CHAPTER - II

G E O L O G I C A L B A C K G R O U N D

PREVIOUS WORK IN GENERAL

The Holocene sediments of the coastal areas of Saurashtra and Gujarat, have practically remained uninvestigated from the point of view of their geological and geomorphological aspects. As a result, little data on their microfaunal content, relevant to the present thesis are available. Whereas, the coastal areas of Saurashtra (formerly known as Kathiawar) because of the extensive occurrence of biogenic carbonate sands, did attract the attention of some earlier workers over almost a century back, the coastline of Mainland Gujarat was not studied at all. The Saurashtra peninsula continuec to receive attention from

time to time and during the last two decades geologists and archaeologists have published quite a few papers pertaining to Quaternary carbonate deposits, their eustatic significance and geochronology. Some microfaunal aspects have also been studied. The coastal areas of Saurashtra overlooking the Gulfs of Kutch and Cambay have been investigated by engineers and geologists in connection with the problems of navigation and of harnessing of tidal energy. Some elementary studies on the floral aspects of Saurashtra coast also need to be mentioned as coastal flora does have an indirect bearing on the lithological aspects of shoreline deposits.

In contrast practically no previous work on the Mainland Gujarat coast prior to the last decade, is available. Though the Mainland Gujarat coastline is marked by interesting geomorphic diversity, its various coastal segments pointing to considerable variations in their environmental parameters, none in the past has made any serious attempt to investigate this part of the West Coast. Only indirect references are made to some of the local features pertaining to one or the other aspects which are have come across in the works of G. S. I. and O. N. G. C.officers.

More recently, in the course of last few years, the research workers of the Department of Geology, M. S. University of Baroda have systematically studied the Saurashtra and Mainland Gujarat coastline, their main emphasis being on the geomorphological aspects. Published and unpublished works of these

investigators provide wealth of information pertaining to the coastal landforms, texture and lithology of sediments, neotectonism and eustatic sea-level changes.

As already stated above, while some information on the microfaunal aspects of the coastal deposits of Saurashtra is available, there is little microfaunal data on the Mainland Gujarat coast, which the present author could use as background information. Practically, in a way therefore, hers is the first ever succinct micropalaeontological study. The present study does not deal exclusively with the descriptive aspects of the microfauna, but her investigations have wider implications, comprising an attempt to explain the microfaunal diversity of the various coastal segments in terms of the prevailing environmental parameters of the respective segments. It is, therefore, appropriate that all available background information even indirectly related to the theme of the thesis be briefly given for the benefit of the reader.

PREVIOUS WORK ON SAURASHTRA

The Saurashtra peninsula has received some attention in the past, specially in respect of the consolidated foraminiferal carbonate deposits, commonly known as miliolites, which occur extensively along the western and southern coast. The miliolite deposits of Late Pleistocene to early Holocene ages have been a subject matter of considerable controversy. While

many geologists have investigated the consolidated sands, none have made any serious attempt to investigate in detail the present day unconsolidated beach material, which is in no way significantly different from its consolidated and slightly older equivalents.

More than a century back, Carter (1849) made an exclusive study of these consolidated carbonate deposits, and described them as granular deposits, composed of oolitic particles of calcareous sand having predominance of the foraminifera belonging to the genus -Miliolina. A few decades later, Fedden (1884) who for the first time published the systematic geological account of the Saurashtra peninsula, gave a more elaborate description of the nature and occurrence of these foraminiferal sand accumulations defining them as finely oolitic grains being mostly organic. He described in great detail the field characteristics of the miliolites from the coastal areas of Porbandar, Veraval, Jafrabad and Gopnath Point, and according to him, these limestones were the product of littoral marine accumulations. Evans (1900) and Chapman (1900) who also studied these carbonate sand deposits, however, suggested an aeolian origin, invoking strong wind action during Late Quaternary times that lifted up the littoral calcareous material and dumped them as backshore coastal dunes.

The Saurashtra coast did not receive any worthwhile attention until the late Fifties, when Shastri & Pant (1959) published a brief note on the foraminiferal content of the

miliolitic rocks. To Shrivastava (1968 a and 1968 b) of the O.N.G.C. goes the credit of a detailed reinvestigation of the Saurashtra coastal area. He prepared a detailed geological map of Saurashtra, especially its coastal areas, and added new knowledge to the miliolite problem. He, for the first time, pointed out that the so-called 'oolites' were in fact, pellets and suggested that the Miliolite Formation consisted mostly of beach sediments deposited in agitated, warm and shallow waters, only a few feet deep, and that during Pleistocene, the sea-level stood much higher than the present.

The present author has no intention of going into the controversy pertaining to the mode of origin of the various miliolite accumulations as it has now been generally accepted that the various exposures of the miliolite rocks along the Saurashtra coast comprise both-littoral marine and coastal aeolian deposits of more than one generations being a direct consequence of fluctuating sea level.

In recent years, significant contributions to the coastal geology of Saurashtra have come from the research teams of Physical Research Laboratory (Ahmedabad), Deccan College (Pune), Geological Survey of India and the M. S. University of Baroda. An attempt at radiometric dating of some coastal rocks of Saurashtra was made by Agrawal (1969;1971) and Gupta (1972;1977). The C^{14} dates of dead corals and shells from the raised beaches of Saurashtra indicated higher sea-level stands of 2-6-meters above

the present level, approximately 1,20,000 years, 30,000 years and 6,000 years B. P. (Gupta-1972;77). Rajaguru and his workers from the Deccan College (Govindan et al, 1975,77; Marathe et. al. 1977; Rajaguru & Marathe 1977) investigated in detail the Miliolite rocks of Southern Saurashtra. To Mathur (1978) and Verma (1979) of G. S. I. goes the credit of producing a wealth of geomorphic, sedimentologic and palaeontologic information on the consolidated as well as unconsolidated carbonate sands of South Saurashtra coast. These workers revised the coastline stratigraphy on the basis of micrcpalaeontological studies. They placed the 'Coast-fringing rocks' of Fedden which were included by him under Dwarka Formation (Pliocene) under Quaternary. "Dead coral reefs" and "Oyster beds" of Fedden were also removed from Dwarka Formation, and placed under Quaternary, indicating Late Pleistocene to Early Holocene age. Verma recorded a fauna of benthonic foraminifers comprising 15 genera belonging to 13 families, the most widespread being Rotaliidae, Elphiidae and Nubeculariidae in order of predominance. He observed the most frequent species in relation to the number of specimen to be Ammonia beccarii, Elphidium crispum, Quingueloculina seminulum, followed by Ammonia annectens, Elphidium indicum, Spiroloculina indica and Quingueloculina venusta. These benthonic forms, according to Verma indicate warm, shallow, agitating nearshore environment, capable of flourishing in a wide variety of environments from estuary, tidal flats, beach, innershelf and shelf, with an ability to survive considerable variations of salinity, temperature and pH. Verma grouped together consolidated

carbonate sands rich in broken fragments of molluscan shells as well as of corals and assigned them a formation status viz. Chhaya Formation, a term initially introduced by Mathur & Mehra (1975) to distinguish such a shell-fragment rich rock from the typical pelletoidal foraminiferal miliolitic formation. Verma has also studied the loose coastal sands but his account is restricted to a systematic description of the various benthonic foraminifers.

Mathur (1979) whose findings are more or less identical to those of Verma, has however given an exhaustive account of the unconsolidated sands of the south Saurashtra coast. He investigated the textural parameters of the beach and dune sands and also worked out the effects of winds. His most important contribution pertains to the study of a phenomenon of pelletisation. He has shown that the pellets in the recent sands are made up of two types:- 1) smooth ellipsoidal or spherical derived from the pre-existing coastal miliolite rocks and (2) micritised skeletal grains of foraminifers and molluscas showing different stages of pelletisation and micritisation. He found them to comprise sand grains in different stages of abrasion of fragments of molluscan shells, bryozoans, echinoderm spines, calcareous algae, ostracodes and of course, abundant benthonic foraminifers.

In more recent years, the coastal areas of west and south Saurashtra have been investigated by the research team

of the M. S. University of Baroda (that includes the present author). Geomorphic aspects of the west coast of Saurashtra have been ideally described by Ganapathi et al (1982) while a preliminary account of the microfaunal characters was given by the present author (Desai & Pandya, 1982).

The northern coast of Saurashtra has remained comparatively uninvestigated from the point of view of Holocene sediments. Though some previous information does exist in literature on the Gulf coast but most of it either pertains to the study of the Gulf of Kutch basin or to the coral reefs. Lyall & Reddy (1982) have given a very brief account of the coastal sediments, but their main theme pertains to the sea bed morphology and bathymetry of the Gulf of Kutch. Shetty & Ambgre (1982) who described the foraminiferal assemblage in the sediments of Gulf of Kutch in a very general manner, have observed that the foraminifers in the clays were mostly of embryonic type whereas they were of large and adult types in the sands. Among the embryonic thin shelled forms, according to these authors, the hyaline were dominant in the silts and clays, while those of the adult forms in the sandy substrate were porcelleneous type. Corals and coral reefs of Jamnagar and Okha coasts have been described by Chhaya & Patel (1982). Some details of the geomorphic evolution of the north Saurashtra coast and sediment characters of the coastal plains are available in the works of Thorat (1979). As such, microfaunal studies of the North Saurashtra coast are yet to be taken up, though the present author has made an attempt to furnish some new data.

Table II-1 : Classification of Quaternary and Tertiary sequence of Saurashtra (after Fedden,1884)

Formation	Approximate geological position
Alluvium (Sand dune, tidal flat, freshwater alluvium, 'ran' clay, raised beaches and miliolite)	Recent and Sub-Recent
Dwarka Beds	? Higher Tertiary or Post-Pliocene
Gaj Beds	Upper Miocene (Lower Manchar in part and Gaj of Sind)
Lateritic rocks	? Lower Eocene- Sub-Nummulitic (Wynne) of Kutch and ? High-level laterite of Deccan
Traps	Cretaceous-Eocene (Deccan Traps)

Table II-2 : Quaternary and Tertiary Sequence of Saurashtra (After Mathur & Mehra 1975).

	Stratigraphic Unit		Lithology	Age
QUATERNARY		ALLUVIUM AND COASTAL DEPOSITS	Freshwater alluvium (sands, clays), coastal deposits (Lime mud; rann clays with carbonaceous material/marine shells; unconsolidated calcareous sands)	Holocene
	MILIOLITE FORMATION	CHHAYA FORMATION	Semiconsolidated to consolidated limestones (Calcirudites); shell limestones, coral reefs and oyster beds	Holocene to Late Pleistocene
		ADATIANA MEMBER	Pelletoid limestones (calcarenites)	Early Pleistocene
		DHOBALIYA TALAV MEMBER	Alternating sequence of pelletoid limestones and fine grained limestone (micrites)	
TERTIARY		DWARKA FORMATION	Flaggy, arenaceous limestones with recrystallised shells; clays	Middle Miocene to Lower Miocene
		GAJ FORMATION	Hard, compact, fine grained limestone with abundant foraminifera; variegated clays	Lower Miocene

Laterite and Deccan Trap

So far as the present study is concerned, the unconsolidated sediments resting over older rocks mostly Miliolite/Tertiary/ Trap are of relevance, but as will be seen in the subsequent pages of this thesis, the present author's observations and conclusions are of vital significance to the above controversy.

The Mainland Gujarat coast geology is rather less revealing. The overall picture of depositional environments and to a certain extent lithologies are different from those of Saurashtra. This is so in the case of Quaternary rocks including the present day coastal deposits. Lithologically and faunistically, the coastal deposits of Mainland Gujarat are quite different from those of Saurashtra. The Mainland coast to the north of Narmada is marked by a thick alluvium of the order of 700-800 meters at places, and the shoreline shows impressive cliffs of alluvium against which abut the mudflats.

Geologically the Mainland Gujarat coast forms the eastern flank of the Cambay basin, the main petroleum bearing Tertiary structure off the West coast. On the basis of the subsurface investigations, Chandra & Chaudhary (1969) have given the following stratigraphy for the Cambay basin (Table II.3).

Table II-3 : Stratigraphy of the Cambay Basin

(After Chandra and Chaudhary, 1969).

Age	Subsurface	
	Narmada Block	Jambusar-Broach Block
Recent	Gujarat Alluvium	Gujarat Alluvium
Pleistocene		Jambusar Formation
Pliocene		Broach Formation
U. Miocene	Jhagadia Formation	
M. Miocene	Kand Formation	
L. Miocene	Babaguru Formation	
	Kathana Formation	
Oligocene		
U. Eocene	Ankleshwar Formation	
M. Eocene		Kalol Formation
L. Eocene	Cambay Black shale	
Palaeocene	Olpad Formation	
U. Cretaceous	Deccan Trap	

The above stratigraphic sequence comprising Deccan Trap, Tertiary and Quaternary sediments is valid between the rivers Mahi and Tapi, beyond which the Tertiaries are absent in onshore area and the Quaternary deposits rest directly over the Deccan Trap. It is obvious that the alluvium tends to thin out to the south of Narmada. Chandra & Chaudhary (1969) considered the thick alluvium to be of Recent age but most other workers (Krishnan, 1968) have assigned a geological age of Middle to Late Pleistocene to older parts of the alluvium. South of Narmada the alluvium is hardly 100 meters thick below which lies the Jhagadia Formation of Upper Miocene age.

The Older Alluvium of Late Pleistocene age is seen to consist of silty clay and is of the order of 50- 250 meters thick. The material of the present day flood plains constitutes the Newer Alluvium, its occurence being restricted to the lower terraces of the major rivers of south Gujarat. Resting over the Older Alluvium are the Holocene coastal sediments and comprise sandy beaches, bars, spits, barriers, dune ridges and mudflats. While describing the coastal stratigraphy of the area between the rivers Auranga and Par. Joottun et al (1982) have described the Quaternary deposites in greater detail as under (Table II.4):

Table II-4 : Coastal Stratigraphy of the area between rivers Auranga and Par (After Joottun et al. 1982).

Shoreline Deposits: Beaches, barriers ridge complex, coastal dunes, Palaeobars and beach rock. Fluvio-Marine Deposits: River mouth bars and mudflats Fluvial Deposits: Recent alluvium, point bars, channel shoals and backswamps Residual Deposits: Alluvium and residual soils		HOLOCENE
River Alluvium (older), Coastal gravel beds		LATE PLEISTOCENE
---------- Unconformity ----------		
Basaltic and doleritic dykes Basaltic lava flows	DECCAN TRAP	UPPER CRETACEOUS TO LOWER EOCENE

In the extreme southern part of the study area beyond Umbargam the Deccan Traps are exposed in the intertidal zone, the overlain sediments being relatively quite thin.

STRUCTURAL FRAMEWORK

The entire coastline including that of Saurashtra and Mainland Gujarat is essentially fault controlled. The coastline configuration, drainage pattern and Cenozoic depositional history are all manifestations of numerous regional faults. The peninsula of Saurashtra points to a structural set up bound by major faults on all the sides (Poddar, 1964). The Saurashtra coast thus comprises following four tectonic zones of instability (Fig.II-2):-

1. Western Cambay basin border fault.
2. Narmada fault.
3. Gulf of Kutch fault.
4. West coast offshore fault.

A perusal of the drainage pattern of the Saurashtra and also the scrutiny of satellite imagery point to a fracture pattern criss-crossing the entire peninsula, the various fractures related to one or the other of the above four bounding faults. Differential tectonism along some of the major fractures appears to have been an effective neotectonic phenomenon during the Quaternary period. Studies by Marathe et al (1977) and Ganapathi (1982) have conclusively established such movements along some major river valleys of south Saurashtra coast. Merh (1980) has further visualized a northward tilting of the Saurashtra landmass during Quaternary along an E-W axis, and according to him it is this tilt that has submerged the Jamnagar coastline while the south western and southern coastlines indicate

TECTONIC MAP OF SAURASHTRA

After Shrivastava(1968) and Biswas(1970)

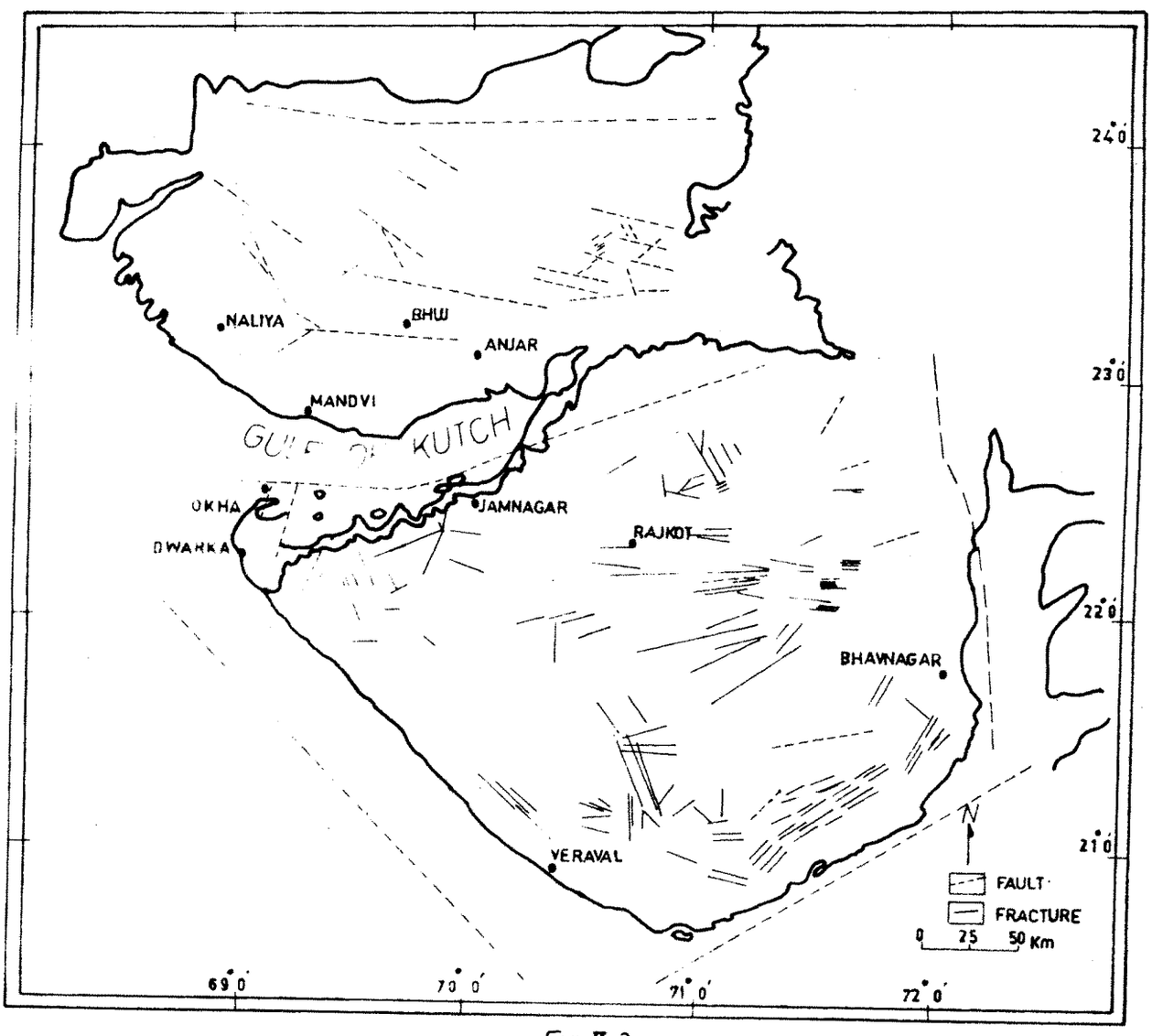

Fig. II 2

emergence. The slowly submerging northern coastline is characterised by a profuse growth of coral reefs, while the emerging coast of the west and south typically contains miliolite deposits.

The Mainland Gujarat coast is also fault controlled (Fig. II-3) and its configuration, Cenozoic depositional history and landforms adequately reflect the tectonic framework of the Cambay basin (Mathur et al. 1968). The various major rivers like Mahi, Narmada and Tapi and also some of the rivers further south have been found to flow along major fault lines. Also a NNE-SSW fault extending from Mahi to Narmada limits the northern coastal block to the east. Along the Mainland Gujarat coast Narmada fault marks a major crustal lineament such that the coastline to its north and south have behaved quite differently during the Tertiary and Quaternary times.

QUATERNARY SEA-LEVEL CHANGES

The west coast in general and the Saurashtra and Mainland Gujarat in particular are ideal sites for studying the effects of eustatic sea-level changes. The miliolite rocks

TECTONIC MAP OF MAINLAND GUJARAT

After Mathur et al(1968)

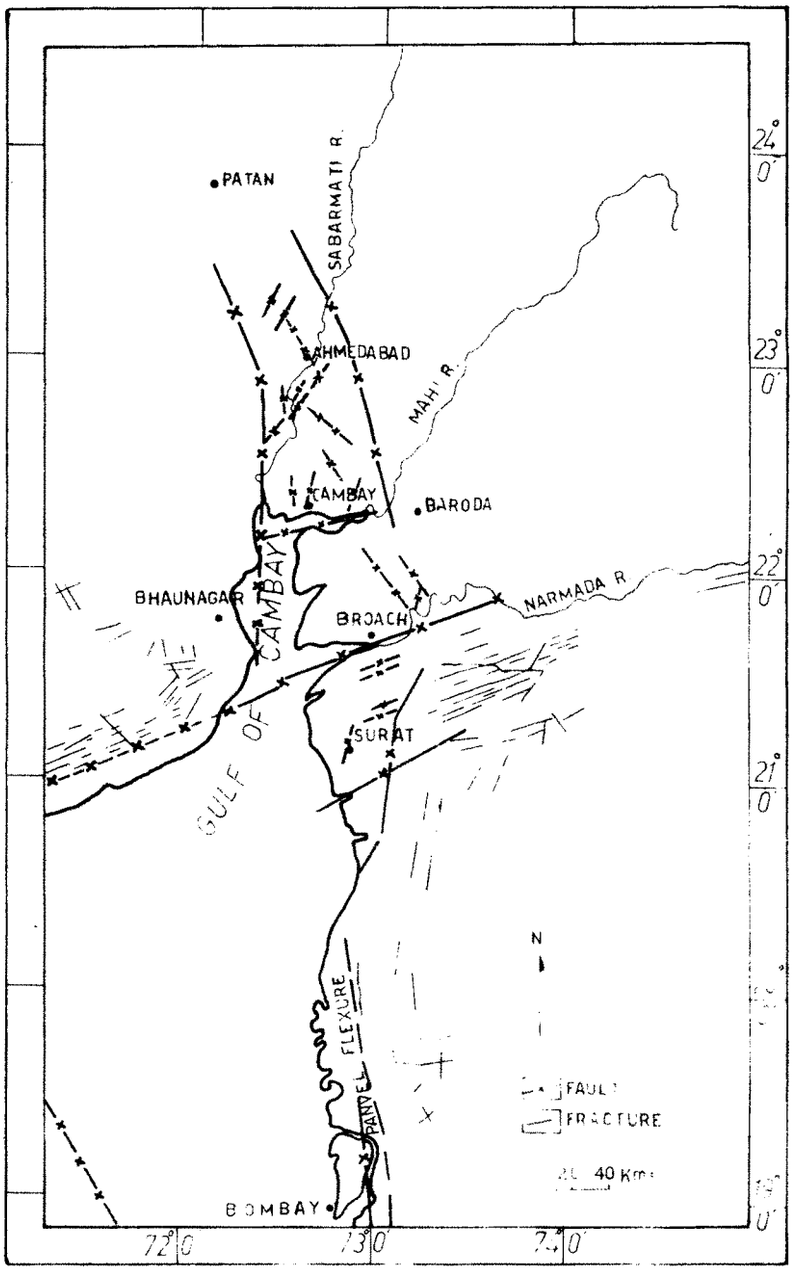

Fig. II.3

of Saurashtra have in the recent past generated a lot of controversy in this respect. Sheets of marine miliolites, fairly inland and at various altitude occuring as high as 200 meters above the M.S.L. have been taken by Verma & Mathur (1978) as indications of two successive higher strandlines related to the glacial and interglacial stages of the Alps. These workers have envisaged the Saurashtra peninsula to form a stable landmass during Quaternary which did not undergo uplift and subsidence. Merh (1980) and his associates are however of the opinion that the various parts of the Saurashtra did undergo differential movements during the Quaternary period along a few major fractures that criss-cross the peninsula. These workers have envisaged the following succession of sea-level fluctuations:-

1. Transgression - rise upto 40 meters above the present sea-level sometimes during Late Pleistocene (perhaps comparable to Tyrrhenian)

2. Regression - so that the sea-level went down at least 10 meters below the present. This event of regression marked the last of the Glacial stage (? Würm) indicating the close of Pleistocene.

3. Transgression - Upto a height of 10 meters above the present day sea-level. Evidences of this sea-level rise are better preserved and is generally referred to as Flandrian Transgression marking the advent of Holocene about 10,000 years ago.

4. Regression - Characterised by a progressive withdrawal of sea upto the present-day sea-level.

While the indications of these fluctuations of strandline are well preserved in the Quaternary sediments of Saurashtra coast, the Mainland Gujarat coast has unfortunately very little direct evidences to point out these sea-level fluctuations. This is mainly because of the differential neo-tectonic movements in the coastal blocks to the north and south of Narmada fault. The Mainland Gujarat coast however, provides good evidences of the Würm regression and Flandrian transgression. The offshore areas provide quite a few evidences of a regressive strandline during which the various rivers had extended their courses westward and excavated entrenched valleys in their upper courses. The Flandrian transgression is better represented in various geomorphic features like raised mudflats and inland sandy ridges. In fact the present day indentation of the coastline with estuarine river mouth provides an excellent example of a submerged coastline. The withdrawal of the Flandrian sea has left its imprints all along the shoreline.

The Mainland Gujarat coast especially south of Narmada shows coastline feature related to the last three events of strandline fluctuations. As regards the 40 meters high strandline there are little evidences north of Tapi, but to its south Joottun et al (1982) have evoked the high strandline marking a limit of the horizontal basaltic terrain (40- 45 meters

above the M.S.L.) beyond which suddenly rise the Trappean hills. According to these workers the flat Trappean ground in front of the hills without any significant thickness of alluvium could be representing an abraded littoral platform during the high strandline.

The present author however is concerned more with the existing environmental conditions prevailing in the different segments of the coastline and has therefore taken in to account the last two Holocene events of transgression and regression.