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INTERPRETATIONS ON THE PATTERN OF WIND AND WATER MOVEMENT OVER LOWER LONG SAND FROM STUDIES ON TEXTURE AND STRUCTURE OF THE SEDIMENTS

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ABSTRACT

Various geomorphic units of the Lower Long Sand — a dominantly sandy tidal shoal of the Bay of Bengal, have been delineated and studied with special reference to sedimentary structures and grain-size distributions. The bed forms and internal structures in each geomorphic unit are unique as regarding their time and space of formation and have been utilized in interpreting the flow dynamics and flow patterns.

The dunes are the most conspicuous structures of the dune field and supratidal zone and they readily point to a dominantly south-southwest direction of wind. The intertidal zone structures *viz.*, swash marks, rhomboid marks and bicrestal ripples indicate a bipolar-bimodal flow pattern. The cross-ripples, capped-off ripples are important to indicate the interference of currents. The rill marks, current crescents and algal crescents form udder the dominant influence of backwash and point to unidirectional movement of water. The grain-size distribution curves of the intertidal zone sand — flats exhibit two saltation populations and reflect wave action under conditions of swash and backwash.

INTRODUCTION

THE LOWER LONG SAND (21°30′ N ; 88°0′E), a tidal shoal rather a tidal island of the Hooghly Estuary is situated in the Bay of Bengal at a distance of about 46 km south-southwest of Kakdwip point of the mainland. The island is subelliptical in outline having a length of about 2 km from north to south and about 1 km from east to west (Fig. 1). The central part of the island has an average elevation of 4 m. The intertidal regions encircling the island range in width commonly between 50 m to 150 m with a slope ranging between 2° to 6° seaward. During storms, the tidal level rises higher up to inundate parts of the supratidal backshore regions. The intertidal regions of the island are under the direct tidal influence of the Bay of Bengal on all sides and, thus, acts as open sea intertidal regions of the estuary.

The present paper is chiefly concerned with the dune structures of the supratidal dune fields and backshore regions and various bed forms of aqueous origin of the open sea intertidal regions. These structures have been studied with their morphological details in order to understand the direction and pattern of wind and water movement over the island. The grain size characteristics of the supratidal and intertidal sand flats have been utilized to interpreting the dynamics of flow.

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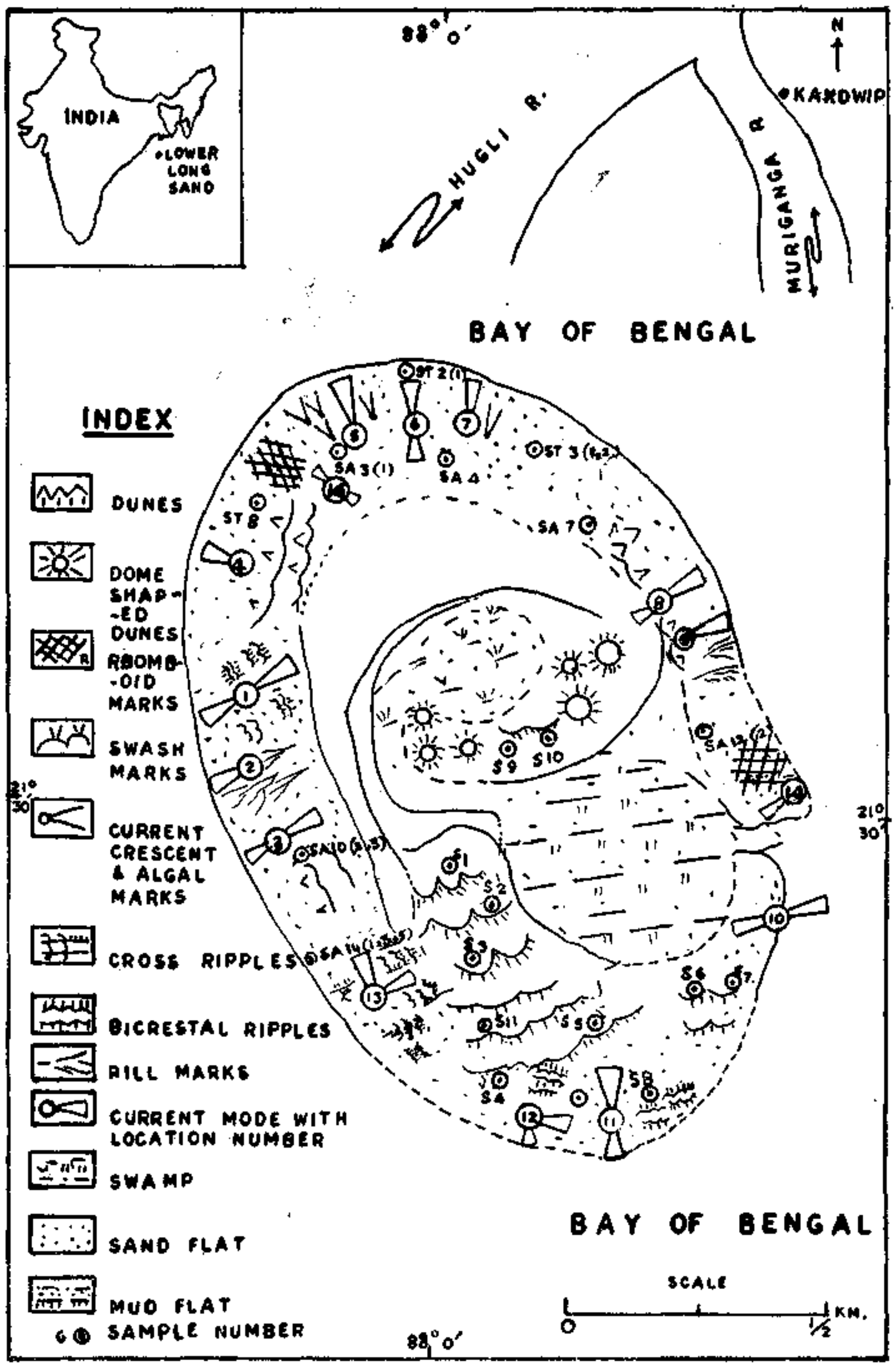

FIG. 1. Schematic map of Lower Long Sand showing current modes from surface structures.

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Geomorphic Units of the Island

From the centre to margin on all sides, the island is characterised by the following geomorphic units :

a. The dune fields indicate zones of highest elevation in the south central part of the island. This elevation of the dune field is primarily attained by scarp faces at the limit of backshore. The dune fields are exclusively supratidal and are characterised by wind action throughout the year. Topography is undulating, often well vegetated, with mature and more or less stable dunes and interdune trough areas.

b. The backshore zone starts from the mean high tide line and extends to the lower limit of sand dunes. This zone also belongs to the supratidal regions. Occasionally, the level of high water exceeds the mean tidal high water level and inundates the backshore regions. Topography is almost flat with minor undulations. This zone is characterised by embryonic dunes which are in process of formation along with certain herbs, grasses, creepers and shrubs.

c. The foreshore region lies between the spring tide mean low water line and mean high tide line. This region represents the true intertidal regions with a seaward gentle slope. The uniformity of the slope is often dissected by parallel to shore running runnels and ridges and also by sinuous tidal creeks. Bed forms like swash marks, rhomboid marks, rill marks, ripples and current crescents are most important of this zone.

d. The shoreface starts from the mean low tide line to farther deeper zones to extend to the transition zone that lies between offshore and shoreface. This zone is characterised by subaqueous ridges and shoals of variable dimensions.

Dunes of the dune field and backshore regions and interpretation of wind-blown direction.

The vigorous wind action in the island seems to be responsible for the movement of the foreshore sands to the backshore and dune fields. The dune field is comprised of more or less stable vegetation-covered dunes of large size compared to less stable embryonic dunes of backshore regions.

Morphologically, the dunes are chiefly of transverse and barkhan types when fully developed. Histograms showing the different geometric elements of dunes are shown in Fig. 2.

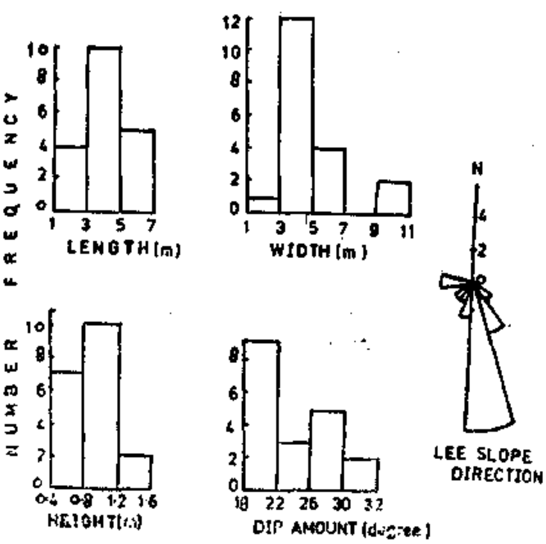

FIG. 2. Dimension and direction of dunes of Lower Long Sand.

At their initial stages of growth dimensionless mound-shaped bodies of aeolian sands are common. Unlike desert dunes, these dunes are soaked with rain water and the sediments forming them have a moderate amount of cohesion. They are in all cases associated with plants. Plants like *Paspalum vaginatum*, *Salicornia* sp., *Opumtia* sp., *Cynodon dactylon*, *Suaeda maritima* and *Aeluropus logopoides* are essentially related to the embryonic stages of dunes. Certain other species as *Ipomaea biloba*, *Launera* sp. and *Sesuvium portulacustrum* are mostly related to the mature dunes. These plants have manifold roles to play in dune formation. (i) the plant roots act as sand binders, (ii) their leaves and stems help fall out of suspended sand, and (iii) plant root matting arrests dune migration and consequently helps stabilization of dunes. These dunes in all respects show close resemblance with other coastal dunes (McKee and Bigarella, 1972).

The crests of dunes are often sinuous in plan and run parallel to southern shoreline. They form under condition of a single dominant wind direction as marked by their southerly and south-southwesterly lee slope directions. The inclinations of their internal cross laminations also indicate more or less the same directions.

Records of wind direction and wind velocity from the island reveal that wind velocity becomes maximum to the order of 30 to 50 km/h during the months of Aptil to June whereas, between December to February wind velocity becomes 1-4 km/h. Further the wind direction during winter months is dominantly toward north and north-east. For other months of the year, wind-blown direction becomes south-south-west, This proves that the wind strength and wind direction during summer are solely responsible for dune formation.

Structures of intertidal zones and interpretations of current patterns

Various bed forms of aqueous origin characterise the intertidal regions and they are very diagnostic to interpret the current patterns responsible for their formations (Fig. 1). The bed forms are as follows :

Swash marks : These are U-shaped markings formed during upward run of wave swash and V-shaped markings during backwash (Emery and Gale, 1951). The distance between successive swash marks vary between 2 cm to 5 m depending on the beach slope. With increasing beach slope the distance between swash marks decreases.

The swash marks are 1 to 2 mm high, thin, sinuous sand ridges produced at the limit of greatest advance of the swash in the intertidal zone. The directions along the axis of the U and V marks indicate the oppositely moving direction of water. The axis of U and V swash marks designate a bipolar and bimodal flow direction (location number 3, 8 of Fig. 1).

Rhomboid marks: These are rhomboidal patterns or diamond-shaped marks (Otvos, 1964) produced by wave backwash on gently sloping (1° to 6°) intertidal zones with materials more than ninety-five per cent of fine to very fine sand. Hoyt and Henry (1963) explained similar releation of rhomboid marks with slope and grain size although with certain differences of values. These marks range in length from 2 cm to 8 cm with the commonest values between 3 cm to 6 cm. The ratio of long to short diagonals ranges between 2 : 1 and 3 : 1.

These structures form under conditions of high back flow of water with a depth of even less than 2 to 3 cm. The long diagonal of rhombs are more or less parallel in localised areas and are oriented at right angles to the shoreline. The direction bisecting the acute angles of the rhombs, thus, points to a bipolar-bimodal flow pattern (location number 16, 14 of Fig. 1).

Current crescents : These are crescentic scour marks of few centimetres length produced mainly by the wave backwash against stationary tools made of sand or mud pellets, globules and small animal shells. The crescents broaden in the direction of flow of water for 2 to 3 cm.

The sand or mud pellets or globules which act as obstacles in the path of wave backwash are mostly derived from the intertidal zones and are produced by the burrowing red crabs *Ocypoda macrocera*. The current crescents are invariably oriented more or less at right angles to the shoreline and point toward the direction of sea, (location number 5, 7 of Fig. 1).

Algal marks: These are semicircular or hook like obstacle marks formed against globular algal bodies. The hooks open along direction of wave backwash and are 2 to 3 cm long and 1 to 3 cm width. It is absolutely a new finding and is not known to be reported earlier.

Algal marks abound in the intertidal zones during winter months of December to January when the seawater suffers extreme fouling by the prolific occurrence of *Halicystis*, a marine alga having a water-saturated globular mass *i.e.*, the vesicle of dark amber to dark green colour. The globose vesiles of 1 to 3 cm diameter are carried to the intertidal zone by wave swash and come to the position of rest during wave backwash. These bodies act as obstacles along the path of succeeding wave backwash. These obstacles tend to accumulate sand on their downcurrent side in the shape of a hook which opens downcurrent and form a semicircular depression of 1 to 3 mm on the upcurrent side. After sometime, the globular mass

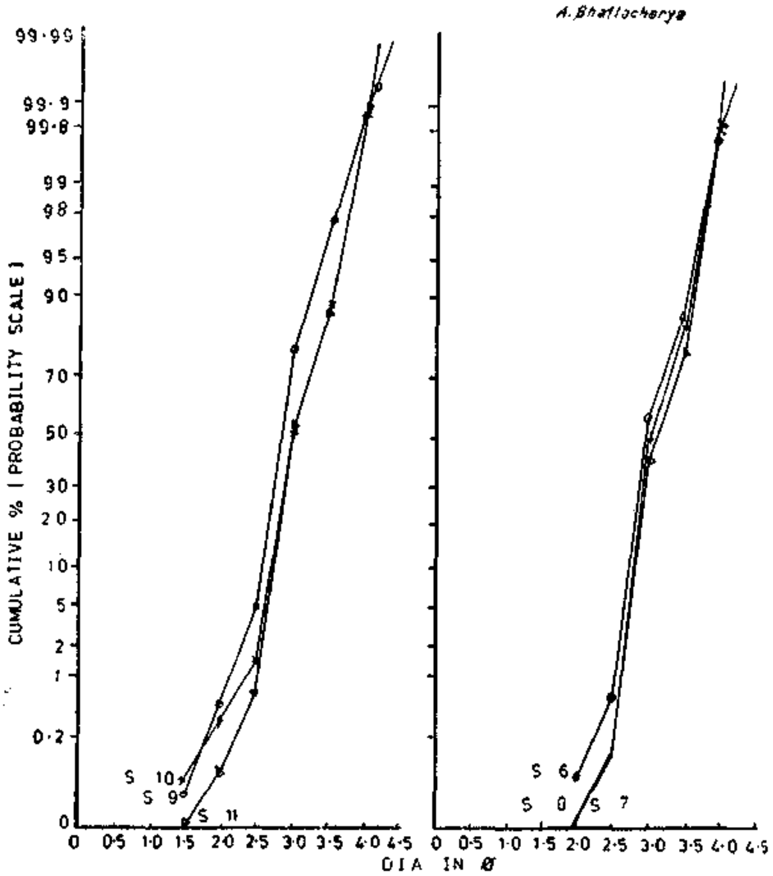

FIG. 3. Dune samples of Lower Long Sand.

breaks down leaving only a thin circular marking on the intertidal zone.

Algal marks develop on very fine sand and silt deposits having slope between 1° to 4°. They are oriented at right angles to the shoreline and point toward the direction of sea.

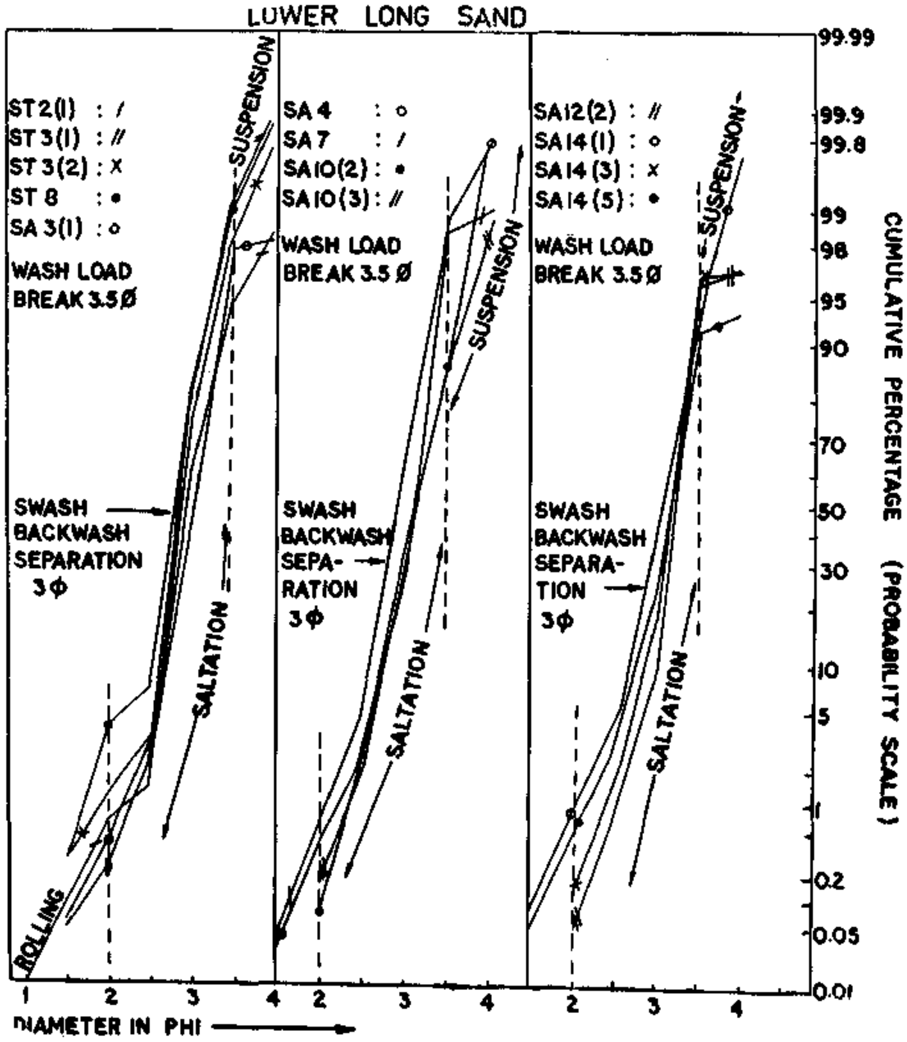

FIG. 4. Cumulative curves of the intertidal zone sandy samples of Lower Long Sand.

Rill marks : These are dendritic structures which originate when a film of water flows over a sediment surface followed by a change from subaqueous to subaerial condition (Reineck and Singh, 1980). The water stored in the parallel to shore shallow depressions or runnels during rising water level is drained out of the sediment during falling water level. The percolating water of these zones accumulate into small rills which subsequently join to form the branching rill marks. The rill marks have U-shaped cross-section and they range in length between 1 to 8 m and in width between 15 cm to 2 m.

The rill marks always widen with more branching toward downslope direction *i.e.* toward the sea. They indicate alignment at right angles to the shoreline.

Bicrestal ripple marks : These are wavy structures with straight or sinuous crestal patterns having wavelength ranging between 10 and 30 cm and ripple height less than 1 cm. The ripples marks are characterised by double crests which often show bifrurcation. These ripple marks are formed by joint influence of wave swash and backwash movement of water. The stronger crest of the ripples with lee slope pointing against the direction of sea is formed by uprush of wave swash. The crests of these ripples may be made flat or capped off by backwash to produce bicrestal ripple marks.

There are gradation from single crested wavy ripples with lee slope pointing against sea direction through bicrestal ripples to again single crested wavy ripples having lee slope pointing the direction of sea. The bicresta ripple lee slopes indicate bipolar-bimodal current direction (location number 10, 11 of Fig. 1).

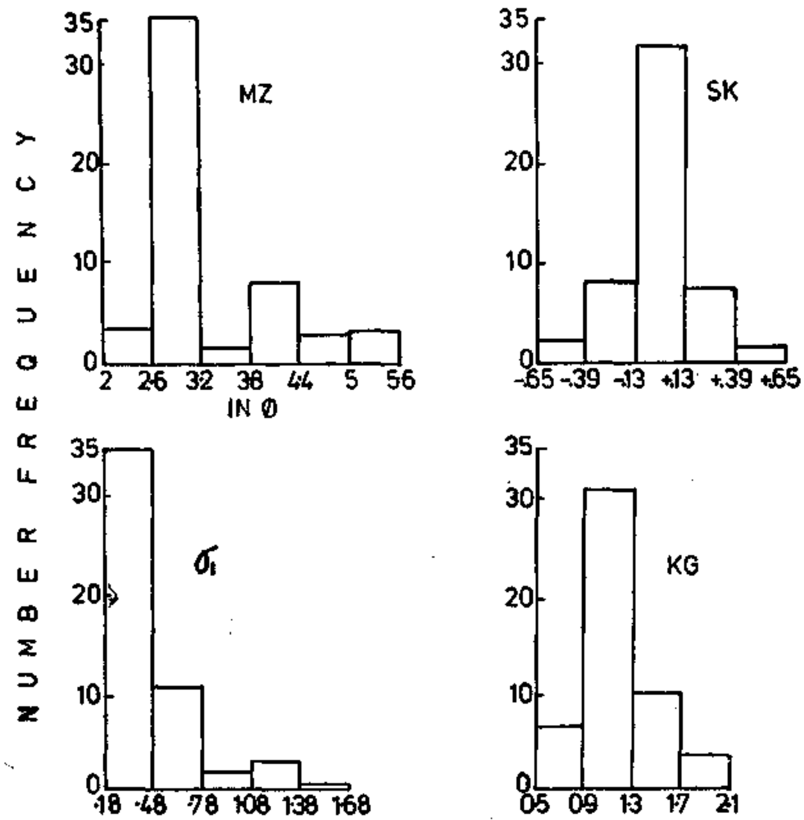

FIG. 5. Variation of size parameters of sediments of intertidal zones.

Cross ripple marks : The intertidal zones in different portions exhibit excellent development of cross-ripple marks of varying scale. These are characterised by two distinct sets of asymmetrical ripple marks differing in both wavelength and ripple height. The two sets intersect at right angles to oblique angles (60°). The average wavelength of the larger set is 5 cm whereas that of the smaller set is 2 cm. The smaller set has affected the crestal parts of the larger set more prominently than the trough regions.

These ripple marks are supposed to result from a single wave on the sloping intertidal zone. A wave swash rushing up the slope in an oblique direction may produce larger asymmetric ripples, whereas, the water on flowing back down the slope during backwash may give rise to a large number of smaller ripples intersecting at angles varying from 90° to 60° or so. These cross ripples, thus, originate simultaneously (Bucher, 1919). McKee (1957) suggested that the two sets differ in their time of formation (location number 12, 13 of Fig. 1).

Texture of the dune field, backshore and foreshore sediments

The sediments of the island are mostly sandy, although mud deposits of about 30 cm thick occur locally on the southern fringe of the island. Apart from this, mud deposits characterise the central marshy region of the island. Twelve samples from the dunes have been analysed mechanically by sieving. The grain-size distribution curves show a more or less straight line pattern indicating the distributions to be almost lognormal (Fig. 3). Each cumulative curve, however, shows inflections at 2.5 and 3.5 phi size and over 95% of the materials in each distribution lie within fine to very fine sand size. These distributions, thus, represent a single saltation population.

Thirteen samples of the intertidal zone have also been analysed by sieving. The grain size distribution curves exhibit prominent inflections at 2 to 2.5 phi and 3.5 phi size which devide each curve into three straight line (lognormal) segments of which the chief segment stands for the saltation mode transport of particles (Fig. 4). A very minor, but significant inflection at about 3 phi reflects a change in flow condition from swash and backwash (Visher, 1969).

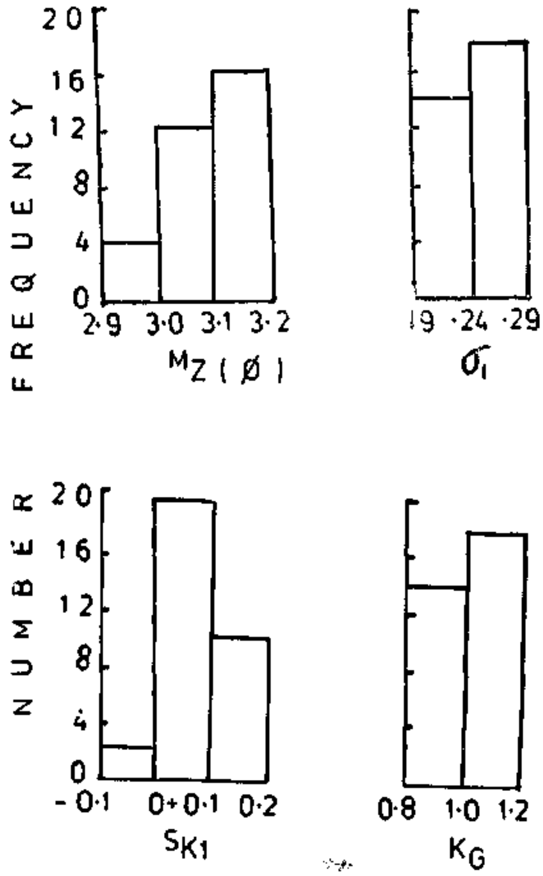

FIG. 6. Size parameters of supratidal zone sediments.

A comparison of the statistical size parameters (after formula of Folk and Ward, 1957) of the sediments of intertidal zone and sand dunes (Fig. 5, 6) shows that the dune sediments are finer in size and better sorted than the adjoining intertidal zone sediments. The dune sands signify their derivation from reworking of the intertidal zone sediments.

REFERENCES

BUCHER, W. H. 1919. On ripples and related surface forms and their palaeogeographic interpretations. *Am. Jour. Sci.*, **47** : 149-210.

EMERY, K. O. AND J. E. GALE 1951. Swash and swash marks. *Trans. Am. Geophy. Union*, **32** : 31-36.

FOLK, R. L. AND W. C. WARD 1957. Brazos river bar : a study in the significance of grain size para meter. *Jour. Sed. Petrol.*, **27** : 3-26.

HOYT, J. H. AND V. J. HENRY 1963. Rhomboid ripple marks, indicator of current direction and environment. *Ibid.*, **35** : 604-608.

McKEE, E. D. 1957. Primary structures in some recent sediments. *Am. Assoc. Petroleum Geophysics Bull.*, **41** : 1704-1747.

——— AND J. J. BIGARELLA 1972. Deformational structures in Brazilian Coastal dunes. *Jour. Sed. Petrol.*, **42** : 670-681.

OTVOS, E. G. JR. 1964. Observation on rhomboid beach marks. *Ibid.*, **34** : 683-687.

REINECK, H. E. AND I. B. SINGH 1980. Depositional sedimentary Environment. *Springer-verlag, New York*, 480 pp.

VISHER, G. S. 1969. Grain size distributions and depositional processes. *Jour. Sed. Petrol.*, **39** : 1074-1106.