Bull. Inst. Oceanogr. & Fish., ARE, 13 (1), 1987: 1 - 23.

SEDIMENTOLOGICAL STUDIES OF THE QUATERNARY SEDIMENTS IN SOME BORE - HOLES, NORTH - EASTERN COAST OF SINAI, EGYPT.

M.A. EL-ASKARY, M.W. EL-DAKKAK, F.A. EL-NOZAHY AND N.A. MOHAMED.

Faculty of Science, Alexandria University.

ABSTRACT

The present study is performed on the subsurface sediments of El-Arish-Rafah district. The different aspects for stydying the borehole samples include their texture, heavy minerals content and clay mineral types. The samples of El-Arish boreholes were found to belong to ten textural classes, those of Zewied boreholes belong to six textural classes while the samples of Rafah boreholes belong to nine textural classes. Rafah samples are finer and better sorted than those of El-Arish and Zewied. Gravels are mainly concentrated in boreholes nearer to the wadies. They showed wider distribution in the eastern parts of wadies than the western parts. This may be due to the marine current which shifted them towards the east.

The recorded heavy minerals include opaques, unstable minerals (amphibole and pytoxene), metastable minerals (epidote, granet and kyanite) and ultrastable minerals (rutile, zircon and tourmaline). Two possible sources are supposed to be responsible for the derivation of heavy minerals. The major portion of them had been derived from the Nile sediments while a minor portion is believed to be derived from the south with materials that have been poured in the sea through the different wadies. The study of clay minerals showed that montmorillonite, illite and leeser amounts of kaolinite are the main components of the muddy and clayey samples.

INTRODUCTION

The area under consideration lies at the extreme northeastern part of Sinai between El-Arish at the west and Rafah at the east (Fig 1). Many boreholes were drilled in the area. Samples of nine of these boreholes, Kindly provided by the authorities of Regwa Company, are the subject

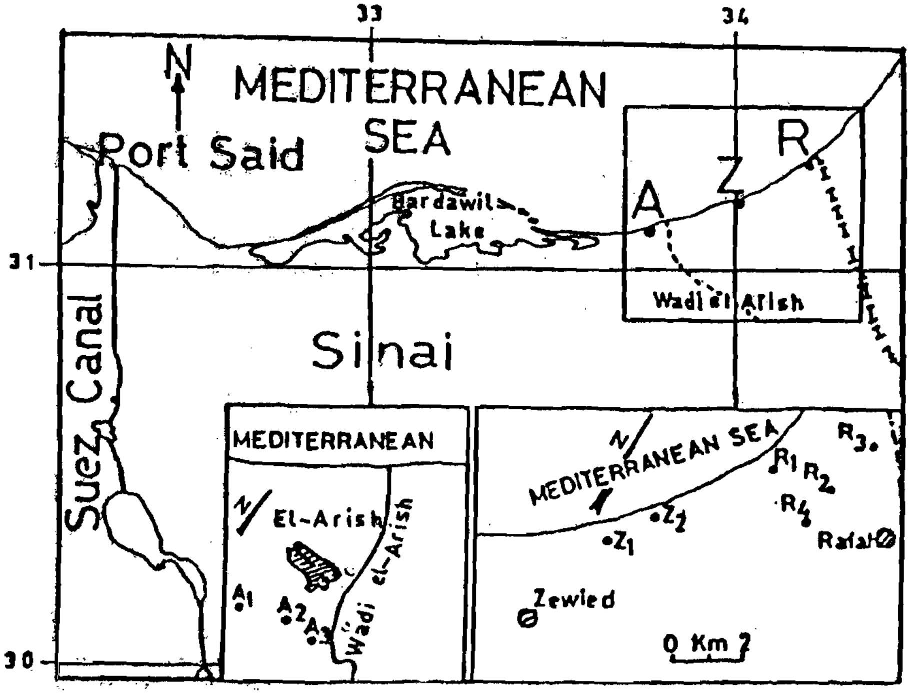

Fig. 1
Map showing the area of study and location of boreholes at El-Arish (A), Zewied (Z) and Rafah (R)

of this study. The selected boreholes are distributed in three main localities: El-Arish (represented by 3 boreholes A_1,A_2 and A_3), Zewied (represented by 2 boreholes Z_1 and Z_2) and Rafah (represented by 4 boreholes R_1,R_2,R_3 and R_4). The studied sediments range in depth between 32 to 84m. from the ground surface.

The main part of the area is covered by sand dunes which effectively obscure all the underlying formations. The slope of the dunes is gradual to the north on the coastal side and steeper on the inland side.

Many wadies traverse the area trending from southeast to north, the most important and largest of which is wadi El-Arish.

Brief studies on the topography, ground water and the type of surface sediments of northern Sinai were given by Hume (1906), Moon and Sadek (1921), Paver and Jordan (1956), Malek (1956), Shata (1959), Shukri and Philip (1959) and El-Dakkak and Mohamed (1986). The latter authors studied in detail the paleoenvironments of the present borehole sediments by means of foraminifera.

The aim of the present study is to determine the different classes of the sediments on the basis of the proportion of their components. Granulometric study aimed to determine the textural classes of the sediments and to investigate the environmental conditions of the different classes.

Heavy mineral analysis of the different units is performed to help in the environmental interpretation and rough determination of the age of sediments. The clay mineral content of some muddy samples is investigated by derivatographic and x-ray diffraction analyses.

RESULTS AND DISCUSSION

Grain Size Analysis:

The grain size analysis data are plotted on Folk's (1954) diagram (Fig. 2). The samples of El-Arish boreholes were found to belong to ten textural classes: sand, silty sand, sandy silt, sandy mud, sandy gravel, gravel, gravely sand, gravely mud, slightly gravely sandy mud and muddy sand gravel. The samples of Zewied boreholes belong to six textural classes: gravel, sandy gravel, gravely sand, gravely muddy sand, muddy sand and silty sand, while the samples of Rafah boreholes belong to nine textural classes: sand, silty sand, gravely sand, slightly gravely sand, muddy sand, gravely muddy sand, slightly gravely muddy sand, sandy silt and sandy gravel. Figure 3 shows the changes of sediment type with depth in the different studied boreholes. The sand and slightly gravely sand units are concentrated in the upper part of the El-Arish and Rafah boreholes, while the gravel and sand gravel units form the upper part of the Zewied boreholes. Gravels dominate in El-Arish and Zewied areas and their percent decreases towards the east and the west from Wadi El-Arish. From the study of figure 4, it seems that the supply of the gravel class is mainly from Wadi El-Arish where the gravels are mainly concentrated in boreholes closer to the Wadi. The vertical distribution of gravel-sand-silt and clay percentages in the studied boreholes is shown in Fig. 5.

The data of mechanical analysis are plotted on cumulative curves (Figs 6 to 11). Average cumulative curves of the studied areas show some overlap (Figs. 12 and 13). Cumulative curves of El-Arish samples show wider grain size range than those of Zewied and Rafah (Fig. 12). The average cumulative curve of both El-Arish and Zewied areas shows some overlap while that of Rafah area is slightly deviated due to the more finer and better sorting character of its sediments. Average histograms of the three areas assured this result (Fig. 13).

The distribution curves of sand (Fig. 6) are separated into two groups. The first includes those of the upper sand samples in the two boreholes R_2 (0-38m) and R_3 (0-6m). They show a single saltation population. Visher (1969) and Gindy et al. (1982) assigned a coastal environment for sands

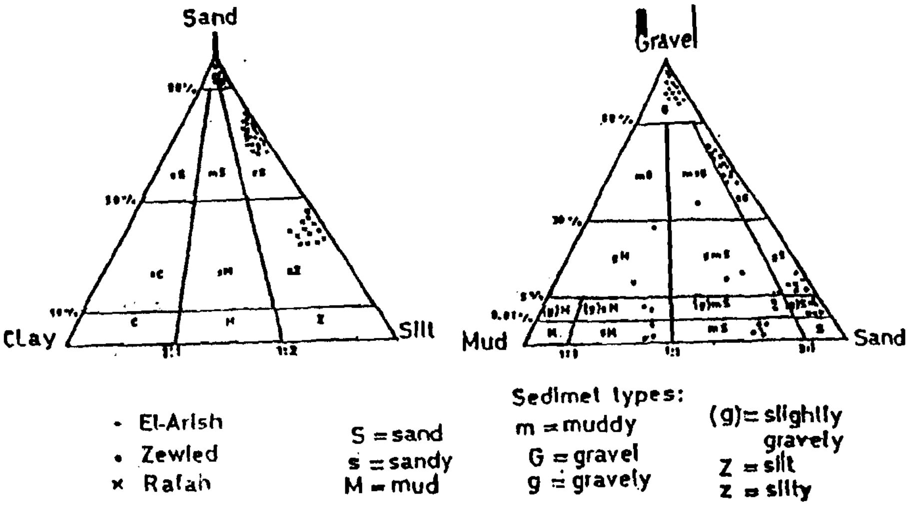

Fig. 2
Sediment types of the reconstructed sedimentary units according to the ternary plots of Folk (1954).

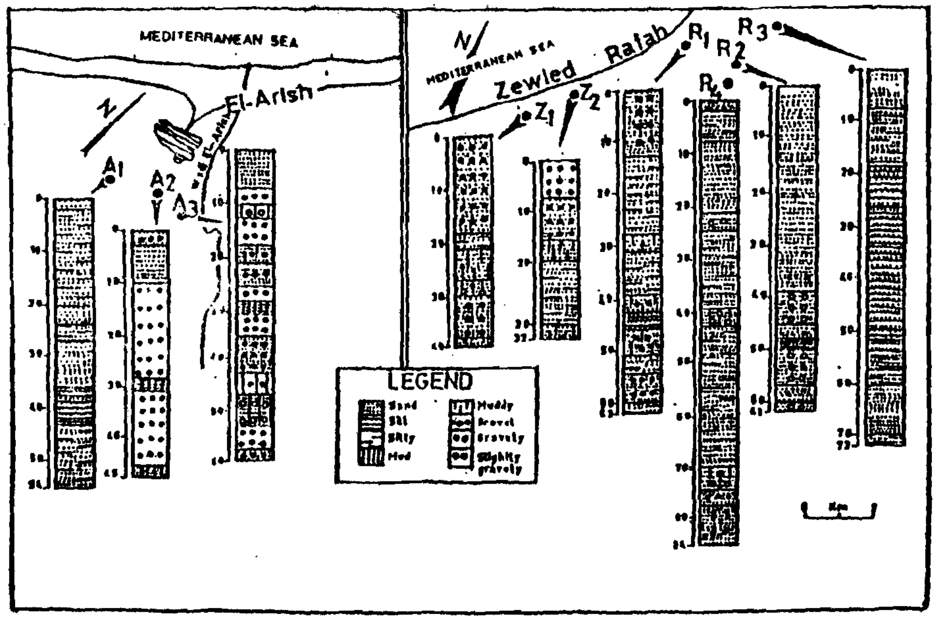

Fig. 3
Vertical distribution of sediment types in the borehole sediments of El-Arish-Rafah stretch.

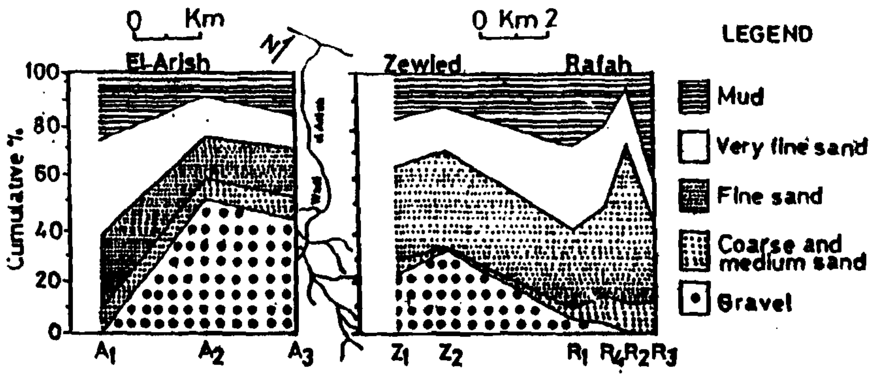

Fig. 4
Texture distribution of the borehole sediments of El-Arish, Zewied and Rafah areas.

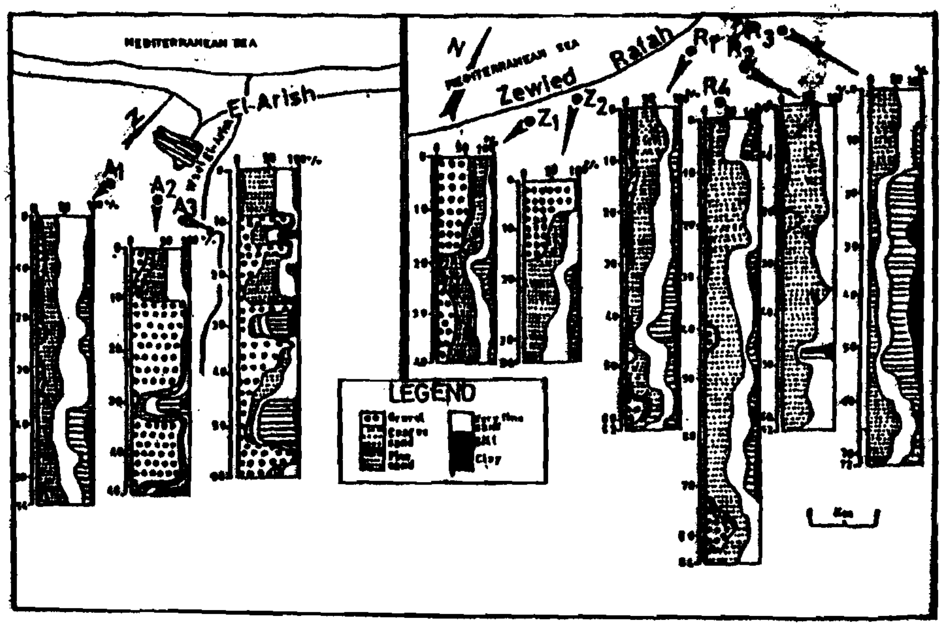

Fig. 5
Vertical distribution of gravel-sand-silt and clay percentages in the borehole sediments of El-Arish-Rafah stretch.

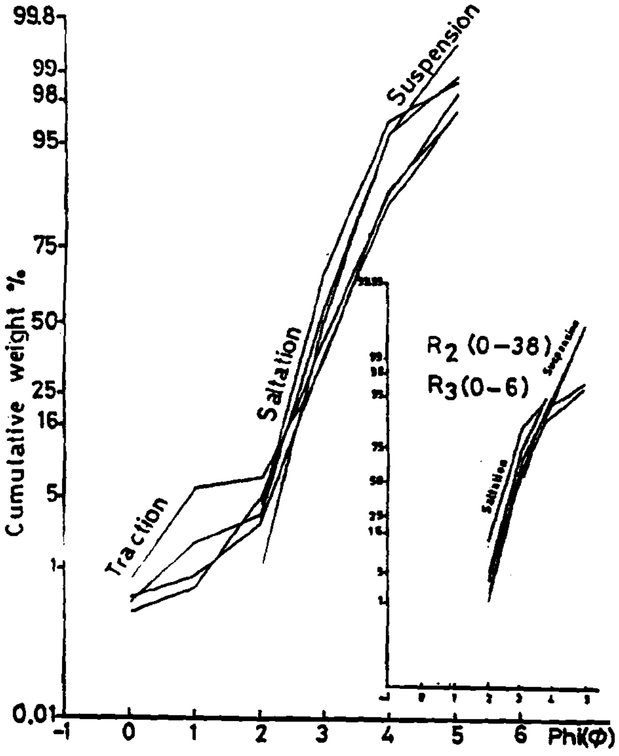

Fig. 6
Representative cumulative curves of sand unit.

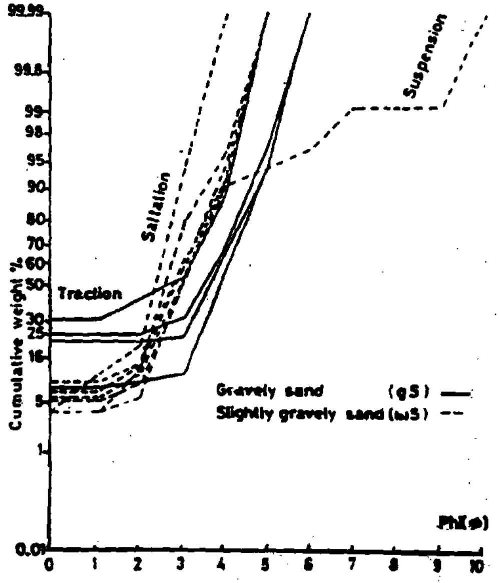

Fig. 7
Representative cumulative curves of gravely sand and slightly gravely sand units.

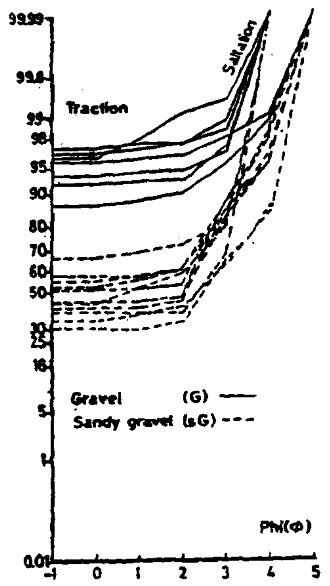

Fig. 8
Representative cumulative curves of gravel and sandy gravel units.

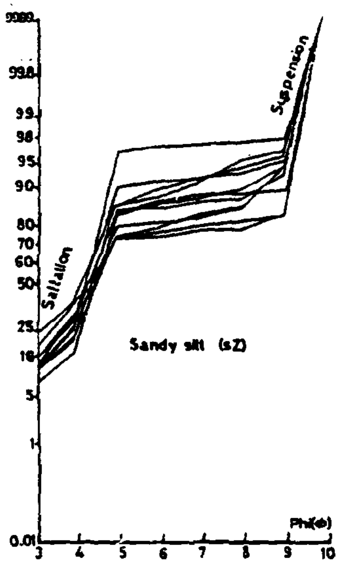

Fig. 9
Representative cumulative curves of sandy silt unit.

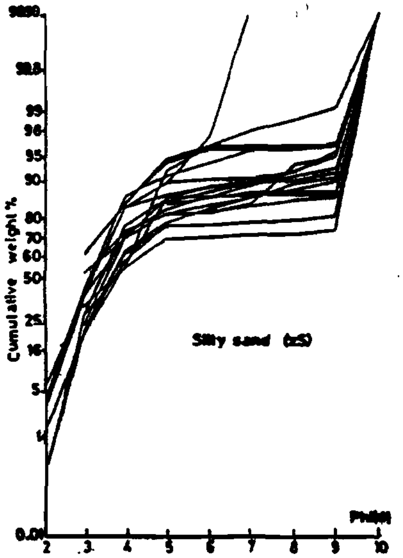

Fig. 10
Representative cumulative curves
of silty sand unit.

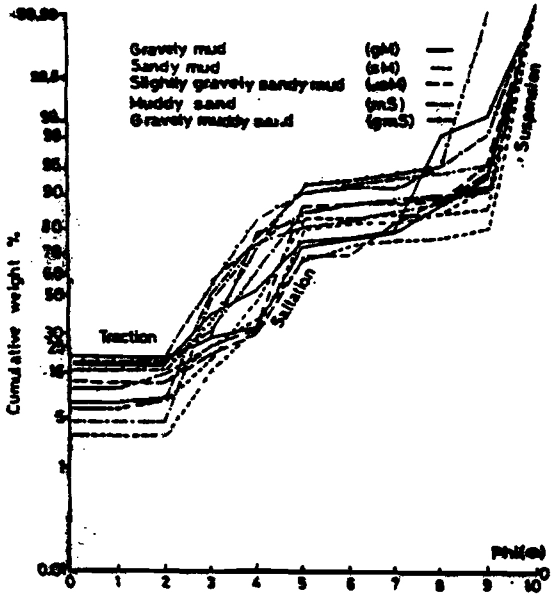

Fig. 11
Representative cumulative curves
of mud units.

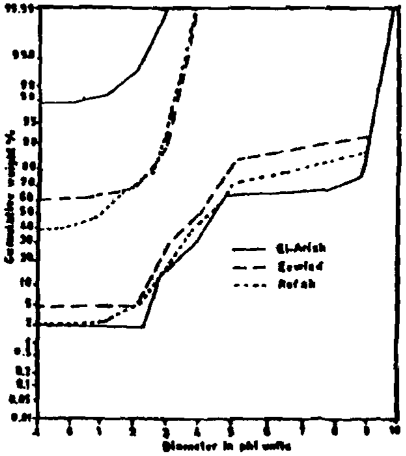

Fig. 12
An overlap of the cumulative curves
of the sediments of the studies areas.

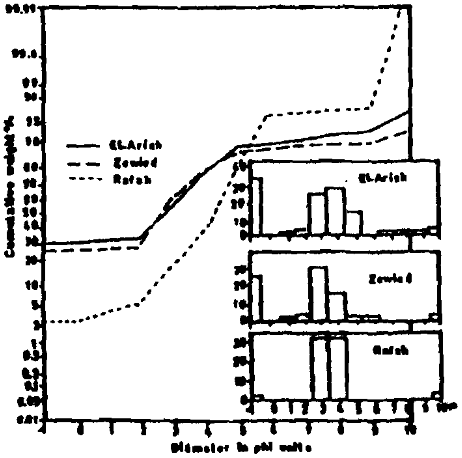

Fig. 13
Averages cumulative curves and histograms
of the sediments of the studies areas.

of similar cumulative grain size curve characteristics. The second group of sand samples shows three or four populations which, according to Visher (1969) and Gindy et al. (1982), represent sands of backshore types. This result is in agreement with that deduced from the graphic mean size Vs. standard deviation relation for sand samples (Fig. 14A). Inclusive graphic skewnees Vs. standard deviation relation gave a good separation between the sand unit samples of El-Arish from those of Rafah. El-Arish samples occupy the river field while Rafah samples occupy the beach field (Fig. 14B).

The cumulative curves of the gravel and sandy gravel units (Fig. 8) are bimodal and are very comparable to those of the gravely sand and slightly gravely sand (Fig. 7). Emery (1955) mentioned that there are four main possiple sources of beach pebbles: sea-cliff erosion, stream discharge, sea-floor erosion and long shore transport from one or more of the first three primary sources. Stream discharge is supposed to be the possible source of the gravely sediments under investigation.

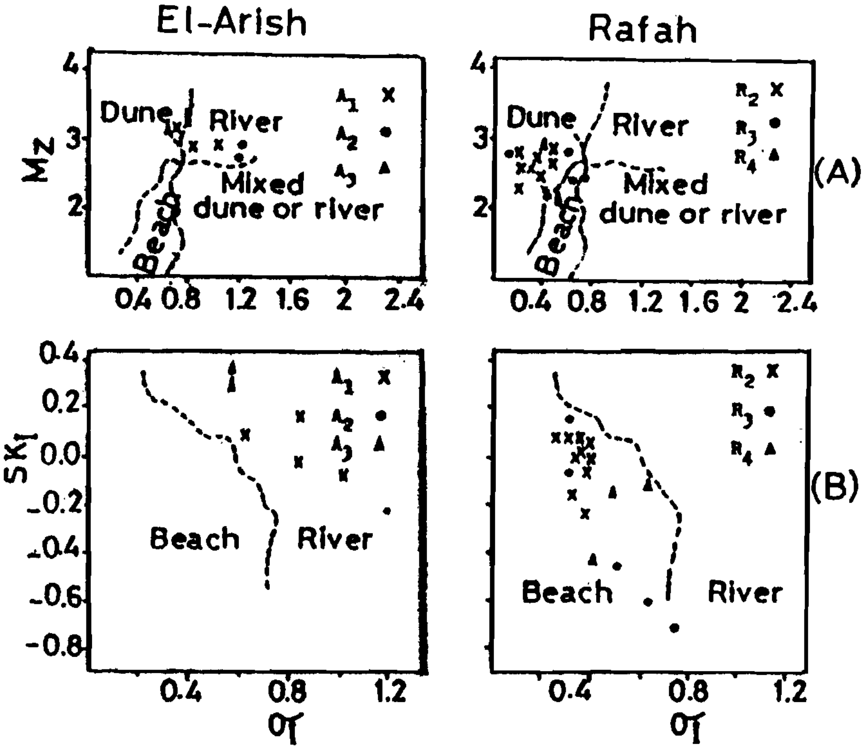

Fig. 14

Scatter giagrams for sand samples

(A)- Graphic mean size Vs. standard deviation (Boundaries after Friedman, 1961 and 1967)

(B)- Inclusive graphic skewness Vs. standard deviation (Boundary line after Friedman, 1967).

The cumulative curves of samples of sandy silt units show one saltation and one suspension population, while those of silty sand have two saltation populations and one suspension population. The cumulative curves of samples of the mud units have four populations: one traction, two saltation and one suspension populations.

Analyses of hydraulic conditions of sedimentation by use of grain-size image have shown the preferential mechanisms by which grains of certain sizes are transported. The grain size image was first presented by Passega (1957). The diagram is constructed by plotting C (one percentile in microns) against M (median diameter in microns) on logarithmic paper (Fig. 15). El-Arish and Zewied samples are characterized by the presence of a grain-size gap between 500 and 1000 µ. This gap marks well the change from transport controlled by turbulence during flooding of Wadi El-Arish and other smaller wadies at Zewied, to transport in which the main motive force, due to the drag of the water is horizontal in the basin after flooding. Samples of Rafah boreholes and borehole (A_1) at El-Arish do not show such gap as their locations are relatively far from the wadies.

The environmental interpretation of the sand grains examined by the scanning electron microscope reveals the effects of chemical action (Fig. 16: A, B, D, E, F, G, H) and mechanical action (Fig. 16:C). This conclusion is supported by the interpretations given by El-Askary and Frihy (1984) and El-Fishawi and Molnar (1984).

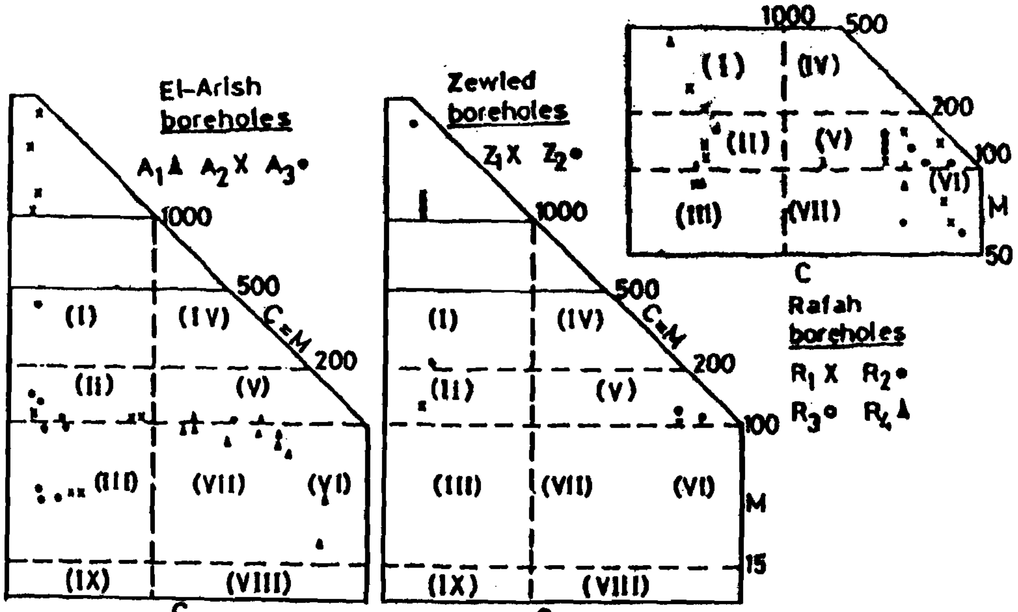

Fig. 15
Plots of El-Arish, Zewied and Rafah borehole samples on the-C-M diagram of Passega and Byramjee (1969).

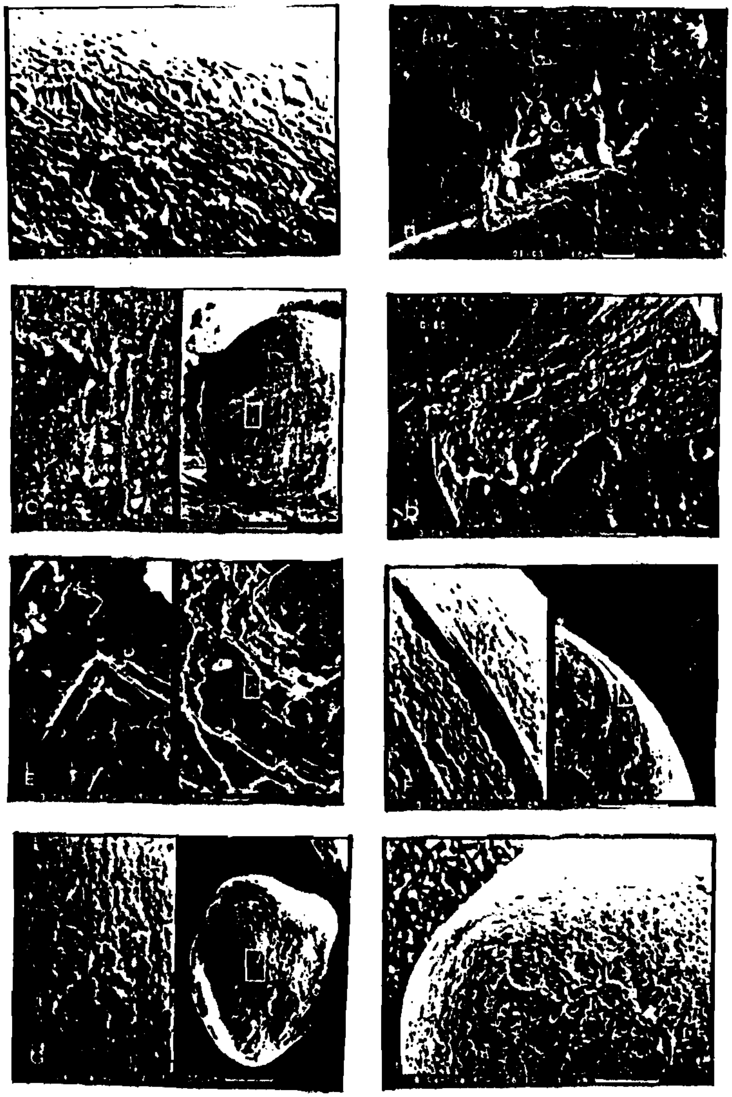

Fig. 16

SEM photographs of some sand grains.

A: Silica precipitation with attachment materials (beach sand, Al-Arish).

B: Groove in association with silica precipitation (chemical beach action, Al-Arish)

C: Flaking and scales (mechanical action, Al-Arish).

D: Blocky conchoidal breakage pattern (beach sand,Zewied).

E: Stepped cleavage (beach sand, Zewied).

F: Curved scratches (beach sand, Rafah).

G and H: Silica precipitation 8chemical beach action, Rafah).

Heavy Mineral analysis :

The aim of this study is to determine the heavy mineral contents and their vertical distributions through the studied boreholes (Figs. 17 and 18). The 4 Ø fraction of 50 samples and the 5Ø fraction of 31 of these samples led to recognize the following heavy mineral groups: opaques, unstable minerals (amphiboles and pyroxenes), metastable minerals (garnet, epidote and Kyanite) and ultrastable minerals (zircon, tourmaline and rutile). The average percentage frequency of heavy minerals in the three studied areas is listed in table (1). The determination of the index figure of the 4Ø fraction of El-Arish samples shows that it ranges from 0.003 to 0.04 with an average of 0.016 and from 0.03 to 0.058 with an average of 0.039 for Zewied samples while the range is from 0.006 to 0.062 with an average of 0.04 for Rafah samples. Similarly, the index figure of the 5 Ø fraction of El-Arish samples ranges from 0.02 to 0.065 with an average of 0.043 and from 0.008 to 0.18 with an average of 0.081 for Zewied samples while the range is from 0.03 to 0.18 with an average of 0.088 for Rafah samples. These data indicate that there is an eastward increase of index figure values from El-Arish to Rafah. This is most probably caused by the eastward longshore currents which transport a considerable portion of Nile sediments to the area under investigation. The vertical distribution of the index figure shows that the upper portions of the boreholes contain relatively higher concentration of heavy minerals (Figs. 17 and 18).

The following are brief remarks for the recorded heavy minerals:

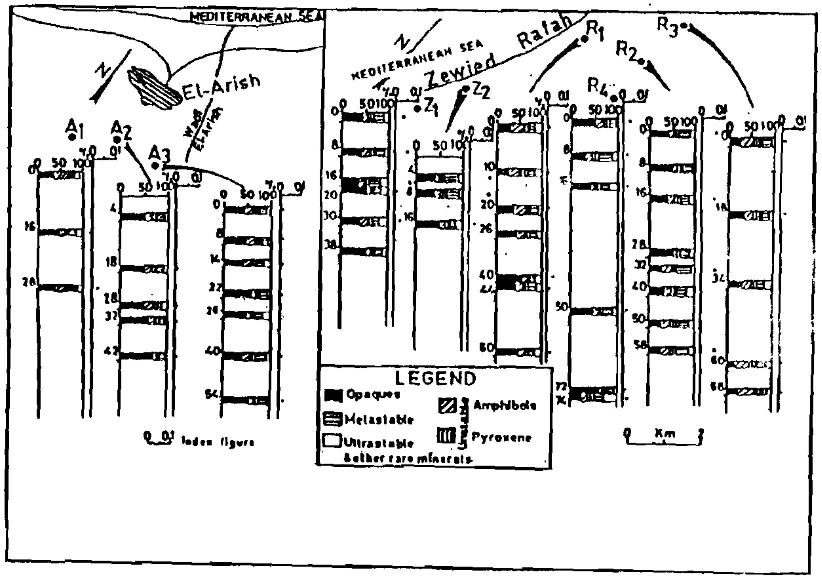

Fig. 17

Vertical distribution of the heavy mineral groups and index figure in the 4 fraction of the borehole sediments of El-Arish-Rafah stretch.

TABLE (1)

Average percentage frequency of heavy minerals in the three studies areas.

	El - Arish		Zewied		Rafah	
	40	50	40	50	40	50
Opaques*	49.4	58.5	46.5	66.8	39.8	62.5
Amphiboles	25.2	16.8	22.8	15.2	27.6	17.0
Pyroxenes	18.1	14.3	16.3	10.9	20.3	14.8
Epidote	21.5	13.6	19.3	8.8	17.5	10.8
Garnet	16.1	7.9	16.2	6.9	17.5	10.8
Staurolite	7.9	8.7	7.0	7.4	4.1	8.0
Rutile	3.0	7.6	4.4	9.6	5.0	7.2
Zircon	2.6	22.8	3.3	34.0	2.1	29.5
Monazite	1.1	1.4	2.8	1.7	1.6	1.4
Biotite	0.1	0.8	0.2	0.4	0.1	0.8
Tourmaline	2.0	1.9	2.5	1.6	1.0	0.8
Titanite	2.0	2.0	2.8	1.5	2.3	0.9
Kyanite	0.4	2.2	2.4	2.0	1.0	0.8

(*) The frequency of opaques was not taken into consideration when calculating the frequency of other minerals.

Opaques :

Opaques are represented mainly by magnetite and ilmenite while hematite and limonite are very rare. Ilmenite is more abundant than magnetite in the 4 Ø fraction and vice versa in the 5 Ø fraction. Opaques show a random vertical variation. The average frequency of opaques in the 4 Ø fraction decreases eastward from El-Arish to Rafah while that of the 5 Ø fraction increases in the same direction.

Non-opaque Heavy Minerals:

Amphiboles and pyroxenes are recorded in all the studied samples, and their frequency in the 4 Ø fraction is higher than in the 5 Ø fraction. Amphiboles are represented mainly by hornblende (prismatic and saw-

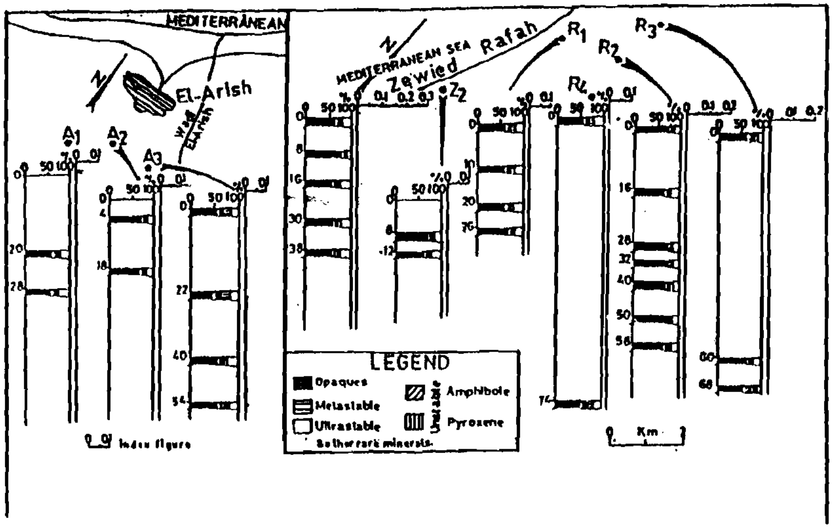

Fig. 18
Vertical distribution of the heavy mineral groups and index figure in the 5 fraction of the borehole sediments of Al-Arish-Rafah stretch.

edged grains of green, bluish green and less common brown). Pyroxenes are represented by augite of the yellowish green and the brownish violet varieties. It is present at irregular, sub-angular to subrounded grains. Inclusions of iron oxides are recorded in some grains. Epidote group is represented by pistachite in most samples as lemon yellow and greenish yellow grains. Garnet is represented mainly by pink and less commonly by colourless varieties. It is present in subangularly shaped grains, some of them contain inclusions of iron oxides. Kyanite is recorded in some samples. Rutile is present in red or reddish brown varieties. Rutile grains are generally prismatic in shape with rounded pyramidal terminations. Zircon is found as colourless small prismatic, bipyramidal or broken grains with rounded edges in some of them. The recorded tourmaline variety is pleochroic from brownish red to dirty brownish green. Inclusions of iron oxides are frequent. Of the remaining minerals, staurolite is recorded in a variety that is usually pleochroic from golden yellow to dark brown, pale yellow or even colourless. Biotite, monazite and titanite are rarely and haphazardly recorded in the studied samples.

Figure 19 shows comparative frequency distribution of the main heavy mineral species in El-Arish, Zewied and Rafah. The histograms indicate that there are some differences in the frequency percentages of the individual heavy minerals in the three areas. The 4 Ø fraction is richer in amphiboles, pyroxenes, epidotes, garnet, and staurolite and poorer in opaques and zircon than the 5 Ø fraction. Fig. 20 shows that all heavy minerals are fluctuated in the different lithological units.

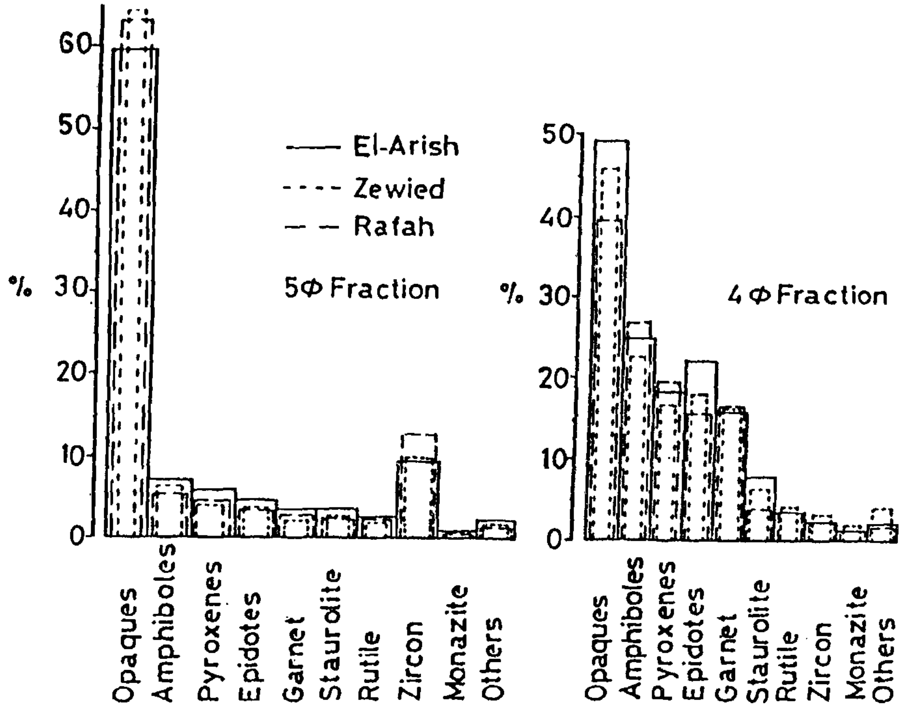

Fig. 19
Average histrograms of heavy minerals in the studied areas.

The heavy mineral content of the studied sediments shows more or less close similarities to those of the Nile (Shukri, 1950), Damietta-Port Said stretch (Anwar et al., 1981) and Arish-Ghaza stretch (Shukri and Philip, 1959) (Fig. 21). This may indicate that the major part of the heavy minerals of El-Arish - Rafah sediments had been derived from Nile sediments.

The studied samples are plotted on the pyroxene, amphibole and epidote ternary diagram of Shukri and Azer (1952) (Fig.22). The plots indicate that the investigated sediments are of Paleolithic age.

Clay Mineral analysis :

Five muddy samples were chosen for derivatographic analysis. The thermal data are tabulated in table 2 and are illustrated in the form of derivatograms (Fig. 23). Identification was based on data given in Todor (1976). Nine muddy samples are selected for clay mineral determination by X-ray diffraction analysis (Fig. 24). Identification of clay minerals was based on the scheme proposed by Warshaw and Roy (1961), Smith (1967), Grim (1968) and Barry (1972). Quantitative values of the clay minerals were obtained (table 3) following the procedure given by Biscaye (1965).

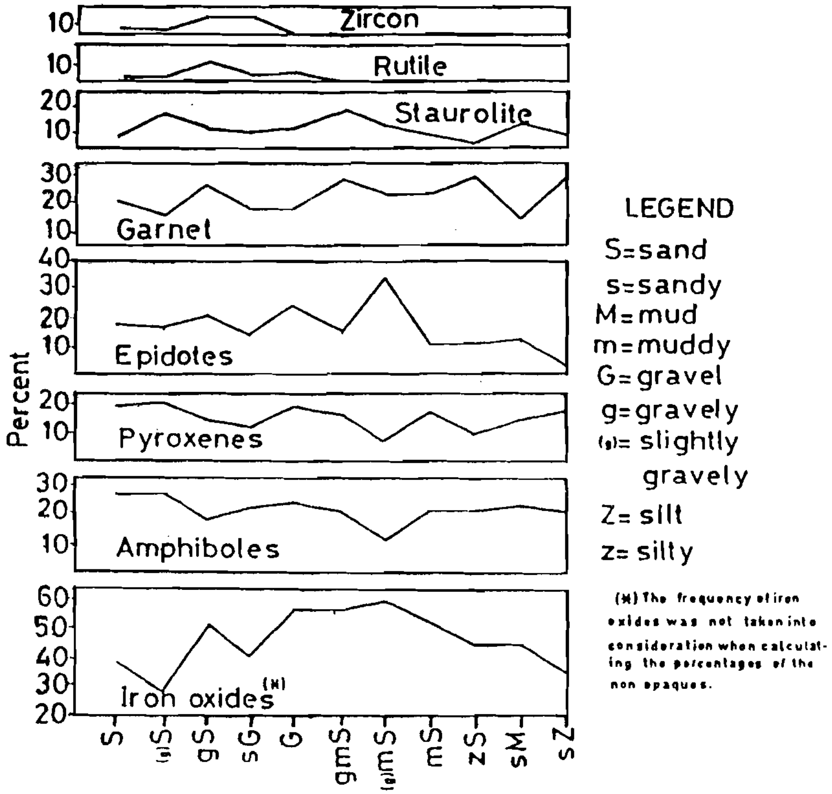

Fig. 20
Relative frequency of the main heavy minerals recorded in the different lithologic units.

Both the thermal and X-ray diffraction analyses show that montmorillonite, illite and lesser amounts of kaolinite are the main components of the muddy and clayey samples.

SUMMARY AND CONCLUSION

Sedimentological studies are carried out on the sediments of nine boreholes penetrated to depths ranging between 32-84m. The borehols are located between El-Arish and Rafah in the extreme northeastern part of Sinai.

The results of grain size analysis are plotted on Folk's diagrams. Different textural classes are recognized which differ in type and number from one locality to another.

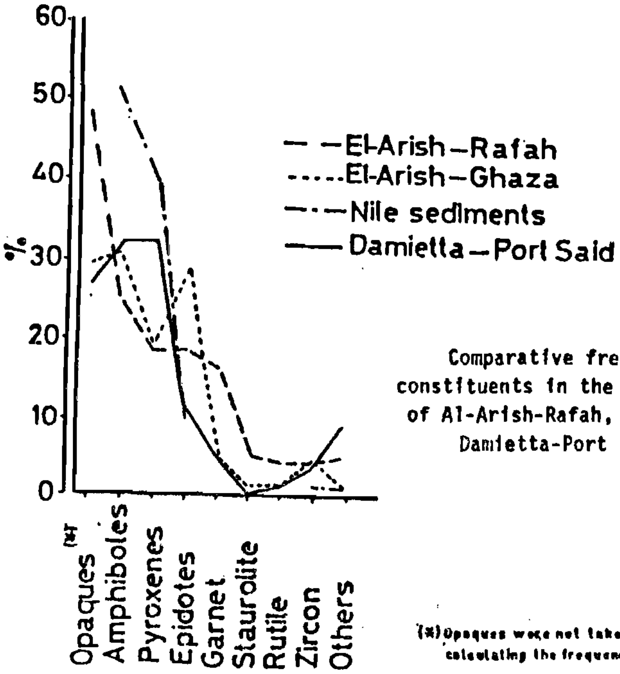

Fig. 21

Comparative frequency percentages of heavy mineral constituents in the 4 fraction of the borehole sediments of Al-Arish-Rafah, beach sediments of El-Arish-Ghaza and Damietta-Port Said stretches and Nile sediments.

(*) Opaques were not taken into consideration when calculating the frequency of other heavy minerals.

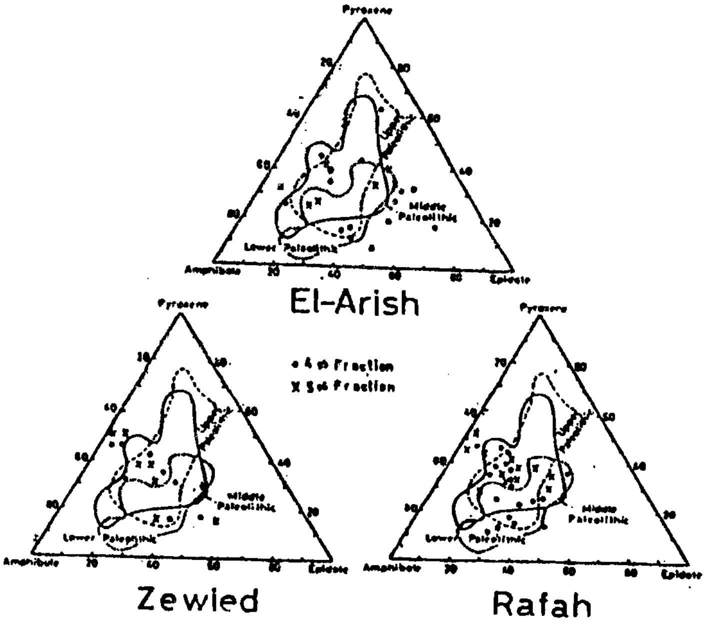

Fig. 22

Plots of El-Arish, Zewied and Rafah samples on the pyroxene-amphibole-epidote ternary diagram. (Boundaries after Shukri & Azer, 1952).

TABLE 2

Results of differential thermal and thermogravimetric analyses

Sample No.	DTA T°C END	DTA T°C EXO	DTG °C	TG mg	TG loss %	Description of peak	Constituent minerals
A_1	100	---	90	25	2.5	Sym., moderate, broad	Montmorillonite with minor illite
	510	---	490	25	2.5	Asym., small, broad	
	550	---	---	---	---	Sym., minor, narrow	
	680	---	680	100	10	Sym., small, broad	
	750	---	740	50	5	Asym., minor, broad	
	---	820	---	---	---	Asym., small, broad	
Z_1	110	---	80	25	2.5	Sym., small, broad	Montomorillonite with illite
	500	---	490	25	2.5	Asym., small, broad	
	520	---	---	---	---	Sym., minor, narrow	
	670	---	650	22	2.2	Sym., small, broad	
	820	---	810	75	7.5	Asym., large, broad	
	---	860	---	---	---	Asym., small, broad	
Z_2	120	---	[illegible]	30	3	Sym., small, broad	Montmorillonite with illite
	500	---	480	10	1	Asym., small, broad	
	570	---	---	---	---	Sym., small, narrow	
	650	---	620	25	2.5	Sym., small, broad	
	820	---	800	100	10	Asym., large, broad	
	---	840	---	---	---	Asym., small, broad	
R_1	130	--	100	50	5	Sym., moderate, broad	Mainly montmorillonite
	---	---	---	---	---	Asym., with shoulder	
	510	---	500	40	4	at high temp. side, small, broad	
	780	---	775	50	5	Asym., moderate, broad	
	---	810	---	---	---	Asym., small, broad	
R_3	110	---	90	25	2.5	Asym., small, broad	Montmorillonite with illite
	520	---	500	25	2.5	Asym., small, broad	
	570	---	----	---	---	Sym., small, narrow	
	660	---	650	50	5	Sym., small, broad	
	780	----	770	50	5	Asym., small, narrow	
	---	810	---	---	---	Asym., small, broad	

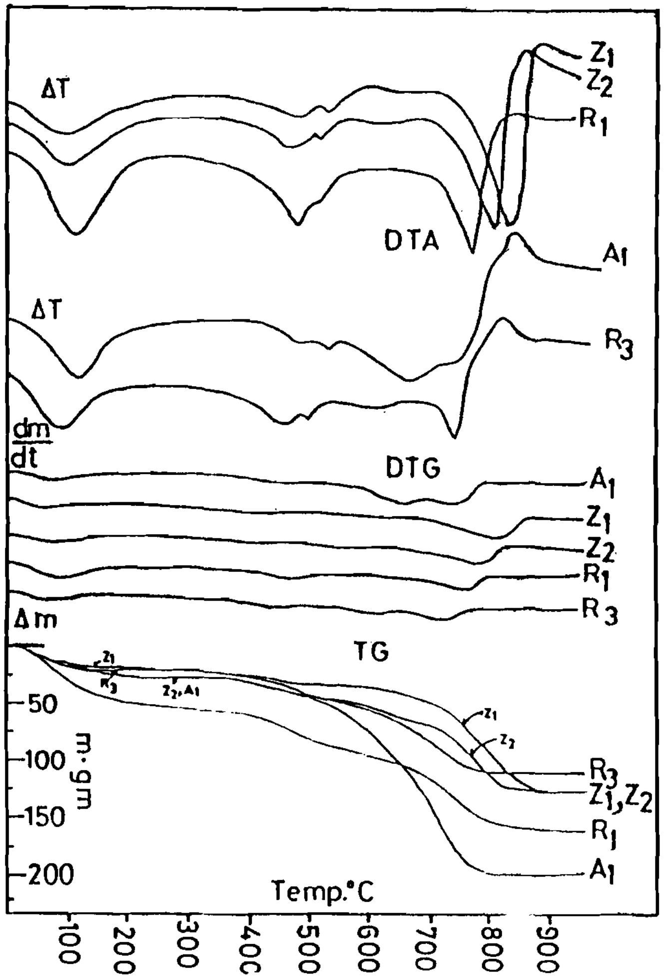

Fig. 23
Derivatograms of representative muddy samples.

The textural distribution throughout the different studied boreholes shows that gravels dominate in El-Arish and Zewied areas and their percent decrease towards the east and west from Wadi El-Arish. This indicates that the supply of gravels is mainly from Wadi El-Arish.

The data of mechanical analysis are plotted on cumulative curves. The average cumulative curve of both El-Arish and Zewied areas shows some overlap while that of Rafah area is slightly deviated due to the more finer and better sorting character of its sediments. The average histograms of the three areas assured this result.

Inclusive graphic skewness vs. standard deviation relation gave a good separation between the sand unit samples of El-Arish from those of Rafah. El-Arish samples occupy the river field while those of Rafah occupy the beach field.

Table (3)

Nature of sediments and percentage of clay minerals

Area	Well No.	depth	Sed. type	Mont.	Illite	Kaolinite
El-Arish	A_1	40-42	Sandy silt	74	10	16
	A_2	28-30	Sandy mud	75	20	5
	A_3	28-30	Sandy mud	90	7	3
Zewied	Z_1	18-20	Silty sand	78	20	2
	Z_2	32-34	Muddy sand	82	3	15
Rafah	R_1	32-34	Silty sand	94	4	2
	R_2	48-50	Sandy silt	80	12	8
	R_3	42-44	Sandy silt	88	10	2
	R_4	54-56	Silty sand	90	2	8

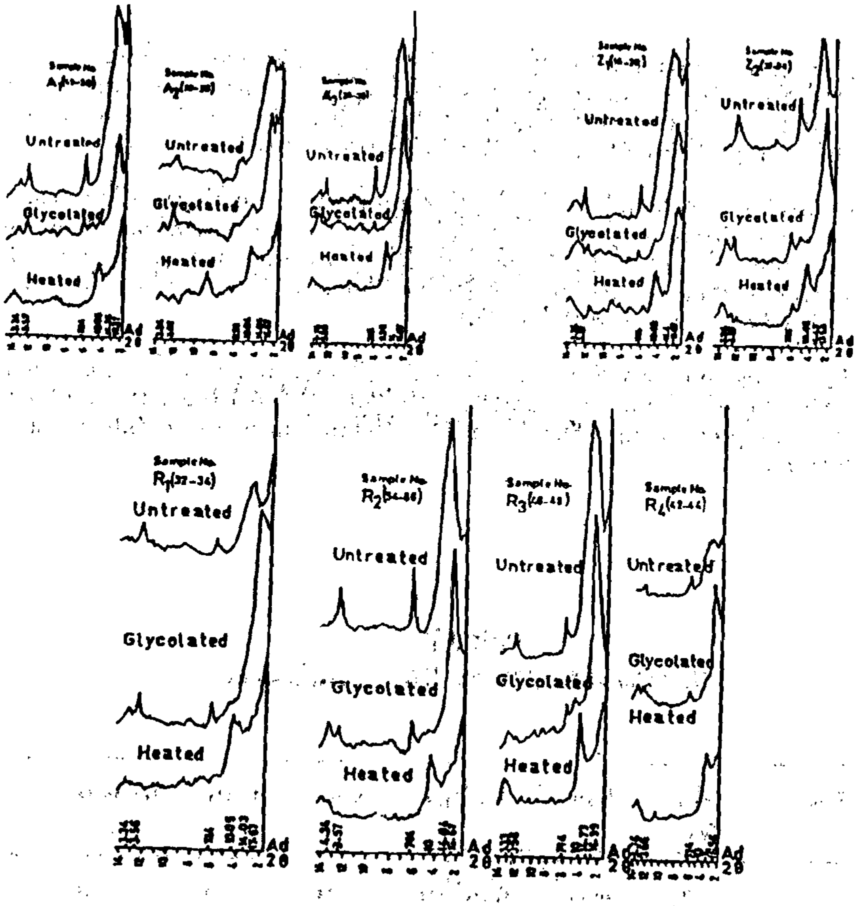

Fig. 24

X ray diffraction patterns of representative muddy samples.

The heavy mineral study reveals the presence of opaques, unstable minerals (amphibole and pyroxene), metastable minerals (epidote, garnet and Kyanite) and ultrastable minerals (rutile, zircon and tourmaline).Two possible sources, mainly Nile sediments and to a lesser extent from materials coming from the southern wadies, are supposed to be responsible for their derivation.

Montmorillonite, illite and kaolinite are the main components of the muddy and clayey samples.

REFERENCES

Anwar, Y.M., El-Askary, M.A. and Lotfy, M.F., 1981. Mineralogy of sediments of Damietta-Port Said district. **Jed. Jour. Mar. Res., 1: 47-63.**

Barry, L.G., 1972. Selected powder diffraction data for minerals. Joint comitte powder diffraction standards, 5 marthmore, 1081 p.

Biscaye, P.E., 1965. Mineralogy and sedimentation of Recent deep-sea clay in the Atlantic Ocean and adjacent seas and oceans. **Geol. Soc. Am. Bull.**, 76: 803-832.

El-Askary, M.A. and Frihy, O.E., 1984. Environmental interpretation of sand grain surface textures in the Rosetta and the Damietta promontories along the Nile Delta coast, Egypt. **N.Jb. Geol. Palaont. Mh.**, 709-716.

El-Dakkak, M.W. and Mohamed, N.A., 1986. Foraminifera as environmental indicators in some Holocene borehole samples of El-Arish-Rafah District, Sinai, Egypt. **Bull. Inst. Oceanogr. and Fish.,Acad.Sci.Res.**, 12: 3548.

El-Fishawi, N.M. and Molnar, B. 1984. Distinction of the Nile Delta coastal environments by scanning electron microscopy: A statistical evaluation. **Acta Mineralogica-Petrographica**, Szeged, XXXVI/2, 247259.

Emery, K.O., 1955. Grain size and marine gravels. **Jour. Geol.**, 63: 39-49.

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. **Jour. Geol.**, 62: 345-359.

Gindy, A.R., El-Askary, M.A. and El-Fishawi, N.M., 1982. The skewnessmedian environmental discriminator for some recent and ancient sediments from Egypt. **N. Jb. Geol. Palaoot. Mh.**, H. 12: 705-722.

Grim, R.E., 1968. **Clay Mineralogy.** Mc Graw-Hill, New York, 596 p.

Hume, W.F., 1906. **The topography and geology of the peninsula of Sinai,** Egypt. Surv. Dept., Cairo, 280 p.

Malek, T.K., 1956. Soil survey of the northwest Sinai project. **Publ. L'Inst. Desert D'Egypte**, No.7.

Moon, F.W. and Sadek, H., 1921. Topography and geology of northern Sinai. **Petrol. Research Bull.**, 10, Government Press, Cairo, 154 p.

Passega, R., 1957. Texture as characteristic of clastic deposition. **Bull. Am. Ass. Pet. Geol.**, 41 ,9: 1952-1984.

Paver, G.L. and Jordan, J.N., 1956. Report on reconnaissance hydrological and geophysical observations in north Sinai coastal area of Egypt. **Publ. L'Inst. Desert D'Egypte**, No. 7.

Shata, A., 1959. Ground water and geomorphology of the northern sector of Wadi El-Arish basin. **Bull. Soc. Geograph, Egypt**, 32: 247-262.

Shukri, N.M., 1950. The mineralogy of Egyptian sediments. **Bull. de L'Inst. du Desert d'Egypte**, Tome III-No. 1.

Shukri, N.M. and Azer, N., 1952. The mineralogy of Pliocene and more recent sediments in Fayum. **Bull. Inst. Desert**, 1: 10-53.

Shukri, N.M. and Philip, G., 1959. The mineralogy of some Recent deposits in the Arish-Ghaza area. **Bull. Fac. Sci.**, Cairo Univ., 35: 73-85.

Smith,H.C., 1967. X-ray powder data file 1-5, American Society for Testing Materials. Philadelphia, 685 p.

Todor, D.N., 1976. **Thermal analysis of minerals**.Abacus press., 256 p.

Visher, G.S., 1969. Grain size distribution and depositional processes. **Jour. Sed. Pet.**, 39 , 3: 1074-1106.

Warshaw, G.M. and Roy, R., 1961. Classification and a sheme for the identification of layer silicates. **Geol. Soc. Am. Bull.**, 72: 1455-1492.