4-RESULTS AND DISCUSSION

4.1- Remote sensing investigation.

According to **Goosen (1967),** physiography is based on geomorphology and can provide a good basis for explaining geomorphology through aerospace image interpretation, using physiographic analysis approach. Such analysis identifies certain physiographic processes, which in turn provide important element clues for delineating soil patterns after predicting some certain soil properties.

Physiography can be defined as the study and description of physical earth surface features, including the processes responsible for their formation and evolution. The interpretation of false colour composite image provides information for mapping of the main land units in El-Alamain and El-Dabaa area Fig (5).

The main soil units are:-

1- Aeolian plain represented by profiles 6, 7, 13, 15, and 16.
2- Piedmont plain represented by profiles 1, 3 and 9.
3- Alluvial plain represented by profiles 4, 5, 8, 10, 11, 12 and 14.
4- Sabkha, represented by profiles 2 and 17.

Table (3): Particle size distribution, texture class, $CaCO_3$ and organic matter contents in the studied soil profiles.

Physio graphic units	Profile No	Depth (cm)	Particle size distribution %					$CaCO_3$ %	O.M %
			C. sand	F. Sand	Silt	Clay	Textural Class		
Aeolian	6	0-35	51.52	42.58	1.07	4.83	Loamy sand	30.20	0.29
		35-85	56.88	36.89	0.40	5.83	Loamy sand	33.60	0.16
		85-150	47.07	45.75	0.75	6.43	Loamy sand	31.20	0.07
	7	0-20	57.59	36.66	1.16	4.62	Loamy sand	46.40	0.17
		20-60	18.54	71.58	0.18	9.70	Loamy sand	28.93	0.41
		60-110	18.35	73.75	0.95	6.95	Sandy loam	28.15	0.61
		110-150	43.61	38.04	5.20	13.15	Loamy sand	35.65	0.43
	13	0-25	60.25	30.77	0.18	8.80	Loamy sand	47.70	0.24
		25-65	51.92	36.05	0.68	11.35	Loamy sand	42.12	0.17
		65-130	62.89	26.66	0.60	9.85	Loamy sand	64.12	0.21
	15	0-25	68.89	18.23	0.95	11.93	Loamy sand	60.99	0.16
		25-70	38.98	46.84	2.23	11.95	Loamy sand	59.43	0.31
		70-150	34.31	41.71	6.95	17.03	Sandy clay loam	38.31	0.31
	16	0-20	73.51	10.89	1.72	13.88	Loamy sand	68.82	0.20
		20-50	45.60	28.20	6.25	19.95	Sandy clay loam	60.21	0.25
		50-90	66.41	21.06	1.25	11.28	Loamy sand	45.51	0.16
		90-150	76.14	10.91	0.75	12.20	Loamy sand	93.84	0.20
Piedmont	1	0-20	49.39	42.29	0.18	7.62	Loamy sand	33.60	0.19
		20-60	47.95	44.25	0.62	7.18	Loamy sand	29.20	0.10
		60-100	48.66	37.54	3.20	10.60	Loamy sand	31.20	0.28
	3	0-15	57.38	36.12	1.27	5.23	Sandy	33.60	0.23
		15-60	25.71	44.19	12.72	7.38	Sandy clay loam	24.80	0.29
	9	0-25	53.08	38.59	1.40	6.93	Loamy sand	66.47	0.12
		25-60	17.37	40.50	18.83	23.30	Sandy clay loam	33.93	0.77
		60-120	14.25	37.15	21.92	26.68	Light clay	33.94	0.98

Table (3): Cont.

Physio graphic units	Profile No	Depth (cm)	Particle size distribution %					CaCO3 %	O.M %
			C.sand	F.Sand	Silt	Clay	Texturel Class		
Alluvial plain	4	0-35	53.80	41.70	1.05	3.45	Sandy	35.20	0.21
		35-70	26.13	59.59	5.28	9.80	Sandy loam	30.00	0.43
		70-100	30.83	44.39	7.60	17.18	Sandy clay loam	28.80	0.37
		100-150	30.34	45.88	8.88	14.90	Sandy clay loam	29.60	0.29
	5	0-15	42.99	52.31	1.10	3.60	Sandy	33.60	0.18
		15-40	23.37	44.75	13.60	18.28	Sandy clay loam	46.40	0.29
		40-80	36.41	49.56	5.20	8.33	Loamy sand	33.60	0.23
		80-150	26.99	52.86	8.77	11.38	Sandy loam	33.60	0.52
	8	0-35	42.63	49.39	0.33	7.65	Loamy sand	30.49	0.29
		35-75	37.48	38.87	8.42	15.23	Sandy clay loam	40.66	0.29
		75-150	42.93	32.04	8.45	16.58	Sandy clay loam	42.53	0.29
	10	0-35	11.89	54.26	10.77	23.08	Sandy clay loam	29.71	0.32
		35-75	11.87	54.15	11.45	22.53	Sandy clay loam	28.15	0.33
		75-140	20.67	51.28	9.37	18.68	Sandy clay loam	34.72	0.47
	11	0-25	31.33	58.89	2.78	7.00	Loamy sand	44.88	0.32
		25-65	7.45	51.20	12.80	28.55	Sandy clay	27.37	0.37
		65-100	10.92	53.68	11.27	24.13	Sandy clay loam	29.24	0.44
		100-150	15.53	50.89	11.15	22.43	Sandy clay loam	31.28	0.39
	12	0-35	32.95	51.42	4.35	11.28	Loamy sand	47.70	0.21
		35-75	27.84	49.03	7.50	15.63	Sandy clay loam	41.91	0.31
		75-150	22.34	44.66	13.22	19.78	Sandy clay loam	34.09	0.29
	14	0-30	49.69	27.93	6.48	15.90	Sandy clay loam	56.14	0.21
		30-70	55.72	29.48	1.70	13.10	Loamy sand	47.70	0.20
		70-150	48.34	34.53	1.50	15.63	Sandy clay loam	68.42	0.20
Sabkha	2	0-25	20.00	46.35	14.25	19.40	Sandy clay loam	22.40	0.40
		25-60	21.76	39.06	13.60	25.58	Sandy clay loam	20.80	0.32
		60-110	26.96	41.09	13.55	18.55	Sandy clay loam	33.60	0.13
	17	0-25	57.47	24.60	2.98	14.95	Sandy loam	60.21	0.27
		25-60	43.87	38.33	3.02	14.78	Sandy loam	63.65	0.30
		60-120	41.33	42.22	3.30	13.15	Sandy loam	68.81	0.28
		120-150	43.43	37.99	3.75	14.83	Sandy loam	51.61	0.34

Table (4) Chemical properties of the soil saturation extract of the studied soil profiles.

Physio graphic units	Profile (No.)	Depth (cm)	pH	EC dSm^{-1}	Soluble cations ($m\ mol/L^{-1}$)				Soluble anions ($m\ mol/L^{-1}$)			
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
Aeolian plain	6	0-35	8.3	2.48	8.9	4.3	11.5	1.06	-	1.9	14.0	9.86
		35-85	8.4	2.67	7.8	2.1	16.9	0.65	-	2.3	16.0	9.15
		85-150	8.4	1.29	5.7	2.2	5.48	0.32	-	1.9	7.20	4.60
	7	0-20	8.7	1.43	5.0	2.4	10.01	0.62	-	2.1	10.0	5.93
		20-60	8.3	3.54	10.6	8.9	16.6	0.90	-	2.2	19.5	15.3
		60-110	8.6	1.01	2.2	1.5	6.9	0.24	-	2.0	6.0	2.84
		110-150	8.4	2.13	7.8	5.4	10.5	0.24		2.0	13.5	8.44
	13	0-25	8.6	0.99	3.9	4.0	4.5	0.66	-	2.0	4.0	7.06
		25-65	8.9	0.83	2.8	3.0	2.84	0.48	-	1.2	4.0	3.92
		65-130	8.1	15.77	24.4	38.2	123.2	2.04	-	1.5	150	36.36
	15	0-25	8.4	0.86	5.0	2.4	3.78	0.70		1.2	6.0	4.68
		25-70	8.5	0.59	3.9	0.8	2.64	0.58		1.9	3.0	3.02
		70-150	8.6	0.75	2.8	0.9	4.37	0.29		1.8	4.0	2.56
	16	0-20	8.6	1.77	4.4	4.0	11.7	0.62	-	1.9	13.0	5.82
		20-50	8.0	20.4	31.1	45.2	222.2	2.06	-	1.8	275	23.76
		50-90	8.9	4.48	7.8	13.3	24.36	1.20	-	1.5	35.0	10.16
		90-150	9.1	32.7	7.2	6.0	22.56	1.02	-	2.0	30.0	4.78
Piedmont	1	0-20	8.4	0.94	2.8	3.0	4.2	0.44	-	2.0	4.0	4.44
		20-60	8.6	1.40	2.2	3.1	10.8	0.54	-	2.0	11.0	3.64
		60-100	8.5	2.17	4.4	2.4	16.6	0.78	-	1.9	15.0	7.28
	3	0-15	8.9	0.92	3.3	2.5	4.5	0.62	-	2.2	5.0	3.72
		15-60	8.9	1.18	2.8	3.0	8.04	0.72	-	1.6	7.0	5.96
	9	0-25	7.9	13.9	31.7	33.6	96.39	2.63	-	1.2	110.0	53.12
		25-60	8.1	9.65	18.3	15.4	66.04	1.34	-	1.2	75.0	24.88
		60-120	7.7	18.63	21.7	23.6	176.75	2.06	-	1.2	190.0	32.91

Table (4) cont.

Physiographic units	Profile (No.)	Depth (cm)	pH	EC dSm^{-1}	Soluble cations ($m\ mol/L^{-1}$)				Soluble anions ($m\ mol/L^{-1}$)			
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
Alluvial plain	4	0-35	8.3	4.13	11.1	12.6	19.38	1.50	-	1.6	26.0	16.98
		35-70	8.4	8.74	6.7	6.5	75.8	1.04	-	1.4	62.0	26.64
		70-100	8.5	1.34	6.7	1.7	7.62	0.66	-	2.1	9.5	5.08
		100-150	8.5	1.08	4.4	1.9	6.0	0.54		2.0	7.5	3.84
	5	0-15	8.6	0.98	6.7	2.2	4.6	0.32	-	2.2	6.0	5.62
		15-40	8.1	4.91	14.4	16.7	20.16	1.05	-	1.1	45.0	6.21
		40-80	8.3	2.73	9.4	8.0	12.78	0.78	-	1.1	17.0	12.86
		80-150	8.4	1.62	8.3	4.3	6.60	0.65		2.1	10.0	7.75
	8	0-35	8.1	6.56	12.8	11.4	43.4	1.94	-	1.8	53.0	14.74
		35-75	8.3	9.13	12.2	11.5	81.9	2.42	-	1.7	90.0	16.32
		75-150	8.3	3.51	9.4	7.4	21.18	0.98	-	1.8	25.0	12.16
	10	0-35	8.5	5.15	7.2	7.5	40.0	0.48		1.9	42.0	11.28
		35-70	8.4	4.60	6.1	4.4	40.0	0.32		1.9	41.0	7.92
		70-140	8.5	0.99	4.4	3.0	4.50	1.00		2.0	5.0	5.90
	11	0-25	8.7	0.75	2.2	2.0	3.78	0.90	-	1.4	4.0	3.48
		25-65	8.6	0.70	2.2	1.5	4.32	0.32	-	1.0	6.0	1.34
		65-100	8.7	1.05	3.9	2.9	3.42	0.35	-	2.0	5.0	3.57
		100-150	8.0	1.66	6.1	3.8	8.52	0.90	-	2.2	10.0	7.12
	12	0-35	8.8	8.07	66.2	15.2	45.0	1.87	-	1.8	60.0	22.47
		35-75	8.9	3.56	7.2	7.0	23.97	0.73	-	2.2	25.0	11.7
		75-150	8.4	1.42	5.6	3.9	6.50	0.56	-	2.0	10.0	4.56
	14	0-30	9.3	2.36	5.6	4.3	14.82	0.54	-	1.3	17.0	6.96
		30-70	9.3	2.98	5.0	14.9	13.2	0.54	-	2.1	17.0	14.54
		70-150	9.3	1.54	1.7	1.50	14.04	1.04	-	1.9	13.0	3.38
Sabkha	2	0-25	8.2	5.13	8.9	9.0	33.8	1.34	-	1.6	43.0	8.44
		25-60	8.1	41.16	38.3	107.0	389.7	3.06	-	1.4	475.0	61.66
		60-110	8.2	31.21	44.4	69.3	316.1	2.06	-	1.4	360.0	70.48
	17	0-25	8.1	16.47	33.3	38.3	138.3	2.06	-	1.6	175.0	35.43
		25-60	8.1	22.85	47.8	60.6	222.2	2.08	-	1.2	300.0	31.48
		60-120	8.3	14.40	25.0	28.7	118.1	2.04	-	1.6	150.0	22.31
		120-150	8.2	10.76	19.4	19.5	88.23	2.08	-	1.4	110.0	17.81

4.2. Soil characteristics.

The most relevant morphological, physical and chemical characteristics of the soil profiles (Tables 3 and 4) representing the main physiographic units of the investigated area are considered. In this accord, the morphological description of the representative soil profiles is given hereafter.

4.2.1. Soils of Aeolian plain

The soils of Aeolian plain cover a large area between alluvial plain in the north and piedmont in the south. The surface of this physiographic unit is almost flat to undulating. It is formed as result of wind activity and is mainly derived from the dissected plateau eroded by the action of strong winds with their loaded sands. This unit represented by profiles 6, 7, 13, 15 and 16. Soil dry colour varies from yellow (10YR7/6) to yellow (10YR8/6). Moist colour is yellowish brown (10YR5/6) to brownish yellow (10YR6/6). Soil texture is restricted between sand to sandy clay loam. The soil structure is undeveloped, where the single grains and massive structures are the only identified. Soil consistence coincides well with soil texture as non sticky to moderately sticky and non plastic to moderately plastic.

Considering the analytical data (Tables 3 and 4), $CaCO_3$ content is very high and ranges from 28.15 to 93.84% with an irregular distribution pattern with depth. The lowest value is detected in the 60 – 110 cm layer of profile 7, while the highest value is in the deepest layer of profile 16. Organic matter content is very low and ranges from 0.07 to 0.61 % and such low content of soil organic matter is expected due to the prevailing aridity of the region and its very scanty vegetation.

Table (4) indicates that soil reaction is moderately alkaline to very strongly alkaline as the pH values ranged between 8 and 9.1. The electrical conductivity of soil paste extract shows that the soils are non saline to strongly saline with EC values ranging from 0.59 to 32.7 dsm^{-1}. The dominant soluble cations are Na^{+} followed by Ca^{++} then Mg^{++}, while K^{+} is the least abundant, except for the deepest layer of profile 6 and uppermost surface layer of profile.15 where Ca^{++} exceeds Na^{+}. The anionic composition is alternatively dominated by Cl^{-} followed by $SO_4^{=}$, while HCO_3^{-} is the least abundant soluble anion.

The morphological description of the representative profiles are given below.

Profile No. : *6*

Location : Longitudes28° 40 East and Latitudes 30° 45 North

Physoigraphic Unit : Aeolian plain

Slope : Undulating

Vegetation : Many desert shrubs

Surface cover : Many fine to coarse gravels and sand dunes

Water table : More than 150 cm depth (deep)

Depth (cm)	**Description**
0 – 35	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Sand; single grains; loose; non sticky; non plastic; many fine to medium roots; many soft $CaCO_3$ concretions; many fine and medium broken shells; strongly calcareous; clear smooth boundary;
35 - 85	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; massive; soft; non sticky; non plastic; Common fine roots; many soft and hard $CaCO_3$ concretions; diffuse smooth boundary;
85 - 150	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; massive; soft; slightly sticky; slightly plastic; very few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. *: 7*

Location : Longitudes 28° 35' East and Latitudes 31° 00' North
Physoigraphic Unit : Aeolian plain
Slope : Undulating
Vegetation : Many desert shrubs
Surface cover : Many fine to medium gravels and dunes
Water table : More than 150 cm depth (deep)

Depth (cm)	**Description**
0 – 20	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; single grains; loose; non sticky; non plastic; many fine to coarse roots; many soft $CaCO_3$ concretions; many fine broken shells; strongly calcareous; clear smooth boundary,
20- 60	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) loamy sand; massive; soft; slightly sticky; slightly plastic; many fine roots; many soft and hard $CaCO_3$ concretions; few fine broken shells; strongly calcareous; diffuse smooth boundary;
60 –110	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; massive; soft; non sticky; non plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
110 - 150	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; massive; slightly hard; non sticky; non plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. : *13*

Location : Longitudes 28° 30̀ East and latitudes 31° 05̀ North

Physiographic Unit : Aeolian

Slope : Almost flat

Vegetation : Fig

Surface cover : Few fine gravels and sand dunes

Water table : More than 130 cm depth

Depth (cm)	**Description**
0 – 25	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; single grains; loose; non sticky; non plastic; many fine to coarse roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
25 – 65	Yellow (10 YR 8/6, dry) to yellowish brown (10 YR 5/6, moist) Loamy sand; massive; soft; non sticky; non plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; clear wavy boundary;
65 - 130	Yellow (10 YR 8/6, dry) to yellowish brown (10 YR 5/4, moist) Loamy sand; massive; soft; non sticky; non plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. : *15*

Location : Longitudes 28° 25̇ East and Latitudes 30° 45̇ North
Physiographic Unit : Aeolian Plain
Slope : Almost flat
Vegetation : Fig
Surface cover : Few fine gravels and sand dunes
Water table : More than 150 cm depth (deep)

Depth (cm)	**Description**
0 - 25	Yellow (10 YR 7/6, dry) to yellowish brown (10 YR 5/6, moist) Sandy loam; single grains; loose; slightly sticky; slightly plastic; many fine to coarse roots; many soft $CaCO_3$ concretions; moderate fine broken shells; strongly calcareous; clear smooth boundary;
25 – 70	Yellow (10 YR 7/6, dry) to yellowish brown (10 YR 5/6, moist) Sandy loam; massive; soft; slightly sticky; slightly plastic; many fine roots; many soft and hard $CaCO_3$ concretions; few fine broken shells; strongly calcareous; clear smooth boundary;
70 - 150	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; weak coarse sub angular blocky; soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; few fine broken shells; strongly calcareous.

Profile No. : *16*

Location : Longitudes 28° 23 East and Latitudes 30° 50 North

Physiographic Unit : Aeolian Plain

Slope : Almost flat

Vegetation : Many desert shrubs

Surface cover : Many fine to medium gravels

Water table : More than 150 cm depth (deep)

Depth (cm)	Description
0 – 20	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; single grains; loose; slightly sticky; slightly plastic; common fine roots; many soft $CaCO_3$ concretions; many fine broken shells; strong calcareous; clear smooth boundary;
20 – 50	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; many fine broken shells; strongly calcareous; clear smooth boundary;
50 – 90	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist)Sandy loam; massive; soft; slightly sticky; slightly plastic; many soft and hard $CaCO_3$ concretions; moderate fine broken shells; strongly calcareous; diffuse smooth boundary;
90 - 150	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; massive; slightly hard; slightly sticky; slightly plastic; many soft and hard $CaCO_3$ concretions; few fine broken shells; strongly calcareous.

4.2.2. Soils of piedmonts

This physiographic unit is represented by the three profiles 1, 3 and 9 and located in the south of the investigated area. Topography is almost flat to gently undulating. The soil profiles are deep to moderately deep with a surface covered with medium to fine gravels and in some places with coarse gravels and overblown sand dunes. Soil dry colour varies from yellow (10YR8/6) to very pale brown (10YR7/4), while moist colour is pale brown (10YR6/3) to very pale brown (10YR7/4). Soil texture ranges between sand to light clay and has no particular trend with depth. Soil structure in this unit is undeveloped where the massive forms are the dominant. Soil consistence being non sticky to very sticky and non plastic to very plastic, thus coincides well with soil texture.

$CaCO_3$ content varies between 24.8 and 66.47 %, the lowest is in the 15-60 cm depth of profile 3, and the highest is in the surface layer of profile 9. Depthwise distribution of $CaCO_3$ tends to decrease with depth, except for profile 1 where calcium carbonate does not show any specific pattern. Organic matter content is very low not exceed 0.98%., Table (3)

The analytical data (Table 4) show that the soil is slightly alkaline to strongly alkaline with a pH values ranging from 7.7 to 8.9. Soils are non saline to strongly saline with EC values ranging between 0.92 to 18.63 dSm^{-1}

The analysis of soluble ions shows that Na^+ is the dominant cations followed by Ca^{++} then Mg^{++} ion and K^+, while in uppermost surface layers of profiles 1 and 9 Mg^{++} exceeds Ca^{++}. The anionic composition is dominated by Cl^- followed by $SO_4^=$ and HCO_3^-, while $CO_3^=$ anion is absent.

Description of representative soil profiles are given in the following.

Profile No. ***: 1***

Location: El- Alamin (longitudes 28° 42 East and latitudes 30° 40 North).

Physiographic Unit : Piedmont Plain

Slope : Flat.

Vegetation : Many scattered desert shrubs.

Surface cover : Sand dunes.

Water table : More than 100 cm depth (deep)

Depth (cm)	**Description**
0 - 20	Yellow (10 YR 7/6, dry) to brownish yellow(10 YR 6/6, moist) loamy sand; massive; soft; non sticky; non plastic; many fine to medium roots; many soft and hard lime concretions; strongly calcareous; clear smooth boundary,
20 – 60	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) loamy sand; massive; soft; non sticky; non plastic; few fine roots; many soft and hard lime concretions; strongly calcareous; diffuse smooth boundary;
60 - 100	Yellow (10 YR 7/6, dry) to very pale brown (10 YR 7/4, moist) loamy sand; massive; hard; non sticky; non plastic; many hard lime concretions; strongly calcareous.

Profile No ***: 3***

Location : Longitudes 28° 40 East and Latitudes 30° 45 North.

Physographic Unit: Piedmont Plain

Slope : Gently undulating.

Vegetation : Many scattered desert shrubs.

Surface cover : Many fine to medium gravels and sand dunes

Water table : More than 60 cm depth.

Depth (cm)	**Description**
0 - 15	Very pale brown (10 YR 7/4, dry) to pale brown (10 YR 6/3, moist) Loamy sand; single grains; loose; non sticky; non plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
15 – 60	Very pale brown (10 YR 7/4, dry) to pale brown; (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately plastic; sticky; moderately; many soft and hard $CaCO_3$ concretions; strongly calcareous.
60 -------	Hard pan.

Profile No. : *9*

Location : Longitudes 28° 20 East and Latitudes 30° 40 North

Physiographic Unit : Piedmont Plain

Slope : Almost flat

Vegetation : Many desert shrubs

Surface cover : Many fine gravels and sand dunes

Water table : More than 120 cm depth (deep)

Depth (cm)	**Description**
0 - 25	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; single grains; loose; non sticky; non plastic; many fine to medium roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
25 – 60	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous clear smooth boundary;
60 - 120	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Clay loam; massive; slightly hard; sticky; plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

4.2.3. Soils of alluvial plain

Alluvial plain physiographic unit is recognized in the middle and extends from east to west in the studied area and is represented by seven soil profiles of 4, 5, 8, 10, 11, 12 and 14. The topography is almost flat to undulating and covered with fine to coarse gravels and sand dunes with deep soil profiles.

Soil dry colour is yellow (10YR8/6) to yellow (10YR7/6) while moist colour is very pale brown (10YR7/3) to pale brown (10YR6/2). Soil texture fluctuates between sand and sandy clay loam. Soil structure is undeveloped, where the single grains and massive structures are the only identified forms. Soil consistence coincides well with soil texture as non sticky to moderately sticky and non plastic to moderately plastic.

Calcium carbonate content is very high and varies from 27.37 to 68.42 %. The lowest value is found in the subsurface layer of profile 11, whereas the highest value characterized the deepest layer of profile 14. Depth wise distribution of $CaCO_3$ content does not portray any specific pattern with depth except for profile 8 where $CaCO_3$ tends to increase with depth. In profile 12 the $CaCO_3$ content decreases throughout the entire profile depths. Organic matter content is very low and ranges from 0.18 to 0.52 %.

Data in table (4) reveal that the soil is moderately alkaline to very strongly alkaline with pH value ranging from 8.1 to 9.3. These soils are non saline to moderately saline as shown by EC values (of the saturated extract) which range from 0.7 to 9.13 dSm^{-1}. The cationic composition is characterized by the dominance of Na^+ followed by Ca^{++} then Mg^{++} and K^+.

On the other hand, Cl^- predominate the soluble anions followed by $SO_4^=$ and HCO_3^-.

Field description of the representative soil profiles is given in the following.

Profile No : *4*

Location : Longitudes 28° 45̇ East and Latitudes 30° 50̇ North

Physiographic Unit : Alluvial Plan

Slope : Undulating

Vegetation : Many desert shrubs

Surface cover : Common sand dunes and few stones

Water table : More than 150 cm depth (deep)

Depth (cm)	Description
0 – 35	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Sand, single grains; Loose; non sticky; non plastic; many fine to coarse roots; many soft $CaCO_3$ concretion; strongly calcareous; clear smooth boundary;
35 - 70	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; massive; soft; slightly sticky; slightly plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary.
70 - 100	Yellow (10 YR 7/6, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; very few fine roots; common soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
100 - 150	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; massive; slightly hard; slightly sticky; slightly plastic; common soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No : *5*

Location : Longitudes 28° 36 East and Latitudes 30° 45 North
Physiographic Unit : Alluvial Plain
Slope : Undulating
Vegetation : Many desert shrubs
Surface cover : Many fine and medium gravels and sand dunes
Water table : More than 150 cm depth (deep)

Depth (cm)	Description
0 – 15	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sand; single grains; loose; non sticky; non plastic; many fine to coarse roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
15 - 40	Yellow (10 YR 7/6, dry) to brownish yellow (10YR 6/6, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; few fine and medium roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
40 – 80	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy loam; massive; soft; slightly sticky; slightly plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
80 - 150	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy loam; massive; slightly hard; slightly sticky; slightly plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. : *8*

Location : Longitudes 28° 42 East and Latitudes 30° 55 North

Physiographic Unit: Alluvial plain

Slope : Almost flat

Vegetation : Many desert shrubs

Surface cover : Many fine to coarse gravels and sand dunes

Water table : More than 150 cm depth (deep)

Depth (cm)	**Description**
0 – 35	Yellow (10 YR 8/6, dry) to very pale brown (10 YR 7/3, moist) Loamy sand; single grains; loose; non sticky; non plastic; many fine to medium roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
35 – 75	Yellow (10 YR 8/6, dry) to pale brown (10 YR 6/2, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
75 - 150	Yellow (10 YR 8/6, dry) to pale brown (10 YR 6/2, moist) Sandy clay loam; massive; slightly hard; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. ***: 10***

Location : Longitudes 28° 35' East and Latitudes 30° 55' North

Physiographic Unit : Alluvial Plain

Slope : Almost flat

Vegetation : Many desert shrubs

Surface cover : Many fine to medium gravels

Water table : More than 140 cm depth

Depth (cm)	Description
0 – 35	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; many fine to medium roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
35 – 75	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
75 – 140	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; slightly hard; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. : *11*

Location : Longitudes 28° 30 East and Latitudes 30° 55 North

Physiographic Unit : Alluvial Plain

Slope : Almost flat

Vegetation : Fig

Surface cover : Very few fine gravels

Water table : More than 150 cm depth (deep)

Depth(cm)	**Description**
0 – 25	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Loamy sand; massive; soft; non sticky; non plastic; many fine to medium roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
25 - 65	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay; massive soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
65 - 100	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive slightly hard; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
100 - 150	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; hard; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. ***: 12***

Location : Longitudes 28° 20' East and Latitudes 31° 00' North

Physiographic Unit : Alluvial Plain

Slope : Gently undulating

Vegetation : Common desert shrubs

Surface cover : Many fine to medium gravels and few stones

Water table : More than 150 cm depth (deep)

Depth (cm)	**Description**
0 - 35	Yellow (10 YR 8/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; massive; soft; slightly sticky; slightly plastic; many fine to medium roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
35- -75	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; weak coarse sub angular blocky; slightly hard; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
75- 150	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; weak medium angular blocky; slightly hard; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. : *14*

Location : Longitudes 28° 20 East and Latitudes 31° 02 North

Physiographic Unit : Alluvial plain

Slope : Almost flat

Vegetation : Fig

Surface cover : Few fine gravels and sand dunes

Water table : More than 150 cm depth (deep)

Depth (cm)	Description
0 - 30	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; massive; soft; moderately sticky; moderately plastic; many fine and coarse roots; many soft $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
30 - 70	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy loam; massive; soft; moderately sticky; moderately plastic; common fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; clear smooth boundary;
70 - 150	Very pale brown (10 YR 8/3, dry) to pale brown (10 YR 6/3, moist) Sandy clay loam; weak coarse angular blocky; soft; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

4.2.4. Soils of Sabkha

This physiographic unit is located in the north eastern and western part of the studied area. The soils of Sabkha are represented by two soil profiles Nos. 2 and 17. Topography is almost flat with deep soil profiles. Soil dry colour is yellow (10YR7/6), while soil moist colour varies from pale brown (10YR6/3) to brownish yellow (10YR6/6). Soil texture is sandy clay loam and sandy loam throughout the entire profile depths of profiles 2 and 17, respectively. Soil structure is undeveloped where the massive structures are the only identified forms. Soil consistence coincides well with soil texture as slightly sticky to moderately sticky and slightly plastic to moderately plastic.

The data presented in Tables (3 and 4) show that, calcium carbonate content ranges between 20.8 to 68.81 % indicating that these profiles unit are calcareous. The lowest content is in the subsurface layer of profile 2, while the highest is in the 60 – 120 cm depth of profile 17. Organic matter content, as it does not exceed 0.4 % in the different layers of soil profiles.

Analytical results (Table 4) show that soil reaction is moderately alkaline as pH values ranging from 8.1 to 8.3. EC_e values ranges from 5.13 to 41.16 dSm^{-1} and distributed irregular downwards indicating that these soils are slightly saline to strongly saline. The dominant cation is Na+ followed by Mg^{++} then Ca^{++}, while K^+ is the least. Soluble anions can be arranged in the descending order of abundance thus $Cl^- > SO_4^= > HCO_3^-$. Description of profiles is given in the following.

Profile No : 2

Location : Longitudes 28° 48 East and Latitudes 30° 57 North.

Physiographic Unit : Sabkha

Slope : Almost flat

Vegetation : Many scattered desert shrubs

Surface cover : Many gravels, stones and shells.

Water table : More than 150 cm depth (deep).

Depth (cm)	**Description**
0 – 25	Yellow (10 YR 7/6, dry) to very pale brown (10 YR, 7/3 moist) sandy loam, massive; soft; moderately sticky; moderately plastic; many fine to medium roots; many soft and hard $CaCO_3$concretions; strongly calcareous; clear smooth boundary.
25 – 60	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) sandy clay; massive; soft; moderately sticky; moderately plastic; few fine roots; many soft and hard $CaCO_3$ concretions; strongly calcareous; diffuse smooth boundary;
60 - 110	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) sandy clay loam; massive; soft; moderately sticky; moderately plastic; many soft and hard $CaCO_3$ concretions; strongly calcareous.

Profile No. : 17

Location : Longitudes 28° 38 East and Latitudes 31° 02 North

Physiographic Unit : Sabkha

Slope : Almost flat

Vegetation : Many scattered desert shrubs

Surface cover : Many fine to medium gravels

Water table : More than 150 cm depth (deep)

Depth cm)	**Description**
0 - 25	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam, massive; soft; slightly sticky; slightly plastic; many fine to medium roots; many soft $CaCO_3$ concretions; moderate fine broken shells; strongly calcareous; clear smooth boundary;
25 - 60	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; massive; soft; slightly sticky; slightly plastic; few fine roots; many soft and hard $CaCO_3$ concretions; moderate fine broken shells; strongly calcareous; clear smooth boundary;
60 - 120	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist)Sandy loam; massive; slightly hard; slightly sticky; slightly plastic; many soft and hard $CaCO_3$ concretions; few fine broken shells; strongly calcareous; clear smooth boundary;
120 - 150	Yellow (10 YR 7/6, dry) to brownish yellow (10 YR 6/6, moist) Sandy loam; massive; slightly hard; slightly sticky; slightly plastic; many soft and hard $CaCO_3$ concretions; few fine broken shells; strongly calcareous.

4.3. Calcium carbonate distribution

Calcium carbonate is one of the important soil components which are usually taken as criterion for soil development. Its presence may be attributed to the parent material from which the soil profile has been originated or through the chemical processes that prevailed in situ. So, it could have been transported after its formation. Accordingly, the deposits of $CaCO_3$ may vary in dimensions from gravel to very fine clay as well as in the form of aggregates.

Data in Table (5) show that the distribution of calcium carbonate in the soil fractions of soil profiles representing the studied physiographic units. Examination of the table reveals that total the $CaCO_3$ content in the studied physiographic units ranged from 28.15 to 93.84; 24.8 to 66.47, 27.37 to 68.42 and 22.4 to 68.81%. Generally, the studied physiographic units characterizes by the high $CaCO_3$ content. This higher content is expected since these soils are formed almost entirely of carbonate, these results are agreement with **Kassim (1977), Harga and El-Shazly (1982)and Abd el Razik (2005)**

The distribution of $CaCO_3$ in the studied physiographic units, data in Table (5) reveal that in the Aeolian plain soils which are represented by profiles 6, 7, 13, 15 and 16, the higher content of $CaCO_3$ occures in the coarse and fine sand fractions within the different layers and varied from 1.22 to 50.31% and from 0.86 to 63.79%, respectively.

Table (5): $CaCO_3$ distribution in the different soils fractions of the studied soil profiles

Physio graphic unit	Profile (No.)	Depth (cm)	Coarse fraction		Fine fraction	
			C. Sand	F. Sand	Silt	Clay
Aeolian plain	6	0-35	49.90	36.30	7.60	5.74
		35-85	49.90	32.51	9.83	7.56
		85-150	49.98	24.03	15.96	9.99
	7	0-20	50.01	37.54	5.52	6.91
		20-60	49.68	31.72	13.02	4.93
		60-110	49.12	0.86	25.34	24.52
		110-150	49.95	33.75	7.20	9.00
	13	0-25	1.22	63.79	23.00	11.72
		26-65	49.94	39.07	6.56	4.31
		65-130	49.94	41.87	7.32	0.75
	15	0-25	49.86	33.40	7.57	8.94
		25-70	49.94	31.24	10.75	7.96
		70-150	50.31	32.27	10.33	7.72
	16	0-20	49.91	35.60	7.72	6.59
		20-50	50.02	27.43	14.91	7.69
		50-90	49.97	33.41	8.28	8.28
		90-150	49.64	37.20	6.10	6.34
Piedmont	1	0-20	56.11	24.76	17.65	8.27
		20-60	49.46	8.03	22.31	19.12
		60-100	48.78	23.31	16.38	9.09
	3	0-15	49.40	33.58	13.39	3.00
		15-60	35.98	49.39	5.68	8.90
	9	0-25	49.10	31.07	10.80	7.36
		25-60	49.09	14.65	14.85	19.60
		60-120	36.25	13.75	2.50	2.50

Table (5) cont.

Physio graphic unit	Profile (No.)	Depth (cm)	Coarse fraction		Fine fraction	
			C. Sand	F. Sand	Silt	Clay
Alluvial plain	4	0-35	57.15	35.91	3.05	3.20
		35-70	51.30	23.38	12.26	13.50
		70-100	49.82	33.35	8.37	8.10
		100-150	49.57	1.98	21.98	25.60
	5	0-15	49.52	37.34	6.35	5.83
		15-40	12.60	36.83	17.64	31.79
		40-80	49.37	27.75	9.08	14.19
		80-150	49.84	4.19	14.06	31.60
	8	0-35	50.60	32.20	11.50	6.90
		35-75	49.69	19.57	8.57	21.55
		75-150	49.38	7.78	12.83	28.77
	10	0-35	33.71	16.18	11.09	38.81
		35-75	25.10	25.00	20.05	30.05
		75-140	49.95	24.95	15.05	9.95
	11	0-25	49.51	22.35	9.33	17.83
		25-65	14.80	44.12	18.50	26.01
		65-100	14.35	35.71	21.41	28.90
		100-150	20.96	29.61	25.24	25.33
	12	0-35	49.24	28.04	9.54	11.66
		35-75	37.96	11.70	31.15	18.13
		75-150	35.85	14.20	28.48	21.57
	14	0-30	51.42	42.51	4.75	4.16
		30-70	48.99	40.24	2.45	6.30
		70-150	50.58	36.12	7.70	6.75
Sabkha	2	0-25	13.75	37.05	20.55	30.25
		25-60	49.80	7.62	24.43	17.88
		60-110	47.50	3.15	20.62	29.40
	17	0-25	51.31	36.08	7.95	7.28
		25-60	50.76	38.51	4.22	8.02
		60-120	49.63	29.83	9.60	10.20
		120-150	50.52	24.43	14.4	11.69

The only exceptions are in the 60-110 cm layer of profile 7 where high content of $CaCO_3$ was recorded in the coarse and fine fraction. These results indicate that the effective role of physical disintegration of these soils.

Soils of piedmont which are represented by profiles 1, 3 and 9 are characterized by the abundance of carbonate in the coarse and fine sand in almost all cases. The distribution of CaCO3 in the coarse and fine sand varies from 35.98 to 56.11% and 8.03 to 49.39%, respectively.

Regarding the soils of alluvial plain which are represented by profiles 4, 5, 8, 10, 11, 12 and 14, the data of $CaCO_3$ size distribution, presented in Table (5) show the high content of carbonates are mainly confined to the coarse and fine sand (coarse fraction), except for the deepest layers of profiles 4, 11 and 12 and the subsurface layer of profile 10 where the size distribution of $CaCO_3$ is detected in the coarse fraction (coarse sand + fine sand) and fine fraction(silt + clay). This reflects the soil texture, mode of deposition and the degree of weathering during and after deposition.

With regard to sabkha soils (profiles 2 and 17). Data in Table (5) reveal that these soils are characterized by the dominancy of $CaCO_3$ distribution in the coarse fraction (coarse and fine sand) with are ranged from 13.75 to 51.31% and 3.15 to 38.51%, respectively. The only exceptions are recorded in the surface and deepest layers of profile 2 where high content of CaCO3 are found in the coarse and fine fractions.

The occurrence of calcium carbonate content in a relation high content in the size of sand, followed by silt and clay show the dominance of physical and chemical disintegration of the existing water during transportation and diposition of sediments **(Khatter *et al.*, 1986).**

The pattern of carbonate distribution in the different fractions could be ascribed to either different sources of parent materials (Quaternary and Tertiary eras) or different depositional regime as well as type and degree of weathering. Particle size distribution of carbonate components in some layers reveal the dominance of carbonate in the fine fraction (silt + clay), at the soils of profiles 7, 4,10, 11, 12 and 2 indicating the chemical weathering predominates the physical ones.

On the other hand, the main portion of $CaCO_3$ in the studied physiographic units is found within the coarse fraction (sand sub fraction). The increase of $CaCO_3$ in the sand fraction may be possibly, due to lime segregation, nearest these sediments to parent rocks and soft nodules formations within the profile horizons of these soils. Therefore, these carbonate could be considered as primary, i.e., inherited from the parent materials forming these soils.

4.4. Grain size analysis

Previous studies reveal that statistical treatment of mechanical analysis data of the whole soil samples not helpful in assessing and describing sedimentary parent materials whereas the examination of the cumulative curves of non-clay fraction is helpful in indicating the differentiation and / or stratification of the soil parent materials. Therefore, statistical evaluation of the mechanical analysis data particularly with regard to the non-clay fraction was performed.

In the present work, graphic presentation of mechanical analysis data of the skeletal grains was done according to **Folk and Ward (1957).** Cumulative percentages were plotted against phi-diameter on an arithmetic probability paper and seven percentiles; $Ø_5$, $Ø_{16}$, $Ø_{25}$, $Ø_{50}$, $Ø_{75}$, $Ø_{84}$, and $Ø_{95}$, the values in Tables (6 and 7) were estimated according to **Griffiths (1967),**

$$\mathbf{Ø = - \log d / \log^2}$$

Where d = diameter of grain in millimeter

The statistical grain size parameters where then determined according to the formulas of **Folk and Ward (1957)** as follows:

a) Mean size

The mean size described using the graphic mean (Mz) calculated by the formula:

$$\mathbf{Mz = (Ø_{16} + Ø_{50} + Ø_{84}) / 3}$$

It is the best expression for delineating the mean because it takes three points into consideration instead of median ($Ø_{50}$) which corresponds to one point only **(Folk and Ward, 1957)**.

Scale of mean size after **Folk (1968)**

Went worth size clas	Millimeters	Phi (Ø)
Gravel	> 2 mm	< -1.00
Coarse sand	2.0 - 0.5 mm	-1.0 to 1.0
Medium sand	0.5 - 0.25 mm	1.0 to 2.0
Fine sand	0.25 - 0.125 mm	2.0 to 3.0
Very fine sand	0.125 - 0.063mm	3.0 to 4.0
Coarse silt	0.063 - 0.031mm	4.0 to 5.0
Medium & fine silt	0.031 - 0.0039mm	5.0 to 9.0
Clay	0.0039 - 0.00006mm	9.0 to 14.0

b) Sorting

Folk and Ward (1957) introduced the inclusive graphic standard deviation (σI) as a measure of sorting. This is calculated by the formulas.

$$\sigma I = (Ø_{84} - Ø_{16})/4 + (Ø_{95} - Ø_{5})/6.6$$

The some authors gave a sorting scale to be used in describing the sorting of sediments in conjunetion with the results of these parameters as fallows:

σ I	Sorting description
Less than 0.35	Very well sorted*
0.35-0.50	Well sorted*
0.50-1.00	Moderately sorted**
1.00-2.00	Poorly sorted***
2.00-4.00	Very poorly sorted***
More than 4.00	

*** Materials transported by wind**

**** Materials transported by wind and water**

***** Materials transported by water**

It is well-known that the sediments transported by wind are well-sorted, while sediments transported by water or weathered in situe are usually poorly sorted (**Inman, 1952**). The frequency generalization cited by **Folk and Ward (1957)** that sorting increase with transport is in many suites simply due to the fact that the mean size of a sediment change with transport and the improvement in sorting is dependent only on the decreasing mean size but not the distance.

c) Skewness:

It measures the symmetrical distribution of 95% of the grains around the graphic mean (Mz). The high positive values mean that the sediments are fine-skewed, hawing excess fine materials rather than coarse ones around the graphic-mean. In contrast, the high negative values mean that the grains are coarse skewed and have excess coarse materials around the graphic mean. Actually, the low values around zero (-0.10 to +0.10) mean relative symmetrical distribution. Skewness is calculated by the formula.

$$SK1 = (Ø_{16} + Ø_{48} - 2Ø_{50}) / 2 (Ø_{84} - Ø_{16}) + (Ø_{5} + Ø_{95} - 2Ø_{50}) / 2 (Ø_{95} - Ø_{5}).$$

Folk and Ward (1957), proposed the following scale to describe the symmetry of sediments when using SK_I as the skewness measure.

SK_I	Class	
	Ace ± Folk and Ward (1957)	Ace ± Folk (1961)
1.00 to +0.30	Very positive skewed*	Strongly fine skewed*
0.30 to +0.10	Positive skewed*	Fine skewed*
0.10 to -0.1	Near symmetrical**	Near symmetrical**
0.1 to -0.30	Negative skewed***	Coarse skewed***
0.30 to -1.00	Very negative skewed***	Strong coarse skewed***

± Ace, according to

* **positive values indicate a tail of fine materials (A tail to right side frequency distribution curves),i.*e* fine skewed.**

** **Perfect symmetrical values (skewed = 0) indicate a normal curve of frequency distribution.**

*****Negative values indicate a tail of coarse materials (a tail to the left side in the frequency distribution curve) *i.e*, negative skewed (coarse skewed).**

d) Kurtosis

It measures the peakedness of the frequency distribution curve *i.e* the ratio of the sorting in the extremes, or the two tails of distribution curve compared with the sorting in the central part. It is a sensitive and valuable test of the normality of a distribution. For normal distribution KG equals 0.50. Excessive peakedness shows KG^- values exceeding 0.50. (Lepto-Kurtic), while excessive flatness shows KG-values below 0.5 (platy-kurtic). **Folk and Ward (1957)** calculated the graphic kurtosis KG^{-} by the formula $KG^{-}= KG/ (KG+1)$.

Where KG = (Ø $_{95}$- Ø $_{5}$) /2.44 (Ø $_{75}$- Ø $_{25}$)

The same authors suggested the following verbal scale to be used on describing the kurtosis of sediments. Data of particle size distribution were plotted as cumulative curves using phi units (Ø). The data of the statistical measures for the soils studied are given in Tables (6,7 and 8) and their cumulative curves are given below.

Scale of kurtosis

"Folk and Word's intervals (1957)"	**Correlation**
$KG^{-} < 0.40$	Very platy kurtic
0.40-0.470	Platy kurtic
0.474-0.526	Meso kurtic
0.526-0.600	Lepto kurtic
0.600-0.75	Very lepto Kurtic
> 0.75	Extremely lepto curtic

Table(6) Particle size distribution of the studied soil profiles.

Physio graphic	Prof. No	Depth cm	2-1 mm	2-0.5 mm	0.5-0.25 1mm	0.05-0.125 mm	0.125-0.053 mm	<0.053 mm
Aeolian plain	6	0-35	5.25	8.46	17.05	19.76	43.65	5.83
		35-85	6.34	9.63	19.55	25.40	32.31	6.77
		85-150	4.72	7.65	20.34	23.10	36.76	7.43
	7	0-20	5.20	7.54	18.75	26.16	35.61	6.74
		20-60	4.62	8.67	17.58	23.40	34.97	10.76
		60-110	3.85	7.75	19.67	21.55	39.24	7.94
		110-150	3.15	7.62	20.15	24.31	37.07	7.70
	13	0-25	20.45	19.30	20.73	21.35	7.32	10.85
		25-65	18.62	12.05	19.15	25.40	11.43	13.35
		65-130	20.30	15.60	20.75	25.00	7.70	10.65
	15	0-25	18.25	12.64	21.70	21.75	13.30	12.36
		25-70	9.75	13.40	19.80	20.30	22.80	13.95
		70-150	10.65	12.25	20.45	21.75	14.83	20.07
	16	0-20	20.75	8.76	21.40	21.85	12.39	14.85
		20-50	21.30	7.46	19.15	20.36	13.97	17.76
		50-90	20.10	9.76	20.43	21.75	15.10	12.86
		90-150	25.70	13.80	19.75	20.87	6.03	13.85
Piedmont	1	0-20	4.16	9.15	18.17	25.93	31.87	10.72
		20-60	3.20	8.25	20.10	26.10	32.55	9.80
		60-100	2.86	7.14	17.30	25.40	33.07	14.23
	3	0-15	5.46	8.24	19.35	28.40	31.25	7.30
		15-60	7.65	9.32	20.41	30.20	12.15	20.27
	9	0-25	3.50	8.51	18.26	23.45	38.70	7.58
		25-60	3.18	8.57	14.20	28.14	37.57	8.34
		60-120	2.37	7.35	18.83	24.20	11.95	35.30

Table (6): Cont.

Physio graphic	Profile No	Depth cm	2-1 mm	2-0.5 mm	0.5-0.25 mm	0.05-0.125 mm	0.125-0.053 mm	<0.053 mm
Alluvial plain	4	0-35	3.80	7.54	16.80	22.70	43.71	5.45
		35-70	6.13	9.59	17.70	21.82	30.48	14.28
		70-100	3.83	7.60	19.65	24.70	23.04	21.18
		100-150	3.34	5.34	20.20	19.85	28.47	22.80
	5	0-15	2.95	5.31	23.17	18.67	45.17	4.73
		15-40	3.37	7.75	18.40	24.38	14.48	31.62
		40-80	3.41	9.65	17.25	22.36	34.00	13.33
		80-150	2.69	8.54	16.26	23.32	29.41	19.78
	8	0-35	4.26	9.39	21.38	25.10	30.91	8.96
		35-75	3.48	8.26	20.15	24.20	20.65	23.26
		75-150	3.74	8.76	19.80	23.16	20.00	24.54
	10	0-35	1.87	7.15	14.25	21.92	23.57	31.24
		35-75	2.35	8.16	15.46	24.45	16.43	33.15
		75-140	3.07	8.53	16.73	25.20	18.85	27.62
	11	0-25	4.33	9.52	19.78	27.31	29.20	9.86
		25-65	4.21	10.26	20.16	21.80	12.02	31.55
		65-100	9.82	11.27	23.18	24.13	15.15	16.45
		100-150	5.53	11.23	17.43	25.10	10.29	30.42
	12	0-35	12.90	10.42	16.80	20.75	23.43	15.70
		35-75	15.40	12.60	17.50	19.65	16.00	18.85
		75-150	13.80	17.40	19.85	25.40	7.85	15.70
	14	0-30	9.65	19.80	21.35	27.30	9.45	12.45
		30-70	15.16	12.60	19.36	25.70	12.33	14.85
		70-150	11.12	15.67	20.30	19.30	17.96	15.65
Sabkha	2	0-25	1.17	8.15	20.10	22.15	16.33	32.10
		25-60	2.71	10.41	19.60	25.46	11.24	30.58
		60-110	3.10	7.60	17.22	21.93	14.94	35.21
	17	0-25	18.75	12.46	20.19	22.45	9.20	16.95
		25-60	17.30	14.60	19.25	21.38	9.67	17.80
		60-120	15.60	17.60	18.50	20.76	11.07	16.47
		120-150	16.34	15.70	20.30	22.36	7.50	17.80

Table (7): Values read from the cumulative frequency curves of the studied soil profiles.

Physio graphic	Profile No	Depth cm	Ø5	Ø16	Ø25	Ø50	Ø75	Ø84	Ø95
Aeolian plain	6	0-35	0	1.1	1.6	2.0	2.5	2.7	3.3
		35-85	0	0.9	1.4	2.3	3.2	3.5	4.4
		85-150	0.1	1.3	1.8	2.8	3.5	3.7	4.5
	7	0-20	0	1.3	1.8	2.8	2.9	3.2	3.6
		20-60	0.3	1.3	1.7	2.7	4.0	4.2	4.7
		60-110	0.4	1.3	1.6	2.5	3.8	4.1	4.5
		110-150	0.5	1.2	1.6	2.8	4.0	4.5	4.7
	13	0-25	0	0	0.3	1.4	2.6	3.0	4.5
		25-65	0	0	0.6	1.8	3.0	3.8	4.5
		65-130	0	0	0.5	1.6	2.8	3.2	4.6
	15	0-25	0	0	0.6	1.9	2.1	3.9	4.5
		25-70	0	0.1	1.8	2.1	4.2	4.5	4.6
		70-150	0	0.6	1.1	2.4	3.8	4.2	4.6
	16	0-20	--	--	0.4	1.8	3.3	4.4	4.5
		20-50	--	--	0.8	2.8	4.2	4.5	4.6
		50-90	--	--	0.8	2.0	3.0	4.3	4.4
		90-150	--	--	0.2	1.5	2.8	3.6	4.3
Piedmont	1	0-20	0.2	1.1	1.7	2.6	2.6	3.0	3.3
		20-60	0.5	1.3	1.8	2.8	3.4	3.7	4.2
		60-100	0.7	1.6	2.1	3.0	3.9	4.2	4.9
	3	0-15	0.1	1.3	1.8	2.6	3.5	3.8	4.5
		15-60	--	1.0	1.5	2.5	4.2	4.5	4.7
	9	0-25	0.3	1.3	1.5	2.9	3.5	3.9	4.5
		25-60	0.5	1.5	2.0	3.0	3.6	3.9	4.6
		60-120	0.7	1.7	2.1	3.1	4.3	4.5	4.7

Table (7) Cont.

Physio graphic	Profile No	Depth cm	$Ø_5$	$Ø_{16}$	$Ø2_5$	$Ø_{50}$	$Ø_{75}$	$Ø_{84}$	$Ø_{95}$
Alluvial plain	4	0-35	0.2	1.2	2.0	3.2	3.5	3.8	4.2
		35-70	--	0.9	1.5	2.6	3.6	4.2	4.5
		70-100	0.3	1.8	2.4	3.8	4.5	4.7	4.8
		100-150	0.6	1.5	1.7	3.0	4.0	4.5	4.7
	5	0-15	0.5	1.4	1.8	3.0	3.5	3.7	4.2
		15-40	0.3	1.2	1.7	2.5	4.2	4.4	4.6
		40-80	0.2	0.9	1.5	2.5	3.6	4.0	4.5
		80-150	0.6	1.5	1.9	3.1	4.0	4.5	4.8
	8	0-35	0.1	1.1	1.6	2.5	3.4	3.8	4.5
		35-75	0.2	1.2	1.8	2.6	4.1	4.3	4.7
		75-150	0.5	1.5	1.9	2.8	4.2	4.5	4.8
	10	0-35	0.6	1.6	2.1	3.3	4.6	4.7	4.8
		35-75	0.4	1.4	1.9	2.8	4.4	4.5	4.7
		75-140	0.3	1.5	2.0	3.0	4.2	4.4	4.6
	11	0-25	0.6	1.1	1.6	2.5	3.5	3.9	4.5
		25-65	0.8	1.2	1.7	2.7	4.0	4.1	4.3
		65-100	0.1	0.7	1.1	2.1	3.2	4.3	4.6
		100-150	0.5	1.0	0.5	2.5	4.5	4.6	4.8
	12	0-35	--	0.6	1.2	2.5	3.8	4.3	4.6
		35-75	--	0.3	1.1	2.3	3.9	4.5	4.7
		75-150	--	0.2	0.9	2.0	3.0	4.0	4.5
	14	0-30	--	0.5	0.9	2.0	2.8	3.8	4.5
		30-70	--	0.6	1.0	2.1	3.0	3.2	4.7
		70-150	--	0.3	0.7	1.8	3.2	3.8	4.4
Sabkha	2	0-25	0.7	1.5	1.8	2.5	4.2	4.4	4.6
		25-60	0.5	1.2	1.5	2.4	4.3	4.5	4.7
		60-110	0.3	1.6	2.0	3.0	4.5	4.6	4.8
	17	0-25	--	--	0.5	1.8	3.2	4.5	4.7
		25-60	--	0.2	0.5	1.9	3.1	4.4	4.5
		60-120	--	0.3	0.8	2.0	3.5	4.5	4.7
		120-150	--	0.5	1.0	2.1	4.0	4.7	4.8

Table (8): The statistical size parameters of the studied soil profiles (According to Folk and Word, 1957)

Physio Graphic units	Profile No	Depth (cm)	M_2	M_2 indication	So	So indication	SK	SK indication	KG	KG indication
Aeolian plain	6	0-35	1.93	Fine sand	0.90	Moderately sorted	-0.43	Coarse skewed	0.93	Meso kurtic
		35-85	2.23	Fine sand	1.31	Poorly sorted	-0.06	Coarse skewed	1.00	Meso kurtic
		85-150	2.62	Fine sand	1.30	Poorly sorted	-0.24	Coarse skewed	1.06	Meso kurtic
	7	0-20	2.82	Fine sand	1.42	Poorly sorted	-0.13	Coarse skewed	0.9	Meso kurtic
		20-60	2.74	Fine sand	1.39	Poorly sorted	0.02	Coarse skewed	0.78	Platy kurtic
		60-110	2.62	Fine sand	1.32	Poorly sorted	0.06	Coarse skewed	0.76	Platy kurtic
		110-150	2.81	Fine sand	1.36	Poorly sorted	-0.03	Coarse skewed	0.72	Platy kurtic
	13	0-25	1.52	Medium sand	1.43	Poorly sorted	0.22	Fine skewed	0.80	Platy kurtic
		25-65	1.92	Medium sand	1.63	Poorly sorted	0.13	Fine skewed	0.77	Platy kurtic
		65-130	1.61	Medium sand	1.50	Poorly sorted	0.15	Fine skewed	0.82	Platy kurtic
	15	0-25	0.20	Coarse sand	1.66	Poorly sorted	0.10	Fine skewed	1.23	Lepto kurtic
		25-70	2.23	Fine sand	1.80	Poorly sorted	0.09	Coarse skewed	0.79	Platy kurtic
		70-150	2.42	Fine sand	1.47	Poorly sorted	-0.02	Coarse skewed	0.70	Platy kurtic
	16	0-20	0.11	Coarse sand	1.78	Poorly sorted	0.19	Fine skewed	0.64	V Platy kurtic
		20-50	0.21	Coarse sand	1.82	Poorly sorted	-0.13	Coarse skewed	0.55	V .Platy kurtic
		50-90	2.11	Fine sand	1.74	Poorly sorted	0.08	Coarse skewed	0.82	Platy kurtic
		90-150	1.72	Medium sand	1.60	Poorly sorted	0.23	Fine skewed	0.68	Platy kurtic
Piedmont	1	0-20	2.23	Fine sand	0.94	Moderately sorted	-0.10	Coarse skewed	0.88	Platy kurtic
		20-60	2.61	Fine sand	1.16	Poorly sorted	-0.25	S.Coarse skewed	0.95	Meso kurtic
		60-100	2.94	Fine sand	1.24	Poorly sorted	-0.13	Coarse skewed	0.89	Platy kurtic
	3	0-15	2.61	Fine sand	1.29	Poorly sorted	-0.09	Coarse skewed	1.06	Meso kurtic
		15-60	2.73	Fine sand	1.59	Poorly sorted	0.04	Coarse skewed	0.71	Platy kurtic
	9	0-25	2.72	Fine sand	1.29	Poorly sorted	-0.23	S.Coarse skewed	0.86	Platy kurtic
		25-60	2.81	Fine sand	1.22	Poorly sorted	-0.23	S.Coarse skewed	1.05	Meso kurtic
		60-120	3.14	Very fine sand	1.31	Poorly sorted	-0.10	Coarse skewed	0.75	Platy kurtic

Table (8) cont:

Physio Graphic units	Profile No	Depth (cm)	M_z	M_z indication	So	So indication	SK	SK indication	KG	KG indication
Alluvial plain	4	0-35	2.72	Fine sand	1.26	Poorly sorted	-0.52	S. coarse skewed	1.09	Meso kurtic
		35-70	2.61	Fine sand	1.51	Poorly sorted	-0.09	Coarse skewed	0.88	Platy kurtic
		70-100	3.43	Very fine sand	1.41	Poorly sorted	-0.47	S. coarse skewed	0.88	Platy kurtic
		100-150	3.01	Very fine sand	1.37	Poorly sorted	-0.09	Coarse skewed	0.73	Platy kurtic
	5	0-15	2.74	Fine sand	1.14	Poorly sorted	-0.37	S. coarse skewed	0.89	Platy kurtic
		15-40	2.72	Fine sand	1.45	Poorly sorted	0.08	S. fine skewed	0.70	Platy kurtic
		40-80	2.50	Fine sand	1.43	Poorly sorted	-0.05	Coarse skewed	0.84	Platy kurtic
		80-150	3.01	Very fine sand	1.39	Poorly sorted	-0.13	Coarse skewed	0.82	Platy kurtic
	8	0-35	2.51	Fine sand	1.34	Poorly sorted	-0.06	Coarse skewed	1.00	Meso kurtic
		35-75	2.73	Fine sand	1.46	Poorly sorted	0.02	S. fine skewed	0.80	Platy kurtic
		75-150	0.11	Coarse sand	1.40	Poorly sorted	0.03	S. fine skewed	0.77	Platy kurtic
	10	0-35	3.20	Very fine sand	1.41	Poorly sorted	-0.24	Coarse skewed	0.69	Platy kurtic
		35-75	2.92	Fine sand	1.43	Poorly sorted	-0.01	Near symmetrical	0.70	Platy kurtic
		75-140	3.01	Very fine sand	1.38	Poorly sorted	-0.15	Coarse skewed	0.80	Platy kurtic
	11	0-25	2.50	Fine sand	1.29	Poorly sorted	0.01	S. fine skewed	0.84	Platy kurtic
		25-65	2.71	Fine sand	1.26	Poorly sorted	-0.03	Near symmetrical	0.62	V .Platy kurtic
		65-100	2.41	Fine sand	1.58	Poorly sorted	0.17	S. fine skewed	0.88	Platy kurtic
		100-150	2.74	Fine sand	1.55	Poorly sorted	0.12	S. fine skewed	0.44	V.Platy kurtic
	12	0-35	2.51	Fine sand	1.62	Poorly sorted	-0.06	Coarse skewed	0.73	Platy kurtic
		35-75	2.42	Fine sand	1.76	Poorly sorted	0.04	S. fine skewed	0.69	Platy kurtic
		75-150	2.11	Fine sand	1.63	Poorly sorted	0.08	S. fine skewed	0.88	Platy kurtic
	14	0-30	2.11	Fine sand	1.51	Poorly sorted	0.10	Near symmetrical	0.97	Platy kurtic
		30-70	2.01	Fine sand	1.36	Poorly sorted	-0.02	Near symmetrical	0.96	Platy kurtic
		70-150	2.02	Fine sand	1.54	Poorly sorted	0.16	S. fine skewed	0.72	Platy kurtic
Sabkha	2	0-25	2.81	Fine sand	1.32	Poorly sorted	0.19	S. fine skewed	0.67	Platy kurtic
		25-60	2.72	Fine sand	1.46	Poorly sorted	0.18	S. fine skewed	0.61	V.Platy kurtic
		60-110	3.10	Very find sand	1.43	Poorly sorted	-0.07	Near symmetrical	0.74	Platy kurtic
	17	0-25	2.12	Fine sand	1.84	Poorly sorted	0.22	S. fine skewed	0.71	Platy kurtic
		25-60	2.21	Fine sand	1.73	Poorly sorted	0.17	S. fine skewed	0.71	Platy kurtic
		60-120	2.33	Fine sand	1.76	Poorly sorted	0.17	S. fine skewed	0.71	Platy kurtic
		120-150	2.41	Fine sand	1.78	Poorly sorted	0.23	S. fine skewed	0.66	V.Platy kurtic

4.4.1. Aeolian plain Soils

These soils are represented by profiles 6, 7, 13, 15 and 16. The cumulative values of the sand fraction are illustrated in Fig (6) and the grain size parameters are shown in Table (8). The mean size (Mz) values of these soils ranged between 0.11 and 2.82 Ø indicating fine to coarse sand fraction. In profiles 6, 7 and 15 are fine sand fraction throughout the entire profiles depths, except for the surface layer of profile 15 which has coarse sand. In profile 13 the soils have medium sand fraction, while in profile 16 the soils have coarse sand in the uppermost surface layer changed into fine and medium sand fraction in the deepest layers.

The standard deviation (Sorting) of the grain size values change between 0.90 and 1.82 Ø, the distribution of the sorting of these values is almost unimodal representing poorly sorted sediment except for the surface layer of profile 6 where the sorting value is moderately sorted. The sorting values indicate that these soils are transported and deposited under water action, while the surface layer of profile 6 was transported and deposited under combined action of both wind and water actions.

The skewness (SK_I) values are in the range of -0.43 to 0.23 Ø representing bimodal distribution. The first and large clustering representing course skewed in profiles 6, 7, 15 and 16 except for the surface layers of profiles 15 and 16 and the deepest layer of profile 16 where skewness values indicate that these layers were fine skewed. In profile 13, the soil profile layers were fine skewed throughout the entire profile depth.

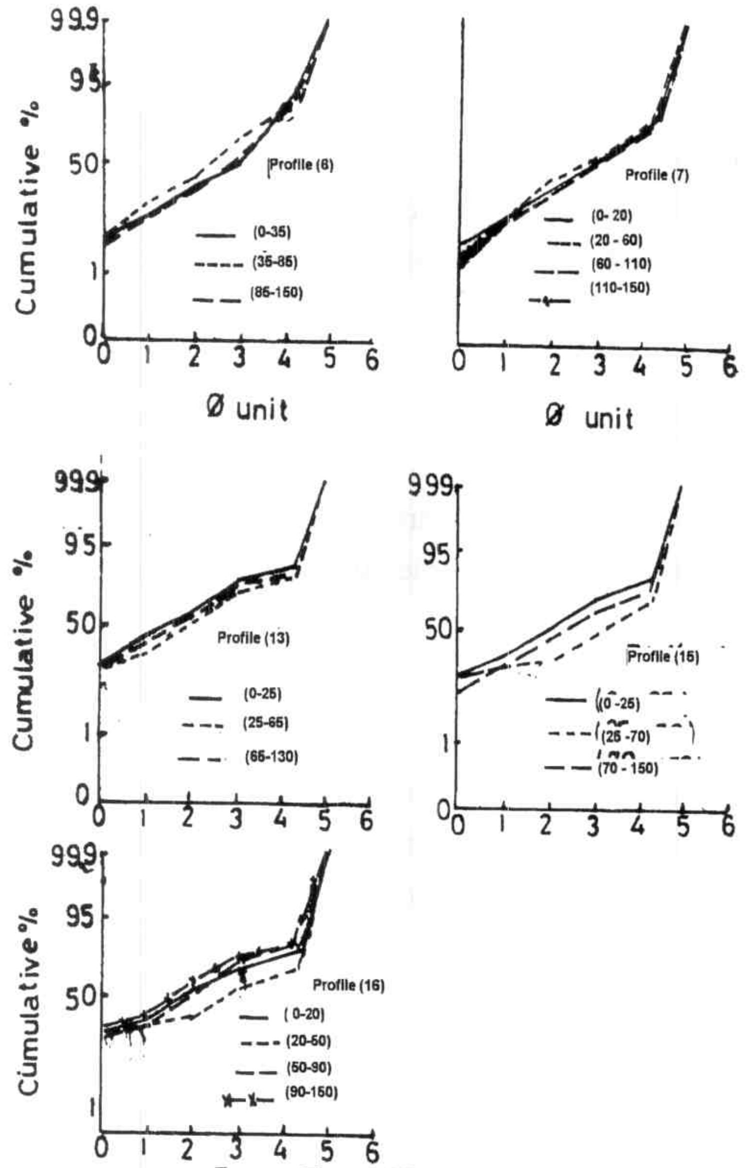

Fig (6): cumulative frequency curves of Aeolian plain soils

The kurtosis values (KG) are between 0.55 to 1.23 Ø. The largest clustering of KG values representing platy or very platy kurtic, while in profile 6 the values of KG representing Mesokurtic dounward the profile depth. The some what normal distribution of KG values corresponds to very low energy environment and very high modification of grain size (**Folk and Ward 1957**).

4.4.2. Piedmont soils

This physiographic unit is represented by profiles 1, 3 and 9. The cumulative curves of these soils and their grain size parameters are shown in Fig (7) and Table (8).

The mean size (Mz) values of these soils are in the range of 2.23 to 3.14 Ø representing fine sand fractions except for the deepest layer of profile 9 where the Mz values indicate that this layer was very fine sand fraction.

The standard deviation (σI) of the grain size values is in the range of 0.94 to 1.59 Ø, the distribution of sorting (σI) of these values is almost unimodal representing poorly sorted sediment. Generally, soils of piedmont are transported and diposited under water action.

The skewness (SK_I) values show a bimodal distribution, ranging from coarse skewed to strong coarse skewed, the large cluster is in the range of SK_I values (-0.13 to 0.04 Ø) distinguishing coarse skewed, while the smallest cluster (0.23 to 0.25 Ø) representing strong coarse skewed.

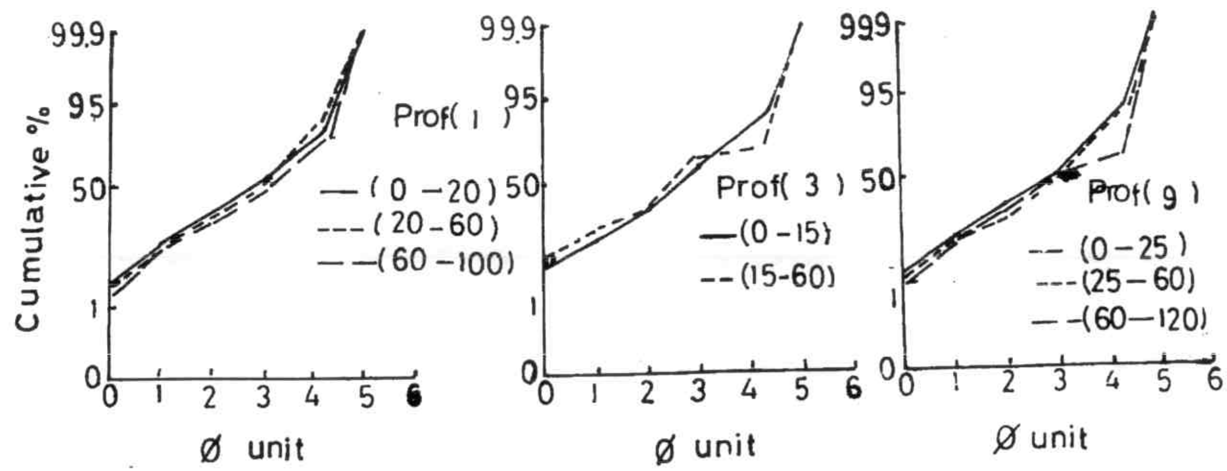

Fig (7): Cumulative frequency curves of the piedmont soils

With few exceptions of mesokurtic case, the main modal of kurtosis is platy-kurtic. As previously mentioned the relative normal distribution of KG values corresponds to very low energy environment and high modification of grain size.

4.4.3. Alluvial plain soils.

These soils are represented by profiles 4, 5, 8, 10, 11, 12, and 14. The cumulative curves of the sand fraction are illustrated in Fig (8) and the grain size parameters are shown in Table (8).

The mean size (Mz) values of these soils are in the range of 0.11 to 3.43 Ø indicating that these soils are fine to very fine sand fraction, while the only case of coarse sand fraction in the deepest layer of profile 8.

The standard diviation (σI) values fall in the range of 1.14 to 1.76 Ø showing bimodal distribution representing poorly sorted sediment. The poorly sorted indicates that the soils are transported and deposited by water action.

The skewness (SK_I) values are in the range of -0.52 to 0.17 Ø, representing bimodal distribution. The first and large clustering is between (SK_I) values of -0.47 to -0.05 Ø representing coarse to strong coarse skewed and the second minor one is between SK1 values of 0.10 and -0.01 Ø indicating near symmetrical skewnees. The third case is between (SK_I) values of the range between 0.02 and 0.19 Ø indicating strong fine skewness. The skewness bimodal distribution is corresponding to the mixing of two modal fractions, i.e., fine and coarse sand.

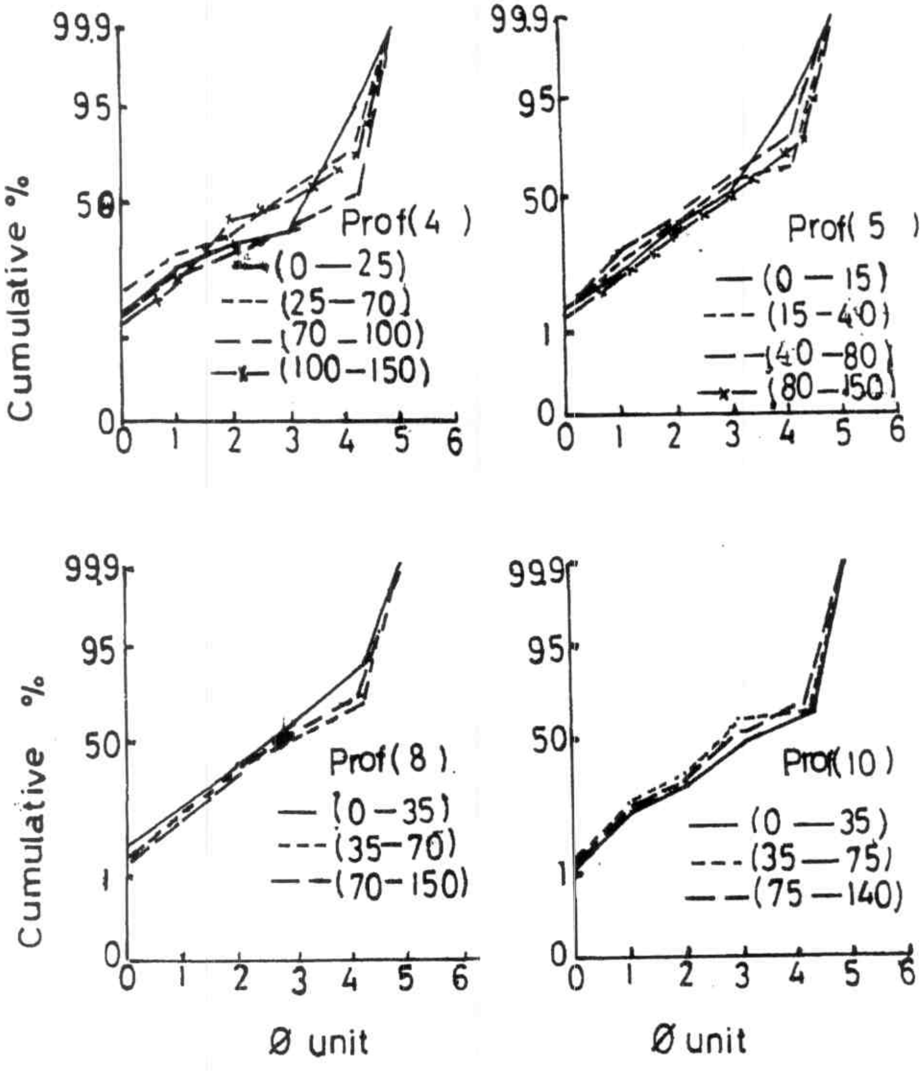

Fig (8): Cumulative frequency curves of the alluvial plain soils

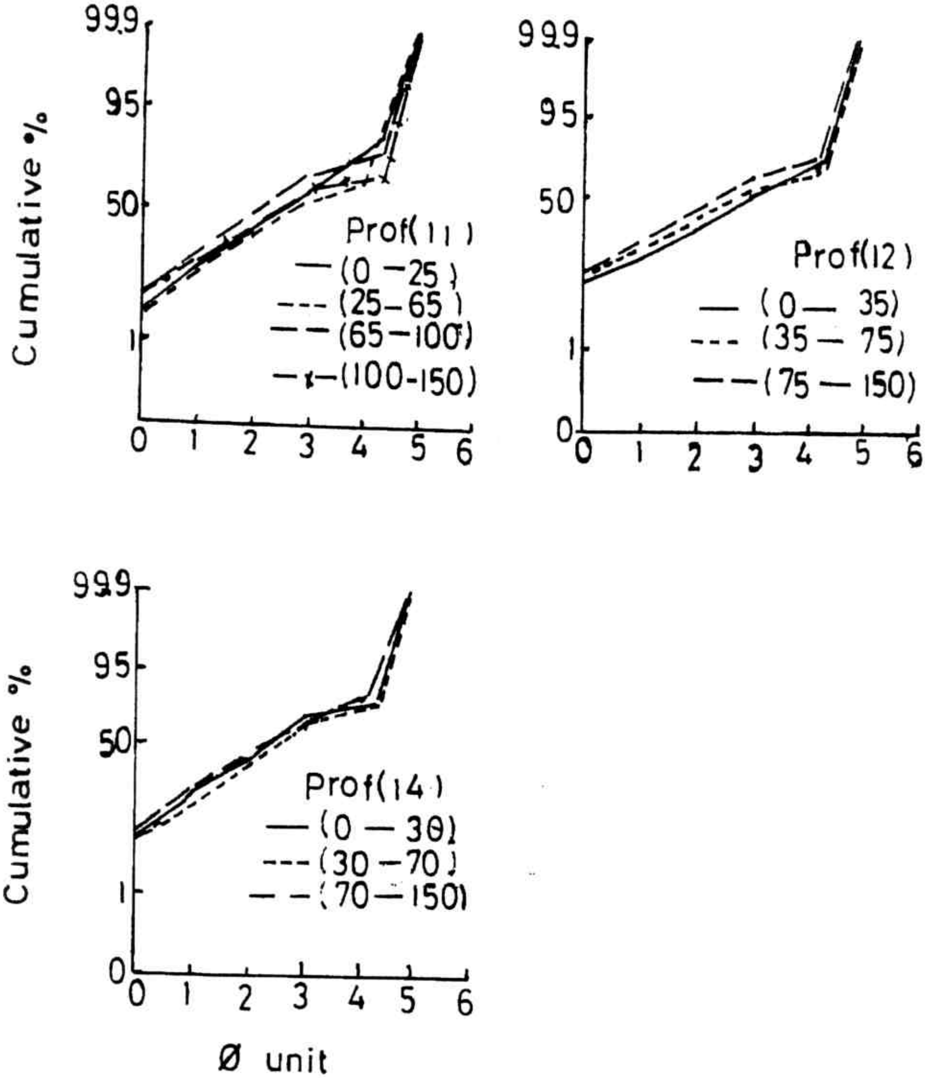

Fig (8):cont.

Fig (8):Cont.

The kurtosis values (KĠ) showed non-normal distribution, representing two different modals of platy to very platy kurtic and meso kurtic. The first modale is equally distributed in these soils. The moderate different values of kurtosis, correspond to low energy environment and high modication of grain size.

4.4.4. Sabkha soils

These soils are represented by two soil profiles (Nos.2 and 17). The cumulative values of the sand fraction are illustrated in Fig (9) and the grain size parameters are shown in Table (8).

The mean size (Mz) values of these soils are in the range of 2.12 to 3.1Ø which is an indication of fine and very fine sand fractions.

The standard deviation values (σ_I) fall in the range of 1.32 to 1.84 Ø. The distribution of standard deviation of these values is almost unimodal, representing poorly sorted sediments. Results indicate that the sediments of these soils are transported and deposited under water action.

The skewness values show a almost unimodal distribution and ranged from -0.07 to 0.23 Ø representing strong fine skewness, except for the deepest layer of profile 2 where the skewness is near symmetrical.

The kurtosis is distributed between KG values of the range of 0.61 to 0.77 Ø representing platy and very platy kurtic. The somewhat normal distribution of KG values correspond to

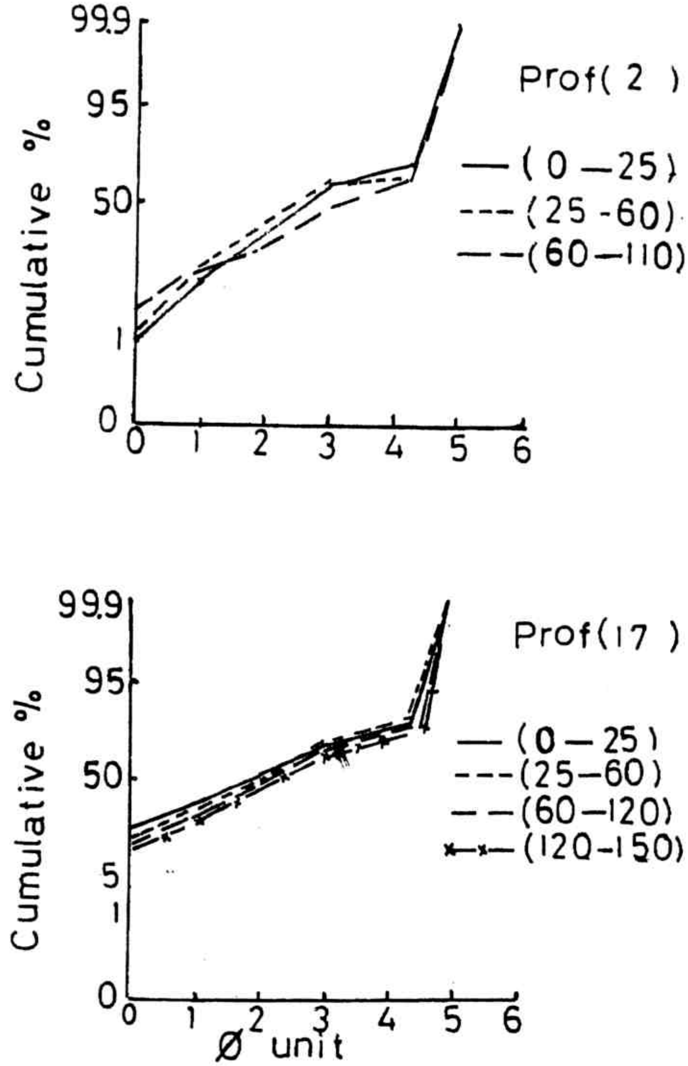

Fig (9): Cumulative frequency curves of the Sabkha soils

very low energy environment and very high modification of grain size. In discussing the mode of deposition of sediments in the studied area, one makes use of the previously mentioned frequency curves as well as the statistical size parameters.

The data showed clearly that these sediments are either of alluvial and aeolian sources or even a mixture of both.

In this connection, it is concluded that water or water and wind are the two main factors responsible for transport deposited, and formation of these soils.

4.5.Trace elements distribution:

Trace elements play a major role in soil fertility Geochemical distribution of trace elements may be used in the differentiation between geological sediments that may act as parent materials for soils. Levels of trace elements could be used as a guide for substantiating the nature of parent materials, together with the pedogenic aspects which lead a prediction of soil genesis and formation, (**El-Demerdashe *et al.*, 1980 a, b; Abdel- Hamid 1981; Hassona *et al.*, 1999; Barkat, 1998 and Abdel-Razik, 1999).**

The trace elements Zn, Cu, Fe and Mn distribution in the studied physiographic units show a wide variation in their contents. Assessment of statistical parameter of weighted mean (W), trend (T) and specific range (R) relating trace elements measurements were carried out.

4.5.1. Total content of trace elements

4.5.1.1. Total zinc

Table (9) shows that the total Zn content in the soils of Aeolian plain which are represented by profile 6, 7, 13, 15 and 16 ranged from 12.1 to 31.1 mg kg^{-1}.

The highest content is recorded in the deepest layer of profile 15, while the lowest content characterizes the 50-90 cm layer of profile 16. Zinc content has a tendency to increase throughout the entire profile depths.

Soils of piedmont which are represented by profiles 1, 3 and 9, have total zinc content that ranged from 14.7 to 44.3 mg kg^{-1}, the lowest content is detected in the deepest layer of profile 1, whereas the highest content of total Zn in the 15-60 cm depth of profile 3.

Concerning the soils of alluvial plain, which are represented by profiles 4, 5, 8, 10, 11, 12 and 14, total Zn content ranged from 12.3 to 50.3 mg kg^{-1}. The highest value is detected in the 75-140 cm layer of profile 10, while the lowest value is found in the deepest layer 14. As a general, the highest values of total Zn content coincide well with fine texture class in this unit.

With regard to the soils of Sabkha, which are represented by profile 2 and 17 data in Table (9) indicate that total Zn content ranges from 0.1 to 57.0 mg kg^{-1} with a tendency to decrease with depth. The highest value is in the surface layer of profile 2, whereas the lowest is in the deepest layer of profile 17.

Table (9): Total and DTPA-extractable Zn, Cu, Fe and Mn of the studied soil profiles.

Physio graphic unit	Prof. (No.)	Depth (cm)	Zn mg kg^{-1}		Cu mg kg^{-1}		Fe mg kg^{-1}		Mn mg kg^{-1}	
			Total	Avai.	Total	Avai.	Total	Avai.	Total	Avai.
Aeolian plain	6	0-35	17.80	0.15	8.50	0.15	3372.2	3.22	96.5	2.93
		35-85	17.30	0.13	9.80	0.43	2744.5	2.45	83.7	2.66
		85-150	19.70	0.17	8.40	0.45	3396.6	2.96	89.8	2.91
	7	0-20	14.60	0.11	11.80	0.36	3268.6	12.09	87.5	11.75
		20-60	18.20	0.16	10.90	0.20	4035.4	2.55	108.6	2.82
		60-110	22.10	0.31	7.30	0.30	3933.0	2.55	105.2	2.75
		110-150	24.70	0.30	10.90	0.39	6429.4	3.86	140.9	3.86
	13	0-25	16.40	0.16	15.60	0.21	3303.3	2.80	100.4	2.55
		25-65	21.50	0.09	13.00	0.11	4454.9	8.37	129.6	8.71
		65-130	16.20	0.18	18.10	0.63	1972.5	8.52	68.3	8.85
	15	0-25	17.30	0.22	10.90	0.34	2511.6	3.68	87.2	4.26
		25-70	20.4	0.34	13.30	0.72	4756.4	2.35	140.8	2.50
		70-150	12.1	0.49	17.50	0.59	6588.1	3.85	171.9	3.97
	16	0-20	20.00	0.09	11.00	0.50	3450.9	2.23	113.7	2.38
		20-50	20.90	0.01	11.90	0.41	5265.8	2.18	130.0	2.20
		50-90	21.10	0.13	9.10	0.45	2718.3	2.11	98.4	2.20
		90-150	16.40	0.18	12.00	0.42	2576.8	1.83	86.5	2.17
Piedmont	1	0-20	18.30	0.08	10.80	0.00	3483.5	2.26	115.0	2.40
		20-60	31.90	0.24	8.20	0.03	2817.5	2.64	92.5	2.89
		60-100	14.70	0.18	11.10	0.03	3965.5	4.57	101.9	4.81
	3	0-15	16.20	0.15	12.40	0.32	2845.3	2.47	98.1	2.32
		15-60	44.30	0.35	14.80	0.09	8745.0	4.25	180.9	4.47
	9	0-25	18.60	0.57	8.90	0.70	2871.2	4.36	84.2	4.22
		25-60	30.10	0.42	18.60	0.29	10414.8	4.12	190.0	3.84
		60-120	33.50	0.59	22.00	0.75	10477.3	5.82	169.2	5.39

Table (9): cont.

Physio graphic unit	Prof. (No.)	Depth (cm)	Zn mg kg^{-1}		Cu mg kg^{-1}		Fe mg kg^{-1}		Mn mg kg^{-1}	
			Total	Avai.	Total	Avai.	Total	Avai.	Total	Avai.
Alluvial plain	4	0-35	23.6	0.20	11.4	0.20	2278.4	4.56	76.2	4.50
		35-70	19.5	0.29	13.1	0.43	6174.0	3.44	139.0	3.75
		70-100	21.2	0.39	17.2	0.28	7540.2	3.17	168.1	3.35
		100-150	26.6	0.37	14.9	0.27	7363.2	3.68	145.8	3.79
	5	0-15	26.2	0.19	11.8	0.20	3892.4	3.14	117.0	3.31
		15-40	19.9	0.29	15.2	0.36	6140.3	8.47	102.9	8.27
		40-80	26.4	0.16	15.9	0.55	5154.8	3.24	122.4	2.70
		80-150	27.8	0.20	14.3	0.25	6420.7	4.29	137.5	4.26
	8	0-35	18.2	0.59	12.4	0.43	4661.0	8.70	111.0	8.64
		35-75	47.3	0.30	16.1	0.47	6479.4	2.82	133.1	2.92
		75-150	22.9	0.28	12.5	0.26	6776.0	3.36	125.6	3.28
	10	0-35	29.5	0.58	19.5	0.63	11468.5	4.71	243.1	4.85
		35-75	29.4	0.53	19.8	0.60	10939.4	6.12	232.7	5.99
		75-140	50.3	0.32	19.1	0.41	8249.6	2.94	195.0	2.72
	11	0-25	20.0	0.61	9.8	0.76	5451.5	4.08	141.0	4.13
		25-65	46.5	0.41	27.4	0.46	13230.7	3.36	269.2	3.46
		65-100	42.3	0.36	22.2	0.70	11743.4	3.77	254.4	3.57
		100-150	37.0	0.23	22.1	0.54	10855.2	4.13	227.6	3.71
	12	0-35	29.7	0.38	15.6	0.49	5941.9	3.73	145.2	3.82
		35-75	30.5	0.31	18.2	0.42	7739.9	6.08	185.0	5.56
		75-150	32.9	0.17	24.7	0.13	10259.9	2.70	235.9	2.54
	14	0-30	25.2	0.09	17.8	0.64	5526.0	2.47	158.2	2.37
		30-70	15.8	0.13	15.0	0.41	2965.6	2.17	94.2	2.44
		70-150	12.3	0.22	10.3	0.35	2781.6	2.37	83.2	2.42
Sabkha	2	0-25	57.0	0.62	22.8	0.81	10541.6	36.80	230.7	36.59
		25-60	42.4	0.30	22.7	0.50	12698.6	3.12	231.5	3.49
		60-110	29.4	0.04	10.4	0.07	6477.6	1.18	128.0	1.11
	17	0-25	21.0	0.08	11.1	0.53	4066.6	1.93	128.0	2.52
		25-60	1.7	0.22	4.0	0.82	1122.6	2.93	30.0	2.83
		60-120	1.5	0.18	2.0	0.66	1114.0	2.14	40.0	2.30
		120-150	0.1	0.14	5.5	0.42	1110.9	1.40	20.0	1.41

With respect to the relation between total Zn and some soil variables in the studied soils, data illustrated a very highly significant positive correlation between total Zn and clay % (r = 0.481***) and silt % (r = 0.561***) and significant positive correlation between total Zn and OM % (r = 0.325*) and fine sand (r = 0.317*). On the other hand total Zn displays a very highly negatively correlation with $CaCO_3$ % (r = - 0.535**) and coarse sand (r = - 0.620***). These results are in agreement with the results detaird by **Hassona *et al.* (1996); Abd El-Razik (2002) and Grais (2006).**

Depthwise distribution of total Zinc

To work out a relationship between the distribution of trace elements and studied physiographic units, the statistical measures, weighted mean, trend and specific range are calculated according to **Oertel and Giles (1963).**

According to **Oertel and Giles (1963),** the weighted mean concentration for a profile is obtained by multiplying the concentration of each sampled horizon of the solum by the thickness of horizon or layer and then dividing the sum of these products by the total thickness of all analyzed horizons or layers. That is analytical result of each horizon is weighted in accordance with the thickness of horizon. In this respect, they mentioned that the weighted mean appears to be most satisfactory measures of trace element status of a soil profile that can be obtained from samples normally taken by soil surveyors.

Some information on any change is concentration with depth is provided by a measures called the trend and defined by

T= (W-S) /W

When W is greater than S, and by

T= (W-S)/S

When W is less than S.

In these equations, (T) denotes the trend, (W) the weighted mean concentration and S the concentration in the surface layer.

Oertel and Giels (1963) also stated that all values for (T) lie in the range from – 1 to + 1 and are in a sense, symmetrical when (T) is small. This symmetry is distorted when (T) is large because a value of +1 is possible but a value of (-1) is impossible.

A small value for (T) does necessarily imply a small range in concentration throughout the profile. Definite information on this feature is therefore provided by the specific range, defined by

R = (H-L)/W

Where, R is the specific range, H is the highest and L is the lowest observed concentrations in the solum, and W is the weighted mean.

In this connection, a small value for (T) may be associated with any value for (R). But a large value for (T) is necessary associated with at least a moderately large value for (R). Values for (R) can not be negative but there is no definite upper limit, values greater than 1 are common and a value as great as 0.99 has been noted.

With the weighted mean concentration for a trace element in a soil profile is probably determined as much by pedogenic processes as by the original concentration in the parent material, **Oertel (1961),** the trend (T) and specific range (R) are obviously determined by pedogenic processes alone (except where the parent material is markedly heterogenous in trace element content). To accomplish a reliable comparison within and between the studied soils on basis of these measures, it is convenient to present the discussion as follows.

Table (10) presents the statistical measures; weighted mean, trend and specific range of total Zn in the studied physiographic units. The computed weighted mean in the aeolian plain soils varies from 16.63 to 25.59 mg kg^{-1} with an increase towards the fine texture. Also, the computed trend indicated more symmetrical distribution of total Zn in profiles 6, 13 and 16 than the other profiles. Specific range indicates that the soils display some homogeneity of their soil material in profiles 13, 15 and 16, while profiles 6 and 7 are formed of heterogeneous soil materials.

With regard to soils of piedmont, data in Table (10) show that the weighted mean of total Zn ranged from 22.3 to 37.28 mg kg^{-1}. The computed trend indicates more symmetrical distribution in the soils of profile 1 than those of the representative profiles. Specific range shows that the soils of profiles 1 and 3 are formed of homogeneous soil materials,

Table (10): Weighted mean (W), Trend (T) and Specific range(R) of total Zn in the studied soil profiles.

Physiographic unit	Profile (No.)	Weighted mean "W"	Trend "T"	Specific range (R)
Aeolian Plain	(6)	18.46	0.04	0.13
	(7)	20.75	0.30	0.49
	(13)	17.87	0.08	0.50
	(15)	25.59	0.32	0.54
	(16)	16.63	-0.17	0.53
Piedmont	(1)	22.30	0.18	0.77
	(3)	37.28	0.57	0.75
	(9)	29.40	0.37	0.51
Alluvial plain	(4)	23.16	0.02	0.31
	(5)	25.95	-0.01	0.30
	(8)	28.31	0.36	1.03
	(10)	39.13	0.25	0.53
	(11)	37.94	0.47	0.70
	(12)	31.51	0.06	0.10
	(14)	15.81	-0.37	0.82
Sabkha	(2)	39.81	-0.31	1.02
	(17)	4.52	-0.78	4.60

whereas the soils of profile 9 constitute heterogeneous soil materials. Table (10) reveals that the weighted mean of total Zn in the soils of alluvial plain varies from 15.81 to 39.13 mg kg^{-1} with a tendency to increase toward the fine texture. The computed trend indicates more symmetrical distribution in the soils of profiles 4, 5, and 12 than the other profiles. The specific range dictates that the soils of profiles 4 and 5 are formed of homogeneous soil materials, while the other profiles formed of heterogeneous parent materials.

Soils of Sabkha, have weighted mean of total Zn ranged from 4.52 to 39.81 mg kg^{-1}. The computed trend indicates less symmetrical distribution of Zn in these soils. The specific range indicates that these soils are formed of heterogeneous parent materials.

4.5.1.2. Total copper

The results of total Cu in the studied soils are given in Table (9). The obtained data indicate that, soils of aeolian plain which are represented by profiles 6, 7, 13, 15 and 16 have a total Cu content ranged from 7.3 to 18.1 mg kg^{-1}. The lowest value is detected in the 60 -110 cm layer of profile 7, while the highest value is found in the deepest layer of profile 13. The vertical distribution pattern of total Cu content does not portray any specific pattern with depth, except for the soils of profile 15 where total Cu tends to increase downward the profile depths.

Soils of piedmont which are represented by profiles 1, 3 and 9 have a total Cu content ranged from 8.2 to 22.0 mg kg^{-1} with a tendency to increase with depth.

The lowest value is in the subsurface layer of profile 1, while the highest value is in the deepest layer of profile 9.

Table (9) shows that the total Cu content ranged from 9.8 to 27.4 mg kg^{-1} in the alluvial plain soils (profiles 4, 5, 8, 10, 11, 12 and 14). The lowest and highest content of total Cu are detected in the surface and subsurface layers of profile 11, respectively. Depthwise distribution of total Cu reveals an increasing pattern with depth in the soils of profile 12, in contrast to profile 14, while it displays an irregular distribution pattern with depth in profiles 4, 5, 8, and 11.

With regard to soils of Sabkha (profiles 2 and 17), Table (9) shows that total cu content ranges from 2.0 to 22.8 mg kg^{-1}. The lowest value is found in 60-120 cm depth of profile17, while the highest value is detected in the surface layer of profile 2.

To substantiate the role of some soil constituents on controlling total Cu content, the correlation coefficient between total Cu and each of these factors were computed. The obtained coefficient correlation imply that the total Cu is very highly positively correlated with clay% ($r=0.673^{***}$) and silt % ($r = 0.615^{***}$) and positively highly significant correlation with OM% ($r = 0.376^{**}$), while has very high negative significant correlation with coarse sand ($r = -0.578^{***}$) and negatively highly significant correlation with $CaCO_3$ % ($r = -0.366^{**}$).

<u>Depthwis distribution total copper</u>

To search for evidence relating the distribution of total copper to the locality of soil profiles, the three measures given by **Oertel and Giles (1963)** have been computed and recorded in Table (11).

Soils of aeolian plain have a weighted mean that ranged from 8.89 to 16.05. The values of trend indicated that total Cu distribution in profiles 6, 13 and 16 are more symmetrical than the rest of the studied profiles. Specific range of total Cu indicates that the soil materials of profiles 7 and 15 are formed from homogeneous soil materials, while the other representative profiles are of heterogeneous soil materials.

With regard to the soils of piedmont, the weighted mean of total Cu ranged from 9.88 to 18.28 mg kg^{-1} with a tendency of increase in the fine texture. The computed trend indicates that total Cu distribution in profile 1 is more symmetrical than the other profiles. The specific range dictates that the soils materials of these soils are formed from heterogeneous soil materials.

Regarding the soils of alluvial plain, the weighted mean of total Cu ranges from 13.05 to 21.49 mg kg^{-1}. The computed trend reveals that total Cu distribution of profiles 5 and 8 are more symmetrical than the other profiles. Specific range of total Cu indicates that the soils of profiles 5 and 8 are formed of homogeneous soil materials, while the rest soil profiles are formed of heterogeneous soil materials.

Table (11) shows that soils of Sabkha have a weighted mean of total Cu that ranges from 4.68 to 17.13 mg kg^{-1}. The values trends indicate that these soils attain the less symmetrical distribution. The specific range of total Cu dictates that the soil materials of these soils are heterogeneous.

Table (11): Weighted mean (W), Trend (T) and Specific range(R) of total Cu in the studied soil profiles.

Physiographic unit	Profile (No.)	Weighted mean "W"	Trend "T"	Specific range (R)
Aeolian Plain	(6)	8.89	0.04	0.16
	(7)	9.82	-0.17	0.46
	(13)	16.05	0.03	0.32
	(15)	15.14	0.28	0.44
	(16)	11.07	0.01	0.26
Piedmont	(1)	9.88	-0.09	0.29
	(3)	14.20	0.13	0.17
	(9)	18.28	0.51	0.72
Alluvial plain	(4)	14.12	0.19	0.41
	(5)	14.63	0.19	0.28
	(8)	13.44	0.08	0.28
	(10)	19.40	-0.01	0.04
	(11)	21.49	0.54	0.82
	(12)	20.84	0.25	0.44
	(14)	13.05	-0.36	0.57
Sabkha	(2)	17.13	-0.25	0.72
	(17)	4.68	-0.58	1.94

4.5.1.3. Total iron

Soils of aeolian plain which are represented by profiles 6, 7, 13, 15 and 16. have total Fe content that ranges from 1972.5 to 6588.1 mg kg^{-1}. The highest value exists in the deepest layer of profile 15, fairly high content of clay, while the lowest value is recorded in the deepest layer of profile 13.

Depthwise distribution of total Fe content in this physyiographic unit dose not portray any specific pattern with depth, except for profile 15 where total Fe tends to increase throughout the profile depth.

Regarding total Fe content in the soils of piedmont which are represented by profiles 1, 3 and 9, have total Fe content that ranges from 2817.5 to 10477.3 mg kg^{-1}. The lowest value is in the subsurface layer of profile 1, while the highest is in deepest layer of profile 9. Depthwise distribution of total Fe dose not show any specific pattern in profile 1, while in profiles 3 and 9 total Fe tends to increase with depth.

Concerning the alluvial plain soils which are represented by profiles 4, 5, 8, 10, 12 and 14, Table (9) shows that total Fe content that ranges from 2278.4 to 13230.7 mg kg^{-1}. The highest value is associated with the subsurface layer of profile 11, while the lowest value is detected in the surface layer of profile 4. Total Fe content tends to increase with depth through the representative soil profiles 8 and 12, with an opposite trend in profiles 10 and 14, while it displays an irregular distribution pattern in profiles 4, 5 and 11.

With regard to the soils of Sabkha (profiles 2 and 17), the contain of total Fe ranges from 1110.9 to 12698.6 mg kg^{-1}. The lowest value is detected in the deepest layer of profile 17, whereas the highest value is in the subsurface layer of profile 2.

To substantiate the role of some soil constituents on controlling total Fe content, the correlation coefficients between total Fe and each of those factors were computed. The obtained coefficients imply that total Fe is very highly significant positively correlated with OM% ($r = 0.500^{***}$), clay % ($r = 0.669^{***}$) and silt % ($r = 0.730^{***}$) and significant positively correlation with fine sand % ($r = 0.301^{*}$). In contrast, total Fe shows a negative very highly significant correlation with coarse sand % ($r = -0.712^{***}$) and negatively highly significant correlation with $CaCO_3$% ($r = -0.515^{**}$). These results agreement with those obtained by **Hassona *et al.* (1996), Barakat (1999), AbdEl-Razik (199 8) and Grais (2006).**

<u>Depthwise distribution of total iron</u>

Applying the statistical measures by **Oertel and Giles (1963)**, Table (12) reveals that the weighted mean of total Fe in the aeolian plain soils ranged from 2992.2 to 5359.2 mg kg^{-1} with a tendency of increase toward the fine texture. The computed trend indicates a more symmetrical distribution of total Fe in profiles 6, 13 and 16 than that of the other profiles. The specific rang of total Fe indicates that the soils of profiles 13 and 16 are composed of homogeneous soil materials, while the other profiles are formed of heterogeneous soil materials.

Table (12): Weighted mean (W), Trend (T) and Specific range(R) of total Fe in the studied soil profiles.

Physiographic unit	Profile (No.)	Weighted mean "W"	Trend "T"	Specific range (R)
Aeolian Plain	(6)	3173.50	-0.06	0.21
	(7)	4537.43	0.28	0.70
	(13)	2992.20	-0.09	0.83
	(15)	5359.20	0.53	0.76
	(16)	3286.88	-0.05	0.82
Piedmont	(1)	3409.90	-0.02	0.34
	(3)	7270.10	0.61	0.81
	(9)	8874.20	0.68	0.86
Alluvial plain	(4)	5934.60	0.62	0.89
	(5)	5783.60	0.33	0.44
	(8)	6203.40	0.25	0.34
	(10)	9822.80	-0.14	0.33
	(11)	10795.30	0.49	0.72
	(12)	8580.40	0.31	0.50
	(14)	3379.60	-0.39	0.81
Sabkha	(2)	9380.70	-0.11	0.66
	(17)	1607.50	-0.60	1.84

In soils of piedmont, computed weighted mean of total Fe ranges from 3409.9 to 8874.2 mg kg^{-1}. The computed trend in these soils indicates more symmetrical Fe distribution in profile (1) than the other representative soil profiles. Specific range of total Fe dictates that the soil materials of the studied profiles are heterogeneous soil materials.

With regard to the soils of alluvial plain, the weighted mean of total Fe ranges from 3379.6 to 10795.3 mg kg^{-1}. The highest value is detected in profile 11, while the lowest value is in profile 14. The computed trend indicates that the soils of profile 10 are more symmetrical than the other soil profiles. The specific range dictates that the soil materials of profiles 8 and 10 are homogeneous while the others are heterogeneous.

Soils of Sabkha have weighted mean ranges from 1607.5 to 9380.7 mg kg^{-1} in the representative soil profiles 17 and 2, respectively. The computed trend indicates low symmetrical distribution of total Fe in these soils. The specific range indicates that soils of Sabkha are composed of heterogeneous soil materials.

4.5.1.4. Total manganese

The results of total Mn content in the soils under consideration are shown in table (9). The data indicate that total Mn content in the aeolian plain soils which are presented by profiles 6, 7, 13, 15 and 16 ranged from 68.3 to 171.9 mg kg^{-1}. The highest content is found in the deepest layer of profile 15, while the lowest content detected in the deepest layer of profile 13. Depthwise distributions of total Mn does not portray any specific pattern with depth, except for profile 15 where total Mn increase downwards.

Table (9) reveals that total Mn content in piedmont soils (profiles 1, 3 and 9) ranges from 84.0 to 190.0 mg kg^{-1}. The highest and lowest values are recorded in the subsurface and surface layers of profile 9, respectively. Depthwise distribution of total Mn did not show any specific patter with depth; except for profile 3 where Mn content tends to increase downward profile depth.

Soils of alluvial plain, which are represented by profiles 4, 5, 8, 10, 11, 12 and 14 are characterized by a total Mn content that ranged from 76.2 to 269.2 mg kg^{-1}. The highest value was recorded in the subsurface layer of profile 11, while the lowest value was detected in the surface layer of profile 4. Depthwise distribution of total Mn indicates a tendency of increase downwards in profile 12 and decreases in profiles 10 and 14, while total Mn follows an irregular distribution pattern in the rest of soil profiles.

Table (9) reveals that total Mn content in the soils of Sabkha (profiles 2 and 17) ranges from 20.0 to 231.5 mg kg^{-1}. The highest content is detected in the subsurface layer of profile 2, while the lowest content is in the deepest layer of profile 17.

Generally, the wide range of total Mn in the studied soils can be attributed to the difference in the type and nature of soil material. The coarse textured of soils are characterized by the lowest content of total Mn content, while the other light textured soils have a fairly low content of Mn. On the other hand, the highest amounts of total Mn are obtained in the fine textured soils.

With regard to the statistical analysis, the correlation coefficient shows that the total Mn is very highly significantly positively correlated with clay% ($r = 0.617^{***}$) and silt % ($r = 0.594^{***}$), significant highly positively correlation with OM% ($r = 0.362^{**}$) and significant positively correlation with fine sand % ($r = 0.329^{*}$), while it is very highly significant negatively correlated with $CaCO_3$% ($r = -0.496^{***}$) and coarse sand% ($r = -0.660^{***}$).

<u>Depthwise distribution of total manganese</u>

Table (13) shows that the computed weighted mean of total Mn of aeolian plain soils ranges from 89.33 to 148.5 mg kg^{-1} with a tendency of increasing toward the fine and medium texture. The values of trend indicate more symmetrical Mn distribution in profiles 6, 13 and 16 as indicated by their small (T) values. The specific range (R) of Mn distribution that the soils of profiles 7 and 16 are homogeneous, whereas the other soil profiles are heterogeneous.

Soils of piedmont have weighted mean of total Mn that ranged from 100 to 160.76 mg kg^{-1}. The computed trend indicates a highly symmetrical distribution of total Mn in profile 1. The specific range of total Mn dictates that the soil materials of these soils are heterogeneous.

Regarding the alluvial plain soils, the weighted mean of total Mn ranges from 101.1 to 230.5 mg kg^{-1}. The computed trend indicated that total Mn distribution in profiles 5, 8 and 10 are more symmetrical than the other profiles. Furthermore, the specific range dictates that the soils of profiles 4 and 14 are homogeneous, while the other profiles are heterogeneous.

Concerning of the Sbakha soils, the weighted mean of total Mn ranges from 46.52 to 184.27 mg kg^{-1}. The computed trend reveals that total Mn distribution in profile 2 is more symmetrical than the soil of profile 17. Specific range of total Mn indicates that these soils are heterogeneous parent materials.

Table (13): Weighted mean (W), Trend (T) and Specific range(R) of total Mn in the studied soil profiles.

Physiographic unit	Profile (No.)	Weighted mean "W"	Trend "T"	Specific range (R)
Aeolian Plain	(6)	89.33	-0.07	0.14
	(7)	113.27	0.23	0.47
	(13)	93.30	-0.07	0.66
	(15)	148.5	0.41	0.57
	(16)	102.0	-0.10	0.43
Piedmont	(1)	100.76	-0.12	0.22
	(3)	160.20	0.39	0.52
	(9)	157.60	0.47	0.67
Alluvial plain	(4)	132.43	0.42	0.69
	(5)	125.70	0.07	0.28
	(8)	124.20	0.11	0.18
	(10)	217.80	-0.10	0.22
	(11)	230.50	0.39	0.56
	(12)	201.20	0.28	0.45
	(14)	101.10	-0.36	0.63
Sabkha	(2)	184.27	-0.20	0.56
	(17)	46.52	-0.60	2.09

4.5.2. Available content of trace elements

4.5.2.1. DTPA-extractable zinc

Data in table (9) reveal that DTPA-extractable Zn in the studied physiographic units ranged from 0.012 to 0.62 mg kg^{-1}. The lowest value was detected in the 20-50 cm layer of profile 16, representing the soils of aeolian plain, whereas the highest value characterized the surface layer of profile 2 representing the soils of Sabkha. In almost all cases the upper most surface layers contains relatively higher Zn content if compared with the deeper layers. Also, in alluvial plain soils which attained fine and medium textures are mostly associated with relatively higher content of DTPA extractable Zn than those of the aeolian plain soils.

According to **Soltanpour and Schwab (1977)**, the index values used for Zn extracted from soils by DTPA method are as follows:-

Low	**0 - 0.9 mg kg^{-1}**
Marginal	**1.0 - 1.5 mg kg^{-1}**
Adequate	**>1.5 mg kg^{-1}**

With regard to the nutritional status of Zn element, it seems evident that the studied soils that belong to low level where the concentration of DTPA-extractable Zn below 0.9 mg kg^{-1}.

The correlation coefficients between some soil constituents and DTPA-extractable Zn were computed. Results imply the chemically available Zn is correlated very highly positively significant with OM% (r =0.451***), highly positively significant with fine sand % (r =0.417**) and silt % (r = 0.404**) and positively significant with clay% (r= 0.316*). On the other hand DTPA-Zn content has a negatively significant correlation with $CaCO_3$% (r = - 0.290*) and very highly negatively significant correlation with coarse sand % (r = - 0.551***).

4.5.2.2.DTPA-extractable copper

Data of extractable Cu with DTPA are tabulated in Table (9). The amounts of extractable Cu in the studied physiographic units vary considerably from 0.004 to 0.82 mg kg^{-1} The lowest value was detected in the surface layer of profile 1 representing the aeolian plain soils, while the highest content was strictly associated with the subsurface layer of profile 17, representing the soils of Sabkha. Moreover, it is evident that in many cases the higher DTPA extractable Cu was associated with the fine and medium texture relative to the coarse texture one is aeolian plain soils.

Referring to the critical levels of DTPA-extractable Cu identified by **Soltanpour and Schwab (1977)**

Low	**0 - 0.5 mg kg^{-1}**
High	**> 0.5 mg kg^{-1}**

The results of the studied soil profiles indicate that the studied soils that belong to low and high level groups represent 67.86% and 32.14%, respectively.

The statistical analysis reveals that DTPA- extractable Cu is positively highly significant correlated with EC_e ($r = 0.372^{**}$) and positively significant correlated with $CaCO_3$ % ($r = 0.291^{*}$) and clay % ($r = 0.338^{*}$). These results agreement with those obtained by **Awad *et al.* (2002).**

4.5.2.3.DTPA-extractable iron

Table (9) depicts the amounts of DTPA-extractable Fe in the studied soils; the table reveals that DTPA-extractable Fe varied widely from 1.18 to 36.8 mg kg^{-1}. The highest and lowest content were detected in the surface and deepest layers of profile 2 representing Sabkha soils respectively. The vertical distribution of DTPA-extractable Fe reveals a tendency for Fe to accumulate in the uppermost surface layers. Considering the critical level of DTPA-extractable Fe which has been reported by **Soltanpour and Schwab (1977)**, the index values of DTPA extractable Fe are as follows

Low	**0—2 mg kg^{-1}**
Marginal	**2.1—4.0 mg kg^{-1}**
Adequate	**>4.0 mg kg^{-1}**

The values of the studied soil profiles indicate that the studied soil samples belong to the low, marginal and adequate level groups representing 7.14%, 60.72% and 32.14%, respectively.

The correlation coefficients between some soil variables and DTPA-Fe were computed. The obtained results show very highly positively significant correlation between DTPA-extractable Fe and EC_e ($r = 0.440^{***}$). These results agreements with those obtained by **Grais (2006).**

4.5.2.4.DTPA-extractable manganese

Data illustrated in Table (9) represent the amounts of DTPA-extractable Mn from the studied soil profiles. From the table, it is evident that DTPA-extractable Mn ranged from 1.11 to 36.59 mg kg^{-1} . The highest and lowest values were detected in the surface and deepest layers of profile 2 (Sabkha), respectively. For further information about the distribution of extractable Mn in the studied physiographic units, the results reveal that DTPA-extractable Mn ranged from 2.17 to 11.75 mg kg^{-1}, 2.32 to 5.39 mg kg^{-1}, 2.37 to 8.64 mg kg^{-1} and 1.1 to 36.59 mg kg^{-1} in aeolian plain, piedmont, alluvial plain and Sabkha soils respectively.

According **Soltanpur and Schwab (1977)**, the critical values of DTPA-extractable Mn are as follows:

Low	**0—1.8 mg kg^{-1}**
Adequate	**>1.8 mg kg^{-1}**

The results of the studied soil profiles indicate that the studied soils are belonging to low and adequate level groups represent 3.57% and 96.43%, respectively.

The correlation coefficient between some soil variables and DTPA- extractable Mn were computed. The obtained data show very highly positively significant correlation between DTPA-extractable Mn and EC_e ($r = 0.440^{***}$)

4.6. Mineralogy of the sand fraction

Residual minerals in the sand fraction particularly those designated as "the heavy minerals" are either inherited from parent materials or altered during soil formation processes. Their contents and distribution are useful tools in evaluating soil profile uniformity and development, the sequence of rock and soil, loss and gain of materials during weathering and assessing processes involved in soil formation.

In this concern, **Haseman and Marshall (1945)** stated that the origin of a soil is reflected in the kind and amount of its heavy minerals which may be sufficient to establish its origin.

The distribution of the residual minerals "index minerals" is used for the evaluation of soil profile uniformity, **Brewer (1955)**. Moreover, the ratio between two or more of the ultra-stable minerals is also suggested, **Barshad (1964), Brewer (1964), and Chapman and Horn (1968).** Also, the ratio between an ultra stable mineral and another one susceptible to weathering, suggested by the same authors, was applied to test the uniformity and development of some soils of Egypt, **Hammad (1968), El-Demerdashe (1970), Kassim (1977), Hassona *et al* (1995) and Hassona (1999).**

The distribution of the sand minerals in the diagnosis layers of the representative profiles is given in Tables (14 and 15). These minerals are distinguished into their two distinctive groups, light minerals and heavy minerals.

4.6.1. Mineralogy of the Light minerals

Table (14) reveals the frequency distribution of light minerals(Sp.gr.<2.85g/cm^3) of the soil profiles under consideration as well as their distribution throughout the entire depth of each profiles. The results revealed that this fraction was almost entirely composed of quartz which constituted more than 93.0% in all the studied profiles.

Quartz grains with homogeneous extinction, i.e., extinguishes completely between crossed Nichols, were commonly detected. In general, the vertical distribution of quartz did not portray any specific pattern with depth.

Feldspars are detected in all the studied soil profiles. They are composed essentially of three numbers namely, orthoclase, plagioclase and microcline.

Orthoclase grains are colourless, partially cloudy with low relief, sometimes displaying simple twinning. Plagioclase grains display a lamellar twinning, and polysynthetic quardraline structure, while microcline grains are platy in shape, colourless, cloudy and show cross hatching between crossed nicols and weak relief in Canada balsam. Regarding the frequency distribution of feldspars, their content varies from 2.0 to 7.0% in the soil under consideration. The highest values of feldspars are associated with the soils of profile 15 (Aeolian plain), while the lowest ones are detected in the soils of profile 2 (Sabkha).

In all cases, the order of abundance is orthoclase> plagioclase> microcline.

Table (14): Frequency distribution of the light minerals (0.125-0.063 mm) of the studied soil profiles.

Physiographic unit	Prof. (No.)	Depth (cm)	Quartz %	Feldspars %			Total %
				Orthoclase	Plagioclase	Microcline	
Piedmont plain	(9)	0-25	96.5	2.0	1.0	0.5	3.5
		25-60	96.0	2.0	1.0	1.0	4.0
		60-120	97.0	1.6	1.0	0.4	3.0
Alluvial plain	(4)	0-35	95.0	2.0	1.5	1.5	5.0
		35-70	95.6	1.4	1.4	1.6	4.4
		70-100	96.1	1.9	0.8	1.2	3.9
		100-150	96.5	2.0	1.0	0.5	3.5
	(8)	0-35	98.0	0.9	0.6	0.5	2.0
		35-75	96.5	1.5	1.3	1.2	4.0
		75-150	97.3	1.2	0.6	0.9	2.7
	(11)	0-25	97.3	0.7	1.3	0.7	2.7
		25-65	96.7	1.1	1.8	0.4	3.3
		65-100	97.2	1.0	1.4	0.4	2.8
		100-150	97.0	0.8	1.8	0.4	3.0
Aeolian plain	(15)	0-25	96.9	1.3	1.5	0.3	3.1
		25-70	95.2	2.5	1.6	0.7	4.8
		70-150	93.0	2.3	2.6	0.8	7.0
Sabkha	(2)	0-25	97.0	0.8	1.4	0.9	3.1
		25-60	96.4	1.2	1.8	0.6	3.6
		60-110	97.3	0.4	1.5	0.4	2.3
	(17)	0-25	95.6	1.5	2.0	0.9	4.4
		25-60	96.1	1.6	1.3	1.0	3.9
		60-120	97.1	1.2	1.0	0.7	2.9
		120-150	96.1	1.6	1.3	1.0	3.9

Depthwise distribution of total feldspars does not portray any specific patterns indicating uniform distribution of their individual minerals except for profile 4 where feldspars tends to decrease with depth.

From the above mentioned results, one may conclude that quartz due to its relatively high resistance to weathering prevailed prior and throughout sedimention course. This content may also be originated or inherited from the parent material itself.

The minute encountered variations may be the result out of the chance of variations encountered in the frequency distribution of light minerals which are expected to be inherited from that parent material involved in soil formation and modified to a less extent, by weathering prevailed during the pre wet climatic conditions then subjected to depositional environments. Moreover, the presence of feldspars could be taken as an indication of the extent of weathering prevailed during soil formation which was not so drastic to cause a complete decay of these minerals susceptible to weathering.

4.6.2. Mineralogy of the heavy minerals

Heavy minerals were defined as those minerals which have specific gravity higher than 2.85 g/cm^3. Such minerals are usually of primary origin. Though heavy minerals usually constitute a small portion of the soil material, yet they play an important role in soil formation and development, the nature and extent of pedological weathering and hence the age of the soil can be deduced from the relative abundance of secondary minerals produced and the presented primary minerals. Heavy minerals are generally studied in terms of two groups:

Opaque and non opaque minerals, Table (15).

4.6.2.1. Opaque minerals

Opaques occur in the form of sub-angular to sub-rounded grains with irregular edges. The opaques are not sub-fractioned into their individual constitutents but are considered as one group. They include magnitite, ilmenite, hematite and limonite. Their distribution on percentage in soils of the current study varies from 33.4 to 42.1%. the highest value is in the surface layer of profile 8 representing the alluvial plain soils, whereas the lowest value is in the lower layer of profile 2 representing the soils of Sabkha. Concerning the pattern of opaques distribution with depth, no specific pattern of distribution is observed, except for the soil of profiles 2 and 17 where opaques tend to increase with depth.

4.6.2.2. The non-opaques

Table (15) shows that pyroboles (pyroxenes and amphiboles) and ultrastable minerals (zircon, rutile and tourmaline) are the most abundant varieties in the non-opaque fraction of the studied soils. Metamorphic silicates (garnet, epidote, kyanite and silimanite minerals) are identified in subordinate amounts, while the other minerals are identified in few amounts. To substantiate the frequency distribution of minerals groups and their individual members the results are presented under the following subheadings:

Table (15): Frequency distribution of heavy minerals of the sand fraction (0.125 – 0.063 mm), of the studied soil profiles.

Physiographic units	Profile No	Depth (cm)	Opaques	Non Opaque minerals																			
				Pyroxenes				Amphibole				Parametamorphic					Ultastable			Accessory %			
				Augite	Hyper thene	Diopside	Total	Hornblende	Glaucophane	Actinolite	Total	Epidote	garmet	Staurolite	Kyanite	Silimnite	Zircon	Rutile	Tourmaline	Biotite	Monazite	Gluconite	Ziosite
Piedmont	9	0-25	39.1	6.3	11.8	1.0	19.1	13.8	2.2	5.3	21.3	8.7	2.4	2.4	3.8	0.9	10.2	1.8	4.1	2.3	1.5	0.9	1.6
		25-60	39.4	6.2	12.4	0.7	19.3	12.6	1.7	5.9	20.2	9.4	2.9	3.2	3.7	0.8	11.3	3.0	4.3	2.4	1.6	0.7	1.4
		60-120	36.2	5.5	15.0	1.1	21.6	15.2	1.9	6.0	23.1	9.9	3.1	2.6	2.8	1.0	11.6	3.2	5.3	1.9	1.4	0.5	1.3
Alluvial plain	4	0-35	37.4	6.1	12.0	0.9	19.0	16.2	2.5	4.1	22.8	11.3	2.4	2.3	2.9	1.0	8.9	2.4	4.1	1.7	1.0	0.5	1.3
		35-70	37.1	6.4	10.7	1.1	18.2	17.1	1.8	4.3	23.2	9.6	2.6	2.8	2.3	1.2	8.4	2.6	4.5	1.4	1.1	0.4	0.9
		70-100	37.5	3.8	10.6	1.3	15.7	12.6	4.0	4.7	21.3	12.5	3.0	2.5	3.1	1.4	11.3	3.0	4.6	1.3	1.3	0.3	0.7
		100-150	37.2	4.5	10.3	1.4	16.2	13.8	4.2	5.2	23.2	11.6	3.2	2.6	2.6	1.7	11.7	3.1	3.0	1.1	1.4	0.6	0.8
	8	0-35	42.1	6.0	11.6	0.8	18.4	12.6	4.1	5.1	21.8	9.2	3.8	2.9	2.8	1.3	12.4	2.5	2.8	2.1	1.6	0.8	1.1
		35-75	40.6	5.8	11.8	1.2	18.8	15.3	2.8	4.9	23.0	9.6	4.1	3.1	3.4	1.2	13.0	2.7	2.9	1.9	1.8	1.1	1.3
		75-150	40.8	5.5	9.6	1.6	16.7	14.2	1.9	4.8	20.9	9.5	4.3	3.6	4.0	1.4	15.0	2.6	2.7	1.8	1.3	1.0	1.2
	11	0-25	40.1	7.0	12.3	1.3	20.6	11.8	2.4	6.2	20.4	11.2	3.2	1.9	2.5	1.1	8.6	3.4	5.1	2.0	1.1	0.3	2.0
		25-65	40.4	6.2	11.8	0.9	18.9	12.6	2.6	6.7	21.9	11.4	3.6	2.0	2.9	1.3	9.4	2.8	5.2	2.1	1.2	0.8	1.1
		65-100	39.4	5.8	12.7	0.8	19.3	12.4	2.8	6.3	21.5	10.7	3.4	2.6	1.8	1.2	11.7	2.7	4.8	2.4	1.5	0.7	0.9
		100-150	38.2	5.4	13.3	0.7	19.4	12.5	2.7	6.2	21.4	10.8	1.1	2.4	1.7	1.5	12.3	2.9	3.6	1.8	1.2	0.6	0.7
Aeolian	15	0-25	36.2	6.0	14.0	1.1	21.1	11.7	2.5	5.8	20.0	9.1	1.6	2.5	1.6	1.3	7.3	2.5	3.8	1.7	1.6	1.0	0.7
		25-70	37.1	5.8	14.1	1.2	21.1	11.5	1.8	5.4	18.7	9.6	1.8	2.3	2.0	1.6	7.1	2.4	3.5	1.6	1.3	1.1	0.5
		70-130	39.4	5.4	13.7	1.6	20.7	11.3	1.4	4.8	17.5	9.2	1.7	2.7	2.9	1.7	6.4	3.1	2.8	1.2	1.4	1.3	0.4
Sabkha	2	0-25	33.4	5.4	11.2	0.5	17.1	14.6	1.8	1.7	18.1	8.8	1.9	1.6	3.2	0.8	3.5	0.8	3.3	1.2	0.6	1.0	0.8
		25-60	33.8	5.2	10.7	0.7	16.6	14.7	1.6	2.8	19.1	9.1	1.7	1.7	3.0	0.7	5.7	0.7	3.6	1.4	0.9	0.7	1.0
		60-100	30.7	5.1	15.0	0.8	20.9	15.3	2.1	3.6	21.0	10.2	1.8	1.8	3.1	0.9	5.8	1.1	3.8	1.6	0.8	0.6	1.2
	17	0-25	40.1	5.8	12.2	1.4	19.4	10.2	1.7	4.5	16.4	8.6	1.8	3.1	2.3	1.6	9.8	2.8	1.7	2.0	1.9	0.8	0.2
		25-60	40.4	4.5	11.8	1.1	17.4	11.7	1.3	4.1	17.1	9.3	1.7	3.4	2.4	1.4	10.4	2.6	3.1	1.8	1.8	0.7	0.3
		60-120	41.0	4.3	10.4	1.3	16.0	12.8	2.1	4.3	19.2	10.1	1.4	3.2	2.8	1.3	11.8	2.4	3.0	1.7	1.7	0.3	0.7
		120-150	41.4	5.1	10.1	1.2	16.4	13.4	2.6	4.7	20.7	11.3	1.3	2.8	2.5	1.0	12.3	2.5	2.8	1.6	1.4	0.6	0.6

A- Pyroxenes

This group of minerals is mainly represented by augite, hyperthene and diopside. Augite is characterized by being an isotropic, green to olive green in plane light, non-pleochric and having an extenuation angle at exactly 45°. Hyperthene is detected as prismatic grains sees as tree-trunk, an isotropic having parallel extenuation and non-pleochroic. Diopside is an isotropic colourless in plane light, having faint interference colour between cross nichol and oblique at 28°. All these minerals are present as irregular subangular to subrounded grains. The values of pyroxene minerals ranged from 15.7 to 21.6% of the non-opaque minerals. The lowest value is detected in the 70-100cm layer of profile 4 (alluvial plain), while the highest value characterizes the deepest layer of profile 9 (piedmont plain). Depthwise distribution of pyroxenes does not portray any specific pattern, except for the soils of profile 15 where pyroxenes tend to decrease with depth. Hyperthene the predominant of pyroxenes represent 9.6 to 15.0% of the heavy minerals; augite and diopside are of less distribution frequency ranging from 3.8 to 7.0% and 0.5 to 1.6%, respectively. A variation in the distribution of pyroxenes reflects variation in parent materials, sedimentation regimes with little, if any contribution of soil formation processes. It seems that, the abundance of pyroxenes indicates that these soils are young from the pedological point of view.

B- Amphiboles

Amphiboles is a major constituent of the non-opaque minerals. The amphiboles are mainly represented by hornblende, gluocophane, and actinolite of which hornblende is the most abundant. They have common features in being pleochroic. They are observed as subrounded grains of different varieties, ranging in colour from light green to dark green and sometimes brown. These variations in colour suggest multi origin of that mineral group. The amphiboles constitute 16.4 to 23.2% of the non opaques. The lowest value is in the surface layers of profile 17 (Sabkha), while the highest occurred in the deepest layer of profile 4 (alluvial plain). Hornblende is predominates the amphibole group with less pronounced occurrence of glocophane and actinolite are in less pronounced percentages.

As amphiboles and pyroxenes are easily weathered and destroyed. Their presence in high percentages can be taken as an indication of the existence of immature condition or recent deposition.

4.6.2.3. Parametamorphic

These include the following minerals: garnet, epidote, staurolite, kyanite and silimanite

A- Epidote

It occurs mostly in subrounded to nearly rounded grains having greenish yellow colour. Epidot mineral ranges from 8.6 to 12.5% of the non-opaque minerals. The lowest amounts are mostly found in the sabkha soils (profile 17), whereas the highest values are detected in the alluvial plain soils (profile 4). The vertical distribution of the epidote mineral show no specific trend in most of the studied profiles, except for profiles 1, 2 and 17 where epidote mineral tends to increase downward the profile depths.

B- Garnet

Garnet characterized by isotropy, and is represented by rounded to subrounded-shaped grains, pink to colourless with the dominance of glassy rose ones. Its distribution percentage in the studied soils (Table 15) varies from 1.1 to 4.3% of the non opaque minerals. The relative high values in the studied physiographic units are mainly in the piedmont and alluvial plain soils in comparison to the soils of aeolian plain and sabkha. The vertical distribution of garnet is irregular in most profiles. In profiles of piedmont (profile 9) and alluvial plain (profiles 4 and 8) garnet distribution has a tendency of an increase with depth.

C- Staurolite

It was detected as reddish brown in prismatic and irregular shap grains. The distribution percentage ranges from 1.6 to 3.6% of the non opaque minerals. The lowest value is in the surface layer of profile 2 (sabkha), while the highest value is in the 75-150 cm layer of profile 8, representing the soils of alluvial plain. The depthwise distribution is irregular with no specific pattern, except for profile 8 (alluvial plain) and profile 2 (sabkha) where it increase with depth.

D- Kyanite

It was detected in its colourless varieties, having two perpendicular sets of cleavage giving an abnormal interference colours between cross nichols. Kyanite constitutes 1.6 to 4.0% of the non-opaque minerals. The highest value is in the 75-150cm depth of profile 8 representing the alluvial plain soils, while the lowest value is in the surface layer of profile 2, representing the Sabkha soils. The vertical distribution shows that profiles 2, 11, 2 and 17 have irregular pattern. Profiles 8 and 15 show an increase with depth, while profile 9 shows a decreases downward the profile depth.

E- Silimanite

Silimanite mineral was detected as colorless prismatic or rectangular grains, showing vertical striations and parallel extinction. Its percentage ranges widely from 0.7 to 1.7% of the non-opaque minerals. The lowest percentage is found in the sabkha soils (profile 2), whereas the highest one characterize the soils of alluvial plain (profile 4) and Aeolian plain (profile 15). The vertical distribution of silimanite does not portray any specific pattern with depth, except for the soils of profiles 9, 4, and 15 where silimanite mineral tends to increase with depth.

4.6.2.4. The ultrastable minerals

These groups of minerals include the following minerals: zircon, rutile and tourmaline.

A- Zircon

Zircon mineral an attractable mineral characterized by prismatic grains with subrounded edges. It is usually present in a colourless variety, while pink and yellow grains really occur, with a very high relief and parallel extinction. Its content varies widely among and within soils representing the different physiographic units, ranging between 3.5 and 15.0% of the non opaque minerals. The lowest value is in the surface layer of profile 2 (sabkha), while the highest value is in the deepest layer of profile 8 (alluvial plain). Also, the data show that the soils of alluvial plain and piedmont plain in attain the highest content while the aeolian plain and sabkha has a relatively lower content. From the distribution pattern of zircon with depth, it seems that zircon exhibits apparent discontinuity which indicates either non-uniformity of parent material or uniformity of depositional regime during soils formation.

B- Rutile

Rutile was recognized by its deep red colour between cross nichols and plane light. It is occurs as prismatic grains having rounded or subrounded terminations with high relief and parallel extinction. The minerals constitute 0.7 to 3.4% of the non-opaque minerals. The lowest value is detected in the subsurface layer of profile 2, representing the sabkha soils, while the highest value is found in the surface layer of profile 11 representing the alluvial plain soils. The vertical distribution pattern with depth did not show any specific pattern, except for the soils of profiles 9, 4 and 2 where rutile tends to increase with depth. Apparent discontinuity of this mineral throughout the entire depths of most profiles throw light on the prevailing sedimentation regimes as well as the chance of variation within the parent material of a unique physiographic unit.

C- Tourmaline

Tourmaline displays different colours, namely; gray, brown, pink and black. It occurs in small prismatic grains. Its content varies from 1.7 to 5.3% of the non opaque minerals. The lowest value is in the surface layer of profile 17 representing sabkha soils, whereas the highest value is in the deepest layer of profile 9 representing piedmont plain soils.

As to the depthwise distribution, data show that profiles 4, 8, 11 and 17 show irregular distribution of tourmaline. Profiles 9 and 2 display a gradual increase with depth, while profile 15 shows a slight decrease with depth. The encountered variations in this very stable mineral among the studied soils are mostly ascribed to variations of their parent materials content of the mineral. Nevertheless, the variations within each profile are mostly due to the depositional pattern. They may also reflect the possible intermixing of multi-parent materials.

4.6.2.5. The accessory minerals

These include the following: biotite, monazite, gluconite and ziosite.

A- Biotite

It occurs mainly as reddish brown flakey variety with sharp edges. It ranges from 1.1 to 2.4% of the non opaque minerals. The lowest content is in the alluvial plain soils (profile 4), while the highest content is in the piedmont plain soils (profile 9). Depthwise distribution shows that, in profiles 4, 8, 15 and 17 biotite tends to decrease with depth. In profiles 9 and 11 biotite does not portray any specific pattern with depth.

B- Monazite

Monazite ranges from 0.6 to 1.9% of the non-opaque minerals with an irregular distribution pattern with depth. The lowest content is in the surface layer of profile 2 (Sabkha), while the highest content is in the surface layer of profile 17. Monazite occurs as nearly rounded or egg-shaped grains of a yellow to brownish yellow colour with dark borders.

C- Gluconite

Gluconite was identified by its dirty colour grains which are non-pleochroic and have parallel extinction. It ranges from narrow limit between 0.3 to 1.3% of the non opaque minerals. The lowest value is recorded in the 70-100cm layer of profile 4, surface layer of profile 11 and 60-120cm depth of profile 17, while the highest value is recorded in the deepest horizon of profile 15 (Aeolian plain).

D- Ziosite

Ziosite was present in subangular to subrounded grains, less commonly in a platy form, pale yellowish green grains, llike small chips of broken glass are also recorded. Data in Table (15) show that ziosite vary in frequency from 0.2 to 2.0% of the non-opaque. The lowest content is in the surface layer of profile 17 representing the soils of sabkha, while the highest content characterized the surface layer of profile 11 representing the soils of alluvial plain.

4.6.3. Uniformity of the soil materials

Homogeneity or heterogeneity of the soil parent material could be established using mineralogical analysis. Certain minerals are more resistant to weathering than other. Thus ratios relating resistant and non-resistant minerals are employed in such evaluation (Brewer 1964). There are two groups of such ratios, the first group concern ratios of resistant minerals which include the following ratios: a) Z/R (zircon/ rutile); b) Z/T (zircon / tourmaline); c) Z/(R+T) [zircon / (rutile + tourmaline)]. The second group is the weathering which includes the followings (a) Wr_1 [(pyroxenes + Amphiboles) / (zircon + tourmaline)]; (b) Wr_2 [hornblende / (zircon +tourmaline)] and (c) [biotite / (zircon + tourmaline)], **Brewer (1964), El-Demerdashe (1970), Hassona *et al* (1995) and Hassona (1999).** Data presented in Table (16) reveal that the values of the two groups of ratios. Regarding the first group of ratios, there was no specific trend regarding the vertical distribution or among the profiles. Thus the general characteristic of the different physiographic units in the studied area is an apparent variability from one location to another and an apparent discontinuity within soil depth. The indicates variation in the depositional regime of the parent materials.

With regard to the second group of ratios, they are lower in the upper most surface horizons relative to the deepest ones especially in the soils of sabkha and Aeolian plain. This indicates that the surface of these soils may have been subjected to relatively higher weathering processes than their subsurface..

Table (16) Weathering ratios and uniformity of the studied soil profiles.

Physio graphic unit	Prof. (No.)	Depth (cm)	Weathering ratios			Uniformity		
			Zr/T	Zr/R	Zr/T +R	Wr_1	Wr_2	Wr_3
Piedmont plain	(9)	0-25	2.49	5.67	1.73	2.83	0.97	0.16
		25-60	2.63	3.77	1.55	2.60	0.81	0.15
		60-120	2.19	3.63	1.36	2.64	0.90	0.11
Alluvial plain	(4)	0-35	2.17	3.71	1.37	3.22	1.25	0.13
		35-70	1.87	3.25	1.18	3.21	1.33	0.11
		70-100	2.46	2.46	1.49	2.33	0.79	0.08
		100-150	3.90	3.90	1.92	2.68	0.94	0.10
	(8)	0-35	4.43	4.96	3.34	2.64	0.82	0.14
		35-75	4.48	4.81	2.32	2.63	0.96	0.12
		75-150	5.56	5.56	2.83	2.12	0.80	0.10
	(11)	0-25	1.69	2.53	1.01	2.99	0.86	0.15
		25-65	1.81	3.36	1.18	2.79	0.86	0.14
		65-100	2.44	4.33	1.60	2.47	0.75	0.15
		100-150	3.42	4.24	1.89	2.57	0.79	0.11
Aeolian plain	(15)	0-25	1.92	2.92	1.16	3.70	1.05	0.15
		25-70	2.03	2.96	1.20	3.75	1.08	0.15
		70-150	2.29	2.06	1.08	4.15	1.23	0.13
Sabkha	(2)	0-25	1.07	4.38	0.85	5.18	2.15	0.18
		25-60	1.58	8.14	1.33	3.84	1.58	0.15
		60-110	1.53	5.27	1.18	4.36	1.59	0.17
	(17)	0-25	5.76	3.50	2.28	3.11	0.89	0.17
		25-60	3.35	4.00	1.82	1.37	0.87	0.13
		60-120	3.93	4.92	2.19	2.38	0.86	0.11
		120-150	4.39	4.92	1.95	2.46	0.89	0.11

Zr = Zircon P = Pyroxene H = Hornblende
R = Rutile A = Amphiboles B = Biotite T = Tourmaline
Wr_1= (P+A)/Z+T Wr_2 = (H)/Z+T Wr_3 = (B)/Z+T

Also indicates that the soils are young from the pedological point of view, as the parent material is still rich in pyroboles which are easily susceptible to weathering.

4.7. Mineralogy of the clay fraction

The importance of the clay mineralogy lies in the fact that clay is one of the most important factors affecting physical and chemical properties of soils which imparts important aspects to their fertility status. Mineralogical analysis can serve as a tool in soil classification.

X-ray diffraction pattern is based on the presence of diffraction peaks characteristic for each of crystalline species present in sample. The intensity of the sharpness of these peaks are dependent not only on the number and the corresponding diffraction plains present in the examined sample but also on the particle size, chemical composition, crystal imperfection, crystal orientation and the pre-treatments during clay separation, **Whittig (1965).** Identification of clay minerals by x-ray diffraction analysis was carried out following the essential principle established by **Whittig and Jackson (1955), Brown (1961), Patterson (1963), Black (1965), Jackson (1969) and Dixon and Weed (1977)** as follows:

1- Smectite (montmorillonite) are identified by the expansion of the based reflection (001) from 14-15.8˚A in the Mg-saturated sample to 16.4-18.0˚A upon glycerol solvation and its collapse to about 10˚A in K-saturated sample and heated to 550˚C for four hours.

2- Kaolinite mineral is identified by the presence of very sharp peaks at about 7.1-7.2˚A (001) and 3.54-3.57˚A (002) in the

Mg-saturated samples. These peaks are not affected by glycerol solvation and they disappear upon heating to 550°C for four hours.

3- Hydrous mica (illite) mineral are detected by the presence of the basel reflections at 9.96-10.28°A peaks upon Mg-saturation which remains constant throughout the different treatments.

4- Palygorskite mineral is identified from the basal reflection (001) of strong intensity at a spacing of 10.5°A peak in the Mg-saturated sample which is not affected by the glycerol solvation treatment. The presence of other diffraction peaks of moderate intensity at 6.44, 5.42, 4.5, 3.68, 3.24 and 2.15°A, further confirm its presence.

5- Chlorite: Occurrence of this mineral is exhibited by a peak at 14°A all over the applied treatments.

6- Interstratified clay minerals are characterized by the presence of small peaks around 20°A in the air-dried sample. It is evidenced also by tailing of the 10°A towards the 14°A and 19°A peaks.

7-Quartz and feldspars are detected from the presence of (3.55-3.33°A) and (4.44-4.26°A) stable diffraction peaks respectively throughout the different treatments.

8-Calcite, dolomite and apatite are identified by their characteristic diffraction peaks at (3.1-3.25), 3.03, 2.89 and 2.81°A.

X-ray diffraction analysis was undertaken for 14 soil samples representing the different physiographic units which contain appreciable amounts of clay fraction.

For further differentiation, a semi-quantitative estimation of minerals was performed on the basis of the relative frequencies indicated by the peak area, **(Jackson 1973).** The data of the semi-quantitative mineralogical composition of the clay fraction are shown in Table (17). Description of the mineralogical composition of the separated clay samples in the studied area are presented in the following.

4.7.1. Clay mineralogy of the piedmont soils

The clay minerals assemblage of profile (9) which represents the soils of piedmont, Table (17) and Figs (10 and 11) are characterized by the dominance of palygorskite followed by kaolinite. Smectite (montmorillonite) and illite minerals are detected in few amounts throughout the entire profile depths. Chlorite is found in trace amounts in 60-120cm depth and disappear in the subsurface layer. Interstratified minerals are absent in these soils. The identified accessory minerals are mainly dominated by quartz and calcite followed by feldspars where dolomite is detected in moderate amounts in the subsurface layer and absent in the deepest layer.

4.7.2. Clay mineralogy of the alluvial plain soils

X-ray diffraction patterns of the clay fraction separated from the soils of this physiographic unit (profiles 4, 8 and 11) are shown in Figs (12, 13, 14, 15, 16 and 17) and Table (17).

Table (17): Semi-quantitative mineralogical composition of the clay fraction (<0.002 mm) separated from the studied soil profiles.

Location	Prof (No.)	Depth (cm)	Clay minerals						Accessory minerals				
			Interstratifed minerals	Illite	Kaolinite	Montimorllonite	Palygorskite	Chlorite	Quartz	Feldspars	Calcite	Dolomite	Apatite
Pied-mont	9	25-60	--	Few	Com	Few	Com	--	Mod	Tra	Few	Mod	--
		60-120	--	Few	Mod	Few	Dom	Tra	Mod	Mod	Com	--	--
Alluvial plain	4	35-70	--	Mod	Com	Few	Dom	--	Mod	Tra	Com	Few	Tra
		70-100	--	Mod	Com	Few	Dom	--	Few	Tra	Mod	--	--
	8	35-75	--	Few	Mod	Few	Dom	Tra	Few	Few	Tra	--	--
		75-150	--	Few	Mod	Few	Dom	Tra	Few	Tra	Com	Mod	--
	11	25-65	--	Mod	Com	Tra	Dom	Tra	Mod	Tra	Tra	--	--
		65-100	--	Mod	Mod	Few	Dom	Tra	Few	Tra	Mod	Few	Tra
Aeolian plain	15	25-70	--	Few	Mod	Few	Dom	Tra	Mod	Tra	Tra	Tra	Tra
		70-150	--	Mod	Mod	Few	Dom	Tra	Few	Tra	Mod	--	--
Sabkha	2	25-60	Tra	Few	Mod	Few	Dom	Tra	Few	Tra	Mod	Tra	--
		60-110	--	Few	Mod	Few	Com	--	Mod	Tra	Mod	--	Tra
	17	25-60	Tra	Few	Mod	Few	Dom	Tra	Mod	Tra	Tra	Tra	--
		60-120	--	Mod	Mod	Few	Dom	Tra	Mod	Tra	Few	--	--

Dom = Dominant (>40%) **Few = (5 -15%)** **Mod = Moderate (15 – 25%)**
Com = Common (25 – 40%) **Tra = Trace (<5%)** **Absent = - -**

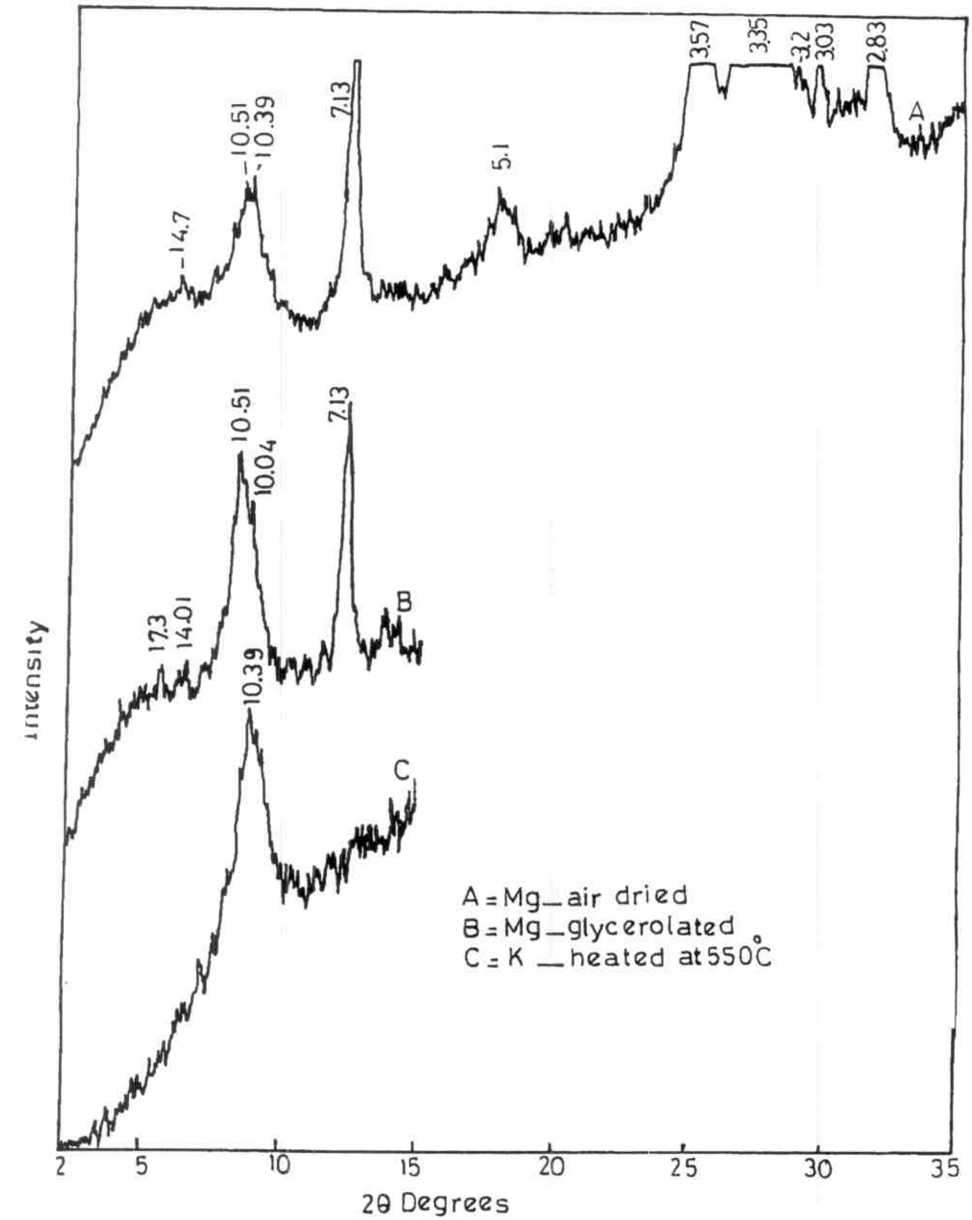

Fig (10): X-ray diffraction pattern of the clay fraction from (25-60 cm depth of profile 9 (piedmont)

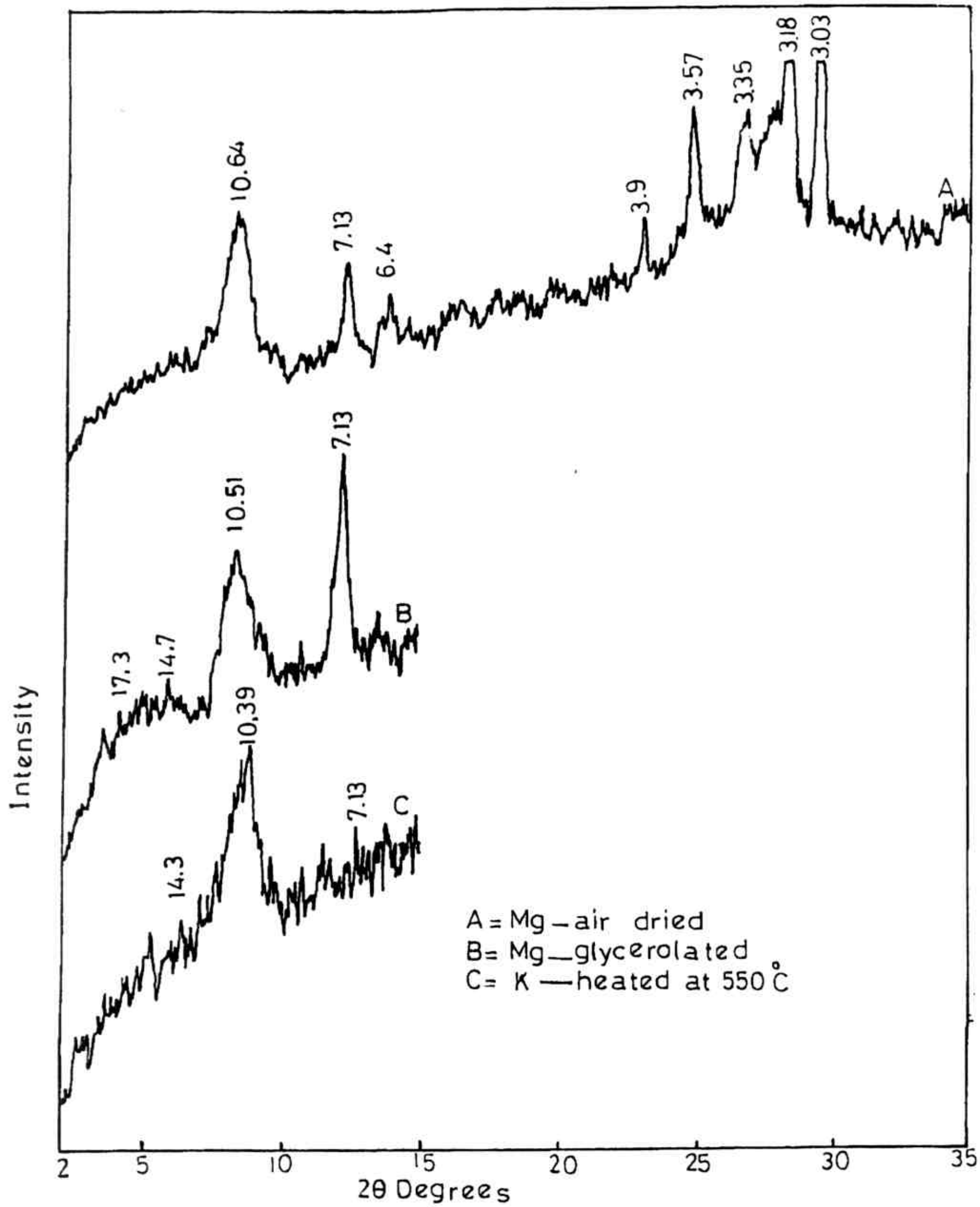

Fig (11): X-ray diffraction pattern of the clay fraction from(60-120 cm depth of profile 9 (piedmont)

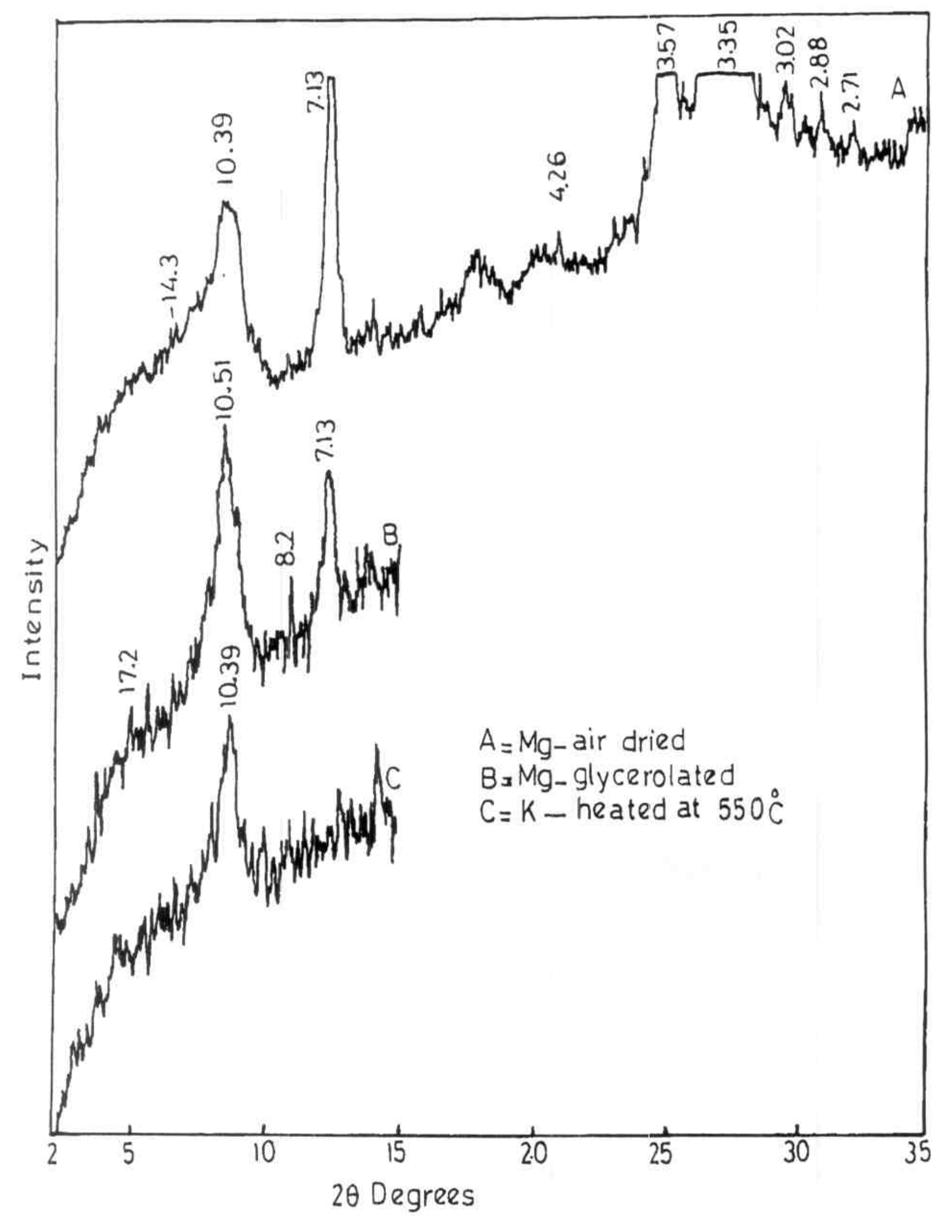

Fig (12): X-ray diffraction pattern of the clay fraction from(35-70 cm depth of profile 4 (alluvial plain)

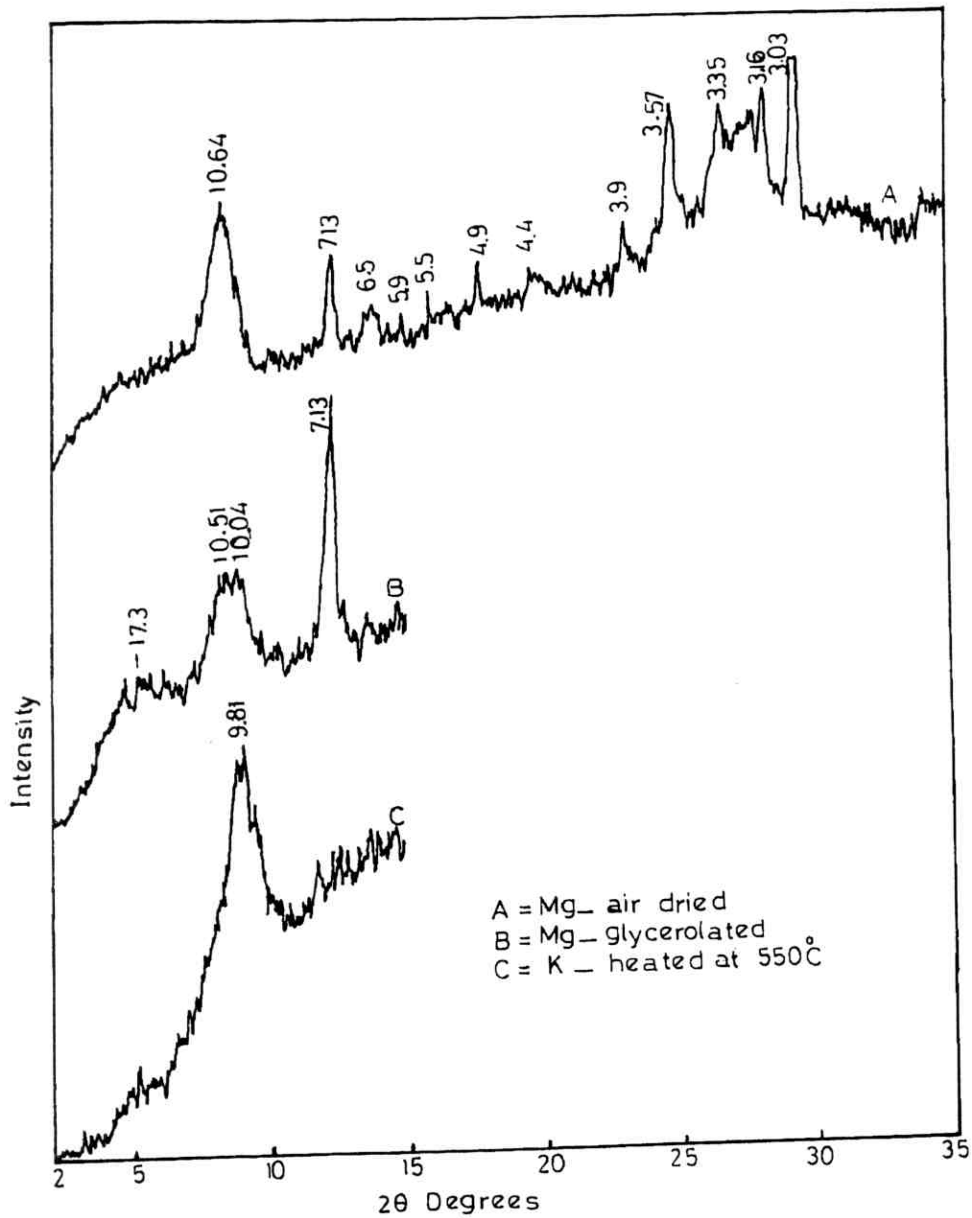

Fig (13): X-ray diffraction pattern of the clay fraction from (70-100 cm depth of profile 4 (alluvial plain)

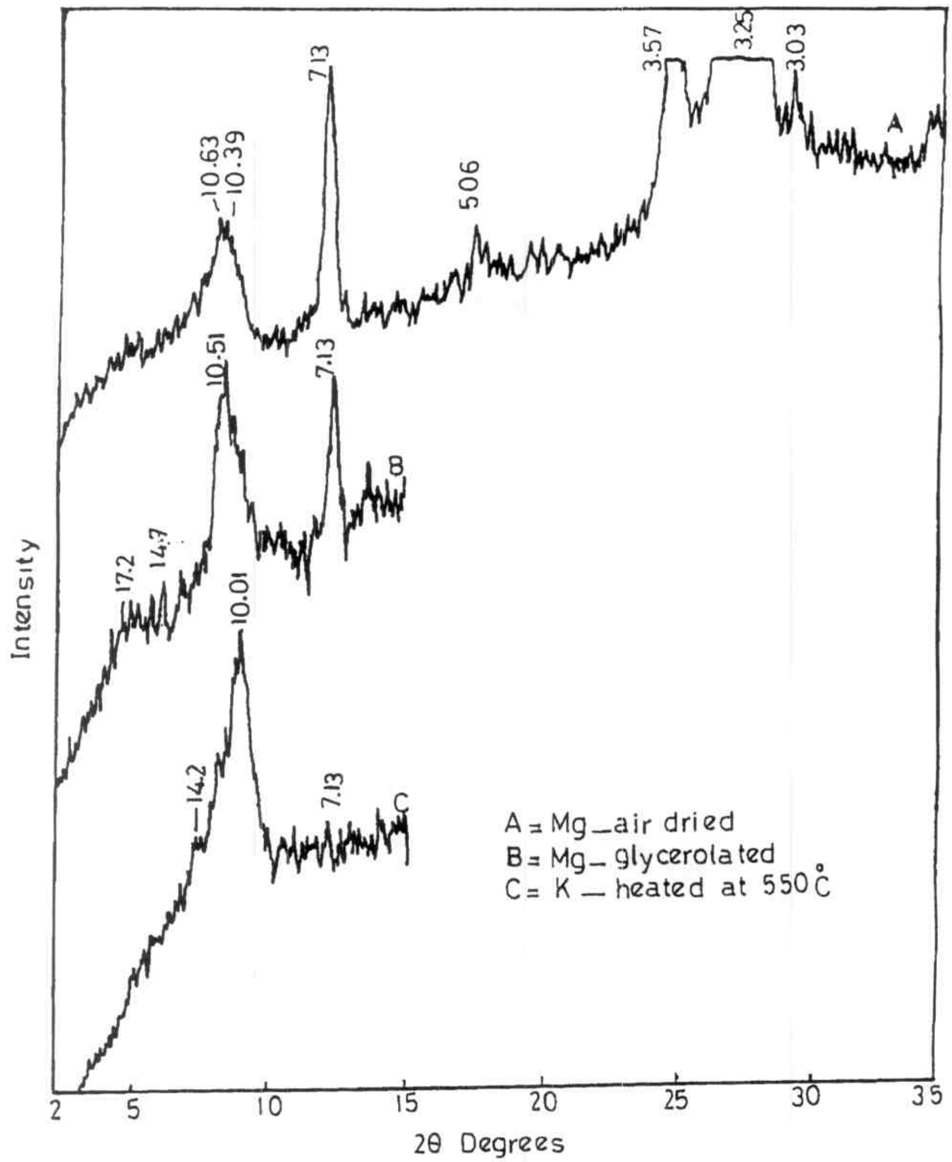

Fig (14): X-ray diffraction pattern of the clay fraction from (35-70 cm depth of profile 8 (alluvial plain)

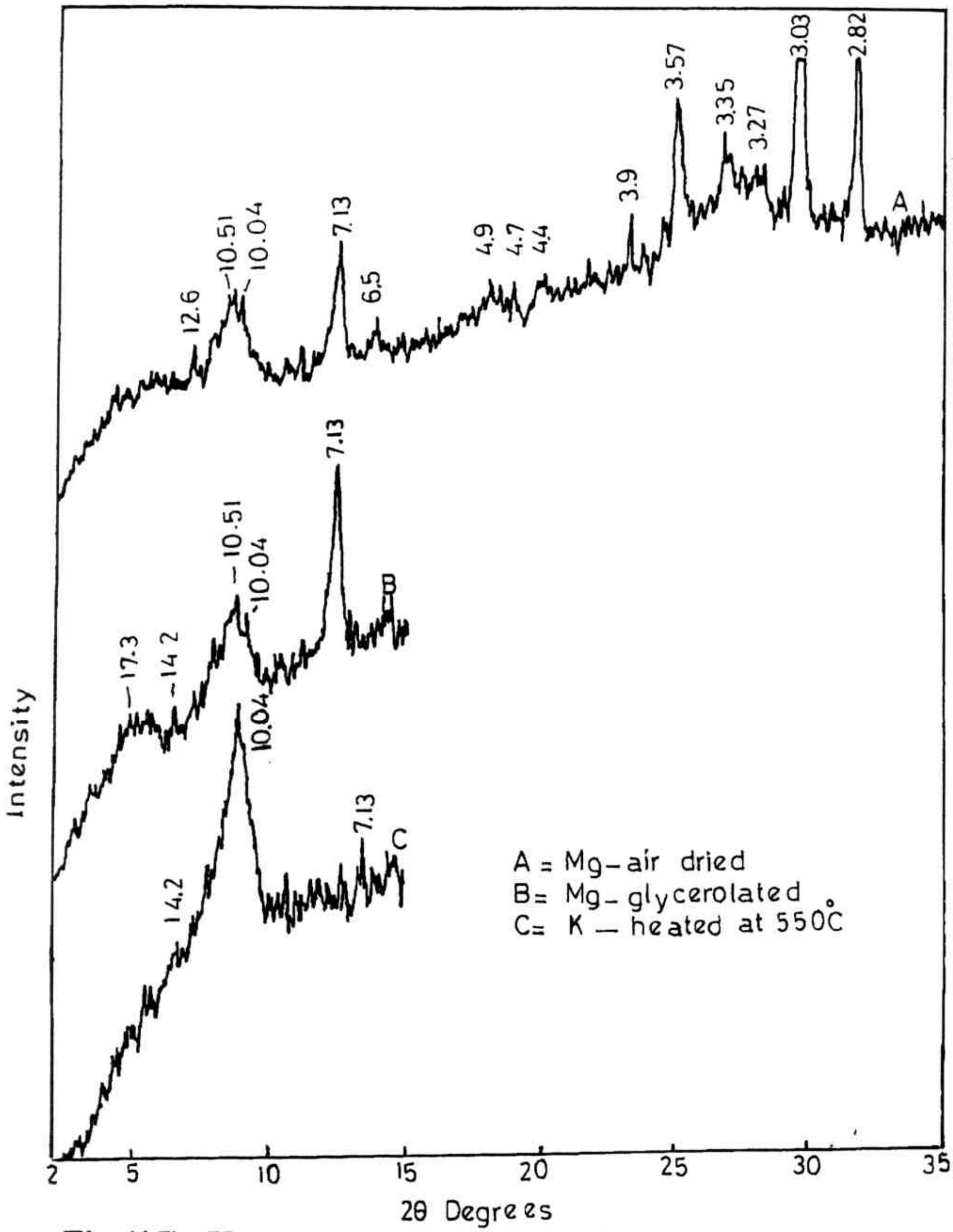

Fig (15): X-ray diffraction of the clay fraction from (75-150 cm depth of profile 8(alluvial plain)

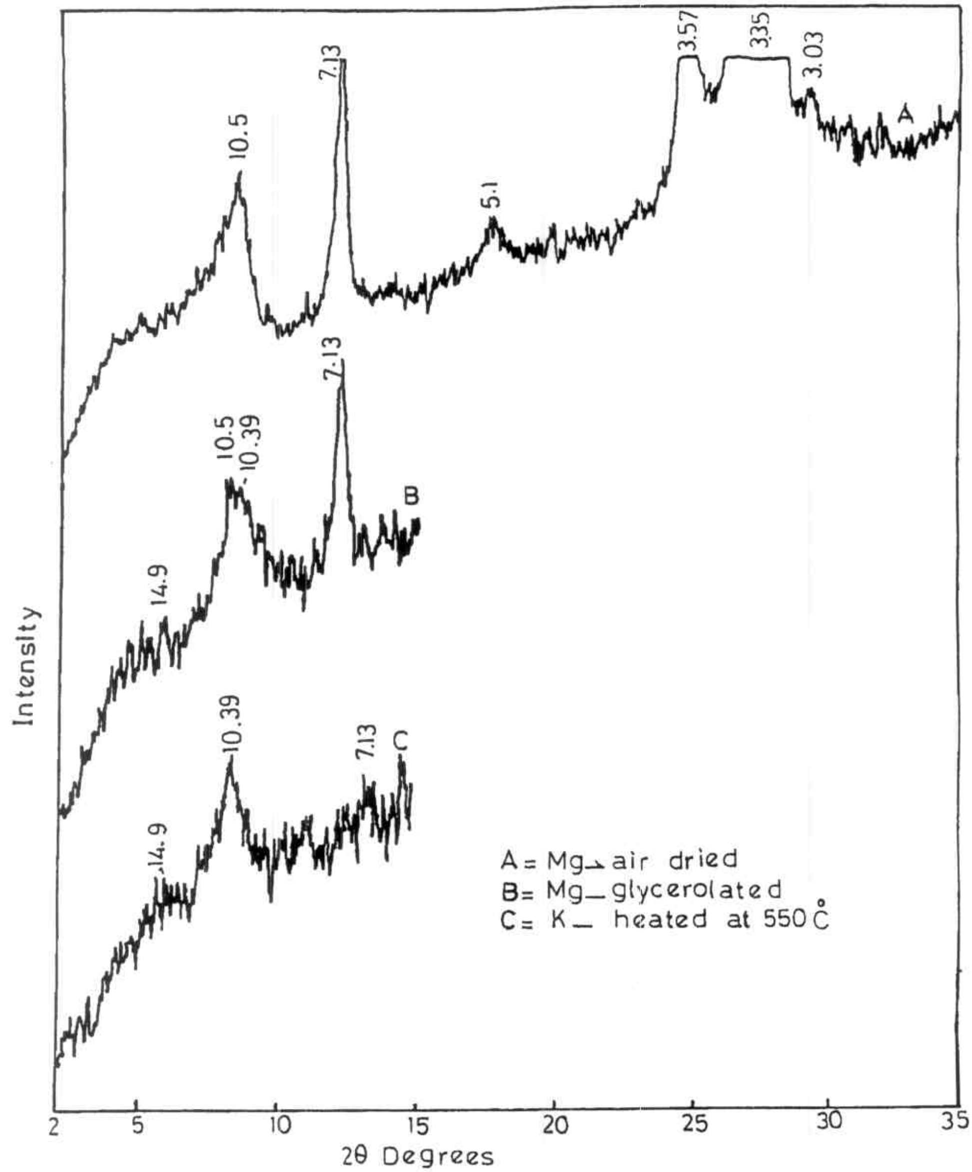

Fig (16): X-ray diffraction pattern of the clay fraction from(25-65 cm depth of profile 11 (alluvial plain)

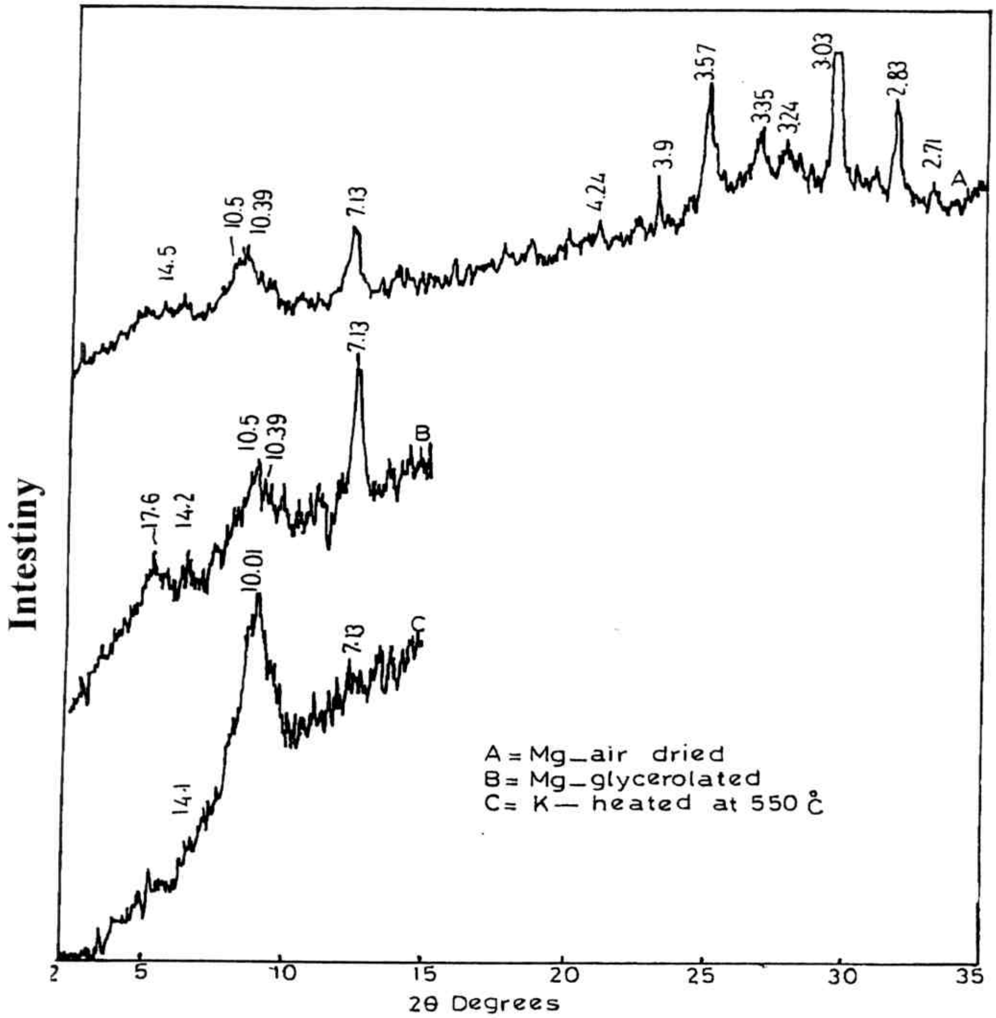

Fig (17): X-ray diffraction pattern of the clay fraction from (65-100 cm depth of profile 11 (alluvial plain)

The clay minerals are characterized by the abundance of palygorskite which is dominant followed by kaolinite which is detected in common and moderate amounts. Smectite (montmorillonite) minerals are few amounts in profiles 4 and 8, while in profile 11; it is trace in the shallower horizon and few in the deeper horizon. Illite is in moderate amounts in profiles 4 and 11 and few in profile 8. Chlorite is traces in profiles 8 and 11 and absent in profile 4. Accessory minerals are mainly calcite followed by quartz then feldspars and dolomite which are in trace. Apatite mineral is detected in trace amounts in the shallower horizon of profile 4 and deeper horizon of profile 11.

4.7.3. Clay mineralogy of Aeolian plain soils

Soils of this unit represented by the 25-70 and 70-150cm horizons of profile 15. the x-ray diffraction patterns of the clay fraction showed that clays are depicted in Figs (18 and 19). Examination of the clay fraction are dominated by palygorskite which is dominant followed by kaolinite which is detected in moderate amounts. Smectite (montmorillonite) minerals are found in few amounts in all profile horizons. Illite minerals are detected in few amounts in the shallower horizon and increase to moderate amounts in the deeper horizon, while chlorite is in traceable amounts in all profile horizons.

The accessory minerals are dominated by quartz followed by calcite, while feldspars, dolomite and apatite are detected in traceable amounts.

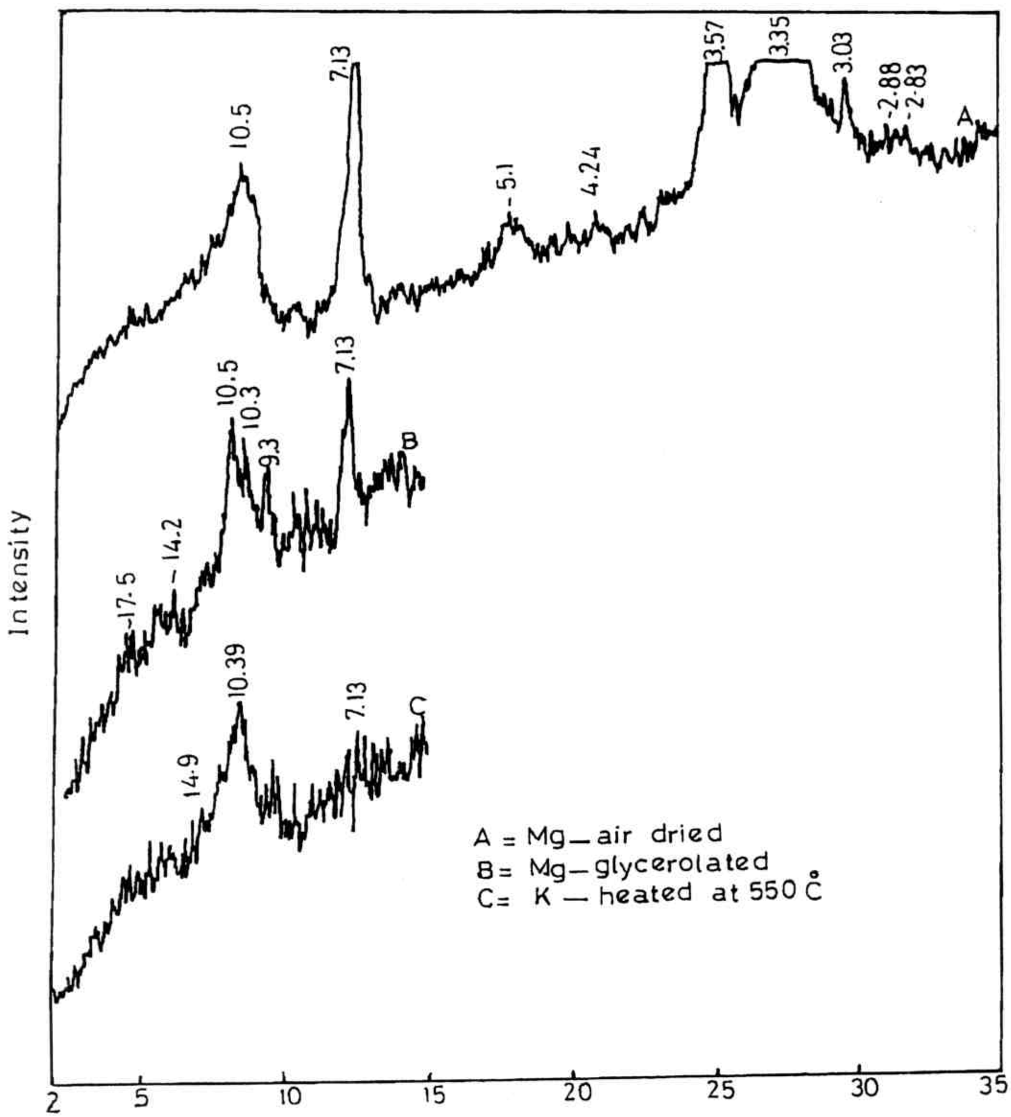

Fig (18): X-ray diffraction pattern of the clay from (25-70 cm depth of profile 15 (aeolian plain)

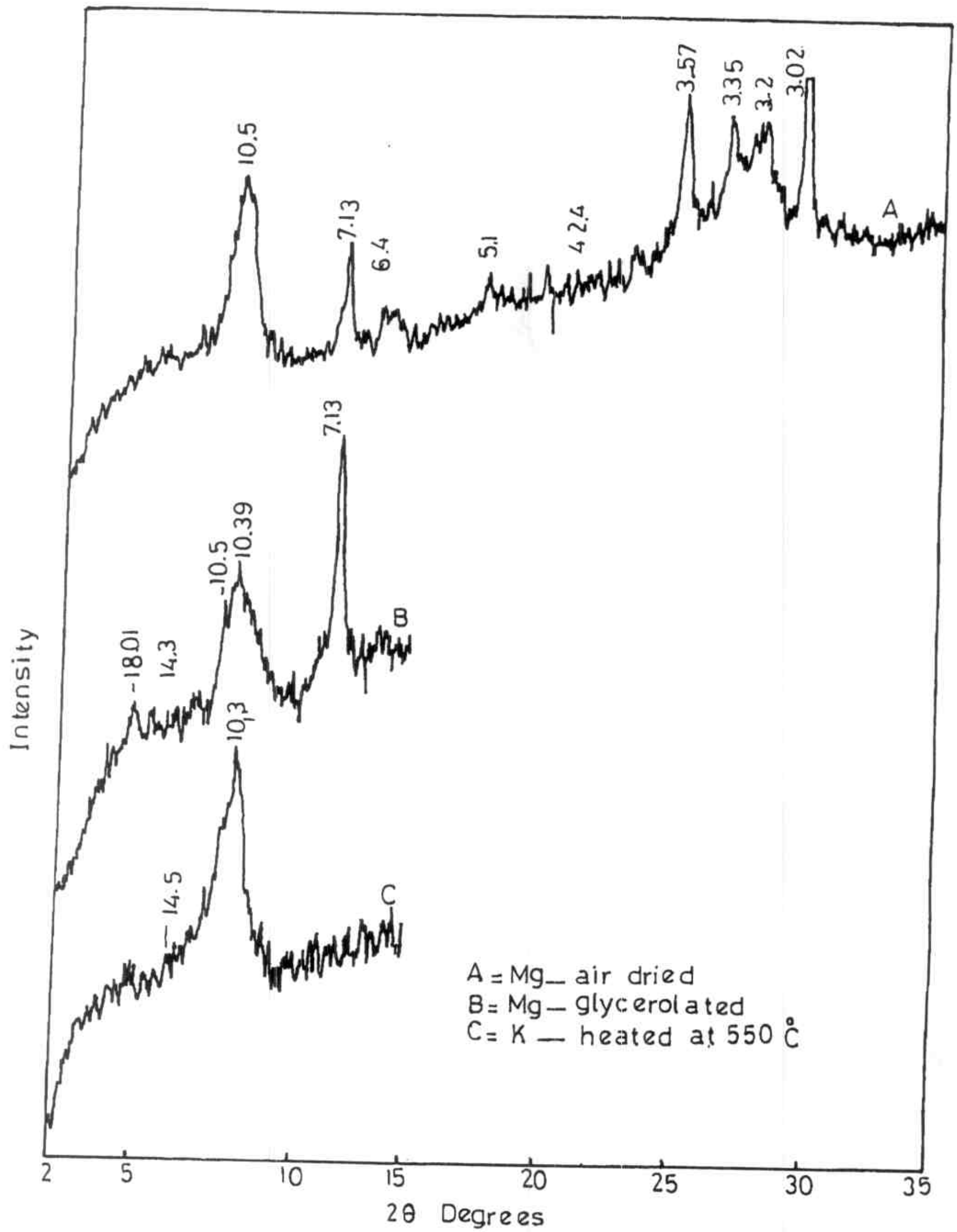

Fig (19): X-ray diffraction pattern of the clay fraction from (70-150 cm depth of profile 15 (aeolian plain)

4.7.4. Clay mineralogy of sabkha soils

Soils of this physiographic unit are represented by profiles 2 and 17 the x-ray diffraction pattern of the clay fraction are depicted in figs (20, 21, 22 and 23). Generally, the clay fraction is dominated by palygorskite minerals which are detected in common to dominant amounts. Kaolinite mineral is the second clay minerals and found in moderate amounts. Smectite (montmorillonite) and illite minerals are in few amounts in all horizons, except for the deeper horizon of profile 17 where illite is in moderate amounts. Chlorite and interstratified clay minerals are detected in traceable amounts and absent in few layers.

The accessory minerals are mainly dominated by quartz followed by calcite, while feldspars and dolomite is in traceable amounts. Apatite is in trace amounts in the deeper horizon of profile 2 and absent in the rest horizons.

From the abovementioned identification of the clay minerals in the studied physiographic units. It can be generally noticed that palygorskite dominate soils clays of all the studied physiographic units followed by kaolinite minerals. It can be concluded that:

1- Palygorskite minerals are detected in all the studied physiographic units. These soils have high content of calcium carbonate and soluble salts. These conditions favor palygorskite formation. These results agreement with those obtained by **Harga (1971), Metwally (1987) and Abdel Razik (2005).**

2- Kaolinite takes the second place in the clay fraction. It confirms the hydromorphic condition of soils and us mostly inherited from parent materials during the drastic leaching of soils in the past humid climate.

3- Smectite (montmorillonite) occurrence is confirmed by the prevailed aridity and the low content of vermiculite is as transitional stage between non-expanding mica and the fully expanding smectite, it expected that they are mostly inherited from parent material from which the soils are drived.

4- The presence of chlorite and illite are explained on the premise that Mg-affected conditions stimulate their formation either through diagenesis or neogenesis.

5- The presence of quartz and feldspars minerals as a major constituent of an accessory mineral may be due to physical weathering occurring at the surface layers of these profiles producing clay size quartz and feldspars which were then translocated to the deeper layers.

6- The presence of calcite and dolomite may suggest a contribution of calcareous parent material (calcareous sandstone and/or limestone)

7- The variations in mineralogical composition of the clay fraction in the study area are mainly ascribed to the multi-origin of sediments (multi-parent materials).

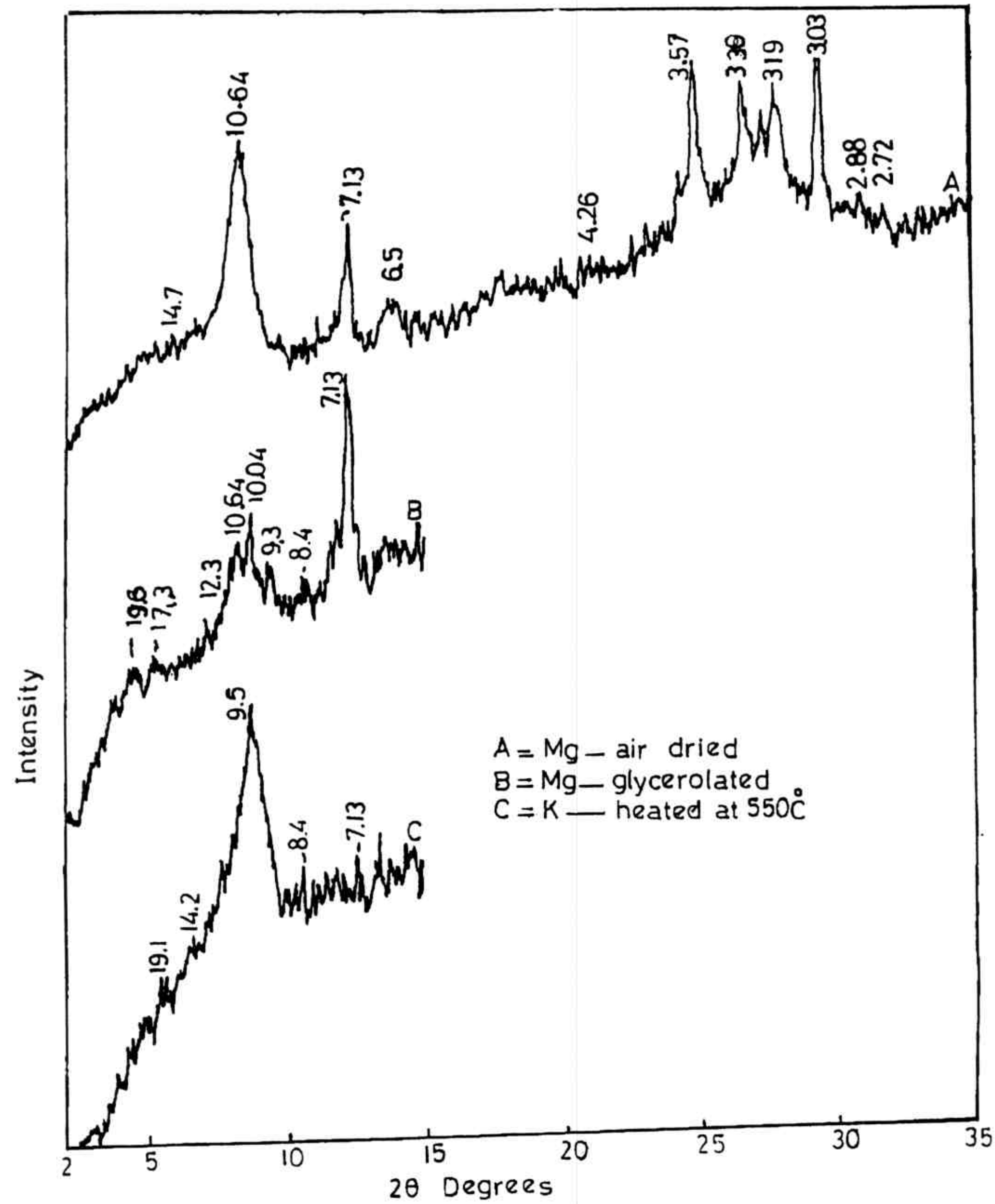

Fig (20): X-ray diffraction pattern of the clay fraction from (25-60 cm depth of profile 2(sabkha)

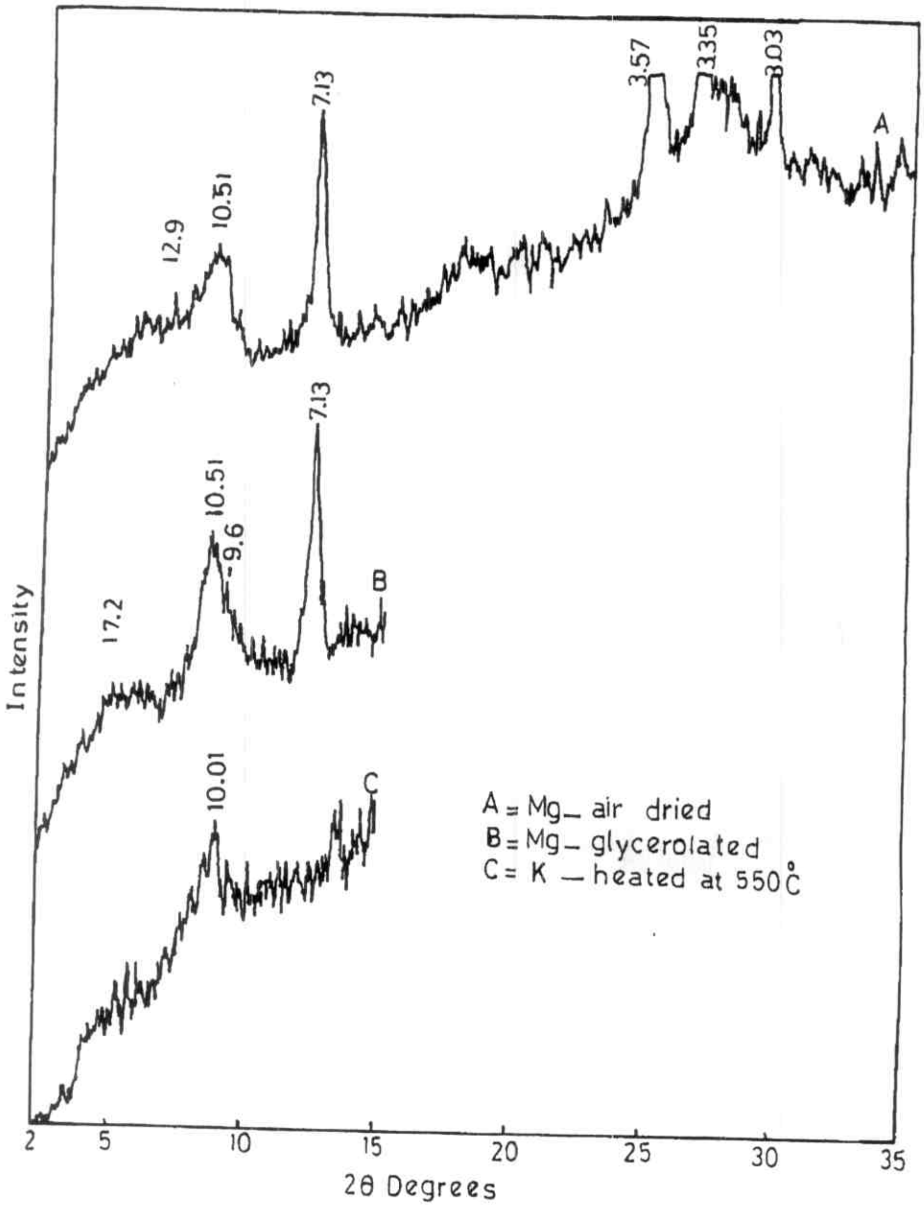

Fig (21): X-ray diffraction pattern of the clay fraction from (60-110 cm depth of profile 2(sabkha)

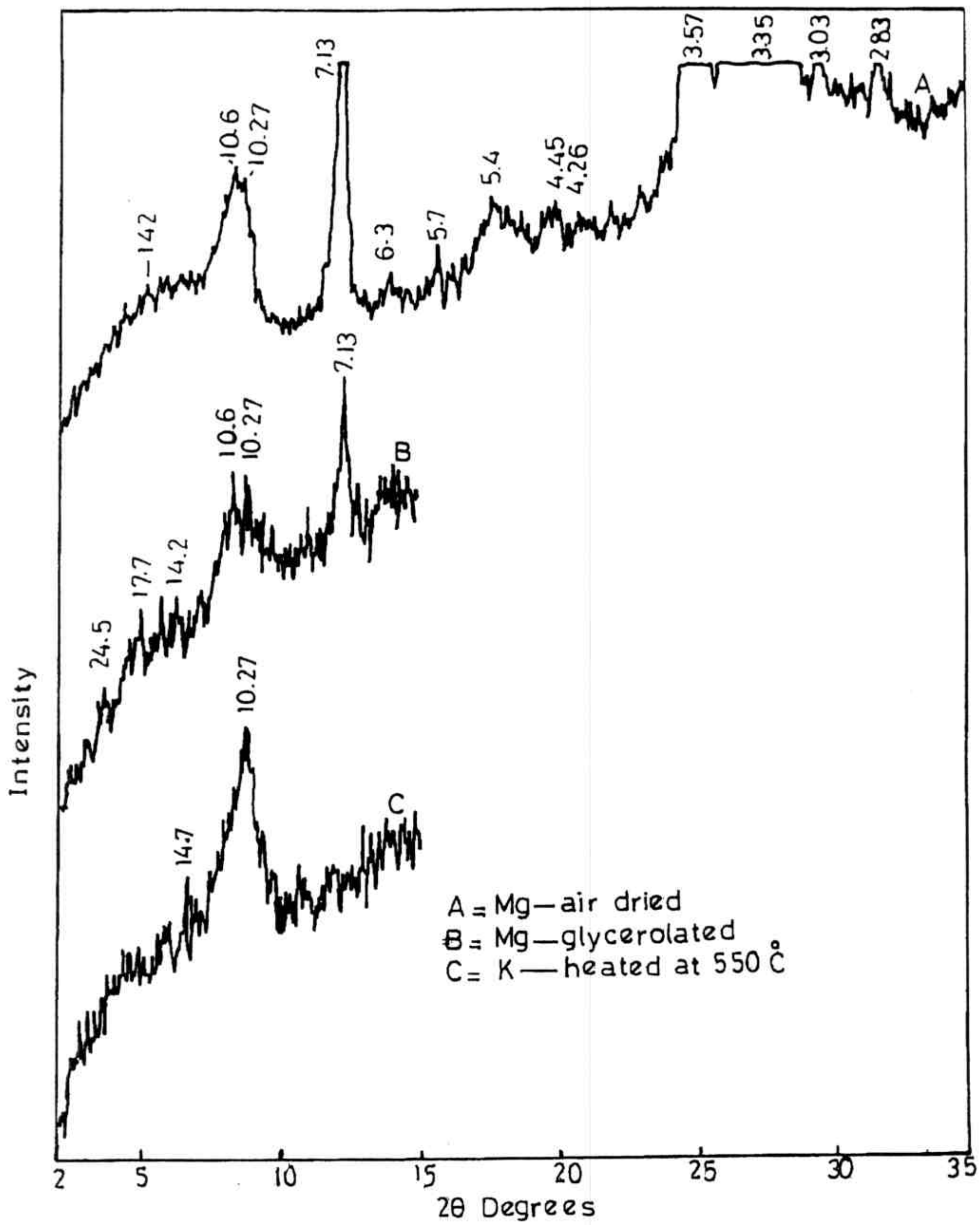

Fig (22): X-ray diffraction pattern of the clay fraction from (25-60 cm depth of profile 17 (sabkha)

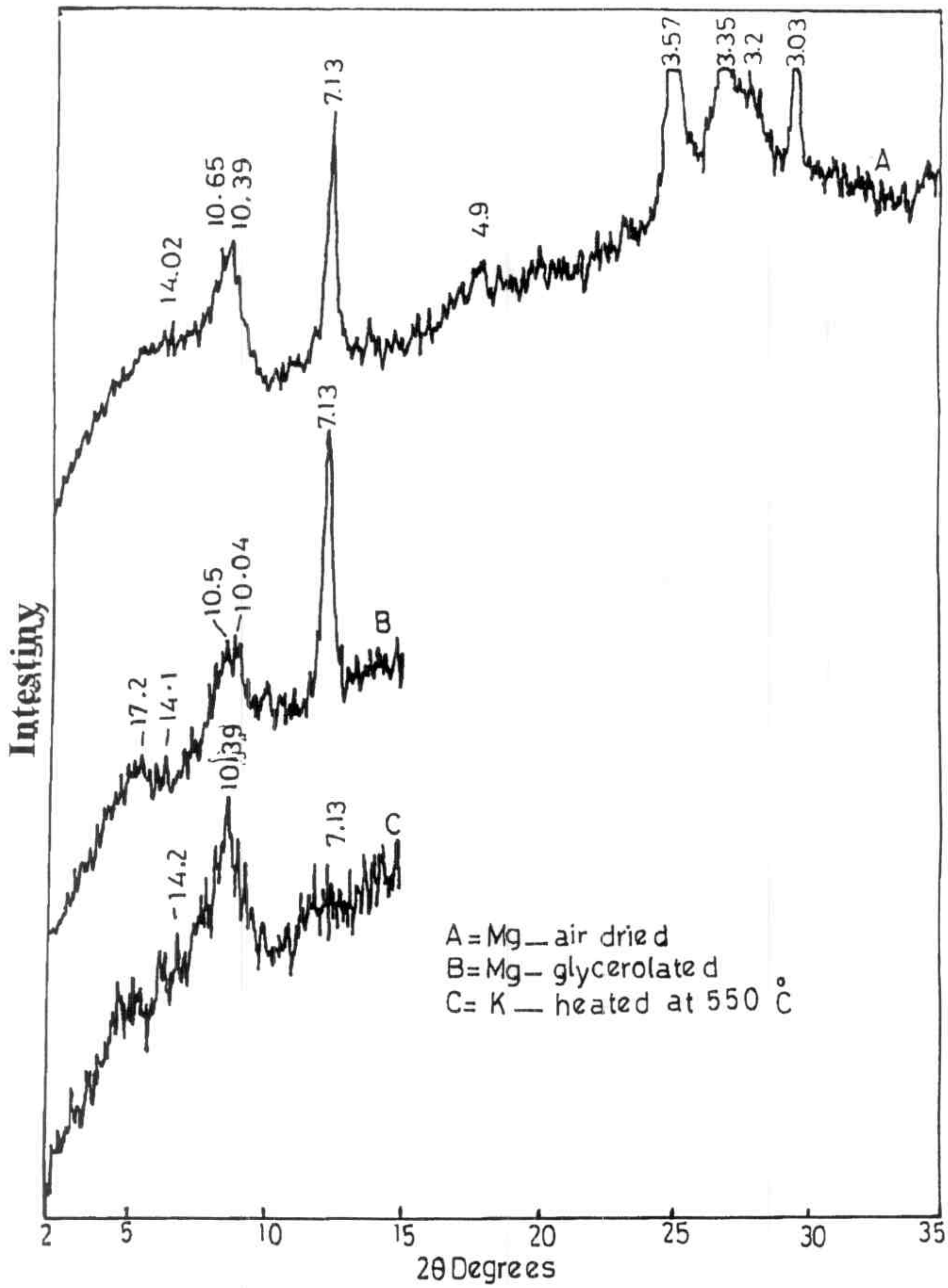

Fig (23): X-ray diffraction pattern of the clay fraction from (60- 120 cm of profile 17 (sabkha)

4.8. Soil classification

Soils were classified according to the **USDA (1975),** taking account of modifications by **USDA (1998),** the main criteria in soil taxonomy were:

1- Presence or absence of diagnostic horizons and other characteristics (i.e. depth to lithic or paralithic contact and motling)

2- Soil texture

3- Soil moisture and temperature regimes

4- Characteristics such as particle size distribution, soil minarlogy and soil depth of the profile control section.

The studied soils are characterized by a torric moisture regime indicated by the control section being in most of the year dry in all parts for more than half the time and the soil temperature at a depth of 50cm being above 5°C. The soil temperature regime is defined as a hyperthermic, since the mean annual soil temperature is higher than 22°C, and the differences between mean summer and mean winter soil temperature exceed than 5°C (Table 1). On the basis of morphological characteristics, physical and chemical analyses, the studied soil profiles were classified to the family level. Classification to the order level indicates identification of the Aridisols order., Table (18).

Table (18): Classification of the studied soil profiles (According to Soil Taxonomy, 2001)

Physio graphic unit	Order	Suborder	Great group	Sub great group	Families modifiers			Profiles No.
					Particle size class	Mineralogy	Temperature	
Aeolian plain	<u>*Aridisols*</u>	<u>*Calcids*</u>	<u>*Haplocalcids*</u>	<u>*Petronodic Haplocalcids*</u>	Sandy Sandy Coarse loamy	Mixed Carbontic Carbontic	Thermic, very deep Thermic, very deep Thermic, very deep	6, 7 13 15, 16
Piedmont	"	"	"	"	Sandy Coarse loamy Fine loamy	Mixed Mixed Mixed	Thermic, moderatly deep Thermic, moderatly deep Thermic, deep	1 3 9
Alluvial plain	"	"	"	<u>*Typic Haplocaalcid*</u>	Coarse loamy Coarse loamy Fine loamy	Carbonatic Mixed mixed	Thermic, very deep Thermic, very deep Thermic, very deep	5,8,12,14 4 10,11
<u>*Sabkha*</u>	"	"	"		Fine loamy Coarse loamy	Mixed Carbontic	Thermic, deep Thermic, very deep	2 17

4.8.1. Order Aridisols

Aridisols are soils that don't have water available to mesophytic plants for long periods. They have one or more pedogenic horizons that may have formed in the present environment or that may be relies from a pluvial period. The surface horizon or horizons are normally light in colour and have soft consistence when dry. The pedogenic horizons may be the result of translocation and accumulation of gypsum carbonate or silicates and of cementation by carbonates of silicates. They also may be only a alteration product of the parent materials without any significant accumulation.

The studied soils were placed under one suborder *Calcids*. The characteristics of this suborder are discussed below.

I) Suborder Calcids

Aridisols which have calcic or petrocalcic horizons within 100cm of the soil surface.

Great group "Haplocalcids"

Haplocalcids are the calcids that:

1- Have a calcic horizon but do not have a gypsic or a petrogypsic horizon whose upper boundary is within 100 cm of the soil surface.

2- Are calcareous in all parts above the calcic horizon after the upper soil to a depth of 18cm has been mixed unless the texture is as coarser than loamy sand.

3- Do not have a duripan whose upper boundary is within 1m of the soil.

4- Do not have petrocalcic horizon whose upper boundary is within 1m of the soil surface, and.

5- Do not have a salic horizon above the calcic horizon.

1- Subgroup "petronodic Haplocalcids"

These soils are the haplocalcids that have, in one or more horizon with a combined thickness of 15 cm or more, 20 percent or more nodules and concretions. These soils do not have a lithic contact within 50cm of the soil surface, a high shrink-swell potential, saturation within water for 1 month or more within 100 cm of the soil surface, a duripan within 150 cm of the soil surface, or durinodes or brittleness.

This subgroup can be classified to six families:

1- *Petronodic Haplocalcids, sandy, mixed, thermic, deep* (profiles 6 and 7).

2- *Petronodic Haplocalcids*, sandy, carbonatic, *thermic, very deep* (profile 13)

3- *Petronodic Haplocalcids*, coarse loamy, *carbonatic, thermic, very deep* (profiles 15 and 16).

4- *Petrodonic Haplocalcids, sandy, mixed, thermic, moderately deep* (profile 1)

5- *Petrodonic Haplocalcids, coarse loamy, mixed, thermic, moderately deep* (profile 3).

6- *Petrodonic Haplocalcids*, *fine loamy*, mixed, *thermic*, deep (profile 9).

2- Subgroup Typic Haplocalcids

Typic Haplocalcids are the Haploclacids that:

1- Do not have alithic contact within 50 cm of the soil surface.

2- Are dry in all parts of the moisture control section for three further or more of the time.

3- When the soil temperature is 5˚C or higher at a depth of 50 cm and

4- Do not have evidence of eugulfment of a former argillic horizon by the calcic horizon.

This subgroup can be classified to five families

1- *Typic Haplocalcids*, *coarse loamy*, *carbonatic*, *thermic*, *very deep* (profiles 5, 8, 12 and 14)

2- *Typic Haplocalcids*, *coarse loamy*, *mixed*, *thermic*, *very deep* (profile 4)

3- *Typic* H*aplocalcids*, *fine loamy*, *mixed*, *thermic*, very deep (profiles 10 and 11)

4- *Typic Haplocalcids*, *fine loamy*, *mixed*, *thermic*, *deep* (profile 2)

5- Typic Haplocalcids, *coarse loamy*, *carbonatic*, *very deep* (profile 17).

4.9. Land evaluation

4.9.1. Land capability classification

Land capability is one of a number of interpretive grouping made primarily for agricultural purposes. The prime aim of the system is to asses the degree of limitation to land use or potentially imposed by land characteristic on the basis of permanent properties. In this respect, many systems have been suggested to evaluate the agricultural limitations affecting land capability under the prevailing conditions. All systems aim at gaining a better knowledge and of the soil properties and defining limitations affecting the agricultural potentials of soils.

To identifying soil limitations and their intensities as well as soil suitability classes according to the current and potential suitability ratings, the parametric soil evaluation suggested by **Sys and Verheye (1978) and Sys *et al* (1991)** was applied. The obtained data in Table (19) show that most of the studied soils are suffering from some limiting factor, i.e. topography (t), soil texture (S_1), $CaCO_3$ (S_3) and salinity (n). That are put into variable intensity degrees, i.e., slight (>85), moderate (85-60) , severe (60-45) and very severe (<45).

According to the evaluation system of **Sys *et al* (1991)** and the estimated Ci ratings, the suitability indices for studied seventeen soil profiles representing the different physiographic units for current classes are assessed and recorded in Table (19). The obtained results show that the estimated current ratings of the studied soil profiles ranged between 12.33 and 38.70

Table (19): Intensity of limitation and suitability classes of the studied soils (according to Sys, *et al.*, 1991)

Soil Mapping units	Profile No	(T)		Wetness (W.)		Cur. Physical conditions				Salinity and Alkalinity		Capability Index(Ci)		Suitability class	
		Cur.	pot	Cur.	pot	S_1	S_2	S_3	S_4	Cur.	pot	Cur.	pot	Cur.	pot
Aeolian plain	6	60	85	80	90	60	100	90	90	96	100	22.39	37.18	N1	S3
	7	60	85	80	90	70	100	90	90	96	100	26.13	43.37	S3	S3
	13	100	100	80	90	60	100	80	90	90	100	31.10	38.90	S3	S3
	15	100	100	70	90	60	100	80	90	100	100	30.24	38.88	S3	S3
	16	100	100	80	90	70	100	80	90	96	100	38.70	45.36	S3	S3
Piedmont	1	100	100	70	85	60	85	90	90	96	100	27.76	45.36	S3	S3
	3	60	85	50	85	70	85	80	90	96	100	12.33	30.95	N1	S3
	9	100	100	70	85	70	100	80	90	90	100	31.75	42.84	S3	S3
Alluvial plain	4	60	85	80	90	60	100	90	90	90	100	20.99	37.18	N1	S3
	5	60	85	80	90	70	100	80	90	96	100	23.22	38.55	N1	S3
	8	100	100	80	90	60	100	80	90	90	100	31.10	38.88	S3	S3
	10	100	100	70	90	70	100	90	90	96	100	38.10	51.03	S3	S2
	11	100	100	70	90	70	100	80	90	96	100	33.86	45.36	S3	S3
	12	60	85	80	90	70	100	80	90	96	100	23.22	38.55	N1	S3
	14	100	100	80	90	70	100	80	90	96	100	38.70	45.36	S3	S3
Sabkha	2	100	100	70	80	70	100	90	90	80	90	31.75	40.82	S3	S3
	17	100	100	70	80	70	100	80	90	80	90	28.22	36.29	S3	S3

* T = Topgraphic limitation S_1 = texture classes S_2 = soil depth S2 = Moderately suitable S3 = marginally suitable
* W = Wetness Cur = current N1 = current not suitable
* S_4 = Gypsum status S_3 = Calcium status

indicates that the soils of the studied area could be categorized into two classes between grade (III) and grade (VI) grades.

1- Soils of grade (III) (S_3)

The rating of this grade is <50 and represented by twelve soil profile which belong to different physiographic units. These profiles are as follows:

Nos; 7, 13, 15 and 16 (Aeolian plain)

Nos; 1 and 9 (piedmont)

Nos; 8, 10, 11 and 14 (alluvial plain)

And Nos; 2 and 17 (sabkha)

These soils have different moderate limitations, Generally five different limitations are recognized; i.e., topography, wetness, texture, $CaCO_3$ and salinity.

2- Soils of grade (VI) (N_1)

The soils of this grade are unsuitable for the current suitability where the rating of this class is < 25 and represented by five soil profiles No 6 (Aeolian plain), No 3 (piedmont); and Nos 4, 5 and 12. These soils have many and severe limitations relating, topography, texture, $CaCO_3$ content and salinity. It is quite to noticeable that the soils of (N_1) class can be corrected by using suitable agro-management practices.

For raising the capability potential of these soils, soil improvement practices should be carried out such land leveling and removing the excess of soluble salts through applying the leaching requirements under an efficient drainage ditches for soils suffering from salinity. Such agro-management practices will be corrected the ratings of soil potential suitability class for the majority of the studied soils and it to be ranged 30.95-51.03 and potential soil suitability becomes as follows:

1- Moderately suitable soils (S_2)

The rating of this soils is 51.03 and represented by profile No 10 (alluvial plain)

2- Marginally suitable soils (S_3)

The rating of this class is 50-25 and represented by profiles Nos 1 to 9 and Nos 11 to 17.

4.9.2. Land suitability for certain crops

Land suitability for certain crops was done according to the system **(Sys *et al* 1991).** Assessment is done in the light of the following crops for the studied physiographic units (Table 20). The studied crops are:

1- Field crops : wheat, beans, sugar cane, sunflower, alfalfa, sesame, cotton, maize, sorghum and barley
2- Vegetable : watermelon
3- Fruits: olive.

Suitability indexes were calculated and the essential crop requirements have been considered. Land evaluation for certain crops in the soils of the current suitability study could be assessed as follows:

4.9.2.1. Soils of aeoline plain

- Marginally suitable (S_3) for sugarcane and sorghum
- Moderately suitable (S_2) for olive
- Non suitable (N) for other crops under investigation

4.9.2.2. Piedmont soils

- Marginally suitable (S_3) for sugar cane and barley
- Moderately suitable (S_2) for olive

4.9.2.3 Alluvial plain soils

- Moderately suitable (S_2) for olive
- Marginally suitable (S_3 for barley, sugar cane, sorghum and wheat.

4.9.2.4. Sabkha soils Moderately suitable (S_2) for olive

- Marginally to moderately suitable for watermelon.

With regard to the land evaluation for certain crops in the soils of the potential suitability the suitability indexes were calculated and shown in Table (20).

Soils of aeolian plain

- Very suitable (S_1) for olive (profiles 7 and 16).
- Moderately suitable (S_2) for sugar cane, sesame, sorghum (profile 7), watermelon and olive (profiles 6, 13 and 15).
- Marginal suitable (S_3) for wheat, sunflower, alfalfa, maize, barley and cotton (profile 7).

Soils of piedmont

- Very suitable (S1) for olive (profile 9)
- Moderately suitable (S_2) for sugar cane and watermelon (profile 9)
- Marginal suitable (S_3) for wheat, sorghum, barley, sesame, cotton (profiles 1 and 3), maize (profiles 1 and 9),

sunflower (profile 1), olive (profile 1), alfalfa (profile 1) and watermelon (profiles 1 and 3).

Soils of alluvial plain

- Very suitable (S_1) for olive (profiles 10 and 14)
- Moderately suitable (S_2) for watermelon, olive (profiles 4, 5, 8 and 12), sugar cane, sesame, sorghum (profiles 5, 10, 11 and 12), barley (profiles 10 and 11) and wheat (profiles 10 and 11).
- Marginal suitable (S_3) for wheat (profiles 4, 5, 8, 12 and 14), sunflower (profiles 4, 8, 10 and 11), alfalfa (profiles 4, 8, 10 and 11, sesame (profile 4), cotton (profiles 5, 8, 10 and 11), maize (profiles 4, 8, 10 and 14), sorghum and barley.

Soils of sabkha

- Moderately suitable (S_2) for olive, watermelon (profile 17), wheat (profile 2) and sugar cane
- Marginal suitable (S_3) for sesame, sunflower (profile 2), alfalfa, cotton, maize, sorghum and barley

From the obtained results, it can be concluded that the present cropping system in the area seems to be remain unchanged. The kind and level of management is the possible change in the present use. This could be due to the nature of the soils of the area. It is characterized by coarse texture soils and have high $CaCO_3$ content and its related problems such as physical properties and salinity. The soils of current study could attain better suitability classes if management and conservation practices are applied in a proper manner.

Table (20) Suitability classification of the studied soil profiles for certain crops.

Physio Graphic unit	Profile No,	Suitability indices for different crops														
		Field crops					Vegetables					Fruits				
		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability	
Aeolian plain	6	Wheat	15.18	N1	35.42	S3	Water melon	9.78	N1	58.85	S2	Olive	45.9	S3	69.84	S2
		Beans	0.83	N1	12	N1										
		Sugar cane	25.30	S3	56	S2										
		Sunflower	11.27	N1	28.13	S3										
		Alfalfa	14.08	N1	33.25	S3										
		Sesame	8.24	N1	52.51	S2										
		Cotton	8.81	N1	22.31	N1										
		Maize	16.96	N1	37.17	S3										
		Sorghum	23.80	N1	41.53	S3										
		Barley	18.79	N1	39.35	S3										
	7	Wheat	18.78	N1	35.42	S3	Water melon	11.51	N1	61.94	S2	Olive	51	S2	76.7	S1
		Beans	0.35	N1	11.85	N1										
		Sugar cane	28.3	S3	58.9	S2										
		Sunflower	11.3	N1	28.4	S3										
		Alfalfa	16.57	N1	39.12	S3										
		Sesame	10.85	N1	61.77	S2										
		Cotton	18.73	N1	33.36	S3										
		Maize	19.79	N1	37.2	S3										
		Sorghum	28.27	S3	58.85	S2										
		Barley	18.79	N1	35.20	S3										
	13	Wheat	3.9	N1	27.78	S3	Water melon	6.90	N1	58.85	S2	Olive	20.25	N1	72.7	S2
		Beans	0.41	N1	12.47	N1										
		Sugar cane	11.1	N1	61.95	S2										
		Sunflower	2.19	N1	14.40	N1										
		Alfalfa	5.87	N1	14.59	N1										
		Sesame	6.5	N1	55.43	S2										
		Cotton	1.91	N1	6.89	N1										
		Maize	2.19	N1	15.50	N1										
		Sorghum	5.56	N1	29.24	S3										
		Barley	6.50	N1	26.16	S3										
	15	Wheat	16.52	N1	29.24	S3	Water melon	11.51	N1	1.95	S2	Olive	48.6	S3	72.7	S2
		Beans	1.54	N1	12.47	N1										
		Sugar cane	18.8	N1	61.95	S2										
		Sunflower	6.54	N1	14.59	N1										
		Alfalfa	6.54	N1	14.59	N1										
		Sesame	11.48	N1	55.43	S2										
		Cotton	6.12	N1	10.33	N1										
		Maize	8.75	N1	16.30	N1										
		Sorghum	14.83	N1	38.87	S3										
		Barley	17.44	N1	27.62	S3										

Table (20): Cont.

Physiographic unit	Profile No,	Suitability indices for different crops														
		Field crops					Vegetables					Fruits				
		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability	
Aeolian plain	16	Wheat	4.36	N1	27.78	S3	Water melon	3.38	N1	61.95	S2	Olive	54.0	S2	80.7	S1
		Beans	0.61	N1	12.47	N1										
		Sugar cane	21.0	N!	61.95	S2										
		Sunflower	3.71	N1	14.59	N!										
		Alfalfa	4.62	N1	16.3	N1										
		Sesame	3.56	N1	58.39	S2										
		Cotton	7.80	N1	15.44	N1										
		Maize	2.92	N1	13.8	N1										
		Sorghum	7.83	N1	18.22	N1										
		Barley	14.05	N1	27.62	S3										
Piedmont	1	Wheat	20.93	N1	39.35	S3	Water melon	9.79	N1	43.39	S3	Olive	34.56	S3	46.8	S3
		Beans	0.93	N1	11.22	N1										
		Sugar cane	29.75	S3	58.85	S2										
		Sunflower	14.13	N1	29.85	S3										
		Alfalfa	16.57	N1	35.00	S3										
		Sesame	10.9	N1	27.60	S3										
		Cotton	13.95	N1	25.00	S3										
		Maize	21.0	N1	37.10	S3										
		Sorghum	19.77	N1	36.82	S3										
		Barley	21.00	N1	39.12	S3										
	3	Wheat	6.61	N1	37.28	S3	Water melon	6.16	N1	37.06	S3	Olive	3.38	N1	13.8	N1
		Beans	1.18	N1	10.07	N1										
		Sugar cane	1.78	N1	52.65	S2										
		Sunflower	1.47	N1	7.88	N1										
		Alfalfa	2.32	N1	12.40	N1										
		Sesame	9.75	N1	49.13	S3										
		Cotton	2.88	N1	26.60	S3										
		Maize	8.4	N1	12.50	N1										
		Sorghum	8.27	N1	44.01	S3										
		Barley	7.83	N1	31.30	S3										
	9	Wheat	8.26	N1	41.5	S3	Water melon	7.31	N1	58.85	S2	Olive	60.02	S2	77	S1
		Beans	1.15	N1	13.9	N1										
		Sugar cane	19.6	N1	58.9	S2										
		Sunflower	2.13	N1	15.5	N1										
		Alfalfa	2.4	N1	15.4	N1										
		Sesame	8.1	N1	58.3	S3										
		Cotton	10.11	N1	15.94	N1										
		Maize	3.5	N1	17.3	N1										
		Sorghum	24.92	N1	46.4	S3										
		Barley	37.0	S3	39.7	S3										

Table (20) : Cont

Physio graphic unit	Profile No,	Suitability indices for different crops															
		Field crops					Vegetables					Fruits					
		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability		
Alluvial plain	10	Wheat Beans Sugar cane Sunflower Alfalfa Sesame Cotton Maize Sorghum Barley	28.1 0.48 31.2 16.7 17.4 12.2 29.5 9.8 37.4 37.1	S3 N1 S3 N1 N1 N1 S3 N1 S3 S3	62.3 13.9 69.8 37.1 41.4 68.6 49.4 41.9 73.3 58.7	S2 N1 S2 S3 S3 S2 S3 S3 S2 S2	Water melon	11.6	N1	98.9	S2	Olive	57	S2	84	S1	
	11	Wheat Beans Sugar cane Sunflower Alfalfa Sesame Cotton Maize Sorghum Barley	13.01 1.83 16.3 6.58 7.65 13.5 4.2 10.9 14.6 13.7	N1 N1 N1 N1 N1 N1 N1 N1 N1 N1	61.9 13.9 69.2 35.2 41.2 68.6 39.1 43.7 58.3 52.2	S2N1 S2 S3 S3 S2 S3 S3 S2 S2	Water melon	12.2	N1	61.9	S2	Olive	23.8	N1	76.9	S1	
	12	Wheat Beans Sugar cane Sunflower Alfalfa Sesame Cotton Maize Sorghum Barley	7.3 0.43 14.7 2.6 3.85 10.3 4.1 9.3 11.8 9.8	N1 N1 N1 N1 N1 N1 N1 N1 N1 N1	41.5 13.2 69.2 14.7 17.2 62.2 16.3 18.2 54.9 39.1	S3 N1 S2 N1 N1 S2 N1 N1 S2 S3	Water melon	10.4	N1	58.9	S2	Olive	21.4	N1	72.7	S2	

Table (20) : Cont.

Physio graphic unit	Profile No,	Field crops: Crop	Field crops: Current suitability		Field crops: Potential suitability		Vegetables: Crop	Vegetables: Current suitability		Vegetables: Potential suitability		Fruits: Crop	Fruits: Current suitability		Fruits: Potential suitability	
Alluvial plain	4	Wheat	13.32	N1	37.39	S3	Water melon	8.31	N1	58.85	S2	Olive	45.9	S3	65.4	S2
		Beans	0.35	N1	11.84	N1										
		Sugar cane	23.9	N1	55.9	S2										
		Sunflower	10.7	N1	29.9	S3										
		Alfalfa	14.8	N1	33.3	S3										
		Sesame	7.4	N1	46.9	S3										
		Cotton	8.8	N1	22.2	N1										
		Maize	18.9	N1	39.1	S3										
		Sorghum	22.6	N1	39.5	S3										
		Barley	18.8	N1	37.2	S3										
	5	Wheat	16.7	N1	37.4	S3	Water melon	10.9	N1	61.94	S2	Olive	51	S2	72.7	S2
		Beans	0.35	N1	11.84	N1										
		Sugar cane	26.8	S3	55.9	S2										
		Sunflower	4.97	N1	12.47	N!										
		Sesame	9.7	N1	61.8	S2										
		Cotton	16.7	N1	35.2	S3										
		Maize	3.87	N1	16.3	N1										
		Sorghum	26.8	S3	55.8	S2										
		Alfalfa	7.30	N1	16.3	N1										
		Barley	17.7	N1	34.9	S3										
	8	Wheat	16.7	N1	41.5	S3	Water melon	17.4	N1	58.7	S2	Olive	76.5	S2	73	S2
		Beans	0.98	N1	12.47	N1										
		Sugar cane	25.1	S3	58.9	S2										
		Sunflower	13.34	N1	33.25	S3										
		Sesame	15.6	N1	52.2	S2										
		Alfalfa	21.0	N1	35.2	S3										
		Cotton	11.02	N1	26.16	S3										
		Maize	5.56	N1	37.2	S3										
		Sorghum	29.9	S3	41.4	S3										
		Barley	29.5	S3	36.8	S3										

Table (20) : Cont.

Physio graphic unit	Profile No,	Suitability indices for different crops														
		Field crops					Vegetables					Fruits				
		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability		Crop	Current suitability		Potential suitability	
Alluvial plain	14	Wheat	5.83	N1	29.3	S3	Water melon	11.6	N1	61.94	S2	Olive	23.8	N1	76.5	S2
		Beans	0.41	N1	12.5	N1										
		Sugar cane	13.9	N1	58.9	S2										
		Sunflower	2.59	N1	15.5	N1										
		Alfalfa	3.56	N1	17.2	N1										
		Sesame	12.2	N1	62.2	S2										
		Cotton	4.1	N1	16.3	N1										
		Maize	8.8	S3	32.6	S3										
		Sorghum	9.3	N1	39.1	S3										
		Barley	6.5	N1	27.6	S3										
Sabkha	2	Wheat	9.61	N1	58.9	S2	Water melon	4.8	N1	49.9	S3	Olive	21.8	N1	61.8	S2
		Beans	0.48	N1	11.19	N1										
		Sugar cane	7.8	N1	52.8	S2										
		Sunflower	5.2	N1	33.6	S3										
		Alfalfa	9.21	N1	44.4	S3										
		Sesame	7.2	N1	49.1	S3										
		Cotton	4.6	N1	44.6	S3										
		Maize	6.8	N1	44.3	S3										
		Sorghum	9.8	S3	42.1	S3										
		Barley	7.02	S3	46.9	S3										
	17	Wheat	1.9	N1N	10.9	N1N	Water melon	5.04	N1	52.51	S2	Olive	32.6	S3	61.8	S1
		Beans	0.98	1	11.9	1										
		Sugar cane	6.9	N1N	58.7	S2										
		Sunflower	1.5	1	9.9	N1										
		Alfalfa	2.71	N1	13.8	N1										
		Sesame	7.2	N1	49.1	S3										
		Cotton	2.2	N1N	14.6	N1										
		Maize	2.4	1	12.3	N1										
		Sorghum	9.99	N1	23.9	N1										
		Barley	3.98	N1	9.65	N1										