SBORNÍK
ČESKOSLOVENSKÉ SPOLEČNOSTI ZEMĚPISNÉ
ROČNÍK 1971 • ČÍSLO 4 • SVAZEK 76

VÁCLAV CÍLEK

GEOMORPHOLOGICAL DEVELOPMENT OF SEASHORE OF INDIAN OCEAN IN VICINITY OF DAR-ES-SALAAM

Abstract: The geomorphological development of Tanzanian shore appeared in a new light when investigations of deposits of black sands on the shore of Indian Ocean in vicinity of Dar-es-Salaam and some 15 km north of Bagamoyo were completed. As a result it is necessary to say that the development of the deposits of black sands occuring on recent seashore line as well as in older sediments cannot be elucidated apart from the solution of the problem of geomorphological development of the seashore as a whole. The main attention was paid to the solution of problems of the development of the seashore since the end of Pleistocene until the present.

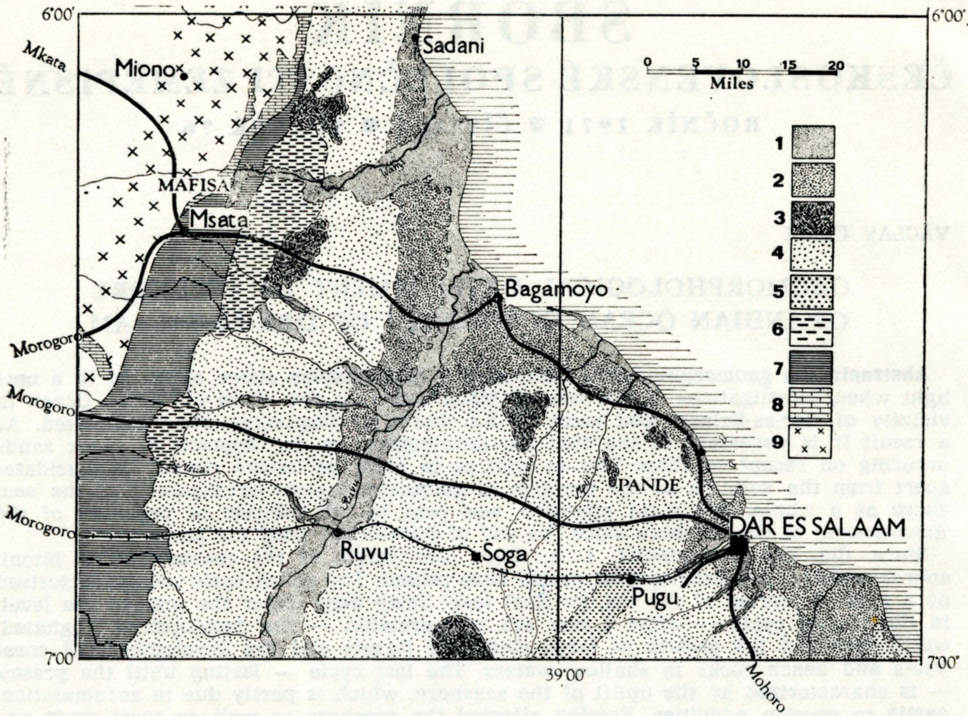
Since the last Interglacial, i. e. since the origin of the coastal terrace Mtoni, approximately three development cycles have passed. The oldest cycle was characterized by a gradual retreat of the sea, its final level being deep under the present sea level. In the second cycle — after a new sea transgression — the development stagnated, which favoured the growth of large mangrove forests and the development of coral reefs and beach rocks in shallow waters. The last cycle — lasting until the present — is characterized by the uplift of the seashore, which is partly due to accumulation, partly to erosion activities. Erosion affected the seashore as well as coral reefs and sandy banks projecting above the water surface.

Introduction

In spring 1970 a group of members of the Tanzanian Geological Survey started geological mapping of the seashore north of Dar-es-Salaam. This was necessary for two reasons: first of all to meet the demants of a growing construction of hotels along the coast in vicinity of the capital, and secondly to enable discovering of black sands deposits. The latter became recently the subject of interest of all world industrial companies because of their content of ilmenite, rutile, garnet, monazite, kyanite, zircon, and other minerals. The extraction of these minerals being very simple and effective they represent an immediate economic profit.

Our group was provided with rough-terrain cars, with a motor boat and a drilling machine. There were no topographic plans, and therefore we had to use aerial photographs. In field work only a small field stereoscope was applied whereas final evaluations of obtained data and detailed determinations of the morphology of the terrain were carried out afterwards by means of a large Wild-stereoscope. Thus a combination of routine geological mapping together with stereoscopic evalution of aerial photographs enabled a reasonable solution of the morphology of this part of seashore.

The area is in many places only difficult of access. There are mangrove swamps, an intricate network of channels and depressions flooded alternately by rising tide, a thick bush as well as dangerous shallow waters with coral reefs. On dry land investigations were carried out predominantly on foot, the shore was investigated from the boat. Our work was seriously handicapped by the hot and humid climate, heavy and frequent rain showers and the thorny bush crowded



1. Geological map of the coastal sediments between Dar es Salaam and Bagamoyo (W. R. Moore 1963).
Explanations: 1 — Holocene, 2 — Upper Pleistocene, 3 — Lower Pleistocene, 4 — Miocene to Pleistocene, 5 — Lower Miocene, 6 — Cretaceous, 7 — Jurassic, 8 — Karroo, 9 — Marble, Usagaran.

with snakes and sometimes also lions. On sea we had unpleasant experiences with strong shore currents, frequent surf and shoals of sharks.

There is only one road leading from Dar-es-Salaam to Bagamoyo. It is asphalted for only some 25 km, becomes dust- and sand-covered, hardly passable by terrain cars. From this main road several lanes lead to the shore. The area between Dar-es-Salaam and Kunduchi is well accessible thanks to an intense construction of hotels along the shore. The only perennial river in the area is the Ruvu emptying in a typical estuary to the Indian Ocean north of Bagamoyo.

Older Literature

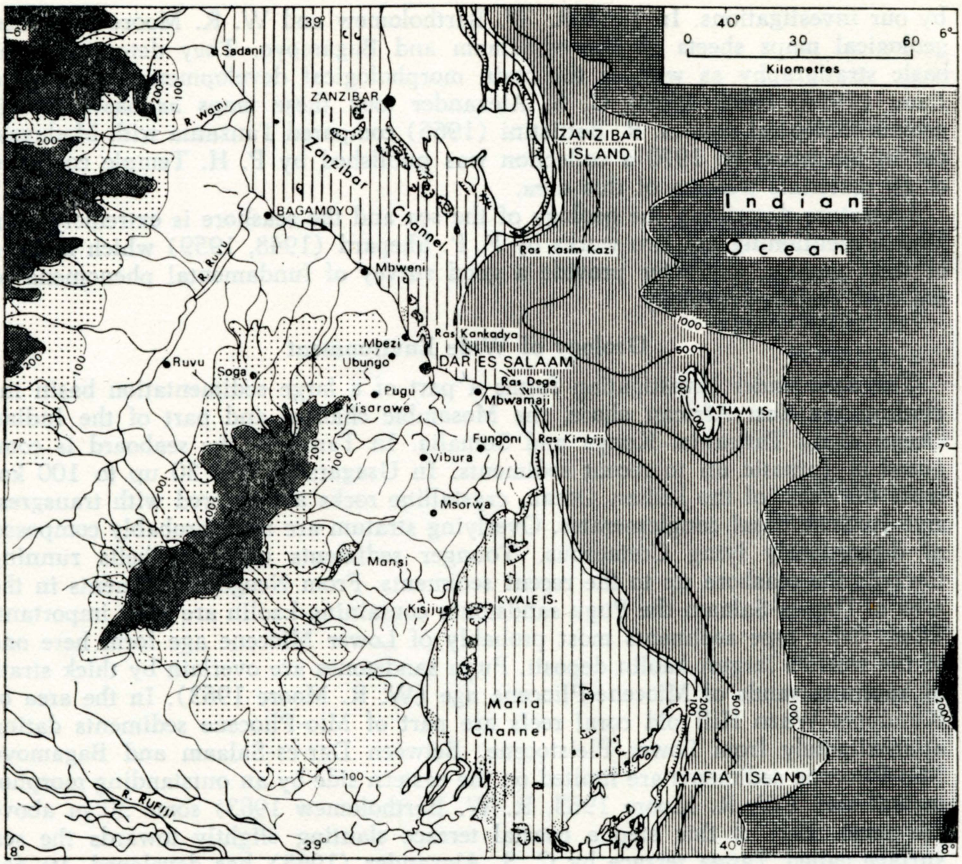
Literature treating of the Tanzanian seashore is comparatively rich. The geology of the shore was described for the first time by German geologists, such as A. Ortmann (1892), E. Werth (1901), W. Bornhardt (1900), W. Koert and T. Tornau (1910), W. Koert (1913), and finally a well arranged work by F. Behrend (1918). For the investigation of the area publication by W. Koert and F. Tornau (1910) is of high importance. It treats not only of the hydrogeology but of the general geological structure of the environment of Dar-as-Salaam. Bore profiles cited in the above work have remained up to the present the only evidence of the stratigraphy of Tertiary and Quarternary sediments in the area of the capital. From English geologists especially G. M. Stokley's work (1937) is worth mentinoning. His views of the tectonics of the area were in many directions confirmed by our investigations. In 1963 R. W. Bartholomew and W. R. Moore published geological maps sheets of Dar-es-Salaam and Bagamoyo. They determined the basic stratigraphy as well as the main morphological development of the area. Later (1966, 1968, 1969) C. S. Alexander took these maps as basis for his geomorphological studies. R. Battistini (1966) compared Tanzania with Madagascar in his work. In 1970 a collection was published by P. H. Temple compiled of all materials treating of this area.

Literature describing the geology of the sea and the seashore is extremely rich. Worth mentioning are two works by F. P. Shepard (1948, 1959) which in spite of their popular character provide a good survey of fundamental phenomena of sea and seaboard geology.

Geòlogy of Wide Environment

The area under investigation forms a part of a large sedimentation basin including the East African shore, the Mosambic channel and part of the Indian Ocean along Tanzania, Kenya and Somalia. In Tanzania the seaboard is composed of Jurassic up to recent sediments. In Usagaran, some 30 up to 100 km from the coast of the Indian Ocean, crystalline rocks are covered with transgressive Jurassic basal conglomerates. Overlying stratum are most probably composed of discordantly lying Cretaceous. Younger sediments occur in belts running towards the seashore up to the recent sediments. From Neogene sediments in the area of Dar-es-Salaam the Pugu sandstones containing kaolin are most important. These delta type sediments most probably of Lower Miocene age form here one of the world's largest kaolin deposit. Pugu sandstones are overlain by thick strata of kaolinite sands of Miocene-Pliocene age (W. R. Moore 1963). In the area of Kunduchi-Wazo Hill old coral reefs are part of Mio-Pliocene sediments dating approximately from Lower Pleistocene. Between Dar-es-Salaam and Bagamoyo Mio-Pliocene sediments are limited on the eastern side by an outstanding morphological step (W. R. Moore 1963, R. W. Bartholomew 1963) some 30 m above sea level. East of this step a coastal terrace slanting slightly towards the sea surface called Tanga terrace by C. S. Alexander (1968) has developed. Its age corresponds to the so-called reef I Tatsimian (R. Battistini 1966) on Madagascar. It is built of Uper Pleistocene sediments composed of grey sands, dark-red coloured argillaceous sands, and dark clays containing kaolin. North of Bagamoyo the terrace is some 6—7 km wide widening further to 15 km in the area of Bagamoyo, and narrowing then to 3 km near Dar-es-Salaam. East of this terrace the so-called lower terrace (W. R. Moore 1963) has developed which was called Mtoni terrace by C. S. Alexander (1969). It corresponds to the co-called reef II Carimbolian on Madagascar (R. Battistini 1966). Between the Tanga and Mtoni terraces a step has formed some 8—12 m high falling abruptly to the sea between Bagamoyo and Kaole (encl. 2). In the remaining area the Mtoni terrace forms a differently wide strip containing Holocene sediments. There they occur here in the form of sandy banks, mangrove swamps, salinas, sandy bars running along the shoreline with beach rocks and coral reefs. Present coral reefs, such as Ras Kiromoni and Kankadya near the shore, and the islands Bongoyo, Pangavini and Mbudya — raising some 3—5 above the maximum sea level — date from Early Holocene. Coral benches around inlands and the shore extending from Dar-es--Salaam as far as Malindi with active coral associations on their margins are of a younger age.

For the morphological development of the area the tectonics and epeirogenetic movements are of much importance. The area under investigation belongs to the tectonics of the active East African graben. From the morphological point of



2. General map of Dar es Salaam area showing relief, drainage and bathymetric data; altitudinal and bathymetric details in metres.

view, two structural units are most evident, i. e. the elevation of Pugu Hills-Wazo Hill, and the fault running along the Ruvu valley. The elevation of Pugu-Wazo Hills represents an outstanding horst at an altitude of about 200 m limited on both sides by a series of faults of northeast to southwest direction. The faults date most probably from Middle Pleistocene and are still active. Their activity is best evident in the growth of coral reefs and in the origin of river beds. In the area of Dar-es-Salaam subsidences in the east and the uplift of horsts caused the submersion of the seashore, and together with low and high tide the origin of deep creeks which form the present Dar-es-Salaam harbour in the mouths of the Kizinga and Mzinga rivers. At the time of uplift of the Pugu Hills horst, the erosion base was changed. The rivers cut down more deeply into the substratum and their beds extended further into the sea. This process culminated most probably with the retreat of the sea (below its present level) in the last glacial epoch. Doubtful is the opinion of P. H. Temple (1970) who believes that submerged stream beds in an advanced stage of their development reached the level of −40 m (W. Koert 1913). In the area under investigation this phenomenon is typical only of Dar-es-Salaam where is it predominantly caused by neotectonic movements. The fault forming the bed of the Ruvu affects considerably the development of the Tanga and Mtoni terraces. The area north of the river is a sunken block with a typical present accumulation.

The prevailing direction of faults is NE-SW up to NNE-SSW. Recent faults were discovered on the island Ras Luale, similar faults reflecting also in the course of the morphological step of the Mtoni terrace.

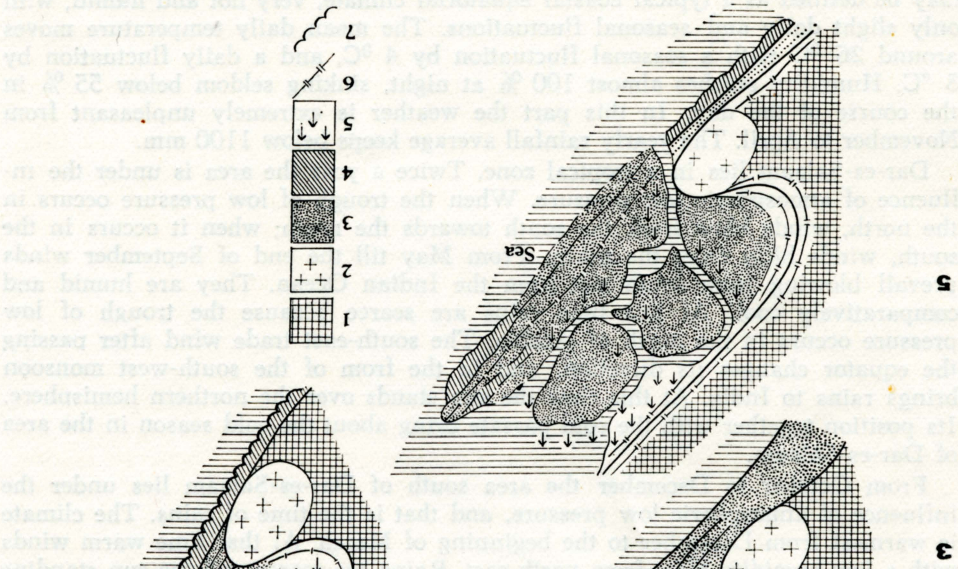
Climate, Hydrography and Fluctuation of Sea Level

According to D. J. Bargman (1970) the climate in the area of Dar-es-Salaam may be defined as a typical coastal equatorial climate, very hot and humid, with only slight daily and seasonal fluctuations. The mean daily temperature moves around 26 ^{0}C with a seasonal fluctuation by 4 ^{0}C, and a daily fluctuation by 8 ^{0}C. Humidity reaches almost 100 % at night, sinking seldom below 55 % in the course of the day. In this part the weather is extremely unpleasant from November to April. The yearly rainfall average keeps below 1100 mm.

Dar-es-Salaam lies in a tropical zone. Twice a year the area is under the influence of atmospheric low pressure. When the trough of low pressure occurs in the north, winds blow from the south towards the north; when it occurs in the south, winds blow from the north. From May till the end of September winds prevail blowing from south-east from the Indian Ocean. They are humid and comparatively cool. At this time rains are scarce because the trough of low pressure occurs in the north of Arabia. The south-east trade wind after passing the equator changes its direction, and in the from of the south-west monsoon brings rains to India. At this time the sun stands over the northern hemisphere. Its position together with the cold passate bring about the cold season in the area of Dar-es-Salaam.

From October to December the area south of Dar-es-Salaam lies under the influence of atmospheric low pressure, and that is the time of rains. The climate is warmest from December to the beginning of March. At that time warm winds with a low humidity blow from north-east. Rains are scarce and the sun standing in the zenith makes the weather very hot. The second period of rains starts in March and lasts until May when the atmospheric low pressure moves back towards the north.

Hydrography is dealt with in the work by P. H. Temple (1970). The prevailing direction of winds and waves is north-east. This direction of currents is influenced from May to September by the south-east trade wind. In the remaining part of the year the coast is affected by currents of NW direction. The strong south-east trade wind is the main cause of origin offshore currents flowing towards the nort. The main offshore current flows close to the shore because the continental gradient in this place is rather abrupt. Consequently this part of the coast is under a constant influence of northern currents. These currents flow at a velocity of 2 m/sec which sinks to 0,25 m/sec at the time of the northern monsoon. These shore currents are very important for the transport of sediments along the shore, for the formation of the morphology of the coast as well as for the origin and development of coral reefs (e. g. coral reefs grow especially at the slip-off bank where the inflow of oxygen and pure water from the ocean is larger). Shore currents are influenced by the shape of the shore and by inflows of fresh water to sea. Near the mouth of the Ruvu an area of brakish water has formed extending further into the sea and stagnating considerably. Other rivers supply water with sediments only in the period of rains from April to May. Very important for the morphological development of the shore is the fluctuation of sea level during high and low tide. There are two high and two low tides with one maximum high tide a day. Consequently, the shore is constantly exposed to the influence of sea waves and gets considerably destructed by surf. In this way sediments get into sea currents. Especially the coast of submergence (slanting parts of the coast) are strongly affected by the far-reaching tide and the coast of emergence becomes eroded. Fluctiations of the sea level reach, for instance, near Bagamoyo as much as 4,12 m; especially in sheltered bays, lagoons and between islands this phenomenon is of a strongly destructive effect. Consequently, these parts display very characteristic geomorphological features as shows the aerial photograph of the island Ras Luale (Fig. 3).



3. The development of Tanzania coast during Holocene period and in future between Dar es Salaam and Bagamoyo.

E x p l a n a t i o n s: 1 — Coast, 2 — Coral reef, 3 — Sands, 4 — Sandstones, 5 — Mangroves, 6 — Ridge, 7 — Line of erosion.

The main results in our investigation were achieved in the area of the Holocene Mtoni terrace. On the inland side it is enclosed by a step 8—12 m high, on the shore by a step 2—3 m high. Holocene sediments are prevailingly composed of argillaceous sands. The main morphological phenomena, i. e. sand ridges are built exclusively of sands. According to their course, and with respect to the soil profile and the vegetal cover C. S. Alexander (1969) divided the Holocene terrace north of the area under investigation into three zones: older, middle and younger. These three sections are most typically developed north of the mouth of the Ruvu on the contact line of the area under investigation and the area described by C. S. Alexander. This part of the shore is a typical example of accumulation going on for the whole Holocene. In this place the Mtoni terrace is almost 2 km wide, with expressive morphological features. In the oldest zone several expressive sand ridges have developed (3—5) marking the gradual retreat of the sea from the maximum water level reached approximately in the last interglacial. These ridges correspond to C. S. Alexander's (1969) older zone. The middle section is interpreted by C. S. Alexander as a system of irregular sand ridges divided very distinctly from the older zone by the phase of erosion. The younger zone has developed in the form of a series of ridges up to the youngest ridge accumulated only recently. In this place we ascertained some 6—8 ridges which perfectly agree in direction with the course of the clifs of both terraces.

Considering C. S. Alexander's division of the Holocene terrace (1969), we come to the conclusion that it is rather mechanical and does not correspond to the actual development of the coast. This is particularly true with regard to the function and development of the middle zone. It does not form a separate section divided from the two others by cycles of erosion. It is a transitory complex between the two periods. It was developing parallelly with the older zone, and goes on developing until the present. Characteristic of this area are mangrove forests intersected with a network of channels and salinas. Different origin results, of course, in a different morphological structure. Similar development of the transitory complex was found everywhere in the area under investigation where the Holocene terrace has developed in a sufficient width, such as in the area of Changwahela, Mpiji River and Kunduchi.

M a n g r o v e   f o r e s t s are typical of the area of the transitory complex, of the environment of river mouths as well as sheltered bays, such as south of Mlingotini or in the environment of Ras Mbegani. Sediments in mangrove forests are considerably different. Mangrove soil is usually composed of dark, strongly argillaceous sands up to black-and-grey clays of a thickness of 0,5 m placed on sands. Dark mangrove clays have developed especially in places of uninterrupted sedimentation in the transitory complex further from the coast. We came across them, however, also in some places directly on the shore where they are burried under younger sands. During gradual emerging of coast mangrove swamps occurring along the shores got destroyed. Mangrove soils are affected by erosion, and at the same time accumulation of sands takes place, covering and destroying these forests. Mangrove forests show a typical zonal structure discovered in Eeastern Africa by German botanists H. Walter and M. Steiner (1936). This zonal structure in the area under investigation was described by M. Cílková (1971).

Very interesting and completely new for Tanzania are the discoveries of the occurrence and development of the so-called *beach rocks*. These rocks are typical of all tropical seashores originating in all places where temperature conditions are fovourable, where the process of sedimentation proceeds uniterruptedly, and where there are enough minerals soluble in water. Beach rocks were found on shores, such as north of the Ruvu, between Bagamoyo and Mbegani, in the area of Changwahela and Kunduchi. Most frequently they occur on the island of Ras Luale, and partly or completely build bars extending out into the sea, e. g. near Changwahela, Malindi, Ndege and Ras Kiromoni. These rocks dip towards the sea and are of a comparatively low solidity. They are predominantly formed of differently hard sandstones composed of grains of quarz cemented with limestone from disolved coral limestones. On Ras Luale these sandstones have developed in a series of facies where quartz-calcareous sandstones of different grain size alternate with sandstones containing different portions of dark minerals. Very often dark minerals — usual in beach sands — prevail and form layers of black sandstones. In some places we came across an almost 100 % content of dark minerals (especially ilmenite and garnet) in beach rocks, which makes them suitable for mining. The black rocks form sometimes interlayers in light sandstones, in other places, however, have developed only irregularly as a result of cementation of black sands deposited in fissures and pockets in the eroded surface of older beach rocks. These rocks were cemented by compounds of iron from decomposed ilmenite.The thickness of beach rocks on Ras Luale reaches approximately 6 m. Sharp lapiés and diversified surface were due to the erosion and corrosion activity of sea water affecting the island during the time of its uplift. The substratum of these rocks is composed of sands washed out repeatedly by surf. Banks of sandstone break along fissures running mostly parallel with the shoreline. Colonies of oysters settle in fissures filling them sometimes completely. During the emerging of the island these rocks get disturbed and newly deposited in the form of sands on recent beaches.

In places where sandstones are outside the reach of erosion and occur at a sufficiently high level above sea water surface, they become cemented while flooded by the sea water. As a result they are unusually hard. Beach rocks originated in several stages. Normally they originate closely under the sea level or under the level of underground water in vicinity of the sea. They originate in quiet sedimentation environments where gradual accumulation of sediments is possible. Unter the influence of atmospheric agencies they get hardenend by means of $CaCO_3$, Fe and other compounds. Indispensable to the origin of beach rocks is the presence of $CaCO_3$ in water. $CaCO_3$ originates from dissolved coral substance. It may therefore be presumed that beach rocks in Tanzania originated predominantly after the origin of coral reefs. R. J. Russel and W. G. McIntire (1965) mention the absence of beach rocks in Southern Africa, which in their opinion is due to a strong surf activity of the sea. This corresponds also to our observations in Tanzania where beach rocks have developed only in places of undisturbed sedimentation. They originated at the time of the so-called transitory complex (middle zone according to C. S. Alexander 1969) which represents the period of stagnation. The composition of *beach sands* was the subject of a detailed investigation. These sands developed not only on recent ridges but on a series of older ones. They are composed of quartz, small portions of clay particles, limestone debris of organic origin, and dark and heavy minerals. On the shore also pumice may be found, i. e. light porous lava brought here by water and deposited on summits of banks after thunderstorms. It is believed to have originated in the Sundy island. Only in one place we came across copal excavated at one time near Bagamoyo and on the Zanzibar island.

Coral reefs are worth mentioning in a separate chapter. In the area under investigation they have developed in vicinity of Dar-es-Salaam up to Malindi. North of here, however, fresh water coming from the Ruvu interfered with their growth. Coral reefs are of different age, the oldest being Wazo-Hill with a series of neighbouring reefs of Lower Pleistocene age. Younger is Malindi which is part of the Tanga terrace (in contrast to R. W. Bartholomew's opinion 1963). This reef is over 10 m high and most probably is older than reefs on Ras Kiromoni and Ras Kankadia. These Holocene reefs originated in the form of fringing coral reefs along the shore — as did reefs in the vicinity of Dar-es-Salaam up to Ras Kiromoni — as coral reefs built on sandy banks (Bongoyo, Pangavini, Mbudya Islands). They originated roughly in two phases. Older parts were raised some 3—5 m above the sea level during the shore uplift, and are considerably corroded by wave action. Prevailing northern currents together with wave attacks disrupted older reefs and reduced their growth on SE side. The ocean water rich in nutritive substances and oxygen, favoured the growth of active corals in the SE direction. As a results most of the coral islands are of irregular shape with older parts projecting towards NW, and are enclosed by younger platforms developed especially on the averted side.

Geomorphological conditions are clearly evident. Characteristic is the position of the reef between the Mtoni and Tanga terraces. North of the Ruvu an abrupt scarp occurs some 2 km from the coast. In vicinity of Bagamoyo varicoloured Upper Pleistocene sediments form another step scarp some 12 m high, falling abruptly down to the ocean. In the area of Ras Luale the scarp touches with its margin the shore at Mbegani and Mlingotini. The mainland has begun to grow in this part of the shore. The original sand banks gave rise to the island of Ras Luale. Between the island and the shore gradual deposition of sands and mangroves takes place in the bay. In the next stage after the shore has been raised, the sea will retreat completely and the bay will become part of the mainland. At the present erosive activity makes itself felt along the whole island. On the side exposed to the open sea erosion of beach rocks and disruption of recent banks takes place. On the side of the bay, due to the activity of low and high tides, extensive semicircular bays have arisen with typical cusps between them. They cut deeply into the originally wider island. In the middle of bays beach sandstones were completely disrupted in some places. In other places, island is only some tens of metres wide (see aerial photograph 3).

Between Changwahela and Ras Luale the Mtoni terrace is about 4 km wide. West of the abrupt scarp several elevations were mapped situated at the same level as its upper margin. Most probably they are remains dating from Upper Pleistocene and forming islands along the coast during sea transgression taking place in the last interglacial. In this area, especially south of the island Ras Luale, extensive mangrove forests penetrate as far as to the bay. Southwards the width of the Holocene terrace has been reduced to 1 km. From Malindi towards Silversands coral reefs have developed along the coast together with sand bars reaching out far into the open sea. These bars in vicinity of Malindi, Ndege and Ras Kiromoni are a typical example of growing mainland in this part of Tanzania.

In the environment of Kunduchi the Mtoni terrace forms a widemouthed bay with mangrove forests in its centre. Towards Ras Kankadia the terrace narrows considerably. Some 12 sands ridges have developed here in a width of about 300 m. In the area of Dar-es-Salaam the course of the scarp as well as the development of terraces is uncertain due to a complicated tectonic development.

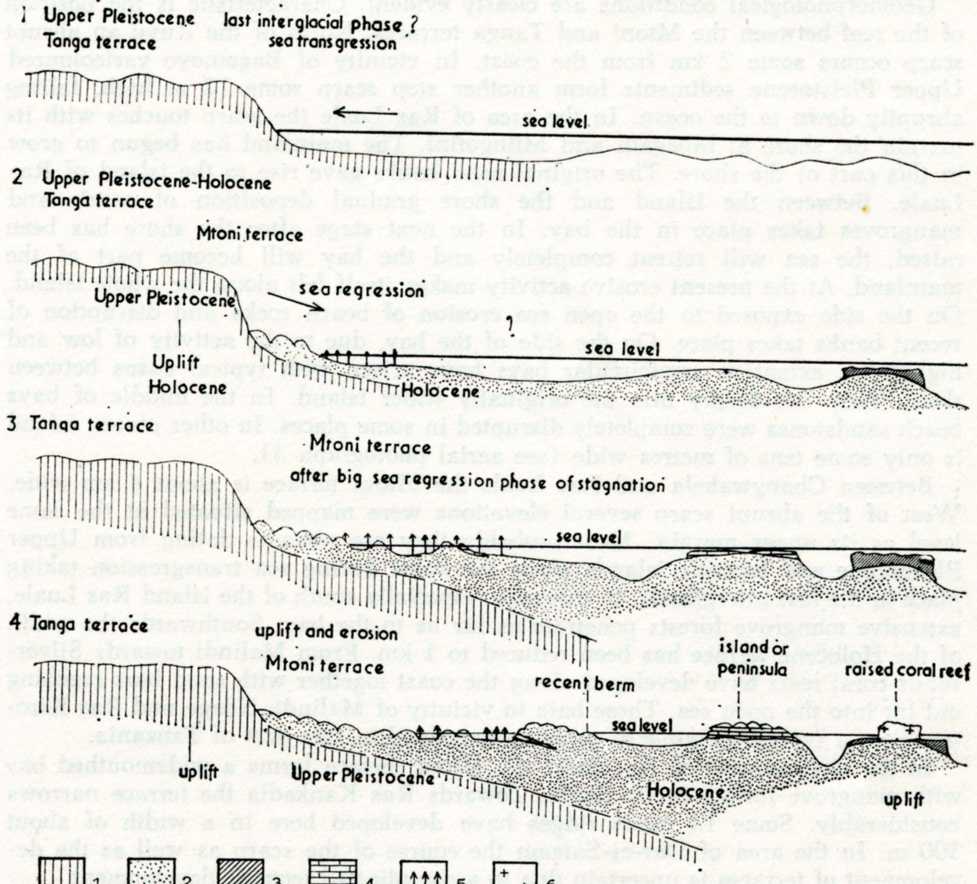
At the present time erosion alternates with accumulation in the area under investigation. Accumulation prevails in the area between Ras Kankadia and Silversands, as well as in some places near Changwahela and north of the Ruvu. Erosion phenomena are common features on Ras Luale. P. H. Temple (1970) was wrong in interpreting semicircular bays to be circular sand ridges.

Part of the shore in vicinity of Changwahela has also been affected by erosion which gradually destroyed the undergrowth of Casuarina trees. In the environment of the Mpiji River mangrove forests were destroyed, and a recent bank was raised in the middle of the mangroves.

Summing up the known facts, we may say that this part of the shore of the Indian Ocean occurs in a stage of uplift. It manifests itself on the one hand by erosion, on the other by sea retreats.

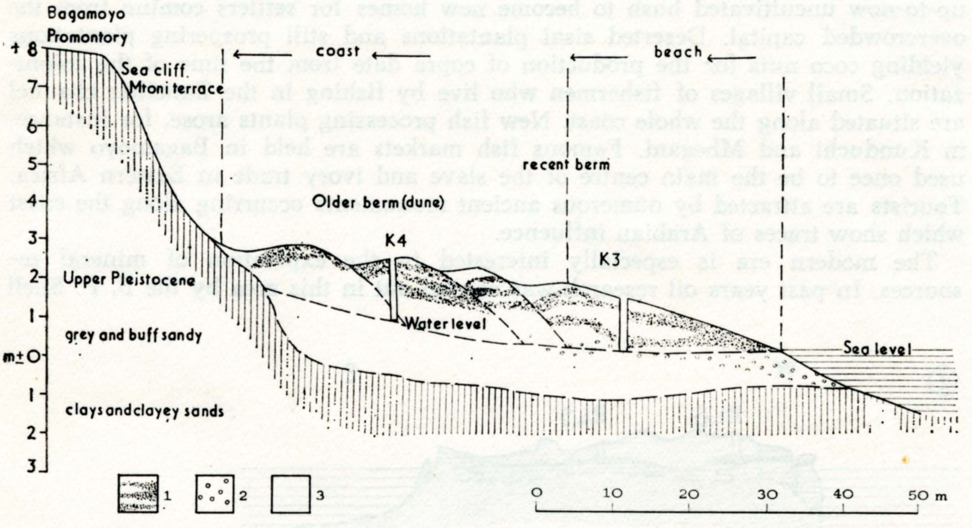
Survey of Morphological Development of the Shore

The development of the shore of Indian Ocean in the area under investigation is marked in Encl. 3 and 4. Encl. 3 shows an example of the shore line turning away from its original direction in the place of a coral reef, such as in vicinity of Ras Kiromoni or Malindi. It is not the rule, however, the change in the course



4. The development of Tanzania coast from Upper Pleistocene till present. Explanations: 1 — Upper Pleistocene, clayey sands, 2 — Holocene-sands, 3 — Living coral reefs, 4 — Beach rocks (sandstones), 5 — Mangroves, 6 — Coraline limestone.

of the coast line being mostly affected by tectonics. As an example we may cite the origin of the former peninsula and the present island Ras Luale. The present stage of development of this island corresponds to stage 4 in the diagram. Stage 5 corresponds to the final development in the future when the whole part becomes part of the mainland. Diagram 4 shows the development of the shore from Upper



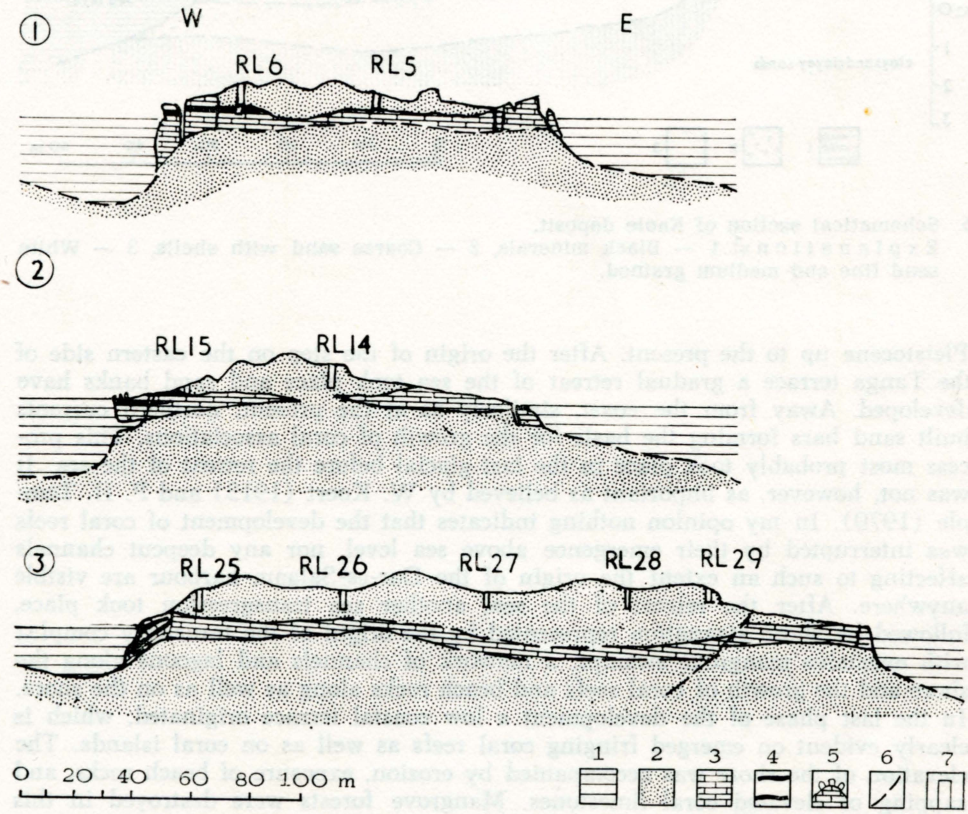
5. Schematical section of Kaole deposit.
Explanations: 1 — Black minerals, 2 — Coarse sand with shells, 3 — White sand fine and medium grained.

Pleistocene up to the present. After the origin of the step on the eastern side of the Tanga terrace a gradual retreat of the sea took place and sand banks have developed. Away from the coast, similarly as at the present, northern currents built sand bars forming the basis for the growth of coral associations. This process most probably took place in the last glacial before the retreat of the sea. It was not, however, as important as believed by W. Koert (1913) and P. H. Temple (1970). In my opinion nothing indicates that the development of coral reefs was interrupted by their emergence above sea level, nor any deepcut channels affecting to such an extent the origin of the Dar-es-Salaam harbour are visible anywhere. After the retreat of the sea, another sea transgression took place, followed by shore stagnation represented by the origin of the transitory complex with extensive mangrove swamps, a network of channels and lagoons along the shore and the growth of coral reefs and beach rocks along as well as on the shore. In the last phase of the development a low coastal terrace originated, which is clearly evident on emerged fringing coral reefs as well as on coral islands. The elevation of the shore was accompanied by erosion, exposure of beach rocks, and sapping of elevated coral limestones. Mangrove forests were destroyed in this process and in their place sand banks were formed. In some places erosion affected even older sand banks, sapped marginal parts of coconut plantations, and destroyed the vegetal cover of Casuarina equisetifolia trees. On the whole, however, the mainland has been growing.

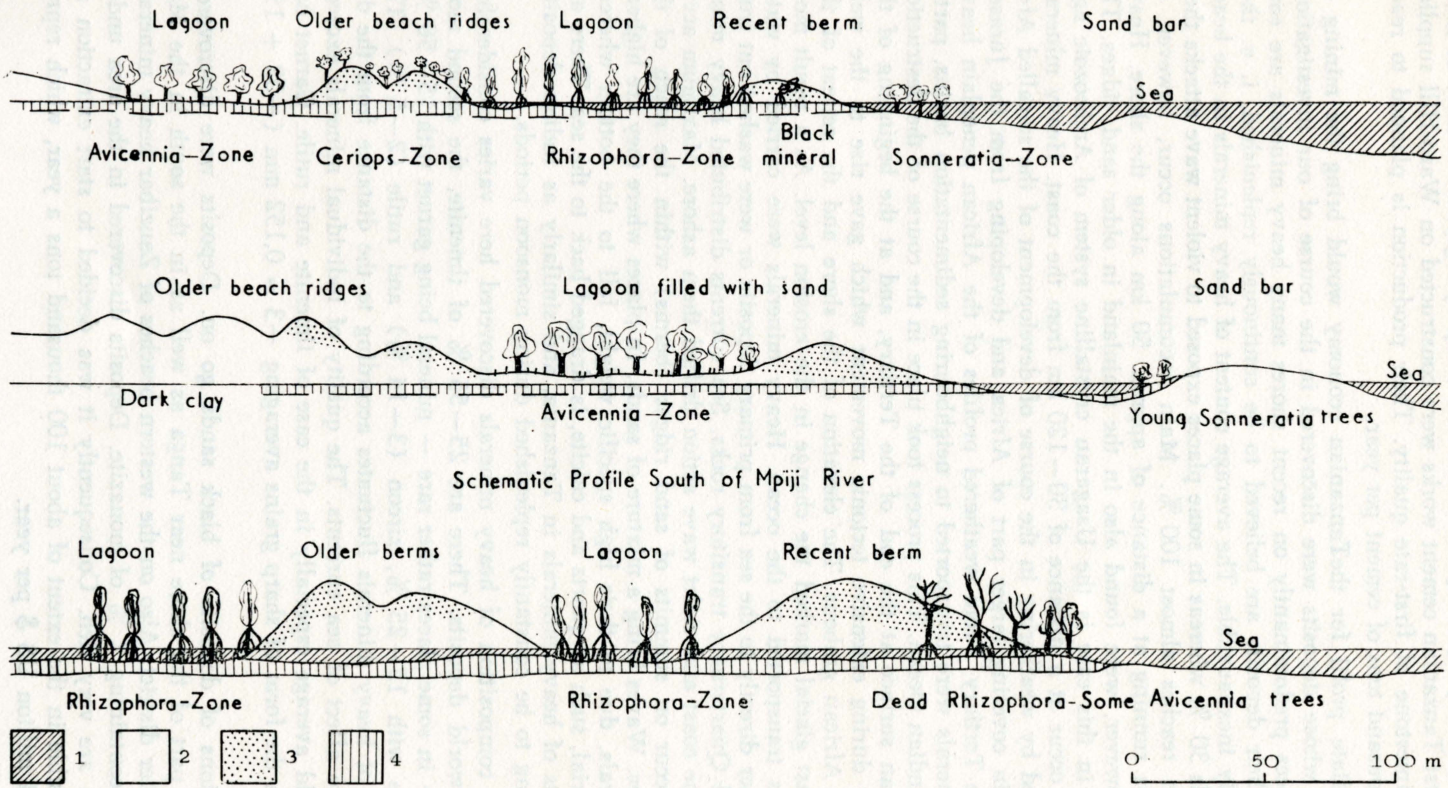
Economic Aspects of the Area

From the economic point of view, the importance of the area extending between the towns Dar-es-Salaam and Bagamoyo, the former centre of the country, has been growing continuously. Hand in hand with the increasing tourist traffic new hotels have been built recently in vicinity of Kunduchi and Silversands. Farther to the north, „ujamaya villages" — cooperative villages are being built in the up-to-now uncultivated bush to become new homes for settlers coming from the overcrowded capital. Deserted sisal plantations and still prospering plantations yielding coco nuts for the production of copra date from the time of the colonization. Small villages of fishermen who live by fishing in the Zanzibar channel are situated along the whole coast. New fish processing plants arose, for instance, in Kunduchi and Mbegani. Famous fish markets are held in Bagamoyo which used once to be the main centre of the slave and ivory trade in Eastern Africa. Tourists are attracted by numerous ancient monuments occurring along the coast which show traces of Arabian influence.

The modern era is especially interested in the exploation of mineral resources. In past years oil research was carried out in this area by the B. P. Shell



6. Cross-sections of Ras Luale Island (northern part).
E x p l a n a t i o n s: 1 — Sea water, 2 — Beach sands and dunes, 3 — Beach rocks-sandstones quarzitic and coral, 4 — Beach rocks-black sandstones with heavy minerals, 5 — Oysters banks, 6 — Dislocation, 7 — RL 36 pit.



7. Schematic sectional profiles south of Mpiji River.
Explanations: 1 — Sea water, 2 — Sands, 3 — Heavy dark minerals, 4 — Dark clays-mangroves.

Company, and newly again by the Italian oil company Agip. In vicinity of Kunduchi the first Tanzanian cement works were constructed on Wazo-Hill supplied with coral limestone of first-rate quality. Their production is planned to reach some 400 thousand tons of cement per year.

An immediate profil for theTanzanian economy would bring the mining of black sands whose deposits were discovered in the course of our investigation. In some places predominantly on recent shores many heavy minerals are concentrated. Their deposits are believed to be continously replenished, i. e. they are practically inexhaustible. The average content of heavy minerals in the beach sands exceeds 30 % whereas in some places exposed to violent wave attacks their concentration reaches almost 100 %. Main accumulations occur, however, in norrow strips running at a distance of approx. 50 km along the shore. Heavy minerals, however, were found also in the mainland in older sand ridges. The parent rock in this case is the Usagaran crystalline system of Archeozoic age. These rocks occur at a distance of 30—120 km from the coast. Heavy minerals were loosened by weathering in the course of development of the so-called African peneplain covering larger part of Africa and developing from the Jurassic until Middle Tertiary. From weathered profiles of the African peneplain heavy resistent minerals were transported to neighbouring sedimentation basins, partly also to the Indian Ocean. This process took place in the course of the destruction of the African surface at the end of the Tertiary, and at the beginning of the Quarternary during extensive tectonic movement which gave rise to the well-known East African grabens. The elevation of the shore and the retreat of the sea in the last glacial marked the change in the erosion level. As a result more material was transported to the ocean. Heavy minerals were carried by water currents either directly to the sea from primary deposits or were washed out from Tertiary and Quarternary transitory rocks. Sea currents distributed heavy minerals along the coast and violet wave action drifted them ashore. Maximum accumulations occur on summits of sand ridges (berms) within the reach of the highest waves. Waves bring a mixture of sands. In places where they are highest, heavy minerals, due to their high specific weight, fall to the bottom whereas lighter material, such as quartz and calcite, is dragged back to the sea. There are huge deposits of heavy minerals in Tanzania, and similarly as Indian deposits, they are going to be constantly replenished during monsoon periods.

Generally composition of heavy minerals discovered here varies considerably from other world deposits. There are 25—55 % of ilmenite, the second most important — in some places rather rare — mineral being garnet with 15—56 %, then kyanite with 15—25 %, zircon (3—14 %) and rutile (2—5 %). The composition of heavy minerals fluctuates according to the distance from the deposit and the affect of sea currents. The quality of individual minerals exceeds general world average especially in the case of ilmenite and rutile. Garnet has developed in the form of sharp grains averaging $-3 \pm 0{,}152$ mm ($-52 + 150$ mesh).

Investigations of deposits of black sands go on. Deposits were discrovered in northern part of the shore near Tanga as well as in the south in the Mosambic frontier district. Also on the western beaches of Zanzibar heavy minerals were found containing 2 % of monazite. Deposits discovered in the area under investigation are very rich. Consequently it was decided to start extraction as soon as possible in the extent of about 100 thousand tons a year, which represents some 4 million US $ per year.

Conclusion

In the course of investigations of beach sands the geomorphological development of the Indian Ocean shore between Dar-es-Salaam and Bagamoyo was studied. Two coastal terraces have developed along the shore, i. e. the Tanga terrace containing deposits of Upper Pleistocene age, and the Mtoni terrace containing Holocene sediments. The main attention was focused to the development of the Holocene terrace, which may be divided into three zones on the basis of morphological features: older, transitory and younger. In the older section a gradual retreat of the sea, and a subsequent submergence of the sea level under the present level took place in the last glacial period. The transitory section ment stagnation and development of large mangrove swamps, and the origin of coral reefs along the shore and on sandy bars. At this time interesting beach rocks started developing. In the younger section the shore was elevated and an about 3m high terrace level originated. It is best evident on coral reefs projecting above sea level. At that time the shore was affected by erosion destructing mangrove forests and forming recent sand ridges. On recent beaches heavy minerals were accumulated by wave action.

Literatura

ALEXANDER C. S. (1966): A Method of descriptive Shore Classification and Mapping as applied to the northeast Coast of Tanganyika. Annals of the Assoc. of Am. Geographers, Vol. 56, No 1, March, pp. 128—140, New York.

ALEXANDER C. S. (1968): The marine Terraces of the northeast Coast of Tanganyika Z. f. Geomorphol., Bd. 7, pp. 133—154, 1 Berlin-7 Stuttgart.

ALEXANDER C. S. (1969): Beach Ridges in Northeastern Tanzania. Geographical Rev., Vol. 59, No 1, Jannuary, pp. 104—122, New York.

BARGMAN D. J. (1970): The climate of Dar es Salaam. Tanzania Notes and Records, No 71, pp. 55—65, Dar es Salaam.

BARTHOLOMEW R. W. (1963): Geological map Q. D. S. 186 — Dar es Salaam. Published. in Tanganyika — Dodoma.

BATTISTINI R. (1966): Le guaternaire littoral des environs de Dar es Salaam (Tanzanie). Essai de corrélations avec le Quaternaire littoral malgache, Bull. Ass. Fr. létude du Quaternaire 3, pp. 191—201, Paris.

BEHREND F. (1918): Beiträge zur geologischen Erforschung der Deutschen Schutzgebiete. Heft 15, Die Stratigraphie des östlichen Zentralafrika, pp. 1—146, Berlin.

BORCHERS D. — STOCKEN C. G. — DALL A. E. (1970): Beach mining at Consolidated Diamond Mines of South West Africa, Ltd.: Exploitation of the area between the high- and low- water marks. Mining and Petroleum Technology (Proc. of the Ninth Commonwealth Mining and Metallurgical Congress 1969), Vol. 1, pp 571—590, London.

BORNHARDT W. (1900): Zur Oberflächengestaltung und Geologie Deutsch-Ostafrika. Deutsch-Ostafrika, Bd. VII, pp. 1—490, Berlin.

CÍLKOVÁ M. (1971): K ekologii a rozšíření mangrovových porostů v Tanzanii. Živa 19, No 5, pp. 162—165, Praha.

CHARLESWORTH J. K.: (1957): The Quaternary Era (with special refference to its glaciation), Vol. 1, pp. 1—591, Vol. 2, pp. 1—1700, Edward Arnold Ltd., London.

COSTER F. M. (1960): Underground Water in Tanganyika. Government Printer Tanganyika, pp. 1—84, Dar es Salaam.

DEACON G. E. R. (1970): Exploiting the oceans. The Advancement of Science. Vol. 26, No 129, March, pp. 313—317.

DE KUN N. (1965): The mineral Resouces of Africa. Elsevier Publ. Comp., pp. 508—511, Amsterdam — London — New York.

EAMES F. E., — KENT P. E. (1955): Miocene Beds of the East African Coast. Geol. Magazine, Vol. XCII, January-December, pp. 338—344, London.

FRANCIS T. J. G. — DAVIES D. — HILL M. N. (1966): Crustal Structure between Kenya and the Seychelles. Royal Society of London, A, Vol. 259, pp. 240—261, London.

HARRIS J. F. (1961): Summary of the geology of Tanganyika. Part IV: Economic Geology, pp. 1—143, Government Printer — Dar es Salaam.
ISAAC W. E. — ISAAC F. M. (1968): Marine Botany of the Kenya coast. 3. General Account of the environment, flora and vegetation. J. of East Africa Nat. Hist. Soc. Nat. Museum, Vol. XXVII, No 1 (116), Jannuary, pp. 7—28, Nairobi.
JOHNS C. (1934): The Quaternary Changes of Ocean Level: cause and consequences. Geol. Mag., Vol. LXXI, Jannuary-December, pp. 408—432, London.
KING C. A. M. (1961): Beaches and Coasts. Edward Arnold Ltd., pp. 1—30, London.
KOERT W. (1913): Beiträge zur geologischen Erforschung der Deutschen Schutzgebiete. Heft 1, pp. 1—264, Berlin.
KOERT W. — TORNAU F. (1910): Zur Geologie und Hydrologie von Dar es Salaam und Tanga. Abhandl. König. Preuss. Geol. Landesanstalt, Hf 63, pp. 1—77, Berlin.
KRENKEL E. (1924): Über Saumriffe an der Küste Zentral-Ostafrikas. Nachrichtenblatt Jhrg. 1, No 1, pp. 1—7, Leipzig.
KRENKEL E. (1957): Geologie und Bodenschätze Afrikas. 2. vyd., pp. 171—218 a 409—484, Leipzig.
MAC NEIL F. S. (1954): Organic Reefs and Banks and associated detrital sediments. Am. J. Science, Vol. 252, July, pp. 385—401, New Haven.
McGILL J. T. (1958): Map of coastal landforms of the world. The Geogr. Rev., Vol. XLVIII, pp. 402—405, New York.
MERO J. L. (1965): The mineral resources of the sea. Elsevier Oceanography series, pp. 6—23, Amsterdam—London—New York.
MOORE W. R. (1963): Geological map Q.D.S. 168 — Bagamoyo. Published in Tanganyika — Dodoma.
MOORE W. R. (1963): Geology of Quarter Degree Sheet 168, Bagamoyo, and a compilation map of Tanganyika, Vol. X, pp. 1—6, Dar es Salaam.
ORTMANN A. (1892): Die Korallenriffe von Dar es Salaam und Umgeb. Zool. Jahrbuch, 6, pp. 631—670, Berlin.
RUSSEL R. J.—McINTIRE W. G. (1965): Southern Hemisphere beach rocks. Geograph. Rev., Vol. LV, Jannuary, pp. 17—45, New York.
SAGGERSON E. P.—BAKER B. H. (1965): Post — Jurrasic erosion — surfaces in eastern Kenya and their deformation in relation to rift structure. The Quaternary J. Geol. Soc. of London, Vol. 121, No 481, Part 1, May, pp. 51—72, London.
SHEPARD F. P. (1948): Submarine Geology. Harper's Series, pp. 1—348, New York.
SHEPARD F. P. (1959): The earth beneath the sea. J. Hopkins Press, pp. 1—275, Baltimore.
STOCKLEY G. M. (1937): Geological Notes on the coastal region of Tanganyika. Tanganyika Notes and Rec., No 3, April, pp. 82—86, Dar es Salaam.
Summary of the geology of Tanganyika (1956): Kolektiv autorů, Part I — Introduction and Stratigraphy. Memoir No 1, pp. 1—9, 235—256, Dar es Salaam.
TEMPLE P. H. (1970): Aspects of the geomorphology of the Dar es Salaam area. Tanzania Notes and Record, No 71, pp. 21—54, Dar es Salaam.
THRELFALL H. R. (1950): Some fysical features of the Dar es Salaam District. Tanganyika Notes and Records, No 29, July, pp. 68—72, Dar es Salaam.
WALTER H.—STEINER M. (1936): Die Ökologie der Ost-Afrikanischen Mangroven. Z. für Botanik, Bd. 30, pp. 5—193, Berlin.
WERTH E. (1901): Lebende und jungfossile Korallenrife in Ost-Afrika. Z. Gess. Erdk., 36, pp. 115—144, Berlin.

Explanations to the air-photos:

1. The vicinity of the mouth of the Ruvu River

North of the mounth is a typical area of accumulation such as occurs between the mouths of the Ruvu and Wami Rivers. The width of the Mtoni Terrace is about 2 kms and three terrace complexes are developed: the older (1), transition (2) and younger (3). The line of the cliff of the terrace parallels the line of the recent berm. The irregular development of the transition complex in which the sedimentation occurs up to the present is a result of a period of stagnation despite the period of uplift and accumulation in the younger complex. In the vicinity of the river mouth there is a widespread development of mangroves along the sea-shore towards Bagamoyo, inland along the river and in the area of the transition complex. North and south of the rivermouth are wide saline flats, used in salt works for the impounding and evaporation of seawater. The mouth of the Ruvu River is moving northwards as a result of the Ruvu Fault (downthrown to the north) and tendency

of estuaries in the southern hemisphere to swing dextrally on entering the sea.
The southern part of the area depicted is composed of Upper Pleistocene deposits on the Tanga Terrace (Bagamoyo Promotory). The Mtoni Terrace narrows southwards, towards Bagamoyo.
The Ruvu River is of small importance as a source of heavy minerals as it is a slow meandering river, transporting only light minerals and clay material. Thus important deposits of heavy minerals are not developed around the mouth and immediately to the north and south.

2. Dar es Salaam area

A dominant feature is the presence of a fringing coral reef around Ras Kankadia and the coral platforms between Oyster Bay and Dar es Salaam port. The submerged channel of the harbour has been widened at its mouth by the scouring action of the tides. The cliff of the terrace is not well developed. Heavy minerals are concentrated on islands opposite the harbour and are present along the shore to both north and south. The presence of coral reefs results, from the small inflow of fresh water from the land as a result of the subsidence comparatively little sediment, especially of heavy minerals, is reaching sea.

3. Ras Luale island

This island is separated from mainland by a narrow channel at the southern end. It originated as a sand bar where is a change direction in the line of the coast. It is an example of the accretion of the mainland. Uplift has resulted in erosion of the shores of the island; on the lagoon side there are examples of cups and semicircular bays. In some places there is complete concentration to 100 % heavy minerals on some of the older berms. There is a rim of beach rocks around the island in different stages of destruction. The lagoon between the island and mainland is mostly filled with sands, with some small islands and patches of mangroves.
Ras Luale island is very narrow sand — bar about 10 kms in lenght on which heavy minerals were deposited by off — shore currents and concentrated by futher wawe action. South of the channel the accumulation of heavy minerals continues in Changwahela deposit. The cliff of the terrace continues on a line parallel to the present sea — ward shore of Ras Luale island. In Changwahela there are elevations which are interpreted as residua of Upper Pleistocene age. It is possible that the development of the island was initiated by a fault perpendicular to the length of the island.

GEOMORFOLOGICKÝ VÝVOJ POBŘEŽÍ INDICKÉHO OCEÁNU U DAR ES SALAAMU

Mezi Dar es Salaamem a Bagamoyem v Tanzanii byla objevena ložiska tzv. černých písků — těžkých minerálů, jako např. ilmenitu, rutilu, monazitu, kyanitu a granátu. Tato ložiska jsou velice bohatá s průměrným obsahem těžkých minerálů více než 30 %, ale jejich výskyt je omezen jen na úzké pruhy podél pobřeží na velké vzdálenosti. Jsou vázána na recentní plážové písčité valy; jen výjimečně se vyskytují i ve starších valech.

Byl vyřešen vývoj pobřeží během pleistocénu až po dnešní dobu, který pro pochopení vzniku, vývoje a rozšíření ložisek černých písků má veliký význam. Rozeznáváme tři vývojové fáze na tanzanském pobřeží od poslední doby meziledové v Evropě. V Tanzanii v té době vznikla mořská terasa, tzv. Mtoni. Zdá se, že dosavadní rozdělení holocenní terasy tak, jak je podává C. S. Alexander (1969), neodpovídá zcela skutečnosti, a morfologický vývoj nastíněný autorem článku se blíží více vývojovým cyklům než mechanickému rozdělení. To se týká tzv. přechodného cyklu, který je skutečnou přechodnou zónou mezi starším a mladším komplexem. Vývoj této přechodné zóny není dosud ukončen a protažení a průběh např. písčitých valů, které se liší od obou ostatních komplexů, je podmíněn nikoliv erozní fází mezi starším a přechodným cyklem, ale pouze odlišnými sedimentačními podmínkami, které probíhaly souběžně s usazováním a morfologickým vývojem v ostatních komplexech. Přechodná zóna je typická vývojem mangrovových močálů, kanálů a říčních koryt spolu s písčitými depresemi a rozsáhlými plochami salin.

Z geomorfologického hlediska nejvýznačnějším znakem oblasti je průběh terasového stupně mezi terasami Tanga (starší — svrchní pleistocén) a Mtoni (recent). Severně od řeky Ruvu je terasa Mtoni více než 2 km široká, ale jižně od řeky spadá terasový stupeň přímo do moře srázem asi 12 m vysokým. V oblasti Ras Luale je sráz velmi blízko pobřežní linie a dochází zde k narůstání pevniny. Mezi ostrovem Ras Luale a pobřežím je vyvinuta rozsáhlá laguna, která se postupně zaplňuje pískem, siltem i bahnem mangrovových močálů; vývoj spěje k úplnému zanešení laguny, která se brzy stane částí pevniny. Mezi Ras Luale a Changwahela je terasa Mtoni asi 4 km široká a uprostřed byly nalezeny protáhlé elevace budované svrchním pleistocénem, výškově shodné s terasovým stupněm. Směrem k jihu se šířka terasy zmenšuje až na 1 km. Mezi Malindi a Silversands jsou v příbřežní zóně vyvinuty typické písčité bary vybíhající směrem severním až severovýchodním od pobřeží do moře. Jsou typickým příkladem postupného narůstání pevniny a představují počáteční stadium ve vývoji lagun na této části tanzanského pobřeží. Vznik těchto barů je podmíněn převládajícími pobřežními proudy tekoucími zhruba od jihu k severu, shodného směru s převládajícími pasátovými větry. V oblasti Dar es Salaamu je průběh terasového stupně nezřetelný v důsledku řady tektonických pohybů. Tektonický pokles pobřeží způsobil podle autora vznik rozsáhlého a hlubokého zálivu daressalaamského přístavu, skutečného „přístavu míru" na tomto pobřeží.

V přítomné době pozorujeme na pobřežní linii střídání jevů eroze a akumulace. Akumulace převládá od Ras Kankadia k Silversands. Eroze je běžná v oblasti Ras Luale a Changwahela. Všeobecně se dá říci, že během stávajícího výzdvihu pobřeží je v činnosti jak eroze, tak akumulace doprovázené růstem pevniny na úkor moře.

Vysvětlivky k obrázkům na křídové příloze:

1. Okolí ústí řeky Ruvu. Typická oblast akumulace je severně od ústí. Šířka terasy Mtoni je zde asi 2 km a jsou zde vyvinuty všechny tři oddíly: starší (1), přechodný (2) a mladší (3). Průběh terasového stupně je mimo okolí ústí řeky zcela shodný s průběhem pobřežní linie. Přechodný komplex vykazuje nepravidelné rozšíření a představuje období stagnace oproti období výzdvihu a akumulace v mladším oddílu. V okolí ústí řeky jsou rozsáhlé mangrovové porosty rozšířené jednak podél moře až k Bagamoyu, jednak podél řeky do vnitrozemí v oblasti přechodného komplexu. Zde jsou severně i jižně od ústí rozsáhlé saliny, využívané jako odpařovací pánve pro výrobu soli z mořské vody. Ústí řeky se posouvá v důsledku poklesu s. kry podél zlomu k S. Toto ústí rovněž potvrzuje pravidlo o stáčení estuárií na j. polokouli doprava. Severní břeh řeky v ústí je nárazový s vývojem písčitého valu, jižní je akumulační s mangrovovými porosty. Jižní část území je převážně budována terasou Tanga — oblastí zvané Bagamoyo Promontory (předhoří) se sedimenty svrchního pleistocénu. Mtoni-terasa se rychle zužuje směrem k Bagamoyu a přechodný oddíl zde chybí. Řeka Ruvu jako zdroj těžkých minerálů je málo významná; je to pomalu tekoucí, meandrující řeka s estuárií přinášející z oblasti krystalických hornin i mladších sedimentů jen lehčí křemité a jílovité podíly do moře.
2. Oblast u Dar es Salaamu. Dominantním znakem je vývoj lemového korálového útesu na Ras Kankadia a existence mladší korálové plošiny mezi Oyster Bay a vjezdem do přístavu. Nápadný je hluboký záliv přístavu vzniklý z původního říčního kanálu v poslední době ledové a dotvářený mladšími poklesovými pohyby na v. straně hrásti Pugu Hills a přílivovou činností moře. Průběh terasového stupně je značně nezřetelný. Oblast Dar es Salaamu je právě vzhledem k tektonickému vývoji výjimkou v této části pobřeží Indického oceánu. Koncentrace těžkých minerálů byla zjištěna na ostrovech před přístavem a velmi nízké koncentrace severně a jižně od města. Je to podmíněno existencí korálových útesů, které odkládají příbřežní proudy a značí nedostatek přítoku sladké vody do moře, dále poklesem pobřeží, na němž vznikají v ústí řek estuárie, a tím slabá unášecí síla vodních toků, přinášejících těžké minerály do moře.
3. Okolí ostrova Ras Luale. Tento ostrov vznikl jako písčitý bar v místě změny směru pobřežní linie činností s. příbřežních proudů. Je příkladem narůstání pevniny v této části Indického oceánu. V důsledku výzdvihu pevniny je jeho pobřeží ovlivněno erozí: na straně otevřeného moře, kde působí hlavně příboj a s. proudy je pobřeží rovné, na straně zálivu jsou neobyčejně vyvinuty polokruhové zálivy s hroty, vzniklé erozní činností přílivu a odlivu při postupujícím výzdvihu ostrova. Zde vznikly druhotně až 100% koncentrace těžkých minerálů při rozplavení starších plážových písků. Většina pobřeží je lemována plážovými horninami v různém stadiu rozrušení. Tento zjev podporuje další akumulaci těžkých minerálů podél ostrova, ukládaných při bouřích za vystouplými pískovci. Ostrov se postupně zmenšuje v důsledku eroze, ale výzdvihem celé oblasti dochází k akumulaci v zálivu a brzy se tento záliv stane součástí pevniny. Jižně od kanálu pokračuje akumulace těžkých minerálů podél po-

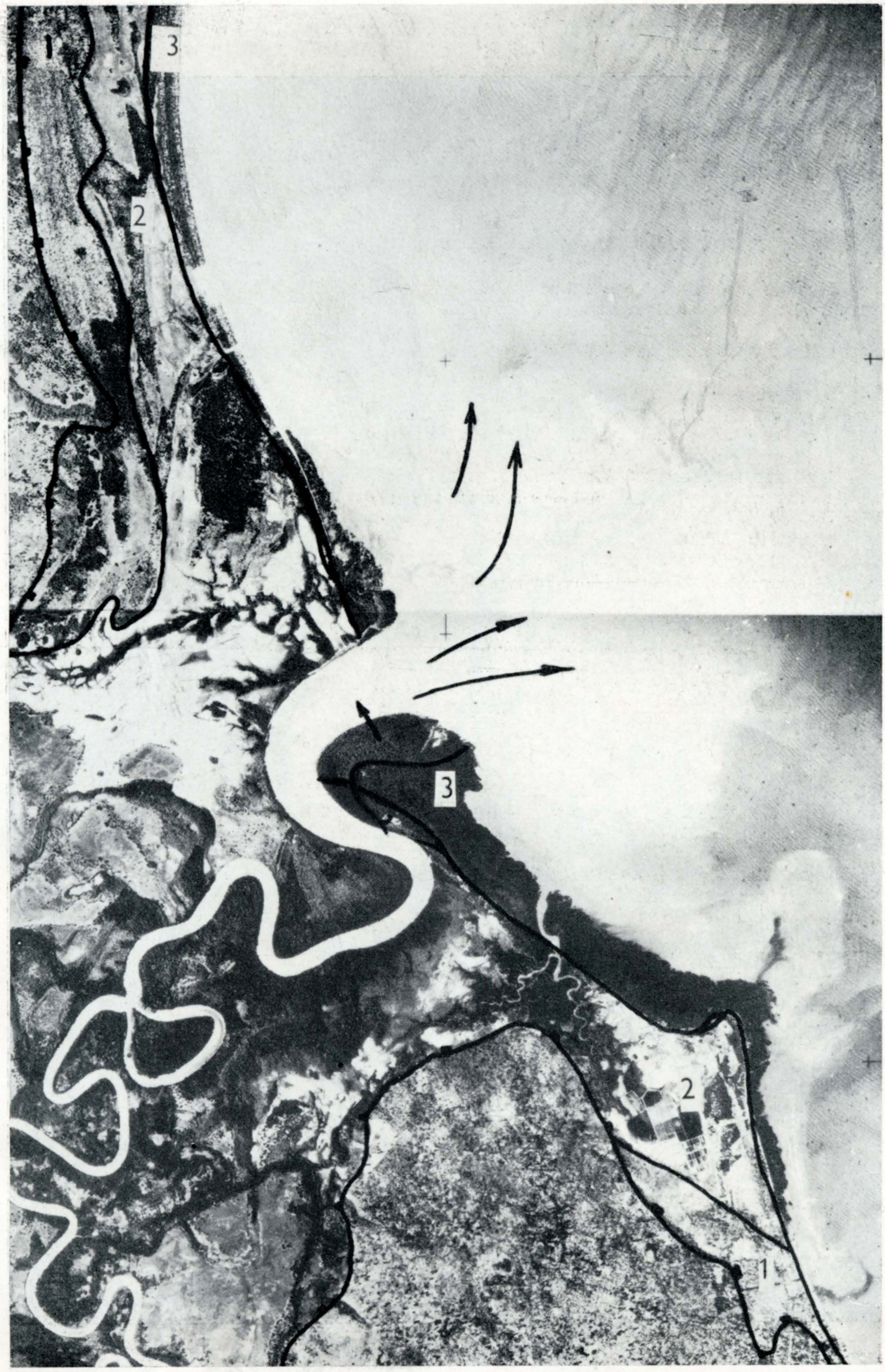
břeží Changwahela. Zde jsou morfologické elevace, které považujeme za zbytky svrchního pleistocénu, které byly ostrovy při transgresi moře v poslední době meziledové. Je možné, že vývoj ostrova byl podmíněn zlomem probíhajícím kolmo na průběh ostrova při jeho jižním zakončení.

4. Pláž na jz. břehu ostrova Ras Luale s černými písky na svahu (berm). V pozadí mělká laguna.
5. Střední část ostrova Ras Luale — pohled z otevřeného moře. Za pláží jsou zřetelené starší písčité valy.
6. Sv. pobřeží ostrova Ras Luale s erodovanými plážovými pískovci s obsahem tmavých minerálů a s puklinami. Na povrchu jsou přisedlé ústřice.
7. Changwahela sever — písčitý val směřující od pobřeží do moře. Na pláži je erozní stupeň.
8. Ostrov Mbudya — pohled na mladší korálovou plošinu. V pozadí je bílá linie recentní pláže na terase Mtoni a vyšší stupeň je terasa Tanga s budovami továrny na výrobu cementu Wazo-Hill (korálový útes spodnopleistocenního stáří).
9. Changwahela sever. Mangrovové porosty *Rhizophora mucronata* s chůdovitými kořeny při pobřeží v malém zálivu se zbytky rozrušených plážových hornin.

(Foto 4—9 V. Cílek.)

Vysvětlivky k obrázkům v textu:

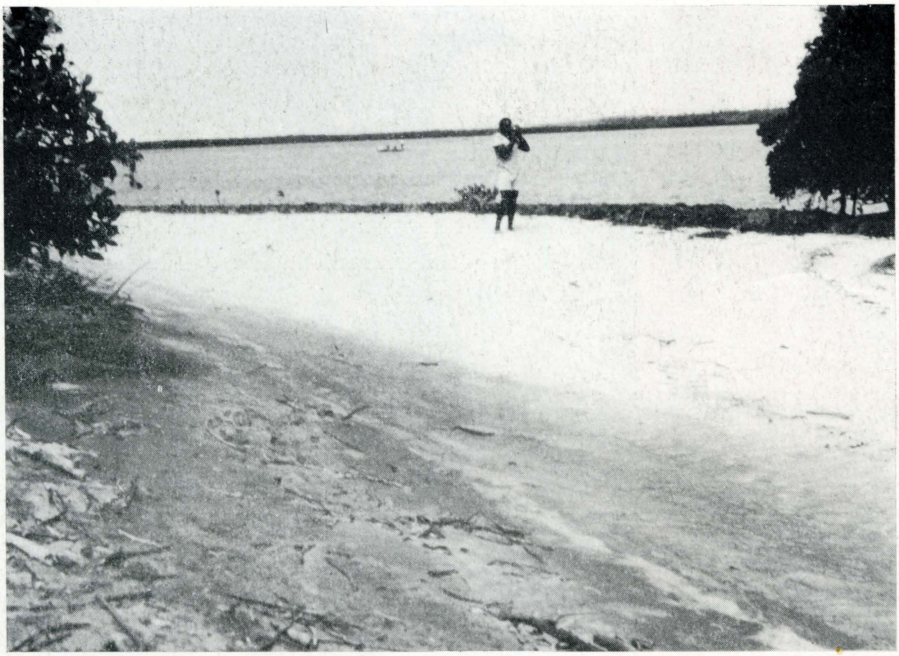
1. Geologická mapa pobřežních sedimentů mezi Dar es Salaamem a Bagamoyem (podle W. R. Moore 1963): 1 — holocén, 2 — svrchní pleistocén, 3 — spodní pleistocén, 4 — miocén, 5 — spodní miocén, 6 — křída, 7 — jura, 8 — karoo (karbon-trias), 9 — krystalické vápence — usagaran, 10 — usagaran — nerozlišeno.
2. Přehledná mapa okolí Dar es Salaamu představující výškové rozdělení, říční systém a bathymetrické údaje; výšky a hloubky v metrech.
3. Vývoj tanzanského pobřeží během holocénu a v budoucnosti (oblast Dar-es-Salaam — Bagamoyo), stadia 1—4 — během holocénu dodnes, stadium 5 — vývoj v budoucnu: 1 — pobřeží, 2 — korálový útes, 3 — písky, 4 — pískovce, 5 — mangrovy, 6 — písčité valy, 7 — oblast eroze.
4. Vývoj tanzanského pobřeží od svrchního pleistocénu dodnes: 1 — svrchní pleistocén, jílovité písky, 2 — holocén, 3 — korálové útesy žijící, 4 — plážové horniny (pískovce), 5 — mangrovy, 6 — korálové vápence.
5. Schematický řez ložiskem Kaole: 1 — černé minerály, 2 — hrubý písek s úlomky skořápek, 3 — bílý jemně a středně zrnitý písek.
6. Příčné řezy severní části ostrova Ras Luale: 1 — moře, 2 — plážové písky a dunové písky, 3 — plážové horniny, pískovce křemité a vápnité, 4 — plážové horniny, černé pískovce s těžkými minerály, 5 — ústřicové lavice, 6 — dislokace, 7 — šachtice.
7. Schematické příčné profily jižně od řeky Mpiji: 1 — moře, 2 — písky, 3 — těžké a tmavé minerály, 4 — tmavé mangrovové jíly.



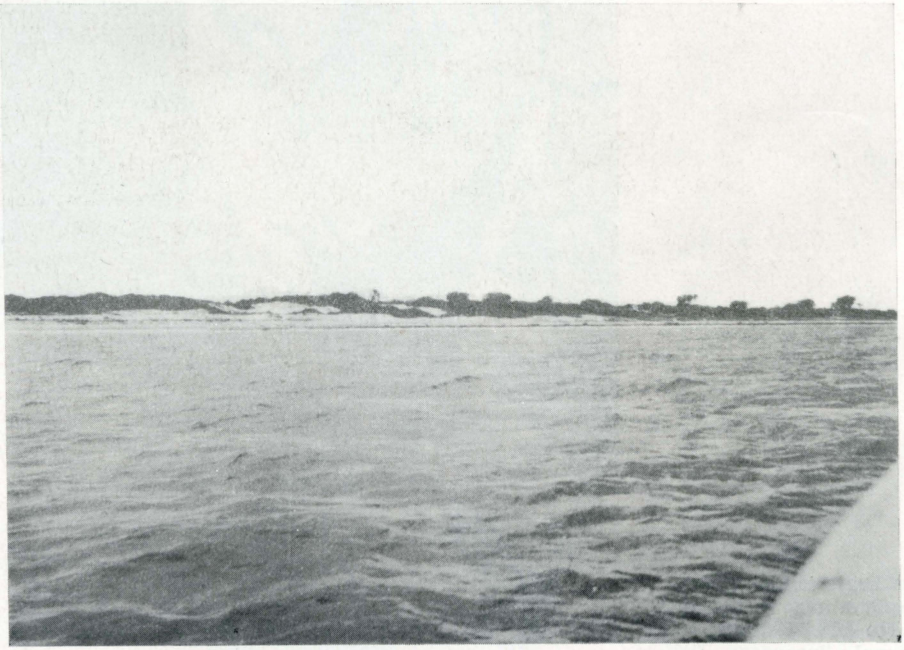
1. The vicinity of the mouth of the Ruvu river. (Explanations see in the text — page 245.)

2. Dar-es-Salaam area. [Explanations see in the text — page 247.]

3. Ras Luale island. (Explanations in the text - page 242.) *(Photos 1—3 Mineral Resources Division, Tanzania.)*

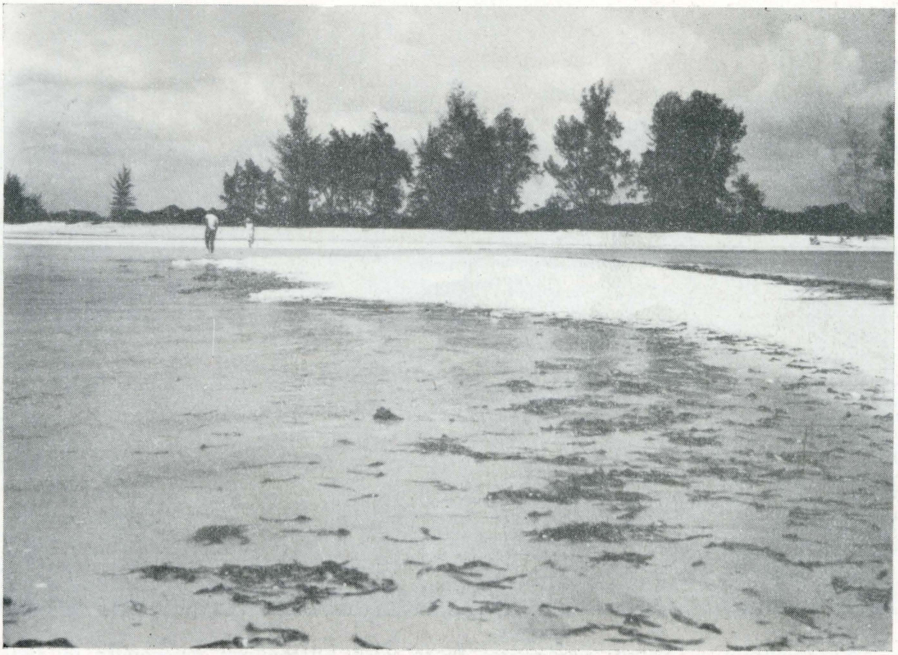


4. The beach an the south-western shore of Ras Luale island with recent berm containing black sands. The lagoon is in the background.



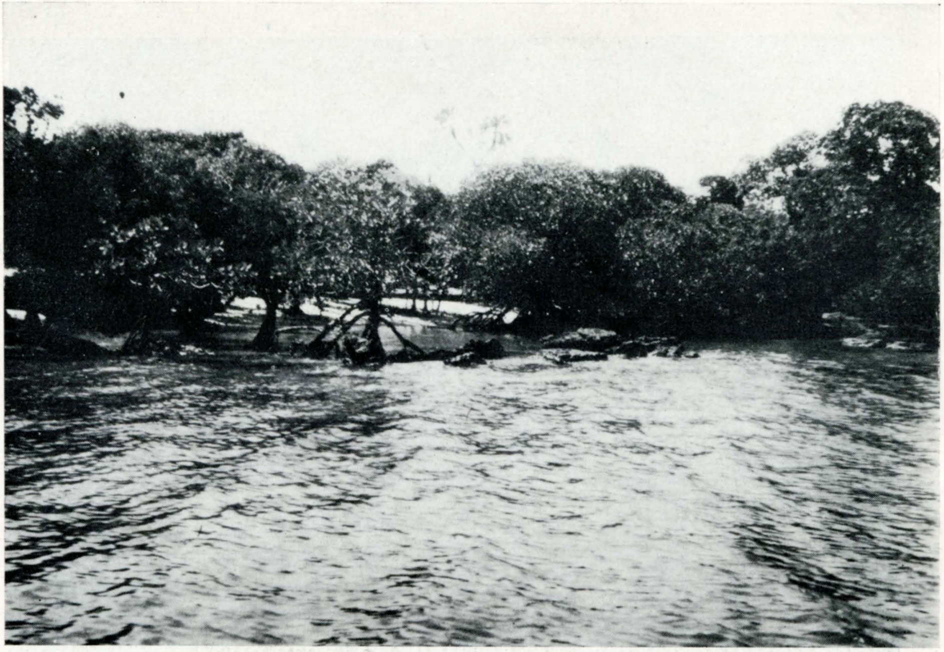
5. Ras Luale island — middle part — from the shore the older beach ridges are visible.

6. Nort-eastern side of Ras Luale with eroded beach sandstones with black minerals and oysters on the surface.



7. Changwahela North, sand bars extend seawards from the shore. An area of erosion with a low content of heavy minerals.

8. Mbudya Island, view on younger coral platform. In blackground white line of recent beach on Mtoni Terrace and higher Tanga Terrace with cement factory Wazo Hill on Lower Pleistocene coral reef.



9. Changwahella — North: Mangroves trees with *Rhizophora mucronata* by the seashore in a small bay with remnants of destroyed beach rocks (typical airy roots).
(Photos 4—9 by V. Cílek.)