

MINERALOGICAL RELATIONSHIPS BETWEEN THE NILE DELTA COASTAL SANDS

N. M. EL FISHAWI¹ and B. MOLNÁR²

ABSTRACT

The mineralogy of the Nile Delta coastal sediments has been examined. This study summarizes the results of mineralogical examinations of 13 profiles collected along the coast. Each profile contains breaker zone, beach, backshore zone and dune samples. The distribution of the translucent heavy minerals in the coastal environmental sands suggests that there are four characteristic suites among the four provinces, generated by the hydrodynamic forces affecting the coast. The inter-connections between hornblende and both garnet+ZTR reveal negative correlations. These relationships can be used to differentiate between coastal environments. Three explanations are offered for the higher concentration of the heaviest minerals in the Burullus beach sands than in the beaches near Rosetta and Damietta: *a*) contributions from offshore old sediments of classic Nile branches rather than the present Nile, *b*) contributions from the land itself, and *c*) minerals have a good chance of being concentrated during coastal erosion.

INTRODUCTION

Published geological information on the heavy minerals of the Nile Delta coastal sands is still scarce. Studies include those of SHUKRI (1950), NAKHLA (1958), RITTMAN and NAKHLA (1958), MASHREF (1962), ANWAR and EL BOUSIELY (1970) and FRIHY (1975). Coastal Erosion Studies (1973, 1976) measured the percentages of magnetite on some stretches along the coast. These studies were concerned with more local effects than the present study. Further, the data of the present study and those of the previous ones are not entirely comparable, because most of the previous studies were concerned with total mineralogy rather than the mineralogy of the size fractions.

During July, 1978, the Nile Delta coast was surveyed between Rosetta and Damietta. The sample net consisted of 13 profiles at 12 km intervals (*Fig. 1A*). Each profile contains breaker zone, beach, backshore zone and dune samples (*Fig. 1B*).

The objectives of the present study were:

1. To investigate the distribution of the heavy minerals.
2. To show the changes in profiles normal to the shoreline.
2. To differentiate between coastal environments.
4. To evaluate the action of the hydrodynamic forces in the distribution of the heavy minerals.
5. To detect the direction of sediment transport and source areas.

¹ Institute of Coastal Protection, Alexandria, Abu Qir, Egypt

² Department of Geology, Attila József University, H-6722 Szeged, Egyetem u. 2—6, Hungary

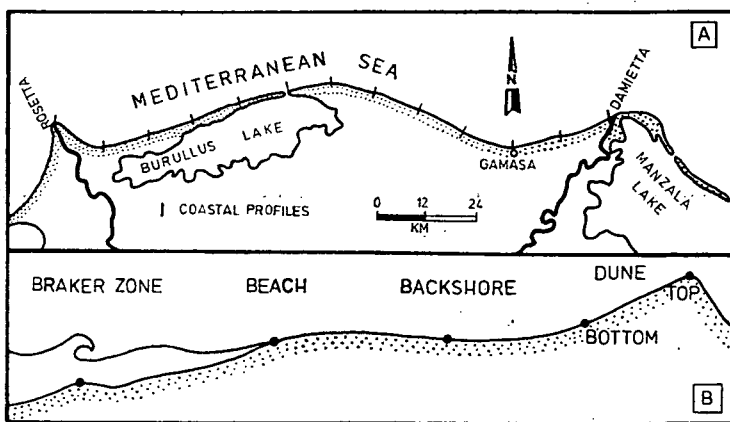


Fig. 1. Location map showing the coastal profiles (A) and sampling sites (B)

The following properties of the heavy residues were used :

1. The quantity (weight percentage) of heavy residue.
2. The number frequency of opaque and non-opaque minerals.
3. Amphibole/opaque ratio.

METHODS OF STUDY

The examined number of samples was 46 and two fractions were selected for each sample. The choice of grain sizes for heavy mineral analysis is of great importance. This choice must be based on the mechanical composition of the sediment in question. The modal size (the size having the highest frequency) and the two successively finer sizes have the greatest significance (SINDOWSKI, 1949). In the present study, the modal size (250—125 μm fraction) and the successively finer size (125—90 μm fraction) were selected for each sample.

Samples under investigation were quartered using a sample splitter, to obtain a representative sample for each locality. Fractions lying between 250 μm and 90 μm were used for this study. The heavy minerals were separated using the well-known bromoform (sp. gr. = 2.89) separation technique, taking into consideration the precautions given by CARVER (1971) in order to obtain a satisfactory separation. After the separation, the heavy fractions were washed with carbon-tetrachloride, dried and weighed. Portions of heavy fractions were mounted in Canada Balsam on glass slides and identified under the polarizing microscope. Mineral frequency was obtained by a line-counting method and about 500 grains were counted for each slide.

Quantity of heavy residue

Figure 2 shows the distribution of the weight percentages of the heavy fractions along the coast and across the different environments; Table 1 illustrates the data. The amount of heavy residue by weight in 250—125 μm fraction of the coastal sands ranges between 4.11% and 30.23%, with an average of 15.05%. In the 125—90 μm

fraction it ranges between 37% and 91.23%, with an average of 65.33%. Therefore, the greater quantity of heavy residue usually occurs in the finer fraction investigated.

On the basis of the relative percentage of heavy residue along the coast, it has been possible to subdivide the Delta coast into 3 stretches. The area between Rosetta and Burullus is characterized by a steady decrease in heavy residue. The greatest concentration is observed in the area between Burullus and Gamasa. The area between Gamasa and Damietta shows the lowest amount of heavy residue.

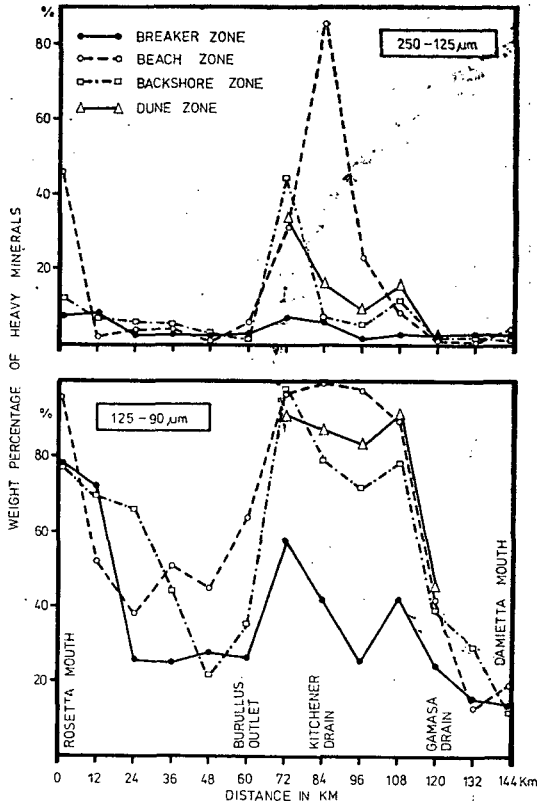


Fig. 2. Quantity of heavy minerals along the Nile Delta coast

Mineralogy of the coastal sands

The main mineral constituents of the heavy fractions are: opaques, amphiboles, pyroxenes, epidotes and garnet. Zircon, tourmaline, rutile, apatite, kyanite, monazite, staurolite, biotite and chlorite are present in subordinate amounts. Weathered minerals are also recorded. The opaque minerals were not studied in detail but were counted together as "opaques", because this was not an objective of the present study. Figure 3 shows the frequency of various minerals observed within each coastal environmental sands, and the lateral variations along the coast. In compiling mineral frequencies, certain varieties were grouped to simplify illustrations. Hornblende

TABLE 1

Weight percentages of heavy fractions on the coastal sands

Distance in km	Breaker zone		Beach		Backshore		Bottom of dune		Top of dune	
	250— 125 μm	125— 90 μm	250— 125 μm	125— 90 μm	250— 125 μm	125— 90 μm	250— 125 μm	125— 90 μm	250— 125 μm	125— 90 μm
0.0	7.49	78.60	26.20	96.49	12.39	78.57				
12	8.63	72.00	1.73	51.73	8.42	69.97				
24	2.60	25.96	2.80	38.46	5.63	65.76				
36	3.22	25.16	3.93	50.79	4.92	44.27				
48	2.50	28.20	0.83	45.07	3.04	22.19				
60	2.83	27.09	6.16	63.88	2.21	36.11				
72	7.35	57.90	30.65	96.94	43.86	97.88	33.93	91.82	32.15	94.96
84	6.00	42.17	86.96	99.43	7.24	78.79	16.48	88.57	28.30	87.50
96	1.49	26.07	22.58	98.45	5.44	72.62	8.90	83.97		
108	2.72	42.11	8.71	89.75	12.64	78.49	15.98	91.51		
120	3.25	25.34	1.99	42.67	2.58	39.45	2.33	46.53		
132	2.71	16.07	1.58	13.34	2.14	29.67				
144	2.58	14.35	3.37	19.31	1.99	13.04				
Average	4.11	37.00	16.73	62.02	8.65	55.91	15.52	80.48	30.23	91.23

and actinolite-tremolite are grouped under the heading of amphiboles. Zircon, tourmaline and rutile (ZTR) are grouped together, etc. From the graphs of *Fig. 3* it is interesting to note that the central part of the coast is characterized by the maximum concentration of the heaviest minerals, while Rosetta and Damietta sands contain lower frequencies of these minerals. It is noticeable that the heaviest minerals are concentrated and have higher frequencies in the 125—90 μm than in the 250—125 μm size fraction. Between Rosetta and Burullus the opaques in the two size fractions tend to behave separately, where they increase in the coarse fraction and decrease in the finer one.

Variation normal to the shoreline

Figure 4 shows the total variation of the heavy residue and number frequencies of heavy minerals normal to the shoreline; Table 2 illustrates the data. The percentage of the heavy residues increases from the breaker zone to the beach, and then decreases slightly to the backshore zone. The percentage progressively increases from the bottom to the top of the dune, where it attains the maximum values. The opaques and translucent heavy minerals vary significantly normal to the coast. In the 250—125 μm fraction, opaques decrease while garnet, pyroxenes and amphiboles increase between the breaker zone and dune sands. On the other hand, in the 125—90 μm fraction opaques and ZTR increase, while amphiboles and pyroxenes decrease.

A sedimentary petrological province is defined as a group of sediments which constitute a natural unit by age, origin and distribution. A province is best defined when it contains minerals that do not occur in significant amounts in any of the other provinces in the same region. Table 2 shows that the translucent heavy minerals of the Nile Delta coastal sands comprise an amphibole-pyroxene-epidote-garnet-ZTR suite. The distribution of these minerals in the breaker zone, beach, backshore and

dune provinces, as indicated by the mean values, suggests that there are four characteristic suites among the four provinces: an amphibole-pyroxene-epidote suite in the breaker zone, an amphibole-pyroxene-garnet suite in the beach, an amphibole-pyroxene-garnet (or epidote) suite in the backshore, and an amphibole-pyroxene-

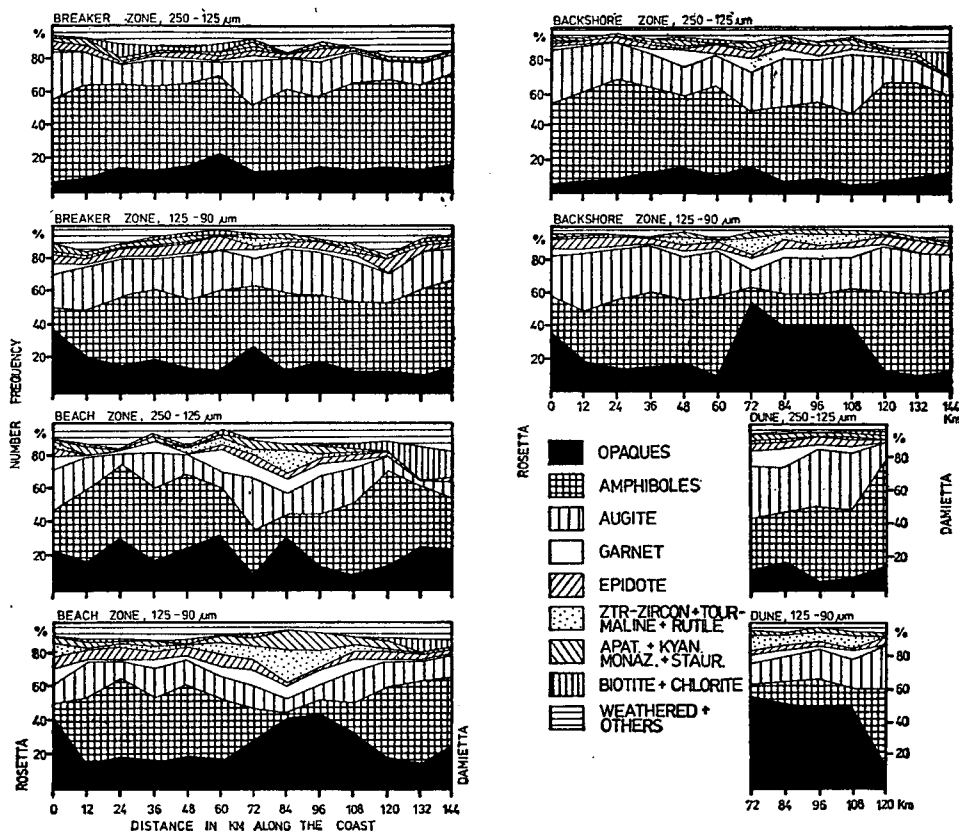


Fig. 3. Distribution of number frequency of heavy minerals along the Nile Delta coast

garnet (or ZTR) suite in the dune. The distribution of opaque heavies also varies by province, as shown in Fig. 4.

The analysis indicates that these four provinces correspond to four well-defined grain size provinces generated by the contrasting hydraulic regimes of the breaker zone, surf zone and wind action. Onshore-offshore transport and differentiation of sediments play an important role in the generation of the heavy mineral suites across the coastal environments. SWIFT *et al.* (1971) found three heavy mineral provinces in the beach, nearshore and offshore. They suggested that the variation had been hydraulically induced by an onshore-offshore differentiation of sea-floor sands. The sensitivity of heavy mineral suites to the local hydraulic regime has long been known (RUBY, 1933; RITTENHOUSE, 1943; BRIGGS, 1965).

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. This

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, ZTR) were left on the beach surface due to the action of waves on the surf zone. SWIFT *et al.* (1971) found that the content of garnet in beach sands is essentially higher than that in nearshore sands.

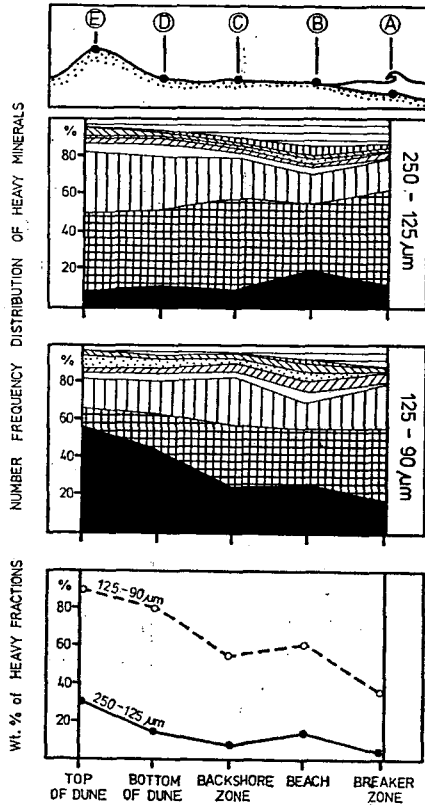


Fig. 4. Heavy mineral variations normal to the shoreline. Legend as in Fig. 3.

It is desirable to compare beach zone mineral concentration anomalies with the concentrations of the same minerals in the nearby dune. The dune sands have higher contents of the heavy residue, opaques, garnet and ZTR than those of the beach sands. The explanation is that the heavy minerals may represent the lag concentrate, due to wind working over the dunes more than the beaches, where wetness prevents much wind action. During this reworking, the wind picks up the light minerals, which may be largely removed, leaving the heavies behind on the dunes. This result agrees in general with the findings of VON ENGELHARDT (1940), STEWART (1956), BRADSSLEY (1957), SHEPARD and YOUNG (1961) and GILES and PILKEY (1965).

TABLE 2

Average frequency distribution of heavy minerals on the coastal sands

Mineral	250—125 μm fraction					125—90 μm fraction				
	Breaker zone	Beach zone	Backshore zone	Bottom of dune	Top of dune	Breaker zone	Beach zone	Backshore zone	Bottom of dune	Top of dune
Opagues	13.52	20.88	9.36	11.42	6.98	16.66	25.31	24.37	43.30	54.54
Hornblende	45.40	30.02	47.80	40.28	40.57	38.06	26.60	31.76	18.85	11.61
Tre.—Act.	4.90	6.01	2.17	0.93	2.62	2.06	4.13	2.31	0.84	0.36
Augite	17.06	15.78	21.84	27.74	32.81	21.81	13.42	24.01	17.59	15.59
Epidote	3.13	1.69	3.27	3.79	3.12	4.57	5.16	4.22	2.77	2.80
Garnet	0.99	4.43	3.29	6.03	4.76	2.23	5.47	2.76	4.00	2.75
Zircon	0.08	1.12	0.06	—	—	0.27	2.07	0.90	3.26	3.77
Tourmaline	0.20	0.53	0.25	0.25	0.51	0.25	0.52	0.22	0.21	0.23
Rutile	0.12	0.65	0.17	0.49	0.25	0.36	2.39	1.32	2.60	2.93
Apatite	0.66	0.64	0.53	0.89	0.88	1.08	1.77	1.41	0.94	1.00
Kyanite	—	0.58	0.07	0.73	1.02	0.09	0.37	—	0.41	0.36
Monazite	—	0.12	0.34	0.35	0.12	0.31	1.56	0.69	0.78	0.91
Staurolite	0.27	0.79	0.72	1.08	3.01	0.06	0.71	0.29	—	0.23
Biotite	1.77	3.16	1.67	1.27	0.51	0.48	1.06	0.13	0.47	—
Chlorite	0.05	1.12	0.10	—	—	0.11	0.39	—	—	—
Weathered	6.19	10.21	5.11	1.87	1.49	5.04	4.84	3.12	2.51	1.48
Others	5.63	1.92	3.31	1.68	1.37	6.00	4.23	2.32	1.56	1.46

Variations along the shoreline

In order to see if coastwise transport plays a significant role, the lateral variation of some selected heavy minerals has been considered through the various provinces. It was found that the opaques, garnet+ZTR and amphiboles of the 125—90 μm fraction vary significantly in a down-drift direction, as shown in *Fig. 5*.

The opaques heavies of the Nile Delta coast reveal a considerable trend. In all provinces between Rosetta and Burullus, opaques decreased most rapidly at first and more slowly later. A rapid increase in opaques was found between Burullus and Gamasa and then a sharp decrease eastwards. Garnet+ZTR reveal the same behaviour as the opaques. The distribution of amphiboles shows a reverse behaviour, in a down-drift direction. There is a rapid increase east of Rosetta and then a slow rise to the Burullus coast. Between Burullus and Gamasa, the amphiboles sharply decrease at first and then tend to increase to Damietta.

Mineralogically, the Nile Delta coast can be subdivided into three stretches, based on opaques and transparent minerals:

1. Rosetta—Burullus stretch: the sediments in this area are characterized by a decrease in opaques and garnet+ZTR, and an increase in amphibole.
2. Burullus—Gamasa stretch: this area shows the greatest content of opaques and garnet+ZTR, and the lowest content of amphibole.
3. Gamasa—Damietta stretch: the sediments are characterized by an abundance of amphibole, and a reduced amount of opaques and garnet+ZTR.

A similar trend of decreasing garnet and increasing amphibols in a down-drift direction has been reported by many authors (PETTJOHN and RIDGE, 1933; MCMAS-TER, 1960; LANGFELDER *et al.*, 1968). The previous studies on the Nile Delta coast

have shown a characteristic decrease in percentage of heavy minerals eastward and westward of the Rosetta headland (RITTMAN and NAKHLA, 1958; MASHREF, 1962). FRIHY (1975) showed that opaques, zircon and garnet decrease, while amphiboles and pyroxenes increase westward of Rosetta mouth. Such trends could be the result of selective down-drift sorting, whereby the heavier mineral grains have a higher probability of being selected for permanent deposition during their intermittent down-drift journey. As regards river sands, the results reported by RUSSELL (1937) for the Mississippi River and by POLLCAK (1961) for the South Canadian River show no significant change in the percentage of heavy minerals downstream.

Amphibole/opaque ratio

The ratio of stable to unstable heavy minerals is a convenient measure of the maturity of recent sands (BULLARD, 1942). Directions by which the sediments moved along the beaches may be indicated by systematic changes in the ratio of certain unstable and stable mineral species. The amphibole/opaque ratio was calculated along the Nile Delta beach sands to represent the unstable/stable ratio.

The features recognized along the beaches have significantly different ratios (Fig. 6). Rosetta sands are comparatively immature, with an average amphibole/

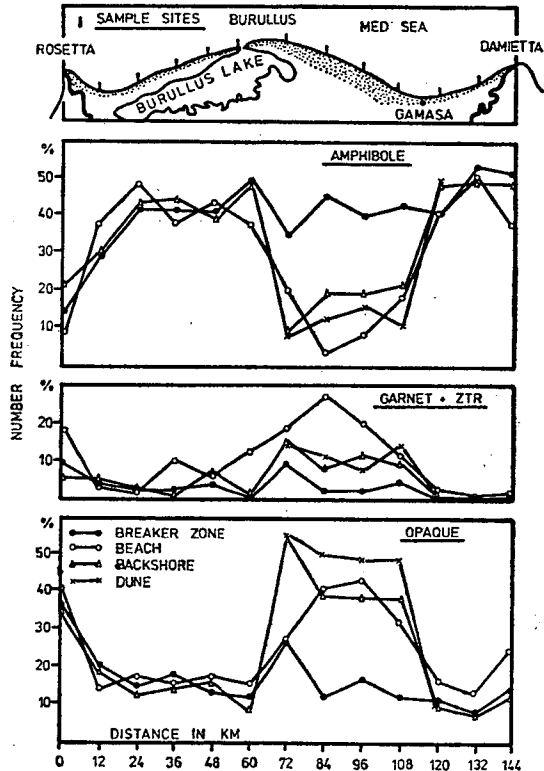


Fig. 5. Lateral variation of opaque, garnet+ZTR and amphibole along the coast for 125—90 μm size grade

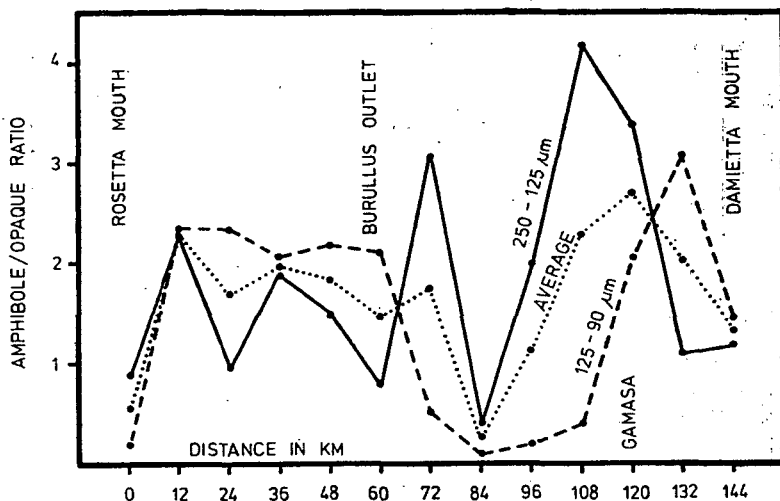


Fig. 6. Amphibole/opaque ratio along the Nile Delta beach sands

opaque ratio of 0.55. The ratio increases between Rosetta and Burullus, and the average value ranges between 1.5 and 2.2. This means that the sediments become mature in a down-drift direction. Between Burullus outlet and location 84 km, the amphibole/opaque ratio decreases and the sediments become immature, with an average ratio of 0.40, as a result of dilution with opaque association from some sources. East of location 84 km the sediments tend to be strongly mature, with an average ratio of 2.70. Near Damietta mouth, the sediments become intermediate in maturity, with an average of 1.30, due to tilution with opaques from Damietta mouth. In conclusion, it can be said that the amphibole/opaque ratio may be used as an indicator to trace the direction of sediment movement along the beaches. The central part of the Nile Delta coast is largely of local origin, formed by reworking and dispersal of older deposits present in the coastal zone itself or in the immediate vicinity on the continental shelf.

Mineralogical relationships between coastal sands

There has been comparatively little work on the heavy minerals of the coastal environments, and publications are seldom encountered except relating to beach sands. So far, there has been no attempt to differentiate between the various coastal sands by heavy mineral analysis.

The relationship between opaques and hornblende, as well as that between garnet+ZTR and hornblende, are shown in Fig. 7 for the 250—125 μm and 125—90 μm size fractions. The association between the values reveals negative correlations; the higher the hornblende content, the lower the opaque and garnet+ZTR contents.

The Nile Delta coastal environments can be differentiated by heavy mineral analysis. The 250—150 μm size fraction gives a better differentiation than the 125—90 μm one, as shown in Fig. 7. For the 250—125 μm size fraction, boundary lines have been drawn and separated fields resulted for each environment.

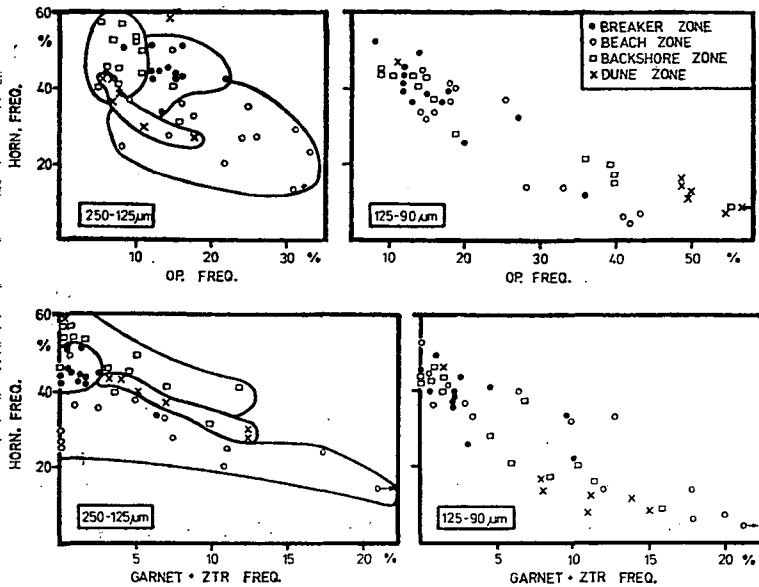


Fig.7. Relationships between opaque and hornblende and that between garnet + ZTR and hornblende for coastal sands

Source of beach minerals

A comparison of beach mineralogy along the Nile Delta coast indicates that the beaches near Rosetta and Damietta contain lower percentages of heavy residue than along Burullus headland. On this basis it can be assumed that Rosetta and Damietta Rivers are not important contributors to the present-day beach sediments.

If longshore drift in an eastward direction is the principal mechanism of sediment supply, an eastward increase in amphibole and decrease in garnet and opaques should be expected. This is apparently the case in the areas between Rosetta and Burullus and west of Gamasa, but not for Burullus headland. The increase of heavy mineral suites and contents in Burullus suggests that the shelf on this part of the coast is the source of sediments. The evidence relating to the source of sediments is based on comparisons between the high opaque, garnet and ZTR contents of Burullus sands and the corresponding low contents of these minerals near Rosetta and Damietta mouths. Therefore, the sediments of the Burullus coast may be derived from outcropping ancient sediments on the shelf formed by the ancient Sebennitic branch during times of a lowered sea level, when sediments from old rivers were carried directly downslope across the exposed shelf to deep water.

To sum up, three explanations are offered for the higher concentration of the heaviest minerals in the Burullus beach:

1. Contributions from offshore old sediments of classis Nile branches, rather than the present Nile, where the heaviest minerals are more abundant in Burullus beaches than in both Rosetta and Damietta beaches. Unfortunately, there is very little information in the literature concerning the detailed mineralogy of the offshore and shelf sediments.

2. Contributions from the land itself, where the backshore flat and coastal dunes contain a high amount of opaques and a considerable amount of garnet and ZTR. It is important to mention that the preferential mechanical concentration of ZTR plays an effective role because of their hydraulic properties.

3. Coastal Erosion Studies (1973) reported that the best conditions for the concentration of the heaviest minerals are where the shore is retreating, especially where there is a reworking of beach sands. Minerals do not have much chance to be concentrated if the coast is actively advancing. In fact, the Burullus headland is retreating due to severe erosion, and as a result it may lead to some concentration of the heavy minerals.

CONCLUSIONS

1. The translucent heavy minerals of the Nile Delta coastal sands comprise an amphibole-pyroxene-epidote-garnet-ZTR suite. The distribution of these minerals in the breaker zone, beach, backshore and coastal dune sands suggests that there are four characteristic suites among the four provinces, generated by the contrasting hydraulic regimes of the breaker zone, surf zone and wind action.

2. The heavy mineral variations normal to the shoreline show a significant trend. In general, the heavy residues, opaques, garnet and ZTR markedly increase, while amphiboles and pyroxenes decrease in moving from the breaker zone across the beach and backshore and up to the dune. The breaker zone sands reveal a higher content of amphiboles and pyroxenes and a lower content of opaques, garnet and ZTR than the beach sands. The reason may be related to the action of the breakers in concentrating the less heavies with the coarse sands, while in the natural separation the heaviest minerals are left on the beach surface due to the wave action. The dune sands have higher contents of the heavy residues and heaviest minerals than the beach sands. The explanation is that the heavy minerals may represent a lag concentrate due to the wind working over the dune more than the beaches, where the wetness prevents much wind action. Therefore, the wind picks up the light minerals, leaving the heavies behind on the dunes.

3. The associations between hornblende and both opaques and garnet+ZTR reveal negative correlations; the higher the hornblende content, the lower the opaque and garnet+ZTR contents. These relationships in the 250—125 μm size grade can be used to differentiate between coastal environments.

4. The coastwise variation in heavy minerals indicates that the beaches near Rosetta and Damietta contain relatively lower percentages of heavy residues and other heavies than the Burullus headland coast. If longshore drift in an eastward direction is the principal mechanism of sediment supply, an eastward increase in amphibole and a decrease in opaques and garnet+ZTR should be expected. This is apparently the case in the Rosetta—Burullus stretch and west of Gamasa, but not for the Burullus headland coast.

5. Three explanations are offered for the high concentration of the heaviest minerals in the Burullus beach sediments:

a) Contributions from offshore old sediments of classis Nile branches rather than the present Nile.

b) Contributions from the land itself, where the backshore and dunes contain considerable amount of these minerals.

c) These minerals have a good chance of being concentrated during coastal erosion.

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 analysis. *Bull. Fac. Sci. Alex. Univ.*, V. 10, p. 141—150.
- BRADLEY, J. S. (1957): Differentiation of marine and subaerial sedimentary environments by volume percentage of heavy minerals, Mustang Island, Texas, *Jour. Sed. Petr.*, V. 27, p. 116—125.
- BRIGGS, L. I. (1965): Heavy mineral correlations and provenances. *Jour. Sed. Petr.*, V. 35, p. 939—955.
- BULLARD, F. M. (1942): Source of beach and river sands on the Gulf Coast of Texas. *Geol. Soc. Am. Bull.*, V. 53, p. 1021—1043.
- CARVER, R. E. (1971): Heavy mineral separation. In: Carver, R. E., ed., *Procedures in sedimentary petrology*, Wiley — Interscience, New York, p. 427—452.
- COASTAL EROSION STUDIES (1973): Detailed Technical Report. Project 70/581, UNESCO (ASRT) UNDP, Alex., 259 p.
- COASTAL EROSION STUDIES (1976): Detailed Technical Report on Coastal Geomorphology and Marine Geology, Nile Delta. Project 73/063, UNESCO (ASTR) UNDP, Alex., 175 p.
- FRIHY, O. E. (1975): Geological study of Quaternary deposits between Abu Quir and Rashid. M. Sc. thesis, Fac. Sci. Alex. Univ.
- GILES, R. T. and PILKEY, O. H. (1965): Atlantic beach and dune sediments of the southern U. S. *Jour. Sed. Petr.*, V. 35, p. 900—910.
- LANGFELDER, J., STAFFORD, D. and AMEIN, M. (1968): A reconnaissance of coastal erosion in North Carolina. Dept. of Civil Eng., North Carolina State Univ., Raleigh, 172 p.
- MASHREF, W. M. (1962): Mineralogical and radiometric study for some black sand deposits on the Mediterranean coast. M. Sc. thesis, Fac. Sci. Ain Shams Univ.
- MCMMASTER, R. L. (1960): Mineralogy as an indicator of beach sand movement along the Rhode Island shore. *Jour. Sed. Petr.*, V. 30, p. 404—413.
- NAKHLA, F. A. (1958): Mineralogy of Egyptian black sands and its application. *Egyptian Jour. Geol.* V. 2, no. 1.
- PETTIDJOHN, F. J. and RIDGE, J. D. (1933): A mineral variation series of beach sands from Cedar Point, Ohio. *Jour. Sed. Petr.*, V. 3, p. 92—94.
- POLLACK, J. M. (1961): Significance of compositional and textural properties of South Canadian river channel sands, New Mexico, Texas and Oklahoma. *Jour. Sed. Petr.*, V. 31, p. 15—37.
- RITTENHOUSE, G. (1943): Transportation and deposition of heavy minerals. *Geol. Soc. Am. Bull.*, V. 54, p. 403—413.
- RITTMAN, A. and NAKHLA, F. A. (1958): Contribution to the study of Egyptian black sands. *Egyptian Jour. Chem.*, V. 1, p. 127—135.
- RUBEY, W. W. (1933): The size distribution of heavy minerals within a water-laid sandstone. *Jour. Sed. Petr.*, V. 3, p. 3—29.
- RUSSELL, R. D. (1937): Mineral composition of Mississippi River sands. *Geol. Soc. Am. Bull.*, V. 48, p. 1307—1348.
- SHEPARD, F. P. and YOUNG, R. (1961): Distinguishing between beach and dune sands. *Jour. Sed. Petr.*, V. 31, p. 196—214.
- SHUKRI, N. M. (1950): The mineralogy of some Nile sediments. *Quart. Jour. Geol. Soc. London*, V. 105, p. 511—534.
- SINDOWSKI, F. K. H. (1949): Results and problems of heavy mineral analysis in Germany: A review of sedimentary-petrological papers, 1936—1948. *Jour. Sed. Petr.*, V. 19, p. 3—25.
- STEWART, H. B. (1956): Sediments and the environments of deposition in a coastal lagoon. Ph. D. thesis, Univ. Calif., 355 p.
- SWIFT, D. J. P., DILL, C. E. and MCHOME, J. (1971): Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast. *Jour. Sed. Petr.*, V. 41, p. 683—690.
- VON ENGELHARDT, W. (1940): Unterscheidung wasser- und windsortierter Sande auf Grund der Korngrößenverteilung ihrer leichten und schweren Gemengteile. *Chemie der Erde*, V. 12, p. 445—465.

Manuscript received, July 5, 1984