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Sedimentary Processes and Mineral Dispersion along Point Calimere, Southeast Coast of India

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Abstract: Grain size parameters provide an insight in to the nature and the energy flux of the multivarious transporting agents which helps in understanding the various processes effecting erosion and deposition. Hence the focus of the present study is to understand the relationship between the characteristics of grain size and the mineral content of sediments from the Point Calimere located in the southeast coast of India. Beach sediments were collected from 9 stations along the Point Calimere coast in 2004. The grain size parameters were analyzed. Further, heavy mineral separation was carried out for all the sediments. From the textural relationship between a source sediment and deposit, the movement of sediments was derived. It is inferred that for bulk sediments, station B1 is active source for all the other stations followed by other stations viz., B5, B7, B8 and B9 while stations B2, B3 and B4 are major sinks in the study area. The sources (except B7) and sinks (additional B6) for Light Minerals are identical to that of heavy minerals. The major direction of sediment transport is north.

Key words: Grain size · Heavy minerals · Light minerals · Bulk sediments · East coast of India

INTRODUCTION

Study of coastal ecosystem has attracted many researchers of the world. Grain size parameters provide an insight in to the nature and the energy flux of the multivarious transporting agents and their purview of depositional environment. This helps in understanding the various processes effecting erosion and deposition. Differentiation of depositional environments has been carried out based on size distribution of sedimentary particles [1]. The constituent composition of the sediments, particularly the heavy mineral concentration, helps in unraveling the provenance of the deposits. Hence the aims of the present study are to document the characteristics of grain size, total heavy mineral content, mineralogical assemblages and morphological variation of quartz grains from the Point Calimere-cuspate- coast, thereby to characterize the sediment source in view of the peculiar environment set up.

Study Area: The study area between Akkrapallivasal and Serthalaikkadu lagoon (10° 20' N -10° 25'N latitude and 79° 25' E -79° 50' E longitude) is a fast emerging typical cuspate foreland located at the southern periphery of Cauvery delta and formed primarily by the deposition of sediments by the southward longshore currents and wave activities both from Bay of Bengal and the Palk Bay. The nearest major sediment source for this coastal segment is the Vellar and Coleroon river which is the major/main distributary of Cauvery, respectively joining the sea at about 225km and 250km north of Point Calimere. Other than Coleroon, none of the other distributaries of Cauvery such as the proper Cauvery, Arasalar, Vettar, Vennar and Maharajasamudram do not contribute much sediments to the coast, as they are mainly irrigation canals with low water supply from the main stream. The small ephemeral streams and rivulets (Agniyar, Paminiyar and Mullipallam) joining the northern and northwestern Palk Bay do contribute to a limited extent, as they drain mainly the Cuddalore sandstone, the Recent coastal

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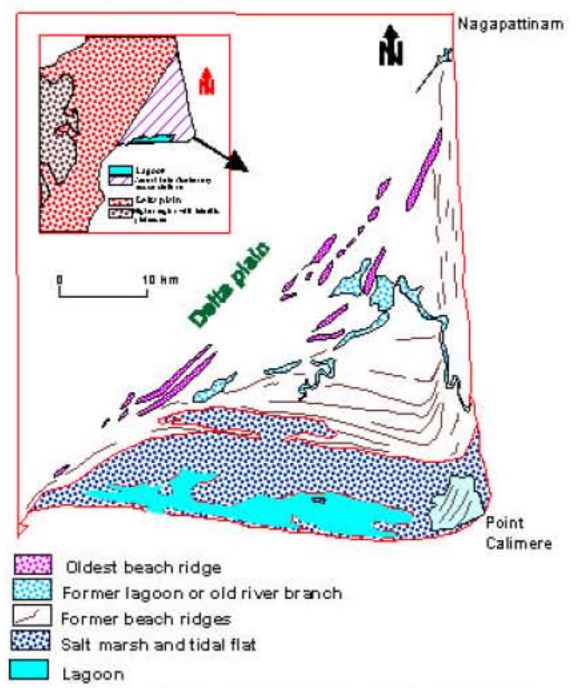
alluvium and other coastal uplands. The Cauvery river drains primarily the Precambrian gneisses and charnockites in the upstream and the cretaceous of Trichirappalli in the downstream. The Hindu [2] reported that extremely exciting possibilities of the Point Calimere nose of Vedaranyam, welding itself with the Jaffna Peninsula and Dhanushkodi becoming a single landmass with Talaimannar in Jaffna, within about 500 years. Further the dating of beach ridges taken up on Tamil Nadu coast had indicated that the sea had withdrawn to the extent of 50km in 5000 years in Vedaranyam-Point Calimere coast.

Loveson [3] classified the coastal zone of Palk Bay into 3 groups; i) Uplands/highlands with scanty vegetation comprised of Cuddalore sandstone formations, ii) Along the lower elevations sedimented Cuddalore sandstones and iii) The coastal lands mainly of micro deltas, swamps and beach ridges based on the geomorphological features. A large amount of sediments from those pediments are removed constantly by rainfall and minor rivers. Because the pediments are placed over the substratum which is appreciably sloping towards the sea, the erosion is found to be intensive along the coastal islands. The eroded sediments brought to the littoral zone are dumped in Palk Bay. As Palk Bay is shallow and protected from the high waves and currents, the material brought by these minor rivers is deposited in the mouth of each river/stream, leading to the formation of micro-deltas in due course, encouraging the formation of new shorelines.

The coastline between Vedaranyam and Rameswaram in Palk Bay is protected from monsoon waves due to the proximity of Srilanka Island. Palk Bay is very shallow and is largely occupied by sand banks and submerged shoals [4]. The large volume of southerly littoral drift along the east coast enters into Palk Bay and is seen getting deposited as spits and shoals. Chandrasekar [5] reported the annual net sediment transport rate is about 1.07 X 10^6 m^3/year in the northerly direction at Nagapattinam. The sediments brought by Vaigai, Vaishali and Valryar rivers and the littoral drift from the north Tamil Nadu coast are the major sources of sediments entering the Palk Bay [6]. Jena [7] estimated that 0.3 X 10^{10} m^3 of sediment gets deposited over a period of 52 years in Palk Bay causing the reduction in the water depth of about 0.32m i.e. 0.006m per year. Natesan and Subramanian [8] stated that the accretion pattern was observed in Palk Bay at Mandapam. The coastal process between Arichamunai and Talaimannar along Adam's Bridge is quite complex which predominantly control the exchange of sediment between Gulf of Mannar and Palk Bay.

MATERIALS AND METHODS

Beach sediments from 9 stations (Fig. 1 & 2 a, b) were collected from Point Calimere coast in 2004. At each station, sediment samples were collected from foreshore using hand auger, were initially washed and dried for further laboratory analysis. After coning and quartering, carbonates and organic matter were removed from the samples by treating it with 1:10 HCl, 30% by volume H_2O_2 respectively. The dried samples were then sieved at a +GF+ DIN 4188 sieve shaker for 15 minutes at half Phi interval [9] (Folk and Ward, 1957). The grain size parameters such as Graphic Mean (M_z), Inclusive Graphic Standard Deviation (σ_1), Inclusive Graphic Skewness (Sk_1) and Graphic Kurtosis (K_G) were determined using the package Grain. Heavy mineral separation was carried out using bromoform [10]. Mc laren [11] established a textural relationship between a source sediment and deposit and a source sediment and a deposit derived from it, based on the movement measures, phi mean grain size, phi standard deviation (sorting) and skewness.



Late Quaternary evolution of southern Cauvery delta

Fig. 1: Late Quaternary Evolution of Southern Cauvery Delta

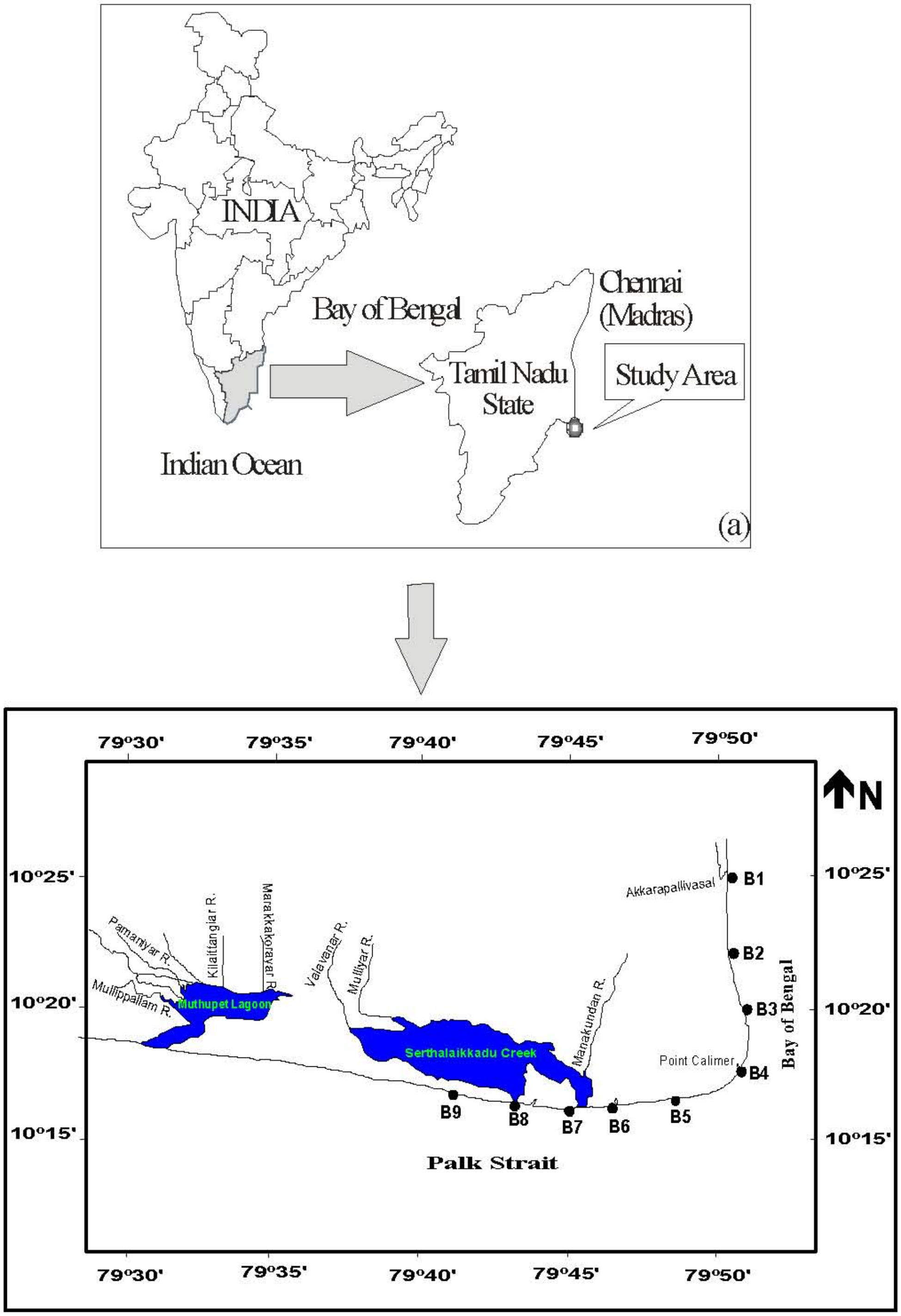


Fig. 2: Study Area

Case I: In this case, sediment is eroded from the source, transported and deposited completely. Erosion of the source sediment occurs if a given level or magnitude of energy in a process, such as a current or a breaking wave, is capable of removing either the whole deposit or parts of the grain size fractions present. In the later situation, the amount of sediment removed decreases from fine to coarse, upto a limit determined by the energy level.

Case III: In this case, sediment in transport undergoes selective deposition due to decreasing energy of the transporting process. As the energy decreases, coarse sediment has a greater probability of coming out of transport than fines.

RESULT AND DISCUSSION

Weight percentage of heavy minerals varies from 3.84 to 25.44 % (av. 9.48 %), Stations B6-B8 register a significant enrichment of heavy minerals (Table 1). Weight percentage of light minerals in the deposit varies from 74.56% to 97.50 % average (90.52%) for Point Calimere coast, with relatively higher percentages at B9 and B1 followed by B5 (Table 1) which are found to have strong wave convergence so that the lighter minerals are removed by winnowing of waves. The high Concentration of light minerals in Point Calimere coast is ascribed, primarily to the progradational activity in the area.

Grain size parameters indicate that finer sediment, higher concentration of light minerals in the Point Calimere Coast (Table 2). The light minerals fall in the category of fine sand whereas the heavies fall in very fine sand in the study area. The sorting of sediments vary from very well to moderately sorted nature which may be due to the fluvial influx or wave convergence (Table 2). The skewness of the sediments is closely related to the environmental energy [12]. The presence of negative skewness implies high energy and winnowing action whereas the positive skewness is attributed to lower energy condition with accumulation of finer sediments. In the study area both negative skewness and positive skewness are observed. These indicate that the area has been subjected to both high energy winnowing action and low energy accumulation of finer sediments.The mean size Vs skewness plot (Fig. 3) clearly illustrates the dominance of inland and beach. The samples from B2, B4 and B8 indicate the offshore origin.

Table 1: Heavy and Light mineral weight percentage at Point Calimere coast

Samples	Heavy mineral %	Light Mineral %
B1	2.75	97.25
B2	8.14	91.86
B3	6.75	93.25
B4	9.76	90.24
B5	3.84	96.16
B6	25.44	74.56
B7	21.30	78.70
B8	11.69	88.31
B9	2.50	97.50

Table 2: Grain size parameters of bulk sediment, light mineral fraction and heavy mineral fraction

	Sample	Mean	Sorting	Skewness	Kurtosis
Bulk Sediment	B1	2.807	0.797	-0.203	0.702
	B2	3.089	0.518	-0.029	0.959
	B3	3.214	0.473	-0.010	0.758
	B4	2.991	0.478	-0.043	0.995
	B5	2.653	0.572	-0.047	0.817
	B6	2.637	0.536	0.006	0.840
	B7	2.331	0.540	0.070	0.832
	B8	2.251	0.772	0.013	0.740
	B9	2.800	0.756	-0.049	0.819
Light Minerals	B1	2.799	0.795	-0.201	0.695
	B2	3.017	0.486	-0.044	1.012
	B3	3.201	0.470	0.011	0.770
	B4	2.956	0.458	-0.039	0.990
	B5	2.637	0.568	-0.017	0.835
	B6	2.563	0.505	0.042	0.919
	B7	2.316	0.529	0.069	0.826
	B8	2.233	0.763	0.015	0.741
	B9	2.782	0.759	-0.029	0.820
Heavy Minerals	B1	3.208	0.731	-0.627	0.727
	B2	3.638	0.296	-0.326	1.392
	B3	3.460	0.454	-0.474	0.999
	B4	3.488	0.410	-0.372	0.990
	B5	3.075	0.450	-0.547	2.266
	B6	3.245	0.349	-0.128	1.918
	B7	3.104	0.458	-0.284	1.519
	B8	3.454	0.502	-0.524	1.208
	B9	3.347	0.449	-0.104	1.269

Tables 3-5 depict the Sediment Trend Matrix (STM) of Bulk Sediments, light minerals and heavy minerals, indicating the source and sinks of the minerals. Table 6 portrays the movement of sediments takes place between the stations. From the analysis, it is inferred that for Bulk Sediments, station B1 is active source for all the other stations. In addition, stations B5, B7, B8 and B9 are also acting as sources. Stations B2, B3 and B4 are major sinks in the study area. Station B6 acts as mixed source and sink. An important point to note is that stations B7 and B8 lead to selective deposits while all other stations make total deposition. If a sedimentary environment is such that total deposition of the sediment in transport can occur, the grain size statistics will maintain these same trends relative to the source sediment. Processes such as shielding, in which fines can be protected from movement by larger clasts or the decreasing ability of the eroding process carry additional sediment with increasing load. The major direction of sediment transport is north.

Table 3: Sediment Trend Matrix of Bulk Sediments

Sediment Source	Sediment Deposit B1	B2	B3	B4	B5	B6	B7	B8	B9
B1		FB+	FB+	FB+	CB+	CB+	CB+	CB+	CB+
B2	CP-		FB+	CB-	CP-	CP+	CP+	CP+	CP-
B3	CP-	CP-		CP-	CP-	CP+	CP+	CP+	CP-
B4	CP-	FP+	FB+		CP-	CP+	CP+	CP+	CP-
B5	FP-	FB+	FB+	FB+		CB+	CB+	CP+	FP-
B6	FP-	FB+	FB-	FB-	FP-		CP+	CP+	FP-
B7	FP-	FB-	FB-	FB-	FP-	FB-		CP-	FP-
B8	FP-	FB-	FB-	FB-	FB-	FB-	FB+		FB-
B9	FP-	FB-	FB+	FB+	CB+	CB+	CB+	CP+	

Table 4: Sediment Trend Matrix of Light Minerals

Sediment Source	Sediment Deposit B1	B2	B3	B4	B5	B6	B7	B8	B9
B1		FB+	FB+	FB+	CB+	CB+	CB+	CB+	CB+
B2	CP-		FB+	CB+	CP+	CP+	CP+	CP+	CP+
B3	CP-	CP-		CB-	CP-	CP+	CP+	CP+	CP-
B4	CP-	FP-	FP+		CP+	CP+	CP+	CP+	CP+
B5	FP-	FB-	FB+	FB-		CB+	CB+	CP+	FP-
B6	FP-	FB-	FB-	FB-	FP-		CP+	CP-	FP-
B7	FP-	FB-	FB-	FB-	FP-	FB-		CP-	FP-
B8	FP-	FB-	FB-	FB-	FB-	FB+	FB+		FB-
B9	FP-	FB-	FB+	FB-	CB+	CB+	CB+	CP+	

Table 5: Sediment Trend Matrix of Heavy Minerals

Sediment Source	Sediment Deposit B1	B2	B3	B4	B5	B6	B7	B8	B9
B1		FB+	FB+	FB+	CB+	FB+	CB+	FB+	FB+
B2	CP-		CP-	CP-	CP-	CP+	CP+	CP-	CP+
B3	CP-	FB+		FB+	CB-	CB+	CP+	CP-	CB+
B4	CP-	FB+	CP-		CP-	CB+	CP+	CP-	CP+
B5	FP-	FB+	FP+	FB+		FB+	FP+	FP+	FB+
B6	CP-	FB-	FP-	FP-	CP-		CP-	FP-	FP+
B7	FP-	FB-	FB-	FB-	CB-	FB+		FP-	FB+
B8	CP-	FB+	FB+	FB+	CB-	CB+	CB+		CB+
B9	CP-	FB-	FP-	FB-	CP-	CB-	CP-	FP-	

C-Coarser; F-Finer; B- Better; P-Poor; + - +ve skewness; - - -ve skewness

Table 6: Sediment Transport Path of Minerals

Stations	Bulk Sediments	Light Minerals	Heavy Minerals
B1	B2, B3, B4, B5, B6, B7, B8, B9	B2, B3, B4, B5, B6, B7, B8, B9	B2, B3, B4, B5, B6, B7, B8, B9
B2	B3	B3, B4	Nil
B3	Nil	Nil	B2, B4, B6, B9
B4	B3	Nil	B2, B6
B5	B2, B3, B4, B6, B7	*B2*, B3, *B4*, B6, B7	B2, B4, B6, B9
B6	B2, *B3, B4*	*B2, B3, B4*	*B2*
B7	*B2, B3, B4, B6*	*B2, B3, B4, B6*	*B2, B3, B4, B6, B9*
B8	*B2, B3, B4, B5, B6, B7, B9*	*B2, B3, B4, B5,* B6, B7, *B9*	B2, B3, B4, B5, B6, B7, B9
B9	*B2*, B3, B4, B5, B6, B7	*B2*, B3, *B4*, B5, B6, B7	*B2, B4*

FB+ indicates Case I; underline (FB-) indicates Case III

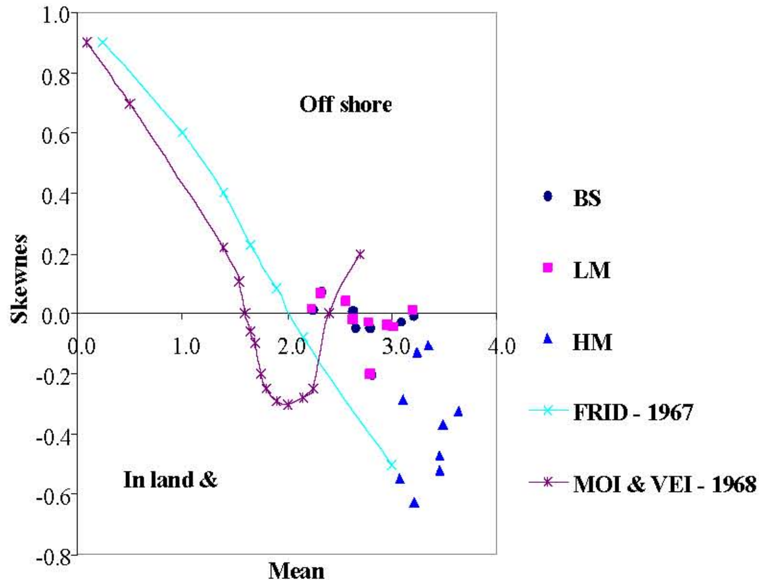


Fig. 3: Scatter plot of Mean Vs Skewness

For Light Minerals, station B1 is the major source in the study area. The light mineral sources are stations B5, B8 and B9. Stations viz., B2, B3, B4 and B6 receive light minerals from other stations. Stations B7 and B8 lead to case III deposition i.e. selective deposition of sediment in transport, because beach face sediments undergo continuous movement through the action of breaking waves and swash and total deposition is unlikely to occur. The major direction of sediment transport is north.

Similar to the behavior of bulk sediments and light minerals, for heavy minerals also station B1 supplies sediment to other stations. Unlike earlier situations, Case I deposition is observed in station 8 while Case III deposition is noticed in station B7. Other minor sources are stations B3 and B5. Various sinks in the study area are B2, B4 and B6. The major direction of sediment transport is north.

Out of the various relationships, majority of the trends are northwards which suggests that longshore transport of beach face sediments is taking place from north to south during this season. This observation agrees with the longshore current direction perceived through conventional data [13] and satellite data [14].

CONCLUSION

Stations between B6 and B8 register a significant enrichment of heavy minerals. Weight percentage of Light minerals indicates relatively higher percentages at B9 and B1 followed by B5. The high Concentration of Light minerals in Point Calimere coast is ascribed, primarily to the progradational activity in the area. Along the Point Calimere Coast, higher concentrations of light and heavy minerals are associated with finer and very fine sand respectively. The sorting of sediments vary from very well to moderately sorted nature which may be due to the fluvial influx or wave convergence. Observation of both negative and positive skewness in the study indicates that the area has been subjected to both high energy winnowing action and low energy accumulation of finer sediments. The samples illustrate the dominance of inland and beach except B2, B4 and B8 indicate the offshore origin. From the Sediment Trend Matrix, it is inferred that for Bulk Sediments, station B1 is active source for all the other stations followed by other stations viz., B5, B7, B8 and B9 while stations B2, B3 and B4 are major sinks in the study area. The sources (except B7) and sinks (additional B6) for Light Minerals are the identical to that of heavy minerals. From the movement of minerals, it is understood that longshore transport of beach face sediments is taking place from north to south during this season.

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