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Gypsum Crystal Habits as an Evidence for Aridity and Stagnation, Northeast of the Nile Delta coast, Egypt

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Abstract: The textural, mineralogical and morphological habits of 25 core samples collected from the north east coast of the Nile delta (east of Damietta branch) have been determined. Both detrital as well as gypsum crystals and roses samples were investigated. Texturally the detrital samples are composed mainly of clayey sand and muddy sand. Two different morphological categories were recorded, single crystal type of different sizes and forms as well as smaller columnar branched type. The two recorded gypsum categories reflect two different mechanisms of formation the first one is super saturation level with calcium sulphate, which lead to the formation of the single crystal and roses followed by evaporative pumping mechanism which is responsible for the formation of columnar branched type. The relatively large size of gypsum roses and crystals indicate continuity in saturated brine level for a long period and reflecting also a state of stagnation period.

Key words: Gypsum roses, Gypsum morphology, Aridity and Manzala Lake.

INTRODUCTION

Evaaporites, as their name means, require warm and arid climatic conditions, where net evaporation exceeds the net inflow of solute bearing water and their presence considered as a good indicator of aridity. The morphology of gypsum precipitated in continental environment is characterized by marked variability and includes prismatic, lenticular, irregular, rosette and numerous other habits. These habits may be used as a guide to depositional environment during growth of the gypsum. Many workers mentioned that one of the most important clues for determining the aridity is the deposition of gypsum roses of different forms. The presence of such gypsum roses is often associated with general arid climatic phase (desert conditions) during the geologic past.

Stanley and Maldonad (1977) studied the Nile cone Late Quaternary cyclicity, they recorded two climatic phases related to Holocene, one was warm –wet climatic phase characterized by high Nile flood between 8200-6600 B.P., the second climatic phase was arid till 2700 B.P. Paulissen and Vermeersch (1989) supported the presence of humid climate (up to 5000 B.P.), this phase was followed by an arid Period extending till the present time. Fontes and Gasse (1989) studied the Holocene and Late Pleistocene phases in North Africa, they indicated the presence of a humid phase during the Holocene dated up to 6000 B.P., this phase was followed by an arid one with the characteristic gypsiferous deposits.

Aim of the Present Study:

This work aims to: (1) discus the different morphological forms of the gypsum crystals and roses recorded in the northeast coast of the Nile delta coast, Egypt, in order to explain the mechanisms which are responsible for their deposition; (2) indicate the relationship between these different gypsum crystals and the associated terrigenous sediments and (3) the use of such crystals and roses as a guide for environmental interpretation and aridity.

The study area (Fig. 1) lies about 17 km east of Dameitta city; it is located between the Mediterranean coastal plain and El Manzala Lake. Morphologically the area is flat topography, characterized by the presence of low beach ridges and small coastal sabkha located between these ridges Sabkha received water from El Manzala lake.

The sabkha resulted from the interaction of aeolian sand and the underlaying deltaic deposits with shallow ground water. The surface is covered by sand ripples, wetty mud, mostly of gryish dark color. The sand is mainly fine to very fine with abundant broken shell fragments. The area is characterized by the abundance of fish farm pools.

Climatic Condition:

The climatic data of the study area was obtained from the Egyptian Meteorological Authority. Climate in the study area is typically as the same prevails on northern coast of Egypt which is characterized by an arid to semi arid conditions with average annual temperature about 22° C. The mean relative humidity is about 70% at the coastal area and decreases gradually inland to about 45%.

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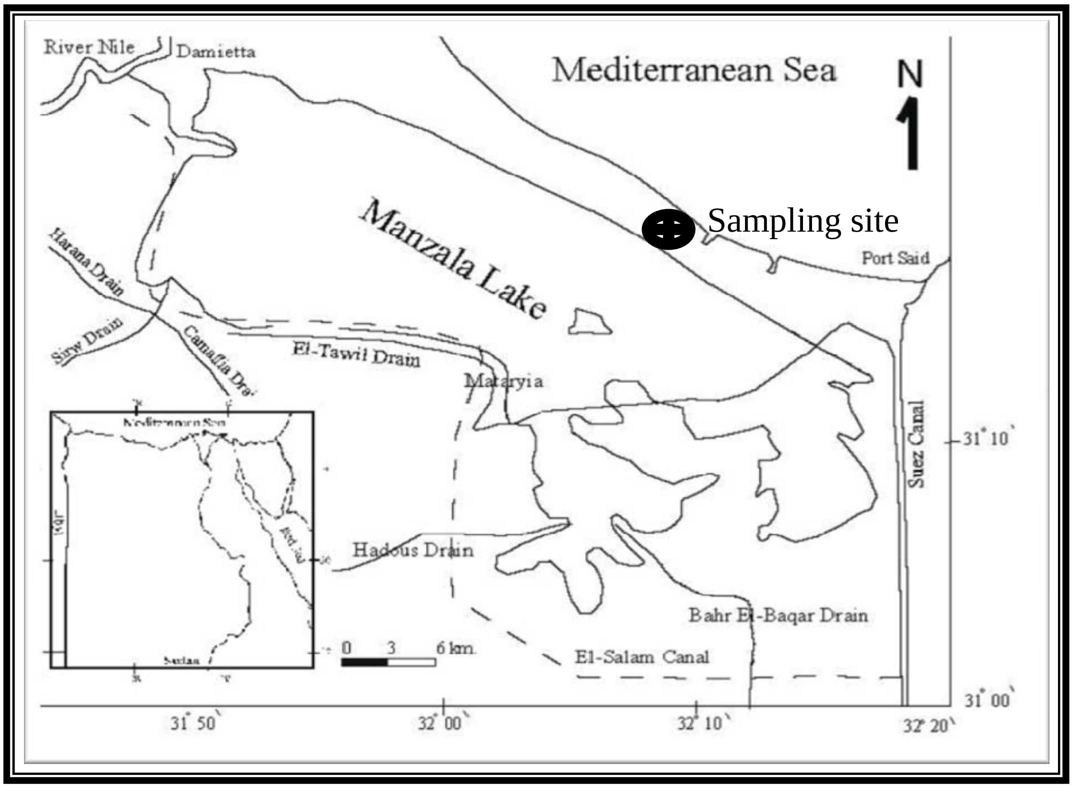

Fig. 1: Location map of the study area.

Sampling:

The samples are collected from the coastal area of the Mediterranean Sea (17km east of Dameitta city). Sediment core samples were obtained by driving transparent plastic tubes into the sediments with a hammer. The sediment was kept in the core by a tight pneumatic seal at the top of the tube, the core then removed and sediment was immediately extruded from the cores under air, the core was cut into different samples at 30 cm interval, a total of 25 samples were obtained. Two types of samples were collected; gypsum crystals and roses samples as well as detrital sediment samples.

Methodology:

The core samples were first analyzed for textural composition by sieving in the conventional way (Lewis, 1984). The bulk samples were subjected to wet sieving to separate the sand fraction (0.063-2 mm) from the finer < 0.063 mm, silt and clay fractions. The finer fractions were subjected to a pipette analysis method. The data were represented graphically in the triangular of sand, silt and clay after (Folk, 1974). The organic matter contents were determined by loss of ignition method (Dean, 1974).

The carbonate contents were determined by treating the samples with HCl 10%. The acid insoluble residue was separated and the carbonate percentage was calculated (Carver, 1971).

The bulk powder of four representative samples of gypsum crystals was analyzed by X- ray diffraction technique, the analysis was carried out at the Metallurgical Research Center (at Tebbin, Egypt) using a Philip x-ray diffractometer with Ni filtered Cu-K alpha radiation.

The very fine sand fraction (0.125-0.063 mm) was chosen (for their high content of heavy minerals) for detailed microscopic investigation. Bromoform was used for heavy mineral separation following the standard laboratory techniques (Lewis, 1984).

Thin sections were prepared from the different types of gypsum crystals and roses for petrographic investigations.

RESULTS AND DISCUSSION

1-Characteristics of Terrigenous Samples:

Grain Size Analysis:

The relative proportions of the total sand, silt and clay in the investigated samples and their graphical representation are given in (Table 1; Fig. 2). Except for the samples at top of the core which are texturally classified as sand, all the other samples are restricted in two fields only , they are classified as clayey sand and muddy sands. Generally, silt and clay fractions decrease from core top towards base, suggesting nearly stable and uniform condition of deposition.

Organic Matter:

The sediments of the area under investigation have values of organic matter varies from 2.59 % to 4.21% for samples at the top of the core and ranging between 14.97% 18.45% for the bottom ones (Table, 1). The organic matter shows a general increase downward, this is because of the downward increase of the clayey content. Generally sediments rich in fine grained components (silt and clay) have the largest percentage of organic carbon due to their large specific area. The retention of anoxic H_2S enriched in pore waters is very important factor for the deposition and preserving of organic matter (Warren, 1986). High organic matter contents in the study area is related to the presence of abundant farm fish pools, the organic matter remains of these farm fish inter mixed with the sediments most probably playing a very important role in gypsum crystallization process.

Table 1: Grain size, organic contents and carbonate distribution in the study core samples.

Core No.	Sample No.	Sand%	Silt %	Clay%	Organic matter contents%	Carbonate%	Sediments classification
Top	1	90.64	1.7	7.66	2.59	15.26	Sand
	2	85.22	4.75	10.03	5.77	11.53	Clayey sand
A	3	80.19	5.61	14.2	7.96	8.27	Clayey sand
	4	74.4	8.72	16.88	14.55	5.27	Muddy sand
base	5	71.16	6.34	22.5	16.41	3.11	Muddy sand
B	1	88.64	2.23	9.13	2.91	18.56	Clayey sand
	2	83.32	5.02	11.66	3.5	13.87	Clayey sand
	3	75.84	8.84	15.32	7.88	8.17	Muddy sand
	4	72.23	7.66	20.11	12.87	4.97	Muddy sand
	5	70.11	6.48	23.41	14.97	4.01	Muddy sand
C	1	92.19	2.53	5.28	4.21	17.39	Sand
	2	86.47	5.91	7.62	5.34	11.88	Clayey sand
	3	82.66	2.32	15.02	8.11	6.21	Clayey sand
	4	77.78	4.5	17.72	13.85	4.23	Muddy sand
	5	73.19	6.4	20.41	17.71	3.36	Muddy sand
D	1	89.9	4.19	5.91	2.67	15.98	Sand
	2	82.73	7.64	9.63	5.79	8.31	Clayey sand
	3	79.23	4.11	16.66	9.55	6.76	Clayey sand
	4	72.84	8.84	18.32	14.22	3.31	Muddy sand
	5	68.1	7.29	24.61	16.89	2.65	Muddy sand
E	1	86.43	3.73	9.84	3.89	14.54	Clayey sand
	2	80.5	6.15	13.35	7.51	8.54	Clayey sand
	3	78.27	4.41	17.32	12.88	5.87	Muddy sand
	4	74.21	5.9	19.89	15.23	2.87	Muddy sand
	5	69.34	8.88	21.78	18.45	2.49	Muddy sand

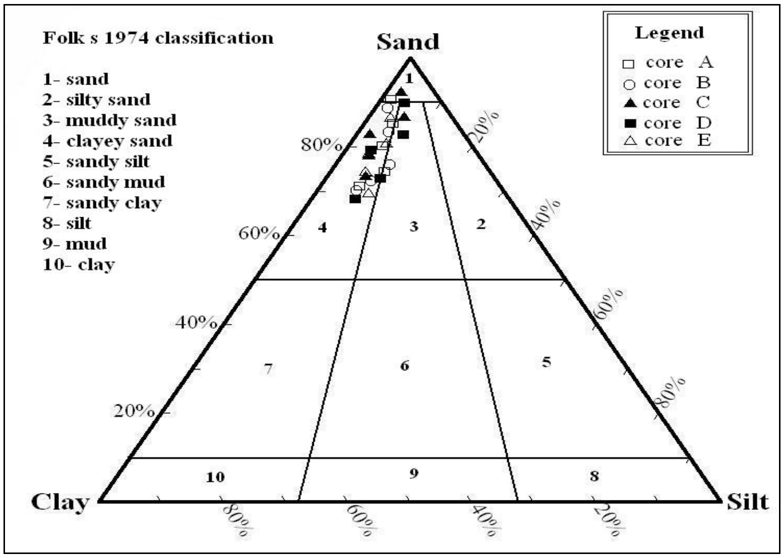

Fig. 2: Types of sediments in the studied core samples based on grain size (After Folk, 1974).

Carbonate Distribution:

Field observation and microscopic investigation of the study samples showed that the recognized carbonate constituents are mainly shell fragment remains. The carbonate contents generally decreases with depth. It varies from 14.54% to 18. 56% at the top to 2.49% to 4.01% at the bottom (Table 1). The general downward decrease of carbonate contents in almost all the studied cores, may be due to the fact that, the biogenic calcareous components which were found to be insufficient at the site of corings or due to the dilution of the sediments by enomerous quantities of detrital sediments. The enrichment of carbonates at surface samples may be attributed to the presence of remarkable amounts of broken shell fragments at the surface of the study area.

Mineralogy of Terrigenous Sand:

A – Light Minerals:

The recorded light minerals consist mainly of quartz forming up to 85%, feldspars about 5% while muscovite forming up to 10 % of the light minerals. The majority of the quartz grains are angular to subangular grains, monocrystalline exhibiting non undulatory extinction. The grains are varying from transparent to mottled, most of the grains are medium to coarse grain size coated with thin film of brown iron oxides.

Feldspars are represented mainly by potassic feldspars. Fresh and altered grains of plagioclase feldspars are recorded in small amounts showing polysynthetic twinning. The potash feldspars are represented mainly by irregular rectangular grains of microcline, characterized by cross hatch twinning. Few grains of altered orthoclase are also recorded. Muscovite occurs mainly as very finely comminuted flakes and shreds with its characteristic high order interference color between cross nicols.

B - Heavy Minerals:

Microscopic examination of the heavy minerals revealed the presence of the following main heavy minerals in decreasing order of abundance; opaque minerals, pyroxenexs, amphiboles, epidotes, biotite, zircon and to less extent tourmaline, rutile , monazite and garnet (Table, 2).

Opaque minerals (averaging 21.64%) represented mainly by hematite, some iron oxy- hydroxides occur as grain coatings to quartz grains or appear as a result of alteration covering the surface of biotite flakes in the form of disseminated spots and inclusions.

Pyroxenes are the most abundant non opaque heavy minerals in the study sediments (average 32.43 %), being represented mainly by greenish yellow to brownish violet, subangular grains of augite. The amphiboles follow pyroxenes in abundance (average 29.37%) represented mainly by hornblende, varies from green to green bottle and brown varities, they occur mainly as prismatic subangular grains. Epidotes (average 9.66%) represented mainly by lemon yellow to greenish yellow, subrounded grains of pistacite. The average of zircon, tourmaline and rutile is (4.7%). Zircon occurs mainly as angular prismatic colorless grains, most of them free from inclusions. Tourmaline and rutile are rarely observed. Biotite occurs as pleochroic, yellowish brown to dark brown flakes, containing inclusions of opaque minerals (average 8.9%).

The recorded heavy mineral suit is similar to great extent with the assemblage of modern Nile sediments (Hassan, 1976).

Table 2: Heavy mineral composition of the studied core samples.

Frequency %	Range %	Average %
Opaques	8 – 30	21.64
Pyroxenes	30 – 39	34.5
Amphiboles	27 - 36	30.6
Epidotes	8 - 15	12.66
Rutile + Zircon + Tourmaline	3 - 6	4.7
Biotite	7 - 13	11.2
Others	0 - 3	1.63

2- Characterization of Gypsum Crystals and Roses:

Morphology of Gypsum Crystals and Roses:

Two different morphological categories are recorded; single crystals type and smaller columnar, branched blocks. These two types are greatly differs not only in their morphology but also in their mechanism of formation.

The paragensis of the recorded single gypsum crystal habits can be illustrated in Fig. (3a, b, c, d, e), and described as following, a- single lenticular type, b-single lenticular with minor twin, c- penetration twin composed of two individual of lenticular crystals, d- complex penetration twin (with secondary complex nucleation occurs near the twin interfaces, e- roses in which the individual petals of these roses are of lenticular type, each of which fans out from parent lenticular crystal according to Cody and Cody (1989).

The branched columnar type is highly varied; its component crystals appear to be arranged around a vertical axis to give columnar appearance (Fig. 4).

Mechanism of Formation:

The two recorded gypsum categories reflect two distinct mechanisms of formation , the first one takes place when the brine reach to supersaturation level with $CaSO_4$ and leads to the formation of the single gypsum crystal and rose of different size (Fig. 5).

The relatively large size of gypsum roses and crystals indicates continuity in saturated brine level for a long enough time reflecting a state of stagnation period. However, it also suggests that nucleation and growth were; in general, relatively slow or near equilibrium conditions. The second following mechanism type which is most probably responsible for the formation of columnar, composite smaller crystals is the evaporative pumping mechanism. On the other hand, the presence of such columnar branched form indicates growth within different degree of compacted sediments Cody and Cody (1989).

Except for minor small lenticular gypsum crystals, the top samples of the investigated cores are characterized by the absence of the different gypsum crystal forms, this is because surface samples having sandy nature rather than clayey and in turn seem to be lack of organic contents. The effect of the organic contents on the nucleation of gypsum crystals is absent at surface.

Recent experimental studies (Cody and Cody, 1989) explore the relationship between organic rich compounds environments and the nucleation behavior and growth morphology of gypsum crystals. Lenticular dominated habit are formed at high temperature with increasing of organic matter penetration twinning developed, by further increasing of the organic matter concentration, a secondary complex nucleation occurred near the twin interfaces, and finally a rosette and rose like aggregates are formed.

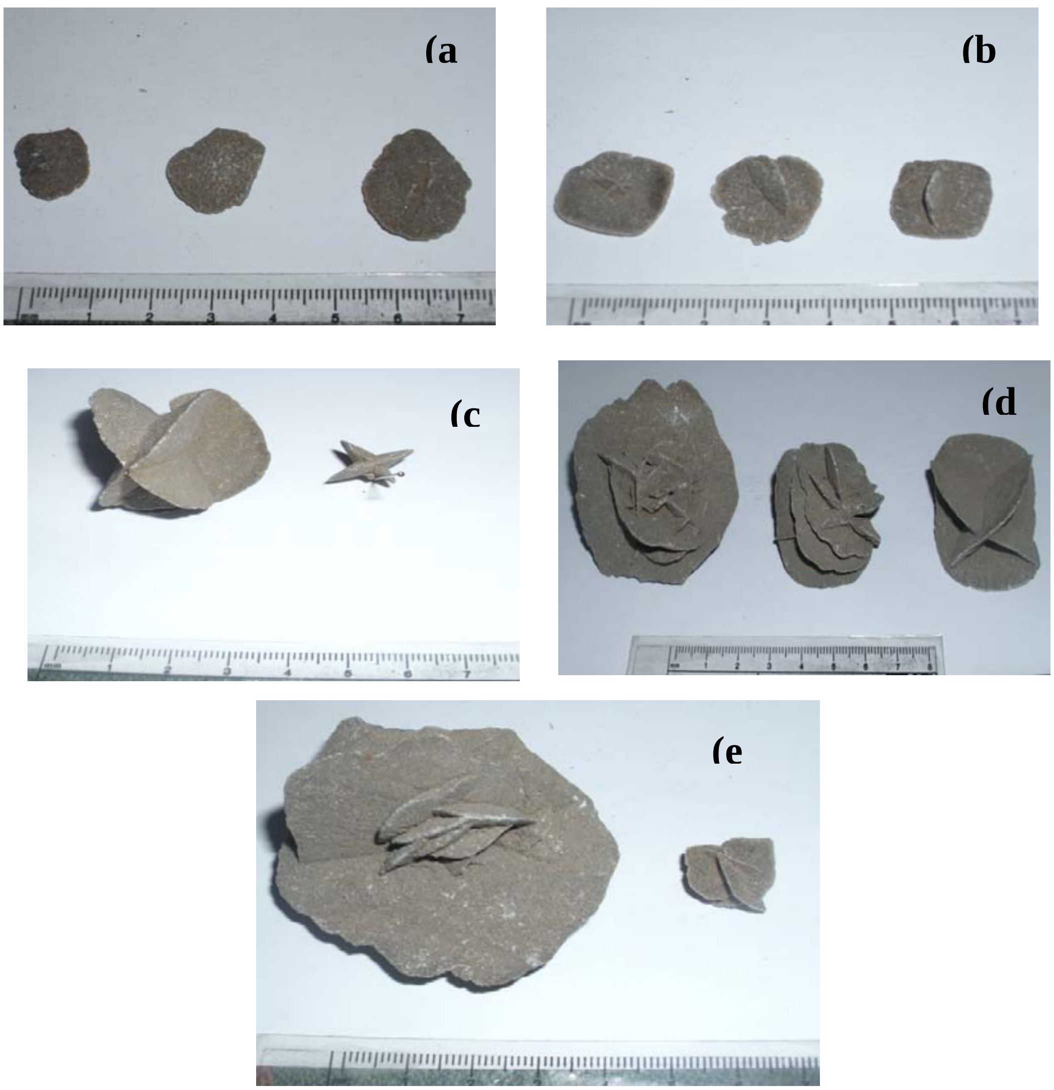

Fig. 3: Paragenesis of gypsum crystal habits.

Attia *et al*. (1997) recorded the presence of lenticular gypsum crystals with varying size in the modern evaporitic settings of the intertidal basins (El-Sheikh Zuweid and El-Fath), Northern Sinai. They mentioned that the biological activities play a major role in the crystallization of gypsum habits; the study area is characterized by enrichment in microbial mats.

Lenticular gypsum used organic matter as a substrate for their growth, this is because the organic molecules containing surface active functional groups (such as fatty acids, glycerol or polysaccharides). These groups are considered as good retards for the nucleation of gypsum crystals (Wang *et al*. 1986).

On the other hand, the sulfate contents are varied according to lithology, higher contents are in the fine grained sediments, while sand with higher permeability has lower values. The sulfate amounts are related to absorption in the clayey sediment.

The temperature, salinity gradient type and amount of the organic matter compounds, nature of the sediments as well as the pH values at the site of growth are responsible for such diversity in the morphology of the gypsum crystals and roses, so they can be used as an environmental guide Hilmy and Ali,1985.

Environmental Significance:

The different gypsum habits recorded in the study samples reflect the environmental condition in the study area, for example, 1- the lenticular gypsum habits is most common at high temperature, NaCl-rich sediments containing abundant specific types of dissolved organic material (Cody, 1979). This is in agreement with the present work where organic matter predominate in the study area they have the ability to excret - amylase enzyme to soil promoting the formation of lenticular gypsum Cody and Cody, (1989). However, Single lenticular gypsum crystals seem to have little environmental significance except that very acidic environments are contraindicated .The increase in size and in number of isolated lenticular gypsum crystals is due to the increase in salinity of the interstitial brines (Cody and Cody 1988). 2-The penetration twins appeared to be diagnostic of gypsum growth in muddy terrestrial environment rich in mica with a pH greater than 7.5(Cody and Cody, 1988). On the other hand, progressive adsorption of organic substances on gypsum faces increases their surface roughness and may be responsible for penetration twin nucleation (Cody and Cody 1988).

3-The rosettes habits are indicative of very warm, arid, saline environment characterized by sediments that contain very large concentration of terrestrial humic compounds. Higher temperatures generally favored better formed and larger rosettes (Cody and Cody 1988).

Environmental pH was found to be very important since, organic compounds is seem to be effective in significantly modifying gypsum habit only at pH greater than 7.5.

Fig. 4: Branched columnar type.

Fig. 5: Complex roses of different sizes ranging from very small to large size.

Petrography of the Gypsum Crystals and Rosettes:

Microscopic investigation of selected thin section of gypsum roses revealed that the study samples consist of two different grain size classes,1- coarse grained minerals represented by, quartz, mica, and feldspars. 2- medium grained minerals which are represented by gypsum, opaques, epidotes, zircon, amphiboles and pyroxenes in decreasing order of abundance. The above mentioned minerals are embedded in a very fine groundmass of gypsum and clay minerals (Fig. 6a, b, c, d).

Quartz grains account for about 35% of the detrital framework constituents, mica flakes forming about 25%, gypsum crystals forming 30% and heavy minerals forming about 10% of the total framework.

Most of the quartz grains are monocrystalline showing non-undulatory extinction, angular and subangular grains are the most common types recorded. Iron oxide coating around the quartz grains are frequently observed.

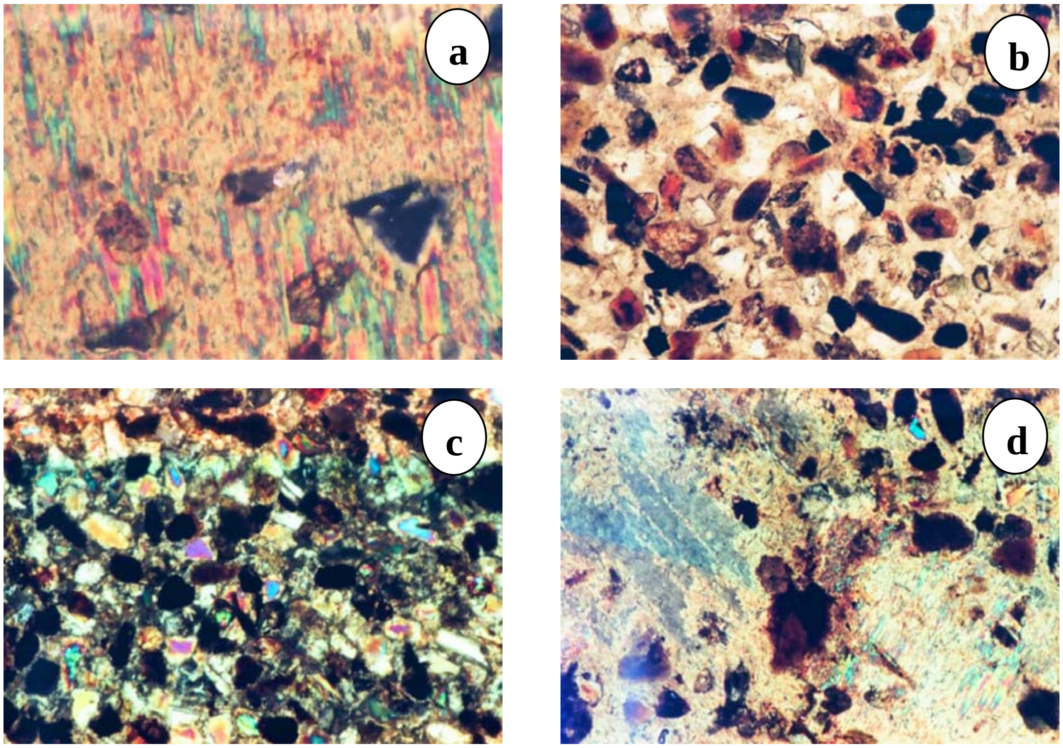

Fig. 6: Petrography of the gypsum crystals and rosettes (a) photomicrograph showing mica grains embedded in groundmass of gypsum (X.40), (b) photomicrograph showing angular to sunangular coarse quartz grains (X.40), (c) photomicrograph showing enrichment of subrounded opaque grains (X.40) and (d) photomicrograph showing quartz grains, opaques, amphiboles and mica embedded in groundmass of gypsum (X.40).

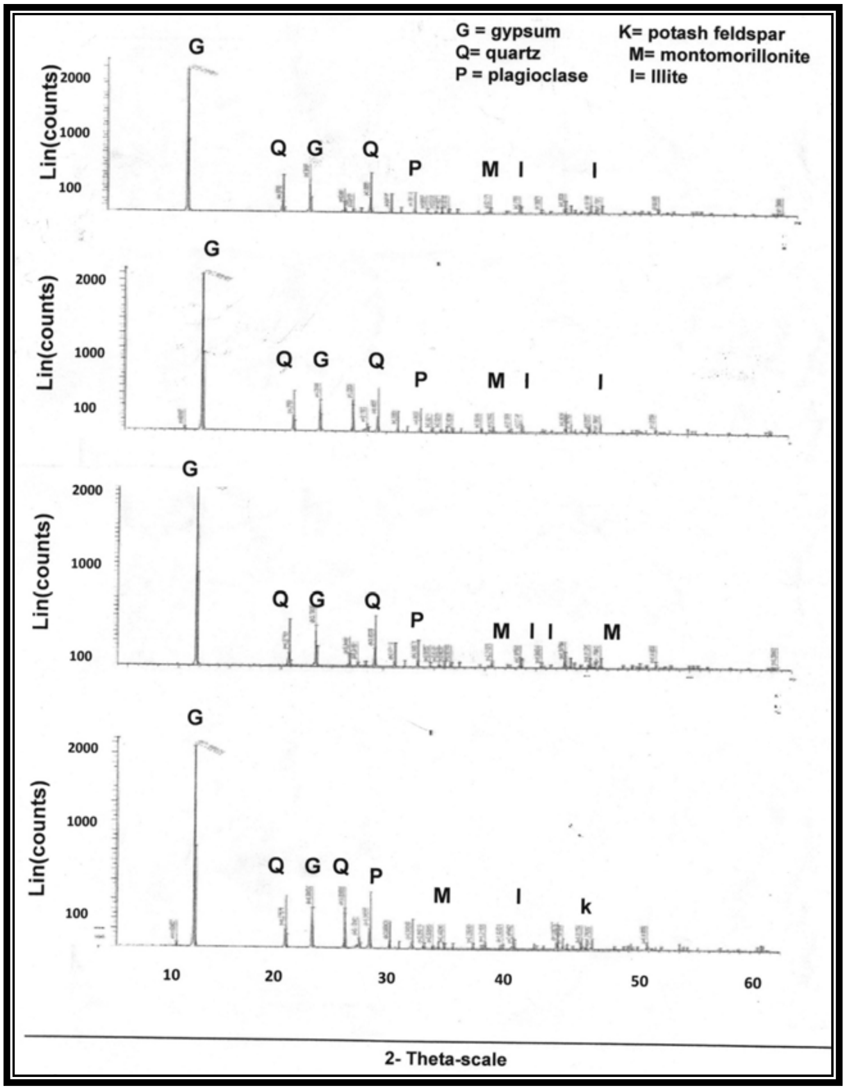

Fig. 7: X-ray diffractograms of representative gypsum roses samples.

Gypsum is represented by acicular prismatic and lenticular colorless crystals Fig 6(a). Mica occurs in two different forms, a- coarse rounded to subrounded grains expressing different colors; yellowish brown, yellowish orange and green color, with iron oxide inclusions (such variety don't show pleochroism). b- tabular, elongated rod shaped crystals, cleavable, yellowish brown in color, (biotite) (Fig 6 d). However they are less common.

The mineralogical assemblage observed in the study sand samples greatly similar in varieties to those recorded in the gypsum crystal thin sections.

X- ray diffraction analysis of the investigated gypsum rose samples were represented in Figure (7) It show patterns of gypsum and quartz as a main components. Less amount of feldspars, montomorillonite and illite are also recorded. The X- ray patterns of gypsum show that the reflection peaks are sharp, high, symmetrical and well defined indicating high state of crystallinity.

The results obtained from petrographic investigation are greatly matched with those recorded from the x-ray analysis.

The relationship between the investigated gypsum crystals and the associated detrital sediments can be illustrated from the relatively dark colored appearance characterizing all the investigated gypsum classes, their color is most probably due to the ability of gypsum to incorporate sand and large amount of organic matter with different species of heavy minerals during the process of nucleation and growth. This is in agreement with the experimental results of Cody and Cody (1989). Microscopic investigations can also confirm this relationship, the heavy and light minerals recorded from the detrital sand samples are greatly comparable to those recorded from the thin sections of the investigated gypsum crystals.

According to the types of sediments found in the study area, two main types of environments of deposition were recognized .(1) an environment influenced by sea water, consisting mainly of sand sediments, rich in shell fragments with few lenticular gypsum crystals, representing relatively high energy condition. (2) Early evaporatic environment where clayey and muddy sediments (with more than 15%silt and clay) rich with gypsum crystals and roses of different forms and sizes.

Summary and Conclusions:

Textural, mineralogical and morphological characters of 25 core samples (containing trrigenous samples as well as gypsum and roses) have been determined. The samples collected from the north east coast of the Nile delta (east of Damietta branch). Texturally the detrital core samples are composed mainly of clayey sand and muddy sand. Generally, silt clay contents increase where sand decreases from core top towards base. The organic matter contents show a general increase downward, while the carbonate contents show an opposite trend, since they tend to decrease downward.

From the mineralogical point of view, the mineralogical assemblage recorded from the terrigenous sand greatly similar in varieties to those recorded from the gypsum crystal thin sections. The light minerals composed mainly of quartz, gypsum and muscovite, while the heavy mineral composed of opaques, harnblende,augite and epidote.

Two different morphological categories of gypsum crystals and roses were recorded, single crystal type of different sizes and forms as well as smaller columnar branched type. The two recorded gypsum types reflect two different mechanisms of formation; supersaturation level with Ca SO_4 leading to the formation of the single gypsum crystals and roses followed by evaporative pumping mechanism which is responsible for the formation of columnar, branched type.

The different gypsum crystal habits recorded in the studied samples are indicative of arid, saline environment characterized by sediments that contain very large concentration terrestrial humic compound with an acidic pH (Cody and Cody, 1989).

On the other hand, the relatively large size of gypsum crystals and roses indicate continuity in saturated brine level for a long period which is a stagnant period.

REFERENCES

Attia, O.E.A., M.A.M. Aref and M.S. l-Banna, 1997. Sedimentological significance of modern evaporate settings, Northern Sinai, Egypt. Egypt. J. Geol., 41(2A): 89-118.

Carver, R.E., 1971. Procedures in sedimentary petrology . John Wily and Sons. Inc. New York, pp: 653.

Cody, A.M. and R.D. Cody, 1989. Evidence of microbiological induction of {101} Montmerte twinning of gypsum ($CaSO_4.2H_2O$). J. Crys. Growth, 98: 721-730.

Cody, R.D., 1979. Lenticular gypsum: occurrences in nature and experimental determinations of effects of soluble green plant material on its formation. J. Sed . Pet., 49: 1015-1028.

Cody, R.D and A.M. Cody, 1988. Gypsum nucleation and crystal morphology in analog saline terrestrial environment. J. Sed. Pet., 58: 247-255.

Dean, W.E., 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. J. Sed. Pet., 44(1): 242-248.

Folk, L., 1974. Petrology of sedimentary rocks. Hemplill, Austin, Texas, pp: 182.

Fontes, J.C. and F. Gasse, 1989. On the ages of humid Holocene and Pleistocene phases in North Africa-Remark on late Quaternary climatic reconstruction for Maghreb (North Africa). Paleogeogr. Paleochim. Paleocol., 70: 393-398.

Hassan, F.A., 1976. Heavy minerals and evolution of the modern Nile. Quaternary Research, 6: 425-444.

Hilmy, M.E. and Y.A. Ali, 1985. Relationships of distance from Sabkha surface to morphology of gypsum crystals in the vertical profile, West Alexandria, Northern Egypt. Egypt. J. Geol., 29(1-2): 131-144.

Lewis, D.W., 1984. Practical sedimentology. Hutchison Ross Publ. Co., Stroudsburg.

Paulissen, E. and P.M. Vermeersch, 1989. Behaviour of large allogenous river systems: The example of the Saharan river Nile during late Quaternary. Bulletin De La Societe Geologique de. France., 5: 73-83.

Stanley, D.J. and G.A. Maldonad, 1977. Nile Cone: Late quaternary stratigraphy and sediment dispersal. Nyture, 266: 129-135.

Wang, T.S.C., P.m. Huang, C.H. Chou and J.H. Chen, 1986. The role of soil minerals in the biotic polymerization of phenolic compounds and formation of humic substances. In: P.M. Huang and M. Schnitzer, interaction of soil minerals with natural organics and microbes. Soil Sci. Soc-Am., Spec. Publ., 17: 251-282.

Waren, J.K., 1989. Evaporite sdimentology, Prentice. Hall, Inc. New Jersey, pp: 285.