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Mineralogy as an Indicator of Various Coastal Environments along Burullus Area, North Nile Delta, Egypt

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ABSTRACT. Distribution of both light and heavy minerals has been investigated in the sand-size samples collected from Burullus coastal area. Sediment movement and provenance are discussed.

Feldspar appears enriched in the barrier sand than in the beach. This remarkable variation along the coast is related to selective sorting processes. Highest ratio of quartz/feldspar is exhibited by the sands of island and western border of the lake. The beach sand appears mature than the barrier sand. While the drains sand appears immature due to its fluvial origin.

Beach erosion east of Al Burg inlet contributes the enrichment of the beach sands by the heaviest minerals; opaques, ZTR and garnet corresponding to low values of these minerals in the western stretch. This pattern is attributed to the modification caused by action of waves and currents that selectively sort and concentrate the heavy minerals according to their different densities.

The light minerals; hornblende, augite and epidote are highly concentrated in the sands of the western beach stretch. A comparison of the distribution of heavy minerals for the beach and barrier sands also reveals a rapid increase of augite sea-ward accompanied with an increase of hornblende and epidote land-ward.

Correlation between opaques and hornblende as well as between ZTR + garnet and hornblende succeeded to differentiate between the various coastal environments.

Introduction

Burullus is the second largest Delta Lake in Egypt. It stretches between both Nile branches and occupies a part of the coastal zone. It is connected to the Mediterranean Sea by Al-Burg inlet and separated from it by a long curving sand barrier. The inlet of the Lake is floored by sand but the southern border and the bottom are made up of lagoonal clays enriched with fossils. Many islands are scattered in the Lake. The Lake is bordered by low dunes to the west of the inlet and by high dunes to the east of the inlet.

The aim of the present work is to investigate the distribution of both light and heavy minerals encountered in the sand samples collected from the Burullus Lake area in order to differentiate between the various coastal sands and to evaluate sediment movement and source.

The mineralogy of the Nile Delta coastal sediments previously studied by Shukri (1950), Shukri and Philip (1955a,b), Nakhla (1958), Anwar and El-Bouseily (1970a,b), Coastal Erosion Studies (1973, 1976), Frihy (1975, 1983), Rashed (1978), Soliman (1980), El-Sabrouti (1984), Badr (1985, 1990), El-Fishawi and Molnar (1985), El-Askary and Frihy (1987), Frihy and Komar (1991) and Stanley (1989).

The evolution of Late Quaternary coastal sediments and the interaction of sea level changes, climatic oscillations and transport processes have been discussed by Arbouille and Stanley (1991), Chen *et al.* (1992) and Stanley *et al.* (1992).

Method of Study

Sixty sand samples were chosen from samples collection of Burullus Lake area. They represent the Burullus headland coast (including both beach and barrier), the Sidi Youssif Abu Rageh (northwestern Burullus Lake), drain Nasser (southeastern Lake) and the Burullus islands (El-Kom El-Akhdar) (Fig. 1).

In the present study, fraction of grain size ranging between (0.125 - 0.063 mm) has been chosen for heavy mineral analysis. This fraction was found to contains the highest heavy mineral contents in the Nile Delta coastal sediments according to Rashed (1978), Anwar *et al.* (1981), Badr (1985) and El-Fishawy & Molnar (1985).

The heavy minerals were separated from each sample using bromoform of specific gravity 2.89. The heavies have been mounted in Canada balsam, examined optically and about 400 mineral grains were counted for each sample. The relative frequency of the heavy mineral constituents is calculated. The common heavy minerals have been described according to the standard works of Milner (1962), Krumbein and Pettijohn (1938) and Tickell (1965).

The separated light fraction was identified by staining techniques described by Van Der Plass (1966). Na-cobaltinitrite was used for staining, after etching the grains with HF. Under the binocular microscope, alkali feldspars appear yellow, plagioclase feldspars become white, while quartz grains remain unaffected. About 400 grains are counted for the light fraction of each sample, then the relative frequency percentages of the light mineral components were determined. In addition, other portions of the light fractions were mounted in Canada Balsam and examined under the polarizing microscope.

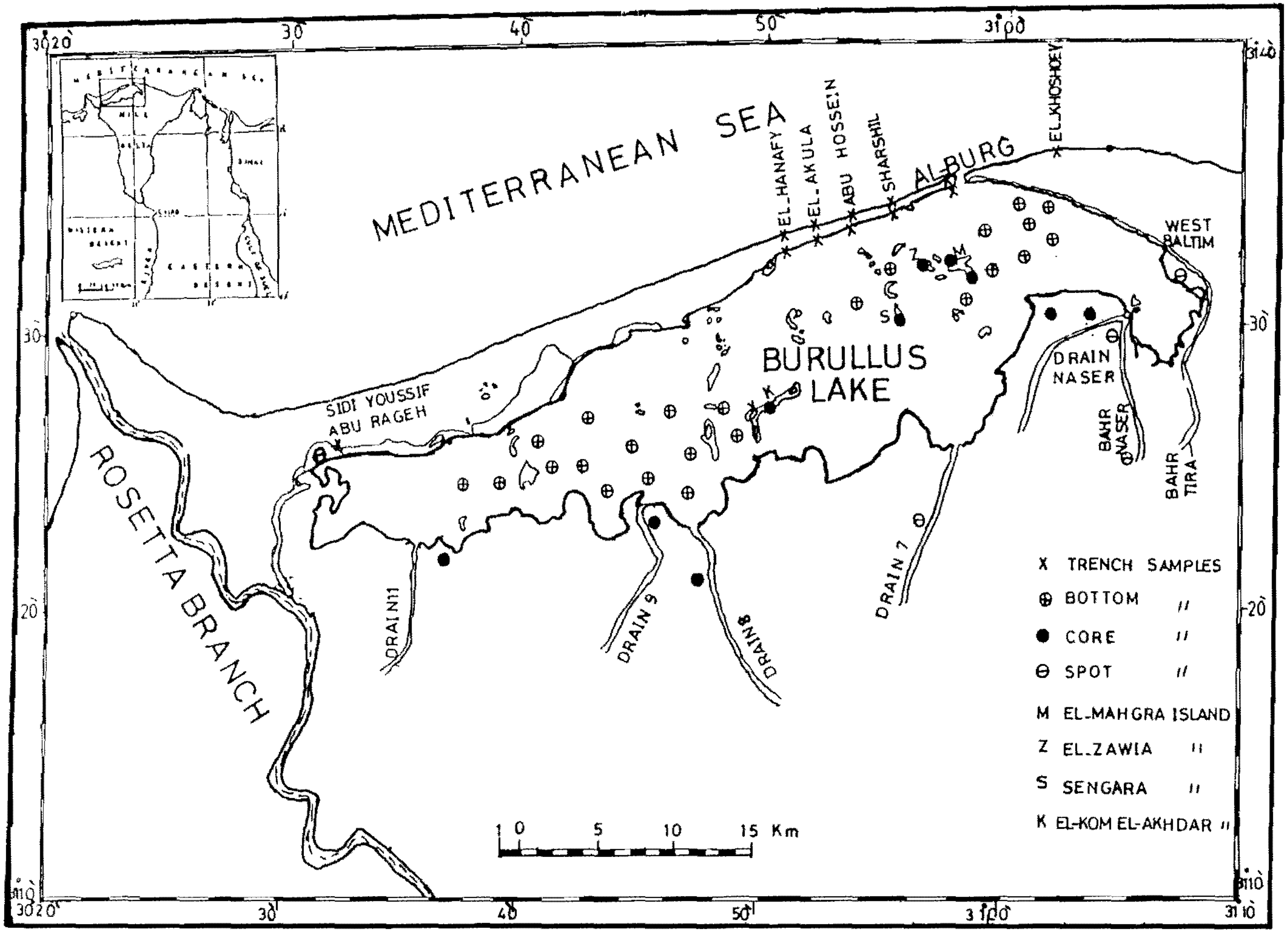

FIG. 1. Location of sediment sampling sites in Burullus Lake area.

Results and Discussion

a. *Mineralogy of the Light Fraction*

The mineral constituents found in 60 samples examined include; quartz, potash feldspars and plagioclase feldspars. Their average values are listed in Table (1).

i. Quartz: Is found to be the most dominant light mineral in all samples. It ranges from 99.1% to 75.1%. The quartz grains are colourless, mostly monocrystalline, subrounded to well rounded. The majority of the quartz grains contain inclusions, mainly iron oxides. The average content of quartz seems to decrease from the beach (92.8%) towards the barrier (87.3%). The sands from island and Sidi Youssif Abu Rageh exhibit the highest average content (97.7% and 96.4% respectively), while sands from drain Nasser have the lowest values (78.1%).

ii. Feldspars: Potash feldspars (mainly orthoclase) are usually more dominant than plagioclase, they range between 18.5% and 0.4%, while plagioclase varies from 6.8% to 0.6%.

It was observed that the sands from drain Nasser display the highest average value of potash feldspar (16.3%) and plagioclase feldspar (5.6%), while sands from the island have the lowest values (0.6% for potash feldspar and 1.7% for plagioclase feldspar).

Concerning the distribution of feldspar in the various coastal environments, it was found that the barrier sands have higher average content of total feldspar (12.7%) (Table 1) than that of beach sands (7.2%). This remarkable variation in the content of feldspar distribution along the coast may be related to selective sorting processes.

The sands studied from the drain Nasser (southeastern border of Burullus Lake) exhibit the highest average values of feldspar (21.9%) suggesting river deposition. Pettijohn *et al.* (1973) attributed the high content of feldspar in the sand to river deposition than in the beach sands.

The quartz/feldspar ratio has been also used as index for the mineralogical maturity of the sands studied according to Pettijohn (1957). The average values of quartz/feldspar ratio are given in Table (1). It is observed that sands from islands and Sidi Youssif Abu Rageh have the highest average ratio of quartz/feldspar (42.5% and 26.8% respectively) indicating more mature sediments than those exhibited by the other localities. They probably are composed of ancient beach sands. It is evident that the beach sand with average value of 12.9% is mature than the barrier sands (6.9%) and both of them have lower values than the previous studied localities. On the other hand, the sands of the drain Nasser have low ratios of quartz/feldspar with an average of 3.6% indicating immature sands. It was known that fluvial sediments contain more feldspar than beach and aeolian sands (Pettijohn 1957).

b. *Mineralogy of Heavy Fraction*

The relative frequency percentages of heavy minerals have been determined in the studied sand samples and depicted graphically in Fig. (2). The most abundant and

TABLE 1. Average frequency distribution of both heavy and light minerals in the various coastal sands.

Locality	Beach (21 samp.)	Barrier (25 samp.)	Western coastal plain (8 samp.)	El-Kom El-Akhdar island (3 samp.)	Drain Nasser (3 samp.)
Heavy minerals :					
Hornblende	11.8	32.3	31.9	29.8	30.6
Augite	49.3	34.5	33.2	12.0	44.1
Epidote	15.3	20.8	27.1	24.1	17.4
Zircon	11.9	4.4	2.4	20.0	0.3
Rutile	1.6	0.9	1.2	2.5	0.6
Tourmaline	2.3	2.4	1.8	2.2	2.2
Garnet	5.2	2.3	1.9	5.1	1.5
Staurolite	0.1	–	–	1.1	–
Kyanite	0.3	0.5	–	0.8	0.4
Apatite	0.1	0.0	–	0.5	0.2
Monazite	0.6	0.2	–	0.5	–
Chlorite	–	–	–	0.8	0.3
Biotite	1.5	1.8	0.6	0.6	2.3
Light minerals :					
Quartz	92.8	87.3	96.4	97.7	78.1
K - feldspars	5.1	9.6	2.6	0.6	16.3
Plagioclase	2.1	3.1	1.0	1.7	5.6
Feldspars					
Q/F ratio	12.9	6.9	26.8	42.5	3.6

identified heavy minerals are opaques, pyroxenes, amphiboles and epidotes. Zircon, rutile, tourmaline and garnet are present in subordinate amounts. In addition, kyanite, staurolite, biotite, chlorite, monazite and apatite are less common and encountered in rare amounts. It is interesting to note that the sands in the eastern beach stretch of Al-Burg inlet are characterized by the maximum concentration of the heavy minerals followed by the sands in the western beach stretch. While those of the other studied localities contain lower frequency percentages. The western beach has experienced widespread erosion by hydrodynamic forces. Waves and currents selectively sort and concentrate mineral grains according to their densities and sizes (*cf.* Pettighon *et al.* 1973). The hydrodynamic forces seem to increase from west to east and the beach erosion at Burullus headland coast probably contributes to the enrichment of the coast sand by heavy minerals. Thus the sediments along this part of the beach are influenced by selective sorting of heavy minerals.

Opaque Minerals

In general it was found that the opaque minerals are the main constituents of the heavy fraction for most of the studied coastal sands. The distribution pattern of the opaque minerals in the various coastal sands is shown in Fig. (3). It is observed that the distribution of opaque minerals in the beach sands reflects higher concentration than in the barrier sands. The maximum concentration of opaques (87.2%) is re-

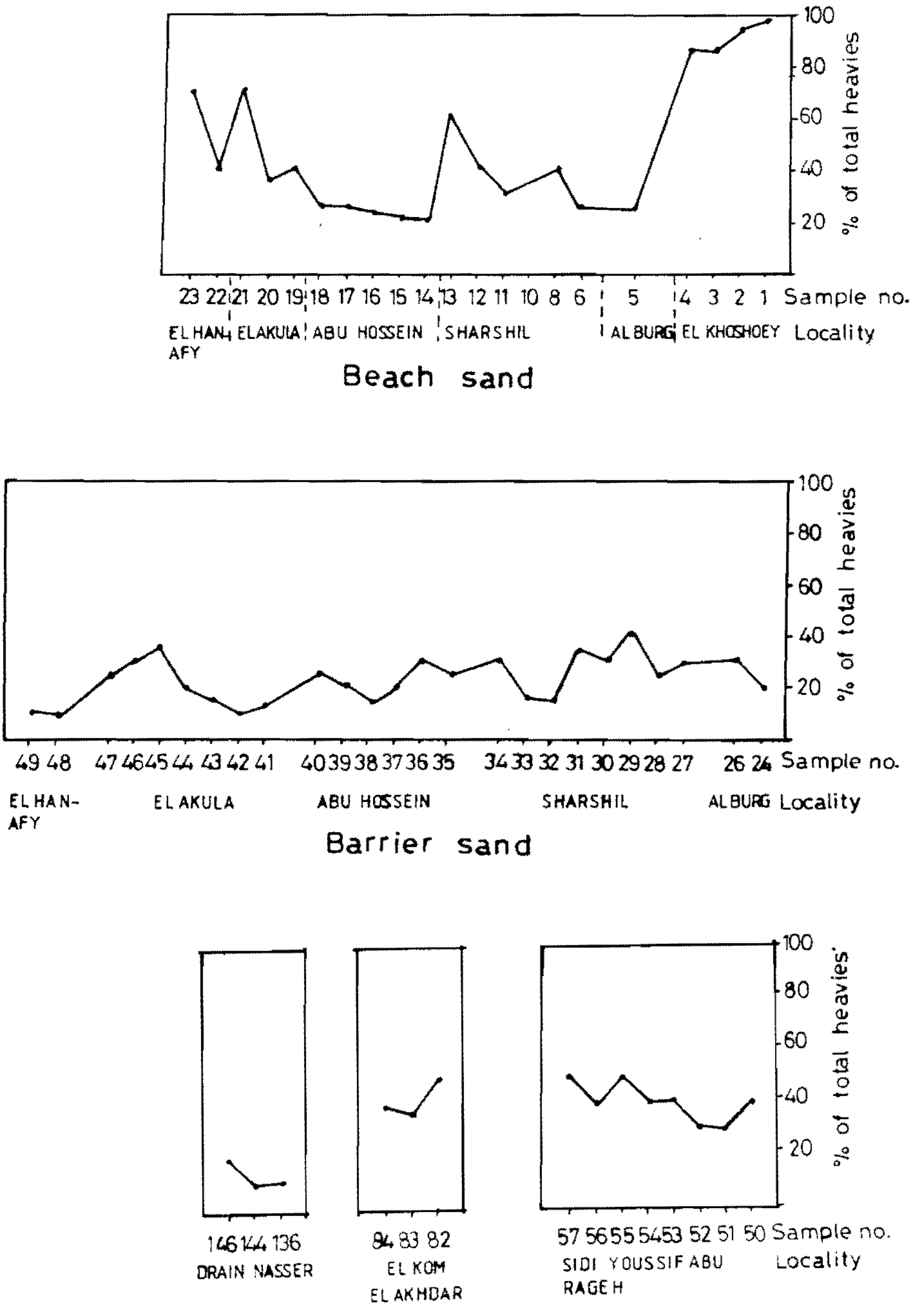

FIG. 2. Distribution of the total heavy mineral percentages in the various coastal sands along Burullus coastal area.

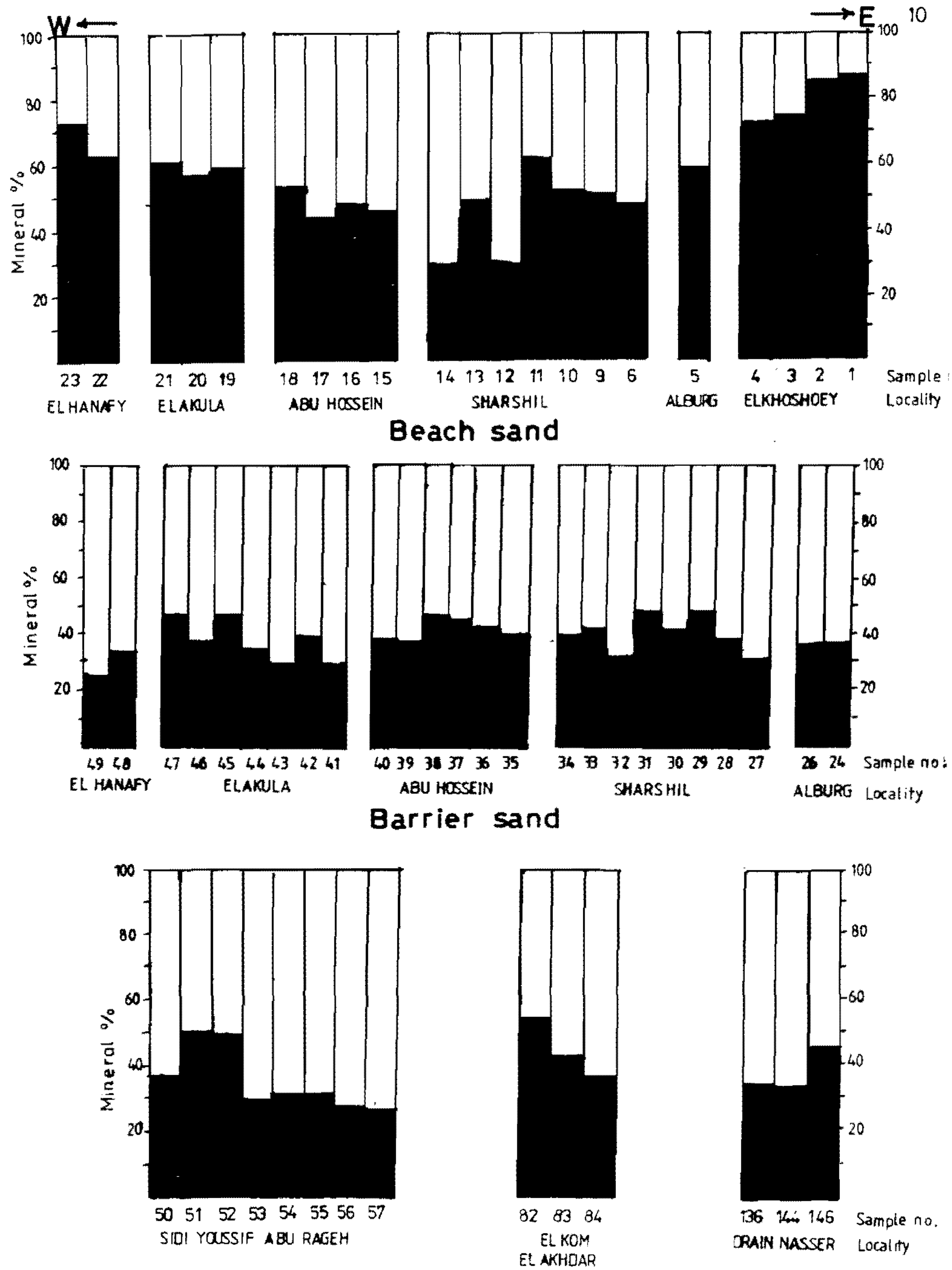

FIG. 3. Bar diagrams showing the relative percentages of opaque and non-opaque minerals along Burullus coastal area.
■ Opaque, □ Non-opaque

corded at El-Khoshoey locality east of Al-Burg inlet. However, it decreases west of the inlet attaining minimum concentration of about 28% at Sharshil locality (Fig. 3). On the other hand, the non-opaque minerals exceed the opaques in the barrier sands.

Non-Opaque Minerals

The distribution of the non-opaque heavy minerals encountered in the various coastal sands is represented graphically in compositional variation bars shown in Fig. (4). It is obviously that the sands in the eastern stretch of Al-Burg inlet at the beach are characterized by the maximum concentration of zircon, rutile, tourmaline, garnet, staurolite, kyanite and monazite. As well as a lower content of the lighter minerals; hornblende and augite (Fig. 4). Grain sorting processes may concentrate the heaviest minerals (opaques, garnet, zircon, rutile and tourmaline) on the beach surface due to the action of waves in the surface zone.

It is also interesting to notice the vertical variation of the heavy mineral constituents throughout El-Khoshoey trench. Opaques, garnet, zircon and rutile show decreasing content with depth accompanied by an increase in augite, epidote and tourmaline (Fig. 4). In fact, the sands in El-Khoshoey trench exhibit a vertical layering colour variation from black at top and white to yellow at bottom. Also it was found that monazite is always associated with black sand. It is suggested that the heavy minerals may represent the lag concentration due to wind action over the beach, where wind picks up the light minerals leaving the heaviest behind.

On the other hand, the sands in the western beach stretch of Al-Burg inlet reveal a higher content of pyroxene and amphibole as well as a lower content of ZTR, garnet, staurolite, kyanite and monazite than those in the eastern stretch (erosion beach zone). This sorting may be related to the action of breakers which tend to concentrate the lighter minerals with coarse sands (accression beach zone).

Interpretation of grain size data according to Toubar (1991), proved that the beach sands west of Al-Burg inlet are characterized by Mz falls in medium grained. While those in the eastern stretch are mainly fine-grained sediments.

The heavy minerals encountered in the barrier sands (Fig. 4) are characterized by higher concentration of hornblende and epidote rather than in the beach sands. Augite is also present in high amounts but less than in the beach. A comparison of the distribution of heavy minerals along the beach and barrier sands reveals rapid increase of augite seaward corresponding to decrease in the amphiboles and epidotes. The distribution patterns of garnet and ZTR in the barrier sands is of similar behaviour like in the beach sands of the western stretch.

Otherwise, the heavy minerals investigated in the western coastal plain sand of Burullus Lake at Sidi Youssif Abu Rageh and drain Nasser in the southern border show dominance of augite, hornblende and epidote (Fig. 4). This mineral association is similar to that found in the Nile Delta sediments. On the other hand, the recorded heavy mineral constituents observed in the sand of El-Kom El-Akhdar island as

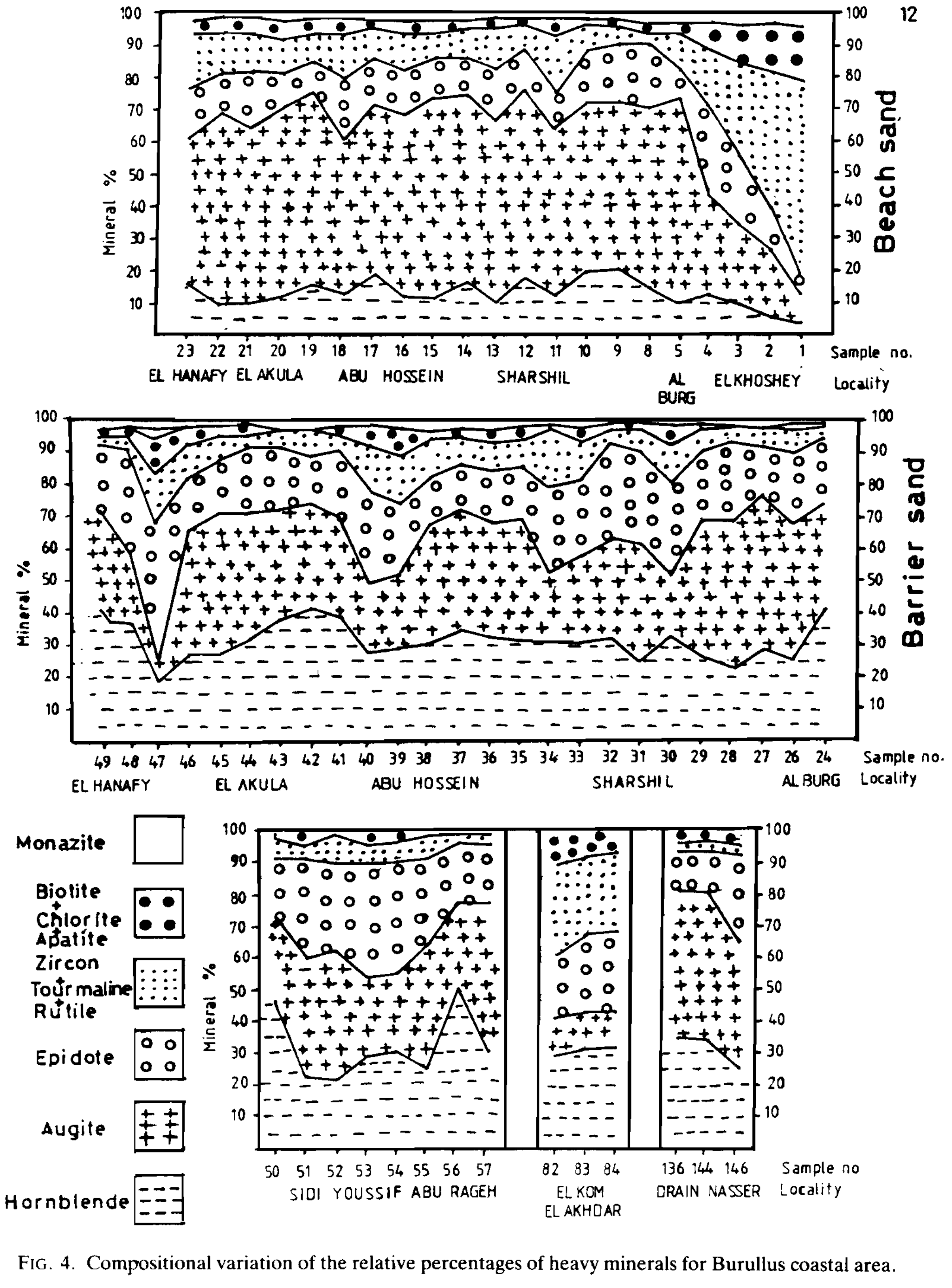

FIG. 4. Compositional variation of the relative percentages of heavy minerals for Burullus coastal area.

shown in Fig. (4) exhibit a different behaviour than in the other studied localities. Augite shows a lower concentration, while ZTR exhibit a higher concentration supporting the higher maturity.

The average frequency distribution of the non-opaque heavy minerals in the different coastal environments at Burullus area was given in Table (1). A comparison between the average heavy mineral distribution of the sands in both beach and barrier has been shown in Fig. (5). It was found that the average percentage of amphiboles (11.8%) in the beach sands is much lower than that in the other studied coastal areas. Augite attains a maximum average value in the beach (49.3%) and also in the drain Nasser (44.14%). Whereas, the minimum average value (12%) is recorded at El-Kom El-Akhdar island. Epidote has the lowest average value (15.3%) in the beach sands. High average value of biotite is recorded in the sands of drain Nasser.

The behaviour of the average values of ZTR shows a lower concentration in drain Nasser (3.1%) and a higher concentration (24.7%) in the island. This may attributed to the immaturity of the sands in drain Nasser as previously mentioned. In contrast the beach sands as a whole exhibit a higher concentration of ZTR (15.8%) than in the barrier (7.7%). Garnet also displays similar high concentration in the beach sands (5.2% and 5.1%) respectively.

Using of Heavy Minerals to Differentiate between the Various Coastal Sands

In the light of the above mentioned general discussion, it will be established that the heavy mineral distribution can be used to differentiate between the various coastal environments.

The relationship between opaques and hornblende as well as between ZTR + garnet and hornblende are constructed for the various coastal sands analyzed and shown in Fig. (6). In general, the inter-mineral correlations between the values separate between the sands studied are considerable discriminated between separate fields (Fig. 6). This results agree in general with findings of El-Fishawy and Molnar (1985). They mentioned that the Nile Delta coastal environments can be differentiated by heavy mineral analysis.

A comparison of beach and barrier mineralogy along the Nile Delta coast (Fig. 6) indicates that the beach contain lower percentage of hornblende than that in the barrier. Furthermore, it can also differentiated between accreted and eroded beaches. Accreted beaches are characterized by lower contents of opaques and ZTR + garnet than that of eroded beaches.

Provenance

Both the heavy and light minerals are used as guides to determine provenances. The quartz grains are mostly single with uniform extinction, they are generally rounded to well rounded. Feldspars are widely distributed. In general, potash feldspars dominate plagioclase in most studied samples. Augite, hornblende and epidote are important constituents in the sands examined. Also ZTR, garnet and relatively kyanite appear sometimes with high concentrations.

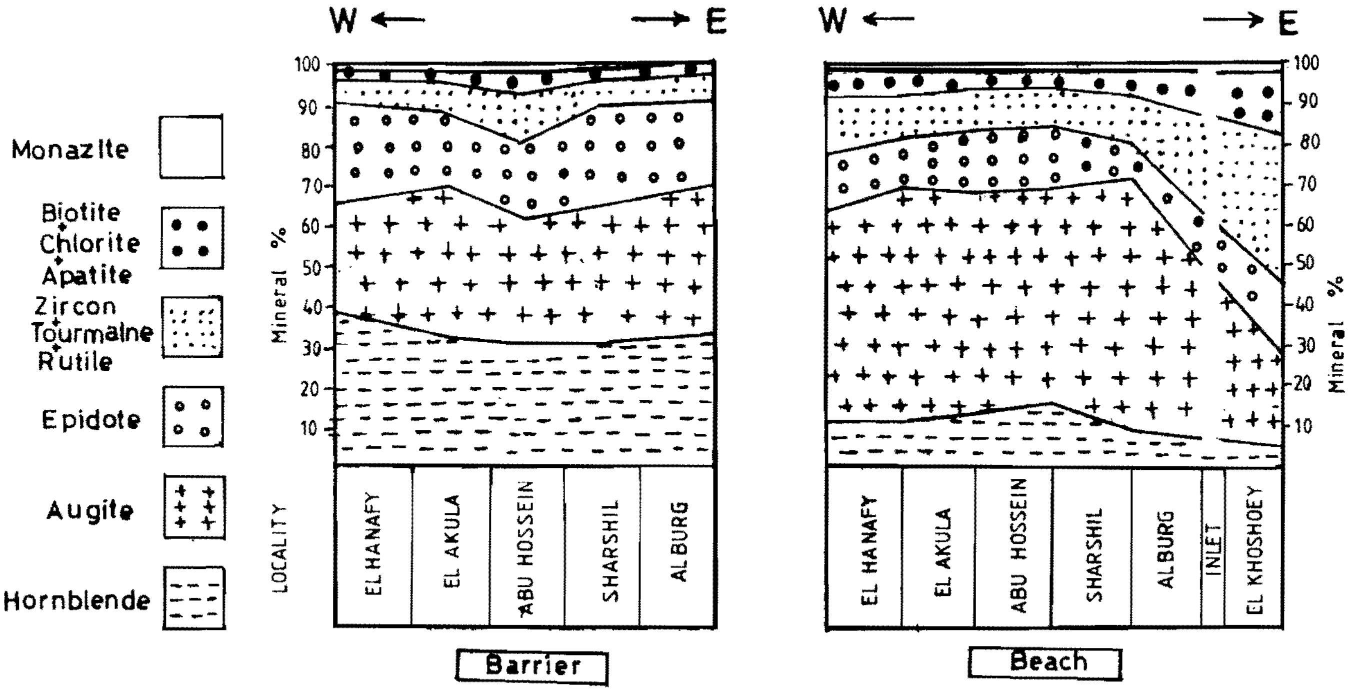

FIG. 5. Lateral variation of average frequency distribution of heavy minerals in the Burullus coastal area.

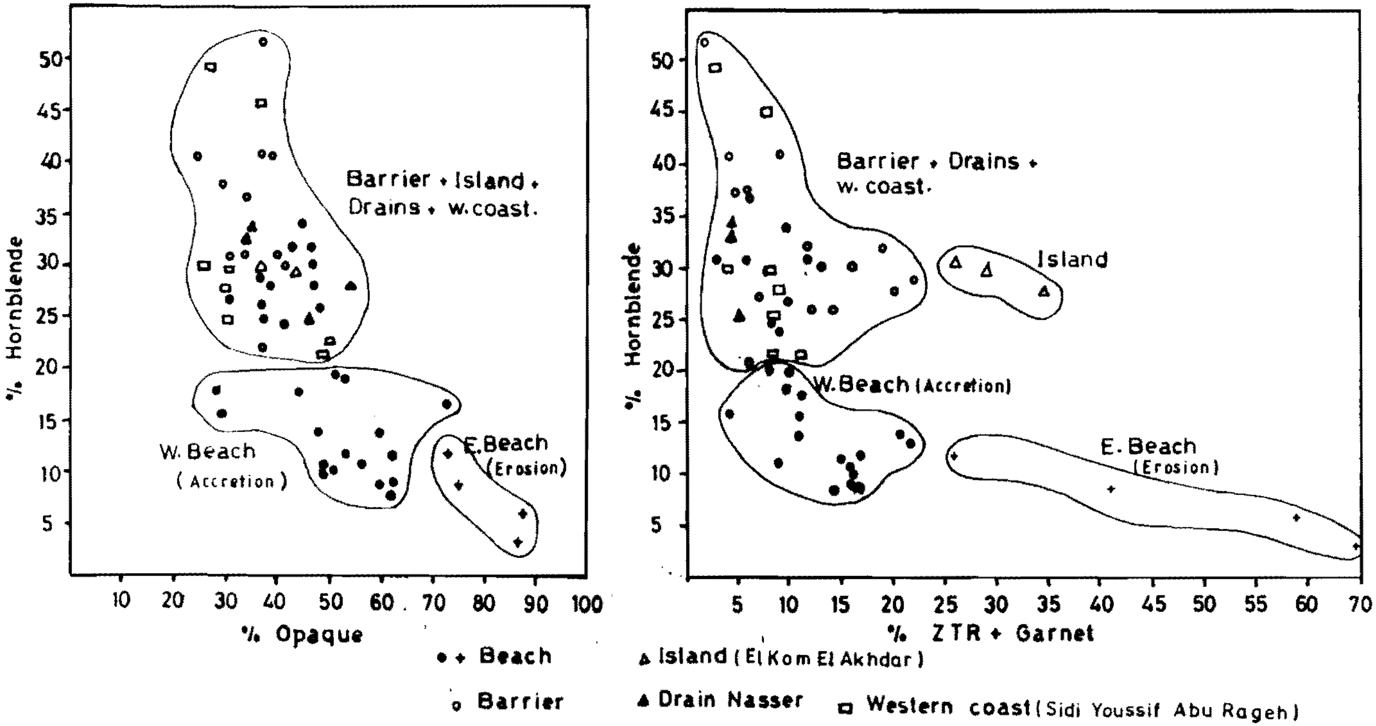

FIG. 6. Relationships between percentages of opaque and hornblende and that between percentages of ZTR + garnet and hornblende for Burullus coastal sands.

The evidence relating to the source of sands is based on comparison between the heavy mineral distribution in the eastern beach stretch of Al-Burg inlet and those in western beach stretch. High opaques, ZTR and garnet contents in the eastern stretch corresponding to low values of these minerals in western stretch. This indicate that the sands of the eastern stretch may be derived from ancient shelf sediments formed by the former Sebennitic branch during times of lowered sea level rather than the present Nile. The mouth of the old Sebennitic distributary was located on what is the inner to middle shelf off Baltim (Arbouille and Stanly 1991). This may indicate that this beach is influenced by other relict sources together with the eroded beach and dune field. However, contribution from the land itself and coastal dunes or due to hydraulic properties of ZTR or preferential mechanical concentration plays an effective role. It was known that the eastern beach stretch is retreating due to severe erosion thus resulting high concentration of heavy minerals.

Conclusion

The present work is carried out to study the distribution of both light and heavy mineral constituents in the various coastal sands along Burullus Lake area. Sixty sand samples are collected from different environments include; beach, barrier, fluvial and aeolian. Important conclusions are drawn concerning the distribution and concentration of the heavy mineral constituents along Burullus coastal area :

1. The average content of quartz seems to decrease from the beach towards the barrier due to the modification caused by action of waves and sorting.
2. Concerning the distribution of feldspar, the barrier sands exhibit higher concentration than those in the beach possibly due to the selective sorting processes.
3. The higher concentration of heaviest minerals in the eastern beach stretch of Al-Burg inlet can be attributed to the sand movement from offshore old sediments formed by the ancient Sebennitic branch during times of a lowered sea level.
4. The western beach zone sands reveal a higher content of augite and a lower content of ZTR than those in the barrier sands. This sorting may related to the action of waves and currents which tend to concentrate and sort the lighter density minerals together with coarse sands along accreted beaches.
5. The bivariate diagrams between opaques and hornblende as well as that between ZTR + garnet and hornblende reveal separate fields between each environment. Thus heavy minerals can be used to differentiate between various coastal environments.
6. Opaques play a significant role throughout the various coastal sands. It reveals a remarkable trend. The beach sands show high content of opaques. While the barrier sands are characterized by an abundance of amphibole and small amount of opaques and ZTR + garnet.

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التركيب المعـــدني كدليل على البيئات الساحليـــة المختلفـــة عند منطقـــة البرلس بشمال دلتـــا النيل بمصر

أمين مصطفى غيث* ، ممدوح أحمد عبد الله ، إبراهيم فهمي الفيومي و ناصر طوبار
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المستخلص . يتضمن هذا البحث دراسة وتوزيع المعادن الثقيلة والخفيفة في العينات الرملية التي جُمعت من المنطقة الساحلية لبحيرة البرلس شمال دلتا النيل حيث تم مناقشة حركة الرواسب ومصدرها .

ومن فحص المعادن الخفيفة بعد صبغها لوحظ أن نسبة الفلسبار الكلي تقل من الشاطيء إلى الحاجز الساحلي باتجاه الأرض وهذا يدل على أن التغير الملحوظ على الساحل له علاقة بعمليات التوزيع ودرجة الفرز .

ولـقـد سجـلت رمـال الجـزر والحـافـة الـغـربية من البحـيرة نسب عالية من الكـوارتـز/الفلسبـار ، كما أظهـرت رمـال الشـاطيء درجة نضج أعلى من رمال الحاجز الشاطيء ، بينما عكست رمال المصارف درجة نضج رديئة نتيجة لنشأته النهرية .

كما لوحظ أن تآكـل شرق بوغاز البرلس ساهم في تركيز نسبة المعادن الثقيلة في رمال الشاطيء حيث امتازت الرمال الشاطئية الساحلية شرق مدخل البرج بأنها غنية بالمعادن الثقيلة عنها غرب مدخل البرج ، كما وجد أن معظمها من المعادن ذات الكثافة العالية مثل الزيركون - الروتيل ، التورمالين والجارنت ، كما وجد أن رمال الساحل الغربي لمدخل البرج تحتوى على نسب عالية من معادن الهورنبلند ، الاوجيت والابيدوت وهذا يرجع إلى تأثير عوامل النقل مثل الأمواج والتيارات الساحلية السائدة بالمنطقة .

وقد تم دراسة توزيع المعادن الثقيلة في كل من رمال الشاطيء والحاجز الشاطيء حيث عكست زيادة في معدن الاوجيت في اتجاه البحر وقلة في نسب الهورنبلند والابيدوت في اتجاه الأرض .

كما درست العـلاقة بين نسبة المعادن المعتمة ونسبة الهورنبلند وأيضًا بين نسبة معادن الزيركون - التورمالين - الروتيل - الجارنت - ونسبة الهورنبلند ولقد نجحت هذه المقارنة في التفرقة بين رمال البيئات الساحلية المختلفة .