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# Granulometric study of Tharuvaikulam and Thirespuram, Gulf of Mannar, southeast coast of India

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**Abstract**

A study was conducted to understand the texture and nature of transportation and deposition of sediments along the shoreline of Tharuvaikulam and Thirespuram, southeast coast of India. The mean grain size of samples in Tharuvaikulam varied between 1.80 and 2.88 ϕ and between 1.65 and 2.90ϕ in Thirespuram. The graphic kurtosis values for samples at Thirespuram ranged from 0.35 to 2.46ϕ falling in very platykurtic to very leptokurtic types. For samples at Tharuvaikulam, the values varied between 0.26 and 3.47ϕ (very platykurtic to extremely leptokurtic). Grain size was plotted on the horizontal axis in arithmetic scale and cumulative weight percentage was plotted on vertical axis in probability scale running from 0 to 100%. It is concluded that the samples fall mainly in the field of medium sand to fine sand, which indicates a moderate wave action along the shoreline of the study areas.

**Keywords:** Granulometry, sedimentology, skewness, kurtosis, soil texture

## Introduction

Sediment texture provides useful information on the mode and extent of transport and environment of deposition of sediments (Mason and Folk, 1958; Friedman, 1961; Sahu, 1964; Visher, 1969). The texture of sediments has a profound bearing on the physico-chemical processes as well as the biological diversity of the development of the environment (Badarudeen, 1997).

According to Udden (1914), the hydrodynamic conditions prevailing during deposition of sediments control the size and composition of the sediments. Passega (1957, 1964) plotted the percentile grain size (ϕ) against median size (M) on log paper and obtained specific patterns characteristic of the agent of deposition. His studies proved helpful to delineate the character of deposition. According to Doeglas (1946), grain size distributions are mixtures of two or more component distributions or populations and that these distributions were produced by varying transport conditions. The fundamental modes of transport for sediments during the course of deposition are surface creep, salt formation and suspension. Inman (1949) established the significance of sorting, skewness and mean size in the study of grain size distributions by using mathematical formulae.

Spencer (1963) suggested that all sediments are mixtures of three or less log normal distribution populations and that sorting is a measure of mixing of these populations. Visher (1969) concluded that the analysis of log-probability grain size distribution curves is a good method for studying sedimentary dynamics and that it is an important tool for confirmation of depositional environment. Several authors have advocated different graphic methods for computation of grain size analysis (Krumbein, 1936; Inman, 1952; Trask, 1952; Folk and Ward, 1957). These relationships and trends may offer clues to find out the mode of deposition and identify environments by size analysis. The present study is aimed at identifying the response of grain-size distribution and granulometric parameters in the study zone and comparing with trends found in other zones (Pedreros *et al*., 1996).

## Material and methods

***Pretreatment of samples***: Sediment samples (n = 24) were collected from the shore lines of Tharuvaikulam and Thirespuram, southeast coast of India (Tuticorin) (Fig. 1). Approximately 100 g of each sample was taken 10 meters away from the shoreline for grain size analyses. The sample was initially treated with 1:1 HCl to remove the calcareous materials (shell materials) present in the sediments. This treatment was repeated until there was no effervescence. The sample was washed with liberal amount of distilled water. After decantation, the samples were dryed and weighed. Sieves from 45 to >325 mesh sizes were taken in such a way to maintain 0.5 $\phi$ intervals following American Society for Testing and Materials standards (ASTM) and a sieve shaker was employed for size separation. To maintain a constant timing, the sieve shaker was attached to a timer and every sample was sieved for 20 minutes. The sieved materials were weighed separately. The values of all fractions were weighed and properly tabulated for granulometric studies and the sands of the respective fractions were kept for further studies.

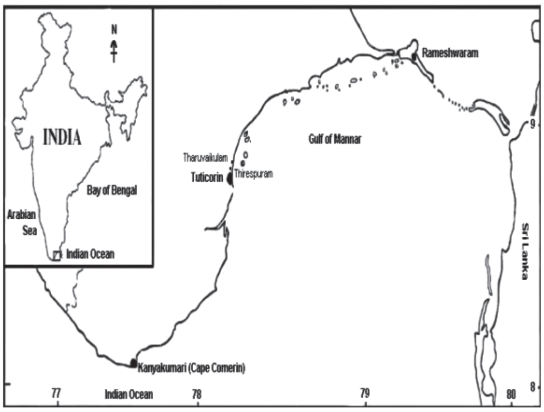


Fig. 1. Location of study areas (Tharuvaikulam and Thirespuram), near Tuticorin, southeast coast of India

***Granulometry***: Methodology followed by Folk and Ward (1957) was used for granulometry study. Parameters such as mean, standard deviation, skewness and kurtosis were calculated for the samples. A less accurate but much simpler method for calculating grain distribution statistics uses only a few points from the plot of grain size (on an arithmetic axis) versus cumulative frequency (on a probability ordinate). The critical points on the resulting curve include the 50$^{th}$ percentile (the sample median: $\phi_{50}$), the 16$^{th}$ and 84$^{th}$ percentiles ($\phi_{16}$ and $\phi_{84}$, respectively), which theoretically represent one standard deviation away from the mean in a normal population. The 5$^{th}$ and 95$^{th}$ percentiles ($\phi_5$ and $\phi_{95}$, respectively) can be used with the other three points. The sample mean (Mz) is computed by averaging the median ($\phi_{50}$) and the values one standard deviation unit to either side ($\phi_{16}$ and $\phi_{84}$):

$$M_Z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

Standard deviation is computed using information on the sample within two standard deviation units of the mean *ie*., ($\phi_5$ and $\phi_{95}$). This is particularly useful in carbonate sediment analysis where the "tails" of the size distribution curve (beyond $\phi_{16}$ and $\phi_{84}$) can be quite variable and therefore, contain important information. The formula for inclusive standard deviation (sorting) is:

$$\sigma = \frac{\phi_{84} - \phi_{16}}{2}$$

If the sample is distributed such that values for the $\phi_5$ and $\phi_{95}$ cannot be derived from the graph, then a less accurate determination (graphic standard deviation) can be made using:

$$\sigma = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

Folk (1966) and Moiola and Weiser (1968) discuss the methods of analysis and statistical handling of the results. Sediment grains occur in a wide range of sizes from microns to centimeters. Grain size is usually expressed as a projected cross section, with the assumption that the particle is roughly circular. Wentworth (1929) divided sediments into four size categories based on grain diameter: cobble/boulder (size larger than 64mm), gravel (size = 2 - 64mm), sand (size = 0.05 – 2mm) and mud (size less than 0.06mm). The results of the grain size parameters for graphical measures (Folk and Ward, 1957) of skewness (SK) and kurtosis (K) were calculated using the formulae:

$$SK = \frac{(\phi_{84} + \phi_{16} - 2\phi_{50})}{2(\phi 84 - \phi 16)} + \frac{(\phi_{95} + \phi_{5} - 2\phi_{50})}{2(\phi 95 - \phi 5)}$$

and

$$K = \frac{\phi_{95} - \phi_{5}}{2.44\ (\phi_{75} - \phi_{25})}$$

These statistical parameters, bivariant and scatter plots were used to infer the possible mechanisms that operated during the transportation and depositional processes.

## Results

The mean grain size of samples for Tharuvaikulam varies between 1.80 and 2.88 ϕ and for Thirespuram, it ranges between 1.65 and 2.90 ϕ indicating that the sediments are mostly medium to fine size in Wentworth's size class and shows a predominance of very fine sand size together with a band of finest means that seem superimposed to the general trend. The coarser means appear fundamentally in the coastal zones. The sorting is 1.9 ϕ, corresponding to moderately sorted sediments. Its distribution shows a high degree of heterogeneity, according to the localization of the supply sources, to the energy of the environment and to the transport processes. Fig. 2 and 3 represent the bivariate plot of standard deviation *vs* mean plots for Tharuvaikulam and Thirespuram respectively. Table 1 shows the seasonal variation of surface temperature, water temperature, rainfall, humidity and pressure at Tharuvaikulam and Thirespuram. Based on the methodology and the scale proposed by Folk and

Table 1. Seasonal variations at Tharuvaikulam and Thirespuram

| Parameters | Tharuvaikulam | | | | Thirespuram | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre Monsoon | | Post Monsoon | | Pre Monsoon | | Post Monsoon | |
| | 2002 | 2003 | 2003 | 2004 | 2002 | 2003 | 2003 | 2004 |
| Surface temperature (°C) | 31.7(0.6) | 30.3 (1.0) | 29.3 (3.5) | 30.2 (2.2) | 31.8 (0.5) | 31.2 (0.1) | 29.4 (2.7) | 29.8 (0.3) |
| Water temperature (°C) | 29.5 (0.9) | 28.3 (1.06) | 30.3 (1.6) | 28.7 (2.1) | 30.9 (1.9) | 29.4 (1.1) | 29.0 (1.0) | 27.8 (0.5) |
| Rainfall (cm) | 25.4 (38.4) | 27.1 (42.6) | 86.5 (65.2) | 68.1 (93.3) | 25.2 (38.4) | 27.1 (42.6) | 86.6 (0.8) | 100.0 (106.4) |
| Humidity (%) | 75.1 (11.0) | 78.3 (4.9) | 80.6 (0.8) | 76.3 (2.3) | 76.2 (9.3) | 78.3 (4.9) | 80.6 (0.8) | 76.0 (1.8) |
| Pressure | 1007.5 (2.0) | 1006.5 (1.5) | 1009.7 (2.7) | 1008.8 (1.4) | 1007.3 (1.8) | 1006.5 (1.5) | 1009.7 (2.7) | 1009.3 (1.5) |

Numbers in parentheses are standard deviations

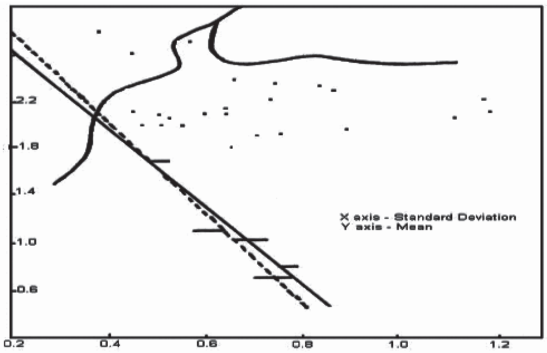


Fig. 2. Bivariate plot of mean *vs* standard deviation after (Friedman, 1961; Moila and Weiser, 1968) for sediment samples from Tharuvaikulam

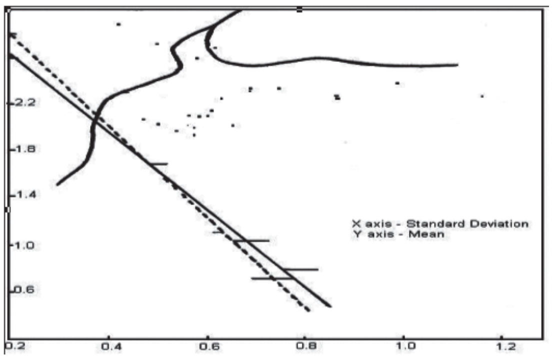


Fig. 3. Bivariate plot of mean *vs* standard deviation after (Friedman, 1961; Moila and Weiser, 1968) for sediment samples from Thirespuram

Ward (1957), the standard deviation values for samples from Thirespuram ranged from 0.45 to 1.62 ϕ (well sorted to poorly sorted) and values for Tharuvaikulam from 0.39 to 1.39 ϕ (well sorted to poorly sorted). The scatter plot of skewness *vs* standard deviation of Tharuvaikulam and Thirespuram are shown in Fig. 4 and Fig. 5 respectively. Fig. 6 and Fig. 7 exhibit the scatter plot of standard deviation *vs* skewness of Tharuvaikulam and Thirespuram respectively.

The skewness values at Thirespuram ranged from 0.39 to -1.76 ϕ (very fine-skewed to very coarse-skewed). For Tharuvaikulam, the values varied between 0.31 and -2.99 ϕ (very fine-skewed to very coarse-skewed). This prevails together with the symmetrical distributions. The negative

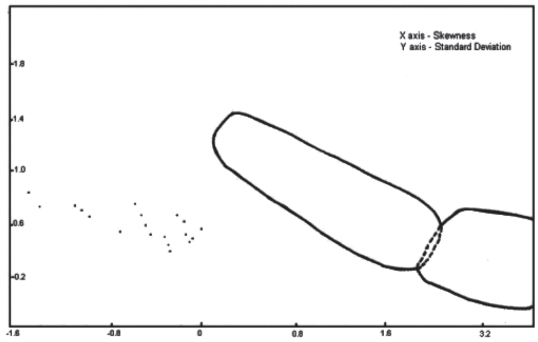


Fig. 4. Scatter plot of skewness *vs* standard deviation (Stewart, 1958) for sediment samples from Tharuvaikulam

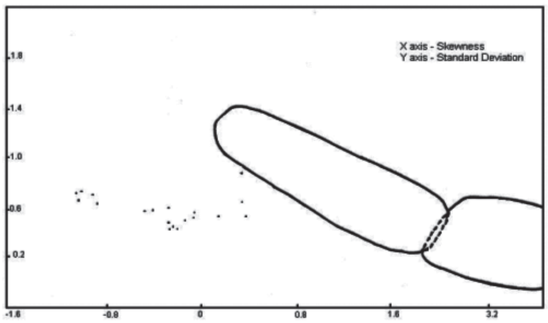


Fig. 5. Scatter plot of skewness *vs* standard deviation (Stewart, 1958) for sediment samples from Thirespuram

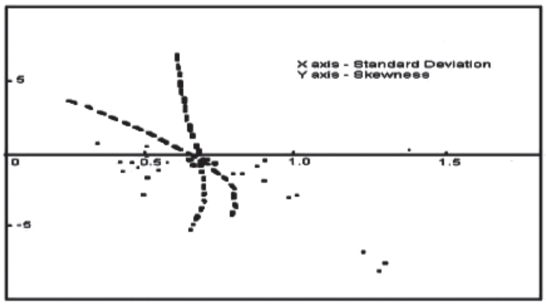


Fig. 6. Scatter plot of standard deviation *vs* skewness (Friedman, 1961; Moila and Weiser, 1968) for sediment samples from Tharuvaikulam

skewness values are found near the coastline (foreshore). The scatter plot of mean *vs* skewness for Tharuvaikulam is indicated in Fig. 8 and for Thirespuram in Fig. 9. The graphic kurtosis values

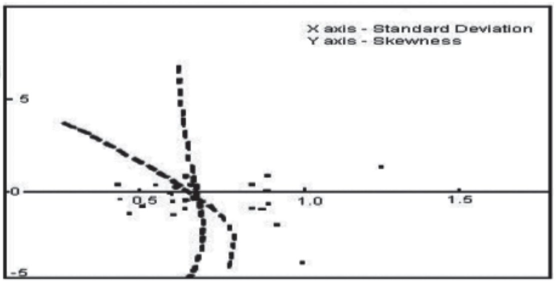


Fig. 7. Scatter plot of standard deviation *vs* skewness (Friedman, 1961; Moila and Weiser, 1968) for sediment samples from Thirespuram

for Thirespuram ranged from 0.35 to 2.46 ϕ falling in very platykurtic to very leptokurtic types. For Tharuvaikulam, they varied between 0.26 and 3.47 ϕ (very platykurtic to extremely leptokurtic). The scatter plot of skewness and kurtosis for Tharuvaikulam and Thirespuram are shown in Fig. 10 and Fig. 11 respectively.

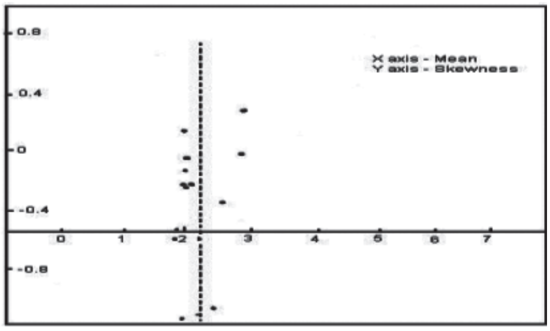


Fig. 8. Scatter plot of mean *vs* skewness (Moiola and Weiser, 1968) for sediment samples from Tharuvaikulam

## Discussion

The average size, nature and depositional conditions of sediments can be explained by using the mean. It is influenced by parameters like velocity of transporting agent, shape and specific gravity, composition, durability, resisting nature of the sediments and the amount of tossing during transportation. If the grain size is larger, the amount of imparting energy required to transport the sediments will be greater. So the mean size of the sediment serves as an index of the measure of abrasion, attrition and accretion.

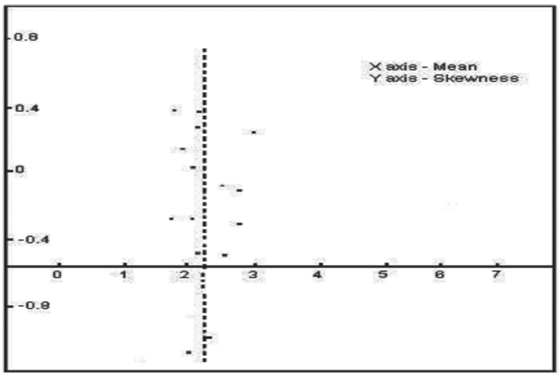


Fig. 9. Scatter plot of mean *vs* skewness (Moiola and Weiser, 1968) for sediment samples from Thirespuram

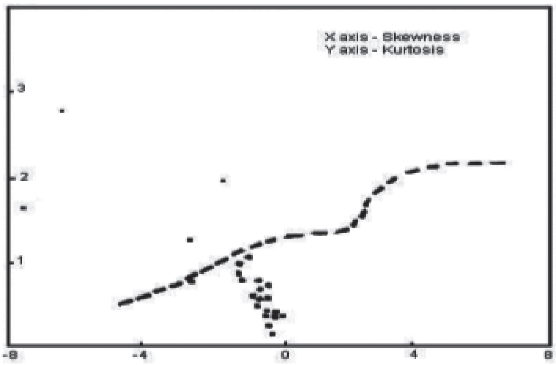


Fig. 10. Scatter plot of skewness *vs* kurtosis (Friedman, 1967) for sediment samples from Tharuvaikulam

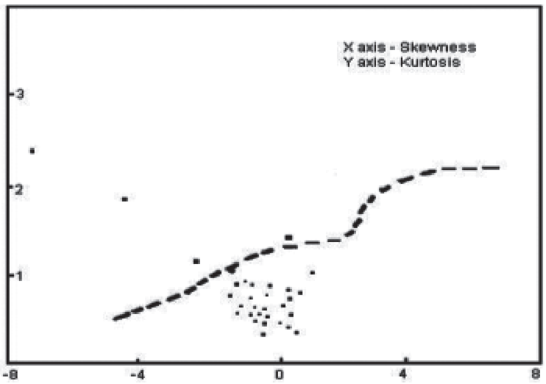


Fig. 11. Scatter plot of skewness *vs* kurtosis (Friedman, 1967) for sediment samples from Thirespuram

The degree of sorting is dependent on the size of the sediments and serves as a measure to decipher the energy or the depositional environment and to know the presence or absence of coarse and finegrained fractions (McKinney and Friedman, 1970). It is one of the most useful textural attributes in classifying sands from different depositional environments. Sorting of sediments is influenced by many parameters like degree of turbulence, velocity of the transporting agent, hydrodynamic properties, nature of sediments supplied to the depositional environment and rate of supply of detritus (McKinney and Friedman, 1970). The best-sorted sediments are usually those with the mean size range between 2.0 and 3.0f, irrespective of the conditions prevailing in the depositional environment (Inman, 1952). Strong variations are generally possible only when depositional processes are very active (Mohan *et al*., 2000). Most of the samples from the two areas are moderately well sorted. The samples collected during September-October from the two areas are moderately sorted. The moderately well sorted sample is attributed to the prevalence of strong convergence of waves of the study area. Angusamy *et al*. (1998) reported that in Tuticorin a high energy environment is indicated by a strong convergence in the north as well as south of spit formation.

The main parameter able to identify grain-size trends is skewness. Three trends were determined to characterize present day sedimentary environments: a) very positively skewed sediments with leptokurtic distributions belong to deposits with a high degree of textural maturity and reworking; b) negatively skewed sediments characterize intertidal environments; c) symmetrical and poorly sorted distributions indicate the permanent fine-settling pathways, whereas positively skewed, coarser and better-sorted sediments point to the occasional extension of suspended matter plumes (Parrado Roman and Achab, 1999). The fine-skewed nature of few samples from the study areas suggests the prevalence of calm environment for the deposition of fine sediments during those particular months.

Moiola and Weiser (1968) reported that the plot of mean *vs* skewness indicates the depositional environment samples which lay close to the beach-dune separation line. Most of the samples at Tharuvaikulam and Thirespuram were close to the beach-dune separation line. The plot of standard deviation *vs* skewness showed the depositional environment of samples of Tharuvaikulam and Thirespuram as beach and river when compared with Friedman (1967) and Moiola and Weiser (1968). The plot of skewness and kurtosis samples from Tharuvaikulam and Thirespuram revealed the river transportation environment, which was similar to the results of Friedman (1967). The skewness and kurtosis parameters have only local significance, but they are useful for the characterization of different sedimentary environments. Skewness is a parameter that responds to transport direction and supply sources. A very negative skewness appears in the transition zones due to the mixture of fine and coarse grain sizes (Blaeser and Ledbetter, 1980). All the plots indicated that the sediments had been derived from a fluvial system and deposited along the beach in a moderately agitated environment.

The analysis of grain-size parameters and principle mode found that very fine sand was dominant and it was the most stable size fraction for the existing energetic conditions for the dominant transport process. The samples fall mainly in the field of medium sand to fine sand, which indicates a moderate wave action along the shoreline of the study areas.

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