CHAPTER V

C O A S T A L G E O M O R P H O L O G Y

V.1 GENERAL

The coastal portion of the study area, also show a considerable diversity, and broadly they can be divided into two main divisions :

1) Coastline of Okha Mandal (Dwarka coast)
2) Coastline between Jamnagar and Okha Rann (Jamnagar coast)

The two coastlines typically illustrate the diversity brought about by the different combinations of lithology, tectonism and marine processes, operating on a terrain. The coastlines show interesting features, on limestone and trap developed in the supra tidal, intertidal and infratidal zones. Of the above two divisions the former is characterised by the presence of sandy ridge, coastal cliffs and inland water estuaries and the latter by occurrence of tidal mud flats with patches of mangroves.

The coast is a line which separates land from seas, and it developes various geomorphic and sedimentological features. There are many excellent works dealing with classifications of coast, and widely accepted classifications are those of Valentin (1962) and Shepard (1963), are as under :

1) Mainland coast with spit or chenier development
2) Barrier island coast
3) Coast with cliffs
4) Coast with sunken morphology
5) Coast with bioherms of warm seas e.g. coral reefs-coastal reef and atoll.

The two main divisions of the coastline have been critically evaluated in the light of the abovementioned criteria.

V.2 DWARKA COAST

1) General Features

Within this nomenclature is included the entire coastline of Okha Mandal, west of Okha Rann and comprises the entire semicircular western coastline between Okha and Okha Madhi, the U-shaped portion from Okha to Positra and the straight NS segment from Positra to Charakla. The entire coastline indicates uplift.

The coastline from Okha Madhi to Okha, is characterised by about 100 to 150 m broad sandy ridge (Plate V.1) rising right from the water line to height of about 7 to 10 m, beyond which the ridge very gradually slopes inland and merges with the agricultural fields. This sandy ridge runs all along the west coast and is cut across by lagoonal outlets, tidal inlets and river mouths. The segment between Okha and Positra is quite different. Here the coastline is cremulated and sandy, but without any ridge formation. On the other hand, the coastline between Positra and Charakla facing east, has a very narrow sandy beach, hardly 15 m wide, and is marked by steep rocky cliffs, against which the coastal sands are resting.

PLATE V.1

Sandy ridge, at low tide time showing foreshore, backshore and top of the ridge.

The coastline to the east of Okha, right upto Charakala, is marked by numerous barrier islands and lagoons (coral reefs).

In general all the three segments, reveal different coastal types, typically forming a coastline of emergence, each having been subjected to different climatic processes to give rise to the existing diversity.

The arcuate coastline from Okha Madhi to Okha along the Western margin, provides a continuous sandy beach, characterised by a 55 km long and 100 to 150 m wide ridge of Recent sands. Attaining a height of 7 m to 10 m, the ridge extends continuously all along the west coast. The sands rise just from the low water line and within a few metres distance, attain heights of several metres, which further inland somewhat decrease in height, ultimately merging with the plains. Comprising dominantly of carbonate grains, the entire stretch is made up of loose sand accumulation; nowhere hard rocks are exposed except at Dwarka and Varwala.

The source of the carbonate sand is from the shoreward part of the continental shelf, the vast

accumulation having been brought about by the action of wave breakers.

Coastline between Okha and Charakla This coastline is under the influence of tidal currents and waves which have less intensity to modify the coastal features. The coastline being on the opposite side of the influence of monsoon winds, coastal dunes, ridges etc. have not developed. On this coast i.e. from Okha to Charakla 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 backshore is covered by a sand blanket. The sandy beach is a narrow strip running all along the coastline with a width of 8-10 m and gently sloping towards the sea. The sand surface does not show structures like ripple marks and rills. The northern part of the segment, is somewhat crenulated with a gradual slope, while the eastern segment is a straight line supported by coastal cliffs of 10-40 m height.

On the east coast, near the water line beach is sandy. Back shore starts with an accumulated debris collapsed from cliffs near foot. The accumulated debris has given a rich growth of vegetation. The cliffs are devoid of vegetal growth. At places, even

steeper slopes are covered by bushes and small flowering plants. The coastal cliff is dissected by number of stream channels to give rise to deep gorges of small length and steep walls. Crestline of the cliff is broad and convex. At some places these cliffs are developed with wave cut caves.

South of Khatumba, the coast shows a transition towards the Rann, such that further south beyond Charakla, the cliffs overlook mud flats instead of the sand. These mudflats gradually merge southward into the Rann.

2) Coastal sand Geomorphology

A typical beach on the sea coast can be divided into four units - sand dunes, backshore, foreshore and shore face. The boundary between backshore and sand dunes is located near the lower limit of the sand dunes. Towards the sea, the backshore extends upto the mean high water line. Thus backshore represents the supratidal zone. The region located between the High Water Line and the mean Low Water Line is called foreshore, and forms the inter-tidal zone. The foreshore is followed by the shore face, the lower limit of which corresponds to the average maximum wave base.

A beach shows regular variations in energy conditions from sand dunes down to shore face.

The mechanism and direction of transport of sand in the region of the beach are strongly controlled by the movement of the water, which in turn is controlled by waves and currents, produced by wave action. The transport is in the form of suspension, surface creep and saltation. The dynamic conditions are such that both symmetrical and asymmetrical wave ripples, small current ripples and mega current ripples are commonly produced. As the morphology of a beach , and the grain size distribution is strongly controlled by wave action, a beach is modified continuously under varying weather conditions, so that a beach is always in equilibrium with the existing hydrographic conditions. To this process of reworking belong the formation and destruction of longshore bars, changing sediment-transport toward sea or land, and changing net transport parallel to the shore.

3) Coastal sand dunes

Along the sea-shore, sand is brought from shore face derived from nearby coastal rocks into foreshore and backshore regions by wave action. The sand above sea level is exposed to wind activities, and it is

reworked into low dunes. Coastal dunes develop where there is sufficient supply of sand, and where a dominant strong wind is present in the onshore direction. These conditions are seen prevailing along the western coast of Saurashtra from Okha to Kodinar. In the nonvegetated areas transverse ridges are developed. While near Mithapur in the vegetated area parabolic dunes are developed with concave leeward side facing NE direction.

4) Backshore

The backshore represents the upper part of beach which remains normally dry, except under unusually highwater conditions, when it is flooded and acted upon by wave and weak currents. However, most of the time it is exposed to wind activity. The backshore sand does not show any surface or internal structure. The surface is smooth gently sloping towards sea. Ripple marks are not developed. Sand is mixed with pieces of molluscan shells, tests and corals. Backshore has a gently concave slope towards sea gradually merging into the foreshore. At places it is separated from foreshore by a cliff of 1 metre height. These are called the beach cusps.

5) Foreshore

This is the intertidal zone without any significant morphological features. The sand saturated with water produces rills, and rill marks are of different types depending upon the grain size, local morphology, slope of sediment surface etc. The tooth-shaped, comb-shaped and fringy rill marks are common on the sandy beach. Asymmetrical ripple marks which are present on the dune surface are absent in this zone. The shallow water zone with a thin blanket of sand produces some asymmetrical ripples. In the study area these are observed between Okha and Okha Madhi.

6) Shore Face

Shore face is always submerged under water, and thus not much information is available. Submerged islands called shoals along with other islands bearing coral reefs are present along the shoreline to the south east of Okha.

V.3 JAMNAGAR COAST

1) General Features

This coast, stretching from Okha Rann to Jamnagar is quite distinct from the Dwarka coast. The coastline is muddy having a foreshore width between 500 m to

11 kilometers with mudflat thickness increasing gradually toward the sea. The mudflats are covered with patches of mangrove plants. At a number of places, it is dissected by creeks, nars and tidal mud channels. Such mudflats or tidal flats are developed along the gently dipping sea coasts with marked tidal rhythms and where enough sediment is available and strong wave action is absent. All these conditions are present in the Gulf of Kutch.

The main part of the tidal flat is located between intertidal zone, and it extends over the supratidal zone, which gets flooded during monsoon. No vegetation is present on this supratidal surface. The climate being humid, warm, mangroves are present on the foreshore mudflats.

The surface of the tidal flats slopes gently from high water level toward low water level, although irregularities are there. Within the intertidal zone, channels are present and they are seen branching toward their landward ends. These channels are mainly meandering channels. Subtidal zone is mostly occupied by channels, submerged islands, shoals, sand bars and coral reefs.

2) Physiography and morphology

Intertidal zone, located between the high water and low water lines, shows a vertical range of 5 to 6 metres. Tidal currents are seen to produce numerous gullies and channels. The currents of high tidal range erode deeper channels than currents of low tidal range. The velocity of tidal currents has been found to be 4-5 km/hr. On tidal flats, small current ripples are abundantly produced. It is interesting to observe that in gullies and channels, the current velocity is somewhat more, and ripples are extensively developed. The direction of ripples is controlled by the current direction, morphological slope and sometimes by strong winds. The direction of waves on tidal flats is highly variable and the waves can come from various directions. This direction is shown by current and wave ripples.

The tidal flat sediment body is elongated parallel to shoreline for over 100 km and is intersected by tidal channels and river estuaries. The tidal flats are characterised by a number of bights where the sediment bodies are semicircular or trumpet-shaped or irregular.

The intertidal flat sediments are fine grained, usually silt, clay and medium to fine sand. Gravels and coarse sand are present in the delta regions only (i.e. Ghi River at Salaya, Sasoi River at Bed etc.). Molluscan shells are present both on mudflat and in channel mud deposits. The intertidal sediments are characterised by mud intercalated with coarse to fine sands. According to Reineck & Singh (1969) this characteristic distribution is controlled by energy and transport mechanism. The major mud deposition in the muddy intertidal zone near high water line is because of low wave and current energy in this region (Gulf of Kutch). Longer duration of low currents also plays important role in the deposition of fine sediment (Postman, 1961). The higher velocity current erodes the sediment. In the gulf, higher velocity currents are rarely produced hence no erosion takes place.

3) Sedimentary structures of Mudflats

In the vertical cross section, clays silts and sand are seen alternatively layered. Sandy layers are deposited during periods of current activity, and mud during slack water periods. At some places sand grains are scattered throughout the mud zone. The

mudflat surfaces show ripple markings during low tide time. Supratidal muds are fine grained and show mudcracks or suncracks as they remain exposed to sun throughout the year, as the area gets flooded only during monsoon or storms. As regards the source of the mud, clays, silt and sand, there is some uncertainty. They do not appear to be added from the landward side. According to Gupta (1977) the studies of landsat imagery have shown that the suspended sediment is brought by currents from the mouth of Indus river, north west of the Gulf. These suspended sediments because of low energy and velocity of currents get distributed and settled.

4) Bioturbation and Fauna of Mudflats

Along the northern coast of Saurashtra, the intertidal zone is covered by plants mainly mangroves. The fauna of tidal flats is characterised by a large number of individuals, the most prominent being the mud fish. The tidal flat sediments are bioturbated by benthonic organism. Bioturbation in mudflats is generally strongest, weaker in mixed flats, and weakest in sand flats. However, this is not always the case, but in the study area the author observed that organism activities are most dominant in mudflats.

Soils are sandy loam to silty loam with moderately alkaline reaction over 7.8 to 7.6 pH. Organic matter is higher and ranges from 1.41 to 2.59%. NaCl is 1% to 3.84% and total dissolved solids are 1.72 to 3.98% showing the intensive residual effect of sea water on soils. $CaCO_3$ varies from 7 to 21%.

A noteworthy feature of the mudflats is the presence of salt pans. These are patches in the form of manmade shallow depressions along the coastal belt with stagnating tidal water. These don't have any vegetal cover. The circum salt pan soils have been found to be heterogeneous from fine sand to silty loam but the reaction is mild to moderately alkaline with 7.6 to 8.00 pH. Organic matter is high and varies from 1.17 to 2.6%. NaCl is 0.88 to 0.94% and the total dissolved solids are 1.27 to 3.65% indicating effect of sea water. $CaCO_3$ percentage ranges from 12 to 24.

5) Tidal channel in mudflats

The tidal channels are the extensions of rivers into the intertidal and subtidal zones. Along the northern coast of Saurashtra there are numerous rivers pouring into the Gulf of Kutch. The courses of these streams extend right upto the subtidal zone. These intertidal

channels which are narrow near the landward side (tens of meters) go on broadening towards the sea as much as 50 metres at the far end. The depth of these channels also progressively increase from 3 metres upto 18 metres (Salaya creek) and the water depth also varies accordingly. These tidal channels contribute substantially to the development of tidal flats. Lateral migrations of channels in cohesive, muddy sediments of mudflats is rather slow and whatever lateral migration takes place is by the process of meandering. The rate of lateral migration depends upon the intensity and direction of waves and currents. In general, higher wave energy means a rapid lateral deposition in channels. High wave activity causes increased erosion on the surface of tidal flats and this sediment is deposited on the channel slopes, a place protected from waves. The bottom of large channels like Bedi Bandar creek is sandy, mixed with shell pieces and mud pebbles. Small channels and gullies of intertidal zone are mainly muddy.

6) Surface structure of mudflats

On the intertidal surface, mainly asymmetrical small ripples are produced. These have their crests parallel to coastline and are common on muddy sediments.

Another character of the ripples is that they have rounded crests and sharp throughs. This is because of receding water level and emergence of deposited sediment. To begin with these are wave ripples but later on during the last phase of the falling water level, they are modified to current ripples. During the final subareal emergence, the ripples produce rill marks, an erosional feature.

Mud cracks are common in the supratidal zone. The cracks are irregular, triangular, rectangular or polygonal in shape. The cracks taper downwards. At a very few places, mud cracks are present in the intertidal zone.

7) Vertical sequences of tidal flat deposits

Horizontal sequence of the sediments from supratidal to infratidal zonal does not show significant variation in grain size and surface features. Still, on foreshore side, the mixing of sand grains is seen to increase. Again, in the offshore zone, it is only mud. The shallow rocky intertidal zone has dominance of sand deposits (near Sikka) mixed with clays.

The vertical sequence of the sediments is obtained from the boreholes drilled at north-east of Salaya in the offshore zone. The top strata comprise sands with shells and corals followed by silty clay with corals, whereas near shore top layers consist of fine clays and mud, then comes clay mixed with sand, shell fragments and coral pieces. Alternate layers of clay and sand are present which indicate cyclic deposition under two different environments : i.e. (i) under turbulent conditions sand is deposited and (ii) during quiescent periods suspended sediments settle down.

8) Diagnostic feature of tidal deposits

Subtidal deposits are mainly channel and sand bar deposits, the subtidal channels having been cut into underlying trap rock. The major part of intertidal zone is made up of channels, mudflats and islands, corals or barriers. The deposits show high population density and strong bioturbation. Molluscan shells, fish bones etc. are common, often with escape traces. Alternating bedding, developed in the form of flaser, lenticular bedding and inter-layers sand/mud bedding is abundant. Surface markings indicating falling

water level and subaerial emergence are common on sediment surface. Supratidal sediments are mostly barren. Bedding surfaces are featureless and show mud cracks only.