CHAPTER-9
ICHNO-SEDIMENTOLOGIC MODELS

9.1 INTRODUCTION

The animal-sediment relationships of the two benthic communities such as crustaceans and polychaetes were studied on various micro-geomorphic units including beaches, ridge-runnel systems, shore platform, berm, lagoon, foredune and tidal mud flats. The deposition of the individual unit of the intertidal zone are govern by various physical, biological and chemical parameters, each feature tend to change progressively with lateral distance along and across the coast with the local environmental gradients. The wave and current energy play significant role in distribution of the sediments and rate of sedimentation. The grain size decrease and rate of bioturbation increases from Wind farm site to Modwa Spit site. Because of these environmental gradients the animal density and diversity are in-pace and controlled by the changing micro-depositional environment of individual sites. The integrated ichno-profiles (Figure. 41 and 42) shows zonation of biogenic structures of crustaceans and polychaetes and degree of bioturbation across the intertidal zone.

Different kind of studies were carried out that dealt with geomorphology, sedimentology, animal taxonomy, trophic types and biogenic sedimentary structures in the intertidal zone from three sites, viz. Wind Farm, Rawal Pir and Modwa Spit. Present studies on the animal-sediment relationship, established the factors governed the distribution of the biogenic structures. Fauna and sediment, grain-size distribution in many benthic habitats have been at least crudely characterised over wide spatial and temporal scales (Snelgrove and Butman, 1994). Many studies have focused particularly on animal-sediment relationship under stimulated and experimental conditions, such as seawater flumes, (Taghon, et al., 1984); water tunnel (Miller et al., 1992) etc. The model proposed in this chapter, were studied under natural conditions, with natural flow regimes. Data on biogenic structures (Table-6) was compiled together, for the distribution of organisms that created the structures and correlated with the observed working depth along with functional groups. Crustaceans and polychaetes numerically dominate the runnels, followed by lagoons, ridges and beach (Table-6). Most of the animals are active bioturbators or bio-irrigators of surface sediments. Filter feeders and sedentary epifauna are less in numbers, consistent with the effect of high turbidity moderate current energy with moderate sediment load. Majority of the animals form

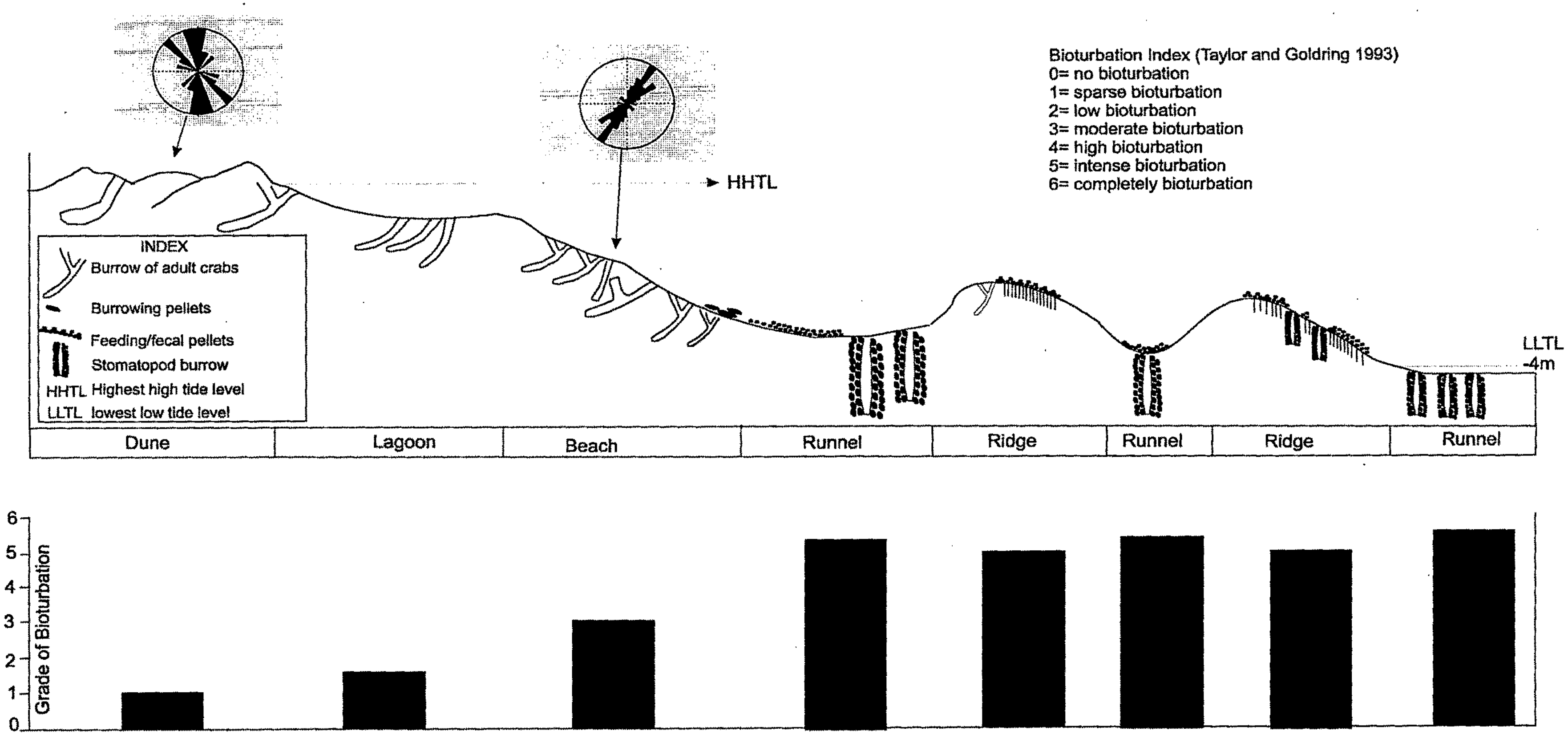


Figure- 41: Profile of the crustacean traces across the intertidal zone.

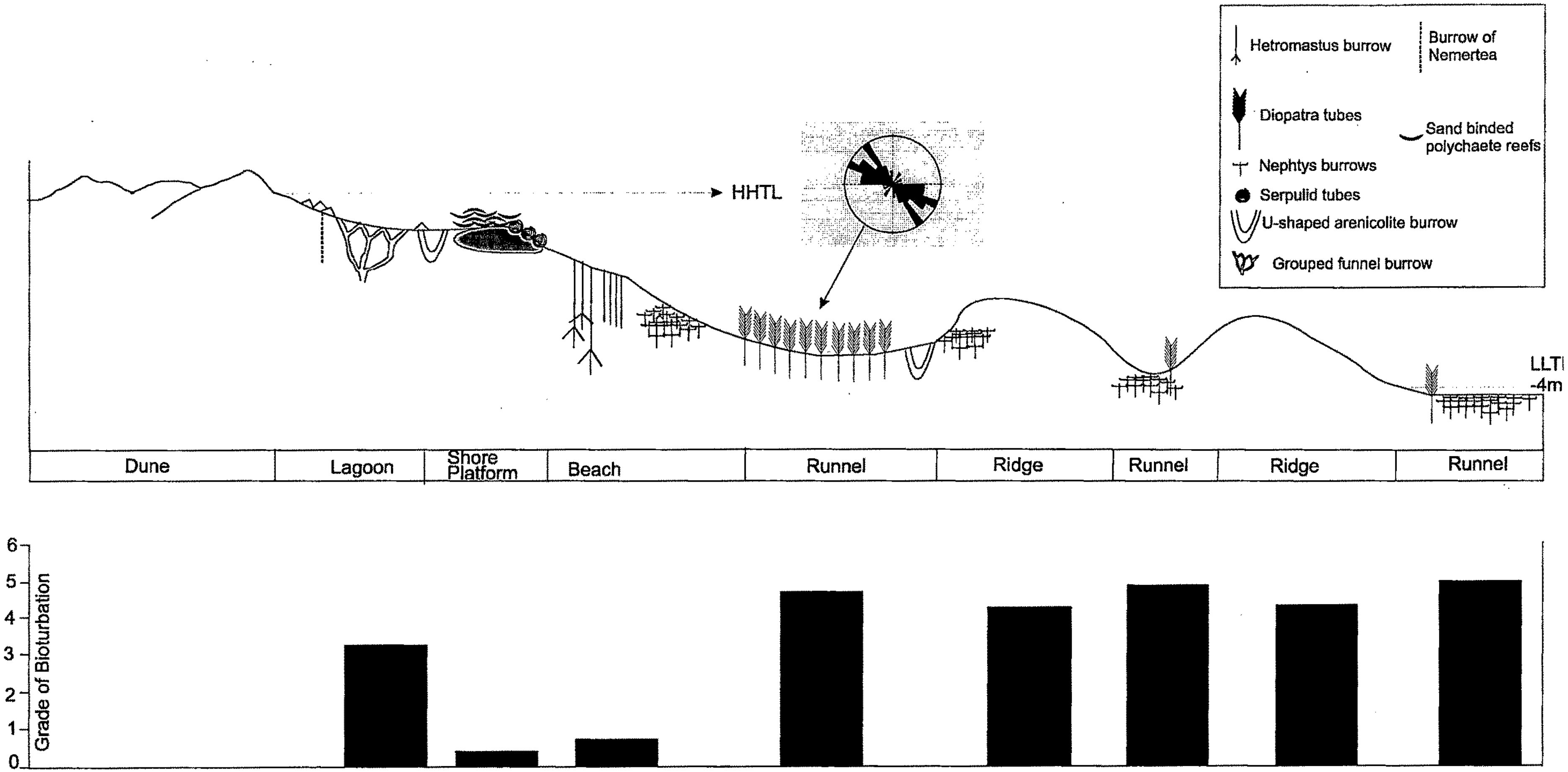


Figure- 42: Profile of the polychaete traces across the intertidal zone.

Organisms	Region of Abundance						Working Depth in Cm	Functional group Codes	Biogenic Structures	
	Beach	Ridge	Runnel	Lagoon	Flats – Sh Plat					
Ocypode (C)	X	X	X	X			-1 to-3	1a, 1b	Pellets; Burrows	Psilonichnus
Uca (C)			X	X			-1 to -3	1a, 1b	Pellets; Burrows	Psilonichnus
Macropathalmus (C)	X						-1 to -3	1a	Pellets; Burrows	Thalassinoides
Plagusia (C)		X					-1 to -3	1a	Burrows?	
Graspus (C)		X					-1 to -3	1a, 1b	Pellets; Burrows	Psilonichnus
Portunus (C)	X						-1 to -3	2c	Burrows	
Matuta (C)		X		X			-1 to -3	1a	Pellets; Burrows	Psilonichnus
Scylla (C)					X		-1 to -5	2c	Burrows	
Neptunus (C)			X				+5 to -3	2c	Burrows?	
Clibanarus (HC)			X		X		0	1a	Trails, bioturbation	
Oratosquilla (S)		X	X	X	X		+5 to –1	1a, 1b, 2a	Burrows	Ophiomorpha
Squilla (S)		X	X		X		+5 to –1	1a, 2a	Burrows	Ophiomorpha
Diopatra (P)			X				+10 to +3	2a, 2b	Tube	Diopatrichnus
Onuphis (P)				X			+7 to –7	1a, 2a	Tube, burrow	
Lumbiconereis (P)			X		X		-1 to –5	2a, 2b	Burrows	
Nereis (P)		X	X	X			0 to -5	1a, 2a	Burows, pellets, mound	Chondrites
Lycastis (P)	X						0 to –5	1a, 2a, 2b	Burrows	
Nephtys (P)	X	X	X	X	X		0 to –5	1a, 2a, 2b 2c	Burows, pellets, mound	Chondrites
Serpula (P)						X	0 to +3	2a, 2c	Tubes	
Clymene (P)				X	X		0 to -5	2a, 2c	Burrows, mound	
Hetromastus (P)			X	X			>-10	1a	Burrows	
Amphinome (P)		X		X	X		0 to –7	1a	Burrows	
Chloeia (P)			X	X			+3	1a	Reefs	
Nemertea				X			+3 to –7	2a	Burrow, mound, grazing	
Archeotectonica (G)			X				0 to –2	1a, 2a	Burrows	
Gastropod			X				0	1a, 2a	Bioturbation	
Bernea (B)					X		0	1c	Borings	
Solen (B)			X	X			0 to –2	1b	Burrows, bioturbation	
Macoma (B)				X			0 to –2	1a, 1b	Bioturbation,	
Fat Innkeeper							0	1c	Bioturbation,	
Starfish							0	1c	Bioturbation,	
Feather Star							0	1c	Bioturbation,	
Barnacle (C)						X	O to +3	2a	Sediment trapping	

Table-6: Distribution of Organisms, their observed working depths, functional group codes and biogenic structures.

intense bioturbation and pelletization of surface sediments have significance for local sediment transport (Schaffner et al, 2001). This data was then compared with the published data, compiled by Thayer (1975), in which, the reworking rates and reworking zones of some organisms of same genus from different parts of the world (Table-7). Based on these data,

Genus/Species	Locality	Individual reworking rate (Cm^3 day^{-1})	Reworking zone (Cm)	References
Amphitrite ornata	Barnstable Harbour, M.A.	12.7	~3	Rhoads, (1967)
Clymenella	Bahaia paraguera Puerto rico	1	5	Magnum, (1964 a,b)
C. Torquata	Barnstable Harbour, M.A.	0.75	20	Rhoads, (1967)
C. Torquata	Barnstable Harbour, M.A.	0.37	20	Magnum, (1964 a,b)
Hetromastus filiformis	Waden Sea The Neatherlands	0.2-1.2	15	Cadee, (1979)
Nephtys incisa	Buzzard Bay, M.A.	-0?	2	Rhoads, (1967)
Nereis diversicolor	N. Caspian sea	0.15		Viltischeva and Karzinkin, (1970)
Nereis succinea	Narraganset bay, RI	0.02	0.2	Cammen (1980.a,b)
Scolopus robustus	Narraganset bay, RI	0.06	13	Myers,(1977a)
Squilla empusa	Rhode island	11	212	Myers (1979)
Ocypode quadrata	padre island, TX	450	60	Hill and Hunter (1979)
Ocypode quadrata	Sapelo island	106	15	Frey and Mayou (1979)
Ocypode quadrata	Sapelo island	>7.6	0.3	Frey and Mayou (1979)
Uca pugilator	Georgia	13.3	0.2?	Kraeuter (1976)

Table-7: Published data compiled on reworking rates and working zone of the individual organisms.

ichno-sedimentologic models were drawn for major geomorphic units and are discussed in light of sediment characteristics, biogenic structures, their trace makers and working depth. The beach, ridge, runnel and lagoon ichno-sedimentologic model corresponds to the upper shoreface, shoreline models of Howard (1972) and Shoreface model of Pemberton et al., (2001).

9.2 BEACH ENVIRONMENT AND BIOGENIC STRUCTURES

Beaches are well developed and narrow in Wind Farm site consisting of clean mature sand, while it becomes broad through Rawal Pir to Modwa Spit sites and consist of immature sand. They are characterised by planer cross laminations with high proportion of coarse grain sediments. The nature of the physical and biogenic sedimentary structures shows a similar pattern in all three sites. The beach in general is characterised by clean, coarse to medium grained sand. The upper beach portion consists of crude disturbed beach laminae on account of bubble sand layer (plate-36) and associated surfacial air trap structures (Patel et al., 2002) with planer cross-stratified and plane bed lamination facies (pate-37) with *Psilonichnus* burrows, marking the distinction between the beach and ridge - runnel system.

Population of adult crustaceans, *Ocypode ceratopathalma*; *Ocypode platytarsis*; *Ocypode roundata* and *Uca annulipes* dominates the beaches. However polychaetes are

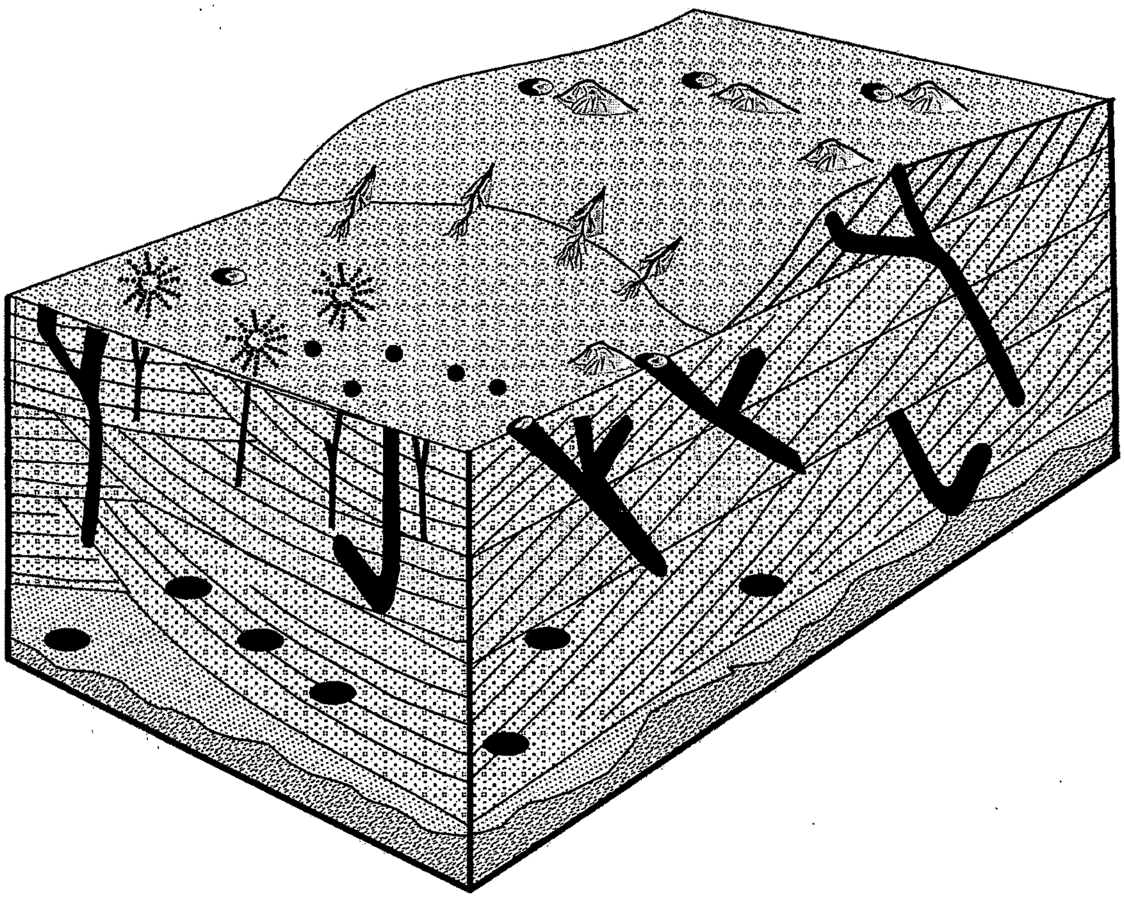


Figure- 43: Ichnosedimentologic model of bech showing cross-bedded units with *Psilonichnus* and *Facechina* ichnocoenosis.

totally absent or sparse from the beach due to its ecologically harsh environmental condition and high degree of exposure. Locally, lower parts of the beach occasionally consist of *Heteromastus* species (Plate-37).

Plate-36 X-radiograph of the upper beach section showing bubble sand layer at top, underlain by chaotic disturbed sand layers.

Plate-37 X-radiograph of lower beach section showing low angle cross laminations in alternating coarse and fine grained sand layers along with straight, long, vertical mucus bound cylindrical burrows of *Heteromastus filiformis* and inclined burrow of crab (upper left).

PLATE-36

PLATE-37

Two ichnocoenoses; *Faecichnia* ichnocoenosis and *Psilonichnus* ichnocoenosis represent the biogenic structures of the beach (Figure-43). *Faecichnia* ichnocoenosis have characteristic traces like, feeding and faecal pellets, and mounds of extruded sediments (Plate-15&16) of burrow modification. This in an important ichnocoenosis in beach environment because it helps in bioturbating and recycling sediments of upper layer and in thinly populated zone. The mean sediment-reworking zone is variable, with feeding and faecal pellet representing upper 2-10 cm reworking zone (Table-6). The sediment mounds surrounding the burrow are recycled and brought up from the depth of about 1-1.5 m. The preservational status of this ichnocoenosis is very poor, but recycled sediments in the core/relief peels were observed as lenses of ghost/foreign sediments.

The *Psilonichnus* ichnocoenosis of the beach is characterised by burrows, which disturbs the sediment and sediment laminations, to greater degree as compared to *Faecichnia* ichnocoenosis. The burrows are widely spaced, monodominant and their bioturbational index is 1-2 BI (Figure-41). The structures are mainly branched burrows of domicile nature, identical to the ichnogenus *Psilonichnus*. They show preferred orientation of its opening towards the seaward direction. The only sediment disturbance is in the form of sediment brought out on the surface during the burrow modification. The dimensions of the wax casts of burrows from the beach indicate domichina type of structures (Plate-14).

In summary the beach ichno-sedimentologic model display medium to coarse grained sediments, with low angle cross stratification and plane bed laminations with characteristic biogenic structures like faecal, feeding and burrowing pellets and *Psilonichnus* burrow (Figure-43), with low bioturbational index (1-2 BI). The presence of deep vertical dwelling burrows of the *ocypodes* on extreme reaches of the beach indicates shifting substrates, scarcity of food supply and maximum duration of exposure causes dryness in sediments. The sediment characteristics with physical, biological and bioturbated evidences inferred moderate wave and current energy for the deposition of the sediments.

9.3 RIDGE ENVIRONMENT AND BIOGENIC STRUCTURES

Ridges and runnels are characteristic of the Mandvi intertidal zone, and are especially well developed in Rawal Pir and Modwa Spit sites. Three to four sets of ridge-runnel systems are observed. The ridges have higher exposure time as compared to the runnel, but seaward side ridges have less exposure time as compared to other ridges. Ridges are characterised by medium to fine-grained sand (60%-80%) with subordinate amount of silt/clay (10%-30%), the finer fraction increases in ridges of the seaward direction. The physical sedimentary structures are represented by cross bedded units, with antidunes, in vertical section it appears

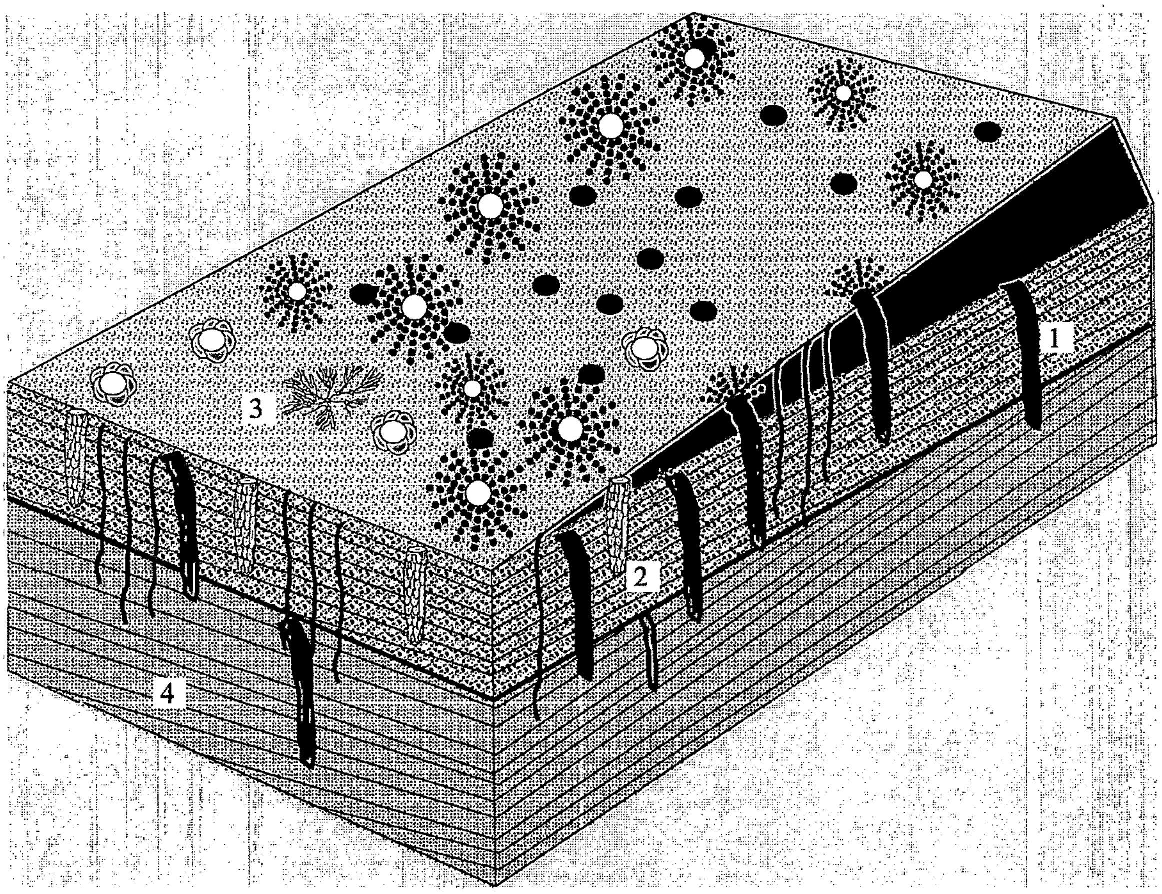


Figure- 44 Ichnocoenosis model of the ridge showing plane bed laminations with *Skolithos* and *Faecichnia* ichnocoenosis (1) *Skolithos*, (2) *Ophiomorpha*, (3) Chondrite and (4) Cross laminations.

as cross bedded and plane laminated units, interrupted by low angle cross stratified sets of antidune. The ridges can be easily separated out from runnel based on primary structures in which various kind of ripple marks are absent from the ridges Though sometimes, megaripples may develop on the junction of the ridge and runnel, and may be preserved as lens of clean coarse sand. Similar lenses were encountered while trenching, relief peels and X-radiography (Plate-38).

Plate-38 X-radiograph of the ridge showing flaser bedding and sand lenses with "Y" and "I" shaped dwelling structures.

PLATE-38

The ridges consists of abundant diverse group of the organisms, includes young and juvenile crustaceans of *Ocypode ceratopathalma, O. platytarsis, O. roundata and Uca annulipes* along with Anomura *Clibanarus infraspinatus*; Stomatopods *Oratosquilla striata; O. indicus*; Prawn *Peneus japonicus* and polychaete species of *Nephtys diabranchis, Nephtys inermis; Nereis costoe, N. unifasciata, N. diversicolour, N.* sp.*; Lycastis indica, Amphinome rostarte*. Definite zonation of these animals (Figure-22 & 23) can be observed based on their distribution of biogenic structures (Figure-41 & 42) in the intertidal zone.

The ridge exhibits well developed biogenic structures (Figure-44) which comprises of four distinct ichnocoenoses includes *Faecichnia* ichnocoenosis; *Skolithos* ichnocoenosis; *Chondrite* ichnocoenosis and *Ophiomorpha* ichnocoenosis. The *Faecichnia* ichnocoenosis have structures similar to the beach but exhibits more dense population of different size and shape of the pellets. The mean reworking depth of crabs of the ridges are -1 to -3 cm. This ichnocoenosis is important in processing of the upper freshly deposited sediments, which are continuously recycled in upper few cm of sediments. The data compiled in Table- 6 &7 (Thayer, 1975), *Ocypode* crustaceans can reworked >7.6 cm^3 day^{-1} with reworking zone upto 0.3 cm; while *Uca* crustacean can reworked 13.3 cm^3 day^{-1} with reworking zone upto 0.2 cm (Frey and Mayou, 1971).

The *Skolithos* ichnocoenosis includes biogenic structures such as *Skolithos* and *Polykladichnus*. These traces are essentially made by polychaetes especially *Amphinome rostarte, Lycastis indica, Oniphus eremita, Nereis costoe, N. unifasciata, N. diversicolour*. The observed working depth of *Nereis* and *Lycastis* trace makers (*Skolithos*), is about 0 to -10 cm (Table-6), while the observed individual reworking rates and zone (Table-7) varies from 0.15 to as low as 0.02 Cm^3 day^{-1} with reworking zone around the surface respectively. The polychaete traces are marked by *Skolithos* ichnocoenosis exhibits well developed variation, from first ridge to fourth ridge near low water line, the density of the *Skolithos* and *Polykladichnus* burrows increases towards sea ward direction and the structures of which are represented by faecal pellets surrounding the simple unbranched burrows.

The *Chondrites* ichnocoenosis comprises of characteristic feeding/dwelling traces made by *Nephtys diabranchis* and *Nephtys inermis* are interface feeders. *Chondrite* ichnocoenosis is an overlapping ichnocoenosis found at the junction of the ridge and runnel towards the seaward direction. The ichnocoenosis is generally well developed on the merging portions of the ridge with runnels where thin layer of water column allows settling of food particles on the surfaces. The observed working depths of the *Nephtys* varies from 0 to -5 (Table-6), and are also able to use the top 5 cm of the sediment as dwelling and feeding purpose. The reworking rates are not known, but its reworking zone is 0.2 cm (Table-7).

Associated with the polychaete traces on the lower ridges, *Ophiomorpha* ichnocoenosis is developed which characteristically made by suspension feeding squllinidean stomatopod species *Oratosquilla striata*. The distinct development of the biogenic structures on the ridges help in local zonation of ichnocoenoses. The bioturbational index of the ridges varies from 2-5 BI, i.e. BI 2 near high water line to BI 5 near low water line.

In summary the characteristic of the ridge ichno-sedimentologic model are, medium to fine grained sediments, with cross-bedded units and antidunes. The characteristics traces are those similar to ichnospecies *Skolithos, Psilonichnus, Polykladichnus, Ophiomorpha, and Chondrites* with disturbed sedimentary structures, which have varying bioturbational index (2-5BI). The ridges of the area are similar to the longshore bars and comprises of alternating layers (Plate-38) of medium and fine grained sediments deposited on account of various bedform migration and shore-normal sediment transport under dissiptive wave conditions. These bedforms are in the form of dunes, nascent dunes, antidunes and current/wave ripples on lower edges of the ridges. The cross-section and the X-ray analysis (Plate-38) of these deposits shows presence of domicile burrows in 'Y' and 'I' shape along with small scale cross stratification, and plane bed. These indicate events of tidal reversal, and its deposition under oscillatory flow conditions. Ridges have bioturbational Index- 5 (Taylor and Goldring, 1993), which indicates intense bioturbation, complete reworking of the sediments. This is caused on account of the organic rich fine to medium grains sediments and intermittently exposures.

9.4 RUNNEL ENVIRONMENT AND BIOGENIC STRUCTURES

The runnels are intervened with the ridges of the Rawal Pir and Modwa Spit sites and characterised by poorly sorted fine-grained sediments. Finally, these runnels grades in to tidal flat of the Modwa Spit site. These are deposited under dominance of unidirectional and oscillatory flow conditions and are represented by symmetrical/asymmetrical small 2D and 3D ripples, and subaqueous dunes. The X-ray analysis of the plate core from various runnels indicates presence of the small-scale ripples, along with hummocks and swaley kind of structures. X-ray analysis of the sediment slab from the runnel indicates ebb oriented cross bedding with intra-set discontinuities (Plate-39), which record various events during the bedform movements and indicates periods of tidal reversal.

The runnel is the most favourable for deposit and suspension feeding animals like crabs *Ocypode, Uca, Scylla;* Hermit crab, *Clibanarus;* Stomatopods *Oratosquilla, Squilla* and polychaetes *Diopatra, Lumbriconereis, Nereis, Nephtys, Oniphus* etc.

The characteristic ichnocoenoses of the runnels are *Chondrites, Skolithos, Ophiomorpha* and *Faecichnia*. The *Chondrite* ichnocoenosis is by far most dominating ichnocoenosis of the runnels consist of branched horizontal structures made by *Nephtys diabranchis* and *Nephtys inermis.* The *Chondrite* is similar to ridges but are densely populated. The *Skolithos* is again dominating, but differs from ridge, having dominating

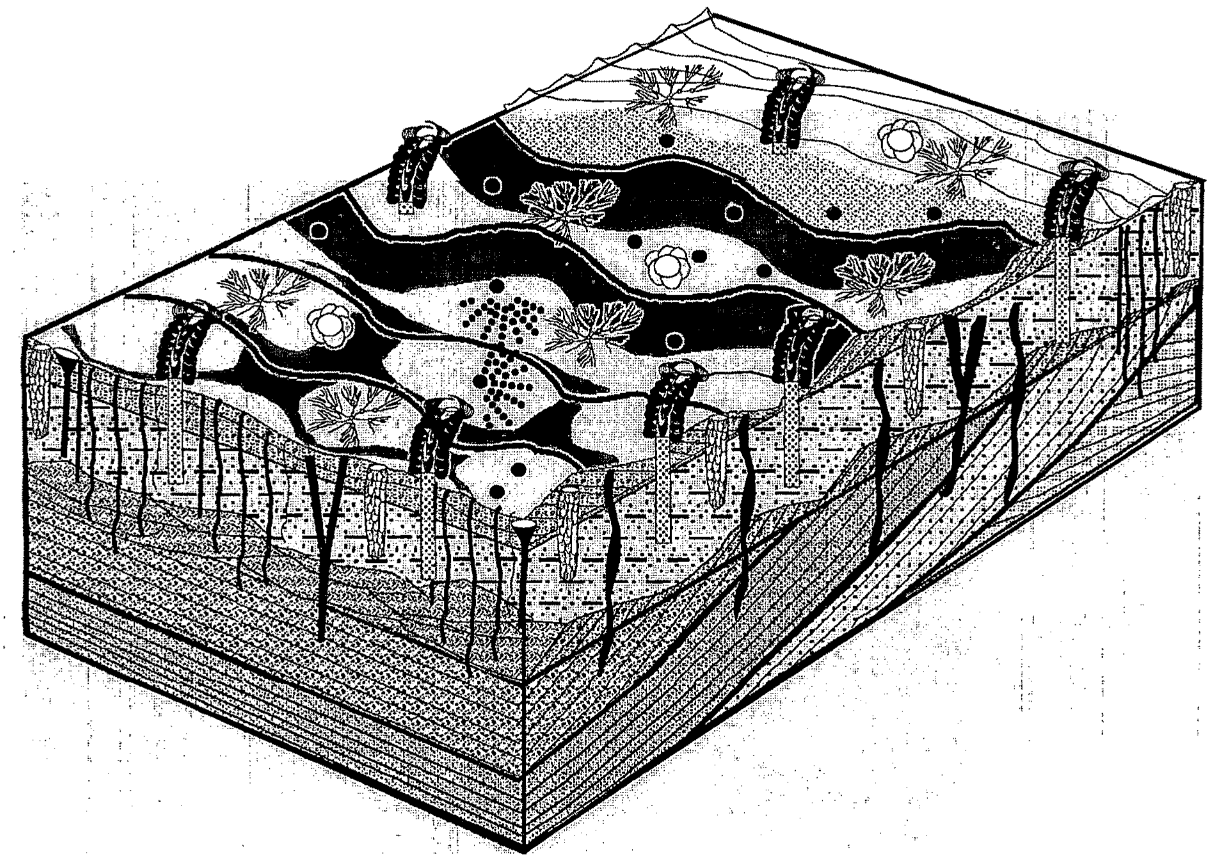
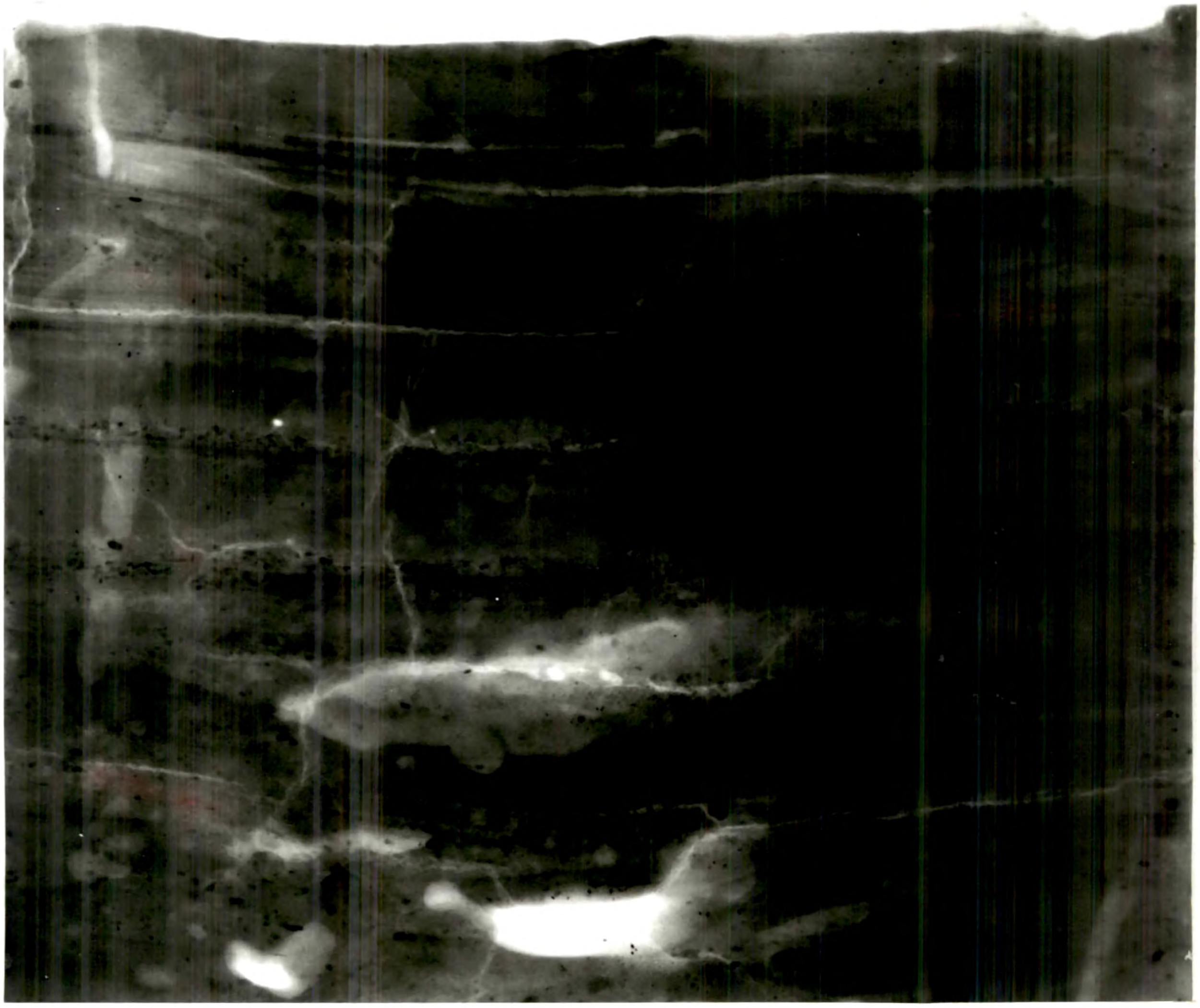


Figure 45 Ichno-sedimentologic model of runnel showing rippled, cross-bedded units with *Skolithos*, *Chondrite* and *Ophiomorpha* ichnocoenosis.

Plate-39 X-radiograph of runnel showing alternating layers of fine and coarse grained sands. Upper fine grained layers comprise of flaser bedding, while lower layers comprises of thin light and dark laminae. Highly bioturbated plate core consists of *Skolithos* and *Thalassinoides*.

PLATE-39



structures like "*Diopatrichnus*", which is an agglutinated tube, made by suspension feeding *Diopatra neapoliatana*. This is abundant, because, the runnels are usually filled with water during the low tide levels. The activity of suspension feeding-*Diopatra* is heightened during the initial period of the low tide level. While during the low tide level with the decrease of the water level activity of the surface-subsurface deposit feeding activity is heightened, and can be seen in the form of ramifying tunnels and in cross section they are represented as small circular rings (Plate-39). The pelleted wall dwelling burrows of the *Oratosquilla* striata are also abundant and some times other crustacean burrows can also be noticed.

The runnel supports structurally and functionally diverse benthic assemblages, dominated by polychaetes (Table-6) and stomatopods. An important bioturbators of runnel are deposit and interface feeding *Nephtys diabranchis* and *Nephtys inermis* which produces extensive network of feeding voids and grooves at sediment surface and up to depth of -5cm. Subsurface feeding and surface deposition of faecal sediments surrounding *Arenicolites* burrows in the form of mound and funnel structures and other biogenic traces, enhances deep sediment mixing. Likewise suspension feeding by *Diopatra neapoliatana* helps in mixing of suspended sediments and its incorporation into the surfacial sediments. Rod shaped pellets of shrimps, mucus binded feeding and faecal pellets of small crustaceans, which are also deposited on the sediment-water interface. Faecal materials deposited at the sediment water interface are readily transported as bedload during strong spring tides (Wright et al., 1997). Runnel thus depict an epifaunal suspension and deposit feeding assemblage associated with the tubes and burrows of polychaetes and small crustaceans, enhance the potential for biodeposition of material from suspension near the bed (Schaffner, 1990). The bioturbational index of runnels are usually high (Figure 41 and 42), as compared to ridges, on account of finer sediments, less exposure time or filled with few cm thick water column and larger availability of food.

In summary runnel is characterised by moderate to poorly sorted sediments with hummocky and swaley cross stratification and rippled bedforms. The characteristics traces are similar to *Skolithos, Diopatrichnus, Ophiomorpha* and *Chondrites* with disturbed sedimentary structures, which have varying bioturbational index (2-5BI). The runnels of the area are similar to the longshore troughs and comprise of various kinds of ripples, deposited on account of various bedform migration and variable flow regimes during and after the tides. These bedforms are in the form of current/wave ripples like, symmetrical, asymmetrical, linguiodal ripples, subaqueous and nascent dunes. The trenching and the X-ray analysis

(Plate-39) of these deposits shows presence of domicile burrows like *Chondrites*, *Skolithos* etc. Associated with this are small scale cross stratification, and wavy bed and intraset discontinuities indicating events of tidal flow variation and flow reversal (Allen et al, 1994) and its deposition under oscillatory flow conditions.

9.5 LAGOON ENVIRONMENT AND BIOGENIC STRUCTURES

The lagoons are developed in Rawal Pir and Modwa Spit sites of the study area, formed on account of ridges merging with the beach. It is characterised by fine-grained muddy sediments, generally shows moderate sorting. Characteristically the lagoons constitute peat layer, overlain by sandy sediments, containing algal mats. The sediments are deposited under varying tidal and flow regime conditions, therefore representing formation of various bedforms like 2D, 3D, dunes, megaripples, lunate ripple complex and symmetrical/asymmetrical small 2D and 3D ripples. The trenching (Plate-5) and X-ray analysis of the plate core from lagoons indicates hummocks and swaley cross stratification along with presence of the small scale rippled and flaser beddings. The bedform shows cross stratification formed by larger bedforms with intra-set discontinuities that indicates periods of tidal reversal.

Various deposit and suspension feeding polychaetes like *Onuphis eremite, Arenicola sp., Chloeia flava, Heteromastus filiformis* and unsegmented worms (Nemertea) like

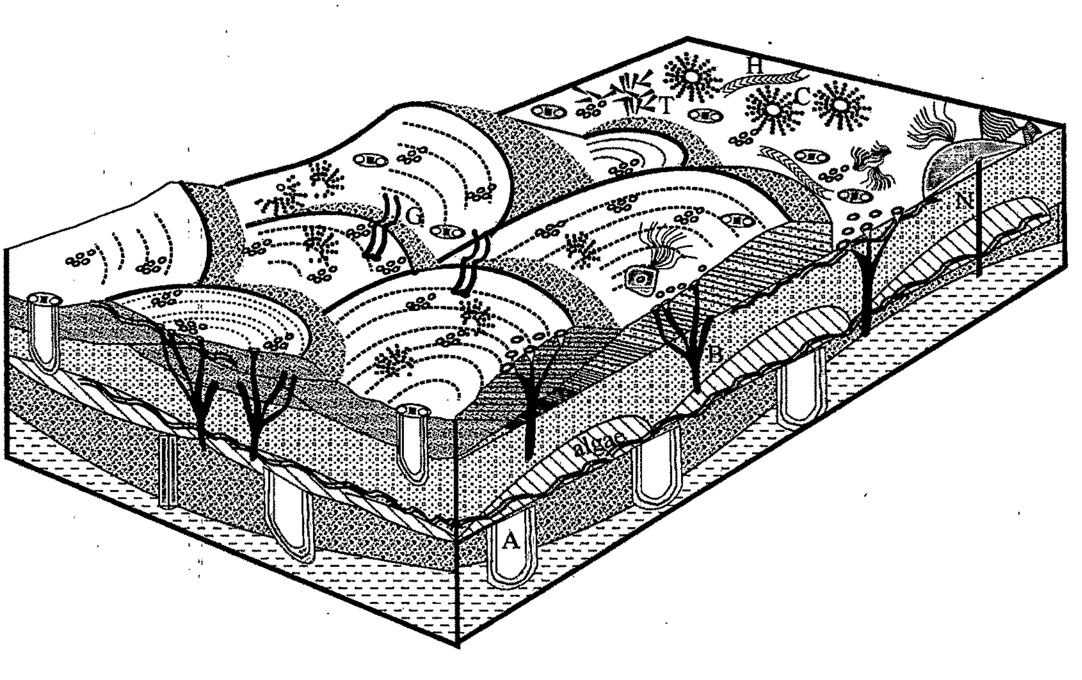


Figure-46 Ichno-sedimentologic model of lagoon showing subaqueous 3D dunes and *Balanoglossites* ichnocoenosis.

Cerebratulus marginatus dominate the lagoon. Deposit feeding crustaceans like *Uca* is monodominant crustacean in lagoon along with stomatopodean *Squilla*.

Lagoon of the Rawal Pir site is characterised by *Balanoglossites* ichnocoenosis and *Faecichnia* ichnocoenosis, while *Skolithos* and *Faecichnia* ichnocoenoses represent Modwa Spit lagoon. The biogenic structures of the Rawal Pir lagoon are characterised by funnel burrows like *Balanoglossites, Arenicolites*. The shafts of the *Arenicolites* and *Balanoglossites* are quite resistant to the sediment deformation by the sediment mixers and the presence of a lining suggests a reinforcement of the burrows. This is because of the shallow RPD layer, or low pore water oxygen and reducing environment in the lagoon along with dense microbial mats that cause change in the substrate consistency by stiffening the surface and cutting off the influx of the bottom oxygen from the water columns in to the sediment (Leszczynski et al 1996). The organisms develop the funnels at the burrow opening in order to circulate oxygenated water in to the burrows. As a result the animals like *Oniphus* get adapted to the condition by modifying the burrow system. The burrows thus made in the lagoons by *Oniphus* have multiple funnel opening and they have tendency to irrigate the burrow system. Nemertea, whose burrow is simple but deep often extending into the anoxic zone (Modwa Spit), also does irrigation of the burrows. Nemertea *Cerebratulus marginatus* is a deep dwelling, deposit feeding worm grazes the algal surface (Plate-29c). The burrows are slender, long, unlined and extends in to the anoxic mud of the lagoon. Associated with this are deposit feeder gastropods *Turritella* which accumulates in to small pools. Crustaceans like *Uca* and *Squilla* modifies their burrows by lining them with plant materials.

In summary the lagoons are characterised by medium to fine grained, moderately sorted sediments, with hummocky and swaley, cross stratification, flaser bedding and rippled bedforms. The characteristic traces are those similar to *Balanoglossites, Arenicolites, Skolithos and Chondrites* with disturbed sedimentary structures, which have bioturbational index =3.

9.6 SUPRATIDAL ENVIRONMENT AND BIOGENIC STRUCTURES

The Supratidal zone of the Mandvi area comprises of fore dunes, berms and dunal accumulations. It comprises of fine grained, very well sorted sediments. The sedimentary structures are characterised by large-scale planer cross stratification with sparse burrows of the adults *Ocypodes* and abundant plant root traces like *Rhizomorphs*. Such type of burrow are identical to the *Psilonichnus* and *Thalassionides* structure and are common element in even carbonate dunes of Bahamas (Curran, 1992) and result of opportunistic mature coloniser like adult *Ocypodes*. The bioturbation rate is very low and the bioturbational index is 1 (BI-1), which can be accounted, for only sparse ocypodes burrows. The *Rhizomorphs* do not disturb much of the sediments, but act as good stabiliser. Poorly bioturbated with well sorted fine-grained sediments and large scale planar cross stratification suggest high exposure index=1 of the supratidal zone.

9.7 SHORE PLATFORM AND BIOGENIC STRUCTURES

The shore platforms are usually of uneven nature, often exposed at Modwa Spit site (Plate-1c) and in the runnel of the Rawal Pir site (Plate-1b). The rocks are colonised by various filter feeding, skeletal hard substrate encrusters like, serpulids, barnacles, oysters etc. Two type of shore platforms are developed in the study area (i) Rawal Pir shore platform (Plate-1b) consisting of rocks and encrusted by mainly serpulids tubes and barnacles and (ii) Modwa Spit shore platform (Plate-1c) characterised by oysters, in the form of oyster reefs, these are characterised by oysters, which grow by generation to generation and provides hard substrates for younger generations after their death. Subordinate amount of serpulids and barnacles are also present.