# CHAPTER - III

# GEOMORPHIC DIVERSITY OF THE COASTLINE

## GENERAL

Quaternary tectonism along various major bounding faults and associated fractures, in combination with eustatic sea level fluctuations have been the major factors responsible for the evolution of the coastline under study. The diversity shown by the coastline of Gujarat in its different parts very well reflects the different combinations of geological histories, neotectonism and shoreline marine processes. The entire coastline can, on the basis of its geomorphic diversity, be divided into a number of distinct segments (Fig. III.1), each segment characterized by its own coastal environment. The varying effects of tidal action,

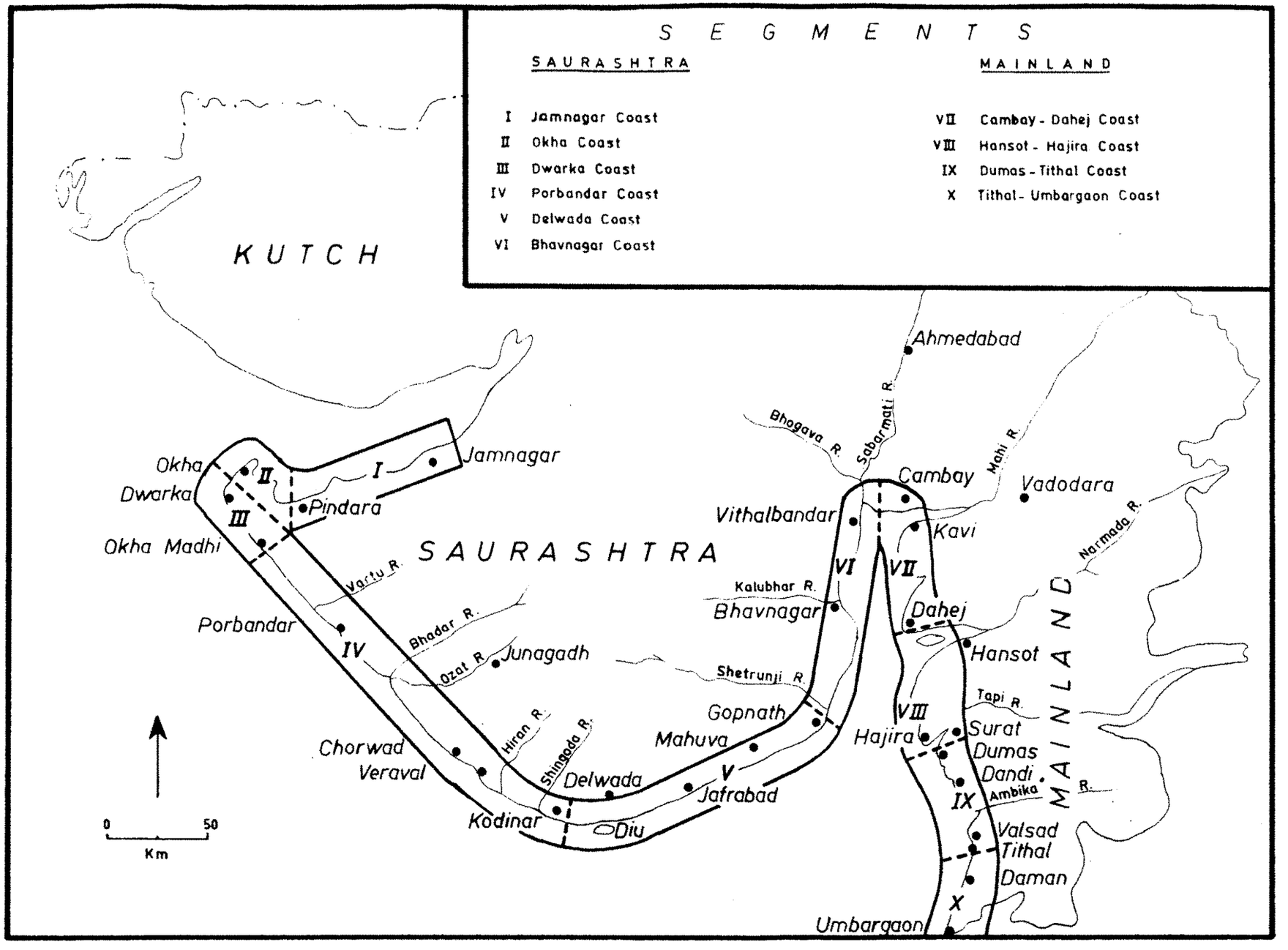



Fig. III.1 COASTAL SEGMENTS REFERRED IN THE TEXT

wave energy and shoreline currents also appear to have played their due roles. The various major and minor rivers flowing across the coastal plains and meeting the sea have appropriately contributed towards the nature and amount of coastal sediments.

The coastal environmental diversity in turn has controlled the nature of the marine fauna. The present author has therefore classified the entire coastline into a number of segments and then she has attempted to prepare segmentwise account of the microfaunal assemblages, especially benthic foraminifers. The present study essentially constitutes a description of the microfaunal association with the associated Sub-Recent to Recent (Holocene) sediments. Geomorphic diversity thus provides an appropriate background to that of the microfauna.

## SAURASHTRA

The coastline of Saurashtra has been divided geomorphologically into the following six segments :

| | | | |
|---|---|---|---|
| I. | Jamnagar coast | (Between Jamnagar and Pindara) | Overlooking the Gulf of Kutch |
| II. | Okha coast | (Between Pindara and Okha) | |
| III. | Dwarka coast | (Between Okha and Okhamadhi) | Overlooking the Arabian sea |
| IV. | Porbandar coast | (Between Okhamadhi and Kodinar) | |
| V. | Delvada coast | (Between Kodinar and Gopnath) | Overlooking the Gulf of Cambay |
| VI. | Bhavnagar coast | (Between Gopnath to Vithalbandar) | |

JAMNAGAR COAST : (Segment I)

This coastal segment extending from Pindara in the west to Jodia in the east has numerous characteristics of a submergent coast. Its actual shoreline is highly crenulated and is quite distinct from the other coastal segments. With a basaltic substrate the width of the foreshore varies between ½ a kilometer to as much as 11 km. Intertidal zone is mostly rocky to muddy, as a result of which the entire coastal segment is marked by thin but extensive mudflats, the thickness of the mud gradually increasing seaward. The phenomenon of submergence has been attributed to E-W trending Gulf of Kutch Fault (Rao 1961); the throw of this fault increases westward as a result of which the lower parts of the various rivers which meet the coastline show increasing drowning from east to west. Air-photos clearly show the extension of stream channels in the offshore parts of the Gulf. According to Thorat (1979), streams of 4th, 5th & 6th orders have their channel extensions submerged, and they extend within the Gulf to distances varying between 6 to 35 kilometers; and the development of creeks, 'nars' and islands reflects the original diversity of the unsubmerged topography. Sandy beaches are rare and are encountered only occasionally. The climate being humid and warm the foreshore mudflats support a luxuriant growth of mangroves. The subtidal zone is occupied by channels, submerged islands, shoals, sand bars and coral reefs.

The Jamnagar coast is famous for its coral reefs. Extending from Okha in the west to a little beyond Jamnagar in the east, fringing reefs have abundantly developed all along the zig-zag

coastline within the limits of the coastal segment. Almost all reefs are restricted within 10 m. depth, and have grown over subsiding trappean substrate. Except Narera island, the rest support living corals and comprise fringing reefs and micro-atolls.

OKHA COAST : (Segment II)

This coastal segment extending eastward upto Positra and then southward upto Charakala is very much different from that of Jamnagar and the two segments typically illustrate the diversity brought about by varying combinations of tectonism and marine processes. Unlike the Jamnagar coast the substrate in this coastal segment consists of shelly, arenaceous limestone of Dwarka Formation (Miocene to ? Pleiocene age). The Okhamandal block as a whole shows a marked uplift difference in substrate rocks, and thus this coastal segment is characterized by emergent landforms. Almost U- shaped, this coastal segment right up to Charakala is marked by numerous barrier island and lagoons (coral reefs). The coastline between Okha and Charakala is under the influence of tidal currents and waves which have less intensity to modify the coastal feature. Moreover, this part of the coastal segment being situated on the opposite side of the influence of monsoon winds, coastal sand-dunes and ridges have not developed. The absence of well defined sand ridges is obviously due to insufficient supply of sand and lack of strong shoreward winds, only the foreshore and part of back-shore is covered by a sand blanket. The sandy beach that runs all along the coastline is rather narrow, 8 to 10 meters wide. The

northern part of the segment between Okha and Positra is somewhat crenulated with a gradual slope. The intertidal portions are narrow, hardly exceeding half a kilometer and are comprised of mudflats. The eastern coast running almost NNE-SSW from Positra to Charakala through Khatumba comprises more or less a straight line with small indentation supported by coastal cliffs ranging in heights from 10 to 40 meters. Foreshore is narrow and sandy, backshore is marked by the accumulated debris, collapsed from the overhanging cliffs. The coastal cliff is dissected by numerous stream channels to give rise to gorges with steep walls. Intertidal mudbanks are almost absent except locally in a few creeks. South of Khatumba the coast shows a transition towards the Okha Rann such that further beyond Charakala, the cliffs overlook mudflats instead of the sand.

It is rather interesting to observe that although this part of Okhamandal coastline is indicative of emergence, yet the offshore portion up to a depth of 10 meter is characterised by numerous coral islands and micro-atolls. Obviously, corals would grow over a subsiding substrate and to explain this anamoly a number of faults in this part of the offshore area have been invoked by Lyall & Reddy (1982).

DWARKA COAST : (Segment III)

This segment includes coastline from Okha to Okhamadhi facing the Arabian sea. Somewhat arcuate and convex, the coastline is characterised by a continuous sandy beach almost 55 km long.

The most striking feature of this coastal segment is the occurrence of a ridge of loose sand about 100-150 meters broad quite close to the waterline, rising to heights of about 7-10 meters. The sands rise rather abruptly from the low water line, and within a few meters' distance, attain heights of several meters. Further inland, this sandy ridge shows somewhat decrease in height, ultimately merging with the rocky plains. This sandy ridge extends almost continuously from Okha to Okhamadhi and beyond, except at a few places where it is cut up by tiny creeks and lagoons. The coast from Okha to Mithapur has an unbroken sand ridge close to the foreshore but from Mithapur to Dwarka the sand ridge is broken by several estuarine mudflats. From north to south, five such estuaries viz. Mithapur, Mojap, Sivrajpur, Rupenbandar and Dwarka are recorded. Of these one at Rupenbandar, just north of Dwarka and the other one (Gomati creek) immediately south of Dwarka are of considerable size and extension. These mudflats typically show the progressive formation of a lagoonal environment on account of the formation of the sandy ridge in the form of spits. Of all these estuaries only the one at Dwarka forms the creek. A worthwhile stream Gomati Nadi flows several kilometers before meeting the sea; rest are tiny local streams of 2-3 km lengths emptying into the mudflats. Nowhere along this coastal segment, Miliolite Formation is encountered either in the foreshore or in the backshore areas, and it is presumed that the substrate comprises limestone of Dwarka Formation.

PORBANDAR COAST : (Segment IV)

The coastline extending southeastward from Okhamadhi right upto Kodinar is remarkably straight and provides several geomorphic and geologic features of interest. The famous miliolite rocks of Saurashtra are mainly restricted to this coastal segment and it is along the foreshore and backshore portions of the segment that the major bulk of geological investigation in the past has been conducted. It is however, surprising that though the coastal miliolites of this area provide a variety of geomorphic features both in the onshore and offshore areas, no attempt has been made to investigate this coastal segment from the point of view of its geomorphic evolution. Geologically, the coastline and the terrain immediately flanking it on the onshore side consists of a trappean basement over which the Tertiary (Gaj Formation and Dwarka Formation) and Quaternary sediments ( Miliolite Formation and Recent beach deposits) are seen to be resting. The coastal plains 5-50 km wide slope very gently seaward and are seen traversed by quite a few longitudinal parallel stabilized miliolite dune ridges. Evidently higher strandlines during the past transgressive phases have given rise to these carbonate sand ridges.

The actual shoreline is straight, extending almost NW-SE. The offshore profile is gentle and the continental shelf is rather shallow and broad extending for distances varying from 10-20 km. This shoreline has been a site of continued carbonate sand formation since Early Pleistocene, and extending

intermittently from Okhamadhi in the NW to as far SE as Kodinar, atleast four generations of coastal dune ridges comprised of miliolites are observed up to a distance of 20 km inland from the present-day shoreline. According to Ganapathi et al. (1982) and Merh et al.(1982) the fossilized dune ridges farthest from the coastline appear to be related to a transgression when the strand-line must have been atleast 40 m above the present sea-level. According to these authors, it was during this high sea stand that marine waters entered several kilometers inland through the valleys of rivers, like Vartu Bhandar, Ojat, Hiran and Shingoda. The next line of dune ridges a little nearer to the coast appears to be related to the last transgression (Flandrian) when the sea-level was 8-10 meters higher than the present. Numerous foreshore features provide a good evidence that prior to Flandrian transgression, the sea had regressed (perhaps during the Würm glacial stage), its level having gone down atleast by 20 to 25 m from the present. The coastal dune ridges that developed during this regression were submerged during the Flandrian transgression and even today the partly or fully submerged, hardened carbonate deposits are seen extensively exposed along the present day shore line in the form of partly submerged dunes, cliffs, wave-cut platforms. The inter-tidal zone as well as near offshore portions of the shelf also reveal considerable unevenness of the substrate which is comprised of miliolite. The present day shoreline is marked by the develop-ment of a prominent coastal ridge made up of loose carbonate sands, extending almost uninterruptedly from NW to SE rising rather abruptly above the high water line. Wherever the shoreline is cut by the river mouths, the sandy ridge is seen to form well

defined spits and bars with lagoonal patches behind them. The beach or lower foreshore, though well defined, is rather narrow, varying from 5 to 150 m in width, with the backshore sandy ridge rising to almost 15 m above the bermline. A salient feature of the foreshore and near offshore is the presence of numerous submerged and dissected stablized miliolite dune ridges which now form either rocky platforms or project out as steep cliffs of 8 to 10 m height from beneath a veneer of loose beach sands.

The coastline is indented by a number of inflowing rivers, their mouths typically forming tidal creeks with lagoons. The prominent ones are those of Kalipani (Ghughadava creek), Vartu (Meda), Kindari, Bhadar, Seel, Noti, Megal, Hiran, Somat, Shingoda and Rupen rivers. Almost all these creeks are characterized by sandy spitbars giving rise to linear backshore lagoonal mudflats behind the coastal ridge. Some of the rivers (Ozat, Madhuwanti, Netrawati, Khari, Saraswati etc.) show a characteristic deflection in their courses flowing parallel to the coastline before meeting the sea. Generally speaking, the coastline from Okhamadhi to Meda is intermittently rocky. Meda to Porbandar, the rocks are absent. At Porbandar a small part of the coast is rocky, but further southeast upto Antroli, the foreshore is exclusively sandy. Beyond this point, right upto Madhavad lighthouse (Kodinar) the coast is characterized by rocky foreshore cliffs. This coastal segment all along, has a rocky miliolitic littoral zone and significantly the substrate for several kilometers offshoreward comprises an uneven miliolitic platform.

An interesting feature of the miliolitic dune formation beyond Veraval towards Kodinar is the appearance of parabolic sand dunes (fairly consolidated) which are seen to extend several kilometers inland. The wings of these crescentic dunes vary in length from ½ km to as much as 2 to 3 km, and point W or S W wards

DELVADA COAST : (Segment V)

East of Kodinar, beyond Madhvad creek, the coastline takes a E-W trend and beyond Diu, extends right upto Gopnath in an easterly direction. Although the Gaj and Dwarka Beds have been reported from this part of Saurashtra, they are nowhere exposed near the coastline. The coastal plains and coastline show mostly river alluvium and unconsolidated beach sands resting over the consolidated miliolites. The foreshore is moderately rocky comprised of miliotic platform, while the backshore is characterized by a fairly broad longitudinal dune complex through which occasional older miliolite dunes peep out. In fact, on proceeding further east towards Madhvad, the backshore unconsolidated sand dunes become more extensive and appear to represent a sandy terrain made up of a variety of aeolian forms. The coastline further eastward is irregular and somewhat dissected; the island of Diu is separated from the mainland Saurashtra by extensive tidal mudflats. Between Madhvad and Diu island a tidal mudflat extends inlandward to almost 6.5 km. An area of about 25 square km is occupied by mudflats here within which a number of rivers including Rupen and Sangavadi empty their waters. The south facing coast of Diu extending for almost 13 km is characterized

by an irregular shoreline and is made up of rocky and cliffy headlands and crescentic sandy beaches. The cliffs show variable heights ranging from 9 to 18 m rising above the high water line; even the intertidal zone specially in the eastern part is made up of miliolitic sheet rock. In fact, the entire island of Diu rising upto a maximum altitude of 30 m represents a gigantic partly submerged ancient miliolitic dune complex. Northward, the shoreline of the Diu island slopes gradually into the mudflats that separate it from the mainland. The mainland coast facing the Diu island is rather uninteresting, devoid of any significant beach formation though a few km inwards to the north, linear rows of parabolic dunes and longitudinal ridges of Miliolite formation rising above the alluvial deposits and ancient mudflats are abundant. Offshoreward, the substrate here is narrow rocky miliolitic. Beyond Diu upto Nawabandar, the coastal morphology is identical to that of the southern coast of Diu, and is characterized by rocky foreshore, cliffs and coastal dune complexes. From Nawabandar to Gopnath Point, the coastline follows a WSW-ENE trend and is rocky and cliffy with sandy beaches, interspersed in between. A number of rivers flow into the sea and quite a few of them form estuarine creeks with inland mudflats, the mouths of which are restricted by spit bars of Recent sands. The coastline from Nawabandar upto Jafrabad is somewhat crenulated, comprised of a rocky foreshore and a backshore marked by discontinuous WSW-ENE trending sand ridges oblique to the coastline. The Jafrabad creek through which the tidal waters are seen to enter backshore areas have given rise to extensive mudflats, almost 12 km long and 2.5 km wide.

The coastline further north-east of Jafrabad is characterized by intermittent sandy and rocky foreshore and extensive unconsolidated backshore carbonate sand dune complexes. Beyond the mouth of Dhantravadi Nadi, again another extensive inland mudflat of wide areal extent is encountered. An interesting feature of this lagoonal mudflat is the spit-like extension of the Recent sand accumulations which restrict the mouth of the mudflat. Beyond this creek for about 75 km up to Methala Point, the coastline is seen to contain mudflats extending several km inland. Offshoreward these mudflats are overlooked by a series of islands. These islands have been found to represent partly submerged portions of an older coastal sand dune ridge related to a past lower strand line. From Methala right upto the Gopnath Point, the coastline is free from mudflats and is characterized by a series of rocky headlands and crescentic sandy beaches. The foreshore beach at places is fairly wide with high water line marked by cliffs. Backshore sandy ridge is more or less absent except for a few sporadic longitudinal ridges and barchans up to Janjhmer. Beneath the sands occur miliolites, the cliff sections of which typically reveal their aeolian nature. Evidently, these represent submerged coastal dunes partly eroded. Substrate is seen to extend for 3 to 4 km offshoreward and consists of sand deposits over a miliolitic littoral shelf.

BHAVNAGAR COAST : (Segment VI)

From Gopnath Point upto Vithal Bandar the coastline is almost NS, overlooks the Gulf of Cambay and provides a fascinating diversity in respect of geology ard geomorphology. The southflowing

river Shetrunji just a little north of Gopnath Point follows a major fault line (Ganapathi, 1981). Because of this fault the geology of the coast to the south of the river is somewhat different from that of the coastal terrain to its north. North of Shetrunji, the Tertiary rocks with the underlying laterites are seen exposed right along the shoreline; the miliolites as well as the carbonate beach sands completely disappear.

Shetrunji river which forms an important river emptying its water into the Gulf of Cambay, has formed an estuarine delta, a coastal accumulation of subaqueous and sub-aerial river-derived sediments remoulded by waves, currents and tides. The delta plain above the low water line has been dissected by several distributory channels. A prominent mouth bar is seen developed here and according to Ganapati (1981) three generations of sea-levels can be recognized, two as offshore features (Sultanpur shoal and Gopnath shoal). The foreshore of the Shetrunji delta lying between high and low water line is marked by a horizontal intertidal mudflat. North of this estuarine delta comprises an alluvial feature. From Mathavada to Gopnath, the coast is rocky, and from north to south is seen to be made up of laterites (Paleocene), pebbly ferruginous sandstone and clays of Lakhanaka Formation (Pleistocene to Early Holocene) and Gaj limestone (Lower Miocene) in succession. Interestingly major mudflats are conspicuously absent between Mathavada and Ghogha. From Mathavada to Kuda, the shoreline runs almost straight and shows quite a few interesting foreshore and backshore features. The foreshore features comprise a wave-cut

platform in its lower part, the upper part of the foreshore marked by a continuous beach from Mathavada to Hatab bunglow. The rocky platform is made up of laterites and Lakhanaka rocks, while northward up to Ghogha Gaj rocks are exposed. This intertidal platform which slopes very gently seaward varies in width from 500-1500 m. The beach in the upper part of the foreshore shows a width variation from 25 m in the south to as much as 200 m at Kuda in the north. The beach slopes gently seaward; landward it is flanked by backshore dunes against which it abuts abruptly. The beach material varies in size from very fine sands to very coarse pebbles and gravels and consists of fragments of quartz, agate, chalcedony with a subordinate proportion of rocks and mega-shell fragments. The backshore feature comprise coastal dune accumulations of two generations. Lithologically, there is not much difference in these backshore accumulations of two ages, both consisting mostly of arenaceous material quartz, agate, chalcedony and rock fragments. According to Ganapati (1981) the dune ridge complex immediately behind the beach is evidently related to the present day shoreline, while an older beach and dune topography just behind the present day dunes points to a past higher strandline. The older dune beach complex appears to be related to a past strandline 6 to 8 m higher than the present (Flandrian).

From Ghogha further northward the highly muddy coast of Bhavnagar begins. The tidal creek of Bhavnagar penetrates the Saurashtra Mainland, meandering through extensive mudflats, and

finally ending up as Kalubhar river. The port town of Bhavnagar is situated near the mouth of the creek just to its south. The tidal mud rests over the rocks of Gaj Formation. Shrivastava (1968) and Ganapati (1981) have marked an EW fault along the Kalubhar river, and have shown that the north side of the fault has gone down by nearly 50 m. It is because of this fault that further north of Bhavnagar Creek, nowhere Tertiary rocks are encountered, and instead a thick Quaternary alluvium occurs. The Kalubhar River that meets the Gulf of Cambay forms an estuary at its mouth, the main channel at this point forming the Bhavnagar creek and a major inlet for the tidal waters. The estuarine tidal-flat is very extensive, occupies almost 225 sq. km area and is a site of deposition of suspended finer sediments brought from the deeper parts of the Gulf of Cambay by tidal waters. The coastline from Ghogha to Bhavnagar is marked by two well defined marine terraces rising approximately 20 and 10 meters above the high water line, the lower terrace is mostly restricted to the Gaj rocks while the upper terrace has been carved out of the Deccan trap. These typical erosional features represent wave-cut platforms generated during two successive higher strand lines of the past (Ganapati, 1981). The coastal scenery further north of Bhavnagar Creek up to Vithal Bandar and beyond provides a sudden change and is seen to consist of extensive tidal mudflats, several kilometers wide, cut up by numerous tidal channels with a very irregular high-water line. The low-water line is rather straight extending almost in a NNE - SSW direction. The tidal flats support extensive mangroves. The outer fringe of the mudflats along the low-water line is seen

flanked by a coastal sand bar. In fact, right from the Bhavnagar Creek northward as one proceeds towards the mouth of Sabarmati and Mahi rivers, development of shoals and mudbanks within the gulf is observed. An offshore island designated as Mal Bank, 23 km long in a NW direction and 15 km wide in its northern part, consisting of sand, silt and clay, possibly represents a submerged mouth bar of Sabarmati and Mahi rivers, developed during a Pre-Flandrian regression. It is further observed that the tidal flats to the north of Bhavnagar Creek, frequently contain islands of alluvium rising above the high water line, this phenomenon provides a good evidence of the submergence of a dissected alluvial topography due to a rise of sea-level. This feature is ideally exhibited at the tip of the Gulf of Cambay where the rivers Sabarmati and Mahi meet the Gulf.

Substrate conditions along this coastal segment from south to north appear to be quite variable. While the offshore areas facing the Shetrunji river, for several kilometers seaward, are made up of thick alluvial material, from Mathavada to Ghogha the littoral zone as well as the adjoining shelf is rocky and made up of coarse, pebbly ferruginous sandstone. North of Ghogha beyond the Bhavnagar Creek, the hard rocks are nowhere encountered, and the bottom of the Gulf near the mouths of Sabarmati and Mahi rivers essentially provides a soft muddy substrate.

The mouth of the river Sabarmati with its wide muddy banks marks the zone of transition, beyond which to the east begins the

Gujarat Mainland coast. The Sabarmati River mouth with Bhogavo river meeting it from the Saurashtra side and the Mahi river emptying its water in the Gulf from the Mainland side, is characterized by vast area of tidal flats and numerous river mouth bars. The overall coastal landscape is marked by a highly crenulated high water line with numerous narrow entrants, through which tidal waters, travel inlandward such that the terrain above the high water line comprises a monotonous flat ground with a gradual almost imperceptible slope towards the Gulf. The entire coastal scene is dominated by mudflats, raised mudflats with numerous islands and projections of elevated portions made up of highly fertile alluvial soil. The geomorphology of this transitional zone provides a good evidence of Late Pleistocene and Holocene events of sea-level fluctuations.

## MAINLAND GUJARAT

The Mainland Gujarat coast is divisible into four segments on the basis of the coastal geomorphology, geological factors and shoreline processes. All these have resulted in a combination of various onshore and offshore features characterizing each segment. Further, coastal waters of each segment are characterized by environments quite distinct from one another. The major rivers that meet the Arabian Sea flowing across this coast provide the dividing lines for the following segments:-

VII. Cambay - Dahej coast - (Between the rivers Mahi and Narmada)

VIII. Hansot - Tithal coast - (Between the rivers Narmada and Tapi)

IX. Dumas - Tithal coast - (Between the rivers Tapi and Par)

X. Tithal - Umbargaon coast - (Between the rivers Par and Varoli).

CAMBAY - DAHEJ COAST (Segment VII)

The coastline extending from the north of river Mahi to that of the Narmada provides a good example of a drowned alluvial coast. This coastal segment comprises a thick accumulation of Quaternary fluviatile sediments that rises abruptly above the high water line forming alluvial cliffs facing the tidalflats. 2 to 4 km wide intertidal zone made up of silty and muddy sediments, is the most striking feature of this segment. The tidal mud is obviously resting over submerged alluvium. The actual shoreline is highly crenulated with numerous tidal inlets. The Dhadhar river which flows almost across the middle of this segment has carved a meandering course with an entrenchment of 6 to 8 m. It is relevant to mention that the rivers Mahi and Dhadhar were responsible for depositing a vast thickness of alluvium during Pleistocene period, and later, the same rivers carved out cliffy channels within their own deposits. This phenomenon of incised meandering and cliffs of alluvium are illustrative of eustatic fluctuations of sea-level.

The vast quantities of sand, silt and clay brought by these rivers are seen deposited as tidalflats, mouth bars and foreshore mudbanks. Sandy beaches are significantly absent and alluvial cliffs rise abruptly above the high water line. An interesting feature of this coast is the presence of numerous islands of alluvium peeping above the tidal mud.

The funnel-shaped estuarine river mouths of Mahi, Dhadhar and Narmada quite broad on the seaward side are muddy and extend for several kilometers inland; tidal waters enter through these inlets to fairly long distances (several km) as a result of which extensive accumulations of tidal mud are encountered along the mouths of all the three rivers. The mouths of rivers Mahi and Dhadhar are marked by vast stretches of muddy shoals, the rivers cutting across the same through networks of braided channels during low tides. The width of the mudflats at the mouth of the river Mahi could be as much as 4 to 5 km. The Dhadhar shows more extensive mud accumulations at places. Near its western extremity the mud banks are as much as 8 to 10 km. wide. The striking mouth bar of Narmada river, Alia Bet is of gigantic dimensions, about 20 km long and 10 km wide at its western flank; it supports a mangrove growth.

The entire coastal segment is marked by wide foreshore mudflat all along its length; the high-water line is highly crenulated. Occurrence of numerous offshore mudbanks and shoals, is another characteristic feature of this coastal segment. Silty and sandy banks of varying dimensions and shapes occur between the mouths of Mahi and Dhadhar; most of them get submerged during high tide though parts of some of the larger ones remain dry during normal high-tides. These mudbanks frequently change their configuration in course of time or even seasonally. Alluvial cliffs rising abruptly above the high water line comprise the main backshore feature. These steep cliffs occur almost all along the

characterized by muddy turbid waters and a soft substrate made up of silt and mud. Wave action is not so well pronounced, and entire sediment distribution is dependent on river water flow and tidal currents.

A significant feature of this part of the Mainland Gujarat coast is the accumulation of extensive mudflats on the left banks of the river mouths, the right banks being almost sandy. This phenomena is attributed to the fact that river waters augment to the rate of flow of the ebb-tide waters and in the process, carry silt and mud farther from the mouth.

HANSOT-HAJIRA COAST (Segment VIII)

This segment forms that part of the Mainland coast just outside the Gulf of Cambay environment, of course considerably influenced by the marine processes operating in the Gulf, ~~to a certain extent.~~ Important geomorphic characteristics of this segment are the development of prominent sandy ridges parallel to the coast and a highly dissected shoreline. The various geomorphic features here are different from those of the coastal segment to the north of Narmada. This segment is replete with estuarine creeks along which tidal waters tend to spread inland over large areas. Being located to the south of 'Narmada Geofracture', it has been showing much less vertical tectonism during the Quaternary period. Hence, its coastline features provide a better glimpse of the Late Pleistocene and Holocene sea-level changes.

As already stated earlier, the coastal sand ridges tend to become quite prominent to the south of Narmada, and ridges of several generations have been recorded. This coastal segment thus, shows three sets of 'en-echelon' discontinuous sandy ridges all along the coast; the two inner ones are quite prominent while the last outer one (westward) is fragmentary and of smaller dimension. The easternmost ridge varies in height from 6 to 20 m and shows a variable width of 1 to 2 km. The next ridge to its west is smaller and rises only 2 to 6 m. and is separated from the former by raised mudflats. The relicts of the westernmost ridge are fragmentary and sporadic represent the oldest coastal sandy ridge, deposited when the sea-level must have been several meters lower than the present and which got drowned during the Flandrian transgression. Small projections of this ridge are seen rising above the present day mudflats and from elongated 'bets'. The middle row of sandy ridge is obviously related to the present day shoreline while the eastern most ridge is related to the transgressive strandline of the past (Flandrian).

The various tidal creeks with extensive mudflats have dissected the sandy ridges. The entire coastal segment is marked by broad stretches of tidal mud, on an average 4 to 5 km wide. The Kim river meanders for about 20 km within the mudflats before meeting the sea. Similar phenomenon is shown by Sena and Tena rivers. The entire inter-~~mudflat~~ tidal zone is characterized by a large number of channels through which waters flow back with the receding tide. Within the mudflats, occur the remnants of

an ancient sand ridge. Off the Sena creek occurs the 1.5 km. long bet of Dandi.

While the mouth of the river Narmada is funnel shaped with a well developed mouth bar (Aliabet),that of the Tapti river is somewhat hook-shaped. A 5 x 3 km mouth bar of Tapti is itself criss - crossed by numerous channels. A striking feature of the Tapti mouth is the adjacent Mindhola creek to the immediate south which is comprised of a wide inland lagoonal mudflat. On the alluvial patch between the Tapti and Mindhola (perhaps an ancient sandy mouth bar) are located the famous holiday site of Dumas and the port of Magdalla.

Raised Mudflats (ancient tidal flats) which are at present above the high water line, make their appearance for the first time in this coastal segment, and it is observed that they become increasingly prominent southward. A sort of gradual transition exists between the raised mudflats and the alluvium. Obviously, these raised mudflats represent the intertidal flats related to the past (+ 8 to 10 m ) high strandline.

In contrast to the coastline to the north of Narmada, the alluvium in this coastal segment is thinner and alluvial cliffs are scarce and sporadic, confined only to the inner parts of the mouths of the river Narmada, Kim and Tapti. When present they form 3 to 5 m high cliffs against which abut the muddy (tidal) banks of the rivers. Also, the alluvial islands are only a few

and isolated occurences of these are restricted to the vicinity of Tapti and Tena rivers.

The substrate continues to be soft and muddy. The action of waves and surfs are quite pronounced, and combine to that of tidal currents.

DUMAS-TITHAL COAST (Segment IX)

This coastal segment delineated by Tapti and Auranga rivers in the north and south respectively, shows a conspicuous change in the coastal landscape. Though it still marks a drowned alluvial coast, it shows a remarkable straightness, typically showing the development of a narrow sandy beach all along the coast. ~~Thus~~ The beach is all along flanked by a backshore sandy ridge over which rest unconsolidated aeolian sands. The Mindhola, Purna and Ambica rivers flow into the sea cutting across the ridge. Through the mouths of these rivers tidal waters enter inland for several kilometers and as a result, extensive tidal flats(lagoons) have developed behind the sandy ridge. Raised mudflats are commonly observed. Alluvial plains rise gradually above the mud-flats and an interesting feature observed is the presence of numerous streams that show considerable meandering with an entrenchment of 2 to 3 meters, not very far from their mouths. Wave and surf action is fairly pronounced. Substrate is soft and muddy.

TITHAL-UMBARGAON COAST (Segment X)

This coastal segment is significantly different. It is marked by an almost continuous sandy beach with rather localized occurrence of mudflats along the various river mouths. The coastal landscape from north to south shows a distinct transition, the alluvium gradually thinning out so much so that at the southern end beyond Umbargaon the coast and the onshore areas become rocky. The coastline comprises a continuous sandy beach with a backshore coastal dune ridge. Interestingly, almost all along behind the coastal ridge occurs an almost continuous strip of raised mudflats, 2 to 6 km wide. The raised mudflats merge into the alluvium. All these coastal deposits (of both backshore and foreshore) tend to gradually thin out, such that to the south of the river Kolak, the lower foreshore is more or less rocky and forms a basaltic platform over which rest relatively thin sand and mud deposits. The sandy ridge rises upto a height of 8 m above the high water line. The beach itself is narrow, never exceeds 100 m in width, and its material shows considerable variations of grain size - fine sands to pebbles. Surf action is much more pronounced and during strong winds waves are seen sometimes eroding the backshore ridge. Substrate conditions in this coastal segment are significantly different and indicate occurrence of shallow rocky platform over which, on account of the waves and tides, the terrestrial sediments are being constantly reworked.

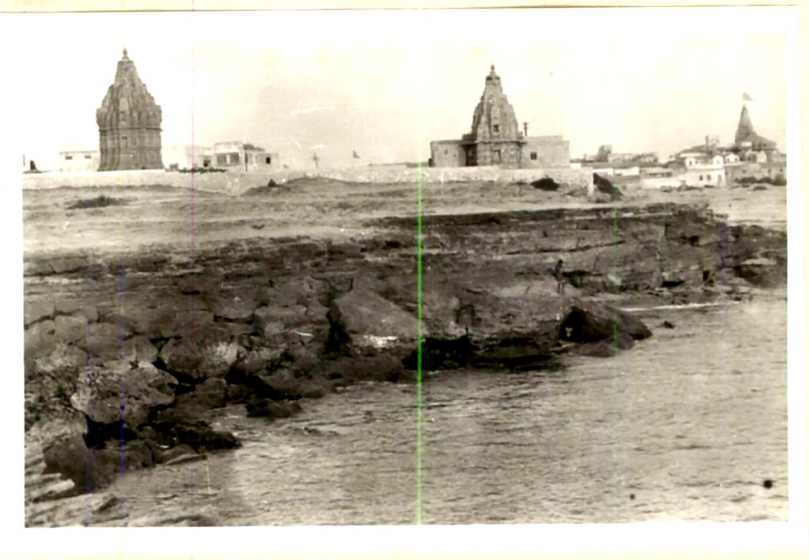
A few selected photographs showing the coastline features from the various segments have been given to provide an idea of the coastal landscape and shoreline features (Plates 1 to 19).

PLATE-III. 1 & 2.

1. A close view of Mangrove swamp in Jamnagar coast. Loc. Rozimata, Saurashtra.

2. Okharann overlooking NE from the village Okhamadhi. Saurashtra.

PLATE-III. 3 & 4.

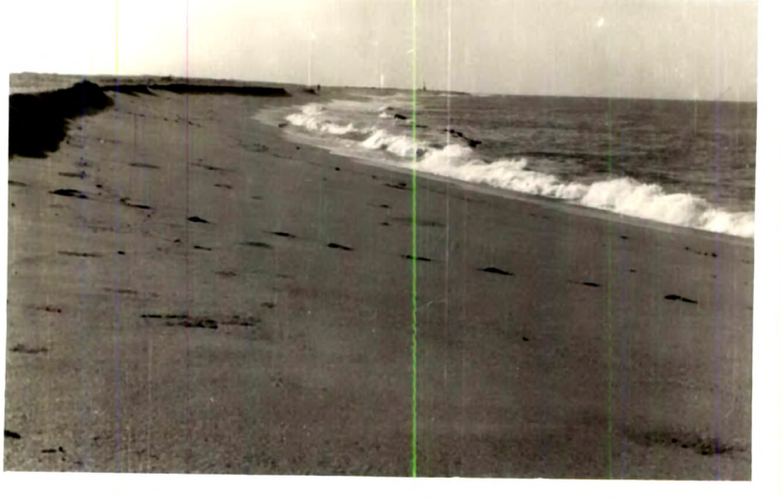


3. Lowcliffs of Dwarka rocks along the Dwarka coast.

4. Rocky miliolite inter-tidal platform covered with recent carbonate sand. Loc. South of Navibandar.

PLATE-III. 5 & 6.

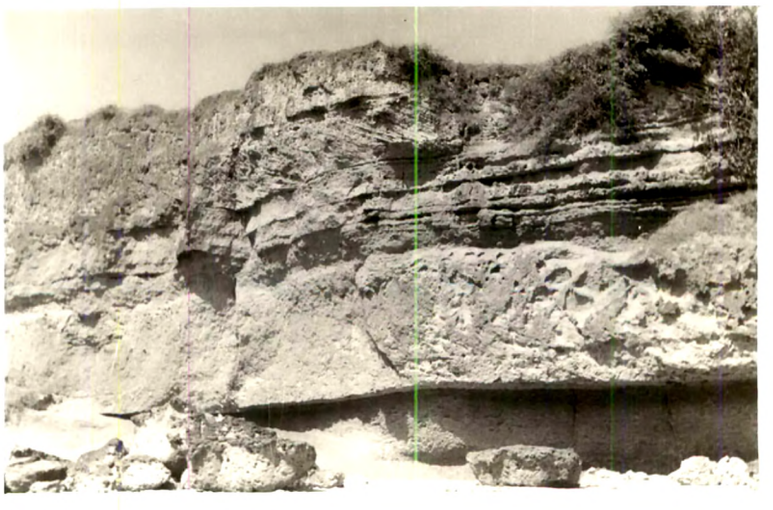
5. Carbonate sand beach with coastal dune in the extreme left background. Loc.Madhavpur, Saurashtra.



6. Chorwad beach showing erosion of coastal dunes by surf action. Loc. Chorwad, Saurashtra.

PLATE-III. 7 & 8.

7. Submerged miliolite cliffs on the south coast of Saurashtra. Loc. Diu Island.

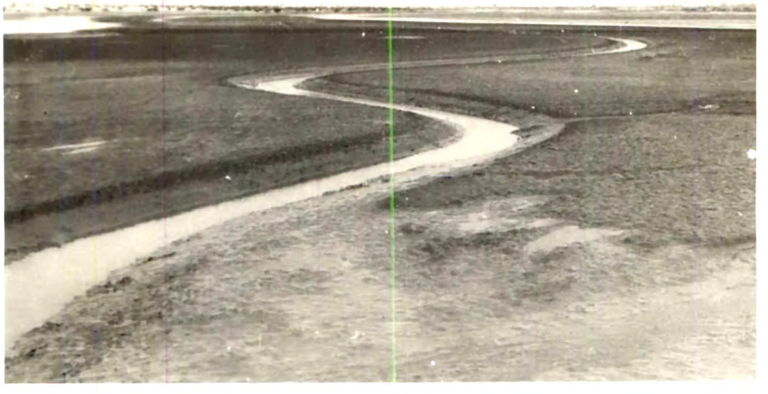


8. Impressive cliff of miliolite showing an abandoned wave-cut platform. Loc. Gopnath, Saurashtra.

PLATE-III. 9 & 10.

9. A panoramic view of the miliolite cliff at Gopnath point.

10. A window view of the Gopnath coast with honeycomb weathered miliolite in the foreground.



11. Meandering tidal channel in mudflat on east coast of Saurashtra. Loc. SE of Dholera.

12. Alluvial cliff on Mahi river. Loc.Dhuvaran.

13. Estuarine mud along Dahej coast.
Loc. Ghugharia creek.

14. Mudballs in the inter-tidal zone at Hajira coast. Loc. Hajira.

15. Coastal sandy ridge at Umbharat coast.
Loc. Vansi village.

16. Cliffy relict alluvium in the estuarine
mudflat near the mouth of Par river.Loc.Umarsadi.

17. Nargol coastline showing the coastal sandy ridge in the background. Loc. Nargol.

18. Coarse sand and shingle beach with coastal ridge in the background. Loc. N.of Bordi.

PLATE-III. 19.

19. Recent sandy ridge at Umbargaon showing casurina plantations. Loc. Umbargaon.