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BEACH SEDIMENTS AND LITTORAL PROCESSES ALONG THE RED SEA COAST OF EGYPT.

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ABSTRACT

The upper and lower foreshore sediments have been analyzed in order to determine the grain size parameters and the carbonate contents. Statistical analyses were used to explain the geological meaning of the grain size parameters and their relationship to the sedimentary processes and hydroynamic energy.

The data show a moderate sorting degree of sediments caused by the combined action of the three factors: nearness to sediment sources, the big variety in shapes and sizes of the reefal products, and the reduced water energy. Skewness and Kurtosis are closely related to the presence or absence of coarse sized coral debris and terrigenous rock fragments and are also related to the ineffective energy.

INTRODUCTION

On the large scale, the area of study is a re-entrant coastline extending for about 425 km. This coastline comprises rich and diverse biological communites of fringing coral reefs, meanwhile, it is bordered from the inland side by high mountains, It is noteworthy to mention that the coastline stretches parallel to the direction of the prevailing wind, being also influenced by short-term variations of sea level caused by tides.

We imagine that the interplay of all of these factors can result in the formation of a special type of depositional environment and may lead to diagnostic sediment characteristics. Thus, in this paper we try to explain the variations in grain size parameters in terms of the environment and to relate such variations to the sedimentary processes and water energy in order to acquire a good understanding of the formation of sediments.

The present work is intended to study the sediments of the beach foreshore area as an example of this environment.

GEOMORPHOLOGY

The most important marine geomorphological features can be seen in figure 1. The bottom topography in the northern part of the area is so

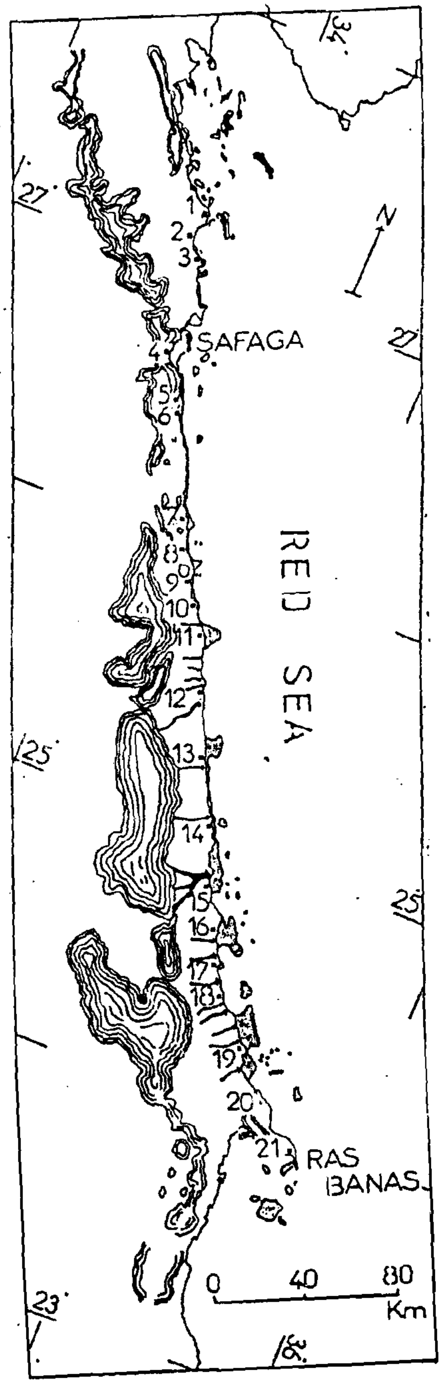

Fig. [illegible]
Area of study and sampling locations.

complicated by a group of rising islands and coral reefs. The southern limit of this area is marked by Gifatin islands lying 15 km offshore and rise to 118 m. From that point, the coastline proceeds SSE being fringed by coral reefs extending for about 1 km seaward. In many parts it is bordered by offshore patch reefs, rocky shoals and islands which become more extensive in the southern third of the study area.

The inland geomorphology is characterized by the high mountains extending along the Red Sea coast. The most prominent features in the north are a series of hills lying close to the sea at distances 3-6 km inland. They extend in a northwest direction for about 80 km being high in the north (409 m) and ends abruptly to 209 in the south. The coastal plain afterwards widens separating the coastline from the main Red Sea hills by 20-30 km (Said, 1962).

At Safage, the Red Sea mountain range again approach the coastline at distances 2-4 km, the summit of this range rising to 2187 m ends in the south by a mountain 834 m high.

Between Safaga and El-Quseir the coast is low rising gradually to mountains 610 m high at 9-15 km inland.

From El-Qusier to Ras Banas, the mountain range lies further inland at 10-25 km. They increase gradually in height in a southerly direction from 1099 m to 1160 m to 1505 m and finally to 1976 m.

Many wadies fan-out downslope of these hills, being dry most of the time and are characterized by sporadic and abrupt fluvial activity.

The coastal plain in this area is sandy and covered by low shrubs.

PHYSICAL OCEANOGRAPHY

Coastal Currents

The average flow at any time of the year takes place in the direction of wind down the length of the Red Sea (Thompson, 1939). The shallow reefs and the islands along the coast together with the irregularities in the coastline account for current variability. However, the high variability of the mean flow is largely due to tidal variations (Patzert, 1972).

Where mountains lie close to the shore, coastal waters are often disturbed by sudden squalls from the hinterland. These occur most frequent during the night and may be violent enough to cause a localized area of very rough water.

In spite of some anomalies, the currents in the Red Sea are predominantly weak (Red Sea and Gulf of Aden Pilot, 1980).

Tides

The Red Sea tides are of semidiurnal type, the tidal range decreases from north and south ends to the central part of the Red Sea (Defant, 1961).

Tidal motion within the sea is composed almost equally of the sea's own respones to tide generating forces and of the co-oscillating tide from the Gulf of Aden (Patzert, 1972).

According to the data published by the U.S. Navy Hydrographic Office (Red Sea maps H.O. 2812 and 2813) and the Red Sea and Gulf of Aden Pilot, 1980 the spring range is about 0.6 m near Hurghda and 0.7 m at El-Qusier.

Bibik (1971) estimated the velocity of the tidal currents of the main lunar semidiurnal wave as 2 cm/sec in the northern part of the Red Sea.

Climate

According to the data of the Egyptian Meteorological authorities, the prevailing wind allover the area and on almost all days are northwesterly.

The high mountains on both sides of the Red Sea constrain the monthly mean atmospheric circulation in the lower troposphere to flow parallel to the sea axis (Patzert, 1972). However, interdiurnal changes may occur above the constraining barrier after the passing of a surge causing the surface northwesterly winds to veer east (Pedgley, 1971).

Complex diurnal wind changes near the coast are caused by the alternative effect of the day-time sea breez and the noctrunal land breeze. This well developed daily pattern is caused by large diurnal differences in local heating (Flohn, 1969). According to Pedgley (1971), the land breeze front may develop during the night to 10-20 km offshore persisting into the morning, the sea breeze front develops during the morning to 10-20 km inland perhaps reaching 100 km by evening. He thus, stated that coastal wind can be considered as being approximate vector sums of the broad-scale flow and the diurnal component. Wind forces of 3-5 prevail in all saesons (Red Sea and Gulf of Aden Pilot, 1980).

The climate is hot and dry in summer and very warm in winter. The mean daily minimum for 30 years is 18° C at Hurghada and 21° C at El-Quseir, while the mean daily maximum is 29° C at both locations (Red Sea and Gulf of Aden Pilot, 1980).

The average humidity ranges between 48 and 52 on the mainland and 70 on islands.

Precipitation is sparse and erratic, the annual number of days with more than 1 mm varies from zero to one.

MATERIALS AND METHODS

At twenty-one localities (Fig. 1) along the Red Sea coast of Egypt, beach sediments were collected at the mean high water and the mean low water marks.

The sediments samples were washed by soaking in distilled water and decantation of the supernatent clear liquid. The samples were then oven-dried and representative portions were taken for analyses.

Grain size analysis was performed using the dry-seiving technique described in Krumbein and Pettighon (1938). The cummulative curves were drawn on probability paper, the statistical parameters: graphic mean (Mz); Inclusive graphic standard deviation (σ_I); Inclusive graphic skewness (SK_I); and graphic kurtosis (K_G) were calculated according to Folk and Ward (1957).

The components of the seive fractions were examined under the binocular microscope.

The total carbonate contents were determined by back titration method after acid treatment.

RESULTS AND DISCUSSIONS

The data indicate that the beach sediments in general are calcareous sands ranging in size between -2 and 4 phi. The variations in mean grain size, median, sorting, skewness, and kurtosis measures as well as in the total carbonate contents along the beach are shown in Fig. 2. All these parameters are presented for both the upper and lower foreshore sediments, hence, the range of variation can be observed. For comparison, the minimum, maximum, and average values of such parameters for the two beach areas are given in table 1.

Cummulative frequency plots (Fig. 3) show that the shape of the curves can not be used for sharp pectorial differentiation between the sediments of the upper and lower foreshore areas. However, the swash-backwash separation (saltation break) can be defined on the curves of the well sorted upper foreshore sands. This conclusion should be taken with caution becuause of the limited number of samples used in this study comparable to that needed for such type of analysis.

Fig. 2 shows that the average range of variation in grain size between the upper and lower foreshore sediments is small falling, within the limits of coarse sand.

Depending on sampling location, the beach receives sedimentary material from one of the three following sources or from a combination of two or all of them:

TABLE 1

The range and mean values of sediments textural partameters and carbonate contents.

Area	Value	Median φ	Mean φ	Sorting φ	Skewness φ	Kurtosis φ	Carbonates %
Upper Foreshore	minimum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	maximum	[illegible]	[illegible]	1.34	[illegible]	[illegible]	[illegible]
	mean	1.37	1.25	0.77	0.04	0.97	50.00
Lower Foreshore	minimum	- 0.45	- 0.42	0.10	- 0.57	0.50	4.00
	maximum	4.10	4.10	1.35	1.75	2.79	99.00
	mean	1.46	1.65	0.76	0.20	1.35	50.10

a. Weathering products from inland.
b. Biogenic materials from offshore.
c. Mixed materials from alongshore drift.

The amount of the provided terrigenous materials is dependent upon the coastal geomorphology, type of rock, degree of weathering, and the exposure of inland mountains. The grain size of such disintegrated materials depends in addition to the above mentioned factors on the proximity of mountains to the coastline and the nature of the coastal plain.

In general, the beach sands allover the area are lacking the fine grained fraction (0.063 mm) due to the fact that the beach recives initially coarse sediments from either sides. As mentioned by Friedman (1967), fine carbonate particles resulting from the breakdown of calcareous materials are always withdrawn from the environment due to upward sucking by the vertical vector of oscillatory motion and directed seaward.

According to the mean grain size data and microscopic examination of the sediment samples, it is possible to divide the study area into five parts having somewhat different sediments grain sizes and composition.

In the northern part (Samples 1,2 and 3), the average mean grain size for the upper foreshore sediments is 0.710 and for the lower foreshore ones is 0.500. The sediments have the lowest carbonate content (9.68 %) and their constituents are dominated by very coarse quartz, which is

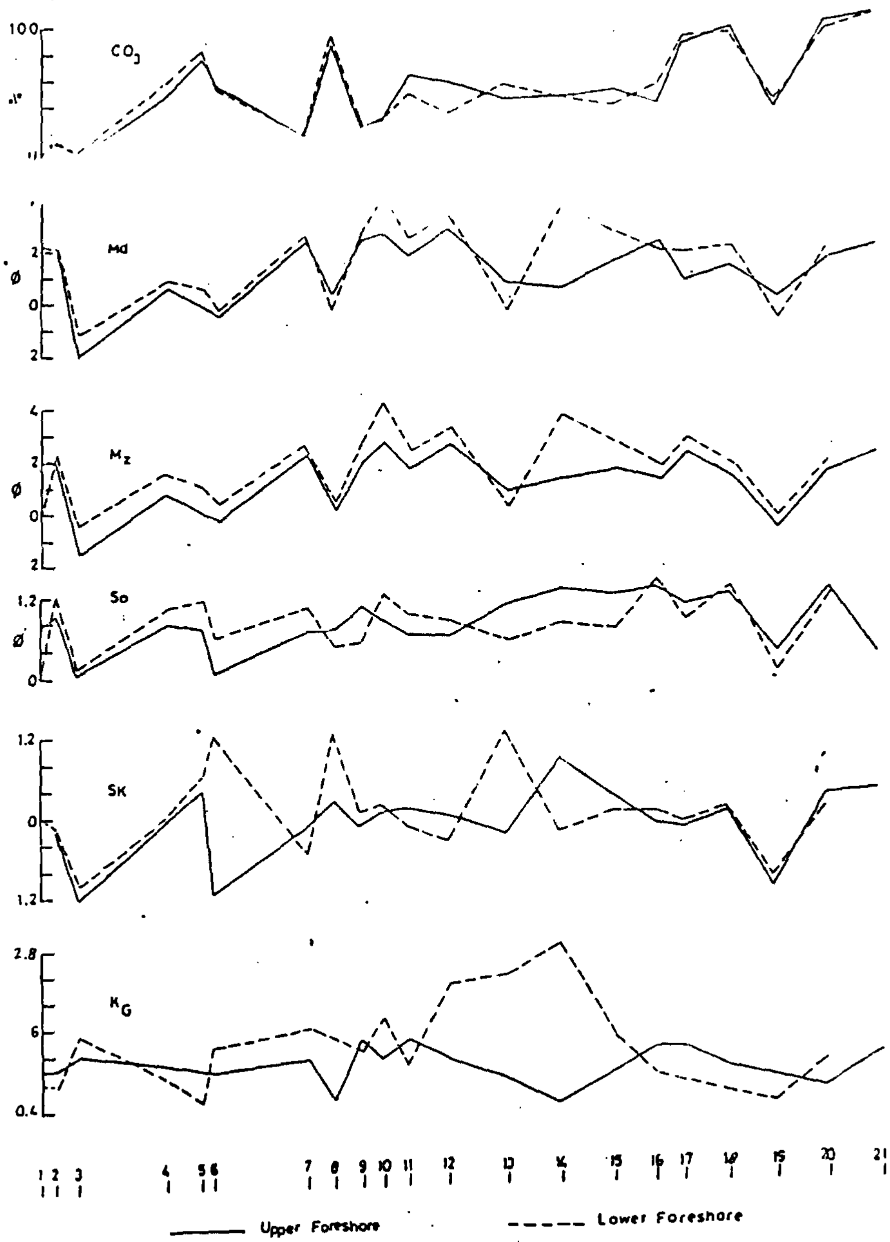

Fig. (2)
Variations in grain size parameters.

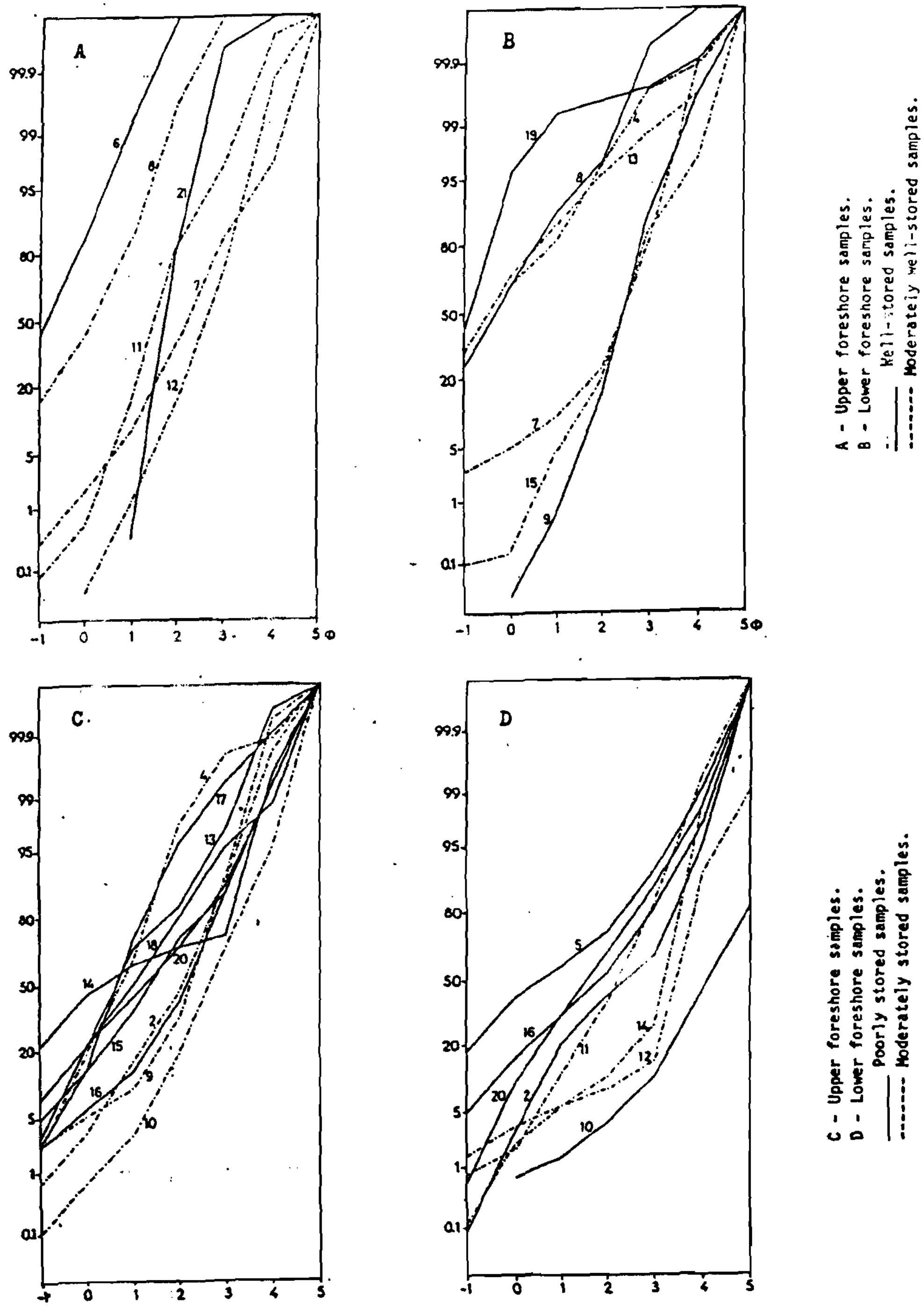

Fig. (3)
Cummulative frequency curves.

apparently derived from the nearby coastal plain. Contribution by reefal products being very limited in this part of the beach due to their continuous removal southwards by coastal currents, helped by the barrier effect of islands and reefs which dissipate wave energy, thus reducing their onshore transport.

In the second part, from Safaga to Ras Abu-Hajar (Samples 4, 5, 6, 7 and 8), rock fragments are present in amounts suggesting the nearness of the mountain source, and may also reflect the nature of the beach in this area which is not totally sheltered by reefs, being subjected to increasing hydrodynamic energy. The average mean grain size in this part of the beach is 0.500 for the upper foreshore sands and 0.960 for the lower foreshore. The sands herein become more calcareous having average carbonate contents of 58.85 %.

In the third part from Ras Abu-Hajar to Ras Hamra (Samples 9, 10, 11 and 12), the beach sediments are dominated by fine quartz sand which is probably of aeolian origin and predeposited in the nearby wadies before its removal by fluvial activity. Thus, the average mean grain size for the upper foreshore is 2.250 and for the lower foreshore is 3.000. The average carbonate content for these samples is 39.59 % suggesting increased rate of terrigenous supply in this area of the beach.

In the fourth part from Ras Hamra to Wadi Gimal (Samples 13, 14, 15 and 16), contribution of rock fragments is noticed reflecting the effect of the more pronounced sizes and slopes of the wadies in this coastal segement. The average mean grain size is 1.320 for the upper foreshore samples and 1.930 for the lower foreshore ones. The average carbonate content is 49.58 %.

In the southern fifth part of the area from Wadi Gimal to Ras Banas (Samples 17, 18, 19, 20 and 21), the beach sands are overwhelmingly dominated by biogenic materials resulting in 92.64 % average carbonate content. In this area the coastal plain is covered by low shrubs which may obstruct the reach of terrigenous materials to the beach. Moreover, biogenic materials are provided as from the breakdown of the bordering reefs as from the alongshore drift which is expected to slow-down approaching Ras Banas promontry due to the effect of the promontry itself and due to the nearness of the Red Sea convergence zone. The average mean grain size for these beach samples is 1.500 for the upper foreshore and 1.850 for the lower foreshore.

The other sediment parameters: sorting, skewness, and kurtosis are shown to be a direct function of:

1. The ratio of the terrigenous and biogenic populations.
2. The limited distance of sediment transportation.
3. The characteristics of hydrodynamic energy.

Due to differences in shape, size, and density of the sediment particles of the two populations, their mixing ratios might affect the sediment parameters especially because they are derived from very near sources, thus, changes in their original characteristics are very restricted.

The data show that in spite of very few exceptions, sorting of sediments is generally moderate. The sorting value (   ) for the upper foreshore sediments ranges between 0.06 and 1.340 having average value of 0.770. While for the lower foreshore sediments sorting ranges between 0.10 and 1.350 with an average value of 0.760. Thus, it is obvious that the degree of sorting is almost the same for the two beach areas. It is above shown that the sands of both areas contain varying mixtures of the two populations of which the terrigenous population is more likely better sorted than the biogenic one. Many authers showed that the breakdown of coral reefs and their indogenous fauna provide heterogenous materials with a great variety of particle shapes and sizes resulting in the formation of multiple modes leading to any kind of textural characteristics (Pilkey et al, 1967; Maiklem, 1970; Friedman, 1967).

From another side, the influence of energy is not sufficient to improve the degree of sorting. Because the coastline stretches parallel to the direction of wind, the waves approach the beach at a very oblique angle causing the swash to flow along the beach instead of flowing diagonally up the beach face (Friedman and Sanders, 1978). In addition, the alongshore wind result in that the waves reaching the coast become short (King, 1972). Such short waves can move sediments from shallow depths only, i.e., bring reef products in their initial state.

The same process is repeated on the upper foreshore due to the fact that during the rising of tide, the zone of swash and backwash shifts from its outer location to inner location (Friedman and Sanders, 1978).

The skewness measure of the upper foreshore sediments ranges between -0.23 and 0.85 with an average value of 0.04 indicating near-symmetrical skewness. For the lower foreshore sediments it ranges between -0.57 and 1.75 having average value of 0.20 showing a fine skweness tendency. The negative skewness is apparently related to the addition of coarse materials from the nearby sources resulting in tailing off the frequency distribution curve to the left side. If the mixing of the fine and coarse populations is equal the skewness is near-symmetrical. When excess fine particles is added but still the coarse mode is more abundant, the tial is on the right side and skewness is positive.

The results of kurtosis indicate that the majority of the lower foreshore sediments are leptokurtic, where, the kurtosis values range between 0.50 and 2.79 with an average kurtosis being 1.35. The upper foreshore samples on the other side are either platykurtic or mesokurtic having 0.38 - 1.38 kurtosis values with an average of 0.97.

The addition of very small amounts of the coarse coral fragments to the lower foreshore sediments result in that the sorting in the tails is worsened while the sorting in the central part remains good and the curve become leptokurtic (Folk and Ward, 1957). Folk and Ward, also, suggested that if the environment of final deposition is not effective in sorting, kurtosis will remain high and the opposite occur if the environment is effective.

INTERRELATIONSHIPS OF SEDIMENT PARAMETERS

A scatter plot of mean grain size versus standard deviation (Sorting) showed a sinusoidal curve indicating improvement in sorting in the direction of coarse and very coarse sands and to a less degree in the fine sand range. The sorting worses in samples with mean grain sizes in the medium and very fine sands (Fig. 4).

On plotting the mean size versus skewness and kurtosis (Fig. 4) possible separation between two fields characterising for the upper and lower foreshore sediments was noticed. However, we could not consider this conclusion final becuse as we stated above, the number of samples is small to give such conclusions.

Other interrelationships are not significant.

CONCLUSION

The Red Sea beach sediments compose of a mixture of a biogenic population derived from the breakdwon of the coral reefs and their communities and a terrigenous population drived from the inland mountains and / or the nearby coastal plain.

The contribution of biogenic population is at minimum in the northern part of the area and is maximum in the south, while in between the two extremeties almost equal proportions of the two populations occur.

The grain size range of these mixed sands lies between -2 and 40 the coarsest portion of which is dominated by coral debris and rock fragments and the finest one is dominated by quarz and Foraminifers.

The sorting of sediments is moderate because of the proximity of the soures and the reduction of hydrodynamic energy by the coral reef barrier structures and wind-wave system as well.

On general basis the sediments are either having near-symmetrical skweness due to equal mixing of the size modes or being fine skewed due to the predominance of the coarse mode.

The upper foreshore sediments are platykurtic to mesokurtic, while the lower forshore ones are leptokurtic. However, in general, kurtosis values are moderate to high indicating moderate to weak energy conditions.

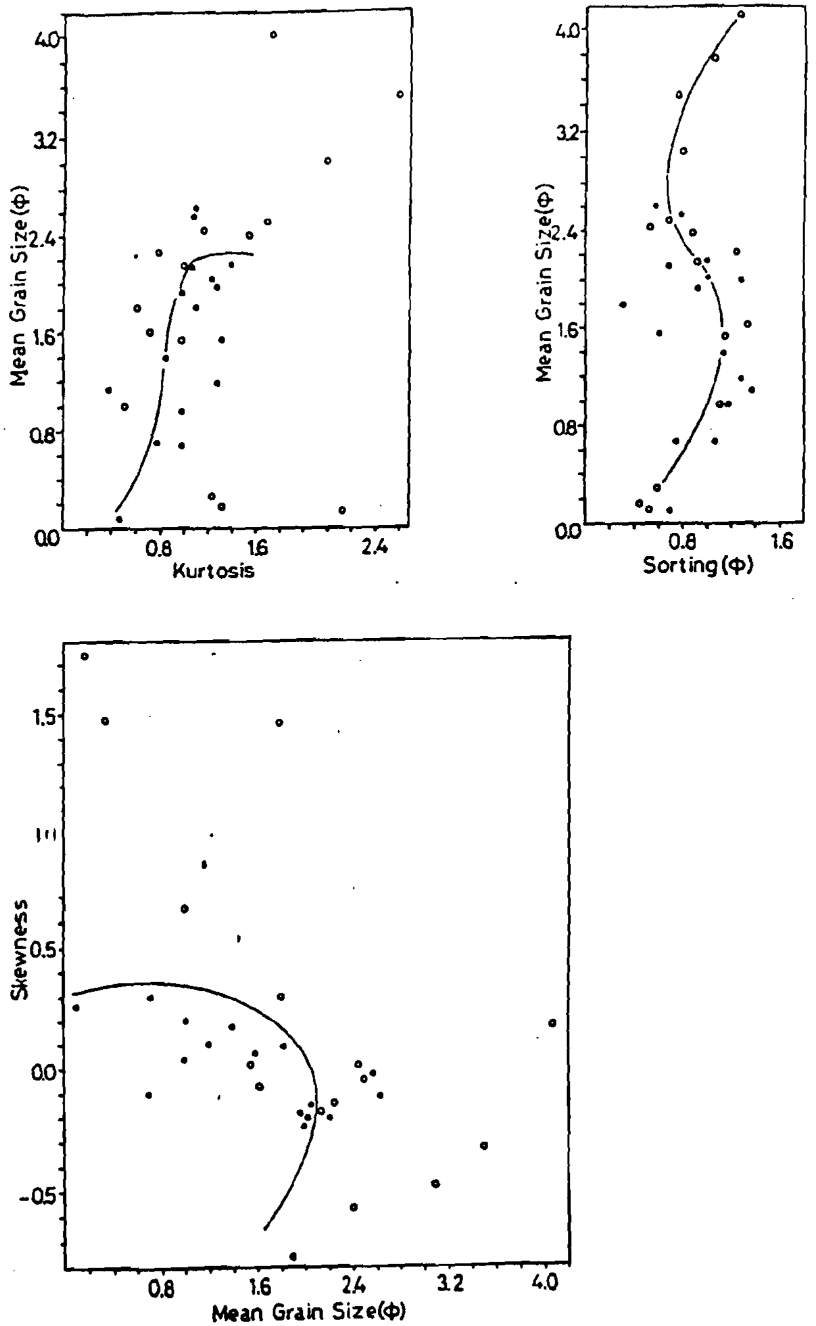

Fig. (4)
Interrelationships of sediment parameters.

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