

GEOLOGIC OCCURRENCE AND SEDIMENTARY SEQUENCE AND
COMPOSITION OF THE SEDIMENTS OF EL-ALAMEIN LAGOONS
ALONG THE WESTERN SIDE OF THE MEDITERRANEAN COASTAL
ZONE OF EGYPT.

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ABSTRACT

The coastal lagoons along the North African coast of Egypt constitute some of the most important environments with regards to the aquatic resources and sabkha sediments. Given the importance of the coastal lagoon environments as national resources and also their scientific values as a natural heritage which should be carefully preserved, our research team started a program, for study of the geology, mineralogy and geochemistry of El-Alamein Lagoons along the western side of the Mediterranean coastal zone of Egypt. The present issue concerns with the geologic occurrence, sedimentary sequence and composition of the sediments of such lagoons. The area of study lies in the Mediterranean coastal zone of Egypt, at a distance of about 110 km west of Alexandria and the Nile Delta. The area extends for about 20 km both east and west El-Alamein village. The Lagoons lie in a depression between modern and Pleistocene beach ridge "the first depression" and consist of eight lagoons, each lagoon is characterized by topographical features including shape, size, relief and nature of the sediments.

INTRODUCTION

The Mediterranean coastal zone of Egypt west of Alexandria attracted many workers, including Blankenhorn (1901 and 1902), Zeuner (1950 and 1952), Philip (1955), Shukri et al. (1955), Butzer (1960), and El-Shazly (1967), who studied the limestone ridges in the area and attributed them to entirely marine origin. In contrast, however, Hume and Hughes (1921), Hume and Little (1928), Ball (1939), Sanford and Arkell (1939), Picard (1943), Hilmy (1951), and Shata (1955 and 1959) considered these ridges of non-marine origin, derived from littoral and coastal sand dunes (aeolian). Recently, Hassouba (1980) considered the upper parts of these ridges as composed of aeolian sediments built on beach deposits. Ball (1939) mentioned that the area intervening between the coastal ridge and the next inland ridge is occupied in some places by salt lagoons and marshes. Hammad (1966), considered that the lagoonal deposits originated during the inundation of sea water over low land where the soluble salts are concentrated and

recrystallized in the form of anhydrite, gypsum, halite and other salts. Moussa (1976), studied the geomorphology and subsurface geology of the area between El-Alamein and Qattara depression to the south and considered the fore-shore lagoons at El-Alamien which extend between Abyar El-Shammam to the east and Sidi Abdel-Rhaman to the west as representing closed to subclosed low land areas generally below sea level.

The present study deals with shape, size, relief, sequence, and nature of the sediments of eight lagoons in the area of investigation.

MATERIALS AND METHODS

Both field and laboratory phases were carried out. Cores, box samples and pits were dug at measured locations on a series of twelve traverses extending from the supratidal zone, at right angles to the coastal ridge, across the tidal flats to the lagoon bodies. One traverse was made across each of the first, second, fourth, seventh, and eighth lagoons, and two traverses were made across the third, fifth and sixth lagoons. Other pits were dug in different places around the lagoons to make proper comparisons of the data. Emphasis is made on the lagoonal sediments and the tidal flats (intertidal zone) with their features. Associated features such as sediments of supratidal and alluvial fans adjacent to the studied lagoons are also considered. Moreover mapping of the eight lagoons has been carried out (Figs. 1-7).

Systematic sampling and preparation of a base map for the area of study by using tapes, compass and alidade together with aerial photographs began on June 1983. Then after, two

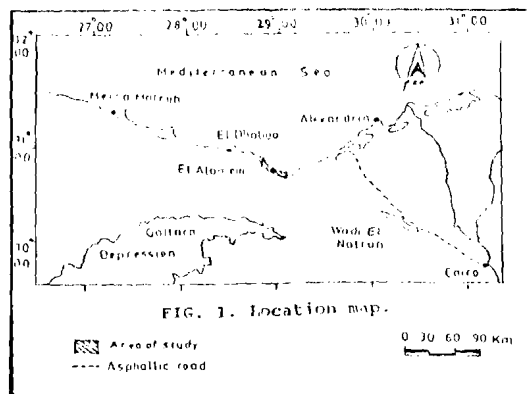


FIG. 1. Location map.

major field trips were made during September and October 1984. Samples were collected from measured positions within the pits in box containers and some core samples were later sawn longitudinally into halves, one half for fabric studies, while the other for mineralogical studies. Laboratory work included the following techniques and methods:

Minerals were identified chiefly by means of X-ray diffraction, infrared spectroscopy and transmitted light microscopy. About 80 sediment samples from different lagoons and tidal flat sediments were treated to determine the percentage of the organic matter, soluble and insoluble constituents. Particle size analysis was made principally to study the particle size distribution vertically and laterally in each lagoon. More than 60 samples of gypseous sand and the other lagoonal sediments were analysed. Terminology and class intervals are expressed in terms of phi values. U.S. standard sieve meshes have been used. The histograms and cumulative frequency curves were examined. Because of the water solubility of some minerals and the sensitivity of gypsum toward heat, special technique for the preparation of thin sections was employed.

RESULTS AND DISCUSSION

Details of pits in traverses, cores and beds in the vertical profile were measured from the intertidal zone, shallow subtidal zone (lagoon margin) and subtidal zone (lagoon sediments) from the surface downward. Soluble content (wt. %), organic matter content (wt. %) and insoluble content (wt. %) of the sediments were determined. The total of soluble and insoluble contents of sediments in each sample is assumed to be 100 (wt. %) of the sediments.

The First Lagoon (AL-1)

This lagoon is a body of quiet water, situated at the eastern end of the studied lagoons, (Fig. 2). It is about 500 m long and average width is approximately 400 m. It is nearly round in shape and represents the smallest of the eight lagoons. This lagoon is separated from the Mediterranean Sea by the coastal ridge. The water depth in the lagoon ranges from few centimeters near shore, to about 1.7 m in the central part of the lagoon. The water seeps from the sea to the lagoon through the coastal ridge, (Fig. 2). The intertidal zone is very narrow and is of about 1-2 m wide along the southern border of the lagoon. The supratidal zone bounds the lagoon from the east and west directions. A traverse extending from the asphaltic road to the coastal ridge in the North was made across the lagoon. The main morphologic features are alluvial fans of loam with Helix shells, shell fragments and land snails. This zone extends for about 500 m then is followed by a break in slope of

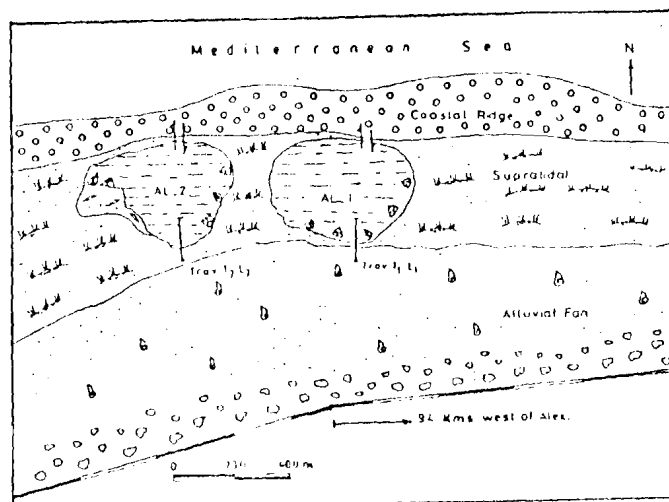


FIG. 2.
Map showing the geologic features and sampling locations in lagoon.

about 19° toward North. It is then followed by the supratidal zone which extends for about 9 m with 80° slope toward the lagoon margin and with an elevation of about one meter above the ground water level. The margin of the lagoon contains shells of *Cardium* and *Gastropods*. No algal or gypsum heads were observed. The pits and samples description are listed as follows:-

Traverse T_1I_1 : Pit $T_1I_1P_3$:

This pit is situated at 18 m from the northern margin of the lagoon (on the supratidal type of sabkha).

Sedimentary Sequence: Bed and Sample No.	Description	Thick (cm)	Depth (cm)
$T_1I_1P_3S-1$	Brown blister surface of carbonate sand (ooids) and plant roots.	0.4	0.4
	Greyish sticky gypseous sand (lenticular to sublenticular fine gypseous crystals seen with slight corrosion mixed with carbonate sand.	2	2.4
$T_1I_1P_3S-2$	Band of nodular gypseous sand, carbonate sand (ooids) and plant roots.	5	7.4
	Greyish sandy layer of carbonate sand (ooids), ostracods and few quartz grains.	15	?

Ground water level was at 40 cm below the surface (August 1964).

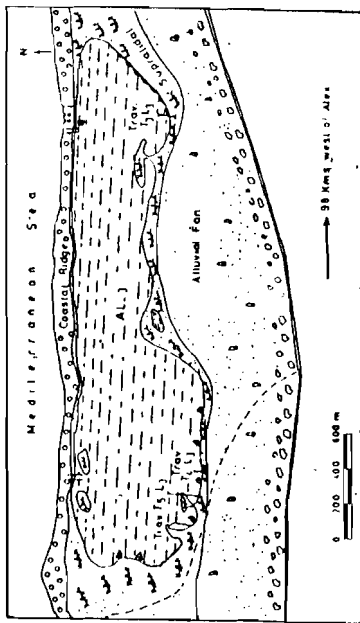


FIG. 3.
Map showing the geologic features and sampling
locations in lagoon.

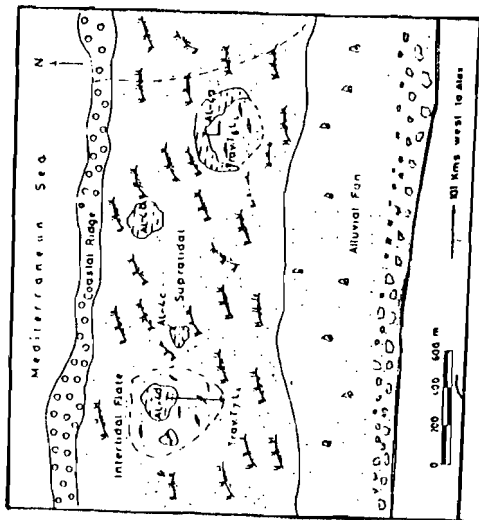


FIG. 4.
Map showing the geologic features and sampling
locations in lagoon.

Legend of figs. 2-7

- | | | | |
|----|-------------------------|----|---------------|
| 11 | Gypsum mounds | 13 | Lagoon number |
| 22 | Gypsum crystals | 2 | Car tracks |
| 3 | Straight cut | 3 | Zigzag cut |
| 12 | Coastal ridge | 15 | Water seepage |
| 20 | Halophyte on hummocks | 16 | Tidal flat |
| 17 | Asphalitic reed | 18 | Algal mounds |
| 21 | Alluvial fan with helix | | |

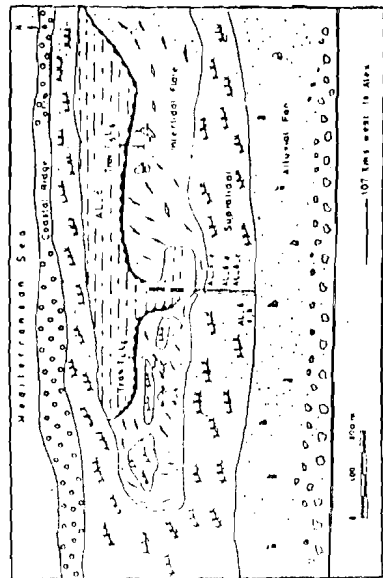


FIG. 6.
Map showing the geologic features and sampling
locations in lagoon.

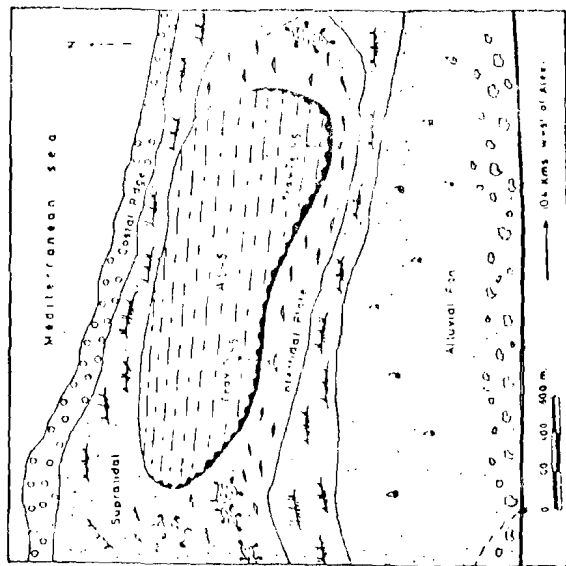


FIG. 5.
Map showing the geologic features and sampling
locations in lagoon.

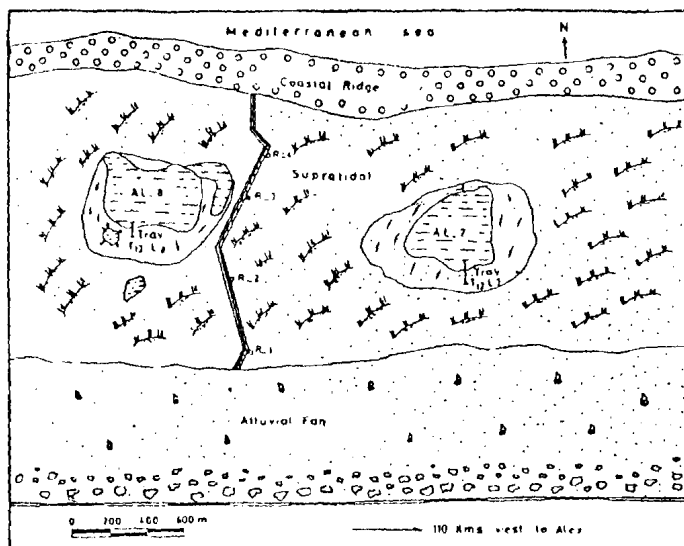


FIG. 7.
Map showing the geologic features and sampling locations in lagoon.

Pit T₁L₁P₂

This pit is situated on the southern margin of the lagoon.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₁ L ₁ P ₂ S-1	Brown salty blister surface with carbonate sand (oids), Gastropod and Cardium shells on surface.	0.5	0.5
T ₁ L ₁ P ₂ S-2	Alternating, black, dark grey and brown sandy layers of carbonate sand (oids) and grains (rounded and srbounded).	30.0	30.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue
T ₁ L ₁ P ₂ S-1	5.82	40.39	53.78
T ₁ L ₁ P ₂ S-2	3.4	24.57	71.95



FIG. 8
Photograph showing part of the fourth lagoon, notice the coastal ridge in the back of the photograph, however in the central part, ruckled, brown surface and wet surface on the top of the intertidal flat zone, and part of small pond.



FIG. 9
Photograph showing part of the fifth lagoon, inner zone of the dumpy intertidal zone, and trash lines with white salty blister surface.

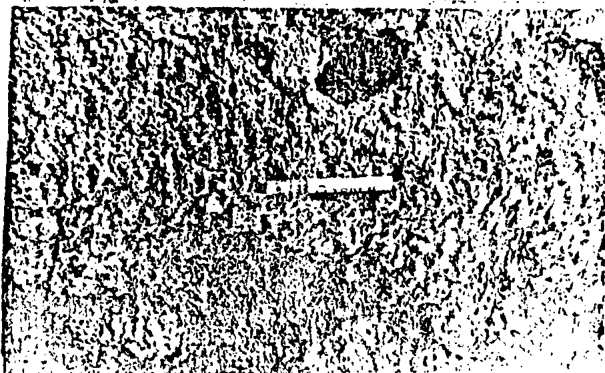


FIG. 10
 Photograph showing ruckled blister surface,
 represent the salt crust surface of sulphate
 and carbonate component on the top of intertidal
 zone (Lagoon 5).

Pit T₁L₁P₁

This pit is situated inside the lagoon at a distance of about 40 m from the southern margin of the lagoon.

The height of the lagoon water was of about one meter above the sediment surface.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₁ L ₁ P ₂ S-1	Veneer of light brown carbonate sand (ooids) followed by green laminae of algae with turrated Gastropods and Cardium shell on the surface.	0.5	0.5
T ₁ L ₁ P ₂ S-2	Spongy and laminated green algal with carbonate sand (ooids).	2.5	3.0
	Greysish black sandy layer of carbonate sand (ooids) and quartz grains.	17.0	20.0

Binocular investigation of the sediment in this pit showed dominance of carbonate sands (ooids), quartz grains (rounded to subrounded), Ostracods, Gastropods, Cardium, shell fragments, and few very fine lenticular to sublenticular gypsum crystals.

Particle size-analysis and its statistical treatment revealed that the sediments are fine sand grains, moderately to poorly sorted with sorting coefficient (σ_I) ranging between 0.89 to 1.2 and skewness (SK_I) ranging between -0.33 to -0.38 (Fig. 11).

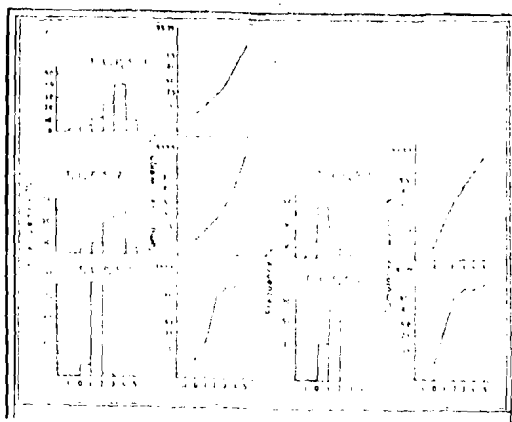


FIG. 11.
Histogram and cumulative curves of the margin and lagoonal sediments (T₁L₁P₄S-1), sample from the alluvial fan.

Pit T₁L₁P₄ :-

Sample (T₁L₁P₄S-1) taken from the alluvial fan is of light brown loamy sands, with Helix, shell fragments and plant debris.

Binocular investigation of the sediments revealed that the sediments are composed of quartz grains (well rounded to rounded), Ostracods, shell fragments and Foraminifera shells.

Particle size-analysis and its statistical treatment revealed that the sediments are medium sand size, moderately sorted with sorting coefficient (σ_I) of about 0.83 and skewness (SK_I) of about 0.14, (Fig. 11).

The Second Lagoon (AL-2)

This lagoon situated at about 10.5 Km to the east of El-Alamein Rest House, is similar to the first lagoon (AL-1) in shape and size. It is of about 500 m long and its width is of approximately 400 m. It is separated from the Mediterranean Sea by the oolitic coastal ridge and its water depth ranges from few centimeters near the margin to about 1.5 m at the central part. The main connection between the Mediterranean Sea-water and the lagoon is by seepage through the coastal ridge, (Fig. 2). The intertidal zone ranges in width from 5 m along the southern border of the lagoon to about 100 m in the western side, where lagoon water floods to form a hypersaline pond in the western direction. As in the first lagoon, the supratidal sabkha zone bounds the lagoon from all directions just next to the intertidal and subtidal zones. A traverse was made from the asphaltic road northward to the coastal ridge, (Fig. 2). The main morphologic features are as following:

(i) Light brown loamy alluvial fan zone with Helix, shell fragments, halophyte plants and land snails. This zone extends for about 500 m, then breaks in slope about 20° N, where it is followed by

(ii) Supratidal sakha zone following the alluvial fan, and extending for about 75-100 m with nibkha, dikaka and blister surface (Ali, 1981), with slope of about 80° N towards the lagoon margin.

The lagoon margin contains a considerable amount of shells of Gastropods and Cardium. No algal or gypsum heads were seen.

The hypersaline pond in the western side of the lagoon contains thick salt crust and small dead fish. The water depth reaches few centimeters.

Traverse T₂L₂: Pit T₂L₂P₁

This pit is situated at about 45 m from the southern margin of the lagoon.

<u>Sedimentary Sequence:</u>			
Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₂ L ₂ P ₂ S-1	Light brown loamy blister surface	1	1
	Fine gypseous sand of black colour changing into grey colour downward.	3	4
T ₂ L ₂ P ₂ S-2	White, rough banded, coarse nodular gypsum with brown streaks.	26	30
T ₂ L ₂ P ₂ S-3	Grey, fine sand later with Cardium, Gastropod and Ostracod shells.	32	62

Ground water level was at 40 cm below the surface.

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue %
T ₂ L ₂ P ₂ S-1	13.08	23.89	63.05
T ₂ L ₂ P ₂ S-3	4.4	29.93	65.65

Binocular investigation revealed coarse, transparent lenticular, sublenticular, euhedral, interlocked and cross-cutted gypsum crystals, cemented by carbonate cement, carbonate sands (ooids) particularly in T₂L₂P₁ S-2 rounded to well-rounded quartz grains, Ostracods, Cardium, Gastropods and Foraminifera tests.

Particle size-analysis and its statistical treatment revealed that the sediments range between fine to coarse sand size, poorly to moderately sorted with sorting coefficient (σ_I) ranging between 0.92 to 1.14 and skewness (SK_I) ranging between -0.14 to -0.44, (Fig. 12).

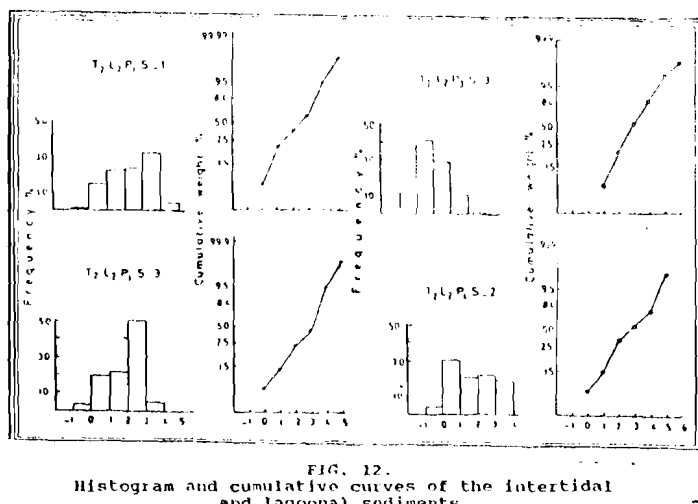


FIG. 12.
Histogram and cumulative curves of the intertidal and lagoonal sediments.

Pit T₂L₂P₃:

This pit is situated at the southern border of the lagoon.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth from surface (cm)
T ₂ L ₂ P ₃ S-1	Brown blister surface.	1.0	1.0
T ₂ L ₂ P ₃ S-2	Black, medium sand gypseous layer.	18	19
T ₂ L ₂ P ₃ S-3	Grey, hard, massive, medium sand gypseous layer.	13.0	32.0

Soluble - Insoluble Residue:

Bed and Sample No.	Organic matter %	Carbonate %	Insol. Residue %
T ₂ L ₂ P ₃ S-2	7.33	20.97	71.69

Binocular investigation of the sediments revealed lenticular to sublenticular, slightly corroded gypsum crystals, rounded to subrounded quartz grains, Ostracods, shell fragments, carbonate sands (ooids) and carbonate lumps.

Particle size-analysis and its statistical treatment revealed fine to medium grain size, moderately sorted with sorting coefficient (σ_1) of 0.98 and skewness (SK_1) of about 0.03, (Fig. 12).

Pit T₂L₂P₄

This pit is situated inside the lagoon at about 60 m from southern margin of the lagoon. The height of the lagoon water above the sediment surface was about 15 cm in this position.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₂ L ₂ P ₄ S-1	Hard, greyish brown surface with bivalve Cardium, Gastropod cemented by carbonate cement.	0.2	0.2
T ₂ L ₂ P ₄ S-2	Dark grey fine sandy layer with plant roots.	29.8	30.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbon-ate %	Insol. Residue%
T ₂ L ₂ P ₄ S-2	17.4	13.58	68.93

Binocular investigation revealed that most components of the sediments are rounded to subrounded quartz grains, Ostracods, Cardium, Gastropods, carbonate sands (coids), shell fragments, and Foraminifera tests cemented by carbonate.

Particle size-analysis and its statistical treatment revealed that the sediments are of fine grain sand size, poorly sorted with sorting coefficient (σ_1) of 1.21 and skewness (SK_1) of 0.07, (Fig. 12).

The Third Lagoon (AL-3)

This lagoon is nearly the biggest one, situated at about 6 km to the east of El-Alamein Rest-House. It is irregular in shape but generally of elongate shape. It is about 3.75 km long with an average width of about 800 m, (Fig. 3). The lagoon attains its maximum width in the western side, and attains its minimum width in its middle part. Small supratidal islands are scattered in the lagoon water body. The lagoon is separated from the sea water by the coastal ridge, and the main connection between the sea water and the lagoon was through the bottom of the coastal ridge. Recently an artificial canal connected the sea water with the lagoon. The morphologic features of this lagoon resemble the first and second lagoons to the east. Two traverses were taken in the eastern and western arms of the lagoon (T₃L₃ and T₅L₃), (Fig. 3). The morphologic units from south to north are as follow:

(i) Alluvial fan, extending for about 500 m from the road toward the lagoon with a break in slope 19° N, is composed of shell fragments, carbonate sands (coids), Helix shells, land snails, rounded to subrounded quartz grains and Foraminifera shells.

(ii) Supratidal type of sabkha zone, following the alluvial fan zone and extending from about 5 m to 170 m in the eastern part with halophyte plants and brown blister surface.

(iii) Low subtidal zone following the supratidal zone. The margin of the lagoon is characterized by banks of

Gastropod and Cardium shells, which decrease in the northern edge. Also brown glazy, colloidal algal heads developed along the eastern and western margins of the lagoon, (Fig. 3). The general type of sediments in the lagoon and intertidal zone are mainly quartz grains (rounded to subrounded), shell debris, carbonate sands (oids), Cardium, Gastropods, Ostracods, Foraminifera shells, some heavy minerals and small lenticular to sublenticular gypsum crystals with carbonate minerals. The salinity increases gradually from the first and second lagoons to this lagoon i.e from east to west, so this lagoon shows higher salinity than the other two lagoons.

Traverse T₃L₃: Pit -T₃L₃P₁.

This pit is situated at the tidal flat at about 10 m from the southern margin of the lagoon.

<u>Sedimentary Sequence:</u>			
<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₃ L ₃ P ₁ S-1	Light brown blister surface.	0.2	0.2
	Black gypseous soil.	0.3	0.5
	Brown sandy later of quartz, ooids and carbonate lumps.	5.	5.5
T ₃ L ₃ P ₁ S-2	Brown laminated sandy layer of quartz, ooids, shell fragment and carbonate minerals.	15.0	20.5
T ₃ L ₃ P ₁ S-3	Gery laminated relatively hard fossiliferous sandy layer of quartz, ooids, shell fragment, some heavy mineral and carbonate minerals.	10.0	30.5
T ₃ L ₃ P ₁ S-4	Grey fossiliferous fine sandy layer with brown laminae and Gastropod shell.	10.0	40.5
T ₃ L ₃ P ₁ S-5	Dark grey, fine sandy later with rare fossil content.	09.5	50.0

Ground water level was at 48 cm from the surface, (August 1984).

Binocular investigation of the sediments in this pit showed that the main components of the sediments are rounded to subrounded quartz grains, carbonate sands (oids), shell fragments, Ostracods, Foraminifera shells, Cardium, Gastropods, echinoid spines, few corroded gypsum crystals and carbonate lumps.

Particle size-analysis of this sediment and its statistical treatment revealed that the sediments particularly (S-4 and S-5) are of fine sand size, moderately sorted with sorting coefficient (σ_1) of about 0.95 with coarse skewness (SK_1) of S-4 = 0.13 and symmetrical skewness in S-5 = 0.01, (Fig. 12).

Pit T₃L₃P₂

This pit is situated at the southern margin of the lagoon.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₃ L ₃ P ₂ S-1	Light brown blisdter surface.	0.2	0.2
	Brown medium fossiliferous sand, the upper laminae is black changed into greyish downward with Cardium and Gastropod occoure in bedded direction.	1.5	1.7
T ₃ L ₃ P ₂ S-2	Hard, fine, grey fossiliferous sandy layer.	2.0	3.7
T ₃ L ₃ P ₂ S-3	Dark grey, fine, fossiliferous layer.	16.3	20.0

The ground water level was at 19 cm from the surface (August, 1984)

Soluble-insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue %
T ₃ L ₃ P ₂ S-1	4.72	52.91	42.15

Binocular investigation of the sediments in the pit showed that the main components of the sediments are carbonate lumps, ooids, shell fragments, rounded to subrounded quartz grains, echiniod spines, Cradium, Gastropod and rare heavy minerals.

Particle size analysis and its statistical treatment revealed that the sediments (S-1), are of fine sand, moderately sorted with sorting coefficient (σ_1) of 0.78 and symmetrical skweness $SK_1 = 0.08$, (Fig. 13).

Pit T₃L₃P₃

This pit is situated at the margin, beside T₃L₃P₂, within the algal heads.

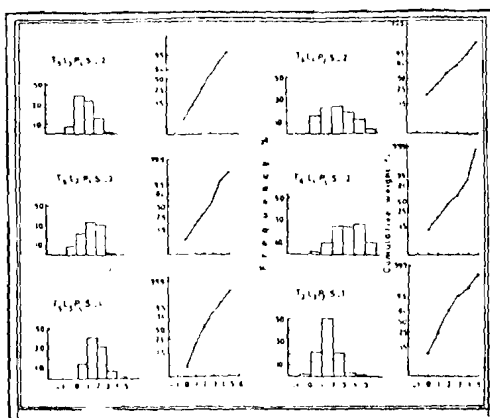


FIG. 13.
Histogram and cumulative curves of the margin and lagoonal sediments.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₃ L ₃ P ₃ S-1	Light brown, smooth, glazy algal head showing lamination with, Cardium Gastropod, and carbonate mineral.	6.16	16.0
T ₃ L ₃ P ₃ S-2	Grey, fine shelly sandy layer with ooids, Cardium and Gastropod.	10.0	26.0
T ₃ L ₃ P ₃ S-3	Grey, fine sticky, fossiliferous sandy layer with predominant turrated white Gastropods.	23.0	49.0
T ₃ L ₃ P ₃ S-4	Dark grey, fine, fossiliferous sandy layer with shell fragments, ooids, Gastropod and Cardium shells.	11.0	60.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbon-ate %	Insol. Residue%
T ₃ L ₃ P ₃ S-1	7.9	48.04	43.99

Binocular investigation of the sediments in this pit showed that, the components of the sediments are carbonate lumps, carbonate sands (ooids), quartz grains (rounded to subrounded), Gastropods, Cardium, shell fragments, Foraminifera shells, echinoid spines, few heavy minerals and algal tissues.

Particle size analysis and its statistical treatment revealed that the sediments from sample T₃L₃P₃ S-2 to T₃L₃P₃ S-5 are of fine sand grains, varying from poorly to moderately sorted with sorting coefficient (σ_I) ranging between 0.94 to 1.11 and skewness (SK_I) between 0.14 to 0.15, (Fig. 13).

Pit T₃L₃P₄

This pit is situated inside the lagoon at 40 m from the southern margin. The height of water above the sediment surface was 75 cm.

<u>Sedimentary Sequence:</u>			
<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₃ L ₃ P ₄ S-1	Hard, grey Crust with Cardium, Gastropod and ooids.	1.0	1.0
T ₃ L ₃ P ₄ S-2	Grey, fine fossiliferous sand.	10.0	11.0
T ₃ L ₃ P ₄ S-3	Dark grey, fine fossiliferous sand.	20.0	31.0
T ₃ L ₃ P ₄ S-4	Dark grey, fine fossiliferous sand with brown and black streaks.	19.0	50.0

Binocular investigation revealed that the sediments in this pit are composed of Cardium and Gastropod cemented by carbonate cement and ooids, rounded to subrounded quartz grains, Ostracods, shell fragments, echinoid spines, Foraminifera tests and few heavy minerals.

Particle size-analysis and its statistical treatment revealed that the sediments in this pit are of fine sand grains, poorly to moderately sorted with sorting coefficient (σ_I) ranging between 0.79 to 1.02 and skewness (SK_I) ranging between 0.35 to 0.30.

Pit T₃L₃P₅

This pit is situated inside the lagoon at 70 m from the southern margin

The height of the water above the sediment surface was one meter in August 1984.

Sedimentary Sequence:

<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₃ L ₃ P ₄ S-1	Brown, loamy, sand on surface followed by black, medium sandy layer with Cardium and Gastropod shells.	10.0	10.0
T ₃ L ₃ P ₄ S-2	Grey, fossiliferous sandy layer with Cardium and Gastropod shell with carbonate cement.	5.0	15.0
T ₃ L ₃ P ₄ S-3	Dark grey fossiliferous sandy layer	2.0	17.0
T ₃ L ₃ P ₄ S-4	Grey sandy layer with Cardium and Gastropod shells.	32.0	47.0
T ₃ L ₃ P ₄ S-5	Dark grey fossiliferous sandy layer.	13.0	50.0

Pit T₄L₃P₁

This pit is situated some 100 m east T₃L₃ traverse on the margin.

Sedimentary Sequence

<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₄ L ₃ P ₁ S-1	Brown blister surface.	0.1	0.1
	Brown loamy, fine sandy layer showing ruckled, sticky brownish green algal laminae	3.0	3.1
T ₄ L ₃ P ₁ S-1	Black, medium sandy layer with Gastropod and carbonate ooids.	16.9	20.0

-Ground water level was at 3 cm from the surface.

Soluble-Insoluble Residue:

<u>Bed and sample No.</u>	<u>Organic matter</u>	<u>Carbon-ate %</u>	<u>Insol. Residue %</u>
T ₄ L ₃ P ₁ S-1	3.17	32.57	69.25

Binocular investigation revealed that the sediments are composed of rounded to subrounded quartz grains, carbonate ooids, Ostracods, shell fragments, Foraminifera shells, echinoid spines, plant root remains and few euhedral slightly corroded gypsum crystals.

Particle size analysis and its statistical treatment revealed that the sediments are of medium to fine grain size, moderately to well sorted, with sorting coefficient (σ_1) ranging from 0.65 to 0.87 and skewness (SK_1) ranging between 0.15 and 0.30.

The Fourth Lagoon (AL-4)

This lagoon is composed of four scattered dessicated small ponds, which seem to belong to one big lagoon (AL-4) (Fig. 4). They are situated at about 3 km west of El-Alamein Rest House. These ponds are irregular in shape and size and vary in size from 200 to 300 m. Supratidal type of sabkha with its characteristic features which is predominated in the northern margin of the lagoon, varies in width from 200 to 400 m, and is separated from the southern margin by intertidal zone, which varies in width from 100 to 300 m. Two traverses were made along the first and the last ponds, (Fig. 4). Traverse T_{6L4} for example extends from the asphaltic road to the coastal ridge. The traverse crossed the following morphologic units:

(i) The light brown loamy alluvial fan extending from the road to about 670 m toward the lagoon with scattered shrubs, shell fragments, land snails, carbonate sands and helix shells, and slope of about 18° toward the supratidal zone.

(ii) Supratidal sabkha zone extending next to the northern end of the alluvial fan, for a distance of about 85 m toward the lagoon. This zone is characterized by condensed hummocks, nibkha and dikaka (Ali, 1981), with brown blister surface and salt crust.

(iii) The intertidal zone, lagoonward is characterized by dumpy surface with scattered small ponds about one meter wide, circular in shape with dried algal heads at the margins, filled with hypersaline water, gypsum and salt crust, (Fig. 8).

Traverse T_{7L4} is similar to T_{6L4} , (Fig. 4), sampled along the last pond Al 4-d, and passed through the following features:

(i) Light brown alluvial fan, extending for about 95 m followed by a break in slope and extends for about 404 m with dikaka, nibkha, small hummocks, shell fragments, Helix shells, carbonate sands and goat foot prints.

(ii) The supratidal zone following the alluvial fan with extension for about 241 m, brown colored surface, with

hummocks, dikaka, nibkha, and blister surface. The last 100 m are getting dark brown with salt crust around the halophyte plant roots. This zone is followed by about 100 m of nearly flat dark brown blister surface with very small hummocky shrubs and the surface getting wet.

(iii) The intertidal zone (Tidal flat), extends for about 300 m, very small gypsum heads 2-10 cm length and width are scattered on the surface of the tidal flat which is getting wet dumpy with shiny gypsum crystals and crumpled salt crust. The water level in these ponds varies from few centimeters close to the margin to about 60 cm inside the pond. These ponds contain hypersaline water. The increase in salinity is due to the closed restricted condition and minor connection with sea water. Gypsum heads were seen around the margin. The scattered gypsum heads started their appearance in the tidal flat and increased in the lagoon margin (southern margin). Gastropod and Cardium decrease in abundance toward the western direction, while they disappear in the western side of the lagoon. The absence of these fauna is due to the high salinity of the water. Description of pits and samples are as follows:

Traverse T₆L₄: Pit T₆L₄P₃

This pit is situated at 50 m south the pond margin in the tidal flat.

<u>Sedimentary Sequence</u>			
<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₆ L ₄ P ₃ S-1	Brown blister surface with small euهدral gypsum crystals flattend on (010) surface.	1.0	1.0
	Brown grey gypseous sand.	3.0	4.0
	Light brown, euهدral platy gypseous sand.	7.0	11.0
T ₆ L ₄ P ₃ S-1	Black, ruckled gypseous sand.	30.0	41.0
T ₆ L ₄ P ₃ S-1	Grey gypseous sand.	19.0	60.0

Pit T₆L₄P₁

This pit is situated at the southern pond margin.

Sedimentary Sequence			
Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₆ L ₄ P ₁ S-1	Brown, ruckled blister surface with salt gypseous crust changing to green downward.	1.0	1.0
T ₆ L ₄ P ₁ S-1	Dark grey to black, sticky, banded, fine gypseous sand with soft, laminated green algal tissue	10.0	11.0
T ₆ L ₄ P ₁ S-1	Black spongy algal lamination with hard gypsum heads with variable thickness.	10.0	21.0
T ₆ L ₄ P ₁ S-1	Dark grey, euhedral gypseous sand.	50.0	71.0
T ₆ L ₄ P ₁ S-1	Grey very coarse gypseous sand.	29.0	80.0

Soluble-Insoluble Residue:

Sample No.*	Organic matter %	Carbonate %	Insol. Residue %	Salt %
T ₆ L ₄ P ₁ S-1	1.6	14.5	35.6	48.31
T ₆ L ₄ P ₁ S-21	27.49	27.19	45.3	-

Binocular investigation of the sediments revealed that the sediments in this pit are composed mainly of gypsum crystals, lenticular, sublenticular, corroded and varying size from fine to very coarse, zoned, twinned and cross-cutted gypsum crystals, cemented by carbonate cement and algal tissues.

The particle size analysis and its statistical treatment revealed that the sample T₆L₄P₁S-2 is fine sand grained, poorly sorted with sorting coefficient (σ_1) 1.2 and skewness (SK_1) 0.8, (Fig 13).

Pit T₆L₄P₂

This pit is situated inside the pond at about 15 m from the southern margin. The height of the pond water above the sediment surface was about 25 cm in this position (August 1984).

Sedimentary Sequence			
Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₆ L ₄ P ₂ S-1	Black to dark grey medium gypseous	10.0	10.0
T ₆ L ₄ P ₂ S-1	Black, medium gypseous sand	10.0	20.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbon-ate %	Insol. Residue
T ₆ L ₄ P ₂ S-1	17.54	9.5	73.0
T ₆ L ₄ P ₂ S-1	14.88	17.0	67.45

Binocular investigation of the sediments revealed that the main components of the sediment are lenticular, sublenticular, and slightly corroded gypsum crystals and cemented by carbonate cement.

The particle size analysis and its statistical treatment revealed that the sediments are medium grained sands, poorly sorted with sorting coefficient (σ_I) ranges 1.18 to 1.48 and skewness (SK_I) ranges between 0.04 and 0.20, (Fig. 13).

Traverse T₇L₄: Pit T₇L₄P₄

This pit is situated inside the pond at about 70 m from the southern margin. The height of the water above the sediment surface was about 15 cm.

Sedimentary Sequence:

Bed and Sample No.	Description	Thick (cm)	Depth from surface (cm)
T ₇ L ₄ P ₄ S-1	Brown, fine gypseous sand.	0.2	0.2
	Black, soft, sticky, laminated, ruckled gypseous sand layer.	2.0	2.2
	Grey, ruckled, laminated gypseous sand.	2.5	4.7
	Black, sticky gypseous sand.	2.0	6.7
	Grey, gypseous sand.	2.0	8.7
T ₇ L ₄ P ₄ S-2	Greyish black, mottled, rigid gypseous sand with few Gastropod.	18.0	26.7
T ₇ L ₄ P ₄ S-3	Grey to white gypseous sand layer.	8.3	35.0

The Fifth Lagoon (Al-5)

This lagoon is a body of quiet water, situated in the middle of the studied area, facing to El- Alamein Rest House, (Fig. 5). It is about 2 km long and of approximately 600 m width. It has a nearly elongated shape, separated from

the Mediterranean Sea by the coastal ridge. The main connection between the lagoon and sea water is through the seepage from the coastal ridge. Two traverses were made in the eastern and western sides of the lagoon, numbered as T₈L₅ and T₉L₅ (Fig. 5). The traverses passed through the following geomorphologic units:

(i) Light brown loamy alluvial fan extending for about 400-500 m.

ii) Supratidal sabkha zone extending for about 100-200 m north of the alluvial fan zone followed by a break in slope of about 17° N then connected with the intertidal zone. This zone is characterized by brown surface with hummocks with halophyte plant, dikaka, blister surface and gypsum crust around the plant roots.

iii) Intertidal zone (Tidal flat), extending for about 100-300 m. The surface is brown, hummocky nature. The water level was near the surface. On the surface, coarse platy gypsum crystals up to 10 cm in length with clearly developed (010) face and slightly developed curved faces are abundant, and the size decreases towards the lagoon margin. Algal heads were developed in the lagoon margin (data concerning the stromatolites and gypsum mounds in the studied area are discussed in details in (Ali and Osman, in press). In the western side of the lagoon, small ponds with hypersaline water, bounded by gypsum heads and gypsum crystals on the surface predominate. The intertidal zone, characterized by lack of vegetation (no halophyte plant) and no halite precipitation was seen at the margin and also no polygons occurred. The lagoon and its southern margin have no fossils, compared with the previous lagoons.

Traverse T₈L₅: Pit T₈L₅P₃

This pit is situated in the intertidal zone at about 20 m from the southern margin of the lagoon.

Sedimentary Sequence:

Bed and Sample No	Description	Thick (cm)	Depth from surface (cm)
T ₈ L ₅ P ₃ 1	Brown, blister surface of medium gypseous sand	0.4	0.4
T ₈ L ₅ P ₃ 2	Brown, medium gypseous sand	4.0	4.4
T ₈ L ₅ P ₃ 3	Black, fine gypseous sand	6.0	10.4
T ₈ L ₅ P ₃ 4	Brownish grey coarse gypseous sand	5.0	15.4
T ₈ L ₅ P ₃ 5	Light grey coarse, rigid gypseous sand	1.0	18.4
T ₈ L ₅ P ₃ 6	Grey to light grey, coarse, rigid, harder than (S 5), gypseous sand.	18.0	36.4
T ₈ L ₅ P ₃ 7	Dark grey medium gypseous sand changing to grey downward.	2.0	38.4

- The ground water level was at 35 cm from the surface.

Soluble-Insoluble Residue:

Sample No.	Organic matter %	Carbonate %	Insol. Residue %
T ₈ L ₅ P ₂ S-1	15.65	16.24	68.11
T ₈ L ₅ P ₂ S-2	12.39	13.19	74.42
T ₈ L ₅ P ₂ S-2	12.53	17.84	69.63
T ₈ L ₅ P ₂ S-2	17.4	19.87	62.73
T ₈ L ₅ P ₂ S-2	18.13	9.71	72.16
T ₈ L ₅ P ₂ S-2	15.53	16.18	68.29
T ₈ L ₅ P ₂ S-2	7.3	13.04	79.66

Binocular description of the sediments in this pit is as follows: The main components of the sediments are gypsum crystals of different sizes, lenticular to sublenticular, slightly corroded in the lower sediments, carbonate lumps, carbonate cement, few carbonate ooids and Ostracod particularly in the lower sediments. The soluble-Insoluble residue results reveal that carbonate % increases upwards in the pit and insoluble residue (mainly gypsum) increases downward.

The particle size analysis and its statistical treatments reveal that the sediments are of fine sand to very coarse sand sizes, poorly to moderately sorted with sorting coefficient (σ_1) ranges 0.74 to 1.55 and skewness (SK_1) ranges between -0.04 and -0.42.

Pit T₈L₅P₂

This pit is situated inside the lagoon at about 70 m from its southern margin. The height of the lagoon water above the sediment surface was about 40 cm in this position.

<u>Sedimentary Sequence</u>			
<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₈ L ₅ P ₂ S-1	Brown, irregular, hummocky, cavernous hard, salt crust layer.	0.2	0.2
T ₈ L ₅ P ₂ S-2	Black, soft, laminated with green laminae of gypseous layer, varying in thickness from place to place.	7.0	7.2
T ₈ L ₅ P ₂ S-3	Grey, ruckled, laminated, medium sand with some shell fragments.	10.0	17.2
T ₈ L ₅ P ₂ S-4	Greenish grey, laminated, medium gypseous sand.	5.0	22.2
T ₈ L ₅ P ₂ S-5	Light grey medium gypseous sand with few Gastropod shell.	7.8	30.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue%
T ₈ L ₅ P ₂ S-1	12.78	58.71	28.51
T ₈ L ₅ P ₂ S-2	2.58	76.61	20.8
T ₈ L ₅ P ₂ S-2	9.44	55.42	35.14
T ₈ L ₅ P ₂ S-2	4.24	12.21	83.55

Binocular description of the sediments in this pit is as follows: The main components of the sediments are rounded to subrounded quartz grains cemented by carbonate cement, carbonate sands (ooids), Ostracods, Algal tissues, lenticular to sublenticular gypsum crystals increase downwards and dominate in T₈L₅P₂S-4, while quartz grains decrease downwards. The gypsum crystals show prismatic, twinned and cross-cutted habits.

The particle size analysis and its statistical treatment reveal that the sediments are of medium sand grains, poorly sorted with sorting coefficient (σ_T) ranges from 1.56 to 1.84 and skewness ranges between 0.07 and 0.12.

Traverse T₃L₅: Pit T₈L₅P₃ (Fig. 5)

The pit is situated inside the lagoon at about 65 m from the southern margin of the lagoon. The height of the lagoon water above the sediment surface was about 70 cm.

Sedimentary Sequence Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₉ L ₅ P ₃ S-1	Brown, soft, crumbly surface.	0.5	0.5
T ₉ L ₅ P ₃ S-2	Black, crumbly changed into grey laminated, medium gypseous sand layer	9.0	9.5
T ₉ L ₅ P ₃ S-3	Black and grey laminated, mottled, medium gypseous sand.	27.0	36.5
T ₉ L ₅ P ₃ S-4	Light grey, laminated, mottled, coarse gypseous sand.	23.5	61.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue%
T ₉ L ₅ P ₃ S-1	27.53	40.67	31.8
T ₉ L ₅ P ₃ S-2	14.23	45.52	40.26
T ₉ L ₅ P ₃ S-3	12.83	16.58	69.6
T ₉ L ₅ P ₃ S-4	12.91	11.15	75.94

Binocular description of the sediments in this pit is as follows: Corroded, irregular habits of gypsum crystals cemented by carbonate cement, carbonate lumps and algal tissues.

The particle size analysis of the sediments and its statistical treatment revealed that the sediments are of medium to coarse sand size, poorly sorted with sorting coefficient (σ_I), ranging between 1.16 and 1.55 and skewness (SK_I) ranging between 0.1 and 0.12 (Fig. 14).

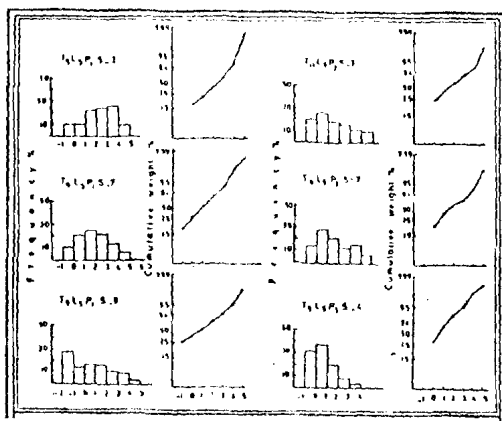


FIG. 14.
Histogram and cumulative curves of the intertidal and lagoonal sediments.

The Sixth Lagoon (A1-6)

This lagoon represents the biggest studied lagoon. It is situated at about 500 m west of the fifth lagoon. It is elongate in shape 3.2 Km in length and approximately about 400 m in width. The lagoon is separated from the Mediterranean Sea by the coastal ridge, (Fig. 6). The geomorphologic features are nearly similar to the fifth lagoon to the east. In the middle part of the lagoon there is an artificial canal extended from the southern margin of the lagoon to southward for a distance of about 500 m. This artificial canal is characterized by an elevated eastern bank consisting of sediment derived from the bottom of the canal. This sediment gives an idea about the nature of sediment underneath the surface. The sediment contains snow white, very large twinned, cross-cutted, interlocked, swallow tails and chevron shaped gypsum crystals. These

Crystals are accumulated in the intertidal zone. However, to the south the sediment contains *Gastropods*, *Cardium*, shell fragments, Foraminifera shells, Ostracod, and algae heads replaced by carbonate and evaporite minerals. (For details, see Ali and Osman in press). Two traverses were sampled, in the eastern and western parts of the lagoon, extending from the supratidal zone in the south to the coastal ridge in the north (Fig. 6).

Traverse T₁₀L₆

This traverse was sampled in the eastern part of the lagoon, (Fig. 6). The tidal flat zone commences with trash lines southward the lagoon. Shiny, twinned, coarse gypsum crystals with flattened (101) faces are scattered on surface. Toward the lagoon crumbly gypsum heads 5-20 cm height and vermiculated shapes are occurred in some places (Brain structure) with large polygons of blister surface and halite precipitation.

Pit T₁₀L₆P₁

This pit is situated at about 50 m south of the lagoon margin in the intertidal zone.

Sedimentary Sequence :

Bed and Sample No.	Description	Thick (cm)	Depth from surface (cm)
T ₁₀ L ₆ P ₁ S-1	Brown blister surface with shiny and twinned gypsum crystals.	0.2	0.2
T ₁₀ L ₆ P ₁ S-2	Green, soft algae lamina	0.1	0.3
T ₁₀ L ₆ P ₁ S-3	Greyish brown, medium gypseous sand.	2.5	2.8
T ₁₀ L ₆ P ₁ S-4	Black, crumbly laminated medium gypseous sand.	13	15.8
T ₁₀ L ₆ P ₁ S-5	Grey changed into greenish grey laminated gypseous sand.	8	23.8
T ₁₀ L ₆ P ₁ S-6	Grey, hard, crumbly laminated gypseous sand.	12	35.8
T ₁₀ L ₆ P ₁ S-7	Light greenish grey, soft, laminated gypseous sand.	6	41.8
T ₁₀ L ₆ P ₁ S-8	Light grey, medium, gypseous sand.	8.2	50

- Ground water level was at 23 cm. from the surface.

Soluble-Insoluble Residue:

Sample No.	Organic matter %	Carbonate %	Insol. Residue %
T ₁₀ L ₆ P ₁ S-3	10.68	18.73	70.59
T ₁₀ L ₆ P ₁ S-4	11.52	17.71	70.77
T ₁₀ L ₆ P ₁ S-5	9.38	8.24	82.37
T ₁₀ L ₆ P ₁ S-6	9.31	13.0	77.64

Binocular description of the sediments in this pit is as follows: The sediments are composed mainly of gypsum crystals of lenticular, euhedral, prismatic, transparent with slightly curved edges, cross-cutted, interlocked and twinned. Some gypsum crystals reveal slightly corroded surfaces, lumps of carbonate minerals and few Ostracods occurred. Size increases downward.

The particle size analysis and its statistical treatment reveal that the sediments are of medium sand size, poorly to moderately sorted with sorting coefficient (σ_1) ranging between 1.06 to 1.28 and skewness (SK_1) ranging between 0.08 and 0.06, (Fig. 6).

Pit T₁₀L₆P₃

This pit is situated inside the lagoon at about 20 m from the southern lagoon margin. The lagoon water above the sediment surface in this position was about 90 cm.

Sedimentary Sequence

<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₁₀ L ₆ P ₃ S-1	Brown, soft, crumbly algae tissues.	0.2	0.2
T ₁₀ L ₆ P ₃ S-2	Green to greenish grey bands of algae Stromatolite with medium gypseous sand and carbonate minerals.	10.0	10.2
T ₁₀ L ₆ P ₃ S-3	Light grey, hard, mottled, medium gypseous sand.	30.0	40.2
T ₁₀ L ₆ P ₃ S-4	Light grey, medium gypseous sand.	9.8	50

Soluble-Insoluble Residue:

<u>Bed and sample No.</u>	<u>Organic matter</u>	<u>Carbon-ate %</u>	<u>Insol. Residue</u>
T ₁₀ L ₆ P ₃ S-1	23.9	23.05	53.05
T ₁₀ L ₆ P ₃ S-2	21.23	25.42	53.35
T ₁₀ L ₆ P ₃ S-3	9.49	14.65	75.86
T ₁₀ L ₆ P ₃ S-4	15.24	12.34	72.43

Binocular description of the sediments reveals that the main components of the sediments are lenticular, sublenticular, and slightly corroded gypsum crystals, lumps of carbonate minerals and algal tissues.

The particle size analysis and its statistical treatment reveal that the sediment are of medium sand, poorly sorted with sorting coefficient (σ_I) ranging 1.23 to 1.30 and skewness (SK_I) ranging between 0.08 and 0.09,

Traverse $T_{11}L_6$: Pit $T_{11}L_6P_3$

This pit is situated inside the lagoon at about 2 m from the southern lagoon margine. Because of the presence of algal heads and salt marshy area, it was difficult to go far inside the lagoon.

<u>Sedimentary Sequence</u>			
<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
$T_{11}L_6P_3S-1$	Brown, Soft, Stickly crumbly algal layer.	0.2	0.2
$T_{11}L_6P_3S-2$	Black, ruckled, banded algal tissues with medium gypsum and carbonate mineral.	16.0	16.0
$T_{11}L_6P_3S-3$	Dark grey, medium fossiliferous gyseous sand chanding to brownish downward.	8.8	25.0

Soluble-Insoluble Residue:

<u>Bed and sample No.</u>	<u>Organic matter</u>	<u>Carbonate %</u>	<u>Insol. Residue %</u>
$T_{11}L_6P_3S-1$	14.11	23.89	62.0
$T_{11}L_6P_3S-2$	22.37	34.88	42.75
$T_{11}L_6P_3S-3$	18.84	38.02	43.14

Binocular description of the sediments in this pit is as follows: The sediments are carbonate minerals, Ostracods, carbonate ooids, gypsum crystals, few quartz grains and algal tissues.

The particle size analysis and its statistical treatment reveal that the sediments are of medium sand size, poorly sorted with sorting coefficient (σ_I) ranging 1.45 to 1.67 and skewness (SK_I) ranging between 0.06 and 0.17.

The Seventh Lagoon (A1-7)

This lagoon is situated at about 2 Km west of the sixth lagoon. It is nearly rounded in shape and irregular in

margins, (Fig. 7). It is about 500 m long and average width is of approximately 400 m. This lagoon is separated from the Mediterranean Sea by the coastal ridge. The main source of lagoon water is through the underground water seepage from the sea. The water depth in the lagoon ranges from a few centimeters at the margins to about 1.5 m in the central part of the lagoon. The lagoon is separated from the east and west directions by the supratidal sabkha zone. The morphologic features around the lagoon are similar to the other lagoons as revealed from the following:

(i) Light brown loamy alluvial fan zone extending for about 800 m.

(ii) Supratidal sabkha zone extending from the northern end of the alluvial fan for about 450 m northward.

(iii) Intertidal zone (Tidal flat) extending for about 200-300 m north of the supratidal zone toward the lagoon and characterized by the brown blister surface with shiny, twinned intertidal gypsum crystals flattened on surface (010) with various sizes. In this zone there are islands of supratidal features were scattered and small ponds containing gypsum heads toward the lagoon margin, trash lines and wet brown blister surface was observed and the margin of the lagoon is nearly flat without mounds of algal stromatolite heads, but soopy feel polygons of blister surface are common.

Traverse T₁₂L₇

This traverse was sampled from the supratidal zone to the coastal ridge. Brown blister surface, shiny gypsum crystals on the surface are common, with decrease in size of gypsum crystals toward the lagoon margins.

Pit T₁₂7₆P₁

This pit is situated at about 100 m south of the lagoon margin in the intertidal zone.

<u>Sedimentary Sequence</u>			
<u>Bed and Sample No.</u>	<u>Description</u>	<u>Thick (cm)</u>	<u>Depth (cm)</u>
T ₁₂ L ₇ P ₁ S-1	Brown blister surface changed into black downward with medium gypseous sand.	3.0	3.0
T ₁₂ L ₇ P ₁ S-2	Light brown, coarse gypseous sand.	16.0	19.0
	Brown, coarse, rigid gypseous sand.	10.0	29.0
T ₁₂ L ₇ P ₁ S-3	Light brown, very hard, massive, coarse gypseous sand.	5.0	34
T ₁₂ L ₇ P ₁ S-4	Greyish green, coarse gypseous sand.	16	40.0

The ground water level was at 24 cm from the surface.

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue
T ₁₂ L ₇ P ₁ S-1	7.3	15.64	77.06
T ₁₂ L ₇ P ₁ S-2	11.15	19.36	69.49

Binocular description of the sediments is as follows: The sediment consists mainly of gypsum crystals of lenticular, sublenticular, prismatic, zoned, interlocked, twinned, cross-cutted crystals and carbonate lumps. The gypsum crystals reveal slightly corroded habits cemented by carbonates downwards.

The particle size analysis and its statistical treatment reveal that the sediments are of medium sand in sample T₁₂L₇P₁S-1 to coarse sand size downward, poorly sorted with sorting coefficient (σ_1) ranging around 1.33 and skewness (SK_1) ranging between 0.09 and 0.17.

Pit T₁₂L₇P₂.

This pit is situated at the southern margin of the lagoon.

Sedimentary Sequence Bed and Sample No.	Description	thick (cm)	Depth (cm)
T ₁₂ L ₇ P ₂ S-1	Brown blister surface with black laminae.	0.2	0.2
T ₁₂ L ₇ P ₂ S-2	Black, soft, sticky, algal stromatolite with fine gypseous sand.	13.0	13.0
T ₁₂ L ₇ P ₂ S-3	Greyish green to black banding of algal stromatolite with medium gypseous sand, each band of about 0.2 cm.	16	23.0
T ₁₂ L ₇ P ₂ S-4	Greyish green, medium to coarse gypseous sand.	8.0	31.2
T ₁₂ L ₇ P ₂ S-5	Grey, coarse, banded gypseous sand.	5.0	36.2
T ₁₂ L ₇ P ₂ S-6	Grey, fine to medium gypseous sand.	3.0	39.2
T ₁₂ L ₇ P ₂ S-7	Greenish grey, hard, coarse gypseous sand.	5.8	45

- The ground water level was at 24 cm from the surface.

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue%
T ₁₂ L ₇ P ₂ S-2	21.38	13.37	65.25
T ₁₂ L ₇ P ₂ S-3	16.94	16.2	66.85
T ₁₂ L ₇ P ₂ S-4	11.39	10.05	78.56
T ₁₂ L ₇ P ₂ S-7	14.85	12.48	72.67

Binocular description of the sediments is as follows: The upper beds are composed of lumps of carbonate, algal tissues, and corroded lenticular to sublenticular gypsum crystals. The small sizes have euhedral prismatic crystals. Downwards the size of the crystals increases with elongate, prismatic, zoned, interlocked, cross cutted and twinned crystals.

The particle size analysis of the sediments and its statistical treatment reveal that the sediments are of fine to medium sand sizes, poorly sorted with sorting coefficient (σ_I) ranges 1.60 to 1.46 and skewness (SK_I) ranges between 0.38 and 0.03.

Pit T₁₂L₇P₄

This pit is situated at the northern margin of the lagoon.

Sedimentary Sequence

Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₁₂ L ₇ P ₄ S-1	Light brown list. surface.	0.5	0.5
T ₁₂ L ₇ P ₄ S-2	Black, soft, laminated sandy layer.	20.0	20.5
T ₁₂ L ₇ P ₄ S-3	Grey, soft, gypseous sand with carbonate ooids.	9.5	35.0

Binocular description of the sediment in this pit is as follows: The sediments are composed of mainly carbonate sands (ooids), carbonate lumps, lenticular, sublenticular, prismatic gypsum crystals and few Ostracods.

The Eighth Lagoon (A1-8)

This lagoon represents the western end of the studied lagoons. It is situated at about 7.5 km to the west of El-Alamein Rest House, (Fig. 7). An artificial canal has been dug between the seventh and the eighth lagoons. This canal is of zigzag shape (zigzag-cut), connects between the

coastal ridges and runs southward to the supratidal zone, (Fig. 7). The canal is about 1 km in length, and about 20 m width. The elevation of the two banks which are bounding the canal is of about 2.3 m above the water surface. This cut is similar to the straight cut located in sixth the lagoon (Al-6). The sediment which is extracted from the canal and represents the type of banks, and in the mean time reflects the sediment underneath the lagoon is composed of shell fragments, *Cardium* sp., Gastropods, Ostracods, Foraminifera shells, Carbonate lumps, laminated stromatolite with gypsum crystals and carbonate minerals between the laminae. The banks have considerable amount of gypsum crystals with crystals reach about 10 cm in length. Various shapes of gypsum crystals predominate, mostly of lenticular, sublenticular, zoned, euhedral, prismatic, twinned and shavron shapes. The morphologic features in the traverses taken from the asphaltic road to the coastal ridge are as following:

(i) Light brown loamy alluvial fan extending from the road to the supratidal zone and for a distance about 700 m.

(ii) Supratidal zone extending next to the alluvial fan toward the north, for distance about 400 m. Small hypersaline ponds were located half way in this zone. Gypsum heads with ruskled shape are predominant at the pond margins.

(iii) Intertidal zone (Tidal flat), separated from the supratidal zone by break in slope of about 0.5 m. This zone extending northward for a distance about 200 to 300 m, is characterized by brown blister surface, small scattered gypsum crystals and scattered small ponds. Gypsum heads are predominant around the pond margins. No fossils were seen in the lagoon margin and no mounds of algal heads but flat laminated stromatolites occurred in the lagoon margin in slightly brown salty surfaces. Trash lines along the margin of the lagoon are present. The lagoon is nearly rounded in shape and includes supratidal islands inside it particularly toward the north. The lagoon is about 500 m long and approximately about 350 m in width. The water depth in the lagoon ranges between few centimeters near the margin to about 1.5 m in the central part. The lagoon is separated from the Mediterranean Sea by the coastal ridge. It is likely that sea water seepage through the coastal ridge, and brine water from the zigzag cut are feeding the lagoon.

Traverse T₁₃L₈

This traverse was taken from the supratidal zone to the coastal ridge northward.

Pit T₁₃L₈P₁

This pit is situated at about 40 m from the southern margin of the lagoon in the intertidal zone.

Sedimentary Sequence			
Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₁₃ L ₈ P ₁ S-1	Brown blister surface followed by brown gypseous sand.	3.0	3.0
T ₁₃ L ₈ P ₁ S-2	Greyish brown, hard, ruckled, gypseous sand.	16.0	19.0
T ₁₃ L ₈ P ₁ S-3	Pale brown, relative hard gypseous sand.	20.0	39.0
T ₁₃ L ₈ P ₁ S-4	Black, gypseous sand layer.	10.0	49.0
T ₁₃ L ₈ P ₁ S-5	Grey, hard gypseous sand.	11	60.0

Binocular description of the sediment in this pit is as follows: The upper sediments are composed of gypsum crystals of lenticular, sublenticular, transparent, slightly corroded, zoned, interlocked, cross-cutted and twinned shape and carbonate lumps. Downward the size increases with less corrosion, zoned and interlocked crystals which predominate with algal tissues.

Pit T₁₃L₈P₂

This pit is situated inside the lagoon at about 15 m from the southern margin. The height of water above the sediment surface was at about 40 cm.

Sedimentary Sequence			
Bed and Sample No.	Description	Thick (cm)	Depth (cm)
T ₁₃ L ₈ P ₂ S-1	Pale brown, soft, ruckled with soopy feel surface.		
	Green laminae of algal tissue.	0.1	0.3
	Black, soft, laminated algal tissues with medium gypseous sand.	9.0	9.3
T ₁₃ L ₈ P ₂ S-2	Grey, soft banded gypseous sand.	6.0	15.3
	Black gypseous sand layer.	2.0	17.3
	Grey gypseous sand layer.	1.5	18.8
	Black, soft, gypseous sand.	3.0	21.8
	Greenish brown, coarse gypseous sand.	4.5	26.3
	Black, soft, gypseous sand.	2.0	28.3
T ₁₃ L ₈ P ₂ S-3	Grey gypseous sand layer.	40.0	68.3
T ₁₃ L ₈ P ₂ S-4	Grey, hard, coarse gypseous sand.	06.7	75.0

Soluble-Insoluble Residue:

Bed and sample No.	Organic matter	Carbonate %	Insol. Residue%
T ₁₃ L ₈ P ₂ S-1	25.68	28.38	45.92
T ₁₃ L ₈ P ₂ S-2	28.78	40.22	30.99

Binocular description of the sediment is as follows: The sediments are composed of lumps of carbonate minerals, algal tissues. Gypsum crystals are lenticular, sublenticular and slightly corroded, and some of them are zoned and twinned. No fossils were seen.

The particle size analysis and its statistical treatment reveal that the sediments are of medium sand size, poorly sorted with sorting coefficient (σ_I) 1.87 and skewness (SK_I) 0.29.

SUMMARY AND CONCLUSIONS

The area studied some 110 km west of Alexandria is a part of the northern coastal zone of Egypt, and extends 20 km east and 20 km west El-Alamein Rest House.

The coastal zone investigated, latitude 31°N, lies near the northern hemisphere arid zone. The annual rainfall is about 16 to 19 cm. The mean monthly average air temperature is about 19°C with a summer maximum of about 30°C. The average relative humidity is about 57%. Annual evaporation is about 10 times the rainfall, so the area is arid enough for the development of hypersaline lagoon and the formation of evaporites. The topography of the region is distinctively characterized by a series of carbonate beach, dune sand ridges and depressions that parallel the coast (Ali, 1981 and West et al., 1979; Ali and West, 1983; West et al., 1983, and Osman, 1986). The most seaward carbonate ridges are Pleistocene in age, and are cemented into firm limestone. The seaward ridge consists mainly of unlithified ooid sands (Hilmy, 1951).

El-Alamein eight Recent lagoons from east to west (AL.1, AL.2, AL.3, AL.4, AL.5, AL.6, AL.7, and AL.8) are located in the shallow first depression that slopes gently northward toward the coastal ridge. These lagoons are bounded on the northern side by the first ridge (Coastal Ridge) and on the southern side by the second ridge (Abu-Sir Ridge). The lagoons are characterized by the following morphological features:

(1) Supratidal zone: This zone extends along the first depression, the width of this zone in the northern and

southern sides of the lagoons varies from the first to the eighth lagoon. This zone ranges from a few meters to about 300 m.

(2) Intertidal zone ((Tidal flat): This zone follows the supratidal zone toward the lagoon margins. It is often separated from the supratidal zone by break in slope of about half to one meter with dip angle of about 7° to 17° N. The width of this zone ranges from 2-400 m. Peculiar small hypersaline ponds of about 1.5 m depth and with steep or overhanging sides occur scattered on the intertidal flat of the hypersaline lagoon particularly the fourth, fifth and the sixth lagoons. The unusual morphology of these ponds is explained by local dissolution of gypsum bed (West et al., 1983). The gypsum heads are best developed at the margins of these ponds. Details of the stromatolites and gypsum mounds are given elsewhere (Ali and Osman, in press). The surface of the sediment in the intertidal flat rises from 10-60 cm (average) above the ground water level and is subjected to regular flooding from lagoon water particularly during the winter season.

(3) Shallow subtidal zone: This zone is next to the lagoon southward, with a width of about 10 m. This zone is covered with water. Algal stromatolite heads of blue green algal species of 10-20 cm, are growing at the margin of the lagoons at and near the water. These algal heads sometimes continue and form mounds of about 3 m in length particularly in the third, fifth and sixth lagoons. Shells of Cardium, turrated Gastropods and shell fragments are characterizing the lagoon margins of the first, second, and third, lagoons. This is because these lagoons receive more water through seepage than the other lagoons, and in turn the salinity is less relative to the other lagoons, to the west.

(4) Alluvial fan zone: These deposits flank the second and third ridges. Alluvial fan that flanks the second ridge on both sides is composed of light brown loam with shells of land snails of genus Ermina (Ali, 1981), shell fragments and halophyte plants. Thin sheets of this loam overlie the supratidal zone.

The sediments of the tidal flats range from medium to coarse sand size, moderately to poorly sorted with sorting coefficient ranging from 0.7 to 2.0. The grains show symmetrical to coarse skewed with SK ranging from 0.1 to 0.3. However lagoon and lagoon margin sediments range from fine to medium sand size, moderately to poorly sorted and near symmetrical to coarse skewed.

Fine grained dolomite occurs in rhomb form through the intertidal and lagoonal sediments, particularly the western lagoons. These dolomite rhombs developed in the carbonate sediments are associated with gypsum and sometimes occur scattered on the surface of the gypsum crystals. The occurrence of fine grained dolomite associated with

sediments from El-Alamein hypersaline lagoons particularly (AL-4, AL-5 and AL-6) resemble those described from hypersaline lakes of western Victoria, Southeastern Australia (Deckker and Last, 1987). Also Ali and Osman (in press) reported similar fine grained dolomite occurred in the same environment, but associated with stromatolites and gypsum mounds. Details of the origin are given elsewhere.

The evaporitic minerals occurring in the studied lagoons consist of gypsum, halite and celestite. Gypsum is the only calcium sulphate mineral present in the investigated lagoons and intertidal sediments; no anhydrite was detected in the investigated samples from the above mentioned zones. Similar fact is reached by Ali and Osman (in press) in the sediments associated with gypsum and stromatolite mounds from the same environment.

The diagenetic changes and precipitation of the evaporite and associated carbonate minerals under lagoonal and tidal flat environment which were reflected in brine chemistry are given elsewhere.

Each lagoon is characterized by topographical features including shape, size, relief and nature of sediments. In general, Hankanson (1981) reported that the shape of each lagoon, its orientation to prevailing winds, and its inflow are of great importance for its water budget.

The mechanics of the water exchange between the lagoons and open sea is through the porous sediments of the coastal ridge as shown in Figs. 2 to 7. Similar situation occurs today in Lake Larnaca on the Island of Cyprus, Lake Tekir-Ghoil in Romania, Lake Assal in Eritrea, and Solar Lake in the Gulf of Aquaba, Sinai (Sonnenfeld, 1984).

ACKNOWLEDGEMENT

We are grateful to Dr. I.M. West, Southampton University, U.K. for his valuable co-operation and expert help in the field.

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