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## The relationship of sediment texture with coastal environments along the Kuala Terengganu Coast, Malaysia

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**Abstract** The subtidal sediments of four coastal environments (beach, berm, surf zone and nearshore sea floor) of Kuala Terengganu have been studied in terms of their textural characteristics and depositional process. Sampling and statistical analyses of the grain size distributions of beach, surf zone and shallow sea-floor sediments at various locations along the coastline show that they varied in their mean grain size as well as values of sorting and skewness. The statistical parameters of grain size distributions thus

allowed recognition of distinct sub-environments. The size distribution of such sediments suggests that the various processes that are responsible for their transportation and deposition are wave, current and wind action. The different energy conditions and the morphology of each coastal environment seem to be reflected in the characteristics of the sediments in each environment.

**Keywords** Sediment distribution · Grain size · Coastal environments · Statistical parameters

### Introduction

An understanding of the coastal environment and the processes involved is necessary in any rational coastal management or planning and coastal engineering endeavor. The causative factors of sediment distribution are cyclic in nature including wind, waves, tides and currents. Man-induced activities could also be considered as one of the factors affecting sediment size distribution. Investigations concerning the physical properties of the sediments are of great scientific value since they reflect the occurrence and abundance of certain rocks or mineralized deposits in the area as well as its productivity. Knowing the characteristics of sediments is important in understanding the properties of the sea-floor through which we can determine the richness and productivity of the benthic organisms and mineral deposits available in the area.

Recently, the study of sediment pattern has tended to become more applied. Taggart and Schwartz (1988) used

geomorphic and sedimentological indicators to determine the direction of shore drift (long-term sediment transport) along a coast line. This is a quick and accurate method to determine the impact of coastal sediment transport regime on coastal zone management decisions, as well as the construction of coastal structures. Furthermore, net littoral drift and sediment characteristics are important components for the environmental impact assessment study. The natures and extents of coastal erosion and accretion at a local or regional scale can also be determined through the use of this indicator. Other studies by Sunamura and Horikawa (1972), Self (1977), Engstrom (1978), Stanley (1986) Mohd Lokman et al. (1998) and Rosnan and Saadon (1989) noted the importance of a variety of sedimentological trends in interpretation of littoral drift direction and their depositional environment.

With the background of using trends in grain sizes to differentiate variations in coastal sediments, grain size trends with respect to environmental settings will now be

considered. This aspect arose out of a major aim of this study to adequately describe the sediments of the different coastal environments within the study area so that similar environmental settings in the geological record could be recognized.

Previous studies by Mason and Folk (1958) and Friedman (1962), covering a wide range of geographical localities, have shown that different environments can be distinguished from the statistical parameters of grain size distributions. Skewness was found to be a very useful parameter for distinguishing between beach and dune sediments. Mason and Folk (1958) pointed out that different physical processes at beaches and dunes affected the initial grain size distributions by adding (or removing) small amounts of fine or coarse sand sized material. In the beach zone, fine sand is winnowed away by breaking waves, causing the sand to be negatively skewed (coarser grained). At dunes, however, fine materials are added during slack periods, causing the sand to be positively skewed (finer grained).

No studies on the use of statistical parameters of grain size distributions to differentiate sedimentary environments in coastal settings have, as yet been carried out in Malaysia. The present study was therefore conducted to see if the study area could be separated into four different environments, i.e. beach, berm, surf zone and near-shore sea floor, on the basis of the statistical parameters of grain size distributions.

## Materials and methods

### Study area

The study area is located on the east coast of Peninsular Malaysia (Fig. 1) and was separated into the northern and southern provinces; the boundary being the Sungai Terengganu mouth. The bathymetric contour lines are generally parallel to the coastline; the depth increasing with distance from the coastline (Fig. 2). The study area lies in the wet tropics, where high rainfall is recorded during the monsoon season. The northeast monsoon prevails between November and January and the rest of the year is the transition and south-west monsoon period. The mean annual temperature lies in the range of 25.6–27.8°C. The temperatures of the surface water are typical of tropical type, being 27–28°C. The water off east coast belongs to the surface type as described by Liong (1974), having warm temperature of more than 25°C and low salinity of less than 34 ppt. The most prominent winds come from northeast directions and southwest winds (Fig. 3).

Winds stronger than 20 km/h are mainly from NorthEast. Wind directions NorthEast winds occupy about 70% of the wind frequency from the sea (Shioz-

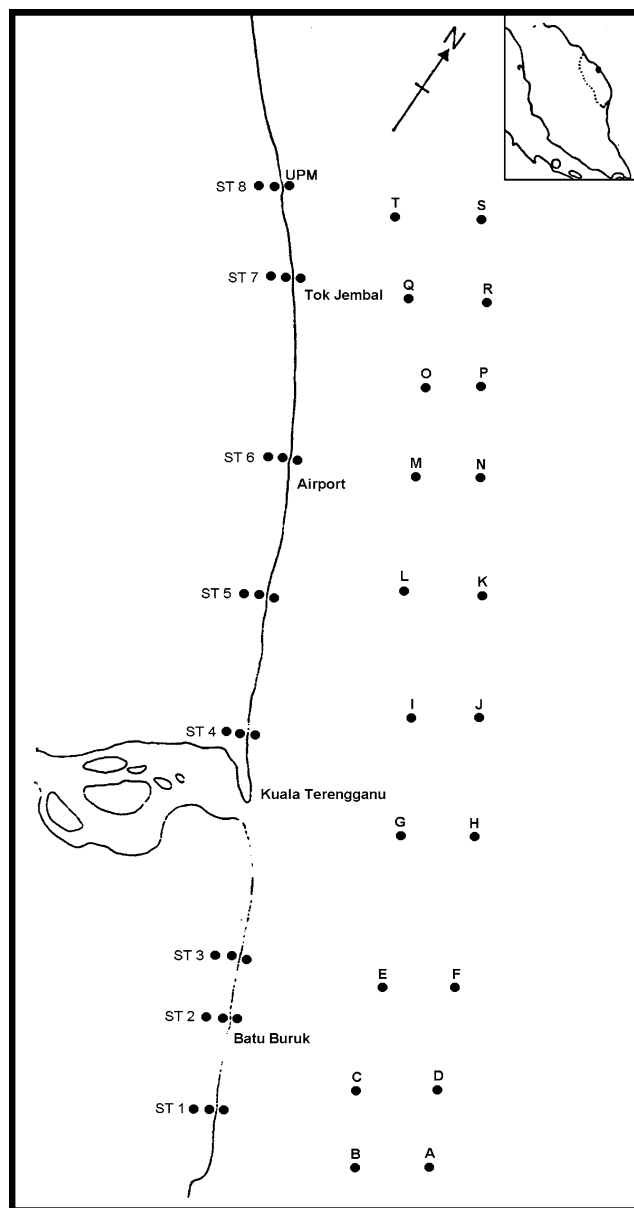
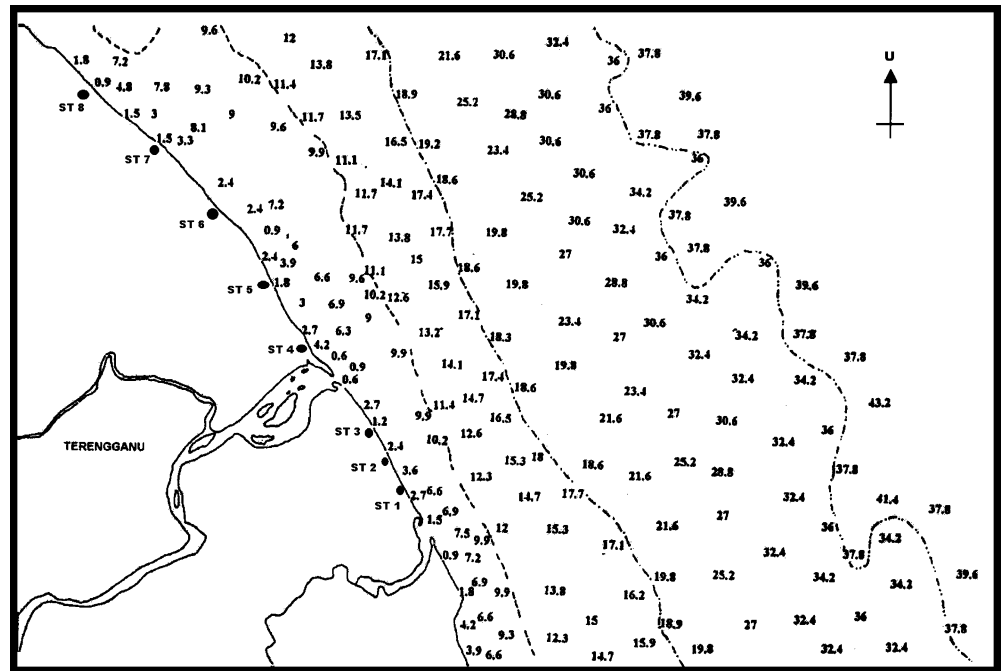


Fig. 1 Map of the study area showing the sampling stations

awa 1984). Raj (1982) states that there are two net directions of present-day beach sediment transport by the littoral drift along the Terengganu state coastline; a north-westward transport, and southward transport, to the north-west, and south of Kuala Terengganu respectively. The average rate of sediment transport for the coast is about 250 cm/day (Phillips 1985). Other studies using sediment grain-size indicate that sediment on the north western part of the river is moving to the north-west and sediment on the south-eastern part of the estuary is moving to the Southeast (Rosnan and Saadon 1989; Stanley 1986).

**Fig. 2** Nearshore bathymetry of part of the study area (depth in meter)



The beach at the north-west region of Sungai Terengganu is relatively steep, compared to the gradual profile in the region south-east of the river. Sungai Terengganu is one of the major sources of river sand. Eroding beaches are the other major source that provides a significant volume of sediment to the long shore transport system (Stanley 1986). The coastline is relatively straight and is aligned at about  $315^\circ$ . Kuala Terengganu airport is located along the coast, 5 km north of Sungai Terengganu. Access to the coastline is by a road located less than one kilometer inland from the coast. To the south-east of the river, the shoreline is aligned at about  $350^\circ$ . The city of Kuala Terengganu is located along this coastline. There are various constructions along the coast including school, hotel, houses, recreational area and the Sultan's palace.

### Sampling

Sediment samples weighing approximately 200 g each were collected in the study area in August 2001 (Fig. 1). A few samples were also collected from the extreme northern and southern ends of the study area. Only the foreshore-beach sediment (i.e. at mid tide level area) data will be presented here, however, because that is the only part of the beach zone where most of the terrigenous sediment occurs. For beach samples, dunese, and surf zone samples were collected by scoop and placed in a plastic bag. Sea sediments were collected by a Smith and McIntyre grab.

### Analysis

The foreshore beach samples, dune and surf zone samples were analyzed using the dry-sieving method as described in the previous section. Most of the sea sediment samples were analyzed by using a particle size analyzer (Laser Diffraction Technique) since the samples are mostly fine material ( $< 63 \mu\text{m}$ ). The four major grain-size parameters—mean, standard deviation, skewness and kurtosis were calculated using the method of moments (McBride 1971); in as much as this is a study of mixing of grain-size modes, shell fragments in all samples were omitted, because this coarse material, which is made up of shell fragment, greatly affects the grain-size parameters.

Statistical analyses using the method of moments (McBride 1971) are usually carried out after obtaining the weights of sediments retained on the different sieves. A sieving program was used to analyze the sediment data. Statistical data used in this study were values of mean, standard deviation, and skewness.

The Mean value was obtained by using the following formula:

$$\text{Mean}(\phi) = \frac{\sum fm}{n}$$

where  $f$  frequency in percent of each size class,  $m$  mid point of each size class,  $n$  number of samples in terms of 100 when  $f$  is in percent.

The standard deviation (sorting) was computed with the following formula:

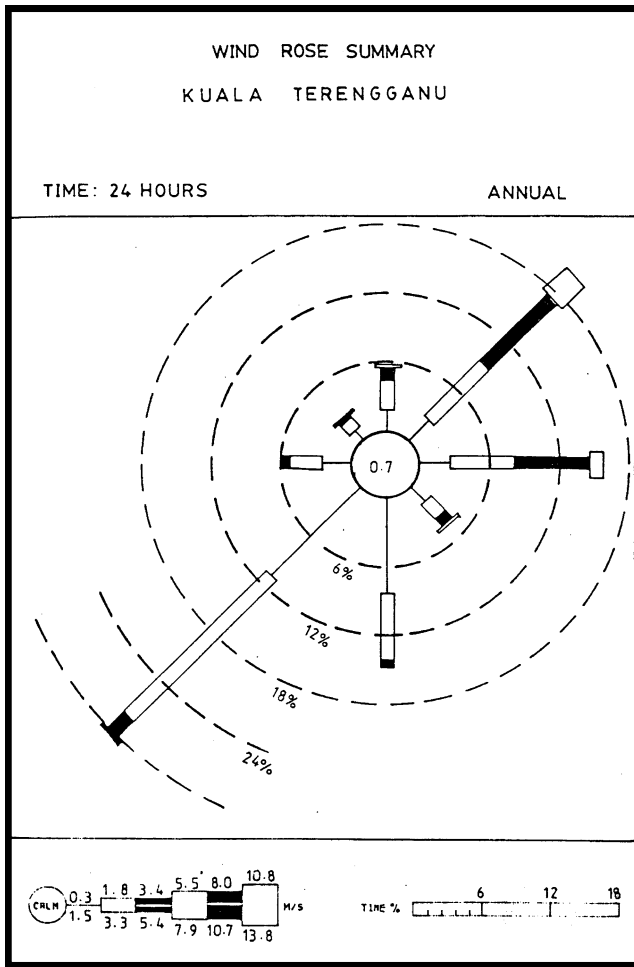


Fig. 3 Wind roses at Kuala Terengganu

$$\text{Standard deviation } (\sigma_\phi) = \sqrt{\frac{\sum f(m-x)^2}{100}}$$

where  $m$  mid point of each size class,  $x$  mean.

The value of Skewness was computed with the following formula:

$$\text{Skewness } (SK_\phi) = \frac{\sum f(m-x)^3}{100\sigma_\phi^3}$$

where  $f$  frequency in percent of each size class,  $m$  mid point of each size class,  $x$  mean,  $\sigma_\phi$  phi standard deviation.

According to Pethick (1984), the use of ‘phi’ units is convenient and simple, with the mean values indicating the index size of the sediment. Standard deviation is the width measurement for the sediment size distribution whereas Skewness measures the asymmetry of the curve of the frequency distribution.

## Results

### Scatter plots of statistical parameters

The variation in the grain-size distributions of sediment from the different environment is shown in Figs. 4, 5 and 6. One of the most effective ways to examine the effects of environmental agents and modal mixing on sediment grain-size distribution is to construct scatter plots of various grain-size parameters against each other. This was carried out for the study area samples and each plot will be discussed separately as follows.

### Mean size versus standard deviation

A scatter plot of the mean size versus the standard deviation of all the samples shows that there is quite a

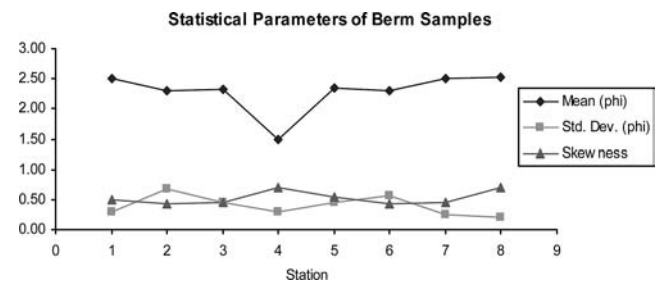


Fig. 4 Statistical parameter of berm samples versus station

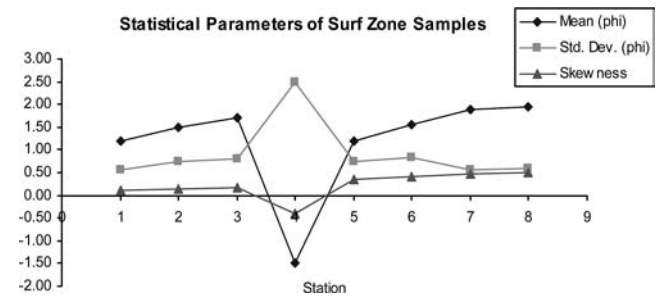


Fig. 5 Statistical parameter of surf zone samples versus station

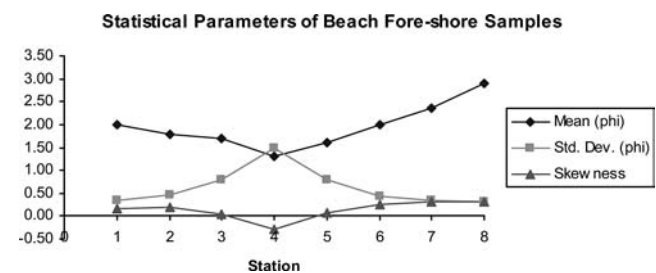


Fig. 6 Statistical parameter of fore-shore samples versus station

**Table 1** Average statistical parameters of grain size distributions at all stations

	All Station				
	Mean		SD		Skewness
	phi	mm	phi	mm	
Beach	1.95	0.259	0.62	0.651	0.13
Berm area	2.29	0.204	0.40	0.758	0.53
Surf zone	1.19	0.438	0.92	0.529	0.22
Sea sediment	3.37	0.097	0.46	0.727	0.43

distinct separation between the samples from different environments (Table 1; Fig. 7). The surf zone samples appear to be slightly coarser, whilst the shallow sea floor and berm samples mostly consist of fine-grained sediments. There is also some distinction between the beach, berm and surf zone samples from the two provinces, i.e. to the north and south of the Sungai Terengganu mouth (Table 2). Although the samples mostly range from being 'poorly' to 'well sorted' (after Folk and Ward 1957; Friedman 1962), the values of sorting are greatly affected by modal mixing. The near-shore, shallow sea floor samples from the two provinces furthermore, show a distinct pattern; the further off-shore samples (Nos. A, D, F, H, J, K, L, P, R and S) being more finer grained and well sorted as compared with the closer to shore samples (Nos. B, C, E, G, I, L, M, O, Q and T), which are fine grained and moderately well sorted (Table 3).

#### Mean-size versus skewness

A scatter plot of the mean size versus skewness shows that in contrast to other findings (Friedman 1962), the surf zone samples show no tendency towards negative skewness with many of them actually showing positive skewness (Table 2; Fig. 8). The beach samples also do not show any tendency towards negative skewness, whilst the berm and near-shore, sea floor samples show a tendency towards positive skewness. Samples from the different provinces also show some difference in skewness values. In the northern province, where coarser grains are dominant over the finer grains, both the sea

**Table 3** Statistical parameters of sea-floor samples

Station	Mean		SD		Skewness
	Phi	mm	phi	mm	
A	2.52	0.174	0.30	0.812	0.52
B	2.40	0.189	0.60	0.660	0.40
C	2.37	0.193	0.41	0.753	0.48
D	1.55	0.342	0.30	0.812	0.79
E	2.50	0.177	0.47	0.722	0.64
F	2.41	0.188	0.58	0.669	0.45
G	2.60	0.165	0.26	0.835	0.47
H	2.52	0.174	0.25	0.841	0.50
I	2.41	0.188	0.35	0.785	0.68
J	2.60	0.165	0.40	0.758	0.70
K	4.10	0.058	0.59	0.664	0.11
L	4.40	0.047	0.50	0.707	0.15
M	4.60	0.041	0.70	0.616	0.30
N	4.70	0.038	0.35	0.785	0.25
O	5.00	0.031	0.52	0.697	0.51
P	4.20	0.054	0.40	0.758	0.55
Q	3.80	0.072	0.43	0.742	0.12
R	3.90	0.067	0.45	0.732	0.35
S	4.00	0.063	0.60	0.660	0.45
T	4.80	0.036	0.3370	0.616	0.15

floor and berm samples are positively (fine) skewed. In the southern province also, where the finer grains are dominant over the coarser grains, the samples are positively (fine) skewed.

#### Standard deviation versus skewness

A scatter plot of standard deviation versus skewness shows that most samples are positively skewed (fine grained) and well sorted, with the most finely skewed and well-sorted samples being those from the berm and near-shore, shallow sea floor areas (Table 2; Fig. 9). This is probably due to the fact that the sampling was carried out long before the start of the Northeast Monsoon.

## Discussion

This study has shown that there are variations in the grain size distributions of sediments from different

**Table 2** Average statistical parameters of grain size distributions in the two provinces

	Southern province					Northern province				
	Mean		SD		Skewness	Mean		SD		Skewness
	Phi	mm	phi	mm		phi	mm	phi	mm	
Beach	2.03	0.245	0.67	0.629	0.13	1.83	0.281	0.53	0.693	0.13
Berm area	2.24	0.212	0.36	0.779	0.57	2.38	0.192	0.47	0.722	0.46
Surf zone	1.02	0.493	1.05	0.483	0.27	1.47	0.361	0.70	0.616	0.14
Sea sediment	3.83	0.070	0.46	0.727	0.38	2.29	0.204	0.44	0.737	0.55

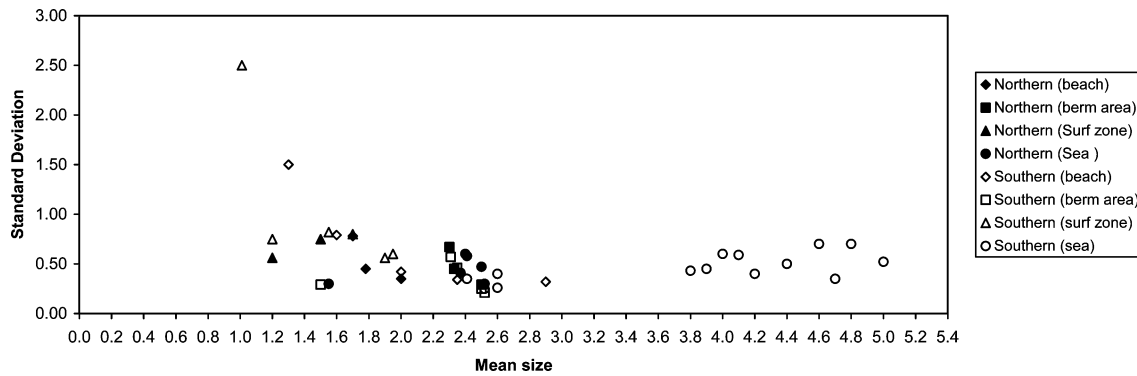


Fig. 7 Plots of mean size versus standard deviation

environments. Grain size distributions can, therefore, be used to differentiate environmental settings. The berms, on the whole, were dominated by fine sand, while the surf zone was dominated by medium to coarse sand. The beach foreshores, however, were dominated by either medium and/or coarse sand, while the sea-floor samples were mainly of silt and fine sand.

From the study, it can also be said that samples from the beach and surf zone areas can be differentiated on the basis of statistical grain size distribution parameters, although both sets of samples are mostly positively skewed. This is considered to be due to the admixture of 'fine' grained particles contributed by rivers through the Sungai Terengganu mouth; these finer materials obliterating any small variation in grain size distributions that may be related to environmental factors. The results therefore indicate that the source material, particularly where more than one grain-size mode is produced in the source area, may also have a strong influence on the grain-size distribution of sediments.

In comparison with other areas along the coastline, the surf zone has been found to be the most dynamic one in terms of the distribution pattern of sediments. Furthermore, the near-shore sea floor, did not show any significant change in sediment distribution with the time of year as only fine sand particles were found through-

out. These areas continuously receive different currents, which cause the fine sand particles to remain in constant motion or sink to the bottom during weak currents.

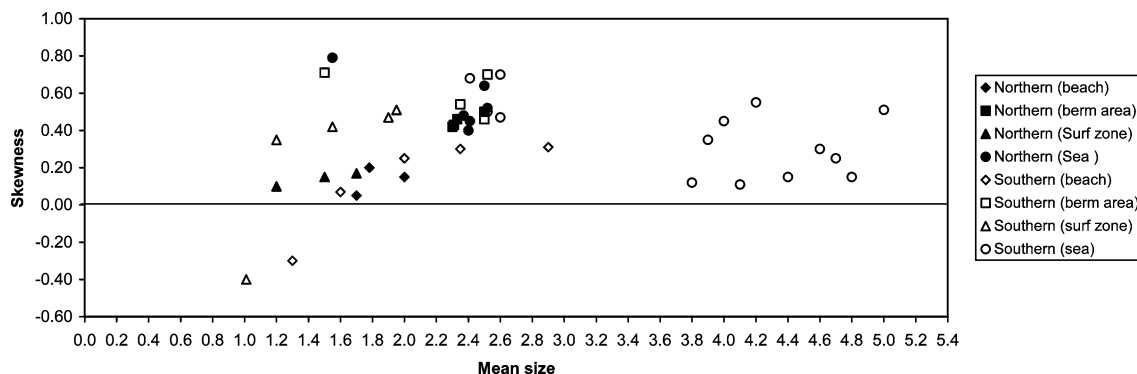
The study has also shown that the beach and surf zone samples along the Kuala Terengganu coastline can be differentiated on the basis of statistical grain-size distribution parameters. Both the beach and surf zone samples showed a wide range in skewness and were mostly positive.

The study has also demonstrated that statistical grain size distribution parameters can be used to differentiate or distinguish particular sub-environments in coastal areas. One can thus predict particular coastal environmental conditions, if the grain size distributions of their sediments are known.

## Conclusion

The beach and surf zone samples of the study area can be differentiated on the basis of statistical grain-size parameters. Both beach and surf zone showed a wide range in skewness and were mostly positive. This is due to the mixing of 'fine' mode contributed from the rivers through the Kuala Terengganu estuary, which obliterates any small variations in the grain size distributions that may be related to environmental fluctuation. Therefore, in general, these results indicate that source material, particularly where more than one grain-size mode is produced in the source area, may have a strong

Fig. 8 Plots of mean size versus skewness



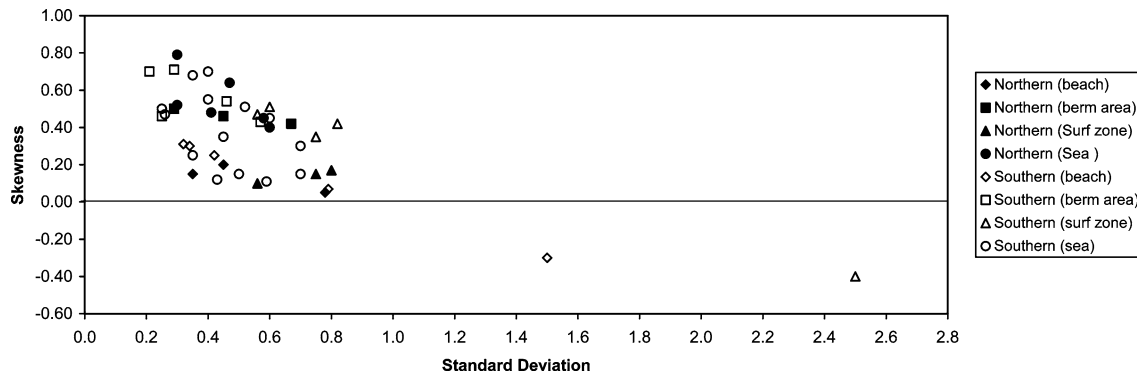


Fig. 9 Plots of standard deviation versus skewness

influence on the grain-size distribution of sediment. This study demonstrates that to a certain geographical area of very distinct environmental condition, the textural parameters can be used to differentiate or distinguish a particular environment. Thus, knowing the sediments characteristics, one can predict or justify the environmental conditions. It can be said that this study has provided new information on the processes that operate along the Kuala Terengganu coastline.

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