Comparative study of the mineralogy and geochemistry of the Burullus and Bardawil lake sediments, Mediterranean Sea Coast, Egypt

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Abstract: The present article is a comparative study on the mineralogical as well as the geochemical characters in Burullus lake sediments and Bardawil lake sediments, Mediterranean sea coast, Egypt. Mineralogically, the heavy mineral assemblage recorded from lake Burullus samples are particularly enriched with unstable minerals (pyroxenes and amphiboles and epidotes) accompanied by lower contents of ultrastable minerals (zircon, tourmaline and rutile), reflecting a provenance dominated by basic igneous rocks. For Lake Bardawil samples, the sediments are characterized by substantially higher contents of ultrastable minerals (zircon, tourmaline and rutile), beside a subordinate component of pyroxenes and amphiboles, minerals of metamorphic affinity such as staurolite and garnet constitute a recognizable part of the total non- opaque fraction. The clay mineral suit detected in lake Burullus samples is uniform in most of the investigated area suggesting constancy of the source area, it is dominated by smectite with subordinate amount of kaolinite and lesser illite contents. The recorded clay minerals in Bardawil samples are a mixture of smectite, kaolinte and illite with variable contents from one location to another reflecting variability in source rocks. Smectite tends to be more abundant in the western samples while illite increases eastwards, however, kaolinite constitutes a noticeable part in most of the investigated samples. The recorded heavy mineral assemblage, the identified clay mineral suit as well as the results obtained from the geochemical data, revealed that, the investigated lake Burullus sediments were derived mainly from one source which is dominated by mafic components. They are most probably derived and related to the Quaternary Nile sediments. On the other hand, the Bardawil lake sediments reflect derivation from more than one source, they originated mainly from reworked sediments especially Nubian sand stone, high rank metamorphic and basic igneous rocks derived from the neighboring sand dunes. Fluvial Niolitic sediments must be considered also as an important additional source.

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1. Introduction

The Mediterranean shoreline of Egypt comprises six coastal lagoons,four of these lagoons (Mariut, Iduku, Burullus and Manzala) aredeltaic brackish water bodies and cover a large area of the lower delta plain. On the other hand, the other twolagoons (Alamin and Bardawil) are non deltaic hypersaline water bodies, due to the absence of fresh water runoff.

Burullus lake lies at the northern part of the Nile Delta between longitudes 30^o 21” and 31^o 35” N, it is very close to Rosett branch. The lake is connected to the Mediterranean sea by el- Burg inlet and separated from it by long curving sand barrier. The lake is shallow; water depths range from 85 to 125 cm. The lake is a brackish water body, received huge amounts of drainage water through several drains. As far as the writer is aware earlier workers on lake Burullus were mainly interested in the biological and chemical aspects of the water masses of the lakes rather than the sediments e.g; El-Safty, 1971 and Daragg, 1974. Other study, El-Sabrouti (1984) gave a specific interest on the Burullus lake sediments. The Bardawil lagoon occupies the coastal plain of northern Sinai, it is about 80 Km long and its maximum width is 18Km. The maximum depth of the water is about 2-3 meter. The lagoon is a hypersaline water body, separated from the Mediterranean by a long sand barrier. In the southern area lagoon waters concentrate to salinity, which cause precipitation of saline minerals, thus forming extensive salt pans, in which the depth is only a few centimeters (Levy, 1977). Further south of these salt pans, sand dunes extend inland to a distance of about 5 Km. The geology of the Bardawill lagoon area have been discussed previously by for example (Mohamed *et al.*,1990; Issawi *et al.*,1999) and the hydrography (Abdel- Mogheeth *et al.*,1989) as well as the geochemistry (Madani,2001) have been described.

The present work was done to investigate the mineralogical composition of both sand and clay fractions, as well as the distribution and abundance of major and trace elements in lake Bardawil sediments, and compare them with those of lake Burullus sediments. In order to evaluate the differences in provenance and other depositional conditions (Fig.1).

2. Materials and Methods

2.1. Sampling

A total of 24 samples were collected from lake Burullus sediments and 17 samples collected from Bardawil lake sediments (Fig.1 A&B). The samples represent surface shore sediments, mostly were collected from profiles ranging in depth from 10-25 cm. The samples were carefully taken to cover the different localities along the banks of lake Burullus, while in Bardawil lake, samples were collected from the different parts of the lake except, the southern part in which salt pans are present in not included in our study. The samples were generally collected from west to east.

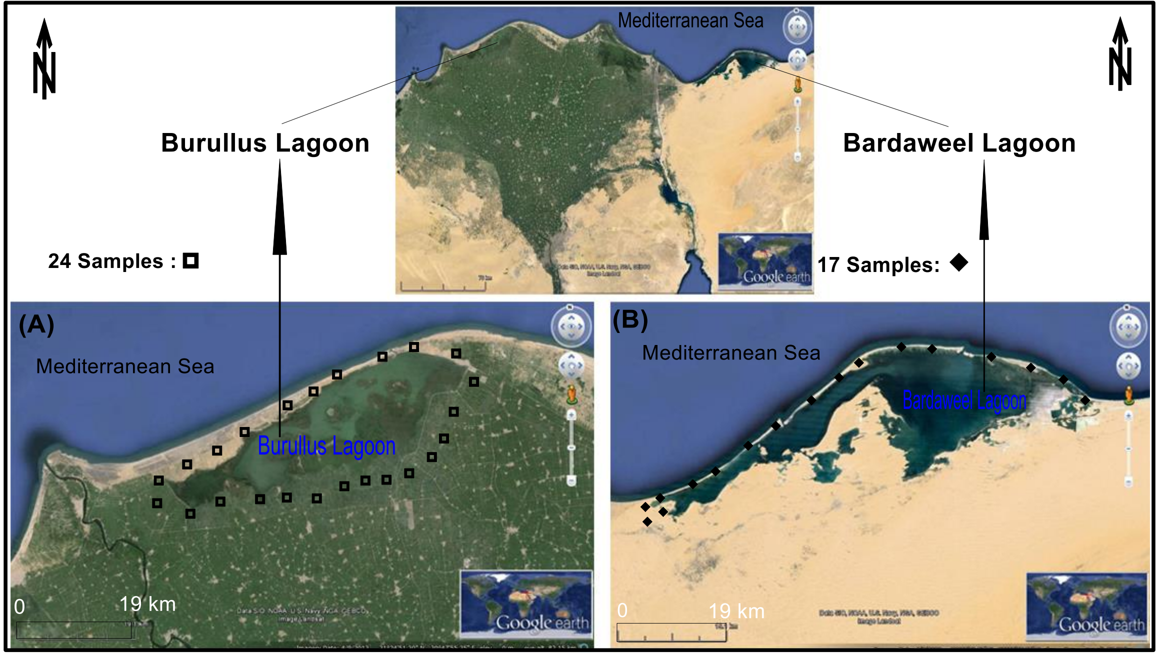

Fig.(1): Location Map and the sites of samples collected from Burullus and Bardawil Lakes sediments

2.2. Methodology

Grain size analysis of the collected samples was carried out following the procedure adopted by Lewis (1984).

The sand fraction was separated by wet sieving. The mud fraction was analyzed by pipette method according to Folk (1974) to determine the distribution of silt and clay fractions. The very fine sand fraction was subjected to heavy mineral separation using bromoform, (Lewis and ,McConchie, 1994). The relative proportions of the heavy mineral species were determined according to (Lewis and Conchie, 1994).

X-ray diffractometry of carefully selected clay rich samples was done to investigate the clay mineral composition. Three oriented mounts were prepared (untreated, glycolated and heated at (55^{0}C for two hours). The analysis carried out at the Metallurgical Research Center (at Tebbin, Egypt), using a Phillip x-ray diffractometer with Ni filtered, Cu –K & radiation. The relative proportions of the recorded clay mineral groups were estimated by comparing the peak height of their strongest reflections as given by Griffn, (1971). The organic matter contents were determined by loss of ignition method (Dean,1974).

The major and minor oxides as well as trace elements of selected samples were analyzed by X-Ray fluorescence technique at the Metallurgical Research Center (at Tebbin, Egypt).

3. Results and Discussion

3.1. Grain size Distribution

The results of grain size analysis (Tables1&2) show that the investigated lake Burullus samples consist mainly of silt, averaging 42 %. The second main component is the clay averaging 36% while sand represent the least abundant content, averaging 22 %. For Bardawil lake sediments; the sand fraction is the most abundant component of the total grain population in most part of the lake, averaging 50 %,the silt fraction averaging 26 %, while clay content; averaging 24 %. Generally Lake Burullus samples are enriched in their mud contents (silt and clay) while Lake Bardawil samples are obviously enriched in their sand content.

The textural nomenclature has been assigned on a triangle diagram after Folk 1974 (Fig.2). The results obtained reveal that, the investigated lake Burullus sediments are texturally classified as three classes; sandy silt, sandy mud, and mud. For the studied Bardawil lake sediments, the samples are texturally classified as sand, sandy silt, sandy mud, sandy clay and muddy sand. Sand sized sediments were predominant at the eastern part of the lake, while mud rich sediments were predominant westwards.

3.2. Mineralogy of sand fraction

3.2.1. Heavy Mineral:

The present article interested only in the distribution of the heavy minerals rather than the light ones to use them as a guide for provenance.

Table (3) gives the relative frequency distribution of heavy minerals in the investigated Bardawil and Burullus lake sediments As a general, the heavy fraction in the Burullus sediments forms a relatively lower part of the sand fraction than that in Bardawil ones, averaging 1.66% and 2.31%; respectively. The recorded heavy mineral suits comprise opaques and non opaques. The opaques constitutes a considerable part of the heavy fraction, especially in Bardawi lake samples, averaging 48.40% while in Burullus samples they averaging 39.8 % (Fig. 3 a&b).The recorded abundance of heavy minerals especially opaques in lake Bardawil samples is most probably due to that the lake received sediments from more than one source, they received huge amounts of heavy minerals from the neighboring sand dunes in addition to the those derived from the Mediterranean sea and drifted to the lake by the long shore west- east currents. In the present study, the percentage of dense opaque minerals are excluded and the proportion of the transparent heavy minerals are considered only and were recalculated to 100%. The percentage of opaque minerals, in most cases is found to be varies from sample to another even within the same area, this variation can not be considered as a function provenance but it seem to be caused by selective processes that lead to accumulation of the denser opaque species and the winnowing of less dense transparent mineral species (El-Fishawi and Molnar, 1985).

Table 1: Percentage distribution of sand- silt and clay contents in the studied Lake Burullus samples

Sample No	Sand%	Silt%	Clay%	Textural class (after folk (1974)
1	21.4	31.80	46.80	Sandy mud
2	24.7	34.90	40.40	Sandy mud
3	19.5	37.50	43.00	Sandy mud
4	22.0	42.60	35.40	Sandy mud
5	15.9	39.80	44.30	Sandy mud
6	26.2	42.30	31.50	Sandy mud
7	20.7	44.20	35.10	Sandy mud
8	28.6	49.40	22.00	Sandy silt
9	30.3	29.80	39.90	Sandy mud
10	33.4	36.30	30.30	Sandy mud
11	29.8	54.20	16.00	Sandy silt
12	35.7	47.10	17.20	Sandy silt
13	17.8	41.70	40.50	Sandy mud
14	20.20	45.40	34.40	Sandy mud
15	18.9	48.20	32.90	Sandy mud
16	11.60	52.30	36.10	Sandy mud
17	19.40	46.40	34.20	Sandy mud
18	20.10	39.70	40.20	Sandy mud
19	29.20	42.00	28.80	Sandy mud
20	23.60	44.50	32.10	Sandy mud
21	16.10	40.90	43.00	Sandy mud
22	10.90	42.30	46.80	Sandy mud
23	13.40	45.20	41.40	Sandy mud
24	19.20	33.60	47.20	Sandy mud
Average	22.02	42.17	35.81	

Table 2: Percentage distribution of sand- silt and clay contents in the studied Lake Bardawil samples

Sample No	Sand%	Silt%	Clay%	Textural class(after Folk 1974)
1	27.80	24.20	48.00	Sandy clay
2	32.00	25.60	42.40	Sandy mud
3	29.70	20.70	49.60	Sandy clay
4	34.60	24.50	40.90	Sandy mud
5	35.00	26.80	38.20	Sandy mud
6	23.10	51.60	25.30	Sandy mud
7	30.40	48.70	20.90	Sandy silt
8	39.60	45.80	14.60	Sandy silt
9	37.40	44.60	18.00	Sandy silt
10	54.00	23.70	22.30	Muddy sand
11	55.30	19.30	25.40	Muddy sand
12	57.70	16.00	26.30	Muddy sand
13	69.40	17.20	13.40	Muddy sand
14	74.70	18.00	7.30	Muddy sand
15	80.40	13.00	6.60	Muddy sand
16	85.20	10.00	4.80	Silty sand
17	90.20	6.80	3.00	Sand
Average	50.38	25.68	23.94	

Table. (3) Averages of the relative frequency in (%) of the identified non –opaque heavy minerals.

Heavy Minerals	Burullus Lake	Bardawil Lake
Opaques	39.8%	48.4%
Non-Opaques	60.2%	51.6%
Pyroxenes	38.15%	12.20%
Amphiboles	30.8%	17.83%
Epidotes	15.39%	8.77%
Zircon	5.2%	20.63%
Rutile	4.03%	15.37%
Tourmaline	1.92%	10.65%
Biotite	1.52%	2.1%
Garnet	1.27%	7.24%
Staurolite	1.06%	3.95%
Others**	0.66%	1.26%
Heavy fractions	1.66%	2.31%

** Others: monazite and kyanite

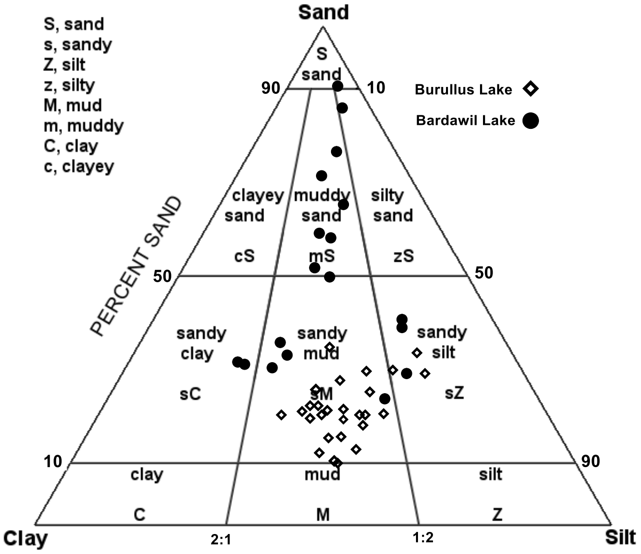

Fig.(2): Textural nomenclature of the investigated lake Burullus and lake Bardawil samples (after Folk,1974).

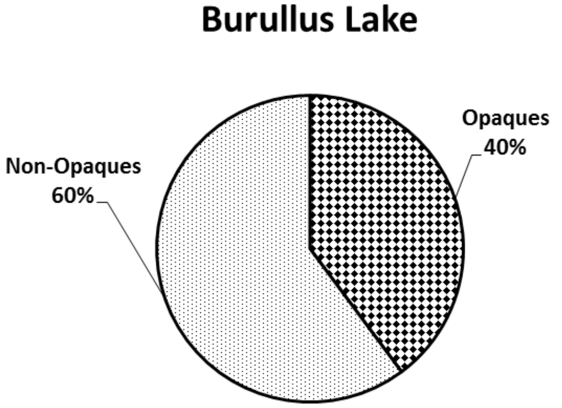

Fig. 3 (a): Percentages of opaque and non -opaque heavy minerals of Burullus Lake samples.

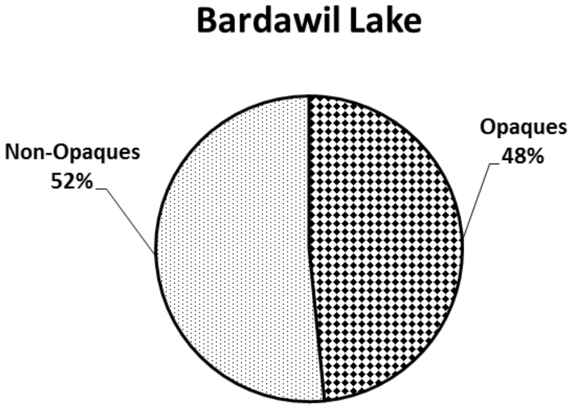

Fig. 3(b): The percentages of opaque and non opaque heavy minerals of Bardawil Lake samples

3.2.2. Heavy mineral distribution

Table (3) and Fig (4) show that the unstable heavy minerals (pyroxenes and amphiboles)constitutes the major part of the total non opaque heavy fraction of Burullus lake samples, reach up to 68.95% compared with those of the Bardawil sediments, (up to 30.03%), they averaging 38.15 % and 30.80 %; respectively in Burullus samples while, they averaging,12.20% and 17.83 %; respectively in Bardawil sediments. On the other hand, the ultra -stable minerals (Zircon, tourmaline and rutile) forming the major part of the non opaque heavy fraction of the Bardawil samples; forming up to 46.65%; averaging 20.63%, 15.37% and 10.65%; respectively while in case of Burullus samples they constitute a relatively small portions forming about, 11.15% of the total non opaques heavy fraction, averaging 5.2 %, 4.04 % and 1.92 %;respectively. Minerals of largely metamorphic affinity; staurolite and garnet constitute a recognizable part in Bardawil samples compared with that in Burullus lake samples. The maximum frequency of garnet and staurolite (7.24% and 3.95 %) recorded from Bardawil samples whereas, the lowest values 1.72 % and 1.06 % are recorded from lake Burullus samples (Table.3 and Fig. 4).

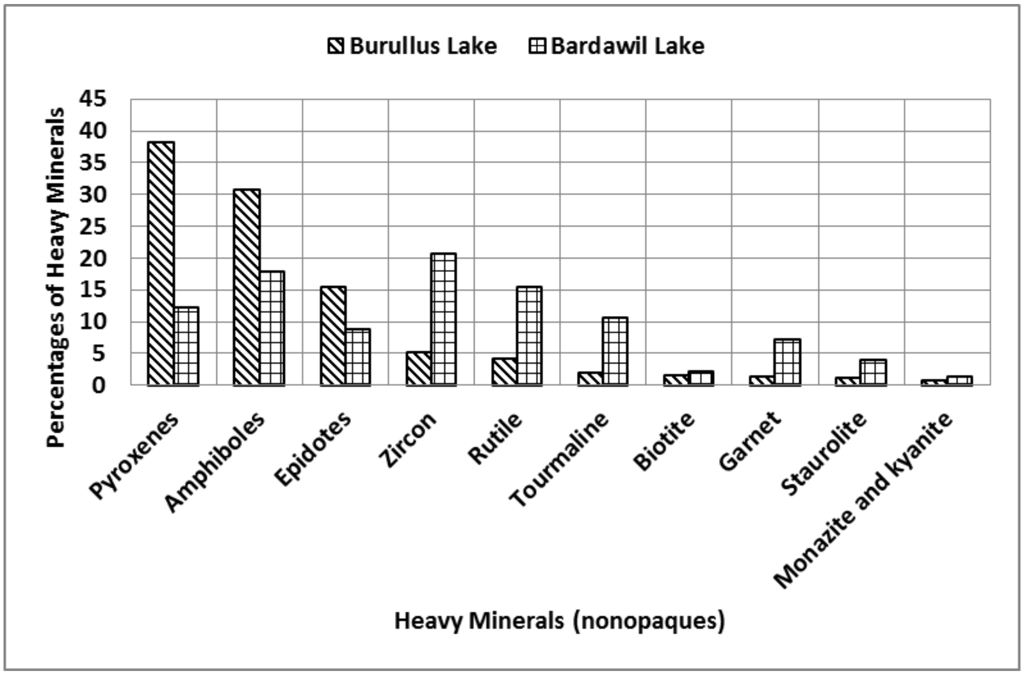

Fig. (4): Frequency distribution of non -opaque heavy minerals of lake Burullus and Bardawil samples.

3.2.3. Heavy minerals description

Pyroxenes are the most abundant non- opaque heavy minerals in the investigated samples of Burullus lake. They are represented mainly by cliopyroxenes, which occur as brownish violet and pale green subangular augite grains. Orthopyroxenes which are less commonly recorded are represented by yellowish green angular grains of hyperthene.

Amphiboles are the second abundant non opaque heavy minerals in Burullus lake sediments. They are represented chiefly by; dark green, bottle green to nearly opaque, subangular to prismatic grains of hornblende. However, brownish yellow grains of oxyhornblende; showing saw teeth marks were frequently recorded. Staurolite is detected as angular to subangular, reddish to yellowish brown grains. Garnet is represented by both the colourless and the pink varieties, mostly occurs as subrounded to rounded grains. Epidotes are mainly of the yellowish green pistacite grains, clinzoisite grains are less commonly observed. Epidotes occur either in the form of irregular prismatic grains mostly in Burullus lake sediments or as rounded and subrounded grains that are commonly observed in Bardawil lake samples. Tourmaline is represented by strongly pleochroic yellowish brown grains. They are mostly varying from rounded to subrounded. Rutile occurs mainly as rounded and subrounded grains, prismatic grains were distinguished in few samples. Both the yellowish brown and the blood- red pleochroic types were recorded. Zircon occurs mostly as anhedral oval shaped with well rounded boundaries, euhedral prismatic type is less commonly observed. The majority of zircon grains are colorless, however, dusty and colored grains are frequently recorded from lake Bardawil samples. Biotite is recorded as irregular flakes of yellowish brown color with inclusions of iron oxyhydroxide.

The heavy mineral assemblage recorded from the Burullus lake sediments are particularly enriched with unstable minerals (pyroxenes especially clinopyroxene, amphiboles and epidotes) which reflect a provenance dominated bybasic igneous rocks. Such heavy mineral suite is greatly matched with that characteristic of the Nile sediments as recorded by many authors (e.g. Hassan 1976, Gazaranti et al.,2006, El-Shahat *et al.*,2006 and 2009). The op cited authors mentioned that the non opaque heavy minerals of the Quaternary Nile sediments are characterized by predominance of pyroxenes, amphiboles and epidotes, other minerals that are present but not common included zircon, tourmaline, rutile, garnet and monazite. As a conclusion the Nile sediments are considered as the sole source for the investigated Burullus lake sediments.

The distribution pattern of heavy minerals in Bardawil lake samples (Table.3 and Fig.4) show that the sediments were inherited from more than one source. The diversity of source rocks Is evident from the suite of heavy minerals which consist of a mixture of substantially higher contents of ultrastable minerals, (zircon, tourmaline and rutile) accompanied by subordinate component of less stable minerals (amphiboles, pyroxenes and epidotes) metamorphic minerals such as (garnet and staurolite) represent also a noticeable part of the total non-opaque heavy fraction. The observed high frequency of Zircon, tourmaline and rutile is strongly indicative that, the investigated sediments originated mainly by recycling of older sediments and/or long transportation, a conclusion confirmed by the rounded and subrounded nature of these ultra- stable minerals grains. The ratios and frequency of distribution of tourmaline, zircon and rutile in the investigated sands are comparable in varieties and frequency to those of the Nubian sand stone as reported by many workers (Shukri *et al.,*1954, and Misak and Attia, 1983). The authors mentioned that, the N.S.S are characterized by abundant Zircon, Tourmaline and rutile while minerals of metamorphic origin such as garnet, hornblende, staurolite and biotite are frequently detected in these sands.

On the other hand, the coexistence of staurolite and garnet accompanied by (amphiboles, pyroxenes, and epidotes) in the studied samples is indicative of initial provenance enriched also by basic igneous as well as high rank metamorphic rocks.

It is worthy to mention that, the neighboring sand dunes are considered as the main source of sediments in Bardawil lake they brought to the lake by the northwesterly wind prevailing in the area..Such dunes consist of sands which have been derived from different sources, the Nubian sand stone and the Miocene sand and sandstones and the crystalline basement rocks are the main sources of these dunes (Misak and Attia, 1983).Moreover, sediments of Niolitic origin can not excluded as an additional important source for Bardawil lake sediments that is proved by the existence of subordinate component of the unstable minerals (pyroxenes, amphiboles and epidotes). Many authors mentioned the recognizable role of the Nile sediments along Northern Sinai coast (e.g AbuZeid and Stanley, 1990).

The sediment brought from the old Nile branch (Palusiac) which was once flowing in the Gulf of El-Tinh in the Mediterranean then transported by the long shore west- east currents to the lake. In conclusion, the Bardawil lake sediments may be considered as a mixture of ultrastable minerals (zircon, tourmaline and rutile) which by recycling have been mixed with abundant epidotes, amphiboles, garnet, staurolite and pyroxenes.

3.3. Mineralogy of clay fraction

The relative proportions of the identified clay mineral species in both the Burullus and Bardawil lake sediments are given in Tables (4& 5 and Fig.5). It is clear that for lake Burullus samples, the clay minerals detected in the different parts of the lake are quite similar with little differences in their relative distribution (Table, 4). Smectite is the dominant clay mineral averaging (67 %) followed by kaolinite (22 %), whereas, illite is the least abundant clay mineral averaging (11 %) (Fig.5). The clay mineral composition of the studied samples is uniform and nearly constant in all the investigated area indicating constancy of the source area. The reflections of the clay minerals in most of the analyzed lake Burullus, samples are broad and diffuse indicate general low degree of crystallinity and suggesting that such clay mineral suit is mainly detrital in origin. The clay mineral assemblage recorded from the Burullus lake samples is generally comparable with that recorded by many authors for different parts of the Nile Delta for example, the sediments of the Damietta Nile Branch (Stanley and Wingerath,1996), Lake Idku (El-Sabrout,1984) (Table. 6 and Fig.6). This suggests that the sediments of Burullus lake are mainly related to Quaternary Nile Delta sediments. The ancient River Nile branches (Sebennitic and Saitic) most probably played a major role for supplying the clay minerals recorded from the lake sediments (El-Sabrouti, 1984).

Table (5) and Fig. (5) show that, the recorded clay minerals in Bardawil lake samples are a mixture of smectite, kaolinite and illite with variable contents from one location to another. Smectite is averaging 39%it tends to be more abundant in the western sediments, varying in content from 27.4 in the eastern part to as much as 55.2% in the western part. Kaolinite, on the other hand, constitutes a noticeable portion in most of the investigated samples averaging (38%).

Table. (4): Relative percentages of clay minerals in the studied Lake Burullus samples

Sample No	Smectite	Kaolinite	Illite
1	59.30	26.30	14.40
2	66.80	21.00	12.20
3	68.20	22.50	9.30
4	64.30	24.20	11.50
5	68.70	18.70	12.60
6	65.50	24.00	10.50
7	74.00	17.40	8.60
8	67.00	20.00	13.00
9	63.20	24.40	12.40
10	70.10	20.30	9.60
11	66.30	21.90	11.80
12	63.90	27.20	8.90
13	69.00	19.00	12.00
14	71.20	17.70	11.30
Average	67.00	22.00	11.00

Table. (5): Relative percentages of clay minerals in the studied Lake Bardawil samples.

Sample No	Smectite	Kaolinite	Illite
1	52.10	33.50	14.40
2	55.20	30.00	14.80
3	46.50	36.70	16.80
4	41.00	39.30	19.70
5	35.10	42.00	22.90
6	31.50	40.20	28.30
7	34.80	38.00	27.20
8	27.40	42.60	30.00
9	30.50	40.10	29.40
Average	39.00	38.00	23.00

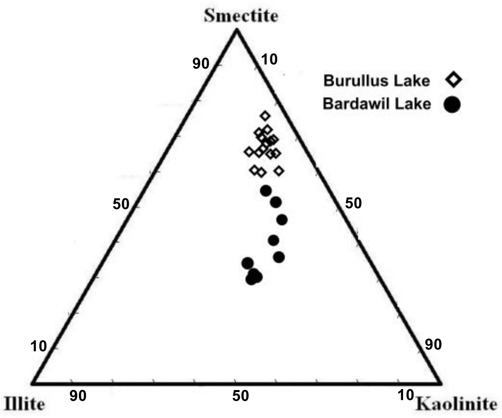

Fig.(5):Ternary diagram showing the clay mineral composition of the investigated lake Burullus and lake Bardawil samples.

Illite is widely varied in content it ranging between14.4% to30% averaging 23%, its content is markedly increased eastward. Smectite content tends to increase with decreasing of illite. The inverse relationships between illite and smectite strongly point to some alteration processes; part of the less stable clay minerals smectite, in the basin of deposition changed into illite. The observed lower content of smectite especially in the eastern part sediments is most probably due to structural transformation into illite under conditions which would favor the formation of illite by fixation of K ions present in sea water. The origin of the identified clay mineral assemblage seems to be of both the detrital inheritance and authigenesis in formation.

The clay mineral assemblage recorded from lake Bardawil sediments is varied from those characteristic of Nile sediments; the former have relatively enhanced proportions of kaolinite and illite (Table 6 and Fig 6). The presence of clay minerals in a mixture of smectite, kaolinite and illite with variable contents are related mainly to variability in source rocks, as well as to probable fluctuating climatic conditions.

As the type of the clay minerals depend upon the source of the parent rocks, the western part in which smectite is the dominant clay mineral is thought to be derived from mafic igneous rocks (Pettijohn,1957) under alkaline conditions. The clay mineral in the western part is most probably have Nilolitic sources, derived from the old Palusiac branch of the Nile which was once flowed through El-Tinh plain as well as from El- Malaha lagoon depression and transported by the east-west current of the Mediterranean sea. On the other hand, the abundance of kaolinite as well as illite eastward most probably related to derivation from pre-existing kaolinte rocks associated with recycled older sediments which are commonly containing considerable amount of illite (Lee, 2002). Such detrital kaolinite most probably resulted from chemical weathering of crystalline source rocks containing abundant feldspars accompanied by subtropical to humic climate conditions favouring kaolinte formation (Chamley, 1989). Illite is resistant to weathering and is quite stable in soil under severe conditions (Lee, 2002).

As a conclusion, the clay mineral suit in Bardawil lake sediments derived from more than one source; Nile sediments is considered as the possible source especially for the western part sediments, however, the marked abundance of kaolinite and illite in the middle and eastern part sediments is mainly related to their derivation pre-existing kaolinite bearing sediments as well as acidic plutonic rocks containing abundant feldspars carried by the north and northwestern winds prevailing in the study area.

Table.(6): Averages percentages of clay minerals of the studied Lake Burullus and Lake Bardawil samples compared with other environment from Nile Delta.

Locality	**Smectite**	**Kaolinite**	**Illite**	**Author**
Rosetta bottom sediments branch	64	22	14	Wahid El-Dein and Shaheen, 2010
Dameitta bottom sediment branch	69	25	6	Stanley and Wingerath,1996
Lake Idku	76	14	11	El- Sabrout and Sukary,1982
Lake Burullus	67	22	11	Present author
Lake Bardawil	39	38	23	Present author

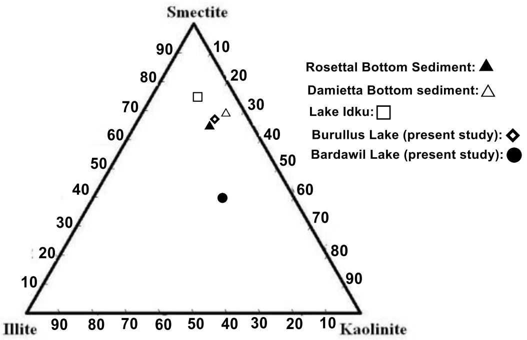

Fig. (6): Ternary diagram comparing the clay minerals identified from lake Burullus and lake Bardawil samples with those reported from other environments of Nile Delta.

3.4. Geochemical Characterization

The concentrations of the major oxides as well as trace elements in the investigated lake Burullus and Lake Bardawil samples are given in Tables (7 & 8).

3.4.1. Burullus Lake sediments

3.4.1.1. Major Oxides

Table (7) and Fig (7) show that obviously, silica, alumina and iron are mostly occur as a major components in the investigated Lake Burullus sediments averaging 57.49%, 14.56 % and 8.79%; respectively followed by CaO, MgO, TiO_2, Na_2O and K_2O in decreasing order of abundance. The SiO_2 / Al_2O_3ratios is always higher than 3, suggesting the predominance of three- layer clays.

The Al_2O_3contents is largely contributed by the clay minerals rather than feldspars which is attributed to the clayey nature of the sediments as evident from textural analysis. The recorded abundance of silica and alumina is due to the clayey silty nature of the samples and the presence free silica as quartz. The MgO content averaging (3%) is higher as compared with the corresponding value of the UCC (2.2%) this pattern is consistent with the abundance of smectite clay mineral which is proved from mineralogical investigations.

Organic matter contents display no specific distribution pattern from one locality to another, however they tend to increase with increasing of Al, they ranging from 1.75% to 0.63% with an average (1.47%). As a general concept, sediments rich in fine grained component (clay) have the highest organic matter contents.

The observed enrichment of Fe_2O_3, averaging 8.79% compared with the value of the UCC (5%) reflect the presence of iron as independent iron oxide minerals which is proved from microscopic investigation in addition to its presence in the structure of the clay minerals. The TiO_2 ranges between, 1.25% to1.67% averaging 1.64 % which is higher than that in UCC (0.5 %).The enrichment of TiO2 % may be due to its ability to accumulate as insoluble form in continental sediments; as well as the high immobility of Ti during weathering (Taylor and McLennen, 1985). On the other hand, Ti tend to be disseminated within the clays as discrete minerals e.g, rutile (Degens, 1965).

The distribution of K and Na are related to their occurrence in the clay minerals smectite and illite. The K content is generally lower than Na content; averaging 1.30% and 2.96%; respectively. Mineralogical investigations revealed that smectite is the dominant clay mineral while illite constitutes a minor component. So the encountered high Na content is most probably related to clay minerals.

Chester (1965) mentioned that the bulk of Na and K is associated with clay fraction. The recorded general depletion of Ca, Na and K oxides in the investigated samples averaging (3.96%, 2.96% and 1.3%; respectively as compared with the corresponding values for the UCC values (4.2 %, 3.9 % and 3.4%) most probably due to their relatively high mobility during weathering processes because of their high hydration energies (Culler,1988). The P_2O_5 content varies between 0.22% to 0.39%, averaging 0.27% which is relatively enriched compared with the average shale (0.17%). Phosphors is probably associated with clay minerals or being adsorbed onto hydrous Fe- oxides (Paropkair, 1990). On the other hand, the presence of biogenic phosphate is most probably possible cause of the relative abundance of P_2O_5 contents.

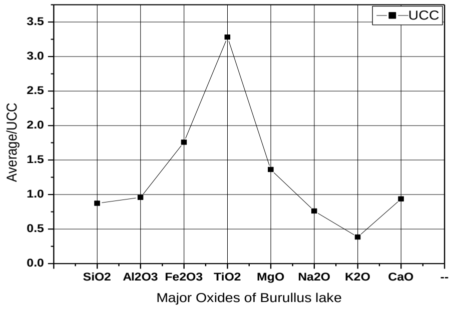

Fig. (7): The average concentrations for major oxides in the studied lake Burullus samples normalized to the Upper Continental Crust (Taylor and McLennan, 1985).

Table 7 Chemical analysis data of major oxides (%) and trace elements (ppm) in the studied Lake Burullus samples

Sample No	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	Na_2O	K_2O	CaO	P_2O_5	OM	Cu	Zn	V	Ni	Co	Cr	Ba	Sr	Zr	Th	Pb
1	55.52	14.40	8.96	1.76	2.93	2.81	1.34	3.59	0.24	1.56	66	105	257	77	38	139	379	259	168	4	13
2	52.46	16.86	9.11	1.55	3.15	2.73	1,55	3.89	0.21	1.71	60	122	240	73	31	152	401	279	175	6	10
3	54.78	15.93	9.61	1.62	3.26	2.90	1.29	4.63	0.25	1.60	54	98	227	87	25	144	396	318	184	5	9
4	53.25	16.44	9.47	1.38	3.12	3.11	1.40	4.81	0.33	1.62	51	113	234	66	29	162	365	326	180	5	12
5	55.43	14.22	8.85	1.69	3.09	2.88	1.51	3.94	0.30	1.54	59	94	225	57	33	129	399	291	179	4	11
6	57.11	13.36	8.78	1.46	2.92	3.15	1.49	3.67	0.28	1.43	49	79	251	62	28	150	420	268	190	5	10
7	51.63	17.38	10.03	1.25	3.20	2.96	1.66	4.09	0.25	1.75	59	88	242	80	30	146	374	321	182	7	8
8	54.88	16.24	9.79	1.41	2.84	3.44	1.41	3.91	0.27	1.67	60	96	229	77	34	122	359	286	196	4	11
9	53.39	15.72	10.11	1.33	3.41	3.27	1.57	4.22	0.29	1.70	48	120	235	82	25	147	388	306	184	6	9
10	55.72	13.89	8.94	1.60	3.19	3.19	1.50	4.13	0.22	1.59	51	85	215	74	22	166	411	293	170	4	6
11	58.17	14.76	7.79	1.36	2.88	3.11	1.28	3.92	0.31	1.28	44	55	167	38	24	113	347	275	199	3	8
12	64.11	12.68	8.16	1.50	2.79	2.97	1.36	3.88	0.39	1.20	36	37	51	23	16	101	336	289	210	5	6
13	54.48	15.53	9.23	1.76	3.26	3.22	1.32	3.96	0.29	1.60	48	71	230	59	27	139	342	297	173	4	7
14	57.30	13.86	7.89	1.29	3.31	2.89	1.29	3.69	0.26	1.42	40	66	188	31	33	126	375	255	211	5	9
15	68.19	11.33	8.55	1.66	2.44	2.76	1.22	3.54	0.24	0.75	33	58	179	26	23	79	315	265	220	6	7
16	73.34	10..68	5.33	1.39	2.18	1.95	1.19	3.05	0.22	0.63	45	45	169	22	15	89	327	237	234	7	6
Average	57.49	14.56	8.79	1.64	3.00	2.96	1.30	3.93	0.27	1.47	50.19	83.25	208.69	58.38	27.06	131.50	370.87	285.31	190.94	5.00	8.88

Table 8 Chemical analysis data of major oxides (%) and trace elements (ppm) in the studied Lake Bardawil samples

Sample No	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**TiO_2**	**MgO**	**Na_2O**	**K_2O**	**CaO**	**P_2O_5**	**OM**	**Cu**	**Zn**	**V**	**Ni**	**Co**	**Cr**	**Ba**	**Sr**	**Zr**	**Th**	**Pb**
1	53.60	14.27	7.88	1.40	2.41	1.64	1.23	5.64	0.25	2.24	18	30	29	15	10	16	322	257	234	8.8	13
2	51.36	17.84	7.63	1.53	2.34	1.77	1.30	5.87	0.28	2.35	18	33	32	12	10	18	298	244	227	10.5	14
3	54.47	13.76	8.10	1.29	2.51	1.82	1.24	6.55	0.22	2.19	16	26	24	11	9	19	319	294	241	7.78	13
4	56.55	15.21	7.95	1.36	2.39	1.69	1.27	5.58	0.24	1.97	17	39	27	13	7	12	310	251	257	12.70	14
5	64.66	13.16	6.77	0.97	1.97	1.36	1.31	5.79	0.18	1.88	14	29	22	10	8	11	294	263	279	14.60	11
6	71.54	12.24	7.11	1.15	1.86	1.33	1.43	6.20	0.14	1.75	11	26	17	7	7	8	289	288	294	15.89	11
7	68.72	14.87	6.93	0.85	1.57	1.23	1.64	6.41	0.18	1.81	13	19	19	10	8	7	277	281	286	11.57	12
8	72.59	11.63	7.23	1.21	1.48	1.19	1.86	5.92	0.15	1.59	7	16	13	9	6	6	283	249	311	14.96	8
9	75.60	9.84	5.91	1.13	0.91	1.14	1.79	6.32	0.14	1.50	7	16	16	6	5	8	269	266	369	15.86	7
10	77.33	11.64	6.59	0.92	1.38	1.09	1.95	5.77	0.11	0.70	5	9	11	5	6	9	272	237	358	13.74	5
11	78.5	8.85	4.89	1.33	1.56	0.93	1.89	5.46	0.09	0.65	4	9	19	5	4	14	264	222	391	12.82	6
12	81.34	7.19	5.64	1.48	1.67	1.03	2.01	5.24	0.16	0.53	4	8	23	6	4	12	260	217	411	14.11	5
13	84.33	6.22	5.33	1.55	1.72	0.79	2.11	5.89	0.13	0.55	3	6	26	5	5	15	230	239	429	15.79	6
Average	68.51	12.05	6.59	1.24	1.83	1.31	1.62	5.90	0.17	1.30	10.54	20.46	21.38	8.77	6.85	11.77	283.42	254.46	314.38	13.14	9.62

3.4.1.2. Trace elements of Burullus lake sediments

Table (7) and Fig (8) The ferromagnesian trace elements Cr, Co, Ni and V in the investigated lake Burullus samples record an obvious high level of concentration, averaging 131.50 ppm, 27.06 ppm, 58.38ppm, and 208.69ppm; respectively as compared with the value of the Upper Continental Crust (UCC) (35,10,20 and 60 ppm). This may be due to the abundant of mafic minerals in the source area. Suggesting derivation from source rocks enriched in their mafic minerals. On the other hand, the observed high concentration of V and Cr may be related to the abundance of the clay components as well as organic in the investigated samples, these two elements are readily adsorbed onto clay as well as onto organic matter during weathering. The observed enrichment of V indicates the accumulation of a V-rich heavy mineral. Vanadium is strongly enriched in basic rocks and often correlates with Mg and Fe (Krauskopf, 1979). The distribution of V is essentially controlled by iron–bearing detrital minerals.

Cu and Zn content are averaging 50.19 ppm and 83.75 ppm; respectively. Which are higher than the corresponding values for the UCC (25ppm and 71 ppm; respectively. The observed enrichment of these two elements is attributed to the abundance of clayey content and organic matter in the investigated samples. Both Zn and Cu tend to be adsorbed by organic matter and clay minerals. On the other hand, because of the similarity in ionic size Zn can substitute for Mg and Fe; Rankana and Sahama, 1960 mentioned that pyroxenes and amphiboles are the main carrier of Zn in igneous rocks. So that the abundance of Zn is most probably controlled by the distribution of these minerals. Pyroxenes and amphiboles constitute the major part of the heavy mineral assemblage of the studied samples as reveled from mineralogical investigation. In sediment basin of deposition, adsorption play an important rule within materials with colloidal properties such as clay minerals, hydroxide minerals as well as many organic matter (Krauskopf, 1979). Most elements such as Zn, Cu, and V have increased with increasing of organic matter contents.

The observed abundance of Ba and Sr (averaging 370.27 ppm and 285.31 ppm respectively) most probably related to the enrichment of the investigated samples in clayey contents. The clay fraction has the ability to concentrate Sr and Ba either by adsorption or by ion exchange in the clay sheet. However, calcitic components can not excluded as an important host of Ba and Sr elements. The general depletion of Pb and Th averaging 8.88 ppm and 5.0 ppm; respectively as compared with the corresponding value of UCC (20 ppm and 10.5 ppm) could be related to the nature of the provenance, which is most probably enriched in mafic rocks rather than felsic ones. The observed low value of Zr averaging 190.94 ppm in most of the investigated samples is attributed to the clayey nature of the sediments. Zircon in sediments is derived from mechanical sorting, so that most of the Zr occurs in the sand size fractions, leading to its general depletion in the clays.

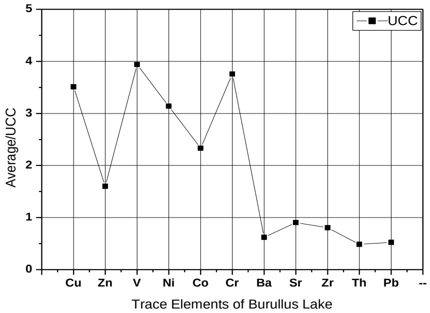

Fig. (8): The average concentrations for Trace elements in the studied lake Burullus samples normalized to the Upper Continental Crust (Taylor and McLennan. 1985).

The distribution of both major oxides and trace elements in most of the investigated samples in Lake Burullus sediments show almost similar chemical composition reflecting derivation from one source, moreover, The enrichment of elements such as Cr, Ni, Co, V, Cu, Zn and Fe relative to the UCC values strongly suggests the dominance of mafic rock provenance as a principle source for the investigated lake Burullus sediments.

3.4.2. Bardawil lake sediments

3.4.2.1. Major oxides

Table (8) and Fig. (9) show that the SiO_2 contents of the studied samples have a relatively wide range, vary from 51.51% 84.33 %,averaging 68.51 % which is higher than the corresponding value for the UCC (66%), SiO_2 tends to increase eastwards. The observed general high concentration of silica can be explained due to the relative abundance of kaolinite and reflect the sandy nature of the studied samples. Fluctuation of silica contents in the studied samples most probably attributed to the concentration of other analyzed elements.

The Al_2O_3 contents range from (17.84% to 6.22%), averaging 12.05 % which is lower than the value for the UCC (15.2%), it is varying from the different parts of the lake. The higher Al content recorded from the western part samples, however, it tends to decrease eastwards. This may be attributed to the nature of the sediments, in the western part they are enriched in their clayey content while eastward the sediments became more enriched in sand component see (Table.2).

Fe_2O_3 ranges between 4.89% to 8.10%, averaging 6.55%. The behavior of iron is largely controlled by the distribution of ferromagnesian minerals. The general abundance of Fe2O3 in most of the investigated samples is attributed to its occurrence as independent iron oxides minerals within the sandy rich samples (as on the eastern part) and / or as hydrate ion adsorbed on the surface of the clay minerals (as on the western part). Fe may also occurs as Fe- oxide or hydroxide coating or adsorbed onto the mineral surfaces.

The MgO ranges from 0.91% to 2.51%, averaging 1.83% it is lower than the UCC value (2.2%), the distribution of Mg is more or less similar to that of Fe (Table.8), this is due to that two elements could be present in the same mineralogical phase, since Mg is only controlled by the ferromagnesian function. The relatively higher values of Mg in the eastern part reflect the presence of sand – sized ferromagnesian minerals while the abundance of smectite clay mineral in the western part samples could be a possible reason for Mg abundance.

The TiO_2 content varies 0.85% to 1.53%, averaging 1.24%. The relatively high content of Ti2O as compared with UCC (0.5%) and with that given by Turkin and Wedepole, (1961) (0.15% for sand and 0.46 % in clays) is most probably attributed to that Ti in addition to aluminosilicate, occur in Ti – bearing minerals such as ilmenite and rutile which are mechanically transported and brought to the site of deposition. These minerals are enriched in the heavy mineral assemblage of the investigated samples as reveled from the microscopic investigations. Liu et. al; 2009 mentioned that titinum and iron are closely associated during sedimentation.

CaO averaging (5.90%) which is higher than the corresponding value for the UCC (4.2%).The higher Ca content, suggesting its biogenic origin. The observed abundance of shell fragments and coralline debris in the investigated samples strongly suggesting the biogenic origin.

Organic matter contents ranging from 0.53% to 2.35%, averaging 1.30%. There is an obvious relationship between organic matter content and grain size of the study sediments. Organic matter shows a noticeable positive relationship with the clayey content The highest frequency is recorded from the western samples which is characterized by the abundance of their clayey contents, while as the sample become more rich in their sandy content (eastern part samples) the organic matter show a noticeable drop (Table. 8). On the other hand, at the eastern part where the inlet between the lagoon and the Mediterranean sea, the organic contents is rather limited because the high tidal currents of the Mediterranean sea in this area prevent accumulation of the organic rich particles.

The Na_2O varies between 0.79 % to 1.82 %, averaging 1.31, it became more abundant at the western part samples. The Na2O content tend to follow the smectite–rich clays. X-ray diffraction analyses show that smectite is the dominant clay minerals in the western part sediments.

Relatively higher K_2O content up to 2.11% is recorded eastward, this can be interpreted by the abundance of illite rather than smectite in the eastern part samples. The chemical data are supported by the mineralogical investigation. K tends to be conserved in the mud rocks because of the chemical stability of illite (Cox *et al.*, 1995).The general lower values of P_2O_5 averaging 0.14% is most probably due to the lake of accessory phases such as apatite and monazite in the investigated samples which is confirmed by the mineralogical investigations.

3.4.2.2. Trace elements of Bardawil Lake sediments

Table (8) and Fig (10) show that most of the Lake Bardawil samples display an obvious low concentration of the ferromagnesian trace elements V, Cr, Ni, and Co. averaging 21.38 ppm, 11.7 ppm, 8.77ppm and 6.85 ppm; respectively which are depleted relative to the corresponding values for the UCC (60 ppm, 35ppm, 20ppm, 10ppm). However, a relatively high concentrations of these ferromagnesian trace elements are recorded from the western part sample this could be attributed to abundance of clay minerals and organic matter contents on which they can be adsorbed and concentrated during weathering process (Fedo *et al.*,1996). Depletion of these elements most probably related to the limited role of the mafic rocks as a dominant source for these sediments except for the western part samples. On the other hand, the observed occurrence of V and Cr on the eastern part samples is due to their association with heavy minerals as indicated by mineralogical investigations.

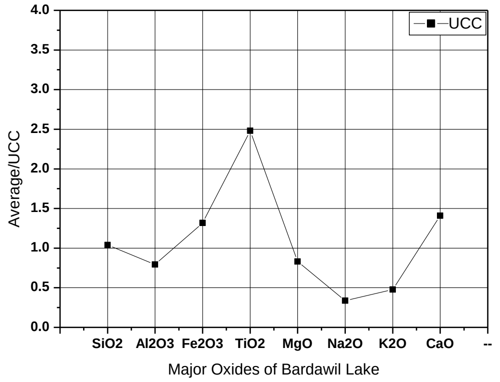

Fig.(9): The average concentrations for major oxides in the studied lake Bardwil samples normalized to the Upper Continental Crust (Taylor and McLennan, 1985)

Zr content ranges between 227ppm to 429ppm averaging 314.38 which is obviously high compared with the UCC value (190 ppm). Zr and SiO_2 show consistent distribution, Zr tends to be increased by increasing of the SiO2 content the higher values are recorded from the eastern part samples that enriched in their sand content reflecting the abundance of Zr with the sand fraction. The enrichment in Zr most probably related to the abundance of heavy mineral zircon in the investigated samples which is proved by mineralogical investigation.

The Th values granges between 7.78 ppm and 16.82ppm, averaging 13.93ppm which is relatively higher comparable to the UCC values (10.5ppm). Ba values in the studied samples range between 230 ppm and 322 ppm with average value 283.83ppm. The maximum values of Ba are recorded from the western part samples indicating that it is originally associated with aluminosilicates as well as organic matter. On the other hand carbonates of foraminiferal tests and shell fragments which are frequently observed in the studied area are usually rich in Ba content. Ba often occurs in higher concentrations in sediments underlying higher productivity zones (Schmitz, 1987). The Sr concentration of the investigated samples appears to be controlled by the presence of aragonitic and calcitic materials and also from corraline debris and shell fragments which, are mostly the host of Sr element. Sr content ranging from 217 ppm to 294 ppm with an average of 254.46 ppm. Pb, Cu and Zn contents display their highest concentration from the western part samples, they averaging 9.62ppm, 10.54ppm and 20.46 ppm; respectively. The observed abundance of Cu, Zn and Pb especially in the western part is most probably related to the abundance occurrence of clayey content and organic matter which act as an important host of these heavy metals.

The observed enrichment of Zr, Ti, V, Fe, and Cr are due to high concentration of heavy minerals in the investigated sand samples especially from the eastern part. This observation is greatly matched with the mineralogical investigation. Whereas, the general depletion of the ferromagnesian elements V, Co, Cr and Ni is most probably related to the limited role of the mafic rocks as a dominant source for these sediments except for the western part samples. The chemical data of the investigated Bardawil lake sediments reveal that the chemical composition is rather variable, reflect derivation from more than one source rock.

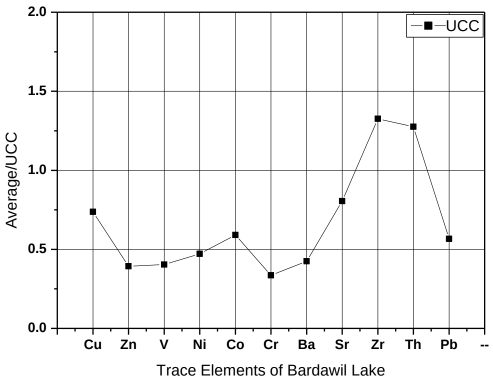

Fig.(10): The average concentrations for trace elements in the studied lake Bardawil samples normalized to the Upper Continental Crust (Taylor and McLennan, 1985).

Generally, lake Burullus samples are enriched in most of the major oxides and trace elements compared with those of lake Bardawil this is attributed to that the Burullus lake sediments are enriched in their mud content while Bardawil sediments are dominated by sandy sediments. The higher concentration in the finer sediments is due to the surface properties of clay minerals. Moreover, the Burullus lake sediments are enriched in their smectite content so it is expected to contain higher concentration of trace elements, as most of them are associated with smectite.

The origin of the studied sediments may be deduced from the discriminate functions diagram after Roser and Korsch (1988). Applying this diagram (Fig.11) to the investigated samples shows that the source of the studied lake Burullus sediments is mafic igneous provenance while the Bardawil lake sediments are derived mainly from quartzes sedimentary provenance in addition to partial contribution from mafic igneous provenance.

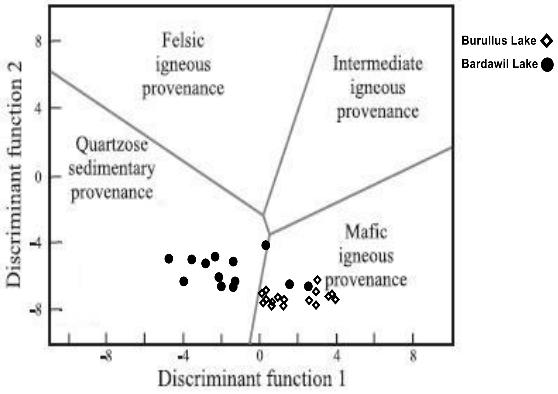

Fig.(11): Discriminant function plot for the investigated lake Burullus and lake Bardawil sediments on the diagram proposed (Roser and Korsch, 1988)

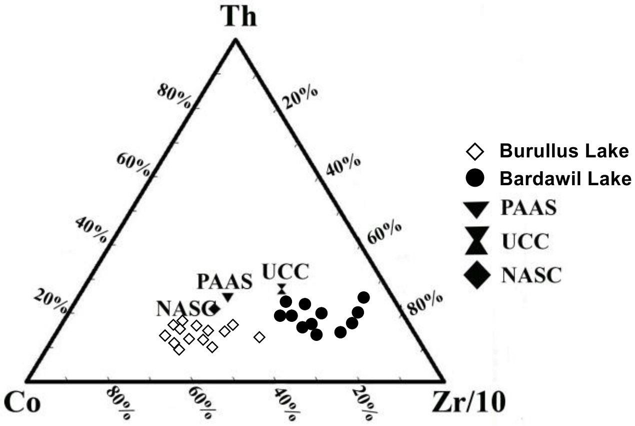

Fig. (12): Ternary diagram illustrating the relationship between Th –Co-Zr/10 in the investigated samples compared with the Upper Continental Crust (UCC), North American Shale Composite (NASC) and Post Archean Australian Shale (PAAS)., date are given by Taylor and Mc Lennan; 1985; Condie, 1993.

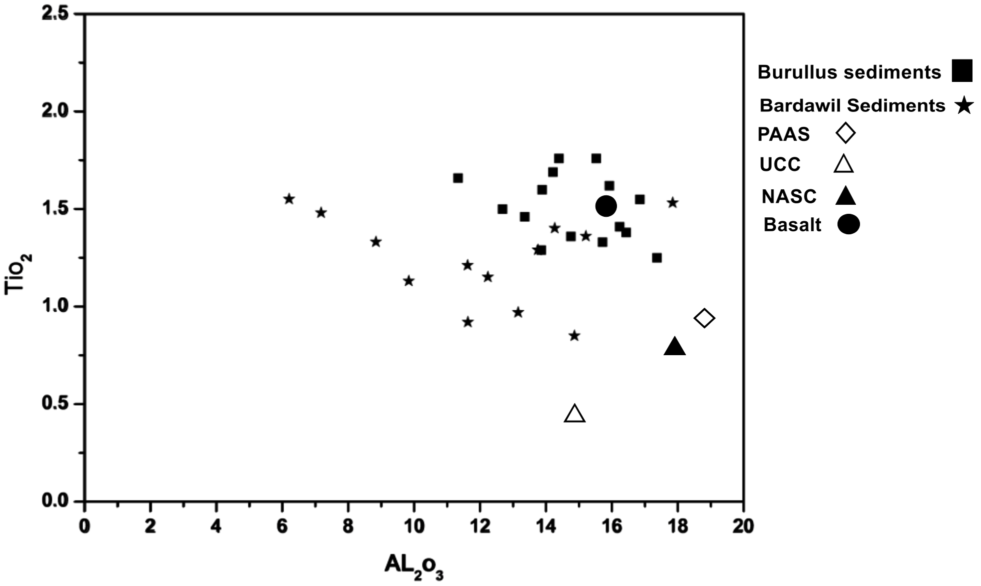

Fig. (13): Relationship between TiO_2 and Al_2O_3 % for the investigated sediments of Burullus and Bardawil Lake sediments. Average data of Upper Continental Crust (UCC), North American Shale Composite (NASC) and Post Archean Australian Shale (PAAS), post Archean basalt are plotted for comparison., date are given by Taylor and Mc Lennan; 1985; and Condie, 1993

Evaluation of sediments provenance can also be illustrated in the Th-Co-Zr/10 diagram (Vital *et al.*, 1999). Figure 12 illustrates that the examined samples of Burullus lake are depleted in Th and enriched in Co as compared with the UCC, PAAS and NASC; respectively. Most of the examined samples are arranged parallel to the co- Zr axis. This pattern of distribution is most probably attributed to the abundance of mafic rocks in the source area. On the other hand, samples of lake Bardawil are plot close to the Zr pole and parallel to the Th- Zr axis they are enriched in Zr and Th. Young and Nesbitt (1998), recorded that, the Ti/Al ratios can be used widely applied as a provenance guide of siliciclastic sediments since both elements are generally considered as the more immobile elements during weathering and diagenesis. The Ti/Al ratio is higher in basic rocks than in acidic rocks. Figure 13 illustrates that the average values of Ti/Al ratios for most of the investigated sediments of lake Burullus is similar to that of basalt and higher than the corresponding values for UCC, NASC, and PAAS. On the other hand, the lake Bardawil samples, which are rich in their sand fraction they show a relatively different pattern, they express a wide spread in their Ti/ Al ratios compared with those of lake Burullus samples which is most probably attributed to textural and mineralogical as well as differences in provenance between them.

4. Conclusion

The present study interested in the distribution of heavy and clay minerals as well as the major and trace elements in Lake Burullus sediments and to compare them with those from lake Bardawill sediments (Mediterranean sea coast, Egypt) in order to evaluate the differences in provenance. Generally Lake Burullus samples are enriched in their mud contents (silt and clay) while Lake Bardawil samples are obviously enriched in their sand content.

The heavy mineral assemblage recorded from lake Burullus sediments is characterized by the dominance of the less stable minerals pyroxenes, amphiboles and epidotes, forming up to 68.95% of the total non-opaque heavy mineral fraction. Lesser components of ultra stable minerals (zircon, tourmaline and rutile) are detected reflecting a provenance dominated by basic igneous rocks. For lake Bardawil sediments, the heavy mineral assemblage consist of a mixture of abundant ultra stable minerals (zircon, tourmaline and rutile), up to about 46.65% of the total non–opaque heavy fraction accompanied with subordinate proportion of less stable minerals, pyroxenes and amphiboles. Metamorphic minerals such as garnet and staurolite constitute also a recognizable component. The distribution pattern of non opaque heavy minerals shows that the sediments were derived from more than one source, they originated mainly from pre existing sediments, especially the Nubian sand stone in addition to partial contribution from basic igneous and high rank metamorphic sources.

The clay minerals detected in the different part of lake Burullus samples, are quite similar with little differences in their relative distribution indicating constancy of the source rocks. Smectite is the dominant mineral followed by kaolinite, whereas, illite is the least abundant clay mineral, the recorded clay minerals are mainly detrital in origin. The clay minerals in Bardawil lake samples occur as a mixture of smectite, kaolinte and illite with variable contents from one location to another which is most probably related to variability of source rocks, as well as to probable fluctuating climatic conditions. Smectite tends to be more abundant in the western samples while illite increases eastwards, kaolinte, on the other hand, constitutes a noticeable part in most of the investigated samples. The origin of the identified clay minerals seems to be of both detrital inheritance and authigenesis in formation.

The distribution of the major and trace elements in the lake Burullus sediments show relatively higher concentrations of Ti, Fe, Cr, Co, Ni and V as compared with the corresponding values for the Upper Continental Crust as given by Tylor and Mclennan (1985). This result suggest the dominance of the mafic components in the provenance area. The distribution of the major and trace elements in the lake sediments show nearly similar chemical composition.

For lake Bardawil, the samples are obviously depleted especially in the transitional elements Cr, V, Ni and Co relative to in the UCC values which could be attributed the limited role of the mafic components as a main source for the sediments in the lake. Whereas, the observed enrichment of Zr,Ti,V, Fe, and Cr are due to high concentration of heavy minerals in the investigated sand samples.

Summing up the mineralogical as well as the geochemical results obtained it canbe concluded that the investigated lake Burulus sediments were derived mainly from one source which is dominated by mafic components. They are most probably derived and related to the Quaternary Nile sediments and suggest that the ancient River Nile branches (Sebnnitic and Saitic) most probably played an important role to supply the sediments to. On the other hand, the Bardawil lake sediments reflect derivation from more than one source, they originated mainly from reworked sediments especially Nubian sand stone, high rank metamorphic and basic igneous rocks derived from the neighboring sand dunes, the sediments brought to the lake from the neighboring sand dunes transported to the lake by the northwesterly winds prevailing in the area. Moreover, fluvial Niolitic sediments must be taken in consideration as a subordinate important source. The sediments brought to the lake from the old Nile branch (Palusiac) and transported along the Mediterranean by the longshore west- east currents.

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