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SIZE DISTRIBUTION OF HEAVY MINERAL GRAINS IN SOME MODERN NILE DELTA COASTAL SANDS, EGYPT

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ABSTRACT: This study includes determination and discussion of the texture and heavy mineral compositions of some modern Nile Delta coastal sands (river, coastal dune, beach-face, and nearshore marine) in order to delineate the process and factors that regulate the size distribution of heavy mineral grains comprising these coastal sands. Textural analysis of unseparated bulk samples indicate that the examined four types of sands differ in their mean grain sizes and degree of sorting. However, analysis of size distribution curves of 10 heavy mineral species or group of species in the four environments having the same general shape and nearly similar in that general order of arrangement. However, these curves vary both in median sizes and sorting. The size distribution of a heavy mineral in the Nile Delta coastal sands appear to depend on: (1) range of grain size fractions in each sample, (2) relative availability of heavy mineral in each size grade of the sample, (3) specific gravity of minerals comprising these sands, and (4) some other unknown factor or factors. Results of size measurement of heavy minerals indicated that increasing specific gravity is accompanied by increasing fineness of the heavy minerals. This study may be useful in search for marine placers and understanding the processes of grain-sorting on the sea beaches.

KEY WORDS: Nile delta, heavy minerals, size distribution.

INTRODUCTION

The Nile Delta coast consists of sandy beaches, approximately 240 km in total length (Fig. 1). The sandy shoreline of the delta is characterized by two promontories associated with the present-day Rosetta and Damietta branches of the Nile river which have delivered sediments to the Mediterranean Sea during recent centuries. Lying between them is the remnant pre-modern Burullus promontory, which was formed by sediments discharged from the former sebennitic branch of the Nile which existed until about the 9th century (Orlova and Zenkovitch, 1974). These promontories are separated by embayments in the coastal configuration, backed by coastal flats, fields of sandy coastal dunes and three large coastal lakes (from west to east: Idku, Burullus and Manzala). The Nile river has been identified as the major source of quartz-rich sediments and sand grade heavy minerals on the continental shelf and along the Mediterranean coast of Egypt and Israel (Hilmy, 1951).

Assemblages of heavy minerals in Nile Delta sand have been used for many years to analyze the sources (Hilmy, 1951; Khalief *et al.*, 1969); transport paths of sediments (Stanley, 1989; Frihy and Komar, 1991; Frihy *et al.*, 1995); paleoclimate (Foucault and Stanley, 1989); environmental discrimination (Lotfy, 1993) and to trace the former Nile branches (Frihy and Lotfy, 1994). Numerous other examples could of course be cited.

All previous studies of heavy minerals in the Nile Delta sands were limited to the whole sample, or for one or two selected size fractions of each sample analyzed. Therefore, to date no studies have been published regarding the size distribution of heavy minerals in sands of the Nile Delta environments. An understanding of such distribution

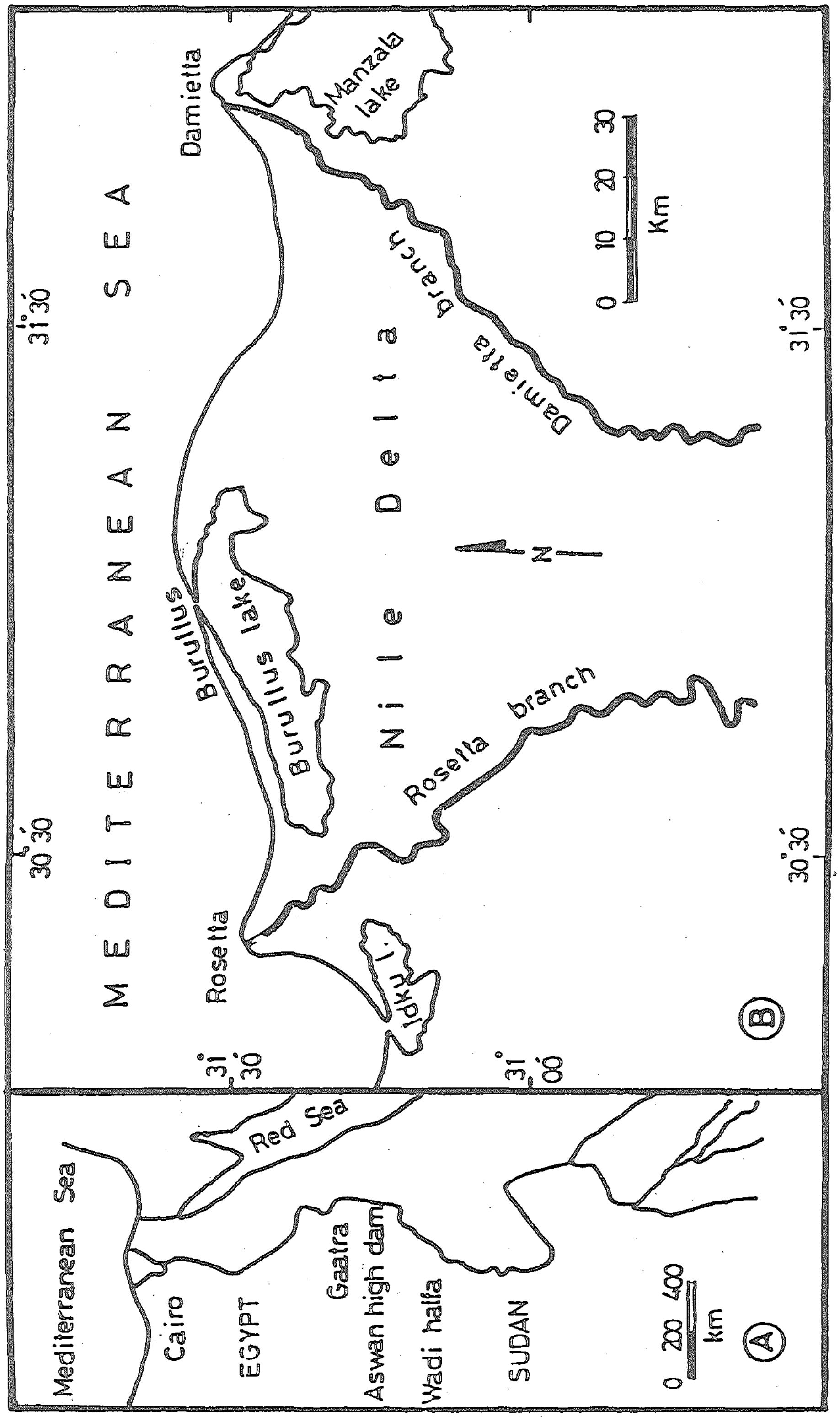

Fig. 1. Locations map for the Nile river (A) and the Nile Delta coast (B).

is essential in exploration for marine placers and for understanding the processes of grain sorting that develop during cross-shore and alongshore sediment transport.

The present study focuses on the textural and mineralogical characteristics of some modern Nile Delta coastal sands with the objective of understanding the principles or factors that regulate the size distribution of heavy minerals in these sands, and processes.

METHODOLOGY

A total of four composite sand samples were collected from four modern coastal environments of the Nile Delta (Nile river, coastal Dune, Beach-Face and Nearshore Marine to about 6m water depth). These four samples (one for each) were obtained by combining several spot samples from different localities of the one and same environment. This composite sample was thoroughly mixed, quartered and a subsample was taken for analysis (Krumbein and Rasmussen, 1941). Such a composite sample obtained from each environmental provenance should eliminate most of the local sorting so that a more representative composition is obtained. The normal weight of a single composite sample analysed was about 500 gm. In the laboratory, the composite samples were dry sieved using half-phi sieve intervals. The mean size (M_z) and sorting ($\acute{O}_I$) were calculated from grain-size data of unseparated bulk samples using the formulae of Folk and Ward (1957). The different size fractions of each sample were subjected to heavy mineral separation using bromoform having a density of 2.8gm cm^{-3}. After separation, the heavy residue in each size fraction intervals was mounted on slides in Canada Balsam, and 400 mineral grains were identified and counted under a high power polarizing microscope using standard petrographic techniques. The count results in each size fraction were converted to a relative number percentage values, facilitating the study of the different size fractions or the four sand samples.

RESULTS AND DISCUSSION

Textural Analysis:

The sieving analysis or on bulk samples of unseparated light and heavy minerals provide the main textural feature of such samples (Table 1; Fig. 2). In principle, the sediments are predominantly medium to very fine sand grains. Finest mean size is found

Table 1. Weight percentages of grain size fractions and statistical parameters within the Nile Delta coastal sands.

	Grain Size Fractions (%)						Statistical Parameters	
Environmetn	-1-0Φ	-0-1Φ	1-2Φ	2-3Φ	3-4Φ	>4Φ	M_z	σ_I
Nile River	1.8	8.2	46.0	40.5	3.3	0.2	1.85	0.7
Beach	0.1	1.3	24.6	65.5	7.46	0.04	2.2	0.46
Coastal Dune	0.0	2.97	43.03	49.00	4.95	0.05	2.05	0.53
Nearshore Marine	0.38	0.42	2.0	22.2	62.00	13.00	3.33	0.6

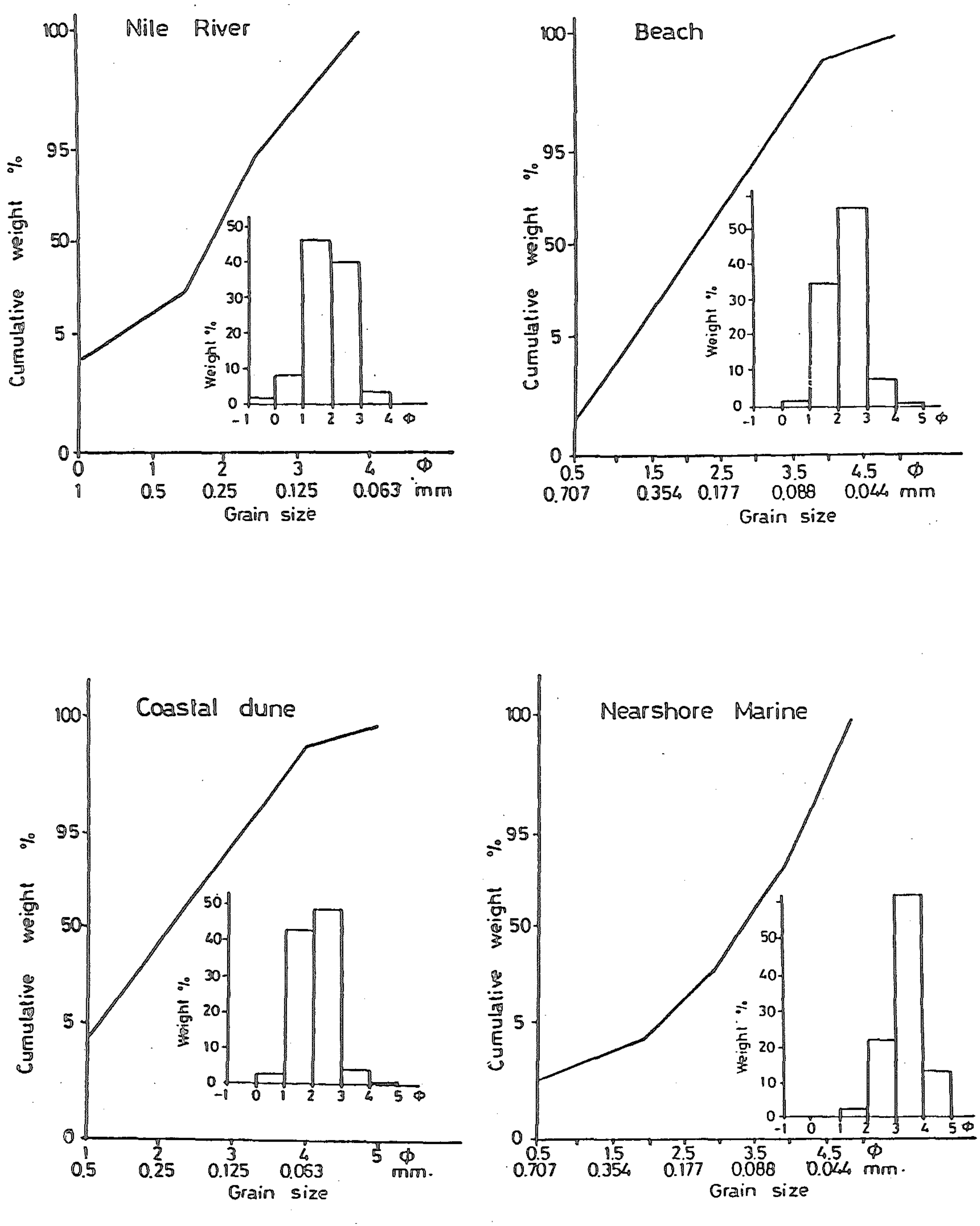

Fig. 2. Cumulative curves and histograms within the Nile Delta coastal sands.

in the nearshore marine sand (M_z = 3.33Φ, 0.099 mm) owing to the presence or higher percentages (97.2%) of finer size fractions (>2Φ, <0.25mm). From the nearshore through the beach and dune to the river environment, there is a steady increase in the coarse grained material (M_z = 1.85Φ, 0.28 mm), where the size fractions (<2Φ, >0.25 mm) are much increased in the river ones (56%).

The above grain size characteristics are also reflected in the shape of histograms and cumulative curves (Fig. 2). Histograms of the four environments have a tendency toward unimodality, but they differ in the modal classes (the class diameters which are more frequent than the adjacent classes). Nile river sand display a mode between 1 and 2 Φ (0.5-0.25 mm); i.e., in the medium sand. In moving through the dune and the beach to nearshore environment, there is a shift in the modal class to the finer sizes between 3 and 4 Φ (0.125-0.063 mm). Thus, the nearshore marine sand retain a higher percentage of finer fractions than those of the other three environments. Cumulative curves drawn on probability paper show that these sands, in general, comprise the three sub-populations, that reflect three modes of sediment transport; i.e, traction <rolling>, saltation and suspension as formulated by Visher (1969). Also, the curves show differences in the position of truncation points and the percentages of sediment of these subpopulations. Compared to the other three environments, the Nile river sand is characterized by higher percentages of sediment in the coarse rolling population (18%) and the lower percentages of sediment in the fine suspension population (less than 1%). Therefore, the different hydrodynamic conditions and the morphology of each environment seem to be reflected in the textural characteristics of these sediments that have been derived from exactly the same source (Nile river).

Mineralogical analysis:

The dominant heavy minerals in the investigated sand samples are opaque (magnetite and ilmenite), epidote, augite and hornblende. The samples also contain smaller concentration of garnet, tourmaline zircon, rutile, monazite and biotite. There are a number of other heavy minerals that occur in very small proportions, including staurolite, kyanite, sphene, apatite, but these are not included in the present analysis due to their sporadic occurrence.

Heavy mineral distribution curves:

In order to show the relationships between the diagnostic mineral species, and their grain size fractions within the sand sample, the cumulative frequency curves for 10 heavy minerals in each of the four samples have been plotted in figure 3. It is evident from these curves that the size distribution of heavy minerals form smooth cumulative curves having the same general shape and nearly similar in its general order of arrangement. However, these curves vary both in mediam sizes and sorting as reflected in the magnitude of the general slope of the cumulative curves. The similarity in relative arrangement of the examined heavy mineral curves in the four samples leaves little doubt that the heavy mineral composition in these sand deposits not only varies with differences in grain size fractions of the sand sample in which they were found, but that the variations are systematic and should be relatable to specific gravity of the respective mineral species comparising these sands. The latter tends to concentrate the heaviest

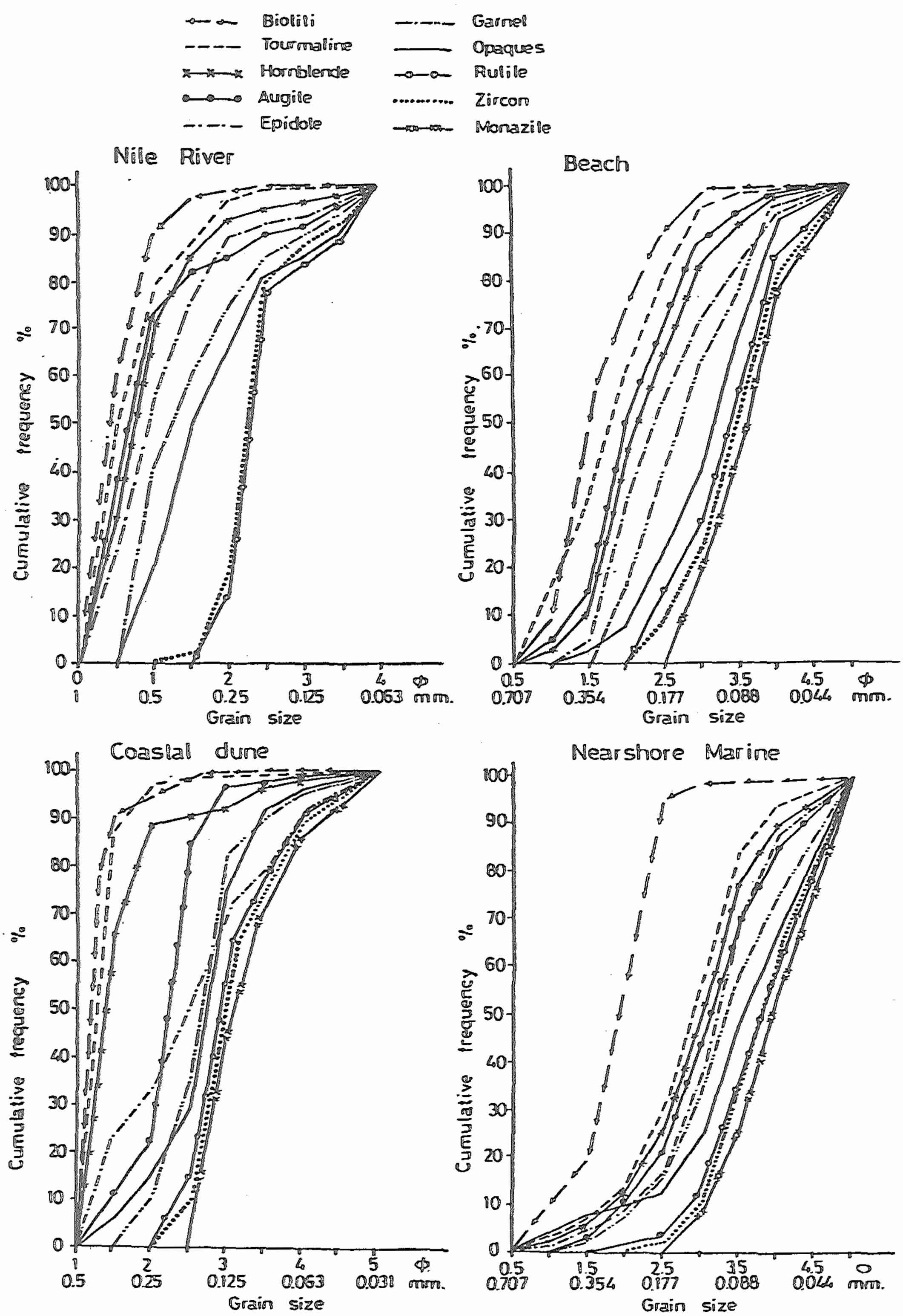

Fig. 3. Cymulative size distribution curves of diagnostic heavy minerals within the Nile Delta coastal sands.

minerals in the finer grained portions of each sample, regardless of whether that sample is predominantly fine grained (nearshore marine) or coarse grained (Nile river). In other words, the general arrangement here (Fig. 3) is roughly in the order of the specific gravities of the minerals. The heaviest minerals (rutile, zircon, opaques and monazite) tend to concentrate in the finer size, while the next lower minerals in specific gravity (augite, epidote and garnet) are increasingly abundant in the intermediate size position. The lowest specific gravity minerals (biotite, tourmaline and hornblende) are concentrated in the successively coarser-grained fractions of each sample. Therefore, the size distribution of heavy minerals within the Nile Delta coastal sand samples appear to depend not upon a sample came from, nor the coarseness or fineness of the particular sample, but upon:(1) range of grain size fractions in each of the samples; (2) its relative availability in each size grade; (3) specific gravity of mineral species or group of species comprising these sands; and (4) some other unknown factor or factors. Previous studies on size distribution of heavy minerals pointed out that the factors that regulate their distribution in sediments are so numerous and complex that their separate effects are difficult or even impossible to untangle (Robey, 1933; Rittenhouse, 1943).

Size measurement:

In the present study, median sizes of the examined heavy minerals in the four samples were obtained graphically from the cumulative size-distribution curves of these minerals. The mineral median size values are tabulated in table 2 and presented in figure 4. For convenience, the minerals have been listed in order of decreasing specific gravity. From the analysis of these data, it was found that: (1) river sand which has the coarsest texture (M_z = 1.85Φ, 0.28 mm) also has the coarsest heavy mineral median sizes, (2)nearshore marine sand which has the finest texture (M_z = 3.33Φ, 0.099 mm) also has the finest heavy mineral median sizes, and (3) high specific gravity value material is

Table 2. Specific gravity of various heavy minerals and its median sizes in phi and millimeter units within the Nile Delta coastal sands.

Mineral	Specific Gravity	Median Size of Minerals in Φ and mm Units							
		Nile River		Beach		Coastal Dune		Nearshore Marine	
		Φ	mm	Φ	mm	Φ	mm	Φ	mm
Biotite	2.98	0.416	0.75	1.500	0.35	1.200	0.44	1.933	0.13
Tourmaline	3.1	0.516	0.70	1.800	0.29	1.300	0.41	2.900	0.13
Hornblende	3.2	0.733	0.60	2.150	0.23	1.400	0.38	3.033	0.12
Augite	3.4	0.666	0.63	2.000	0.25	2.233	0.21	3.133	0.11
Epidote	3.45	0.933	0.53	2.4000	0.19	2.500	0.18	3.233	0.11
Garnet	4.0	1.250	0.42	2.733	0.15	2.683	0.16	3.350	0.1
Rutile	4.25	2.300	0.20	3.400	0.09	2.933	0.13	3.800	0.07
Zircon	4.65	2.233	0.21	3.500	0.09	3.000	0.13	3.833	0.07
Opaques (Magnetite and ilmenite)	5.0	1.533	0.35	3.200	0.11	2.750	0.15	3.566	0.08
Monazite	5.27	-	-	3.633	0.08	3.100	0.12	3.933	0.07

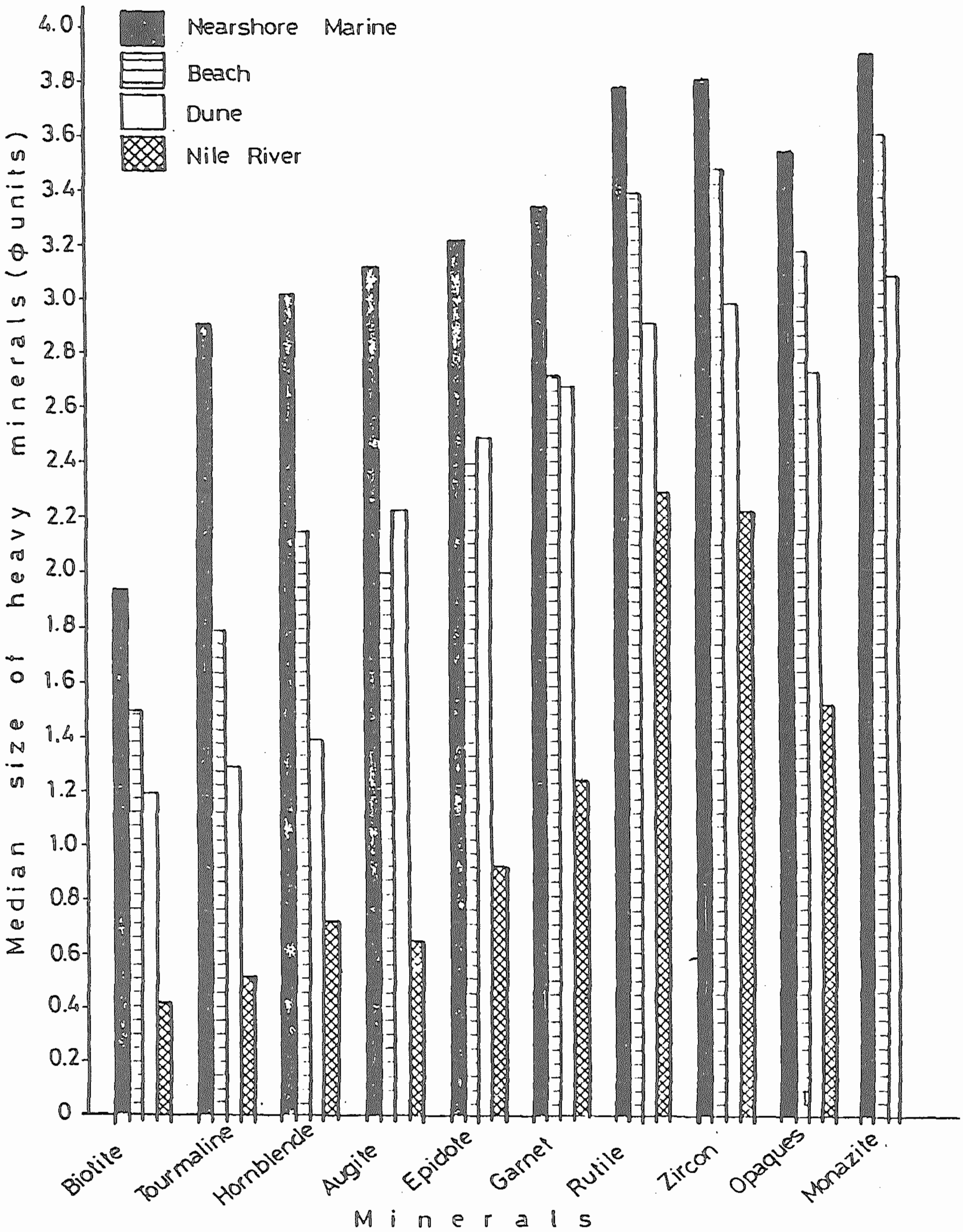

Fig. 4. Histograms showing reltaion between the diagnostic heavy minerals within the Nile Delta coastal sands.

accompanied by increasing fineness of heavy minerals, and low specific gravity is accompanied by increasing coarseness of heavy minerals. Of particular interest are zircon and rutite, which are notably finer in sizes than the opaques (Table 2; Fig. 4) but both are of lower specific gravity values than opaques. Deficiency of coarse zircon and rutile as well as a wide range of opaques specific gravity value are the explanation of this apparent discrepancy. Finally, the difference in the median size of the same mineral in the four samples may be caused by inherent character of the minerals that are available for deposition (the relative size, shape, and surface characteristics of the mineral grain).

CONCLUSIONS

The texture and heavy mineral compositions in some modern Nile Delta coast sand samplés were studied in order to know about the principles or factors that regulate the size distribution of heavy minerals comprising these sands. Results reveal that these sands differ in their mean grain size and degree of sorting. However, the size distribution of heavy minerals in these samples appear to depend, not upon the source of sample and the coarseness or fineness of the particular sample, but upon:(1) range of grain size fractions of each of the sample; (2) its relative availability in each size grade; (3) the specific gravity of mineral species or group of species comparising these sands, and (4) other unknown factor or factors. In general, increasing specific gravity is accompanied by increasing fineness of the heavy minerals. Accumulation and interpretation of such comprehensive data about the size distribution of heavy minerals and its median sizes in the coastal sands, in the writer's opinion, is essential in the search for marine placers and understanding the processes of grain sorting that develop during cross-shore and alongshore sediment transport.

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