COASTAL EVOLUTION

The evolution of a coastline is controlled by the tectonic movements, present and past climates and their resulting environments. The coasts tend to develop towards a smooth, uncomplicated outline at varying rates which are functions of the lithology and structure of their constituent rocks and their exposures to the forces of erosion.

The present coastline of India has a humbline straightness over long stretches. The shelf has a gentle uniform gradient, cliffs and offshore islands are comparatively
scarce while barriers and spits are common pointing to recent emergence of Indian Peninsula. The coast under study is highly indented and rocky with cliffs, notches, promontories, alternating with rias and estuaries. The coastal plain is absent and the offshore submarine topography is steep as compared to the northern part of west coast. These features are indications of regional submergence. On the other hand the occurrence of straight sea beaches, bay head beaches and spits are indicative of an emergent coastline. Thus, the existing geomorphic set up of the study area provides an evolutionary sequence where in tectonism, eustasy and subaerial processes of erosion and deposition have all played an important role.

The geomorphological evolution of the Peninsular India commenced with the separation of India from Madagascar during Maestrichtian (70 my B.P., Powell 1979). Erosion and scarp retreat from the new continental margin created a coastal belt backed by an escarpment (Ollier, 1985). The Deccan Volcanism at the Cretaceous - Tertiary boundary covered the peneplaned surface. Rifting in its western part and its subsidence in the Arabian sea during Palaeocene was followed by the establishment of the east flowing drainage system. The Eocene or Early Oligocene period probably was a stable period during which high-level laterites were formed
(Kale and Rajguru, 1988). The impingement of the Indian plate with the Eurasian plate during Early Miocene (Powell, 1973), gave rise to the West coast fault zone which suffered the last faulting during Pliocene concurrent to the Makran fault (Krishnan, 1965). The geological past indicates that Early Miocene to Middle Pliocene was marked by marine transgression. Due to the subsidence along faults parallel to the coast, a broad step-like topography was formed. The fluvial and marine erosion initiated the removal of the trap blanket from west to east leaving behind plateau-like surfaces at different heights which form the present mesas. The retreat of the trap is confirmed by the west flowing rivers rapidly eroding head wards and capturing the well established drainage on the older plateau surfaces. The best example of river capture is the Dudhsagar fall (Wagle, 1987). Due to the removal of basaltic cap the streams started following the structural weakness and trends of the earlier peneplaned Precambrian surface. At the same time, the exposed Dharwarian rocks were again peneplaned and were lateritized during the stable phase at the end of Pliocene or Early Pleistocene (Kale and Rajguru, 1988).

A rough mutual parallelism of the ghats, the western coastline and the low level laterites extending to the foot of the
scarp suggests that the lava plateau formerly extended much further west toward the Arabian sea. There is biological evidence to suggest that the ghats were once washed by the Arabian sea. Also, the thicker laterite cap towards the west and a thinner one at the east indicates the gradual retreat of the traps from west to east.

The Late Pliocene regression which was an after effect of the Hercynian uplift resulted into the Pleistocene glaciation. The glaciation took place in four stages with five interglacial periods (Krishnan, 1982). The first major transgression took place only during the Middle Pleistocene when the sea level went up to almost + 25 m. The last glacial stage was a period of regression when the sea level went down to almost - 138 m (Kale and Rajguru, 1983). Regressive conditions prevailed upto 12,000 yrs B.P. and with the advent of Holocene, the sea started rising again, attaining the present level about 5000 - 6000 yrs B.P.

The Holocene rising sea abraded the exposed rocks and formed wave-cut benches at different levels. These benches, as reported by Nair et. al., are at present submerged and occur at -92, -85, -75 and -55 m. The radiocarbon ages 9000 to 11,000 yrs B.P. indicate that these benches were formed during the transgressive phase of the Early Holocene sea. The presence
of laterite beds forming abrasion platforms at the depth of 20 to 34 m below the present sea level along the estuaries can also be attributed to the higher sea level of Holocene which caused the drowning of rivers giving rise to estuaries. Almost during the same period, the Pikene, Grande, St. Jacinto and Kambariam islands were formed. Some of these might have been inselbergs on the coastal plains or detached portions of headland due to erosion or tectonic activity but have since been changed to islands because of drowning of the low lying areas around.

As mentioned earlier, the transgressing sea during Holocene attained the present level about 5000 - 6000 yrs B.P. but the occurrence of features such as platforms, cliffs and beachrock above the present day high tide line point towards a fact that the sea level has been above the present level in the course of last 6000 yrs. The platforms mark the lowest level to which the abrasion by waves reached. A subsequent recession of sea exposed these platforms and are at present observed at an elevation of about 5m above MSL. The cliffs also occur at same elevations and are fronted by vast wave-cut platforms or beaches indicating that these cliffs were formed by the erosive action of high strand line and are now abandoned.
According to Fiego (1950) and Wagle (1987) the present Marmagao and Aguada headlands and Panjim city were islands now joined to the coast. The author suggests that these islands might have been formed when the sea level was higher than the present i.e. between 6000 and 3000 yrs B.P. They were later on joined to the mainland due to accumulation of sand in the shadow areas giving rise to tombolos and spits when the sea started gradually receding about 3000 yrs B.P. That the sea level was below the present during Mid-Holocene is suggested by the stratigraphic location and radio carbon dates of the wood specimen of Colva beach (Kale and Rajguru, 1983).

The beach rocks are formed in the spray zone by the consolidation of beach sediments. Therefore, their occurrence at an elevation of about 3-5 m above MSL is a definite indication of a pre-existing higher sea-level. Though, the precise dates for the beachrocks in the study area are not available, the average age of the coastal beach rocks, according to Ghatge (1985), range between 5,200 to 1100 yrs B.P. indicating a sea level + 5 m during this period.

Simultaneous to the formation of the beaches during this period (present day exposed beach rock), coastal dunes were also formed by the reworking of beach sediments by wind. The
later regression up till the present shoreline has left these dunes far inland. Where the present straight beaches exist, these dunes are fronted by a system of younger dunes indicating the progradation of shoreline. The dating of sediments from beachrock and older dunes would be, however, necessary to arrive at final conclusions.

The recession in the sea level is further marked by the beach rock and laterite wave-cut platforms exposed in the present inter-tidal zone. These platforms are covered by beach sands pointing to the recent progradation of beaches. The beaches in the study area are characteristically long and straight with some spits protruding into the river mouths. The waves are refracted as they approach the coast obliquely and thus converge at headlands causing erosion and diverge causing deposition of sediments. The oblique approach of waves induce longshore currents, the predominance of which is responsible for formation of spits along north as well as south directions in the study area. When beach and longshore sediments are transported to the updrift bank of the stream faster than the stream can carry it away, some of it gradually accumulates at the mouth of the river, diverting the stream in the net shore drift direction (river Sal). The erosion of headlands and deposition of sediments in the adjacent low lying areas has given rise to the
pocket beaches. Also tombolos are being formed along the southern part of the coast. All these facts point towards a recent emergence of the coast.

However, the sediment transport trends worked out during the present study suggests that the present day beaches are stable showing neither net deposition nor a net erosion of sediments in a particular direction. But the indented nature of the coastline with rias and estuaries indicates that the coast has not yet attained maturity.