GEOLOGICAL SIGNIFICANCE OF BURROWS PRODUCED BY THE CRAB *UCA MARIONIS* ON SALT MARSH RIVER BANK OF INNER SUNDARBAN DELTA COMPLEX, INDIA

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ABSTRACT

For the first time, a methodical analysis of the burrows produced by the famous red crabs, *Uca marionis*, on an ideal salt marsh river bank of inner Sundarban delta complex has been made with an eye to evaluate its various geologic importance. Burrows are revealed as good indicators of many crucial sedimentological processes. Moreover, their environmental, geomorphological and palaeontological momentousness have been brought forward confidently.

The animals are found characteristically to burrow along a long and narrow zone composed of firm clay-dominated substrate, produced by rapid deposition under very low energy condition. This "burrow zone" runs parallel to the river course and characteristically lacks continuity across the tidal creeks due to significant lowering of burrow density by the sharp increase of interstitial water content of the sediment. Indicative of low energy conditions are complete and untruncated burrows with organic lining towards bottom and sediment domes around openings. Frequent presence of "escape structure" reveals high rate of deposition. Existence of deep to shallow untruncated burrows with "parallel laminated to burrowed" sequence (Howard, 1971) also supports an active phase of deposition. Wide zone of deformation around burrow openings is suggestive of a firm substrate with low water content. Current improved biogenic grading of fecal pellets appears to be a good indicator of tidal current directions. All the burrows generally possess almost straight, cylindrical and unbranched shaft with a single circular opening. All the burrows dip at very high angles away from the river towards the immediate flood plain. This criterion is thought to be helpful in fixing the direction of the nearest flood plain. Characteristic changes of burrow morphology, particularly gradual stoutening of burrows, have been found to be solely dependent on the growth of the animal and hence, are useful in ontogenetic and evolutionary studies of their own.

INTRODUCTION

This paper reports a detailed study on the geological significance of burrows produced by the crab *Uca marionis* on a salt marsh river bank in inner Sundarban delta complex, a part of Bengal Delta, and presents, for the first time, a model showing variations of burrows in response to the growth of the organism. Members belonging to this genus are very characteristic of many salt marshes, for example, Sapelo Island, Georgia (Teal, 1958 ; Basan and Frey, 1977) ; Beaufort, North Carolina (Allen & Curren, 1974) ; Seychelles, Indian Ocean (Braithwhite and Talbot, 1972) and many others. Burrows of genus *Uca* from Sundarban delta complex have not been dealtwith so far in any literature. Interesting to note is that this genus is omnipresent in all the salt marsh river (often meandered) banks of inner Sundarban deltaic parts, particularly where the muddy and saline river water is depositing mainly clay with silt in alternate layers, the river banks are actively building and the natural vegetation is represented by profusely developed mangrove flora. The studied area (Fig. 1a), in and around the village Chunakhali (Lat. 22°14′50″ & Long. 88°45′20″), which may be considered as a type area for this sort of study, covers about 16200 sq meter area with the existence of river flood plain, natural

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levees, river terrace and a point bar successively towards the river bottom. Moreover, the area is located near a sharp meandering bend on a building western bank of the river Vidyadhari which is migrating here slowly towards east. The area, in part, suffers periodical submergence by tidal river water.

Simply, white wax has been used satisfactorily for casting the burrows. The crab species is authoritatively identified by zoologists of Zoological Survey of India (correspondence number F. 209-4/79-CD./4177) and the authors have also accepted the

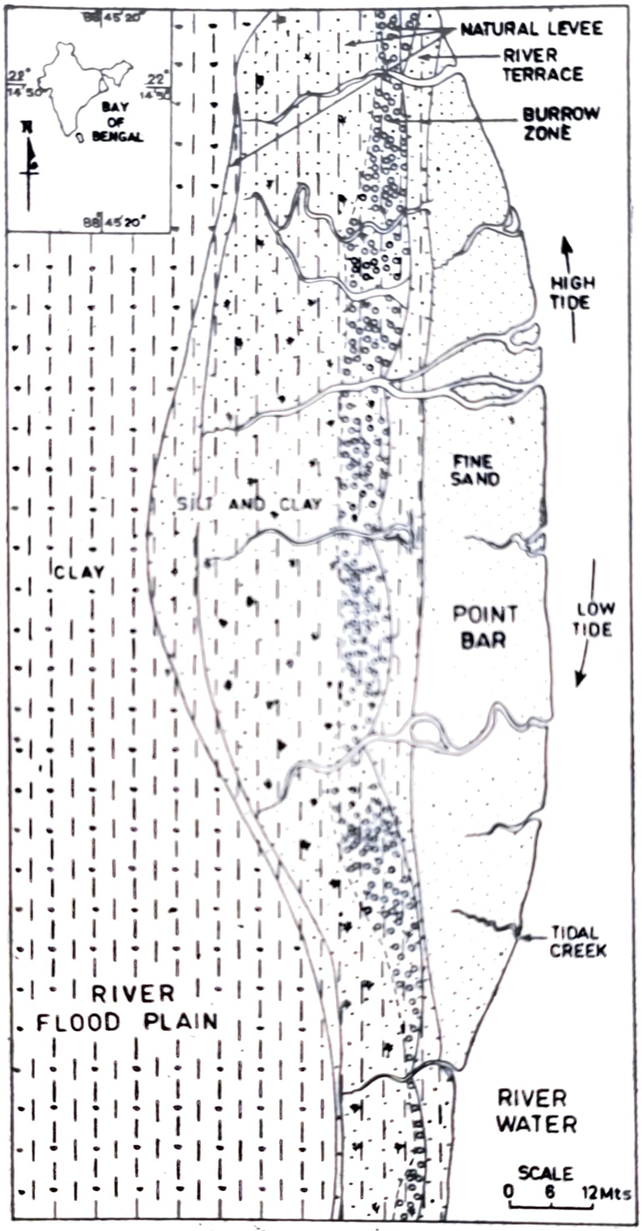

Fig. 1a

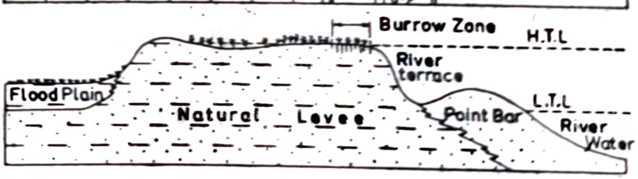

Fig. 1b

Fig. 1. a. Map of the studied area showing different geomorphological units (river flood plain, natural levee, river terrace and point bar), sediment types (Clay, Silt and Fine sand), "burrow zone" (area covered with small circles) and distribution of tidal creeks and bushy mangrove vegetation.
b. A schematic cross section of the area showing geomorphological units, sediment types, burrow zone, distribution of bushy mangrove vegetation, low tide limit (L.T.L.) and high tide limit (H.T.L.).

same identification. The burrows which are being dwelled by *Uca marionis* are only considered and surfacial workings around the burrows openings are also taken into account.

LOCAL GEOMORPHOLOGY

The schematic profile section (Fig. 1b) through the area illustrates the position of different geomorphological sub-units. River flood plain is the low laying horioznta1 plain land of vast area and is composed purely of structureless clay. It becomes submerged only during the periods of over bank flow of water. Natural levee forms a very narrow and raised discontinuous zone composed of fine silty to clayey sediment and is well developed towards the convex side of the meandered bends of the river. River terrace, a step like unit on the bank, runs almost parallel to the river courses. The point bar, a long and narrow sand body, is being grown by lateral accretion of sediment. It is aligned parallel to the local river courses and suffers complete submergence during high tides.

Sediment

The river bank is almost entirely composed of clay with few fine silt layers. The point bar is composed of totally fine sands. Overall, the bank is clay dominated. The organic matter content of sediments, in the form of broken shell fragments of gastropods and pelecypods, is also high.

BURROWS

The burrowing organism

The burrowers, *Uca marionis*, are locally known as "red crab" and they are found to define almost a continuous zone of inhabitation (10-15 meters wide) running parallel to the river bank. The inner border of this zone (Fig. 1b) is bounded by the river terrace. This zone will be referred here as "burrow zone" which lacks its identity in and around tidal creeks. The "burrow zone" is also occupied by fairly dense bushy elements of the mangrove flora. Members of this genus are exclusively deposit feeders (Basan & Frey, 1977; Teal, 1958; Allen & Curren, 1974). The upper surface of the burrow zone is almost horizontal.

Burrow morphology (Plate 1)

The parameters (Fig. 2) taken into account in the present study to describe the details of the burrow structures are illustrated in the foot note. These parameters have been measured only from the complete burrow casts.

Vertical length can be attributed to the vertical penetration power of the burrowers. Actual length, likewise, is a measure of actual penetration power. So, in case of horizontal burrows, the organisms cannot be said to possess vertical penetration power. Similarly, organisms, producing only vertical burrows, do utilise its actual penetration power in the form of vertical penetration. Hence, a comparison between actual and vertical lengths of linear nonbranching burrows will give a clear idea about the burrowing capacity of organisms, shapes, sizes and orientations of the burrows.

Minimum circumference of the burrow proximates the area required by the organism to pass through. For that, it gives an idea about the size of the organism indirectly. Maximum circumference in the same burrow, hence, indicates the space required or utilized within the sediment by the organism to hold its structure and functions. Burrow showing a great difference in values of these two circumferences would indicate that the organism requires a lot of space to run its functional activities. Bimodal distribution of circumference variation along a burrow indicates that the animal divides its functional activities

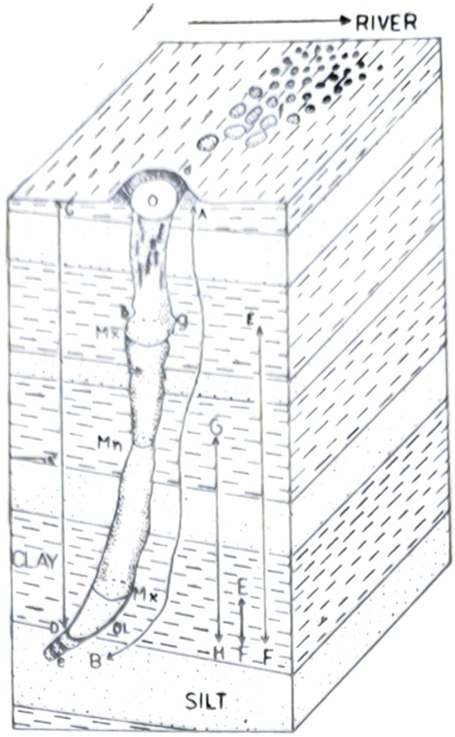

Fig. 2. A schematic representation of burrow morphologies and parameters within a sediment block. AB—actual length, CD—vertical length, Mx—maximum circumference, Mn—minimum circumference, EF—heights of maximum circumference, GH—height of minimum circumference, O—opening, d—domal structural around opening, e—escape structure, OL—organic lining, S—scratch marks, g—grooves, b—bulbs, Q—dip of the laminations, f—fecal pellets.

Vertical length—Vertical distance from the bottom to the topmost part (opening) of the burrow cast.
Actual length—Length along the burrow cast.
Maximum and minimum circumference—Circumference measured at the broadest and narrowest part of the burrow cast.
Heights of maximum and minimum circumference—Vertical heights from the base to the planes of maximum and minimum circumference of the burrow cast, respectively.

in two different zones. Again, the positions of maximum circumferences indicate clearly the depths of functional activities which is, in turn, related to the surrounding environment.

Owing to the habit of *Uca marionis*, an individual makes several separate burrows, one after another, as it grows older and does not stick to a single burrow throughout its life. So as to point out the major changes of the burrow forms with the growth of the organism, the burrow casts have been arranged (Plate 1) in accordance with the growth of the organism as evidenced from their size and other morphological changes. Each burrow, thus, represents a single part of the growth history of the animal.

The general features of all burrows produced by *Uca marionis*, independent of its growth, are single circular opening, almost straight and vertical unbranched shaft and rather narrow and smoothly rounded bottom end. Apparently, all the casts look alike but, different parameters when analysed, show the following trends :

(1) Vertical lengths (Fig. 3a and KL of Fig. 3b) of the burrows decrease remarkably as the animal becomes older, i.e., vertical penetration power gradually decreases.
(2) Burrows of early growth stages show clear bimodal circumference variation, i.e., in each burrow there are two prominent bulbous areas. The circumference

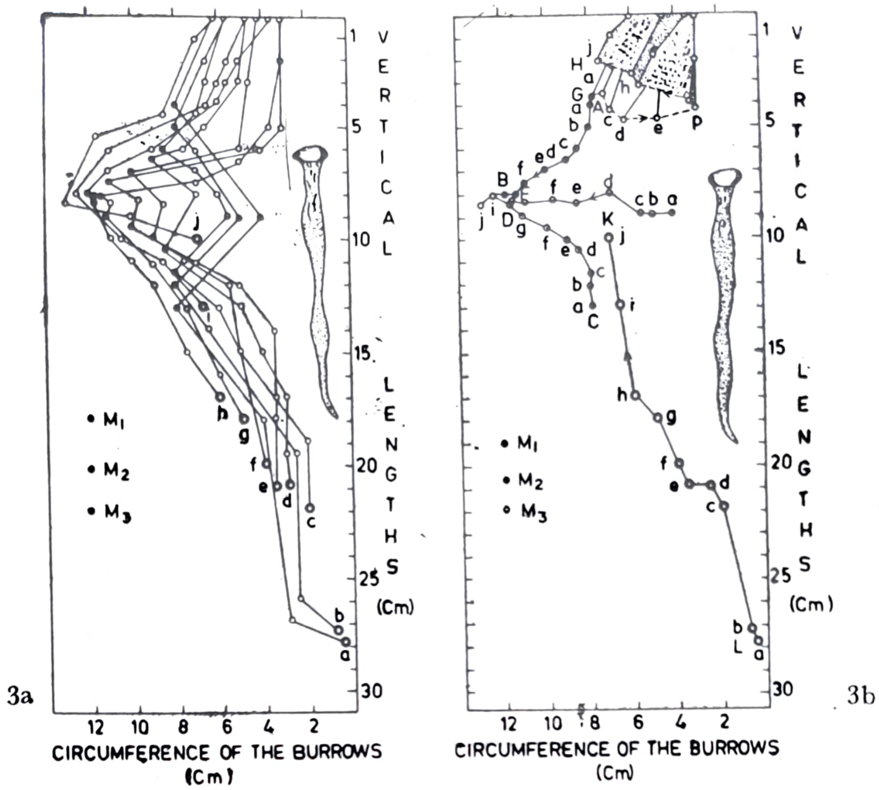

Fig. 3. Graphical representation of the measured parameters of burrow casts. a, b, c......j represent the cast numbers arranged according to the growth of the organism. Cast a and j stand for earliest and latest stage, respectively.

a. Curves (total 10 in number) representing the nature of changes of circumference of burrow casts with the change of vertical lengths. M_1 and M_2 are the positions of maximum circumference, called lower and upper mode, respectively. M_3 is the position of minimum circumference.

b. AB—upper maxima development curve, CD—Lower maxima development curve, EF—Minima development curve, GH—circumference variation curve at the openings shown on a curved plane, KL—maximum vertical length variation curve of the casts. In each case, the arrow head indicates the direction of oldest stage of growth.

variation curves (Fig. 3a) through different growth stages show several peculiarities. In early stages, the upper mode (M_2 in Fig. 3a) gradually descends while the lower one (M_1 in Fig. 3a) ascends (curves AB and CB respectively in Fig. 3b). Ultimately in "i" stage two modes coincide to form a single mode (12.5 cm, Fig. 3b) which, in the long run, descends slightly with increase in numerical value towards the oldest stage. The minima (M_3 in Fig. 3a) in between these two modes exists and retains a fixed height ($\approx$8.5 cm below oepning) for long time and at last vanishes in "i" stage (curve EF, Fig. 3b). Actually, the convergence of two circumference maxima (modes) to a common point in between causes extinction of the said minima. It is evident from the above analysis that functional activities of *Uca marionis* inside the burrows are confined in two separate zones for most of the time of the life period and towards the older stages they require a single zone for the same.

(3) Circumference of the openings decreases in the middle order stages and then increases (curve GH, Fig. 3b) at the older stages exactly up to a limit possessed by the youngest stage. In other words, recapitulation of the opening size of the younger forms by the older ones is evident, a fact not reported so far from anywhere.

(4) Numerical values of maximum circumference increase consistently like that of minimum circumference (curves AB, CD, EF ; Fig. 3b). These are due to gradual increase of functional activities and body size of the organism with its growth. Moreover, these indicate that the burrows become stout gradually.

(5) Average circumference of the burrows increases with decrease in the vertical lengths (Fig. 3c). This also supports the fact just mentioned above.

All the changes of the burrows with the growth of the organism, *Uca marionis*, have been epitomised in a model (Fig. 4).

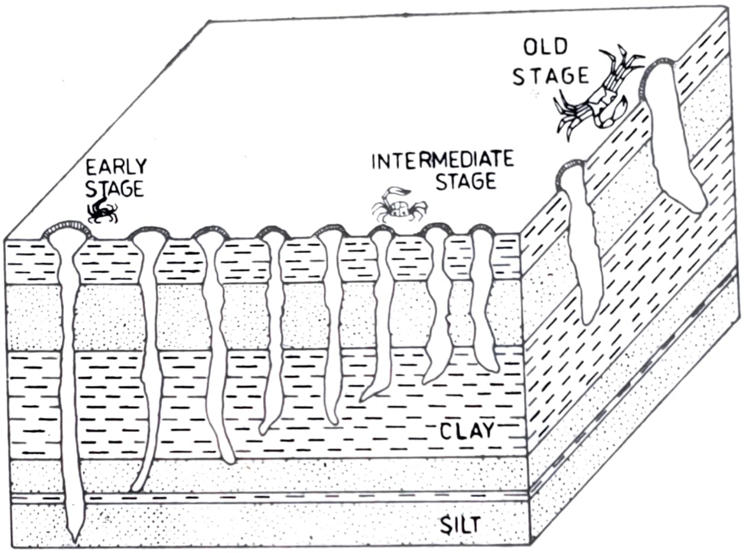

Fig. 4. A model showing the gradual change of burrow morphologies with the growth of the animal *Uca marionis*. Growth stages have been broadly divided into 3 stages (early, intermediate and old).

The inner surface of the burrow shafts, i.e., the outer surface of the casts, contains almost parallel scratch marks just beneath the opening and numerous small hemispherical grooves and bulbs in their middle part followed downward by very smooth lower part (Fig. 2) due to the presence of lining of organic matter. Biostratification, left preserved at the bottom of many burrows, is composed of concave upward lamina stacked for a height of 1 cm to 2 cm. The material composing this structure is different from that composing the host sediment. Moreover, there is so remarkable difference in layering between this structure and the host sediment that this has been identified as "escape structure" (GOLDRING, 1964, FARROW, 1971 and SCHAFER, 1972) and not as a "collapse structure" of HOWARD, 1971.

The following are the generalised statements derived from the above discussion.

Simple, linear and nonbranching burrows with single circular opening indicate a very simple mode of inhabitation. The ability of the organism to penetrate the sediment vertically decreases as it grows older along with the decrease in actual burrowing power. Functional activities are localised within the burrow at two separate levels for youngs and adults. Older forms do confine these in a single level. Adults are found to take more protection of their burrows forming rather smaller openings. Gradual stoutening of the burrows is a characteristic feature of this species. Presence of organic lining indicates a stable and undisturbed burrows, not being affected by the scouring action of the river water. Frequent presence of "escape structure" reflects an active phase deposition without any erosion (FARROW, 1971, GOLDRING, 1964 and REINECK, 1970).

Moreover, orientation of the burrows may be helpful in fixing the direction of nearest river flood plain. Burrows dip generally towards the flood plain at very high angles.

CONCLUSION

The burrows of *Uca marionis* on an actively building, clay dominated, salt marsh river (meandering) bank define a definite, long and narrow "burrow zone" parallel to the river course. Burrows are distinct, unbranched, complete and untruncated with almost straight cylindrical shape and circular openings. All of them dip at very high angles away from the river towards immediate flood plain. Changes in burrow morphology are seen to be totally controlled by the growth of the organism. Gradual stoutening of the burrows with growth is evident. Organic lining is always present towards the bottom part of the burrow followed downward by frequent "escape structure". The surfacial activities produce sediment domes around openings and biogenic grading of fecal pellets which is improved later by current action. Burrow density decreases remarkably in highly water laden sediment in and around tidal creeks. Co-existence of deep to shallow untruncated shafts with "parallel laminated to burrowed" sequence is suggestive of active accretion (deposition) without any erosion.

The burrows indicate a high rate of sedimentation without any erosion in low energy condition. Tidal current directions can be detected from the current improved biogenic grading of fecal pellets. Wide deformation zone around opening reflects a firm bottom sediment with low water content. Growth dependent changes of burrow morphologies are useful in determining ontogenetic stages and evolutionary history of the organism. River flood plain can be located in the direction of burrow inclination. Tidal creeks mark the discontinuities in "burrow zone". *Uca* burrows invariably indicate a salt marsh environment of their growth. More precisely, *Uca marionis* burrows, in all probability, indicate a clay dominated, rapidly depositing and fluviatile environment within a deltaic platform.

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EXPLANATION OF PLATE

Plate 1

Photographs of the burrow casts arranged according to the growth of the organisms. Cast number a and j correspond to the earliest and oldest stages of growth, respectively. The burrowers (adult *Uca marionis*) can also be seen in the plate.