LOCAL AREAL VARIATION OF BEACH SANDS ALONG THE COAST OF ALEXANDRIA CITY, EGYPT

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Summary:

Beach foreshore sands on fifteen beaches on the 38 km stretch of the coast of Alexandria City are examined to determine whether distinct areal variations exist among sand textural parameters and compositional properties on beaches which have relatively moderate to low wave energies. Variations in sand textural parameters are noticeable, however, and they appear to be related to dynamic conditions and to directions of sand transport.

The beaches are covered with sands that locally vary in texture and origin. The beach sands are of two principal types: quartz-dominant sands and white loose carbonate ooltic sands. Shells, shell- fragments, rock-fragments, and heavy minerals are also common constituents in the beach sands of this part of the coast of Egypt. Longshore variations in sand textural parmeters of the study beaches, suggest dispersion by seasonally reversing longshore currents. Net-sediment transport is from the west to the east, especially in the summer. During the winter, a westward flowing longshore current and sediment transport are common features.

I- Introduction

During the past thirty years much attention has been directed towards the usefulness of the textural parameters in the recognition of the sedimentologic environments (Folk and Ward, 1957; Mason and Folk, 1958; Harris, 1958; Shepard and Young, 1961; Friedman, 1961, 1965, 1967, Duane, 1964; Passega, 1964 and others), and in distinguishing between beach-energy environments (King and Barns, 1964; Son, 1972; Loring and Nota, 1973; Engstrom, 1974; Nordstrom, 1975, 1977; Anwar, et al. 1977). Also, much has been written on the longshore transport of sediments as summarised by Johnson (1956), Ingle (1966), Bowen (1969), Komar and Inman (1970), Longuett Higgins (1970, 1972), and Self (1977).

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The present paper does not intend to review the early literature but discusses and interprets the local areal variation of beach sands of a section of the Egyptian Mediterranean coast in the light of possible coastal processes acting on the shore.

The Mediterranean coast of Egypt has been extensively studied in terms of geography, regional marine geology and coastal geomorphology (Vatova, 1935, El-Edwy 1937, Steuer 1937, Said 1958, Mohamed 1968, El-Awady 1972, Moussa 1973, El-Wakeel et al., 1974, El-Wakell 1964, El-Sayed 1974, Sharaf El-Din 1974, Orlova and Zinkovitch 1974, Misdorp and Sestini 1976 a, Misdorp and Sestini 1976 b, Summerhayes et al. 1978, El-Wakeel and Sayed 1978, and Anwar et al. 1979).

The beach sediments of the Mediterranean Egyptian coast have not received extensive attention (Hilmy 1951, Sestini et al. 1976, El-Wakeel and El-Sayed 1978).

The purpose of this paper is, therefore, to contribute to these investigations by studying the local areal variations in the texture and composition of beach sands along the coast of Alexandria City. Hence, samples of beach foreshore* were taken from 15 beaches in the Alexandria city area (Fig. 1) to determine whether distinct areal differences exist among grain size characteristic and compositional properties of sands on beaches which have relatively moderate to low wave energies. In addition, textural and compositional studies are made to determine the source and despersion of these sands and the processes occuring along the beach. Beaches of Alexandria were selected as the study area because they afford a variety of sediments and coastal processes in small geographical region. It was anticipated that the basic similarity of mechanisms operative in the beach environment of the coast of Alexandira City, would tend to produce similarities among the grain size parameters. However, it was further assumed that distinctions or identificable characteristics of grain size parameters would result from the different wave energies and different source areas identified in several distinct portions of the shoreline continuum.

* The term "beach foreshore" in the present study is synonymous with "beach face" or "subaerial beach" (Weigel 1953, Dolan 1965).

2- Area of Investigation

The Alexandria area stretches along the Mediterranean Coast of Egypt between the Abu- Qir headland in the east to El-Agami in the west, a distance of 38 km. It lies between 31° 08' - 31° 21' N and 29° 47' - 30° 04' E (Fig. 1). The shoreline of Alexandria is generally oriented south-southwest-north-northeast, and has several embayments, out of which two embayments were artificially transformed into two harbours: the Eastern and Western Harbour. The former was the old harbour but now used for yachting and fishing, while the latter is the main commercial harbour of Egypt. The coast, between El-Anfushy and El-Montazah, is bounded on its landward side by strong sea wall which has been constructed to protect the build-up area of Alexandria City from the storm waves striking the coast during the winter.

The bottom topography of the shelf area off Alexandria is very irregular, in parts being suggestive of a Karstic topography (Misdorp and Sestini, 1976 b). It is characterised by a series of reefs and rocky submerged ridges depressions which extend offshore more or less parallel to the present shoreline. These represent the ancient shoreline which subsided as a result of the downwaraping of the earth's crust along the Nile Delta coast (Ross and Unchupi, 1977). There are three ridges, with depths at the top of 9, 18, 36 m, and numerous terraces that have been traced off Alexandria Western Harbour (Misdorp and Sestini, 1967 a). At the external edge of each terrace there are ridges, rocks and pinnacles, that may be small algal reefs, often rising to the depth of the next (shoreward) terrace. It appears that the main ridges are in the same system as the limestone-dune sand ridges west of Alexandria. The El-Agami - Ras El-Tin, with an eastern interrupted extension as represented by rock islets which are sparsely extended just off shore, and a second, un-named ridge, terminate at the Sultan Shoal Reef, 2.5 km northwest of Nelson Island. The third more external ridge terminates northwest of Ibrahimia (L. 29° 45').

The regional geology of the coast of Alexandria can best be outlined under two principal subdivisions based on differences in lithology, particularly of the carbonate content, and the variation in the degree of consolidation of the sands wheh form its beach. These subdivisions are the eastern part and western part. The eastern part specifically extends from

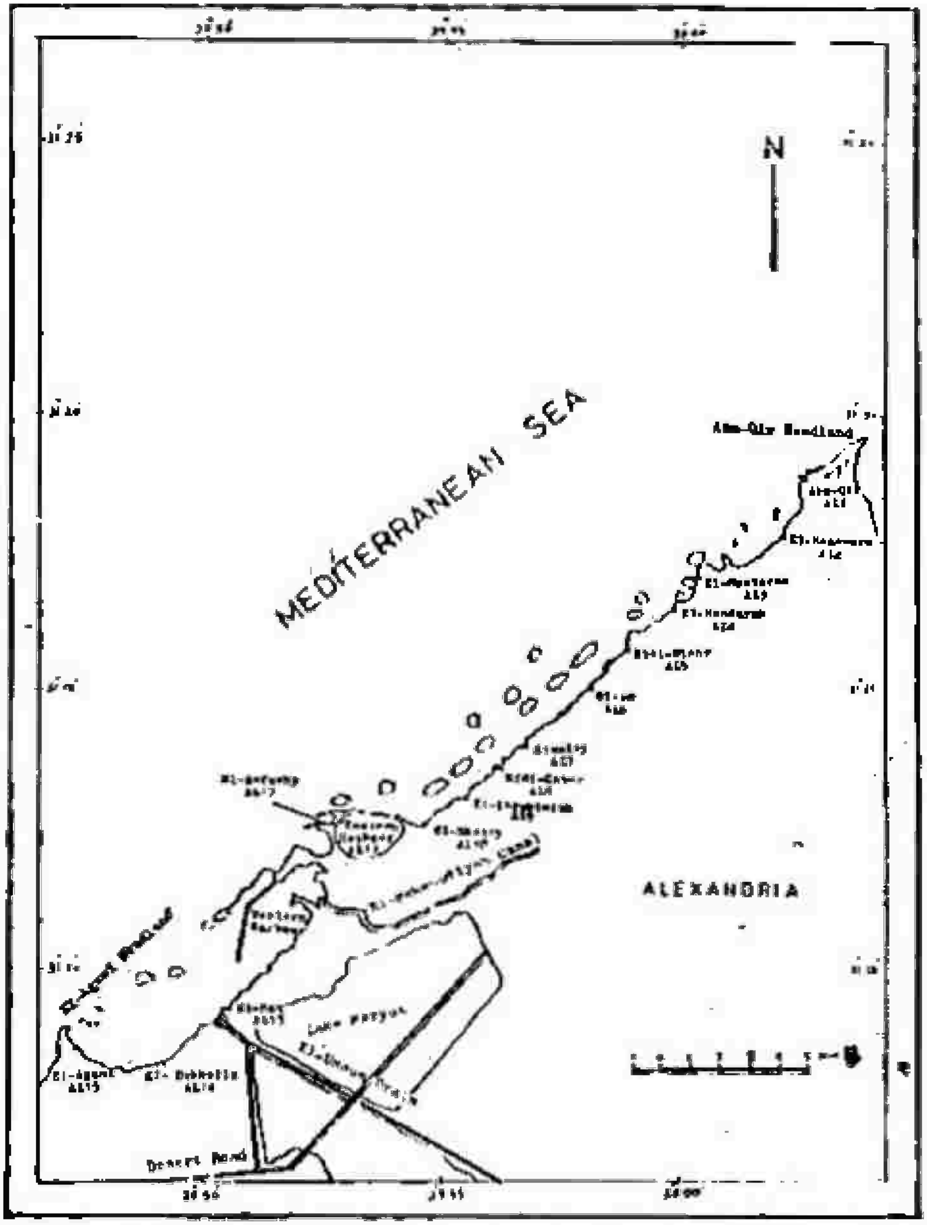

Fig.1- Location of the study area.

Abu-Qir to El-Antushy. The beach sands vary from loose to fairly indurated deposits of quartz. Shells and shell-fragments as well as heavy minerals are common in beach sands of this part of the Alexandria coast. The western part extrends from El-Dekhiela to El-Agami. The beach sands in this part are composed of loose carbonate sands, oolitic in texture, while in colour, well-polished and well-rounded. Away from the sea-water, these loose carbonate oolitic sands gradually alter to fairly consolidated oolitic limeston, cemented by a secondary calcium carbonate, probably calcite (Hilmy 1951, Shata 1955, Shukri and Philip 1956), forming ridges skirting the coast in the west of Alexandria region (Shata 1957, Shahin 1965), specifically from El-Dekhiela to Marsa Matruh (Fig. 2). According to Hilmy (1951), the age of these carboante "oolitic" beach sand and limestone, along the Egyptian Mediterranean coast, ranges from Pleistocene to Recent. These fragmental sands have their origin in cretatceaous-Eocene limestone formations of the nearby West Desert, and were deposited in some sort of littoral dune formation, now represented by the consilidated limestone ridges (Hume and Hughes 1921, Hume and Little 1928, Hume 1929, Sandford and Arkel 1939, Ball 1939).

Geomorphologically, the beaches along the coastal zone of Alexandria City form one geomorphological unit as compared to the other adjoining coastal parts, identified on the basis of the general differences in topography and lithology of the Mediterranean coast of Egypt. These beaches appear to be exposed to the same hydrological conditions. They are shaped largly by marine processes and terrestrial agents.

According to Shukri and Philip (1955), the shoreline of Alexandria exhibits typical characteristics of a young shoreline. It extends more or less straight with slight undulations forming small embayments. In general, the shoreline is in most places rocky, with narrow sandy beaches in the embayments. The beaches of the study area have smooth surfaces and slope regularly seaward, at an ever-decreasing gradient. The width of the beaches varies from 10 m to 80 m. The widest beaches are found on the most easterly and westerly flanks of the area, ie. Abu-Qir and El-Maamoura beaches in the east, and El-Agami beach in the west. The beach-face slopes range between 2° and 14° in steepness, with the majority between 2° and 6°. The wider beaches have the most gentle beach-face slopes (El-Maamoura:

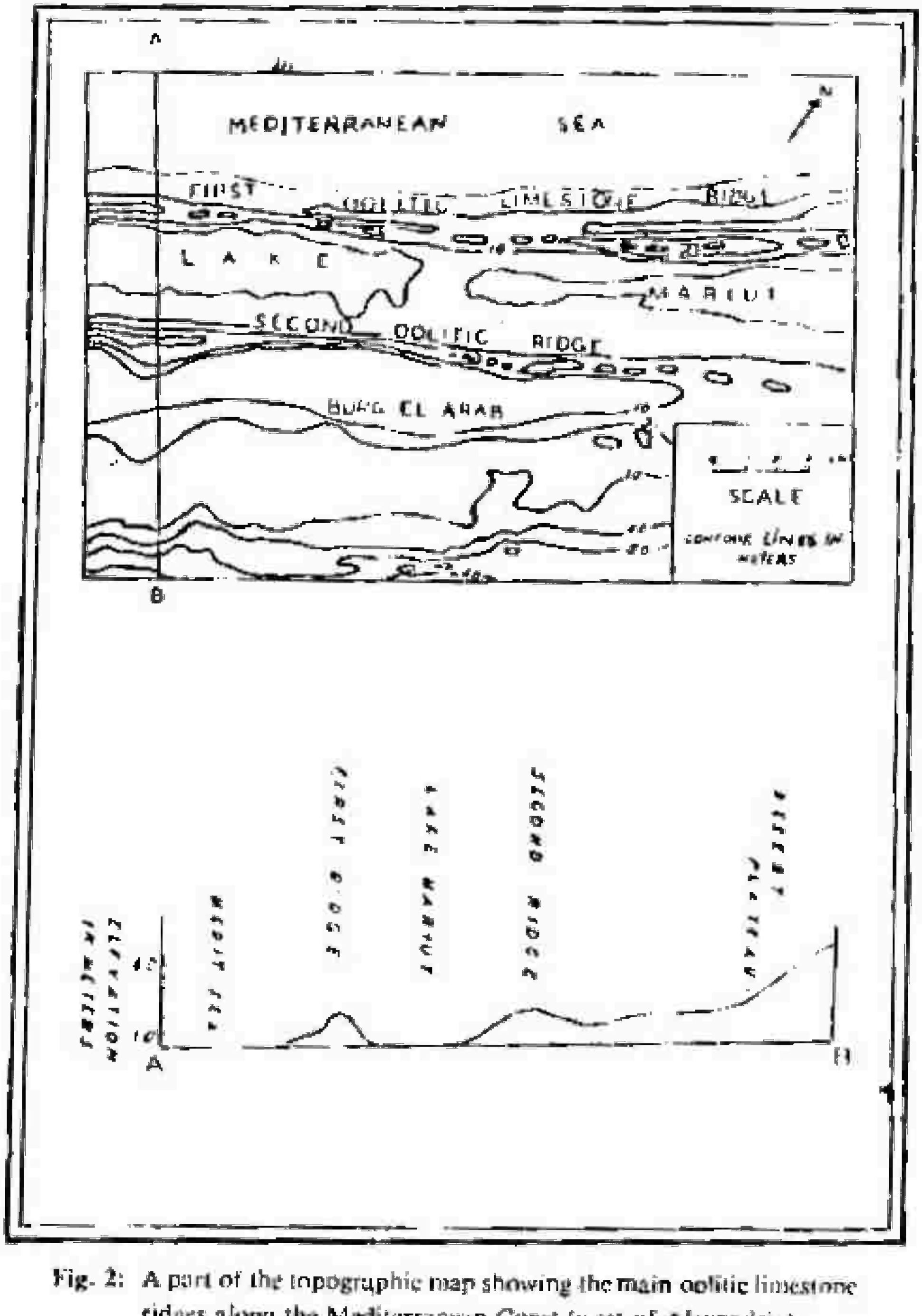

Fig. 2: A part of the topographic map showing the main oolitic limestone ridges along the Mediterranean Coast (west of Alexandria).

2.5 , El-Agami: 4). The steepest slopes (8 -14) are found on the narrow beaches such as those of Sidi-Gaber, Gleem, and Stanly.

beaches such as those of Sidi-Gaber, Gleem, and Stanly.

The coastal zone of Alexandria was influenced by three main sources of the sediment-rich water prior to the construction of the Aswan High Dam in 1964. The first and most important source was that from the Rosetta mouth of the Nile, at about 45 km to the east of Abu-Qir headland. The River Nile used to discharge large amount of deposits, that were estimated to be 100×10^9 m^3/yr prior to 1902 reduced to 35×10^9 m^3/yr between 1902 and 1964 (Aleem 1972, Sharaf El-Din 1947). Since 1964, irrigation projects associated with this dam prevent almost completely the discharge of fresh water from the Nile into the Mediterranean, with measurably deletrious effects on continental shelf fisheries and coastal stability (UNESCO, 1973, 1976). The second source was the Mahmoudiyah fresh-water canal, opening into the Western Harbour, which is now abandoned, and is replaced by the Nubariyah fresh-water canal, opening also into the Western Harbour. The third source is the drainage water pumped out from El-Omoun drain into the Mediterranean Sea at El-Max. This drainage water was estimated to be 1.374×10^9 m^3/yr (irrigation Department, 1966).

As aforementined, the beaches of Alexandria are consituted of loose sediments and therefore, are susceptible to great changes on application of energy. Most of the energy driving nearshore and beach foreshore processes along the coast of Alexandria comes from the Mediterranean Sea, acting as the medium for transfer of energy to the loose materials, in the form of waves, currents, tides, and winds which are the primary agents affecting the coast.

Wave action along the coast of Alexandria is seasonal in nature with the winter, storm, season (November to March) and summer, swell, season (Aprial to October). In general, there are about fifteen storms per year (2 in Nov., 3 in Dec., 4 in Jan., 1 in Feb., and 5 in Mar.) out of which seven (2 in Nov., 3 in Dec., 2 in Jan.) are moderately heavy accompanied by strong winds and heavy rain. The waves have periods ranging from 7-8 sec. in storm season to 9-10 sec. in swell season. Wave heights of about 0.80 m are average. During the storm season the average wave heights are 1.3 m (with maxima never over 3.0 m). The predominant directions of waves during stormy season usually are from NW and NNW, though waves from N, NNE and NE are not uncommon, especially in December and March. Swells approach the coast generally from NNW and NW with an average height of 0.60 m.

Longshore currents induced within the breaker zone are mainly responsible for the longshore transport and movement of the sand load. Eastward currents predominate during the summer months (Fig. 3), while westward currents as well as negligibile currents resulting from the perpendicualrity of waves are common features during the winter months (UNESCO, 1973, 1976). Longshore currents with speeds up to 100 cm/sec. has been measured locally along the Mediterrenean coast of Egypt (Gorgy 1966, Sharaf El-Din 1974). More recent measurements (Monohar 1976) indicate that over 50% of the time the eastward currents are up to 80 cm/sec., and this is almost twice as much as the east-west direction.

The coastal area of Alexandria is a microtidal environment (mean range 0.26 m, maximum range 1.17 m). Records from the Western Harbour Tide Gauge Station show that tides are predominately semi-diurnal. The tidal variation are, however, relatively small, and when they are not accompanied by meteorologically induced waves and currents, the tidal currents themselves will not sufficiently powerful to shift significant amounts of materials towards the shore. The tidal variations, therefore, constitute no significant factor for the mechanisms of sediment transport and shore processes on the coast of Alexandria. Wave and tide conditions can change redically for short periods of time when cyclonic fronts and squalls, locally called "Anwaa", strike the coast during winter months.

Wind directions vary seasonally along the coast of Alexandria (Fig. 3). The predominant wind is on shore north-westerly during summer months. These winds induce swell which is refracted to produce east-moving longshore drift in the summer months. Obliquely south-westerly and north-easterly winds are predominant during winter months (Nov. - Mar.), the latter winds being more frequent and potentially significant in producing west-moving longshore drift according to Manohar (1976). Onshore northerly winds prevail throughout of the year (climatological Normals, 1980) and give rise to prevailing waves and swells that efficiently transmit energy and momentum to the shore of the study area. On the contrary, contribution by off shore winds is regarded as insignificant considering the

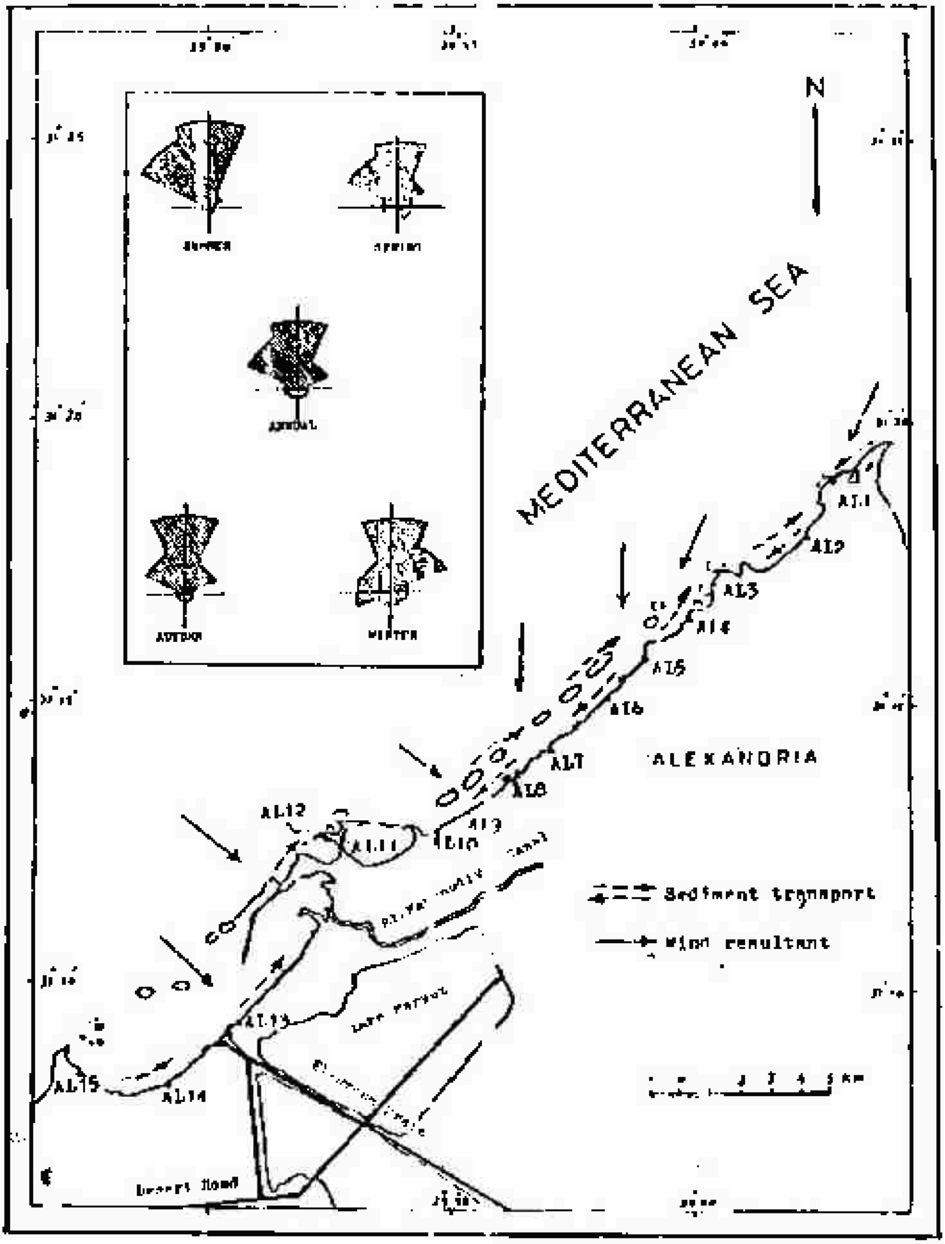

Fig. 3: Seasonal and annual wind frequency by direction, and onshore wind resultants and direction of nearshore sediment dispersal along the Alexandria Coast.

general inability of wind to transport coarse sand (Blatt et al., 1972), and because less than one fourth of the wind directions for Alexandria Coast has an off shore component. As regards the velocities of wind, there is a marked seasonal variation of wind velocities, and storms (squalls) are most frequent and intense from November to April.

3- Procedures

In order to determine the situation regarding local areal variation in beach sands along the coast of Alexandria City, direct observations were made and information and data were gathered both in the field and laboratory.

3.1 Collection of Samples

Sediment samples were collected exclusively from the upper part of the beach foreshore, i.e. between the still-water level and ordinary high water mark or sometimes the limit of wave uprush (Fig. 4), including that part of the deposit act upon by the swash waves that have broken near the strandline, of the 15 study beaches.

A plane for sampling the beaches was designed according to the hypothesis that longshore variations in grain size parameters and lithologic composition of beach sand would provide significant information regarding sand source and direction of littoral movement. It was estimated that the space between the beach locations along this coast would be small enough to reveal variations of a sufficient magnitude to obtain useful information. Accordingly 15 profile lines were fixed on the 15 study beaches. Each profile was located approximately in the middle area of each beach, and perpendicular to the strandline.

In order to obtain all possible variations in the conditions of deposition as well as in the size characteristics of beach sediment, samples should be collected in different seasons. Therefore, the entire suite of samples was collected during the period from September 1982 to August 1983 with the number of sampling sites per beach being proportional to beach-face length in a manner such that a sample was collected for at least 10 m of beach-face length starting from the base line on the backbeach to the point of intersection of still-water level and the beach-face surface.

After the general location of a given sampling site was determined, the precise section of the upper foreshore was determined in a random fashion to represent as far as possible the various kinds of beach sand. At each prescribed site, four closely spaced samples, 1 m. apart, were obtained using a cylindrical tube, 5 cm. in diameter, which extended 15 cm. normal to the beach-face to obtain more of less average sample over a number of

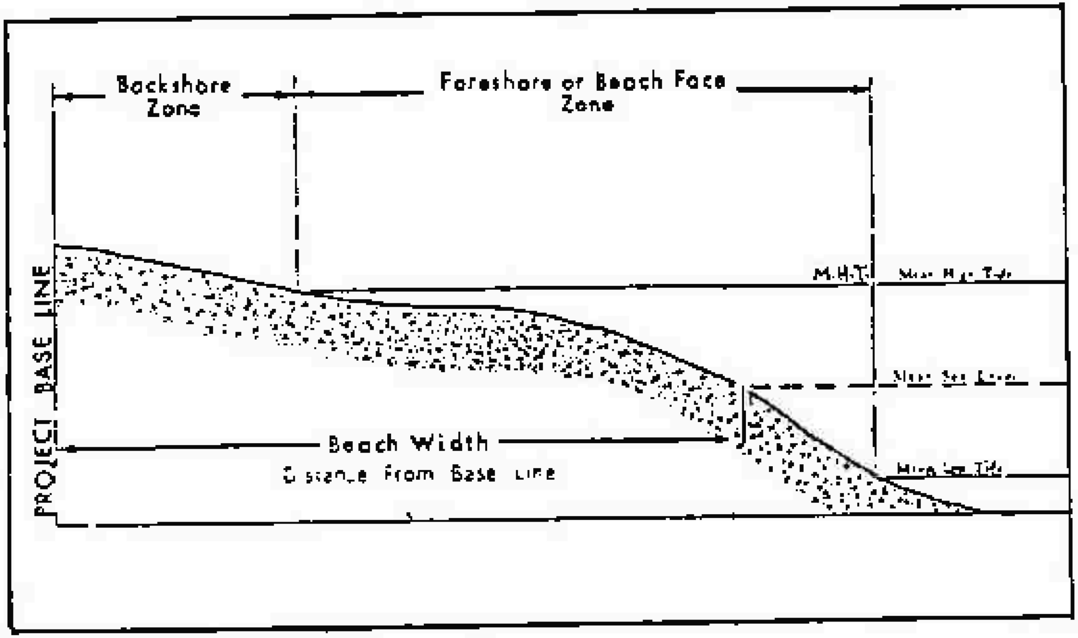

Fig. 4: Generalized beach profile in the study area.

laminae. This was done after the beach-face slope had been measured in degrees by Abney level. The four samples were then combined into a single composite sample as Krumbein (1934) suggests.

3.2 Grain-size analysis

In laboratory, all samples were treated by standard techniques of washing in distelled water to remove salt which might will have produced aggregates, oven drying, and splitting by a mechanical sample splitter to obtain a split of 250g. from each sample for sieving, and the remainder were subjected to mineral tests. Each sample was sieved by hand through the -1.75 and -1.50 sieves to remove coarse shell material. The remainder were then shaken for 15 minutes on a Soiltest Sieve Shaker using a strack of sieves representing 0.5 intervals from -1.5 to 4.0 *. The fraction retained on each sieve was weighted to 0.01 gram and the weight was converted to a percentage of the total sample weight.

The method of moments (Friedman 1961, 1967; Griffiths 1962, 1967) was used to determine the several basic parameters of the Size-Frequency distributions. The mean grain size (m), standard deviation, i.e. Sorting (S), skewness (SK), and Kurtosis ($K\varphi$) for all samples were calculated using four computational formulae proposed by Greenwood (1960). All computations were carried out on a digital personal computer (Hitachi, AH 200) Using a MSX-BASIC Computer program for standard moment statistics.

3.3 Mineral analysis

The 1.0 φ -1.5 φ (medium sand) fraction was chosen for lithologic composition study since this fraction was present in all samples and contained all major constituents. The study was done by means of thin section techniques and point counting using the line method described by Galehouse (1977). Assuming the thin section is representative of the size fraction, correct identification of 300 grains assures that the true number frequency of a constituent lies within 6% of the calculated value with 95% confidence level (Van der Plas and Tobi, 1965).

Classification of quartz grains follows Blatt (1967). A monocrystalline quartz grain is one in which a single quartz crystal occupies 90% or more of the grains cross-sectional area in thin section. Plutonic polycrystalline quartz is composed of two to five indivdual cryatals with plutonic igneous

* φ (phi) $\log_2 \varphi$ mm [illegible] use in Sedimentology

texture, while metamorphic polycrystalline quartz shows characteristically metamorphic feature. Granite includes all plutonic igneous rock fragments composed primarily of quartz and feldspar.

The percentage of carbonate in each sample was determined as follows. About 20 grams of each sample were treated with dilute hydrochloride acid (1:3) for carbonate dissolution, were filtered, washed, dried at about 110 C. and reweighted. The percentage of carbonate in each sample was thus determined by the difference. Qualitative tests made on the filterates from all samples indicate nothing in the way of bases but calcium.

The 3.0-4.0 phi fraction resulting from the grain-size analysis was chosen for heavy-mineral separation as it was found to be relatively rich in heavy minerals. This fraction, for each sample, was first treated with hydrochooric acid (1:3) to remove the acid soluble material (mainly carbonate), and then seperated into heavy and light minerals by means of the traditional method of separation: the bromoform with centrifuge, followed by the identification of individual (or groups of minerals) using a binocular microscop. (Milner 1962), and the calculation of the percentage of each.

4- Results and Discussion

The beach foreshore sands along the coast of Alexandria have mean grain sizes between $-0.25\ \phi$ and $+\ 3.07\ \phi$ with most majority between $+\ 1.0\ \phi$ and $+\ 2.5\ \phi$. The dispersion of sand particle size (i.e. sorting) is between $0.44\ \phi$ and $0.79\ \phi$, which means that sands are moderetely well to well-sorted. Most beach foreshore sands have asymmetrical size distributions about the mean. Skewness of beach foreshore sands ranges from $-0.90\ \phi$ to $+\ 1.25\ \phi$, while kurtosis varies from 0.33 to 3.85 . A sediments is presented in Table 1.

The sands on the beach foreshores of the study area are composed of quartz, fledspar, rock fragments, carbonate, shell hash and heavy minerals of which ampliboles, pyroxenes and opaques are the most common. Average lithologic composition of beach foreshore sands along the coast of Alexandria are listed in Table 2.

4.1 Areal variation of sand texture

The primary evidence for selective sorting by longshore currents comes from a study of the variations in texture of beach foreshore sands along the study Coast from east to west. Figure 5 summuries the results of grain-size analysis for beach foreshore sands versus distance.

Table I: Average values of size parameters of beach foreshore Sediments (standard diviation in parenthesis)

Site No.	Beach	Size statistics (Phi unites)				Site No.	Beach	Size Statistics (Phi unites)			
		M_n	S	Sk	K			M_n	S	SK	K
AL-1	Abu-Qir	1.09 (.30)	0.62 (.14)	+1.02 (.18)	0.33 (.121)	Al-9	El-Ibrahimiah	1.46 (.32)	0.57 (.23)	+1.25 (.20)	1.46 (.37)
AL-2	El-Maamoura	2.58 (.23)	0.56 (.09)	-0.39 (.10)	1.86 (.27)			1.16 (.23)	0.55 (.09)	+0.18 (.12)	1.17 (.21)
AL-3	El-Montazah	1.92 (.32)	0.60 (.22)	+0.49 (.15)	1.35 (.34)	AL-11	Eastern Harbour	1.96 (.29)	0.57 (.13)	-0.27 (.17)	1.51 (.12)
AL-4	El-Mandarah	1.98 (.29)	0.59 (.14)	-0.29 (.11)	1.85 (.22)	Al-12	El-Anfushy	2.19 (.30)	0.44 (.16)	-0.55 (.19)	3.85 (.27)
AL-5	Sidi Bishr	1.18 (.23)	0.62 (.07)	-0.19 (.09)	1.30 (.27)	AL-13	El-Max	2.76 (.27)	0.48 (.18)	-0.47 (.21)	3.05 (.34)
AL-6	Gleem	0.15 (.18)	0.79 (.13)	-0.90 (.12)	1.15 (.19)	AL-14	Dekheila	3.07 (.30)	0.47 (.14)	-0.17 (.19)	2.45 (.27)
AL-7	Stanley	0.82 (.27)	0.61 (.14)	+0.24 (.17)	0.79 (.22)	AL-15	El-Agami	2.08 (.22)	0.49 (.07)	-0.20 (.11)	2.62 (.25)
Al-8	Sidi Gaber	-0.25 (.29)	0.71 (.23)	+0.04 (.23)	1.08 (.15)						

M_n = Mean grain size

S = Standar deviation (Sorting)

SK = Skewness

K = Kurtosis

Mean grain size

From the fieldwork observations and the study of the statistical data given in Table 1, it is found that the mean grain size of the beach foreshore sands of this part of the Mediterranean Coast of Egypt is, in general, related to beach face slope. The coarsest materials are associated with the narrow steep beachs such as those of Gleem (+ 0.15 φ) and Sidi Gaber (-0.25 φ). The larger grain size (lower phi values) of these beaches may be partly attributed to a large sea wall, some 2 m in height, encircles the back of the beaches. This helped to trap the coarse-grained material and the finergrained sediments were washed back into the nearshore zone. The coarser-grained material of these beaches cannot be winnowed away but the finer-grains are transported either seawards by currents or landwards by swash, leaving the coarse-grains as a lag deposit. The sand becomes finer (higher phi values) on the wider flat beach foreshores of El-Maamoura (2.58 φ) in the east and El Agami (2.8 φ) in the west of the study area.

It was also noticed in the field that grin size is larger at the sea ward zone of the beach foreshores than at the upper end. This could be due to the fact that much energy is dissipated within the lower end of the beach foreshores rather than their upper end. The seaward coarsening of beach sediments size is also brought about by the finer sediments being either winnowed out from the seaward zone and concentrated at higher beach levels by swash zone processes, or swept seaward.

Spatial variations in the mean grain size of foreshore sediments of Alexandria coast are shown in Figure 5A. Inspection of the graph line in Figure 5A. indicates that, although the eastern portion of the coast (El-Maamoura, El-Mandarah) shows a decrease in mean grain size (higher phi values) the mean size increases (lower phi values) in the middle portion and then the mean size decreases again in the western portion of the coast (El-Max, El-Agami). It was anticipated that mean grain size would be inversely related to wave energy as a review of the literature suggests. As King (1972, p. 302) stated "it is generally true that the particles size is larger where the wave energy is greater. This relationship applies both in space and time". Bascom (1951), Ingle (1966) and Hodgson (1966) have also all noted that grain size increases as wave energy increases along a coastline.

Only a small proportion of the variation in mean grain size could be ex-

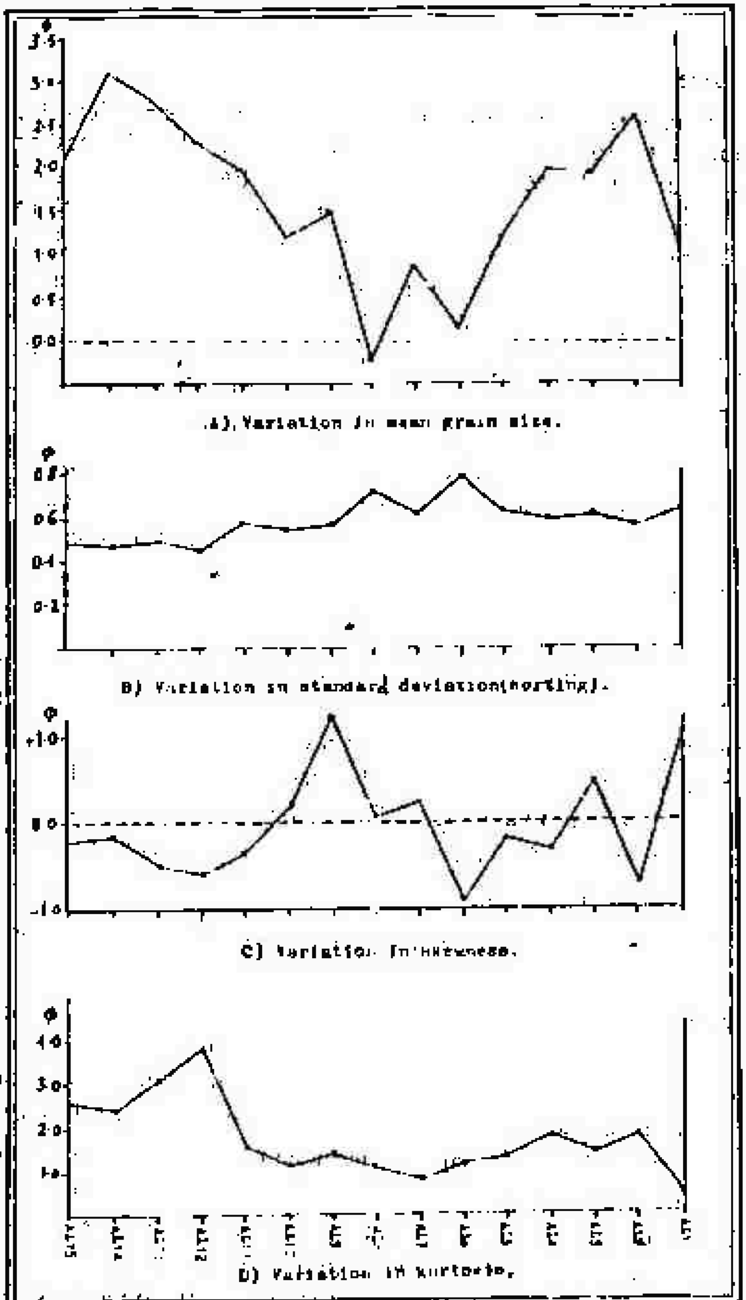

Fig. 5: Schematic illustration showing variations in texture of beach foreshore sands (beaches are arranged in order from east to west but are not to scale. Locality abbreviations at base of diagram are the same as in Fig. 1).

plained by any of the process variables. However, the general inadequency of the process variables to explain the variation in mean grain size must be attributed to marked differences in the grain size distributions available to nearshore coastal processes. There must be available at each beach enough material in the various size categories for the variation in process to become manifest. The sidements on the beaches of the middle area and eastern flank of the study coast are belived to represent waterborne sediments, mainly quartz with abundance of heavy minerals, transported mechanically by the River Ninle, derived mainly from upper Nile basin and subsequently mixed with shell fragments on the beach. In addition, sidements on the beaches of the western flank, mainly pure carbonate "oolites", are beleived to be derived from the Western Desert Tertiary limestone formations, as wind-borne carbonate sands which have bean reworked by the agitating water movement of the beach waves (Hilmy 1951). As Sahu (1964) has noted, the mean grain size of sidements can be attributed either to the average kinetic energy (velocity) of the depositing agent or to the size distribution of the available materials. Shepard (1959) has concluded, except for local situations, that the relative coarsness of sand is not related to wave exposure but rether to the type of soure material present. Folk (1966) has also commented on the importance of source materials in controlling the statistics of grain-size distributions.

The comparison of the beach sand-size based on the derived statistical parameter: the mean grain size can mask subtle variations within the set of grain size distributions. A different way to compare simultaneously the entire grain size distributions can be made by a contour mapping in the space-frequency-size domain along the study coast. This grain size "spectra map" reveals the obvious characteristicts and subtle variations which can be isolated, correlated and their relative importance estimated.

Based on the data set of the resulting size-frequency distributions of the study beaches, a grain-size spectra map was constructed (Fig. 6). This map shows a gradual increase of dominant grain size from El-Agami to Sidi-Bishr, and gradual decrease from Sidi-Bishr to El-Montazh. It also shows that the high percentage of Medium-Coarse materials at Abu-Qir beach is not part of the general trend. It suggests two different Sedimentation processes. In addition, there is a sinuous parallelism of the 10, 20 and 30% contours. The periodicity of the undulations of these contours could be

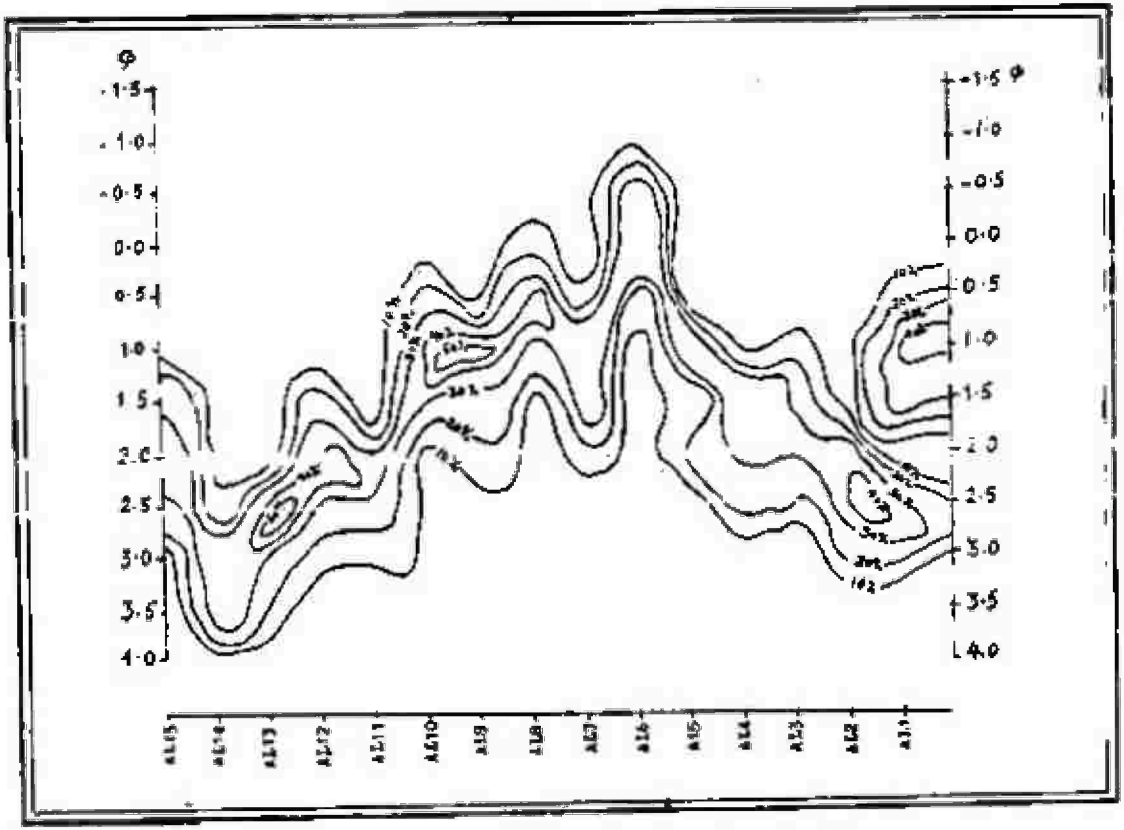

Fig. 6: Grain size spectra map of Alexandria beaches (beaches are arranged in order from east to west but are not to scale. Locality abbreviations at base of diagram are the same as in Fig. 1)

related to a sedimentation process. Another observation, perhaps related to the first, is that there are three closures of the 40% (excluding the other 40% near Abu-Qir beach). At Alexandria coast area the ness of coarse material could be attributed to storm surges and currents which carried coarser material across the beaches modified the essentially pattern of the contour lines. It is also postulated that minor storm modified the pattern by carrying tongues of coarser material across the beaches here and there. Finally, in view of the fiding at Alexandria coast, the pattern of the contour lines may be the rule in the size variations along the beaches.

Sorting

The degree of sorting of the foreshore sediments in the study area, as measured by the phi standard deviation of grain-size distribution, has been illustrated in Fig. 5B. Analysis of Alexandria littoral sand indicates that no definite trend is present, as to show a pattern which seems to fit the area. The range of values of sorting is from 0.44 phi to 0.79 phi. This relatively small range of the values between the study beaches (Table:1) is not unexpected, as Folk (1967) has noted that there seems to be no difference in sorting between beaches with gentle wave action and those with moderate to vigorous surf. It is also postulated that the relatively small range of sorting values, here, may represents fluctuations about some fixed value throughout the environment. The present study seems to support the hypothesis that beach foreshores may tend toward a fixed spread of their size frequency in a given stretch of beach foreshore. In a given stretch of beach foreshore the average action of the waves may be approximately uniform, so that selective processes, on which the spread of the distribution depends in part, may be fairly constant. Local fluctuations in the value of the spread may arise in part from slight changes in the slope of the beach, as well as from accidental variation in the last large waves to strike any given point during the storm period.

Moderately well sorting on El-Max, El-Dekheila and El-Agami beaches may be interpreted in relation to the composition of sands on these beach foreshores. Apparently the carbonate sands of these beach foreshores, although strongly contrasted in their composition as a group (oolitic carbonate) with that of the beach sands east of El-Max where admixture of quartz grain and different shell fragments are dominant, become slightly varied in sorting values with the change in the mean grain size, perhaps reflecting the effect of the mean uniformity in the composition of the carbonate as pure calcium carbonate. This may indicate that these particular sands are better sorted the finer they are.

Relatively high values of phi standard deviation (less well-Sorted sands) on beach foreshore area from Sidi-Bishr to Abu-Qir may be attributed to the relatively high mobility of the beach in response to littoral currents and energy flux of wave induced longshore currents. At Abu-Qir, the predominant directions of the monthly energy flux are NNE and NNW followed by NE (UNESCO, 1973).

The unusually high sorting values (poor sorting) on Gleem, stanely and Sidi-Gaber beaches may be attributed to the unusually large grain sizes (Table 2) of these beaches. Mean grain size has a strong influence on sorting characteristics of a sedimentary deposit. It has been observed that sorting coefficients commonly decrease with increasing size (Friedman 1968). This reversal in the relation between mean size and sorting has not commonly been observed in beach sediments, although river sediments do exhibit this phenomenon (Folk and Ward 1957). Coarse and fine sediments alike are put in motion as the threshold velocity increases above that required to move fine sand, producing a poorly sorted deposit. However, it appears that an upper size limit around 0.0 phi exists for this size-sorting relationship (Folk 1968; Sonu 1972). In this context, it is possible that larger particle percentage of the beach sediments reflects high swash-backwash velocities associated with higher waves. These higher swash-backwash velocities did not exercise any degree of selection on available materials, resulting in poor sorting on deposit. Conversely, lower velocities, capable of moving only small percentages of coarse particles, were more restrictive in the selection of particle sizes moved, resulting in better sorting upon deposition. Once introduced into the foreshore, regardless of mechanism, the coarse materials encourage infilteration of fines and tend to constitute a persistent, often-inherited mode whose presence invariebly leeds to poorer sorting values for foreshore sediments. It is apparent from the general range of the observed mean grain sizes that some of the Alexandria beach foreshore sediments exhibit this well documented sand size sorting relationship.

Skewness

Skewness is far more difficult moment measure to interpret in relation to the physical condition of deposition. However, it can be considered to indicate the selective action of transporting agent (Krumbein and Pettijohn 1938), and to reflect the relative frequency of occurance of energy flucations above or below the average (Greenwood 1969). According to Duane (1964), the areas of low-energy levels are characterised by positive skewness values, while negative skewness values are indicative of areas of erosion. Hence, a mixture of positive and negative skewness values would thus indicate a region in a state of flux.

Several workers have concluded that most beach foreshores, with Alexandria beaches providing no exception, display a negative skewness (Moson and Folk 1958; Friedman 1967; Duane 1964; Chappell 1967; Hails 1967), indicating a grain size distribution rendered asymmetrical by the presence of a relatively large coarse tail of sediment. Negative skewness of beach sands may result either from an addition of material to one end of a normal frequency distribution or conversely from a subtraction of material (a "winnowing") from the tail (Friedman 1961; Folk and Robles 1964; Martins 1965; Sevon 1966). The relatively low skewness values (Table 1) indicate that the study beach sands have nearly symmetrical dispersion of particle size-distributions, while high skewness values are expected to result from mixing of two lognormally distributed particle populations (Spencer 1963).

Using the mean skewness value for distincting between beach foreshores of the study area can be misleading, however, since this statistic is bidirectional in values to either side of zero may cancel each other out. This is the case at Sidi-Gaber beach foreshore where the mean skewness value indicates a fairly symmetrical distriibution (+ 0.04φ) but the standard deviation indicates a relatively greater despersion of skewness values as might be expected considering the variability of processes during the study period.

The coarse sands on the narrow steep foreshore of Gleem beach (-0.90) have a rather strongly negative skewness. This may be interpreted as suggesting that increasing foreshore slope steepness increases backwash velocity enough to remove much of the fine tail, producing strongly negatively skewed sediments. As the mean grain size of the sediment shifts toward the coarser particle sizes a reduction of the coarse tail occurs because the upper limits on the size of beach sediment exist. The result is a decrease in the magnitude of the negative skew. Also, a shift toward the coarse end of the distribution increases the opportunity for the infilteration of finer materials which can cancel out the effect of the coarse tail. This the case at Sidi-Bishr beach foreshore which has low negatively skewed sands (Sk. - 0.19 φ). Moreover, Friedman (1961) and Sonu (1968) have also both noted a tendency toward positive skewness in coarse-grain beach sediments. The skewness value of the beach foreshore sands on Stanley (Sk: + 0.24 φ) and El-Shatby (Sk. + 0.18 φ) substantiates this finding.

The strongly positively skewed sediments is found on the smoothly sloping beach surface of El-Ibrahimiah (Sk: + 1.25 φ). This may be attributed to the fact that a high degree of permeability of beach surface well allow entrapment of finer particles within the interstices, and the sediment will show positively skewed character. Similarly, greater admixture of fine may finally result in a sediment of symmetrical skewness, such as on Sidi-Gaber beach foreshore (Sk: + 0.04 φ). Friedman (1961) has also shown that beach sediments near river may retain the positive skewness of the flavial sediments since they have not had time to adjust to their new environment. This is the case at Abu-Qir beach (about 45 km west of the Rosetta Mouth) where the Skewness value reaches + 1.02 φ. Thus the longshore variations in skewness indicate the interplay between marine and fluvial processes.

Not consistent with the literature is the less negatively skewed fine beach sediment at El-Dekheila (Sk: -0.17 φ) amd El-Agami (Sk: -0.20 φ). Apparently the sediments at these beaches become less negatively skewed as mean grain size becomes finer, perhaps reflecting the addition of a mode to the fine end of the distribution. Such an addition may, as well, give rize to a shift of mean-size values.

Kurtosis

Kurtosis, measuring the concentration of frequencies within the central part of the distribution relative to the concentration in the tails, is the least understood of the Greenwood 1969), and is over-sensitive to random fluctuations (Baker 1968). Most of the Kurtosis values (Table: I) are high (more leptokurtic) on the beach foreshores of the Alexandria coast, indicating that sorting in the central part of the grain-size distributions is better than in the tails. Sahu (1964) suggests that a high kurtosis value reflects a depositing medium where velocity fluctuations were restricted to those carring material of size coincident with that size in the central 50% of the distribution for a greater length of time than normal.

Most appropriate to the kurtosis characteristics of Alexandria beach foreshore sediments are the observations of Folk and Ward (1957) on the relations between grain-size parameters and gravel and sand modes in a bimodal river bar in Texas. Alexandria beach foreshore sediments contain, on the average 8-12% coarse material. Flok and Ward report that addition of small amount of coarse material (3-10%) to the larger sand mode produces a strongly leptokurtic distribution and, as coarse material constitues larger and larger percentages of sediment, kurtosis is reduced in absolute value, the distribution becoming more platykurtic, assuming either no change or poorer sorting in the central part of the distribution.

The present work shows that kurtosis value increases (leptokurtic) as sands become negatively skewed (Table. 2) and decreases as sands become less negatively or even positively skewed. This is consistance with the observation of Folk and Ward (1957) that sands with 7 to 20% coarse material are highly leptokurtic and negatively skewed. Negative skewness indicates that the finer mode is more aboundant than the coarser mode. Smaller modes toward better sorting producing leptokurtosis in the grain-size distributions of Alexandria beach foreshore sediment.

Measurements of littoral currents, that are induced by the prevailing north-westerly wind within the breaker zone, indicate that net longshore transport of sand over most of the year is esatward. During the summer months up to october, the eastrly currents with a maximum magnitude of 80 cm/sec predominate over the westerly currents (Manohar 1976) and transport sediment northeasterly. During winter storm months, the wind reverses direction causing westward flowing longshore currents driven by northeast with a maximum of 40 cm/sec which exceeds those towards the east and transports considerable amounts of River Nile derived materials as far as 60 km southwest of the Rosetta moth. The November month is a transitional period with more current reaching the coast perpendicularly. Easterly currents predominate again from March, i.e toward the end of the storm season (Manohar 1976).

4.2 Areal variation of lithologic composition of the beach sands

A comprehensive study of gross lithologic composition was undertaken for the purpose of identifying longshore variations in beach foreshore sand composition and for tracing the source of sand along the coast of the study

TABLE 2: Average lithologic composition of beach foreshore sands (Values are in percent)

Constituents	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Stanley	[illegible]	[illegible]	[illegible]	Eastern Harbour	[illegible]	[illegible]	[illegible]	[illegible]
MONOCRYSTALLINE GRAINS	48	49	43	48	45	67	41	48	44	38	31	22	8	1	5
Quartz	48	46	42	45	45	74	41	46	44	38	31	22	5	2	1
K-feldspar	16	13	10	10	21	27	19	16	16	11	17	10	4	2	1
Plagioclase*	10	8	11	15	13	9	6	7	10	10	13	8	3	1	–
Muscovite	2	3	3	3	3	1	3	1	3	1	2	1	–	–	–
Unidentified minerals	2	2	2	0	1	1	0	1	2	2	–	1	1	3	–
RATIOS															
Quartz to total feldspar	3.0	2.1	1.5	1.6	1.3	1.8	1.5	2.0	1.0	1.6	1.6	1.2	0.7	0.3	1.0
K-feldspars to plagioclase	1.6	1.4	1.6	1.2	1.6	1.9	2.4	2.3	1.4	1.0	1.5	1.2	1.3	2.0	0.0
ROCK FRAGMENTS															
Plutonic polycrystalline quartz	5	6	6	4	3	4	5	3	4	3	4	2	–	–	–
Metamorphic polycrystalline quartz	2	1	1	1	1	2	1	2	1	2	2	1	–	–	–
Granite	2	2	3	2	2	2	2	1	1	2	2	1	–	–	–
Volcanics: Trachyte /Basalt	3	4	4	2	3	2	3	3	1	2	2	–	–	–	–
Cryptocrystalline Calcium carbonate	5	8	4	3	4	4	7	8	9	13	30	43	66	75	78
Shale	3	3	3	3	1	2	1	2	1	3	1	2	1	1	2
Shell materials	2	2	2	3	4	9	10	11	12	6	4	3	–	–	–
Total Carbonate	36.4	42.9	[illegible]	40.2	75.9	40.4	41.6	[illegible]	[illegible]	[illegible]	[illegible]	64.7	40.2	97.8	[illegible]
HEAVY MINERALS															
Rutile	–	–	–	–	–	–	–	–	–	–	5	6	4	–	–
Amphibole	29	28	26	33	30	30	30	28	24	25	38	24	26	–	–
Pyroxene	19	19	22	21	24	24	20	23	37	26	23	21	23	–	–
Epidote	4	5	4	6	5	4	2	1	8	8	10	8	8	–	–
Tourmaline	–	2	3	–	–	–	–	–	–	–	2	5	3	–	–
Mica (biotite)	5	6	4	4	6	5	6	13	9	9	5	6	5	–	–
Opaque	45	40	41	31	37	38	33	31	33	39	28	30	32	–	–

* Nearly all sodium-rich plagioclase in the Albite to Andesine range.

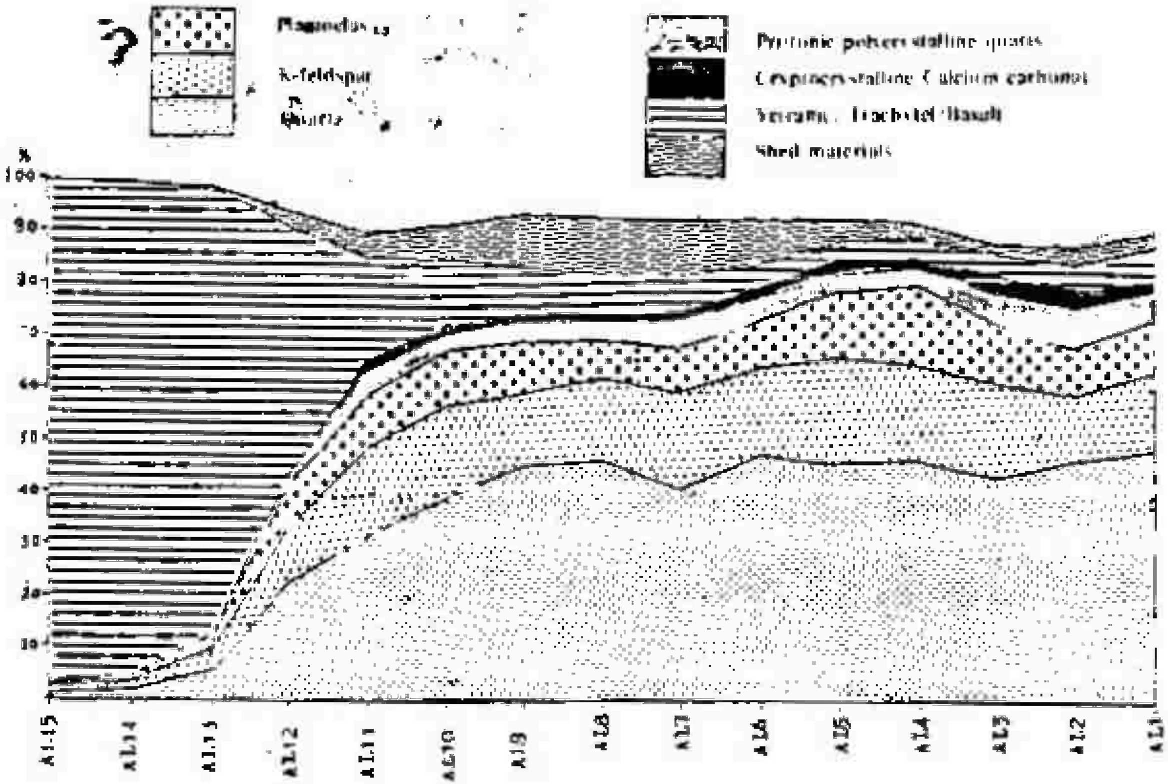

Fig. 7: Schematic illustration showing longshore variations in lithologic composition of beach foreshore sands. (Locality abbreviations at base of diagram are the same as in Fig. 1 ?)

area. This method departs somewhat from the conventional approach in which heavy mineral assemblage is used to determine beach sand provenance. In as much as heavy minerals constitute only a small fraction of Alexandria beach foreshore sands and appear mostly in the finer sizes (3-4 φ or more), their implications regarding the provenance of medium to coarse sand are vague. Their utility in delineating sedimentary provinces and general dispersal patterns, however, warrants comparison of results of this study with those of recent studies of heavy minerals in Alexandria region and the nearby Nile Delta coast (Moussa 1973; El-Sayed 1974; El-Wakeel et. al., 1974; Sestini et. al., 1975; UNESCO 1976; Stanley and maldonado 1977).

The composition of the beach sediments vary along the Alexandria beaches (Fig. 7). Hence, several constituents show distinct differences in relative abundance on beach foreshores. For example, quartz and total feldspar are more abundant on the beaches from Abu-Qir to El-Anfushy. The frequency variations of quartz and totall feldspar on these beaches are 22-27% and 18-34% respectively. Ratios of quartz to total feldspar and K-feldspar to plagioclase also show strong differences on the beach foreshores of the study area. K-feldspare is dominant over plagiocalse on nearly all the beach foreshores. Most of the quartz grains are well-rounded a characteristic probably due to its transportation by the Nile River from distance source and by subsequently attribution by the coastal water.

Sedimentary constituent: cryptocrystalline calcium carbonate sand increases in dominance over quartz west of El-Anfushy beach (i.e. from El-Max to El-Agami) but decreases from El-Anfushy towards the east (Fig. 7). The percentages of this constituent range from 3% to a maximum of 98% at El-Agami beach. The grains of carbonate sands show a well-rounded character and a highly polished surface. The roundness may be attributed to the continuous agitation by wind and coastal water. The high polish surface of the grains is probably impart an inherited characteristic from the desert environment in the area of the source rock. It is belived that the carbonate sands are originated from the limestone coastal ridge and they represent wind-borne clastic carbonate sands which have been reworked by the agitated nature of the sea waves. According to Hilmy (1951), the limestone coastal ridges added the so-called "oolites" to the Egyptian Mediterranean coast, but they do not show an eaxct similarity in character

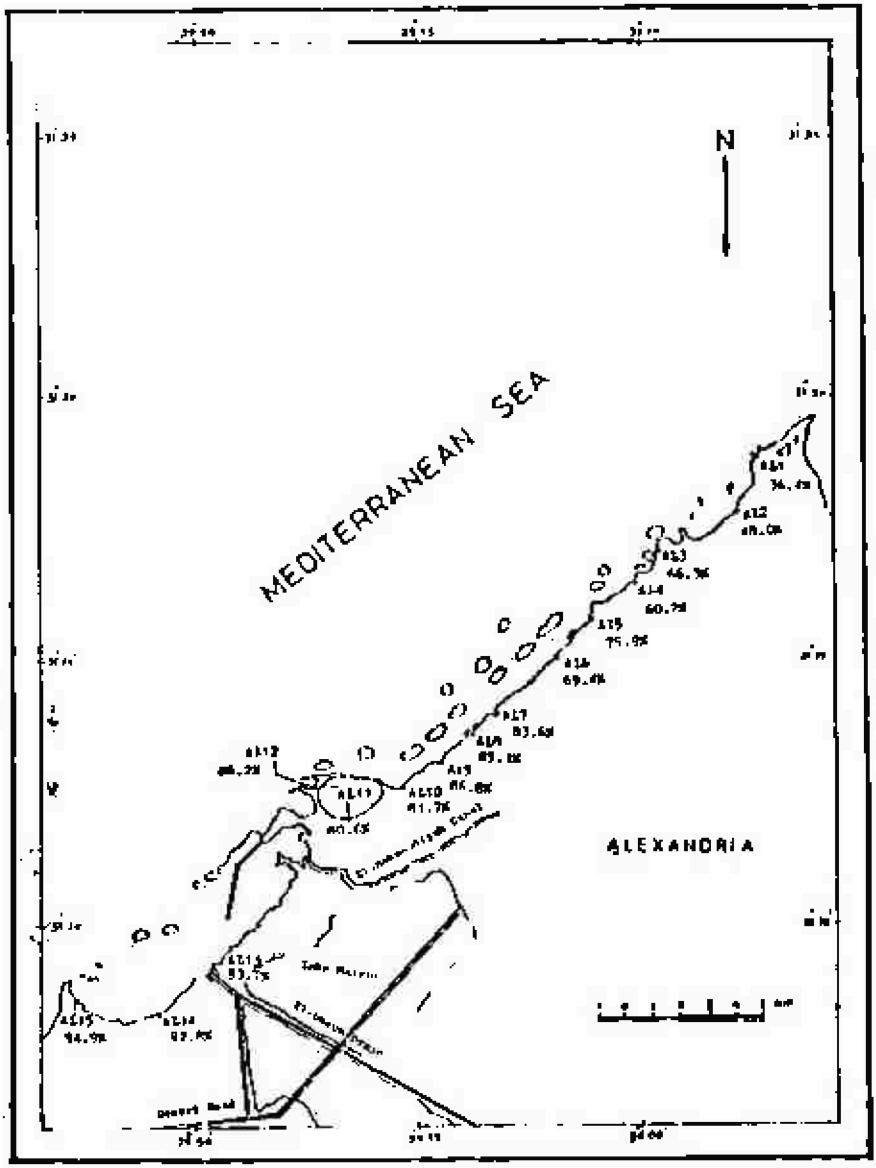

Fig. 8: Areal distribution of total carbnate

and mode of origin to the true authigenic oolites. Hilmy preferred, however, to call these carbonate sands "pseudo-oolites"

The mineralogy of the meduim grained sand from beach foreshores of the eastern part of the area contains more plutonic rock fragments (plutonic polycrystalline quartz) and volcanic constituents (Trachyte/Basalt), and is thus comparable to medium sand from the beach foreshores at the western part. Metamorphic and igneous rock fragments (e.g. granite) are virtually absent in medium sand from El-Max, Dekheila and El-Agami beaches. Substantial quantities of shell material are present in the sediments of the study beaches with more concentration in the area between Sidi-Bisher and El-Shatby beaches.

It is possible that selective sorting occurs at the mouth of the Nile River near Rosetta (some 45 km to the east of Abu-Qir headland), and selective transportation by sea water enriches wave-formed heavy concentrates. Apparently, the heavy, coarse grains such as volcanic rock fragments carried in suspension by the Nile River has been dumped along the coast close to the mouth of the river, while through the action of sea waves and longshore currents the lighter finer grains such as quartz and feldspar has been transported and distributed along the length of the coast further west.

The calcium carbonate content of the beach foreshore sands is found, generally, to increase with increasing distance from east to west, until a content of 94.9% is reached westward near El-Agami (Fig. 8). In the eastern part of the area the shell fragments are not very common and quartz and feldspar sands are dominant, while in the middle part of the area (i.e. Gleem-Ibrahimiah) the calcium carbonate is represented by shell fragments. The sediments covering the western part of the area (El-Max, El-Dekheila and El-Agami beaches) were found to be of maximum carbonate content (92.8-94.9%). In this part the calcium carbonate is mainly due to the granular carbonate sands. According to Moussa (1973) the total carbonate content ranges from 37.55% in sands of Abu-Qir beach, then sharply decreases eastwards to 0.96% at Rosetta beach. This result is attributed to the scarcity of calcareous remains of shells and marine organisms, and the occurrence of carbonate-poor Nile deposits.

The percentages of heavy-mineral association of 13 beach foreshores are listed in Table: 2. Heavy minerals are characterised by the predominace of

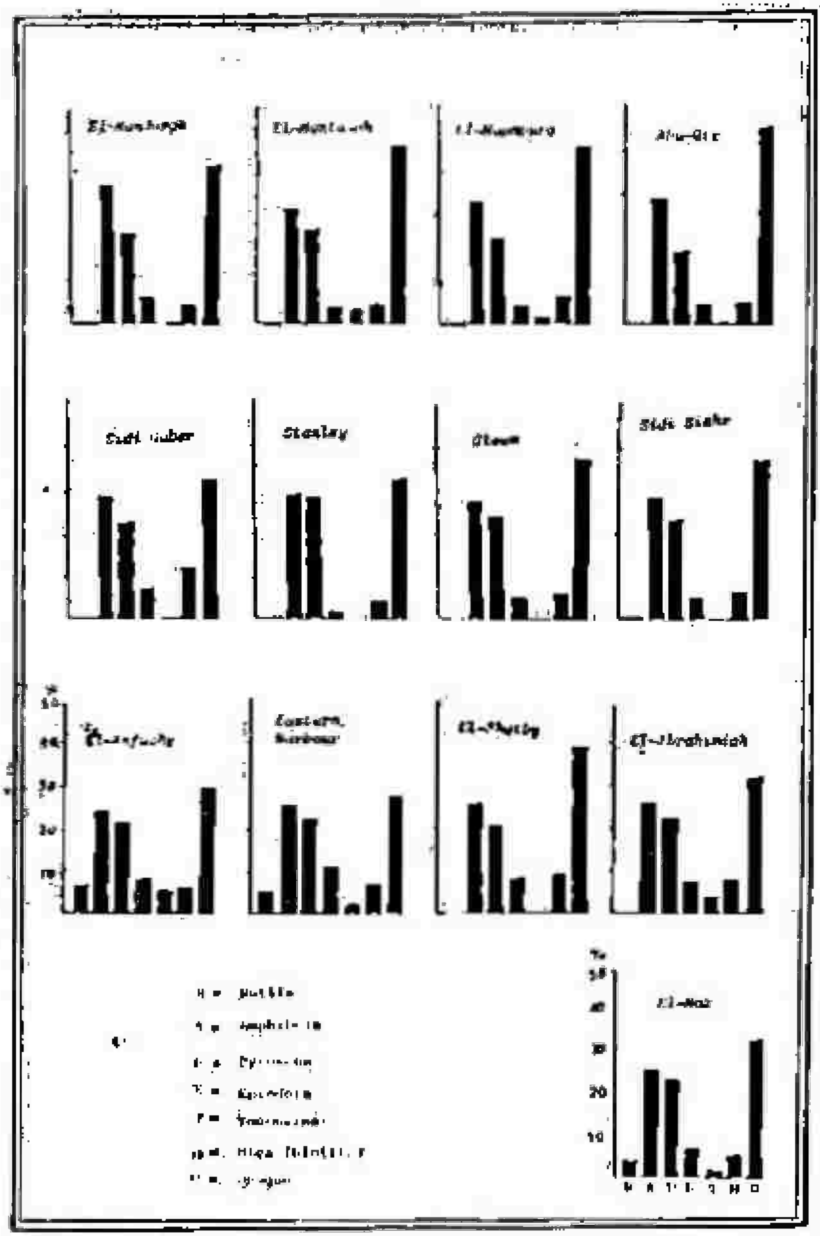

Fig. 9. Frequency diagram of heavy minerals of beach foreshore sediment

Opaques, amphibole and pyroxene. The frequency variations of opaques, amphibole and pyroxene are 28-45%, 24-32% and 17-29% respectively. Among the minor constituents, epuodote and Mica (biotite) were found to have frequency ranges of 2-10% and 4-11% respectively (Fig. 9). Rutile is found in the sands of Eastern Harbour, El-Anfushy and El-Max, while tourmaine exists in the sands of El-Maamoura, El-Montazah, El-Ibraheimiah, Eastern Harbour, and El-Anfushy. The beach sands west of Dekheila are very poor in heavy-mineral concentration as they are mostly composed of crystocystalline calcium carbonate sands in "pseudo-oolits" plus very minor amount of fine quartz which probably represents dust impurities carried by wind and mixed with the carbonate sands. In a whole amount of the heavy minerals from El-Agami beach foreshore sands only six grains of amphibole, four of pyroxene, two of tourmaine and one of rutile were observed. This pattern of concentration is significant in that it shows that the heavy mineral constituents carried by the Nile River are not distributed farther west than Dekheila beach foreshore. The westward decrease in heavy mineral concentration has been also observed by Mohamed (1968), Moussa (1973) and El-Wakeel and El-Sayed (1978).

It is interesting to note that the heavy minerals have been extensively used in coastal studies, to trace the source of beach sands and direction of sand movement or dispersal (Wassef 1964; UNESCO 1973, 1976). In particular, Opaque minerals (e.g. magnitite, pyrite, etc.), being the most common of the heaviest minerals (S.g. = 3.0), give good patterns of percentages decrease away from a source (Wassef 1964).

Longshore currents disperse sediment eastward in summer and westward in winter. Net sediment transport for the entire year is to the east as indicated by the continuous deposition, of greater amount of mud in the Eastern Harbour, causing the shallowing its area and choking its opening, than the Western Harbour area which is affected by two main sources of sediment-rich water. The first is the Numbariyah fresh-water canal (and previously the Mahmodiyah Canal). Opening into the harbour, while the second is the drainage water pumped out from El-Omoum drain into the sea at El-Max, i.e. into the area lies immediately west of the Western Harbour.

It is believed that the Nile River and the limestone ridges skirting the coast in the westerly flank of the study area are source of the lithoclasts in the Alexandria beaches. The effect of the Nile sediments is demonstrated by the existence of heavy minerals encountered with the quartz sands covering the eastern part of this area. Also, during flood time, especially before the construction of the High Dam, large quantities of Nile water loaded with immense amounts of sidements reached as far as localities west of Abu-Qir Bay. The heavy-mineral assemblage in sediments covering the beach foreshores of the area is closely related to the Nile assemblages previously identified by Shukri (1950). Thus, it is beleived that the constituents of heavy minerals are transported into the Alexandria coastal area from the Nile River mouth near Rosetta by westward flowing longshore currents deriven by northeast winds during the winter.

5- Conclusion

Based on the analysis and discussion of the results, just mentioned, it is possible to make some concluding remarks about the areal variation in texture and composition characteristics of the study beach foreshore sands. However, concluding remarks advanced here need to be subjected to repeated testing by statistical analysis to permit more accurate conclusions to be drawn.

The texture and composition of beach foreshore sands in the coastal area of Alexandria city indicate that they have marine and fluvial sources. The changes in grain size parameters among the fifteen beaches examined in this study appear to be related to dynamic conditions and to directions of sand transport. The maximum mean grain size (minimum phi) occurs on the middle area beaches (from Sidi-Bishr, in the east, to Al-Anfushy, in the west) and decreases repidly westwards but gradually eastwards. The average phi standadr deviation is relatively lower (indicating moderately well-sorted sediments) between Al-Agami and El Anfushy and increases significantly (indicating relatively poorer sorting) immediately east of El-Anfushy. Thus, coarse sediments are associated with relatively poor sorting indicating that these two parameters are linked to some degree. Selective sorting occurs at the eastern and western flanks of the area with lighter and finer fractions being dispersed by longshore currents. Strongly negatively skewed sediments are associated with relatively steep sloping foreshores covered with coarser material such as those of Gleem and Sidi-Gaber, while weakly negatively skewed sands are associated with meduim-fine sands covered the relatively flat foreshores of El-Mandarah, Sidi-

Bishr, and Eastern Harbour. The winnowing effect of backwash is reduced by the flat slopes, and fines are not removed but trapped among the course materials, producing weakely negatively skewed foreshore sediments. Positive skewness is found on beach foreshores characterised by a high degree of permeability of fine particles, and at the most easterly flank of the study area, i.e. near Rosetta mouth where fluvial influence is greatest. Therefore, shewness indicates the interplay between marine and fluvial processes in the coastal area of Alexandria City. More platykurtic sands are associated with the relatively coarse texture, more negatively or even positively skewed sediments found on beach foreshores of Gleem, Stanley, and Sidi-Gaber, while more leptokurtic sands typify the medium-fine, less negatively skewed sediments which characterise the relatively flat foreshores of El-Anfushy and El-Max.

Net sediment transport over the year is eastward by the littoral currents. During winter, the wind reverses direction causing westward flowing longshore current which transports considerable amounts of Nile River derived materials as far as 60 km west of the river mouth near Rosetta.

The sands of the beaches of Alexandria are, in general, of two principal types: quartz-dominant sands and white loose oolitic carbonate sands. The quartz sands are believed to represent water-borne sediments transported mechanically by the Nile River, derived mainly from the Abyssinian Plateau, and subsequently mixed with shell fragments on the beach. The oolitic carbonate sands are beleived to be originated from the limestone coastal ridges striking the coast in this area, as wind-borne carbonate sands which have been reworked by the agitating water movement of the beach waves, acquiring further well-rounded character or their grains. The remaining constituents are shell fragments, rock fragments and heavy minerals (opaque, amphibole and pyroxene being most common). The heavy minerals encountered in the beach sands of the study area have the same characteristics as those of the Nile deposits. A westward decrease of heavy mineral concentration is observed from Abu-Qir to El-Dehkeila, a result has been mentioned by other worker. The decrease in heavy mineral concenteration is mainly attributed to the occurrence of carbonate sands.

The present study reveals that the beaches of Alexandria City could be classified according to their sand types and texture characteristics into three units: The first extends from Abu-Qir to Sidi-Bishr, and is covered with relativley medium-fine quartz sands admixed with shell fragments and to some extent with Nile deposits which demonstrated by the existence of heavy minerals encountered with the sands covering this unit. The second unit, between Sidi-Bishr and El-Anfushy, is covered with coarse sands varying from loose to fairly well indurated deposits. The sands covered this unit, between Sidi-Bishr and El-Anfushy, is covered with mwsium-coarse sands varying from loose to fairly well indurated deposits. The sands covered this unit are mainly composed of quartz and feldspar with little amount of heavy minerals and more shell fragments. The third unit from El-Anfushy to El-Agami (west) is covered with fine, white loose oolitic carbonate sands admixed with minor amounts of fine quartz and heavy minerals.

Clearly, although there seems to be some textural and compositional variations along the coast of Alexandria City, a more detailed statistical study based on daily and/or seasonal field data of preocess and respnse variables would be required to identify and delineate the appropriate micro-environments within the study beach foreshore region.

Acknowlegements

The author gratfully acknowleges the kind advice and help of Professors G.H. Gouda, and H. Abu-El-Enin of Department of Geography, University of Alexandria, who provided input in all phases of the study and critically reviewed and suggested improvements to the manuscript. The author is also indebted to many postgraduate students at the Department of Geography, University of Alexandria, who assissed in field work. Special thanks are given to the Departments of Soil, University of Alexandria, and University of King Saud, El-Qassim, Saudi Arabia, for permission to use the Soil Laboratory.

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