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MINERALOGICAL CHARACTERISTICS OF THE WESTERN NILE DELTA COAST SEDIMENTS

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ABSTRACT

In this paper, results of 3 years of heavy mineral investigations are presented. Fourteen annual nearshore profile samples were collected along the coast between Rosetta and Burullus. Each profile includes backshore, beach and nearshore samples up to 6 m depth. Coastal dune samples from east of Burullus are also studied.

The sediment of the Rosetta headland are characterized by the greatest concentration of heavy minerals. It declines in the central part and then relatively increases towards Burullus. The heaviest minerals decrease normal to the shoreline while the lighter ones increase.

High concentration of the heavy mineral at Rosetta and Burullus sediments may be related to:

(1) Contribution from offshore old sediments of classic Nile branches rather than the present Nile.

(2) Contribution from the land itself, where the dunes and backshore contain great amount of these minerals.

(3) These minerals are concentrated during severe coastal erosion.

INTRODUCTION

The heavy minerals are among the minerals of the parent rock surviving destruction. It may be supposed that the processes operating during transport of sediment would modify the composition by selective sorting. The selective transport of the heavy minerals plays an effective role in concentration and distribution of these minerals along the coast.

Previous studies of the mineralogy of the Nile Delta coastal sediments include those of SHUKRI (1950), NAKHLA (1958), MESHREF (1962), ANWAR and EL-BOUSIELY (1970), COASTAL EROSION STUDIES (1973), FRIHY (1975), RASHED (1978), EL-NOZAHY and BADR (1986), EL-FISHAWI and MOLNAR (1985) and AL-ASKARY and FRIHY (1987). Some of these pervious studies were carried out on whole samples.

The mineralogy of the nearshore profile sediments has been investigated. This study delineates the results of mineralogical examinations of the 14 annual nearshore profiles collected along the coast between Rosetta and Baltim (*Fig. 1*) during 1984—1986. Each profile includes backshore, beach and nearshore samples up to 6 m depth.

The mineralogical examination was also carried out on 5 sample series collected during 1987 from coastal dunes between Burullus and Baltim. Each series includes beach, windward side, top and leeward side samples.

The aims of the present study were:

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(1) To investigate the distribution of the heavy minerals during the three years.
(2) To evaluate the changes of nearshore profile sediments along and normal to the shore.
(3) To trace the direction of sediment movement.
(4) To differentiate between coastal environments.

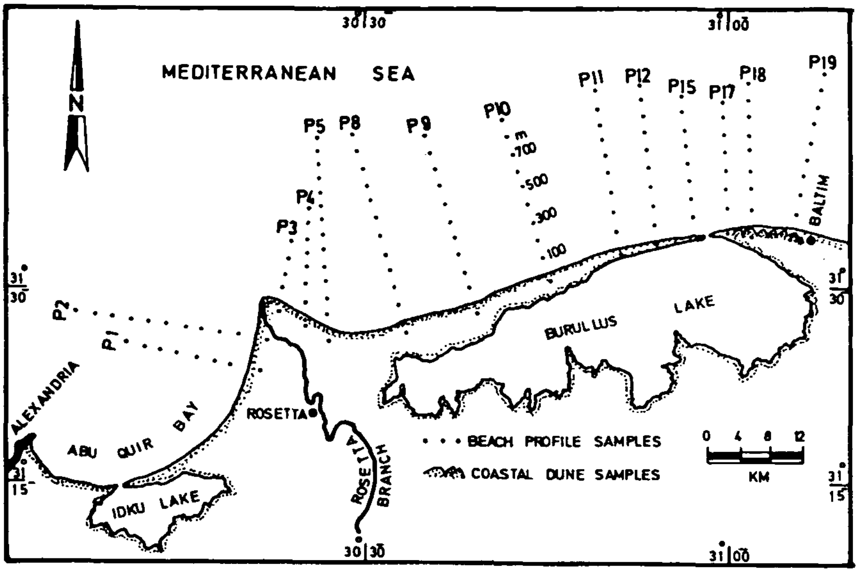

Fig. 1. Location map of the study area showing beach profile and coastal dune samples.

METHODS AND TECHNIQUES

The mineral analysis was applied on 3 Φ and 4 Φ size fractions (250 — 125 and 125 — 63 μm) which contain the highest heavy mineral residues. The samples were washed by stannous chloride and hydrocloric acid (10 %) to remove the iron oxide coatings on grains and carbonates. The heavy minerals were obtained by using bromoform (sp. gr. 2.89) separation technique, taking into consideration the precaution given by CARVER (1971) in order to obtain a satisfactory separation. The obtained heavy mineral fraction was washed by alcohol, dried, weighed and heavy mineral contents were calculated for each sample. The heavy mineral fraction was mounted in Canada balsam on a glass slide for microscopic investigation. Counting was carried out for 400 grains for each sample by a line-counting method. The frequency percentages of heavy mineral individuals were calculated.

HEAVY MINERAL RESIDUES

Table 1 shows the weight percent of heavy mineral residue of nearshore profile sediments and the total average in the 3 and 4 Φ fractions. It is observed that total average weight percent in the 3 Φ fraction ranges between 9.37 % and 17.89 %, while it is 42.42 % and 72.40 % in the 4 Φ fraction. This indicates that heavy minerales are more concentrated in the finer fraction.

TABLE 1.

Average weight percent of heavy mineral residues normal to the shoreline

Distance (m)	Weight percent of heavy minerals							
	3 Φ				4 Φ			
	1984	1985	1986	Average	1984	1985	1986	Average
Backshore	17.62	18.51	11.45	15.86	79.49	66.76	70.95	72.40
Beach	12.00	12.93	15.34	13.42	70.10	74.62	55.19	66.64
100	08.27	12.48	07.80	09.52	64.43	66.26	47.11	59.27
200	08.59	08.39	11.13	09.37	47.76	61.61	45.31	51.56
300	12.05	15.57	12.24	13.29	58.44	59.49	32.64	50.19
400	14.72	11.01	12.19	12.64	57.30	46.16	30.81	44.76
500	12.72	10.04	13.53	12.10	48.58	43.16	38.53	43.42
600	14.23	13.69	12.19	13.37	47.07	43.27	41.01	43.78
700	19.31	11.05	11.25	13.87	46.95	43.12	37.20	42.42
800	09.92	14.83	12.28	12.34	36.36	43.06	49.72	43.05
900	24.40	15.63	11.34	17.12	45.05	56.80	54.55	52.13
1000	20.57	—	15.21	17.89	43.67	—	48.21	45.94

Depending upon the weight percent of heavy minerals along the shore (*Fig.* 2), the studied area can be subdivided to:

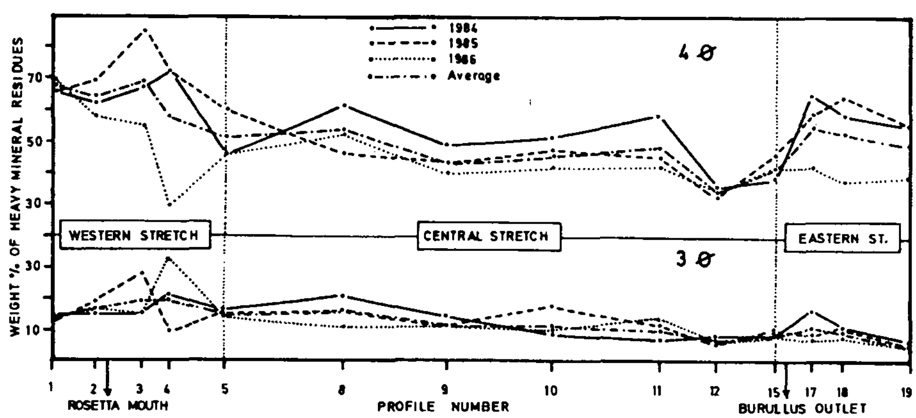

Fig. 2. The average percent of heavy mineral residues of the nearshore profile sediments.

Western stretch. It lies astride Rosetta mouth and contains profile Nos 1, 2, 3 and 4. The average weight percent of heavy minerals ranges between 52.41 % and 72,87 % in the 4 Φ fraction. The backshore, beach and the surf zone sediments are characterized by high concentrations of heavy residue. The reason for this high concentration may be related to the modification caused by the underflow action of the waves and sorting according to density and size during transportation and deposition.

The greatest concentration of heavy minerals is found towards the western stretch than the eastern one. The reason may be related to the westward dominate littoral current (57 %; FANOS 1986). Furthermore; the relict bottom sediments of the old Canopic branch may have played an effective role in increasing the concentration of heavy minerals in the western side.

Central stretch. It extends between Rosetta mouth and Burullus outlet and includes profile Nos. 5, 8, 9, 10, 11, 12 and 15. This stretch is characterized by the lowest amount of heavy residues where the percent of heavy minerals ranges between 43.09 % and 49.09 % for the 4 Φ fraction.

The weight percent of heavy minerals shows high concentrations in the backshore, beach and the surf zone, then it fluctuates seaward. Some peaks of high concentrations are observed seaward.

Eastern stretch. It extends east of Burullus outlet and indcludes profile Nos 2, 17, 18 and 19. The weight percent of heavy minerals in the 4 Φ fraction ranges between 40.07 % and 60.34 %. The heavy residue indicates higher concentration in this stretch than in the central one.

An attempt was made to indicate the relationship between accretion or erosion and the weight percent of heavy mineral residue of the nearshore profile sediments. The western stretch (*Fig.* 2) has been subjected to severe erosion in 1985. Conditions during 1986 lead to minor erosion with some accretion (EL-FISHAWI and BADR, 1989). The effect of these features is reflected on the heavy mineral residues where high percents are recorded in 1985. The central stretch shows a higher rate of accretion in 1986 than in 1985. As a result, the percent of heavy mineral residues in 1985 is higher than that in 1986. This phenomenon is also observed in the eastern stretch. This leads to the conclusion that higher concentration of heavy minerals is recorded at the severely eroded beaches while low concentrations are encountered at less eroded or accreted beaches.

When the sea attains its maximum high level, the powerful waves constantly act on the submerged beach. The waves sort out light and heavy minerals which are not accessible during periods of low sea level. When the sea level reaches its original lower position, the lighter minerals have been carried out seaward while the heavier owner are left on the beach. It is observed that the beach erosion at Rosetta and Burullus areas plays a significant role in concentrating the heavy minerals in coastal sands. This is in agreement with RAO (1957) and COASTAL EROSION STUDIES (1973).

The distribution of weight percent of heavy mineral residues normal to the shoreline is illustrated in Table 1. For the 4 Φ fraction, the average weight percent of heavy residues of the backshore, beach, breaker zone (100—300 m distance) and seaward sediments of about 1000 m distance is found to be 72.40 %, 66.64 %, 50.19 % and 45.94 %, respectively. Therefore, the weight percent of heavy residues generally decreases seaward due to decreasing effect of the hydrodynamic forces.

COASTWISE VARIATION OF HEAVY MINERALS

The recorded heavy mineral constituents of the coastal sediments are composed of a great variety of minerals. The most common of which are opaques, amphiboles, pyroxenes, epidote, garnet, zircon, tourmaline, rutile, apatite, kyanite, monazite, staurolite, biotite, chlorite, glauconite and altered minerals.

Fig. 3. shows the frequency distribution for various heavy minerals in fractions 3 and 4 Φ. The following is a brief account on the distribution and behaviour of some indicative heavy minerals on the coastal sediment:

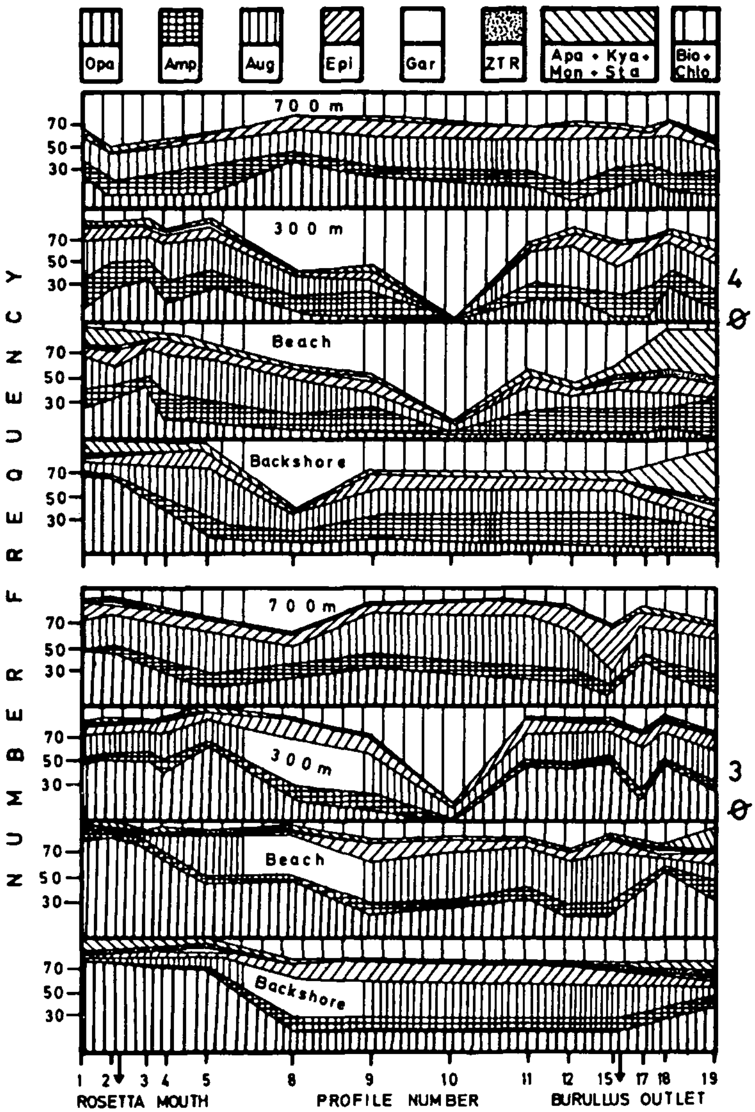

Fig. 3. Heavy mineral variations along the nearshore profile sediments, 1985.

The average percent of opaques ranges between 16.79 % and 35.13 % in the 3 and 4 Φ fractions, respectively which indicates high concentration in the finer size grade. The maximum concentration of opaques is observed astride Rosetta mouth (50.83 %) and decreased eastward attaining 34.62 % in the central stretch then it increases again attaining 40.12 % in the eastern stretch. The average percent of opaques decreases with time where it is found to be 19.85 %, 17.69 % and 12.83 % in the 3 Φ fraction and 39.72 %, 36.99 % and 28.69 % in the 4 Φ fraction of 1984, 1985 and 1986, respectively.

The average percent of amphiboles ranges between 18.82 % and 9.53 % in the 3 and 4 Φ fractions. This indicates that amphibole contents increase in the coarse fraction. It is observed that amphiboles increase eastward and westward from Rosetta mouth. In the 3 Φ fraction during 1986 amphiboles of the western, central and eastern stretches are found to be 16.62 %, 19.12 % and 22.74 %, respectively. This indicates that the content of amphiboles increases in a down drift direction. Such behaviour of amphiboles is the reverse of that of opaques. Similar trends were arrived at by PETTIJOHN and RIDGE (1933), LANGFELDER *et al.* (1968), RASHED (1978), EL-FISHAWI and MOLNAR (1985) and EL-NOZAHY and BADR (1986).

Average augite in the three stretches is higher in the finer fraction (4 Φ) than in the coarser one (3 Φ), being 24.30 % and 21.27 %, respectively. Augite concentrates astride Rosetta mouth and increases westward and eastward. The central stretch is characterized by higher concentrations around profiles 10 and 18 which are very near to the trace of the old Saitic and Sebennetic branches.

The average percent of garnet ranges between 0.46 % and 0.52 %. The garnet content in beach sands is higher than that in the nearshore area. Similar to opaques, the concentration of garnet decreases in a down-drift direction. The percent of garnet decreases with time where it is found to be 0.75 %, 0.50 % and 0.32 % in the 3 Φ fraction and 0.65 %, 0.41 % and 0.32 % in the 4 Φ fraction during 1984, 1985 and 1986, respectively.

The average percent of zircon + tourmaline + rutile (ZTR) ranges between 1.00 % and 1.38 % in the size 3 and 4 Φ fractions. These minerals are considered to be of the heaviest ones which increase shoreward. It is observed that these minerals decrease westward and eastward from Rosetta mouth. The average percent of ZTR decrease with time, being 1.59 %, 0.88 % and 0.52 % in the 3 Φ fraction and 2.39 %, 1.04 % and 0.71 % in the 4 Φ fraction during 1984, 1985 and 1986, respectively.

The percent of biotite and chlorite minerals ranges between 27.96% and 15.02% in the size 3 and 4 Φ fractions, respectively. Biotite and chlorite increase gradually away from Rosetta mouth, i.e., the minimum concentration is found astride Rosetta mouth. The reason may be related to the effect of the littorial current on sediment available for transportation. The concentration of biotite and chlorite in the central stretch is higher than those of eastern and western stretches. The reason may be related to the fact that these minerals are flaky and have not been able to be deposited in turbulent conditions but are carried away with currents and deposited in more calm areas. Similar result is arrived at by ANWAR and EL-BOUSEILY (1970), RASHED (1978), EL-FISHAWI and MOLNAR (1985) and EL-NOZAHY and BADR (1986). The average percent of biotite and chlorite increases with time, being 22.97 %, 25.67 % and 35.23 % in the 3 Φ fraction and 11.87 %, 14.84 % and 18.36 % in the 4 Φ fraction during 1984, 1985 and 1986, respectively.

VARIATION OF HEAVY MINERALS NORMAL TO THE COAST

Under the effect of waves and wind induced currents the deposition and concentration of heavy minerals are subjected to sorting processes. Therefore, an attempt was made to study the distribution of heavy minerals normal to the shoreline in fractions 3 and 4 Φ during the three years. Opaque and translucent heavy minerals vary significantly normal to the shoreline. *Fig. 4* shows the number frequencies for some indicative minerals.

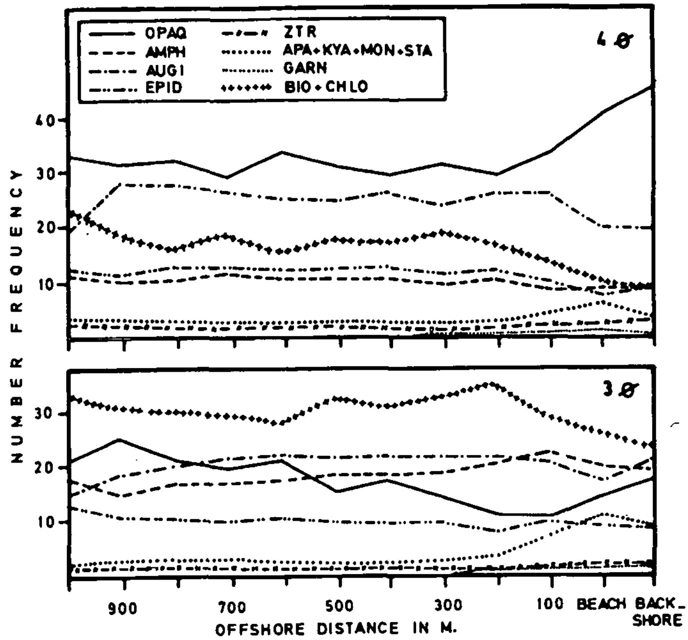

Fig. 4. Heavy mineral variations normal to the shoreline, 1984-1986,

Generally, the heaviest minerals increase in the beach and decrease seaward. For example, it is observed that the concentration of opaque minerals in size grade 4 decrease seaward. The average content of opaque minerals for backshore, beach, breaker zone (100 m distance) and nearshore zone (900 m distance) being 47.1 %, 41.7 %, 34.1 % and 31.2 %, respectively.

On the other hand, the concentration of opaque minerals in the 3 Φ fraction decreases from the backshore to the breaker zone, then it increases gradually seaward. The average content of opaque minerals in backshore, beach, breaker zone and nearshore zone is found to be 17.1 %, 14.2 %, 10.2 % and 24.4 %, respectively.

Generally, the biotite, chlorite, amphibole, augite and epidote minerals increase seaward with some fluctuations (*Fig. 4*). For example, the average content of biotite and chlorite minerals in the 3 Φ fraction for the backshore, beach, breaker zone (100 m distance) and nearshore zone (900 m distance) being 22.0 %, 23.2 %, 28.5 % and 37.7 %, respectively. The breaker zone sediments reveal a higher content of amphiboles and augite and a lower content of opaques, garnet and ZTR than in the beach sediments. Such a sorting may be related to the action of breakers which tend to concentrate the less heavies with the coarse sands. In the natural separation, the heaviest minerals (opaques, garnet and ZTR) were left on the beach surface due to the action of waves on the surf zone. This is in agreement with SWIFT *et al.* (1971), RASHED (1978), EL-FISHAWI and MOLNAR (1985) and EL-NOZAHY and BADR (1986). The low abundance of biotite and chlorite on the beach and breaker zone is due to their hydraulic properties which prevent their settling in the high energy condition. Similar result was arrived at by MOHAMED (1968).

An attempt was made to differentiate between windward, top and leeward side of the coastal dunes between Burullus and Baltim and to correlate between their average heavy mineral contents with that of the nearshore zone. The variation of the heavy mineral content along the coastal dunes is shown in *Fig. 5* while *Fig. 6* shows the frequency number of heavy minerals.

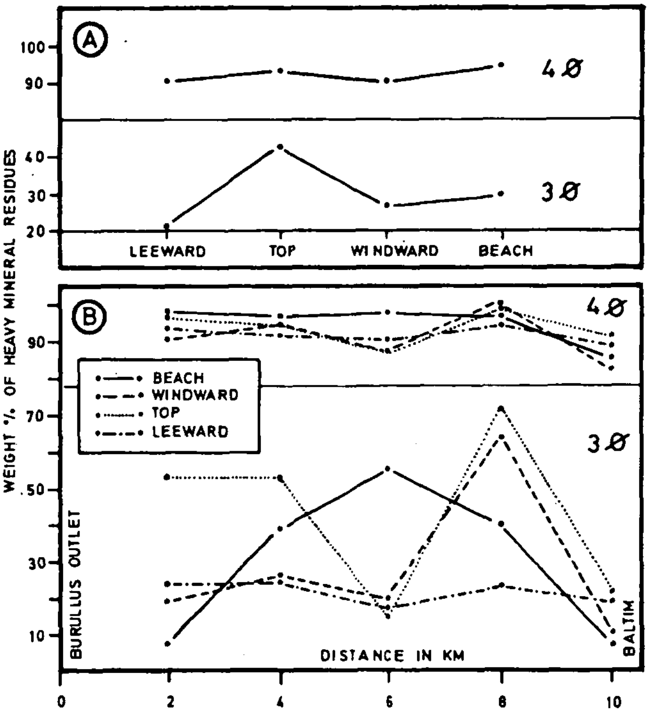

Fig. 5. The average percent of heavy mineral residues of the coastal dune sands. A. Variation normal to the shoreline. B. Variation along the shoreline.

Like in case of nearshore sediments, it is found that the weight percent of heavy mineral contents is higher in the size 4 Φ than in the 3 Φ. The weight percent of heavy mineral contents in beach, windward, top and leeward side of dunes are 29.78 %, 27.57 %, 42.75 % and 21.55 % in the 3 Φ fraction and 94.03 %, 90.08 %, 93.21 % and 90.56 % in the 4 Φ fraction, respectively. It is indicated that the heavy mineral content in the 3 Φ fraction increases from the beach to the top of dunes, where it attains the maximum values. Then it decreases in the leaward side (*Fig. 5*).

The percent of opaque, ZTR, augite and epidote minerals in the 4 Φ fraction is higher than that of the 3 Φ fraction. On the other hand, the percent of garnet, (apatite + kyanite + monazite + staurolite), (biotite + chlorite) and amphibole minerals increases in the 3 Φ fraction.

It is desirable to compare between the heavy minerals of the eastern nearshore stretch with those of the nearly dunes. The dune sands have higher contents of the total heavy residue, opaque, garnet, ZTR and (apatite + kyanite + monazite + staurolite) minerals than those of the backshore, beach and nearshore sands. This

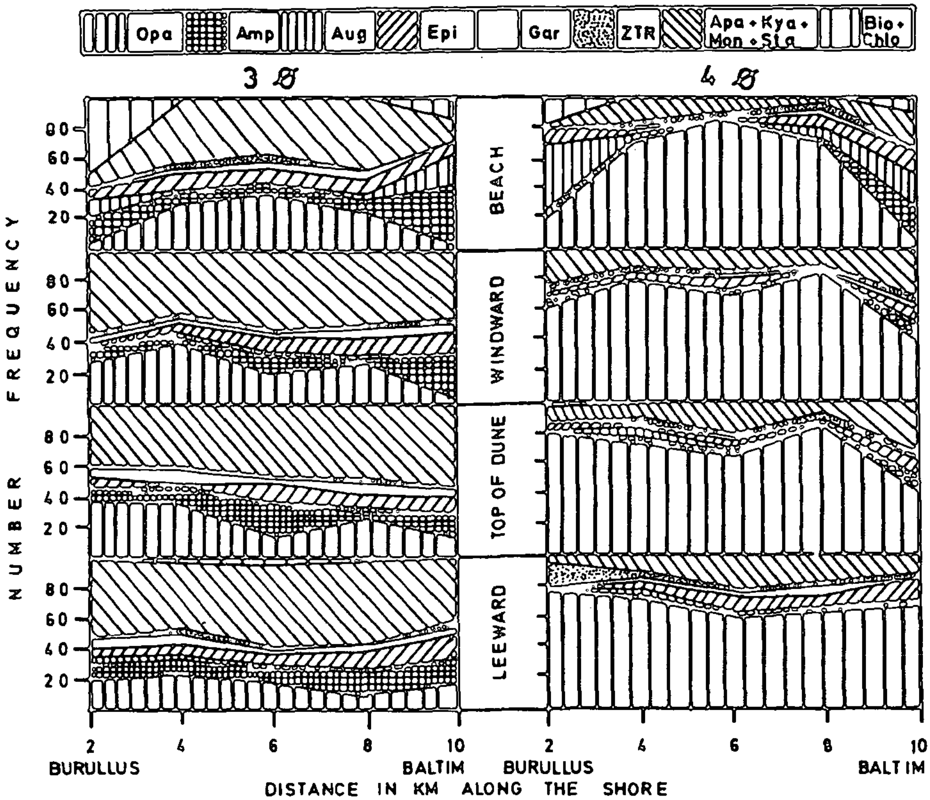

Fig. 6. Heavy mineral variations along the coastal dune sediments, 1987.

can be explained in such a way that the heavy minerals of the dunes may represent the lag concentrate, due to wind working over the dunes more than the beach and backshore, where wetness prevents much wind action. During this reworking the wind picks up the light minerals, which are largely removed, leaving the heaviest behind on the dunes. This is in agreement with STEWART, (1956), SHEPARD and YOUNG (1961), GILES and PILKEY (1965) and EL-FISHAWI and MOLNAR (1985).

CONCLUSIONS

(1) The longshore drift between Rosetta and Baltim, which is the principal mechanism of sediment supply, is towards the east. In that direction, the heaviest minerals (opaque, garnet and ZTR) decline while lighter ones (biotite, chlorite, amphibole, augite and epidote) generally increase.

(2) It is indicated that the severe beach erosion at Rosetta and Burullus areas plays a significant role in concentrating the heavy minerals in eroded beaches. On the other hand, high concentration of heavy minerals astride Burullus outlet may be related to the offshore supply of the sediments related to the old Nile branches (Saitic and Sebennitic).

(3) In the natural separation the heavy minerals vary significantly normal to the shoreline. The heaviest minerals increase in the beach surface due to the action of waves. On the other hand, the lighter minerals increase seaward due to their settling in a gradual decrease of energy levels.

(4) The breaker zone sediments reveal a higher content of less heavies and lower content of more heavies than in the beach sediments. Such a sorting may be related to the action of breakers which tend to concentrate the less heavies with the coarse sands. On the other hand, the low abundance of biotite and chlorite in the breaker zone is due to their hydraulic properties which prevent their settling in high energy conditions.

(5) The heavy mineral content increases from the beach to the top of dunes, where it attains the maximum values, then it decrease in the leeward side. The dune sands have higher contents of heaviest minerals that the backshore, beach and nearshore sands. The heavy minerals of the dunes may represent the lag concentrate, due to the fact that the wind working over the dunes more than the beach and backshore, where wetness prevents much wind action. During this reworking the wind picks up the light minerals which are largely removed, leaving the heaviest minerals behind on the dunes.

REFERENCES

ANWAR, Y. M. and EL-BOUSEILY, A. M., (1970): Subsurface studies of the black sand deposits at Rosetta Nile mouth, Egypt. Part II: Mineralogical studies. Bull. Fac., Alex. Univ. **10**, 141—150.

CARVER, R. E., (1971): Heavy minerals seaparation. In: Carver, R. E., ed., Procedures in Sedimentary Petrology. Wiley-Interscience, New York. 427—452.

COASTAL EROSION STUDIES, (1973): Detailed Technical Report. Project 70/581, UNDP/UNESCO/ASRT, Alex., 259 p.

EL-ASKARY, M. A. and FRIHY, O. E., (1987): Mineralogy of the subsurface sediments at Rosetta and Damietta promontories, Egypt. Bull. Inst. Oceano. Fish., Egypt. **13 (2)**, 111—120.

EL-FISHAVI, N. M. and BADR, A. A., (1989): Volumetric changes of nearshore sediments between Rosetta and Burullus, Egypt. International Union for Quarternary Research, INQUA, **11**, 39—42.

EL-FISHAWI, N. M. and MOLNAR, B., (1985): Mineralogical relationships between the Nile Delta coastal sands. Acta Miner. Petr., Szeged, **27**, 89—100.

EL-NOZAHY, F. A. and BADR, A. A., (1986): Mineralogy of the continental shelf sediments of Abu-Quir Bay, Northern coast of Egypt. Geojournal, **13 (4)**, 347—358.

FANOS, A. M., (1986): Statistical analysis of longshore current data along the Nile Delta coast. Water Science, Water Research Center, Cairo. **1**, 45—55.

FRIHY, O. E., (1975): Geological study of Quarternary deposits between Abu Quir and Rashid. M. Sc. Thesis, Fac. Sci., Alex. Univ. 103. p.

GILES, R.T. and FILKEY, O. H., (1965): Atlantic beach and dune sediments of the southern U.S. Jour. Sed. Pet. **35**, 900—910.

LANGFELDER, J., STAFFORD, D. and AMEIN, M., (1968): A reconnaissance of coastal erosion in North Carolina. Dep. of Civil Eng., North Carolina State Univ. Raleigh, 172 p.

MESHREF, W. M., (1962): Mineralogical and radiometric study for some black sand depostis on the Mediterranean coast. M.Sc. Thesis Fac. Sci. Ain Shams Univ.

MOHAMED, M. A., (1968): Continental shelf sediments of the Mediterranean Sea north of the Nile Delta in U.A.R. M. Sc. Thesis, Fac. Sci., Alex. Univ. 90 p.

NAKHLA, A. A., (1958): Mineralogy of Egyptian black sand and its application. Egyptian Jour. Geol. **2 (1)**, 1—22.

PETTIJOHN, F. J. and RIFGE, J. D., (1933): A mineral variation series of beach sands from Cedar Point, Ohio, Jour. Sed. Pet. **3**, 92—94.

RAO, C. B., (1957): Beach erosion and concetnration of heavy mineral sands. Jour. Sed. Pet. **27 (2)**, 143—147.

RASHED, M. A., (1978): Sedimentological and mineralogical studies of the coastal samples of Abu-Quir Bay, Alexandria. M.Sc. Thesis, Fac. Sci., Alex. Univ., 157 p.

SHEPARD, F. P. and YOUNG, R., (1961): Distinguishing between beach and dune sands. Jour. Sed. Pet. **31**, 196—214.

SHUKRI, N. M. (1950): The mineralogy of some Nile sediments. Quatr. Jour. Geol. Sci. London **105**, 511—534.
STEWART, H. B. (1956): Sediments and the environments of deposition in a coastal lagoon. Ph. D. Thesis, Calif. Univ. 355 p.
SWIFT, D. J. P., HILL, C. E. and MCHOME, J., (1971): Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast. Jour. Sed. Pet., **41** (3), 683—690.

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