

DEPOSITIONAL PROCESSES INFERRED FROM THE LOG PROBABILITY DISTRIBUTION

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ABSTRACT

396 sand samples collected by means of grab, between 3 to 13 m water depth, in three adjacent bays, viz. Kalbadevi, Mirya and Ratnagiri, west coast of India have been analysed for the study of textural parameters. The bivariate plots, prepared from the different textural statistics have shown overlapping environments, mainly among beach, dune and river. CM patterns have indicated the presence of graded suspension in Mirya and Kalbadevi bays, and uniform suspension in Ratnagiri bay. Multi-group discriminant analysis has shown two different environments over three different bays. Log-normal probability curves have been drawn and the results inferred have indicated the environmental conditions of dune for Kalbadevi bay, beach for Mirya and river for Ratnagiri bay.

INTRODUCTION

In recent years, a number of methods and applications have been introduced in the field of sedimentology in order to deduce the problems concerning the depositional processes by means of sand grain size distribution. Friedman (1961, 1967 and 1979) has advocated the study of textural parameters by an arithmetic approach, i.e. the moment method, whereas Folk and Ward (1957), Mason and Folk (1958) and Folk (1974) have approached the same problem through graphic methods. Subsequently, the results of both the methods have been successfully utilised by many workers as bivariate plots for distinguishing the different environments of deposition.

Sahu (1983) has introduced a different approach through multi-discriminant analysis by using all the four statistical parameters together for distinguishing certain typical depositional environments. Likewise, Passega (1957, 1977) has put forth the method of CM pattern which has approached the same problem by means of texture and environment as a whole. Visher (1969) has been able to recognise different depositional environments through various populations, each having characteristic straight line segments in the plot of the cumulative frequency of the respective sample.

METHODS OF STUDY

The techniques of surveying, sampling and mapping the three bays, viz. Kalabadevi (K), Mirya (M) and Ratnagiri (R) have been discussed elsewhere (Rajamanickam and Gujar, 1984). The top surface sediments of about 1 cm thick from each grab were removed uniformly from all the three bays and analysed for grain size studies following Folk (1974). In view of the uniformity maintained in

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removing the sandy materials the samples were treated as a single sedimentation unit. Weight percentages were calculated at half phi interval for all the samples and the same have been computed for obtaining textural parameters, using both moment and graphic methods. The cumulative weight percentages have been plotted on probability paper. After scrutinising all the curves of different tracks, the values of three typical tracks in each bay, one in the north, the other in the centre and another in the south have been selected for presentation here.

RESULTS AND DISCUSSION

All the three bays are located adjacent to each other (Fig. 1) and exposed to similar conditions of wind, waves and tides. However, they are different to each other in many unique factors, specially in their sediment supply. Siddiquie *et al.* (1979) have shown differences in heavy mineral distribution particularly of ilmenite and magnetite, and noticed rich ilmenite in K-bay and slightly lesser ilmenite, in M-bay and poor ilmenite in R-bay. As far as magnetite is concerned vice versa is true. Hinterland and coastal rocks around these bays are one and the same, and magnetite and ilmenite have almost identical density range and chemical resistivity. Geology of the area shows similar type of source rocks ever since Deccan flow erupted in this region, i.e. from Upper Cretaceous. The basement rocks could not be traced in the catchment areas. In spite of having common hinterland and more or less uniform physical properties of the minerals, the observed drastic change in their mineral content, led Siddiquie *et al.* (1979) to assign a variation in the source rocks. Out of these three bays, R-bay receives more sediments from the existing coastal rocks as compared to the other two bays. Rajamanickam and Gujar (1982) have mooted the idea of difference in the composition of the sediment influx between the modern river discharge and the earlier sands available in the other bays. They tried to differentiate the sands as Palaeo- and Recent-sands by using the textural characteristics (Table 1). Accordingly, it was found that K and M bays sands do not show significant difference in their nature and they betray overlapping environments of deposition consisting of beach/dune/barrier island/lagoonal salt-marsh facies, whereas the R-bay clearly indicates the dominance of river/lagoon type of depositional environment (Fig. 2).

TABLE 1 : CHARACTERISTIC PROPERTIES IN THE SEDIMENT TEXTURE AMONG THE THREE BAYS

Texture	Kalbadevi	Mirya	Ratnagiri
Mean, frequency distribution	1.28 to 4.19 ϕ (3.32 ϕ Ave.)	2.30 to 4.80 ϕ (3.45 ϕ Ave.)	0.98 to 6.45 ϕ (3.95 ϕ Ave.)
Mode-Primary	Bimodal 3 to 4 ϕ	Bimodal 3 to 4 ϕ	Bimodal 3 to 4 ϕ
Secondary	1 to 2 ϕ Finer sediments in center are surrounded by coarser ones	0 to 1 ϕ General decrease of grain size from E to W except in southern part of bay	0 to 1 ϕ Gradual decrease of grain size seawards
Standard Deviation	0.39 to 2.59 ϕ (0.74 ϕ Ave.) Moderately to well sorted good negative correlation with mean	0.55 to 1.50 ϕ (0.83 ϕ Ave.) Moderately to well sorted no such correlation	0.58 to 2.57 ϕ (1.18 ϕ Ave.) Poor to moderately sorted good positive correlation with mean
Skewness	1.0 to 0.9253 (0.11 Ave.) Sands in middle are negatively skewed and on either side of the same positively skewed	-1.00 to 1.00 (0.19 Ave.) Predominantly negatively skewed	0.50 to 1.00 (0.61 Ave.) Mostly positively skewed
Stochastic	1.28 to 27.58 (9.76 Ave.) Variations in these values are directly related to grain size	0.17 to 14.19 (7.27 Ave.) Do not show much variation except in the central part	1.39 to 16.38 (4.82 Ave.) Gradual seaward decrease

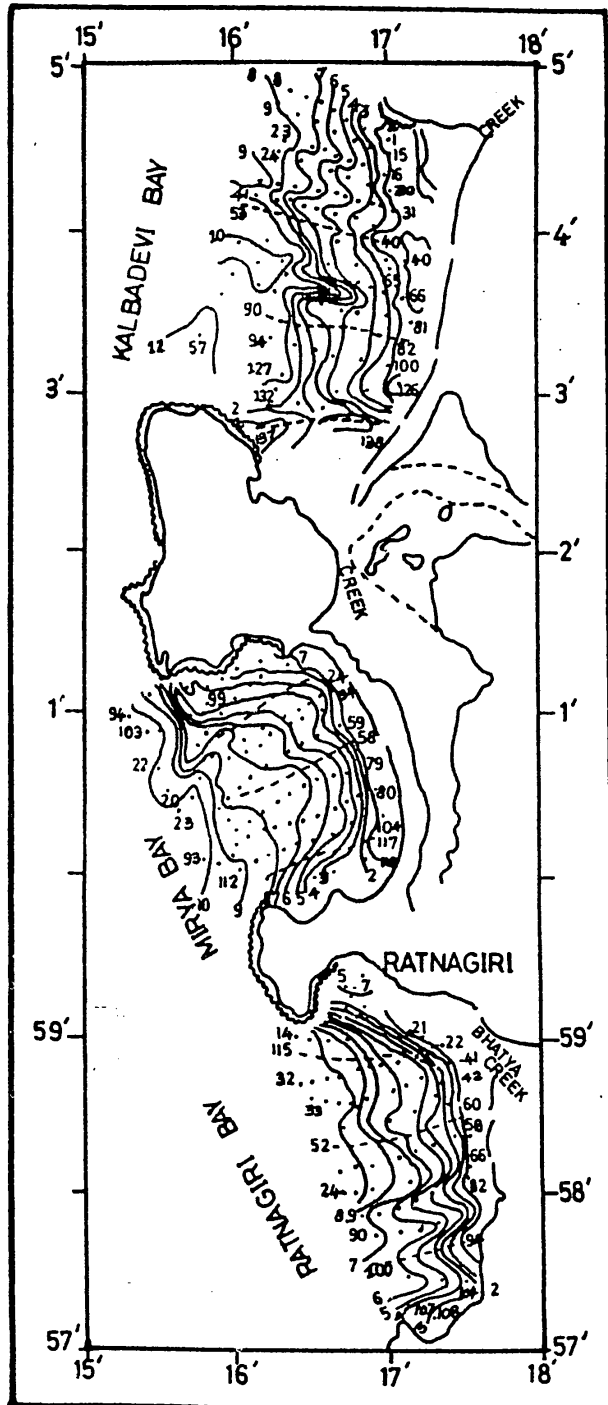


Fig. 1. Map showing position of samples and bathymetry for Kalbadevi, Mirya and Ratnagiri Bays, Maharashtra.

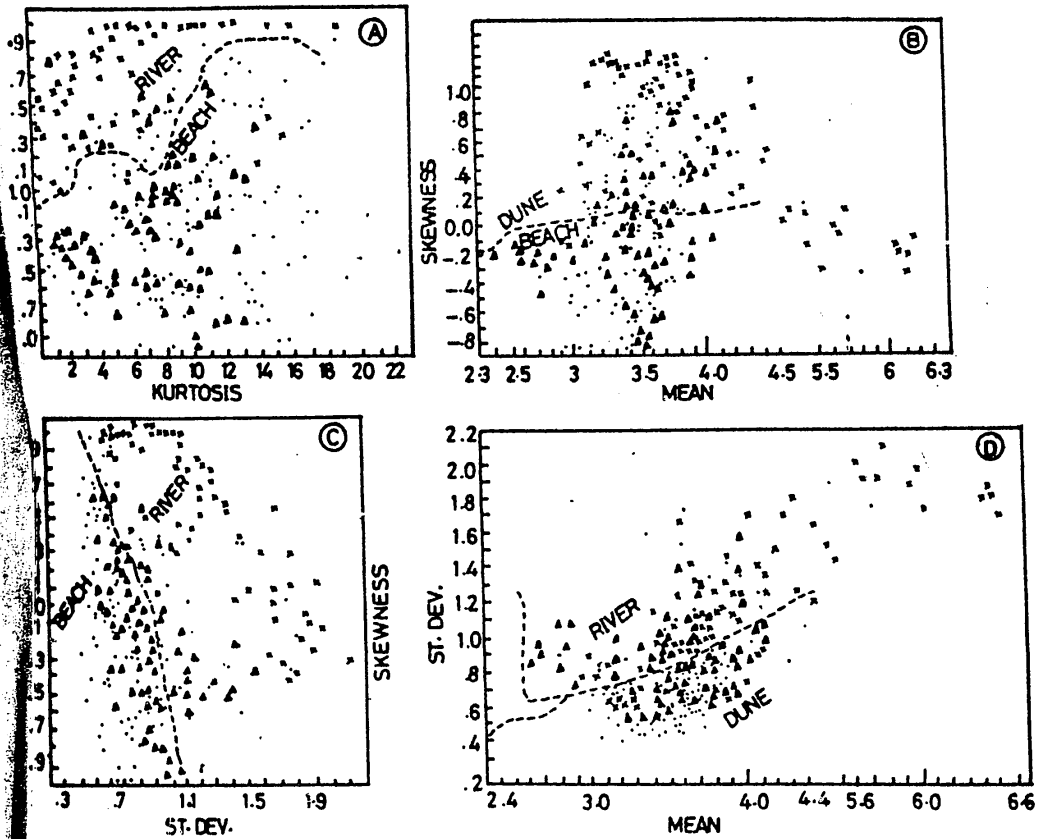


Fig. 2. Bivariate plots of (A) Kurtosis vs skewness, (B) Mean vs skewness, (C) Standard deviation vs skewness, and (D) Mean vs Standard deviation for the sediments from Kalbadevi, Mirya and Ratnagiri bays (after Friedman, 1961)

From the results of multigroup discrimination studies, Rajamanickam and Gujar (1988) have assigned a depositional environment of aeolian to K-bay, beach to M-bay and shallow marine to R-bay (Fig. 3). However, because of the higher values of standard deviation (0.74ϕ) obtained in K-bay, it can also be treated along with the R-bay in getting fresh sediments through the rivers Kalbadevi creek to K-bay and from Kajvi river to R-bay. The additional materials brought by these drainages must have probably shadowed the original characters of the sediment materials existing in the depositional basin into shallow marine conditions (Fig. 3), while in Mirya lack of such possibilities allowed the sediments to retain their original characters of beach. CM patterns (Fig. 4) suggested the presence of uniform suspension in R-bay. Rajamanickam and Gujar (1986) have described the derivation of the sands of K and M bays to a palaeo-source, entirely different from the present day river discharge in R-bay.

Although at present in shallow marine conditions, the results of the bivariant plots place the sands of K-bay dominantly to a dune characteristics (Mean vs skewness : Mean vs standard deviation), M-bay mainly to beach (Kurtosis vs skewness) and R-bay chiefly to riverine shallow marine conditions (Standard deviation vs skewness). The CM pattern also shows difference in being the sands of uniform suspension in R-bay and graded suspension in K and M bays. Rajamanickam *et al.* (1986) from the study of wave refraction in the adjacent bays have projected that the sediments from one bay to another are not getting mixed up because of the convergence prevailing opposite to promontories in between the bays. Similarly, here also, it is felt that the K and M sediments are not transported from one to another and maintained their original characters.

Likewise, log probability curves have also been constructed and the results are given in Table 2. Accordingly, the sands in K bay are significantly uniform in consisting of three populations but dominantly of saltation population and the slopes are more or less uniform indicating the well sorted nature of the population. The good sorting of the saltation population is suggestive of larger amount of reworking undergone by these sands. When one attempts to scrutinize further within the bay, the bottom track samples display the presence of not only higher amount of surface creep fraction but also comparatively poor sorting. This might have happened due to the minor amount of admixture of coarser nature of debris introduced into the bay through the southern creek (Fig. 1). Further, this track has shown a sharp truncation in the finer fraction unlike the other two tracks where the truncation is more or less smooth, and the same may be assigned to the influence of the breaking waves, caused by the tidal shoal existing close by this track (Fig. 1). The dominant saltation population with coarse truncation between 1 and 3 ϕ and fine truncation at 4 to 7.5 ϕ and low percentage of surface creep and insignificant amount of suspension population may be attributed to the predominant dune environment of deposition. Since there is higher amount of surface creep population with poor sorting and smooth truncation at finer end as compared to the ideal curves of dune (Visher, 1969), it may be inferred that the sands of original dune environment have undergone a transformation under the strong wave action.

The data in Table 2 for Mirya bay indicates that bottom tracks, which are situated in the protected zone where wave action is much less, are different to the other two tracks, in having almost only three populations without proper surface creep truncation. The difference may be due to the reduction in wave action, causing the zone similar to the foreshore conditions. The truncation points of each curve show high variation leading to large differences in the slopes and sorting of the populations. However, each of these sands comprise two saltation populations, which suggests the presence of foreshore beach environment related to swash and back wash. As suggested by Visher (1969), the cause of mixing of different provenances and the different shapes of the particles may not be applicable here, due to the non-existence of fresh land supply to this bay and lack of characteristic changes in the mineralogy of the sands as compared to the neighbouring bays.

— BOUNDARIES OF DIFFERENT DEPOSITIONAL ENVIRONMENTS

- B-BEACH
- R-RIVER
- TU-TURBIDITE
- Sh-M-SHALLOW MARINE
- GM-POSITION OF GRAND MEAN

DEPOSITIONAL ENVIRONMENT OF STUDIED BAYS

- + K-KALBADEVI BAY
- + M-MIRYA BAY
- + R-RATNAGIRI BAY

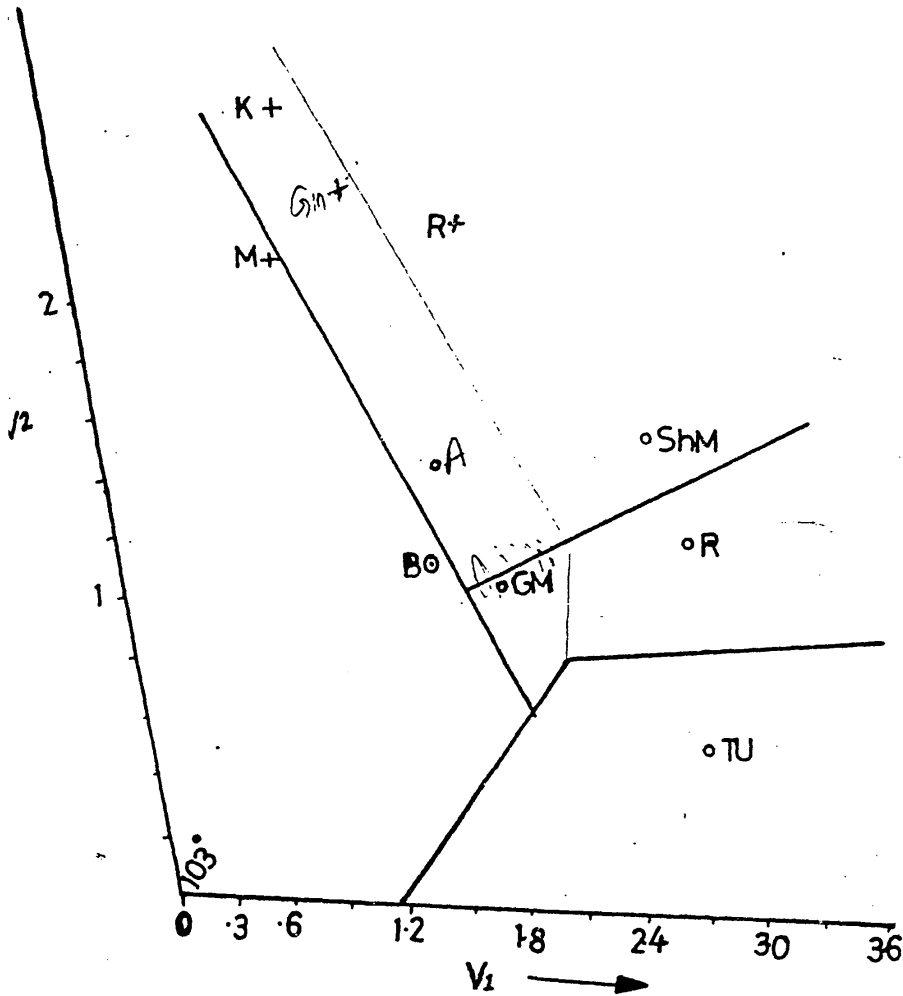


Fig. 3. Depositional environment of studied bays (after Sahu, 1983).

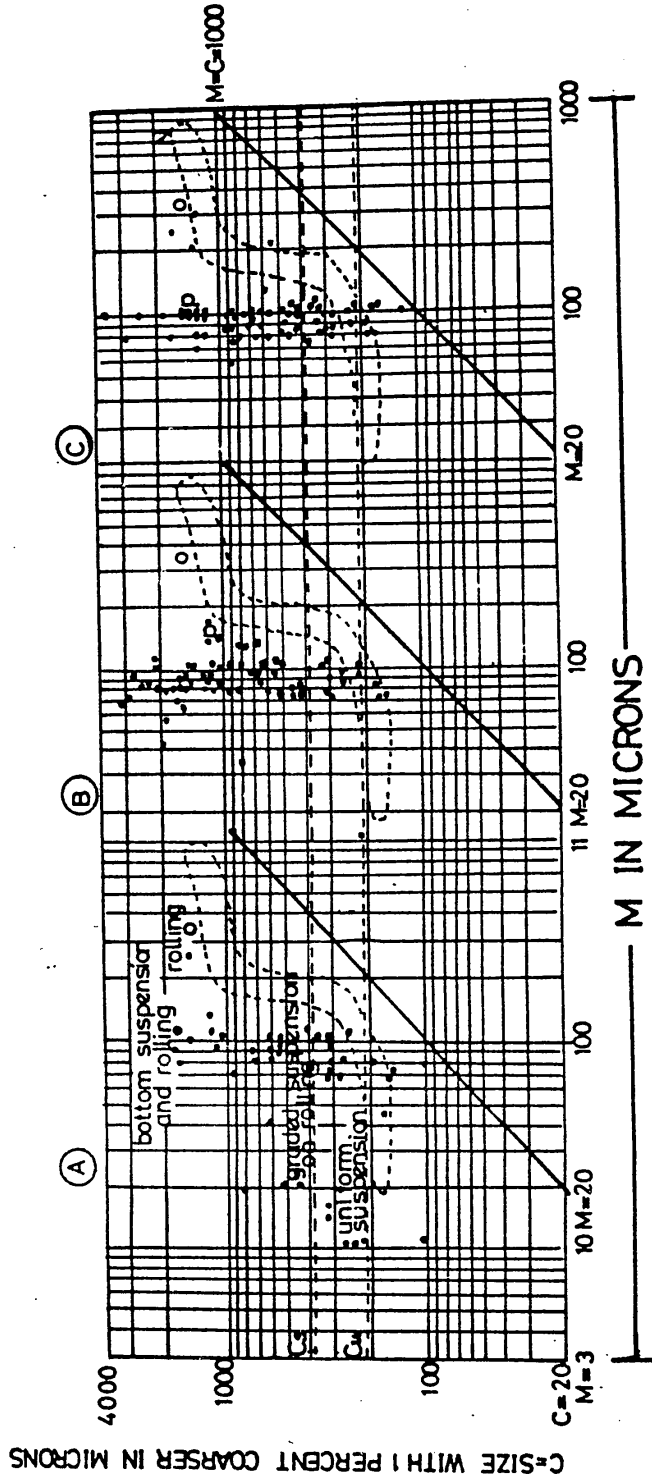


Fig. 4. CM pattern for the sediments from : (A) Ratnagiri Bay, (B) Mirya Bay, and (C) Kalbadevi Bay.

TABLE 2 : QUANTITATIVE DISTRIBUTION OF DIFFERENT POPULATIONS IN THE THREE BAYS

Bay	Track	A-Saltation Population				B-Suspension Population				C-Surface Creep Population			
		Percent	Sorting	C.T. Phi	F.T. Phi	Percent	Sorting	A & B Mixing	F.T. Phi	Percent	Sorting	C.T. Phi	A & B Mixing
Kalba Devi	B	88-89	Good	1-2.5	4-5.5	0.01-1	Fair	Little	4-5.5	1-10	Poor	1-2.5	Little
	M	80-98	Excellent	2-3	6-7.5	0.02-5	Fair	Average	6-7.5	0.5-20	Poor	2-3	Little
	T	82-95	Good	2-3	5-7	0.01-2	Fair	Average	5-7	0.2-10	Poor	2-3	Little
Mirya	B	85-90	Good	0-1	4-4.5	0.1-2	Fair	Little	4-4.5	0.2-2	Fair	0-1	Average
	M	75-99	Good	1-3	4.5-6	0.3-5	Good	Little	4.5-6	5-18	Fair	1-3	Fair
	T	70-85	Good	2.5-3	4.5-6.5	0.1-1	Fair	Little	4.5-6.5	3-18	Fair	2.5-5	Fair
Ratnagin	B	60-80	Fair	No Limit	4-4.5	10-60	Poor	Little	4-4.5	0-10	Poor	No Limit	Little
	M	50-90	Fair	1.5-2.5	4-4.5	5-50	Poor	Little	4-4.5	1-3	Poor	1.5-2.5	Little
	T	30-80	Fair	2-3	4-4.5	5-70	Poor	Little	4-4.5	1-10	Poor	2-3	Little

C.T. = Coarse Truncation Point.
 F.T. = Fine Truncation Point.

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The values shown in Table 2 for R-bay suggest that the sands consist predominantly of suspension population with appreciable surface creep and poorly sorted saltation population. The values of the northern track (top) of this bay displays three characteristic populations of about 0-10 percent surface creep and 5-70 percent suspension population. Each sample behaves differently in the track. Though they resemble the general pattern of the type samples of Visher (1969) of tidal delta which is close by the bar and low tide action, they differ in having higher suspension population and lower surface creep population. The proximity of the existing sand bar at the Kajvi river mouth—that too, perpendicular to this track, might have influenced the sand distribution in this track. The more the suspension seen in the curve, the more the sample is found to be away from the bar and deeper in position. The values in the centre of the bay show a restricted size range of saltation population and surface creep truncation of 2.5 to 3.5 ϕ which is relatively finer as compared to other types of tidal sands. Here, the saltation population is poorly sorted whereas the surface creep population is better sorted. Since this zone is in the place of interaction of waves and tides, these values are found to differ from the other two which are placed in the north, (top) behind the bar and direct to the river confluence, and in the south (bottom), a protected area from the tides and waves. In the south, the values behave differently without any definite truncation among the populations. It does not show any resemblance to the typical values proposed by earlier workers (Visher, 1969, 1972). Though the values obtained from the plots from all the three tracks can be related to the river sands, the differences in the distribution of different populations are significant and their peculiarity in different truncation limits with varied percentages of populations from sample to sample indicate the need to assign them a new type of value representing the role of more than one depositional unit, or a mixing type of environment, made of recent and relict.

When the pooled up characters shown in Table 2 for all the curves of the three bays are compared with Visher's (1969) data, K-bay sands with three well-defined populations, mainly comprised of saltation, are well correlatable to dune sands, whereas the M-bay with two distinct saltation populations of swash and back-wash resembles the beach sands and the R bay sands with appreciable suspension population and large differences within the sands of the bay are comparable to the sands of fluvial processes. The study of grain-size textural parameters by applying various methods lead to the inference that the environment of deposition for the K-bay sands can be considered to be of the older dunes while that of M-bay of older beach and R-bay sands to the mixed ancient riverine and modern tidal inlet. Supplementing the possibilities are the presence of dunes along the coast of K-bay and the existence of a narrow beach in between the bay and the creek along M-bay. Above all, the bathymetry (Fig. 1) of K-bay shows greater undulations as though the dunes are still maintained below the water level, whereas the M-bay shows a gradual seaward slope except for the central topographical high. Similar observations have also been made along the east coast of India (Mohana Rao *et al.*, 1989).

The influence of the large river confluence is shown in the values obtained from the curve of R-bay by the probable resemblance to the fluvial processes, caused by the river, tides and waves. The unambiguous typical values of more or less regular nature in each bay of both M and K bays are suggestive of the presence of a single depositional unit which is not yet fully diluted by another type of sediment or has not lost its original characters by undergoing the reshaping and sorting. This is also supplemented by the presence of weak secondary mode which is likely to be the share from the existing coastal material. In the case of R-bay, the anomalous behaviour of the curves from sample to sample within the bay may be attributed to the existence of more than one depositional unit that is the present day rivers contribution which has almost shadowed the older characteristics of the sediments. This is also evidenced by the difference in kurtosis values from the other two bays and the mineral composition that is the magnetite dominance in this bay (R-bay) unlike the ilmenite prevalence in the other two bays.

CONCLUSION

Though the three bays are adjacent to each other, grain size textures show variations of appreciable nature. The bivariate plots suggest overlapping environments of beach/dune barrier island in Kalbadevi and Mirya bays and river/lagoon type in Ratnagiri bay. CM pattern indicates the presence of graded suspension in Ratnagiri bay leaving the possibility of palaeo-source in the other two bays. Multi-discriminant analysis suggests beach environment for Mirya bay and shallow marine conditions for the other two bays. The log-probability curves show an earlier dune environment for K-bay, beach conditions for M-bay and mixed type of environment probably of recent and relict type for R-bay.

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