International Journal of Theoretical & Applied Sciences, 9(2): 168-177(2017)

ISSN No. (Print): 0975-1718
ISSN No. (Online): 2249-3247

Depositional Mechanism as Revealed from Grain size Measures of Rameswaram Coast, Ramanathapuram District, Tamil Nadu, India

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(Received 19 September, 2017 Accepted 12 October, 2017)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Rameswaram coast of Tamilnadu, India has been studied for grain-size spectrum and textural parameters namely mean, sorting, skewness and kurtosis. Texturally sediments are mostly medium sand, well sorted to moderately sorted, coarse skewed to fine skewed, platykurtic to leptokurtic in nature. Abundance of the medium sand demonstrates the prevalence of moderate energy condition in study area. Several geomorphic features has been discussed which are the signatures of the interaction of marine and Aeolian processes. Linear discriminate function analysis (LDF) of the sample indicates a shallow marine depositional environment with less influence of fluvial process. The CM pattern of Rameswaram coastal sediment shows a clustered distribution of sediments in the NO and OP segments, indicating a bottom suspension and rolling mode of deposition. The inference to be drawn from these studies is that the variation in sedimentological parameters is governed by wave dynamics and littoral transport of the sediments.

Keywords: Textural parameters, Linear discriminate function (LDF), CM pattern, Rameswaram, Tamilnadu.

I. INTRODUCTION

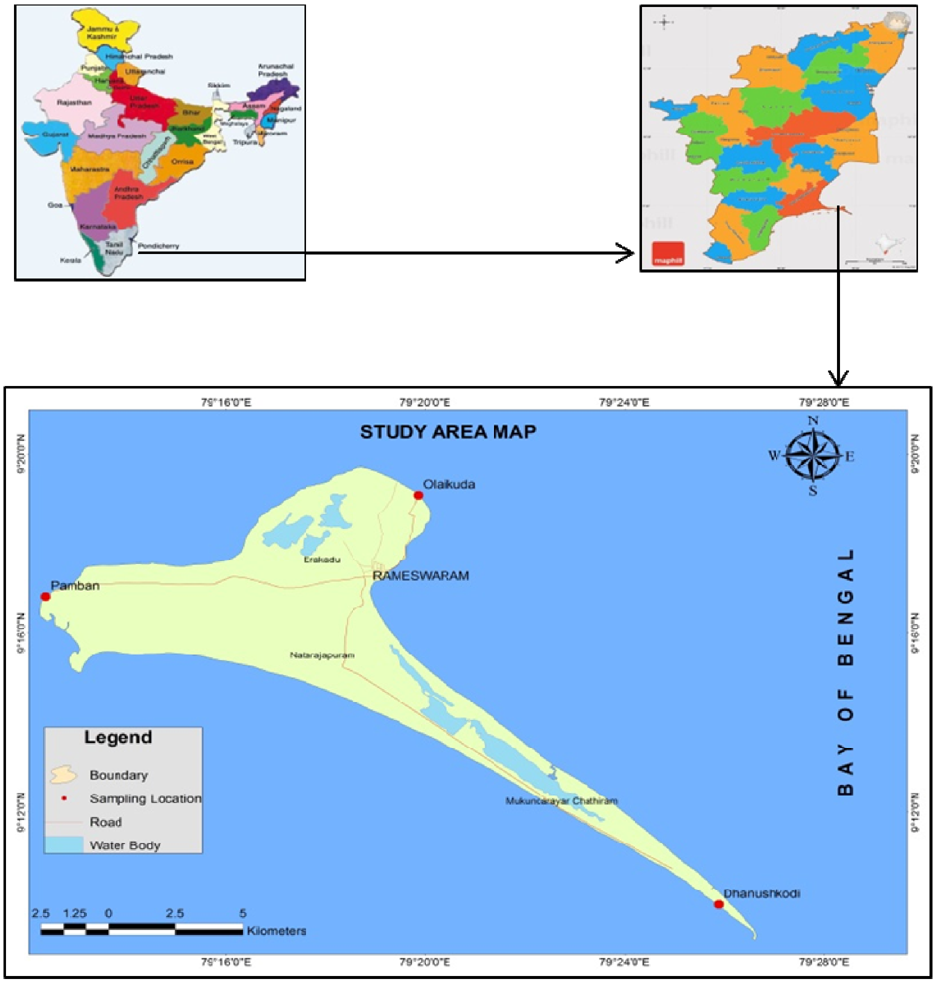
Being a dynamic zone where air, water and land interact and in view of its strategic and economic importance, coastal zone is a focus of specific attention among the scientific community. The increasing demand for exploring and exploiting non-living coastal resources like placer deposits emphasises the need to hoard inventories of coastal processes that include aspects of sediment systematics such as grain size. Grain size is one of the most significant physical property of sediment and commonly used parameter for understanding the processes involved in transportation and deposition of sediments [1-6]. The parent lithology and the climatic conditions influence characteristics of sediments in the provenance stage and further modified it during the transportation stage [7]. In addition, during depositional process the particle size is characterizing with the energy conditions of the environment and flow regimes [8-10].

Many studies have been carried out on sediment characteristics and distribution pattern in the shelf region of east and west coast of India [11-16]. However, information on sediment characteristics for Rameswarm Island is lacking.

Earlier studies have indicated that the south east coast of India was affected by natural disasters like cyclone induced surges, tsunamis etc., resulting in triggering, reallocation and redistribution of sediments in the shelf region. Thus, information on the sediment characteristics is highly essential to understand the textural features and the processes operating around the Island. Therefore the present study has been undertaken to fulfil the information gap.

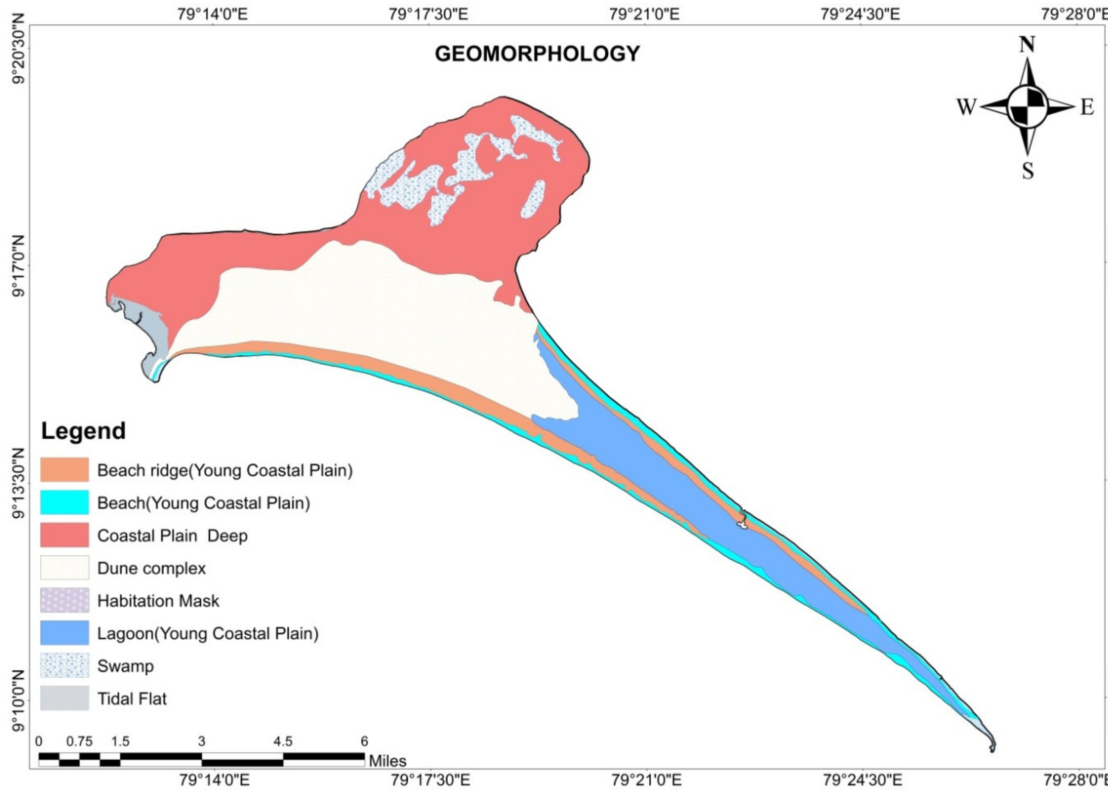
II. MATERIAL AND METHODS

Studies were carried out in parts of Rameswaram Island, Ramanathapuram District, Tamil Nadu. The study area falls in 58 O/7 and 58 O/8 toposheet of survey of India in a 1:50000 km scale. For georeference of latitude and longitude, survey of India toposheets was used and base map was prepared under GIS environment using Arc GIS 10.1. Rameshwaram is an island separated from mainland by the Pamban channel and is located on the eastern part of Ramanathapuram district (Map- 1) which is bounded between the latitudes E 79°12' 30" and E 79° 27' 30" and longitudes N 9° 8' 55" and N 9° 19'.



Map 1- Showing Study area.

The coast of Rameshwaram has several topographic expressions (Map- 2), which are the signatures of the interaction of marine and aeolian processes [17]. Previous studies carried out in this island invariably established that the island has been subjected to erosion by various processes [18-20]. Rameswaram has a severe threat of sea level variations [21] and indeed is one of the most affected islands of the country. It has been exposed to natural disasters like storm surges, cyclones, and erosion in the past. A widely varying nature of landforms and their disposition along the beaches and inland represents the successive phase of transgression and regression of sea level [22]. Among the various depositional landform features, the formation of a spit can be considered a feature of recent age [23]. The southwestern shore of Rameswaram has a tongue-shaped spit. The Rameswaram spit may have been the result of littoral current from Palk Bay to the Gulf of Mannar during the northeast monsoon period [24]. The shoreline is relatively straight and smooth. Beach ridges are found along both the northern and the southern coasts. In the study area, well-developed marine terraces were noticed at Olaikuda. Discontinuous patches of dunes were also noticed along most of Rameswaram Island. The size of such dunes is comparatively high along the southern coast of the island. The tail-like portion observed in the southeastern part of the island extending to Dhanushkodi consists of two barrier ridges on the north and south sides and a linear lagoon between the two [18]. Long stretches of lagoon are clearly visible along the tail-like portion of the island and are well connected with the sea through small inlets.



Map 2. Coastal geomorphology around Rameswaram Island.

The sediment samples were collected at Olaikuda (OLKD), Dhanuskudi (DNSKDI) beach and Pamban (PMBN) harbour point during month of June 2016. Sampling has been carried out by core sampling method using PVC (Polyvinyl Chloride) pipe of 2.5 inch diameter and of one meter length. At OLKD and PMBN, due to the presence of beach rocks core was taken to less than one meter. The core samples then capped and carefully carried to the laboratory and kept in the refrigerator. The exact sample locations were noted with the help of Global Positioning System (GPS) receiver. 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 grams by coning and quartering method. These representative samples were then washed with distilled water to remove salt content and further treated with 1:10 parts of HCl to remove shells and organic content. Later these samples were washed frequently with distilled water and dried in hot air oven at 60°c temperature. Sieve analysis was performed by using a series of standard ASTM test sieve (From #25 to #325 sieve sizes) of quarter phi interval to get uniform size fractions in Ro tap sieve shaker for 20 minutes. The grain size data obtained after sieving is processed to calculate all the statistical parameter such as Mean (Mz), Standard Deviation (σI), Skewness (Ski) and Kurtosis (KG). CM plot prepared as suggested by Passega to understand the transportation mechanism. The G-Stat software package was used for obtaining the CM diagram. Linear discriminant function [25] was used for interpretation of depositional environment of the sediments.

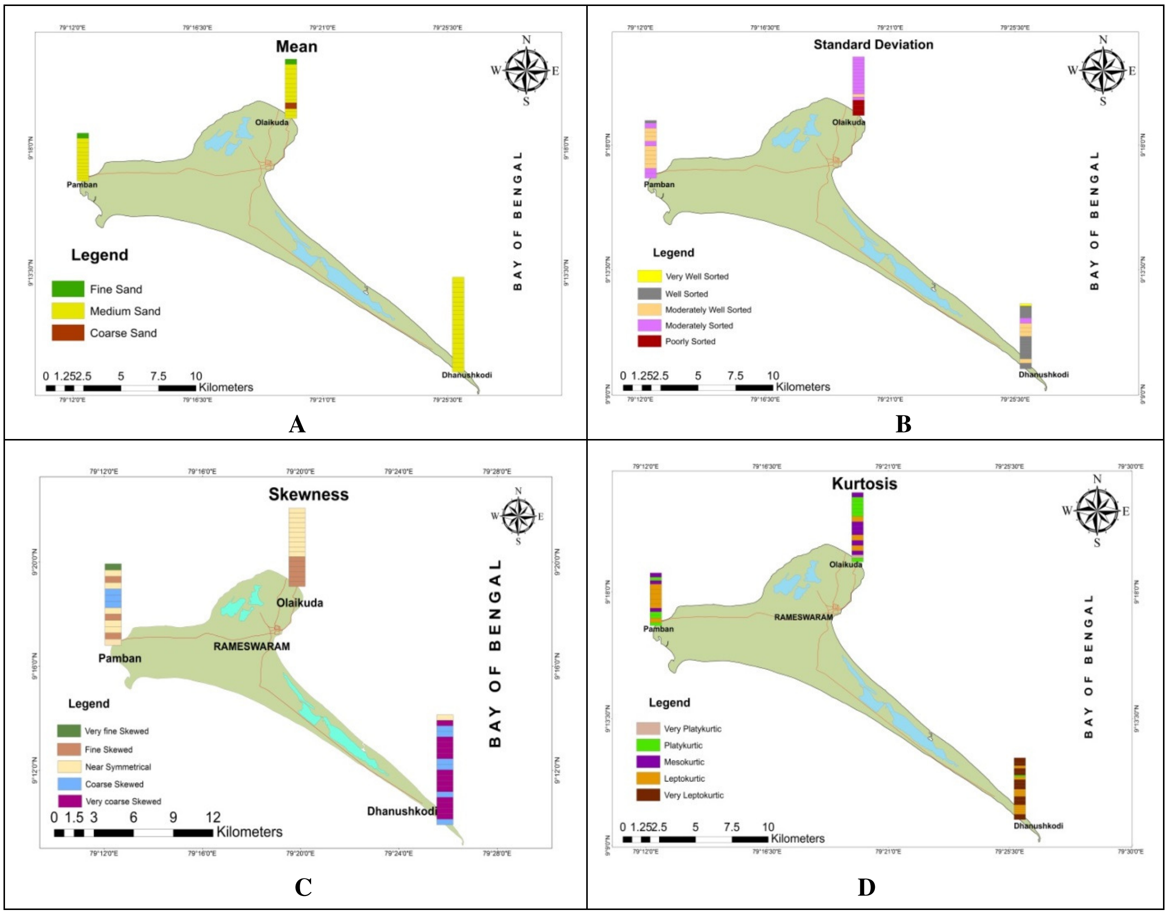
III. RESULT

The statistical parameters like mean (Mz), Standard deviation (σI), Skewness (Ski) and Kurtosis (KG) has played a major role in delineating the influence of depositional process. Generally Standard deviation and Skewness are considered to be the indicators, which are environmentally sensitive while the mean is a reflection of the competency of transport mechanism.

A. Graphic Mean

Mean size indicates the central tendency or the average size of the sediment and in terms of energy; it indicates the average kinetic energy / velocity of depositing agent [25]. Taking into account the fact that most of the sediments consist of particles of various sizes, mean diameter represents the easiest way to provide a granulometric characterisation of a sediment through a single value [26].

In the study area, the vertical mean size ranges between 0.740Φ (At 60cm depth) and 2.073Φ (At 5cm depth) with average mean of 1.457Φ at OLKD, 1.443Φ (At 30cm depth) and 1.867Φ (At 5cm depth) with an average of 1.687Φ at DNSKDI, 1.017Φ (At 60cm depth) and 2.103Φ (At 5cm depth) with average of 1.481Φ at PMBN respectively (Fig. 1A, Map -3A). The mean size indicates that most of the samples belong to medium sand category. The distribution of medium sand in this region might have accrued from the dislodging of coarser sediments by the panning action of high velocity waves and also high energy environment [27]. It has been observed that around 40cm to 70cm depth the variation is more towards coarser indicating a high energy condition at the time of deposition. 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 [25].



Map 3. (A-D) Showing variation of statistical parameters in the study area.

B. Graphic Standard deviation

According to Khan [28], standard deviation is a poorly understood measure that depends on the size range of the available sediments, rate of depositing agent and the time available for sorting. The sorting variations observed, attribute to the difference in water turbulence and variability in the velocity of depositing current [29]. The values obtained range from 0.669Φ (At 60cm depth) to 1.225Φ (At 70cm depth), 0.312Φ (At 5cm depth) to 0.726Φ (At 30cm depth), and 0.405Φ (At 5cm depth) to 0.804Φ (At 10cm depth) at OLKD, DNSKDI and PMBN respectively (Fig. 1B, Map-3B). The Standard deviation value of OLKD suggests that most of the samples are moderate (75%) to poorly sorted (19%) with only few are moderately well sorted (6%). This indicates low to fairly high energy current [4, 30]. In DNSKDI area, most of the sample belongs to well sorted (75%) to moderately well sorted (20%) shows a reflection of the higher wave energy and strong shore currents of the coast [31].

In PMBN area sorting value suggests that most of the sediments are moderately well sorted (61%) to moderately sorted (31%) in character. The moderately well sorted sample is attributed to the prevalence of strong convergence of waves [32].

C. Graphic Skewness

The graphic Skewness measures the symmetrical distribution, i.e. predominance of coarse or fine-sediments. It reflects the symmetry or asymmetry of the frequency distribution of the sediment and the measure of the particle size. If the skewness is negative, the sample is coarsely skewed, that is the mean is towards the coarser side of the median. When the skewness value is positive the sample is described as finely skewed i.e., the mean is towards the finer side of the median. The samples show the skewness values ranging between -0.083Φ (At 5cm depth) to 0.533Φ (At 80cm depth), -0.560Φ (At 90cm depth) to -0.022Φ (At 5cm depth), -0.297Φ (At 30cm depth) to 0.326Φ (At 5cm depth) at OLKD, DNSKDI and PMBN respectively (Fig -1C, Map -3C).

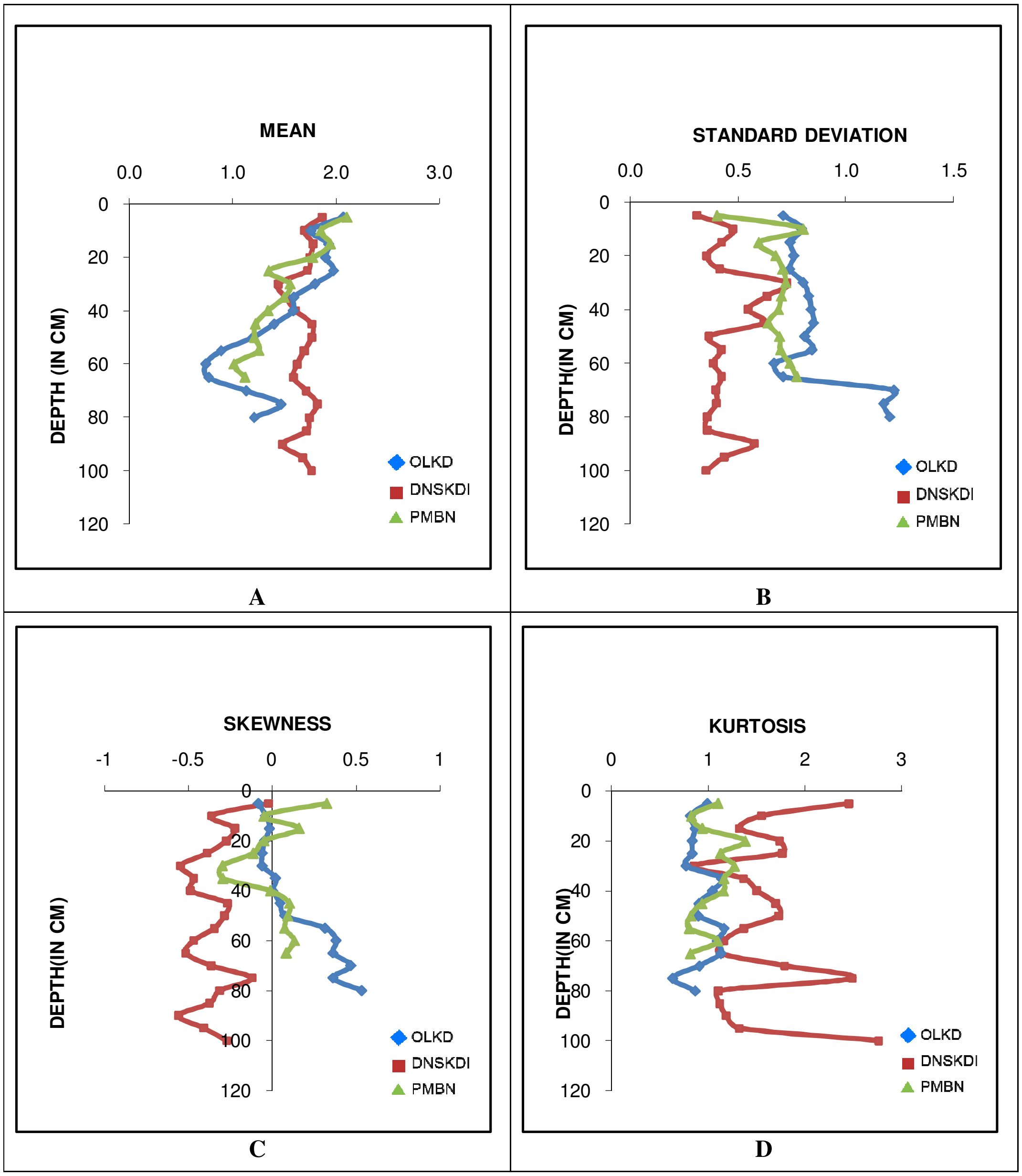


Fig. 1 (A-D). Inverted graph showing depth wise variation of statistical parameters.

At OLKD, 62% sediments are nearly symmetrical and 38% are very fine skewed. Near symmetrical sediments indicate that deposition has been taken place due to mixing of bimodal sources [27]. According to Duane [33], 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. At DNSKDI, sediments show very coarse skewed (65%) to coarse skewed (30%) nature which implies that the velocity of the depositing agent operated at a higher value than the average velocity for a greater length of time than normal [25]. Sediments of PMBN shows variable skewness value where 46% are near symmetrical and 23% of sediments shows fine skewed and 23% shows coarse skewed nature. It implies the prevalence of high and low energy environment in different wave direction, entailing a mixed distribution of coarse and fine sediments. Due to back and forth movement of waves, coarser sediments are retained and get entrapped amidst finer sediments.

D. Graphic Kurtosis

The graphic kurtosis (KG) is the peakedness of the distribution and measures the ratio between the sorting in the tails and central portion of the curve. It is also a function of internal sorting or distribution. Kurtosis value of the sediments in study area ranges from 0.634Φ (At 75cm depth) to 1.168Φ (At 55cm depth), 0.855Φ (At 30cm depth) to 2.766Φ (At 100cm depth), and 0.806Φ (At 55cm depth) to 1.387Φ (At 20cm depth) at OLKD, DNSKDI and PMBN respectively (Fig. 1D, Map -3D). At OLKD, sediments fall under mesokurtic (38%), platykurtic (37%), Leptokurtic (19%) and very platykurtic (6%). Mesokurtic character of sediments indicates moderate winnowing action of the depositing agent. Platykurtic nature indicates poor winnowing action without sorting i.e., all size fractions jumbled up. The leptokurtic behaviour of sediment indicates the variation of energy conditions of the depositional basin. At DNSKDI, almost all sample belongs to very leptokurtic (50%) and leptokurtic (45%) character indicating continuous addition of finer or coarser materials after winnowing action and retention of their original character during deposition [34]. At PMBN, most samples belong to leptokurtic (46%) and platykurtic (31%) character with 23% are mesokurtic. The variation in kurtosis value indicates reflection of the flow characteristics of the depositing medium [35]. Extreme high or low values of kurtosis imply that part of the sediments achieved its sorting elsewhere in a high energy environment [36].

Linear Discriminant Function (LDF). According to Sahu [25], the variations 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 1) of OLKD indicates that sediments were deposited under Aeolian and Beach process under shallow agitating water process in shallow marine and turbidity environment. In case of DNSKDI and PMBN, most of the samples deposited under aeolian and beach process in shallow marine and turbidity environment.

Table 1: Showing Linear Discriminant Function percentage of different location.

	Y1	Y2	Y3	Y4
OLAIKUDA	Aeolian (50%) Beach (50%)	Shallow agitated water (75%) Beach process (25%)	Shallow marine (81%) Fluvial (Deltaic) (19%)	Turbidity (100%)
DHANUSHKODI	Aeolian (100%)	Beach process (100%)	Shallow marine (100%)	Turbidity (100%)
PAMBAN	Aeolian (69%) Beach (31%)	Shallow agitated water (8%) Beach process (92%)	Shallow marine (100%)	Turbidity (100%)

Scatter Plots. Sedimentologists have attempted to use scatter graphs of grain size parameters to distinguish between 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 [37]. An attempt has been made here to utilize these scatter diagram in study area and 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 location shows an increase in sorting value with decrease in size of the sediments. It is also observed that, as the mean size increases the sediments are mostly moderately well sorted. Griffiths [38] 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 OLKD shows that with decrease in mean value, sediments get positive skewness.

At DNSKDI, skewness value decreases with decrease in mean value giving indication of high energy environment. At PMBN like OLKD sediment shows negative skewness with decrease in sediment size but at finer end it shows positive skewness value which may be due to the variations under the influence of littoral current.

Mean vs. Kurtosis. The relation between mean-size and kurtosis (Fig. 2C) is complex and theoretical [2]. 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 OLKD shows that as size of sediment increases kurtosis value also increasing. Scatter plot of DNSKDI and PMBN shows that with decrease in sediment size, kurtosis value increases. The plot of present values shows that the sediment-admixture is dominated by medium-sand.

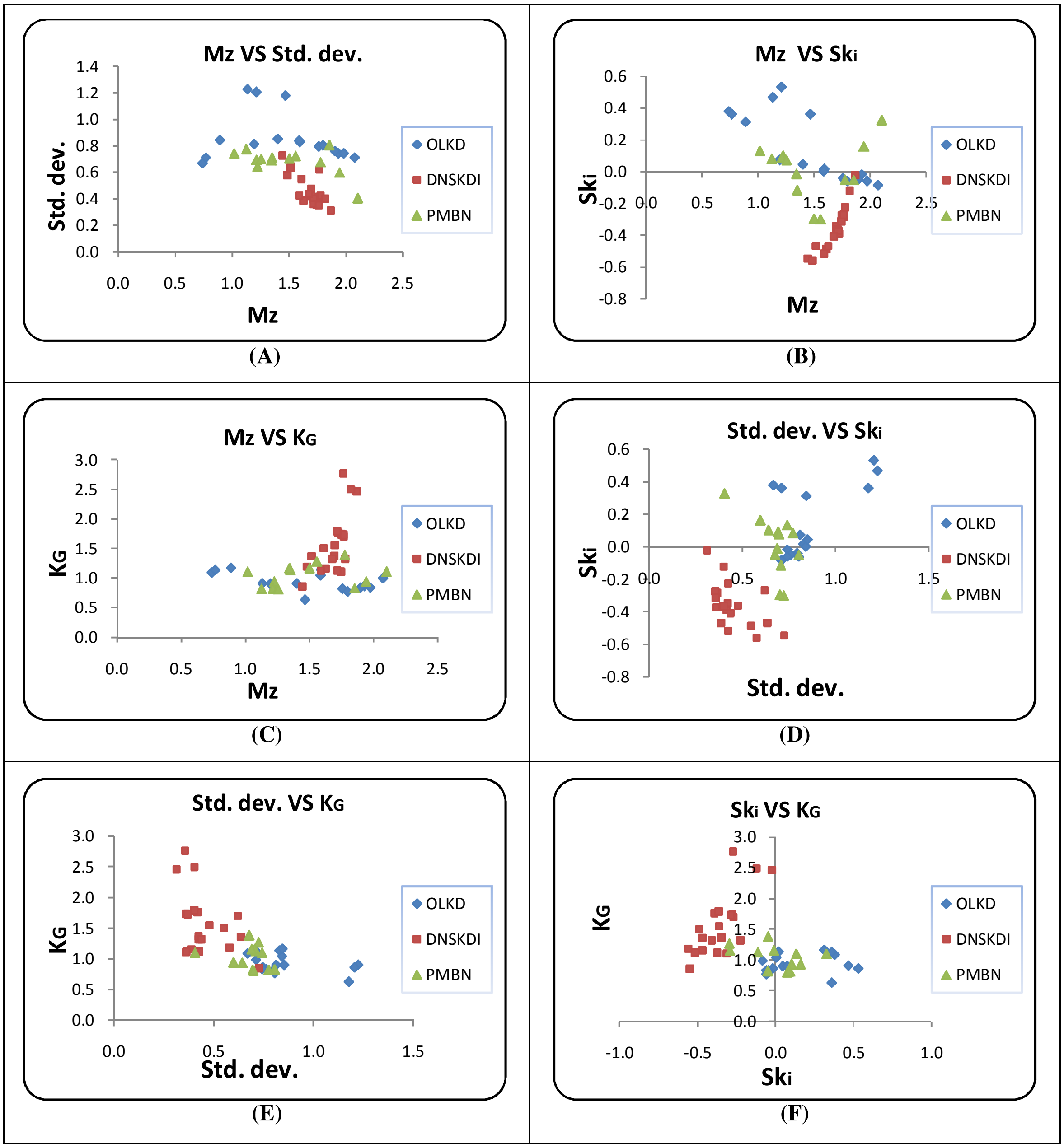


Fig. 2 (A-F). Scatter diagram showing relation between statistical parameters.

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 [39].

Standard deviation vs. Skewness. The plot between standard deviation and skewness of OLKD (Fig. 2D) 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 [39,40]. Scatter plot of DNSKDI and PMBN shows that with decrease in sediment sorting gives a negative skewness value.

Standard deviation vs. Kurtosis. The plot between standard deviation and kurtosis (Fig. 2E) of all three stations shows that sorting value decreases with increase in kurtosis value which infers that, most of the sample shows leptokurtic behaviour with increase in sorting value.

Skewness vs. Kurtosis. The plot between skewness and kurtosis (Fig. 2F) shows that kurtosis value decreases with increase in skewness value at OLKD and PMBN whereas at DNSKDI, kurtosis value increases with increase in skewness value. Friedman [36] showed that most sands are leptokurtic and are either positively or negatively skewed. This could be explained by the fact that most sands consist of two populations: one predominant population and one very subordinate, coarse (leading to negative skewness) to fine (leading to positive skewness).

C-M PLOT. Passega [41] introduced C-M plot to evaluate the hydrodynamic forces working during the deposition of the sediments.

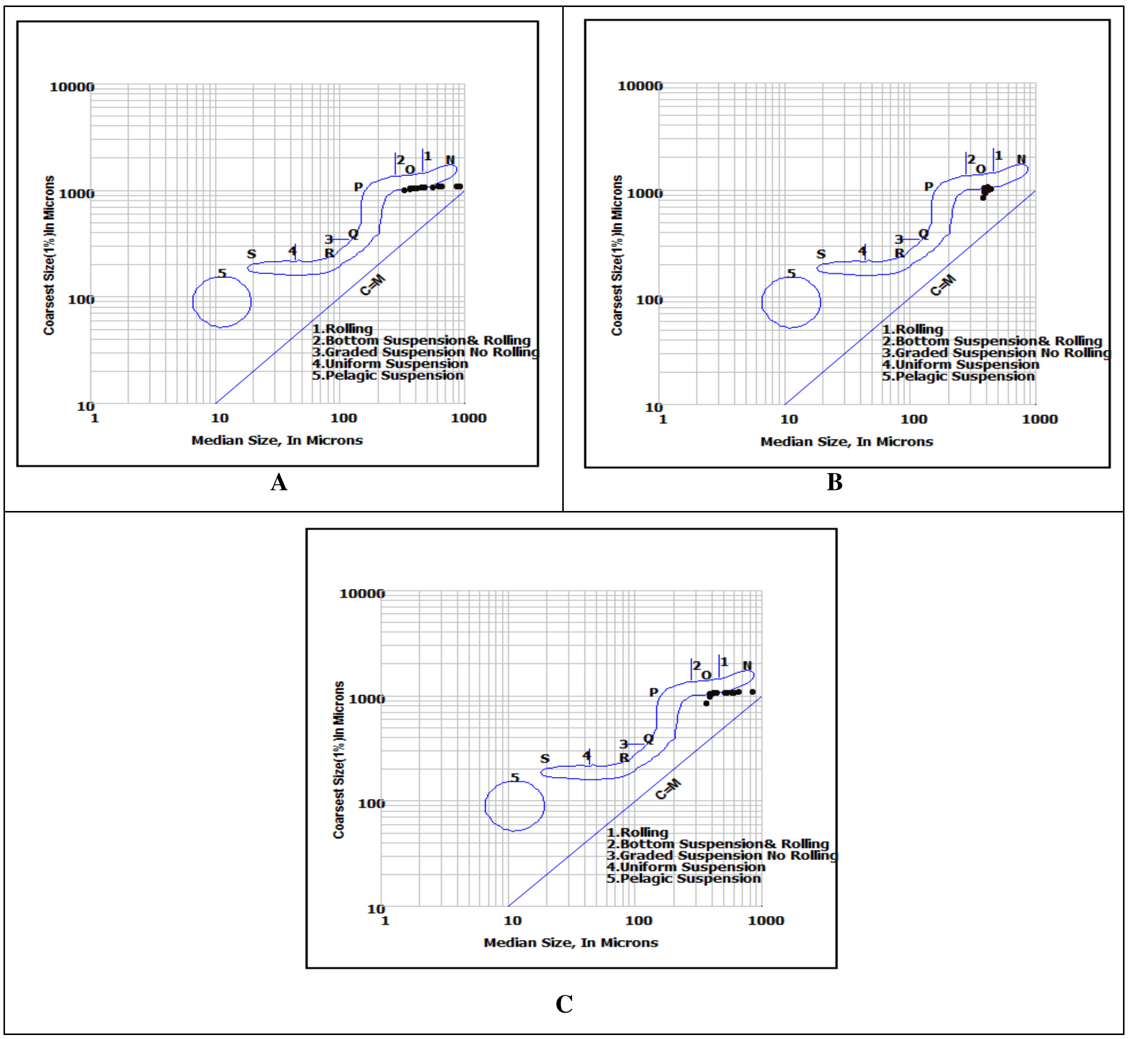


Fig. 3. CM Diagram of (A) OLKDA, (B) DNSKDI and (C) PMBN.

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 [42] divided the CM pattern into different sector namely NO, OP, PQ, QR, and RS for different mode of transport. The plotted result of sediments at all location (Fig. 3 A-C) shows that all the samples fall in bottom suspension and rolling condition.

IV. CONCLUSION

The textural parameters of coastal sediments of Rameswaram indicates mostly medium sand , well sorted to moderately sorted, coarse skewed to fine skewed, platykurtic to leptokurtic in nature. Dominance of medium sand infers moderate 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. Linear Discriminant Function (LDF) value of OLKD indicates that sediments were deposited under Aeolian and Beach process under shallow agitating water condition in shallow marine and turbidity environment. In case of DNSKDI and PMBN, most of the samples deposited under Aeolian and beach process in shallow marine and turbidity environment. Scatter diagram clearly establish the relation between different textural parameters. The CM plot of all location shows that all the samples were deposited as bottom suspension and rolling condition.

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