Organisms and their lebensspuren on the open-sea tidal flats of the east coast of India

A.Chakrabarti
Department of Geology and Geophysics
Indian Institute of Technology.Kharagpur-721302, West Bengal

Introduction

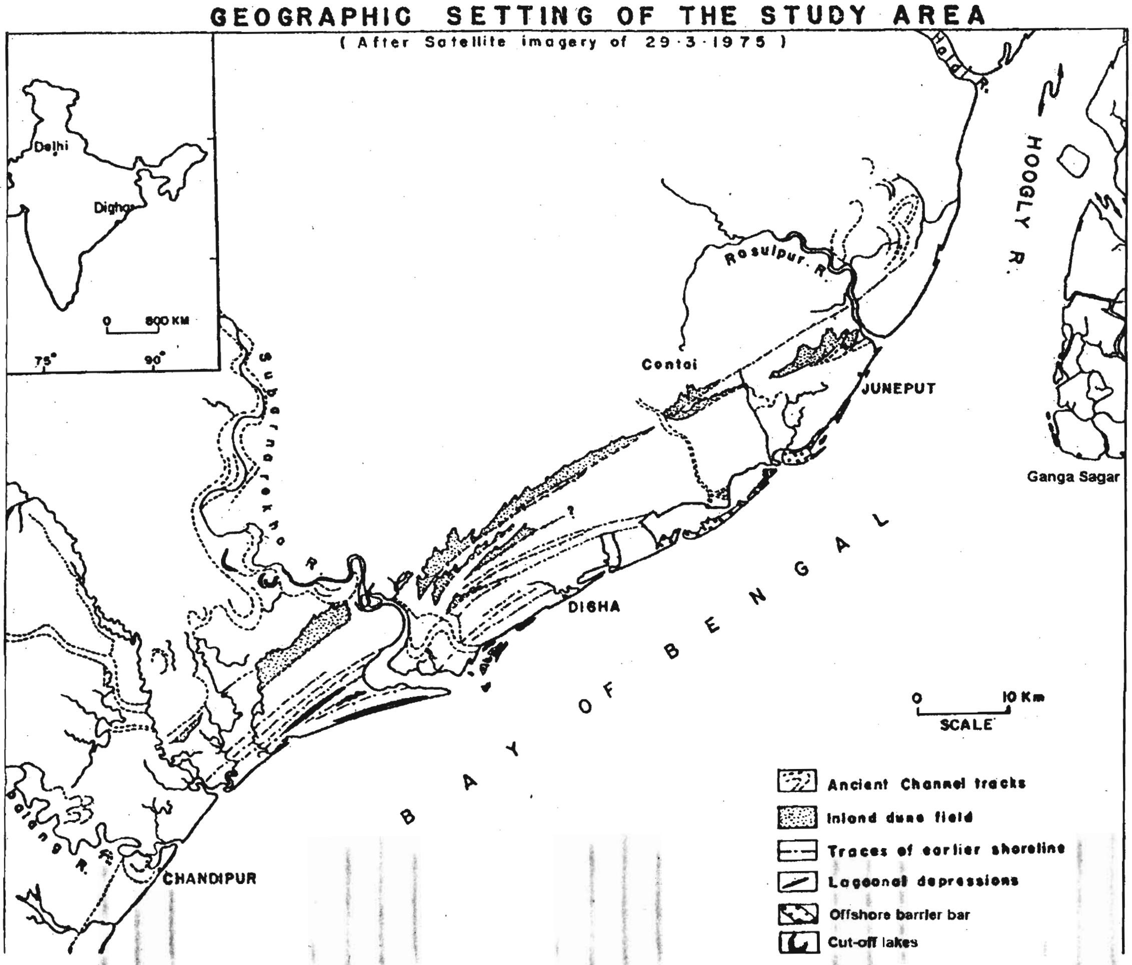
It is needless to say that for predicting or modeling depositional environments in rock records, biogenic structures and ichnofabric generated by biogenic activity, like physical sedimentary structures, play an important role. In the early part of the nineteenth century it was rather inappropriate or even tactless to open up discussions about the study of biogenic structures. However, by late 1920's European scientists' community realized the importance of ichnology, and started observing tracks, trails and burrows generated by organisms on modern tidal flats (Richter, 1927; Krejci-Graf, 1932 etc.). With time the subject of ichnology gained its popularity and people working on modern sedimentary environments started describing biogenic structures present in the environments. That different animal communities thrive in different climatic set-ups needs no argument to buttress The variation in the sediment composition as well as the climate, impart a strong influence on the assemblage of the organisms from place to place. As a result, one may encounter different animal-sediment relationship in the same depositional environment under different climatic set-ups. This contention becomes obvious if we compare the animal-sediment relationship of the same tidal flat environment developed under different climatic set-ups. For example, one will not find the polychaete *Arenicola marina* of North Sea tidal flats in India or even in Korea.

Of all the modern environments, the tidal flat environment is best studied.. Various scientists worked on different inter-tidal environments of the world such as, around Sapelo Island of Georgia coast (Frey and Howard,1969; Hertweck,1972; Howard and Dorjes,1972), Boundary Bay tidal flats(Swinbanks and Murray,1981), from sub-arctic intertidal flats of Baffin island Canada(Aitken et al.,1988), from tidal flats of Korea (Lee and Koh,1994), from North Sea coast of Germany, Dutch Wadden Sea (Schafer,1952; van Straaten,1952; Reineck,1956; Seilacher,1964, Dorijes,1970, Hongguang et al.1985, Cadee,1976,1990), from Bay of Fundy (Risk and Yeo,1980) etc. Compared to the ichnological study made by European, American and other workers in this sedimentary environment, little work has been directed towards this aspect in India (Chakrabarti, 1972, 1981, 2000). Therefore, the glossary of the biogenic structures described by them, which are used for the identification of tidal flat environments in rock records, need supplementation from tropical climatic set-ups registering the effects of monsoon. With a little risk of redundancy, this article intends to describe the biogenic structures or lebensspuren registered by the tropical tidal flat domain in the east coast of India.

Study area:

The study area forms a part of the coastal belt, lying between Sagar Island and Chandipur (Fig.1), of the east coast of India. The region is situated in the sub-tropical, humid region with the variation in the temperature from 9 C (winter) to 36C(during smmer months). The maximum annual rainfall never exceeds 220cm.

GEOGRAPHIC SETTING OF THE STUDY AREA



Cyclonic storms occassionally hit the coast during September. The tidal range lies between 4.69 (Spring) and 1.82(neap) meters. During calm winter months long-period swales prevail, whereas during summer and monsoon months with the initiation of the southwesterly winds short period waves predominate.

Geomorphological set-up of the coastal stretch varies from place to place. In the Chandipur area of Orissa, the landwardmost zone of the coast is characterized by a monotonous lowland modified by fluvial processes of the main stream, the river Burahbalang, whereas the landward part of the coastal stretch around Digha registers different lines of Dune belts, and marine terraces of different levels (Chakrabarti,1974). In the Juneput area these dune belts are again missing. In a similar way, the inter-tidal expanses in these places exhibit different characteristics.

In the Chandipur area the tidal flat is nearly 2 km wide. The western part of the tidal flat is a monotonous silty flat surface, whereas the eastern part is studded with clusters of sandy bars interspersed with tidal channels. Compared to the Chandipur tidal flat, the intertidal zone of the Digha area has a higher slope having a width varying between 500m in the west to 200m in the east. Near the Subarnarekha river mouth, the coastal outgrowth is accomplished by stages of development of barrier bars, lagoons and salt marshes. All these cuspate bars are capped by dunes of low heights. The intertidal area of Juneput is wider than that of the Digha area and is characterized by ridge and runnel system, although the same pattern of lagoon/barrier bar/salt marsh system is the dominant pattern of coastal outgrowth. Although all these areas display different types of geomorphic pattern, a scrutiny of the surface features imparted by the organisms reveals that certain biogenic structures can be unequivocally used to delineate the sub-environments within these open-sea tidal flats.

Macro-organisms and their lebensspuren:

The different organisms present in these tropical tidal flats belong to different taxonomic groups. Crustaceans, p[olychaetes, and molluscs occupied more than 90% of the total species number and abundance. Crustacean are represented mainly by Ocypodid crabs such as *Ocypoda macrocera*, *O. quadrata*, O. platytarsis, Dotilla blandfordi, D. clepsidrodactylus(Alcock), Scopimera sp. Illyoplax pusilus (DE

HAAN), Macrophthalmus telescopicus (OWEN), M. pectinipes, M. sulcatus (Edwardi) and shrimps e.g. Callianassa minax, Calianassa bengalensis . Polychaetes_are dominated by Neries sp., Lumbrineris simplex (southern), L. polydesma (Southern), Loimia medusa (Savigny), Owenia fusiformis (Delle chiaje), Diopatra sp. Euclymine annandelei. Saccoglossus sp is the only form of enteropneusta present in this region. The different species of mollusca are Mactra abbreviata, M. violacae, Natica tigrina (Roeding), Polynices didyma, P.tumidus, Cerithidea singulata, Nassarius stolata, Acrilla gracilis. Anthozoan are represented by Utricina wigleyi, Cavernularia sp. In both sandy and muddy regions gobid fish such as Scartelaos viridis (Mam-Buchanan) are found.

Different organisms mostly restrict their activities in different areas depending on the exposure level with respect to tidal inundations. These organisms generate various types of biogenic structures both in the form of tracks,trails(Fig.2) or burrows (Figs.3&4) characters. Since these different macro-organisms have different bioturbation and burrowing potentials,the micro-environment of tidal flat can be identified from the nature of their lebensspuren including ichnofabric.

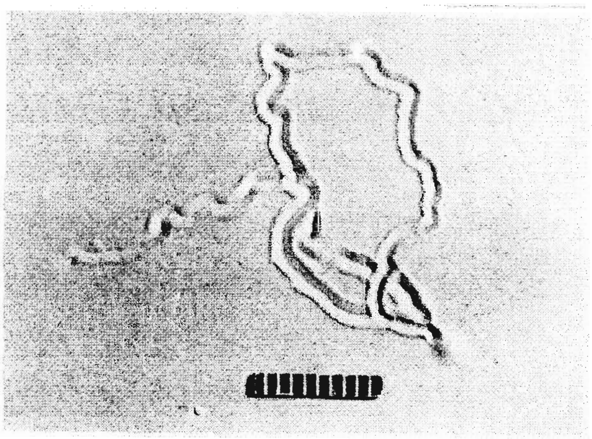


Fig.2: Trails of *Natica tigrina*

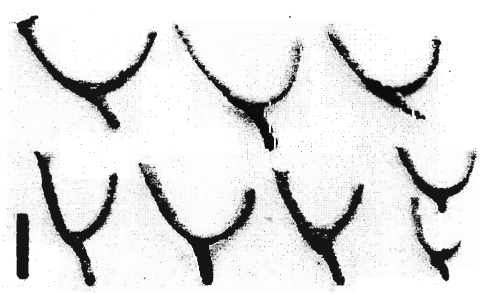


Fig.3: "Y" burrows of adult crabs Fig.4: "U" burrows of juvenile crabs

Surface Biogenic Structures:

Biogenic activity ranges in intensity from an isolated burrow to total dearrangement of sedimentary layers. The most pervasive lebensspuren along this coastal tract are the feeding traces and burrows of ghost crabs such as, *Ocypode macrocera* etc. and bubbler crabs e.g, *Dotilla blandfordi, Scopimera sp.* Illyoplax pusillus etc. The ghost crabs generally prefer a sandy substrate and areas of high exposure levels between tidal inundations. On the other hand, the bubbler crabs such as *Dotilla blandfordi* or *Scopimera* Sp. or *Illyoplax pusillus* have a wide range of tolerance and are active throughout the tidal flats. In fact, they are also active in the tidal point bars (Chakrabarti, 2000). The different lebensspuren, made by them, also depend on the substrate conditions. For example, on moist surfaces these tiny crabs make volcanic mounds or button-shaped features while sealing their burrow mouths to avoid predation, whereas on dry sandy surfaces they make various designs with their feeding pellets (Chakrabarti,1972))

Unlike ghost crabs, the beach crab, *Macrophthalmus telescopicus* can withstand a surface of high water saturation, and their activity, restricted to middle to lower part of the tidal flat, generates flowery designs on the substrate during foraging. In the low water region, the ocypodid crabs are rarely found, and the major biogenic activity is done by Callianassa sp. Their burrow mouths are ornamented with mounds of materials pumped from below having a girdle of cylinder-shaped clayey fecal pellets.

Apart from the crustaceans these intertidal regions are also ornamented with the dwelling tubes of polychaetes *Owenia fusiformis, Loimia medusa, Diopatra* Sp., *Lumbrineris simplex etc.* The burrow tubes of *Owenia* sp. is agglutinated with sand and other drifted materials, whereas those of *Diopatra* sp. is studded with tiny shell and drifted wood fragments. The burrow mouth of the polychaete *Nereis* sp. and *Loimia medusa* is marked off by a dendritic drainage pattern generated due to flushing of water (Das and Chakrabarti,1984). It may be pointed out that all thin slender burrows can not be regarded as dwelling burrows of polychaetes. The slender siphonal passage of the shell *Macoma birmanica* commonly found in the marshy region of the Sagar island can be miscontrued as dwelling burrows of polychaetes.(Chattopadhyaya et al.1993). The sand gobid fish, *Scratelaos viridis, Pisodonophis boro*, make vertical burrows. They are common in the estuarine region of the Chandipur flat. The low water region of the Chandipur flat is dominated by resting burrows of anthozoans *Utricina wigleyi, Cavernularia* Sp, and grazing trails of gastropods Cerithidea cingulata and *Umbonium vestiarium Polynices tumudis etc.* Apart from these tracks and trails one may get both resting and moving traces of star fish.(Fig.5)

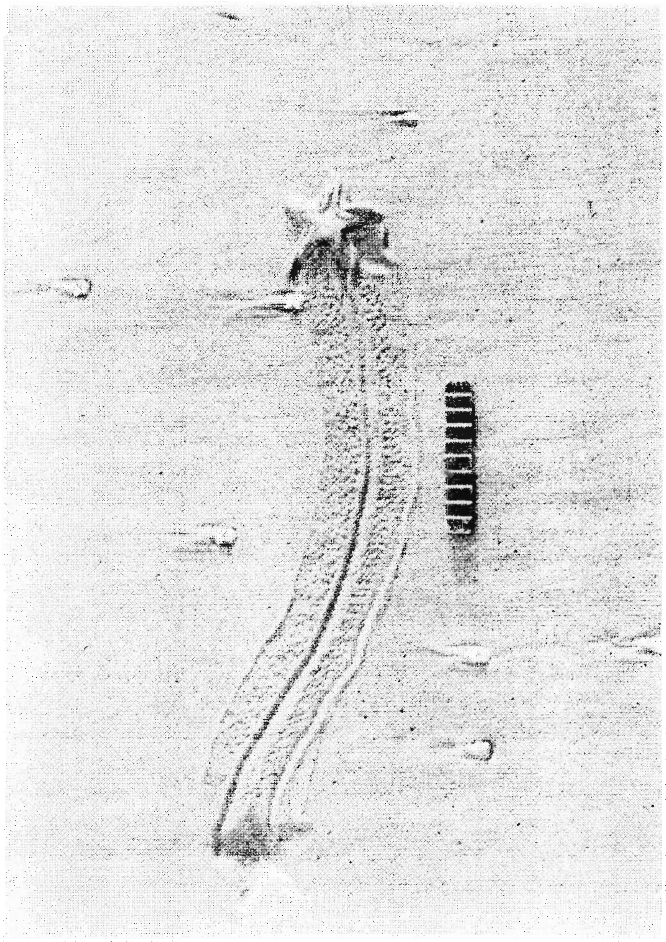


Fig.5: **Resting and moving traces of star fish**

Burrow patterns and ichnofabric

It is well known that ocypodid crabs live in burrows. As ghost crab grow older and larger in size, a gradual change of their life pattern from completely aquatic to quasi-marine has been noted. Casting of burrows with bees wax reveals that the burrow patterns of the ghost crabs (*Ocypode* Sp.) thriving in these tidal flats resemble the English letters J, U, and Y (Chakrabarti,1981). "J" and "U" burrows are incomplete "Y" burrows. On the other hand, the tiny bubbler crabs have short vertical burrows with bulbous ends. The burrows of ghost crabs living in the backshoreforeshore transition zones are inclined shoreward, whereas those found in the shoreward part of barrier bars are randomly oriented. Filled burrows of ghost crabs in vertical sections are cigar-shaped. Since these burrows are filled passively, collapse structures are noted in the burrow fills. However, their burrows do not have linings compared to burrows of *Callianassa*, although one may get collapse structure in both the burrows. The beach crab, *Macrophthalmus telescopicus* have spiral burrows (Chakrabarti and Das, 1983).

Although all the ocypodid crabs are sediment feeders, the back-filling of burrows of bubbler crabs registers a definite pattern having concave-upward of concave –downward laminations in the burrow fills. Such patterns, for obvious reasons, are dependent on the upward or downward direction of movement of the organism during foraging. This pattern is clearly discernible in peeled box-cores. In sections perpendicular to burrow orientation, this art of burrow fill appear as concentric rings. Interestingly, this concave upward filling can be misinterpreted as escape structure. Peeling of sediments has also revealed the conical nature of the the resting burrow of anthozoans thriving in the lower part of the tidal flat.

Conclusion:

The study reveals that the lebensspuren registered by the tropical tidal flats of the east coast of India are different from the North Sea tidal flats (Reineck et.al.,1968). On the other hand, the nature of burrows of ghost crabs bears a strong similarity with those found in the Texas coast of U.S.A. (Hill and Hunter, 1973) other parts of the world. This, in turn, suggests that distribution and species composition of macrobenthic community is climate-dependent. However, the study shows that macrobenthos zonation, characteristic biogenic structures etc. relate to geomorphic features and dynamic zones of the tidal flat. For example, the ghost crab community is primarily active in the upper part of the tidal flat, whereas the beach crab occupies the middle flat of medium energy flats. Similarly, the lower part of the flat is dominated by Callianassa Sp. in sandy and medium energy beaches whereas, anthozoans are common in silty, low -energy tidal flats. This, eventually provokes us to have more data on the lebensspuren of tidal flats under different climatic set-ups. I hope that future studies of recent tidal flats should devote much time and care should be given to description of biogenic structures in tidal flats under varying conditions in order to support the fundamental paradigm of geology that present is the key to the past. Such study will enrich the glossary of lebensspuren which will be required for correct identification of the depositional environment in rock records.

References:

Aitken,A.E., Risk,M.J. and Howard,J.D. 1988. Animal-sediment relationships on a subarctic intertidal flat, Pannirtung Fiord, Barren Island, Canada. Jour. Sedimentary Petrology, Vol.58. p.969-978

Cadee,G.C., 1976. Sediment reworking by Arenicola marina on tidal flats of the Dutch Wadden Sea. Netherland Journal of Sea Research,Vol.10,p.440-460

Chakrabarti A, 1972. Beach structures produced by crap pellets, Sedimentology, v 18, p 129-134.

--------------, 1981. Burrow patterns of *Ocypode ceratophthalma* (PALLAS) and their encironmental significance, Jour Pal, v 55, p 431-441.

Chakrabarti A and Das S, 1983. Burrow patterns of *Macrophthalmus telescopicus* (OWEN) and their environmental significance. Senckenbergiana Maritima, v 15, p 43-53.

Chattopadhyay G, Chakrabarti A and Hertweck G, 1993. Biogenic Structures Related to Feeding Activities of *Macoma birmanica* from the Mangrove Areas of the Sagar Island, NE India, Frankfurt am Main, v 23, p 99-107

Dorjes,J.,1970.Das Watt als Lebensraum *in* Das Watt , Ablagarungs und Lebensraum (Ed.H.E.Reineck)

Duncan G A, 1986. Burrows of *Ocypode quandrata* (Fabricius) as related to slopes of substrate surfaces. Jour Pal, v 60, p 384-389.

Frey,R.W. and Howard,J.D. 1975. Endobenthic adaptations of juvenile thalassinidiean shrimps. Bull.geol.Soc.Denmark, vol.24, p.283-297

Frey R W and Mayou T V, 1971. Decapod burrows in Holocene barrier island beaches and washover fans, Georgia, Senckenbergiana Maritima, v 3, p 53-77.

Hertweck,G. 1972. Georgia coastal region, Sapelo island, U.S.A.: Sedimentology and Biology.V. Distribution and environmental significance of lbensspuren and in-situ skeletal remains. Senckenbergiana maritima. Vol.4.125-167.

Hongguang,M, and Zhiying,Y, and Cadee,G.C..1995. Macrofauna distribution and bioturbation on tidal confluences of the Dutch Wadden Sea. Netherland Jour. Of Aquatic Ceology, vol.29(2) p,167-176

Hill G W, and Hunter R E, 1973. Burrows of ghosh crab Ocypode quadrata (Fabricius) on the barrier islands, south central Texas coast. Jour Sed Pet, v 43, p 24-30.

Krejci-Graf, K. 1932 Definition der Begriffe Marken,Spuren, Fahrten, Bauten, Hieroglyphen und Fucoiden.Senckenbergiana, vol.14.p.19-39

Schafer, W. 1962. Aktuo-Palaontologie nach Studien in der Nordsee 666p. Frnkfurt. Am M. (Kramer)

Seilacher, A. 1964.Biogenic sedimentary structures *In* Approaches to palaeoecology. (Ed. Imbrie,J and Newell,N.D.) p.296-316

Lee,Y. and Koh, C., 1994. Biogenic sedimentary structures on a Korean mud flat. Spring-Neap variation. Netherland Journal of SeaResearch, Vol.32.p.81-90

Risk,M.J. and Yeo,R.K.,1980. Animal –sediment relationship in Minas basin, Bay of Fundy.*In* The coastline of Canada. Geological Survey of Canada paper No.80p.189-194

Richter,R. 1927. Die fossilien Fahren und Bauten der Wurmer, ein Uberblick uber ihre biologischen Grundformen und derengeologische Bedeutung. Palont. Zeitschriftl.9.p.195-240

Reineck, H E, 1970. Das Watt. Frankfurt am Mein, p 142

Seilacher,A. 1964. Biogenic sedimentary structures. I*n* approaches to palaeontology (Eds J.Imbrie, and N. Nowell) p.296-316.

Swinbanks,D.D. and Murray,J.W., 1983. Biosedimentological zonation of Boundary Bay Tidal flats, Fraser River Delta, British Columbia. Sedimentology vo.28, 201-237.