UNEP

REGIONAL SEAS

Mario B. Fay:

Maziwi Island off Pangani (Tanzania):

History of its destruction and possible causes

UNEP Regional Seas Reports and Studies No. 139

Note: This document was prepared under projet FP/5102-86-02-1209 by Prof. M.B. Fay as a contribution of the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) to the Global Climate Change Programme of the United Nations Environment Programme (UNEP).

For bibliographic purposes this document may be cited as:

Fay, M.B.: Maziwi Island off Pangani (Tanzania): History of its destruction and possible causes. UNEP Regional Seas Reports and Studies No. 139. UNEP. 1992

Preface

In spite of the uncertainties surrounding the predicted climate changes, greenhouse gases seem to have accumulated in the atmosphere to such a level that the changes may have started and their continuation may now be inevitable.

The environmental problems associated with the potential impact of expected climate changes may prove to be among the major environmental problems facing the marine environment and adjacent coastal areas in the near future. Therefore, in line with the Decision of the Fourteenth Session of the UNEP Governing Council on "Global Climate Change"[1], the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of UNEP launched and supported a number of activities designed to assess the potential impact of climate changes and to assist the Governments in identification and implementation of suitable response measures which may mitigate the negative consequences of the impact.

Task Teams on Implications of Climate Change have so far been established for nine regions covered by the UNEP Regional Seas Programme (Mediterranean, Wider Caribbean, South Pacific, East Asian Seas, South Asian Seas, South-East Pacific, Eastern African, West and Central African and the Kuwait Action Plan region).

The initial objectives of the Task Teams are to prepare regional overviews and site-specific case studies on the possible impact of expected climate changes on the ecological systems, as well as on the socio-economic structures and activities of their respective regions.

The regional overviews, are intended to cover the marine environment and adjacent coastal areas influenced by or influencing the marine environment.

The regional overviews, prepared by the Task Teams are planned to be presented to the Intergovernmental Meetings convened in the framework of the relevant Regional Seas Action Plans in order to draw the countries' attention to the problems associated with expected climate change and to prompt their involvement in development of policy options and response measures suitable for their region.

Once the site-specific case studies developed by the Task Teams (impact studies) is achieved, emphasis will be placed on providing assistance to national authorities in defining specific policy options and suitable response measures.

To complement the activities being undertaken by the Eastern African Task Team, a consultant was commissioned to carry out a preliminary study on the disappearance of Maziwi Island off the Tanzanian coast in the early 1980's. The study was undertaken in October 1989.

The tasks of the consultant were to:

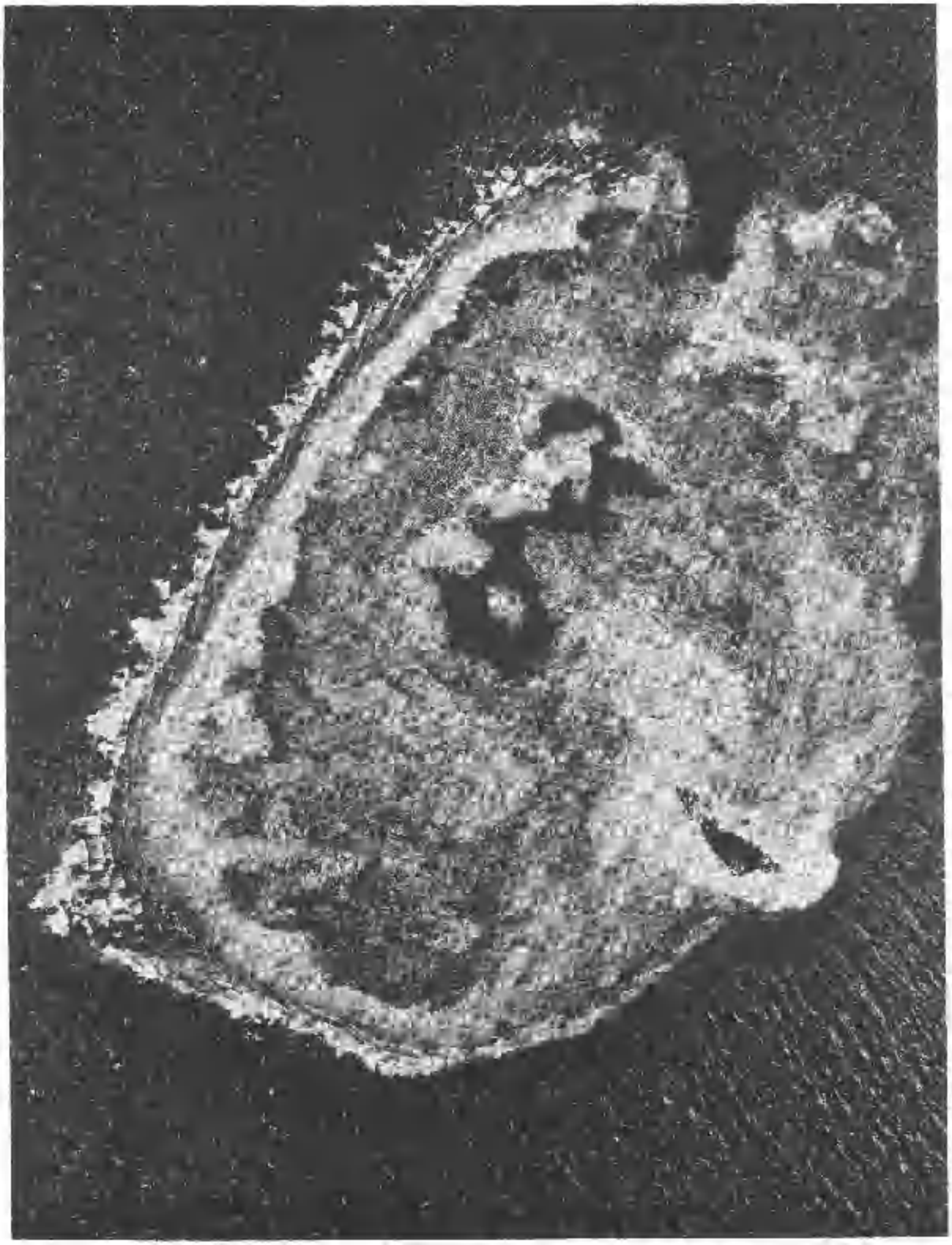
(i) compare aerial photographs from different years of the island;

(ii) compile seismic and meteorological data for the critical period;

(iii) carry out field work around the Maziwi coral reef in order to ascertain the former position of Maziwi Island; study the present topography of the reef; study the distribution of sand on the reef flat and around the reef; collect samples of sand for laboratory analysis; and estimate current velocities, wave direction and amplitudes around Maziwi Island; and

(iv) carry out laboratory analysis; mineralogical and granulometric properties of the sand collected from Maziwi coral reef.

This document is a comprehensive report on the findings of the study as outlined in (i) to (v) above, including conclusions and concrete proposals on further studies on Maziwi and other islands of the Eastern African region which might be subject to similar circumstances.



The Island that disappeared (Maziwi Island)

Aerial photograph of Maziwi Island taken in 1975.
Photo courtesy of Dr. Lutz Werding.

Contents

Introduction

Since at least two decades most of those sections of the shoreline of Tanzania which are built up by unconsolidated sediments have been showing a tremendously increased rate of erosion. Many good examples of this rapid coastline retreat can be studied in the area north of Dar es Salaam (Beach Erosion Monitoring Committee 1982) and between Pangani and Tanga (northern Tanzania). The average rate of coastline displacement for the Dar es Salaam area is estimated to be about 3 metres/yr, in certain places this rate exceeds 5 metres/yr (Fay, in prep.). Along the most developed parts of the coast (i.e. tourist hotel complexes north of Dar es Salaam) this development means a catastrophe to the national economy jeopardizing the Tanzanian efforts of promoting the tourism industry.

Large parts of the backshore area in this region are composed of Holocene terrigenous sands (ancient beach ridges, Alexander 1969). North of Dar es Salaam this belt is up to 0.5 km wide. Pangani town is situated on a more than 1 km wide strip of ancient beach ridges running approximately parallel to the present shoreline. Since these sands are only very little exposed above the present high tide level (centimetres to decimetres), it can be assumed that they formed after the last post-glacial rise of sea level, i.e. after 7000-5000 years B.P. (Seibold & Berger 1982, p.117). These, in geological terms, very young sand accumulations are presently being eroded and redistributed along the beaches and in the shallow parts of the continental shelf. Although a few sections of the coast still show a seaward shifting of the beachline (i.e. portions directly downdrift of interruptions of the beach, which means usually areas north of river mouths and tidal channels), the general trend has reversed from progradation to retrogradation.

Similar observations can be made in the extensive mangrove swamp areas in the estuaries and deltas of the Tanzanian coast. In the Ruvu delta, mangroves are rapidly eroded (pers. comm., A.K. Semesi, University of Dar es Salaam). According to the Fishery Officers in Pangani, all mangrove swamps along the river Pangani estuary presently undergo erosion.

Due to the predominant southeasterly winds, longshore transport along the coast north of Dar es Salaam is commonly directed northwards. Exceptions from this trend can only be observed at strongly embayed sections where the general wave pattern is disturbed by intensive refraction around headlands. According to the observations made by the author and by other researchers (Bryceson & Stoermer 1980), waves generated during the season of the NE-monsoon are not able to reverse this trend significantly.

There has been a controversial discussion among scientists working in Tanzania about the possible causes for the increased rate of coastal erosion. Various factors have been made responsible: Extraction of sand from rivers for construction purposes, destruction of the fringing and barrier coral reefs by dynamite fishing, removal of vegetation from the mangrove swamps, rise of the relative sea level (Beach Erosion Monitoring Committee 1988; Fay & Griffith 1987).

Due to lack of basic data, no satisfactory answer can be given up to now. What is mainly missing is the following information:

- Data on historical shoreline changes.
- A series of topographic maps and air photographs of sufficiently large scale and accuracy to allow analyses of shoreline retreat during the last decades. Air photos are available since 1953, but they do not cover the entire Tanzanian coast.
- Records on the former and present sediment discharge of the rivers (most of them flowing seasonally only).
- Continuous and reliable tidal gauge data of the Tanzanian harbours for the last decades.
- A coastal inventory and a littoral data base, as suggested by Quélennec & Ibe (1989), forming a basis for identifying areas which are presently or might be in the near future subject to erosion and for initiating research into such areas.

This study on a small island off the Tanzanian coast ought to be regarded as a first step towards a better understanding of the processes which are presently causing coastal erosion along this part of the East African coast.

Why Maziwi Island?

Maziwi Island (also Maziwe Island) is (or better: was) located at the northern end of the Zanzibar Channel approximately 50 km south of the town of Tanga (northern Tanzania), 8 km southeast of the mouth of the Pangani river (fig.1). Latitude and longitude values are 05 degrees 30'S and 39 degrees 04' E, respectively. The closest settlement is Pangani town, from which the island can be visited by using a boat. Pangani is accessible from Tanga on an all-weather dust road.

Maziwi Island was famous for being the most important single nesting ground in East Africa for three species of endangered marine turtles: *Lepidochelys olivacea* (olive ridley turtle), *Chelonia mydas* (green turtle), and *Eretmochelys imbricata* (hawksbill turtle)(Frazier 1974, Shedd 1974). During the period July to October 1974 more than 25 females nested on Maziwi Island, which was the highest concentration of nesting turtles in Tanzania (Shedd 1974, p.2). Lack of vertebrate predators and only occasional visits by humans (fishermen, who used the island for stop-overs) made Maziwi Island an almost ideal sanctuary for turtles. Hence, the Tanzanian Government intended to protect the island by Game Laws ("Maziwi Island Reserve"). In 1982 it was reported that Maziwi Island was submerged and therefore unsuitable for nesting of turtles (IUCN/UNEP 1982, p.36, Mainoya & Pratap 1988).

Choosing Maziwi Island for a case study on beach erosion processes has a number of merits compared to mainland beaches:

- Since the island was not inhabited by humans, certain causal factors of beach erosion, such as sand extraction, considerable devegetation, and marine construction works, can be excluded.

- The terrestrial part of the Island has always been sufficiently small to let people who regularly visited it (fishermen) notify any changes of the beachline configuration. A loss of 50 metres of land on an island with a diameter of only a few hundred metres might be much more conspicuous than the same loss of land along a mainland coast with scattered settlements.

- At least a few scientists (zoologists) visited Maziwi Island for studies, and reliable information can be obtained from their scientific reports.

Investigation methods applied

Air photographs and maps

Although air photos of the Pangani coast are available from November 1953, September 1961, January 1976, and June 1982, Maziwi Island was completely shown only on photos taken on 14th December 1982, and its westernmost part on the 1st June 1982 photos. During this time, the island was already submerged. In order to have an impression of the current situation, the author took oblique-view air photos of Maziwi Island on 3rd November 1989.

The following sea charts have been used:

- British Admiralty sea chart No. 3310 (Africa-East Coast, Dar es Salaam to Wasin Island, scale 1:300,000, published 1966).

- German sea chart No. 127 (Indischer Ozean, Kenianische und Tansanische Kueste, Mombasa bis Ras Kanzi, scale 1:300,000, published 1974 with minor corrections 1982, by Deutsches Hydrographisches Institut, Hamburg)

Review of publications and unpublished reports

Reports of J.G. Frazier and co-workers on the marine turtle population on and in the waters around Mazlwi Island. Determined and described samples of the former vegetation of the island are kept in the collection of the Department of Botany, University of Dar es Salaam.

Site investigations

Maziwi Island was visited by the author on five days during low tide (4th, 5th, 6th, 9th, and 10th November 1989). The size of its remaining terrestrial part during low and high tides, inclination angles of beach slopes, ripple patterns and other sedimentary structures, the boundary to the surrounding coral platform and the distribution of remnants of the former vegetation were studied. The submarine part down to a depth of 35 metres was investigated by SCUBA diving. The water depths on the northern and western side of the Island were determined by echo sounding. Samples for laboratory studies were taken from the supratidal, intertidal, and subtidal parts of the island.

Short visits were paid to the mainland beaches around Pangani town.

Interviews with Pangani fishermen

Four fishermen from Pangani town, who used to fish in the waters around Maziwi Island since 1924, 1926, 1948, and 1955, were questioned about the history of disappearance of the island and about the current and wave regimes of the study area. On one day the fishermen accompanied the author to the island and gave information on the spot.

Geography and geology of the Pangani area

The coastline in the northern part of Tanzania (Pangani-Tanga area) is characterized by alternating sandy beaches (composed of Holocene and Pleistocene terrestrial sands; recent carbonate sands on pocket beaches), outcrops of raised Pleistocene coral reef limestone (forming cliffs), and estuaries or small deltas with extensive growth of mangroves. The Pangani mouth is an estuary partially fringed by mangrove swamps.

Locally, fringing coral reefs are developed. At a distance of several kilometres (mainly 5 to 8 km) from the shoreline a NNE-SSW trending barrier reef occurs, which is interrupted by down to 40 metres deep and several kilometres wide channels. Some of the reefs are attached to raised Pleistocene limestones (i.e. in the Tanga area), others could have grown up from the sea floor during the post-glacial rise of the sea level 15,000 to 5,000 years ago. Assuming a sea level rise from -40 metres to the present position during the period 9000 to 5000 years B.P. (Seibold & Berger 1982, p.117) and a maximal vertical growth rate of hermatypic corals of 1 cm per year (Schuhmacher 1976, p.179), coral growth could have coped with the rising sea level.

Some of the reefs have been given names, such as (from N to S) Fungu Tongone, South Head Reef, Mwamba Mawe (drying up to 0.6 m during neap tides), Maziwi Island, Fungu Ya Zinga, Fungu Ushongu, Fungu Datcha, and Kipumbwe Reefs (fig.1). Of those, only Fungu Tongone (approx. 25 km northeast of Pangani) and Maziwi bear (or had borne) small (terrestrial) islands with vegetation. Small intertidal sand spits (composed of carbonate sand) are found quite commonly on these reef platforms. In the vicinity of Maziwi Island intertidal sand spits occur on Fungu Ya Zinga and Fungu Ushongo. According to the Pangani fishermen, these sand spits had never borne any vegetation.

The Pangani mouth is located between the Zanzibar Channel to the south and the Pemba Channel to the north. The water depths in the Zanzibar Channel do not exceed 60 metres, indicating that, geologically, Zanzibar is part of the African continent. In contrast, Pemba Island is separated from the mainland (and from Zanzibar) by a more than 800 metres deep submarine canyon, a tectonical and morphological graben structure along the Tanga fault zone (Kent et al. 1971, p.94, fig.42) which shows structural similarities with the rift valleys in eastern Africa (fig.2). Between Zanzibar and Pemba Islands, this canyon trends ESE-WNW, then turning into a north-northeasterly direction, running approximately parallel to the shoreline of the mainland.

The coral reef structure on which Maziwi Island was situated has a nearly oval shape (length of long axis 2.2 km, length of short axis 1.35 km, trend of long axis approx. 30 degrees). The terrestrial part of Maziwi Island was located on the western side of this platform. The maximum water depth, measured by echo sounding, in the lagoon between the mainland and the island was 42 metres (at mid-tide). The base of the Maziwi coral reef lies at 30-35 metres depth. On the back-reef side (W) the coral facies is replaced by lagoonal calcareous, sandy muds or silty sands (at depths greater than 30 metres), which are strongly bioturbated. On the fore-reef side (E) the sea floor, beneath the base of the reef slope, continues dipping steeply towards the submarine canyon mentioned above, reaching the 200 metres depth contour at a distance of 4 kilometres, only. This corresponds to an average slope of the sea floor of 3 degrees.

Climate, currents, waves and tides in the area

Climate

The climate of the entire Tanzanian coast is warm and humid with mean day-time temperatures ranging from 22 to 30 degrees C and an average precipitation rate of 1100 mm per annum.

The coastal area is affected by seasonally blowing winds (trade winds or monsoons) whose directions depend on the position of the equatorial trough: The SE-monsoon from March to September/October and the NE-monsoon from October to March. Between March and May winds are generally weak and accompanied by heavy rainfall (long rainy season). From June to September/early October winds are strong, often stormy, and the precipitation rate reaches its minimum. From October to December winds are usually weak and directions tend to vary. This is the period of the "short rainy season". From January to March winds blow constantly from NE with variable, but usually low intensity. This period is commonly dry and very hot.

Wind velocity data are not available for the Pangani area. For the Dar es Salaam area, wind speeds vary between 1.5 and 8 m/s (average 5 m/s) during the period of the NE-monsoon. During the SE-monsoon season winds are generally stronger with an average of 8 m/s (Beach Erosion Monitoring Committee 1988, p.21).

Currents

The area is influenced by the generally north-flowing East African Coastal Current, whose velocity varies between 0.25 and 2 m/s, the higher speeds occurring during the period of the SE-monsoon. According to the Pangani fishermen, during the NE-monsoon (October to March), surface currents are directed southward on both, the landward and seaward sides of Maziwi Island (fig.3). During the SE-monsoon (April to September) currents are running in the opposite direction. These currents are generally weak and not able to move sediment of sand size. During the author's diving excursions it was not observed that any sand-sized sediment particles were transported due to currents.

However, according to the fishermen there seems to be a strong wind-generated current flowing E-W from the open sea towards Maziwi Island always for about two weeks at the end of the NE- and SE-monsoon periods. This current is especially strong during nights, when the wind is blowing most intensively.

Waves

The general wave pattern around Maziwi Island is oriented E-W, varying sligthly with the season (wave approach from NE to E during the NE-monsoon, from SE to E, occasionally also S during the SE-monsoon). Waves break, during low tides, at the reef front on the eastern side of the island. Due to refraction along the reef slope and on the coral reef flat, waves approach the western part of the island from N and S (figs.4-6). During high tides waves do not break any more at the eastern margin, but travel across the reef platform and cause sand to move in a westerly direction.

Wave periods observed during the time of the author's field work were ranging from 6 to 8 seconds, corresponding to deep-water wave lengths of 50 to 100 metres. According to the information given by the

Pangani fishermen, normal deep-water wave heights are generally less than 0.5 metres. During storms, i.e. in September, waves heights rarely exceed 2 metres.

Tides

Tides along the Tanzanian coast are semi-diurnal. Tide tables for the ports of Dar es Salaam and Zanzibar are published by the Tanzania Harbours Authority. The minimal/maximal theoretical tidal range values (for 1987, extreme neap/spring tides) are 0.33/3.82 and 0.38/4.56 metres for the Dar es Salaam and Zanzibar harbours, respectively. Tidal range data are not available for Pangani. The author estimates that the maximum tidal range in this area is approximately 4 metres.

Although tidal currents are spectacular in the Pangani estuary and mouth, strong tidal currents were not observed by the author around Maziwi Island during his field work. The fishermen could not give any clear information on this item.

All fishermen interviewed agreed that there has been no significant change in the current pattern or in the wave climate since the time they started fishing in the waters around Maziwi Island.

The present status of Maziwi Island

The largest part of Maziwi Island is a shallow coral reef flat reaching the sea level only during neap tides. This coral flat is characterized by coral species showing massive growth forms (e.g. *Porites*, *Goniastrea*, *Montastrea*). Branching types of stony corals (e.g. *Acropora cf. scandens*) and octocorals (*Tubipora musica*) are scarcely found. Crustose coralline red algae contribute considerably to the framework of the reef. The voids between the coral colonies are filled with calcareous sand and gravel originated from the destruction of the reef by breakers, swell and boring organisms as well as from the decay of the skeletons of calcareous green algae (i.e. *Halimeda*) and articulated coralline red algae. Nodules of crustose coralline red algae contribute to the sediment, too.

On the western margin of the reef platform a sand spit composed of carbonate particles (obviously derived from the coral reef flat) occurs (figs.7-10). From the air this sand spit looks tongue- to hook-shaped, its convex side pointing north and westward. The easternmost portion of the sand spit is founded on the coral platform, while its central and western parts cover the back-reef slope and marginal parts of the back-reef lagoon.

Millman (1974, p.195f.) classified carbonate sand cays on reef flats into six types:

1. Submerged sand bar, possibly only emergent at low tide.
2. The simple low-lying sand or shingle cay.
3. The low-lying cay with pioneer strandline plant communities, such as creepers and shrubs.
4. Higher standing cays with more complex and better-developed plant cover, often including trees.
5. Sand cays with mangrove growth and sometimes mangrove swamps.
6. Cays with exposed platforms or interiors of older rocks.

The present Maziwi sand spit belongs to type No.1 of this classification.

Supra- and intertidal part of the sand spit

The length of the sand spit exposed to air during low tide (E-W) is about 320 metres, its width (N-S) 130 metres. The vertical distance between low tide level and the top of the sand spit is about 3.5 metres. The size of its uppermost part, which is usually still positioned above high tide level, is about 70 metres (E-W) by 40 metres (N-S). Occasionally, during extreme spring tides, this part of the sand spit seems to be submerged, too.

Angles of inclination of the beach slope, measured at approximate midpoints between low and high tide levels, are uniformly 6 degrees on the northern, western and southern flanks, and 1 to 2 degrees on the eastern flank. The uppermost part of the sand spit is nearly horizontal.

The sand is entirely composed of carbonate particles derived from the surrounding reef platform. Terrigenous constituents, such as quartz, are missing. The sand is medium-grained (medians between 0.31 and 0.41 mm for samples taken in the central part of the beach slope) and moderately well to well sorted. Gravel-sized fragments of corals and abraded coralline red algae nodules ("rhodolites") are found scattered on the surface of the beach slope; accumulations of them occur close to the foot of the beach slope.

The grain size-beach slope relationship can be used to estimate the degree of exposure of a beach to wave attack (Wiegel 1964, fig.14-17, cit. Pettijohn et al. 1973, p.481). According to this relationship, the northern, western, and southern flanks of the sand spit are classified as "protected", the eastern flank as "exposed".

Slightly asymmetrical, ladderbacked oscillation ripples with truncated crests characterize the easternmost, lowest portion of the sand spit. The crests of the wave ripples are oriented E-W; the average ripple length is 20 cm. The type of asymmetry of the wave ripples (azimuth of steeper flanks approx. north) indicates transportation of sand from S to N. The lee-sides of the small current ripples occurring in the troughs of the oscillation ripples dip towards east.

In the western part of the sand spit, rill marks are common features found at the foot of the beach slope. The beach slope shows plane bedding with swash marks. Close to the high tide mark, burrows of crabs (*Ocypode sp.*) frequently occur. Small wind ripples can occasionally be observed on the uppermost, dry part of the beach.

The coral reef flat in the vicinity of the sand spit to the southeast, east, and northeast is composed of dead coral blocks partially covered by calcareous sand. A fragmented and slightly tilted sheet of beach rock is exposed on the southeastern side of the sand spit during low tide.

Subtidal part of the sand spit

To the north, west, and southwest the subaerial part of the sand spit is fringed by a very gently inclined platform, which is built up by medium-grained calcareous sand characterized by oscillation ripples and patchy growth of seaweeds. At a distance of 70 to 100 metres from the beachline and at a water depth of 3 to 4 metres below low tide level a sharp break occurs. The slope of the sea floor rapidly increases from less than 2 to 40-45 degrees, and oscillation ripples are replaced by a plane bed. At one point along this slope (close to the southern margin of the sand spit at 8 m depth) a still living coral colony was observed, which was just about to be covered by sand. No sessile fauna or flora was observed, another indicator for rapid, still continuing sedimentation of sand. The only macro-organisms found were numerous specimens of bottom-dwelling fish (stonefish, a warning to future researchers!). On the southwestern flank of the sand spit the base of this slope lies at 5 to 10 m water depth. The sand at the base is coarse-grained to very coarse-grained and contains a high proportion of pebble-sized coral fragments.

Seawards the sea floor is only weakly inclined and composed of medium to fine-grained sand and isolated coral colonies. On the western and northern side, the slope angle decreases again at depths between 25 and 30 m, and here the medium-grained sand is replaced by a slightly silty fine-grained carbonate sand, which is strongly bioturbated by worms (lagoonal facies below wave base). Also this sand consists nearly of 100% of calcium carbonate particles derived from organisms. In a thin section of one impregnated sample from this place only very few siliciclastic grains were seen. The terrigenous influence on sedimentation in this area is, therefore, very little. Besides its smaller grain size, the lagoonal sand differs from the fan deposit in its content of tests of calcareous foraminifera and about 0.1 mm large, oval, micritic particles which are probably faecal pellets.

Here, a very pronounced thermocline was felt during diving at a depth of approximately 23 metres, which might be related to upwelling deep-water from the nearby submarine canyon. The entire structure of this part of the sand spit resembles the leeward side of a large sand dune migrating over a reef slope.

To the south there is a transition from the sand facies into the reef flat facies with living corals. To the east of the sand spit, corals are dead, and the surface of the reef flat looks abraded, indicating that large parts of the reef flat were once covered by sand.

In the vicinity of the sand spit, remains of trees, some of them more than 6 metres long, give evidence of a former vegetational cover of Maziwi Island. The wood of the stems is in an advanced stage of decay, intensively drilled and penetrated by marine organisms (mainly *Teredo sp.*). Some of the stems still show parts of the roots, indicating that the trees were not cut by people, but fell into the sea due to erosion.

Summary of the observations

The sand spit at the western edge of the Maziwi coral platform can be regarded as a (mainly submarine) fan deposit shifting from east to west across the back-reef slope into a 40 metres deep lagoon, covering fine-grained lagoonal sands. Only a small proportion of the fan (<1%) is exposed above high tide level. The total volume of sand accumulated in the fan is estimated as 1.5 million cubic metres. The sand is derived from central parts of the reef platform, most likely from those areas which are still covered by a thin blanket of sand and where no living coral colonies occur. Terrigenous constituents are missing in this sand and are also very rare (<1%) in the fine-grained lagoonal sediments near to the sand spit.

The strongest wave attack takes place on the eastern side of the spit during high tides, when the waves are not broken by the coral reef. Sediment transport in the intertidal zone is by beach drift (swash-backwash towards west), in the shallow subtidal zone by wave drift, and along the slopes of the underwater fan by gravitation (grain flow). The measured slope of 40 to 45 degrees corresponds to the angle of internal friction ("angle of initial yield") which can be expected for moderately to poorly sorted sands with rough grain surface texture (Allen 1982, pp.60ff.).

The history of Maziwi Island

Based on the reports of fishermen, scientific papers of zoologists, and on the field observations of the author, the history of Maziwi Island is reconstructed as follows:

Until the 1960s a (terrestrial) island existed on the Maziwi coral reef platform. It has been shown on maps dating back to the early colonial times of East Africa (fig.11, Stuhlmann 1894). Originally, the shape of this island was roughly circular with a diameter of 500 to 600 metres, corresponding to a terrestrial surface area of 20 to 28 hectares. The fishermen reported that about 45 minutes were needed to walk once around the island. The island was elevated about two metres above maximum high tide level, its base was the reef flat surface, about 4 metres below maximum high tide level. Based on these figures, the total volume of calcareous sand that was accumulated on the reef platform amounts to 1.2 to 1.7 million cubic metres. This corresponds well with the estimated volume of the present submarine sand fan of 1.5 million cubic metres. The position of the island was to the east of the present sand spit, which did not exist by that time (fig.12). Its maximal extension is roughly indicated by the distribution of the thin blanket of coral sand on the reef platform.

Generally sand cays or sand islands on coral reef platforms are formed by sweeping of calcareous sand from the interstices of a reef flat into mound-like structures by vagaries of wave refraction around and on a coral reef (James 1980). During storms even material from the fore-reef slope may be washed up onto the reef flat. Maziwi Island was built up in this way more than 100 years ago.

The island was situated on the western, more protected leeward side of the coral reef platform. Such a position seems to be typical for the cays on the majority of the small Indian Ocean islands. Milliman (1974, p.195) presumes that this feature is due to the lack of coralline algal ridges on most of the Indian Ocean reef flats which results in a greater exposure to wave and swell energy than on the more protected Pacific Ocean reef flats where algal ridges are usually well developed, resulting in cays preferably forming on the windward side of the reef flats.

Maziwi island was vegetated by up to 25 metres high trees of the species *Casuarina equisetifolia* L.

Brexiaceae; Suahili name: Mkungurufu). Shedd (1974) reported also *Ipomea pes-caprae*, a beach pioneer species, to occur. While *B. madagascariensis* is a woody shrub growing to a height of 3 metres, *C. equisetifolia* is a "tree quick growing in dry and infertile areas and therefore widely planted for ornament, firewood or soil stabilisation and shelter. The nodular roots fix nitrogen" (Wilmot-Dear 1985, p.7). It is common on "sandy areas above or even on seashore above high tide mark, coastal bushland" (l.c.). It is native to Australia, SE Asia and Polynesia, and was most likely introduced to East Africa by early traders or settlers (l.c.). The Germans used to plant these trees for ornament and shelter along the beaches (e.g. harbour road in Pangani town, also there 20 to 25 metres high; sea fronts in Dar es Salaam), and it is therefore possible that these trees were planted on Maziwi Island during the German colonial period. The fishermen gave contradictory answers to the author's question, whether or not the trees were placed in a regular pattern and whether they were of approximately equal height. Therefore, self-sowing by sea-borne fruits cannot be excluded. Very few planted coconut palms existed on the island.

The chance of a sand cay on a reef flat to survive for a long time depends mainly on its ability to stabilize the accumulated carbonate sand. A high degree of stability can be attained by growth of a dense and deeply rooted vegetational cover (Milliman 1974, p.196). A cay may thus reach a state of labile equilibrium with the eroding forces. Maziwi Island had obviously reached this state, and according to the sand cay classification of Milliman (1974, see above) it belonged, during this period, to type No.4. Any change of this state of labile equilibrium could, however, lead to a destruction of the island by migration of sand into the lagoon.

Between the 1920s and the 1950s Maziwi Island lost little of its beaches (not more than about 15 metres on all sides according to the Pangani fishermen). No considerable shifting of sand and no building-up of new beaches was observed during this period. The rate of erosion increased tremendously during the second half of the 1960 decade. The first *Casuarina* trees were eroded on the eastern side of the island during the second half of 1968 (mainly during high tides in combination with storms between June and September). The most intensive erosion took place on the eastern side, but the other beaches were affected as well. Several tens of metres were lost within one year. The eroded sand was carried westward by beach drift forming new beaches closer to the western margin of the coral platform. Shrubs (but no *Casuarina* trees) started growing in the supratidal zone of the newly formed beaches. During the early 1970s, the migrating sand reached the western reef edge. Part of it moved down the reef slope into the lagoon and the submarine fan began to form.

Until 1974 the terrestrial part of Maziwi Island had shrunk to the size shown in fig.12. The approximate size and position of the island in July-October 1974 is documented in a sketch given by Shedd (1974). Frazier (1974) describes the situation as follows: "Erosional forces cause the Island's terrestrial area to be constantly shifting, keeping the vegetation in a continual state of flux. Consequently there are large building beaches and beach platforms where sand has been recently deposited, and climax woodland with dense vegetation does not have the opportunity to dominate" (p.1).

Shedd (1974) observed that "Unusually high spring tides were eating away metres of shoreline. Nests (of turtles) that were two and three metres above the crest were entirely washed out before the incubation period (48 to 62 days, author after Shedd 1974) was over, and nests that were ten and fifteen metres inland were flooded during these tides" (p.6f.). The zoologists used to transfer eggs of turtles that were laid below the beach crest: "We dug them out ... and we transferred them to a safer place inland. All of these sites were eroded away before a week passed" (l.c.). "The east side of the island was surrounded by fallen trees which formed an effective impasse (for the turtles) from sea to beyond the beach crest. The west side was the only side with a deep water approach - no reef surrounding it. There was very little vegetation on the west as it was often flooded by high tides. The north and south sides were surrounded by the reef" (l.c., p.11). Shedd supplied a sketch showing a typical beach profile during this period and the difficulties turtles were facing in climbing up to the dry beach (fig.13).

The last *Casuarina* tree fell most likely in 1977. In 1978 the entire area of the "original" island was submerged. The newly formed sand spit to the west bore only shrubs which were not higher than 2 metres and, therefore, not older than a few years. The length of the vegetated part of the spit was about 50 meters. Between 1978 and 1982 the sand spit shifted to its present position. The last (small) vegetation disappeared most likely in 1980.

Assuming a constant annual rate of erosion between 1968 and 1982, the island must have lost about 100,000 cubic metres of sand per year into the lagoon. Since 1982 the sand spit has not changed its position significantly. Obviously, the same amount of sand that is presently carried down its submarine slopes into the lagoon, is supplied to the spit from the coral reef platform. It can, therefore, be assumed that a state of equilibrium was reached again, when all sand was submerged below spring tide level. This assumption is also supported by the author's observations on other intertidal/subtidal sand spits. Fungu Yasin, a sand spit at the northern end of a large coral platform 24 km NNW of Dar es Salaam has not changed its size or position at least for the last two decades. The same seems to be true for the sand spits on Fungu Ya Zinga and Fungu Ushongo south of Maziwi Island.

A chance of natural re-building of a large terrestrial sand island on the Maziwi coral platform in the near future does not exist. Sand once lost into the deep back-reef lagoon is lost for ever, at least measured on a human time scale. The amount of new calcareous sand produced by abrasion and by decay of skeletons of organisms is an insufficient source. Furthermore, there are reasons to presume that the forces which are responsible for the disappearance of the island are still active (see below).

Causes of the disappearance of Maziwi Island

The Pangani fishermen being questioned whether the vegetation on Maziwi Island was cut by people for firewood or other purposes answered that only dry wood was collected by fishermen during their stop-overs on the island for making small camp fires. The only incident in which living vegetation was purposely removed occurred about 25 years ago, when people from Pemba Island came to Maziwi Island and cut small trees for charcoal production. These activities were immediately stopped by the Tanzanian Government.

The fishery officers in Pangani reported that dynamite fishing was a common practice in the area before nets were introduced a few years back. This fishing method has definitely damaged the ecosystem of the coral reef community, and it might have reduced the overall growth rate of the reef (i.e. the capability of the hermatypic organisms to cope with a rising sea level), but it has not destroyed the existing geological structure "coral reef".

Since direct interference of humans with the ecosystem of Maziwi Island can be largely excluded as a main causal factor (not considering global factors, such as increased carbon dioxide content in the atmosphere due to burning of fossil fuels and vegetation), possible reasons for the disappearance of the terrestrial part of the island might have been:

(a) Rapid tectonic subsidence (e.g. caused by an earthquake).
(b) Erosion due to extraordinarily heavy storm event(s).
(c) Wave erosion due to a higher sea level or due to a significantly changed long-term wave climate.
(d) A combination of (a)-(c).

Subsidence of land due to crustal movements

The seismic data available for this section of the East African coast exclude the possibility of rapid subsidence caused by an earthquake. There have not been any earthquake tremors during the last decades with epicentres close to Pangani and of magnitudes high enough (at least magnitude 5 on the Richter scale) to initiate such movements. This conforms with the observations of old inhabitants of Pangani town, who are not aware of any such events having occurred since their childhood.

The author had all earthquake epicentre and magnitude data from 15 July 1971 to 27 September 1986 available, but unfortunately no earlier data. During this period, earthquakes of low magnitude (closest to Pangani) occurred on 07.06.1973 at 06 degrees 00' S/40 degrees 50' E (in the oceanic crust east of Zanzibar) and on 05.05.1975 at 05 degrees 00'S/40 degrees 30'E (in the oceanic crust E of Pemba Island). A series of weak earthquake tremors was reported between 14.05.1985 and 03.12.1985 east of Pemba and Zanzibar between 5 and 6 degrees S and at around 41 degrees E. All of the epicentres were much too distant from Pangani (>100 km) to cause any crustal movements in this area. The coast between Dar es Salaam and Tanga seems to be seismically very quiet.

The movements along the NNE-trending Tanga fault (vertical throw of more than 3000 metres), which resulted in the formation of the submarine canyon or graben between the mainland and Pemba Island, are of pre-Middle Jurassic age. Subsequently only minor warping occurred, and there is no indication of any reactivation of this fault during the Holocene (Kent et al. 1971, p.98).

The general trend of crustal movements along the East African coast since the Pleistocene has been positive (uplift). Raised Pleistocene coral reef terraces, which occur almost everywhere in the coastal belt from Mozambique to Somalia, give evidence of this phenomenon.

Furthermore, Maziwi Island is situated at a sufficiently large distance from any river delta (80 km from the Wami River delta) to exclude the possibility of local subsidence due to rapid deltaic sedimentation. The Pangani river mouth is an estuary, a river valley drowned during the post-glacial rise of sea level, and fluvial sediment discharge into the sea is low.

Meteorological factors

All fishermen the author interviewed said, they were not of the impression that wind, current, or wave regimes around Pangani have changed, compared to the time they first began fishing (1924, 1926, 1948, 1955). The period of the year during which erosion of the Maziwi Island beaches was most intensive, June to October (SE-monsoon), has always been stormy and waves have been high. Unfortunately, precise meteorological data for the Pangani area (even recent ones) are not available, and, to the author's knowledge, also wave periods and amplitudes have never been measured. However, there is no reason to assume that any significant changes have occurred since the 1920s.

Sea level rise

All fishermen said, their impression was that, the sea level today is higher than in former times. They estimated a rise by 1 to 1.5 feet (30-45 cm) since the 1920s. Although these figures seem to be overestimated, their observation conforms with the globally observed trend. According to the data published by UNEP (1987, p.113, table 2.6), a eustatic rise of the global relative sea level by 10 cm during the period 1920 to 1980, seems to be a realistic estimate. Such a rise will inevitably affect the equilibrium of sand supply - sand removal along beaches, will cause sand to be deposited further offshore, and will cause retreat of most low-lying coastlines composed of unconsolidated sediment by a horizontal distance hundreds to a few thousands times the amount of the vertical rise (see Pilkey 1983). Even a small rise of the sea level will disturb the sensitive state of labile equilibrium under which a vegetated sand cay like Maziwi Island can exist.

The extremely rapid erosion of the beaches of Maziwi Island occurred only during high tides in the stormy period between July and October. During low tides waves and swell approaching from east broke (and still break) at the reef front. During high tides waves had to travel across the only very gently inclined reef flat for more than half of a kilometre before they reached the beach of the island, dissipating a large proportion of their energy by friction with the coral flat surface. Since the orbital diameter of a wave decreases exponentially with the distance from the surface of the sea, a rise in sea level of only 10 centimetres, which cannot be compensated by upward growth of the reef-building organisms due to various reasons (e.g. damages to the ecosystem caused by dynamite fishing), would considerably diminish the loss of wave energy due to friction with the sea floor.

A sea level rise not compensated by coral growth will also allow a larger number of waves to reach the beach. A simple computer simulation model (modified after Martinez 1987) assuming a wave period of 8 seconds, a deep-water wave amplitude of 2 metres (mean) varying according to a Rayleigh distribution, and a breaking criterion of (height of breaking wave/water depth) = 0.78 shows that, after a rise of sea level by 10 cm, particularly during mid-tide a considerably higher proportion of waves will reach the beach without being broken (5 to 15% more compared to the number of waves reaching the beach before the sea level rise, figs.14a,b). During high tide no changes occurred, because already initially, before sea level rise, nearly all waves proceeded to the beach face unbroken.

In any case, the amount of wave energy dissipated at the sandy beach will increase and will affect the sensitive balance between the various physical parameters which permitted the island to exist for many decades or even for centuries.

This factor alone, the rise of the sea level, could be the reason, why the terrestrial part of Maziwi Island disappeared within less than two decades. The sediment this island was composed of was especially suitable for being eroded easily, once a disequilibrium situation occurred. It was not only unconsolidated (loose sand), but also incohesive (no clay, fine silt or organic components).

The critical period for Maziwi Island began in the late 1960s. About the same time an increase of the rate of erosion of many beaches in Tanzania was observed. The Pangani fishermen reported that in a village close to Pangani (Buyoni) people had to shift their huts to places further inland since 1963. There was no erosion before this time. Erosion of the Funguni beach, a few hundred metres north of the Pangani river mouth started in the early 1970s and is still continuing. Heavy mineral placers (mainly composed of garnet and ilmenite), which can only form on open shores under erosive conditions (high wave energy combined with little sediment supply, Fay 1988, Tanner 1961), and fallen vegetation are clear indicators. This beach was prograding before this time. South of Pangani the first coconut palm trees fell into the sea in 1987. The road along the Pangani harbour was probably flooded for the first time during the 1960s. In September 1987 and September 1988 high floods occurred in the Pangani estuary and damaged the embankment. The three kilometres long protection wall which was built by the Germans at the end of the 19th century, is now collapsing making Pangani town vulnerable to flooding (Daily News of 18 November 1989, Dar es Salaam).

The rate of erosion along the beaches north of Dar es Salaam has increased since the 1960s and has meanwhile reached an alarming magnitude. Ocean Road in Dar es Salaam and several places along other beaches in this area were flooded during a spring tide in September 1987. According to reports of villagers, the dry parts of sandy beaches on Mbudya and Bongoyo Islands north of Dar es Salaam were flooded during this tide for the first time. It must be assumed that the situation is similar for most parts of the Tanzanian coast, but unfortunately little research has been done until now.

Possible implications for other coral islands

The fate of Maziwi Island demonstrates what might (not must) happen to similar islands in the near future if the sea level continues to rise. Particularly vulnerable are islands whose terrestrial area consists entirely or largely of unconsolidated sediments, like many atolls in the Indian and Pacific Oceans (Laccadives, Maldives, Chagos Archipelago, Diego Carcia, Amirante Islands, Aldabra, Farquhar, Cocos Islands and others in the Indian Ocean; a large number of atoll islands in the Central and South Pacific, like the Caroline, Marshall, Gilbert, Ellice, Fiji, and Bora Bora Islands). Compared to these Islands Maziwi Island was very small, and it was never inhabited by people. Many of these atolls are densely inhabited.

Along the coasts of most mainlands, a loss of a strip of several hundreds of metres or even a few kilometres of coastal land by erosion usually does not mean a significant loss of land if the total area of a country is considered. If the Tanzanian coast retreats by one kilometre in average, the country would lose less than 0.1% of its total terrestrial area. Under the same circumstances the Maldive Islands would virtually vanish. Examples of the probable fate of some of the smaller South Pacific Islands are given by Hulm (1989).

The high stabilization and restoration costs for beaches along mainland coasts are, therefore, under national-economic and environmental aspects only justified for towns, harbour entrances and other valuable constructions. For undeveloped or poorly developed shorelines many scientists concerned with coastal processes recommend the no-action option, accepting coastal erosion as a phenomenon which cannot be successfully fought by engineering methods on the long range (see Pilkey 1983). It is clear that this option does not exist for small islands.

The author's preliminary study on the disappearance of Maziwi Island could not be based on quantitative oceanographic data, because such data have simply never been obtained in this area in the past. Even scientists who worked on the island during a period, when it was about to be destroyed, were not aware of the fact that they were witnessing its death, but recommended that the island become a marine game reserve.

Maziwi Island was situated on a coral platform in an area of high tidal range. Most of its sand was lost when high tides were accompanied by strong winds of the SE-monsoon. The situation is different for most of the islands in the Indian and Pacific Oceans. Tidal ranges are usually much smaller (e.g. approx. 0.6 metres only on Mauritius, Fagoone 1988), and coral reefs are, therefore, much more efficient in breaking waves and reducing wave energy than along the East African coast. On the other hand, the impact of storms is generally greater on these islands. The spectacular example of the destruction of Maziwi Island, however, shows that the rate of erosion on such islands can be much higher than along beaches of mainlands, which may result in the disappearance of a whole island within a few years. Continuous monitoring of the shore processes and, if necessary, prompt decisions on appropriate beach defense measures, are absolutely essential prerequisites for successfully fighting erosion of island beaches.

Recommendations for further studies along the Tanzanian coast

Maziwi Island

The present preliminary study lacks accurate oceanographic data (waves, tides, currents). The conclusions the author draws of his own observations and the information given to him by other persons would have a stronger scientific base, if such data were available. It is therefore suggested to obtain these data during the coming year(s). Of particular interest are data on the winds, currents, and on the wave climate in the vicinity of the island during the SE-monsoon season. Such studies could be combined with studies on other islands in this region (see below).

Other islands off the Tanzanian coast

A large number of smaller and larger islands (not considering Pemba, Zanzibar and Mafia Islands) occur off the coast of Tanzania. Virtually all of them are situated on ancient or Recent coral reefs. The great majority of these islands are composed of raised reef limestone exposed a few metres above high tide level and forming a rocky shore with cliff development. Unconsolidated sediments (carbonate sands, mangrove swamp deposits) occur mainly in pocket beaches or on the lagoonal sides and are, therefore, better sheltered than Maziwi Island which had no such protection at all. This is most likely the reason why it became the first victim of the sea level rise. However, from reports of people who visited some of these islands it seems to be clear that almost all beaches composed of unconsolidated sediment, even mangrove swamps, are currently undergoing severe erosion.

In order to exclude the possibility that the disappearance of Maziwi Island was a unique event due to local factors, the author suggests case studies (similar to the present one) to be done on a small number of these islands in the region. The following islands between Pangani and Tanga are regarded to be suitable (fig.15):

Fungu Tongone

A small island 25 km south of Tanga, very similar to Maziwi Island (type 1 or 2 of Milliman 1974, p.195f.). Air photographs of 1982 show only a sand spit on the western side of a coral platform obviously shifting into the back-reef lagoon, and the author assumes that it has experienced or is about to experience the same fate as Maziwi Island.

Karange and Yambe Islands

Larger islands situated southeast of Tanga and consisting of raised reef limestone fringed by mangrove swamps and sandy beaches. The mangrove swamps on these two islands have been studied during the past years by Dr. A.K. Semesi, botanist at the University of Dar es Salaam. The two islands belong to types 5 or 6 of the classification of Milliman (l.c.).

There is a good chance that air photos from various years are available for comparative studies. The studies should also include measurements of the meteorological and physical oceanographic parameters relevant to erosion throughout the year (wind, precipitation rate, tides, waves, currents, sediment transport directions and rates), forming the base for developing a computer simulation model which can be used to explain the erosional processes on these islands quantitatively and to make predictions about future developments.

Fungu Kizimkazi

A most interesting place for further studies is Fungu Kizimkazi (also known as Latham Island) situated 56 km southeast of Zanzibar and 50 km off the mainland coast of Tanzania (fig.16). Fungu Kizimkazi lies outside the continental shelf and raises from a depth of more than 500 metres up to sea level. It "marks the culmination of a large submerged bank known from seismic survey to be a structural upwarp far out in the Indian Ocean, and is more nearly analogous to the three large islands (Pemba, Zanzibar, Mafia) near the coast than to the other small features" (Kent et al. 1971, p.49). The structure is possibly caused by uprise of a salt dome in the subsurface. Evaporites are known to occur in the uppermost Karroo (Lower Jurassic) of the southern mainland of Tanzania (e.g. Mandawa anticline).

The island's terrestrial part is only a few hundred metres in diameter and consists of sand covered by guano derived from seabirds which use this place for nesting (type 2 of Milliman l.c.). Probably because of excessive manuring by guano, the island does not bear any vegetation. A meteorological (tidal) station was established here during colonial times which is meanwhile out of function.

Fungu Kizimkazi is "the most important seabird breeding station along the entire eastern Africa coast and the only known breeding ground of the Masked Booby and Crested Tern" (Howell 1988). Furthermore, the island is known as a breeding site for green turtles. It has been proposed to become a marine protected area (category VI, Resource Reserve, IUCN/UNEP 1984, p.59).

The author suggests a short study to be performed on the present status of the island with respect to erosion. This study should include a prediction of the consequences for this island of a further rise of the sea level and of the likelihood that this important seabird sanctuary will disappear within the coming decades.

Coast of Tanzania mainland and of the large islands (Zanzibar, Pemba, Mafia Islands)

Tanzania urgently needs the establishment of a coastal inventory and of a littoral data base for her entire shoreline, comparable to the one existing for the West and Central African region (UNEP/UNESCO/UN-DIESA 1985). As a first step, the author suggests a modern classification of the coast to be worked out, following the guidelines given by Quélennec & Ibe (1989). This can be achieved by analysis of air photos accompanied by ground control methods. The results of this study will be used for identification of coastal segments undergoing or being endangered by erosion and as a base for advising the Tanzanian Government regarding future coastal development plans and coastal protection/restoration measures.

Fortunately, the largest part of the Tanzanian coastline, except for the vicinity of towns and cities, is still poorly developed. The negative experience of the rapid development of the beaches north of Dar es Salaam since the early 1970s, all of which are now affected by intensive erosion as well as by desperate efforts of individuals and companies trying to save their property, must not be repeated in other areas in future. These formerly beautiful beaches are now lost as residence areas; houses, hotels, and other constructions being continuously damaged or destroyed. They are lost as recreational areas, too; ruins, collapsed sea walls and groins will spoil the beaches and tidal flats for many decades. If no buildings had been built near to the beach and if a set-back line of several hundred metres had been introduced twenty years ago, the economic problem of beach erosion would not have arisen for a long time. The beach had retreated landward eroding mainly coastal bushland, but it had continued to exist as a natural environment. It is obvious that some of the beach protection measures have even caused a more intensive erosion along unprotected sections of the beach (e.g. Bahari Beach Hotel and the coast north of it). The proposed establishment of a littoral data base would help to avoid such fatal mistakes in future. On the advice of the Coastal Erosion Monitoring Committee of the University of Dar es Salaam, the Tanzanian Government introduced in 1988 a set-back line of 150 metres from any beach for new constructions. In practice, however, people continue to build on the beaches, and backing of this measure by legislation seems to be necessary so that individuals who ignore it face prosecution (Coastal Erosion Monitoring Committee 1988, p.52).

If Tanzania should contribute to the global monitoring of short and long-term sea level fluctuations, self-recording tidal gauge stations are required to be installed in the major harbours of Tanzania (Tanga, Dar [illegible] and staff for operating the stations must be trained. The marine charts published during the 1960s show several tidal stations along the Tanzanian coast (e.g. off Pangani, Latham Island). According to the information the author received from colleagues, none of them is still in operation. Up to now, only one modern device has been installed in the Dar es Salaam port in July 1986. Due to lack of trained manpower, tidal staff readings have not been taken daily, as required for calibration, and, therefore, possible calibration errors do not allow drawing any conclusions about eventual small annual changes of the mean sea level.

References

Alexander, C.S. (1969): Beach ridges in northeastern Tanzania. -- Geogr.Rev.,59, pp.104-122.

Allen, J.R.L. (1982): Sedimentary structures. Their character and physical basis. Vol.1. -- Developments in Sedimentology, 30A, 593 pp., Amsterdam-Oxford-New York (Elsevier).

Beach Erosion Monitoring Committee (M. Fay, C.J. Griffith, I.A. Hemed & K.M. Lwiza) (1988): Beach erosion along Kunduchi Beach, north of Dar es Salaam. -- 55 pp., Dar es Salaam (National Environment Management Council).

Fagoone, I. (1988): Coastal marine ecology and fisheries of Mauritius. -- Proc. of workshop on ecology and bioproductivity of the marine coastal waters of eastern Africa, pp.75-84, Dar es Salaam (University of Dar es Salaam).

Fay, M. (1988): The formation of beach placers and its relationship to coastal erosion: A case study on the coast north of Dar es Salaam (Tanzania). -- Abstract, Workshop on ecology and bioproductivity of the marine coastal waters of eastern Africa, p.17, Dar es Salaam (University of Dar es Salaam).

Fay, M. & Griffith, C.J. (1988): Beach erosion along the coast north of Dar-es-Salaam (Tanzania): Magnitude and possible causes. -- Abstract, Geosom 87, p. 63, Mogadishu (Somali National University).

Frazier, J.G. (1974): Maziwi Island Game Reserve: A proposed management programme. -- Unpubl. report, 3 pp.

Howell, K.M. (1988): The conservation of coastal water birds of Tanzania. -- Proc. of workshop on ecology and bioproductivity of the marine coastal waters of eastern Africa, pp.162-173, Dar es Salaam (University of Dar es Salaam).

Hulm, P. (1989): A climate of crisis: Global warming and the island South Pacific. -- 22 pp., Port Moresby (The Association of South Pacific Environmental Institutions).

IUCN/UNEP (1982): Conservation of coastal and marine ecosystems and living resources of the East African Region. -- UNEP Regional Seas Reports and Studies No.11, 73 pp., UNEP.

IUCN/UNEP (1984): Marine and coastal conservation in the East African region. -- UNEP Regional Seas Reports and Studies No.39, 293 pp., UNEP.

James, N.P. (1980): Reefs. -- In R.G. Walker (ed.): Facies models, Geoscience Canada, Reprint Series 1, third printing, pp.121-132, Toronto (Geological Association of Canada).

Kent, P.E., Hunt, J.A. & Johnstone, D.W. (1971): The geology and geophysics of coastal Tanzania. -- Geophysical Paper No.6, Natural Environment Research Council, Institute of Geological Sciences, 101 pp., London.

Martinez, P.A. (1987): Wave: Program for simulating onshore- offshore transport in two dimensions using the Macintosh computer. -- Computers & Geosciences, 13, pp.513-540.

Mainoya, J.R. & Pratap, H.B. (1988): Marine conservation strategy for sustained bioproductivity of marine coastal waters in Tanzania. -- Proc. of workshop on ecology and bioproductivity of the marine coastal waters

Milliman, J.D. (1974): Marine carbonates. -- 375 pp., Berlin-Heidelberg-New York (Springer).

Pettijohn, F.J., Potter, P.E. & Siever, R. (1973): Sand and sandstone. -- 618 pp., New York-Heidelberg-Berlin (Springer).

Pilkey, O.H. (1983): Shoreline Research. -- In: P.G. Brewer (ed.), Oceanography, The present and future., pp. 87-100, New York-Heidelberg-Berlin (Springer).

Quélennec, R.E. & Ibe, A.C. (1989): Methodology for inventory and control of coastal erosion in the West and Central Africa Region. -- Draft paper, UNEP.

Schuhmacher, H. (1976): Korallenriffe. -- 275 pp., Muenchen-Bern-Wien (BLV).

Seibold, E. & Berger, W.H. (1982): The sea floor. An introduction to marine geology. -- 288 pp. Berlin-Heidelberg-New York (Springer).

Semesi, A.K. (1988): Status and utilization of mangroves along the coast of Tanga, Tanzania. -- Proc. of workshop on ecology and bioproductivity of the marine coastal waters of eastern Africa, pp.174-181, Dar es Salaam (University of Dar es Salaam).

Shedd, M.L. (1974): Report on the turtles of Maziwe Island Tanzania, July-October 1974. -- Unpubl. report, 49 pp.

Stuhlmann, F. (1894): Mit Emin Pascha ins Herz von Afrika. -- 901 pp. & 2 maps, Berlin (D. Reimer).

Tanner, W.F. (1961): Offshore shoals in area of energy deficit. -- Jour.Sedimentary Petrology, 31, pp.87-95.

UNEP (1987): Environmental data report. -- 352 pp., Oxford-New York (Basil Blackwell).

UNEP/UNESCO/UN-DIESA (1985): Coastal Erosion in West and Central Africa. -- UNEP Regional Seas Reports and Studies No. 67, 242 pp., UNEP.

Wiegel, R.L. (1964): Oceanographical engineering. -- 532 pp., Englewood Cliffs (Prentice-Hall).

Wilmot-Dear, C.M. (1985): Casuarinaceae. -- In R.M. Polhill (ed.): Flora of tropical East Africa, pp.1-8, Rotterdam-Boston (A.A.Balkema).

Acknowledgements

The author wishes to thank the following people for their assistance in preparing this study: In Pangani Mr. I.S. Tupa, District Natural Resources Officer, Mr. M.G. Luhui, District Fisheries Officer, Mr. C.D. Kauta and Mr. A. Abdallah, Assistant Fisheries Officers, Mr. A. Mwenjudi, Assistant Forest Officer, the fishermen A. Semwaza (fisherman since 1924), H. Akida (since 1926), M. Amuor (since 1955), and H. Hamoud (since 1948). My fellow diver was Mr. H. Nagorsen of NTC, Dar es Salaam. Mrs. E. Mputy assisted in fieldwork and in running the interviews. I am grateful to Mr. J. Niskala and Dr. R. Clausnitzer, who visited Maziwi Island in 1977 and in August 1978, respectively. Both of them gave me valuable information on the status of the island *during this period* (Dr. Clausnitzer took an 8 mm amateur film). Mr. S. Mkumbege did the laboratory analyses of the sediment samples, and Dr. A Msindai made earthquake data of the East African region available to me.

APPENDIX

Figures 1 - 28

Table 1

Explanation of figures

Fig.1: Location map. (from British Admiralty chart no.3310,scale 1:300,000,1966)

Fig.2: Physiographic map of the sea floor along the East African coast showing Zanzibar (Z.) and Pemba Islands and the 800 metres deep submarine canyon in between (from Bruce C. Heezen & Marie Tharp 1968).

Fig.3: Position of coral reefs (after air photograph June 1982) and currents (according to reports of Pangani fishermen) around Maziwi Island.

Fig.4: Wave refraction pattern around Maziwi Island.

Fig.5: View from air towards east onto Maziwi Island. The small coral reef in the foreground (bearing a sand spit at its northern end) is Fungu Ya Zinga. Photo taken on 3 November 1989 at 17 hours.

Fig.6: View from air towards southwest across the Maziwi coral platform. Observe wave pattern (waves approaching island from east) and breaking waves at reef front during low tide. The small supratidal part of the sand spit situated on the western side of the reef platform is clearly recognizable by its darker colour. In the background the shoreline of the mainland south of Pangani. Photo taken on 3 November 1989 at 17 hours.

Figs.7,8: Air view and sedimentary facies distribution around the sand spit on the western side of Maziwi Island near to low tide. The photograph shows how the sand spit has moved across the back-reef slope. A-B and C-D lines indicate the locations of the cross sections shown in figs. 9 and 10, respectively. Photo taken on 3 November 1989 at 17 hours.

Fig.9: North-south cross section through the Maziwi sand spit showing the calcareous sand now covering the former back-reef slope. Note that horizontal and vertical scales are different.

Fig.10: East-west cross section through the intertidal part of the Maziwi sand spit showing the calcareous sand overlying coral reef flat facies in the east and the former reef edge in the west. Note that horizontal and vertical scales are different.

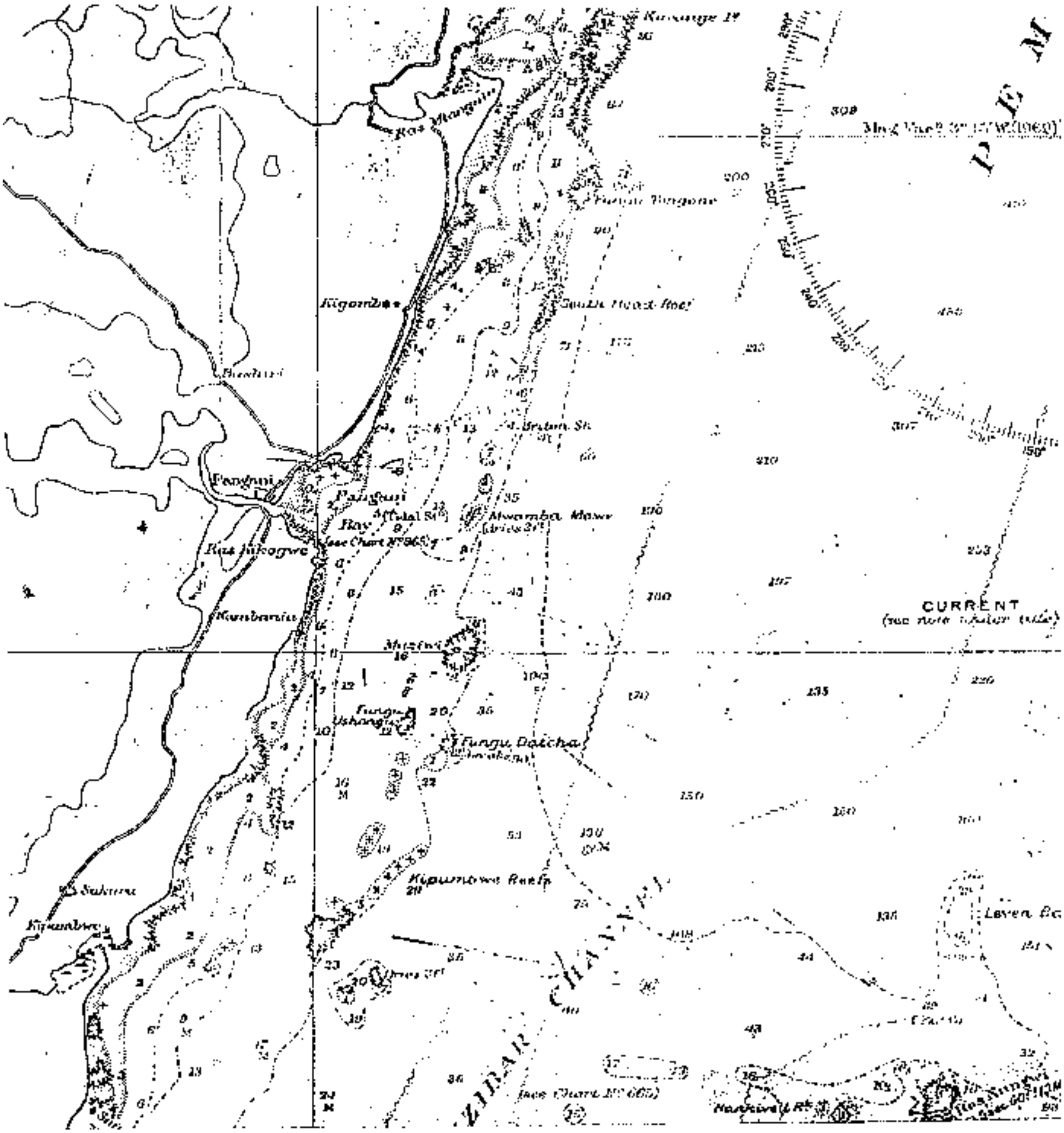
Fig.11: Stuhlmann's geological map of coastal Tanzania (1894) showing Maziwi Island off the Pangani river mouth.

Fig.12: Reconstruction of the shifting of the terrestrial part of Maziwi Island. Red line - approximate beachline before 1968; green line - approximate beachline in July/October 1974 (after Shedd 1974); blue line - present high tide level on sand spit. Note the back-reef edge in the lower left corner and in the middle of the right margin of the photograph. The sand spit has shifted from a more central position on the coral reef platform across the back-reef edge and slope into the deep lagoon (dark blue) between 1968 and 1982. The original position of the terrestrial part is roughly indicated by the extension of a thin blanket of calcareous sand on the reef platform shown as diffuse light coloured patch on the photograph. Air photo taken on 3 November 1989 at 17 hours.

Fig.13: Sketch showing the difficulties for turtles to climb the strongly eroded, steeply inclined beach slope of Maziwi Island in 1974. "A turtle comes up against a sand wall which has been created by erosion during high tides. The turtles which came up against this were not able to climb it to get onto dry beach above the beach crest" (Shedd 1974, p.8, fig.1).

Fig.14a,b: Results of a computer simulation showing the absolute (a) and relative increase (b) of the number of waves reaching the sandy beach unbroken after a 10 cm sea level rise (see text).

Fig.15:	Map showing Fungu Tongone, Karange and Yambe Islands proposed for further research (from German sea chart no.127, scale 1:300,000).
Fig.16:	Map showing the position of Fungu Kizimkazi (Latham Island) proposed for further research *(from German sea chart no.127, scale 1:300,000).*
Fig.17:	View towards west from the eastern end of the Maziwi sand spit. Note the truncated oscillation ripples in the foreground (direction of crests E-W). Inclination angle of beach face on the eastern side is 2 degrees.
Fig.18:	Beach slope on the northern side of the Maziwi sand spit with swash marks. The mainland coast is shown in the background.
Fig.19:	Calcareous gravel concentrated on the plane-bedded sandy sediment surface of the northwestern beach slope. Angle of inclination is 6 degrees.
Fig.20:	High tide mark on the Maziwi sand spit.
Fig.21:	View towards the eastern end of the Maziwi sand spit at mid-tide. Due to refraction waves approch the sand spit from south (right) and north (left) and collide on the spit (breakers).
Fig.22:	The photograph shows the place where the waves break in fig.21, now at low tide. A regular system of asymmetrical ladderbacked oscillation ripples formed (cigarette box for scale). The crests are oriented east-west and are always steeper on the northern sides of the crests, pointing to sand transport from south to north across the ridge (and probably further into the lagoon).
Fig.23:	Fishermen still use Maziwi Island for stop-overs. Note the remnants of trees (shown in figs.24,25) in the water to the right of the boat.
Figs.24,25:	*Stems of Casuarina trees on the northern side of the sand spit give evidence* of the former vegetation on Maziwi Island. These remains of trees are found in large numbers all around the sand spit.
Fig.26:	Burrows of *Ocypode* are frequently found on the sand spit close to the high tide mark.
Fig.27:	But the turtles have gone.
Fig.28:	View towards south onto the Maziwi Island sand spit during mid-tide. The water depth at the position of the boat is approximately 40 metres.



Ras Mangani
Kigombe
Pangani
Pangani Bay
Ras Mkogwe
Kumbaniu
Mwamba Mawe
Maziwi
Fungu Dotcha
Kipumbwi Reefs
Sakura
Kipumbwi
CURRENT
Leven Ba
Fungu Tongone
South Head Reef

Fig. 1

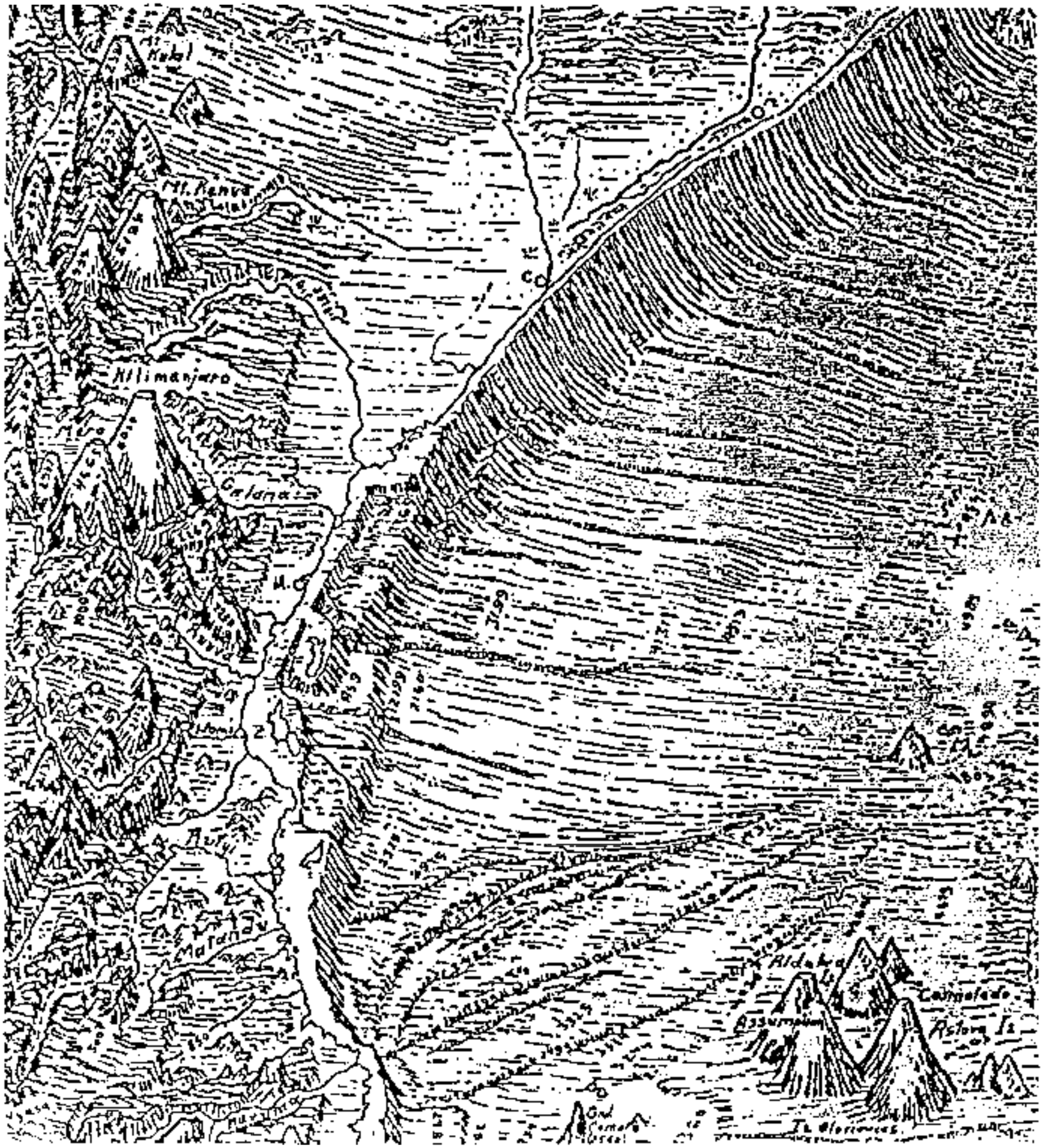
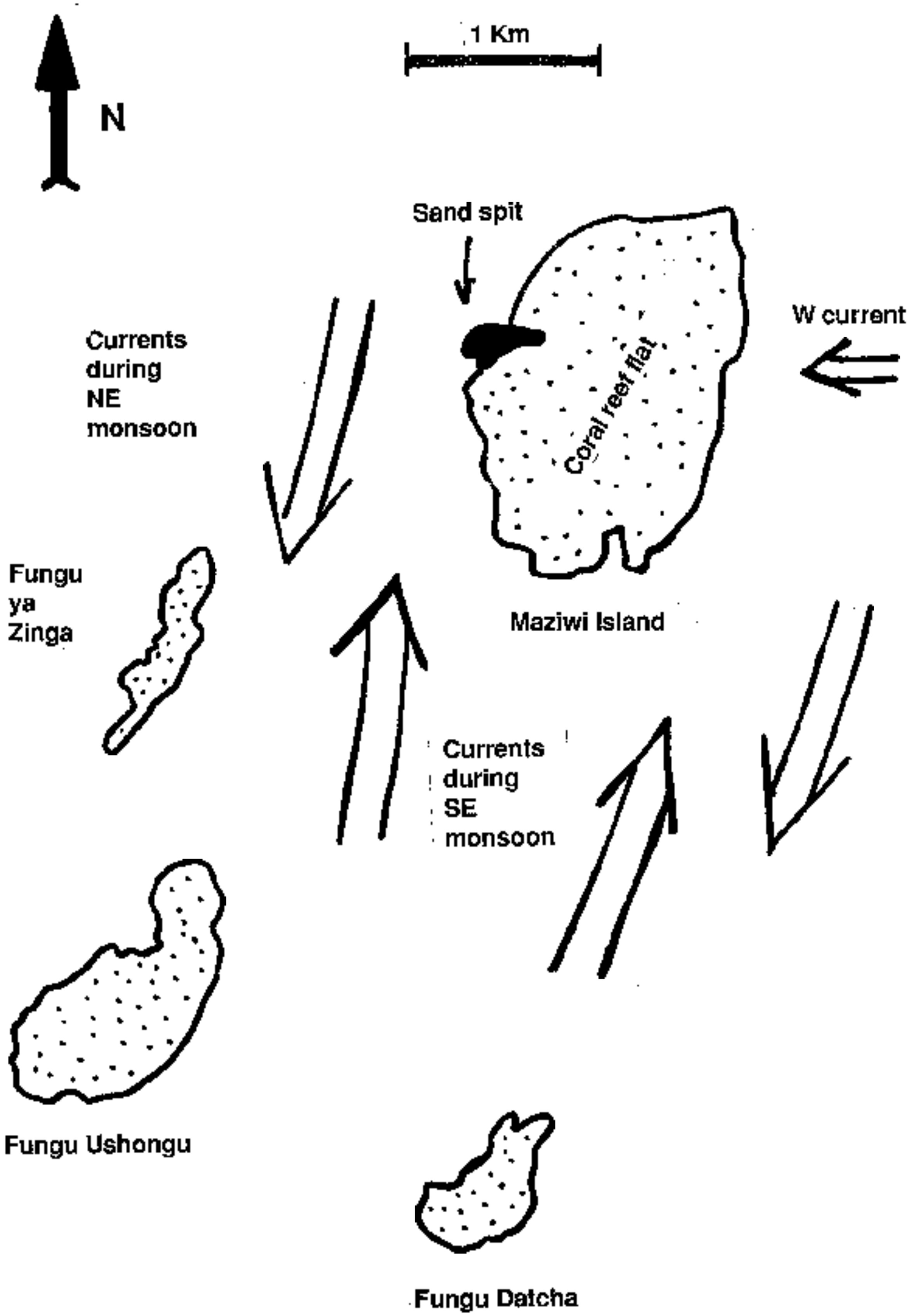

Mt. Kenya
Kilimanjaro
Galana
Aldabra
Cosmoledo
Assumption
Astove Is

Fig. 9



N
1 Km
Sand spit
Currents
during
NE
monsoon
W current
Coral reef flat
Fungu
ya
Zinga
Maziwi Island
Currents
during
SE
monsoon
Fungu Ushongu
Fungu Datcha

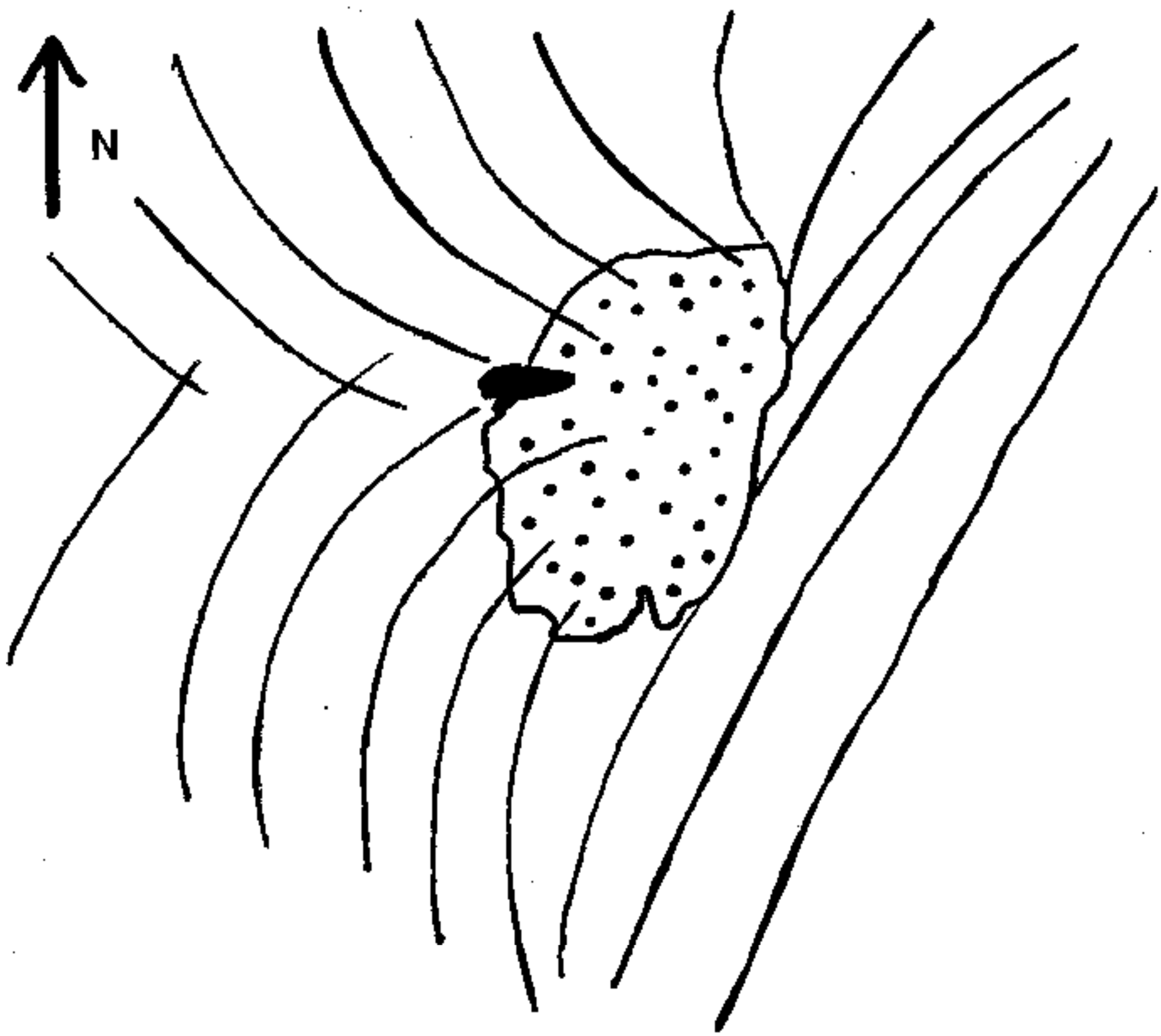


Fig. 4

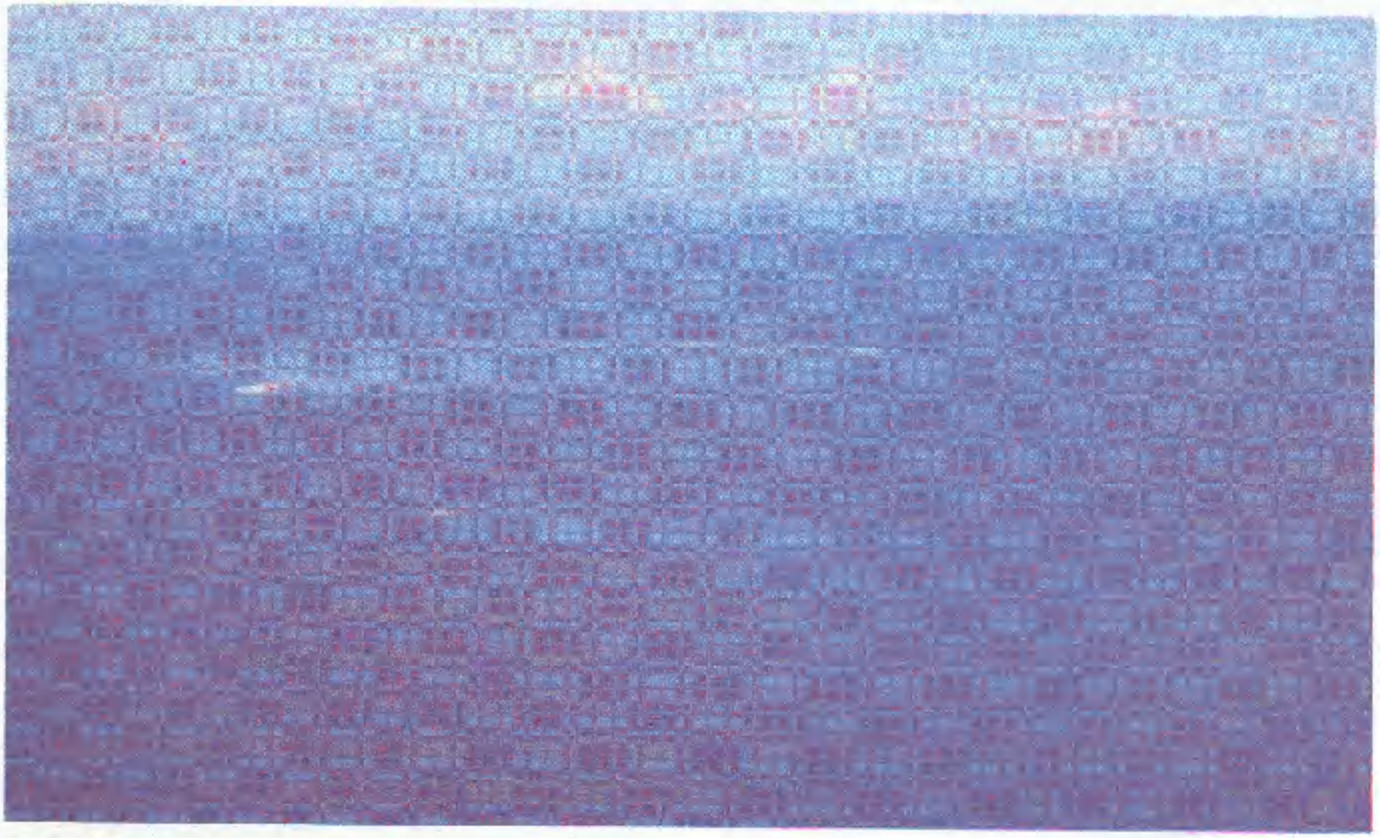


Fig. 5

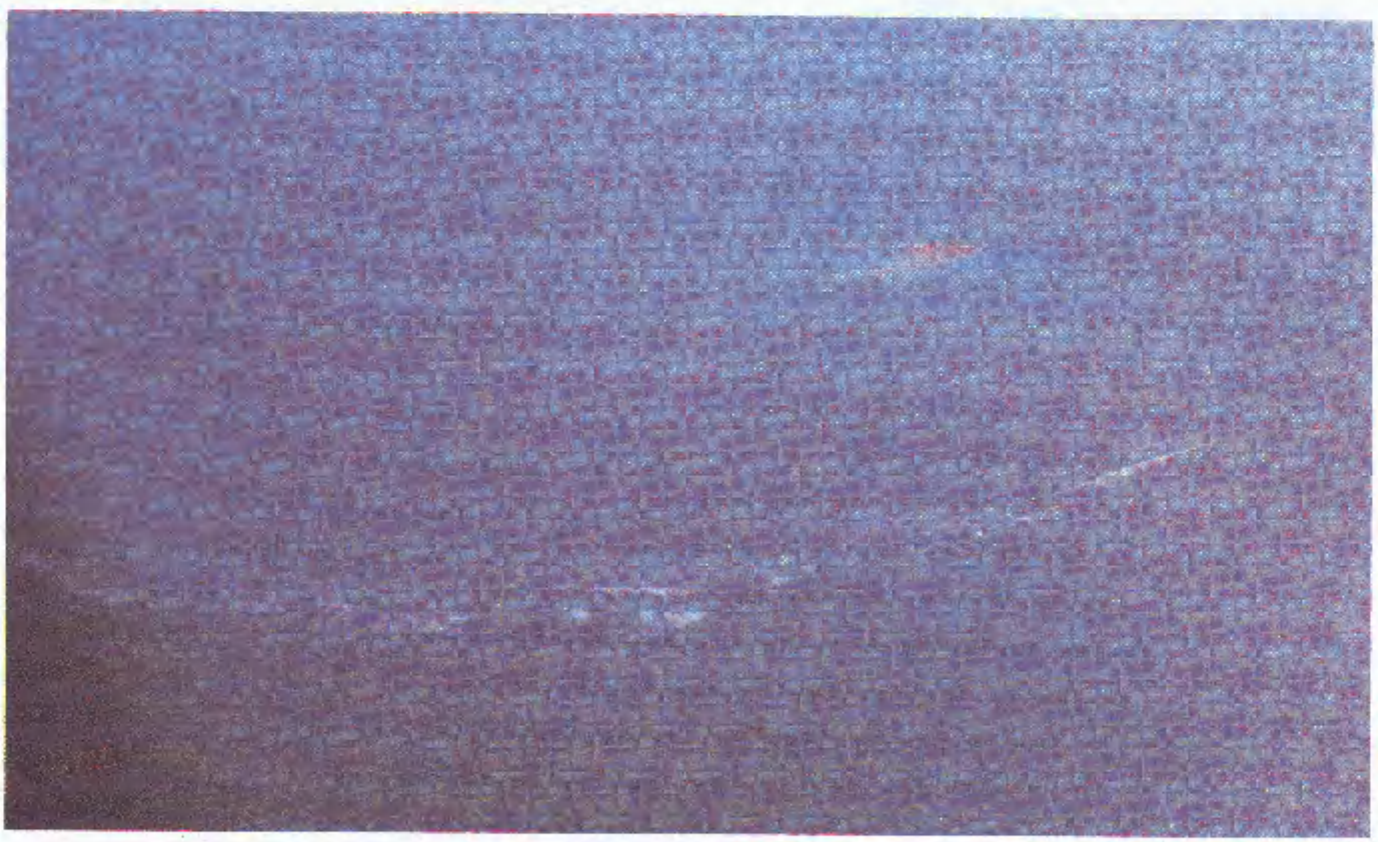


Fig. 6

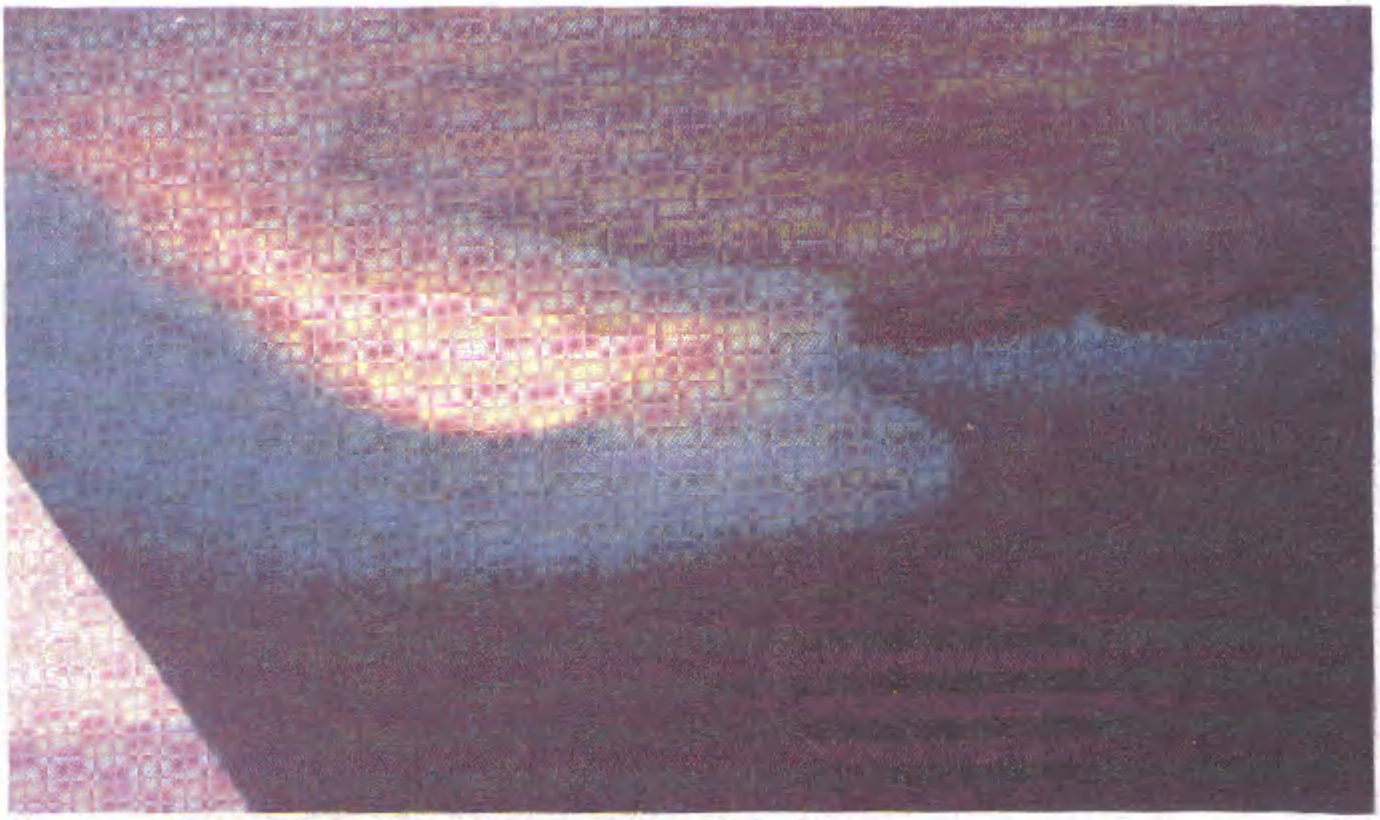
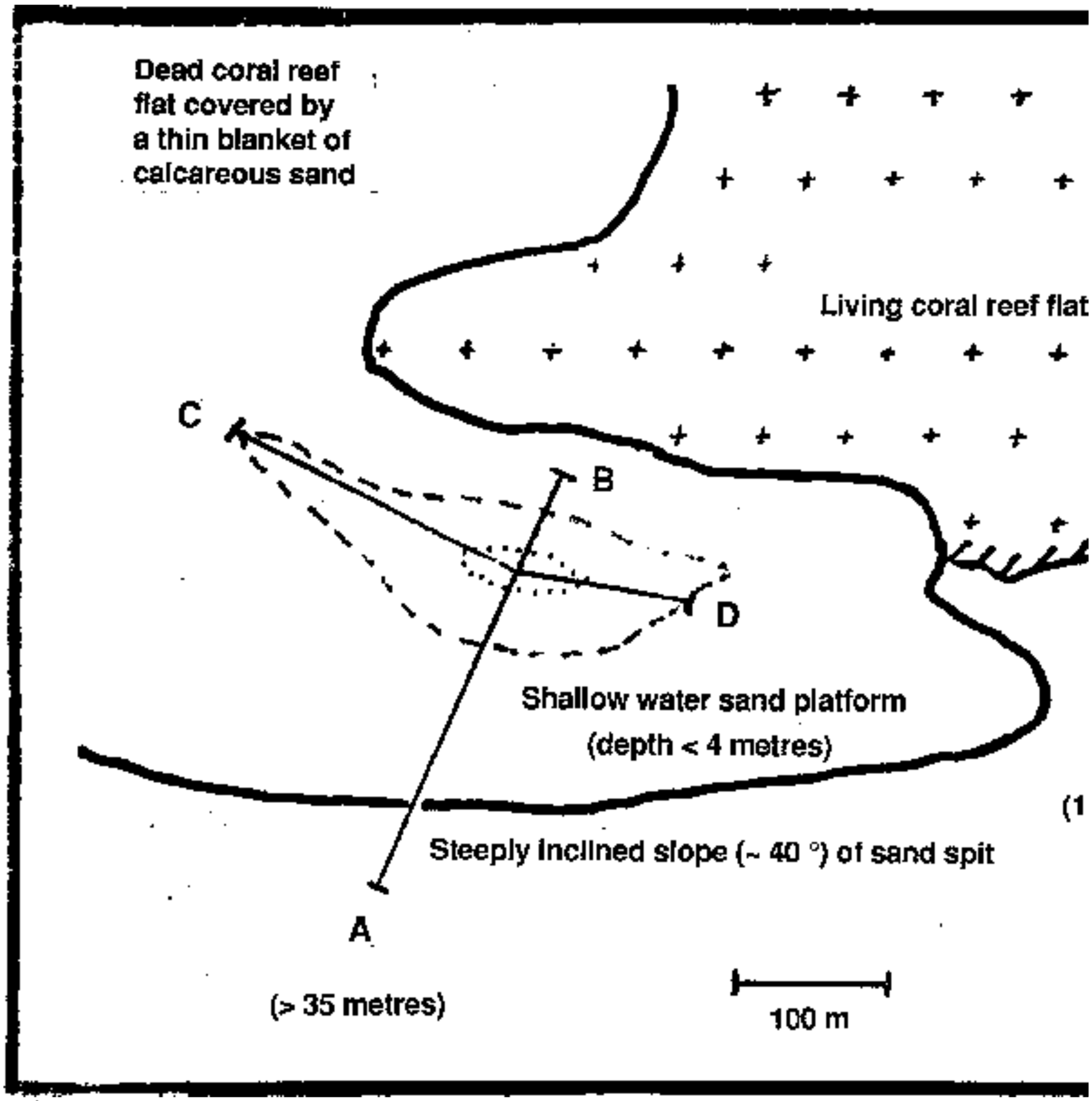


Fig. 7

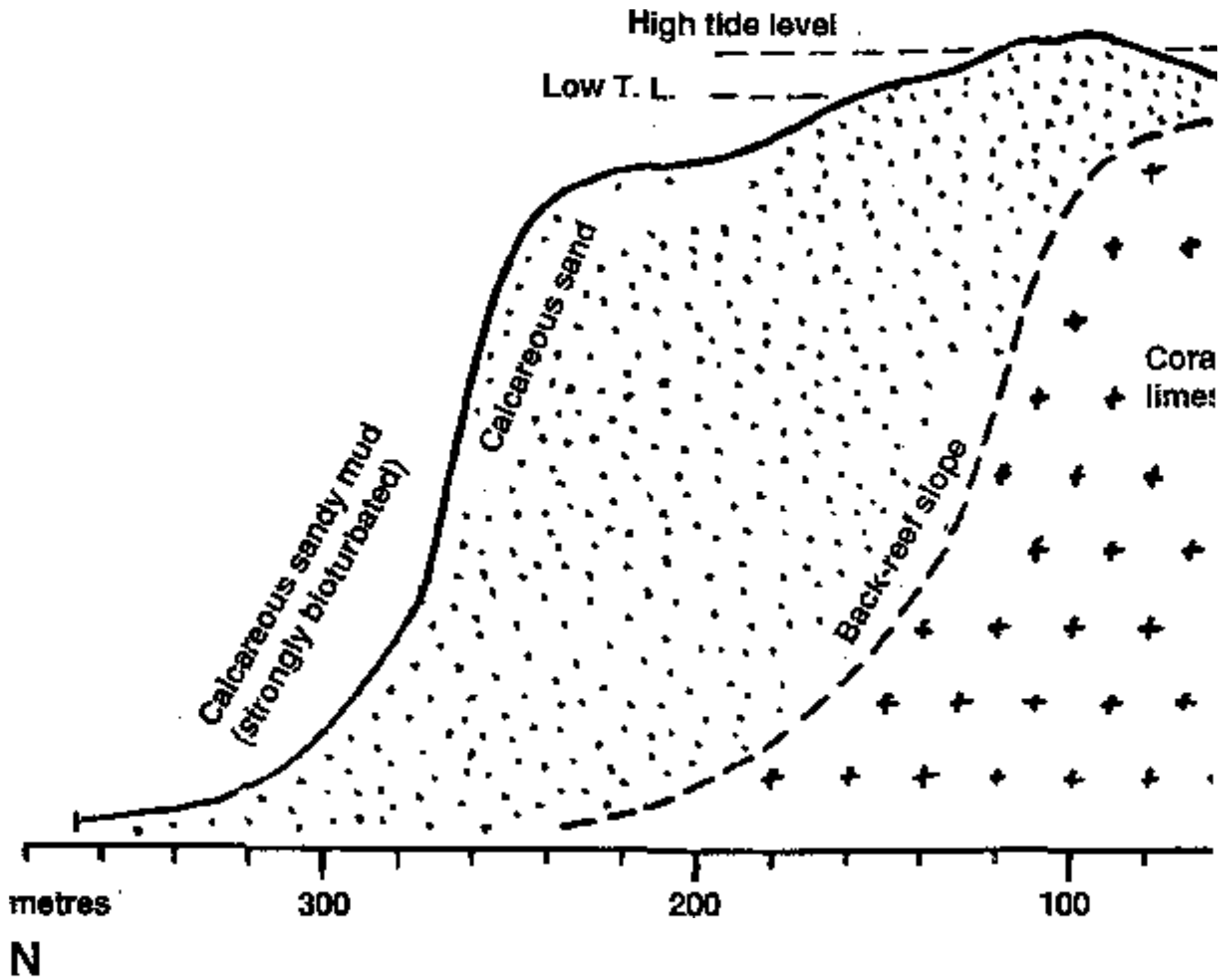


— — — Low tide level

• • • • • • High t

Fig. 8

A



High tide level
Low T. L.
Calcareous sandy mud
(strongly bioturbated)
Calcareous sand
Back-reef slope
Cora
limes
metres
300
200
100
N

Fig. 9

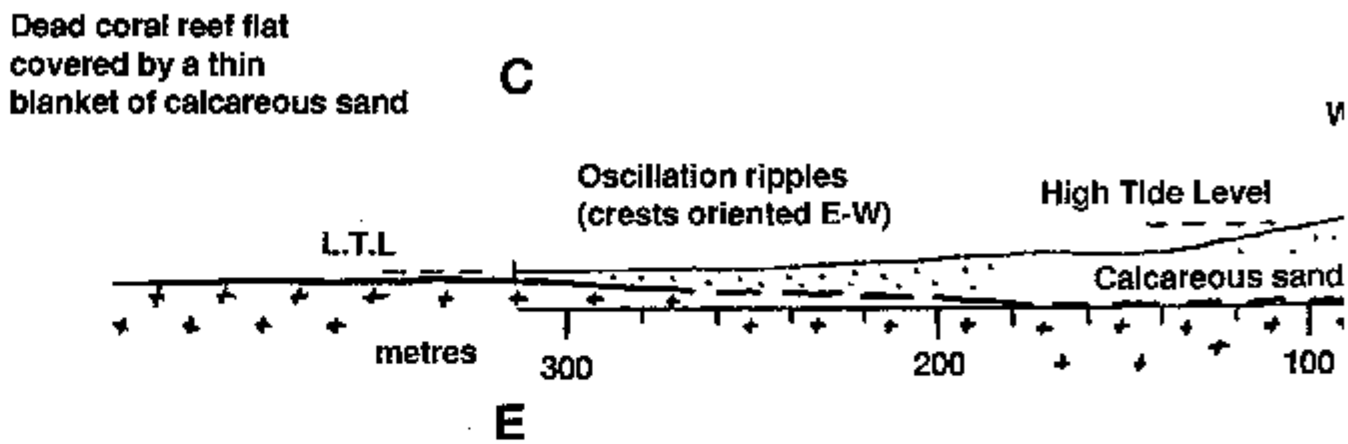

Dead coral reef flat
covered by a thin
blanket of calcareous sand
C
W
Oscillation ripples
(crests oriented E-W)
High Tide Level
L.T.L
Calcareous sand
metres
300
200
100
E

Fig. 10

Fig. 11

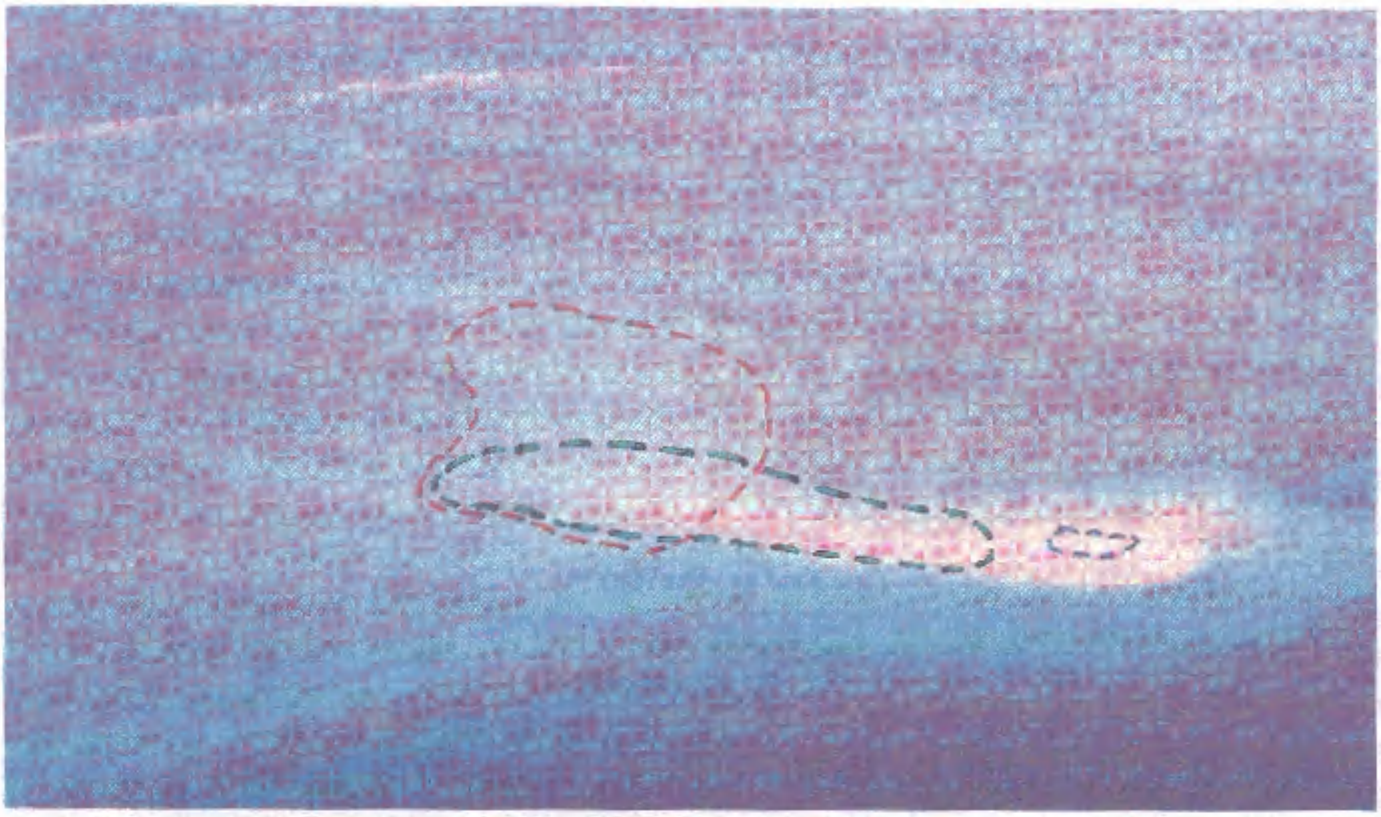
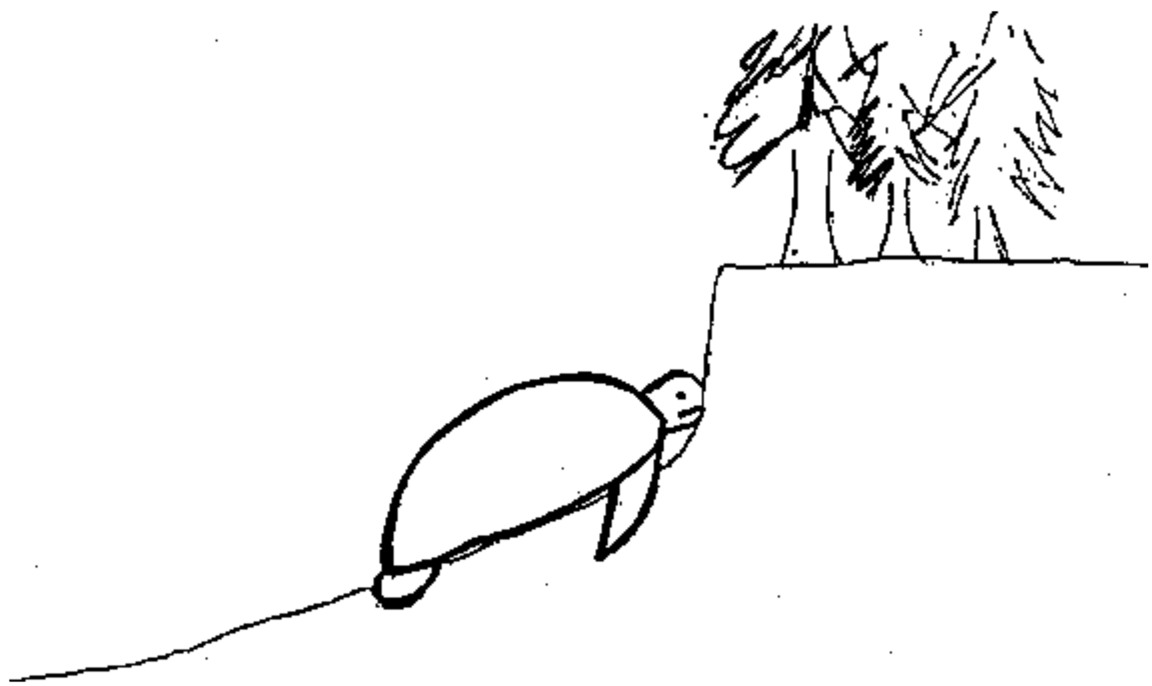
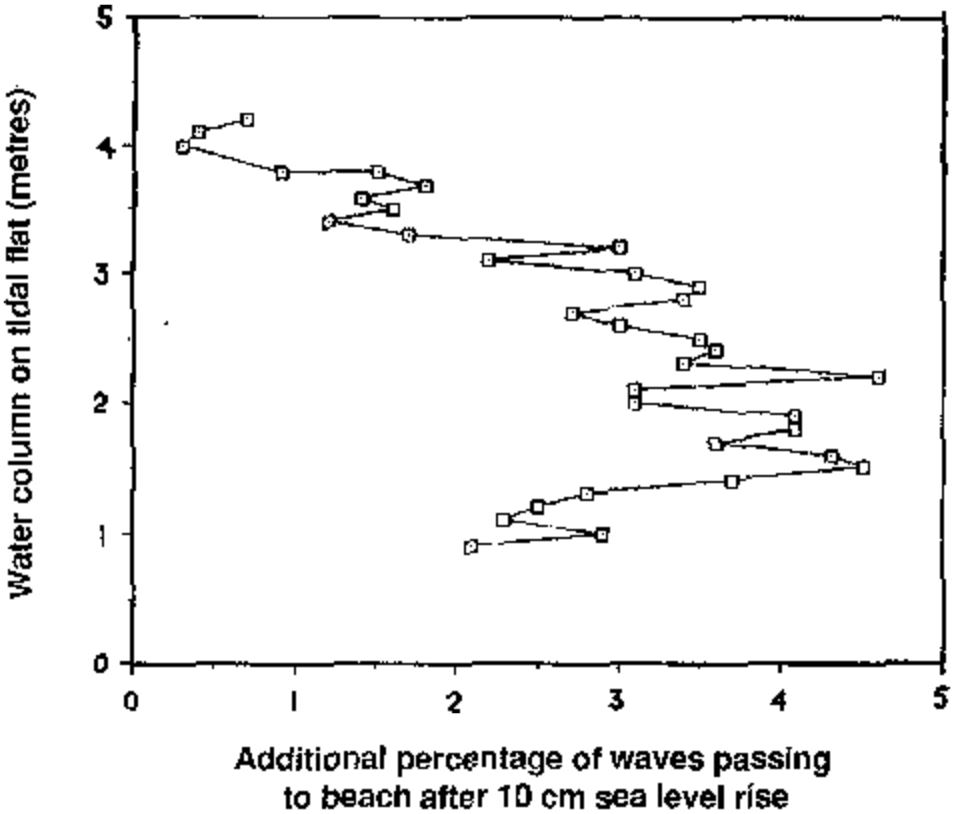


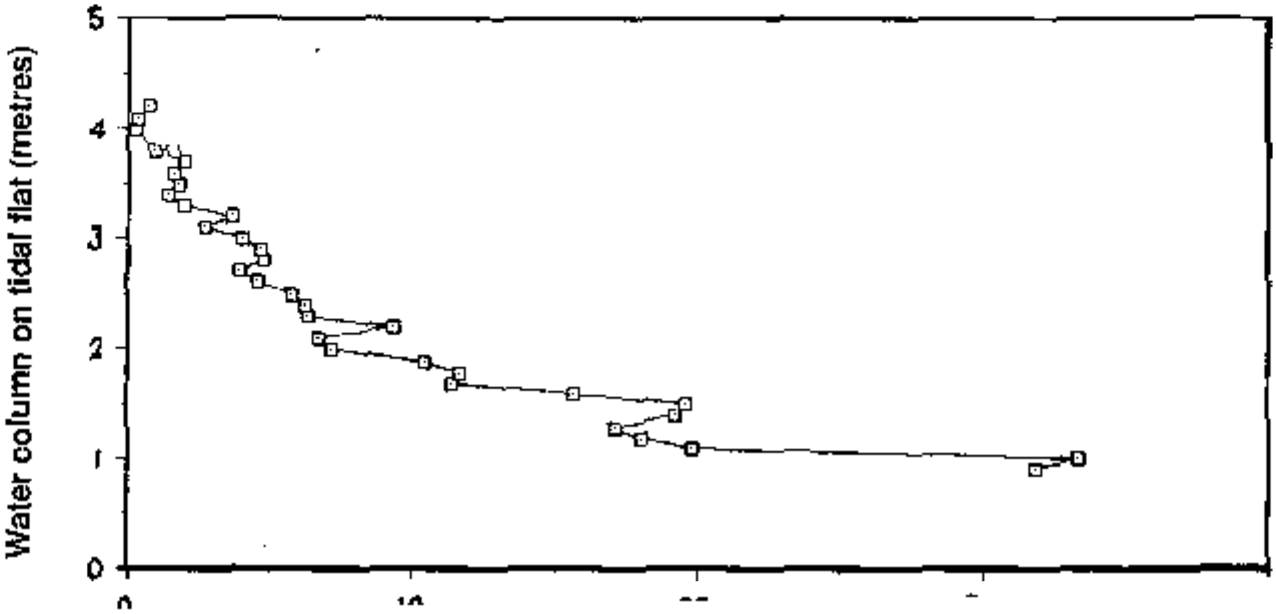
Fig. 12



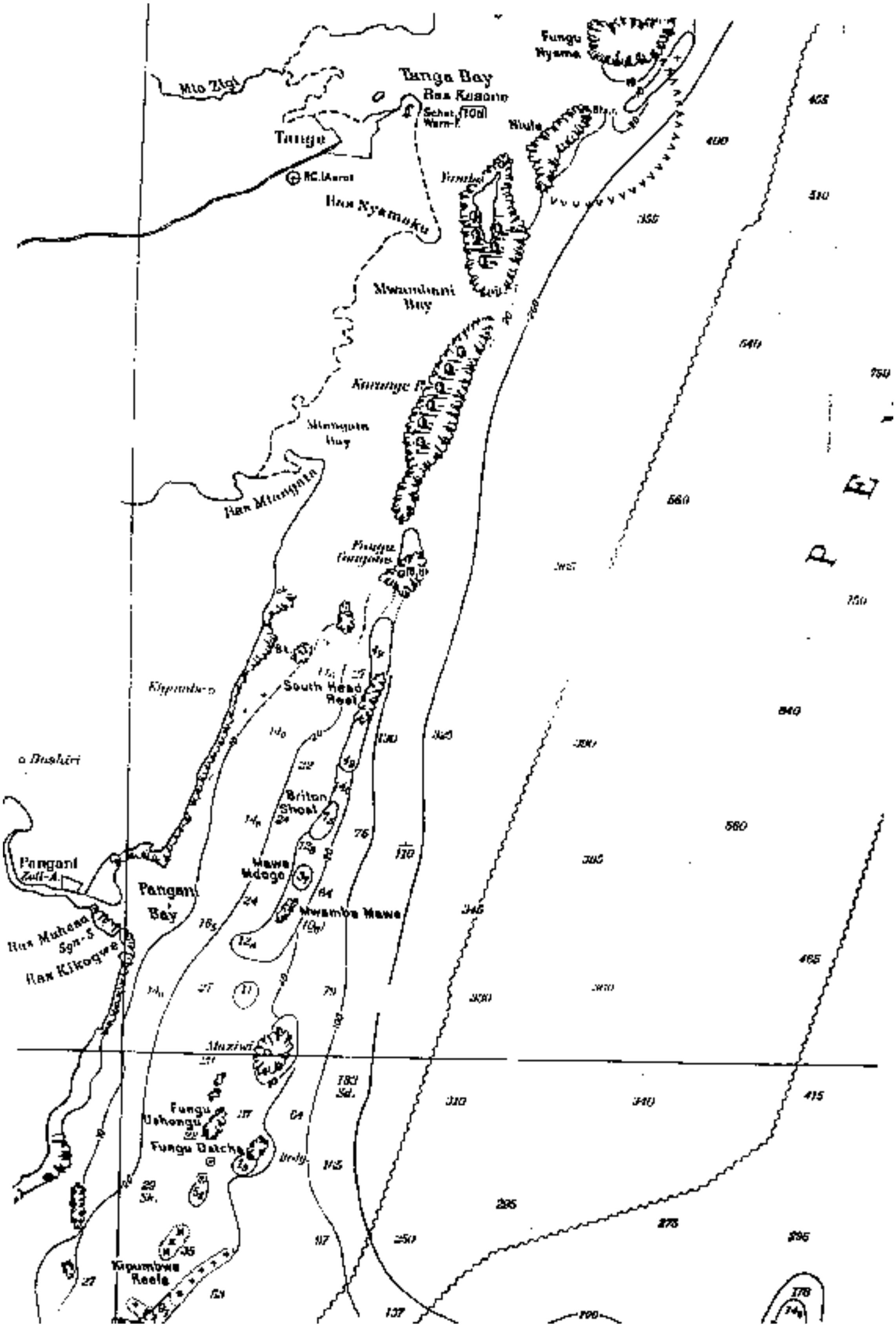


Water column on tidal flat (metres)
Additional percentage of waves passing
to beach after 10 cm sea level rise

a



Water column on tidal flat (metres)



Tanga Bay
Ras Kasone
Tanga
Mto Zigi
Fungu Nyama
Ras Nyamaku
Mwambani Bay
Ras Mtangata
South Head Reef
Briton Shoal
Mawe Mdogo
Mwamba Mawe
Pangani
Pangani Bay
Ras Muhesa
Ras Kikogwe
Maziwi
Fungu Ushongu
Fungu Datcha
Kipumbwe Reefs

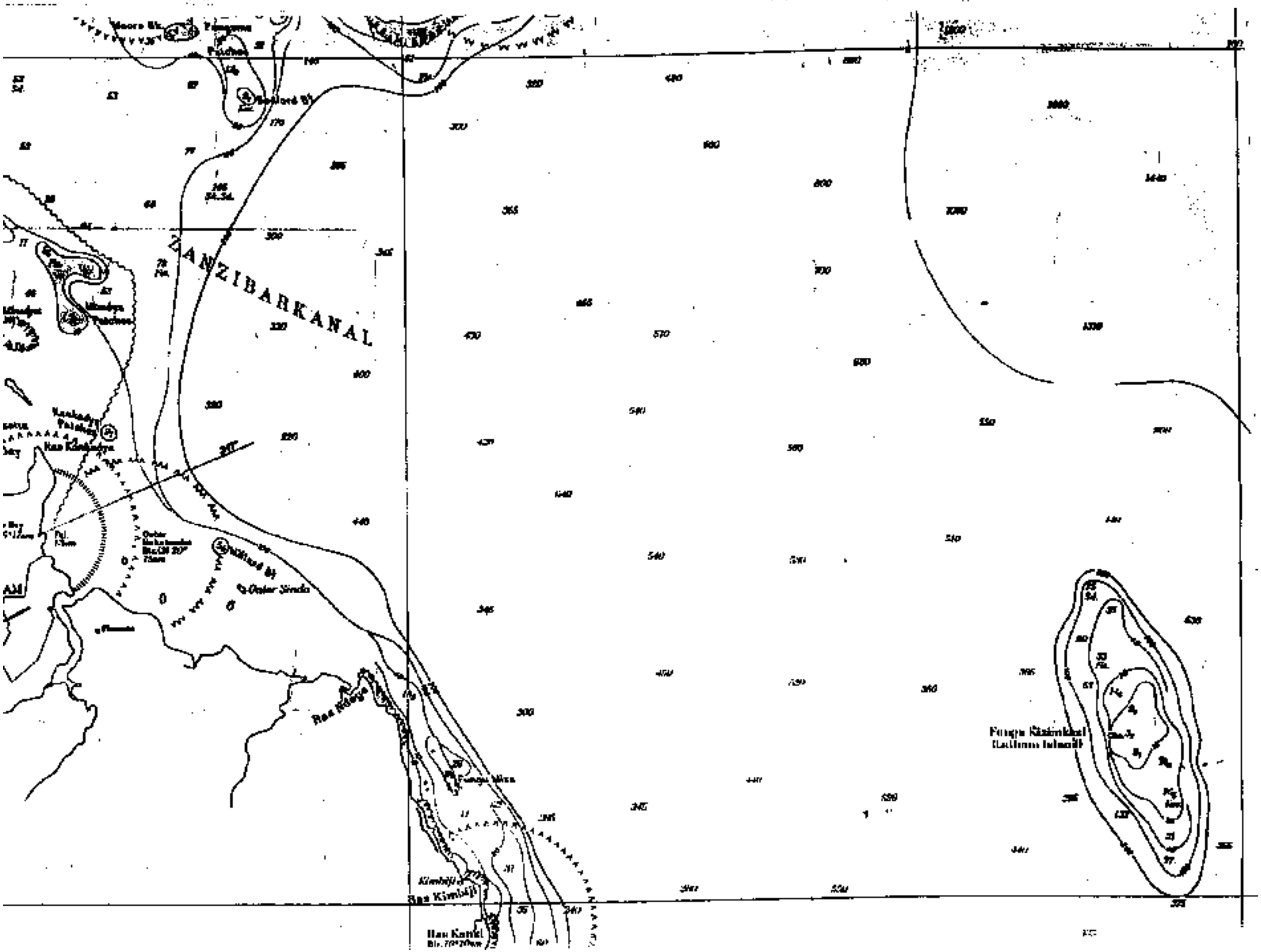

ZANZIBARKANAL

Fig. 17

Fig. 18

Fig. 19

Fig. 20

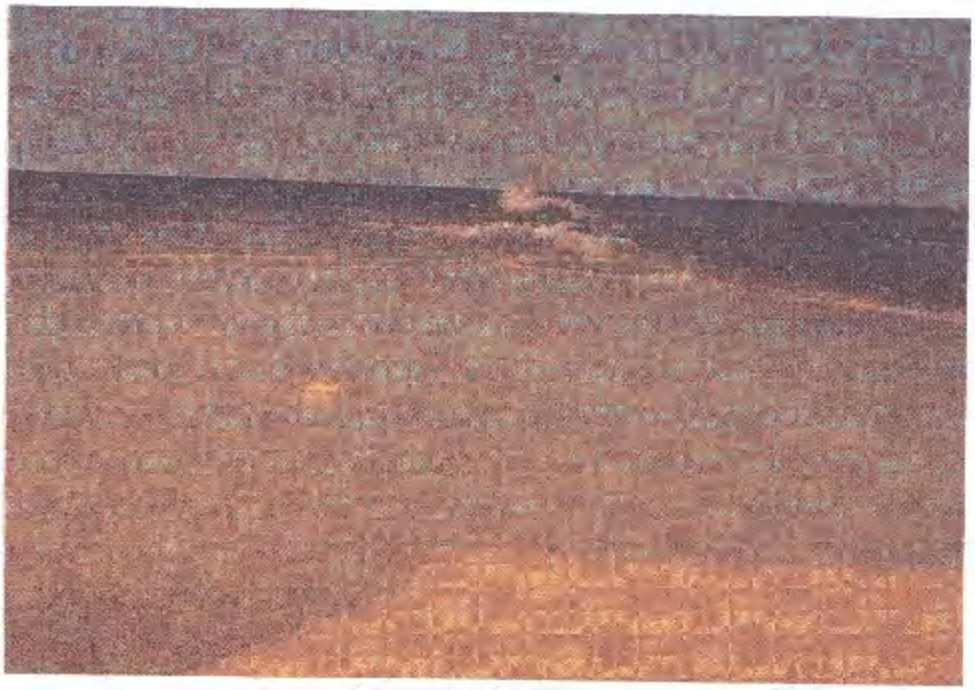


Fig. 21

Fig. 22

Fig. 23

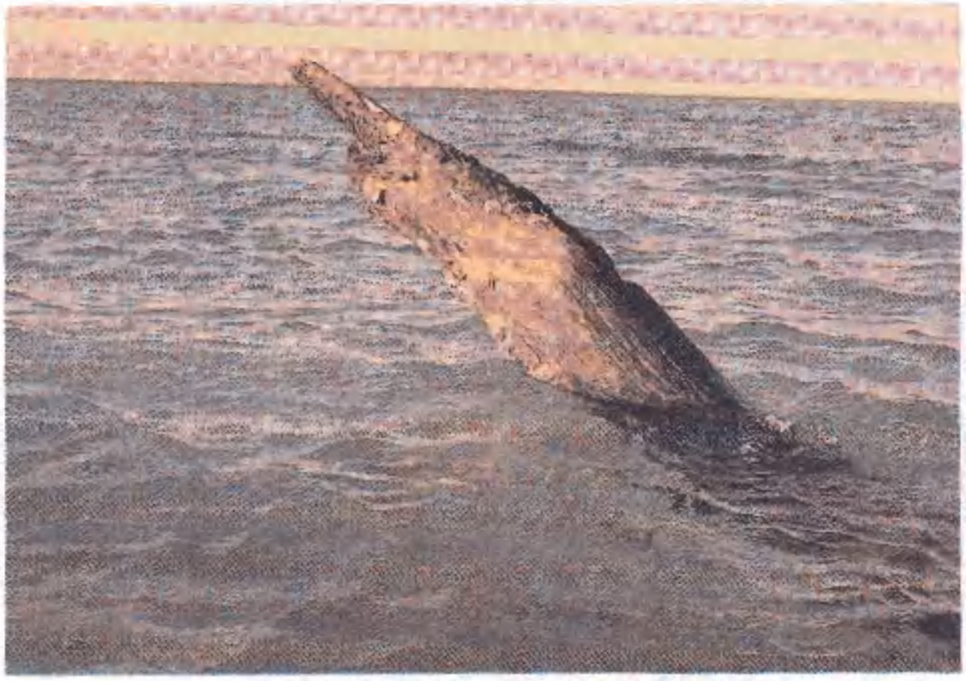


Fig. 24

Fig. 25

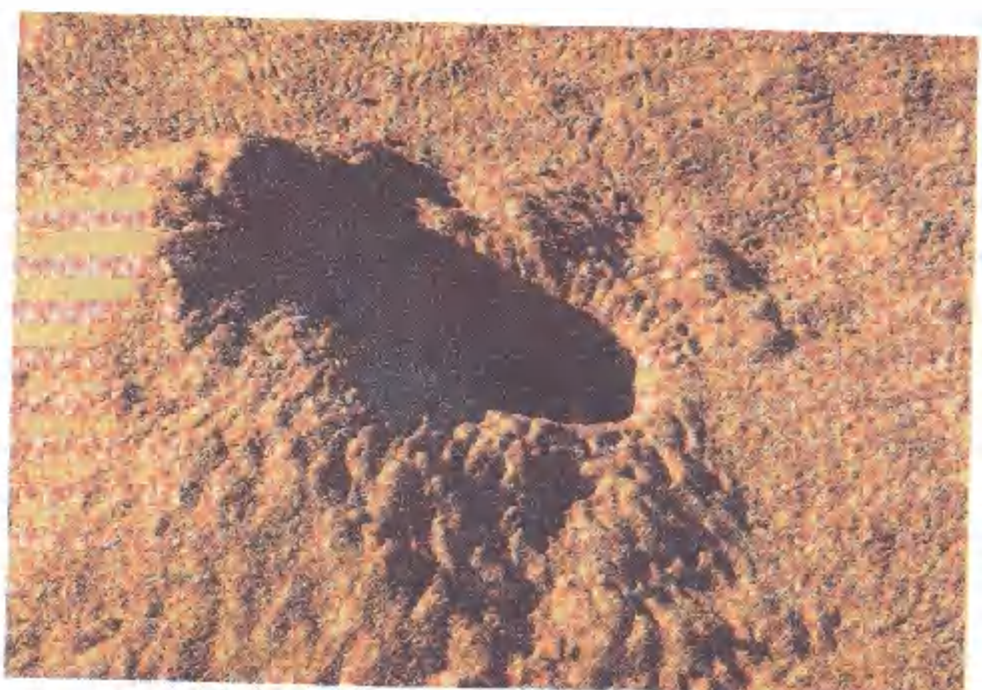


Fig. 26

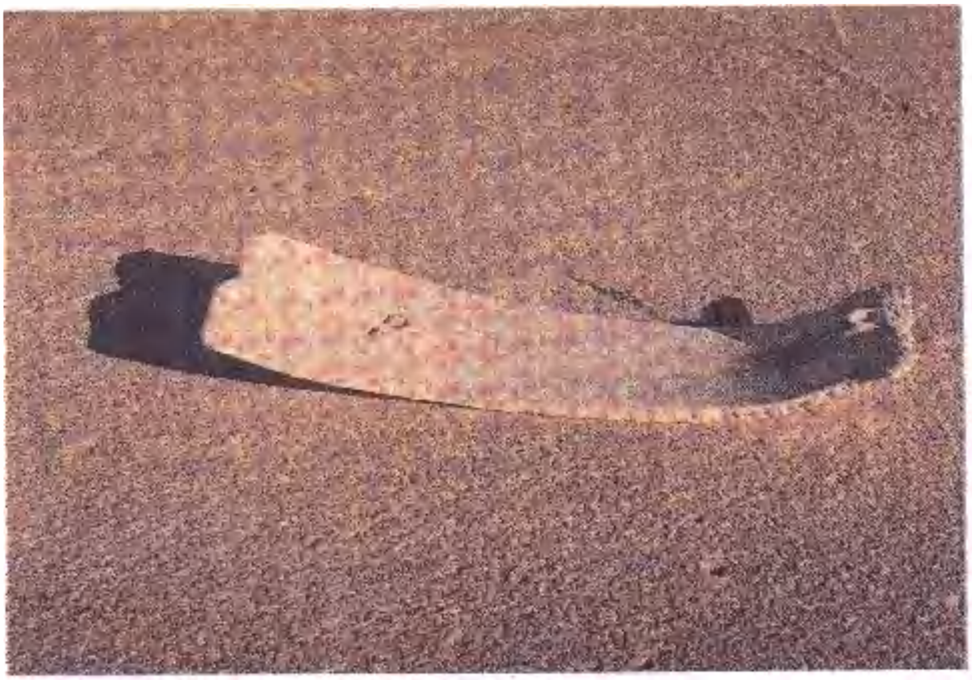


Fig. 27

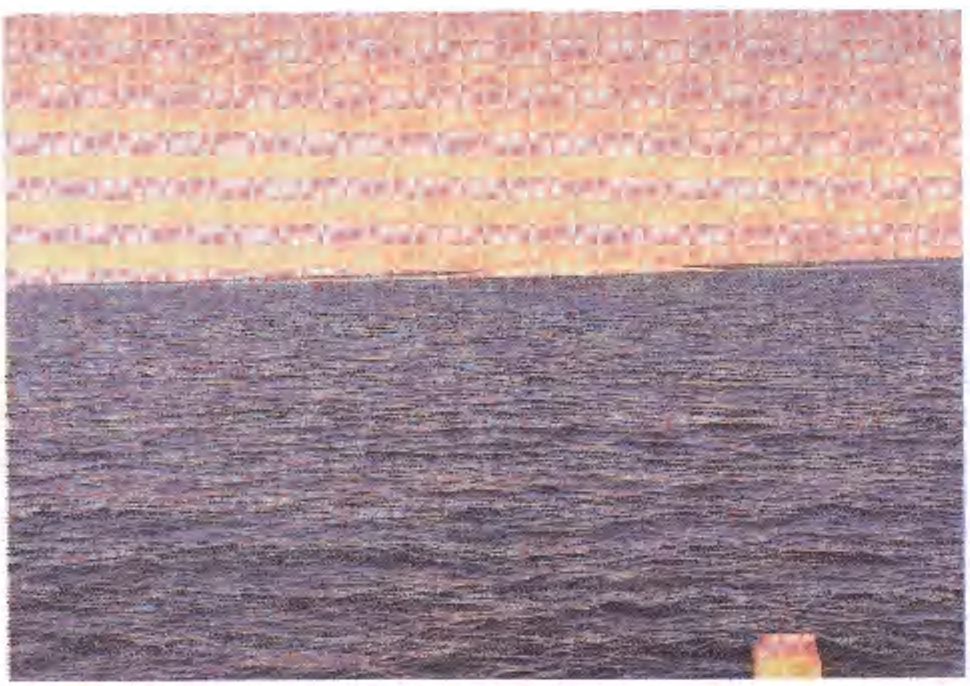


Fig. 28

TABLE 1: Grain size parameters of calcarenites from the M
(based on moments)

Sample No.	Position on sand spit	Median(phi/mm)	Mean(phi/mm)	Sorting(ph
051189/3	base of slope W-side, depth 5 m	-0.34/1.27	-0.55/1.46	1.16
051189/2	base of slope W-side, depth 10 m	0.57/0.67	0.54/0.69	0.93
041189/1	base of slope N-side, depth 25 m	2.72/0.15	2.68/0.16	0.72
051189/1	lagoon, N-side of spit, depth 35 m	2.69/0.15	2.64/0.16	0.69
101189/1	N-side, mid-beach slope, 6°	1.28/0.41	1.13/0.46	0.72
101189/2	E-side, mid beach slope, 2°	1.52/0.35	1.41/0.38	0.47
101189/3	S-side, mid-beach slope, 6°	1.56/0.34	1.40/0.38	0.55
101189/4	W-side, mid-beach slope, 6°	1.68/0.31	1.59/0.33	0.46
101189/5	Top dry beach	1.40/0.38	1.27/0.42	0.58

Note: $phi = -\log_2 \frac{D}{D_o}$, where D = grain diameter in millimetres and D_o = 1 mm.

Verbal description of samples:

051189/3: Very coarse-grained, gravelly calcarenite; moderately sorted; nearly symmetrical distribution; platykurtic.

051189/2: Very coarse-grained, slightly gravelly calcarenite; moderately sorted; nearly symmetrical distribution; leptokurtic.

041189/1: Fine-grained calcarenite; moderately well sorted; negatively skewed; leptokurtic.

051189/1: Fine-grained calcarenite; moderately well sorted; negatively skewed; leptokurtic.

101189/1: Medium-grained calcarenite; moderately well sorted; negatively skewed; leptokurtic.

101189/2: Medium-grained calcarenite; well sorted; negatively skewed; mesokurtic.

101189/3: Medium-grained calcarenite; moderately well sorted; very negatively skewed; mesokurtic.

101189/4: Medium-grained calcarenite; well sorted; negatively skewed; leptokurtic.

101189/5: Medium-grained calcarenite; moderately well sorted; negatively skewed; mesokurtic.

Issued and printed by

UNEP

Oceans and Coastal Areas Programme Activity Centre
United Nations Environment Programme

Additional copies of this and other publications issued by
the Oceans and Coastal Areas Programme Activity Centre
can be obtained from:

Oceans and Coastal Areas Programme Activity Centre
United Nations Environment Programme
P.O. Box 30552