Coastal Process Around Tamirabarani River Mouth, Thoothukudi District, Tamilnadu- Evidence From Granulometric Studies

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Abstract- *Grain size is one of the basic trait of sediments hence its determination is necessary to interpret the depositional environment. Research has been carried out along the Tamirabarani river mouth, a part of east coast of India using various statistical parameters. Textural studies of vertical core samples reveal the predominance of fine sand, well sorted to moderately sorted, coarse skewed to fine skewed and platykurtic to leptokurtic character. Abundance of the fine sand demonstrates the prevalence of moderately low energy condition in study area. Several geomorphic features has been discussed which are the signatures of the interaction of marine, riverine and aeolian processes. Linear discriminate function analysis (LDF) of the sample indicates a shallow marine and turbidity environment of deposition. The CM pattern of sediments shows a bottom suspension with rolling and graded suspension with no rolling mode of deposition. The inference to be drawn from these studies is that the variation in sedimentological parameters is governed by wave dynamics, fluvial action with littoral transport of the sediments.*

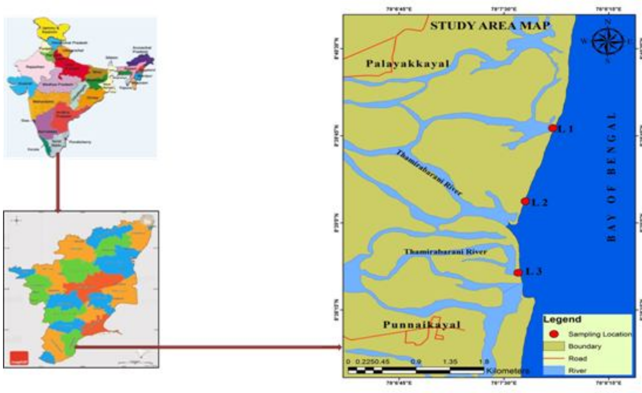
I. INTRODUCTION

The successive phases of transgression and regression by aeolian, fluvial and beach processes are considered to be responsible for the evolutionary landscape of the east coast of India. The particle size and the morphology of sediments are the major tools to interpret the source or provenance of sediments, transportation modes and depositional environments (Greenwood, 1969; Friedman, 1967 and Pettijohn, 1984). Distribution pattern of grain size are highly influenced by sediment transportation mechanisms, which are energy dependent process and comprise long shore sediment transport, swash and backwash motion, wind deflation and tidal currents (Chauhan, 2014). Earlier studies have indicated that the south east coast of India is affected by natural disasters such as cyclone, induced surges and variability in river discharge, tsunami etc. resulting in triggering, reallocation and redistribution of the sediments in the beach region. Study area along Tamirabarani river mouth is a dynamic coastal zone often affected by various wave pattern, the study of which will decipher the conditions of depositional system and transportation mechanism in this mixed zone.

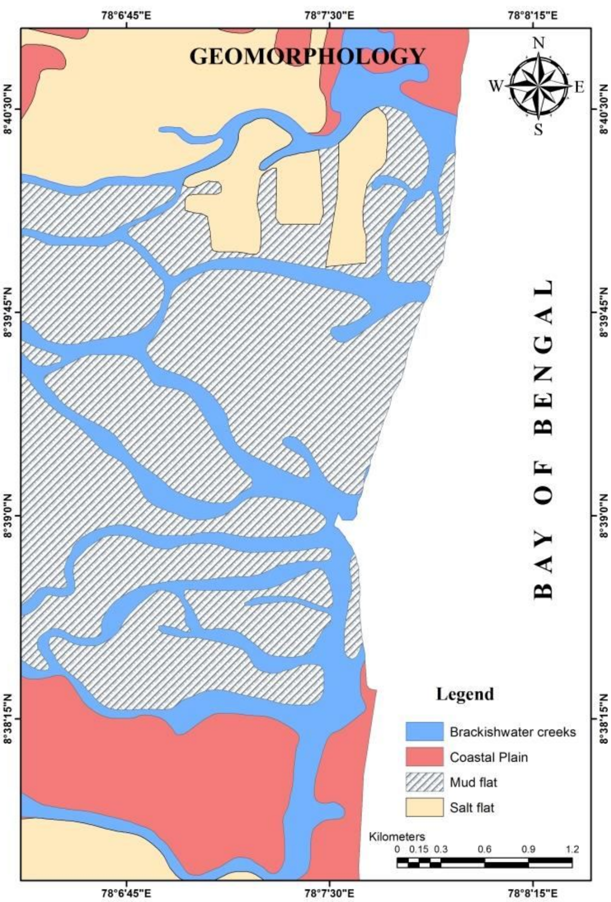
II. STUDY AREA

Studies were carried out along the Tamirabarani river mouth, Thoothukudi district, Tamil Nadu. The estuary lies within the latitudes 8°40’ to 8°35’ N and longitude 78°10’ to 78°13’ E and falls in survey of India toposheet no 58 L/2 (1:50000 km scale) (Map-1). Tamirabarani River, one of the main river sources in southern part, originates from the eastern slopes of Western Ghats and joined with its headwater tributaries. Then the river flows eastward in a nearly flat terrain and drains into Gulf of Mannar near Punnaikayal. As most of its extensive catchment areas lie in the Western Ghats, the river enjoys the full benefit of both the monsoons, which make the river perennial.

The lithology of the study area encompasses mainly of Archean formations that comprises about 90% of the aerial distribution of rock type in the catchment area consisting of charnockites, granitic gneiss, calc gneiss, calc granulites, crystalline limestones and quartzites (Kumarasamy, 2010). The coastal belt of the study area is occupied by tertiary formations and recent sediments, which occur in the form of a narrow zone parallel to the coastline with the thickness increasing towards the shore. Sediments reaching this river mainly comprise of alluvium towards the east and un-calcified gneiss along the west (Vargehese, 2011). Geomorphologically (Map-2) the area consists of coastal plain, mudflat, salt flat, brackishwater creeks, delta fronts. Beach ridges, dune complex and swamps found predominantly in either side of the estuary. Flood plains spread across western and northern parts of estuary whereas the delta fronts occupy the eastern part.



Map-1 Showing study area



Map-2 Showing Geomorphology map of study area

III. METHODOLOGY

The sediment samples were collected at Tamirabarani (TMBR) River mouth by core sampling method using PVC (Polyvinyl Chloride) pipe of 2.5 inch diameter. The core samples then capped and carefully carried to the laboratory for further analysis. The exact sample locations were noted with the help of Global Positioning System (GPS). The core sample was sub sampled with an interval of 5cm and collected in clean dry polythene bags for laboratory analysis. All the sediment samples were air dried and then amount of the samples were reduced to nearly 100 g by repeated coning and quartering to ensure uniformity and to prevent errors in the analysis. These representative samples were then washed with 10% HCl to remove carbonates and then with distilled water. Washed samples were dried in hot air oven at 60°c temperature. Sieve analysis was performed by using a series of standard ASTM test sieve of quarter phi interval to get uniform size fractions in Ro tap sieve shaker for 20 minutes. The grain size data obtained was used to calculate all the statistical parameter such as Mean (Mz), Standard Deviation (σI), Skewness (Ski) and Kurtosis (K_G) as suggested by Folk and Ward (1957). CM plot (Passega, 1964) prepared to understand the transportation mechanism. Linear discriminant function (Sahu, 1964) was used to understand the depositional environment of sediments.

IV. RESULT AND DISCUSSION

The most frequently used statistical parameters like Mean (Mz), Standard deviation (σI), Skewness (Sk_i) and Kurtosis (K_G) were calculated by the method suggested by Folk and Ward (1957) using percentile value. In the present work, these four parameters were used to represent grain size characteristics of sediments.

Mean (M_Z)

Mean grain diameter, the most widely used distribution parameter, is regarded by most authors (Folk, Ward, 1957; Passega, 1964) as an indicator of the average energy of sediment transportation. In the study area, the vertical mean size ranges between 1.450Φ (75cm depth) and 2.853Φ (85cm depth) with average mean of 2.339Φ at Station-1 (Table-1, Fig -1A), 1.420Φ (100cm depth) and 2.460Φ (30cm depth) with an average of 2.134Φ at Station-2(Table-2, Fig -1A) and 1.000Φ (5cm depth) to 3.017Φ (80cm depth) with average of 2.364Φ at station-3 (Table-3, Fig -1A) respectively. The mean size indicates that most of the samples belong to fine sand category with a few belongs medium sand category. This suggests that the sediments were deposited under low energy condition, as sediments usually become finer with decrease in energy of the transporting medium (Folk, 1974; Eisema, 1981). The variation in mean size is a reflection of the changes in energy condition of the depositing media and indicates average kinetic energy of the depositing agent (Sahu, 1964).

Standard Deviation (σ_I)

Graphic standard deviation measures sorting of sediments and indicate the fluctuation in energy conditions of depositional environment but it does not necessarily measure the degree to which the sediments have been mixed (Spencer, 1963). The standard deviation values obtained in the range from 0.393Φ (60cm depth) to 0.893Φ (65cm depth), 0.395Φ (75cm depth) to 0.772Φ (95cm depth), and 0.499Φ (90cm depth) to 1.160Φ (15cm depth) at Station-1(Table-1, Fig -1B), Station-2 (Table-2, Fig -1B) and Station-3 (Table-3, Fig -1B) respectively. The Standard deviation value at north of study area (Station-1) suggests that most of the samples were well sorted (47.3%) with few are moderately well sorted (26.3%) to moderately sorted (26.3%). Strong energy condition prevailed for the deposition of various size fragment at a depth range of 40-80cm. The variation may be due to monsoonal cyclone or storm occurred in this region. Moderately well sorted and well sorted indicates the influences of stronger energy condition of depositing agents or prevalence of strong energy condition in the basin (Lahkar A.C. and Hazarika I.M., 2000). According to Friedman, the various ranges of sorting in sediments were indicates the different environments. At Station-2, most of the samples belongs to well sorted (60%) to moderately well sorted (35%) shows a reflection of the higher wave energy and strong shore currents of the coast (Biju Sabastian, et.al, 2002). At Station-3, sorting value suggests that most of the sediments are moderately sorted (66.6%) with a few are poorly sorted (16.6%) and moderately well sorted (11.1%) in character. This is indicative of low to fairly high energy current (Friedman, 1961; Blott & Pye, 2001). Poorly sorted and moderately sorted character with high standard deviation values in the depth range of 0-65cm indicate the slight variation in energy conditions due to monsoonal changes.

Skewness

It is used to determine the symmetry of the distribution, i.e. predominance of coarser or finer sediments. The negative value denotes coarser material in coarser tail i.e., coarse skewed, whereas, the positive value represent more fine material in the fine tail i.e., fine skewed. The samples exhibit skewness values ranging between -0.396Φ (65cm depth) to 0.456Φ (10cm depth), -0.386Φ (95cm depth) to 0.268Φ (25cm depth), -0.435Φ (30cm depth) to 0.571Φ (10cm depth) at Station-1(Table-1, Fig -1C), Station-2(Table-2, Fig -1C) and Station-3 (Table-3, Fig -1C) respectively. At Station-1, 47% sediments are nearly symmetrical, 21% are fine skewed and a few are very fine skewed (15.7%) and coarse skewed (10.5%). At Station-2, sediments show near symmetrical (45%), fine skewed (20%), coarse skewed (20%) and very coarse skewed (15%) nature. Sediments from Station-3 shows 38.8% of coarse skewed, 33.3% very coarse skewed, 16.6% near symmetrical and 11.1% were very fine skewed. Near symmetrical sediments indicate that deposition has been taken place due to mixing of bimodal sources (Venkatramanan et al., 2011). According to Duane (1964), positively skewed sediments indicate winnowing of sediments. The positive skewed clearly show the prevailing low energy condition and near symmetrical nature of sediments implies moderate energy environment of deposition. The negative skewness shown by majority of the samples at Station-3 of the study area indicates high energy medium of transport (Friedman, 1961) and multidirectional sediment transport (Martins 1965).

Kurtosis

The graphic kurtosis (KG) is the peakedness of the distribution and measures the ratio between sorting in the tails and central portion of the curve. According to Cadigan (1961), it is also a function of internal sorting or distribution. Kurtosis value of the sediments in study area ranges from 0.814Φ (20cm depth) to 1.503Φ (70cm depth), 0.699Φ (55cm depth) to 1.721Φ (40cm depth), and 0.693Φ (10cm depth) to 1.931Φ (90cm depth) at Station-1 (Table-1, Fig -1D), Station-2 (Table-2, Fig -1D) and Station-3 (Table-3, Fig -1D) respectively. At Station-1, sediments fall under mesokurtic (52.6%), leptokurtic (31.5%), platykurtic (10.5%) and very leptokurtic (5.2%). Mesokurtic character of sediments indicates moderate winnowing action of the depositing agent. The leptokurtic behaviour of sediment indicates the variation of energy conditions of the depositional basin. At Station-2, sediments fall under platykurtic (55%), leptokurtic (25%), very leptokurtic (10%) and mesokurtic (10%) character. Platykurtic nature indicates poor winnowing action without sorting i.e., all size fractions jumbled up. At Station-3, most samples belong to leptokurtic (33.3%), mesokurtic (27.7%) and platykurtic (22.2%) with 16.6% very leptokurtic in character. The variation in kurtosis value indicates reflection of the flow characteristics of the depositing medium (Cardigan, 1961). Friedman (1962) suggested that extreme high or low values of kurtosis imply that part of the sediments achieved its sorting elsewhere in a high energy environment.

Table -1 Graphic measures from grain size analysis of sediments at Station-1

Depth	Mean	St.dev	Skewness	Kurtosis	Remarks
5	2.130	0.500	0.392	1.071	FS,WS,VFSk,MK
10	2.163	0.474	0.456	1.034	FS,WS,VFSk,MK
15	2.613	0.563	-0.090	0.918	FS,MWS,NS,MK
20	2.360	0.450	-0.013	0.814	FS,WS,NS,PK
25	2.450	0.469	-0.068	0.969	FS,WS,NS,MK
30	2.827	0.507	0.223	1.202	FS,MWS,FSk,LK
35	2.573	0.547	-0.035	0.999	FS,MWS,NS,MK
40	1.853	0.828	-0.036	1.106	MS,MS,NS,MK
45	2.007	0.691	-0.052	1.255	FS,MWS,NS,LK
50	1.897	0.782	-0.052	1.085	MS,MS,NS,MK
55	1.837	0.761	-0.028	1.037	MS,MS,NS,MK
60	2.767	0.393	-0.105	1.277	FS,WS,CSk,LK
65	2.207	0.893	-0.396	0.834	FS,MS,VCSk,PK
70	2.763	0.426	0.364	1.503	FS,WS,VFSk,VLK
75	1.450	0.801	0.111	1.066	MS,MS,FSk,MK
80	2.440	0.452	-0.100	0.961	FS,WS,NS,MK
85	2.853	0.470	0.284	1.328	FS,WS,FSk,LK
90	2.670	0.472	0.153	1.448	FS,WS,FSk,LK
95	2.587	0.518	-0.221	1.201	FS,MWS,CSk,LK
Max	2.853	0.893	0.456	1.503	
Min	1.450	0.393	-0.396	0.814	
Avg..	2.339	0.579	0.041	1.111	

MS- Medium Sand, FS- Fine Sand, WS- Well sorted, MWS- Moderately Well sorted, MS- Moderately sorted, NS- Near Symmetrical, FSk- Fine Skewed, VFSk- Very Fine Skewed, CS- Coarse Skewed, VCSk- Very Coarse Skewed, LK- Leptokurtic, MK- Mesokurtic, PK- Platykurtic, VLK- Very Leptokurtic.

Table -2 Graphic measures from grain size analysis of sediments at Station-2

Depth	Mean	St.dev	Skewness	Kurtosis	Remarks
5	1.703	0.522	-0.108	1.158	MS,MWS,CSk,VLK
10	2.300	0.502	0.028	0.861	FS,MWS,NS,PK
15	2.227	0.474	0.177	0.972	FS,WS,FSk,MK
20	2.037	0.548	0.227	1.332	FS,MWS,NS,LK
25	2.097	0.425	0.268	1.205	FS,WS,FS,LK
30	2.460	0.530	-0.306	0.774	FS,MWS,VCSk,PK
35	2.370	0.450	-0.101	0.803	FS,WS,CSk,PK
40	1.940	0.593	-0.077	1.721	MS,MWS,NS,VLK
45	2.293	0.452	0.122	0.814	FS,WS,FSk,PK
50	2.190	0.455	-0.006	0.793	FS,WS,NS,PK
55	2.373	0.419	-0.101	0.699	FS,WS,CS,PK
60	2.347	0.418	-0.089	0.826	FS,WS,NS,PK
65	2.267	0.446	0.075	0.928	FS,WS,NS,MK
70	2.223	0.402	0.153	0.851	FS,WS,FSk,PK
75	2.317	0.395	-0.020	0.826	FS,WS,NS,PK
80	2.400	0.460	-0.144	0.865	FS,WS,CSk,PK
85	2.307	0.486	0.040	0.799	FS,WS,NS,PK
90	1.910	0.653	-0.011	1.317	MS,MWS,NS,LK
95	1.503	0.772	-0.386	1.254	MS,MS,VCSk,LK
100	1.420	0.709	-0.352	1.143	MS,MWS,VCSk,LK
MAX	2.460	0.772	0.268	1.721	
MIN	1.420	0.395	-0.386	0.699	
AVG	2.134	0.506	-0.031	0.997	

MS- Medium Sand, FS- Fine Sand, WS- Well sorted, MWS- Moderately Well sorted, MS- Moderately sorted, NS- Near Symmetrical, FSk- Fine Skewed, CSk- Coarse Skewed, VCSk- Very Coarse Skewed, LK- Leptokurtic, MK- Mesokurtic, PK- Platykurtic, VLK- Very Leptokurtic.

Table -3 Graphic measures from grain size analysis of sediments at Station-3

Depth	Mean	St.dev	Skewness	Kurtosis	Remarks
5	1.000	0.877	0.537	1.246	MS,MS,VFSk,LK
10	1.410	1.026	0.571	0.693	MS,PS,VFSk,PK
15	2.180	1.160	-0.421	0.820	FS,PS,VCSk,PK
20	2.373	0.791	-0.258	0.881	FS,MS,CSk,PK
25	2.327	0.909	-0.294	0.790	FS,MS,CSk,PK
30	2.257	0.925	-0.435	0.955	FS,MS,VCSk,MK
35	2.473	0.897	-0.256	0.945	FS,MS,CSk,MK
40	2.093	0.966	0.067	0.968	FS,MS,NS,MK
45	2.680	0.996	-0.361	0.909	FS,MS,VCSk,MK
50	2.647	0.847	-0.228	0.945	FS,MS,CSk,MK
55	2.287	0.751	0.060	1.163	FS,MS,NS,LK
60	2.357	1.000	-0.354	1.157	FS,PS,VCSk,LK
65	2.327	0.948	-0.353	1.251	FS,MS,VCSk,LK
70	2.807	0.772	-0.325	1.617	FS,MS,VCSk,VLK
75	2.773	0.601	-0.035	1.478	FS,MWS,NS,LK
80	3.017	0.628	-0.185	1.267	VFS,MWS,CSk,LK
85	2.727	0.727	-0.233	1.810	FS,MS,CSk,VLK
90	2.810	0.499	-0.144	1.931	FS,WS,CSk,VLK
MIN	1.000	0.499	-0.435	0.693	
MAX	3.017	1.160	0.571	1.931	
AVG	2.364	0.851	-0.147	1.173	

MS- Medium Sand, FS- Fine Sand, VFS- Very Fine Sand, WS- Well sorted, MWS- Moderately Well sorted, MS- Moderately sorted, PS- Poorly Sorted, FSk- Fine Skewed, CSk- Coarse Skewed, VCSk- Very Coarse Skewed, VFSk- Very Fine Skewed, LK- Leptokurtic, MK- Mesokurtic, PK- Platykurtic, VLK- Very Leptokurtic.

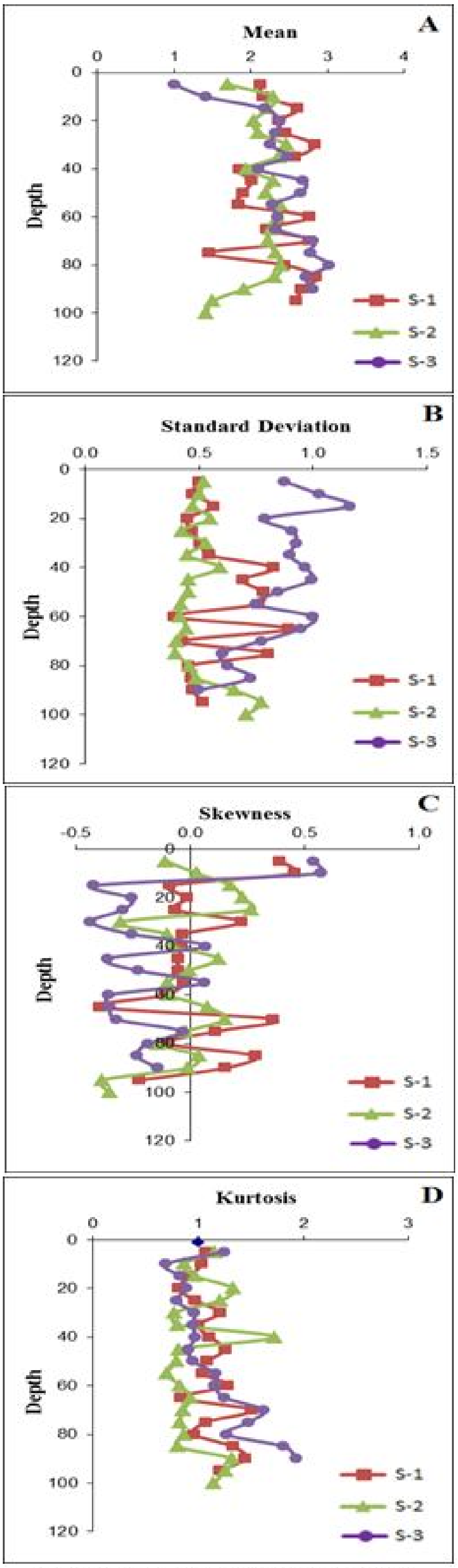


Figure -1 (A-D) Showing depth wise variation of statistical parameters for all stations

V. SCATTER PLOTS

Sedimentologists have attempted to use scatter graphs of grain size parameters to distinguish different depositional settings, via bivariate plots, which are based on the assumption that these statistical parameters reliability reflect differences in the fluid-flow mechanisms of sediment transportation and deposition (Sutherland and Lee 1994). An attempt has been made here to utilize these scatter diagram in study area to understand the geological significance using four size parameters.

Mean vs. Standard deviation

The mean vs. standard deviation plot (Fig -2A) of sediment in all stations shows an increase in sorting value with decrease in size of the sediments. Griffiths (1967) explained that both mean grain size and sorting are hydraulically controlled, so that in all sedimentary environments the best-sorted sediments have mean size in the fine sand size range.

Mean vs. Skewness

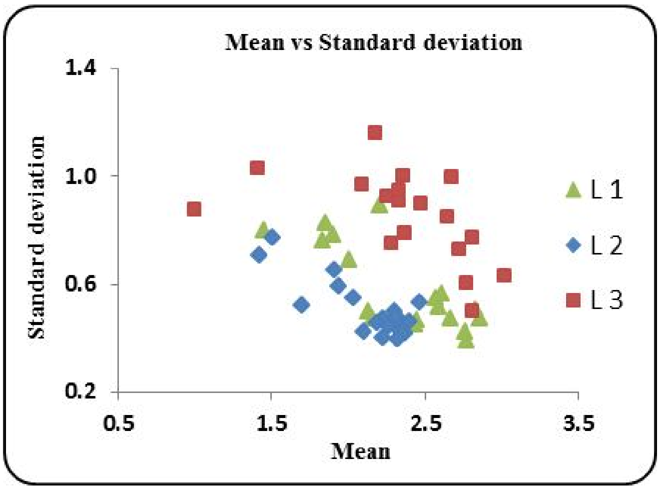
Mean vs. skewness plot (Fig -2B) of station-1 and station-2 shows an increase in skewness value with decrease in size of the sediments. At station-3, sediments show negative skewness with decrease in size of sediments. The percentage of positive skewed samples were relatively less comparatively with negatively skewed, which indicates that the basin were undergoing erosion or non-position (Duane, 1964).

Mean vs. Kurtosis

The relation between mean-size and kurtosis (Fig -2C) is complex and theoretical (Folk and Ward, 1957). The mixing of two or more size-classes of sediments, which basically affect the sorting in peak and tails i.e. index of kurtosis. Mean vs. kurtosis plot of all the stations shows that, finer the sediments higher the kurtosis value. The plot of present values shows that the sediment-admixture is dominated by fine sand. The varying proportions of sediments mixed with dominant sand mode makes the sorting worse, particularly in the tails; hence, there is a presence of platykurtic and leptokurtic to very leptokurtic condition also (Ashok et.al,. 2009).

Standard deviation vs. Skewness

From the plot between standard deviation and skewness of station-1and station-2 (Fig -2D), it has been observed that most of the samples show positive skewness remain well sorted. The plot between standard deviation and skewness at station -3 produce a scattered trend i.e., sorting improves with negative skewness, which may be due to two conditions, i.e., either unimodal samples with good sorting or equal mixture of two modes (Ashok et al., 2009, Harsha Sundar et al., 2010).



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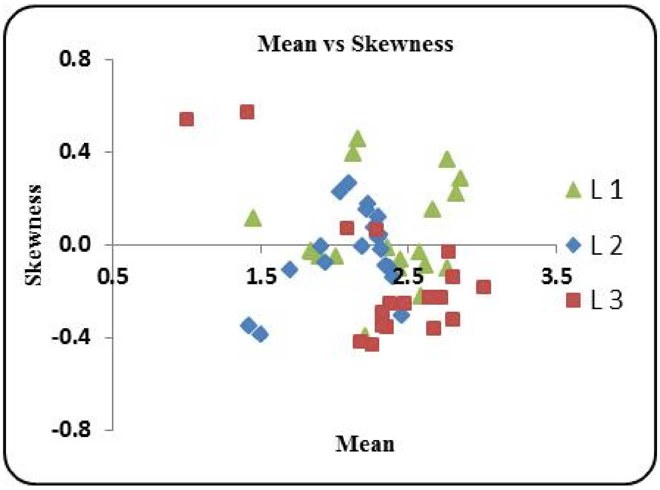

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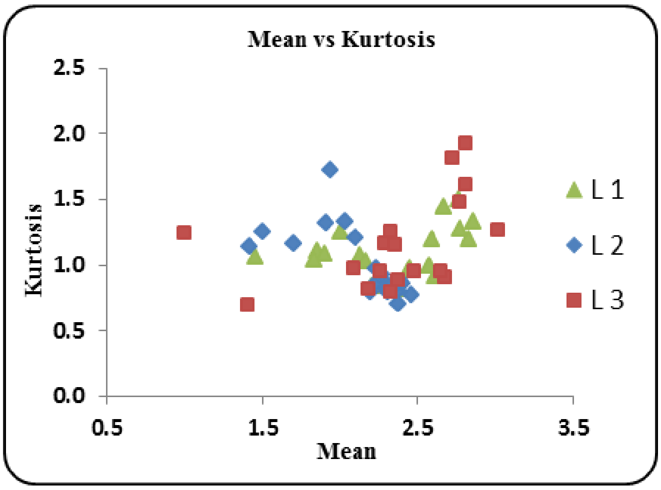

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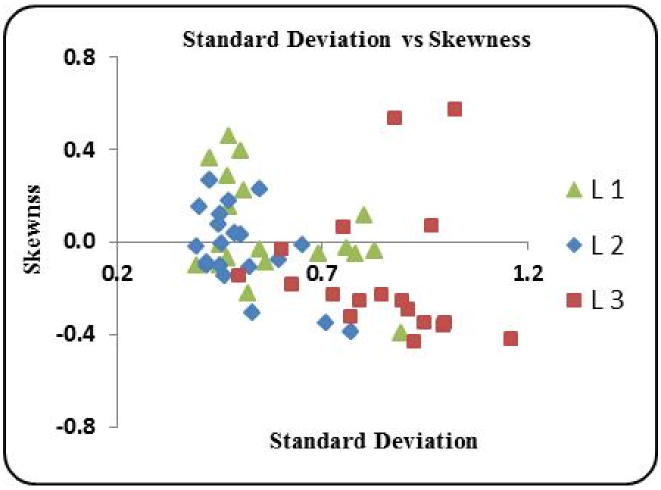
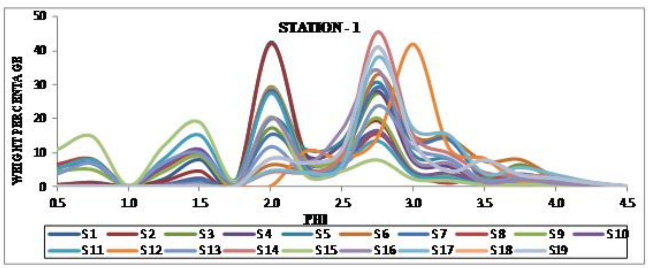


D

Figure-2(A-D) Showing Scatter Plot Between Statistical Parameters

VI. FREQUENCY CURVE

Frequency curve exhibit the pictorial representation of actual weight percentage of different fraction of sediments. According to Friedman (1978), the size factor mode is the peak of a simple frequency curve. The mode is important statistical parameter, especially the sediments containing



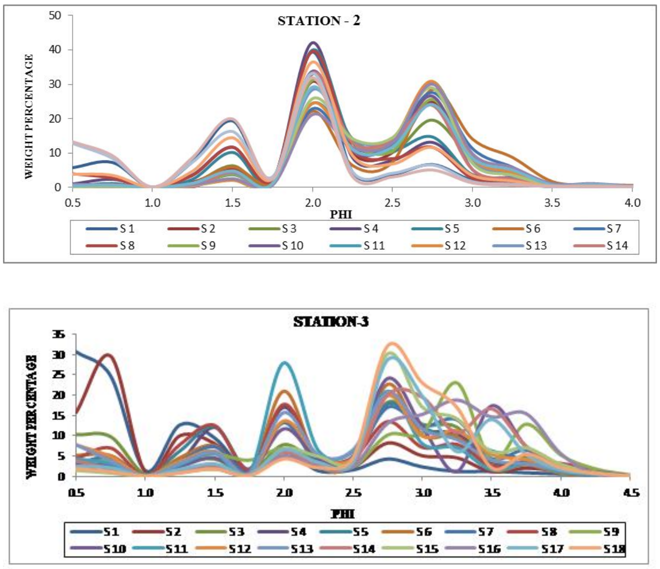


Figure- 3 Showing Frequency distribution curve for all stations

several subpopulations each of which has its own mode. The presence of several modes in sand suggests that the particles have been derived from several parent deposits. In such multi-population (polymodal) sands, the phi value and magnitude give information on mixing of sediments. Change in the mode reflects the history of the sand. The frequency distributions for the samples at station-1 shows equal unimodal(47%) and bimodal(47%) character with a few shows polymodal(6%) character. At station-2, most of the sediments shows bimodal(65%) character compared with unimodal (35%) nature. This bimodality is acquired by the discharge of fine sediments from Tamirabarani River. The unimodality of sediment reflects the lack of sediment deposition from the river. Most of the sediments at station-3 shows polymodal(44%) character whereas unimodal(28%) and bimodal(28%) character sediment distributed equally. Polymodal nature of sediments indicate different source of deposition (Fig.-3).

LINEAR DISCRIMINANT FUNCTION (LDF): According to Sahu (1964), the variation in the energy and fluidity factors seem to have excellent correlation with the different processes and the environment of deposition. However, as there is strong penchant to find out the total effect of the various parameters on the grain size variations in the beaches, the process and environment of deposition has been deciphered by Sahu’s linear discriminant functions of Y1 (Aeolian, beach), Y2 (Beach, shallow agitated water) , Y3 (shallow marine, fluvial) and Y4(Fluvial Deltaic and Turbidity).

Linear Discriminant Function (LDF) value (Table No.-1) of station-1 and station-2 indicate that sediments were deposited under aeolian and beach process in shallow marine and turbidity environment. In station-3, most of the samples deposited under Aeolian and shallow agitating water process under shallow marine and fluvial conditions in turbidity action. The variation in depositional condition is mainly due to interaction of both fluvial action and littoral current awith influence of monsoonal activities in the study area.

Table No. - 2 Showing Linear Discriminant Function percentage of all locations

	Y1	Y2	Y3	Y4
LOCATION-1	Aeolian (100%)	Beach process (79%) Shallow agitated water (21%)	Shallow marine (100%)	Turbidity (100%)
LOCATION-2	Aeolian (100%)	Beach process (100%)	Shallow marine (100%)	Turbidity (100%)
LOCATION-3	Aeolian (89%) Beach (11%)	Shallow agitated water (94%) Beach process (6%)	Shallow marine (72%) Fluvial (Deltaic) (28%)	Turbidity (100%)

CM PATTERN

Passega (1957) introduced C-M plot to evaluate the hydrodynamic forces working during the deposition of the sediments. It is a relationship of ‘C’ i.e. coarser one percentile value in micron and ‘M’ i.e. median value in micron on log-probability scale. Passega (1964) divided the CM pattern into different sector namely NO, OP, PQ, QR, and RS for different mode of transport. The plotted result of Tamirabarani coast sediments shows that most of the samples fall in NO and OP sectort which indicate bottom suspension and rolling condition of deposition (Station -1 and Station-3) while a few fall in PQ sector indicating under graded suspension and no rolling mode of deposition (Station-2) (Fig.-4).

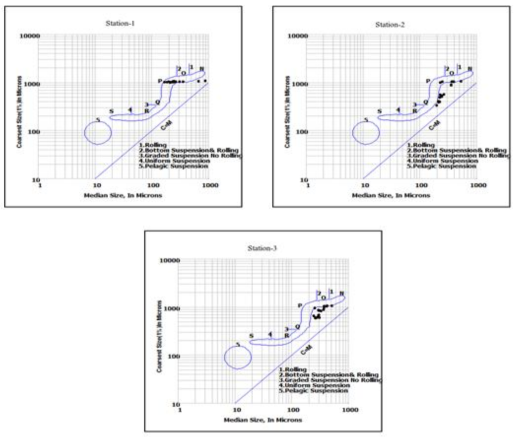


Figure- 4 Showing CM diagram (Passega, 1964) for all stations

VII. CONCLUSION

The textural parameters of Tamirabarani coastal sediment show dominance of fine sand which infers low energy conditions of deposition. The variation in sorting value indicate continuous addition of finer to coarser material at varying proportion The sediment, in general, show dominantly fine skewed to coarse skewed nature. Variation in kurtosis value from platykurtic to

leptokurtic infers energy fluctuation of depositing medium. Various scatter plots between mean, standard deviation, skewness and kurtosis explain the dynamic process operating in the region together with the influence of climatic seasons. Linear Discriminant Function (LDF) value of station-1 and station-2 indicate that sediments were deposited under aeolian and beach process in shallow marine and turbidity environment. In station-3, most of the samples deposited under Aeolian and shallow agitating water process under shallow marine and fluvial conditions in turbidity action. The variation in depositional condition is mainly due to interaction of both fluvial action and littoral current awith influence of monsoonal activities in the study area. The frequency curves vary from unimodal to bimodal in places of river discharge from the Tamirabarani, as a result of which an additional sub-population is deposited. Otherwise, the nature of the frequency curve is controlled primarily by wave dynamics and littoral currents. The sediments are mostly rolled and deposited by suspension mode. It may be due to excess input of fine grained material during different seasons. Some of the samples fall under graded suspension and no rolling category which is acquired by comparatively more percentage of fine grained riverine sediments. So variations of grain size characteristics along this beach are believed to have resulted from wave refraction, fluvial action and long shore currents. This study demonstrates the usefulness of selecting several locations to better understand the beach environment of deposition.

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