# CHAPTER-1
# INTRODUCTION

## 1.1 ANIMAL-SEDIMENT RELATIONSHIPS

Animal-sediment relationship is the study of interaction between the organisms and sediments that alters the original sediment fabric to serve a wide spectrum of the essential requirements of their life like, respiratory, feeding, reproduction, protection, etc. These sediment-processing activities of animals in turn form bioturbation structures (tracks, trails and burrows), in which, animal may spend their entire life or part of their life. These biogenic structures are autochthonous in nature having wide environmental implications that helps to facilitate in understanding behavioral and ecological analysis of endemic species.

In interpreting the geological records of shallow marine sediments, biogenic sedimentary structures affecting the substrate are important and decisive in documenting marine to nonmarine transitions. The intertidal zone is the most easily accessible area in the marine environments, often containing rich and diverse groups of benthic life. Therefore, it is necessary to understand the ecological constrains (physical, chemical and biological processes) involved in the deposition of the sediments in the present day intertidal zone.

Two benthic animals, viz., crustaceans and polychaetes were studied in the intertidal zone of the Mandvi area in the Gulf of Kachchh. They are the most abundant and diverse organisms in the various geomorphic units. Their behavioral activities are in the form of tracks, trails and burrows. These clearly document their usefulness in understanding neoichnologic constrains of the intertidal environment. The quality and quantity of present day biogenic sedimentary structures indicates relative importance of bioturbation *versus* physical disturbances of sedimentary structures. The close examination of the biogenic sedimentary structures helps in determining the various micro- depositional environments within the intertidal zone.

## 1.2 AIM OF THIS STUDY

The prime objective of the study was to observe, record, examine and analyze the bioturbation structures in light of their trace makers (Crustaceans and Polychaetes) from the different geomorphic units of the intertidal zone. This study has essential field based component with supporting laboratory analysis. The physical and biogenic structures are

photographed in field and were also studied by applying different techniques like, trenching, X-radiography, casting and peeling methods. The broad methodologies followed are as under:

i. The area was mapped with help of the Indian Survey Topographic Sheet Number 41F/5 on scale of 1:50,000 and potential area marked for crustaceans and polychaetes association.

ii. Animals were collected and preserved in formalin and later identified at species level in the laboratory.

iii. Behavioral activity of crustaceans and polychaetes were observed, studied and photographed. Population variations along and across intertidal zone were also recorded and monitored.

iv. For detailed analysis of physical and biogenic sedimentary structures, oriented, undisturbed rectangular box-cores as well as relief peels were collected from different geomorphic units of the intertidal zone. The box cores were subsampled for textural analysis. The systematic sampling of sediments were also done along and across the intertidal zone for textural analysis.

v. Replicas of burrows were obtained by pouring molten wax through burrow openings during the low tides. Length, diameter and penetration of the burrows in sediments were measured and noted from wax cast.

vi. Abundance and diversity of the biogenic sedimentary structures were analyzed in the light of trace makers, substrate consistency and hydrodynamic conditions. These structures were also compared with the fossil counterparts and classified based on ethology and trophic types.

vii. Based on present day field and laboratory data, Ichno-sedimentological models were reconstructed for the Mandvi coast.

## 1.3 THE REGION OF KACHCHH

"*Kachchh*" an ancient crescent shaped land of great antiquity takes its name from the geographical characteristics and topographic features resembling a tortoise. The district stretches from $22^0$-44'-11" to $24^0$-41'-25" north latitudes and $68^0$-09'-46" to $71^0$-54'-47" east longitudes (Figure-1). The Kachchh district has coastline of approximately 352 km, with nine ports. In general, the coast is flat and broken by small and big creeks.

Kachchh coastline can be divided in to two stretches (1) the Arabian Sea segment - from Lakhpat to Mandvi and (2) the Gulf of Kachchh segment - from Mandvi to Shikarpur. Thus, the Mandvi region (study area) experiences effect of both, open sea and gulf sea.

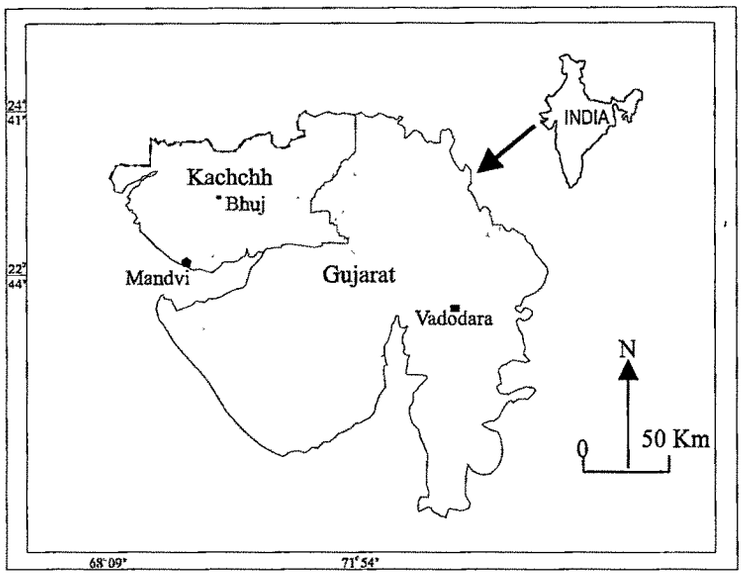


**Figure-1: Location map of the study area.**

### 1.3.1 Communication

Bhuj, a capital of the Kachchh district is very well connected with other parts of the country by rail, road, and air services. Broad gauge rail services are available for Gandhidham and Bhuj from Ahmedabad, while meter gauge rail service is available from Palanpur to Gandhidham. Bhuj is also well connected by daily air service from Delhi, Mumbai and Ahmedabad. Bhuj is also connected by National Highway No. 15 from New Delhi via Radhanpur and from Ahmedabad by Highway No. 8A. Mandvi town is 60 km far from Bhuj and connected by state highway. It is also connected by state highway from Gandhidham via Mundra. The villages of the study area are well connected by tar and metalled roads.

### 1.3.2 Climate

A very dry climate and scanty uncertain rainfall characterize the climate of the Kachchh district even during the southwest monsoon season. The cold season from December to February is followed by the summer season from March to about Mid June. Mid June to Mid September constitutes the southwest monsoon season. October and

November form the post monsoon transition period between rainy season and cold season. The annual rainfall in the district is approximately 346.6 mm.

The annual rainfall varies from 419.9 mm at Mandvi on southern coast to 334.1 mm at Lakhpat on the northwest coast. About 94% of the total rainfall are received during the southwest monsoon season, and July being the rainiest month. The day temperature in the coastal parts of the district is generally less as compared to the interior parts of the district. After October, day and night temperature rapidly decreases till January, which is the coldest month. The mean daily maximum and minimum temperatures in January for Mandvi are $25.6^0$c and $14.7^0$C respectively. At Mandvi the highest maximum temperature recorded was $42.9^0$C on 3rd May 1966 and lowest minimum was $5.2^0$C on 30th January 1971. Humidity in the coastal plains is high throughout the year exceeding 60% on an average. Winds are generally light to moderate with time increase in force during the late summer and southwest monsoon season. Coastal part experiences stronger winds, especially during the monsoon season. April to September winds blow mostly from west to southwest. During the rest of the year wind blows from the north and northeast in the afternoon.

### 1.3.3 Geology

The Kachchh region is a peri-continental rift basin in the western most part of

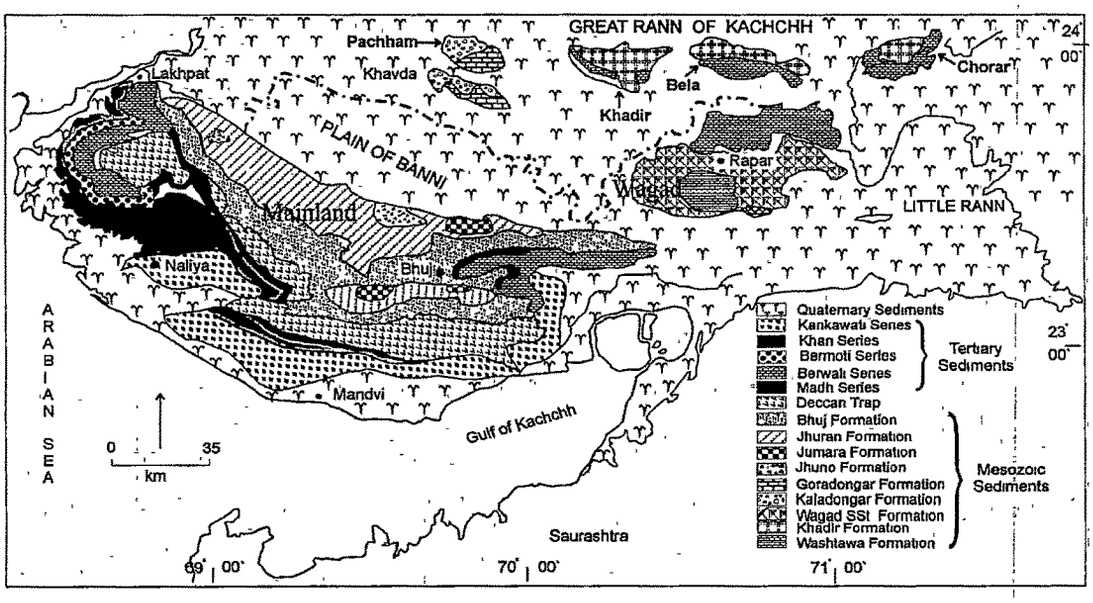


**Figure 2: Geological Map of the Kachchh region, after Biswas and Deshpande (1972)**

Indian peninsula (Biswas, 1987). The basin is an E-W embayment opening out towards

the Arabian Sea. Its inception took place in the Bajocian times (Singh et al 1982). This basin is the southern end of the Indus shelf and is bordered on the North by the fossil rifts of the Thar and Southern Indus basin (Zaigham and Malick, 2000). The basin has a thick succession (+3000 m) of the Mesozoic strata followed by a thin (+900 m) Tertiary sequence (Biswas, 1977). The rocks overlying the basal granitic conglomerates in Khadir and syenitic rocks of the Meruda Hill are thought to be the oldest Mesozoic sediments

| AGE | MAINLAND | | | PATCHAM | | | E. KUTCH (KHADIR-BELA-WAGAD) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Formation | Member | Litho | Formation | Member | Litho | Formation | Member | Litho |
| NEOCOMIAN / ALBIAN | BHUJ | Upper +260m | X-bedded sst, clay-stone | | | | | | |
| | | Ukra +30m | Sst, Sh, Fossilifer | | | | | | |
| | | Ghuneri 325m | Sst- sh, Plant, fossils | | | | WAGAD SST | Gamdu + 165 m | Felds-sst, sh, red iron-stone Plant Fossil |
| | JHURAN | Katesar 190m | X-bedded sst,fossils | | | | | | |
| KIMMERIDGIAN TO TITHONIAN | | Upper 300m | Thin-bedded calc sst, | | | | | Kanthkot 200m | (Upper) Sst-sh |
| | | Middle 160m | Shales | | | | | | (Middle) X-sst |
| | | Lower 120m | Shale / sst Fossils | | | | | | (Lower) Sil-sh |
| OXFORDIAN | JUMARA | Dhosa Oolite 113m | Sh, oolitic- lst bands | | | | WASTHAWA | Bamanka Shales 160 m | Sh, fossils |
| CALLOVIAN | | Middle 75m | Sst - Lst, Golden Oolite | GORADONGAR | Modar Hill | | | Gadhada 189m | Sh and sst |
| | | Lower 89m | Green shales | | Raimalro | | | Hadibhadang 280m | (Upper) Lst and cherty |
| | JHURIO | Upper 70m | Bedded limestone | | Gadaputa | | KHADIR | | (Middle) Sst |
| BATHONIAN | | Middle 85m | Sh with Golden Oolite | | Flagstone | | | | (Lower) Shales Fossils |
| | | Lower 139m | Lst-Sh, interbed--ded | KALA DONGAR | Kala Dongar Sand stones | | | Cheriyabet 25m | Petrmectic Granite-Couble-Conglo. And arkose |
| | | | | | Kuar Bet | | | | |
| | | | | | | | | Precambrian | Granitic basement |

**Table-1 Stratigraphy of Mesozoic rocks of Kachchh (Biswas, 1978)**

(Biswas, 1971). The Mesozoic rocks are exposed in six discontinuous areas (Figure-2) Viz., (1) Kachchh Mainland (2) Pachham Island (3) Khadir Island (4) Bela Island (5) Chorar Island and (6) Wagad highland. Vast plains separate these outcrops, which comprises the Great and Little Ranns of Kachchh and Banni (grassland) plains. Wynne (1872) was the first to suggest a two-fold subdivision of the Mesozoic rocks of Kachchh. Later Waagen (1875) divided the stratigraphy of the Mainland Kachchh into four units (Viz., Patcham, Chari, Katrol and Umia) and Rajnath (1932) divided stratigraphy into five units (Patcham, Chari, Katrol, Umia and Bhuj) based on palaeontological characteristics. Rajnath (1932, 1942) gave detailed classification of the Kachchh and also pointed out several unconformities and suggested sea level fluctuations, but the only problem with his classification was that, the units were not linked with the type-sections. Agrawal (1956, 1958) was first to doubt the validity of the present classification, and proposed the term 'Habo Series" instead of "Chari Series". Later, Biswas (1977) proposed nine lithostratigraphic units (Table-1) for Kachchh Mesozoic sedimentary sequence considering the International Stratigraphical Code of Nomenclature.

The Tertiary sequence is well exposed in the western and southern parts of the Kachchh region and along the areas bordering the south of Pachham, Khadir, Bela islands and Wagad highland. The Tertiary sequence is highly fossiliferous, consisting of abundant foraminifers, which are worked out by many paleontologists. Carter (1853) was the first to suggest five-fold classification of the Tertiary sediments, later on Wynne (1872) divided into six groups. The Time stratigraphic classification (Table-2) of the Tertiary of Kachchh was proposed by Biswas (1965, 1972) and the lithostratigraphic classification was proposed by Biswas and Raju (1973), the biostratigraphy was done by Mohan and Soodan, (1967, 1970); Raju (1969, 1971) and Tandon, (1970). In addition to this, many workers, who have contributed in understanding the stratigraphy and depositional environment of these rocks includes podar, 1963; Tiwari, 1952, 1957; Tiwari et al, 1964; Sengupta 1964; Tiwari and Singh, 1969; Pandey 1982, 1986; Singh 1978; Saraswati and Bannerji 1984a, 1984b, Mohan and Bhatt, 1968 and Samanta, 1970. It is also well known for its Trace fossils content and were worked out by Patel and Shringurpure (1989a, 1989b, 1990, 1992, 1996, and 1998) and Patel and Bhatt (1999).

| Age | Series | Stage |
|---|---|---|
| Holocene | Recent deposits | |
| Late Pleistocene | Miliolite Formation | |
| ----------Unconfirmity---------- | | |
| Pliocene | Kankawati Series | |
| Miocene | Khari series | Vinjhan Stage (Helvatian to Burdigalian) |
| | | Adia Stage (Aquitanian) |
| Oligecene | Ber Moti Series (116 ft) | Waior Stage (Chattian) [36 ft] |
| | | Ramanian Stage (Rupelian- Lattorfian) [80 ft] |
| ----------Paraconfirmity---------- | | |
| Eocene | Berwali Series (310 ft) | Babia Stage (Lutetian) [185 ft] |
| | | -----Disconfirmity------ |
| | | Kakdi Stage (Ypresian) [125 ft] |
| ----------Disconfirmity---------- | | |
| Paleocene | Madh Series (160ft) | |
| ----------Unconfirmity---------- | | |
| U. Cretaceous to Paleocene | Deccan Trap formation | |

**Table- 2:Time Stratigraphic classification of Tertiary rocks of Kachchh (Biswas-1965;1972)**

### 1.3.4 The Gulf of Kachchh

The Gulf of Kachchh covers an area of about 7325 sq. km. It is an east-west seismically active zone, extends roughly 170 km towards east and about 75-km wide at its mouth and narrowing down to 18 km near Kandla, finally merges with Little Rann of Kachchh. The bottom topography is very conspicuous due to arrangement of shoals (Figure-3) aligned in prominent east-west direction (Srivastava and John 1977). Among these shoals, the Lushington shoal is the largest. In the study area, the Ranawara shoal is present at isobath of 30 m and is important in diverting and cutting the tidal energy. A

deep central channel (+50 m) orienting ENE-WSW, extending 36 km from north of Guar shoal to Ranawara group of shoals (Figure-3), with occasional depth greater than 75 m. The Gulf may be said to be 60 km across Ranawara shoal. However, the southern 30km

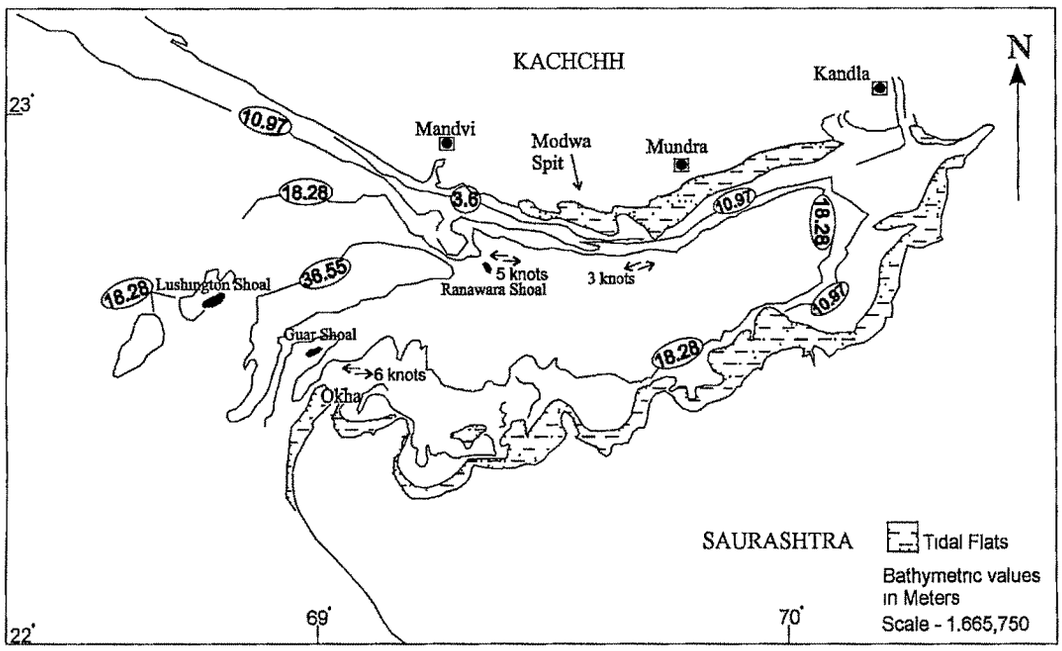


**Figure-3: Bathymetric Map of Gulf of Kachchh (Srivastava and John, 1977)**

area of this is interspersed with coral reefs and extensive intertidal flats. The northern portion between Mandvi and Ranawara shoal is composed of shallow sand patches (3-5 m), leaving a wide, clear, channel about 30-40m deep with an expression of the deeper central channel extending north of Guar shoal to east-northeast towards Ranawara shoals.

The Gulf of Kachchh is also one of the three important macrotidal sites of India (the other two are Gulf of Khambhat and Sundarbans). The tidal range in the Gulf is about 4m at the mouth and increases upto 7 m in the inner Gulf. This macrotidal range is associated with high-speed water flow during ebb and flood tides. The currents are very strong of about 4-5 knots at the surface near the Mandvi area, while it decreases upto 3 knots near Modwa Spit (Naval Hydrographic Charts). Their magnitude and direction show marked changes throughout the study area. The strength of the current decrease in the axial part near the shoals to about 3knots and it further decreases near the Okha to about 2 knots. The surface currents in the Mandvi area are in the direction of NE and SW during flood and ebb tide respectively.

## 1.4 STUDY AREA

### 1.4.1 Location

The study area is near the Historic port of Mandvi (Figure-4), stretching from $22^0$ 50' and $22^0$ 46' N latitude and $69^0$ 18' and $69^0$ 30' E longitude. Since it is situated on the mouth of the Gulf, the western part is influenced by open sea while the gulf environment influences the eastern part. Due to differential control of the marine agencies and offshore bathymetric configuration, the intertidal zone of the study area registers different micro-morphic facets. These different morphic facets, invites various kinds of benthic communities, hence are best suited for their behavioral study.

The coastal zone of the study area is low lying, with maximum elevation of 17m above the msl in the eastern side that decreases towards the west. The various coastal landforms developed in the study area are controlled by various prominent structures like Median High of the Kachchh region and E-W directed shelf fault (Patel et al., 2001). In general, the study area comprises of various geomorphic features, such as, tidal mudflats, berms, beaches, ridge and runnel systems, raised beaches, sealed river mouth, stabilized and non-stabilized dunes and lagoons.

### 1.4.2 - Site Description

Intertidal zone of the study area is reasonably wide and comprises of numerous geomorphic units across the coastal plains. For considering the varying morphological features, the area is divided into three zones which includes- Wind Farm, Rawal Pir and Modwa Spit (Figure-4).

#### 1.4.2.1 Wind Farm Site

This site is located on the western side of the Mandvi town and is influenced by the open sea conditions. The waves, here are stronger and tides attains a maximum height of about 5 m. It has a macro-tidal setting with semidiurnal tides. There is a distinct diurnal inequality in the tidal range. The bathymetric contour becomes wider spaced in contrast to the adjoining western part, where they are closely spaced and influence by the open sea.

The coastline in this section takes an inward turn from the Bhada village. The intertidal zone exposed in this area has an average width of 500 m. Shoreline is bordered by coastal dunes of varying heights. In the Wind Farm site the coastline is curved of

cusplate and takes a landward curvature. On the basis of the geomorphic characters as well as sediment textures it can be broadly divided into (i) a sandy sloping beach face (average~$5^0$), with an average width of 40 m and (ii) a wide planner flat fronting beach face.

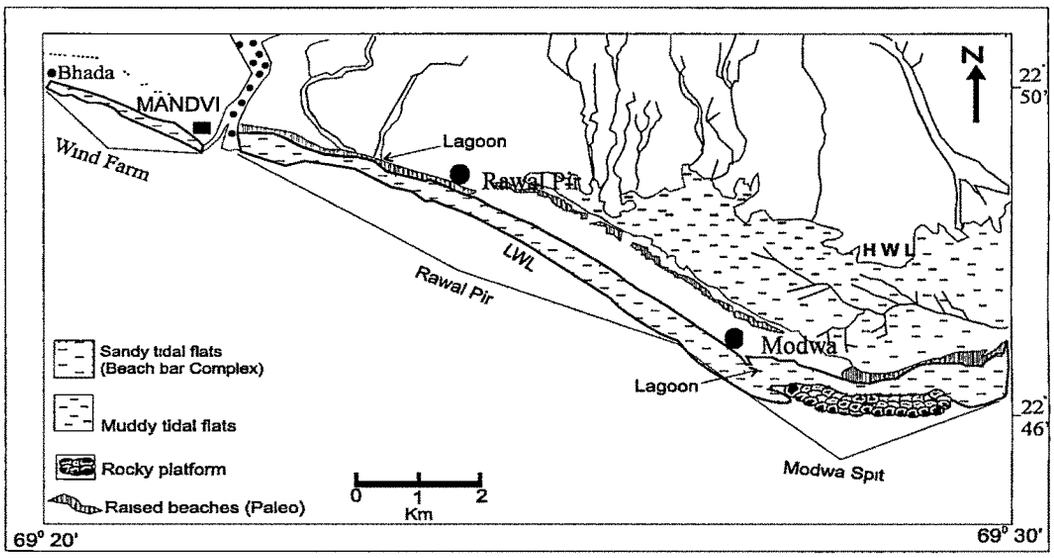


**Figure-4: Site map showing general geology of the study area**

1.4.2.2 Rawal Pir Site

This is the middle part of the study area and is characterized by straightening of the coast and has a very broad and smooth beach. The bathymetric setting is different as compared to Wind Farm site. Here, the bathymetric contours are more widely spaced. The wave and current energy becomes somewhat sluggish as compared to the Wind Farm site. The intertidal zone is composed of four to five sets of ridge-runnel systems, which are constantly modified and finally merge with the beach. In the runnels, there are remnant patches of the earlier tidal marsh beneath the sandy intertidal zone. The mouths of small rivers are welded by sandy materials and form a lagoon. On landward side, stabilized incised coastal dunes are presents that are occasionally situated on a raised beach. On the basis of the geomorphic characters and sediment textures it can be broadly divided in to (i) sandy sloping beach with an average width of 60m (ii) small lagoon and (iii) wide intertidal zone intervened by five set of ridge-runnel systems.

1.4.2.3 Modwa Spit Site

Modwa Spit site falls on the eastern side of the study area and characterized by wide intertidal zone as compared to Wind Farm and Rawal Pir sites. Tidal flat

environment is seen for first time in the extreme west. Beaches are wide and flat with occasional development of the lagoonal condition. The bathymetric contours are very widely spaced and the energy level of the waves and current decreases considerably. The orientation of the shoreline is roughly $140^0$-$320^0$ at the end of the Modwa Spit and coastline takes in turn landward side. There is a wide variation in the textural differences of the sediment within the area. Hard substrate conditions are provided by Pleistocene rock, which helps in development of and oyster reefs. This site is broadly divided into (i) berm, (ii) slopping beach face with an average width of 80-m, (iii) wide planner flat fronting beach face and (iv) tidal mud flats. This flat can be laterally subdivided into (i) non-barred silty planner flat and (ii) bared sandy pools and banks, tidal channels, etc. Berm, sand dunes and lagoons back the sand beach, which is characteristic of the Modwa Spit site.

## 1.5 PREVIOUS WORK

Many workers have worked on the recent sediments of the Kachchh peninsula since 1872 by Wynne. Siveright (1907), on the basis of the Arabian merchants gave the account of the sea conditions and said, around 9-$10^{th}$ century Rann and its surrounding areas were sea and the Patcham, Khadir, Bella, Chorar and Nagarparkar were islands. Oldham (1893) suggested for the first time, the influence of the Indus River in sedimentation in the Rann area based on the presence of Mica, later on Stewart and Pilkey (1966) also confirmed his views. Platt (1962) gave an account of the recent sediments of the Kachchh area while Patel and Allahabadi (1988) studied the Milliolites of the Kachchh area. Glennie (1970), Glennie and Evans (1976); studied the sediments of the Kachchh coast and Rann sediments. Roy and Merh (1977 & 1982) attempted geomorphic study of the Great Rann of Kachchh, Merh and Patel (1988) gave the stratigraphic account of the Quaternary sediments of the Rann and Kachchh area and Muley and Gupta (1982) studied the recent sediment of the Gulf of Kachchh. Lyall & Reddy (1982) studied bathymetric configuration, while Srivastava and John (1977) worked on current tidal regimes of the Gulf of Kachchh. Gupta (1971) provided the detailed account of the silting of the Rann of Kachchh and suggested sedimentation rates of about ~2mm/year in the little Rann of Kachchh. Chauhan et al. (1992) Chauhan and Almeida (1993) and Kar (1988, 1993, 1999) provided a generalized geomorphic account of the coastal region,

tectonic settings and sedimentation. Rao (1988) provided a structural setting based on its seismic reflection data. Wagle (1979) studied geomorphology of the Gulf of Kachchh while Nair et al (1982) provided evidences of high velocity tidal streams as mode of transport of the Indus sediments into the Gulf of Kachchh. Jain and Bhatia (1976) studied recent foraminifers and Jain (1978) reported recent ostracods fauna from the Mandvi area. Nigam and Chaturvedi (1999) gave the account of the recent foraminifers from the Kachchh area. Patel et al (2002) discussed the origin of air trap structures on the beach bar complex in the intertidal zone of the Mandvi area.

History of the Ichnological studies in the Kachchh region dates back as far as the work of Wynne (1872), that made remarks on the "annelid marking". After that Shringarpure et al (1976) in their work on the foraminifers of the Wagad region reported the presence of the trace fossils. Badve and Ghare (1978) reported twelve ichnospecies in a compiled work on the Jurassic ichnofauna of the Kachchh from the Gajansar beds. Howard and Singh (1985), Kulkarni and Ghare (1989, 1991); Ghare and Kulkarni (1986) added further data on the ichnology from the Kachchh area. Shringarpure (1984, 1985, and 1986) added considerable literature on the ichnology of Kachchh. Patel (1990) studied in detail the trace fossils of the carbonate sediments of the Tertiary age and described more than 67 ichnospecies from the western Kachchh region. Bhatt (1996) studied the Mesozoic sediments of south of Bhuj and described more than sixty ichnospecies. Fursich (1998) provided an account of the environmental control of the trace fossils of the Mesozoic rocks of the Kachchh region.

Neoichnologic work on the Kachchh coast remained uninvestigated. However, the initial works on the sedimentation and neotectonism by Glennie and Evans (1976) and Kar (1996) do made passing remarks on the crustacean burrows on the Kachchh coastline. Patel and Desai (1999) studied in detail the animal-sediment relationship of the benthic organisms in the tidal flat environment of Mundra area. A good account of behavior and burrowing characteristics of crustacean, polychaetes and gobid fish was given by them. Patel et al (2001) has given ichnological evidences for delineating the tectonic activity of the coastal area. Patel and Desai (2001) have also discussed the effect of Kachchh earthquake of 2001 on behavior of the Squllidean crustacean species *Oratosquilla striata*- a mantis shrimp.