Chapter 2

COASTAL GEOMORPHOLOGY
2.1 BACKGROUND

The coastline of India extending over 7000 km is quite variable both in form and nature. The eastern coastline is generally deltaic, gently indented and extensively developed. On the contrary, the western coastline is highly irregular, steep-cliffed and wave eroded (Ahmed, 1968). The Kerala coast in the southwest part of this complex coastline is very dynamic in nature and is subjected to seasonal changes in beach configuration brought about by high waves and currents. The shoreline of Kerala can be grouped mainly into erosional or retrograding coastal segments and depositional or prograding coastal segments. However, there are also stretches, which are more or less free from any changes. The erosional coastal segments are characterised by sea cliffs, stacks and shore platforms. Features like wide beaches, bars, tombolo and beach ridge/dune complexes and lagoons characterise the depositional sectors.

2.2 NATURE OF THE KERALA COAST

According to Nair (1987) the shoreline of Kerala, which is generally straight and trending NNW-SSE, is highly irregular and indented especially around the promontories. Stretches of shoreline between promontories are usually depositional in nature. Based on the vulnerability and dynamism of shorelines, Nair (1987) characterised the Kerala coast into permeable, gently sloping, sandy, semi-permeable, cliffed-sedimentary, impermeable and crystalline shorelines. Thrivikramji (1979) proposed a classification, in which, the Kerala coast was divided into a few typical coastal environments viz. strand plain shoreline/permeable shoreline, cliffed shoreline with a seasonal beach and a compound coast.

Estuaries and lagoons show a general N-S to NNW-SSE or E-W to WSW-ENE trend with wide variation in width. The estuaries are generally the submerged river mouths popularly known as kayals. Estuaries and lagoons are thus considered as the product of submergent and emergent aspects of the coast (Nair, 1987). Faulting, uplifting and downwarping are recorded in a number of places in the western coast and offshore. The geometrical linearity of the coastline and the straight trend of some of the rivers clearly reflect a tectonic control.
in their formation, which were also evident from satellite imageries. Most of the rivers are flowing to the west and debauch in the sea. Due to the interaction of the fluvio-marine interface, offshore bars start building up and gradually obstruct the stream mouths and water bodies. With the formation of sand bars in the offshore, large spits are formed, ultimately cutting the geometry of the coast to a great extent.

Thus, it is evident that the Kerala coast was subjected to various degree of tectonic activity and different stages of transgression and regression. The landforms are considered as the resultant response of a variety of interacting processes that have operated with varying magnitude and frequency during the late Quaternary period. Late Quaternary coastal evolution and sea level changes can be well understood only when a detailed account of geomorphological set up of the area is made available. Here, an attempt is made to precisely map the late Quaternary landforms along the two transects with respect to the PMSL and to analyse its possible influence on the transgression and regression phenomenon of the northern Kerala coast.

2.3 METHODOLOGY

Detailed physiography of the region of investigation is represented diagrammatically in the Figures 2.1 & 2.2 prepared from a study of Survey of India toposheets (1:50,000 and 1:25,000), air photos (1:15,000 scale) and satellite imageries (1: 50,000), supplemented by fieldwork. In the base map, topographic features, major road network, rivers, railway line etc. were transferred from the Survey of India toposheets. The roads, water bodies and geomorphic features were updated using the air photos. The elements of photographic interpretations viz. shape, size, tone, shadow, pattern, texture, site and resolution were taken into account for the identification of landforms. Along the Punjavi (Transect I) and Onakkunnu (Transect II), plane table mapping and theodolite survey of the geomorphic units were carried out in 1:2250 and 1:5000 scales respectively.

2.4 TRANSECT ELEVATION SECTIONS:

The region consists of isolated hills of laterite protruding through the late Quaternary
Fig. 2.1: Geomorphic map of Punjabi transect
Fig. 2.2: Geomorphic map of Onakkunnu transect
Fig. 2.3 Transect elevation section of Punjavi (Transect 1) and Onakkunnu (Transect 2) showing the location and length of cores.
sediments of the coastal plain (Plate I). The late Quaternary sediments consist of flood
plain deposits (Plate II), estuaries (Plate III), a wide strand plain of sub-parallel elongate
beach ridges (Plate IV) and swales (Plate V). It is also apparent that the trends of these
ridges parallel the present coast. Extensive anthropogenic activities are prevalent in this
area (Plate VI), due to which most of the ridges are obliterated. The characteristic features
of the two transects are illustrated below:

Based on the plane table mapping and theodolite survey, configurations of different
geomorphic units were worked out. Reduced levels at each of the swale and ridge
positions were determined with reference to PMSL by precise leveling (Fig 2.3). Based
on the reduced levels, cross-sections of elevations of transects with respect to PMSL were
prepared. Location of cores and their corresponding depths are also shown in the Figure.

2.4.1 Punjavi Transect

This transect extends over a length of 2.4 km, the eastern boundary of which is bounded
by the flood plain deposits of Nileswaram River in the east and the beach in the west (Fig
2.1). The width, area and elevations of ridges and swales vary from one another. Swale
width varies between 50 m to 300 m, whereas the ridge width varies 120 m to 380 m. The
average height of the ridge (swale bottom to ridge crest) is 3.2 m. Along this transect,
ridges and swales maintain a striking parallelism with the coastline. Dimensional
variation of these ridges and swales are shown in Table 2.1. The ridges support mainly
cashew plantations and other mixed trees. The swales are either reclaimed or used for
paddy cultivation sparingly.

2.4.2 Onakkunnu Transect

Extending from Padanna beach to Onakkunnu in the east, this transect which is 6.4 km in
length, is also offset by lateritic outcrops (Fig 2.2). The dimension of the ridges and
swales vary from one another. Swale width varies from 500 m to 1100 m, whereas the
ridge width varies from 450 m to 1100 m. Average height of the ridge is 3.9 m. Unlike the
northern transect, the inner most ridges are curvilinear in nature. The ridges lying close to
the shoreline are almost parallel to the present-day coast. Towards the fore dune side, the
barrier ridges are backed by the Ettikulam estuary. In Ettikulam estuary there are three
elongated discontinuous sand dunes, which are vegetated and stable.

Table: 2.1. Distance (km from beach), elevation (above PMSL) and the width (km) of
strandlines of Punjavi transect.

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<th>Width</th>
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Table: 2.2 Distance (km from beach), elevation (above PMSL) and the width (km) of
strandlines of Onakkunnu transect.

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<td>6.12</td>
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15 MORPHOLOGICAL FEATURES

Eight sets of beach ridges and swales were identified in Onakkunnu transect and seven
sets in Punjavi transect. In general, the ridges and swales are aligned roughly parallel to
the present-day shoreline. The flood plain deposits of Nileswaram River obliterate the
eastern most beach ridge/swale in Punjavi transect. The two transect locations are distinct
in their geomorphological set up. In Punjavi transect, the strand lines are aligned parallel to the coast. Whereas, in Onakkunnu transect the inner most ridges are curvilinear in nature (refer Fig 2.2), but towards the fore dune side, the ridges retain parallelism to the coast. The curvilinear nature of the innermost ridges indirectly points to the nature of the then embayment of coast, which could have been curvilinear during the Holocene period.

In both transects, innermost ridge top lies slightly above 7.5 m and the fore dune is at 4 m. By joining the successive ridge tops and swale bottom, general seaward slope is evident from the inner most ridge/swale to the sea.

2.5.1 Coastal Landforms

The coastal landforms are considered to be the products of variety of interacting processes with varying magnitude and frequency that have operated during the late Quaternary period. The landforms in the study area are primarily the result of mixed action of fluvial, estuarine and marine activities.

2.5.1.1 Fluvial and estuarine landforms

The depositional processes of Nileswaram River and Karingote River have lead to the development of fluvial landforms in the form of river valleys and flood plain deposits. Large areas of silty clay surface of the flood plain have been extensively cultivated for paddy, coconut, plantain, tapioca and other types of crops. The flood plains abutting against the lateritic outcrops are considered as the landward limit of the wave activity during the Holocene.

2.5.1.2 Marine landforms

The strand plains, which are considered as marine landforms, are constituted by beach ridges and swales. Beach ridges are sub parallel ridges of sand, shell or pebble, varying in amplitude from a few inches to many feet. Swales are the depression between the beach ridges. Spacings between the ridges are quite variable.
In the Onakkunnu transect, the Ettikulam lagoon is composed of 10 islets among which, six are showing typical augen shape. On verification of the Survey of India toposheet of 1914, this lagoon was connected to the sea by two inlets. However, at present, it is connected to the sea through the Karingote River mouth. Thrivikramji (1987), considered these islets of Ettikulam lagoon (including the boomerang islets of northern part) as remnants of an ancient barrier island. The linear segment of three stable islands in Ettikulam lagoon are fully cultivated and densely settled suggesting its stability.

### 2.6 ORIGIN OF BEACH RIDGES

The strand lines of Kerala coast have been subjected to extensive studies in recent years (Samsuddin et al., 1992; Suchindan et al., 1996; Haneesh Kumar et al., 1998). Samsuddin et al. (1992) inferred that in the initial stages of its deposition, the strand plain sediments were associated with a wave-dominated environment. With the emergence of the coast, the strand plain sediments remain detached from the aqueous environment, thus exposing to the sub-aerial action of weathering processes. From the morphostratigraphic study of strandlines, the innermost ridges are the morphological manifestation of sea level maxima during mid-Holocene (Suchindan et al., 1996). Based on the study of satellite images, Mallik and Suchindan (1984) illustrated that beach ridges are formed due to repeated regression and transgression of the shore and their orientation controlled by changes in direction of approach of the wave front.

However, the factors that are responsible for growth of ridges are not very well understood. There are diversified views among different authors. According to Johnson (1919), multiple ridges arise through continued shallowing of the offshore profile, usually because of abundant sediment supply. Another school of thought (Bird, 1960) is that, continued growth of new fore dune, which gradually cuts off sand supply to its predecessors, becomes relatively stable. If the shoreline progradation continues, alternating episodes of cut and fill will lead to the formation of a series of parallel ridges separated by swales.
Curay (1959) and Curay and Moore (1964a) attributed successive accretion of new beach ridges to the coast by up building and emergence of longshore bars. It was postulated that after sufficient influx of sand into the nearshore zone, a submerged longshore bar is built upward, until it emerges above sea level during conditions of low wave action. With continued low wave action, this bar is enlarged, until it captures the wave action and becomes a new beach ridge. Former beach is thereby isolated, leaving an elongate depression between the new and old ridges. If conditions of high wave action continue, the newly created beach ridge is destroyed and the sand either pushed up on to the face of the old ridge or else removed to deeper water. With continuance of low waves, more sand is piled on the seaward face and on top of the newly emerged beach ridge, eventually becoming a permanent beach ridge with dune capping.

Based on the mode of origin and morphology, four reasonably well-defined sandy beach ridge types have been identified by Tanner (1987, 1995) and Tanner and Damirpolat (1988). Swash-built and settling lag ridges are geometrically regular, only a few tens of meters above the adjacent soils and commonly occur in ridge sets and systems. But the eolian and storm surge ridges do not show these characteristics. Swash-built beach ridges have diagnostic map spacing, accretion rate, periodicity, cross bedding and granulometry. The cross bedding and granulometry of this beach ridges indicate fair weather waves on a sandy beach in contrast with settling lag ridges, which have the same external geometry, but, deposited without important wave work. Each swash type sandy beach ridge was made by a sea level rise-and-fall couplet, position of swale marking the lower position. The mechanism reflects the fact that transverse profile from beach to sea is gently concave upward, with maximum curvature close to shore. Gently curved, essentially parallel, beach-type cross bedding of the beach ridges in the study area shows that they are swash-built type (Plate VII). Moreover, the textural composition of the present day beach and beach ridges are almost similar, hence inferred almost similar condition to the origin of present day beach and that of beach ridges (This aspect is dealt with in detail in the Chapter III).
In explaining evolution of the barrier islands of Kerala, Kunte (1995) illustrated different stages of its formation with respect to beach ridges viz., (a) initial emergence of land during which paleo-beach ridges were formed (regression phase), (b) subsequent submergence of the land, which is characterised by the engulfment of beach ridges (transgression phase) and (c) emergence of the coast during which, the breaching (regression phase) of ridges and barrier island formation took place.

The innermost beach ridges of the study area have been modified to varying degree since they were first formed. Stream activity, slope degradation and eolian reworking of sand are responsible for the modification of the ridges. In the Punjabi transect the characteristic of the innermost ridge is obliterated to a great extent by the flood plain deposits of Nileswaram River. Two types of slope degradation have influenced the morphology of beach ridges. The first involves removal of sand from ridge crests and swales. Rain impact, anthropogenic activities and surface run-off appear to be primarily responsible for degradation of the ridge morphology.

### 2.7 MORPHOLOGICAL EVIDENCES ON SEA LEVEL CHANGES

The northern Kerala coast consisting of well preserved raised strand plain sequences with sand/clay deposits, spits, stacks, submerged offshore terraces, a continuous offshore sand bar etc., are considered as evidences of sea level change during the late Quaternary. Apart from the morphological evidences, stratigraphic sequences are well preserved in the cores collected from the coastal plains of northern Kerala. This has ultimately resulted in the inference of complex sequences of marine, estuarine and freshwater deposits. Records of these high stands of sea level could be deciphered from a series of paleo-shoreline deposits ranging in elevation from +7.73 m to −3.91 m (Fig 2.3).

The two transects, namely Punjabi and Onakkunnu are distinct in their geomorphological setup, where, seven and eight sets of beach ridges and swales were identified respectively. Along the Onakkunnu transect, the Thekkekad, Vadakekad and Kokal islands, which are situated in the Ettikkulam estuary show striking parallelism to the trend of
Fig. 2.4 Cross section of Transects I & II showing approximate seaward gradients
strand line. This is considered as a surface manifestation of regressive episode. Along the central Kerala coast, the coast-parallel beach ridges are reported to be the product of regressive and transgressive episodes during the Holocene (Mallik and Suchindan, 1984). Radiocarbon dating of shell samples collected from the Thekkekkad island from a core-depth of 6.3 m below PMSL gave an age of $2830 \pm 30$ YBP. This shows that the deposition of shell associated with regressive phase took place around 3000 YBP. The subsequent regressive phase must have helped the growth of sand bars into islets, which later got separated from the sea, resulting in the formation of Ettukulam estuary with the linear islet series trending parallel to the coast. An earlier report on the origin of sand bar along this coast also attributed to the regression of the sea during 5000-3000 YBP (Rajendran et al., 1989).

Spot heights with respect to PMSL of ridge-top and swale-bottom were used to draw an east-west profile (Fig 2.3) to understand the disposition of the successive ridges and swales. In both the transects, the inner most ridge-top is situated at an elevation of about 8 m and the fore dune at about 4 m above PMSL. A general seaward slope is evident from both the profiles (Fig 2.4). The seaward dipping alternating bands of heavy/light minerals observed from pits further confirm this observation (Plate VII). Approximate seaward gradients of the strand plain sequence is estimated to be around 1:53 and 1:150 for Punjavi and Onakkummu respectively. The seaward slope of the ridge top and swale bottom indicate that the coastal strand plain is the result of marine regression during different periods.
Plate I  Panoramic view of the coastal plain area

Plate II  Flood plain deposits of Ettikkulam River
Plate III  View of the Ettikkulam Estuary

Plate IV  Beach ridge and swale system
Plate V  Closer view of the swale

Plate VI  Mining of beach ridges
Plate VII  Alternating bands of heavy and light minerals showing seaward slope