COASTAL GEOMORPHOLOGY AND MINERAL RESOURCES

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INTRODUCTION;

The coastal zone contains the nearshore area together with the entire continental shelf and the resources of the overlying waters as delimited by existing international agreements. This chapter will deal with two important aspects related to coastal zone. The first one will be the coastal geomorphology. The second part will deal with the mineral resources of this coastal zones. In this connection, although a vast area encompassing continental margin also needs to be considered, we will restrict our selves only to the near-coastal regions.

India is bestowed with a coast line having a length over 6000 Km. including the coasts of Laccadive islands and the group of islands comprising Andaman and Nicobar. Various human activities are associated with these coastal tracts such as fishing, transportation (port and harbours), mining etc. Moreover, these coast lines are subject to modifications both by natural phenomenons (submergence, emergence, sea level fluctuations, erosion, deposition) as well as by human activities (mining, construction of docks, harbours and break water walls etc.). Hence it is imperative for us to understand the coastal zones in proper perspective for their efficient management.

GEOMORPHOLOGY:

Geomorphology is a difficult subject and coastal geomorphology is still more difficult because of the fact that the coastal regions are meeting the line of the subaerial and marine processes of erosion and deposition. The near-coastal geomorphology of India may be studied under the following heads (Ahmad, 1972):

OFFSHORE FEATURES:

The features in this category are continental shelf and offshore islands. But in the present context we will restrict only to the coastal zones.

SHORE FEATURES:

(1) DEFINITION OF SHORE: The shoreline is a junction of sea and land. The zone between the highest and lowest tides can be called the shore. The part of the shore zone that lies between the
ordinary low and high tide has been called as ‘foreshore’ and that immediately above the same as ‘backshore’.

(2) CONSTRUCTIONAL FEATURES OF THE SHORELINE:

(a) Beach: Beach refers to debris coarser than mud i.e. sand, which is deposited in the shore zone. The chief agent that leads to the deposition of beach is sea waves with minor contribution from the sea currents. A beach is very commonly a temporary deposit. It is alternatively deposited and removed in what has been termed as ‘beach cycles’. The essential constituents of beach are

1. upper beach located in the backshore zone and generally of coarser material.

2. Lower beach is the foreshore zone. The slope and grade of sediments change rather remarkably at the junction of upper and lower beach.

3. Beach ridges or berms, particularly on shingle beaches.

Beaches are more common and more extensive on low coasts like the eastern shore of India and relatively scarce on steeper or cliffed shores of western shore of India. However ‘bar-beaches’ are common along Kerala coast, ‘crescent beach’ in rocky areas and ‘pocket beaches’ in region between Ratnagiri and Goa.

(b) Offshore Bars and Barriers: One of the important component the beach is the barrier beach. These features are formed mainly by waves out of sediments eroded from the submarine floor sea-ward of the bar. Later the bar grows vertically and horizontally and marshy areas (colonized by certain vegetation) on the margins of the lagoons expand at the expense of water-spread in the lagoon which might be reduced only to narrow creeks. When the bars extend over more than 10 miles broad and over 100 feet in height, then it is called as barrier. Such barriers are found south of Krishna delta, off Nellore etc. Generally the width of the barrier on the eastern coast ranges from 3 to 7 km. It is generally covered by sand and sand hills which rise to a height less than 10m. The typical vegetation is casuarina or coconut along with palmry, cashewnut and some thorny bushes and coarse grasses. Mangroves are seen in the delta areas. Along west coast barriers and associated lagoons are most strikingly developed in certain stretches of the Kerala coast. Elsewhere they are practically non-existent. These barriers are small in width. The bars and barriers are generally associated with most spectacular occurrences of lagoons or back waters locally called as Kayals. Many of these kayals are long and narrow, and parallel to the shore.

Spits: In some areas barriers have been pushed so inland that they are converted into spits by their appendage at one or
other end to some headland e.g. the 55km long spit between Allepy and Cochin.

Tombolos: are the spits which join islands to the mainland, e.g. north of Vijayadurg on west coast and Tuticorin on the east coast.

(c) Lagoons and lakes: These are brackish during dry season but are rendered fresh during the rainy season when the salty water is diluted or displaced by the large quantities of fresh water falling in the lagoons or draining from the nearby catchments. The largest among the lagoons are Chilka lake, Pulicat lake near Madras and lake Vembanad in Kerala. These lagoons are invariably associated with streams. Many of these lagoons are parallel to the shore and elongated. Some of them are transverse to the coast and enter deep into the coastal interior up the valleys of rivers.

(d) Deltas: Deltas are quite significant among the Indian shore features confined to the eastern coast.

Deltas are the deposits occurring at the river mouths due to deposition of the terrigenous material brought from the continents. The larger among the deltas are those of Ganges, the Mahanadi, the Godavari and the Cauvery. Generally the deltas are associated with land projecting towards sea. The protuberance is the result of the dominance of deposition and land-building, so that despite the subsidence, the land gradually extends over the adjoining continental shelf.

(e) Littoral Concrete and Coral Reefs: There is a remarkable formation in the shore zone of some parts of the western littoral of India called as littoral concrete. It is regarded as aggregates of shore sand and pebbles and marine shells and corals. Probably these are raised spits and beaches and are subsequently cemented by carbonate. Occurrences of these are common in the regions of Saurashtra and Bombay.

(iii). Erosional Features of the shore:

(a) Cliffs: Cliffs are vertical escarpments and occur within the reach of the highest storm level of the sea. These are comparatively less abundant on the east coast relative to the west coast.

(b) Coastal Terraces: It is obvious that the existence of cliffs is also associated with sea caves, stacks, natural bridges, promontories and coastal terraces. They are particularly prominent between Mangalore and Bombay where the shore is indented in detail and the coastal hinterland is rocky and rugged.

The main cause of the occurrence of cliffs, shore terraces
and associated features is the existence of hard rocky country near the water line. Given resistant rock in head-lands projecting toward water, and fairly long duration for the waves to be effectively operative, cliffs and abrasion platforms of varying magnitudes are inevitable.

(iv) Rias, Estuaries and Estuarine marshes:

Rias: Are river systems partly or wholly flooded by the sea due to Flandrian Pleistocene glacial transgression or subsidence of land areas.

Estuaries: These are the river mouths where tides make themselves felt. Estuaries largely occur on the west coast.

Estuarine marshes: The estuaries occurring in low-land areas particularly the Cambay region are characterized by mud flats and marshes with vegetative growth.

There are a few Estuarine mouths on the east coast; the ria shore is most prominent on the west between Ratnagiri and Bombay and estuaries dominate the Gulf of Cambay.

(v) Classification of the Indian Shorelines:

The complexity of most shorelines makes them difficult to fit into a unified scheme of classification. However, we will use the widely accepted classification of Johnson (1919) as cited by Easterbrook (1969) which separates shorelines into four main categories.

1. Shorelines of submergence, formed by partial submergence of a land mass as a result of rise of sea level or subsidence of the land. Such shorelines are characterized by drowned valleys, deep embayments, and a very irregular configuration.

2. Shorelines of emergence, formed by uplift of the land or lowering of sea level. Such shorelines are characterized by relatively straight coasts of low relief, marine terraces, and offshore bars.

3. Neutral shorelines, whose essential characteristic are independent of either submergence or emergence. Among the various examples of these shorelines are a. Deltas, alluvial plains, outwash plains. b. Volcanic shorelines. c. Coral reefs. d. Faulted shorelines.

4. Compound shorelines, characterized by features of more than one of the categories listed above. For example, a shoreline which exhibits both marine terraces and drowned valleys, as a result of fluctuations in relative sea level, is called compound.
Broadly speaking the Indian shorelines can be classified as follows:

(1) The neutral deltaic shoreline: In this category the deltas of the Ganga, Mahanadi, Godavari, Krishna and Cauvery belong. Such a shore having a gentle off-shore profile and irrespective of emergence and submergence such a shore continues to grow sea-ward.

(2) The emergent shoreline: Between the Ganga and Krishna rivers the shore is characterized by remarkably straightness, universal development of beach dunes and spits, gentle profile and non-marshy shore zone.

(3) Emergent Coromandal shoreline: The entire shoreline between the Krishna delta and Cape Comorin has a dominantly emergent aspect in its remarkably straightness, a very gentle profile both in the foreshore and backshore, universality of off-shore bars that have been driven landward so that only the last vestiges of the lagoons, and frequency of shore dunes etc. exist.

(4) Compound shoreline of Kerala and Karnataka: The shoreline is remarkably straight, has dominance of off-shore bars largely driven to the mainland and gentle off-shore profile. But behind the straight bars and spits there are numerous water-bodies of irregular plan. These spits and bars have straight line on the western side but are irregular on the eastern side. These backwaters are also locally marked by the existence of islands, sometimes rocky, pointing to the submergence of the mainland prior to the formation of the off-shore bars.

(5) Submergent rocky indented shoreline of Maharashtra: The shoreline from near Karwar to Bulsar, roughly coincident with Maharashtra coast and Deccan lava region has dominantly submergent aspect in its high degree of indentation marked by ria-like shore, and rocky promontories and headlands, numerous cliffs and rock plains, stacks, sea-waves and bridges and a number of off-shore rocky islands.

(6) Submergent Estuarine Shoreline: The Gujarat shoreline round the Gulf of Cambay north of Bulsar up to near Bhavnagar has submergent aspect. The shoreline is indented with deep estuarine inlets of the sea. There are a number of estuarine islands and sand flats. The terrain of the land is low alluvial plain. Mud flats and marshes are very common in this shore zone.

(7) Compound shoreline of southwest Kathiawar: Between Bhavnagar and Diu the shoreline is fairly indented. There are a number of rocky islands and cliffed points but the submergent aspect is not so marked or dominant as in the Maharashtra shorelines.

(8) Compound shoreline of S.W. Kathiawar: The shoreline
from Veraval to about Dwarka is remarkably straight and has a dominantly emergent aspect. There are bars and spits on the mouths of several streams. It is a shore adjoining a low-level plain tract and the off-shore profile is also extremely gentle. But along with these features there is marshy belt particularly near Porbandar or Navibandar or Miani near the estuaries of streams which indicate extremely low-level plain topography of the area. While the estuaries and marshes suggest submergence of the bars, spits and the remarkable straightness of the shore suggest emergent aspect.

(9) Submergent shoreline of the Gulf of Kutch: The shoreline of the Gulf of Kutch, particularly its southern shore, is very indented despite the low-level plain surface of the coastal interior and has a submergent aspect indicated by marked indentations, deep inlets, a number of off-shore islands and several estuarine river mouths. Marshes exist side by side with occasional rocky cliffs both in the mainland as well as in the islands.

(10) Neutral shoreline of the Laccadive Archipelago: The Laccadive group of islands are a series of coral atolls. The atolls, however, are marked by crescentic coral reefs on the east while in their western parts the lagoons are enclosed only by coral banks that are just at or below the sea-level. In such areas the shoreline is formed by the coral organism and is independent of submergence or emergence. Coral reef building is the dominant process here in determining the shore features.

(11) Compound shoreline of the Andamans and Nicobars: Although the shorelines of this region are highly indented and shore markedly of submergent aspect, there are a number of other characteristics that cannot be ignored. Thus coral reefs fringe most of the shores. Then there are frequent cases of raised coral reefs and other types of raised beaches. These give definite proof of recent emergence. But side by side there are frequent occurrences of sea cliffs carved out in different rock types. This points to recent submergence. The same appears to be indicated by submerged patches of magrove forests. Therefore, the shoreline is classified as compound.

MINERAL RESOURCES:

The mineral resources commonly restricted to the near-shore areas can be divided into three main categories (Murty et. al., 1987; Gujar et. al., 1988; Paropkari et. al., 1992).

TERRIGENOUS DEPOSITS: These include nearshore placer deposits (<20m water depth) which comprise heavy minerals consisting ilmenite, magnetite, monazite, zircon, rutile and garnet. Heavy mineral placers are known from many localities along the Indian coast. Onshore they consists of high-grade beach and low-grade dune sands. The most important beach-sand deposits are found in
the following regions:

1. Over a stretch of 22 km between Neendakara and Kayankulam, Quilon district, Kerala (popularly known as NK or Quilon deposits).

2. Over a stretch of 6 km from the mouth of the Vallier river to Colachal in Manavalakuruchi and adjoining coastal tracts in Kanyakumari district in Tamil Nadu.

3. The newly discovered deposit in Chattarpur coast stretching for 18 km over an area of 26 sq. km in Ganjam district, Orissa.

Similar deposits with varying proportions of ilmenite, zircon, magnetite, monazite and garnet have been described from Konkan coast, Maharashtra; Tirunelveli, Rannad and Tanjore districts of Tamil Nadu; Visakhapatnam, Bhimunipatnam areas of Andhra Pradesh and the coastal areas of Orissa.

Recent investigations by Sengupta et al. (1992) in the coastal zones of Sonapurapeta, Andhra Pradesh and Digha, West Bengal have shown that the ilmenite present in the sediments has TiO₂ content ranging between 45 to 51% and have suggested that these sands have high economic potential.

Extensions of these onshore beach pachers to the offshore areas had been proved along the coast of Neendakara and Kayankulam (Kerala coast) by Prabhakara Rao (1968). He explored shallow offshore areas upto a depth of 12m and suggested that these sediments have originated from the east of these region. The heavy minerals (4 to 56%) consists of kyanite, sillimanite, zircon, garnet, ilmenite, leucoxene and rutile.

The ilmenite along the beaches of Konkan coast, Maharashtra contain upto 0-74% ilmenite and the reserves have been estimated at about 4m tonnes. In the same region a detailed survey of 130km long strip from Jaigad in the north to Vijayadurg in the south was carried out by the National Institute of Oceanography (NIO). The heavy mineral concentrations are upto 90% and assemblage comprises of ilmenite and magnetite with minor quantities of augite, epidote, zoicite, tourmaline, topaz, rutile, zircon, limonite and kyanite (Siddique et. al., 1982). The reported TiO₂ content is 40-57% in the ilmenites of the Kalbadevi bay and trace element analysis of these concentrates indicate appreciable concentrations of vanadium and chromium. The seismic profiling have revealed 4-5 major reflectors. The thickness of heavy mineral bearing sands varies from 8-10m and more thicker sands (more than 10m) are associated with river mouth and buried ancient river channels. Representative drilling in Mirya bay (by Ratnagiri Port Authorities) has indicated that the sands extend down to a depth of about 3m. Considering the total area of 13 bays surveyed, the sand containing heavy minerals covers an area of approximately 96 sq. km. and with an average ilmenite
concentration of 10% and 1m thickness, the reserves are inferred to be of the order of 12.5 m tonnes. But taking into account the results of seismic surveys the probable reserves will be many times more (Siddique et. al. 1982). The extensive onshore and offshore deposits offer a good prospects for an integrated development.

**BIOGENOUS DEPOSITS**: The near-shore biogenous deposits include coral and shell deposits of shallow areas. Calcareous shells occur in shallow area of continental shelf, usually in areas of high benthic productivity, where they are concentrated by hydrodynamic processes. The important sites where limeshell productions are reported are Vembanad lake, Kerala and Pulicat lake, Andhra Pradesh. Out of the total limeshell production in India, Kerala's contribution is about 80-90%, and rest comes from Karnataka and Tamil Nadu. Gujarat (Jamnagar) is the sole producer of calcareous sand. Coral and coral limestones are produced in Ramanathpuram and Rameshwaram districts of Tamil Nadu.

The deposits of coral and shelly sands occurring in relatively shallow areas, both in the lagoons of Laccadive Islands, off the Andaman Islands and in the Gulf of Mannar and Palk straits appear to be promising. In addition, a few deposits of limeshells are found in coastal districts of the Andhra Pradesh, Gujarat, Kerala, Karnataka and Tamil Nadu.

**Laccadive Islands**: The area occupied by continental margin around Laccadive islands is 109,600 sq. km. (Shelf area between 0-200m water depth, 8400 sq. km. and slope between 200-2000m water depth 101,200 sq. km.).

Deposits of coral and shell sands occurring in the shallow areas and lagoons of Laccadive islands, appear to be promising economically. The Laccadive are a group of coral atolls, submerged reefs and banks. Siddique and Mallik (1973) surveyed eleven of these lagoons in detail and reported a reserves of 288 m tonnes of calcareous sand in the lagoons to a depth of about 1m. The inferred reserves in some lagoons where no detail survey could be carried out are of the order of 423 m tonnes to a depth of one meter. The reserves at greater depth are expected to be many times more and inferred reserves in the lagoon between 1 to 2m below the lagoon floor are about 712 m tonnes.

**CHEMOGENOUS DEPOSITS**: As such no chemogenous deposits (authigenic mineralization) of economic significance occur within near-shore zones. However, there are the reports which indicate possibility of such deposits in the deeper parts of Andaman and Nicobar group of islands.
Andaman and Nicobar:

The area occupied by shallow submerged platform of the islands areas of Andaman and Nicobar is about 157,200 sq. km. (Shelf 0-200m water depth 38,400 sq. km. and slope 200-2000m water depth, 118,800 sq. km.).

Phosphorite nodules were earlier reported off the northern Andaman island. In late 1960, extensive sampling for phosphorites was carried out in the vicinity but the results were not encouraging.

Other deposits which are likely to found in the deep sea within the vicinity of these islands are the hydrothermal deposits. However, no details are available at present.
REFERENCES


