Sedimentary structures of tidal flats: A journey from coast to inner estuarine region of eastern India

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Sedimentary structures of some coastal tropical tidal flats of the east coast of India, and inner estuarine tidal point bars located at 30 to 50 kilometers inland from the coast, have been extensively studied under varying seasonal conditions. The results reveal that physical features such as flaser bedding, herringbone cross-bedding, lenticular bedding, and mud/silt couplets are common to both the environments. In fact, flaser bedding and lenticular bedding are more common in the point bar facies during the monsoon months than in the coastal tidal flat environments. Interference ripples, though common in both the environments, show different architectural patterns for different environmental domains. Interference ripples with thread-like secondary set overriding the earlier ripple-form, resembling wrinkle marks, are the typical features in estuarine point bars near the high water region. Because structures which are so far considered as key structures for near-coastal tidal flats are common to both the environments, caution should be exercised for deciphering palaeo-environments, particularly for Proterozoic rocks, where one has to depend only on physical sedimentary structures.

1. Introduction and history of tidal flat study

Tidal flats can be defined as sandy to muddy or marshy flats emerging during low tide and submerging during high tide (intertidal zone). The zone above the high water line is supratidal zone, and the area below the low-water line is subtidal zone. There is, however, no clear demarcation between supratidal and intertidal areas. According to Eisma (1997), intertidal deposits are not isolated units and they are part of a larger system which includes supratidal and subtidal units. Mapping of estuaries reveals that tidal flats are formed generally as depositional features at the expense of tidal channels, and are, in turn, engulfed by salt marsh vegetation (Redfield 1967).

Tidal flats could be sheltered or open-sea with sediments, which could be either siliciclastics or

carbonates. Reineck (1972) classified sheltered tidal flats as mud-flat, mixed-flat and sand-flat as one proceeds from high tide line to low tide line. Although he used the term progradational, it is now accepted that barrier islands form only where there is at least local transgression. Because of their intertidal character, wide point bars in the inner estuarine region of large tidal rivers can also be included within the sheltered tidal flat category. Geyl (1976) introduced the term 'tidal neomorphs' for tidal landforms related to channels of tidal streams.

The most intensively studied modern tidal environments are tidal flats, tidal inlets, deltas and subtidal shelf banks. Attention has been focussed on siliciclastic tidal flats of North Sea (Evans 1965; Reineck 1972), including the Wadden Sea (Van Straaten 1954; De Raaf and Boersma 1971; Eisma 1997), the Gulf of California (Thompson

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1968), Georgia coast (Hertweck 1972; Howard and Reineck 1972), Southern New Hampshire (Anderson 1973), Bay of Fundy, James Bay and Hudson Bay of Canada (Dalrymple *et al* 1982; Amos 1991; Martini 1991), Gironde estuary of France (Allen 1972), Mont Saint-Michel Bay, France (Larsonneur 1975), Gulf of Gaeta of Italy (Hertweck 1971), Inchon Bay of South Korea (Alexander *et al* 1991), Gomso Bay, Kyunggi Bay, West coast of Korea (Chang *et al* 2000; Choi and Park 2000), Bohai Bay and West Yellow sea of Mainland China (Wang 1983; Wang *et al* 1990), Pacific coast of Japan (Yokokawa and Masuda 1991). The study of modern tidal flats in India, however, is still fairly limited (Chakrabarti 1972, 1974, 1977, 1980, 1981; Mukherjee *et al* 1987; Bhattacharya 2000).

Van Straaten (1954) provided a model to identify mud flat sequences in the stratigraphic record. He suggests that a fining-upward sequence results from the dual action of lateral shifting of tidal channels and creeks, and continuous supply of finer-grained sediments from the sea. Reineck (1972) modified the tidal creek model and gave a systematic cross section across the tidal flats of the North Sea. The Dutch and German scientists worked exhaustively on the sedimentary and biogenic structures and documented facies typical of North Sea and other modern tidal flats.

Because the tidal range of coastal water varies from less than 5 cm along the eastern part of north Siberia to more than 15 m in the Bay of Fundy in Canada, the sedimentation pattern varies with geographic settings having varying tidal regimes. Davies (1972) pointed out that tidal regimes determine the duration of drying out of the flat between tides as well as the intensity of tidal currents defined by the time available to move water masses. This, in turn, affects the development of sedimentary structures as well as the distribution of organisms in the intertidal zone and therefore, the animal-sediment relationship.

Ever since the systematic study for the identification of tidal flat environment in rock records through comparison of sedimentary structures formed in recent tidal flats was initiated, scientists have been facing problems in the proper application of these features for the interpretation of palaeo-environments. Many features are not unique to a single sedimentary environment; for example, formation of flaser bedding or lenticular bedding depends on the clay accumulation which needs a sheltered condition and high suspended load. Therefore, such features need not be formed only in the sheltered tidal flats, for example, North Sea, but also be formed in the sheltered inner estuarine landforms of tropical rivers where monsoonal discharge can supply substantial clayey material as

suspended load. For the identification of palaeo-tidal flats or tidalites, most sedimentologists use sedimentary and biogenic structures documented by Dutch and German workers on temperate tidal flats. The structures developed under tropical settings were never taken into consideration.

The present study documents certain ubiquitous physical structures that are found both in the near-coastal as well as in the inner estuarine tidal point bars of the tropical coasts of India.

2. Study area

The locale of study is restricted to the east coast of India lying between Sagar Island, West Bengal, and Chandipur, Orissa; and also includes the tidal point bars located nearly 30 to 50 km inland from the present-day coast (figure 1).

This region experiences sub-tropical, humid climate in which the effects of monsoonal discharge are very marked. The average annual rainfall is 1650 mm, most of which is restricted to the monsoon period, *i.e.*, between July and September. During this period, freshwater discharge also alters the salinity condition in the estuarine regions of rivers. The maximum discharge for the river Rupnarayan over the past 50 years has been recorded as 15,860 m³/sec. The width of the Rupnarayan River is 715 m. The concentration of total dissolved solids in the river water of the Rupnarayan during the monsoon months is 29.2 ppm as against 142 ppm during summer.

Tides are semi-diurnal in this region. The high flood level and mean water level of the river Rupnarayan are 5.85 m and 0.38 m respectively. Near Digha area, the main tidal range varies between 4.89 m (equinoctical, spring) and 1.87 (equinoctical, neap). During calm winter months, long period swells are common in this coastal region, whereas the summer and the monsoon months are characterized by short period waves. The average wind speed is 25 knots. The coastal region experiences cyclonic weather each year during the monsoon months when wind speed ranges between 45 and 50 knots. Rip currents are not active in this area.

3. Geomorphological setting of the tidal flats

The geomorphic settings for the coastal tidal flats under study vary from place to place. Around Chandipur, SW of the estuary of the river Subarnarekha (figure 1), the coast can be divided into two broad morphozones: (a) a landward zone characterized by monotonous lowland modified by fluvial processes of the main stream, the river

Figure 1. Geographic setting of the study areas (after satellite imagery of 29.3.1975).

Burahbalang, and **(b)** a seaward zone bordered by a single line of shore-parallel coastal dune lying on old marine terraces. The line of coastal dune is fronted by the open sea tidal flat (figure 2).

The tidal flat has two distinct morphometric facets, **(a)** a sandy sloping (av. 6 degrees) shoreward zone with an average width of 30 m, and **(b)** a wide silty flat matted with ripples, having an average width of 1.5 km. Near the Burahbalang estuary, the silty intertidal flat is ornamented with clusters of river-mouth bars of varying dimension, criss-crossed by tidal channels of varying depths (Mukherjee *et al* 1987). Initiation of mangrove growth can be seen near the Burahbalang estuary. The width of the intertidal flat has dampened the wave activity in this region; consequently the effect of tidal action can be felt in an otherwise open-sea wave-dominated domain. The general geomorphic map of the area is shown in figure 2.

The coastal stretch around Digha lies in the eastern fringe of the Subarnarekha delta, and is characterized by different lines of beach ridges/dune belts, and marine terraces of different levels (Chakrabarti 1974). The coastal outgrowth near the Subarnarekha river mouth is accomplished by different stages of development of barrier beaches, lagoons, and salt marshes with mangrove outgrowth. Development of aeolian dunes of low heights is common on these barrier beaches. The geomorphological map of the area drawn from air-photos is given in figure 3.

The intertidal region of Digha has an average width of 400 m, and is characterized by remarkable straightness of the shoreline and smoothness of the flat. It is bounded on the landward side by a dune belt situated on the old marine terrace. Backshore is absent in the eastern part of the area, whereas in the west, the backshore is formed. The western part is characterized by shore-parallel low-height barrier beaches and tidal channels (figure 4). Unlike the Chandipur flat, the intertidal region of Digha area is not densely matted with ripples. However, low-height barrier beaches are sculptured by ripples with lee directions pointing shoreward (figure 4).

The waves around Digha coast approach the shore at an angle of nearly 70 degrees and are very active in the non-barred part of the coastal stretch causing erosion.

The intertidal area of Juneput is also wave-dominated, and is characterized by the development of ridge and runnel system. A combination of lagoon/barrier bar/salt marsh is the dominant pattern of coastal outgrowth in this area. Unlike Digha area, shore-parallel growth of coastal dune is absent. Average width of the intertidal area is 800 m, and because of its wide expanse waves do not impinge the flat with strong forces. The growth

of offshore shoals is noticeable. The geomorphic map of the area, as constructed from air-photos, is shown in figure 5.

Compared to the intertidal expanses of the coastal region, the tidal point bars of the river Haldi at Terapekhya and Norghat, and of the river Rupnarayan at Kolaghat have a smaller width. Of the different point bars, the one developed in the river Rupnarayan at Kolaghat is about 150 m wide. It is a composite form of several small bars dissected by small creeks during the monsoon period. These point bars are relatively stable in their geographic position, though their outcrop patterns vary during the monsoon period (figure 6).

4. Size properties of intertidal sediments

The size characteristics of different intertidal sediments show wide variation. The upper sandy part of the Chandipur tidal flat is composed mostly of fine sand (2 to 3 phi size), whereas in the wide silty flat more than 80% of the sediments are finer than 3.5 phi size. Sediments in the river-mouth bars are coarser, with graphic mean size varying between 1.8 and 2.85 phi.

The sediments of Digha area are bimodal to polymodal in character. The average values of mean size of sediments for upper, middle and lower part of the intertidal zone are 3.31, 2.14 and 3.46 phi respectively (Chakrabarti 1977). The sediments of the Juneput area are finer than those of the Digha area. The graphic mean size of sediments lies between 2.85 and 3.51 phi. Biogenic activity plays an important role in the distribution of sediments on the tidal flat surface (Chakrabarti 1980). The graphic mean size of point bar sediments varies between 2.83 and 3.15 phi. During the monsoon, there is a high influx (52%) of muddy sediments through small creeks draining the upland area (Chakrabarti 2003).

5. Surface sedimentary structures

The major bedforms observed in tidal flats are ripples of diverse and complex forms. It is well known that bedforms are controlled by water depth, bed shear and grain size (Middleton and Southard 1984). However, the final architecture of bedforms in tidal flats is mainly governed by the combined influence of variable flow directions controlled by waves and tides during falling tide level (when shear velocities decline), wind stress and recession of water level on various sloping surfaces. As a result, a great variety of bedforms on the intertidal surface is expected when abandoned by the tide.

Figure 2. Geomorphic setting of the tidal flat around Chandipur, Orissa.

Figure 3. Geomorphic setting of the intertidal region around Digha, West Bengal. Different morphometric facets are identified from air-photos.

Figure 4. A general view of the intertidal expanse in the western part of Digha showing low-height barrier beach matted with ripples and a shore-parallel tidal channel.

5.1 *Types of ripple architecture in near-coastal tidal flats*

Different intertidal regions under study represent different energy levels of waves and currents that are governed by the width of the intertidal zone and by exposure to the open sea. This exerts a strong control on the ripple patterns to be developed on the surface of different morphometric zones of the tidal flats. In Digha area, where manifestations of wave energy in the form of swash/backwash system dominates over tidal energy, the intertidal surface, barring runnels and tidal channels, is not intensely matted with ripples as is observed in the Chandipur or Juneput tidal flats. In Digha and in other areas, where the tidal flat surface experiences a strong effect of swash/backwash system of waves, antidunes of large wave lengths (figure 7) or rhomboidal ripples (figure 8) of different dimensions and patterns are commonly formed. The tidal point bar surface which mainly experiences the effects of ebb or flood currents fails to register features related to swash/backwash system.

'Sinuous' to 'straight-crested' oscillation ripples with 'tuning fork' type of bifurcation (Reineck and Singh 1973, cf. figure 24) are common in the wave-dominated coastal tidal flats (figure 9). However, such forms can also be found in the point-bar environment.

Interference ripples having secondary ripples of different patterns characterize all tidal flats (figures 9 and 10). In the near-coast areas there are many forms of interference ripples. The most common form is the 'ladder-back' ripples with the development of secondary current ripples on the stoss side or in the trough regions of early formed ripples which could be current or wind-induced wave ripples. These secondary ripples, in places, override the earlier forms (figures 10 and 11).

Interference ripples, including 'ladder-back' forms, are also present on tidal point bars. However, a new pattern with thread-like ripples of very small heights overriding the early-formed current ripples (figure 11) has been noted near the landward side of the point bar surface. These tiny secondary ripples can be easily misconstrued as wrinkle marks in rock records. Although the hydrodynamic conditions for the generation of these microstructures are yet to be critically assessed, these tiny ripples are formed only during the recession of tides. The thread-like ripples in places show 'tuning-fork' type bifurcations. When the secondary ripple set of the interference ripple becomes prominent, the composite ripple structure looks like 'piano reeds' (figure 10), a common feature in the near-coastal tidal flat where the possibility of having strong secondary current, particularly in tidal channels, is not unlikely.

In tidal channels of wave-dominated coasts a new form of interference pattern, the 'pyramidal ripple' (Chakrabarti 2003) has been noted (figure 12). Such ripples can also register interference of a third set of ripples from minor flow or rill marks depicting pseudo-ripple. In tidal point bars, pyramidal form of ripples, formed on linguoid current ripples, are characterized by 'pit and mound' structure (figure 13), in places ornamented with thread-like tertiary ripples.

During the monsoon period, particularly when cyclonic storms prevail, the pattern of interference ripple changes. Coastal tidal flats show large crescent-shaped dunes with secondary ripples developed in the lee-sides of earlier bedforms (figure 14). Cyclonic storms also generate large scour pools in coastal tidal flats in which 'brick pattern ripples' (Matsunaga and Honji 1980) or ripples showing 'crocodile skin' structure can be found. Such scour pools with the structures mentioned above are not uncommon on point bars. In this tropical setting, scour pools commonly form on intertidal surfaces only after storms, and their presence in rock records may be correlated with storm conditions.

The wave-dominated near-coastal intertidal zones show antidunes or swash/backwash ripples and rhomboidal ripples of varying forms and dimensions. On the other hand, low energy coastal tidal flats are characterized by 'parallel-crested' ripples with 'tuning fork' type of bifurcation, and sinuous bifurcating ripple-trains with the development of 'eyed' structures on ripple crests. The bifurcating ripples also occur in the runnels of wave-dominated beaches and in the scour pools of tidal point bars.

Linguoid ripples are common in fluvial environment, and tidal point bar environments are also no exception. Because, coastal tidal flats include tidal

Figure 5. Geomorphic setting of the area around Juneput, West Bengal as identified from air photos. Unlike Digba area, the different lines of dune belts are absent. The area is marked by salt marshes.

Figure 6. Point bar exposed near Kolaghat, West Bengal. Spade for scale.

Figure 7. Large antidunes generated from swash/backwash system operative on the intertidal area of Digha.

Figure 8. Equally spaced rhomboidal ripple, a common feature of Digha area. Scale 10 cm long.

channels, the existence of linguoid ripples in tidal channels is not unlikely (figure 15).

Double-crested ripples are commonly developed on water-saturated, silty surfaces of coastal tidal flats as well as on tidal point bar surfaces (figure 16), particularly on silty substrate. Rill marks

Figure 9. Sinuous bifurcating ripples with the 'eyed' forms (marked by arrow) due to closure of ripple crests, ladder-back ripples in the trough region. Pen 13 cm long for scale.

Figure 10. Interference ripples of equal dimensions giving rise to 'piano-reed' structure. Scale 10 cm long.

developed on this surface, in places, reveal more complicated outer morphology.

From the foregoing, it is evident that barring rhomboidal ripples and antidunes, most of the ripple forms found on coastal tidal flats also occur on tidal point bar surfaces. However, recognition of antidunes in rock records is difficult. Therefore, the use of ripple architecture for the identification of near-coastal tidal depositional environment becomes uncertain. The 'thread-like' secondary ripples overriding the primary ripples recorded in the point bar environment have not so far been found in open-sea tidal flats, and the structure can be used as a possible indicator of estuarine tidal flat environment.

5.2 Bipolarity of ripple orientation and tidal flat environment

It is commonly believed that bipolarity in the ripple orientation in rock records should be an ideal

Figure 11. Thread-like secondary ripples overriding the earlier forms, a common feature in the estuarine point bar around Kolaghat. Pen 13 cm long for scale.

Figure 13. 'Pit and mound' structure formed on ripple crests, a common feature in tidal point bar. Pen 13 cm long for scale.

Figure 12. Pyramidal ripple formed by the interference of ripples of equal dimensions. 'Rill marking' produces pseudo-ripple. Coin 2.5 cm diameter as scale.

Figure 14. Large crescent-shaped dunes developed on the intertidal surface immediately after a cyclone. Development of sinuous bifurcating ripples can be seen. Scale 10 cm long.

signal for the identification of tidal flat environment. However, the lee directions of ripples in these tidal flats rarely bring out strong bipolarity. Furthermore, near the river mouths, one might get an angular relation between the early-formed dunes directed towards the shore and the secondary dunes overriding it (figure 17).

In estuarine tidal flats or in the back-barrier facies, one may encounter oppositely oriented lee directions from the outer morphology (figure 18). The opposite orientation of the outer morphology could be generated through the subsequent modification during flow reversal. In tidal point bars, the gradual decline of water level with receding tide creates another set of secondary ripples with lee directions at right angle to the ebb or flood direction. This eventually raises doubts on the general consensus that tidal flat environment in rock record can be recognized from the bipolarity in palaeocurrent pattern. If all the measurements on ripple orientation from different sub-environments of a

Figure 15. Development of linguoid ripples in the tidal channels of the intertidal expanse at Digha, West Bengal.

tidal flat are treated together in a rose diagram, as traditionally followed in palaeocurrent study, one may find two or more major directions, which are

Figure 16. Double-crested ripples formed on the silty surface of tidal point bar. Pen 13 cm long.

Figure 18. Ripple forms generated at different times with oppositely-oriented lee directions, represent the effects of ebb and flood. Knife 35 cm long as scale.

Figure 17. Superimposition of two sets of ripples, with lee directions oriented at right angles.

Figure 19. Large crescent-shaped ripples fading out to parallel-crested ripples as observed in the Chandipur area. Black scale 10 cm long.

disposed at angles with each other. Thus, the standard concept of bipolarity in identification of tidal flats in rock records is not unambiguous. Ambiguity arises from the fact that tidal currents are characterized by several scales of unsteadiness.

It has been observed that crescent-shaped ripples are common in the tidal channels of open-sea tidal flats. These forms, in places, are modified laterally to straight-crested ripples of low heights, which look very similar to longitudinal ripples (figure 19) formed by wind waves on shallow water depth (cf. Van Straaten 1954). The dispersal of these straight-crested forms again casts doubts about the bipolarity concept of ripple orientation where ebb and flood tides should have equal competence.

6. Subsurface sedimentary structures of tidal flats

Subsurface sedimentary structures are studied through peeling techniques (Chakrabarti 1984).

Box coring from different transects of the tidal flats were taken and resin casting with a combination of Araldite (CIBA product CY205) and Hardener (CIBA product HY951) has been done. For finer-grained sediments, a different method involving emulsion of polyvinyl acetate and polyvinyl alcohol with N/10 Formic acid was used. Due to colour contrast in the sediments, a freshly cut surface of the box core can give an idea about the sedimentary structures present in it.

Major types of sedimentary structures in tidal flats include horizontal or parallel lamination with uniform and non-uniform laminae in the sandy substrate of wave dominated flats (figure 20), ripple lamination (figure 21), mega-ripple lamination on sandy substrate (figure 22), climbing ripple lamination (figure 23), hummocky cross stratification (figure 24), scour-and-fill lamination, tidal bedding (figure 25), tidal rhythmites, flaser and lenticular bedding, herringbone cross stratification, contorted

Figure 20. Horizontal lamination, the typical structure found in the Digha area. Vertical sinuous burrow of gobid fish preserved. Coin for scale.

Figure 21. Epoxy peel of a box core showing small ripple lamination overlying parallel lamination. Intense bioturbation (lower part of the peel) has erased the early-formed structures. Coin 2.5 cm for scale.

or convolute lamination (figure 25), bubble sand, etc.

Climbing ripple lamination with different angles of climb (figure 24) has been observed in coastal

Figure 22. Epoxy peel of a box core showing mega-ripple lamination with oppositely-oriented ripple laminae as observed in the sandy barred tidal flat of Chandipur area. Coin 2.5 cm diameter for scale.

Figure 23. Epoxy peel of a box core showing climbing ripple lamination with different angles of climb. Coin 2.5 cm for scale.

tidal flats of Chandipur area where the substrate is composed of fine sand and silt. These climbing ripple laminated units were eroded and covered by scour-and-fill laminations.

During the monsoon months, the wide silty tidal flat of Chandipur registers more mega-ripple laminae, whereas during calm winter months small ripple laminae are the common sedimentary structures. During the monsoon period, hummocky

Figure 24. Hummocky cross stratification, a feature observed in Chandipur after a cyclone during the monsoon months. Coin 2.5 cm length.

Figure 25. Tidal bedding showing mud/silt couplets. Oppositely oriented ripple laminae represent tidal action. Convolute lamination at the base. Coin for scale.

cross stratification may be formed immediately after monsoon cyclones (figure 24). Herringbone cross stratification is rare in these open-sea tidal flats. Because of wave-dominated character, cross stratification in these open-sea flats is mostly

Figure 26. An isolated ripple train entrapped in laminated mud, observed in the Kolaghat area.

unidirectional, and points towards the shore. The effects of ebb and flow is exhibited, in places, by oppositely oriented ripple laminae (figure 21).

In tidal point bars, on the other hand, structures such as flaser stratification, herringbone cross bedding, mud and silt couplets, tidal rhythmites are common than in the near-coastal tidal flats. These structures are profusely developed during the monsoon period when upland discharge contributes high suspension loads in rivers. The pattern of mud and silt laminae varies from near-horizontal stratification to convex-upward type depending on the architecture of the underlying surface. In a single ripple bedform, such an alternation of mud and silt can also be seen in the ripple laminae (figure 25). When the suspended load is high, burial of a single train of ripples under a thick mud cover can be noted (figure 26). In a wavy laminated unit, a fining upward character, from laminated fine sand to laminated mud, has also been noted.

From the above findings, it appears that structures like flaser bedding, herringbone cross stratification, lenticular bedding, etc. are profusely developed in the inner estuarine point bars. Therefore, the question arises whether these features can unequivocally be connected to near-coastal tidal flat environment, as suggested by earlier workers (Reineck and Wunderlich 1968). A comparison of the sedimentary structures developed in the wide rippled silty tidal flat of Chandipur and of Digha during different seasons (figures 27 and 28) reveals that certain structures are more common in the high-energy Digha area than in the low energy Chandipur flat. No individual feature is capable of identifying a particular depositional setting.

Figure 27. Seasonal and aerial variation of the subsurface sedimentary structures as revealed from the box cores taken from different morphozones of Chandipur tidal flat, Orissa.

In the wave-dominated intertidal region of Digha, the subsurface sediments are characterized by horizontal lamination, whereas tidal flats matted with ripples are marked by ripple cross laminae inter-layered with horizontal laminae.

Table 1 gives a comparative analysis of the percentage distribution of different sedimentary structures as observed in box cores collected from different intertidal areas around Digha, Juneput, Chandipur and Kolaghat. In quantifying the

Figure 28. Seasonal variation of the subsurface sedimentary structures as revealed in the box cores collected from the intertidal zone around Digha, West Bengal.

Table 1. *Percentage distribution of different sedimentary structures as registered by tidal flats in different areas.*

Nature of structure	Digha	Juneput	Chandipur	Kolaghat
Ripple cross bedding	11.9	48.5	25.6	30.5
Low angle stratification	12.8	5.3	—	—
Climbing ripple lamination	—	1.3	9.8	—
Herringbone stratification	0.2	1.4	2.1	6.0
Wavy lamination/HCS	1.9	5.1	14.3	3.4
Flaser and laminated mud	—	0.3	1.7	6.2
Mud/silt couplet	—	0.6	—	8.1
Scour-and-fill structure	—	10.9	11.7	6.1
Horizontal lamination	71.9	13.8	18.5	18.0
Lenticular bedding	—	1.8	8.9	2.1
Convolute lamination	—	—	0.5	11.5
Tidal bedding	—	0.6	2.1	7.1
Bioturbation	1.0	11.0	5.2	—

relative distribution of different structures in a peel, the percentage of the thickness occupied by each structure in relief peel has been calculated considering the length of the peel (22 cm) as 100%.

7. Conclusion

The study shows that indiscriminate use of certain structures to identify different tidal environments in rock records might lead to erroneous results. Greater emphasis should be placed on the

physical sedimentary structures developed in the tidal point bars under tropical conditions with high suspended load to discriminate transitional estuarine tidal flats from near coastal tidal flats in rock record.

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