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Granulometric Studies on Modern Barrier System of the Right Bank of Krishna Delta, East Coast of India

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Granulometric studies have been undertaken on 3 sand spits present on the right bank of the Krishna river confluence with the Bay of Bengal. The size parameters (mean size, standard deviation, skewness and kurtosis) and CM diagrams are discussed. The past and the present growth rates of the delta are evaluated to support the granulometric studies. Major spits I and II have reached stability while spit III, which emerged at the mouth is still in active growth. The progradation of the Krishna delta is due to the development of the bars and spits, leading to the consequent filling of the lagoonal areas. The present progradation of the deltaic facies ultimately may pave the way for the disappearance of the bay.

Phenominal changes occur mainly along the coastal parts of most of the deltas. Changes that are observed even within a short period of time are of immense value to understand the modern deltaic processes that are affecting the evolution of spits and bars[1]. Earlier studies on Krishna delta pertain to geomorhic features[2] and the evolution of delta progradation[3-6]. The present investigation mainly deals with the granulometric studies of the barrier system and its development on the right bank of the Krishna river at its confluence with the Bay of Bengal.

Study Area

The Krishna river is the second largest river in south India with a drainage basin of 258948 km^2. The maximum discharge[7] of the river is of 1027 $m^3.sec^{-1}$. The solid material carried in suspension by the river at Vijayawada anicut is estimated as $156.5 \times 10^6 m^3.y^{-1}$. The major geological formations traversed by the river consist of Deccan traps, unclassified crystallines, Cuddaphas and Khondalites.

The area of the present investigation (lat. 15°40′ to 16°10′N and long. 80°30′ to 80°55′E) covers about 1225 km^2. The maximum elevation in this area is 13 m above MSL. The slope is very gentle towards the sea with an average value 1:0.0002. On the southern most right bank boundary of the Krishna delta 3 sand spits are present (length, 8.75, 9.75 and 3 km; width 575, 550 and 275 m respectively and average height of these spits is 1.25 m).

Methods

Surfacial sediment samples (400) were collected from various sedimentary depositional environments of the lower Krishna delta during 1985-1987, of which 55 samples were from the sand spits examined presently. Shell fragments were removed from the samples before sieving. All the sand samples were subjected to mechanical analysis with 0.5 ϕ interval, using A.S.T.M. sieves on a Ro-tap shaker. In the case of samples containing > 5% silt and clay, pipetting method of grain size analyses was used to calculate the sand silt and clay ratios. The granulometric parameters were computed by the modified graphic method[8].

Relationship between mean size and standard deviation, mean size and skewness, standard deviation and skewness, and skewness and kurtosis was tested for the sand spits of Krishna delta. CM pattern diagrams representing C (one percentile) and M (median)[9-11] were prepared to find out the energy condition favouring deposition.

In the present work, aerial photographs of 1968 (1:60000 scale), 1978 and 1983 (1:20000 scales) were studied. Information on the barrier system was also collected from 1987 landsat imagery. Toposheets of 1928 on 1:63360 scale were available as the earliest record showing the shape of delta front. For purpose of comparison the features identified from the airphotos of different scales were brought to 1:60000 scale with the help of an aerosketch master.

In order to get the actual shape, dimensions, relief of these spits, planetable and dumpy level surveys were carried out with micro optic aledade during January 1985 and January 1987. The earlier study of Nageswara Rao[3] was also considered for comparison.

Results and Discussion

Average values of the graphic parameters of grain size distribution along the sea, lagoon sides and the central portion of the sand spits are presented in Table 1. Since spit III is fairly narrow and small in size only average value of the parameters of the sea side and lagoon side are determined.

The ϕ mean size of these spits varies from 2.9 to 3.3 ϕ. When compared to the sea side (2.85 ϕ) and lagoon side (3.02 ϕ), the central portion of the spit has relatively fine fractions (3.28 ϕ). In general the fine fractions increase from the sea side towards the lagoon side indicating the direction of transport of the sediments towards the lagoon side which can be due to the wave action and longshore currents[12,13]. However the results (Table 1) show that this observation do not apply to spit III. Spit III is located on the southern end of the Nizampatnam bay and as such the intensity of wave action is very high throughout the year. At the same time, it may be pointed out that it is a newly emerged spit and is still active in growth. No systematic variations of the grain size observed in this spit may be due to these two reasons. Further there is a gradual decrease of fine fractions from spit I to spit III. All these clearly indicate increasing energies of the wave action and shore currents from spit I to III due to the delta arc and sheltered nature of the bay.

Table 1—Average Textural Parameters of Lower Krishna Delta Spits

Location	Mean size (Mz ϕ)	Standard deviation (Sd ϕ)	Skewness (Sk ϕ)	Kurtosis (KG ϕ)
		Spit I		
A	2.971	0.671	0.271	0.903
B	3.270	0.610	0.260	0.860
C	3.218	0.806	0.106	1.108
		Spit II		
A	2.836	0.713	0.080	0.927
B	3.295	0.522	0.037	1.172
C	3.070	0.668	0.051	1.128
		Spit III		
A	2.964	0.650	0.084	1.054
B	2.880	0.766	0.186	0.997

A = sea side; B = central and C = lagoon side

Standard deviation varies from 0.52 to 0.81 ϕ indicating a moderate sorting. The low values at the centre of the spits with respect to the values of the sea side and lagoon side indicate a better sorting at the central portion. Skewness of the samples varies from 0.37 to 0.27 ϕ indicating the dominance of coarse population over the fines. Kurtosis, indicative of peakedness of the samples, varies from 0.86 to 1.17 ϕ. A general increase in kurtosis observed from sea side to lagoon side indicates platy to leptokurtic nature of the sediments in that region due to decreasing energy conditions towards lagoon.

The scatter plot of mean size *vs* standard deviation (Fig. 1a) shows that most of the samples are moderately sorted. Sorting improves with increase of the coarse fraction from spit I to III. The mean size and skewness indicate that the sediments are nearly symmetrical (Fig. 1b). The relation between standard deviation and skewness shows a circular trend (Fig. 1c). The sands are symmetrically skewed with standard deviation ranging from 0.55 to 0.75 ϕ. A positive relationship exists between skewness and standard deviation for spit II and spit III. The skewness changes from positive to nearly symmetrical with mostly mesokurtic nature (Fig. 1d).

CM pattern of sediments of the spits are approximately spindle shaped (Fig. 2) and are indicative of

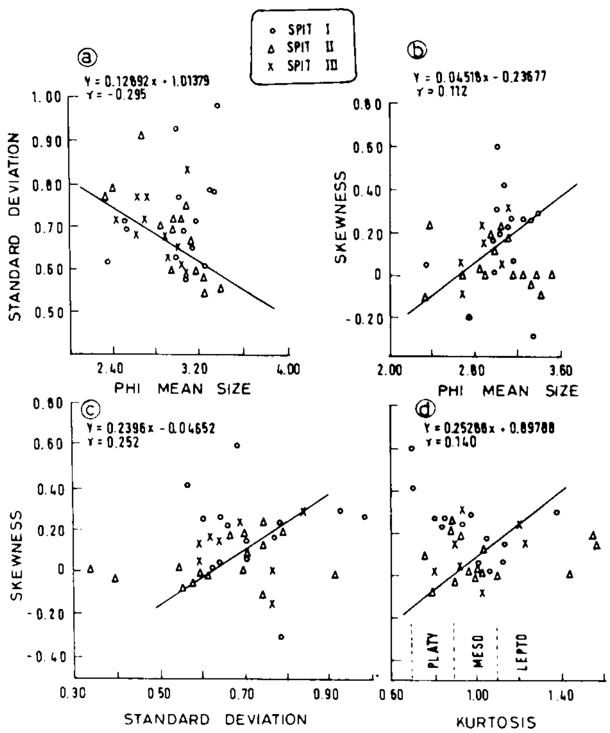

Fig. 1—Scatter plots of phi mean size *vs* standard deviation (a) and skewness (b) and skewness *vs* standard deviation (c) and kurtosis (d)

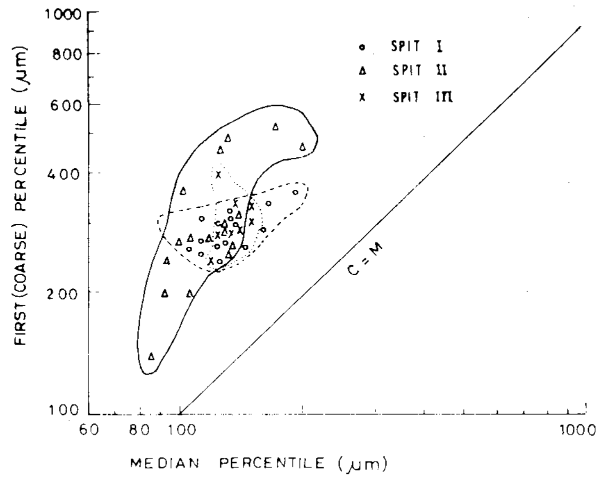

Fig. 2—C M patterns of spits

moderate depositional energy conditions. Spits I and III show moderate energetic conditions. The deviated samples (Fig. 2) reflect the higher energy conditions caused by the tidal inlet flows. The spit II area has high energetic condition due to long shore currents, direct wave action[14] and inflow of the Krishna river discharge through the Mutthaiah canal.

Depositional conditions of sedimentary environments are reflected through the grain-size parameters. It is established that medium to fine sediments with moderate sorting, positive skewness and high kurtosis infer depositional conditions[15]. It is further observed that the sediments are more rounded than the source sediments. The grain size parameters presented in the Table 1 indicate different states of sedimentation on the spits favouring an overall depositional processes.

The physico-dynamic conditions of waves, currents and winds are also favourable for a rapid deposition[14]. Thus the sedimentological and oceanographic parameters indicate a rapid growth of the spits followed by lagoon filling resulting in delta progradation in the south western region of Krishna delta.

The present spits II and III of the delta were not shown in the toposheets of 1928 prepared by Survey of India and at that time this area was under water. Vaidyanadhan[16,17] in his studies on physiographic features of India based on toposheets and aerial photomaps focussed the full-fledged sand spits I and II[17]. They came into existence due to variety of dynamic forces like cumulative action of both fluvial and marine processes. Nageswara Rao and Vaidyanadhan[18] did not observe new spit(s) except the growth in dimensions of the earlier spits. They opined that the spit I had more or less completed its phase of deposition and growth by 1978 and the rate of deposition was nominal. A thick growth of vegetation was a later development on this spit. In the present study small spit, 350 m long and an offshoot of spit I, was observed subaerially with the tip of this spit submerged towards sea, parallel to the coast (Fig. 3, marked as "a"). Existence of spit II was recorded as early as 1978 and was found under active deposition. Swamy and Rao[4] reported that the spit II was 9 km long and full-fledged, whereas it is further observed that the spit has grown now in northwest direction and extended to a length of 9.75 km. The spit III extended to a length of 2 km. Spit III presently has extended 1 km more within the past 2 y due to active deposition (0.58 $km^2.y^{-1}$). The development of spits were computed on the basis of past

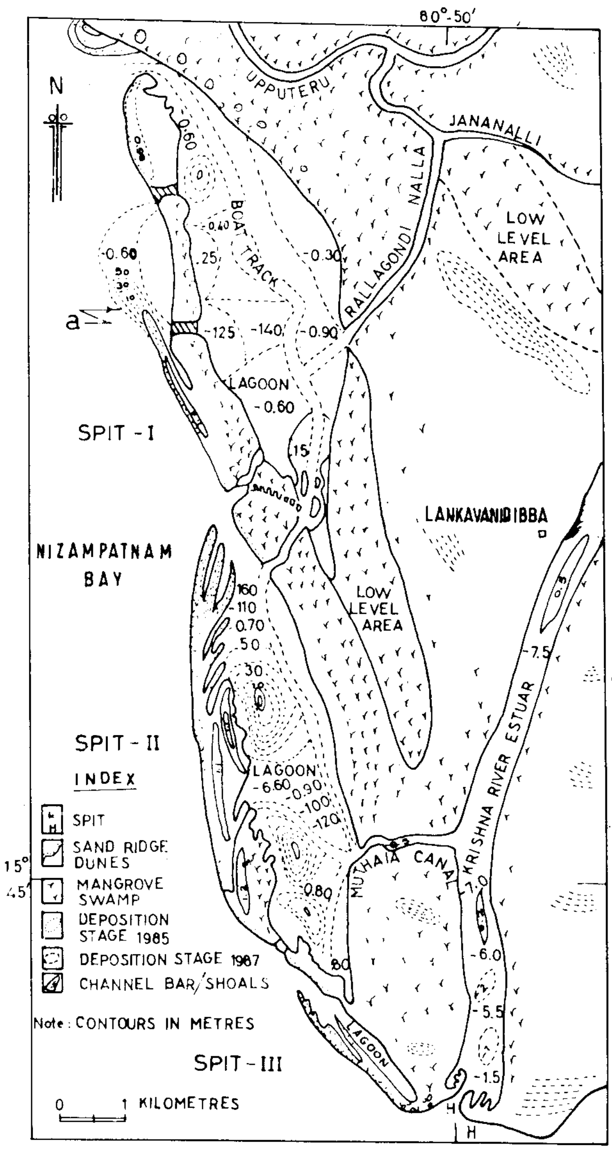

Fig. 3—Recent stage of barrier system development [based on present studies and surveys]

(1978) and present (1985, 1987) surveys. The sediments found in these areas were transported by Krishna main distributary from the provenance and the shelf sediments brought by the coastal and long-shore currents[14]. Morelock *et al.*[19] made similar observations along the Italian coast. A comparative study of available toposheets, aerial photographs and field investigations of different periods shows that the reclamation of Krishna delta was about 20, 10, 4.2 and 1 km^2 respectively from 1928-1968, 1968-1978, 1978-1985 and 1985-1987. The average rate of growth was 0.58 $km^2.y^{-1}$ since 1928. The Krishna outer delta prograded at the rate of 3.34 $m.y^{-1}$ to seaward since Holocene (Flandrian) transgression[20]. The sediments transportation and deposition of fluvio marine processes[4,5,20] towards coast begain around 7000 yBP. The growth of the delta was mainly due to the development of bars at the mouth of the main distributary and the subsequent siltation of the lagoonal areas. These spits enclosed about 24.5 km^2 area of lagoons by sediments brought in through tidal creeks which will results in siltation in these lagoons within 45 y. The simultaneous growth of mangroves might have also helped to hold the sediments[21]. Thus the progradation of Krishna delta may be understood mainly due to the barrier spit-lagoon development and subsequent continuous lagoon filling since Holocene period. The fluvial system and the progradation of the deltaic facies ultimately may pave the way for the disappearance of the bay[5].

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