CHAPTER VIII

GEOLOGICAL HISTORY

NEOTECTONICS

A review of the geological literature on the Quaternary of the Indian coast shows that the presence of raised beaches, coral reefs, oyster beds and other features connected with the strand lines of Quaternary at levels higher than the present level (Fig.VIII.1) are explained by assuming the upward movement of land relative to sea. Similarly, the presence of submerged forests and other land features below the sea level are accounted for by the tectonic subsidence of the coast.
There has been a realisation within the last two decades that the raised features and the submerged features can also be explained in terms of eustatic changes in the level of the sea during Quaternary periods of glaciation and inter-glaciation, which caused world-wide regressions and transgressions of the seas.

As no coast is perfectly stable, it is rather difficult to separate the tectonic and eustatic effects on any coast. However, in the areas of relative stability, the raised and submerged features can be taken safely to be the result of eustatic rise and fall of the sea-level alone.

The problem of the stability of Indian coast during Quaternary, has not been studied in detail. The only area, which has received special attention of researchers is the Saurashtra coast and parts of Bombay-Goa coast of western India. In these areas, efforts have mainly been made by recent workers to prove that the coast was relatively stable during Quaternary (Gupta, 1972; Agrawal & Guzder, 1974; Verma & Mathur, 1975; Mathur & Verma, 1976; Verma & Mathur, 1977, 1978).

The correlation of the radiometric dates of the raised features of Saurashtra with the late Pleistocene
and Holocene sea levels of other parts of the world has made the geochronologists think in terms of stability of Saurashtra. The field investigators, who have found no direct or indirect evidence of the tectonic deformity in the Quaternary sediments, are also tempted to suggest stability of this coast.

On the other hand, the photogeologists interpret the striking straight coastline feature of Saurashtra, which gives it a rectangular shape, strongly suggestive of fault scarp shoreline. Along these faults the peninsula are supposed to have been reactivated during Quaternary. The postulated fault along the southeastern coast is supposed to be the continuation of Narmada zone of weakness (Poddar, 1964; Shrivastava, 1968b).

Seismologists claim the whole of Kutch and Saurashtra lie in a seismic belt, where catastrophic earthquakes have occurred (Lele, 1973) and hence the region is tectonically active even today. The mean sea level studies on the west coast of India are indicative of a rising trend of the coast, which have been taken as the result of the instability of the coast (Lele, 1967). It appears that Lele (op.cit.) considered Saurashtra and Kutch, which form two of the three
main physical sub-divisions of Gujarat, to comprise a single geo-tectonic unit. However, a close look at the seismic activities in the recorded history show that both the regions have quite diverse seismic history. Kutch falls in the seismic zone No. V whereas Saurashtra falls in seismic zone No. III. Saurashtra has never been the epicentre of any earthquake felt in western India. On the other hand, Kutch has been the epicentre of the earthquakes which brought large scale changes in the distribution of land and sea in 1819, and the one which resulted in mortality of human and cattle life in 1962. If the seismic activity of an area is the measure of its tectonic stability, the inference drawn from the absence of earthquakes in Saurashtra, is strongly suggestive of its tectonic inactivity during recent times. The area is not known to have even the microseismic activity which goes a step forward in supporting the stability of Saurashtra in recent times.

As stated earlier, the straight shoreline feature of the southeastern Saurashtra coast has been interpreted as the continuation of the Narmada-Son lineament. It is
therefore, most essential to find out if the Saurashtra peninsula was subsequently reactivated along this fault any time during the Quaternary.

In order to investigate this, the surface and subsurface data from southern coast near Jafarabad (which is supposed to be directly on the postulated fault) was studied by Verma & Mathur (1977), the results of which are summarised below:

(i) there is no faulting and folding on any scale in the Quaternary sediments of the area to suggest any movement,

(ii) the Tertiary sedimentaries, which directly underlie Quaternary carbonates of the area, do not show any vertical shift due to faulting. This was proved by both surface mapping as well as by borehole log studies,

(iii) the Tertiary sedimentaries consisting of littoral deposits, are not known to occur in Saurashtra at an elevation higher than 30 m above sea level. Had Saurashtra peninsula been uplifted to the magnitude postulated by some workers, the deep water facies of Tertiary would have been exposed.
(iv) the uninterrupted carbonate sedimentation throughout the Quaternary would have not been possible had Saurashtra suffered large scale tectonic uplifts after the deposition of miliolite rocks. The extensive uplift of the source area (mainland) would have inevitably produced conditions unsuitable for carbonate sedimentation, and in that case the late Pleistocene-Holocene Chaya carbonate rocks and the modern carbonate sands would have not been deposited. The high relief produced as a result of tectonic uplift would have resulted in extensive deposition of terrigenous sediments in place of carbonates. Thus, it is difficult to visualise tectonic uplift of Saurashtra in post-miliolite times. On the other hand, there are overwhelming evidences in favour of its stability during early Quaternary, and its tectonic tranquility even today.

**EVOLUTIONARY MODEL**

Shrivastava (1968b) presented a sedimentational model for Quaternary of Saurashtra in which it was
proposed that the post Tertiary sedimentation is controlled by crustal movements along the pre-existing basement faults. It was suggested that entire peninsula was down faulted in Pleistocene causing widespread marine transgression during which the formation of miliolite limestone took place. Following this, the process of uplifting set in, in the Sub-Recent, which is still continuing.

There are hardly any convincing evidences in favour of such a large scale uplift of Saurashtra during Quaternary, and as such the succession of marine and aeolian deposits of Quaternary is required to be explained by a different process, taking into cognisance the relative stability of the Saurashtra coast. This can most satisfactorily be done if the origin of Quaternary carbonates is linked with a regressive sea as conceived by Zeuner (1959) in which the 'highs' of the Quaternary seas during successive interglacials were lower than the one just preceding it. This is precisely the way the Quaternary sea appears to have behaved in Saurashtra.

In the model of sedimentation proposed here the following additional conclusions have been taken care of:
1. that there has been continued carbonate sedimentation throughout Quaternary,

2. that the marine deposits of Quaternary are present even at considerable high levels,

3. that the aeolinites of the interior highlands represent coastal deposits analogous to that being formed today, and were formed by a process of short distance wind transportation,

4. that the similar aeolinites have formed even along the present day coastal margins.

During the major part of late Tertiary, most of the Saurashtra region stood above the level of the sea, and there are no evidences of marine deposits of that period in Saurashtra. Dwarka beds which were earlier thought to represent Pliocene in Saurashtra have been proved to be Miocene in age by the author (Mathur, 1972).

During early Pleistocene, Saurashtra witnessed a major transgression, but this was not because of a large scale faulting along its pre-existing basement faults, but was perhaps because of the eustatic rise in
the sea-level. A large portion of the landmass was submerged under the sea (Fig.VIII.2a). On the crenulated shores thus formed, which enjoyed warm water conditions with little influx of terrigenous sediments from the inland because of insufficient drainage, the typical bank sediments containing pellets, oolites and superficial oolites were laid down. These sands now form the calcarrenites of Miliolite Formation.

As the sea regressed at a later date in response to the first worldwide glaciation, large parts of the pelletal sands were exposed. These sands were wind-blown by westerly and southwesterly winds to form the aeolinites of the interior highlands. Thus, the distribution pattern of the miliolite rocks of the interior highlands as seen today is the consequence of deposition under marine conditions and their subsequent accumulation as littoral dunes by aeolian processes.

During the subsequent interglacial period, the sea did not attain the level it had reached during the first transgression as explained in Zeuner's theory of falling sea levels during Quaternary. During this transgression, again the conditions of deposition were identical to those
of the first transgression. The only difference was that the marine banks were shallower with smaller derial expanse in which pelletaloid sands continued to be deposited. It was in this manner that the second series of miliolite rocks at lower levels were deposited.

The next regressive phase saw the development of a second series of aeolinites and to this category belong the parabolic dunes of the study area.

The above sequence of events must have been repeated several times during the successive interglacial and glacial periods, till the sea-level reached close to the present level in the late Pleistocene.

Thus, the miliolite rocks of early Pleistocene were deposited in the setting characterised by a model of shallow partly enclosed seas, bank-marginal beach and banks with ria-valleys, the tidal currents having played a key role in carbonate sedimentation in the shallow channels also.

In the late Pleistocene, the sea had regressed close to the present shoreline (Fig.VIII.2b). The islands of early Quaternary had more or less disappeared
and now formed the hills of the mainland. Besides, trappean hills, the limestone mounds near the coast and other aeolinites formed the raised features of the mainland. There was still no drastic change in the general depositional conditions on the coasts. Aided by absence of discharge of terrigenous material from the mainland to cloud the clear waters of its coast and other suitable ecological conditions, coral reefs grew which formed the barrier reefs. In the stretch between the reefs and mainland shallow lagooms must have developed in which oysters thrived. On the banks of the coral reefs, beaches having an admixture of first and second order carbonates were deposited. In the calm waters away from the barriers, the sand that now forms the calcirudites of Chaya Formation was deposited.

The Chaya rocks of late Pleistocene to Holocene were thus deposited in the setting that fits in well with the model of an offshore, barrier reef with beach and a shallow lagoon bordering the mainland.

The available radiometric dates indicate that the level of the sea on the Saurashtra coast during the interglacial around 120,000 years B.P., the
interstadial around 30,000 and 6,000 years B.P. reached about 2 to 6 metres above the present level. The sea-level stood at −100 metres about 9,000 – 11,000 years B.P.

Obviously, during the negative fluctuation of the sea-level in the immediate past a large expanse of the continental shelf must have been exposed, and the aeolinites, which now constitute the coastal ridges, were deposited. Some of these are now even submerged.

MODERN SEDIMENTARY ENVIRONMENTS

The present day model of sedimentation appears to be only slightly different from that prevailing during the deposition of Miliolite and Chaya rocks. The depositional conditions favourable for lime deposition to prevail still continue. The present depositional settings are- an open sea, limestone barriers with beaches attached with the coast and marshy mangrove swamps (Fig. VIII.3).

Thus, the Quaternary geological history of Saurashtra is the history of continued carbonate sedimentation in a warm regressive sea in which the environments of sedimentation changed from (i) a combination of bank, bank-marginal
beach and off shore to (ii) a shallow lagoon bordering mainland, barrier reef with beach and an offshore to (iii) a tidal flat protected by a limestone barrier with beach and an offshore.

The present southern Saurashtra coastline is a prograding one as is evidenced by the presence of old tidal flats with rill-marks about 5.8 km inland and three set of parallel coastal dunes. This progradation has been the effect of lowering of the sea-level in the Holocene.

The hot and arid climate and lack of surface water drainage, inhibiting the supply of large quantity of terrigenous detritus to the shelf margins of its coast throughout the Quaternary, are responsible for the continued pure carbonate productivity in the area. No doubt, Saurashtra is an unique area in the country which has enjoyed the distinction of continued prevalence of pure carbonate sedimentation during the Quaternary.