

# Geomorphology of Goa and Goa Coast. A review

2271

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## Abstract

This review on the geomorphology of Goa and the Goa coast included studies on the interpretation of LANDSAT images, aerial photographs and extensive field work. Physiographically the region can be broadly classified into: 1) the coastal tract; 2) sub-ghat region and 3) the high ranges of the Western Ghats. The drainage is dominated by two directions: 1) directly to the sea (from E to W) and 2) the NW or NNW direction in accordance to the geological structure. The overall landforms are the result of a combination of structure, lithology, intrusion, volcanism, denudation and Quaternary sea level changes. Laterite covers the major portion of Goa and typically occurs as plateau landforms. The different laterite levels observed from 120 m level to sea level was the result of sea level fall. Remnants of the plateau surfaces showing deep lateritic weathering profiles are common in the northern part of Goa. The southern part presents a rugged topography with hills having an altitude upto 600 m. The coast is prograding along beaches and retreating along the cliffs and headlands. Fluvial, marine and aeolian features are common along the coast. The presence of laterite beds along the estuaries at a depth of 27 to 35 m below present sea level indicates a drowned valley. Based on the disposition of landforms the present coast is neither emergent nor submergent but it is a combination of both. Occurrence of laterites conglomerate beds, beach rock, beach ridges, old tidal flats beyond the present day high water line are the evidences of the sea level oscillations during the Quaternary.

KEY WORDS: geomorphology, remote sensing, Goa coast, sea level.

## Introduction

Along the central west coast of India, the Goa state lies between latitude 14°48' and 15°48'N and longitudes 75°40' and 74°20'E representing part of the Konkan coast. It is a narrow coastal strip located at the foot of the Western Ghats. In some places there is a steep scarp which starts at the plains at an elevation of about 100 m rising to a height of nearly 1000 m. The greatest distance between the Ghats and the sea is about 40 km, but several hills are scattered throughout this strip. The earlier descriptions of Goa are provided by geologists who studied the area. They were not specifically interested in the geomorphology but more on the lithology and geological structure of the coastal provinces.

## Geology and climate

A major part of Goa is covered by the pre-Cambrian and Cuddapah rocks, The rock types representing the Dharwars are quartzites, metagraywackes and banded haematite quartzite. These unfossiliferous meta-sediments of Cuddapah age are profusely intruded by basic dykes. The Deccan traps cover the ancient crystalline formations in the northeast. Laterites and lateritic soils of variable thickness are found to occur capping the rocks from the high plateaus of the Sahyadri down to the sea level.

The area, being situated well within the tropics and flanked by the Arabian Sea to the west and Western Ghats to the east, has a tropical maritime and monsoon type of climate. Other climatic features are the regular

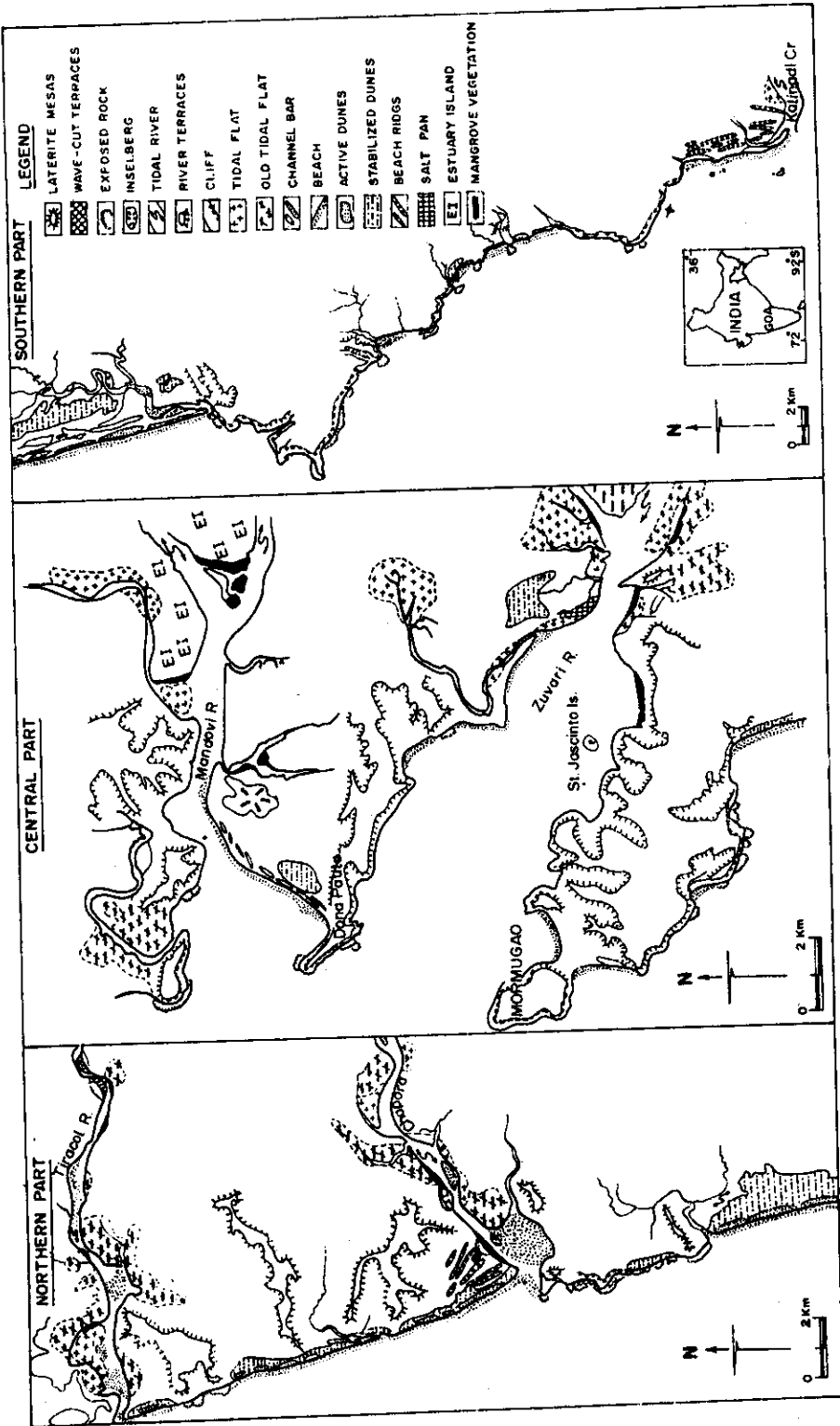


Fig. 1

and sufficient rainfall during the south-west monsoon, mainly from June to September and the tropical weather during the rest of the year. The annual rainfall is in the order of 250 to 300 cm.]

## Geomorphology

Telles (1911) and Feio (1956), described the geomorphic problems of Goa paying special attention to the Ghat Escarpment. It is a sinuous border at whose front there is relief which is often nearly as high as the plateau further inland. The escarpment was considered by them as an erosional. They believed that the difference of levels of the order of 1000 m between the Deccan Plateau and the littoral region indicate a high probability of tectonism. They proposed a fault or a group of faults exist, positions of which not exactly known but which is probably not(?) very far from the present shoreline.

Wagle and Misra (1975), however, on the basis of aerial photointerpretation and field check in Goa and adjoining areas observed intensive headward erosion of the rivers and came to the conclusion that the present western face of the Western Ghats is merely a product of circumdenudation of an old table land.

De Souza (1965) physiographically classified the Goa area into three regions: 1) the coastal tract consisting of beaches, rugged sea-cliffs, small isolated pocket beaches, recent broad alluvial plains, vast estuaries, older spits, dunes, beach ridges, broad hard wave cut platforms etc.; 2) the tract between the coast and the ghats, *i.e.*, the «sub-ghats» region and 3) the high ranges of the western ghats rising to elevations of 900 to 2500 m above m.s.l. On the other hand Rao *et.al.* (1985), used LANDSAT images and aerial photographs to interpret geomorphic and morphotectonic features of Goa. Three main physiographic zones are identified, *viz.*, the narrow coastal plains on the west, followed by a vast, dissected tableland, and the steeply rising Western Ghats. Four planar, or erosional, surfaces range in age from Late Mesozoic to Late Tertiary.

Sinha (1985), used the physiographic boundaries to delineate four landscape positions of interest, such as hills (Laterite soils), rolling to undulating upland (lateritic

soil and red loam soil), coastal plains (coastal alluvium), and flood plains (saline and nonsaline soil).

LANDSAT images were studied by Bhattacharya *et.al.*, (1985), in order to delineate the broad geology, geomorphology and lineaments of a part of the west coast of India covering the Goa area. Their study has not given any direct evidence of faulting along the west coast.

Rao and Subramanian (1985), stated that the geomorphology of Goa is the result of a combination of several geomorphic processes associated with climatic and eustatic sea level changes, as well as tectonic movements. They also indicated that there is some relationship between the landforms and mineral occurrences.

Sriram and Prasad (1979) noticed that the remnants of planar surfaces, showing deep lateritic weathering profiles, are common in the northern part of Goa. The southern part, however, presents a rugged topography with hills having an altitude upto 600 m, especially near the coast.

According to Pant *et.al.*, (1985), a cross section of the Goa landscape comprises an imposing chain of hills of Western Ghats in the east, the undulating topography with moderate hills alternating with low broad valleys in the central part and the coastal plains in the west.

## Laterite mesas

Nearly two thirds of the area of Goa is covered by a mantle of laterite ranging in thickness from a couple of metres to over 40 metres. Generally maximum thickness of laterite is observed along the coast which thins to the interior. The laterite mesas occupy almost all the coastal belt of the Goa area. They crop out through more or less steep escarpment and have almost flat surfaces.

De Souza (1968), while discussing the geomorphic features of the laterites of Goa, states that the laterite covers the major portion of Goa and typically occurs as plateau landforms. Furthermore, the plateau-top laterite in Goa shows characteristics identical to the «high level» type and it has differentiated layers similar to other reported *in situ* deposits. However, it is possible to recognise a «high» and a «low» level variety of laterite

within Goa on a single hill feature and its adjoining lowlands.

According to Dikshit (1976), the flat hills on the Goa coast are covered with a mantle of laterite and present a contrast with the Bombay coast. The coastal plain in the northern part of Bombay derives its origin from a combination of marine and fluvial activities working in succession, whereas the lateritic plateau in the south has remained virtually unaffected.

Sriram and Prasad (1980), while discussing the geomorphological evolution of the lateritic terrain of Goa composed a sequence of events that are recognised as repetitive, slow regional emergence with intermittent phases of quiescence leading to the formation of the planation surface, the traces of which are recorded at about 900 m, 700 m, 300 m and 200 m above present sea level.

Wagle (1982), described the coastal laterite mesas. Their height varies from 40 to 100 m from m.s.l. The ground checks indicate that they occupy mainly three levels, *i.e.*, between 40-60 m, 60-80 m, and 80-100 m. The tops are covered with massive laterite ranging in thickness from 20 to 40 m.

Hypsographically (Kale and Rajaguru, 1983), the landscape of Goa is characterised either by well indurated lateritic hilltops or by nonlateritic plateau on the coast from a lower sea level. Resting on the slopes of these coasts are lateritic terraces with a homogenous or heterogenous character.

Geomorphic and genetic studies of laterites of Goa (Sriram and Jena 1985) indicate that though there is no direct geomorphic control in the residual iron and manganese ores, the altitudes of their occurrences indicate that they are mostly confined to planation surfaces below 200 m. The process of lateritisation on the 200 m planation surface after its emergence is probably responsible for the conversion of the banded iron formation and manganeseiferous chert into exploitable residual ores of iron and manganese, respectively.

## Drainage

Rivers draining the area originate from the Sahyadri ranges and have reached their base level of erosion within a distance of 20-30 km. They are under tidal influence for most of their length towards the coast. The

rivers run mostly straight with sharp bends and meandering is a rare phenomenon. They have picked out the lineaments and lines of weakness in preference to the general direction of the slopes. The drainage network is predominantly in two directions following the regional trend. Though these rivers are having tremendous headward eroding capacity, and rainfall and climate are also favourable for the formation of delta, no delta is found developed anywhere along the coast. This perhaps may be because of submergence or due to the strong dispersion of sediments at the mouth of the rivers by waves and currents (Wagle, 1991).

Feio (1956), observed that the drainage in Goa is dominated by two directions: 1) directly to the sea (from east to west), and 2) the NW or NNW direction in accordance to the geological structure.

Desai and Peshwa (1978) studied the drainage anomalies on the west coast region of Maharashtra and Goa based on remote sensing data and explained that the lithology and structure controlled the drainage. The Dharwarian strike in central Goa controls the river Mondovi for nearly 15 km, while in the eastern region the river is controlled by fractures parallel to the axes of cross folds.

According to Rao *et al.*, (1985), the drainage in Goa is consequently to the west via the faulting direction formed during the post-Deccan trap period, and has mainly evolved in the midTertiary.

Based on the morphometric analysis of seven major river basins of Goa (Iyer and Wagle 1987), the plots of stream order versus stream numbers, and stream order versus mean stream lengths, are found to satisfy Horton's Laws. It is also observed that the drainage has adjusted very well to the structures of the country rocks.

## Coast

Goa state has a long coastline of about 105 km, constituted by alternately situated headlands, estuaries, bays and world famous beautiful beaches. The coast shows marine, fluvial and aeolian features. Erosion and accretion features indicate that the coast is prograding along beaches and retreating along cliffs and headlands. Based on the disposition of the landforms the present coast

is neither of emergent nature nor of submergent nature, but it is a combination of both.

Feio (1958) verified the similarity in evolution among the littoral zones of Goa, Portugal and northeast of Brazil and he admitted that the regression observed from 120 m level to the present sea level was the result of sea level fall. Based on the physiographic features De Souza (1965), indicates Goa coastline as a coastline of submergence of the «ria» type which has now reached the «late youth» stage of development.

Vaidyanadhan (1968), based on the topographic maps of Goa, marked the geomorphological features like filled bays, marshy areas, sea cliffs, stacks, tidal flats, tombolos, etc.

Ahmed (1972), in his book entitled «Coastal Geomorphology of India», marginally touched on the Goa coast. He considered this coast as submergent rocky indented coast because of high degree of indentation marked by ria-like shore, and rocky promontories and headlands, numerous cliffs and rock plains, stacks, sea-caves and numbers of offshore rocky islands.

Dikshit (1976), while discussing the geomorphic features of the west coast of India between Bombay and Goa, touched on the coastal geomorphology of Goa and summarised the evidence that throws some light on the tectonic history and the eustatic changes in the area. The coast south of 18°30'N shows regular cliffs, drowned valleys, and bayhead beaches, all contraposed against the laterite plateau of Konkan. This contrast in coastal forms within a distance of 100 km can be analysed in the light of climate, lithology and tectonic history of the different regional components of the coast. The rivers have estuaries bordered by littoral terraces that are covered with silt. The terraces, usually 10 m above sea level, extend even into the non-estuarine areas. These are really ancient abrasion platforms which now appear as littoral terraces alternating with coastal hills, tidal flats and beaches.

Sriram and Prasad (1979) surmised that the present coast emerged during the Neogene and presumably before the onset of Pleistocene glaciation. Submergence could be either due to a eustatic rise of sea level or to faulting and subsidence of landmass or to both.

According to Guzder (1980) the occurrence of laterite gravel close to sea level in Goa is evidence of sea level oscillations dur-

ing the Quaternary.

Wagle (1982), based on observations and the interpretation of aerial photographs of the Goa coast, identified fluvial, marine and eolian features such as, tidal flats, river terraces, mesas, wave-cut platforms, old beach ridges, dune, etc. The islands near the coast are parts of coastal headlands now isolated from the retrograding coast. Some islands are merged with the mainland by tombolos or alluvial plains. The presence of laterite beds along the estuaries at a depth of 20, 27 and 34 m below present sea level (Feio, 1956) indicates a drowned valley.

Subramanyam and Rao (1982) studied coastal Goa and Karnataka to evaluate the genetic evolution of landforms and the interrelationship between the landforms and the landuse pattern. The present day landform distribution possibly reflects evidence of Tertiary denudational processes which acted upon various rock types, which have undergone either upward or downward movement since Archaen times. Effects of eustatic changes, particularly towards the coast, are also evident.

The stratigraphic location of the Colva wood that was found in a well excavation, about 500 m from the present high tide line, and the radiocarbon date of that wood sample suggest that during mid-Miocene the sea level was lower than it is at the present (Kale and Rajaguru, 1983).

Bird (1985) and Bird and Schwartz (1985) have also taken into account Goa's coastline while describing the west coast of India in their books.

Wagle (1987), while describing the geomorphology and evolution of the coastal and offshore areas of Maharashtra and Goa, presented a general geomorphological picture of the coastal area and the processes operating therein.

Hill facies, 1-2 km inland from the present shore are the abandoned seacliffs. They are no longer undergoing wave attack. Beach rock, cavernous weathering, sea caves and sea arches are seen well beyond the present highest high tide level indicating lowering of sea level (Wagle, 1989).

## Conclusions

The above review shows that although

geomorphological studies of Goa date back to the beginning of this century, progress in understanding has been very slow till 1962. After a sufficient background of geomorphology has been gained it seems that many other geomorphological aspects need careful studies not only by geomorphologists and geologists but also by other Earth scientists. The most important aspects still to be studied include: 1) relative sea level

changes and their evidence; 2) dating of former shorelines; 3) relationship of geomorphic forms to the ground water table; 4) river bed studies; 5) study of estuaries, their origin and evolution.

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