

Geochemistry of the Gypsiferous Sediments of the Abis Area, a Reclaimed Part of Lake Maryut in Northern Egypt

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ABSTRACT

The Abis area is one of the pieces of land that have been reclaimed recently from Lake Maryut which lies to the south and east of Alexandria city in northern Egypt. Seventy samples taken from fourteen profiles were analyzed. The Eh and pH values were also determined in the soil samples. Analyses of the ground water samples found below each profile are also given. From the results of these analyses it was concluded that oxidizing conditions are prevailing in the sediments studied which have neutral pH values. The gypsum present was probably formed in these sediments by evaporation and crystallization in the cavities and interstices of clayey sand sediments from solutions saturated with previously formed calcium sulfate.

INTRODUCTION

Abis area is one of the pieces of land that have been recently reclaimed from Lake Maryut, situated to the southeast of Alexandria City in northern Egypt (Fig. 1). The elevation of Abis area is generally below sea level, it reaches -4.5 m level in some places.

As this area is closely related to Lake Maryut, it may be of interest to give a short review of this lake. It lies along the Mediterranean Coast of Egypt west of the Nile Delta at lat 31° 07'N. and long. 29° 57'E. Different studies on the Lake Maryut were carried out by Shafe (1955) Shukri et al. (1955 a, b) and EL-Wakeel (1970). They regarded its previous communication with the Mediterranean Sea and the River Nile through the ancient canopic branch. The present lake is brackish with no direct communication either with the sea or the Nile. It receives large amounts of drainage water from a number of drains, the most important of which is El-Unoum drain. The water level of the present lake is kept by pumping at about 3 meters below sea level there is seasonal variation of the

sulfate content in Lake Maryut which shows a maximum increase during April and October and minimum decrease during February and July. The regional variation in the SO_4/Cl ratio was attributed to the effect of drainage water which has a high sulfate content.

Abis area is underlain by layers of clastic sediments of approximately horizontal attitude, having grain sizes ranging from clay to sand. From the results of granulometric analyses (Ghowail 1972), it has been inferred that most of these sediment layers although laid down in a lagoonal environment, are of fluvial origin. These sediments were presumably supplied by a tributary of the Nile River. A few sandy intercalations, however, have the granulometric characteristics of beach sands and indicate that the Mediterranean coastline has been migrating back and forth repeatedly.

Gypsum has been observed in the sediments of Abis area during the reclamation work and had attracted attention because of its possible importance for agricultural purposes. Gypsum crystals are found either filling in cavities, fractures and fissures, or as intercalary big crystals. The sediments are formed mainly of quartz grains, clay minerals and shell fragments, with a small amount of iron oxides, altered glauconite, chlorite, biotite, siderite, orthoclase and aragonite. The present work is concerned with the geochemical conditions which played a strong role in the formation of this gypsum in Abis area. For this purpose, samples taken from 14 profiles distributed over the area (Fig. 2) were chemically analyzed. Some other samples of subsurface water were also analyzed.

RESULTS OF THE CHEMICAL ANALYSES OF SOIL AND GROUND-WATER SAMPLES

The results of chemical analyses of 70 of soil samples taken from the mentioned profiles ranging in depth from

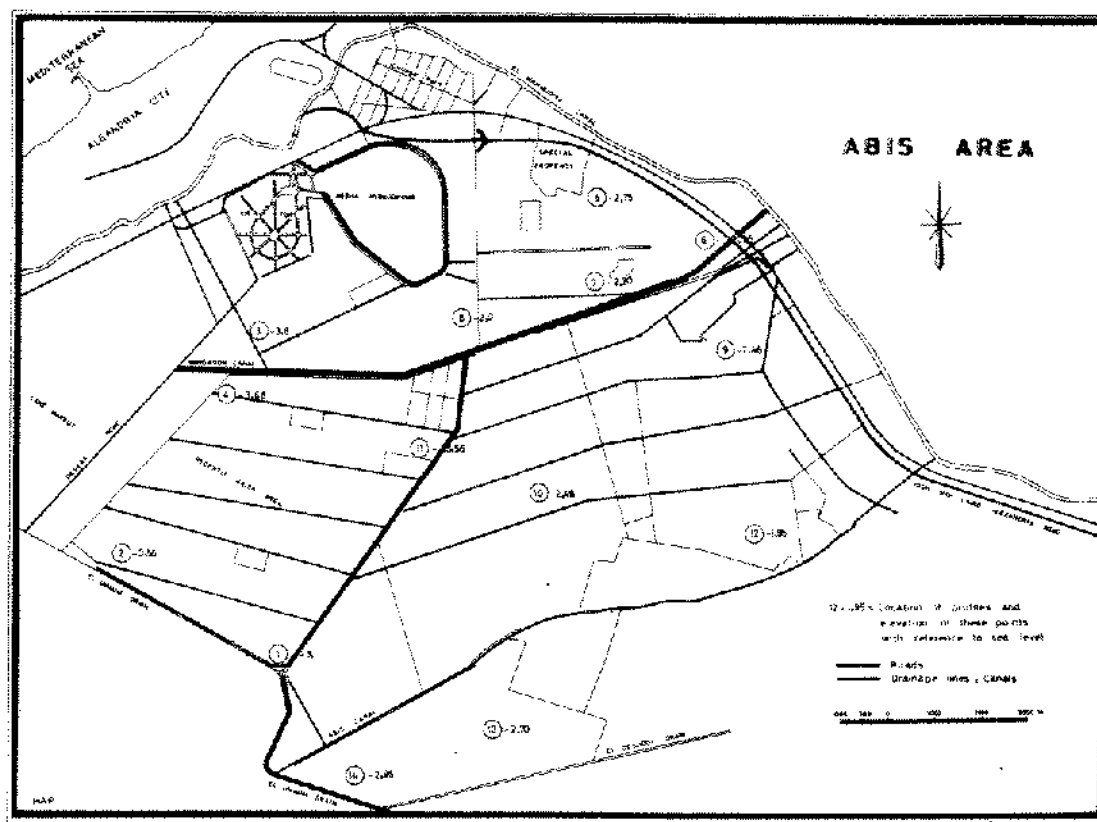


Figure 1.

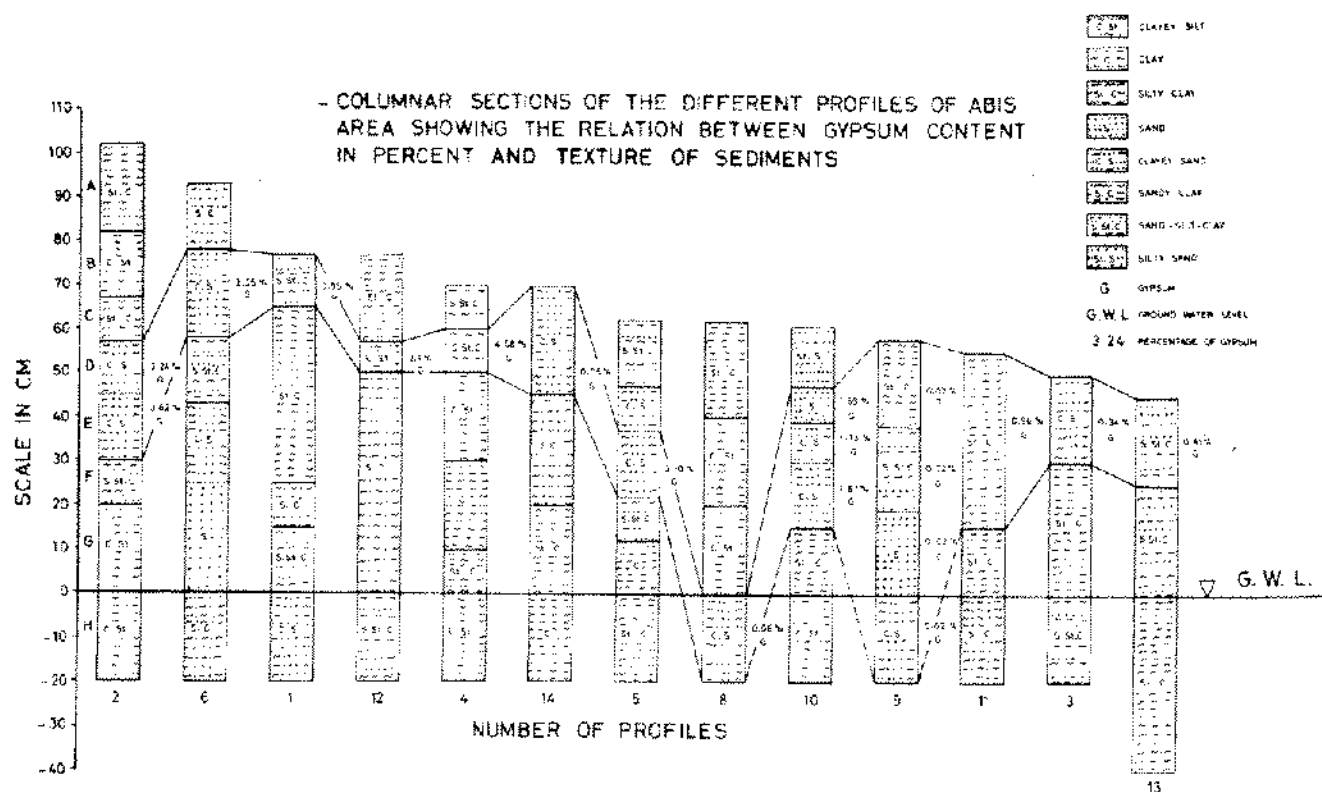


Figure 2.

TABLE I

Gypsum content, calcium carbonate, organic matter and total iron percentages of soil samples taken from Abis area (1971).

Number of profile	Depth of layer cm.	Gypsum meq./100 gm of soil	CaCO ₃ %	O.M. %	Total iron %	Number of profile	Depth of layer cm.	Gypsum meq./100 gm of soil	CaCO ₃ %	O.M. %	Total iron %
1	A 12	58.10	40.50	1.39	1.70	B	33	0.0	3.74	0.32	3.46
	B 52	42.20	24.10	1.39	2.20	C	43	0.0	4.93	0.57	4.42
	C 62	25.20	31.60	0.79	1.40	D	58	0.0	3.74	0.25	3.12
	D 77	7.15	45.50	0.71	1.80	E	73	0.0	4.93	0.57	4.42
	E 97	30.50	48.00	0.36	1.90	F	83	1.98	4.04	0.65	7.04
2	A 20	22.11	17.10	2.89	2.10	G	113	2.09	4.85	0.54	2.90
	B 35	12.06	16.50	1.70	2.20	H	133	0.76	4.85	0.52	2.75
	C 45	15.00	25.00	1.20	2.00	8	A 22	0.25	27.10	1.73	2.95
	D 57	47.70	9.55	0.34	0.80	B	42	0.25	4.85	0.54	2.85
	E 72	53.30	14.60	0.40	0.70	C	62	0.25	6.78	0.56	2.85
	F 82	36.18	22.10	1.14	1.40	D	82	0.76	4.85	0.17	2.25
	G 102	22.00	27.60	0.86	1.60	9	A 20	0.25	11.60	0.88	4.10
	H 122	9.00	19.80	0.91	1.20	B	39	0.25	7.73	0.43	2.70
3	A 20	3.98	27.30	1.71	3.72	C	58	0.25	3.90	0.02	0.75
	B 50	0.27	20.40	1.32	5.48	D	78	0.25	7.75	0.17	1.45
	C 70	0.27	85.00	0.91	2.88	10	A 14	2.04	15.45	0.58	1.40
4	A 10	30.20	20.00	1.29	1.10	B	22	19.61	15.45	0.21	1.65
	B 20	53.30	17.70	0.95	1.10	C	31	20.14	15.45	0.31	1.46
	C 40	30.70	22.20	1.24	1.40	D	46	21.73	21.25	0.31	1.70
	D 60	12.06	15.60	1.27	1.50	E	61	0.25	22.20	1.44	3.20
	E 70	16.85	27.20	1.03	1.90	F	81	0.38	8.75	0.50	2.75
	F 90	28.65	45.50	0.81	1.60	11	A 40	11.13	27.10	1.44	5.80
5	A 15	7.42	13.25	1.43	3.46	B	55	0.38	34.80	1.12	2.00
	B 25	12.72	11.18	0.55	3.94	C	75	0.25	58.00	1.01	2.00
	C 40	34.98	9.99	0.54	2.62	12	A 20	2.65	31.90	1.96	2.25
	D 50	24.65	8.80	0.71	3.46	B	27	24.38	46.30	0.62	3.10
	E 62	0.54	9.99	1.15	5.16	C	77	1.40	8.75	0.58	4.75
	F 82	0.27	4.64	1.23	4.56	D	97	4.77	9.70	0.68	2.15
6	A 15	0.0	11.40	2.21	4.56	13	A 20	4.83	30.90	0.83	2.40
	B 35	27.03	9.00	0.81	3.94	B	45	3.18	30.90	0.77	1.85
	C 50	3.00	3.33	0.52	5.10	C	85	0.38	29.00	1.34	3.10
	D 68	3.71	2.55	0.45	3.04	14	A 25	0.53	34.80	1.34	2.10
	E 93	4.24	1.96	0.32	3.68	B	50	0.25	67.75	0.43	1.20
	F 113	0.25	38.75	0.79	1.85	C	70	0.25	67.75	0.35	3.10
7	A 23	0.0	6.11	0.63	3.10	D	90	0.25	30.90	0.79	2.55

0.70 to 1.20 meters (Fig. 2) are given in Table I. The samples were analyzed for total calcium carbonate, total iron, the organic matter and the gypsum content. The total calcium carbonate was determined by neutralization of the added excess acid by sodium hydroxide, and the organic matter by potassium chromate and ferrous sulphate (Richards et al., 1954). Total iron was determined colorimetrically (Jackson, 1958). Gypsum was determined by the acetone method (Bower and Huss, 1948).

Thirteen samples of ground-water found below each profile are also analyzed. The results are given in Table II. The following is a concise discussion of the results of the chemical analyses for both sediments and ground-water samples.

1. Generally, the higher quantity of gypsum is found in subsurface layers at a depth of about 15 cm from surface and extends downward till about 50 cm depth, (Fig. 2).
2. Gypsum is formed in top layers, probably by evapo-

ration from the ground-water close to the surface and having both calcium and sulphate ions in sufficient amounts according to the solubility product principle. The ground-water rises by the capillary action. Wisler and Brater (1956), mentioned that "the thickness of the capillary fringe* in granular material is a function of the effective particle size and generally increases as the grain size decreases. The fringe thickness may range from a few inches in coarse gravel to 8 ft. in silty material and is probably much greater in very fine-grained sediments.

3. Generally, there is no relationship between gypsum and calcium carbonate, organic matter and total iron content.

4. The amount of total calcium carbonate is more or

*The capillary fringe is the belt overlying the zone of saturation and containing interstices, some or all of which are filled with water that is in connection with and is a continuation of the zone of saturation, being held above that zone by capillarity acting against the force of gravity.

TABLE II

Chemical analysis of the ground water of 14 profiles taken from Abis area (1971). *

Number of profile	Cations meq./L				Anions meq./L			
	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	HCO ₃ ⁻	CO ₃ ⁼⁼	SO ₄ ⁼⁼	Cl ⁻
1	56.15	98.57	325.00	9.00	1.48	2.96	116.78	367.50
2	36.49	33.48	120.00	4.30	2.97	2.96	66.97	121.40
3	16.08	80.45	495.00	12.70	3.78	0.0	52.85	582.50
4	65.59	127.61	465.00	14.00	0.0	2.96	120.74	548.50
5	12.06	6.47	110.00	2.60	12.83	0.0	45.83	75.00
6	34.17	22.38	100.00	2.40	9.06	0.0	39.00	113.00
8	10.05	48.45	175.00	4.95	12.83	0.0	14.62	213.25
9	3.02	16.48	140.00	2.20	27.93	0.0	8.78	127.50
10	20.10	55.95	395.00	6.40	9.06	0.0	62.40	406.75
11	42.20	119.65	375.00	7.45	12.83	0.0	72.15	460.00
12	26.80	25.85	53.50	2.70	4.85	0.0	88.61	15.39
13	9.27	8.28	30.00	0.83	2.91	0.0	22.86	22.61
14	17.00	14.20	114.00	2.50	3.88	0.0	77.44	66.38

* The ground water of profile No. 7 is very deep.

less a consequence of the numerous shell fragments found in the soil rather than precipitated calcium carbonate.

5. The organic matter content is generally found in high quantities at surface layers due to the presence of plant roots.

6. Total iron in soil samples varies from 0.75 to 7.04%.

7. Generally, the profiles located near the lake (for example profiles 3, 4), are of higher salt content than the profiles which are found far from it (Fig. 1).

It can be concluded from the above relations that the precipitation of gypsum is related to the amount of sulfate content and the water table level, from which sulfate is precipitated during concentration in certain permeable layers of clayey sand grain size (Fig. 2).

The water table level depends on that of the lake, the water drainage and amount of rainfall during the winter season. During the dry season in summer, water goes up through the pore spaces by capillary action to the surface of the soil, where it evaporates and its dissolved salts are deposited. Mahlis et al., (1970), on their work on Lake Maryut showed that its average sulfate chlorinity ratio is higher than that of sea water and lower than the ratio for river waters. Regional variation in the SO₄⁼⁼/Cl⁻ ratio are attributed to the effect of drainage water having a high sulfate content, and that there is a significant seasonal and regional variation of this ratio.

The amount of sulfate ions in the ground-water (Table 2) shows a relatively high amount which varies from one profile to the other. Generally, it is related to the amount of gypsum in subsoil layers as well as the distance from the deposited gypsum.

Profile No. 7 (Fig. 2) which has the level of ground-

water far from the surface has no gypsum close to the surface but it increases with depth which confirms the role of evaporation and deposition of gypsum out of the ground-water.

DISCUSSION OF pH AND Eh VALUES OF SOIL SAMPLES TAKEN FROM ABIS AREA

Precautions were taken, for the determination of the redox potential (Eh), to prevent any contact between soil and air and the atmosphere. In the field, soil samples were taken in rectangular boxes, the surface of the soil samples is sprayed immediately by a plastic material (polyester dissolved in tolyen). The sprayed material penetrates through the soil material to about 2 millimeters and dries after few seconds leaving a very thin film coating the surface of the soil sample. The Eh value was determined in the laboratory using platinum electrodes (Zobell, 1947). At the same time pH of soil samples was determined.

The oxidation-reduction potential or Eh values (shown in Table III) of the soil samples taken from Abis area indicates that all of them have positive values, i.e. oxidized conditions, except one sample has a negative value (-0.015 V), because this sample extends 40 cm below ground-water. This particular sample is in the weakly oxidized zone. The oxidized Eh values of the samples under study range between 0.105 to 0.525 V with an average of 0.408 V.

Sometimes these measurements have lower values in the subsoil layers than the other ones (profiles 1, 2 and 4 and Table III). The other Eh values are almost constant in the different profile layers.

TABLE III

pH and oxidation-reduction potential (Eh) measurements of the samples taken from Abis soil (1971).
G. W. L.—Ground-Water level

Number of profile	Depth of layer cm.	Eh Volt	pH	Number of profile	Depth of layer cm.	Eh Volt	pH
1 A	12	0.380	7.2	B	33	0.435	8.08
B	52	0.405	6.7	C	43	0.490	7.75
C	62	0.325	7.0	D	58	0.460	7.82
G.W.L. D	77	0.215	6.9	E	73	0.497	7.20
E	97	0.265	6.8	F	83	0.485	7.50
2 A	20	0.355	6.9	G	113	0.478	7.58
B	35	0.215	7.1	H	133	0.485	7.40
C	45	0.375	7.3	8 A	22	0.468	7.05
D	57	0.410	7.1	B	42	0.468	7.55
E	72	0.175	6.9	G.W.L. C	62	0.473	7.50
F	82	0.390	6.9	D	82	0.455	7.25
G.W.L. G	102	0.405	6.8	9 A	20	0.440	7.80
H	122	0.105	7.1	B	39	0.459	8.20
3 A	20	0.470	7.1	G.W.L. C	58	0.444	7.80
G.W.L. B	50	0.440	7.1	D	78	0.444	7.70
C	70	0.440	7.5	10 A	14	0.449	7.35
4 A	10	0.525	7.4	B	22	0.454	7.50
B	20	0.375	6.9	C	31	0.464	7.30
C	40	0.345	8.1	D	46	0.459	7.45
D	60	0.425	7.1	G.W.L. E	61	0.139	7.82
G.W.L. E	70	0.185	8.7	F	81	0.431	7.50
F	90	0.155	7.5	11 A	40	0.459	7.10
5 A	15	0.310	7.40	G.W.L. B	55	0.439	7.10
B	25	0.390	7.60	C	75	0.377	6.65
C	40	0.410	7.50	12 A	20	0.377	7.40
D	50	0.430	7.50	B	27	0.430	7.50
G.W.L. E	62	0.415	7.40	G.W.L. C	77	0.455	7.40
F	82	0.410	7.40	D	97	0.480	7.30
6 A	15	0.460	7.30	13 A	20	0.445	7.67
B	35	0.480	7.40	G.W.L. B	45	0.475	7.10
C	50	0.510	6.90	C	85	-0.015	7.30
D	68	0.510	6.80	14 A	25	0.410	7.70
G.W.L. E	93	0.492	6.90	B	50	0.473	7.43
F	113	0.435	7.15	G.W.L. C	70	0.455	7.55
7 A	23	0.447	7.85	D	90	0.435	7.48

The presence of the iron oxide and the glauconite altered to dark brown iron oxides as shown by the study of thin sections confirms the slightly oxidizing conditions actually prevailing in the section. The oxidation conditions found in some of the samples taken below the water table level are maintained by the oxygen which is carried downward by moving waters (Larsen and Chilingar, 1967) in as much as they are not very far from surface.

The pH values of the soil samples ranged between 6.65

and 8.7. Generally, it is found in the neutral range, slightly above or below 7, with an average of 7.4.

It is known that the oxidation of pyrite or marcasite needs sufficient oxygen and heavy tropical rainfall (high $\text{CO}_2 + \text{O}_2$). In other words it needs very high Eh (about 900 mV) and low pH (about 2) (Fairbridge, in Larsen and Chilingar, 1967). These conditions of pyrite oxidation are not prevailing in Abis area, where the Eh is about 408 mV and pH is about 7.4.

CONCLUSION

It can be said that the gypsum formation at Abis area cannot be due to the direct oxidation reduction process, in as much as a suitable environment for such an oxidation process is not available. The formation of gypsum by evaporation and crystallization out of solutions saturated with previously formed calcium sulphate is more favourable in environments such as found in the Abis area, i.e.

1. The ground-water is found near to the surface and has both calcium and sulfate ions in sufficient quantities.
2. This ground water rises by capillary action especially in summer until it reaches the more permeable layers, where the less soluble salts (gypsum) precipitate.

This conclusion indicates that irrigation and drainage programs would eventually lower the rate of formation of gypsum in Abis soil, with the important consequence from the agricultural point of view.

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