Chapter 53

LAKE NYASA PORTUGUESE COAST AND ITS SEDIMENTS

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INTRODUCTION

On the course of geological work in the Lake Nyasa region, several observations were made on coastal features and beach sediments which allowed some preliminary conclusions to be drawn on sedimentary and coastal processes active in the lake shore.

The purpose of this paper is to present these conclusions together with the data on which they are based.

GENERAL INFORMATION

GEOGRAPHY

Lake Nyasa is the southern and easternmost of the African Great Lakes and is situated between parallels 9° 30' and 14° 30' S and meridians 34° and 35° E Gw. It is elongated, about 580 km long by 15 to 90 km wide, and roughly oriented N-S. It covers an area of some 30,860 km^2 and is rather deep, with depths in excess of 700 m.

Its coasts and waters belong to three politically different territories, Tanganyika, Nyasaland and the Portuguese Province of Mozambique.

The lake drainage basin, although generally narrow, is wider in the western side where it shows an average width of about 100 km. In the Portuguese (Mozambique) sector it is a very narrow strip, 275 km long and from 10 to 45 km wide.

GEOLOGY

The lake occupies a great depression of tectonic origin integrated in the big African Rift Valley.

The older geological formations of the area are the Precambrian highly metamorphosed sediments and associated intrusives, that form the basement complex, upon which later sediments were deposited. The first of these were Karroo continental sediments which began accumulating during Permian times. They are made up of sandstone and shale with subordinate tillite, marl and coal beds. Karroo sediments continued being deposited until early Jurassio times, when

general uplift of the basement stopped sedimentation and started an erosional cycle from which a great Jurassio peneplain resulted. Large scale tectonic movements, at the close of the Triassic period, resulted in the faulting down of several blocks topped by Karroo sediments into more resistant basement rocks, which offered some protection against dennudation, allowing part of the Karroo sediments to be preserved to this day. Later, in the beginning of the Cretaceous, the basement subsided again and more sediments were deposited over the area. From then on, more stable conditions prevailed with widespread further dennudation which culminated at Miocene and resulted in almost total erosion of the Cretaceous formations of which only a few remnants are found today.

The large scale Rift faulting that resulted in successive drops along the present lake coastline, forming the lake basin, began then. During the Tertiary and the Pleistocene, faulting continued, bringing eventually the lake to its present level (Dixey, F., 1941).

On the Mozambique sector of the lake drainage basin the predominant outcropping formation is the basement complex. Its lithology varies widely. Highly metamorphosed rocks, gneisses, migmatites, granulites, etc. dominate, but granitio and basic intrusions also occur. Karroo sediments outcrop as a narrow strip oriented NE-SW reaching the lake shore about the middle of the Portuguese section of the coast (Fig. 1). Among Karroo sediments shale and sandstone are the main types (Borges, A. et al., 1953).

HYDROLOGY, HYDROGRAPHY AND METEOROLOGY

The lake gets all its water from the rain that fall on its drainage basin. The amount of this varies considerably both in space and time. Figures available for average annual rainfall range from about 2,800 mm to less than 635 mm (Pyke, J. G., 1958). On the other hand, for a given place, annual rainfall may vary from less than 60% of average (dry years) to more than 200% (wet years).

About 85% of annual rainfall corresponds to a wet season of 4 months, December to March. November, April and May are transitional months during which an additional 12% falls. June to October are the dry months.

Intensity of rainfall is usually high and can be extreme. Maximum intensity recorded was 152 mm in one hour (Pyke, J. G., 1958)

Rain water falling on the drainage basin,not retained by vegetation or ground, runs to the lake in numerous small rivers and streams. These, in the major part of the Portuguese section, only flow during and immediately after rainstorms, as could be expected from the high rainfall intensity and steep topography already mentioned. Only where the basin beoomes wider as in the extreme south and, specially, on the Karroo formations, are rivers better develo-

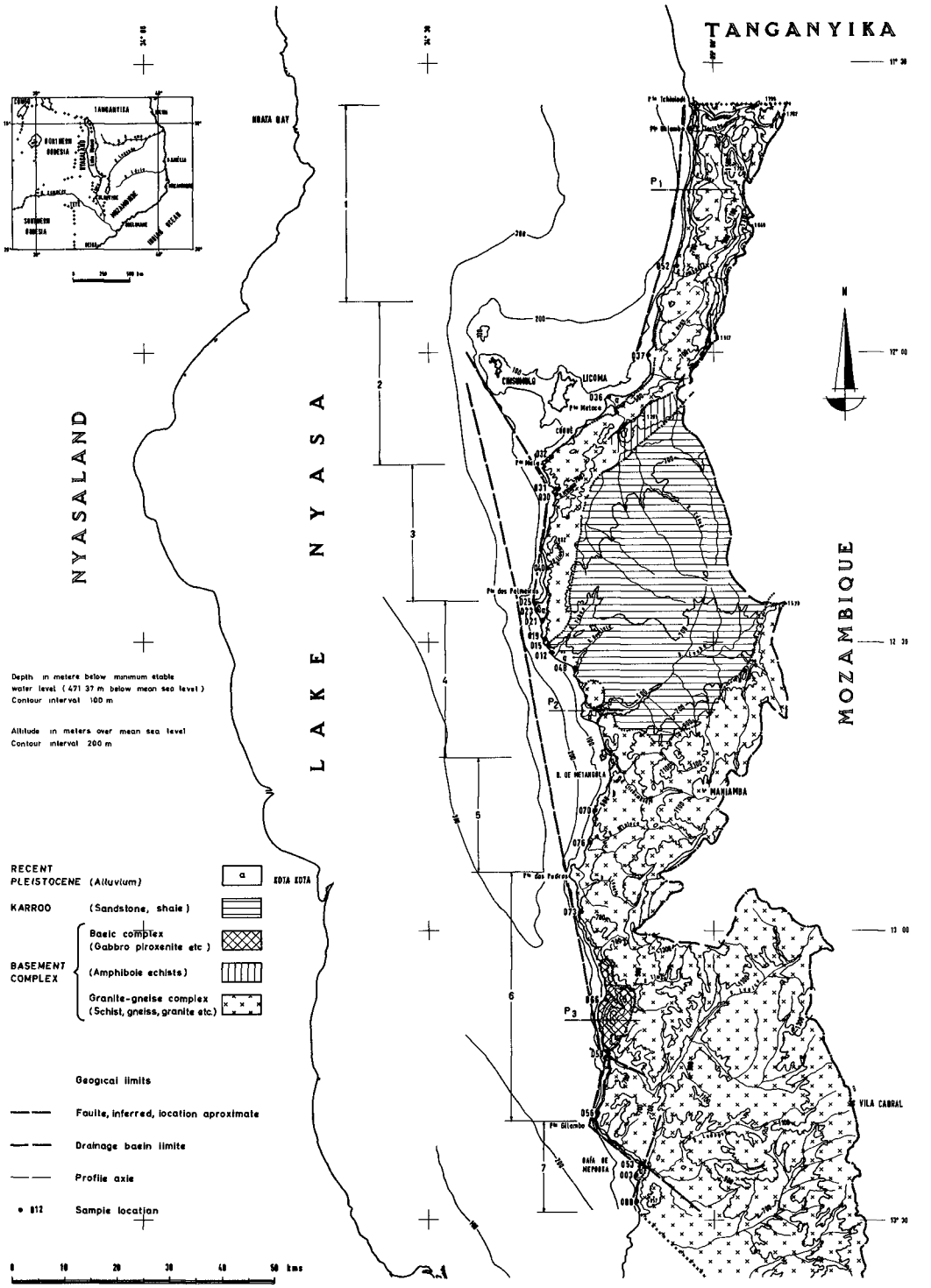

TANGANYIKA
NYASALAND
MOZAMBIQUE
LAKE NYASA
NKATA BAY
LICOMA
MANIAMBA
VILA CABRAL
KOTA KOTA
N
Depth in meters below minimum etable water level (471 37 m below mean sea level)
Contour interval 100 m
Altitude in meters over mean sea level
Contour interval 200 m
RECENT
PLEISTOCENE (Alluvium)
KARROO (Sandstone, shale)
BASEMENT COMPLEX
Basic complex (Gabbro piroxenite etc)
(Amphibole echists)
Granite-gneiss complex (Schist, gneiss, granite etc.)
Geogical limits
Faulte, inferred, location aproximate
Drainage basin limite
Profile axie
Sample location
0 10 20 30 40 50 kms

FIG 1

ped but, even these, barely flow during the dry season.

Lake water is lost by evaporation at an average annual rate of about 1,700 mm, and also, in a minor proportion, by discharge into the Zambeze through the Shire River that flows from the suthern end of the lake.

The lake water level depends mostly on rainfall and evaporation and,so, it shows an annual variation, that averages 1.10 m but can be as high as 1.80 m, with a maximum in May and a minimum in December (Instituto Hidrográfico, 1963). This variation is superimposed on a long term one whose law is still obscure but might be related to the Shire River discharge, which shows great variability, or to long term rainfall trends. Anyway, it is known that since 1850 the lake mean level dropped steadily, perhaps some 4 m, until 1914. From then, the lake rose about 4.5 m to reach a maximum in 1937 and, since then, has fluctuated within 3 m below this level although not yet having exceeded it (Pyke, J. G., 1958).

The dominant winds on the lake are from the South, West and Northwest. Northwest wind is the strongest but South wind dominates for longer periods. It is also a strong wind, specially from June to August, reaching as much as 50 km/h and blowing normally for 3 to 5 days, sometimes for 10 consecutive days. West and Northwest winds can rise a strong sea while blowing but, due to absence of an appreciable fetch, this soon dies, as quickly as the wind falls. South wind has much better fetch, the whole length of the lake, and as it blows frequently for long periods, rises a stronger sea, as high as 3 m, that dies slowly many hours after the wind (Instituto Hidrográfico, 1963).

No currents of any appreciable strength have been detected on the lake. If they exist, they are certainly weak, perhaps temporary and related to the wind. Also, no preceptible tides are observed and this is certainly due to the unfavourable form and dimensions of the lake (Instituto Hidrográfico, 1963).

COASTAL MORPHOLOGY

The coastline is, at least in its major part, shaped by faulting. This was accomplished rather recently in geological time and sub-aerial erosion has, as a rule, not yet had time to erase the characteristic topography. As a result the coastline shows a zigzag pattern, and profiles normal to it usually display steep slopes. In the Portuguese section the main exception to this rule is found in the area where the soft Karroo sediments reach the lake shore. These have been extensively eroded and give a low coastline, as shown in Fig. 2, profile 2.

Most of the coast is rocky, as could be expected, but many beaches are nevertheless found. Their distribution was investigated in the Portuguese sector of the coast which, for descriptive purposes, can be divided into 7 sections, as depioted in Fig. 1:

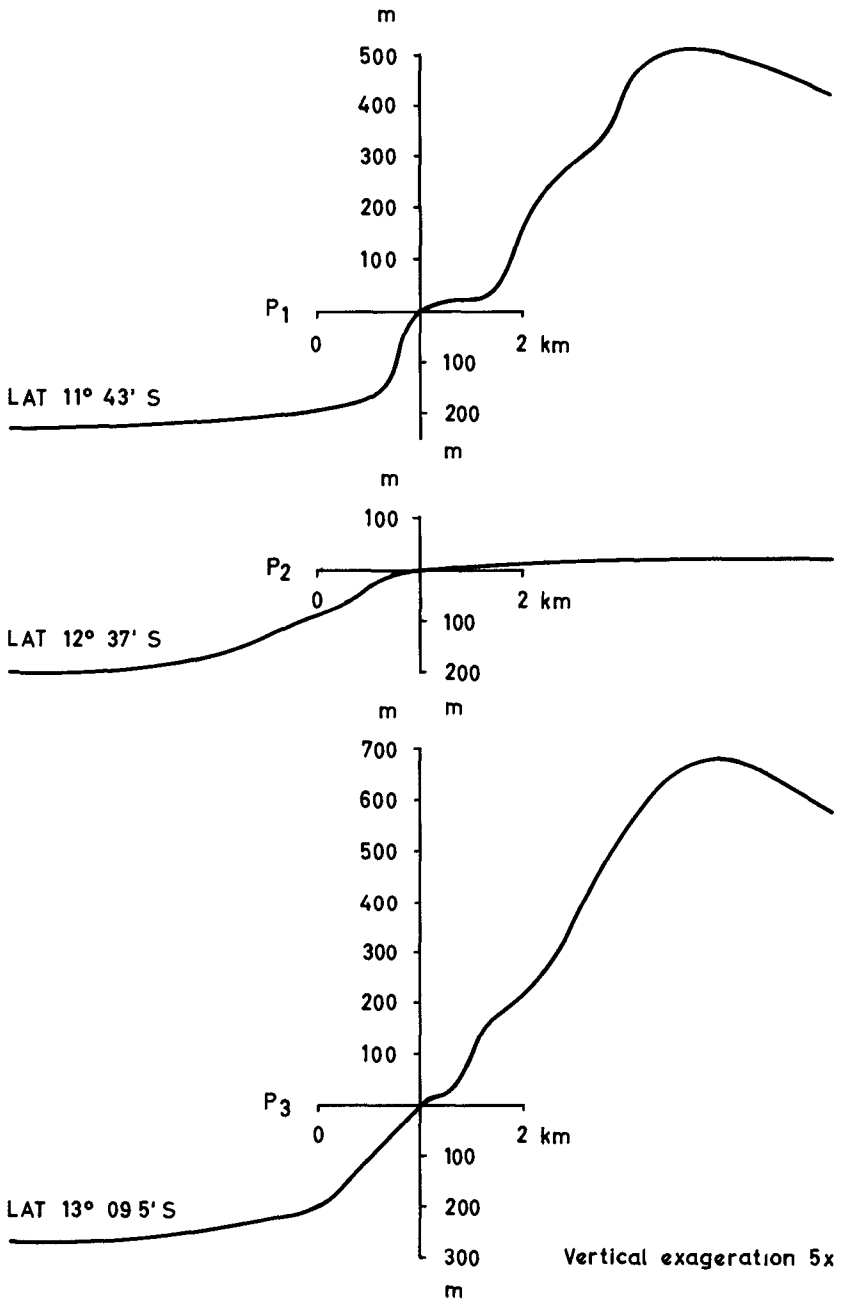

m
500
400
300
200
100
P1
0
2 km
100
200
m
LAT 11° 43' S
m
100
P2
0
2 km
100
200
m
LAT 12° 37' S
m
m
700
600
500
400
300
200
100
P3
0
2 km
100
200
300
m
LAT 13° 09 5' S
Vertical exageration 5x

FIG. 2

Section 1 - From the northern border to Point Messule, oriented aproximately N-S,is mostly rocky with very steep offshore slopes.

Section 2 - From Point Messule to Point Mala, oriented NE-SW, shows predominance of beaches, and has not so steep offshore slopes, as it is on the border of the platform from which Licoma and Chissumulo Islands rise.

Section 3 - From Point Mala to Palmeiras' Point, oriented N-S, predominantly rocky, and with steep offshore slopes.

Section 4 - From Palmeiras' Point to Metangula Peninsula, oriented NW-SE, with beaches dominating largely (rock only showing at a few scattered points), and very gentle offshore slopes.

Section 5 - From Metangula to Pedras' Point,oriented NNE-SSW, with beaohes alternating with rocky coast in about equal amounts and offshore slopes gradually increasing southward.

Section 6 - From Pedras' Point to Point Gilambo, with a N-S trend but arching slightly, with the oonvex side landward, showing dominance of rooky coast although some relatively large beaohes occur its southern limit. Offshore slopes begin steep, become gentler around the middle of the section, and then increase again.

Section 7 - From Point Gilambo to the southern border, shows a NW-SE trend and is predominantly rocky,with offshore slopes deoreasing to the South.

As can be seen, the coast shows an alternanoe of rocky and beachy stretohes, with beaches dominating generally on sections protected from South wind wave aotion. The only exception is section 4, which shows high dominance of beaches, although oriented NW-SE and thus well exposed to the waves coming from the South. This is due, no doubt, to its relation to the Karroo formations (Fig. 1) which,being much softer than normal basement rocks, supply much more beach material.

On sections described as predominantly rocky some beaches also occur. These are generally situated at the bottom of bays and coves, but many are found projecting from the coast, at the mouth of streams bording deltas that result from the accumulation of material brought by these.

Sand spits, allways showing a northward drift of sedimentary material, are sometimes found along section 4, some of them at the tip of the largest deltas. Quite often, these spits are well developed and isolate small lagoons.

SEDIMENTOLOGY

Beach material is usually fine to medium sand,but in qui-

te a few instances it contains a rather high proportion of poorly rounded gravel. Cumulative curves of this sands (Fig. 3) often show two modes, one between 1ϕ and 2ϕ (0.50 to 0.25 mm) and another at -3ϕ to -1ϕ (8 to 2 mm), implying mixture of at least two different types of material. This correlates well with field observation that suggested mixing of wave transported sand with runoff transported sediments.

Sorting varies considerably, also as a result of mixing. Sand of beaches totally derived from the accumulation of material transported by longshore drift show very good sorting with a grain size distribution closely aproximating lognormality (samples 021,078, 081, Fig. 3). On beaches where mixing has occurred, sorting can be extremely poor as a result of considerable amounts of coarser and finer material having been added to the longshore drift transported sand (samples 056,066,Fig. 3).

Mineralogically,beach sands are detrital quartz sands with considerable amounts of feldspar and heavy minerals, these last beeing frequently concentrated in localized zones of the beaches. Sometimes a small amount of organogenic carbonate material is found, as shell fragments, but it never makes more than about 1% of the sand.

Heavy mineral composition was investigated in detail in order to obtain data on provenance and tranportation of beach material. Techniques used included detailed fractionation of samples obtained from the heavy mineral concentration zones,both by electromagnetic and heavy liquid separation, followed by mineral counts on selected fractions. Other fractions were only examined for qualitative mineral composition.

On the whole it was found that almost all samples showed quartz, alkali feldspar, acid plagioclase, red garnet, hornblende, epidote, sphene and opaque minerals (magnetite,hematite,ilmenite) in variable amounts, while basic feldspar, bronzite, staurotide, biotite, muscovite, monazite, diopside, zircon, kyanite, sillimanite and andalusite could be used to define mineral provinces by its presence or absence.

Along those sections of the coast where beaches dominate and offshore slopes are gentle, the mineral content of beach sands could, in many instances, be traced to the rocks outcropping on the drainage areas of rivers reaching the lake in the close proximity,or just to the South of the beaches. This clearly demonstrates a northward longshore drift, probably due to South wind wave action. As an example we can take section 4 where the Karroo formations reach the lake (Fig. 1). These relatively soft rocks furnish abundant beach material, as is shown by the large deltas at the mouth of rivers draining the area, mineralogically characterised by the presence of monazite and zircon (also epidote and garnet in well rounded grains). In beach sands monazite and zircon can be found from the southern limit of the Karroo formations, over the northern one, well into section 3 (Fig. 4). They reappear later, north of Cobué River mouth, in section

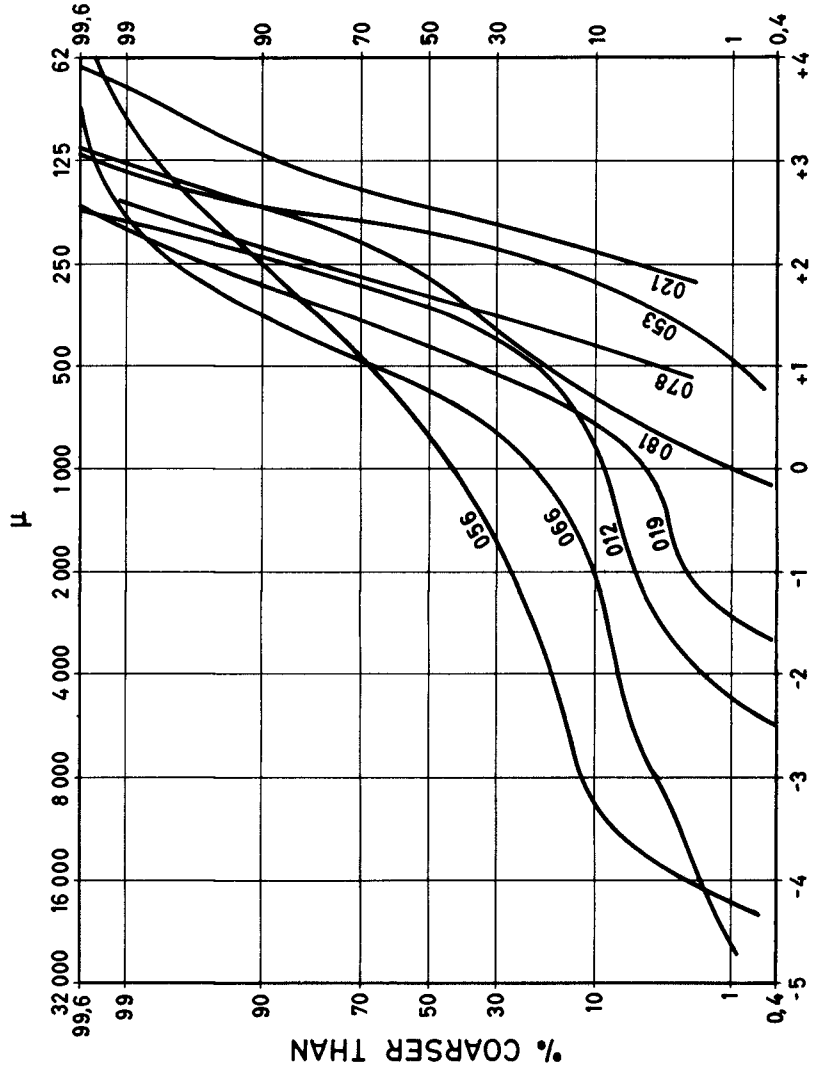

μ
62
125
250
500
1 000
2 000
4 000
8 000
16 000
32 000
99,6
99
90
70
50
30
10
1
0,4
% COARSER THAN
ø
+4
+3
+2
+1
0
-1
-2
-3
-4
-5
021
053
078
081
056
090
012
010

FIG. 3

2, due to this river having the major part of its drainage basin in the Karroo, although it reaches the lake out of it. Northward from there, monazite and zircon can be followed for the rest of section 2, and all of section 1. It must be noted, however, that monazite and zircon also show, although in small amounts, in beaches just south of Cobué River, suggesting a temporary reversal of longshore drift direction, probably due to Northwest wind wave action to which section 2 is particularly exposed.

On rocky sections of the coast, generally with steep offshore slopes, evidence of a northward longshore drift was also found whenever the mineral content of river alluvium and of beaches to the North and South of the river mouth, was investigated. Nevertheless, in these sections longshore drift seems to be, generally, more limited, probably due to quick loss of sand to the depths of the lake. Even, in some instances, although conditions were favourable, no indication of any longshore drift could be at all found. This happened, for instance, in section 6 where a small gabro-diorite intrusion outcropps in the middle of the regional granite-gneiss complex, reaching the lake shore (Fig. 1). This is reflected by the presence of abundant bronzite and labradorite grains on the beaches along the intrusion (Fig. 4). Samples taken north and south of the intrusion limits failed to show any of these minerals, suggesting that longshore drift, along this section, is very small or even absent.

As has been said, heavy minerals often show concentrated as patches of dark sand in localized zones of the beach surface. Their distribution was also investigated in depth and it was found that they formed mor or less regular strata a few centimeters thick, alternating with light coloured sand layers, generally many times thicker, revealling a well defined layered beach structure.

A typical beach profile (Fig. 5) shows a lakeward dipping more or less flat foreshore limited on the lake side by a foreshore step, and landwards by a beach scarp. Behind this scarp there is usually a berm that either dies against the first mountain slopes or merges into an alluvial plain. Foreshore slope varies widely being steepest on beaches of rocky sections with steep offshore slopes, and gentlest on large beaches bording deltas. Sometimes a double berm is found and this is thought to be related to an old and higher maximum level of the lake waters.

Heavy mineral concentrations visible on the beach surface are usually localized at the foreshore step and beach scarp crests (Fig. 5). They were often observed while being built up on the foreshore step by wave action. Small breakers lapp gently up the step depositing its charge as they lose speed. Backwash, being no so powerfull as much of the water sinks into the sand, picks up mostly the lighter material leaving the heavy grains behind.

CONCLUSIONS

The following conclusions are to be considered as preli-

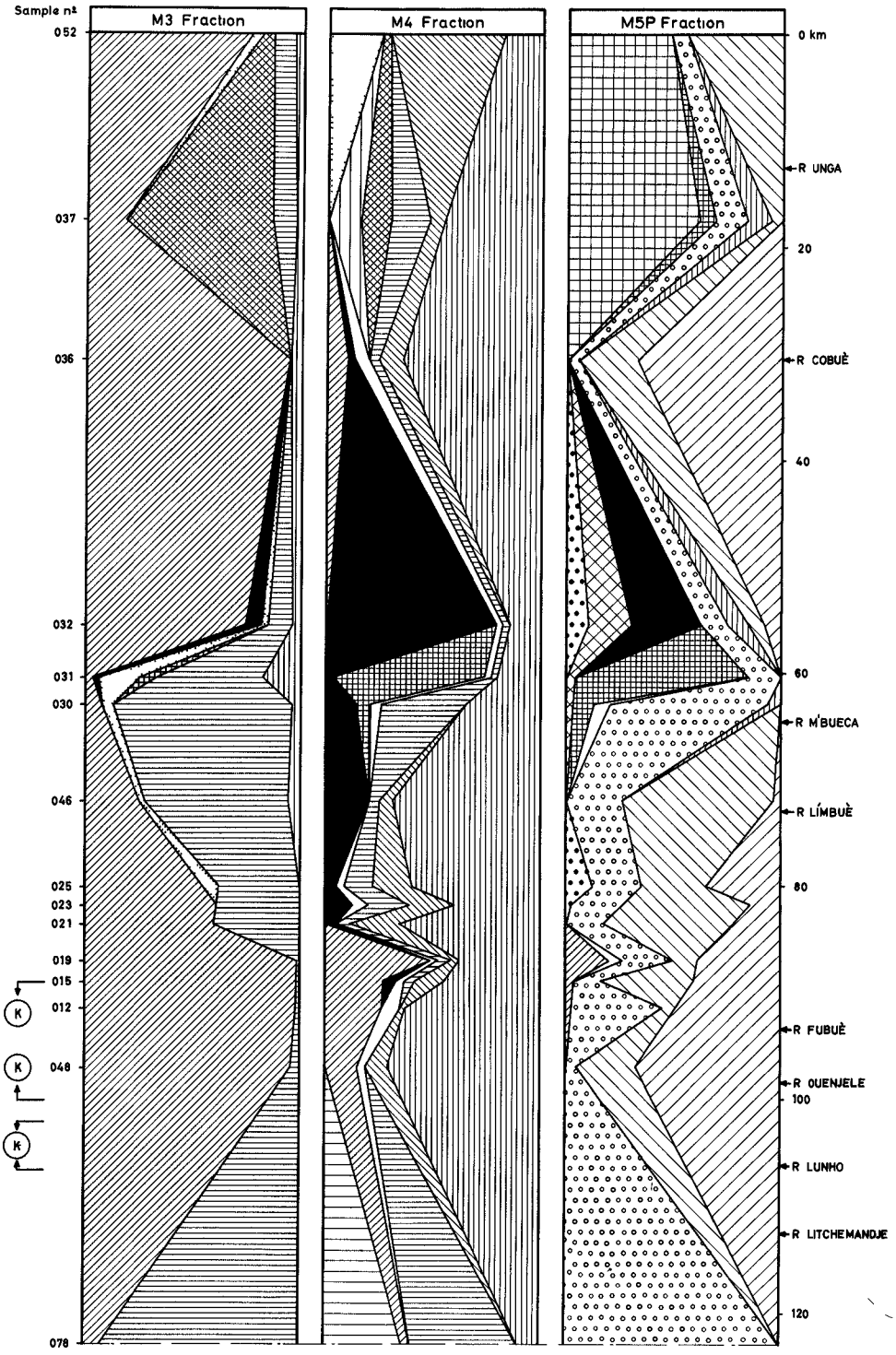
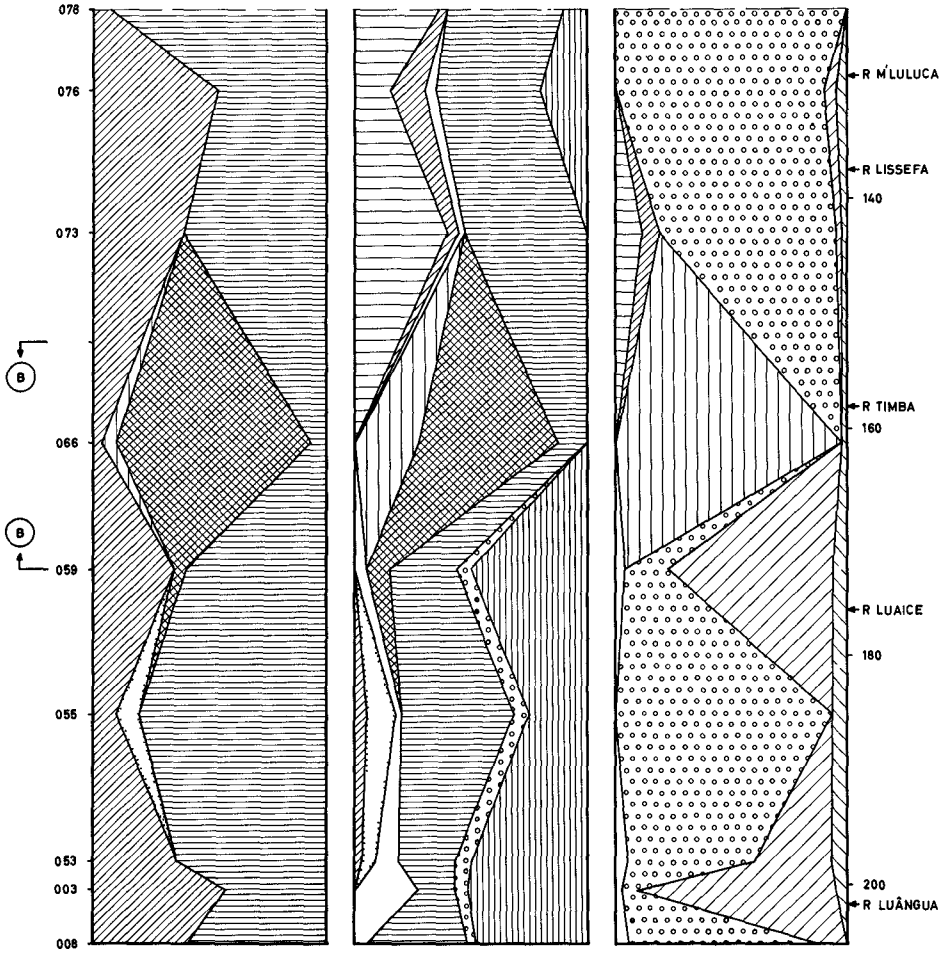

Sample nº
M3 Fraction
M4 Fraction
M5P Fraction
052
037
036
032
031
030
046
025
023
021
019
015
012
048
078
K
K
K
0 km
R UNGA
20
R COBUÈ
40
60
R M'BUECA
R LÍMBUÈ
80
R FUBUÈ
R OUENJELE
100
R LUNHO
R LITCHEMANDJE
120

FIG. 4



LEGEND

EPIOOTE
HORNBLENOE
GARNET
MONAZITE
STAUROTIOE
BIOTITE
MUSCOVITE
BRONZITE
LABRADORITE
DIOPSIDE
OTHERS
ZIRCON
RUTILE
SILLIMANITE
KYANITE
SPHENE
ANDALUSITE
K
K
KARROO LIMITS
B
B
BASIC INSTRUSION LIMITS

FIG 4 (CONT)

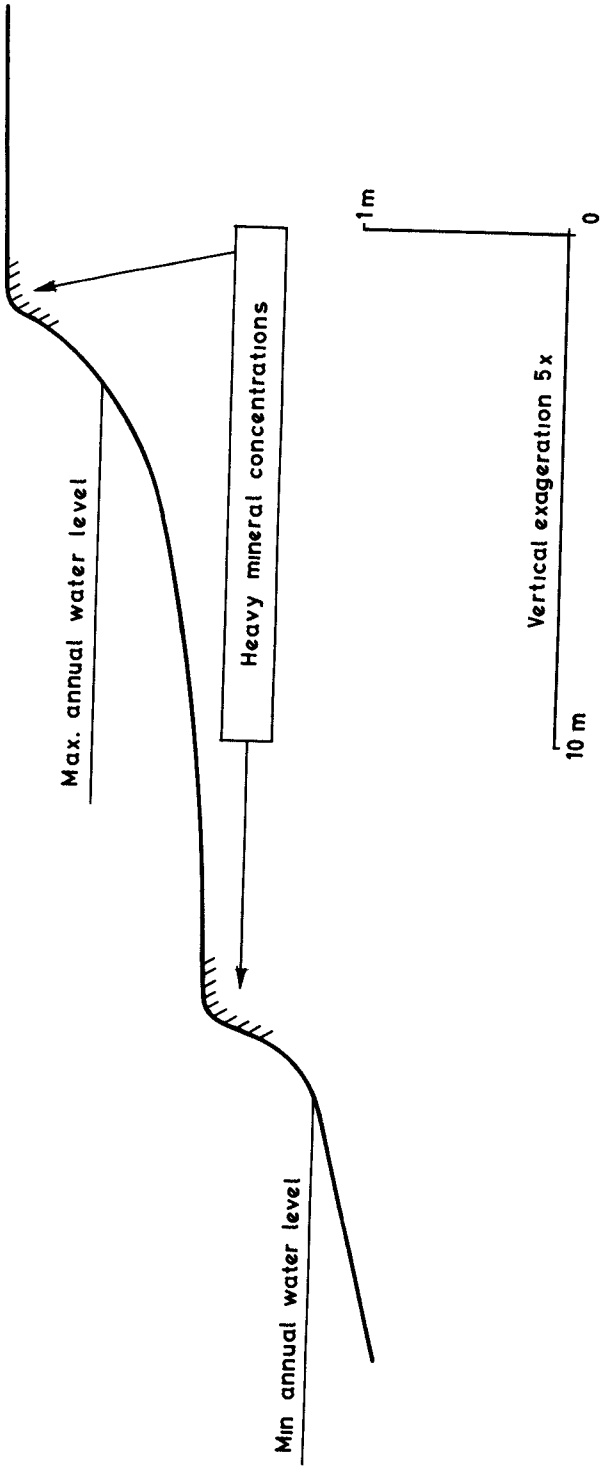

Max. annual water level
Heavy mineral concentrations
Min annual water level
1m
0
Vertical exageration 5x
10 m

FIG. 5

minary. They apply only to the Portuguese section of the lake coast and should not be generalised to the rest of the lake without further research.

1 - Although the shoreline is generally rocky, this is mostly a result of the tectonic origin of the lake basin,and the beaches and deltas that develop locally along it show sediment supply to the shore to be, on the whole, higher than sediment loss to the bottom of the lake, i. e.,sedimentation prevails over erosion.

In fact, high rainfall rate and intensity, as well as topographic conditions (also a result of faulted tectonics), concur to a high rate of sub-aerial erosion on the drainage basin and hence to a high sediment supply to the lake shore.

On the other hand, erosive capacity of the lake waters is low. Most of the beach material is brought to the lake during and immediately after the short rainy season by the streams and rivers,and large accumulations of sediments build up at the mouths of these. From then on, sediments start being eroded and moved alongshore by the waves but, as water level soon begins to fall, most material is left behind, out of reach of the waves. When the rains come again and the lake level rises, extensive erosion of last season deposits neces sarily occurs, but this seems to be overcompensated by the arrival of fresh material since definite indications of beach accreation can be found along the whole shore.

2 - Longshore drift is, on the whole, in a northward direction, as shown by the variation of beach sand mineralogy along the shore and by the sand spits found on some sections of the coast. This direction must be the result of South wind wave action. There are indications that temporarily andor locally this direction can be reversed, probably due to Northwest wind wave aotion, but net transport is allways to the North.

Distance of transportation alongshore, as also shown by the variation of beach sand mineralogy, seems to be generally limited and conditioned by the steepness of the offshore slopes. Along most of the sections, since they have steep slopes, sand must be lost to the depths at an high rate, thus resulting a generally short distance of transportation. Longer distance transportation is only found along the few seotions with gentler offshore slopes.

3 - Favourable conditions for the local accumulation of sediments as beaches seem to be, by order of importance, high supply of sedimentary material, gentle offshore slopes (which may depend on sediment supply or tectonics) and protection from South wind wave action.

ACKNOWLEDGMENTS

Thanks are due to the Instituto Hidrográfico in general and, specially, to the staff of the Missão Hidrográfica de Moçambique

which made the hydrographic survey of the Portuguese sector of the lake, for the valuable help received during field work.

We are also indebted to the Instituto de Investigação Cientifica de Moçambique, for partly financing this investigation.

Finally, we wish to thank our colleague Luis M. de Castro, for his help on the preparation of this paper.

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FIGURE CAPTIONS

Fig. 1 - General geological and teotonic sketch of the Portuguese section of Lake Nyasa drainage basin, with location of the samples mentioned in the text. P_1 to P_3 refer to profiles shown on Fig. 2. The division of the coast in sections 1 to 7 follows the description given in the text.

Fig. 2 - Profiles more or less normal to the lake shore, showing typical steepness of inshore and offshore slopes (P_1 and P_3), and the very different character of the coast where the Karroo formation reaches the lake shore (P_2).

Fig. 3 - Cumulative curves of typical beach sediments. These are generally mixtures of well sorted, wave transported, medium to fine sand (e. g.,samples 078 and 021) with poorly sorted material deposited directly on the beach by runoff.

Fig. 4 - Variation of beach sand mineralogy along the coast. Mineralogio composition was determined quantitatively only on 3 of the fractions in which the samples were split by means of electromagnetic and heavy liquid separation.

Fig. 5 - Typical beach profile, showing the most common locations of surface heavy mineral concentrations.