-	
23.		01	20	15	25	30	10	Admixtures of sand and broken shells
24.		05	28	12	30	20	10	Admixtures of sand and broken shells
25.		14	20	10	45	10	15	Admixtures of sand and broken shells.

of angular grains depicts the low energy medium of transport, the short distance of transport which is likely to be from the drainage basins of the coastal rivers, the relative resistance of quartz grains to wear and the relatively 'recent' time of exposure of the materials.

Angular grains are common on the Light House beach probably because of the pulverization of sand grains knocked against the rock boulders of the west mole by the waves. Large quantities of angular grains, with very sharp and freshly cut edges and whose original outline was roundish, were found on the beach berms and breaker zone of the Light House beach up to a distance of 400 metres west-ward. It was found out that the waves that break on the rocks of the West mole develop a 'reverse current' between the low-water and high water marks that carry these broken grains westwards. Some of the stained sand grains dropped from the top of the mole to the breaker zone were found during field work to be deposited at points from ten to four hundred metres westwards of the West mole.

The angular sediments on the Victoria beach are likely to be those sediments pumped there for beach replenishment, from the Lagos lagoon. While the angular sands of the Light House beach derive from the intensity of deposition and their resultant pulverization, and those of the Victoria beach from its nourishment with sands from the Lagos lagoon.

Old beach sands are generally rounded to well-rounded in shape as demonstrated by samples LAG 71/40-51 shown in Table 5.2. The roundish nature of the sediments result from the combined effects of prolonged period of reworking by waves and littoral drift during the time of deposition. It is therefore being established that in general the degree of roundness of the sand grains in the coastal zone of Lagos could be used as an index of the energy of the transportational and depositional agents. The angularity of the recent beach sands is not an indication of weak transport media, but a combination of high wave energy and the influence of human action in the construction of the West mole on the Light House beach, and on the Victoria beach, the result of the pumping of sands from the lagoon bed for beach nourishment. In this case, the degree of roundness can be used to indicate the intensity of the palaeogeomorphic processes involved in the evolution of the landforms rather than that of the contemporary processes.

Furthermore, the well rounded nature of the sand-grains of older landforms confirms their marine and submarine origin. Hence the origin of the sediments in most of the landforms sampled except the undulating plains could be said to be marine and sub-marine, while the sediments of the undulating plains were terrestrially derived.

STRUCTURAL CHARACTERISTICS:

The structural characteristids of sediments as defined by Pettijohn (1957) include the grain pathology, fabric, mineraology, bedding and concretionary development. Grain pathology according to Pettijohn (1957) is one of the surface features present on the grain which might have resulted from changes that have occurred in it since deposition. These might include grain etching, pitting, crystal growth and staining. Apart from these surface features, this thesis also examines the changes in colour and mineral aggregate as a result of the precipitation of unstable minerals, as evidence of typical overall environmental changes in the area of study.

GRAIN PATHOLOGY:

Most of the sediments in the coastal zone especially those of the older landforms such as old beach ridges, beach plains and the undulating plains display combinations of surface marks such as red, and grey stains, etching and pitting, crystal growth and aggregations. Sediments from the undulating plains have a thick matrix of clay materials, reddish coloured grains of sand and reddish coating as demonstrated by samples LAG 71/61, 62 and 63 in Table 5.2. Both the Prior and Inner sandy-barrier formations consist of sands with red stains, pitting and with admixtures of reddish sands. The occurrence of the reddish colour, red stains and the pits in these sand grains reflects the intensity of oxidation taking place in the sediments as a result of exposure to weathering. The reddish materials are precipitates of iron and alluminium derived from weathering. The depth of the reddish profile varies from over 20 metres in the undulating plains (Mushin bore hole, Nigeria Geological Surveys 1960) to four metres on the Prior barrier and about ten centimetres on the Inner barrier. This variation in depth can be explained by the time-intensity concept of Krynine (1945) which states that the depth of the weathering profile is a function of the duration of weathering and the magnitude of the weathering agents. It follows therefore, that weathering occurred in the undulating plains over a longer period of time than on any other landforms in the coastal zone.

CONCRETIONARY DEVELOPMENT:

One of the phenomenon occuring within the sediments in the coastal zone is the development of 'Cuirrasse' sand-crete and silicrete. Both the cuirrasse or what is erroneously referred to as 'laterite' (Adepegba 1969), and the sandcrete are generally bounded together by precipitates of iron and alluminium. The difference between them is that the sandcretes are smaller aggregates of quartz about 0Ø in diameter while cuirrasse may be as large as -2Ø in diameter.

The silicretes are bounded together by the precipitation of silica and generally occur in the horizons with high level of underground water, below the weathering front in the beach ridges or in the upper horizons of the beach plains. These aggregates are generally referred to as concretions in this thesis.

The concretions occur in large quantities in the undulating plains, and on the Prior barrier formation, while traces of them are found too, on the Inner barrier formation. They occur in the weathering profiles and are consequently the products of weathering. Weathering therefore constitutes an effective agent of sediment modification in the coastal zone. The occurrence of concretionary structures is not solely an indication of a high intensity of weathering but also that of a humid climate with alternation of periods of wet and dry seasons. It is certain that the precipitation of the ferro-magnesian minerals took place during a humid climate and the aggregation of the residue probably occurred during a relatively drier climate. This evidence goes further to confirm the occurrence of dry and wet phases of climate in this zone, especially when similar evidence has been adduced in other parts of West Africa to explain the changes in the climates of past. (Le Bourdiec 1958, Davies 1964).

MINERAL COMPOSITION: The minerals found in the sediments include quartz, silica, iron, alluminium, calcite and accessory minerals like kyanite, staurelite, rutile etc. However, the classification followed in this thesis is general because the minerals are separated in to four groups: viz: minerals which pass through the 200 B.S. sieve mesh are referred to as silt or clay, quartz minerals, calcareous materials and the heavy minerals. No effort was made to estimate or measure the quantity of minerals such as iron, silica etc. because the knowledge of their quantity in irrelevant to the theme of this work.

The four groups of minerals are shown in Table 5.3. as they occur in parts of the coastal zone. The choice of the 200 B. S. sieve mesh as the dividing line for the silty and clay grade derives from the fact that they fall into the fine-sand grade of the American Society of Civil Engineers as published by Ladd etal (1969) and helps to determine the percentage of compressible material within each landform, since the materials of this grade are generally compressible under pressure, Casangrande (1932) Ladd etal (1969). The choice of quartz derives from its sutability for devising the provenance of the sediments as well as the stability of the sediments in general under the influence of sub-aerial weathering. Calcareous materials can be used to determine the origin of sediments as well as their stability, especially if a high percentage of the sediments consist of them. The heavy minerals, are significant as has been mentioned earlier for the determination of the provenance of the sediments as well as a measure of the effectiveness of weathering and the other agents of denudation.

As sh..n in Table 5.3, quartz forms the largest group of

GENERAL MINERAOLOGICAL CONTENT OF THE SEDIMENTS

TABLE 5.3

Serial No.	Sample location	% Silt or Clay	% Quartz	% Calcareous Materials	% Heavy Minerals
1.	Victoria beach	10	55	33	2
2.	Commander Shoal	-	60	37	1
3.	Light House beach	-	80	19	1
4.	Lawani Beach	2.5	69	27	1.5
5.	Maroko Mangrove Swamp	40	52	7	1
6.	Lagos University Mangrove Swamp	48	50	1	.5
7.	Tarkwa Bay Mangrove Swamp	45	45	10	-
8.	Iganmu Swamp	70	28	1	1
9.	Breached sand ridge-Maroko	8	88	10	2
10.	Prior barrier at Amuwo	40	55	3	2

minerals in the coastal zone. The domineering position of quartz gives the impression of identical source regions for the sediments in the area, and most likely from the rocks of the basement complex in the hinterland of South Western Nigeria. As most of the quartz grains show evidence of marine deposition, it is probable that they were deposited initially into the sea-bed by rivers when the sea level was lower. The occurrence of large quantities of quartz grains in effect underlines the fact that most of the less stable minerals have been weathered, and this confirms the effectiveness of weathering as an agent of mineral decomposition in this area. The occurrence of large quantities of materials of finer grade in the swamps underlines the fact that those areas may be highly compressible if heavy structures are constructed on them.

The occurrence of calcareous materials in every one of the samples in Table 5.3, indicates the influence of marine/submarine or lagoonal agencies in the evolution of the landforms. The table shows that a high percentage of calcareous material (27-37%) occurs in recent landforms such as on the Victoria beach, Commander Shoal on the Lagos Harbour, and on the Light House beach, while on old landforms such as the Prior barrier and Iganmu swamp their percentage of occurrence is relatively low (1 - 10%). This demonstrates the vulnerability of calcareous materials under intensive weathering as occurs in this coast.

The general low percentage of occurrence of heavy minerals is also an evidence of the intensity of weathering which decomposed most of the less stable ones and perhaps transport rigour which might have caused the reduction of some of them to the clay grades.

The directions of transport of the heavy minerals along the coastal zone is shown in Fig. 5.6, while Table 5.4 shows the detailed occurrence of the heavy minerals in each sample examined. Of all the heavy minerals, hornblende is the most unstable (Pettijohn 1957), hence its occurrence as a residual in this area of intensive weathering needs clarification. Only very few hornblende occur in the older landforms such as breached-ridges and beach plains, while it occurs in a greater quantity on the sea beaches. This might be due to their existence under the sea for very long time where they avoided the attack by weathering, while those occurring in older landforms might lie within the level of underground water and thus escape weathering.

However, the occurrence of these heavy minerals aids the identification of the source and direction of transport within this Coastal zone as shown in Fig. 5.6 on page 235. Of the heavy minerals only zircons, kyanite and hornblende come within the littoral drift zone while all except limonite, and hornblende, come from the sea bed. All the coastal rivers transport hornblende while the Ogun transports zircons, staurolite, tourmaline, garmet and limonite.

HEAVY MINERAL ANALYSIS OF SAND SAMPLES FROM LAGOS COAST

(NUMBER OF MINERAL GRAINS)

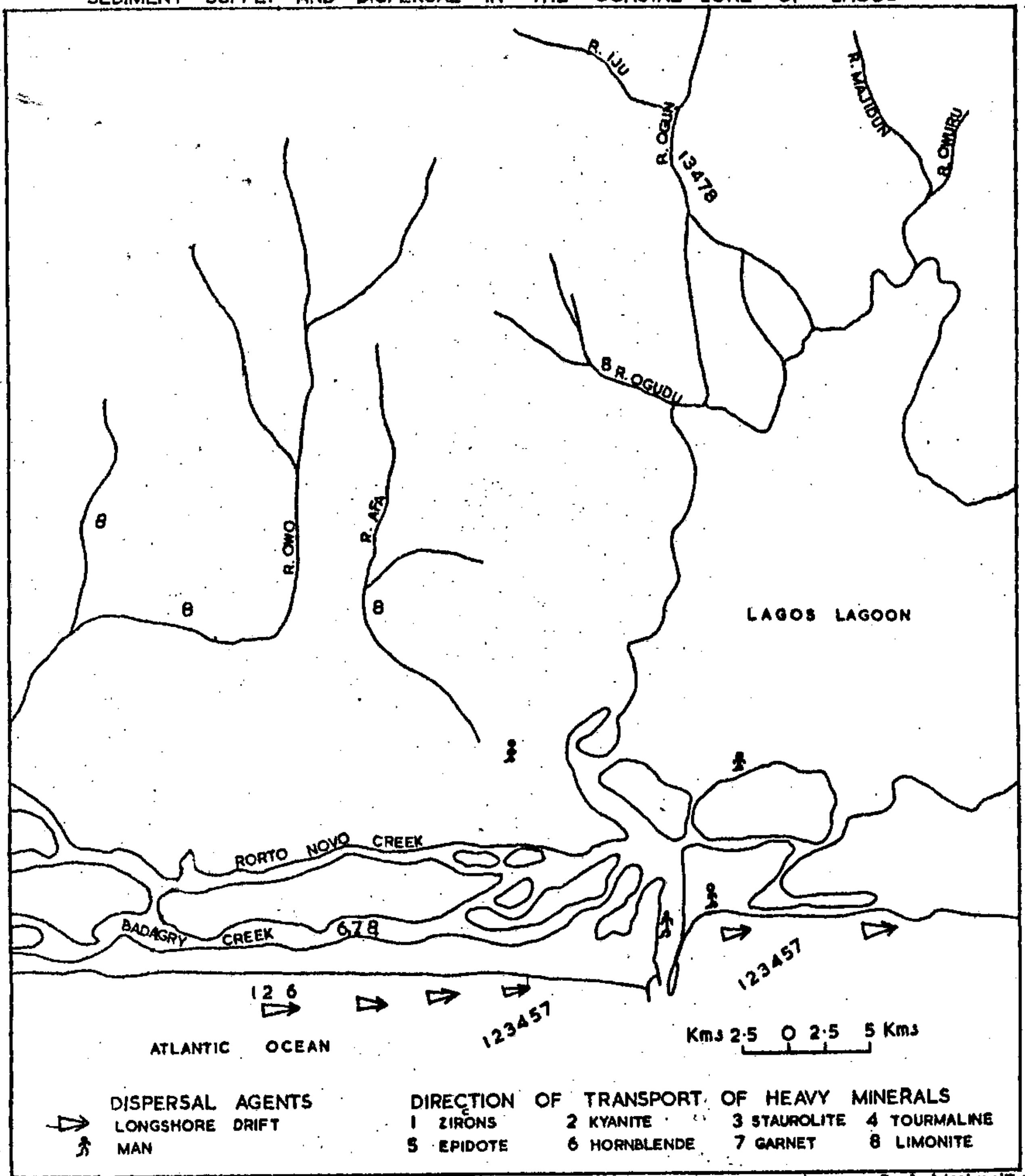
TABLE 5.4

SAMPLE NUMBER		SAMPLE LOCATION	ZIRCON	KYA-NITE	STAURO LITE	TOURMA LINE	EPI-DOTE	HORN BLENDE	LEMO NITE	GARNET
1	001	Victoria Beach, Lagos	3	4	-	2	2	1	-	2
2	006	Victoria Beach Lagos	2	3	2	1	3	3	-	1
3	017	Light House Beach Lagos	4	5	2	1	3	-	-	1
4	018	Light House Beach Lagos	2	2	1	1	3	-	-	2
5	020	Light House Beach Lagos	3	5	3	1	1	1	-	2
6	013	Kuramo Beach Ridges	4	2	1	3	1	1	-	1
7	015	Alagutan Beach Ridges Victoria B	3	1	1	2	1	1	-	2
8	055	Lagoon Deposit	5	2	1	2	1	-	-	1
9	028	Old Beach Ridges	3	1	1	-	-	-	-	2
10	047	Beach Plains Maroko	5	3	1	1	1	1	-	-
11	050	Beach Plains	5	3	1	-	-	1	1	2
12	053	Beach Plains	3	1	1	1	-	-	2	-
13	034	Beach Plains	4	1	1	2	-	1	3	-
14	051	Beach Plains	3	2	1	-	-	1	1	1
15	048	Beach Plains	4	1	2	-	-	1	1	2
16	048	Breached ridges	3	3	1	-	-	1	2	1

TABLE 5.4 (Cont'd)

SAMPLE NUMBER		SAMPLE LOCATION	ZIRCON	KYA-NITE	STAURO LITE	TOURMA LINE	EPI-DOTE	HORN BLENDE	LIMO-NITE	GARNET
17	043	Breached ridges	2	3	1	1	2	–	–	1
18	029	Old Beach Ridges	5	1	3	–	–	–	–	–
19	028	Old Beach L.H. Beach	3	2	3	2	2	3	–	–
20	056	Lagoon Deposit L. H. B.	2	3	3	2	1	6	–	1
21	059	Lagoon Deposits L. H. B.	3	4	1	5	2	1	–	1
22	058	Lagos Lagoon Sands	3	1	2	1	–	–	–	1
23	Ojota	Quarry	4	1	2	2	2	1	8	1

FIG. 5·6
SEDIMENT SUPPLY AND DISPERSAL IN THE COASTAL ZONE OF LAGOS



By A. Adegboye '74

This goes to confirm the previous assumptions that the sediments in the coastal area did not only originate from the immediate hinterland, but also that the coastal rivers were responsible for their transport.

BEDDING CHARACTERISTICS:

It was not possible to cut profiles through the soil to considerable depth, because of the absence of necessary equipment, and the loose **nature** of the sediments which left bedding plains undefined. The succession of strata in general includes alternating beds of sand, silt and clay which is generally reminescent of the medium of deposition. Example of this succession is illustrated in Fig. 1.6 on page 23.

Although the knowledge of the stratigraphic succession of sediments is crucial to the objectives of this study, emphasis would be laid on evidence available from other sources, since it was not possible to get actual profiles through the soil. Core samples were taken to ascertain the depth of contemporary swamps in the Coastal zone with a view to recognising the thickness of the silty materials that may be compressible in case such locations are developed.

The depth of some of the swamps is illustrated in Table 5.5 below. The depths vary between 3 metres in University of Lagos swamp to about 70 metres at Iganmu before contact was made with the sandy layer below. The depths illustrate the magnitude of compressible materials in the swamps and would guide the processes of their reclamation.

Apart from the swamps, no other areas consist of thick bed of compressible materials, except the Ogun-Majidun plain which has been classified as highly compressible aboue. In general therefore, the succession of strata depicted in Fig. 1.6 and Table 1.1 would be used as a guide to the determination of the stratigraphy of the coastal zone. More detailed stratigraphic data are available in the Offices of Oil Companies who classify them as 'Commercial Secret' and were not available for my use.

INFERENCES FROM SEDIMENT CHARACTERISTICS

An attempt is made below to summarise the derivations from the analysis of sediments under two broad headings:- theoretical and practical i.e., those facts affecting the character of the land and are usable as a guide to land resource development.

The analysis elucidates the problems of the physical processes of sedimentation as they might have influenced the evolution of the coastal landforms. Sources of sediment supply for the past and contemporary landforms, the media of transport into the coastal zone were identified. The map in Fig. 5.6 illustrates this on page 235 above, while Table 5.6 carries information about these aspects also.

Both the textural and structural characteristics of the sediments show a marine origin of all landforms except the undulating plains whose origin is shown as fluvial in origin and both wave and litoral drift were in operation during the evolution of the

DEPTH OF SELECTED SWAMPS IN THE LAGOS COASTAL ZONE

Table 5.5

CORING LOCATION	THICKNESS
1. University of Lagos Swamp	3 metres
2. Bariga Swamp	5 "
3. Itirin lagoon Swamp	4 "
4. Tarkwa bay "	5 "
5. Iganmu "	Above 70 metres (Courtesy of Foundation Engineering Co. Nig.Ltd 1972).

landforms respectively. The relief of the beaches has been influenced by the pattern of distribution of sediments. The beach gradient of 8° between Apese village and Lawani where the mean diameter of the sands is between .8ø and 1ø, whereas on the Light House beach with materials finer than 2.5ø, the beach gradient is about 2°. Also the variation in the sizes of the sand grains affects the intensity of beach erosion, because intensive erosion takes place in the coarser material of the Victoria beach, while it is largely unnoticed in the Light House beach with finer materials.

The overall surface and underground drainage patterns seem to be influenced by the sediment character, since permeability is a function of increase in grain size and sorting (Krumbein & Monk 1941) and porosity is also a function of grain size, sorting and packing (Pettijohn, 1957) the coarse grained sediments with better sorting coefficient are characterised by high rate of permeability. But in the swamps and flood plains with fine grains and poor sorting the reverse is the case.

From Table 5.1, it is possible to notice that the coarse texture of the sediments in this area is greater than the lower limit of the coarse-sand grade of 5ø used by the American Society of Engineers (Ladd etal" 1969). However, in Table 5.3, it is shown that some parts such as Iganmu swamp, Tarkwa bay swamp, the Prior barrier at Amuwo and Maroko mangrove swamp consist of a

SOURCES OF THE HEAVY MINERAL SUITES

TABLE 5.6

HEAVY MINERAL	SOURCE ROCK	LOCATION OF SOURCE ROCK	ROUTE OF TRANSPORT
1. ZIRCONS	Granulitic Gneiss	Iseyin	R. Ogun
	Quartzite & Quartzite schist	Ibadan/ Olokemeji, Upper Ogun	"
	Quartzite & Phyllites	Atacora range Togo	R. Mono
2. KYANITE	Acid-Gneiss	Dahomey	Longshore drift.
3. STAUROLITE	Mica Schist	Ibadan Syncline	Ogun R.
4. TOURMALINE	Pegmatities & Migamatites	Aro & Ikereku	Ogun R.
5. EPIDOTE	Quartzites	Ibadan Olokemeji	"
6. HORNBLENDE	Biotite-Gneiss	Ado Rock	Yewa
	Biotite-Schist	Aboko Hill	"
	Hornblende - Gneiss	" "	"
7. GARNET	Older granites	Wasimi	Ogun R.
8. LIMONITE	Cretaceous sandstones	Wasimi	Ogun R.

relatively high percentage of finer materials. It follows that for purposes of land resource developments, those parts with finer material greater than 70% could be regarded as highly compressible and liable to subsidence after de-watering and compaction e.g. Ogun - Majidun Alluvial plain, and Iganmu swamp. These areas with Coarser material greater than 70% may be classified as relatively stable areas, and they include the sandy-barrier formations and the undulating plains.

Furthermore, the swamps listed in Table 5.3 are likely to be potentially floodable areas because the materials in the clay grade are greater than 30% which is the critical percentage at which the soil is expected to retain water (Taylor 1947). The liquid limit of all other landforms tabulated in 5.3 may be high and be easily reclaimed for development.

The high rate of permeability of the sediments contributes to the rate of water see-page from the sea and lagoons noticeable in enclosed swamps during the rise and fall of the tides. In effect, this activity warns against low foundations which may be flooded by the rising level of underground water during the tidal cycle or seasonally during the rains.

The dynamics of erosion and sedimentation in the coast derive from the character of the sediments, especially the rapid removal of materials on the Victoria beach and the accumulation of sediments in the Lagos Harbour. Erosion on the Victoria beach is aggravated by the coarse texture of the sandgrains which become vulnerable to high waves, and the development of a west-east littoral drift from the beach.

In Lagos Harbour, the fine materials in suspension from both the Badagry and Porto Novo Creeks in the West, the Lagos lagoon to the North and Five Cowrie Creek to the east sink when in contact with the sea-water, and nourish the Brugos Shoal.

During the analysis, it was found that the undulating plains and the Prior barrier consist of large quantities of Concretions, which could be used in other parts of the Coastal zone to aid the rapid reclamation of the swamps. Also, the occurrence of shoals or sand banks in the lagoon with sand grains with a mean diameter of between 1.3Ø and 1.5Ø provides an alternate source of sand for construction purposes, instead of relying on barrier sands as at present.

In general, the sediments within the Coastal zone, by virtue of their coarse nature and predominance of quartz minerals and the prevailing humid climate, may not have reached a stage of maturity stage. Maturity of sediments can be measured by the relative degree of finess of grains or by the absence of unstable minerals (Pettijohn 1957). The effect of weathering can be seen in the rapid decomposition of the ferromagnesion minerals on the Prior barrier and in the undulating plains, and it is expected that the same activity would extend to more recent landforms such as the

Outer and Inner barrier formations, and the swamps when they are reclaimed. Therefore in any programme of land resource development in this coastal zone, consideration should be given to the role of weathering and soil formation to avoid subsidence or general lowering of the land as a result of sediment compaction.

There seems however to be a relationship between the grain size characteristics of the sediments and the morphological properties of some of the Coastal landforms. It has been found out that landforms with relatively low angles of inclination with generally flat summits consist of finer grains while those landforms with relatively steeper slope angles with markedly elongated distinctive relief features consist of coarser grains. For example, the flat-topped beach ridges of the Prior, Inner and Outer barriers west of the Lagos Harbour consist of very fine grains whose median diameter ranges between 2.5ϕ and 3.6ϕ as shown in samples LAG 71/30 - 39 and 17 - 24 in Table 5.1. Apart from being flat-topped, the beach-ridges display low-angles of inclination generally varying between 2° on the Outer barrier and about 4° on the Prior barrier West of the Lagos Harbour.

On the other hand, the beach ridges east of the Lagos Harbour are well defined, elongated and the slope angles vary between 6° and 8° at Ilado and Lawani respectively, while sand cliffs are out into the Outer barrier by waves in this sector, especially on the Victoria beach. This area of relatively salient relief and well defined slope inclination consists of relatively coarse sands varying between .7∅ and 1.9∅ in median diameter and shown in samples LAG 71/09 - 16 and 25 - 29 in Table 5.1.

The undulating plains and the beach plains are areas of contrasting landform type and grain size chracteristics. Apart from being the areas of most salient relief in the coastal zone, the undulating plains consist of well defined north to south ridges and valleys, and displayed the steepest slope angles of about 10°. Also, the landforms consist of the coarsest sediments varying between 0 ∅ and - .8∅ in Md. size as shown in samples LAG 71/61 - 65 in Table 5.1. However, the beach plains which are generally flat consist of finer sediments ranging between 2.5∅ and 3.5∅ as shown in Table 5.1 in samples LAG 71/47 - 54.

From the analysis above, it seems as if coarser grain sizes develop into well-defined landforms while finer grain sizes aid the development of very faint relief on the landforms in this coastal zone. This might have been due to the 'differential erodibility' of fine-grained and coarse-grained sands, which is higher in the latter and lower in the former.

Furthermore coarser sediments are susceptible to wave or gulley erosion because of their higher degree of permeability and loose nature, whereas finer sediments seem to be prone to erosion by sheet wash because of the compact packing of the grains and the reduced rate of permeability.

It follows therefore that the finer texture of thesand grains of the landforms west of the Lagos Harbour and the Coarse texture of those of the landforms east of the Harbour influenced the chara er of their morphological properties described above.

The study of the sediment characteristics has thrown a lot of light on vital aspects of land resource management in the area. First, the details of the land character have been exhumed, and a close relationship between the landforms and the character of their sediments has been established, thereby allowing for a better classification of the land based on both the surface and subsurface properties of the terrain as advocated by Brink (1969). Evidence has been brought to explain the dynamics of erosion, acretion, flooding, dra nage and subsidence, which are geomorphological problems common to this coast as examined in chapter three. In the next chapter an attempt is made to classify the area into landform units using the sediment character as one of the criteria.

CHAPTER SIX

CLASSIFICATION OF LANDFORM UNITS IN THE COASTAL ZONE OF LAGOS

6.1 INTRODUCTION:

This chapter describes the procedure used in the classification of the area into landform units of similar attributes and presents the classification as well as part of the techniques used in the study of land-resource development in the coastal zone of Lagos. The previous chapter elucidated the data about the character of the sediments in the area, while the details about the character of the various landforms have been carefully examined in chapter two. This chapter, therefore assembles the data from these sources, classifies them into 'homogenous' units on the basis of selected criteria to be enumerated. A land classification map of the area, based on the data collected is also produced.

Land classification is an important method used in land resource surveys either for the compilation of land inventory in general (Christian and Stewart, 1947, Haatjens 1961, Mabbut and Stewart 1963 and most of the land resource surveys of CSIRO in Australia), for land use appraisal (Forbes 1961), (Lebon 1962) or for engineering capabilities of the land, (Aietchison and Grant 1968, Dowling 1968). Apart from this, the ultimate classification of the land into units of similar attributes is an important aspect of applied geomorphology, because it makes geomorphology practical and aids the rational planning of Land for the various land users as advocated by Dixey (1962) and described by Tricart (1961). Since the principal objective of this study is to demonstrate the significance of planned development of land resources, especially for settlement expansion in the Lagos area, the classification of the land does not only conform with the practice by scholars from other parts of the world, but also aids the planning of settlement expansion in the area.

The area classified as the Lagos Coastal Zone does not include the built-up areas, because they were neither sampled during field work nor did they fall in to the category of areas needed for future land use planning. If there is any programme of urban - redevelopment in Lagos Metropolitan area, a different study of the built up areas can be embarked upon. However the areas classified include the sand ridges, swamps and depressions which have not been developed for settlement within the areas of jurisdiction of Lagos and Ikeja Divisions of the Lagos State. This area is illustrated in Fig. 3.5 on page 165.

Before any reliable land classification exercise can be carried out, a detailed analysis of the land character must have been completed and assembled. The land character used as criterion for classification depends on the purpose for which the classification is meant.

Certain classifications of the land for over-all inventory may rely on landform associations, vegetation, hydrography and perhaps soils as the criteria for classification, (Christian and Stewart 1947, Christian 1957), while others whose aim is to elucidate the engineering properties of the land may include relief texture, drainage density, soil strength, soil texture, soil water and the gradient of the slopes (Aietchison and Grant 1968). For the objectives of this thesis, the following criteria have been selected. They are, land morphology, drainage, sediment characteristics, depth of weathering profile, processes of evolution, vegetation cover, and the location of each land unit within the area. The criteria chosen are broadly based to satisfy the needs of probable users of the subsequent land classification map such as Engineers, Town planners and Architects.

For the coastal zone of Lagos the land classification criteria used are based on the land attributes dealt with in chapters two, where the relief characteristics were described and the sediment characteristics of the landforms as described in chapter five. It is thus a classification based on the convergence of evidence from the genesis of landforms, as demonstrated by Mabbut (1968) Stewart (1968), the hydrography and superficial materials as recommended by Beckett and Webster (1965). It was not possible to rely on detailed slope anslysis as well as other morphometric properties of landforms because there are no maps available with adequate contour intervals for this type of analysis, and much of the terrain is inaccessible for detailed field work hence a morphological mapping exercise based on field measurements and topographical map analysis could not be carried out.

Apart from these difficulties, the lowlying nature of the terrain, calls for a different approach to the classification of the land. Hitherto morphometric properties feature prominently in land classifications as shown in the works of Parry et al (1968); Aitchison and Grant (1968) and was also advocated for by Savigear (1965) in his Techniques of morphological mapping. The works quoted above however, were carried out in areas with well marked relief features, where base maps at suitable scales are available. In view of the sharp contrast that exists in terms of available facilities for mapping in Lagos area and areas covered by the works cited above, it occurred to the author that different criteria could be used to advantage in the Lagos area where the sediment properties of grain sizes, sorting, sediment structures and fabrics are of significance to geomorphological interpretation as well as engineering classification (Ladd et al 1969). Similarly the hydrography of the area, such as surface and underground drainage features, and morphological characteristics of the land units which are identifiable are again pertinent to the demand of Town planners, Architects and Civil Engineers in making plans for land development.

This approach enhances the elucidation of the interacting character of factors of landform development e.g. morphogenesis, the superficial deposits, the hydrography and the morphometric properties of the land.

6.2 GEOMORPHOLOGICAL CLASSIFICATION

Geomorphological classification derives from the quest of Geomorphologists to obtain more knowledge about the spatial distribution of landforms, their inherent characteristics and to make the subject more relevant to the needs of mankind with reference to land use planning. In the coastal zone of Lagos, where the meagre land resources with their limited spatial extent and poor terrain conditions constitute major obstacles to urban expansion, inspite of the great demand for land for various land-use categories; the use of geomorphological techniques to evaluate the land for better planning purposes, and to elucidate the detailed geomorpholigical character of the land, is of great importance.

The need to understand the geomorphological character of the land in any exercise to find solutions to the problems of the human environment has been demonstrated in the works of Linton (1951) Tricart (1961) Dixey (1962) Klimazewski (1963) Savigear (1965) Vink (1968) Mabutt (1968) Olofin (1972) and Demek (1972). The techniques of geomorphological mapping and the classification of landforms, have been employed to a great advantage in the various works cited above.

And this thesis is largely in agreement with the points of view thereby expressed because any landform analysis based on the classification and mapping of geomorphological attributes of the land is more reliable than any one based on other criteria such as vegetation and/or soils. Furthermore as each part of the land surface is the end-product of an evolution governed by the lithology, past and present landform processes, climate and time, it is necessary to examine and analyse the characteristics enumerated above to enhance a better understanding of the character of the land. An understanding of these land attributes fall within the scope of geomorphological investigations and no other discipline deals with them as such. To substantiate this further, (Currier 1952) pointed out that terrain intelligence is within the primary field of the geomorphologist to provide, and he is better equipped, well trained, experienced and aware of the complex interrelationship of phenomena than the Engineer to interprete such basic data. It is in recognition of this role of geomorphology that most of the present day land resource surveys and their classification maps have to be based on geomorphological principles.

There are three types of land classification methods known to the author at present, and they include (i) the land system of the CSIRO in Australia which is basically used to take the inventories of land resources in the uninhabited parts of Australia (ii) the recurrent landscape pattern of the Military Experimental

Establishment in Britain used mainly for military engineering and also adopted by the Soil Mechanics Division of the CSIRO in Australia and (iii) the Uroschische system in Russia used mainly to identify the agricultural capability of the land and in more recent times the engineering capabilities of the land. Apart from their derivation from geomorphological principles, these classifications are based on the identification of the hierachy of land units delimited on the basis of the similarity of their attributes, but ordered according to size, such as land element, land facet, recurrent landscape patterns, land province etc. (Becket and Webster (1965)) or the land unit, land system, complex land-system categories of the CSIRO (Christian 1968). The methods used in these classifications are significant because they constitute the scientific and applied aspects of landform study.

However geomorphological classification promotes and understanding of the detailed evolutionary history of landforms, their material composition and the processes of morphology, and enhances the understanding of the spatial relationship of various units of classification. In its application however, groups of identical units are recognized and the data bank for various land users notably those interested in land resources planning, are provided.

In this thesis however, the units of classification are the 'land unit', the recurrent landscape pattern, and the land region.

These units as mentioned earlier on, are derived from the similarities in their attributes such as Landform morphology, sediment character, hydrography, depth of weathering, processes of evolution, vegetation cover and the engineering properties of soil strength.

The 'land unit' as used in this thesis, is an area of a high degree of homogeneity of attributes, which is to a great extent an area of similar genesis, and which is recognizable from aerial photographs as having typical features where ever they occur throughout the region. They include the swamps, beach ridges, beach plains etc. This unit of classification is similar to the 'land unit' described by Christian (1957) and used by CSIRO (Christian 1964), the land facet of Beckett and Webster (1965) and the 'Unit landforms' of Lueder (1959). It is identical in morphological aspects with the 'Landforms' of Savigear (1965). It is the smallest unit of land that could be of interest to the planner in this area.

Most of the landforms in the coastal zone are identical in shape, form and genesis, as such they are repeated in scattered locations throughout the coastal zone. Hence the term 'recurrent landscape pattern' is used to describe a repeated pattern of land units in the coastal zone. Such recurrent patterns include the sandy-barrier formations, the estuarine formations and the high plains of the north.

This term was first used in the M. E. X. E. classifications by Beckett and Webster (1965) and later by Brink et al (1966) to define associations of repeated land-facets and has been adopted here to describe recurrent land units throughout the coastal zone. It is also related closely to the land system unit of Classification of Christian (1957).

The largest unit is the 'land region' extending throughout the coastal zone of South-Western Nigeria. The land region consists of land forms of related genesis, processes of evolution and morphological characteristics, which are derived from marine and fluvio-lagoonal processes and possess identical characteristics of surface materials (Allen 1965) drainage net-work (Udo 1971) and Vegetation type (Adejuwon 1970).

The units of classification described above are essentially suitable for scientific enquiry on land resource development, because the hierachical arrangement of the landforms illustrates their genetic relationship as well as their spatial distributional pattern. The land classification map in Fig. 6.2 illustrate these attributes in detail. For land resource development, the classification took into consideration the following land attributes: (i) the morphological properties, (ii) morphogenesis, (iii) character of superficial deposits and (iv) engineering properties as the bases of differentiation. The scheme of classification differs from others such as those of the CSIRO, (Christian 1957) because of its incorporation of both the genetic and sediment properties in the list of attributes used for differentiating the units, and also from that of the MEXE. (Beckett & Webster 1965), because of the incorporation of the genetic aspects of landforms which seem unimportant to the M.E.X.E. system. It is a combination of the genetic and landscape approach advocated by Mabbut (1968) and the engineering classification of the land used by Clark (1973). The choice of definitive criteria for each land-unit makes it not only recognizable anywhere but makes its occurrence and those of its attributes predictable elsewhere. Thus the definitive features of the 'units' are fundamental and can resist the forces of change over a relatively long time. The ordering of the units illustrates the close relationship between low order and higher order units, for example the beach ridges and the sandy-barrier formations where beach ridges are delimited as representing a homogenous unit in form, genesis, and 'potentiality', and the sandy barrier formations which are landscapes made up of beach ridges, breached ridges, and beach plains. In essence, the low order, that is, the land unit category is variable in character, but unified as an entity of a recurrent landscape pattern. The recurrent landscape patterns, which are mainly four in the coastal zone, include, the sandy barriers, the estuarine and swampy formations, the lagoon complexes and the high plains. They constitute the 'land region' characteristic of the Coastal Zone of South Western Nigeria.

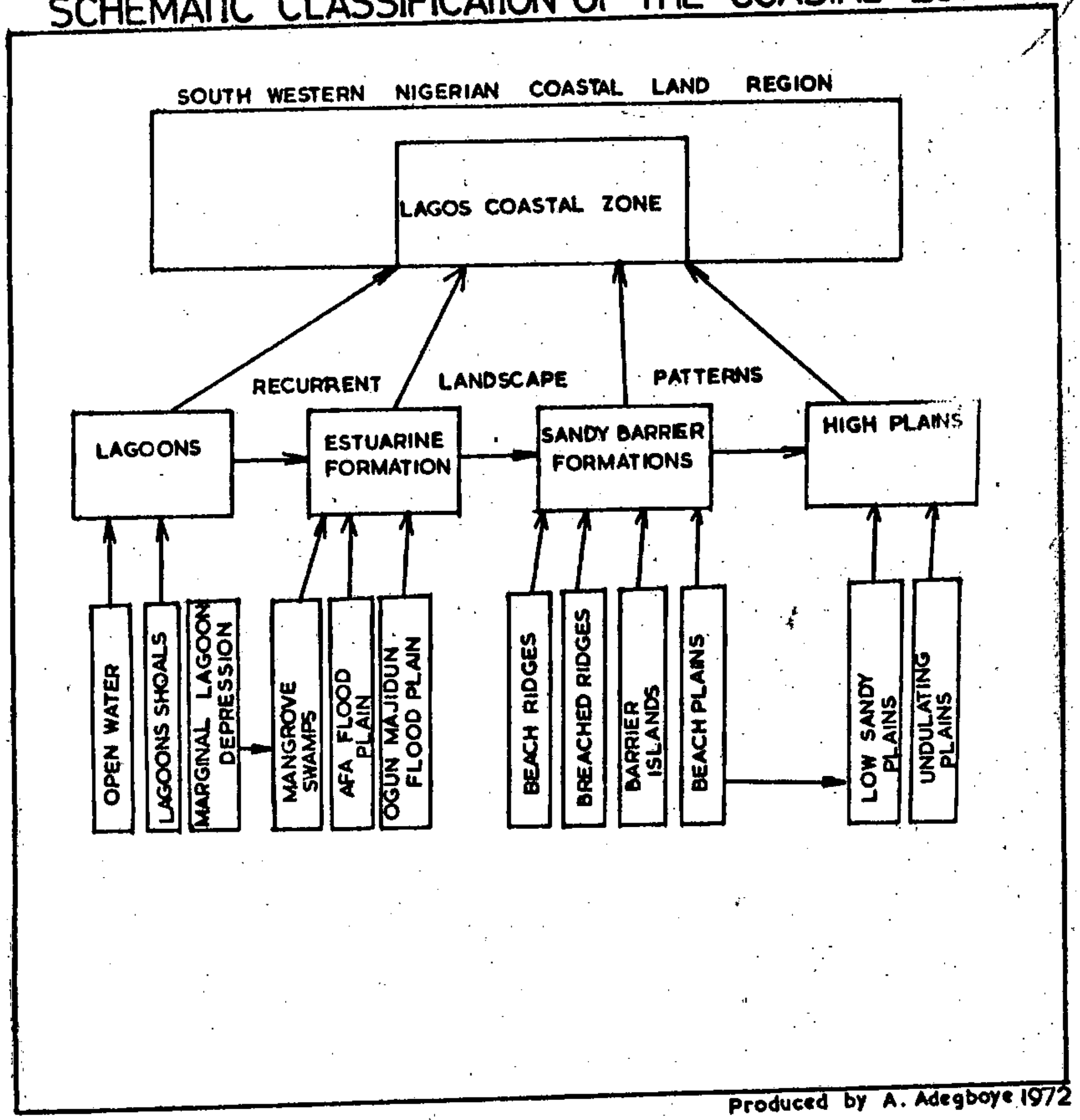
The overall classification of the terrain in the coastal zone is shown schematically in Fig. 6.1 below. Since the primary objective of this work is to aid planning and the zoning of land uses for Housing, road building, reclamation, Harbour dredging, recreation and sand quarrying in Lagos, the data about each of the land units are given in Tables 6.1, 6.2, 6.3 and 6.4, while the classification is translated into a map in Fig. 6.2 and the Recurrent landscape patterns are shown in block diagrams in Figs. 6.3, 6.4, 6.5 and 6.6 respectively.

6.3 GEOMORPHOLOGICAL MAPPING

Although the land area in the coastal zone of Lagos has been divided into basic units for land resource development as shown in Fig. 6.2, the application of the data in the classification can rarely be possible without their translation into maps. Although the map in Fig 6.2 contains some details which are meant to guide the planners who may be ill-equipped to understand the detailed geomorphological character of the area, a separate geomorphological map on a scale 1:20,000 of the area containing more information is compiled in Fig. 6.7.

The geomorphological map may be incomprehensible to non-specialists as it is noted above, it may be useful to fall-back upon the map to obtain detailed information if for example, those on the land classification map have been exhausted.

FIG.6·1
SCHEMATIC CLASSIFICATION OF THE COASTAL ZONE



Produced by A. Adegboye 1972

For example, if more details are needed to differentiate between land units for the purposes of land use zoning, the geomorphological map becomes the pictorial data-bank for planning. Apart from the applied aspect, it affords a cartographic and scientific understanding of the spatial relationship of phenomena, such as processes and form of landforms and distribution of superficial materials over the terrain; the details of which cannot be easily apprehended in the field. Hence geomorphological mapping has been the dominant approach to geomorphological surveys and research in most developed countries during the last two decades as shown by the works of Gellert (1961) Tricart (1962), Klimazewsiki (1963), Bakker (1963), Verstappen (1962) and Demek (1963 and 1972).

Some similar mapping techniques which were partly geomorphological in character have also been developed in other parts of the world. These include the morphological mapping techniques of Savigear (1965) and landform mapping techniques of Doornkamp (1969). Both the morphological and landform mapping techniques derive their criteria from the morphological properties of the land, but did not emphasise the form/process relationship nor indicate landform genesis. They are nevertheless significant contributions to knowledge in as much as they depict the form and shape of the land especially the slope characteristics. These approaches are mainly scientifically oriented and are restricted to areas of salient relief features where the slope characteristics are well shown.

UNITS OF LAND CLASSIFICATION

Table 6.1

LAND REGION LAND REGION	R. L. P. R. L. P.	LAND UNIT LAND UNIT	LOCATION LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
Coastal Zone of Lagos	High Plains of the Northern part	Low sandy Plains (Code A1)	Itire, Ijesha Isolo and coker villages	Flatish terrain Gradients $1^{o} - 2^{o}$.	Liable to flooding	Coarse sand Md. 1∅ Weathered up 40 cms. Angular grains with clay matrix	Fluvial deposition and later modified by weathering	Low dense bushes; and generally of secondary succession	Relatively stable	Construction can start in these areas
"	"	Undula-	Onisigun Erunkan, Ogudu Ojota Villages	Steep sided ridges of about 8^{o} inclination. Broad water logged depressions	Ridges are well drained while depressions are water logged	Ferruginised sands with concretions. Depth of weathering greater than 4 metres. Angular sand grains (Md. -1∅.	Fluvial deposition, Weathering and laterization.	Wooded bushes	Very stable Soil materials useable for filling depressions	"

THE HIGH PLAINS RECURRENT LANDSCAPE PATTERN IN BLOCK DIAGRAMS

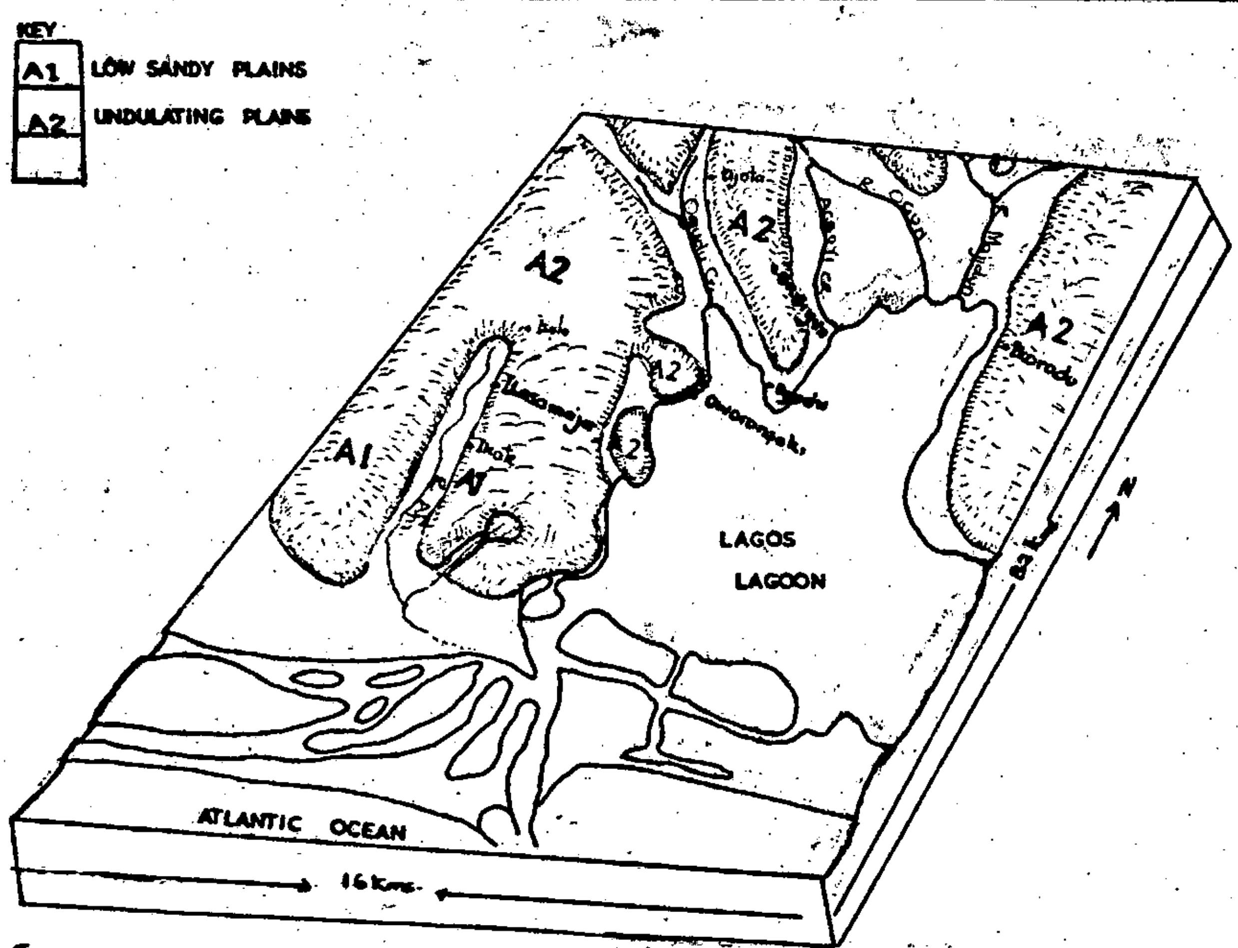


FIG. 6.3.

By A. Adegboye 1972.

UNITS OF LAND CLASSIFICATION

TABLE 6.2.

LAND	R.L.P.	LAND UNIT	LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
Coastal zone of Lagos	Estuarine Formations and Mangrove swamps, "Code =B"	(B1a) Igamu swamp	Between Oto village in the East and Iganmu & Ijora villages in the West.	A basin-like depression between the low sandy-plains in the north and the built up area of Apapa and Ajegunle. Very flat bottomed.	Centripetal drainage. Recieves supply of water R. Afa, and other short streams from the low sandy plains, and the town drains from Surulere. The area is flooded throughout the year.	Over 70% finer than 5ø. Consists of fine sand, silt and Alluvium. Very thick alluvial stratum 70 metres.	Deposition of alluvial deposits and withdrawal of 'fossil lagoon' Reclamation by Vegetation especially Mangroves.	Cypress articulatum and Mangroves.	Highly Compressible Soils. Very low liquid and plastic limit. Cracks after evaporation.	Reclamation with Coarse sands, construction of drainage dykes, and raising the height of the depression, and exposure for some time before construction work can take place.
		(B1b) Afa Swamp	Western extension of Iganmu swamp but the flood plain of R.Afa.	Flatish terrain between Ridges of Prior barrier and sandy cliffs of the low sandy plains	High level of Underground water. Flooded during the rains.	Over 70% alluvium Fine sand/silt and thin layers of peat. Depth of Alluvium over 70 metres.	In filled embayment left after lagoon retreat.	Raffia Palms Ferns, and low bushes	Highly compressible. May be plastic. Liable to shrinkage after exposure.	" "

Table 6.2 (Cont'd)

LAND REGION	R. L. P	LAND UNIT	LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
		B1c. Ogun/Majidun Flood Plain.	Between Onisigun village and Ebute Ikorodu in the N. E. part	Deep embayment being filled by fluvial deposition. Generally flat bounded east and west by near vertical cliffs.	A deltaic formation draming into the Lagos lagoon. Very high level of under - ground water	Over 70% alluvium. Coarse sand/ fine silt/ and clay/ peat Depth of Alluvial deposit is 18 metres.	Fluvial deposition and in filling of a broad embayment. Reclamation by vegetation e.g. Mangrove.	Mangrove vegetation palms and Cypress articulatum	Highly Compressible. Liable to shrinkage after exposure.	" " Very good land for Market gardening.
Coastal Zone of Lagos.	Estuarine formations and Mangrove swamp.	(B2a) Mushin Swamp	Between Ogudu Creek and Mushin Sub-urban area.	Depression between two cliffs of the old shore line. Flat bottomed.	Centre petal flooded through out the year.	Over 70% of sediments finer than 50. Silt/ clay/ thin layers of peat. 4-5 metres deep.	Withdrawal of an arm of the Lagos lagoon. Vegetation Colonization and reclamation.	Phyzophora Mangroves.	Upper stratum is compressible. The lo layer	Removal of silty/clay deposit, re-filling with coarse sands and raising the height so that surface drainage flows out in the Lagos
		(B2b) BARIGA SWAMP	Between Bariga and Mushin Sub-urban areas	"	"	"	"	"	"	"
		(B2c) Maroko Swamp	Between Yaba and Ebutemetta along the lagoon foreshore.	"	"	"	"	"	"	"

Table 6.2 (Cont'd)

LAND REGION	R. L. P	LAND UNIT	LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
		B2d Tarkwa bay Swamp	North of the Light House beach	Depression between the beach ridges. Old lagoon channels cut off by the moles of the Training wall.	Generally flooded throughout the year.	Fine sand/ silt and Clay in the upper layers and below 3 metres very fine sands 30	Abandoned lagoon channels, Reclamation by Mangroves.	Rhyzophora Mangroves.	Upper stratum is compressible. The lower layers are stable, but are water logged.	Construction of Concrete walls round this swamp. Filling of the swamp with coarse sands. Surface water to drain into the Lagoons.
		(B2E) Moba Swamp	East of Moba village along the Epe channel of the lagoon system.	Flatish terrain	Flooded during the flood tide. High level of underground water.	Coarse and and silt.	Lagoon withdrawal due to Mangrove Colonization.	Rhyzophora Mangrove.	Submerged land but stable sands mainly.	"
		(B2F) Okesuna-Ikoyi Swamp.	Marginal swamp North of Lagos and Ikoyi Islands	Flatish terrain extending from the limit of Housing to the water front.	High level underground water: Scattered pools of water.	Coarse sand with fine silt.	Lagoon withdrawal and drainage.	Ferns, Palms and Mangrove trees.	Okesuna swamp is highly comppessible Ikoyi swamp is more stable.	"
		(B2G) Maroko swamp	East of Maroko village and peripheral to the lagoons	Flat terrain	Generally flooded.	Coarse sand and silt.	Lagoon withdrawal and vegetation colonization	Mangrove trees and Imprerata Sp.	Submerged but consists of sand mainly.	"
		(B2H.) Ogoyo Swamp	South of Ogoyo village.	Depression across the beach ridges.	High level of underground water.	Thick beds of alluvial materials.	Fluvial deposition.	Thick and wooded forest.	Soft soils. depth not measured.	"

ESTUARINE FORMATIONS AND SWAMPS RECURRENT LANDSCAPE PATTERN

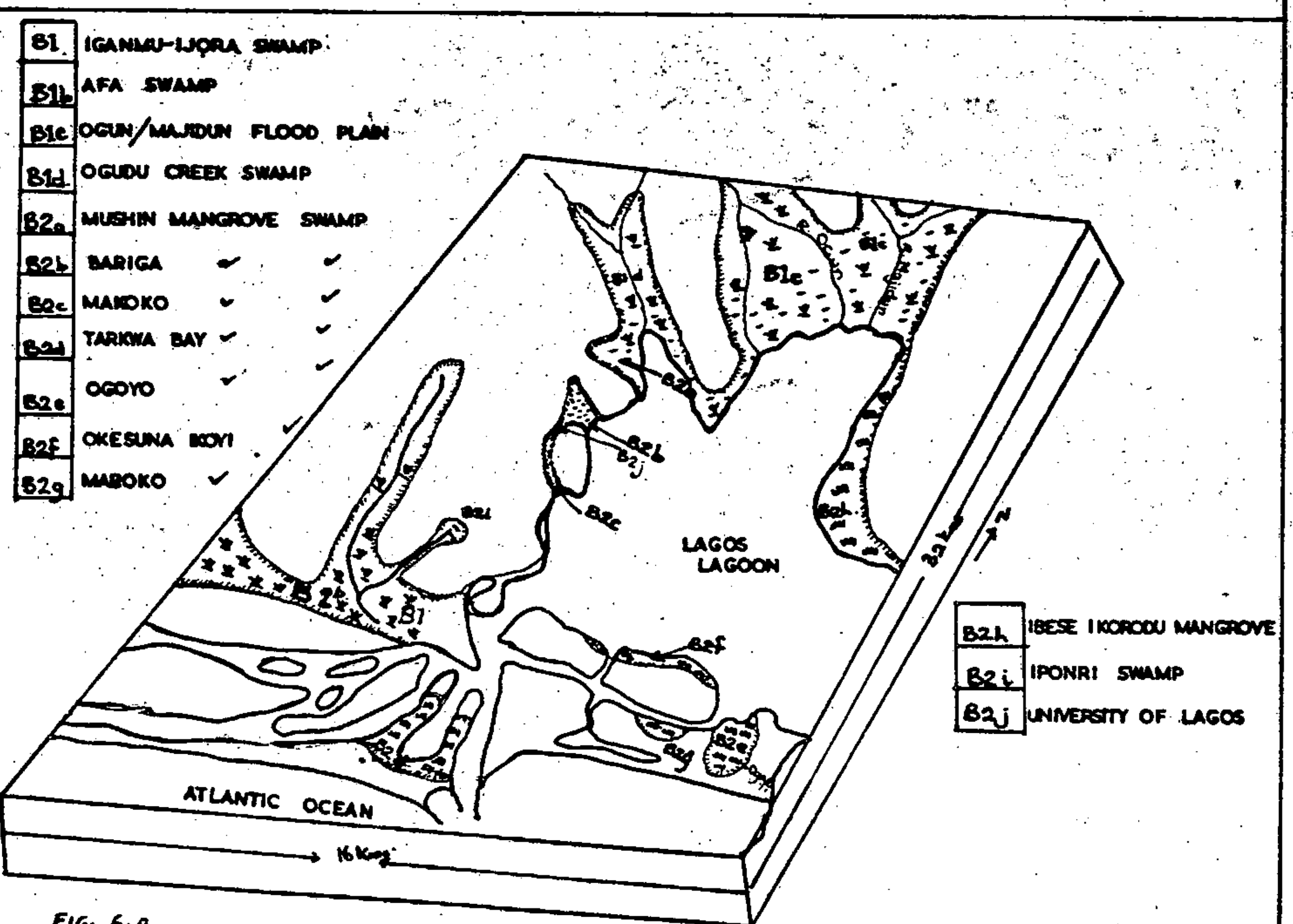


FIG. 6.4

UNITS OF LAND CLASSIFICATION

Table 6.3

LAND REGION	R. L. P.	LAND UNIT	LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
Coastal zone of Lagos.	Lagoon Complex (C)	(C1a – h) Lagoon shoals	Sand banks in the lagoons and creeks	Oval shaped accumulation forms in the lagoon. Generally submerged.	Submerged	Coarse grained sands with admixtures of silt.	Lagoon deposition	–	–	Consists of Coarse sands which may be used for reclamation.
	(C2a–J) Quiet water	Parts of the lagoon complex and clearly shown in Fig.6.2 C2c and C2j are on the Atlantic Ocean.	Quiet lagoon water with relatively broad sandy beaches.	–	–	–	–	–	–	Could be used as recreation centres.

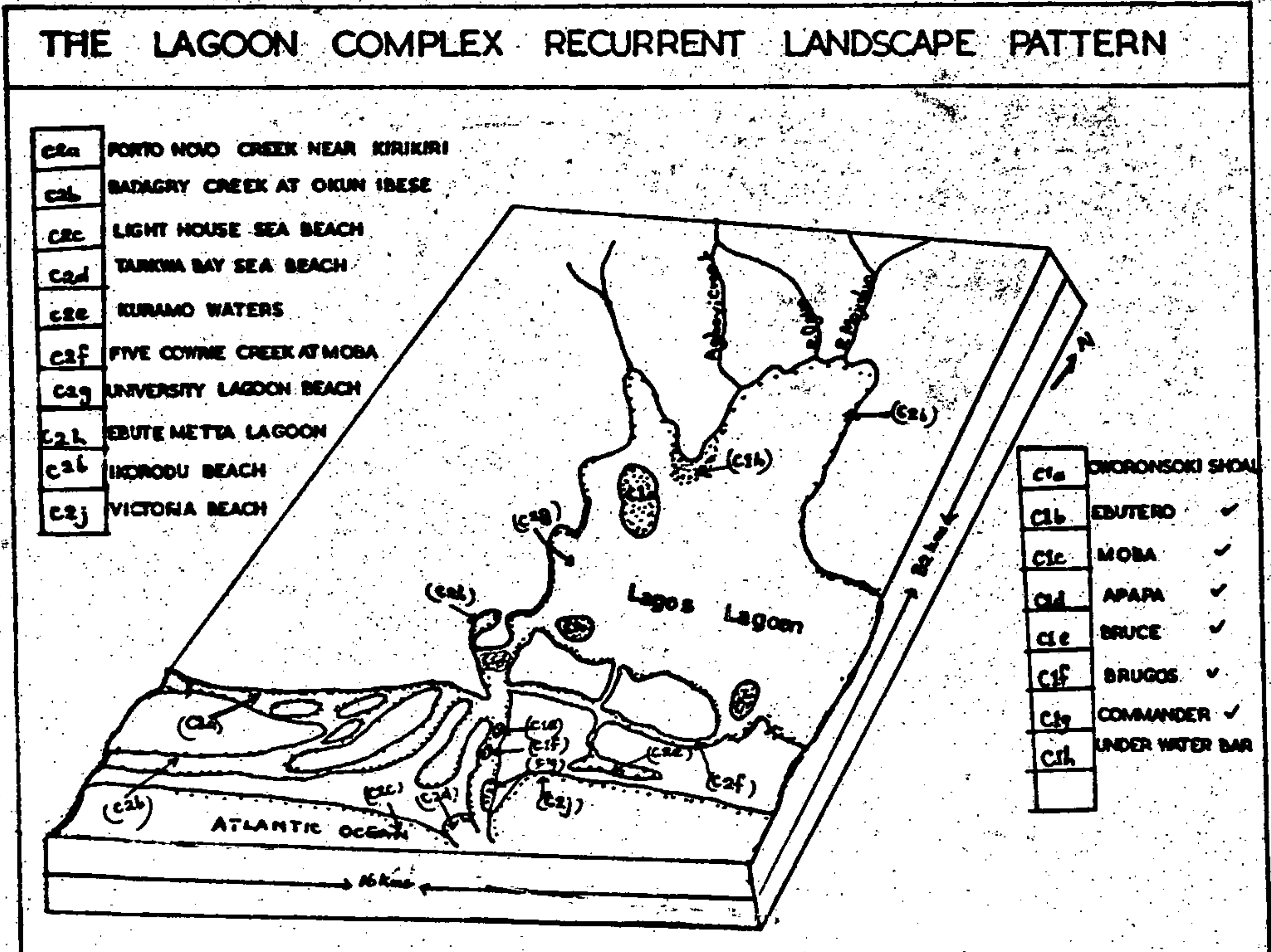

THE LAGOON COMPLEX RECURRENT LANDSCAPE PATTERN
C2a PORTO NOVO CREEK NEAR KIRIKIRI
C2b BADAGRY CREEK AT OKUN IBESE
C2c LIGHT HOUSE SEA BEACH
C2d TARKWA BAY SEA BEACH
C2e KURAMO WATERS
C2f FIVE COWRIE CREEK AT MOBA
C2g UNIVERSITY LAGOON BEACH
C2h EBUTE METTA LAGOON
C2i IKORODU BEACH
C2j VICTORIA BEACH
C1a OWORONSOKI SHOAL
C1b EBUTERO
C1c MOBA
C1d APAPA
C1e BRUCE
C1f BRUGOS
C1g COMMANDER
C1h UNDER WATER BAR
Lagos Lagoon
ATLANTIC OCEAN
16 kms
N

FIG. 6.5

UNITS OF LAND CLASSIFICATION

Table 6.4

LAND REGION	R. L. P.	LAND UNIT	LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
Coastal zone of Lagos.	Sandy barrier formations	'D1a' Prior barrier beach ridges.	North of Ajegunle and South of Afa swamp.	East-west elongated ridges. Slope gradient varies between $4^{o} - 8^{o}$ About 4m. above Sea level.	Flood free through out the year.	Coarse sand of about 3ϕ-3.6ϕ. Matrix of precipitated iron and silica oxides.	Wave/littoral drift deposition. Weathering and soil formation processes.	Thick bush.	Very stable.	Could be developed without reclamation or drainage for settlement Expansion.
		'D1b' Inner barrier ridges.	South of Porto Novo Creek and North of Badagry Creek.	East-west elongated beach ridges Gradient 2^{o} - 4^{o}. About 2m. above sea level.	Generally flood free.	Coarse sand of about 2.5ϕ - 3ϕ.	"	"	"	"
		'D1c' Outer barrier beach ridge	South of Badagry Creek and North of the Atlantic ocean.	East-west elongated ridge with broad wave beaten sandy beach. About 1.5m. above sea level.	Generally flood free.	Coarse sand with Mz of 3ϕ - 3.6ϕ.	Wave deposition.	Imperata Cylindrica and Parspalum.	Stable.	"
		'D1d' Inner barrier beach ridges East of lagoon outlet.	Ilado, Maroko, Lawani, Igbosere and Alagutan villages	East-west elongated sand ridges Height varies between 3 and 4 metres. Gradient falls between 8^{o} and 10^{o}.	Generally flood free. Rapid infiltration of water.	Very Coarse sand with Mz. between 1ϕ and 1.8ϕ	Wave deposition. Weathering and soil formation processes.	Palms, Imperata. Cylindrica.	Stable.	"

Table 6.4 (Cont'd)

LAND REGION	R. L. P.	LAND UNIT	LOCATION	LANDFORM MORPHOLOGY	DRAINAGE	CHARACTER OF SEDIMENTS	PROCESSES OF EVOLUTION	VEGETATION COVER	SOIL STRENGTH	REMARKS
	Sandy barrier formations	(D2A) Beach Plain	Between Ojo and Okokona iko villages	Very flat terrain	High level underground water during the rains	Coarse sediment Mz.2.5∅ -2.8∅. Deep weathering profile.	Wave deposition. Flattering by either wave floods or sheet wash	Imperata Cylindrica Palms.	Stable	Should be drained and elevated before any form of construction takes place.
		((D2B) Beach Plain	Maroko	Very flat terrain.	Floodable during the rains.	Coarse sediments 1.7∅ - 2∅. 35%silty material.	Lagoon withdrawal, Ridge flattering by floodwaters.	Imperata Cylindrica	May be Compressible.	" "
		D3. Isolated barrier Island	Inner barrier west of the outlet.	Isolated Islands Roundish in shape and about 30cm. above sea level.	Floodable. High level of underground water.	Coarse sand. Consists of of silt deposits.	Breaching of the Inner barrier by the Porto Novo and Badagry Creeks.	Mangrove trees and grasses.	Compressible.	Could not be developed in isolation hence it should be developed in the same way as (D2b) above.
		D.3a Breached beach ridges.	East of Maroko.	Isolated sandy mounds in the Beach plain. 30cm. higher than the plain.	Flood free	Coarse sand.	Breached breach ridges.	Palms.	Stable	" "

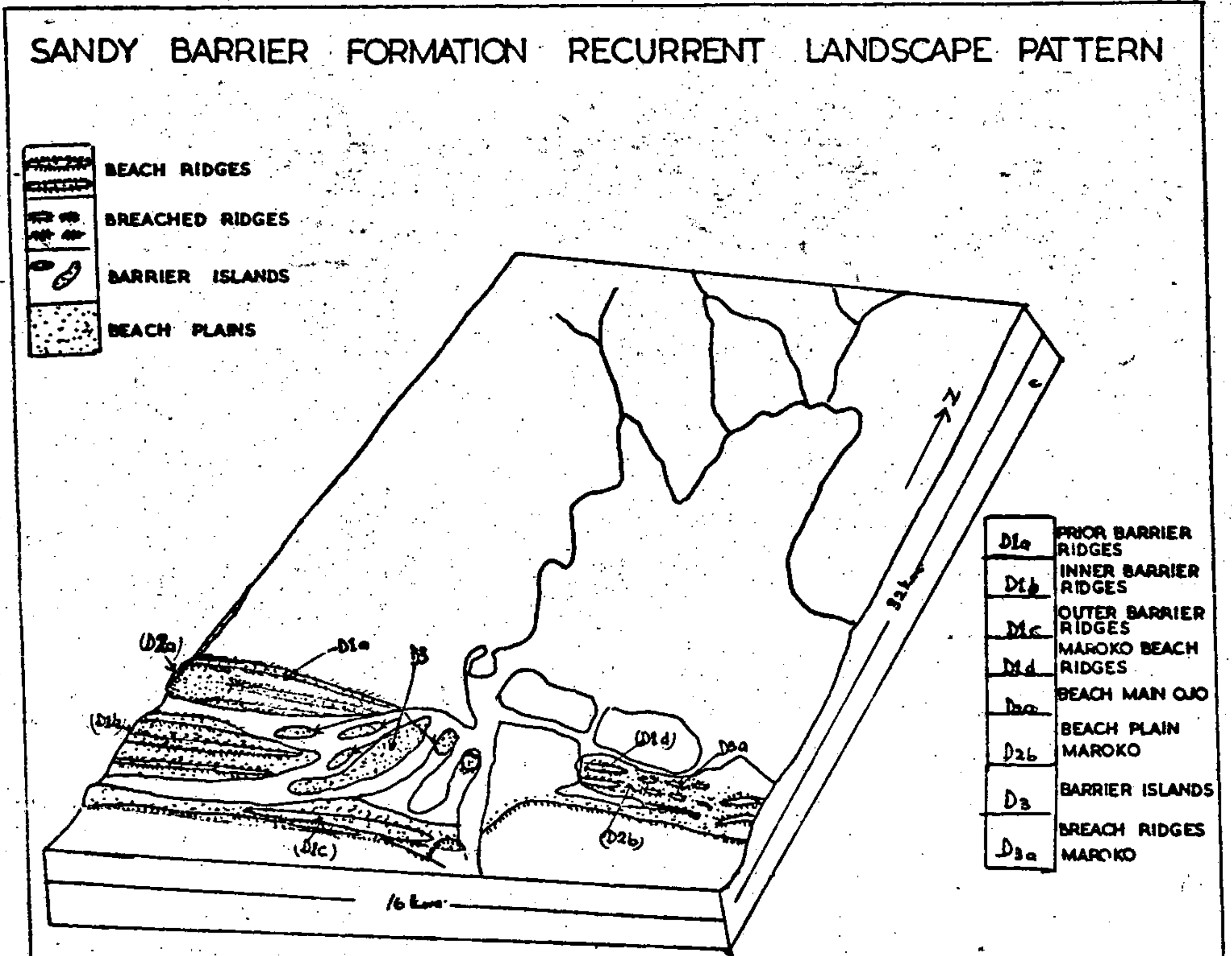


Fig. 6.6.

BY. A. Adegboye.

They are however of secondary importance in lowlying areas as in the Lagos area, where the landform character can best be illustrated from the characteristics of sediment types, past and present processes of morphology and stratigraphical successions. For the purpose of the geomorphological map in this thesis; mapping techniques show both the 'external', and 'internal' and genetic properties of the land on the map.

Demek (1972) identifies three types of geomorphological maps and they include the basic geomorphological map, designed mainly for scientific inquiry, the applied geomorphological maps designed mainly for practical applications and emphasizing certain relief features and, the special geomorphological maps for use in other specialist fields such as geology, geophysics and engineering. There are also similar to those suggested by Vestappen (1968) which include geomorphological maps, morpho-conservation maps and hydro-morphological maps. The two maps in Figs. 6.2 and 6.7 in this thesis compare with types one and two of the mapping systems of Vestappen (1968) and Demek (1972). The land classification map in Fig. 6.2 is essentially performing the functions of morpho-conservation map except that slope classes and lithology are not indicated. Thus enhancing the best use to be made of each land unit. The second map in Fig. 6.7 is essentially elucidating the genesis; age, processes, hydrography, form and distribution of the landforms in the coastal zone west of the Lagos Harbour up to the western boundary of the area of study.

This area is selected for mapping because it comprises all the units of classification shown in Fig. 6.2; and the character of each land unit depicted can be extrapolated on identical units in the area unmapped. The map in Fig. 6.7 is compiled on a scale of 1:20,000 as against that 1/40,000 used in Fig. 6.2 to show greater details. Furthermore, the land character is shown on a larger scale so that the association of attributes is readily recognised for effective classification into units in the classification map. For example the details about the land units in the area west of the Lagos harbour are clearly recognisable at double the scale in the geomorphological map.

The legends used in the geomorphological map include those of Verstappen (1968) and Demek (1972) for attributes of general occurrence while some innovations were introduced in respect of local forms and special attributes shown such as lagoon shoals, and grain size variations. These are shown in the legends attached to tho maps. Colouring was not used because facilities for colour print are not available in Nigeria at the moment, and may be difficult to obtain elsewhere.

This chapter has contained the applied aspects of this work and it has so far classified the land into units for the purposes of scientific inquiries and planning. It has shown the break down in tabular and cartographic forms and it is hoped that planners in Lagos area would use the opportunity afforded by the contents of this chapter in their planning programmes. The next chapter is an examination of the relevance of the contents of this thesis to planning problems in the coastal zone of Lagos.

CHAPTER SEVEN

GEOMORPHOLOGY AND PLANNING: THE CASE OF THE COASTAL ZONE OF LAGOS

7.1 INTRODUCTION

This chapter is a detailed appraisal of the application of geomorphological principles to the understanding of the problems of the environment with regards to land use planning in the coastal zone of Lagos. It begins with a broad examination of the principles of applied geomorphology in relation to planning problems and in understanding the environmental problems throughout the world and assesses the contributions of this study to planning and understanding of the problems of land subsidence, beach erosion and flooding in the Coastal zone of Lagos. Furthermore, it examines broadly, the engineering character of each land unit with a view to guiding the planning programmes for settlement expansion and suggests conservation measures for the problems already created in the settled areas as a result of the mis-management of the land, e.g. land subsidence, flooding and beach erosion.

Geomorphology is an indispensable discipline to aid physical planning especially from the standpoint of regional and urban development in which land evaluation becomes paramount. The significance of geomorphology derives from its concern with the study of landform evolution, spatial organisation, internal properties and general response to environmental changes through time. In essense it is concerned with the study of the physical character of the land on which various land uses are planned and executed. Thus any planning programme without adequate consideration for the character of the land or its geomorphology may likely fail. It is in the recognition of this role of geomorphology that Russel (1949) Bryan (1950) called for a geographical geomorphology, where the knowledge of landform evolution hitherto regarded as part of physical geology would be made available to the geographer to make use of in landuse planning.

The growth of this idea led to the birth of what Vink (1968) called 'Planological physical geography' and Dixey (1962) described as Applied Geomorphology. In fact before this time the International Geographical Union had created a sub-commission on Applied Geomorphology to study the possibilities of applying the data from geomorphological studies, and the principles of geomorphological study to the understanding of the problems of human environment.

Since this development, geomorphological principles have been used in planning programmes at least in land resource surveys for agriculture, mining industrial, and settlement purposes etc.

The work of CSIRO in Australia, MEXE in Britain, the Directorate of Overseas Surveys in Britain and scholars such as Klimazewski (1963) Bakker (1963) Tricart (1962) and Olofin (1972), have clearly illustrated the contributions that the application of Geomorphological investigations could make to land use planning. The data collected from these surveys are used in land use planning in various areas. The surveys carried out by the CSIRO are primarily used for data collection about each land unit from where sepcialized branches of the organization carry out detailed analysis of possible land uses that can successfully be introduced to such a terrain (Christian 1964).

From the above it is shown that although the significance of the application of geomorphological principles is recognised, it has not been applied practically to specific planning projects except in Russia where the Faculty of Geography in Moscow University participated in the surveys for the Architectural aspect of the General plan for Moscow (Bakhtina and Smirnova 1968). Much of the investigations and surveys carried out for land uses are generally done by specialized disciplines, such as Engineering for Housing, road building and airfield construction surveys (Aitchison and Grant 1968) and soil science for soil survey and soil productivity; (Ignatyev 1968). All these specialized disciplines make use of limited relevant attributes of land and neglect others, and hence the failure of most of their projects, because only few aspects of the land are taken into consideration, (Currier 1952). Most of the problems of the environment such as flood hazards, land subsidence, erosion are regarded as engineering problems and the solutions applied to them are not generally a lasting one. It is therefore necessary to explore the possibility of adopting applied geomorphological techniques in environmental management. It is pertinent to conclude that applied geomorphology has not yet gained sufficient recognition and with more publications about its effectiveness, its principles would gradually be adopted for specific planning projects and solution of environmental problems.

7.2 THE SIGNIFICANCE OF THIS STUDY TO PHYSICAL PLANNING PROBLEMS IN LAGOS

In the examination of the character of the three geomorphological problems selected for this study in the Lagos area, it was demonstrated that all of them result from lack of foresight in planning, and land mismanagement. It was also shown that in the newly developed parts of Lagos Metropolitan area such as Surulere and Iganmu, surface drainage and flood constitute problems, and this underlines the fact that the planners are yet to recognize the significance of geomorphological principles in land use planning in the coastal zone.

This study therefore would be introducing a new aspect into physical planning programmes in the Lagos area.

This study elucidates the fundamental geomorphological character of the coastal zone and demonstrates the relationship between the landforms and the contemporary geomorphological processes. For an example, along the sea beaches; it identifies the dynamics of erosion, accretion and the problem of floods as vital factors of change in the form of the land. The elucidation of the various factors at work in the evolution of the coastal landforms demonstrates to whoever is concerned with the planning of the area that the area is highly sensitive to changes, and hence cognizance should be taken of the factors at work and consideration given to the physical characteristics of the environment in general before any successful land use planning programme can be executed.

In chapter three for example, it was demonstrated that most of the problems of the coastal zone especially those of beach drifting, flood hazards land subsidence derive from inter-ference with the natural processes at work. For example, the undernourishment of the Victoria beach was described as sequal to the temporary arrest of the littoral drift behind the West mole; and the subsidence and collapse of buildings was due to the compaction and mass shrinkage of refill materials in reclaimed areas. The failure of the conservation measures applied to those problems, especially beach drifting was ascribed to the non-recognition of the basic geomorphological factors incolved during the application of engineering solutions per se.

Furthermore, some areas shown in the land classification map in Fig. 6.2, especially in the lagoon complexes can become resort centres or recreation centres. Such areas include the Kuramo waters, Five Cowrie Creek, Lagos Lagoon near the University of Lagos, the Porto Novo Creek at Kirikiri and at Ojo villages and the Light House beach. At present only the Victoria beach, the Ikoyi park and Tarkwa Bay are used as recreation centres. These areas are shown on the map and can be developed as resorts with settlements built around them. For example settlements built east of the Victoria beach could make use of both the Kuramo water and the Five Cowrie Creek and those west of Ajegunle could use Kirikiri and Ojo beaches while the waters around the University of Lagos could be developed for the inhabitants of Ebute Metta, Yaba and Surulere.

Construction work in Lagos is of very great magnitude and intensity that sands used in mixing cement for construction work are quarried from the beach ridges and even from the outer barrier beach. This contributes immensely to the loss of land on the beaches and may induce beach erosion. The sands from the lagoons are quarried indiscriminately that most lagoon beaches are now being eroded, for example, the fore shore of Gedegede and Maroko. The land classification map indicates areas within the lagoon with large deposits of sand, referred to as shoals and some of them can serve as sources of materials for construction purposes.

This thesis also affords land planners the opportunity to arrange land uses according to their need for land and other location factors, so that industrial zones would not be juxtaposed with residential quarters as in Apapa and Yaba. Also, if the land units suggested for housing are used for the purpose, the high land prices for land in Lagos may likely fall because the cost of reclamation might not be included. Where the land has been reclaimed, particular land uses which could pay for the cost of the land may be sited there. Apart from all these, the availability of more land would reduce congestion in the city of Lagos and also in the metropolitan areas. The review of the problems of flooding, land subsidence and beach drifting in Lagos in chapter three does not only elucidate the significance of the recognition of the geomorphological forces in the solution of the problem, but also demonstrates the significance of an integrated or a multidisciplinary approach to terrain problems. It demonstrates that although the Engineer possesses the technology to construct on the land, the Architect to draw up designs for the land, their projects may be unsuccessul without taking cognizance of the fundamental aspects of the land character. While this thesis is not saying that the Geomorphologist has got all answers to landscape problems, it is emphasising an integrated approach to the study of the use of the terrain especially in the coastal zone of Lagos. In the foregoing pages, the capabilities of the land units in the way the Engineer would understand them are explained and a list of conservation measures is given in the last pages for the geomorphological problems in the Coastal zone in general.

In Table 7.1 below a general pattern of the character of the land which may be of interest to the Engineers is shown; and for detailed appraisal of the characteristics, Table 6.1 would be of immense use. However, Table 7.1 shows two distinct areas: one which needs reclamation and effective drainage and the other which does not need these before the development of the resources for land use. Thus for the Civil Engineer, the data available above may likely guide the determination of the depth of foundations, the structure and height of buildings in the areas with more stable soils. But in the less stable areas such as the estuarine formations and swamps, the data in Table 7.1, give an insight into their character and therefore would form a basis for the type of reclamation, the type of materials to be used, the direction of drainage channels and the depth of foundations needed in the reclaimed area before any construction work can take place on them.

Apart from these, there are sources of materials for construction purposes, road surfacing and refilling of depressions such as sands and 'laterite' (ferruginised sands). Sand is used in building and other construction work in Lagos as a mixture of cement to develop concrete, as well as in road surfacing and in the reclamation of swamps. These sands are quarried from the beds of the lagoons and, the beach ridges of the Inner and Outer barriers at Maroko and Alagutan villages. Most of the sands from the lagoons are quarried near the shore, for example at Maroko; thus deepening the near-shore areas of the lagoon beaches, and includes rapid erosion when the lagoon waves develop in this areas. Also, the quarrying of sand from the sandy barriers would provoke a loss of land which could have been used for settlement expansion and that of the outer barrier may develop into a breach of the Victoria beach by the sea and cause disastrous floods. In order to avoid these problems, it is possible to explore the use of the sands from the Lagoon shoals which are found in particular locations in the lagoons, and which constitute dangers to navigation especially the Bruce, Bruges and Commander shoals. By quarrying sands from shoals, the dangers of siltation would be reduced in the lagoons and the land on the barrier formations would be conserved. Thus the shoals could be a source of material for construction work.

The ridges on the highplains especially at Ojota, Ogudu Orisigun, Mushin and Isolo are potential sources of ferruginised sands which are used for reclamation and road surfacing in Lagos. Although these sands are reweathered and therefore shrink, they are preferable to using silt or clay soils in reclaiming swamps. In fact, if reconnaissance surveys of swamps are carried out before filling them with sands, the occurrence of shrinkage may likely be reduced.

From the analysis of the three geomorphological problems in chapter three, some guidelines for the engineering aspects of the solution of the problems have been given. The first is on land subsidence which derives from the weathering, shrinkage of refill materials in areas formerly reclaimed under static loading of houses. Second, the coastal zone of Lagos consists of sedimentary deposits which are characterised by alternating beds of sand and silt/clay deposits, and as such this property should be borne in mind when sinking foundations.

The problem of flood has been found not only to be climatic but also a function of the loose nature of the sediments, proximity to the ocean and the occurrence of numerous lagoons, creeks and rivers, and the low relief which combine to influence both the surface and underground drainage. For this reason flooding is not seasonal, it is only aggravated by the rains.

Beach erosion is identified as a phenomenon which is world wide, but the peculiar character of that of the Victoria beach at the lee of the stone moles which reduced the littoral drift from the west and induced the development of a variety of currents at the Lagoon outlet and along the stone moles, as well as the development of another west to east sand drift on the beach makes it of both geomorphological and Engineering interest. Also the coarser nature of refill sands used in replenishing the beach tends to make it more vulnerable to erosion.

The Town and land-use planners and Architects too can benefit from the work in this thesis, because the land has been divided up for them on the basis of the dominant attributes for settlement expansion. From the scale of the land classification it is possible for them to estimate the alignment of streets, the spacing of buildings and the type of structures to be erected on them. This enables them to plan ahead for the growing population as well as the need of land for other landuses such as industrial estates etc. The examination of the problems of land subsidence, flooding and beach drifting exposes the planner to the unknown aspects of the problems especially the geomorphological aspects and elucidates the relationship between geomorphological forces and land character in the coastal zone. Thus apart from constituting guidelines for future land use planning programmes, the anslysis of the problems suggests the techniques of reducing their recurrence.

This may guide the total replanning programme envisaged for Central Lagos in the nearest future. This thesis in general elucidates the relationship between geomorphology and urban physical planning in the Coastal zone of Lagos and examined certain areas of common interest between geomorphologists and the Civil Engineers, the Town Planners, land use planners and the architects in executing land development programmes in general and in the Coastal zone of Lagos. From the point of view of geomorphological principles, some of the problems examined in chapter three can be reduced if some conservation measures are taken, hence the next paragraph lists a number of conservation measures which can help in reducing the problems.

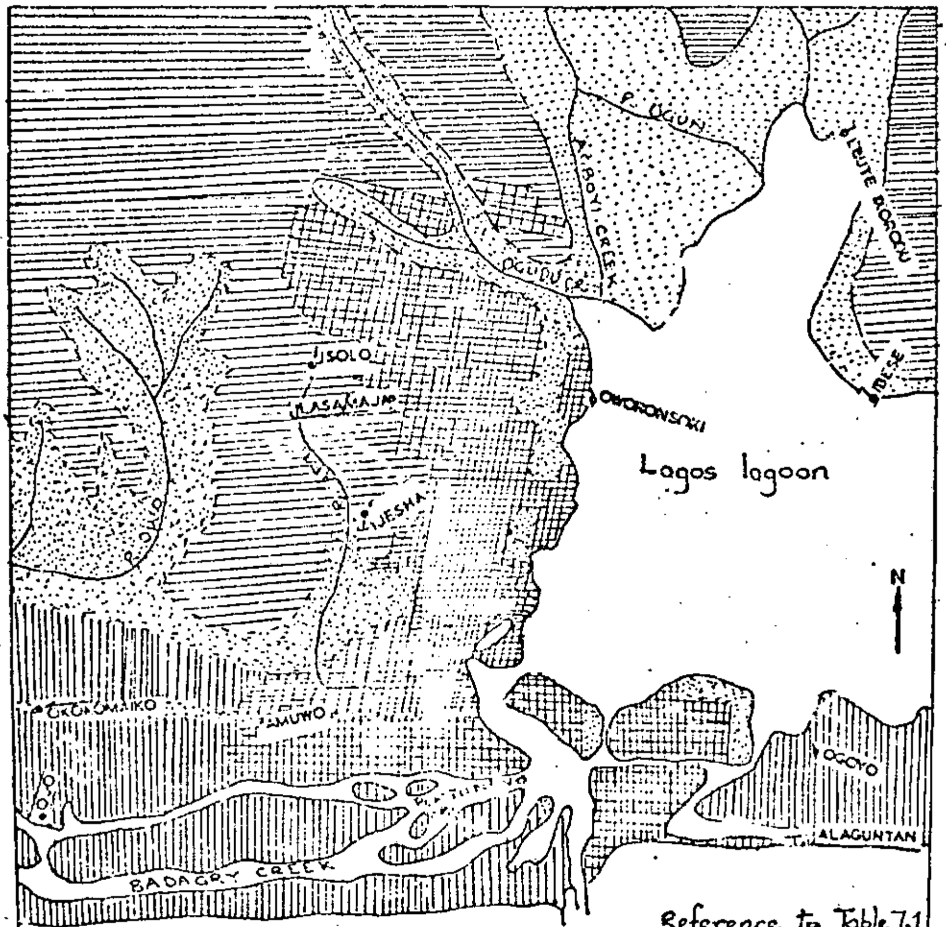
7.3 THE ENGINEERING ASPECTS OF LAND CLASSIFICATION

The Engineer is mainly interested in the location of a particular land unit on the landscape and its characteristics such as the grain size range, the degree of compressibility, the relief and the drainage characteristics and the suitability of the soils for use as materials for construction (Dowling 1968). These characteristics featured prominently in the factors used in the classification of the terrain for transport routes (Brink and Williams 1964) and for Military Engineering (Becket and Webster 1962).

For the purposes of settlement expansion, the Engineer may be interested mainly in the location and configuration of land units, the character of each unit such as the grain size range of sediments, the percentage finer than $+5\phi$, the drainage characteristics, and the 'strength' of the soil. The latter factor can be determined by a complex mathematical calculation which this thesis has not attempted to do but this characteristic could be infered from the fabric of sediments and their over all bedding patterns. As for the location and configuration of land units in the Coastal zone, the map in Fig. 6.7 illustrates these characteristics; while the characteristics of each recurrent landscape pattern which is of interest to the Civil Engineer are listed below in Table 7.1.

Fig 7.1

TERRAIN UNITS OF SIMILAR ENGINEERING PROPERTIES.



KEY.

Waterlogged and compressible locations. (Holocene deposits)

Flood-free and stable locations. (Holocene deposits)

Flood-free and stable locations. (Plio-Pleistocene deposits)

Built-up areas.

Unit boundaries.

5 0 5 10kms.
Scale

Produced by A. Adegboye (1972)

TABLE 7.1

BASIC ENGINEERING PROPERTIES OF THE RECURRENT LANDSCAPE PATTERNS

	Recurrent Land-scape Pattern	Grain Size Range of sands	% Finner than 5Ø	Drainage	Soil Strength
1	High Plains	-2Ø - .5Ø	10%	Well drained	Compact and resistant
2	Sandy barrier	.8Ø - 3.6Ø	20%	High rate of Permea-bility. Level of Undergrourd water is high.	Loose but resistant
3	Estuarine formation	1.3Ø - 2.2Ø	70%	Swampy and flooded	Compressible Cracks when dry
4	Lagoons and Marginal Swamp	0Ø - 5Ø	30%	Submerged by water	Loose sands and Resis-tant. Compressible

7.4 SUGGESTED CONSERVATION MEASURES FOR THE GEOMORPHOLOGICAL PROBLEMS:

1. LAND SUBSIDENCE

The principal causes of land subsidence in this area so far identified are (i) drying out and shrinkage of superficial deposits especially in reclaimed swamps and (ii) 'static loading' of reclaimed areas with heavy building structures. There may be other causes such as the general down warping of the basement rock in the

South-Western Nigeria land region hence it is necessary that an integrated approach to the problems of land reclamation in the coastal zone is adopted. Specialists from the fields of geophysics, hydrology, geomorphology and engineering can conduct a joint study of the problem. As a geomorphological panacea to this problem in the coastal zone, the following conservation measures are suggested.

(i) The moisture and clay contents of refill materials should be reduced because most of the swamps are already flooded with water and composed of materials with over 70% of silt and clay content. Thus an addition of the two materials during reclamation may increase the size of compressible materials in the reclaimed area and hence its probability to subside.

(ii) Reclaimed land should be left to solidify for at least five years before its development for various land uses; while foundations should be deeper in reclaimed areas than elsewhere. Since the cost of reclamation and deep foundation would be very high for an individual, it is necessary that only land uses that could pay for effective operation of these processes should be allocated to such areas. For example a land user such as an industry could be allocated to such areas as it is practised at Iganmu area at present. The land classification map would aid this type of land use zoning.

(iii) The materials used in reclamation should consist of either coarse sands from the lagoon floor especially the lagoon shoals or the ferruginised sands from the high plains in the north because of their relative resistance to shrinkage. The use of refuse and human waste should be discontinued since most of these decompose and shrink.

(iv) Plans for private and residential buildings should not be approved for sites on swamp lands which have not been certified ready for construction.

(v) The recurrent landscape patterns comprising the sandy barrier formations and the high plains are readily available for development without any form of reclamation. Apart from all these, it is possible for the refill materials in reclaimed areas to shrink as a result of the natural processes of diagenesis, hence it is necessary that 'sand banks' for the refill of any depressed area be built all over the reclaimed areas.

FLOOD HAZARDS

Although the problems of flooding and drainage in the Lagos area have been ascribed in chapter three to the geomorphological factors such as poor surface and subsurface drainage, relief, climate and the lagoon environment, the examination of the characteristics of the problems suggest that most of the flood ridden areas described in that chapter have emerged as a result of human mismanagement.

Therefore the conservation measures suggested below would concentrate on efforts that would assist a better and effective management of the land. The land classification map in Fig. 6.2 has grouped the lands into a hierachy and has shown their potentialities. Thus areas of high flood potentiality such as the Estuarine formations and the Mangrove swamps have been shown on the map and their extent is readily recognisable. Thus in developing this group of landforms they should be reclaimed in a way that they are raised above the level of water and made to dip towards the lagoons, so that the incidence of lagoon water flowing into drains and arresting the flow of water as it occurs in Moloney Street Lagos and Ijora may be reduced.

In the planning of streets and roads, the alignments should be made in a way that they are not against the slope of the land. Where the gradient of the land is very low, drains should be terraced at intervals to enhance the rapid flow of water. Drainage channels should not be orientated towards a blind-end as in Animasaun Street in Surulere or in Iganmu area. They should be led into the lagoons and properly cleared of refuse and sediment deposits to enhance rapid flow.

BEACH EROSION

The problem of erosion on the beaches has been described in chapter three as resulting from a combination of the impact of human interference on the beach and the natural processes occuring at the lee of longshore drift across a lagoon outlet while the effect of world wide erosion of beaches ascribed to sea level rise (Brunn 1962) cannot be ruled out. The erection of the three stone moles at the entrance of the Lagos harbour has been found to reduce the transport of sediments from west to east across the lagoon outlet. Thus the undernourishment of the Victoria beach calls for sand replenishment which has been introduced but has not reduced the incidence of erosion. Further investigation shows that another littoral drift develops from the Victoria beach and nourishes beaches eastwards as a continuation of the natural processes of sand drift characteristic of the Atlantic coast of the Gulf of Guinea. Thus, the sands used for replenishment might be indirectly transported as the 'new' littoral drift for beach nourishment east of Victoria beach. Apart from this, the lagoon sands used in beach nourishment consist of about 32% of silt and fine materials which drift to the offshore areas instead of remaining on the beach, while the lagoon sands and the Victoria beach sands are coarser than the usual drift sands from the Light House beach (see Table 5.1). The differences in grain sizes between the natural littoral drift sands (2.5ø - 3.6ø) and the Victoria beach sands (1ø - 1.8ø) is a factor in the rapid erosion of the beach materials.

The wave processes also account for the erosion in as much as the offshore areas are very deep and the heavy swales are not refracted, the beach materials become vulnerable under the force of these waves. These characteristics call for the following conservation measures.

(i) Replenishment of the Victoria beach with sands from the Light House beach. This would enhance homogeneity of size and hence more compact packing and resistance to erosion, while the problem of the sands accumulating on the Light House beach by passing the west mole and silting the Lagos Harbour, may be reduced.

(ii) To retain the sands on the Victoria beach, efforts should be made to construct a break water in the offshore areas of the beach. This would refract waves of high amplitude and hence reduce the rate of removal of sands, and behind the breakwater a sand bar would develop that would form the source of supply of sediments for litteral drift. It is envisaged that a quiet water would exist between the break water and the beach which could form a recreation centre. By these processes, a balance would be maintained between all forces - the threat of erosion to the Victoria beach, the siltation of the Lagos Harbour channel and the establishment of a recreation zone on the beach and the continuation of beach nourishment east of the Victoria beach would be satisfied. The ground plan of such a break-water is shown below in Fig. 7.1.

This chapter has so far tried to illustrate the relationship between physical planning and geomorphology and from the case study of the Coastal zone of Lagos, described above it is

THE POSITION OF THE SUGGESTED SUBMERGED BREAKWATER

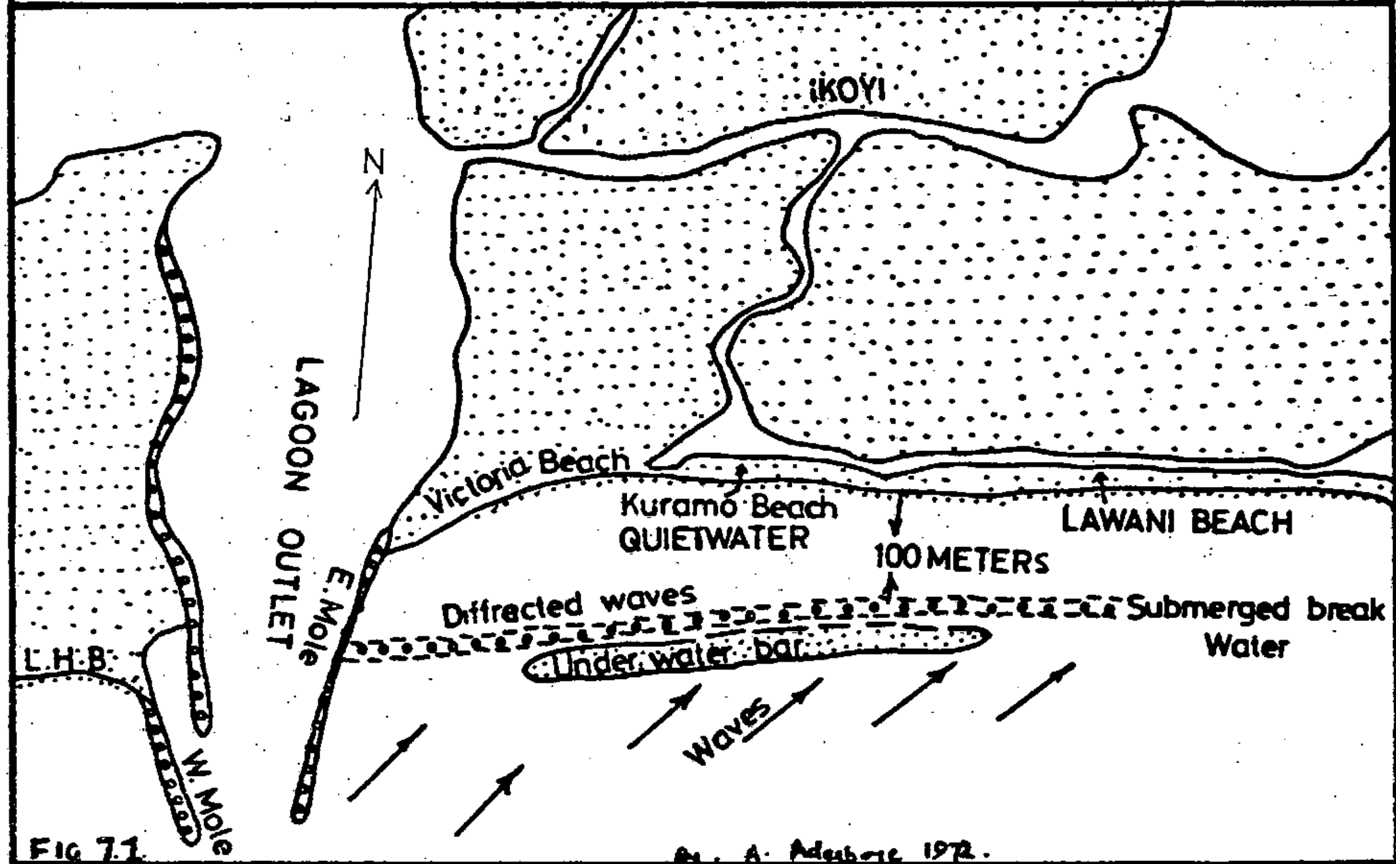


FIG 7.1

By. A. Adegbore 1972.

obvious that geomorphology is an indispensable aspect of planning for environmental management. Although this thesis has not considered all the geomorphological problems existing in the area, the ones chosen have illustrated how the techniques of geomorphology can be employed to aid planning programmes. It is envisaged that in the nearest future, the relationship between Planning and Geomorphology would be recognized and made use of, for the benefit of the inhabitants of the area.

The thesis has been written in two parts, and its derivations are summed up in two parts as well. This is to illustrate the dual advantage of an applied study, where theoretical and applied discoveries are made.

CHAPTER EIGHT

CONCLUSION

The coastal zone of Lagos had witnessed four phases of sea transgressions and regressions since the Quaternary, during which the sea had retreated gradually in a shouthward direction all over the coastal environment. The changes in the sea-level were probably not unconnected with the world-wide fall in sea level, attributed to glacio-eustatism in Europe and America. The sea-level fluctuations were marked by the evolution of specific land-forms, e.g. the marginal surface of Ikeja Plains, sandy-barrier formations, and lagoon depressions. The marginal surface of Ikeja Plains in the north were largely moulded from fluvial deposits during periods of regression, and the sandy-barrier formations built from marine deposits during periods of regression as well, while the lagoons and creeks were subsequent to the evolution of the sandy-barrier formations.

Altogether four phases of sea-level fluctuations have been identified in the area as attested to by the existence of three roughly parallel sandy-barrier formations which marked periods of sea regressions, and the lagoon depressions that separated the barrier formations most probably, represented portions of sea-water impounded during the regressions. This is further illustrated by the succession of Sand, 'mud', or clayey strata in the profiles cut through the Quaternary deposits, (Mobil Oil 1960), where sandy deposits represented periods of regression; and the 'mud' or clay, periods of sea transgressions. The sandy-barrier formation hypothesis suggests that the Marginal surface of Ikeja Plains; and the three successive barrier formations were built during periods of low-sea-level, while similarly the Iganmu – Afa depression, the Lagos lagoon, Badagry, Porto Novo, Five Cowrie and Kuramo creeks were remnants of impounded sea water after transgressions. If this trend continues, under normal conditions, it is expected that another sandy-barrier would be built in the present off-shore areas, or if the reverse is the case, the present outer barrier may be obliterated by sea-erosion.

The present is a period of relative transgression on this coast as shown by the increased rates of erosion, and in the other parts of the world as recorded in the works of Bloom and Stuiver (1963), Schell and Stuiver (1965), Shepard and Curray, (1966), and Jelgersma (1966); as well as the general reports of increased shore erosion throughout the world. The present rate of the eustatic rise of sea-level has been put at one metre per one thousand years (Scholl and Stuiver 1965) (Jelgersma 1966). This height was calculated from dated shells and sediments from old beach ridges, and from tidal records. Unfortunately there is no facility for dating in this country and the tidal gauge is kept in the Lagos lagoon away from the open sea, so that measurements of actual sea-level oscillations are not available. It is most likely that the present transgressive phase has reached its maximum; as submerged 'bars' are found in the offshore areas of the Light House beach, and it is most likely that similar features might be found somewhere east of the Victoria beach, where beach erosion is minimal.

The relative ages of the sandy-barrier formations could be tentatively outlined by recognising the succession of sandy-barrier formations in a north-south direction. It follows that the older barriers are found in the northern part of the area, becoming more recent towards the south, since their evolution followed the retreat of the sea. Consequently the oldest landforms are those of the High Plains of the north, followed by the Prior, Inner and Outer barriers in that order.

The study revealed that the climate in this area fluctuated variously between the Quaternary and the present, and this has probably taken the form of alternating wet and dry phases, not too different from those of the present. This was deduced from the occurrence of beds of laterites in the Coastal Plain sands to the north, and concretions, like silicretes, sandcretes, stained red grains, and very deep weathering profiles in some of the Holocene deposits. It is believe that the precipitation of minerals into oxides takes place under humid conditions, while the induration and ferrugunization takes place under relatively dry conditions. It follows therefore, that the beds of concretions and "cuirrasse" were precipitated under humid conditions and agregated under dry conditions. Also, the sea level change hypothesis supports the idea of climatic fluctuation, since lower sea level or regression and high sea level or transgression have been respectively correllated with both interpluvials and pluvials in Africa, (Davies 1964) and glacial and interglacial in Europe (Tricart 1961). Consequently, the periods of regression and transgression already documented along this coast, would most probably correspond with periods of fluctuations of dry and wet climates in the area.

However, the establishment of a more reliable and exact sequence of climatic fluctuations has eluded this study because the sediment types, especially those of laterites are not available in their stratigraphical sequence so as to illustrate their succession, and neither was any geochemical method used to identify the fauna and flora within the deposits, to know whether they were living under arid or humid conditions. However, it is estimated that the present seemed to be a wet phase, with high temperatures and a large amount of rainfall. It is most likely that the wet phase has reached its climax, as there are longer periods of drought in a year for the past seventy years in the coastal zone and increase in the percentage of concretions within the recent sediments, so that the probability that a dry phase is near, may be relatively high.

The evolutionary history of the landforms in the coastal zone cannot as shown above be divorced from the consequences of the sea-level fluctuations characteristic of the period since the Quaternary. Thus the major process of evolution was sediment accumulation from terrestial sources during the regressions and marine sources during transgression. The evolution of the Ogun-Majidun Flood Plain, as well as that of Afa stream, was sequel to the invasion of their lower courses by a transgressive sea, which widened them into broad embayments, and which were later sedimented from fluvial deposits during subsequent regressions.

From the study of the orientation of sandy-barrier formations and associated beach ridges, it was revealed that as Runcorn (1969) asserted, the direction of the south-west wind has been constant along the coast since at least the Quaternary. It follows that, since the sandy-barrier formations have been orientated in a west to north-east direction, the south-west wind, which influences the direction of the waves and littoral drift that moulded the landforms has been constant in the south-western direction since at least the evolution of the 'Prior' barrier.

It is most likely that if the direction of the wind remains constant, future sandy-barrier formations are likely to be orientated in a west to north-east direction as well.

Although the direction of the wind has been constant, the energy of the waves and consequently the rate of supply of sediments have been fluctuating. This is exemplified by the variation in the height and breadth of beach ridges and barriers.

The study of superficial deposits forms another major aspect of this thesis. The overall analysis of grain size distribution of sediments revealed that over seventy per cent of the sediments are quarts, twenty per cent organic materials and alluvium and precipitated iron and alumina, eight per cent calcareous materials and two per cent accessory minerals. The preponderance of quartz, suggests that most of the unstable minerals like mica, and feldspar have been weathered, leaving the relatively stable ones. Further examination about the petrology of the sediments suggest that most of them originated from the sedimentary rocks and the basement complex which outcrop in the immediate hinterland of the area of study and other parts of the Guinea coast. Such rocks include the Amphibolites of Dahomey, the Pegmmatities and Migmatites of Abeokuta, and the Tertiary sediments of south-western Nigeria and Dahomey. Although most of the beach sediments were derived from the sea bed, their identical minersology with those of the hinterland, suggests that they were land derived sediments formerly deposited into the sea when the level was lower, probably a regressive phase, and perhaps during the late Tertiary period. This is attested to by the fact that the canyons of some of the coastal rivers have been found deep in the continental shelf (Allen 1965) while most of the rivers had entrenched-valleys through which they flowed when the sea level was lower. As the sea level rose, waves started to drift the sediments shorewards and build them up into sandy barriers.

On the basis of the hypothesis above, the origin of sediments in the coastal zone has been found to be terrestrial from the immediate hinterland, and the media of transport were the coastal rivers, while the waves and longshore drifts were subsequent distributing agents. It was also established that most of the sediments from the land at present are deposited into the lower reaches of the rivers and in the lagoons, and these are responsible for the rapid shoaling up of the lagoons and the lack of supply of fresh sands into the sea; as the fringing lagoons prevent a direct contact between the rivers and the sea.

Experiments in the field show that a west-east littoral drift is initiated at the Victoria beach to compensate for the original one from the west which has been tentatively halted by the west mole, and to nourish the beaches east of the Victoria beach.

The existence of this process helps partially to explain the instability of the Victoria beach sands because, the materials which would have formed part of the beach are transported away, thus increasing its under-nourishment which is due largely to the stoppage of the west-east littoral drift on the Light House beach. It follows that unless a constant supply of sands, probably double the amount being eroded, is supplied to the Victoria beach, the erosion would remain permanent as the natural processes would continue.

The sediments in the coastal zone are found to be coarse in texture as over eighty per cent is coarser than +4ϕ which is the lower limit of the coarse sand of the ASTM (1969). The coarse texture of the sediments illustrates the 'recent' time of deposition and the stability of the minerals making up the sediments in that intensive communition has not taken place in them, despite the intensity of chemical weathering characteristic of the area.

Sediments in areas west of the Lagoon outlet which have been transported by littoral drift, and the strongest waves from the western part of the Guinea coastlands are finer (mean diameter 2.5ϕ) than those east of Victoria beach, with a mean diameter of 1.5ϕ which were not transported over long distances by the littoral drift and as such the wave impact on them is less.

The study further revealed that subsurface drainage is a function of the grain size, sorting texture and structure of sediments. On the beach ridges, where sediments are coarse and loose and are well sorted, capillary action of water is enhanced while flooding and surface flow rarely occur, but in the depressions and mud flats where sediments are fine, cohesive and poorly sorted, the grain voids are sealed up by either cements and/or fine materials, so that flood occurs on them even in the dry season when the level of underground water should be low. The generally loose nature of the sediments promotes subsurface seapage of water from the sea to the land and vice-versa during the tidal cycle so that the level of stagnant pools rises and fall with the tides.

The other aspect of the study concems the application of geomorphological techniques to the study of land resource development in the Lagos coastal zone. It was revealed that there is a close relationship between the problems of beach erosion, flood hazards and land-subsidence and the geomorphological character of the coastal zone in general. It was demonstrated in chapter three for example, that the high incidence of flooding in the coastal zone derives from a combination of the high level of underground water, the surface flow of water by the way of the tides and the underground seepage of sea water on one part and the heavy rainfall associated with the humid tropical climate of the area on the other.

Furthermore the occurrence of intensive land loss to the sea on the Victoria beach and the contrasting gain of land on the Light House beach result from the interruption of the west-east littoral drift behind the West mole on the Light House beach, and the subsequent under nourishment of the Victoria beach as well as the development of an east west littoral drift on this beach. It follows therefore, that in understanding the character of the land in general and in particular in this coastal zone, a detailed knowledge of the geomorphology must be obtained.

It was discovered in chapter three that most of the geomorphological problems became aggravated by human mismanagement due to man's poor knowledge of the geomorphology of the area. A case in question is that of land subsidence which results mainly from the shrinkage of refill materials after reclamation.

It was found that techniques of land reclamation in Lagos apart from being sub-standard, do not take cognizance of the distribution of sediment fabrics, the amount of soil moisture, and the high intensity of weathering characteristic of this region. Hence, the use of refill materials such as moist silt and clay and house-hold refuse in reclamation in the city is not recommended. This thesis therefore establishes that so far in Lagos area, land resource development programmes have been executed without initial geomorphological surveys to identify the character of each land unit and to develop them and allocate land uses to them according to their capability.

Apart from problem identification, this thesis adopts particular techniques for land resource development in general and in this area in particular. These are the techniques of geomorphological mapping and land classification. With these techniques the details about the external and internal properties of the land in the coastal zone were exhumed and presented in a cartographical form in Fig. 6.7 while the coastal zone was classified into units, based on identical attributes derived from the geomorphological character of the coastal zone. These units were categorized into three hierachies and were shown in Figs. 6.3, 6.4, 6.5, 6.6 in block diagrams and in tabular form in Tables 6.1, 6.2, 6.3 and 6.4 respectively. Thus the coastal zone consists of four recurrent landscape patterns, each group contains a number of land units which are differentiated on the basis of some selected criteria. The character of each land unit can be deciphered quickly in the maps and tables, so that it can be used in planning for settlement expansion, and other spatial development programmes.

From the system of land classification, it is noted that the swamps and estuarine formations are most liable to flooding because they consist more of clay and silt than sand. Thus they remain the most compressible part in the coastal zone.

However, the sandy-barrier formations and the High Plains constitute the most suitable land for development purposes.

The use of these techniques helps in understanding the character of each land unit and this understanding should aid the rational allocation of land use types to areas of suitable or commensurate capability. The map itself helps in the identification of the spatial distribution of the land units and could help in the planning of the direction of settlement expansion and the zoning of land-use types. In essence therefore, this aspect of geomorphological analysis becomes relevant to the needs of an urban planner.

Although the recommendations of the applied aspect of this thesis have not been utilized, nor has any of its type been made use of in this area, the entire work calls for a review of the planning procedure in Lagos area and in the country in general. The land classification map demonstrates the uniqueness of the land units over space and thus calls for a thorough investigation of the land to unearth this character before the development of its resources for human use. Furthermore, the use of this technique in evaluating the capability of the land for settlement expansion is only one aspect of applied geomorphology. The same techniques with a slight change in the choice of criteria can be used in the evaluation of the land for regional planning, agricultural productivity and recreation etc.

It is thus being emphasized here that the close link that exists between the character of the land and its geomorphological history, should be used to advantage in the understanding of the nature of the land, before its development. Hence a geomorphological survey becomes indispensable in order to achieve this.

In the course of this study, techniques and facilities from other disciplines such as Chemistry, Civil Engineering, Geology and Botany were used in the analysis of the data, while the derivations from the thesis could concern the work of the architect, the Town planner, Land Economist and the Civil Engineer in particular. It follows that the question of land resource development to be complete and rational should be multidisciplinary, so that each specialist would employ his own skills in the exercise. In the Lagos coastal zone therefore, it is necessary that this joint research project be inaugurated since nearly every specialist has a stake in the land. The role of geomorphology here is to present a land data bank in cartographical and written form to guide the prospective land users.

Since the users were not involved in the collection of data, it is important that the geomorphologist is consulted when his data are to be made use of. It is this form of integrated approach to land resource development that this thesis advocates.

On the whole applied geomorphological study has been shown to be a more comprehensive and utilitarian technique of landform study required to aid land resource management. In its combination of theoretical analysis of landform evolution with the examination of the distributional pattern of landform attributes and the classification of the land into units of similar attributes, a great deal has been achieved as shown in the first two chapters of this thesis, while the examination of the land deterioration problems, underlines the relationship between geomorphological forces and the land problems. Also, the classification of the land into units and the provision of the data bank in map form complete the utilitarian significance of the subject. Apart from this it makes the subject more geographical and more relevant to the needs of man. The multiple achievements through this technique makes it an indispensable method of environmental study.

This study reveals other research frontiers which include sedimentation characteristics in the Lagos Harbour, the hydrology of the coastal zone and the evaluation of the land units in the area of study. The study of sedimentation characteristics in the Harbour will help the understanding of the causes of siltation in the Harbour and methods of arresting it: Similarly, the understanding of the hydrology of the coastal zone will enhance the prediction of flood characteristics and produce suggestions for solving them.

During the course of this study, some difficulties were encountered which are worth enumerating with a view to guiding future studies of this type in the area. The first is the multidisciplinary character of the study which required that one had to shuttle between the Geology, Chemistry, Air survey, and Engineering departments in Ibadan and Lagos. One had to go to Ibadan for example for sediment analysis, and the separation of heavy minerals was carried out with the help of the Chemistry department; while the analysis of Aerial photographs was carried out in the Air survey division of the Department of Surveys Ministry of Works and soil testing was carried out in the Engineering Department of the University of Lagos. These were time consuming and indeed energy sapping, hence efforts should be geared towards equipping Departments enough to cope with these difficulties. Secondly the difficult terrain found in Lagos area involving the lagoons and creeks and marshes as well as poor transport facilities on them, limited the area covered in this study to readily accessible areas and also reduced the sampling sites to those areas accessible to the field worker. Hence it would be advisable that engine-powered boats be made available for future studies involving theLagos coastal zone to reduce accessibility problems. Furthermore sample corers should be provided for department depth samples especially when it is necessary to understand the succession of the strata of the sediments. It would also be advisable that Companies who possess valuable information about a particular area, for example depth samples or sections of soils, should make them available on request for scientific purposes, because apart from Mobil Oil Nigeria Limited, no other company was prepared to offer any assistnnce for this work on the character of the depth samples they possess.

APPENDIX I

STATISTICAL FORMULAE USED IN THE CALCULATION OF THE GRAIN-SIZE CHARACTERISTICS.

(From McCammon 1962)

I. MEAN. $\frac{\phi 16 + \phi 50 + \phi 84}{3}$

II. STANDARD DEVIATION OR SORTING COEFFICIENT $\frac{\phi 84 - \phi 16}{4} = \frac{\phi 95 - \phi 5}{6.6}$

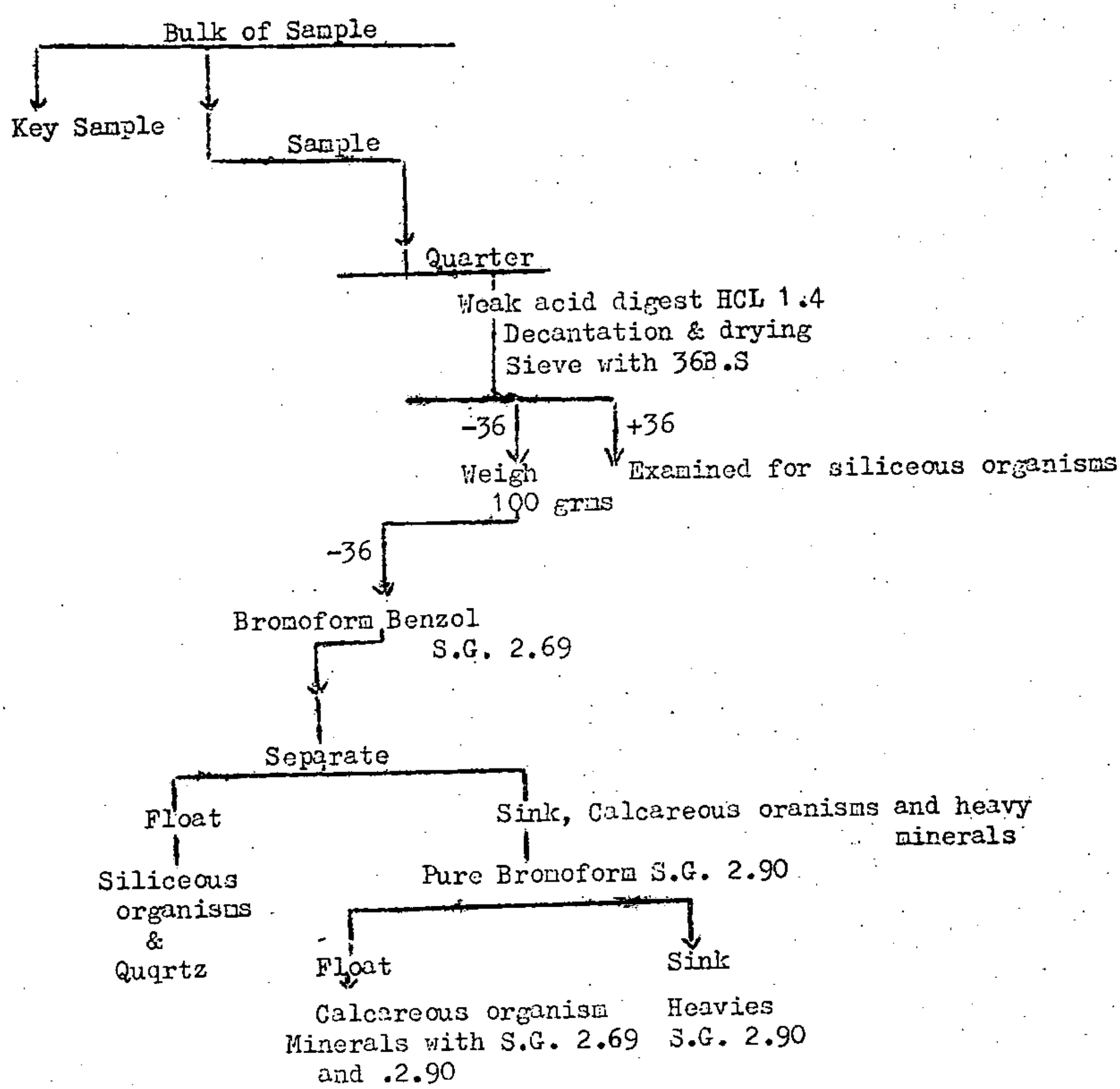
III. SKEWNESS $\frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$

IV. KURTOSIS $\frac{\phi 95 - \phi 5}{2.44\ (\phi 75 - \phi 25)}$

N.B. $\phi = -\log_2$ of the diameter in millimeters.

APPENDIX II

FLOW DIAGRAM FOR THE SEPARATION OF HEAVY MINERALS



After Milner (1961)

APPENDIX III

COMPUTER PROGRAM USED IN CALCULATING THE MOMENT MEASURES OF THE SEDIMENT

```
C      PROGRAM TO CALCULATE THE MEAN,
C      STANDARD DEVIATION, SKEWNESS, AND KURTOSIS
C      OF A NUMBER OF SAND [illegible] SAMPLES FROM
C      THE COAST OF LAGOS
       READ N
       DO 4 I = 1, N
       READ 1, A, B, C, D, E. F, G
1      FORMAT (7F8.4)
       AMEN = (B + D + F)/3.
       SORT = (F - B)/4. + (G - A)/6.6
       SKEW = (B + F - 2. *D)/2.* (F - B)
              + (A + G - 2. *D)/2. * (G - A)
       TOSIS = (G - A)/2.44 * (E - C)
       PRINT 2
                                bbb,,,,b   bbb....b  45H^b         bbb....b
2      FORMAT (3ØH^b  SAMPLE      10  MEAN     10   ,      SORTING    10
                         bbb....b
            SKEWNESS       10       KURTOSIS^b,/)
       PRINT 3, I, AMEN, SORT, SKEW, TOSIS
3      FORMAT (I4, 6X, F12.8, 4X, F12.8, 5X, F12.8, 6X, F12.8,III)
4      CONTINUE
       STOP
       END
```

APPENDIX IV

LIST OF ABBREVIATIONS

1.	A.A.A.G.	=	Annals of the Association of American Geographers.
2.	A.S.C.E.	=	American Society of Civil Engineers.
3.	C.S.I.R.O.	=	Commonwealth Scientific Industrial Research Organisation.
4.	E.C.A.F.E.	=	Economic Commission for Asia and East.
5.	Hcl.	=	Hydrochloric Acid.
6.	L. E. D. B.	=	Lagos Executive Development Board.
7.	L.S.D.P.C.	=	Lagos State Development and Property Corporation.
8.	M.E.X.E.	=	Military Engineering Experimental Establishment.
9.	N.P.A.	=	Nigerian Ports Authority.
10.	T.I.B.G.	=	Transactions of the Institute of British Geographers.
11.	R. L. P.	=	Recurrent Landscape Pattern.

APPENDIX V

REPORTS OF BEACH EROSION IN WEST AFRICA

1. Victoria beach in Nigeria.
2. Escravos beach in Nigeria
3. Bonny beach in Nigeria
4. Cotonou beach in Dahomey
5. Cape Coast beach in Ghana
6. Secondi beach in Ghana
7. Aby Lagoon beach in Ivory Coast

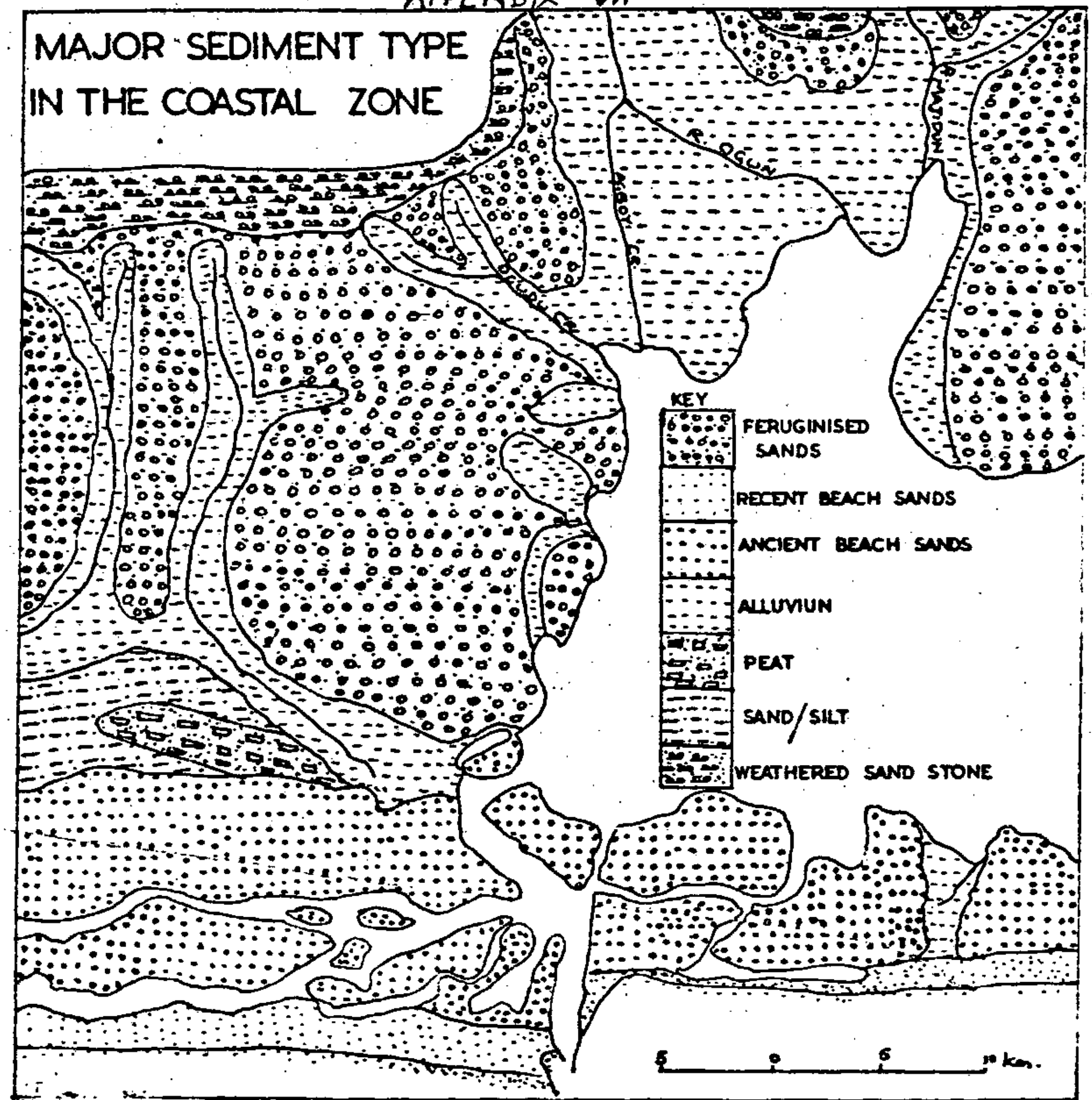
Courtesy of Nigeria Ports Authority 1974

APPENDIX VI

DEFINITION OF TERMINOLOGIES USED

1.	Landform	-	Landscape features which have form and material relationship and are recognizable by typical surface features wherever they may occur in the area, for example beach ridges.
2.	Landunit	-	A homogenous unit of the landscape in terms of selected Criteria e.g. River flood plains, Mangrove swamps.
3.	Recurrent Landscape Pattern.	-	An association of genetically related land units. It is similar to the Landsystem of the C.S.I.R.O. and the relief Units of Young (1969). e.g. Sandy-barrier formations.
4.	Land region e.g.	-	A large area in which all landforms are related in genesis, composition and form. e.g. The Coastal zone of Lagos where all landforms developed from the accumulation of sediments from Marine and terrestrial sources.
5.	Region	-	The sedimentary basin of S. W. Nigeria.
6.	Area	-	The area of study i.e. The Lagos Coastal Zone.
7.	'Part'	-	That part of the area of study being discussed.
8.	Sandy-barrier formation.		A single landform complex consisting of beach ridges, plains, swales and barrier islands.
9.	Nearshore zone	-	An area between the beach and about 20 metres into the sea.
10.	Offshore zone	-	Deeper water beyond the distance of 20 metres away from the sea beach.
11.	Swash zone	-	Area between the breaking point of waves and the beach berms.
12.	Beach	-	The wave beaten sandy deposits on the outer barrier.

APPENDIX VII



By A. Adegboye 1972.

APPENDIX VIII

TABLE FOR STATISTICAL ANALYSIS OF SEDIMENT SAMPLES

LOCALITY: Lawani Village - Barrier Beach II

IDENTIFICATION NUMBER: LAG/026 DEPTH: 45 cms.

COLOUR OF SEDIMENT: Whitish sand

STRATIGRAPHIC POSITION: Old beach sand

NATURE OF GRAINS: Loose sands with admixtures of organic materials.

TOTAL WEIGHT = 100 grams.

MESH SIZES	B.S.7	B.S.14	B.S.25	B.S.52	B.S.100	B.S.200	B.S.200	OTHERS
GRAIN WEITHT	-	1	5	30	50	11	3	-
%	-	1	5	5	50	11	3	-
% CUM	-	1	6	36	86	97	100	-

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