CHAPTER III

GEOMORPHOLOGY
INTRODUCTION

The coasts have been constantly undergoing physical change in the geological past and the present. Hence, out of almost all landforms known to us the coastal landforms are the most dynamic. The coast is a zone of intense energy input; this energy transported by waves, arrives at the coast and is available for work. The result is that the processes of sediment transport are set in motion that cause morphological change. These changes will continue indefinitely, unless, by chance, a landform is produced in which the energy inputs are dissipated without any net sediment transport (Pethick, 1984). Precisely, the formation of
landforms is regulated by the processes of erosion and deposition operating under the influence of natural agencies. So also in the study area, the dynamic marine, fluvial and aeolian agencies are manifested in the coastal landforms which include tidal flats, beach, spit, island, wave-cut platforms, cliffs, dunes, mesa and planation surfaces.

In order to get a concise and systematic picture of these features - their size, shape and association, geomorphic mapping has been carried out. For this study, remote sensing technique has been used as it provides a synoptic view of an entire area and the features therein. A geomorphic map has been prepared using IRS, LISS II and LANDSAT MSS (band 2, 3, 4) data of year 1990. These data were enlarged with Procom (1:50,000 scale) and visual interpretation was carried out. Inherent elements within an image that can provide clues towards the identification of various features include tone, texture, shape, associated features and spatial pattern. An image interpretation key has been formulated with the help of topographic maps, aerial photographs and ground truth (Table III.1). The final maps have been then prepared (Fig. III.1, 2, 3, 4).

The identified landforms have been classified according to the ITC system of geomorphology (Verstappen and Zuidam, 1968).

Forms of marine origin

- Tidal flats
- Beach
### Image Interpretation Key

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Category</th>
<th>Tone</th>
<th>Texture</th>
<th>Shape</th>
<th>Association</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tidal Flats</td>
<td>grey/ blue/ brown</td>
<td>smooth</td>
<td>irregular</td>
<td>rivers/ creeks</td>
<td>blue tone is due to water</td>
</tr>
<tr>
<td>2</td>
<td>Beach</td>
<td>white</td>
<td>smooth</td>
<td>linear/ crescent</td>
<td>sea</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Spit</td>
<td>white</td>
<td>smooth</td>
<td>linear</td>
<td>beach</td>
<td>extending into the sea</td>
</tr>
<tr>
<td>4</td>
<td>Island</td>
<td>red</td>
<td>smooth</td>
<td>irregular/ rounded</td>
<td>sea</td>
<td>red tone is due to vegetation</td>
</tr>
<tr>
<td>5</td>
<td>Cliff</td>
<td>dark</td>
<td>smooth</td>
<td>linear</td>
<td>sea</td>
<td>detected by absence of beach</td>
</tr>
<tr>
<td>6</td>
<td>Dunes</td>
<td>white, red</td>
<td>smooth</td>
<td>linear</td>
<td>beach</td>
<td>stabilized/ unstabilized</td>
</tr>
<tr>
<td>7</td>
<td>Planation surfaces</td>
<td>pale red, grey</td>
<td>medium/ patchy</td>
<td>irregular</td>
<td>inbetween hills</td>
<td>red tone is due to agriculture, grey due to settlement</td>
</tr>
<tr>
<td>8</td>
<td>Rocky ridges</td>
<td>red/ greenish blue</td>
<td>smooth</td>
<td>irregular</td>
<td></td>
<td>greenish blue tone is due to stony waste</td>
</tr>
</tbody>
</table>
Spit
Island
Wave-cut platforms
Cliffs

Forms of aeolio-marine origin
Coastal dunes

Forms of denudational origin
Mesa
Planation surfaces
Rocky ridges
Dissected plateau

FORMS OF MARINE ORIGIN

Tidal flats
Tidal flats are wide expanse of fine grained soft mud along the shore. They generally consist of deposits of clay, silt, ooze etc. (King, 1972). In the study area, the tidal flats are mainly found along creeks and river estuaries and can be classified as high tidal flats (Davies, 1972). These appear as irregular patches with grey to blue tone and fine texture. They extend for about 8 km
Plate III.1  *Tidal flats along river Chapora*

Plate III.2  *High tidal flats near Kalapur*
inlandward along river Terekhol, 19 km along river Zuari and 11 km along river Chapora (Plate.III.1 and 2).

Beach

A beach is defined as a shore consisting at least partly of unconsolidated material. Most often that material is of sand grade (2-1/16 mm), but the sand may be replaced by cobbles or shingle, thus a boulder beach or shingle beach (Fairbridge, 1968). Beach can be distinguished on the satellite picture as a linear feature with smooth texture and white tone associated essentially with the sea.

The entire coastal tract of the study area is marked by well developed beaches that can be described under two heads: (a) rocky beaches and (b) sandy beaches. The rocky beaches are restricted to the headland topography and are formed mainly on account of marine action and subaerial weathering. The headlands are eroded along joints and fractures as a result of which blocks of rock get detached and accumulate at the foot of the headlands. Such beaches are seen around Wagator, Anjuna, Bogmalo, Sidao and Donapaula (Plate.III.3).

Two types of sandy beaches are encountered in the study area viz; pocket beach and continuous beach. The short and narrow crescent shaped beaches located in between the headlands are called the pocket beaches. These are encountered at Polen, Bogmalo, Danda, Sidao, Navshi, Kegdweli, Nerul, Donapaula, Baga, Anjuna and Wagator (Plate.III.4).
Plate III.3  Rocky beach at Nerul

Plate III.4  Crescent Beach at Kegdiveli
The beach at Wagator (1.5 km) is separated from Anjuna beach (2 km) by rocky headlands. The foreshore is very well developed and gently sloping. The backshore is narrow as compared to the foreshore and terminates into beach rocks. At Anjuna, the foreshore is not prominently demarcated from the backshore which terminates at the dunes.

The foreshore at Kegdiveli beach (0.5 km) is 15 m wide dipping not more than 5°W, adjacent to which is a very narrow backshore. This trend of foreshore and backshore extent is continued forward to Nerul beach also.

A broad foreshore sloping 7°W backed by a narrow backshore consisting of numerous broken shell fragments and very coarse sand (shingle), is the characteristic of the Sridao beach. Similarly at Navshi, the foreshore is 25 m dipping 3°W and the backshore is 3m.

Also at Bogmalo is about 1 km long crescent shape beach between two headlands. The foreshore is very gently sloping (0-3°) extending for 35 m into a narrow backshore (8-10 m). The beach at INS Hansa also follows a similar trend having gentle and wide foreshore and a narrow backshore.

The 1.5 km long Polen beach has a steeply sloping foreshore (17°W) and narrow backshore.

Colva beach is the longest beach of the study area running NNW-SSE and extending for about 26 km from Morar to Palu terminated by a spit in the river Sal in the south and a headland in the north. The foreshore is 40-60 m wide (Plate III.5) with a narrow backshore (10-15 m). The beach is moderately
Plate III.5  Wide and gently sloping foreshore, Colva beach

Plate III.6  Straight continuous beach at Calangut
sloping (0-5°) with a steeper slope of about 8-10° in the extreme north and south.

Between rivers Zuari and Mandovi is a 5 km long Miramar beach running NE-SW. The beach slopes about 0-5° reaching 10° at places. The foreshore extends for about 80-100 m and backshore about 20-25 m for most of the part but narrows down towards extremes at Donapaula and Panaji in the south and north respectively.

Calangut is a 7 km long beach extending from river Mandovi to Baga trending NNW-SSE. The foreshore is 30 m wide, sloping moderately towards the sea (0-5°) and backshore is 20 m wide (Plate III.6 and 7).

Running NNW-SSE between rivers Chapora and Terekhol lies a 12 km long near continuous strip of Hermal beach. At extreme north near Kerim the foreshore slopes steeply about 14-19° and is 12 m wide (Plate III.8). The backshore is broader comparatively (25 m). Towards Hermal in the south, the slope decreases to about 0-3°, the foreshore widens (60 m) and the backshore becomes comparatively narrow (15-20 m). The beach ends into spits at both the extremities.

**Spit**

Spit is a small low, narrow tongue of land commonly consisting of sand or gravel deposit, deposited by longshore drifting and having one end connected to the mainland and the other protruding into open water, usually the sea,
Plate III.7  Narrow backshore at Calangut beach

Plate III.8  Spit with steep slopes in river Terekhol, Kerim
across the entrance of a bay or an estuary, a finger-like extension of the beaches (AGI Glossary, 1972).

A few well developed spits are demarcated in the study area. Spit on a satellite picture appears as a feature associated to the open coast with white tone and smooth texture.

The beaches of Colva and Harmal protrude out into the river giving rise to conspicuous spits at Mobar, Morjim and Kerim. The spit near Mobar south of Colva slopes about 10° and it deflects the river Sal to the south (Plate III.9). The spit in river Chapora near Morjim is hook shaped and has slightly deflected the Chapora river to the south. On the other hand, the spit in river Terekhol is steeply sloping (14-19°) but predominant deflection of the river is not observed (Plate III.8).

Island

An island may be defined as a relatively small body of land surrounded entirely by water (Fairbridge, 1968). Island can be delineated from satellite picture as nearly rounded feature with red tone and smooth to moderate texture on account of vegetation. The islands along the Goa coast are 2-6 km away from the coast and are restricted within the ten meter depth contour. The main islands are St. Jacinto, Marmagao, Pikene, Grande and St. George (Plate III.10 and 11).
Plate III.9  Spit in river Sal, Betul

Plate III.10  Pikene island
Plate III.11  
St. Jacinto island in the Marmagao bay

Plate III.12  
Gently sloping wave-cut platforms, Aguada
Wave-cut platforms and Cliffs

The fundamental erosion form of coastal geomorphology is the littoral abrasion feature or wave-cut platform, known under a number of more or less synonymous terms - the platform of marine abrasion or of marine erosion, the wave-beveled platform, bench or terrace. It is defined as the rock shelf that is produced by the combined action of the direct attack on the cliff-base, the tide and wave action on the wave-base and the undertow (Fairbridge, 1968). These platforms cannot be identified from satellite picture but appear to be merged with the rocky coast. Aerial photographs help in delineating these platforms. They are seen as light to medium tone, near horizontal surfaces adjacent to the sea and backed by cliffs. Wave-cut platforms are observed at Aguada, Anjuna and Baga (Plate III. 12 and 13).

In certain cases the lower ancient platforms in the present day intertidal zones have been covered with sands except some patches which are at a little higher elevation. These patches of platforms devoid of sand cover are seen exposed at Sridao, Navshi, Kegdiveli, Nerul and Anjuna (Plate III.14). These intertidal platforms are near horizontal on account of excessive marine erosion and parted away from the cliffs by sand deposits.

Cliff is any high, very steep to perpendicular or overhanging face of rock or earth rising above the shore of the sea (Campbell, 1972). Cliffs are detected on the satellite picture by the coinciding high and low water lines.

The cliffs have been reduced to moderate slopes by subaerial weathering at most of the places (Plate III. 15) whereas verticality of the cliffs has been
Plate III.13  
*Sea cliff fronted by shore-platforms, Baga*

Plate III.14  
*Shore-platform exposed in intertidal zone, Anjuna*
Plate III.15  Moderate coastal slopes, Baga

Plate III.16  Sea arch, Aguada
maintained at Cape-de-Rama, Bogmalo, Aguada, Baga and Anjuna (Plate. III.13).

Sea caves are common along rocky coast unlike the sea-arches and stacks which are very rare. One such sea arch is observed at Aguada (Plate. III. 16). The remnants of sea arches, commonly known as stacks are observed at Aguada and Harmal (Plate III.17).

Beach rock

Beach rock is beach sand consolidated in place by interstitial cement chiefly calcium carbonate (Fairbridge, 1968). The beach rocks are exposed in Kutch and Saurashtra almost all along the coast and in small pockets along the Maharashtra and Goa coast. As compared to other parts of the west coast, beach rocks are poorly developed along the Goa coast. They occur as patches in the intertidal zone as well as above the present high water line. Beach rocks mainly consist of sand, pebbles of laterite, shell fragments, microfaunas and some wood particles.

At Wagator and Anjuna the beach rocks are found in the backshore area and are well cemented (Plate. III.18). At Bogmalo the consolidated beachrock is observed below the tourist resort in the backshore area. Also, semi-consolidated beach rock consisting of sands mingled with laterite pebbles is observed at about 3-5 m above MSL.
Plate III.17  Stacks at Aguada

Plate III.18  Beach rock at Wagator
FORMS OF AEOLIO-MARINE ORIGIN

Coastal Dunes

Coastal dunes cover small areas and are defined as a topographical feature of aeolian origin composed of sand grains deposited downwind from the natural source of sand (Fairbridge, 1968). The coastal dunes occur adjacent to the beaches and parallel to the shoreline (Plate II.19). They can be distinguished as stabilised or older sand dunes and active or recent sand dunes. The active dunes are devoid of vegetation cover and hence have signatures resembling those of a beach in contrast to the stabilised dunes with a distinct red tone owing to the vegetation. The coastal dunes are about 3-4 m high and extend for 2-3 km inlandward. Near Mobor, the active dunes are very well developed oriented in N 40° E but most of them have been destroyed by human interference (Plate III. 20 and 21). Similar set of dunes is also seen at Colva, Miramar, Calangut and Harmal. The coastal dunes seem to be developed along the open beaches as compared to the pocket beaches where the dunes are almost absent.

FORMS OF DENUDATIONAL ORIGIN

Mesa

The term mesa is applied to flat topped hills and mountains cut-off on one or more sides by steep escarpments (Fairbridge, 1968). Laterite-capped mesas are the most prominent and widespread landforms in the study area.
Plate III.19  Coastal dunes parallel to the shoreline, Calangut

Plate III.20  Inland coastal dunes, Mobar
Plate III.21  *Inland coastal dunes destroyed by human interference, Mobar*

Plate III.22  *Planation surface, Sinkerim*
They are recognised on air photos by their light to medium tone and relatively flat tops. The surface has pitted appearance but the slopes are marked by dark tone due to dense vegetation.

The average elevation of these mesas varies between 40-100 m above MSL. They occupy mainly three levels i.e. between 40-60 m, 60-80 m and 80-100 m (Wagle, 1987). On the seaward side there is an abrupt fall giving rise to cliffs.

**Planation surfaces**

The relatively low lying land between rocky ridges, dissected plateaus and mesas has been marked as planation surfaces. These can be delineated by their patchy texture with speckled red, grey, greenish blue and white tone. The red tone indicates dense vegetation whereas the blue tone is due to stony waste and quarries.

The planation surfaces are found within an elevation of about 20 m to 50 m above MSL with a gentle slope. These appear to have been formed due to the subaerial erosion leading to peneplanation of the hill ranges (Plate III. 22).

In the present chapter the characteristics of the Quaternary landforms in the study area have been described based on the author's field observations. However, in order to understand the processes involved in the formation of these landforms several laboratory studies have also been carried out. The laboratory methods and the results thus obtained are presented in the next chapter.