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HEAVY MINERAL ANALYSIS OF LATE QUATERNARY BOREHOLE SEDIMENTS IN LAKE BURULLUS AREA, EGYPT.

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ABSTRACT

A study of four 30 m. deep boreholes drilled in the midway of the Nile Delta coast has been undertaken. The subsurface sediments from top to 30 m. depth have been divided according to their heavy mineral assemblages into two stages. The earlier stage (I), is synchronised with the upper late Paleotithic age. Its top is recorded at 24 m. depth to the south from lake Burullus and sinks deeper northwards. The recent upper stage (II) corresponds to the Neolithic age. It is subdivided into two phases. The lower or earlier phase (I) is characterised by subarial low energy condition of deposition similar to stage (I). The last phase (II) is represented by alternative brakish and marine ediments deposited under high energy condition.

INTRODUCTION

Many studies have been published on the sedimentology of the Nile delta deposits, but mineralogy and specially their heavy minerals have recieved little attention, Shukri 1949, 1951, 1954; Shukri and Azer 1952; Kholeif 1972; Kholeif et al. 1969; Nawar 1978; Frihy 1983.

The present mineralogical study in the Lake Burullus area is a continuation of previous study carried out on the western part of the Nile delta (Abu Quir area). It is shown that there are some aspects of similarity in the mineralogical characteristics of sediments between Abu Quir area and that of Burullus area.

This paper deals with the mineralogy of four boreholes, 30 m depth, taken around Lake Burullus. The Lake is one of the Nile delta lakes situated along the Mediterranean coast of Egypt in the mid distance between the two main Delta promontories Rosetta and Domietta, (Fig. 1 a). Three boreholes were taken on the barrier bar separating the lake from the Mediterranean Sea to the east from its outlet, and the fourth one on the southern border, (Fig. 1 b). Because of loss, or contamination of some of the samples collected at 1 meter depth interval, only seventy one samples have been studied. The sandy matrix of heavies has been examined in details.

The purpose of this study is to distinguish the sedimentary succession of the boreholes into different lithofacies of successive stages in the Delta development as well as the source area of each stage.

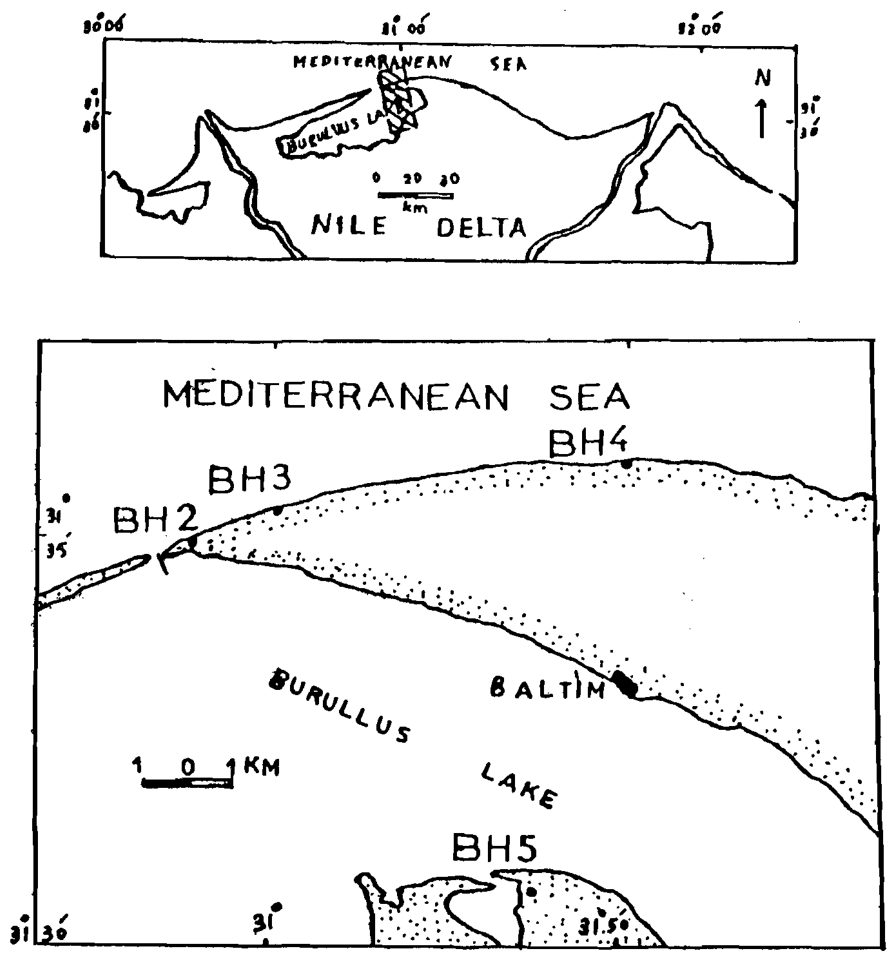

Fig. (1.a)
Area of study (hatchered area) and the boreholes around lake Burullus.

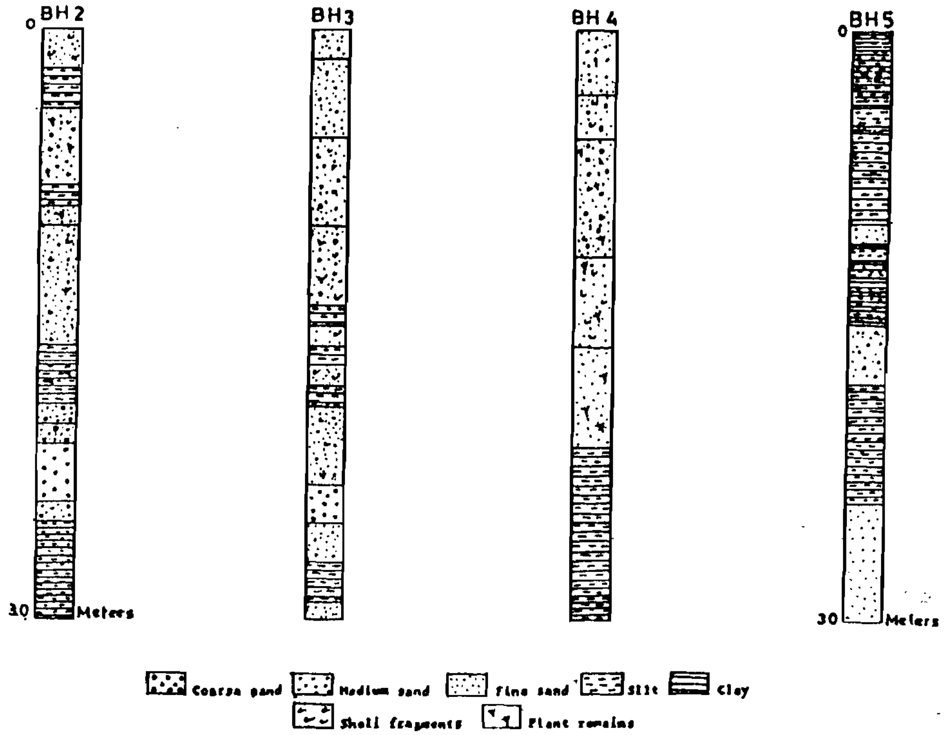

Fig. (1.b)
Lithologic logs of the four boreholes.

METHODS OF STUDY

All the samples of the present study have been obtained from Churn drill boreholes, at every meter interval. Sand samples were washed, dried and sieved to obtain the 3-4 0 fraction for mineralogical examination. The muddy samples were also examined, they were first dispersed in dilute ammonia (Lithology of the investigated boreholes is indicated on Fig. 1 b) and subsequently fractionated by decantation and seiving of the coarser fractions where the same size grade as that in sand samples was taken for this study. The 3-4 0 fraction was then treated with bromoform to separate the heavy and light minerals. The residues were then mounted in immersion oils and analyzed microscopically.

About 300 grains were counted from each crop and the relative frequencies of the minerals present were calculated. Some 36 detrital mineral species have been observed in the heavy fractions of the sediments examined in the present work.

Index Figure of Heavy Minerals:

The index figures of the analyzed samples, (Fig. 2) vary from 0.9 to 88%. In boreholes BH 2, 3, and 4 situated to the north of Lake Burullus, the index figure attains the maximum value at depth between 8 and 13 meters, with an average of 10 meters. above this limit the maximum heavy mineral percentage ranges from 46.6-60.8%) with an average of 53.2%, while below it the index figure ranges from (11.2-19.6%) and averages (14.0%).

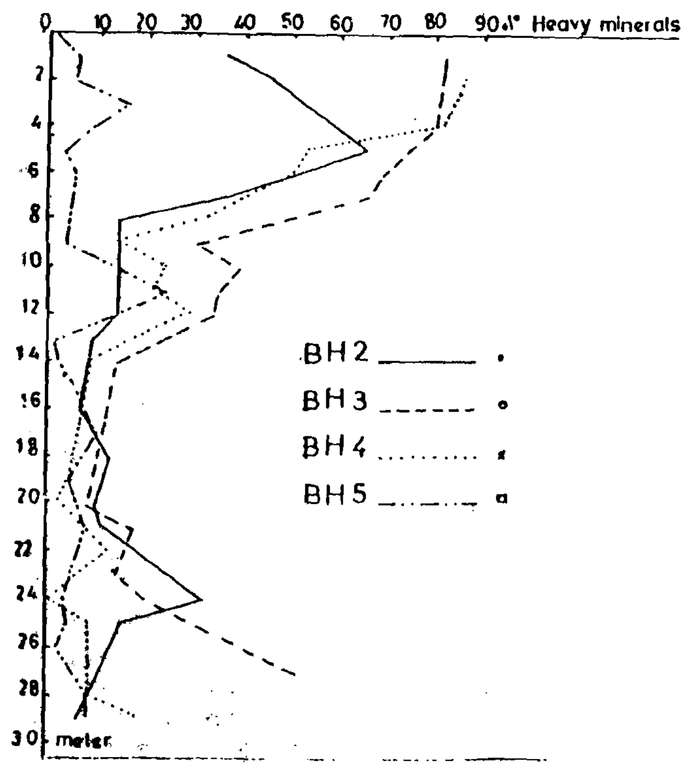

Fig. (2)
Weight percentage of the heavy minerals in the different Burullus boreholes.

Somewhat remarkable variations are observed in the index figure of heavy minerals in borehole BH5 situated on the southern border of Lake Burullus (Table, 1). The last is characterised by low weight percentages of heavies, without any difference between the layers. The index figure in BH5 ranges between (0.4 and 16.9%) and with an average of (6.8%).

The upper part of the northern boreholes (BH2, 3 and 4) contains heavies about four times that in the lower one. The lower part of the northern boreholer heavies two times that in the southern borehole BH5.

Mineralogy of Heavy Sand Fraction:

In the examined sand samples, the following main groups of heavy minerals have bean found: opaques, pyroxenes, amphiboles, epidotes, and zircon arranged in a descending order of abundance. Other minerals are found in the order of less than 1%.

The description and significance of the recorded detrital minerals are given in the following pages (Fig. 3).

Iron Minerals (Opaques)

In this group ilmenite, hematite, magnetite, lemonite, leucoxene are encounered in a descending order of abundance. The most frequent species of opaques is ilmenite. Opaques occur in well reounded to rounded grains. There is a clear antipathetic relation between the opaques and the pyroxenes, where the former increases with a decrease of the latter and viceversa.

Iron minerals are on the whole the most abandant of all the minerals present (excluding borehole BH5), ranging from 11.4 to 71.1% and their average lies between 23.1 and 54.3%.

Pyroxenes

Pyroxenes are represented by both the monoclinic and the orthorombic varieties. The monoclinic pyroxenes are the most dominant of all pyroxenes, and are represented by colourless and violet brown augite and diopside.

The orthorombic pyroxenes are mostly represented by hyperthenes, and enstatite is rarely present.

On contrary to the other boreholes pyroxenes predominante over the other minerals in the upper part of the southern borehole BH5. Some augite grains have inclusions of black globules of ilmenite. Augite occurrs mostly in rounded grains, sometimes showing (hacksaw or saw-tooth) terminations. The rhombic pyroxenes occur as subrounded to subangular prismatic grains.

The pyroxenes vary from 9.4 to 55%, with an average of (21.2-37%).

Table (1)

Average percentage of the principle heavy minerals present in the upper and lower layers of Lake Burollus boreholes.

Borehole Number	Layer	Index Fig. (weight %)	Opaques	Pyroxenes	Amphiboles	Epidotes	Zircon	Garnet	Rutile	Staurolite	Sphene	Tourmaline	Pyrite-Marcasite
BH2	Up.	46.6	35.1	37.0	12.0	4.2	1.7	0.6	1.2	0.6	+	+	+
	Low.	13.0	40.5	26.3	18.8	6.3	4.9	1.2	0.8	0.6	+	+	1.2
BH3	Up.	52.4	54.3	23.6	8.5	3.1	3.7	1.1	1.8	0.7	+	+	-
	Low.	19.6	49.6	21.2	11.2	2.4	3.8	1.3	1.3	0.9	+	+	-
BH4	Up.	60.8	49.3	24.7	10.4	0.9	3.6	1.7	0.9	+	+	-	+
	Low.	11.2	37.2	35.3	18.8	1.3	2.1	0.7	6.0	1.0	+	+	1.8
BH5	Up.	6.8	23.1	37.0	12.3	0.6	1.2	+	+	0.6	+	-	16.2
	Low.		33.5	25.3	20.9	0.7	1.6	1.1	0.9	1.7	-	+	+
Mean of BH2.3.4	Up.	47.8	47.3	27.8	10.1	2.7	3.1	1.1	0.7	0.6	+	+	+
	Low.	12.5	38.0	29.6	17.3	3.1	3.3	0.7	0.8	0.9	+	+	+

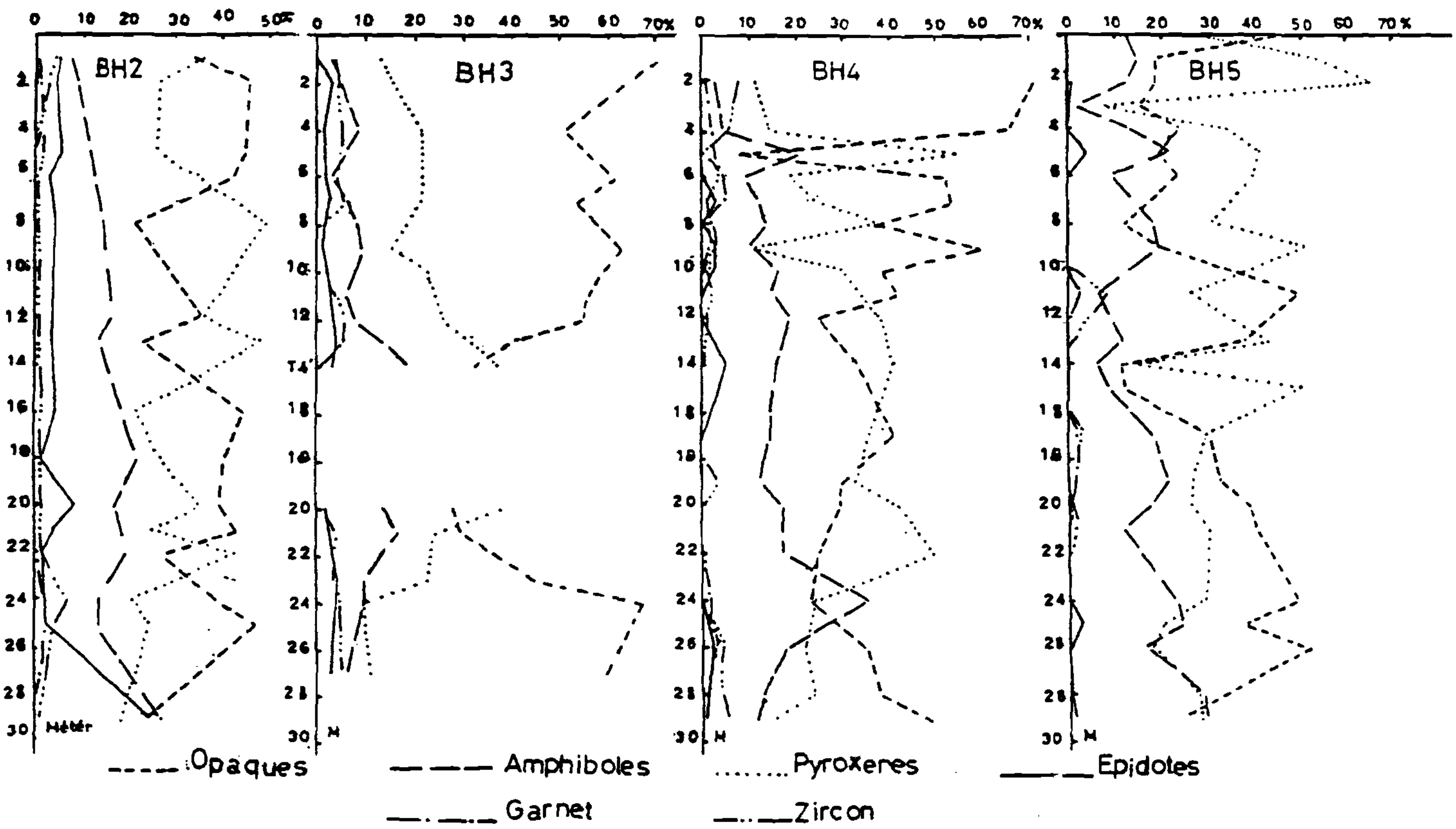

Fig. (3)
Frequency distribution of the principel heavy minerals
in the lake Burullus boreholes.

Amphiboles

They occupy the third rank in the frequency distribution of heavy minerals. They are represented mainly by three members of hornblende. a) the bottle green, b) the sodic bluish green and c) the basaltic brown variety. Actinolite-tremolite series is represented by very small amounts at certain levels. Brown hornblende is the least abundant, while the dirty yellowish or bottle green variety is ubiquitous. Hornblende occurrs in rounded prismatic grains, but some grains show the saw-tooth termination.

The frequency percentage of amphibloes ranges between 1.7 and 35% and their average varies between 8.5 and 20.9%.

The amount of amphiboles is less then half that of pyroxenes in most of the borehole samples. This rate of frequenty does not continue at the same level within the whole length of boreholes BH5 and BH2, where at depth 24 m in BH5 and at depth 29 m in BH2 and downwards the percentage of amphiboles exceeds or equals that of pyroxenes. This inversion limit is observed in Abu-Qir area, but at higher level of 9-10 m depth, (Nawar, 1979).

Zircon

Zircon is found as prisms, in very rounded grains, as egg-shaped, and rarely in broken crystals with one pyramidal termination. Frequently it is found as clear colourless grains contain inclusions of other minerals, arranged parallel to the length of the grains.

Zircon is an ubiquitous mineral, and its frequency ranges between 1.2 and 4.9%.

Epidotes

It is one of the main groups of minerals present in the studied sediments. They are found as yellowish, greenish rounded or irregular grains with clear pleochroism. Most of the grains show slight decomposition specially along the borders.

The epidotes are present in all examined samples, with a frequency ranging between 0 and 25% and their average varies between 0.9 and 6.3%.

Rutile

It occures in red to dark red, almost rounded or elongated rounded grains, and few grains are yellowish in colour. Rutile is recorded in about 90% of the examined samples excluding borehole BH5 and ranges between 0.0 and 3.9% and averages from 0.0 to 1.8%. In the southern borehole BH5 rutile is absent in most samples of the upper part and ubiquitous in the lower half.

Staurolite

It is found as golden yellow or yellow pinkish, rounded or platy grains and rarely in irregular grains. Staurolite ranges from 0.0 to 4.1% and their average varies from 0.0-1.7%.

Granet

Granet is represented by two varieties, the pale pink almandine and the colourless grossularite, where the first is more dominant. The grains are rounded to subrounded. It sometimes reaches 4.0% of the heavy minerals and averages of 1.3%.

Tourmaline

It is represented by its dark brown variety (schorlite). It is found in the lower part of the boreholes. Tourmaline does not exceed 1.1% of the heavy fractions.

DISCUSSION OF RESULTS

The mineralogical analysis of the investigated borehole samples proved that they are mainly consist of iron ores (opaques) which dominates in all samples, followed by the pyroxene group then the amphibole group. Zircon, epidote, garnet, tourmaline, staurolite, rutile, and sphene are dispersely present in small amounts.

The ternary diagrams were drawn using the main constituent minerals; opaques, pyroxenes and amphiboles (Fig. 4, a and b).

Three provenances have been identified as follows:

a) The opaques-pyroxenes provenance:
It is characterized by the preponderance of pyroxenes over amphiboles. Pyroxenes constitute more than 70% of the examined samples.Hences the provenance will be designated as the pyroxenes provenance. This provenance includes the northern boreholes BH3 and BH4, the upper 24 meters of the southern borehole BH5 and the upper 28 meters of the northern borehole BH2. This provenance will be nominated as the pyroxenes provenance.

b) The mixed opaques, pyroxenes, hornblende provenance:
It is characterized by the equilibrium or predominance of amphiboles over pyroxenes. This provenance constitutes 20% of the examined samples and forms the lower layer in boreholes BH5 (6 meters thick) and BH2 (one meter thick). It contains the highest frequency of tourmaline, epidote, granet, staurolite, rutile, and the remarkable amount of zircon. For abbreviation this zone will be called the mixed hornblende provenance.

c) The opaques provenance:
It is represented by scattered samples that constitute less than 10% of the total number of samples.

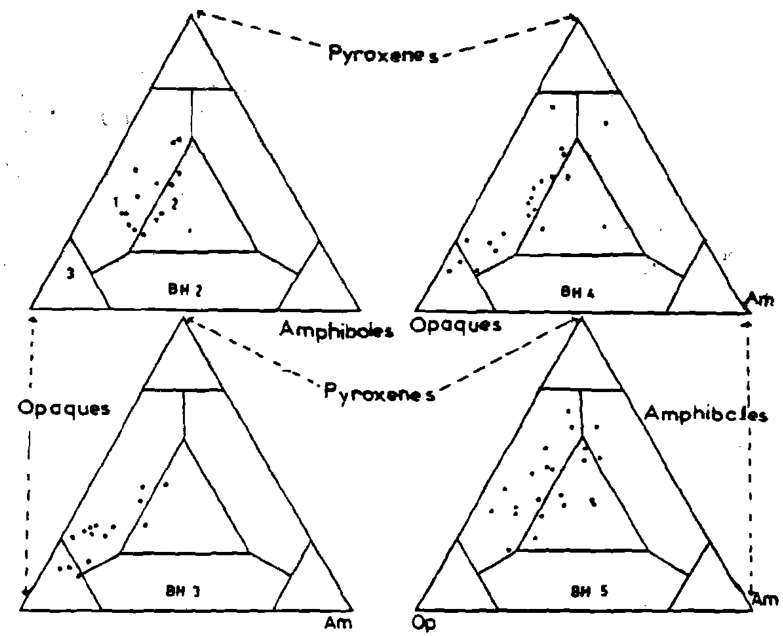

Fig. 4.a
Ternary diagrams showing the presence of three heavy minerals provinces. 1- Pyroxene-Opaqques, 2- Mixed province and 3- Opaques provinces.

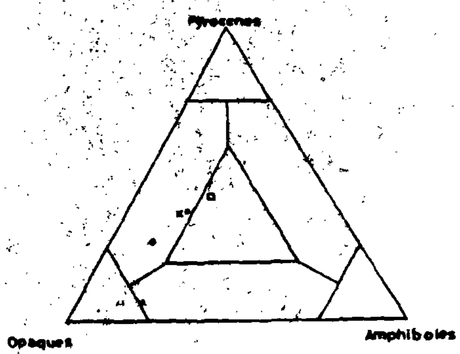

Fig. 4.b
Ternary diagram showing the average volume percentage of the principel heavy minerals in the different boreholes (• BH_2, x BH_3, • BH_4, ◘ BH_5).

Mineralogical analysis showed that there is an antipathetic relation between pyroxenes and amphiboles on one hand and between pyroxenes and opaques on the other hand (Fig.3).

Pyrite and marcasite have been recorded in high frequency in the upper 15 meter part of the southern borehole BH5, where they are found as filling material in brakish water frustules of diatoms, and at 24 meters depth in marine foraminiferal shells (Cebieides sp). However, the abundance of pyrite is associated with the absence of benthonic fauna, while traces of benthonic activity in the upper pyroxene layer are a positive evidence of anaerobic condition of deposition, (Reineck and Singh, 1975), the case which is not met with in the northern boreholes.

Using the data of the ternary diagrams the boreholes are splitted into two layers; the upper (pyroxene provenance) constitutes the whole length of BH3 and BH4 and the upper 28 m and 24 m in BH2 and BH5 respectively. The lower layer in BH2 and BH5 (one meter and 6 m thick respectively) is related to the hornblende provenance. The variation in the mineral assemblage indicates the change of the source area.

According to the results of the index figures, the upper pyroxene layer is differentiated into two sublayers. The average depth of the dividing limit is 10 m. This difference of the index figure implies the different conditions of deposition. The high index figure in the upper sublayer (in the northern boreholes BH2, 3 and 4) indicates the deposition in subaerial condition (Bradley, 1957). This condition is proved by the presence of silty clay shingle and broken shells of **Cardium edulus**. The lower pyroxene sublayer is characterized by the low index figures that reflect the dominance of brackish environment of deposition.

Grain size analysis of Burullus borehole samples has been excuted by Selim and Zazou (1987). Results of mechanical analysis are compared with those of heavy minerals. It has been concluded that there is an antipathetic relation between iron ores and degree of sorting of sediments specially in the northeastern and southern borholes BH4 and BH5. The increase in the amount of iron ores corresponds to a high degree of sorting.

Results of mechnical and mineralogical analyses showed that boreholes BH2 and BH5 can be splitted into two layers. The lower mixed hornblende layer (1 m and 6 m thick, respectively) is relatively more sorted than the upper one. In controversy, the upper (pyroxene) layer is poorly sorted implying high energy condition of deposition.

Shukri (1949) stated that the presence of augite in appreciable amount is observed in the upper Paleolithic period and more recent Nile sediments specially in the upper Sebilian ($8^3 \times 10^3$ B.C.).

It is reported by Shukri (1951) and Shukri and Azer (1952), that the first occurrence of augite in appreciable amount and in varieties similar to those of today sand deposition in the Nile teraces with 30 and 15 m hieght shows that the Atbara and Blue Nile (or at least one of the two) were connected with the Nile during lower Paleolithic but of less amount that that of today. Only in the middle Paleolithic and later times the mineral composition of the Neolithic sediments is similar in all aspects to that of today.

The tables published by Shukri (1951) on the mineralogy of some Nile sediments and samples collected from the Blue Nile and Atbara showed that the Blue Nile sediments have a predominanace of amphiboles over pyroxenes, while Atbara sediments are characterized by paucity of amphiboles with appreciable amounts of pyroxenes.

CONCLUSION

The heavy minerals of four 30 m deep boreholes, drilled in the midway of the Nile Delta coast, have been analyzed and studied. According to the frequency percentage of the mineral assembleges, the boreholes can be divided vertically into two stages. Each stage represents a distinguished source area.

1- **First stage**: which is the earlier stage ranging from 24 m depth downward south of lake Burullus and has not been reached in boreholes sited to the north of the lake. It is characterized by a blend of metamporphic and Volcanic source area provided by the White Nile and the Blue Nile respectively. It shows that hornblende is equal to or predominant over pyroxenes, and both are in a reasonable amount, with plenty of iron ores. According to the mineralogical composition of this stage, it is in accordance with the late upper Paleolithic. Sediments of stage 1 are free from any biological remnants indicating subaerial condition of deposition.

2- **Second stage**: It is represented by the upper subsurface 24 m of sediments on the southern side of lake Burullus. It is more than 30 m thick to the north from the lake. Stage two corresponds to the pyroxene provenance indicating a volcanic source area. It resembles that of Atbara and Blue Nile mineral asseblage mentioned by Shukri (1951), and it is related to the Neolithic Recent period.

Using the heavy mineral concentrations, stage II has been splitted into two phases as follows:

a) the lower (Neolithic) phase I is characterized by a relatively low percentage of heavy minerals (Table 1) implying subaerial and brakish low energy condition of deposition.

b) the upper Recent phase II is characterized by very high concentration of heavy minerals denoting deposition in high energy condition. Its sediments has been deposited in alternative brakish and marine environments. It extends from 11 m depth upward.

The levels and description of chronological units are summarized in the following table:

The levels and description of chronological units

Stage	Phase	approc level meter	Description
Second	Recent	base at 10-12	Fossiliferous & unfossiliferous alternative sand & mud layers with gravels & brocken marine & brakish water shells. Very high index figure
Neolithic-Recent	Neolithic	base at 24-30	Fossiliferous & unfossiliferous alternative sand & mud layers, plant remains, Cardium edulis, mica: Reasonable amounts of heavy minerals.
First Late Paleolithic	upper late Paleolithic	top at 24-29	Unfossiliferous fine sand. 6 m thick at the base of the bore hole south from lake Burullos. Not reached in the boreholes north of Lake Burullus.

Lake Burullus borehole sediments showed that the lower mixed hornblende layer (24 m depth) contains comparable amounts of pyroxenes and amphiboles, confirming that the Nile Delta received its sediments from both the Atbara and Blue Nile at the time of their deposition. The mixed hornblende layer seems to be deposited during the upper late Paleolithic or at least Paleo-Neolithic time. The last stage of the Nile Delta development represented by the upper pyroxene provenance layer has a mineral assemblage similar to that of the Atbara tributary. The pyroxene layer is syngenetic to the Neolithic, Recent period.

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