Chapter 2

Unit Characterization

General

As stated earlier, the present study is primarily aimed at a coastal geomorphological mapping, especially of the features related to the ancient shore line, and collection of a detailed record on the geological characteristics of thus identified geomorphic variants, to prepare a comprehensive model that illustrates the response of the southwestern coast of Saurashtra to the geo-environmental changes during the Late Quaternary time. A clear outline of various geomorphic units and the geological units composing them, hence, found inevitable. In this chapter various geomorphological components of the coastal system are defined with their descriptive as well as genetic characteristics In the later part, the dominant stratigraphic units of the Quaternary sequences are characterized in their sedimentological perspective

Coastal Geomorphic Units

The coastal geomorphic system is a most sensitive system that always tries to be in equilibrium with its environment by either deposition of sediments or erosion of the once formed landscape. Both, the depositional as well as erosional features thus provide an insight on the coastal response to eustatic or tectonic changes in the region; particularly, those pertaining to the Quaternary time. The depositional features are many, but the beach and beach ridges are most commonly interpreted. The erosional record is generally described as the coastal cliffs and platforms. A good number of publications are now available that provide a rigid framework of their extent with reference to the mean sea level and/or high water and low water levels, and so make it possible to link their unusual occurrences to the past sea levels. The most commonly seen geomorphological domains are defined in the forthcoming paragraphs.

Beach and Beach Ridges

Komar (1976) defined a beach as the zone in which coastal sediments are affected by wave processes, but commonly the deposition of sediments along the shoreline are referred to as the beaches (Reinick & Singh, 1980). A beach may be extending for kilometers in a linear form or it may have a very limited extent like a pocket beach; in general, majority of beaches are curved in outline and many of them are made up of a series of regularly spaced curved features. Offshore wards, a typical beach profile has minor geomorphic units like runnel, ridge, trough, bar, etc. that may or may not be always found developed. A marked landward ridge which forms the landward limit of wave swash is referred to as the berm. The morphology of a beach is highly dynamic and changes with wave energy, sediments supply, longshore currents and substrate physiography Thus, it is capable of maintaining a dynamic equilibrium with the coastal environment. In general, a beach contains sand to gravel size clasts that may be detrital and/or biogenic carbonate in nature. The beach deposits are also characterized by low angle planar and trough cross-stratification along with the biogenic structures mainly related to the *skolithos* and *glossofungite* ichnofacies. The surface structures like various types of ripples and rill marks also occur. The southwestern coastline of Saurashtra, between the Okha and Veraval, is characterized by the occurrences of linear sandy beaches with a dominantly medium to very coarse grained carbonate sediments. Whereas, the southern coast mainly hosts pocket beaches near the cliff base.

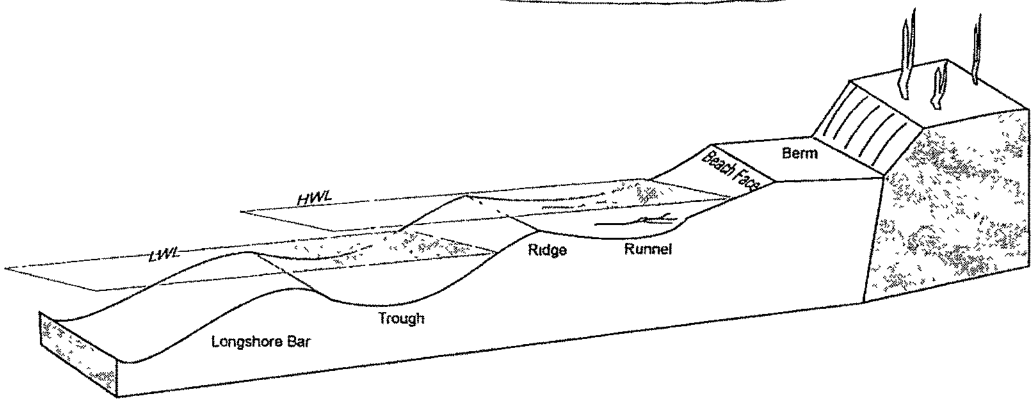

Figure 2.1 A typical beach morphology (After Pethick, 2000)

Beach ridge is the most common and extensively used term in the coastal geomorphology with reference to its use as palaeo sea level indicator. Johnson (1919) introduced this term for the ridges constructed by waves along the successive shore positions. Earlier views regarding the beach ridges were biased for only those ridges (active/relict) which were built in supratidal or intertidal region, discarding the dune ridges from the designation (Taylor & Stone, 1996). However, the aeolian deposits also found place in some of the definitions (Bates & Jackson, 1980; Carter, 1986) wherein, all mound like large constructional forms of the upper beach, capable of preservation, were considered under the beach ridges. Carter (1988) and Carter & Wilson (1990) also referred to onshore migrating swash bars and/or to the stranded end products as beach ridges. The stabilized onshore beach ridges were, in general, considered as wave built as well as wind built by Australian workers (Price, 1982). Otvos (2000) has recently redefined the beach ridges as "stabilized, relict, intertidal and supratidal aeolian or wave built shore ridges that may consist either silisiclastic or calcareous clastic matter of wide range from fine sand to cobble and boulders". The term excludes all sandy, pebbly or shell rich backshore berm ridges behind an active foreshore until they are separated from the shoreline, thus, restricting the use of the beach ridges to unravel the ancient sea levels.

Beach ridges have a range of dimensions from few meters to tens of meters. It is associated with many other landforms of the coastal environment, varied sedimentological composition and even ambiguous sedimentary structures (Otvos, 2000) Figure 2.2 illustrates the definition of beach ridge with the other morphological units associated with the beach ridges, like berm and swale.

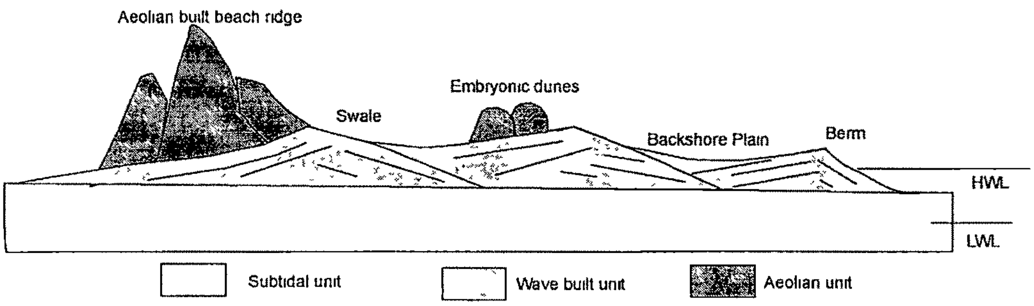

Figure 2 2 A typical beach ridge profile with associated landforms and depositional facies (After Otvos, 2000)

A berm is an ephemeral, not commonly occurring coastal geomorphic feature and so, not necessarily present on every coastline. Berm is shore parallel body of triangular cross section with horizontal to slightly landward dipping surface and steep seaward dipping slope (Hine, 1979). With the accretion of the sediments the berm may alter into berm ridge, a more permanent feature and essentially wave built in nature. The upper foreshore slope of the berm ridge is characterized by parallel to low angle (3° to 5°) cross laminations dipping towards the sea, whereas, the landward berm surface exhibits subhorizontal to gently landward dipping stratifications.

Swales are a long. narrow, generally shallow, trough like elongated depressions between two successive beach ridges, and are roughly aligned with the coastline. They form small valley (depressions) between two successive beach ridges. Generally the swales are filled up with the subtidal or supratidal sand

Bates & Jackson (1980) have described the semi-parallel narrow foredune sets usually developed along the foreshore margin of the high tide limit. The relict foredunes are also considered as beach ridges under a wind built type (Otvos, 2000). Very commonly, the wave built berms and backshore zones are veneered by aeolian sand that forms embryonic foredunes along the wrack lines. Expanding in size while combining with adjacent small dune mounds, these swash aligned embryonic dunes may gradually merge to develop a full fledged foredune ridge. The foredune origin of the beach ridges has been recognized by several workers (McKenzie, 1958; Price, 1982; Hesp, 1984; Lichter, 1997). To distinguish the wind built beach ridges, Short (1988) used the term "foredune ridge plain". Otvos (2000) excluded different types of massive, solitary foredunes occurring behind the foredune ridge from the definition of the beach ridges. The limited number, highly uneven spacing and very large dimensions of these dunes provide ample characteristic to differentiate them from the wind built beach ridges. Only elongated shore parallel foredunes that develop immediately behind the foreshore zone and may become part of a progradational sequence can be called as the wind built beach ridges (Otvos, 2000). The textural contrast between the backshore and overlying dune lithofacies may be profound on uniformly coarse or medium grained sandy/pebbly beaches overlain by finer and better sorted dune sands; such differentiation is very difficult when both the lithosomes are constituted by fine to medium sands. The regional field studies are, therefore, important while characterizing the beach ridges rather than routine sediment analysis to distinguish between the wave built and aeolian built beach ridges. Sedimentary structures and associated landforms in the field provide more appropriated information on the beach ridges while making their use in the reconstruction of the past sea levels.

Tidal Flats

Tidal flats are developed where enough sediments are available and the wave action is not strong enough to disturb the sediments (Reineck & Singh, 1980). Generally, such a kind of condition favorable for their development is behind the barrier islands, lagoons and near estuaries. They dip very gently from high water line to the low water line having irregular shape. The striking features of the tidal flats are tidal channels developed within them which are branched towards the landward side. These channels are formed due to fluctuation in the tidal currents. The fluctuation in the form of bipolar currents is manifested by the herringbone cross-bedding in the channel sediments. Where the current velocity reaches up to 30-50 cm/sec small-current ripples are produced abundantly.

Coastal Dunes

Coastal dunes occupy broad zone along the coast (Cooper, 1967) and abut against the backshore region of a beach. Sediments from the intertidal area get regularly and periodically exposed to the onshore winds to be reworked in the form of coastal dunes. Coastal dune sand is usually very well sorted and of fine to medium grain size. Where the beach sediments are fine grained, there is not much difference in the beach and dune sediments. The primary requirements for the formation of dunes are availability of enough sand and dominant strong wind in the onshore direction. These coastal dunes acquire various shapes depending upon the coastline configuration and the wind direction. Cooper (1967) distinguished two types of ridges in non-vegetated region viz. (i) transverse dunes - where wind blows constantly from same direction, these are normal to wind direction and migrate slowly, and (ii) oblique dunes - where the wind blows from two quarters at different times; they are stationary and does not migrate. The coastal dunes can attain a height of more than 20m and if conditions are favourable, can cover a large area to form extensive dune fields. The cut faces of dunes exhibit high angle planar tabular and wedge type cross-stratifications, very large troughs and also noticeable grain-fall laminations on its lee side. The coastal dunes also show cross-bedding with abundant curved erosional surfaces; the foreset laminae being as steep as 30^{o} to 40^{o} and convex upward (Mackenzie, 1964). According to Gripp (1968), coastal dunes develop on stable and especially prograding shores.

Cliffs and Shore Platforms

These two are primary erosional coastal geomorphic units which commonly occur on any rocky coastline. Cliffs are the steep faces of the rock on the coastline resulting from the continuous attack of the waves on the rock face. They can be implicitly defined as marked break in slope of the hinterland. Figure 2.3 illustrates the cliff and associated features on the coastline.

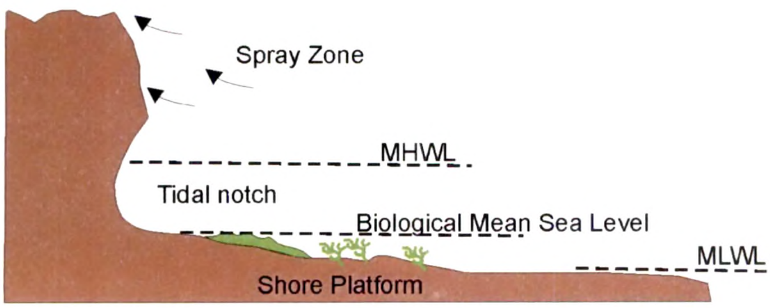

Figure 2.3 A typical cliff profile showing shore platform and tidal notch (After Rust & Kershaw, 2000). MHWL and MLWL represent Mean High Water Line & Low Water Line respectively.

Shore platforms extend from the base of the cliff towards the shore. They are sea ward sloping quasi-horizontal erosional remnant of the coastal slopes with varying angel between 0-3° (Flemming, 1965; Trenhail, 1980). The width of the shore platform may vary between few meters to thousands of meters. Borers, raspers and grazers (all forming the biological activity) commonly occur on the shore platform as the nutrients are easily available The shore platforms occurring at an ambiguous elevation have been interpreted as suggestive of the higher sea levels along the rocky coastline (Trainhail, 2001)

Tidal Notches

Tidal notches or nips are an indentation or undercutting of few centimeters to several meters deep, left by the sea erosion in the coastal rocks (Pirazzoli, 1986) These are the most common and useful indicators of the past sea level. Based on their occurrences and morphology on a cliff, the rate of the sea level change or the rate of the tectonic movements can be determined; as the smooth notch with a steep cliff at its base indicate sudden rise whereas, the rippled notch indicate episodic fall in the sea level (Pirazzoli et al , 1996) Marine notches are found best developed in limestone terrain and hence, much work is available on the tropical limestone coasts. Marine notches are now well established tool for the reconstruction of the sea level changes or tectonic movements. They have been studied in detail for the purpose on the Mediterranean coastline (Pirazzoli, 1986; Pirazzoli et al., 1996) and also on the coastline of the Sicily and Greece (Rust & Kershaw, 2000; Kershaw & Guo, 2001). The important processes which give rise to the formation of the marine notches are physical, chemical and biological processes which could corrode the rock. The biological activities occurring on the shore have been attributed to play more important role in the formation of the marine notches (Pirazzoli, 1986)

Based on the marine erosion and biological activity, Pirazzoli (1986) proposed three distinct zones of the formation of marine notches; the infra-littoral zone which experiences the complete immersion in the sea water, mid-littoral zone that is characterized by the intermittent immersion by tides or waves and supratidal zone which covers the highest level of the marine influence above high tide level. Thus, the notches have been classified in to three broad categories as per their formation zone, and in order of predominance they are the mid-littoral notches, the infra-littoral notches and the supra-littoral notches.

The precision of the notch as the sea level indicator increases if the site is sheltered, tidal range is low and cliff face is vertical. Figure 2.4 illustrates the effect of the exposure of the notch to the open sea and the notch forming processes where the mid-littoral notches are developed. Mid-littoral notches include (i) the tidal notches and (ii) the wave or surf notches

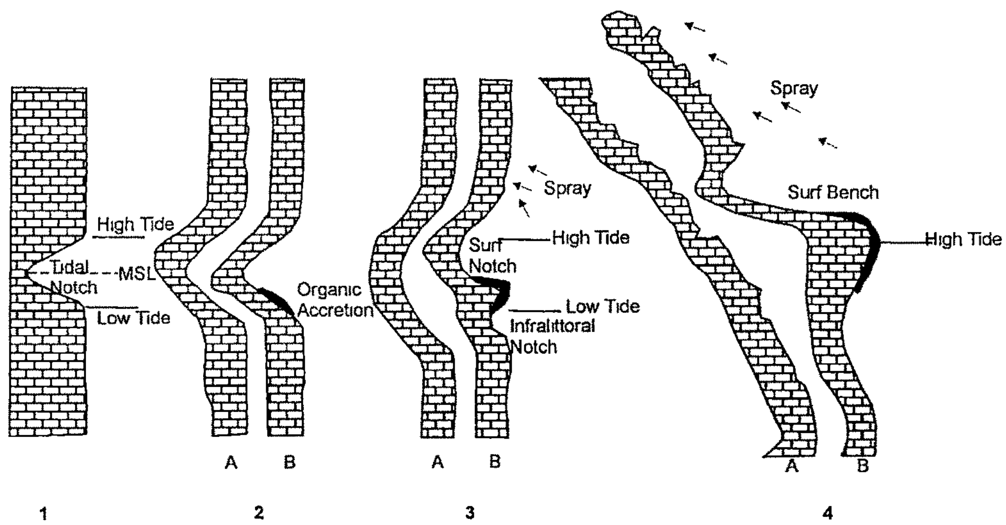

Figure 2 4 Variations in the morphology of the tidal notch profiles with changing site sheltering 1. Very sheltered, 2 Moderately sheltered, 3 Moderately exposed and 4 Very exposed conditions, (A) and (B) represents profile without organic accretion and with organic accretion respectively (After Pirazzoli, 1986)

Tidal notches are the most common and the most useful sea level indicator. They attain recumbent V or U shape according to the tidal range. Physical abrasion taking place on the coastline with the help of available sand and gravel plays an important role in the formation of the tidal notches. Physically abraded tidal notches are easy to distinguish form the chemically or biologically formed notches, as the notch formed by such processes is more polished.

Surf notch which differs from the tidal notch occurs at higher elevations as they form on the coasts exposed to the strong surf and spray actions characterized by the turbulent waters. A surf notch profile is commonly asymmetric with a flat floor extending to the vertex which may be quite low in the notch profile. The main criteria to distinguish between the tidal notch from the surf notch is the absence of a surf bench which is commonly associated with the later. This surf bench is generally encrusted by the organic accretion on it (Fig 2.4).

A notch can also be developed totally under water as reported from Curcao (Focke, 1978) and Bermuda (Neumann, 1966), that are called as the infra-littoral notches. In the infra-littoral zone the biological activity becomes important that modifies the shape of the notch either by boring or by encrustation Such kind of notches is also reported formed due to the undercutting of the coastal aeolianites (Gill, 1972). The supra-littoral notches resembles with the wind hollows found in the crystalline rocks. These occur well above the mean high water line and are usually mechanically formed due to the granular disintegration of the coastal rocks by prominent spraying effect. The granular disintegration might be occurring due to alternate drying and wetting of exposures as well as the formation and dissolution of the salt crystals. The epilithic algae and rasping snails (*Littorina, Nerita,* etc.) living in the spray zone also contribute a lot in abrading the rock surface to form supra-littoral notches. However, the infra-littoral and supra-littoral notches are poor indicators of the past sea levels.

The above described geomorphic features predominantly occur in the study area. They were primarily appreciated using the satellite data and SOI topographic sheets, and also in the field; they were used to reconstruct the Quaternary sea levels. Figure 2.5 shows a typical coastal cliff with associated tidal notch and a shore platform, whereas Figure 2.6 illustrates the occurrences of shore parallel ancient beach ridges and other geomorphic features at higher resolution with the use of the IRS 1D, LISS-III data of a part of the study area. The details of their field occurrences are given at length in the forthcoming chapter.

Figure 2.5 An impressive coastal cliff near Jafrabad showing raised tidal notches and a rocky shore platform.

Coastal Geological Units

The coastal Quaternary sequences of Saurashtra are distinctly made up of bioclastic carbonate sediments, difficult to differentiate on a cursory look. The deposits are investigated by several workers to deduce the depositional environment as being a topic of controversy, much famous as the 'Miliolite Problem' in the geological literature. The approaches were mainly remained overgeneralized with a focus on the marine and/or aeolian deposition of these carbonate sequences of the region, mostly based on local studies. Some recent work could, however, identify distinct stratigraphic breaks in the sequences which were used to identify various depositional events with minor breaks (Patel & Bhatt, 1995). A formal lithostratigraphic classification of the Quaternary sequences has been proposed by Mathur & Mehra (1975) wherein, two distinct Formations viz., the Miliolite Formation and the Chaya Formation have been recognized based on their textural characteristics. A good number of radiometric dates have also been made available by Baskaran (1985) and Baskaran et al. (1989). Based on the geochronological data Baskaran (*op cit.*) could recognize three events of carbonate deposition viz., M-I (50-70ka), M-II (75-115ka)

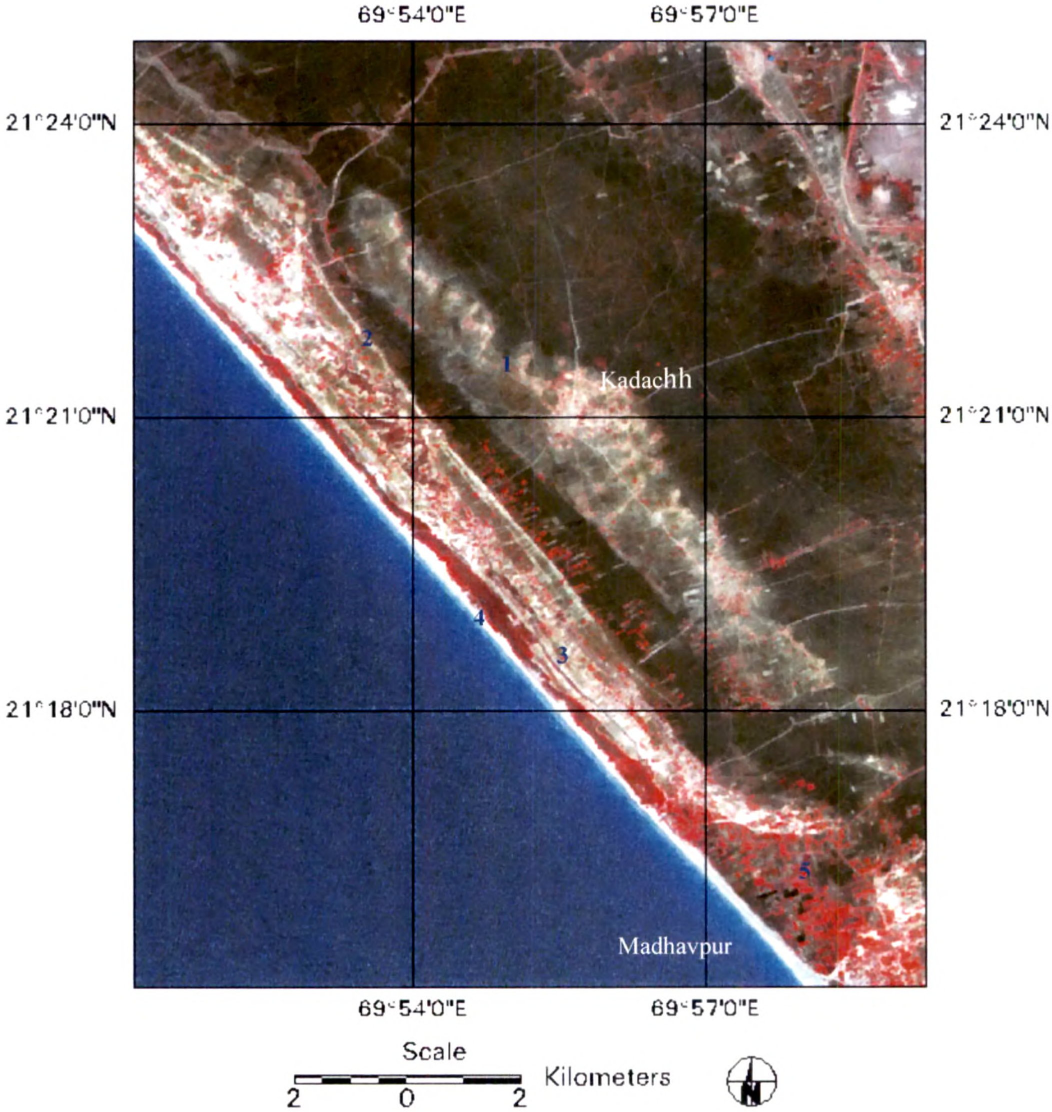

Figure 2.6 IRS 1D, LISS-III Geocoded satellite imagery processed with the ERDAS imagin software v. 8.5 showing the geomorphic features near Madhavpur area. 1. Beach ridge one, 2. Beach ridge two, 3. Beach ridge three, 4. Beach ridge four, 5. Ancient Ojat river mouth.

and M-III (140-210ka). Recently, Bhatt (2003) has synthesized all possible available details on the Quaternary carbonate deposits of Saurashtra and Kachchh, and illustrated their episodic deposition by both, marine and aeolian processes linked with the oscillatory sea level changes along the Saurashtra coast with minor influence of the neotectonism. The studies in this way available have greatly facilitated the present author to readily differentiate various depositional lithounits contained by the geomorphic units described above. The forthcoming chapter contains a detailed account on the field characteristics of these litho-variants along with the bounding surfaces and local facies variations. An attempt is made here to differentiate and define major geological units with its general megascopic and microscopic characteristics.

Unit-1

Stratigraphically, this forms the oldest and innermost Quaternary unit that must have been deposited in the near shore marine environment. The limestone are typically reddish brown (5YR 6/4 to 5/6) in colour and consists of recrystallised shells of oyster along with pebbles and gravels of the underlying rocks of the Gaj and Dwarka Formations (Fig. 2.7a) Although, they contain bryozoan and echinoid fragments along with the foraminifera, very fine grained angular quartz sand is dominating in the micrite cement to designate it to the (impure) biomicrite as per the Folk (1962) classification (Fig 2.7b); this also helps in differentiating this older unit from the younger carbonate ridges. This unit is exposed about 10km landwards in the Mangrol area whereas, it occurs at the base of impressive coastal cliffs in the Mahuva-Gopnath area. This unit is extensively pedogenized in the southern Saurashtra forming a marker horizon of the red coloured palaeosol (*Terra rossa*) that shows granular soil peds and in places, calcified rhizocretions (Fig. 2.8). Under the microscope, infilling of the microsparite in the fractures can be seen in the otherwise very fine micritic groundmass spotted with dark colour organic matter (Fig. 2.9).


Figure 2.7a A field photograph of unit-1 showing recrystallized oyster shells and gravel/pebbles of older rocks. (Length of the hammer 30cm)

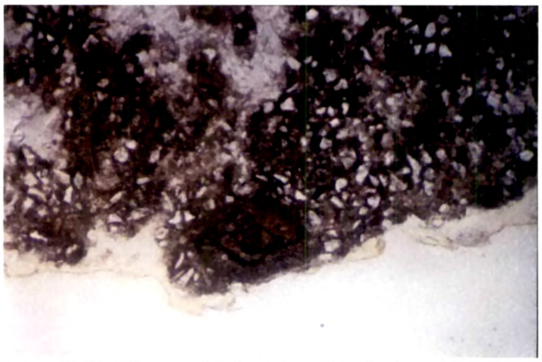
Figure 2.7b Photomicrograph of unit-1 exhibiting its typical biomicrite character. Note the dominant presence of angular quartz grains. (PPL, Photo length 6mm)


Figure 2.8 The prominent palaeosol developed over the unit-1 showing rhizocretions. (Length of the pen 10cm)

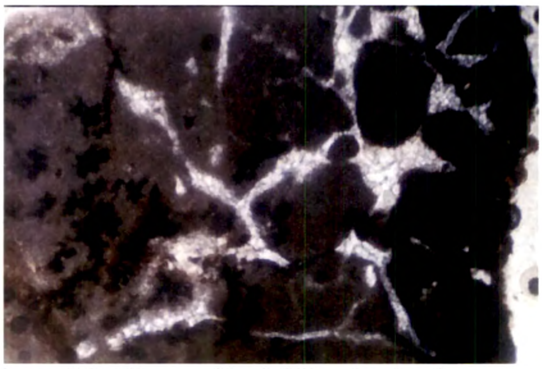
Figure 2.9 Microsparitic infilling in the fractures of palaeosol as seen under the microscope. (PPL, Photo length 4mm)

Unit-2

Over a profound palaeosol horizon and/or duricrusted erosional surface, rests the successive two units forming ancient beach and beach ridge. The typical shell rich poorly sorted coarse grained unit forms marine miliolites with gravels and pebbles of the older unit, differentiable due to its very much recrystallized and arenaceous nature (Fig. 2.10). Under the microscope, this unit exhibits its high degree of diagenesis in the form of flattened and broken shell fragments and also the freely grown neo-sparite with relict boundaries of the original allochems (Fig. 2.11). This unit merges landward with the

Figure 2.10 Reddish brown colored recrystallized shell rich limestone of unit-2 as exposed near Arena. (Diameter of the keychain 5cm)

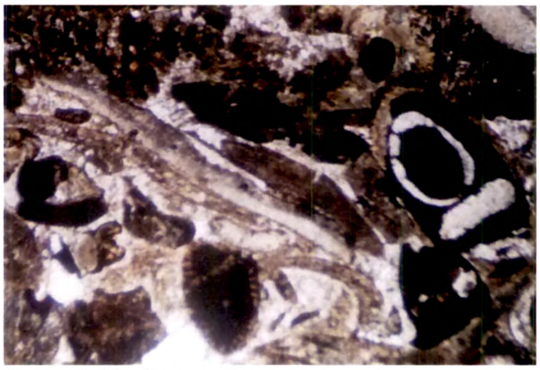

Figure 2.11a Flattened and broken shell fragments indicating a fair degree of compaction in unit-2. (PPL, Photo length 6mm)

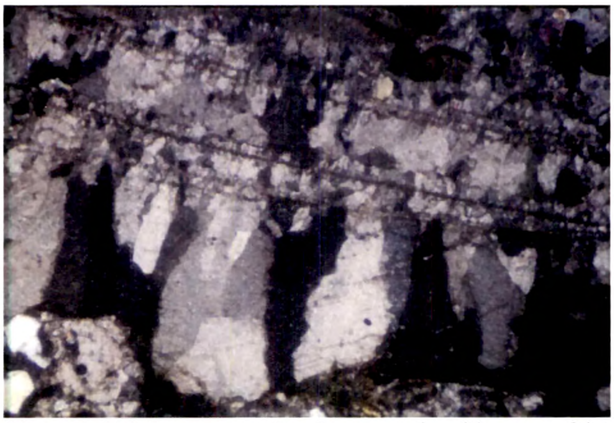

Figure 2.11 b Large crystals of neo-spartie with a very faint preservation of shell boundaries and morpholgogy of the first generation cement suggesting a high degree of limestone diagenesis. (XPL, Photo length 6mm)

aeolianites. However, in the coastal quarries it occurs at much deeper level underlying the impressive wind built beach ridge that constitutes the unit-3.

Unit-3

This unit forms type example of the miliolite due to its very fine to medium grained well sorted texture and moderate to high angle planar cross stratifications (Fig. 2.12). The rocks are slightly pinkish in colour and diagenetically mature in comparison with the typical white colured Adityana exposures.

Figure 2.12 Typical miliolite constituting unit-3. The high angle planar cross-stratifications and a distinct erosional surface characteristic of aeolianites. (Hammer length 30cm)

As per Folk (1962) classification, this unit can be called as bio-pelsparite (Fig.2.13). In places like Ratiya, Madhavpur, Mangrol, etc., it shows a characteristic presence of well rounded reworked clasts of the unit-1 (Fig. 2.14). The coast parallel ridge that attains a height of about 20m is composed of mainly this unit and it extends shoreward to form the shore platform along the major part of the southwestern Saurashtra coast. Some of the stacks and rocky islands made up of this unit are described earlier as the submerged aeolianites (Patel, 1991a). As it satisfies the definition given by Otvos (2000) in all regards, this has been considered as the aeolian/wind built beach ridge.

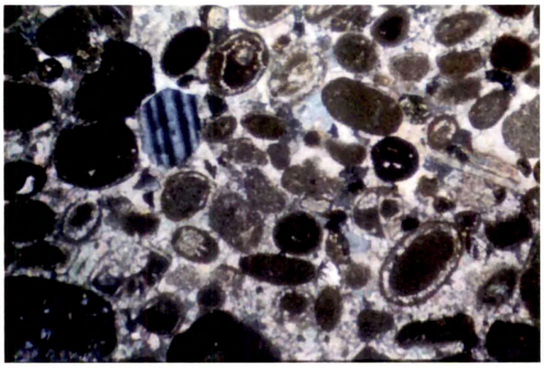

Figure 2.13 General textural and compositional characteristics of unit-3 miliolite. (XPL, photo length 6mm)

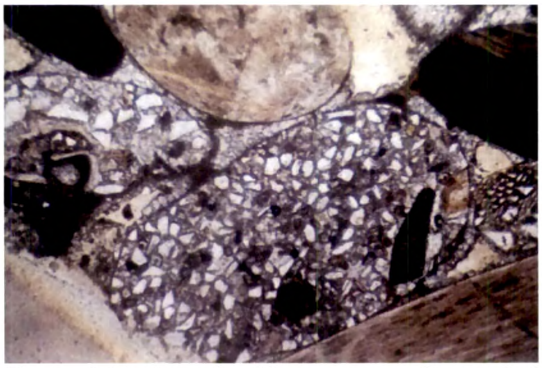

Figure 2.14 A noticeable presence of reworked lithoclasts of unit-1 showing angular quartz grains. (PPL, photo length 4mm)

Unit-4

This forms a prominent lithounit recognized as the calcirudites and has been mapped as the Chaya Formation by Mathur & Mehra (1975). Bhatt (2000) has designated, however, them to the Okha Shell Limestone Member. This occurs adjacent to the present shore, forming in general, shore parallel mound and at places gently sea ward dipping sheets (Fig. 2.15). The unit is very much rich in the gravel to pebble size fragments of various shells and corals (Fig. 2.16a) and hence, is also described as the shell limestone (Patel et al., 1992), the term then after also adopted by other workers like Merh & Chamyal (1993). Bhatt & Patel (1998) have described its occurrences from southwestern Saurashtra coast with petrographic details and also suggested its significance in the study of Late Quaternary sea level changes in the region. The unit is characterized by biomicrite that shows unaltered allochems like molluscan shell fragments, coralline algae and bryozoan fragments with subordinate amount of the peloids; all cemented primarily by void filling micrite, but also the first generation fibrous aragonite (Fig. 2.16 b). The unit constitutes the wave built beach ridge that attains maximum height of about 5m amsl. The surface is much karstified to exhibit honeycomb weathering with a very thin film formed due to its recrystallization under the meteoric environment.

Figure 2.15 Gently seaward dipping shell limestone of unit-4 exposed near Okha.

Figure 2.16a A close up of unit-4 outcrop showing a predominant composition of shell fragments. (Diameter of lens cap 5cm)

Figure 2.16b Photomicrograph of unit-4 showing first generation rim of fibrous aragonite cement with a thin micrite substrate. The intergranular pores are also infilled with aragonitic micrite. (PPL, photo length 6mm)

Unit-5

Near Mithapur, Madhavpur and Mangrol the shell limestone unit is associated with the prominent occurrences of dead coral reef and reef limestone. This is chiefly constituted by massive coral like *Favia* and branching coral like *Acropora* along with the coralline algae *(Lithothamnion, Amphiroa, etc.)*, and also complete shells as well as fragments of Mollusca (Fig. 2.17). The occurrences of Mithapur - Okha area are dated using $^{230}Th/^{234}U$ and AMS techniques by workers like Gupta & Amin (1974), Somayajulu et al. (1987) and Mathur & Pandey (2002); the age range between 34ka and 176ka, but the unit has been thought to be linked with the MOI substage 5e (Bhatt & Patel, 1998). The unit is recently designated a formal lithostratigraphic status as the Aramda Reef Member (Bhatt, 2000). Its prominent occurrences in the Okhamandal area have been studied in detail by Pandey et al. (2003). Accordingly, four distinct lithological assemblages constitute this unit; in stratigraphic order, they are coral framestone, algal framestone, coral bafflestone and algal rudstone suggestive of in general a shallowing or upward prograding reef environment.

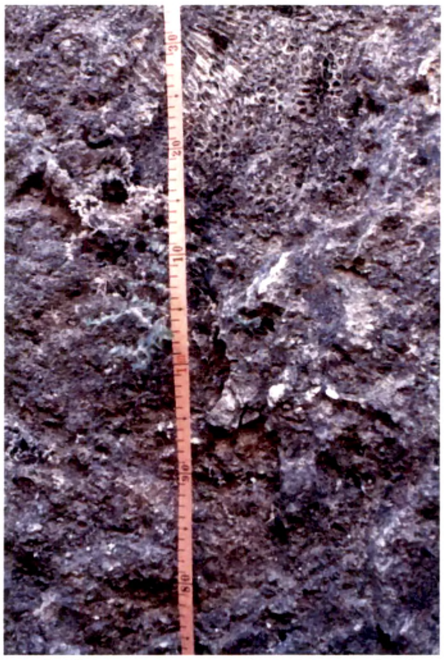

Figure 2.17 An outcrop of the unit -5 showing characteristic presence of coral fragments in reef limestone near Mangrol.

Figure 2.17a A Close up of reef limestone containing molluscan shell fragments. (Diameter of the coin 2cm)

Figure 2.17b Fragments of coralline algae *Amphiroa Fragilissima* as seen in the unit-5 under the microscope

Unit-6

The coastal plain of southwestern Saurashtra is characteristically dotted with a number of circular, semi-circular and crescent shaped mounds of white coloured, very well sorted and fine grained miliolite limestone that exhibits typical dunal beddings. These aeolianites seems to be younger than the major miliolite formation, as they rest on it. The rock is dominantly of biopelsparite variety characterized by the foraminifers belonging to the *Miliolidae* family and peloids cemented by the intergranular pore-filling microsparite (Fig. 2.18). The unit constitutes

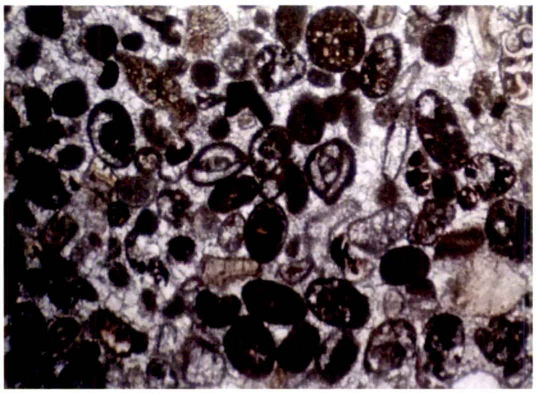

Figure 2.18 A typical nature of unit-6 aeolianite (miliolites) showing a good presence of foraminifera belonging to Miliolidae family. (PPL, photo length 6mm)

the fossilized backshore dunes formed behind the beach ridge three, composed of unit 4. Geomorphologically, this unit represents an ancient coastal landscape in association with the unit- 4 and 5.

Unit-7

The another prominent lithounit forms a younger geomorphic feature occurring as barren, and/or covered under the shrubby vegetation, extensive saline flats (raised tidal flats) behind the active tidal flats along the south Saurashtra coast (Fig. 2.19). It consists of tidal clays and thin laminations of fine sand along with scattered occurrences of bioclasts pockets. These have been related to the oscillations in sea level pertaining to the Holocene time.

Figure 2.19 Barren saline raised mud flat as seen along the southern Saurashtra coast.

Unit-8

The previous unit is found stratigraphically associated with the semi-consolidated and bioturbated beach sand forming the youngest beach ridge, dominantly wave built in character (Fig.2.20). However, it is not much prominent physiographically, and occurs in general underlying the wind built beach ridge of the Holocene high sea.

Figure 2.20 Skolithos ichnofacies in semi-consolidated beach sand occurring at 3m amsl on the Mangrol coast. (Length of pen 10cm)

Unit-9

The Holocene wind built beach ridge occurs more significantly along the Porbandar – Veraval coast. Some relict forms also occurs behind the prominent raised tidal flats along the south Saurashtra coast, but the area exhibits more significantly the northeastwards extended dune fields behind the foreshore deposits. As per Otvos (2000), although it may be much massive, such occurrences should not be designated as the beach ridge. This unit is characterized by in general massive very fine to fine grained well sorted sand deposits; the cross stratifications therein becomes visible only when it is slightly moist (Fig. 2.21).

Figure 2.21 A cut face of unit-9 showing in general homogenous nature of the stabilized dune sand near Mangrol. (Length of scale 20cm)