4-RESULTS AND DISCUSSIONS

4-1 Morphological, physical and chemical characteristics:

Soils are the product of the integrated environmental factors which act upon the parent material. With respect to the areas under investigation, the soils were formed and developed under desert to semi-desert climatic conditions. In arid regions, the pedological processes are relatively limited. The mineral profile development under such climatic conditions tends to have little influence on the soils since the slight variation in depositional activity during the soil's deposition causes more significant changes in the profile.

The morphological characteristics of soil profiles could be taken, as indications of the physico-chemical processes that might have taken place. They could also indicate the type or types of parent materials, the mode of deposition and the nature of soil forming factors.

The studied profiles in different locations varied in their morphological features from one profile to another as it could be seen from the morphological field sheets. The differences among horizons within each soil profile with respect to properties as colour, texture, structure and distribution of concretions. could be attributed to the nature and regime of soil formation and the intensity of pedogenic processes.

The morphological, physical and chemical properties of the studied profiles are given below.

4.1.1- Soils of El-Tina plain

El-Tina plain is located in the northwestern part of Sinai Peninsula. It has triangular shape with one side about 40km long running along the Suez Canal and one side of 35km along the coast. This geomorphic unit is represented by profiles 1 to 11 and the landscape is almost flat. Soil parent material is mostly of lacustrine origin, with a possible intermixing with aeolian sediments, particularly in the uppermost surface layers. The elevation varies between 0 and 2m a.s.l. Vegetation is natural common desert shrubs. The soils constituted sediments formed from clay, sand and coarse sand. The soil overlain was structureless, having single grain to weak coarse subangular blocky. The main pedological features identified within profile depth are accumulation of gypsum crystals, few lime concentrations and few salt crystals. Soil colour was between dark brown (10YR 3/3) and yellow (10YR 7/6) when dry; very dark gray (10YR 3/1) and brownish yellow (10 YR 6/6) when moist.

The analytical data of the soil profiles are given in Tables 2 and 3 . The soils are fine to coarse textured, being loamy sand to clay. The clay content differs from one layer to another, as it ranged between 6.0% and 46.3%. Sand content ranged between 86.0% and 36.0%.

Calcium carbonate ranged between 0.02% and 6.4%; being particularly high in profile 3. The distribution of $CaCO_3$ throughout the soil profiles shows an increase with depth. The organic matter content was generally low and did not exceed 1.4% with a tendency of decreae with depth.

Table (2) Particle size distribution, textural class, $CaCO_3$ and O.M content of the studied soil profiles El-Tina plain.

location	Geomorphic unit	Prof. No.	Depth (cm)	Particle size distribution C.S %	F.S %	Silt %	clay %	Textural Class	$CaCO_3$ %	O.M %
El-Tina plain	El-Tina plain	1	5—30	11.2	46.9	17.2	24.5	S.C.L	0.35	1.1
			30—80	3.8	44.5	16.8	34.9	Light clay	0.02	1.06
			80—150	2.5	48.5	11.5	38.4	Light clay	3.9	1.02
		2	20-60	6.9	42.5	20.2	30.4	Light clay	0.5	1.3
			60-110	3.5	42.5	22.2	31.8	Light clay	1.9	1.2
			110-150	7.1	42.7	14.8	35.4	Light clay	4.9	1.05
		3	10—25	2.4	46.1	19.9	31.6	Light clay	0.4	1.05
			25—80	1.6	46.3	16.9	35.2	Light clay	4.7	0.9
			80—125	0.8	51.9	11.4	35.9	Light clay	4.9	0.8
		4	0—8	0.5	55.9	19.7	23.9	S.C.L	0.3	1.4
			10—60	37.9	25.0	13.4	23.7	S.C.L	0.2	0.9
			60—90	69.0	12.7	7.1	11.2	sandy loam	0.9	0.7
			90—150	74.0	12.0	8.0	6.0	loamy sand	1.7	0.6
		5	0—10	22.6	42.3	15.5	19.6	S.C.L	0.4	1.0
			10—40	16.1	35.4	18.9	29.6	Light clay	0.2	0.8
			40—90	12.6	37.2	20.9	29.3	Light clay	0.3	0.6
			90—150	19.0	51.3	10.2	19.5	S.C.L	2.5	0.23
		6	0—10	4.6	56.1	14.5	24.8	S.C.L	0.5	1.05
			10—40	13.2	38.9	20.8	27.1	Light clay	1.6	0.93
			40—70	5.6	40.2	29.2	25.0	Light clay	1.5	0.9
		7	0—10	38.9	34.5	12.3	14.3	Sandy loam	0.4	1.07
			10—45	71.7	11.1	7.1	10.1	Sandy loam	0.3	0.98
			45—90	26.0	31.0	10.4	32.65	Sandy loam	2.8	0.9
			90—150	68.7	15.3	7.0	9.05	Sandy loam	1.1	0.4
		8	0—20	14.1	44.2	13.5	28.2	Sandy clay	0.5	1.15
			20—50	1.9	47.7	9.5	40.9	Light clay	0.4	1.07
			50—100	12.8	38.9	18.8	29.5	Light clay	1.1	0.89

Table (2) cont.

Location	Geomo-rphic unit	Profile. No	Depth (cm)	Particle size distribution C.S %	F.S %	Silt %	Clay %	Textural Class	$CaCO_3$ %	O.M %
El-Tina plain	El-Tina plain	9	0—20	37.5	41.1	9.2	12.2	S.C.L	5.0	1.11
			20—45	0.50	35.5	22.9	41.1	Light clay	6.2	0.93
			45—90	38.3	24.8	13.3	23.6	S.C.L	4.8	0.64
			90—150	67.4	15.5	7.0	10.1	Sandy loam	1.0	0.8
		10	0—35	19.4	37.9	15.5	27.2	S. clay	4.4	0.87
			35—85	2.2	39.5	13.4	44.9	Heavy.CH	5.5	0.82
			85—150	0.6	39.6	13.5	46.3	eavy.C	4.4	0.82
		11	0—25	20.9	37.8	18.6	22.7	S.C.L	6.4	0.76
			25—75	5.1	44.4	17.8	32.7	Light clay	4.9	0.65
			75—150	2.1	36.3	18.5	43.1	Light clay	5.6	0.5

Table (3) Chemical composition of the soil saturation extract and gypsum content of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	pH	E.C dS/m	Soluble ions in soil saturation extract: Cations (meq / L)				Anions (meq / L)				Gypsum
						Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	%
El – Tina plain	El –Tina plain	1	0-30	7.0	187	150	2413	5400	150	--	1.6	4400	3717	8.60
			30-80	7.6	165	208	1457	2200	41	--	1.4	3300	605	1.42
			80-150	8.2	157	156	1177	2000	55	--	3.2	2800	585	1.9
		2	20-60	7.3	169	104	1086	2300	50	--	1.0	2700	839	1.4
			60-110	7.3	185	156	1511	3100	58	--	1.0	3400	1424	0.6
			110-150	8.3	143	156	1224	1700	43	--	2.4	2200	921	3.0
		3	10-20	7.1	182	156	1273	1400	48	--	1.8	2500	371	6.7
			20-80	8.2	145	156	1273	2400	74	--	2.4	3500	401	1.0
			80-150	8.3	189	156	1130	2400	82	--	3.2	3900	360	0.9
		4	0-8	7.0	219	156	796	4500	23	--	1.6	5000	473	2.0
			10-60	7.5	171	156	692	2300	34	--	1.8	3000	180	6.7
			60-90	8.1	110	208	558	1100	23	--	2.8	1600	187	2.6
			90-150	8.2	133	364	506	1500	30	--	2.8	2000	389	2.6
		5	0-10	7.0	192	156	1302	3700	63	--	2.2	5500	281	8.1
			10-40	7.6	139	313	987	1600	30	--	1.2	2300	628	9.6
			40-90	7.5	143	413	1401	1400	27	--	1.6	2000	1242	1.5
			90-150	7.7	142	521	1250	1500	27	--	2.0	2000	1296	1.5

Table(3) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	pH	E.C dS/m	Soluble ions in the soil saturation extract								Gypsum
						Cations (me / L)				Anions (me / L)				
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	%
El- Tina plain	El- Tina plain	6	0-10	7.0	201	156	2289	3400	71.0		2.0	5200	714	2.7
			10-40	7.3	193	150	2225	3800	53.0		0.8	4000	1573	0.6
			40-70	7.5	183	156	2225	3000	55.0		1.2	4300	1135	0.86
		7	0-10	79	104	156	1035	1400	14.0		1.2	1500	1104	2.6
			10-45	7.8	152	210	1695	2200	41.0		1.4	3500	645	0.8
			45-90	8.3	127	263	928	1600	32.0		1.6	2000	821	4.4
			90-150	7.0	206	263	1404	4700	55.0		1.0	4800	1621	2.1
		8	0-20	7.3	211	105	1038	4700	48.0		1.0	5500	390	4.6
			20-50	7.3	201	156	1749	3900	45.0		1.0	4300	1548	6.4
			50-100	7.7	169	105	1562	2500	43.0		1.6	3000	1208	0.5
		9	0-20	7.6	212	156	1035	4400	79.0		1.2	5300	369	4.0
			20-45	7.2	131	156	1035	1200	68.0		1.6	2300	157	0.8
			45-90	7.9	150	105	609	2300	48.0		1.6	2300	759	2.3
			90-150	8.1	122	105	1038	1500	41.0		2.6	2500	182	0.3
		10	0-35	7.0	176	105	1419	3200	68.0		1.0	4400	391	9.9
			35-85	7.6	156	105	1799	2100	39.0		1.0	4000	42	1.6
			85-150	7.5	142	263	594	1800	34.0		1.2	2900	90	0.8
		11	0-25	7.0	179	105	1640	3000	63.0		1.2	4500	277	8.7
			25-75	7.5	159	105	1085	2300	43.0		2.0	2500	1038	0.7
			75-150	7.7	130	156	1220	2400	30.0		1.8	3000	804	0.8

Data of chemical composition (Table 3) indicate that soil reaction is neutral to moderately alkaline; and pH values ranged from 7.0 to 8.3. The soils are extremely saline as indicated by EC which ranges from 110 to 219 dS/m . The formation and accumulation of salts in these soils, in general, may be due to a possible seepage of saline water from Suez Canal and/or the Mediterranean sea to the ground water of this area. There was also a pattern of increased soluble salts towards the uppermost layers of profiles especially in the surface layers which is expected under the present arid conditions.

With regard to the analysis of saturation extract, table(3) shows that Na^+ is dominated the soluble cations followed by Mg^{++} then, Ca^{++}, while K^+ is the least abundant. The anionic composition usually follows the order $Cl^- > SO_4^{--} > HCO_3^-$. The presence of very high contents of Na^+ and Cl ions suggests the presence of high contents of NaCl which indicates , lacustrine-lagonal or even marine contribution to such sediments.

Gypsum content is considerably high, ranged from 0.3 to 9.9% with no specific distribution pattern throughout the depth of profiles. Presence of high values of gypsum content in the soils may be mainly attributed to the precipitation from the enriched underground water table by SO_4^{--} ions. Another mechanism describes gypsum accumulation especially in top profile layer is evaporation from shallow saline water that seep in the adjacent lake lands such as Manzala lake.

The following is morphological descriptions of the representative soil profiles of El-Tina plain.

Profile No.: 1

Location : El-Tina plain

Elevation : About 0.5 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) **Description**

0—5 Salt crust

5—30: Gray (10YR 6/1, dry) to gray (10YR 5/1,moist) sandy clay loam; weak coarse anglar blocky; sticky; plastic; very firm many salt crystals; non calcareous; clear smooth boundary;

30—80 :Dark brown (10YR 4/1; dry) to dark brown (10YR 3/3, moist) clay; weak coarse anglar blocky; very sticky; very plastic; very firm; many salt crystals; non-calcareous; diffuse smooth boundry,

80—150 :Dark brown (10YR 4/3; dry) to very dark grayish brown (10YR 3/2, moist) clay; weak coarse anglar blocky; very sticky; very plastic; very firm; many salt crystals; noncalcareous.

Profile No.: 2

Location : El-Tina plain

Elevation : About 0.5 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) : Description

0—20 Salt crust

20—60 Gray (10YR 5/1, dry) to dark gray(10YR 4/1,moist) clay; weak coarse anglar blocky; very sticky, very plastic; very firm many salt crystals; non calcareous; clear smooth boundary;

60—110 Gray (10YR 5/1, dry) to dark gray (10YR 4/1,moist) clay; weak coarse anglar blocky; very sticky, very plastic; very firm many salt crystals; non calcareous; diffuse smooth boundary;

110—150 Brown (10YR 5/3;dry) to dark brown (10YR 3/3,moist) clay; weak coarse anglar blocky; very sticky very plastic; very firm; many salt crystals; noncalcareous.

Profile No.: 3

Location : El-Tina plain

Elevation : About 0.5 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 125 cm deep

Depth (cm) : Description

0—10 : Salt crust

10—25 Brown (10YR 5/3, dry) to dark brown(10YR3/3,moist)clay; weak coarse anglar blocky; very sticky, very plastic; very firm; non calcareous; diffuse smooth boundary;

25—80 Dark brown (10YR 3/3, dry) to very dark gray (10YR 3/1,moist) clay ; weak coarse anglar blocky, very sticky, very plastic; very firm; non calcareous; clear smooth boundary,

80—125 Brown (10YR 5/3;dry) to dark brown(10YR 3/3,moist) clay; weak coarse anglar blocky; very sticky; very plastic; very firm; non calcareous.

Profile No.: 4

Location : El-Tina plain

Elevation : About 1.0 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm)	**Description**
0—8	Gray (10YR 5/1, dry) to dark gray(10YR 4/1,moist) sandy clay loam ; weak coarse subanglar blocky, moderately sticky; moderately plastic; hard; many salt crystals; non calcareous; clear smooth boundary,
8—10	Salt crust
10—60	Gray (10YR5/1,dry) to dark grayish brown (10YR4/2,moist) sandy clay loam; weak coarse subanglar blocky, moderately sticky; moderately plastic; firm; many salt crystals; non calcareous; clear smooth boundary,
60—90	Very pale brown (10YR 7/4;dry) to brown (10YR5/3,moist) sandy loam; single grains; slightly sticky; slightly plastic; loose; non calcareous; clear smooth boundary;
90—150	Very pale brown (10YR 7/4;dry) to dark brown (10YR4/3,moist) loamy sand; single grains; non sticky; non plastic; loose; many salt crystals; non calcareous.

Profile No.: 5

Location : El-Tina plain

Elevation : About 0.30 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) : Description

0—10 Brown (10YR 5/3, dry) to dark brown(10YR3/3,moist) sandy clay loam; massive; hard; moderately sticky; moderately plastic; many soft $CaSO_4$ crystals ;calcareous; clear smooth boundary,

10—40 Dark brown (10YR 4/3, dry) to dark gray (10YR 4/1,moist) clay ; weak coarse anglar blocky, very sticky, very plastic; very firm; many soft $CaSO_4$ crystals; moderately calcareous; diffuse smooth boundary;

40—90 Dark brown (10YR 4/3;dry) to very dark gray (10YR 3/1,moist) clay; weak coarse anglar blocky; very sticky very plastic; very firm; ; many soft CaSO 4 crystals; moderately calcareous; clear smooth boundary;

90—150 Yellowish brown (10YR5/6;dry) to brown (10YR 5/3;moist) sandy clay loam; weak coarse subanglar blocky; moderately sticky; moderately plastic; loose; non calcareous.

Profile No.: 6

Location : El-Tina plain

Elevation : About 0.30m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : At 70 cm deep

Depth (cm) : Description

0—10 Brown (10YR 5/3, dry) to dark brown(10YR3/3,moist) sandy clay loam; weak coarse subanglar blocky; moderately sticky; moderately plastic; firm; non calcareous; clear smooth boundary,

10—40 Dark brown (10YR 4/3, dry) to dark gray (10YR 4/1,moist) clay ; weak coarse subanglar blocky, very sticky, very plastic; firm; non calcareous; clear smooth boundary,

40—70 Brown (10YR 5/3;dry) to dark gray (10YR 4/1,moist) clay; weak coarse subanglar blocky; very sticky very plastic; firm; non calcareous;

70cm : Water table.

Profile No.: 7

Location : El-Tina plain

Elevation : About 0.70m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) : Description

0—10 yellowish brown (10YR 5/6, dry) to dark yellowish (10YR 3/6,moist) sandy loam ; massive; slightly sticky; slightly plastic; hard; non calcareous; clear smooth boundary;

10—45 yellow (10YR 7/6, dry) to brownish yellow (10YR6/6,moist) sandy loam; single grains; slightly sticky; slightly plastic; loose; non calcareous; clear smooth boundary;

45—90 Brown(10YR4/3;dry)to dark brown (10YR3/3,moist)sandy; single grains; non sticky; non plastic; hard non calcareous; clear smooth boundary,

90—150 Yellow (10YR 7/6;dry) to brownish yellow (10YR6/6,moist) sandy loam; single grains; slightly sticky; slightly plastic; loose; non calcareous;

Profile No.: 8

Location : El-Tina plain

Elevation : About0.30 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : At 100 cm depth

Depth (cm)	**Description**
0—20	Brown (10YR 5/3, dry) to dark brown(10YR3/3,moist) sandy clay; weak coarse subanglar blocky; less sticky; plastic; very firm; non calcareous; diffuse smooth boundary;
20—50	Dark brown (10YR 3/3, dry) to very dark gray (10YR 3/1,moist) clay; weak coarse subanglar blocky, very sticky, very plastic; very firm; many soft $CaCO_3$ concretions; many $CaSO_4$ crystals; non calcareous; clear smooth boundary,
50—100	Brown (10YR 5/3;dry) to dark gray (10YR 4/1,moist) clay; weak coarse subanglar blocky; very sticky very plastic; very firm; non calcareous.

Profile No.: 9

Location : El-Tina plain

Elevation : About 0.40m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) : Description

0—20 Light brown (10YR 6/2, dry) to dark gray (10YR 4/1,moist) sandy clay loam ; weak coarse subanglar blocky; moderately sticky; moderately plastic; hard; many soft and hard $CaCO_3$ concretions; many soft and hard $CaSO_4$ crystals; slightly calcareous; clear smooth boundary,

20—45 Brown(10YR 4/3, dry) to very dark gray (10YR3/1,moist) clay; weak coarse subanglar blocky; very sticky; very plastic; firm; many soft $CaCO_3$ concretions; many soft $CaSO_4$ crystals; slightly calcareous; clear smooth boundary,

45—90 Brownish yellow(10YR6/6;dry)to pale (10YR6/3,moist)sandy clay loam; weak coarse subanglar blocky; moderately sticky; moderately plastic; friable; many soft $CaCO_3$ concretions; skightly calcareous; clear smooth boundary;

90—150 Yellow (10YR 7/6;dry) to yellow brownish (10YR6/6,moist) sandy loam ; single grains; slightly sticky; slightly plastic; loose; non calcareous.

Profile No.: 10

Location : El-Tina plain

Elevation : About 0.70 m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) : Description

0—35 Brown (10YR 5/3, dry) to dark brown (10YR 3/3,moist) sandy clay weak coarse subanglar blocky; sticky; plastic; firm; many soft and hard $CaCO_3$ concretions; many soft and hard $CaSO_4$ crystals; slightly calcareous; clear smooth boundary,

35—85 Dark brown(10YR 3/3, dry) to very dark gray (10YR3/1,moist) clay; weak coarse subanglar blocky; very sticky; very plastic very firm, few $CaSO_4$ crystals; skightly calcareous; diffuse smooth boundary,

85—150 Dark brown(10YR4/3;dry)to dark gray(10YR4/1,moist) clay; weak coarse anglar blocky; very sticky; very plastic; firm; few $CaSO_4$ crystals; slightly calcareous;

Profile No.: 11

Location : El-Tina plain

Elevation : About 0.20m.a.s.l.

Geomorphic unit : plain

Slope : Almost flat

Vegetation : None

Surface cover : Salt crust

Water table : More than 150 cm deep

Depth (cm) : Description

0—25. Brownish yellow (10YR 6/6, dry) to pale brown(10YR 6/3,moist) sandy clay loam ; weak coarse subanglar blocky; moderately sticky; moderately plastic; very firm; many soft $CaCO_3$ concretions; many soft $CaSO_4$ crystals; slightly calcareous; clear smooth boundary,

25—75 Brown (10YR 5/3, dray) to dark gray (10YR 4/1,moist) clay; weak coarse subanglar blocky; very sticky; very plastic; firm; few soft $CaCO_3$ concretions; slightly calcareous; clear smooth boundary,

75—150 Brown (10YR 4/3;dry)to dark brown (10YR 3/3,moist) clay ; weak coarse subanglar blocky; very sticky; very plastic; very firm; few soft $CaCO_3$ concretions; slightly calcareous.

4.1.2-Soils of the elevated sand dunes plain

This geomorphic unit is represented by profiles 12,13,14 and 15 and occupies relatively higher elevations than that of El-Tina plain.
Soil of this unit could be divided into three land types, a)- sand flat, b)- low inland dunes and, c)- hummocks. Soils of the sand flat are almost flat, coarse in texture, slightly calcareous and covered in some places with a thin salt crust, halophites are scattered in several places. In the inland dunes areas, the soils are slightly calcareous, moderately saline and cover a relatively rough area in south El-Tina plain. Hummocks covered with dense vegetation are common in the southeastern part of El-Tina plain. The soils constitute sediments of coarse texture. The morphological features identified within profiles depth are soft spots of lime.

Soil structure is single grains to massive. Soil colour ranges from brownish yellow (10YR 6/6) and yellow (10YR 8/8) when dry to yellowish brown (10YR 5/4) and yellow (10YR 7/6) when moist.

The analytical data of soil profiles representing this geomrphic unit are given in tables 4 and 5. The data show that soil texture is sandy except for profile 15 which has an almost unique texture dominated by sandy loam throughout the profile depths.

Calcium carbonate content varies between 1.8 % and 6.6 %. Data indicate no specific pattern of $CaCO_3$ distribution along the profile depth except for profiles 12 and 15 which display a tendency of $CaCO_3$ decrease with depth.

Table (4) Particle size distribution, textural class, $CaCO_3$ and O.M Content of the studied soil profiles.

Location	Geomorphic unit	Prof.No.	Depth (cm)	Particle size distribution C.S %	F.S %	Silt %	Clay %	Textural Class	$CaCO_3$ %	O.M %
El-Tina plain	Elevated sand dunes	12	0-30	88.2	4.9	2.9	4.2	Sand	4.4	0.2
			30-70	89.9	4.5	2.4	3.2	Sand	2.6	0.1
			70-150	89.4	3.8	2.7	4.0	Sand	2.6	0.1
		13	0-30	90.0	5.0	2.2	2.5	Sand	3.1	0.05
			30-65	96.0	1.4	0.9	1.7	Sand	3.5	0.1
			65-150	93.6	4.1	0.4	1.9	Sand	3.1	0.1
		14	0-20	81.4	16.7	0.6	2.3	Sand	6.1	0.1
			20-70	84.7	11.4	1.2	2.7	Sand	5.3	0.1
			70-150	86.4	9.3	1.1	3.2	Sand	6.6	0.1
		15	0-15	54.7	30.6	2.2	12.3	Sandy loam	4.4	0.2
			15-55	73.7	19.5	1.5	5.3	Sandy loam	2.2	0.1
			55-100	60.8	29.5	3.2	6.5	Sandy loam	1.8	0.1
			100-150	58.8	34.1	1.8	5.3	Sandy loam	1.8	0.1

Table (5) Chemical composition of the soil saturation extract and gypsum content of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	pH	E.C dS/m	Soluble ions in the soil saturation extract								Gypsum %
						Cations (me / L)				Anions (me / L)				
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	
El- Tina plain	Elevated sand dunes	12	0-30	8.2	1.0	3.2	2.9	3.5	0.5		2.0	3.0	5.1	0.13
			30-70	8.1	1.3	4.1	3.5	5.0	0.4		1.2	4.0	7.8	0.17
			70-150	8.0	1.1	3.1	2.9	4.6	0.4		0.2	4.2	6.6	0.22
		13	0-30	7.9	0.4	1.2	0.6	2.8	0.3		0.6	2.0	2.3	0.13
			30-65	8.2	1.0	2.6	2.1	5.1	0.6		2.2	5.0	3.2	0.17
			65-150	8.1	0.4	1.2	0.5	3.1	0.2		0.8	2.2	2.0	0.24
		14	0-20	7.6	0.5	1.2	1.0	2.3	0.3		1.0	2.9	0.9	0.18
			20-70	7.9	0.5	1.0	0.8	2.6	0.2		1.0	2.9	0.7	0.18
			70-150	7.8	0.9	0.8	0.7	0.9	0.3		0.6	1.4	0.7	0.23
		15	0-15	7.7	0.9	2.4	2.2	4.2	0.4		2.2	2.8	4.2	0.18
			15-55	7.9	0.7	1.6	0.6	4.1	0.2		1.7	2.2	2.6	0.21
			55-100	8.1	1.0	3.6	2.1	4.1	0.2		0.8	4.0	5.2	0.23
			100-150	7.8	1.4	1.8	1.0	12.1	0.2		1.4	11.0	3.4	0.28

Pofile No.: 15

Location : El-Tina plain

Elevation : About 4.0m.a.s.l.

Geomorphic unit : Elevated sand dunes plain

Slope :Gentelly undulating

Vegetation : Few scattered desert shrubs.

Surface cover : Sand dunes

Water table : More than 150 cm deep

Depth (cm) : Description

0—15 Brownish yellow (10YR 6/8, dry) to yellowish brown (10YR 5/6,moist) sandy loam; single grains; loose; slightly sticky; slightly plastic; few fine roots; slightly calcareous; clear smooth boundary,

15—55 Brownish yellow (10YR6/8,dry) to yellowish brown (10YR5/6,moist) sandy loam; single grains; loose; slightly sticky; slightly plastic; slightly calcareous; diffuse smooth boundary,

55—100 Brownish yellow (10YR 6/6;dry)to yellowish brown(10YR 5/4,moist)sandy loam; massive; soft; slightly sticky; slightly plastic; non calcareous; diffuse smooth boundary,

100—150 Yellow (10YR 7/6,dry) to yellowish brown(10YR 5/4, moist) sandy loam; massive; soft; slightly sticky; slightly plastic; non calcareous.

4.1.3-Soil of El-Qaa plain

El-Qaa plain is situated in the southwestern part of Sinai peninsula and it slopes from north to south and from east to west direction, with an elevation ranging between 0.0 and 200 m above sea level. The plain is open towards the Gulf of Suez south of El-Tor. The main geomorphic unit in El-Qaa plain are: 1) Wadis 2) alluvial fan and, 3) coastal plain.

4.1.3.1-Soils of the wadis

This geomorphic unit is represented by profiles 16, 17 and 18 and it occupies the largest part of El-Qaa plain. Soils of this unit are mostly located near the mountainous areas on the eastern and western sides. The surface is mainly covered with coarse-grained deposits with some boulders and cobbles transported from the mountainous areas. Soil colour ranges between yellow (10YR 7/6) and light yellowish brown (10YR 6/4) when dry and pale brown (10YR 6/3) and brown (10YR 5/3) when moist.

The analytical data of soil profiles representing this geomorphic unit are given in Tables 6 and 7. These data show that texture of soils of this unit is variable from sand to silty clay with the sand fraction ranging between 42 and 96.4%. Calcium carbonate content ranges from 6.8 to 39.2% indicating a highly calcareous nature of soils. High carbonate contents reflects the influence of parent material on the formation of these soils. Organic matter content is low, not exceeding 0.4%, reflecting the hyper-arid climatic conditions of the area and the absence of vegetation cover.

Data in Table 7 show that the soil is mildly alkaline, as indicated by pH values which ranges from 7.6 to 8.0. Electrical conductivity

Table (6) Particle size distribution, textural class, $CaCO_3$ and O.M content of the studied soil profiles .

Location	Geomorphic unit	Prof. No.	Depth (cm)	Particle size distribution C.S %	F.S %	Silt %	Clay %	Textural Class	$CaCO_3$ %	O.M %
El- Qaa plain	wadis	16	0-12	40.0	45.3	7.0	7.7	Sand	7.3	0.20
			12-30	41.8	44.5	8.0	5.7	Sand	9.3	0.12
			30-40	45.5	40.8	6.0	3.7	Sand	9.6	0.10
			40-75	39.6	44.7	10.0	5.7	Sand	9.2	0.10
			75-150	38.1	41.2	12.0	8.7	Sand	0.2	0.09
		17	0-10	6.5	15.5	47.0	31.0	Silty clay	30.2	0.40
			10-40	5.9	66.8	22.7	4.6	S. Loam	24.0	0.10
			40-80	27.3	58.9	10.3	3.5	Loamy.S	24.0	0.10
			80-120	57.3	38.0	3.5	1.2	Sand	38.0	0.03
			120-150	52.9	43.5	2.3	1.3	Sand	39.2	0.04
		18	0-10	24.7	55.6	4.1	15.6	Loamy.S	17.9	0.20
			10-60	35.7	54.6	2.0	7.7	Sand	14.8	0.12
			60-150	33.4	52.9	4.0	9.7	Loamy.S	14.2	0.07

Table (7) Chemical composition of the soil saturation extract and gypsum content of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	pH	E.C dS/m	Soluble ions in the soil saturation extract								Gypsum %
						Cations (me / L)				Anions (me / L)				
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
El – Qaa plain	Wadis	16	0-12	7.9	0.65	2.1	5.0	2.3	0.8		2.0	2.0	6.15	0.50
			12-30	8.0	1.6	4.2	7.7	8.9	1.3		2.2	4.0	13.3	0.30
			30-40	7.8	3.1	8.3	6.0	17.8	1.7		1.8	11.0	20.9	0.30
			40-75	7.8	5.7	26.0	12.1	22.0	2.5		4.0	21.0	37.6	0.40
			75-150	7.8	5.0	31.3	10.6	18.2	1.9		1.2	20.0	40.8	0.40
		17	0-10	7.9	32.5	72.3	51.6	201.0	2.2		4.9	278.3	41.7	0.18
			10-40	7.6	20.8	56.0	32.0	118.6	1.5		4.7	136.6	40.0	0.26
			40-80	7.6	12.4	25.9	18.2	79.5	0.5		3.7	85.2	35.7	0.20
			80-120	8.0	4.0	23.9	6.0	12.6	0.1		6.2	13.0	80.6	0.08
			120-150	7.7	1.8	12.3	3.3	3.5	0.1		3.1	3.5	11.5	0.73
		18	0-10	7.7	19.6	52.1	43.1	186.5	1.3		1.6	170.0	108.4	1.90
			10-60	7.7	28.8	62.5	56.6	265.0	1.2		1.4	265.0	117.7	5.50
			60-150	7.9	29.8	72.9	39.0	300.0	1.3		2.0	267.0	144.2	4.50

ranges from 0.65 to 32.5 dS/m . These values indicate that the profile 16 and the deepest layers of profile 18 have non-saline to slightly saline soils, while profile 17 and the uppermost layers of profile 18 have extremely saline soils.

Soluble cations in profile 17 and the uppermost surface layers of profiles 16 and 18.are dominated by Na^{+}, followed by Ca^{++} then Mg^{++}, while K^{+} ions are the least abundant among soluble cations. On the other hand, Ca^{++} ions dominate soluble cations in the deepest layer of profiles 16 and 18 followed by Na^{+}.

Soluble anions in profiles 16 and the deepest layers of profile 18, are characterized by the dominance of $SO_4^{=}$ followed by Cl^{-} then HCO_3^{-} . In profile 17 and the uppermost surface layers of profile 18 the anions follow the order $Cl^{-} > SO_4^{=} > HCO_3^{-}$.

Gypsum content ranges between 0.08% and 5.5 % with an irregular distribution pattern with depth.

Profile No.: 16

Location : El-Qaa plain

Elevation : About 29m.a.s.l.

Geomorphic unit : Wadi

Slope :Gentelly undulating

Vegetation : Few scattered desert shrubs.

Surface cover : Many fine to coarse gravels and few boulders

Water table : More than 150 cm in depth

Depth (cm) : Description

0—12 Brownish yellow(10YR 6/6, dry) to pale brown (10YR 6/3,moist) sand ; single grains; loose; non sticky; non plastic; few soft lime concretions; slightly calcareous; clear smooth boundary,

12—30 Brownish yellow (10YR 6/6, dry) to pale brown (10YR6/3,moist) sand; single grains; loose; non sticky; non-plastic; moderate soft lime concretions; moderately calcareous; clear smooth boundary,

30—40 Brownish yellow (10YR 6/8;dry)to yellowish brown(10YR 5/8,moist)sand ; massive; soft; moderate soft lime concretions; moderately calcareous; diffuse smooth boundary,

40—75 Brownish yellow (10YR 6/8,dry) to pale brown (10YR 6/3, moist) sandy; massive; slightly hard; non sticky; non plastic; moderate soft and hard lime concretions; moderately calcareous; diffuse smooth boundary;

75—150 Brownish yellow (10YR 6/8,dry) to brown (10YR 5/3, moist) sandy; massive; hard; non sticky; non plastic; few soft lime concretions; slightly calcareous.

Profile No.: 17

Location : El-Qaa plain

Elevation : About 35m.a.s.l.

Geomorphic unit : Wadi

Slope :Gentelly undulating

Vegetation : Few scattered desert shrubs in the depressions.

Surface cover: Many fine gravels and few stones.

Water table : More than 150 cm in depth

Depth (cm) : Description

0—10 Very pale brown(10YR 7/3, dry) to pale brown (10YR 6/3,moist) silty clay ; massive; soft; sticky; plastic; many soft and hard lime concretions; many fine to coarse roots; strongly calcareous ; clear smooth boundary,

10—40 yellow (10YR 7/6, dry) to yellowish brown (10YR5/6,moist) sandy loam; massive; soft; slightly sticky; slightly plastic; many soft and hard lime concretions; strongly calcareous; clear smooth boundary,

40—80 Brownish yellow (10YR6/6;dry) to yellowish brown (10YR 5/4,moist) loamy sand ; massive; slightly hard; non sticky; non plastic many soft and hard lime concretions; strongly calcareous; clear smooth boundary, 80—120 Yellow (10YR 7/6,dry) to yellowish brown (10YR 5/4, moist) sand; massive; slightly hard; non sticky; non plastic; many soft and hard lime concretions; strongly calcareous; diffuse smooth boundary,

120—150 Yellow (10YR 7/8,dry) to yellowish brown (10YR 5/6, moist) sand; massive; hard; non-sticky; non-plastic; many soft and hard lime concretions; strongly calcareous.

Profile No.: 18

Location : El-Qaa plain

Elevation : About 20m.a.s.l.

Geomorphic unit : Wadi

Slope : undulating

Vegetation : Few scattered desert shrubs

Surface cover: Many fine to coarse gravels and few stones.

Water table : More than 150 cm in depth

Depth (cm) : Description

0—10 Very pale brown(10YR 7/4, dry) to pale brown (10YR 6/3,moist)loamy sand ; single grains; loose; slightly sticky; slightly plastic; many soft and powder lime concretions; strongly calcareous ; clear smooth boundary,

10—60 Very pal brown(10YR 7/3, dry) to pale brown(10YR6/3,moist)sand; massive; soft; non sticky; non plastic; many soft and hard lime concretions; strongly calcareous; clear smooth boundary, 60—150 Light yellowish brown (10YR 6/4;dry)to brown (10YR 5/3,moist) loamy sand ; massive; slightly hard; slightly sticky; slightly plastic; many soft and hard lime concretions; strongly calcareous.

4.1.3.2-Soils of the alluvial fan

The alluvial fan soils, represented by profiles 19 and 20 occupy large area of Qaa plain. The surface is undulating, barren from natural vegetation, characterized by narrow vertical and lateral cracks. The field observations and the analytical data in Tables 8 and 9 indicate that, those soils are mainly formed from alluvial origin. The soils are deep. Soil colour range between yellow (10 YR 8/6) and pale brown (10YR 6/3) when dry and pale brown (10YR 7/3) and grayish brown (10YR 5/3) when moist. The soils have coarser texture ranging from sand to loamy sand. Calcium carbonate content varies widely between 1.7 and 10.3 %. In profile 19, data indicate no specific pattern of $CaCO_3$ distribution throughout the profile depth, while in profile 20, $CaCO_3$ displays a tendency to increase with depth. Organic matter content is extremely low, not exceeding 0.04% owing to the prevailing aridity since the high temperature and dry climate encourage rapid decomposition of organic matter.

Soils are mildly alkaline, as indicated by their pH values which range from 7.5 to 8.0. Also, data show that the electrical conductivity (EC) ranges from 0.3 to 0.7 dS/m, indicating non-saline soils.

Soluble cations are dominated by Ca^{++}, followed by Na^{+} then Mg^{++} while K^{+} ions are the least abundant of soluble cations. With

Table (8) Particle size distribution, textural class, $CaCO_3$ and O.M content of the studied soil profiles .

location	Geom-orphic unit	Prof. No.	Depth (cm)	Particle size distribution C.S %	F.S %	Silt %	Clay %	Textural Class	$CaCO_3$ %	O.M %
El-Qaa plain	Alluvial fan	19	0-30	64.3	19.0	12.2	4.5	Loamy sand	4.1	0.04
			30-80	59.7	13.9	19.2	7.2	Loamy sand	10.3	0.02
			80-120	66.7	13.6	15.0	4.7	Loamy sand	7.2	0.01
			120-150	68.5	18.2	10.3	3.0	Sand	2.9	0.01
		20	0-20	78.2	17.9	2.7	1.2	Sand	1.7	0.02
			20-70	72.6	22.3	4.7	0.7	Sand	1.9	0.02
			70-110	78.3	13.3	6.7	1.7	Sand	2.1	0.03
			110-150	71.1	24.3	4.1	0.5	Sand	2.3	0.02

Table (9) Chemical composition of the soil saturation extract and gypsum content of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	pH	E.C dS/m	Soluble ions in the soil saturation extract								Gypsum %
						Cations (me / L)				Anions (meq / L)				
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	
El- Qaa plain	Alluvial Fain	19	0-30	7.8	0.4	2.8	0.6	0.9	0.3		3.4	1.3	0.3	0.3
			30-80	7.7	0.3	1.6	0.5	1.0	0.5		1.8	1.0	0.2	0.4
			80-120	7.9	0.5	2.8	2.8	1.7	0.4		3.5	1.1	0.4	0.7
			120-150	7.9	0.4	1.5	1.5	1.7	0.3		2.5	1.2	0.3	0.7
		20	0-30	7.5	0.7	3.2	0.8	1.4	0.5		0.9	1.1	5.0	0.1
			30-80	8.0	0.4	2.5	0.5	0.7	0.3		2.4	1.0	0.2	0.2
			80-120	7.8	0.4	2.3	0.5	0.7	0.2		1.1	1.4	1.6	0.2
			120-150	7.9	0.5	2.5	1.1	1.0	0.3		2.1	1.2	1.2	0.4

regard to the anions composition, data show that HCO_3^- dominates anions, followed by Cl^- then $SO_4^=$, while $CO_3^=$ is entirely absent in all profiles.

Gypsum content is low and ranges from 0.1 to 0.7% with a tendency of increase down the soil profile.

Profile No.: 19

Location : El-Qaa plain

Elevation : About 40m.a.s.l.

Geomorphic unit : Alluvial fan

Slope :Gentely undulating

Vegetation : Many desert shrubs.

Surface cover : Many fine to coarse gravels and few Stones.

Water table : More than 150 cm in depth

Depth (cm)	**Description**
0—30	Very pale brown(10YR 8/3, dry) to pale brown (10YR 6/3,moist)loamy sand, single grains; loose; slightly sticky; slightly plastic; very few soft lime concretions; slightly calcareous; clear smooth boundary,
30—80	Very pale brown(10YR 8/3, dry) to pale brown(10YR6/3,moist) loamy sand; massive; soft; slightly sticky; slightly plastic; moderate soft and hard lime concretions; moderately calcareous; clear smooth boundary,
80—120	Pale brown (10YR 6/3;dry) to grayish brown (10YR 5/2,moist) loamy sand; massive; slightly hard; slightly sticky; slightly plastic; few soft lime concretions; slightly calcareous; clear smooth boundary,
120—150	Yellow (10YR 7/6,dry) to very pale brown (10YR 7/3, moist) sand; massive; soft; non sticky; non plastic; non calcareous.

Profile No.: 20

Location : El-Qaa plain

Elevation : About 24m.a.s.l.

Geomorphic unit : Alluvial fan

Slope :Almost flat

Vegetation : Few scattered desert shrubs.

Surface cover : Many fine to coarse gravels and many boulders.

Water table : More than 150 cm in depth

Depth (cm) : Description

0—20 Yellow (10YR 7/6, dry) to brownish yellow (10YR 6/8,moist) sand; single grains; loose; non-sticky; non-plastic; non calcareous; clear smooth boundary,

20—70 Yellow (10YR7/8,dry) to yellowish brown(10YR6/8,moist) sand; massive; soft; non sticky; non plastic; non calcareous; diffuse smooth boundary,

70—110 Yellow (10YR7/6;dry) to yellowish brown (10YR 5/6,moist) sand; massive; slightly hard; non-sticky; non-plastic; non calcareous; diffuse smooth boundary,

110—150 Yellow (10YR 8/6,dry) to pale brown (10YR 6/3, moist) sand; massive; hard; non-sticky; non-plastic; non-calcareous.

4.1.3.3-Soils of the coastal plain

This geomorphic unit is represented by two profiles (Nos. 21and 22) in south El-Tor and occupies the coastal strip of the Gulf of Suez. Topography is almost flat and the surface slope is gently sloping to the west. The in situ examination of these soil profiles shows that profiles 21 and 22 are deep. Soil colour ranges from yellow (10YR 8/6) to brownish yellow (10YR 5/6) when dry and from brown (10YR 5/3) to brownish yellow (10YR 6/3) when moist.

The analytical data of soil profiles representing this geomorphic unit are given in Tables 10 and 11. These data show that texture is loam in the top layer and changes into loamy sand and sandy loam in the deepest layer in profile 21, while profile 22 is sandy textured throughout.

Calcium carbonate content ranges from 3.5% to 38.1% . The vertical distribution of $CaCO_3$ does not portray any specific pattern with depth. Organic matter content is extremely low, not exceeding 0.1%.

With regard to the analytical data of soil profiles representing this geomorphic unit, the soil is mildly alkaline as indicated by pH values which range from 7.5 to 8.0, while the electrical conductivity of the soil saturation extract ranges from 3.2 to 33.4 dS/m, indicating that the soils range from non saline to extremely saline.

Data of soluble cations show a dominance of Na^+ followed by Ca^{++} then Mg^{++}, while K^+ is the least abundant among soluble cations. Considering the anionic composition of soluble salts, data show that the dominant anions are Cl^- followed by $SO_4^=$ then HCO_3^-.

Gypsum content is very low and ranges from 0.2 to 0.8% with an irregular distribution pattern with depth.

Table (10) Particle size distribution, textural class, $CaCO_3$ and O.M content of the studied soil profiles .

Location	Geomorphic unit	Prof. No.	Depth (cm)	Particle size distribution C.S %	F.S %	Silt %	Clay %	Textural class	$CaCO_3$ %	O.M %
El-Qaa plain	Coastal plain	21	0-25	11.2	43.9	37.0	7.9	Loamy	38.1	0.02
			25-65	17.5	68.5	10.6	3.4	Loamy. S	26.5	0.10
			65-100	12.8	68.8	16.6	1.8	Sandy .L	32.8	0.05
			100-120	2.9	65.8	28.0	3.3	Sandy .L	3.5	0.02
		22	0-30	27.4	66.6	4.6	1.4	Sand	9.5	0.05
			30-70	20.8	73.8	4.2	1.2	Sand	8.2	0.03
			70-120	68.0	29.0	2.0	1.0	Sand	5.4	0.03
			120-140	58.0	34.0	6.5	1.5	Sand	5.6	0.05

Table (11) Chemical composition of the soil saturation extract and gypsum content of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	pH	E.C dS/m	Soluble ions in the soil saturation extract: Cations (me / L)				Anions (me / L)				Gypsum
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	%
El-Qaa plain	Costal plain	21	0-25	7.9	3.2	16.6	6.1	8.4	0.9		3.4	6.6	21.9	0.2
			25-65	7.5	11.2	42.0	17.6	51.6	2.2		1.7	88.2	22.4	0.2
			65-100	7.7	13.8	38.5	22.7	76.0	1.9		4.7	110.0	23.3	0.8
			100-120	7.8	24.0	23.6	23.2	191.0	1.3		10.0	124.0	111.5	0.2
		22	0-30	7.7	5.0	5.9	2.0	40.0	1.3		3.2	39.3	7.5	0.80
			30-70	7.8	14.5	17.3	9.8	115.4	2.9		6.6	123.4	15.0	0.76
			70-120	8.0	18.2	53.0	36.3	89.7	3.3		8.9	151.2	21.9	0.76
			120-140	7.9	33.4	46.3	35.5	248.3	4.2		5.8	308.0	21.4	0.01

Profile No.: 21

Location : El-Qaa plain

Elevation : About 1.5m.a.s.l.

Geomorphic unit : Coastal plain

Slope :Gently sloping

Vegetation : Few scattered desert shrubs.

Surface cover : Sand dunes and very fine gravels

Water table : At 120 cm depth

Depth (cm) : Description

0—25 Very pale brown(10YR 8/3, dry) to pale brown(10YR 6/3,moist) loam; single grains; loose; moderately sticky; moderately plastic; many soft and hard lime concretions; strongly calcareous; clear smooth boundary,

25—65 Yellow(10YR 7/6, dry) to brownish yellow (10YR5/6,moist) loamy sand; massive; soft; slightly sticky; slightly plastic; many soft and hard lime concretions; strongly calcareous; clear smooth boundary,

65—100 Brownish Yellow (10YR 6/6;dry) to brown (10YR 5/3,moist) sandy loam; massive; soft; moderately sticky; moderately plastic; many soft and hard lime concretions; strongly calcareous; clear smooth boundary,

100—120 Brownish yellow (10YR 6/6,dry) to yellowish brown (10YR 5/4, moist) sandy loam; massive; slightly hard; moderately sticky; moderately plastic; very few soft lime concretions; slightly calcareous.

Profile No.: 22

Location : El-Qaa plain

Elevation : About 1.0m.a.s.l.

Geomorphic unit : Coastal plain

Slope :Gently undulating

Vegetation : Few scattered desert shrubs.

Surface cover : Sand dunes and very fine gravels

Water table : At 140 cm depth

Depth (cm) : Description

0—30 Yellow(10YR 7/8, dry) to brownish yellow (10YR 6/6,moist) sand; single grains; loose; non sticky; non plastic; moderately soft and hard lime concretions; few fine roots; moderately calcareous; clear smooth boundary,

30—70 yellow(10YR 7/6, dry) to yellowish brown (10YR5/6,moist) sand; massive; soft; non sticky; non plastic; moderate soft and hard lime concretions; very few fine roots; moderately calcareous; diffuse smooth boundary;

70—120 Yellow (10YR 7/6;dry)to yellowish brown (10YR 5/6,moist) sand ; massive; slightly hard; non sticky; non plastic; few soft lime concretions; slightly calcareous; diffuse smooth boundary,

120—140 yellow (10YR 8/6,dry) to yellowish brown (10YR 5/8, moist) sand; massive; hard; non-sticky; non-plastic; very few soft lime concretions; slightly calcareous.

4.2.-Cation exchange capacity and exchangeable cations:

1- Cation exchange capacity (C.E.C)

The ion exchange properties of soil are, generally, considered to be related entirely to clay, fine silt fraction, colloidal organic matter and mineralogical composition, Wicklander (1964). The results of the cation exchange capacity and the exchangeable cations of the studied soils are given in Table (12). The data indicate that the soil profiles representing the soil of El-Tina plain (profiles 1 to 11) have cation exchange capacity, varying between 16.5 and 53.2 me/100g soil. The lowest value characterizes the subsurface layer of profile 7 which represents the lighter texture (sandy loam) and has a relatively low content of clay, while the highest value is that of the 20—50 cm depth of profile 8 which is clay in texture, and has a relatively high content of clay.

Soils of elevated sand dunes which are represented by profiles 12,13,14,and 15 display C.E.C values in the narrow limits and in the range of 2.7—6.8 me /100g soil. This is attributed to their light texture which is sand or loamy sand with very few, if any, content of colloidal particles.

With regard to the soils of El-Qaa plain, the present data reveal that C.E.C. ranges between 1.5 and 9.8 me /100g soil. The highest C.E.C. value is that recorded for the 0—10 cm layer of profile 17 representing the soils of wadis, while the lowest is that of the 30—70 cm layer of profile 22 representing the soil coastal plain. This in fact

Table (12) Cation exchange capacity (CEC) and exchangeable cations in the studied soil profiles.

Location	Geomor-Phic unit	Prof. No.	Depth (cm)	CEC Me/100g	Exchangeable cations me / 100g				Exchangeable cations in percent of total C.E.C			
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
El - Tina plain	El - Tina plain	1	5-30	41.9	11.6	21.8	7.0	1.5	27.7	52.0	16.7	3.6
			30-80	42.7	6.9	29.4	6.0	0.4	16.2	68.9	14.1	0.94
			80-150	52.9	9.9	31.5	10.0	1.5	18.7	59.5	18.9	2.83
		2	20-60	49.5	15.3	29.0	8.0	2.7	30.9	58.6	16.2	4.4
			60-110	44.6	12.2	24.2	8.2	0.2	27.4	54.3	18.4	0.45
			110-150	48.5	13.9	27.3	7.0	0.3	28.7	56.3	14.4	0.6
		3	10-25	48.5	12.7	23.5	10.8	1.5	26.2	48.5	22.3	3.1
			25-80	48.5	13.5	27.6	7.0	0.5	27.8	56.9	14.4	1.0
			80-125	52.7	13.7	30.4	9.0	0.3	25.9	57.7	17.0	0.6
		4	0-8	39.0	9.6	20.2	7.0	2.2	24.6	51.8	17.9	5.6
			10-60	49.1	10.1	30.0	8.0	1.0	20.6	61.1	16.3	2.0
			60-90	21.5	6.0	11.2	4.0	0.3	27.9	52.1	18.6	1.4
			90-150	19.8	5.0	10.2	3.5	0.3	25.3	51.5	17.7	1.51
		5	0-10	37.4	6.0	20.6	10.5	0.9	16.0	55.1	28.1	2.4
			10-40	40.2	9.0	22.9	7.1	1.4	22.4	56.9	17.7	3.5
			40-90	50.6	11.3	27.4	10.0	1.9	22.3	54.2	19.8	3.8
			90-150	39.6	10.5	23.7	5.0	0.4	26.5	59.8	12.6	1.0
		6	0-10	41.3	10.4	24.3	6.0	0.5	25.2	58.8	14.5	1.2
			10-40	43.9	12.3	24.0	6.0	1.6	28.0	54.7	13.7	3.6
			40-70	47.6	14.2	23.2	9.5	0.7	29.8	48.7	19.9	1.4
		7	0-10	18.7	5.5	9.4	3.0	0.8	29.4	50.3	16.0	4.3
			10-45	16.5	3.1	11.2	2.0	0.2	18.8	67.8	12.1	1.2
			45-90	42.7	10.4	23.1	8.0	1.2	24.3	54.0	18.7	2.8
			90-150	18.3	12.2	13.6	2.0	0.53	66.7	74.3	10.9	2.9
		8	0-20	39.9	10.1	22.3	6.0	1.5	25.3	55.9	15.0	3.8
			20-50	53.2	16.2	30.4	6.0	0.6	30.4	57.1	11.3	1.1
			50-100	44.0	12.8	24.1	6.0	1.1	29.1	54.8	13.6	2.5
		9	0-20	36.8	11.9	21.0	3.0	0.9	32.3	57.1	8.2	2.4
			20-45	52.5	16.3	27.0	8.0	1.2	31.0	51.4	15.2	2.3
			45-90	30.1	8.1	16.0	5.0	0.79	26.9	53.2	16.6	3.2
			90-150	24.2	4.2	16.0	3.0	1.0	17.4	66.1	12.4	4.1

Table (12) Cont.

Location	Geomor-Phic unit	Prof. No.	Depth (cm)	CEC Me/100g	Exchangeable cations me / 100g				Exchangeable cations in percent of total C.E.C			
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
El-Tina plain	El-Tina plain	10	0-35	41.2	10.1	22.0	8.0	1.1	24.5	53.4	19.4	2.7
			35-85	43.2	11.2	22.0	9.0	1.0	25.9	50.9	20.8	2.3
			85-150	46.8	12.3	23.0	10.0	1.5	26.3	49.1	21.4	3.2
		11	0-25	39.9	10.8	21.8	6.0	1.3	27.1	54.6	15.0	3.3
			25-75	44.9	11.8	24.2	8.0	0.9	26.3	53.9	17.8	2.0
			75-150	50.3	12.4	28.7	9.0	0.3	24.7	57.1	17.9	0.59
El - Tina plain	Elevated sand dunes	12	0-30	3.4	2.3	1.2	0.1	0.1	67.6	35.3	2.9	2.9
			30-70	2.7	1.4	1.3	0.2	0.1	51.9	48.1	7.4	3.7
			70-150	4.0	2.7	1.3	0.1	0.2	67.5	32.5	2.5	5.0
		13	0-30	4.9	3.0	2.3	0.2	0.2	61.2	46.9	4.1	4.1
			30-65	4.3	2.3	2.2	0.1	0.1	53.5	51.2	2.3	2.3
			65-150	5.3	2.8	2.9	0.1	0.2	52.8	54.7	1.9	3.8
		14	0-20	3.6	2.2	1.4	0.7	0.3	61.1	38.9	19.4	8.3
			20-70	2.8	2.0	0.5	0.2	0.1	71.4	17.9	7.1	3.6
			70-150	3.9	2.6	0.7	0.2	0.4	66.7	17.9	5.1	10.3
		15	0-15	6.3	2.0	2.2	1.8	0.3	31.7	34.9	28.6	4.8
			15-55	6.8	2.0	2.9	1.6	0.3	29.4	42.6	23.5	4.4
			55-100	4.9	1.3	1.7	1.5	0.4	26.5	34.7	30.6	8.2
			100-150	7.4	3.0	2.6	1.6	0.3	40.5	35.1	21.6	4.1

Table (12) Cont.

Location	Geomor-Phic unit	Prof. No.	Depth (cm)	CEC Me/100g	Exchangeable cations me / 100g				Exchangeable cations in percent of total C.E.C			
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
El -Qaa plain El -Qaa plain	Wadis	16	0-12	5.97	2.9	1.6	1.2	0.27	48.0	26.8	20.1	4.5
			12-30	6.27	2.0	2.2	1.8	0.27	31.9	35.1	28.7	4.3
			30-40	7.4	3.0	2.6	1.6	0.20	40.5	35.1	21.6	2.7
			40-75	6.8	2.0	2.9	1.6	0.34	29.4	42.6	23.5	5.0
			75-150	4.9	1.3	1.7	1.5	0.44	26.5	34.7	30.6	9.0
		17	0-10	9.8	6.2	2.6	0.5	0.5	63.2	26.5	5.1	5.1
			10-40	4.6	2.2	1.4	0.7	0.3	47.8	30.4	15.2	6.5
			40-80	2.8	2.0	0.5	0.2	0.1	71.4	17.8	7.1	3.5
			80-120	2.6	1.5	0.5	0.5	0.1	57.6	19.2	19.2	3.8
			120-150	1.7	0.7	0.5	0.4	0.1	41.1	29.4	23.5	5.9
		18	0-10	8.1	4.6	0.5	2.7	0.32	56.7	6.2	33.3	3.9
			10-60	5.1	2.6	1.2	1.2	0.14	50.0	23.1	23.1	2.7
			60-150	5.4	2.3	1.7	1.2	0.20	42.6	31.5	22.2	3.7
El -Qaa plain	Alluvial Fan	19	0-30	5.0	2.6	1.9	0.1	0.4	52.0	38.0	2.0	8.0
			30-80	6.0	2.8	2.9	0.1	0.2	46.6	48.3	1.6	3.3
			80-120	5.7	3.0	2.3	0.2	0.2	52.6	40.4	3.5	3.5
			120-150	4.7	2.3	2.2	0.1	0.1	48.9	46.8	2.1	2.1
		20	0-20	3.7	2.3	1.2	0.1	0.1	62.1	32.2	2.7	2.7
			20-70	3.0	1.4	1.3	0.2	0.1	46.7	43.3	6.7	3.3
			70-110	4.0	2.5	1.2	0.1	0.2	62.5	30.0	2.5	5.0
			110-150	4.3	2.7	1.3	0.1	0.2	62.7	30.2	2.3	4.6
El -Qaa plain	Coastal plain	21	0-25	9.5	4.3	2.6	2.0	0.7	45.3	27.4	21.1	7.4
			25-65	3.9	2.6	0.7	0.2	0.4	66.6	17.9	5.1	10.3
			65-100	4.8	2.3	1.2	0.9	0.4	48.0	25.0	18.7	8.3
			100-120	5.7	1.8	1.2	2.2	0.5	31.5	21.0	38.5	8.7
		22	0-30	1.7	0.5	0.4	0.6	0.2	29.4	23.5	35.2	11.7
			30-70	1.5	0.4	0.3	0.6	0.2	26.6	20.0	40.0	13.3
			70-120	1.8	0.5	0.3	0.7	0.3	27.7	16.6	38.8	16.6
			120-140	2.1	0.5	0.4	0.8	0.4	23.8	19.0	38.0	19.0

coincides very well with the textural variations and clay content between the soil profiles and their layers.

Exchangeable cations:

Soluble salts in the soil system govern the equilibrium between dissociated ions in soil solution and those adsorbed on the soil exchange complex. Therefore, it is desirable to examine the nature of exchangeable sites on soil complex under such equilibrium condition to assess the mode of soil reactions with respect to soil management and water regimes.

Regarding the nature of exchangeable cations in the different soil profiles, the data in Table (12) indicate that the dominant exchangeable cation in profiles representing the soils of El-Tina plain is Mg^{++} which ranges from 48.7 to 74.3 % of total exchangeable cations, followed by Ca^{++}, 16% to 66.7% .

The data also indicate that Ca^{++} dominated the exchangeable cations in profiles, representing the elevated sand dune soils (profiles 12,13,14,and 15) with values ranging from 40.5 to 71.4% except for the uppermost surface layer of profile 15 in which Mg^{++} exceeds Ca^{++} .

In the soils of El-Qaa plain, the data in Table (12) reveal that exchangeable Ca^{++} predominated the other cations on the exchange complex in the soils of the wadis (profiles 16,17,and 18) and most profiles of soils of the alluvial fan (profiles 19 and 20). The other exchangeable cations follow the order $Mg^{++} > Na^{+} > K^{+}$. In few cases as in the soils of the coastal plain (profile 22), Na^{+} predominates exchangeable cations followed by Ca^{++} then Mg^{++}, the pattern of exchangeable cations in the studied profiles reflects the origin of soils and their environmental conditions of aridity and lake and sea water intrusion to the soils.

4.3.-Amorphous inorganic materials.

Amorphous mineral materials are usually present in soils as a result of inheritance from the parent materials, from which the soil was derived; or as a result of chemical degradation of minerals. (Fieldes and Swindale, 1954 and Rich and Tomas,1960.). The principal forms of such materials are oxides, or hydrous oxides of iron, aluminum, silicon and manganese. They may also be present as coatings on the crystalline particles (Follett et al. , 1965) and play an important role in the cementation and aggregation of soil particles. Thus, the presence of completely cemented layers of hardpans and fragipans, can be caused by these materials. This is widerspead, and such an irreversible flocculation may occur during soil-forming conditions. it may occur, in semi arid as well as arid conditions, although it is prevailent under humid tropical conditions (Barshad 1964).

Fitzpatrick (1980) pointed out that the initial stages of hydrolysis would form amorphous materials, which may crystallize gradually to produce a number of new substances, and translocate within the soil profile. The type, amount and distribution of amorphous materials can be used as a criteria for measuring the degree and type of soil formation.

The data given in Table (13) represent the amounts and distribution of the amorphous silica, alumina and iron oxides. Their total content range as follows: 1.49-3.9 in El-Tina plain,0.36-1.42% in elevated sand dunes, 0.42-1.45% in the wadis, 0.8-1.23% in the alluvial fan and 0.58-1.50% in the coastal plain.

Table (13) Amorphous inorganic materials of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Amorphous inorganic %			Total %
				SiO_2	Al_2O_3	Fe_2O_3	
El- Tina plain	El- Tina plain	1	5-30	1.4	0.89	0.89	3.18
			30-80	1.8	0.54	0.54	2.88
			80-150	1.6	1.00	1.01	3.61
		2	20-60	1.3	0.40	0.38	2.08
			60-110	1.1	0.50	0.45	2.05
			110-150	1.3	0.40	0.44	2.14
		3	10-25	1.4	0.60	0.59	2.59
			25-80	1.3	0.60	0.63	2.53
			80-120	1.5	1.20	1.20	3.90
		4	0-8	0.9	0.96	0.96	2.82
			10-60	1.2	0.30	0.31	1.81
			60-90	1.2	0.20	0.39	1.79
			90-150	1.2	0.10	0.20	1.50
		5	0-10	1.4	0.10	0.17	1.67
			10-40	1.4	0.10	0.31	1.81
			40-90	2.4	0.10	0.24	2.74
			90-150	1.9	0.10	0.26	2.26
		6	0-10	1.4	0.22	0.44	2.06
			10-40	1.3	0.29	0.41	2.00
			40-70	1.6	0.38	0.66	2.64
		7	0-10	1.4	0.07	0.28	1.75
			10-45	1.4	0.06	0.78	2.24
			45-90	1.3	0.07	0.23	1.60
			90-150	1.3	0.15	0.15	1.60
		8	0-20	1.4	0.36	0.89	2.65
			20-50	1.3	0.27	0.90	2.47
			50-100	1.3	0.11	0.48	1.89

Table (13) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Amorphous inorganic %			Total %
				SiO_2	Al_2O_3	Fe_2O_3	
El –Tina plain	El –Tina plain	9	0-20	1.23	0.14	0.39	1.76
			20-45	1.50	0.25	0.78	2.53
			45-90	1.20	0.15	0.14	1.49
			90-150	1.12	0.18	0.19	1.49
		10	0-35	1.33	0.14	0.57	2.04
			35-85	1.4	0.28	1.16	2.84
			85-150	1.5	0.28	0.78	2.56
		11	0-25	1.23	0.17	0.65	2.05
			25-75	1.53	0.15	0.66	2.34
			75-150	1.38	0.41	1.20	2.99
	Elevate sand dunes	12	0-30	0.47	0.03	0.08	0.58
			30-70	0.58	0.03	0.04	0.65
			70-150	0.70	0.03	0.61	1.34
		13	0-30	0.44	0.002	0.11	0.55
			30-65	0.87	0.01	0.08	0.96
			65-150	0.73	0.002	0.08	0.81
		14	0-20	0.73	0.003	0.12	0.85
			20-70	0.29	0.01	0.11	0.41
			70-150	0.29	0.002	0.07	0.36
		15	0-15	1.16	0.01	0.25	1.42
			15-55	0.29	0.01	0.11	0.41
			55-100	0.29	0.01	0.16	0.46
			100-150	0.29	0.004	0.21	0.50
El –Qaa plain	El Wadis	16	0-12	0.84	0.03	0.34	1.21
			12-30	0.65	0.04	0.50	1.19
			30-40	0.89	0.05	0.34	1.28
			40-75	0.60	0.04	0.45	1.09
			75-150	0.57	0.03	0.41	1.01
		17	0-10	0.77	0.11	0.55	1.43
			10-40	0.42	0.06	0.35	0.83
			40-80	0.36	0.04	0.30	0.70
			80-120	0.34	0.02	0.30	0.66
			120-150	0.43	0.01	0.32	0.76
		18	0-10	0.04	0.09	0.32	0.45
			10-60	0.73	0.03	0.34	1.10
			60-150	0.66	0.05	0.9	1.10

Table (13) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Amorphous inorganic %			Total %
				SiO_2	Al_2O_3	Fe_2O_3	
El- Qaa plain	Alluvial fan	19	0-30	0.55	0.12	0.56	1.23
			30-80	0.54	0.12	0.52	1.18
			80-120	0.51	0.10	0.49	1.10
			120-150	0.53	0.10	0.52	1.15
		20	0-20	0.38	0.04	0.38	0.80
			20-70	0.46	0.04	0.47	0.97
			70-110	0.42	0.06	0.43	0.91
			110-150	0.46	0.07	0.41	0.94
	Coastal plain	21	0-25	0.89	0.11	0.51	1.51
			25-65	0.28	0.02	0.39	0.69
			65-100	0.11	0.01	0.51	0.63
			100-120	0.40	0.06	0.76	1.21
		22	0-30	0.51	0.03	0.28	0.82
			30-70	0.31	0.02	0.25	0.58
			70-120	0.39	0.02	0.26	0.67
			120-140	0.48	0.03	0.43	0.94

Soils of El-Tina plain which are represented by profiles 1 to 11 contain silica oxides as the dominant constituent of the amorphous materials (0.9 to 2.4 %) . On the other hand, alumina content was the lowest among amorphous constituents (0.06 to 1.2 %),while amorphous iron content lies in between silica and alumina contents. The contents of free oxides indicate a dominance of the sedimentary metamorphic parent material. Depthwise distribution of total amorphous content, shows a tendency of an increase with depth in profiles 1,2,6, and 11 while in profiles 3,5,7,9 and 10 there was no specific pattern with depth.

Likewise soils of elevated sand dunes which are represented by profiles 12,13,14,and 15 are also characterized by the dominance of amorphous silica over other amorphous constituents. Alumina is the least and iron has intermediate levels between silica and alumina. Ranges of contents of amorphous silica, iron and alumina are 0.29 to 1.16 %, 0.04 to 1.07 and 0.004 to 0.03 %, respectively. Total amorphous inorganic materials shows no definite distribution pattern in profiles, 13, and 15,but shows a decrease with depth in profile 14.

With regard to the soils of the wadis which are represented by profiles 16,17,and 18, Table (13), data reveal that amorphous silica predominates followed by iron then alumina. Ranges of amorphous silica, iron and alumina were 0.04 to 0.89%, 0.01 to 0.11% and 0.30 to 0.55%, respectively. Total amorphous oxides decreases with depth from 1.2 to 1.0% in profile 16, and increases with depth from 0.45 to 1.1% in profile 18, while it displayed an irregular pattern in profile 17. The relative increases of amorphous oxides in the deepest layers of profiles 16 and 17 are probably due to the downward mobility and translocation of this component.

Table (13) shows the amorphous silica, alumina and iron in alluvial fan soils which are represented by profiles 19 and 20. There is a dominance of amorphous silica followed by amorphous iron then amorphous alumina. Contents of amorphous silica, alumina and iron were 0.38 to 0.55%, 0.04 to 0.12 % and 0.38 to 0.56 %, respectively. Depthwise distribution of total amorphous materials showed no specific pattern with depth.

As to the soils of the coastal plain, Table (13) indicates that amorphous silica predominates followed by iron then alumina in profiles 21 and 22 except for the deepest layers of profile 21 in which amorphous iron is predominant followed by silica then alumina. Amorphous silica content varies from 0.11% to 0.89%, while amorphous alumina and iron contents vary from 0.01 to 0.11% and from 0.25% to 0.76 %, for each, respectively.

Therefore, amorphous materials in most samples indicate a low degree of mineral degradation and weathering . This reflects the resistance of the minerals and the parent rocks particularly under the prevailing aridity in the study area.

4.4-Trace elements in soils:

Sixteen elements are known to be essential for the plant growth. Among these elements are "trace elements" or " micronutrients", such as Fe, Cu, Zn, Mn, Mo, B, Co, Ni, and V.

Geochemical distribution of trace elements has devoted attention owing to their possible use in the differentiation between geologic sediments that may act as parent materials for soils, Aubert and Pinta (1977).

In the same connection, the levels of these elements could be used as a guide for substantiating the nature of parent materials, together with the pedogenic aspects which lead to the prediction of soil genesis and formation, (Hassan 1979, El-Demerdashe et al. 1980 a,b, Abd El-Hamid 1981 and Hassona et al. 1995)

The current study evaluates Fe, Mn, Cu and Zn distribution as related to geomorphic aspects in soils of the studied area. It also includes a study of the factors governing the total of these elements. A brief discussion of each of the concerned trace elements is given hereafter.

4.4.1-Total iron.

Total iron contents in the studied soils, Table (14) shows that soils of El-Tina plain which are represented by profiles 1 to 11 have total Fe content that ranges from 11.05 g kg^{-1} in the deepest layer of profile 4, to 74.40 g kg^{-1} in profile 5 (40—90cm layer). Depthwise distribution of total Fe shows no specific pattern.

In soils of elevated sand dunes, total Fe varies widely from 1.50 g kg^{-1} to 8.50 g kg^{-1}, (table 14), the lowest level is found in the

Table (14) Total Fe weighted mean (W), trend (T) and specific range (R) in the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Fe			
				Total g kg^{-1}	Weighted mean(W)	Trend (T)	Specific Range (R)
El-Tina plain	El-Tina plain	1	5-30 30-80 80-150	37.40 50.00 37.15	41.62	0.1	0.31
		2	20-60 60-110 110-150	45.30 44.25 39.40	43.08	-0.049	0.14
		3	10-25 25-80 80-125	47.00 43.70 36.50	41.31	-0.12	0.25
		4	0-8 10-60 60-90 90-150	41.25 29.20 13.95 11.05	19.40	-0.53	1.56
		5	0-10 10-40 40-90 90-150	26.25 39.45 74.40 21.00	42.84	0.39	1.25
		6	0-10 10-40 40-70	68.10 50.15 45.90	50.89	-0.25	0.44
		7	0-10 10-45 45-90 90-150	16.00 14.00 54.60 17.35	27.65	0.42	1.47
		8	0-20 20-50 50-100	18.70 39.00 41.60	36.24	0.48	0.63
		9	0-20 20-45 45-90 90-150	43.50 13.60 44.19 17.40	28.28	-0.35	1.1

Table (14) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Fe Total gkg^{-1}	Fe Weight mean(W)	Fe Trend (T)	Fe Specific Range (R)
El-tina plain	El-tina plain	10	0-35 35-85 85-150	19.10 44.35 68.10	48.75	0.61	1.01
		11	0-25 25-75 75-150	36.60 65.90 46.20	51.17	0.28	0.57
	Elvated sand dunes	12	0-30 30-70 70-150	2.75 4.00 1.50	2.41	-0.12	1.0
		13	0-30 30-65 65-150	3.25 3.25 3.20	3.22	-0.01	0.02
		14	0-20 20-70 70-15	4.75 1.50 1.70	2.06	-0.57	1.57
		15	0-15 15-55 55-100 100-150	8.50 3.75 2.50 4.00	3.93	-0.54	1.53
El –Qaa plain	wadis	16	0-12 12-30 30-40 40-75 75-150	5.40 6.08 2.91 7.42 5.62	5.90	0.07	0.76
		17	0-10 10-40 40-80 80-120 120-150	7.72 7.51 4.05 6.55 6.23	6.10	-0.21	0.59
		18	0-10 10-60 60-150	7.34 2.01 1.85	2.27	-0.69	2.4

Table (14) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Fe Total g kg^{-1}	Fe Weighted mean(W)	Fe Trend (T)	Fe Specific Range (R)
El - Qaa plain	Alluvial Fan	19	0-30 30-80 80-120 120-150	3.01 2.18 6.80 3.85	3.86	0.21	1.14
		20	0-20 20-70 70-110 110-150	5.27 5.19 3.69 5.47	4.90	-0.07	0.37
	Costal plain	21	0-25 25-65 65-100 100-120	5.80 9.20 3.62 4.20	6.03	0.04	0.93
		22	0-30 30-70 70-120 120-140	4.80 4.40 5.60 3.25	4.76	-0.01	0.51

<u>Notes:</u> W= [.∑ (c x d) ÷ P ; where C = concentration of element in layer and "d" = thickness of layers ; P = depth of profile(i.e. sum of thickness of all layers of profile.

T = (W- S) ÷ W for cases of W> S
or (W- S) ÷ S for cases of S> W
S being contents of uppermost surface layer and W the weight mean.

R = (H-L) ÷ W
(H being the highest concentration and L the lowest one)

70-150cm layer of profile 12 and in the 20—70cm layer of profile 14. The highest level is found in the surface layer of profile 15. The low content of total Fe in soils of elevated sand dunes may be associated with their coarse texture.

Soils of the wadis contain total Fe that varies from 1.86 to 7.72 g kg^{-1} with an irregular distribution pattern with depth. The least content is found in the deepest layer of profile 18, whereas the highest is in the surface layer of profile 17.

Table (14) reveals that total Fe in soils of the alluvial fan which are represented by profiles 19 and 20 ranges between 2.19 and 6.58g kg^{-1}. The vertical distribution of total Fe shows a relative concentration in the middle layer of profile 19 and in the deepest layer of profile 20.

With regard to the soils of the coastal plain which are represented by profiles 21 and 22, total Fe content ranges from 3.23 to 9.20g kg^{-1} with an irregular distribution pattern with depth. The highest content is detected in the subsurface layer of profile 21, whereas the lowest content is found in the deepest layer of profile 22.

From the data, it is clear that the soil profiles representing the soils of El-Tina plain are characterized by high content of total iron as compared with the other geomorphic units. On the other hand, the lowest content of total Fe is found in soil profile representing soils of El-Qaa plain which are coarse textured.

Assessment of W, T, and R parameters:

Considering the weighted mean “W”, data presented in Table (14), reveal that such measure for total Fe is characteristic for each geomorphic unit.

For soils of El-Tina plain, values of "W" for Fe ranges between 19.40 and 51.17g kg^{-1} with no particular pattern of distribution. Values of " T " in profiles 1, 2, 3, 6, and 11 indicate more symmetry than in profiles 4, 5, 7, 8, 9, and 10. Values of " R " indicate that the soil parent materials in El-Tina plain are heterogeneous.

With regard to the soils of elevated sand dunes, values of "W" for Fe ranges between 2.07 and 3.93g kg^{-1} with a tendency for an increase eastwards. Values of "T " indicate that Fe distribution in profiles 12 and 13 is more symmetrical than in other profiles, and, soils of the elevated sand dunes are formed of heterogeneous materials, as indicated by the values of their "R".

In the soils of wadis, values of "W" range between 2.28 and 6.11g kg^{-1} with no particular pattern of distribution. Values of " T " indicate a more symmetrical distribution of Fe in profiles 16 and 17 relative to profile 18. Values of " R " indicate that the soils of the wadis originate from heterogeneous soil materials.

Concerning the soils of the alluvial fan (profiles 19 and 20), table(14) shows that values of " W " for Fe range from 3.86 to 4.88g kg^{-1} with a tendency to increase from south to north. Values of " T " indicates that profile 20 which shows a small T value is more symmetrical than profile 19; and values of "R" indicate that the soils are formed of heterogeneous materials.

Soils of the coastal plain, have weighted mean "W" of Fe that range from 4.76 to 6.03g kg^{-1} with a tendency of decrease in North-South direction. The computed trend " T " indicates that the soils of this geomorphic unit are more symmetrical. The "R" values indicate that the soils materials of both profiles are heterogeneous.

Further information about the relationship between total Fe and soil variables could be elucidated from the correlation coefficients presented in table (15). The table is conducted to substantiate the role of some soil constituents on controlling total Fe content, the correlation coefficient between total iron and each of these factors were computed, Table (15). The obtained coefficients show positive significant correlation between total Fe and each of EC, silt, clay, (silt + clay), CEC and organic matter. In contrast, there was a significant negative correlation between total Fe and each of pH, and, sand $CaCO_3$. These findings are in close agreement with those of El- Gundy et al. (1990).

4.4.2-Total Manganese:

Data in Table (16), reveal that total Mn content in the soils of El-Tina plain ranges from 295 to 1200 mg kg^{-1}. The lowest content of Mn is in the deepest layer of profile 4, while the highest content exists in the 40—90 cm layer of profile 5. The vertical distribution of total Mn does not portray any specific pattern with depth, except for profile 8 where Mn tends to increase with depth.

Soils of the elevated sand dunes which are sandy show lower Mn content, which varies widely between 10 and 165 mg kg^{-1}. The lowest content is recorded in the 55—100 cm layer of profile 15, while the highest is in the subsurface of profile 12.

Soils of wadis show a range from 102 to 412 mg kg^{-1}. with an irregular distribution pattern with depth. The highest value is in the 10-60 cm layer of profile 18, while the lowest is in the deepest layer of the same profile.

Table (15)Values of Correlation coefficient(r) between a number of Soil parameters and constituents, and the concentration of total micronutrients in the studied soil profiles.

Soil constituents	Total elements of:			
	Fe	Mn	Zn	Cu
EC	0.799	0.883	0.762	0.719
PH	-0.382	-0.423	-0.405	-0.404
Sand %	-0.771	-0.752	-0.694	-0.654
Silt %	0.441	0.446	0.414	0.387
Clay %	0.829	0.807	0.736	0.694
Silt + clay %	0.767	0.753	0.690	0.650
CEC	0.874	0.892	0.775	0.752
$CaCO_3$ %	-0.367	-0.398	-0.208	-0.190
O.M %	0.760	0.829	0.693	0.658

(1) values of significant r : = 0.217 at 0.05 level(*)
= 0.283 at 0.01 level (**)

Table (16) Total Mn weighted mean (W), trend (T) and specific range (R) of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Mn			
				Total (ppm)	Weighted mean(W)	Trend (T)	Specific Range (R)
El–Tina plain	El–Tina plain	1	0-30 30-80 80-150	580.0 910.0 780.0	783.3	0.26	0.42
		2	20-60 60-110 110-150	780.0 865.0 795.0	817.3	0.05	0.104
		3	0-10 10-25 25-80 80-125	1000.0 645.0 1010.0 730.0	842.2	0.12	0.43
		4	0-8 8-10 10-60 60-90 90-150	1100.0 375.0 870.0 295.0 500.0	612.7	-0.44	1.3
		5	0-10 10-40 40-90 90-150	590.0 820.0 1200.0 890.0	959.3	0.38	0.64
		6	0-10 10-40 40-70	895.0 1145.0 665.0	903.6	0.01	0.35
		7	0-10 10-45 45-90 90-150	350.0 1100.0 605.0 525.0	671.5	0.48	1.12
		8	0-20 20-50 50-100	690.0 810.0 1055.0	908.5	0.24	0.40
		9	0-20 20-45 45-90 90-150	880.0 1110.0 1070.0 695.0	901.3	0.23	0.46

Table (16) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Mn Total (ppm)	Mn Weight mean(W)	Mn Trend (T)	Mn Specific Range (R)
El–Tina plain	El–Tina plain	10	0-35 35-85 85-150	825.0 865.0 855.0	851.33	0.03	0.04
		11	0-25 25-75 75-150	625.0 925.0 850.0	837.5	0.25	0.35
	Elvated sand dunes	12	0-30 30-70 70-150	60 165 55	85.33	0.30	1.29
		13	0-30 30-65 65-150	40 40 50	45.67	0.12	0.22
		14	0-20 20-70 70-15	120 20 20	33.33	-0.72	3.00
		15	0-15 15-55 55-100 100-150	130 40 10 30	36.67	-0.72	3.27
El – Qaa plain	Wadis	16	0-12 12-30 30-40 40-75 75-150	144.0 117.0 188.0 158.0 219.0	184.5	0.22	0.55
		17	0-10 10-40 40-80 80-120 120-150	168.0 149.0 145.0 195.0 144.0	160.5	-0.05	0.32
		18	0-10 10-60 60-150	191.0 412.0 102.0	211.3	0.1	1.5

Table (16) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Mn			
				Total (ppm)	Weight mean(W)	Trend (T)	Specific Range (R)
El – Qaa plain	Alluvial Fan	19	0-30 30-80 80-120 120-150	294.0 185.0 297.0 132.0	226.1	-0.23	0.73
		20	0-20 20-70 70-110 110-150	65.0 82.0 79.0 118.0	88.5	0.27	0.60
	Coastal plain	21	0-25 25-65 65-100 100-120	119.0 128.0 116.0 151.0	126.5	0.06	0.27
		22	0-30 30-70 70-120 120-140	116.0 188.0 185.0 102.0	159.2	0.27	0.55

In the soils of the alluvial fan, total Mn content ranges between 65 to 297 mg kg^{-1}. The lowest content is recorded in the surface layer of profile 20, while the highest is recorded in the 80—120 cm layer of profile 19.

Soils of coastal plain which are represented by profiles 21 and 20 have total Mn content of between 102 and 188 mg kg^{-1} with an irregular distribution pattern with depth. The highest content is in the surface layer of profile 22, and the lowest is in the deepest layer of the same profile.

Assessment of W, T and R parameters:

Generally, in El-Tina plain relatively higher total Mn contents are shown in such heavy textured soils that contain slight to moderate contents of $CaCO_3$, while the highly calcareous light textured sandy soils of El-Qaa plain have comparatively lower contents of total Mn.

The computed weighted mean "W" for total Mn in soils of El-Tina plain, Table (16), shows a ranges of 615.9 to 959 mg kg^{-1} with no particular pattern of distribution with depth. The computed trend "T" reveals that Mn distribution of profiles 2, 3, 6, 9, and 10 are more symmetrical than other profiles. The specific range "R" indicates that the soil materials of profiles 1, 3, 6, 9, and 11 show homogeneity whereas the other profiles are composed of heterogeneous soil materials.

With regard to the soils of elevated sand dunes, the weighted mean of Mn ranges from 33.3 to 85.3 mg kg^{-1} with a tendency to increase in east-west direction. The computed trend "T" indicates that profile 13 is more symmetrical than the other profiles and there is a decrease of Mn symmetrical distribution to the East. The specific range

"R" shows that the soil materials of profile 13 and 14 displyed homogeneity.

Soils of the wadi, show weighted mean "W" ranging from 160.5 to 211.3 mg kg^{-1} with a tendency of increase in a North-South direction. The computed trend "T" shows that the soils of profile 17 are more symmetrical than those of profiles 16 and 18. The specific range "R" shows that the materials of these soils are heterogeneous.

With regard to the soils of alluvial fan, the weighted mean "W" of Mn are 226.1 and 88.5 mg kg^{-1} shows a tendency to increase towards West to East direction. The computed trend "T" indicates that Mn distribution is symmetrical. The specific range "R" shows that the soils are of heterogeneous materials.

Considering soils of the coastal plain, the weighted mean "W" ranges from 126.5 to 159.2 mg kg^{-1} with a tendency to increase to the south direction. The computed trend "T" shows that a decrease of Mn distribution to the south. The specific range "R" shows that the soil materials are heterogeneous.

The correlations between total Mn and soil variables are shown in table (15). There were highly significant positive correlation between total Mn and each of EC, silt, clay, (silt + clay), CEC and organic matter, and a negative correlation with pH, sand and $CaCO_3$.

The obtained results are in close agreement with those of El-Gundy et al. (1990).

4.4.3.-Total Zinc:

Total zn content in the studied soils, (table 17) indicates that soils of El-Tina plain which are represented by profiles 1 to 11 have a total Zn content that ranges between 16.3 to 85.3 mg kg^{-1} The lowest Zn

Table (17) Total Zn weighted mean (W), trend (T) and specific range (R) of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Zn Total (ppm)	Zn Weighted mean(W)	Zn Trend (T)	Zn Specific Range (R)
El-Tina plain	El-Tina plain	1	0-30 30-80 80-150	64.7 63.9 78.0	70.64	0.084	0.2
		2	20-60 60-110 110-150	61.3 71.5 57.1	63.9	0.04	0.23
		3	0-10 10-25 25-80 80-125	60.9 70.8 55.8 50.9	56.2	-0.08	0.35
		4	0-8 8-10 10-60 60-90 90-150	65.8 24.5 32.6 16.3 44.1	35.6	-0.46	1.4
		5	0-10 10-40 40-90 90-150	29.1 73.8 74.9 34.0	55.3	0.47	0.83
		6	0-10 10-40 40-70	72.9 58.1 48.9	56.3	-0.23	0.43
		7	0-10 10-45 45-90 90-150	51.2 22.7 21.7 21.3	23.7	-0.54	1.3
		8	0-20 20-50 50-100	22.1 80.8 84.4	70.9	0.69	0.88
		9	0-20 20-45 45-90 90-150	72.5 35.5 73.5 60.1	61.7	-0.15	0.61

Table (17) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Zn			
				Total (ppm)	Weighted mean(W)	Trend (T)	Specific Range (R)
El-Tina plain	El-Tina plain	10	0-35 35-85 85-150	50.9 60.7 72.3	63.4	0.20	0.34
		11	0-25 25-75 75-150	72.1 85.3 82.7	81.8	0.12	0.16
El-Tina plain	. Elvated sand dunes	12	0-30 30-70 70-150	10.0 10.0 12.0	11.1	0.099.	0.18
		13	0-30 30-65 65-150	12.0 10.0 14.0	12.7	0.053	0.32
		14	0-20 20-70 70-15	10.0 12.0 10.0	10.7	0.07	0.19
		15	0-15 15-55 55-100 100-150	10.0 10.0 5:0 10.0	8.5	-0.15	0.59
El – Qaa plain	Wadis	16	0-12 12-30 30-40 40-75 75-150	31.2 27.0 34.6 31.4 32.2	31.4	0.032	0.24
		17	0-10 10-40 40-80 80-120 120-150	21.01 23.8 54.7 46.3 41.9	41.5	0.49	0.81
		18	0-10 10-60 60-150	25.2 41.1 29.5	33.1	0.24	0.48

Table (17) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Zn Total (ppm)	Zn Weighted mean(W)	Zn Trend (T)	Zn Specific Range (R)
El – Qaa plain	Alluvial Fan	19	0-30 30-80 80-120 120-150	30.01 23.4 30.01 42.0	30.3	0.01	0.62
		20	0-20 20-70 70-110 110-150	22.3 21.7 27.4 22.5	23.5	0.05	0.24
	Coastal plain	21	0-25 25-65 65-100 100-120	27.7 28.8 27.6 31.0	28.6	0.03	0.12
		22	0-30 30-70 70-120 120-140	18.5 23.9 28.8 31.6	25.6	0.28	0.5

content characterizes the 60—90 cm layer of profile 4, while the highest content is in the 25—75 cm layer of profile 11. Total Zn content ranges from 5 to 14 mg kg^{-1} in the soils of elevated sand dunes (represented by profiles 12, 13, 14 and 15). The highest content is recorded in the deepest layer of profile 13, while the lowest is found in the 55—100 cm layer of profile 15.

Soils of the wadis which are represented by profiles 16, 17, and 18 contain from 21.01 to 54.7 mg kg^{-1}. The lowest is in the surface layer of profile 17, and the highest is in the 40—80 cm layer of the same profile. The vertical distribution of total Zn content does not portray any specific pattern with depth.

Total Zn content in soils of the alluvial fan (profiles 19 and 20) ranges from 21.7 to 42.0 mg $kg^{-1}$with an irregular distribution pattern with depth. The lowest Zn content is in the 20—70 cm layer of profile 20, while the highest Zn content is in the deepest layer of profile 19.

With regard to the soils of the coastal plain, (table 16) these soils have Zn content that ranges from 18.5 to 31.6 mg kg^{-1}. The highest content is in the deepest layer of profile 22, and the lowest is in the surface layer of the same profile.

<u>Application of W,T and R parameters.</u>

The statistical measures of Oertel and Giles (1963) reveal that the Zn weighted mean "W" in soils of El-Tina plain ranges between 23.7 and 81.8 mg kg^{-1} with no particular pattern. Also, the computed trend "T" indicates a symmetrical distribution in profiles 1,2, 3, and 11 than the other profiles. The specific range "R" shows that the soil parent materials are heterogeneous. The weighted mean for soils of the elevated sand dunes ranges from 8.5 to 12.7 mg kg^{-1} with a considerable increase in an east-west direction. The computed trend "T" shows that profiles 12 and 14 are more symmetrical than profiles 13 and 15. The specific range "R" indicates that soils of elevated sand dunes (profiles 12, 13 and 15) had heterogeneous parent materials, while "R" values for profile 14 is zero indicating heterogeneous parent materials.

Soils of wadis which are represented by profiles 16, 17 and 18 have weighted mean "W" that ranges from 31.3 to 41.5 mg kg^{-1} with no particular pattern. The computed trend "T" indicates an increase in symmetrical distribution to the north. The specific range " R" shows that soils of wadis are formed of heterogeneous materials.

The computed weighted mean "W" of the soils of the alluvial fan are 30.2 and 23.5 mg kg^{-1}in profiles 19 and 20, respectively. The computed trend "T" indicates more symmetrical Zn distribution in profile 19 than in profile 20. The values of specific range "R" indicate that the soil profiles are composed of heterogeneous materials.

With regard to the soils of coastal plain, the weighted means "W" of Zn are 28.6 and 25.6 mg kg^{-1} in profiles 21 and 22, respectively, with a decrease to the south direction. The computed trend "T" indicates more symmetrical distribution of total Zn in profile 21 than in profile 22. The specific range "R" indicates that the soils parent material are heterogeneous.

The relationship between total Zn and soil variables could be elucidated from the correlation coefficients "r" presented in Table (15). To substantiate the role of some soil constituents in controlling total Zn content, the correlation coefficients between total Zn and each of these factors was computed for the studied profiles, Table (15). The obtained coefficients show that total Zn has a positive highly significant correlation with EC, silt %, clay %, sum of silt + clay, CEC and organic matter content. It has a highly significant negative correlation with pH and sand % and no significant correlation with $CaCO_3$ content. These findings are in agreement with those El-Gundy et al. (1990).

4.4.4-Total Copper

Soils of El-Tina plain which are represented by profiles 1 to 11 have a total Cu content that ranges from 18.9 to 89.0 mg kg^{-1} (Table 18). The lowest content is in the deepest layer of profile 7, while the highest is in the 45—90cm layer of profile 9. As to the vertical distribution of total Cu, it displays an irregular pattern except for profiles 2 and 7 where Cu tends to decrease with depth, and profiles 8, 10 and 11 Cu where it tends to increase with depth.

Soils of the elevated sand dunes (profiles 12, 13, 14 and 15) have total Cu content ranging between 2 and 20 mg kg^{-1}, with an irregular distribution pattern with depth. The highest level is recorded in the subsurface of profile 12, while the lowest content is detected in the 55-100cm layer of profile 15.

Total Cu content ranges from 17.5 to 59.1 mg kg^{-1} in the soils of wadis. The lowest level is detected in the surface layer of profile 16, whereas the highest level is found in the surface layer of profile 18. Depthwise distribution of total Cu displays an irregular pattern in profiles 16 and 17, while in profile 18 Cu tends to decrease with depth.

Table (18) Total Cu weighted mean (W), trend (T) and specific range (R) of the studied soil profiles.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Cu Total mg kg^{-1}	Cu Weighted mean(W)	Cu Trend (T)	Cu Specific Range (R)
El- Tina plain	El- Tina plain	1	5-30 30-80 80-150	57.2 43.5 43.9	46.4	-0.19	0.29
		2	20-60 60-110 110-150	78.4 50.8 45.0	57.5	-0.27	0.58
		3	0-25 25-80 80-125	64.4 58.8 47.6	55.1	0.14	0.30
		4	0-8 10-60 60-90 90-150	54.0 60.3 22.8 60.0	52.2	-0.03	0.72
		5	0-10 10-40 40-90 90-150	32.9 67.4 84.4 39.9	59.0	0.44	0.87
		6	0-10 10-40 40-70	78.3 50.5 61.1	58.8	-0.25	0.48
		7	0-10 10-45 45-90 90-150	31.2 32.0 21.2 18.9	23.5	-0.25	0.55
		8	0-20 20-50 50-100	24.7 56.6 66.7	55.3	0.55	0.76
		9	0-20 20-45 45-90 90-150	58.7 33.0 89.0 37.1	54.9	-0.06	1.02

Table (18) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Cu Total mg kg^{-1}	Cu Weighted mean(W)	Cu Trend (T)	Cu Specific Range (R)
El- Tina plain	El- Tina plain	10	0-35 35-85 85-150	45.8 53.6 66.9	57.5	0.20	0.36
		11	0-25 25-75 75-150	58.9 59.6 72.7	66.0	0.10	0.20
El- Tina plain	Elvated sand dunes	12	0-30 30-70 70-150	10.0 20.0 10.0	12.6	0.21	0.78
		13	0-30 30-65 65-150	12.0 10.0 16.0	13.8	0.13	0.43
		14	0-20 20-70 70-15	10.0 10.0 5.0	7.3	-0.27	0.69
		15	0-15 15-55 55-100 100-150	10.0 3.0 2.0 3.0	3.4	-0.66	2.35
El –Qaa plain	Wadis	16	0-12 12-30 30-40 40-75 75-150	17.5 33.7 33.2 21.9 25.2	25.4	0.31	0.64
		17	0-10 10-40 40-80 80-120 120-150	20.5 30.1 20.2 30.2 30.2	26.9	0.24	0.37
		18	0-10 10-60 60-150	59.1 54.4 45.2	49.2	-0.17	0.28

Table (18) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Cu			
				Total mg kg^{-1}	Weighted mean(W)	Trend (T)	Specific Range (R)
El –Qaa plain	Alluvial Fan	19	0-30 30-80 80-120 120-150	16.9 12.3 12.9 26.01	16.1	-0.05	0.85
		20	0-20 20-70 70-110 110-150	36.2 10.2 21.5 12.2	17.2	-0.52	1.5
	Coastal lpain	21	0-25 25-65 65-100 100-120	20.7 22.8 25.9 19.2	22.7	0.09	0.30
		22	0-30 30-70 70-120 120-140	18.04 20.7 13.8 12.3	16.5	-0.10	0.5

Considering the soils of the alluvial fan (profiles 19 and 20) total Cu content ranged between 10.2 and 36.2 mg kg^{-1} with an irregular distribution pattern downward the profile depth. The lowest content is detected in the subsurface layer of profile 20, while the highest content is detected in the surface layer of the same profile.

Table (18) reveals that total Cu content in the soils of coastal plain varies within a narrow limit from 12.3 to 25.9 mg kg^{-1}. The vertical distribution pattern of total Cu does not portray any specific pattern with depth.

In brief, the amounts of total copper are relatively low in the soils of El-Qaa plain and those of the elevated sand dunes. These low values may be due to parent rocks having low contents of Cu-bearing minerals. The highest content of total copper is found in the soils of El-Tina plain which are characterized by their fine texture and high clay contents.

Assessment of W, T, and R parameters:

The computed weighted mean "W" of soils of El-Tina plain ranged from 23.5 to 66.0 mg kg^{-1}, with no particular pattern. The computed trend "T" reveals that Cu distributions of profiles 3, 4, 9 and 11 are more symmetrical than in the other profiles. The specific range "R" shows that the soil materials of the representative profiles are heterogeneous.

Soils of the elevated sand dunes have a weighted mean "W" that ranges from 3.4 to 13.8 mg kg^{-1}, with a tendency of a decrease to the East direction. The computed trend "T" indicates that Cu distribution in profile 13 is more symmetrical than in profiles 12, 14, and 15. The specific range "R" indicates that the soils of elevated sand dunes are composed of heterogeneous materials.

4.5-Mineralogy of the sand fraction:

Residual minerals, particularly those designated as " heavy minerals", are either inherited from parent materials or altered during soil formation processes. Their content and distribution are considered among the useful tools in evaluating profile uniformity and development, the sequence of rock and soil, losses and gains of materials during weathering and the processes involved in soil formation. In this concern, Buckaman and Haim (1942) and Haseman and Marshall (1945) stated that the origin of a soil is reflected on the kind and amount of heavy minerals present, and that qualitative and rough quantitative determination of such minerals may be sufficient to establish soil origin. This is important, particularly in cases where the kind and relative abundance of heavy minerals in the possible parent source materials has to be established.

Arrangement of heavy minerals, according to their resistance or susceptibility to weathering was reported by a number of investigators, among them are Pettijohn (1941) and Weyl (1952). In the early forties Marshall (1945) proposed a quantitative methods for studying soil profile uniformity, based on the distribution of resistant minerals (index minerals), and this method was later confirmed by Brewer (1955) and is now still widely used.

The ratio between two or more of the highly resistant minerals was suggested by Barshad (1964), Brewer (1964) and Chapman and Horn (1968). The ratio between a mineral which is highly resistant to weathering and a mineral which is susceptible to weathering, was also suggested by the same researchers and has been applied to test the uniformity and development of Egyptian soils by Hammad (1968), El-Demerdashe(1970), Kassem (1977), Shata(1984), Hassona et al. (1995) and Hassona (1999).

In this connection, Haseman and Marshall(1945) mentioned that the ratio between zircon and tourmaline could be taken as an evidence of variations in depositional environments or geological differences between the profile layers. Other ratios were suggested for testing the uniformity of parent materials. Ruhe (1956) suggested the ratios of " Zircon plus tourmaline" to "pyroxenes plus "amphiboles" and "feldspars" to "quartz". Chapman and Horn (1968) suggested the ratio of Titanum oxide to Zircon oxide TiO_2 /ZrO_2, .

The distribution of sand minerals in the diagnostic layers of the representative profiles is given in Tables (19 and 20). These minerals are distinguished into their two distinctive groups, i.e., light and heavy minerals:

4.5.1 Light minerals

Light minerals of sand fraction are those minerals having a specific gravity less than 2.85 g/cm. The light minerals are composed almost of quartz and feldspars. Quartz constitutes more than 92.49 % in all localities (Table 19), and is present as single or composite grains and may exist in uniform extinction, i.e., extinguished uniformity between crossed nichols, undlose wavy extinction. Depthwise distribution of the minerals does not show any specific trend for any of the studied geomorphic units, except for the coastal plain soils (profile 21) where quartz tends to decrease with depth.

Feldspars are identified as orthoclase, plagioclase and microcline with a relative abundance of the former two minerals. Orthoclase

Table (19) Frequency distribution of light minerals in the sand fraction (0.125 –0.063 mm.).

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Quartz	Feldspars			
					Orthoclase	Plagiclase	Microcline	Total
El – Tina plain	El – Tina plain	1	5-30	96.27	0.91	2.17	0.62	3.70
			30-80	94.14	1.85	2.78	1.23	5.86
			80-150	95.14	1.52	2.74	0.60	4.86
		5	0-10	93.33	2.32	3.49	0.86	6.67
			10-40	95.61	1.67	2.19	0.63	4.49
			40-90	96.05	1.13	2.54	0.28	3.95
			90-150	95.09	1.53	2.45	0.93	4.91
		7	0-10	92.91	2.03	3.71	1.35	7.09
			10-45	95.67	1.08	2.53	0.72	4.33
			45-90	92.59	2.69	3.70	1.02	7.41
			90-150	95.74	1.77	1.77	0.72	4.26
		8	0-20	96.09	1.42	1.78	0.71	3.91
			20-50	94.83	1.03	3.11	1.03	5.17
			50-100	92.49	2.31	4.05	1.15	7.51
		10	0-35	96.82	0.87	1.73	0.58	3.18
			35-85	94.43	1.55	3.09	0.93	5.57
			85-150	97.26	0.91	1.51	0.32	2.74
		11	0-25	94.20	1.74	3.19	0.87	5.8
			25-75	93.15	2.19	3.55	1.01	6.75
			75-150	96.04	1.22	2.13	0.61	3.96
	Elevated sand duens	12	0-30	98.20	0.60	1.00	0.20	1.80
			30-70	97.90	0.64	0.85	0.61	2.10
			70-150	98.91	0.15	0.75	0.19	1.09
		14	0-20	97.31	0.89	1.80	--	2.69
			20-70	98.40	0.20	0.60	0.40	1.20
			70-150	98.95	0.35	0.60	0.10	1.05
El – Qaa plain	Wadis	16	0-12	94.80	1.68	2.62	0.90	5.20
			12-30	98.05	0.30	1.25	0.40	1.95
			30-40	95.50	1.20	2.80	0.50	4.50
			40-75	96.15	1.05	2.03	0.77	3.85
			75-150	94.47	1.90	3.37	0.26	5.53
		18	0-10	97.30	0.23	2.23	0.24	2.70
			10-60	95.31	1.43	2.98	0.28	4.69
			60-150	97.60	0.44	1.72	0.24	2.40

Table (19) cont.

Location	Geomorphic Unit	Prof. No.	Depth (cm)	Quartz	Feldspars			
					Orthoclase	Plagiclase	Microcline	Total
El – Qaa plain	Alluvial Fan	20	0-20	95.4	1.60	2.40	0.60	4.60
			20-70	94.9	1.10	3.30	0.70	5.10
			70-110	95.8	1.30	2.20	0.80	4.30
			110-150	96.3	0.70	2.30	0.70	3.70
	Coastal plain	22	0-30	99.05	0.20	0.48	0.27	0.95
			30-70	98.74	0.43	0.62	0.21	1.26
			70-120	98.26	0.69	0.85	0.20	1.74
			120-140	97.97	1.0	0.81	0.22	2.03

exhibits low index refraction, cleavage and cloudy alteration products, while plagioclase is characterized by its carlsbad twinning under crossed nichols. Microcline is detected by its cross-hatching. These minerals constitute from 0.95% to 7.51% of the light minerals in the studied soils. The highest content of feldspars within the depthwise distribution was mostly associated with the deepest layers of profile 8 representing the soils of El-Tina plain. The lowest content is detected in the surfsce layer of profile 21 representing the soils of coastal plain. On the other hand, profile 8 of El-Tina plain, and profile 21of the coastal plain (El-Qaa) both display a gradual increase of feldspars and plagioclase with depth. In soils of the alluvial fan, the wadis, other profiles of El-Tina plain and the elevated sand dunes, no distinct pattern of feldspars distribution is observed.

From the above mentioned results, one may conclude that quartz, due its relatively high resistance to weathering, was not affected much by the weathering which prevailed prior to and throughout the sedimentation course. This content may have also been originated (or inherited) from the parent material itself and the minute variations encountered may be the result of a natural variation within such parent material. In fact, most of the variations encountered in the frequency distribution of light minerals are expected to be inherited form the parent material involved in soil formation, and modified, to a less extent, by weathering during the pre-wet climatic conditions; then subjected to depositional environments. Moreover, the presence of feldspars could be taken as an indication of a non-drastic weathering which must have prevailed during soil formation and evolution which was not so intense as to cause a complete decay of these minerals which are susceptible to weathering.

4.5.2-Heavy minerals:

Table (20) reveals that the main constituents of the heavy minerals are the opaques with non-opaques in much lower proportions; such as pyroxenes, amphiboles, epidotes, zircon, glauconite, tourmaline, garnet, kyanite, rutile, and biotite. To discuss the obtained results in a proper manner, the non-opaque minerals are considered as 100%. However, the opaque percentages are also recorded.

The obtained results indicate that pyroxenes, amphiboles and epidotes are the most abundant minerals in the non- opaques. Zircon, garnet, rutile and tourmaline are present in relatively moderate amounts, while the remaining minerals are found in less pronounced amounts :

Opaque minerals.

Opaques are identified in subrounded to rounded shaped grains. However, in some cases, they are markedly angular.

The opaque minerals were counted as such because the identification of their individual minerals is not easy. Opaques in the soils of El-Tina plain varies considerably between 36.9 and 49.7% (Table 20). The lowest content is recorded in the deepest layer of profile (5), while the highest content is recorded in the surface layer of profile10.

The vertical distribution of opaque does not portray any specific pattern with depth, except for profile 8 which showed a tendency to increase with depth.

Soils of the elevated sand dunes (profiles 12 and 14) have opaque minerals content that ranges from 42.6% to 54.2%. The highest value is

Table (20) Frequency distribution of the heavy minerals in the sand fraction(0.125-0.063mm) of the studied soils

Location	Geomorphic Units	Prof No.	Depth (cm)	Opaques	Pyroboles								Parmetamorphic				Ubibuitous			Biotite	Epidote	Monazite	Glouconite	Others
					Pyroxenes				Amphiboles															
					Augtes	Hyper-thene	Diop-side	Total	Horn-blende	Glauc-phane	Actin-olite	Total	Garent	Staur-olite	Kya-nite	Silim-anite	Zircon	Ruite	Tour-maline					
El-Tina plain	El-Tina plain	1	0-30	45.3	28.7	2.4	3.1	34.2	15.8	1.9	3.6	21.3	3.2	1.6	1.9	1.8	5.6	2.4	3.2	2.1	12.6	2.3	5.3	2.5
			30-80	44.9	26.4	2.6	1.9	30.9	14.9	2.0	5.2	22.1	3.4	1.5	2.1	1.9	4.9	2.6	2.9	1.8	11.8	1.8	4.9	4.9
			80-150	47.6	27.3	2.7	2.7	32.7	13.6	1.8	4.5	19.9	2.7	2.7	2.7	2.7	6.3	1.8	2.7	2.7	13.6	1.8	4.5	0.7
		5	0-10	46.6	29.4	2.8	2.1	34.3	14.0	2.1	7.0	23.1	3.5	3.5	5.6	4.9	3.5	0.7	2.1	0.7	13.3	0.7	3.5	0.6
			10-40	44.9	32.6	1.9	3.2	37.7	16.3	2.6	5.2	24.1	2.6	2.6	1.9	1.9	2.6	1.3	3.2	1.9	13.0	1.3	2.6	2.7
			40-90	48.6	34.0	3.0	3.8	40.8	15.1	3.0	7.9	25.6	3.0	3.0	2.2	1.5	2.2	1.5	1.5	1.5	11.3	0.6	3.8	0.9
			90-150	36.9	38.0	2.3	1.7	42.0	14.6	2.3	7.6	24.5	2.9	1.1	2.3	1.7	1.7	1.1	4.1	1.1	11.7	1.1	1.7	3.0
		7	0-10	41.8	39.5	2.1	5.7	47.3	12.9	1.4	3.6	17.9	2.1	1.4	1.4	1.4	3.6	2.1	1.4	1.4	14.4	0.7	0.7	4.2
			10-40	43.1	30.4	2.3	1.5	34.2	15.1	2.3	3.8	21.2	7.6	6.0	1.5	3.8	1.5	1.5	1.5	3.0	15.1	--	--	3.1
			40-90	49.8	34.8	2.3	5.8	42.9	10.4	3.5	5.8	19.7	4.6	2.3	1.1	3.5	1.1	2.3	5.8	2.3	9.3	0.7	1.1	3.3
			90-150	48.6	33.6	3.2	3.9	40.7	12.1	2.9	3.2	18.2	3.8	1.9	2.3	2.7	2.6	1.6	5.1	3.2	10.4	0.6	1.6	5.3
		8	0-20	41.8	28.7	2.1	2.1	32.9	14.4	2.1	7.2	23.7	5.0	5.7	2.9	1.4	5.0	1.4	2.9	2.9	9.3	0.8	3.6	2.5
			20-50	43.4	33.3	1.3	1.3	35.9	16.6	2.6	6.0	25.2	5.3	2.6	2.0	1.3	3.3	2.0	2.0	6.6	6.6	1.0	1.2	5.0
			50-100	46.3	30.9	1.6	1.4	33.6	15.3	3.0	5.7	24.0	4.8	1.9	2.5	1.0	4.2	1.7	2.5	4.3	7.5	0.9	2.5	8.6
		10	0-35	49.7	30.0	4.0	2.0	36.0	18.0	2.0	4.9	24.9	4.9	2.0	4.0	2.0	4.9	3.0	2.0	2.0	7.0	1.2	3.0	3.1
			35-85	41.1	34.9	4.9	1.4	41.2	21.0	2.1	7.0	30.1	4.9	1.4	1.4	2.1	2.8	1.4	2.1	1.4	7.0	0.7	0.7	2.8
			85-150	42.4	33.0	3.7	1.3	39.0	22.7	1.7	3.9	28.3	3.1	2.3	1.8	2.7	3.1	2.3	3.1	0.8	5.4	1.6	0.8	2.7
		11	0-25	42.9	37.6	2.2	0.7	40.5	18.8	3.0	6.0	27.8	3.7	3.0	2.2	1.5	3.7	2.2	1.5	0.7	7.5	1.5	0.7	1.8
			25-75	47.2	35.7	2.7	0.9	39.3	17.8	1.8	4.4	24.0	4.4	2.7	0.9	1.8	2.7	2.7	2.7	1.8	11.6	1.8	0.9	1.8
			75-150	43.2	33.9	4.2	0.8	38.9	17.0	2.5	6.7	26.2	3.4	2.5	1.7	1.7	1.7	1.7	1.7	7.6	6.7	1.7	2.5	2.0

Table (20). Cont.

Location	Geomorphic Units	Prof No.	Depth (cm)	Opaques	Pyroboles								Parmetamorphic				Ubibuitous			Biotite	Epidote	Monazite	Glouconite	Others
					Pyroxenes				Amphiboles															
					Augte	Hyper-thene	Diop-side	Total	Horn-blende	Glauc phane	Actin-olite	Total	Garent	Staur-olite	Kya-nite	Silim-anite	Zircon	Ruite	Tour-maline					
El – Tina plain	Elevated sand dunes	12	0-30	48.6	4.7	13.2	7.7	25.5	25.9	0.8	1.0	27.7	10.5	5.7	2.1	1.8	6.9	13.1	2.4	0.8	2.8	--	0.8	--
			30-70	42.6	5.6	10.6	9.5	25.7	19.1	1.6	1.1	21.8	3.1	5.9	4.5	2.3	10.4	15.1	6.3	1.4	3.7	--	--	--
			70-150	47.9	5.4	12.7	16.7	29.2	10.5	1.0	2.6	14.1	4.8	5.3	4.2	--	9.2	14.3	6.3	0.8	6.9	4.3	--	--
		14	0-20	54.2	9.4	6.3	15.1	30.4	19.9	3.3	3.0	26.0	3.1	1.3	3.7	2.1	6.3	3.1	5.4	3.1	15.5	--	--	--
			20-70	53.3	12.1	1.3	11.9	25.3	23.3	3.7	2.9	29.4	4.5	1.3	0.7	2.9	7.6	2.8	6.3	2.6	16.7	--	0.9	--
			70-150	50.6	15.0	3.3	13.3	33.1	29.4	5.5	0.8	37.8	1.6	3.7	0.2	0.6	5.7	2.4	2.4	2.4	10.0	--	--	--
El- Qaa plain (South Sinai)	Wadis	16	0-12	43.3	2.9	25.3	7.2	35.4	9.3	3.6	2.6	15.5	7.4	3.5	3.2	0.1	15.2	4.5	2.1	0.3	12.6	0.1	0.1	--
			12-30	30.8	2.1	26.1	5.3	35.5	10.5	4.9	1.8	17.2	6.6	2.2	4.5	1.5	12.4	4.8	2.5	1.9	12.6	0.2	0.3	--
			30-40	23.1	2.3	32.9	5.3	40.5	9.1	3.1	1.5	13.7	3.2	1.9	3.1	--	14.2	4.1	5.4	1.9	11.5	0.3	0.2	--
			84-75	48.2	2.7	35.6	4.9	43.2	5.2	1.8	1.3	8.3	8.4	1.3	5.0	0.1	14.3	3.9	3.1	2.2	9.8	0.2	0.2	--
			75-150	47.5	4.9	34.5	6.1	45.5	8.6	3.2	1.8	13.6	6.9	1.8	3.7	0.4	15.9	1.8	1.5	1.2	7.0	0.3	0.4	--
		18	1-10	32.1	2.5	7.5	1.7	11.7	32.9	10.8	6.1	49.8	0.8	2.4	0.7	--	4.2	1.1	5.9	0.5	21.7	1.2	--	--
			10-60	22.8	1.9	8.9	2.6	13.4	32.5	12.1	1.9	46.5	8.6	1.2	4.3	0.4	2.3	0.5	1.2	0.5	20.5	0.6	--	--
			60-150	21.3	2.2	9.2	3.1	14.5	35.5	10.1	5.1	50.7	7.3	2.5	2.3	0.2	9.4	0.2	1.9	0.2	10.3	0.5	--	--
	Alluvial Fan	20	0-20	45.2	7.4	22.5	8.9	38.8	10.1	6.1	1.6	17.8	6.1	3.6	3.5	0.8	9.4	4.6	3.4	1.2	10.5	0.2	0.1	--
			20-70	54.3	4.5	28.2	7.5	40.2	9.4	3.3	0.4	13.1	5.2	0.2	5.4	1.3	15.2	4.1	5.1	1.8	8.1	0.4	--	--
			70-110	57.2	1.8	30.4	8.2	40.4	9.8	4.5	1.4	15.7	5.8	2.3	2.1	--	14.1	6.2	3.1	1.1	9.2	--	--	--
			110-150	60.2	2.5	26.1	5.3	33.9	15.6	5.6	0.9	22.4	5.5	2.5	1.7	1.3	10.3	5.2	5.2	1.6	10.1	0.2	0.1	--
	Coastal plain	22	10-30	46.5	0.6	9.9	5.6	16.1	10.2	4.9	1.2	16.3	11.5	4.1	1.1	1.0	15.6	12.7	2.8	2.7	14.3	--	1.5	--
			30-70	48.3	3.3	16.5	4.9	24.7	14.8	3.8	1.5	20.1	10.9	2.9	3.1	0.1	10.6	10.2	4.3	0.5	12.4	--	0.2	--
			70-120	59.2	1.8	8.2	4.7	14.7	8.9	4.4	2.8	16.1	9.8	3.5	2.5	0.2	16.6	9.1	7.6	7.3	18.4	--	--	0.4
			120-150	42.9	4.9	8.9	8.7	22.7	13.9	0.9	1.2	15.5	6.8	0.2	1.1	0.1	9.5	13.8	4.0	3.5	21.4	1.4	--	--

found in the surface layer of profile 14, while the lowest value is recorded in the subsurface layer of profile (12). Depthwise distribution of the opaques varies considerably from one profile to another in these soils. In profile 14 the opaques tend to decrease downwards. In profile 12 an abrupt decrease of opaque characterized the 30—70 cm layer, while the deepest layer has nearly the same content as in the top layer.

Soils of the wadis which are represented by profiles 16 and 18 have opaque minerals range of 21.3 to 48.2% . The lowest content characterized the deepest layer of profile 18, while the highest content is detected in the 40—75 cm layer of profile 16. Depthwise distribution of the opaques exhibits two different patterns where two layers, each of them has nearly similar contents to the other with a relative decrease in the top layers (profile 16), while opaque tends to decrease with depth in profile 18.

With regard to the soils of the alluvial fan which are represented by profile (20). the opaques constitute 45.2 to 60.2 % with a tendency to increase with depth.

Soils of the coastal plain (profile 22) have opaque minerals range from 42.9 to 59.2 % with an irregular distribution pattern with depth. The lowest value is detected in the deepest layer, while the highest value is in the 70—120cm layer.

In conclusion it is clear that, except for some layers, which display a rather uniform pattern of opaque distribution, most profiles exhibit a decrease of opaques with depth. Moreover, none of the studied profiles portrays any specific pattern pertaining to locality or to geomorphic units.

Pyroboles:

Pyroxenes.

This group of minerals is mainly represented by augite, hyperthene and diopside. Augite is characterized by being anisotropic , green to olive green in plane light, non-pleochroic and having an extenuation angle at exactly 45. Hypersthene is found as prismatic grains which seem to be as trees-trunk, anisotropic having parallel extenuation and non-pleochroic. Diopside is anisotropic, colourless in plane light, having faint intereference colour between cross nichols and oblique at 28. All these minerals are present as irregular subangular to subrounded grains.

Considering the distribution of pyroxenes in the studied geomorphic units, Table (20) shows that pyroxenes as a whole, constitute 30.9 to 47.3% of the non opaque minerals in the soils of El-Tina plain. The lowest value is recorded in the 30—80 cm layer of profile 1, while the highest percent is recorded in the surface layer of profile 7. With regard to the individual members of pyroxenes, data show that augite, hyperthene and diopside constitute 26.4—39.5 %, 1.3—4.9 % and 0.7—5.8%, respectively of the non opaque minerals. Among the pyroxene minerals, augite is the dominant one followed by hypersthene and diopsite with an exceptional case in some layers where diopsite constitutes the dominat mineral followed by hypersthene.

Soils of elevated sand dunes which are represented by profiles 12 and 14 have total pyroxenes of 25.3 to 33.1% of the non opaques minerals. The highest content is recorded in the deepest layer of profile 14, while the lowest content is detected in the 20—70 cm layer of profile 14. The individual minerals of pyroxenes have a widely variable distribution within and between profiles. For instance, augite constitutes 4.7—15.0 % of the non opaques, while hyperthene and diposite ranges from 1.3 to 13.2% and 7.7 to 16.7%. The lack of any distribution pattern of minerals within profile depth is clearly observed except for diopside and augite in profiles 12 and 14 which tend to increase with depth.

With regard to the soils of the wadis which are represented by profiles 16 and 18, table 20 shows that pyroxene minerals content ranges from 11.7 to 45.5% of the non- opaque minerals. Hypersthene is the dominant minerals followed by diopside and augite. The vertical distribution pattern of pyroxenes in profile 16 shows no regular distribution pattern with depth; but in profile 18 pyroxenes tend to increase downwards in the profile depth.

Soils of the alluvial fan (profile 20) have pyroxenes that ranges from 33.9 to 40.4% of the non opaque minerals with an irregular distribution pattern with depth. The lowest content is found in the deepest layer, while the highest percent is detected in the 70—110cm layer. Hypersthene dominates the pyroxene minerals followed by diopside and augite. The frequency distribution ranges between 22.5 to 30.4%, for hypersthene 5.3 to 8.9% for diopside and 1.8 to 7.4% for augite.

As shown in table 20, the pyroxenes in coastal plain (profile 22) ranges from 14.7 to 24.7% with dominance of the hypesrthene minerals followed by diopside and augite. Data show that hypersthenes, diopside and augite constitute 8.2—16.5%, 4.7—8.7%, and 0.6—4.9%, for each mineral, respectively.

Commenting on the above mentioned distribution of pyroxenes one can conclude that most of the variations encountered may by due to the nature of parent material, its sedimentation regime with little, if any, contribution of soil formation processes.

Amphiboles.

The amphiboles group is mainly represented by hornblende , glaucophane and actinolite of which hornblende is the most important. They have common features in being pleochroic. They constitute a considerable part of the heavy minerals. 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.

Data in table 20 reveal that the soils of El-Tina plain have amphiboles content ranging from 17.9 to 30.1% of the non-opaques. Depthwise distribution of amphibole minerals does not portray any specific pattern with depth. Among this group of minerals, hornblende is the predominant as it constitutes 10.4 to 22.7% of non-opaques, while actionolite and glaucophane form less pronounced amounts.

Amphiboles constitute 14.1—37.8% of the non-opaque in the soils of elevated sand dunes, table (21). This mineral group tends to decrease with depth in profile 12,while amphiboles display an opposite trend in profile 14. Hornblende predominates the amphiboles group with less pronounced occurrence of glucophane and actinolite.

With regard to the soils of the wadis, table (20) shows that the amphiboles content constitute 8.3 to 50.7% of the non- opaque minerals. The lowest percent is detected in the 40 to 75cm layer of profile 16, while the highest content occurred in the deepest layer of profile18. As usual in the studied soils, hornblende is the predominant one

(5.2—35.5%) among amphiboles; glaucphane and actinolite constitute lower amounts ranging from 1.8 to 12.1% and from 1.3 to 6.1 % of non-opaques,for each mineral, respectively .

Considering the amphiboles content of the soils of the alluvial fan, table (20) reveals that the content ranges from 13.1 to 22.4% of the non-opaque minerals with an irregular distribution pattern with depth. Hornblende predominates while glaucophane and actinolite constitute less amounts.

Soils of the coastal plain contain amphiboles that range from 16.1 to 20.1% of the non opaques with hornblende being dominant followed by glaucophane then actinolite.

Parametamorphics

These minerals are mainly represented by garnet, staurolite, kyanite and silimanite.:

Garnet.

This mineral is characterized by isotropy. It is represented by rounded to subrounded- shaped grains, pink to colourless with the dominance of glassy rose ones. Its percent varies widely in most geomorphic units, being in the range 2.1—7.6%, 1.6—10.5%, 0.8—8.6%, 5.2—6.1% and 6.8—11.5% for soils of El-Tina plain, elevated sand dunes, wadis, alluvial fan and coastal plain, respectively. The vertical distribution of granet is irregular in all profiles representing the studied geomorphic units except those of the coastal plain (profile 22) whose those garnet content has a tendency of gradual decrease with depth.

Staurolite

It is identified as a coloured mineral of golden yellow colour in plane light and between cross nichols. It is non-pleochroic, having subangular shape, rarely subrounded. The mineral percent ranges from 0.2 to 6.0% of the non- opaque minerals. The highest value is recorded in the subsurface layer of profile 7 representing the soils of El-Tina plain, while the lowest values are detected in the subsurface and deepest layers of profile 20 of the alluvial fan and profile 22 of the coastal plain. The vertical distribution shows that profiles 1,5,7,10,12,16,18,20 and 22 have irregular pattern. Profiles 8 and 11 show a decrease with depth, while profile 14 show an increase.

Kyanite.

It is detected in colourless varieties, having two perpendicular sets of cleavage and gives an abnormal interference colours between cross nichols. Its percentage ranges widely from 0.1 to 5.6% of the non-opaque minerals. The depthwise distribution is irregular with no specific pattern of distribution, except for profiles 1 and 14 where kyanite tends to increase with depth.

Silimanite.

Silimanite is found as colourless prismatic or rectangular grains, showing vertical striations and parallel extinction. In the studied areas, silimanite constitutes 0.1 to 4.9% of the non opaque minerals. The highest value is recorded in the surface layer of profile 5 in the soils of El-Tina plain, while the lowest value is found in the surface and 40—75 cm layer of profile 16 and the subsurface and deepest layers of profile 22 representing the soils of the wadis and the coastal plain, respectively.

Moreover, the mineral is entirely absent in some layers of profiles 12,16,18 and 20.

Ubibutous minerals:

Zircon.

Zircon, an altrastable mineral, is characterized by prismatic grains with subrounded edges. It is usually present in a colourless variety, while pink and yellow grains rarely occur, with a very high relief and parallel extinction.

Zircon in El-Tina plain soils constitutes 1.1 to 6.6% of the non-opaques. In the other land forms ranges were 5.7—10.4%, 2.3—15.9%, 9.4—15.2 and 9.5—16.6% in cases of elevated sand dunes, wadis, alluvial fan and coastal plain soils, respectively.

Considering the vertical distribution of the mineral, El-Tina plain, elevated sand dunes, wadis, alluvial fan and coastal plain display unique patterns with depth. In the soils of El-Tina plain (profiles 5 and 11), zircon shows a slight decrease with depth. From these pattern, it seems that zircon exhibits apparent discontinuity which indicates either non-uniformity of parent material or uniformity of depositional regime during soils formation.

Rutile.

This mineral is recognized by its deep red colour between cross nichols and plane light. It is detected as prismatic grains having rounded or subrounded terminations with high relief and parallel extinction. The mineral content is variable in the studied profiles. Its ranges in the different geomorpghic units are 0.7% to 3.0%, 2.4 to 15.1%, 0.2% to

4.8%, 4.1 to 6.2% and 9.1 to 13.8% in El-Tina plain, elevated sand dunes, wadis, alluvial fan and coastal plain, respectively. As to the depthwise distribution profiles there was no regularity, except for the soils of profiles 14 and 18 where rutile tends to decrease with depth.

In brief, the distribution of this ultra- stable mineral "rutile" shows no specific pattern of distribution pertaining to locality or geomorphic units. This could be explained on the basis that the studied soils have multi-origin and were derived from multi-parent materials and /or variations associated with depositional regime.

Tourmaline.

It is identified as prismatic grains having rounded edges. It is characterized by different colours of which the dominant is pleochroic from reddish violet to dark brown yellowish red; gray and blue may be found, but in subordinate amounts. From the frequency distribution of the mineral, Table 20 shows that elevated sand dunes profiles attain the lowest tourmaline content which varies between 2.4 and 6.3%, while the coastal plain has a relatively higher content. El-Tina plain, wadis and alluvial fan show ranges of tourmaline of; 1.4 to 5.8%, 1.2 to 5.9% and 3.1 to 5.2% of the non-opaques, respectively.

As to the depthwis distribution, data reveal that profiles 5,7,8,11,12,16,18,20 and 22 show irregular distribution of tourmaline. Profile (1) displays a slight decrease with depth, while profile (10) shows a gradual increase with depth. The encountered variations in this very stable mineral among the studied soils are mostly ascribed to variations of their parent materials which is reflected on their 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.

Biotite.

Biotite shares with tourmaline the phenomenon of darkness in the plane light but can be distinguished by its one –set of cleavage. The mineral constitutes variable percentages of the non-opaques ranging between 0.2 and 7.6% in the studied soil profiles. The lowest content is in the deepest layer of profile 18 (wadis), while the highest is in the deepest layer of profile 11 (El-Tina plain).

The pattern of distribution shows no distinct trend either with respect to profile location or to depth. This indicates the multi-origin nature of the parent materials or multi-depositional course, as well as, the natural variations within the parent material.

Epidotes.

Epidotes group is represented mainly by epidote and ziosite, which are generally found in sharp angular to subangular grains having greenish yellow colour. These minerals are detected in all of the studied soil and their contents vary from 2.8 to 21.7% of the non-opaques. The lowest content is in the elevated sand dunes (profile 12), while the highest is in the wadis (profile 18).

Monazite.

It is characterized by yellow colour, high relief, rounded grains and parallel extinction. Monazite in the areas under study ranges between 0 and 4.3% of the non-opaques. Table (20) reveals that monazite is absent in all layers of the elevated sand dunes (profiles 12 and 14) and the coastal plain soils (profile 22) but in the 70—150 cm layer of profile 12 and the deepest layer of profile 22, it occured.

Glauconite.

Glauconite is identified by its dirty colour grains which are non-pleochroic and have parallel extinction. Glauconite is seemingly a rare mineral among the heavy minerals of the study areas since it constitutes 0.1—5.3% of the non-opaques in few profile layers and being absent in many layers. It is absent in the 10—40cm layer of profile 7 (El-Tina plain), the deepest layers of profile 12 and the surface and deepest layers of profile 14 (both profiles represented elevated sand dunes). It is also absent in all layers of profile 18 (the wadis), the middle layers of profiles 20 (the alluvial fan) and the deepest layers of profile 22 (the coastal plain).

4.5.3-Uniformity of soil materials

Evaluation of the homogeneity or heterogeneity of the soil parent material using mineralogical analysis could be established through the assumption that certain minerals are more resistant to weathering. The ratios relating these minerals were also employed in such evaluations (Brewer 1964).

In this connection, the ratios of zircon/ tourmaline, zircon/rutile and zircon / (tourmaline + rutile) as well as the ratios between the total content of pyroxenes, amphiboles, epidote and garnet (representing the more weatherable minerals) and the total content of zircon, tourmaline and rutile (representing the weathering-resistant minerals) are taken as criteria for the evaluation of soil profile uniformity and weathering intensity (Hammad,1968, El-Demerdashe et al. 1976, Hassona et al. 1995 and Hassona 1999).

Data presented in table 21 and Figs 12 and 13 illustrate the weathering ratios and their depthwise distribution in the studied soil profiles. These data show the following:

1) Soils of El-Tina plain which are represented by profiles 1,5,7,8,10,and 11 are formed of multi-origin and or/multi depositional regimes, as indicated by the irregular trend of the uniformity ratios and weathering ratios with depth. These evidences indicate the heterogeneity of the soil parent material. Also, the analytical data show that these soils are enriched in pyroboles rather than (zircon + tourmaline). This suggests that these soils are young form the pedological viewpoint.

2) Soils of the elevated sand dunes which are represented by profiles 12and 14 are shown to be rather uniform at least in their subsurface layer as indicated by most weathering ratios. Moreover , the soil may also be considered young from the pedological point of view, as the parent material is shown to be rich in the pyroboles which are susceptible to weathering.

3) Soils of the wadis (represented by profiles 16 and 18) show that their materials derived from multi origin sediments, as revealed from the non-smoothness of the distribution pattern of resistant minerals and weathering ratios (table 21).

4) Soils of alluvial fan (represented by profile 20) seem to have been formed from heterogeneous parent materials as indicated by the non smoothness of distribution pattern of resistant minerals and weathering ratios.

Table (21) Uniformity weathering ratios of the studied soil profiles.

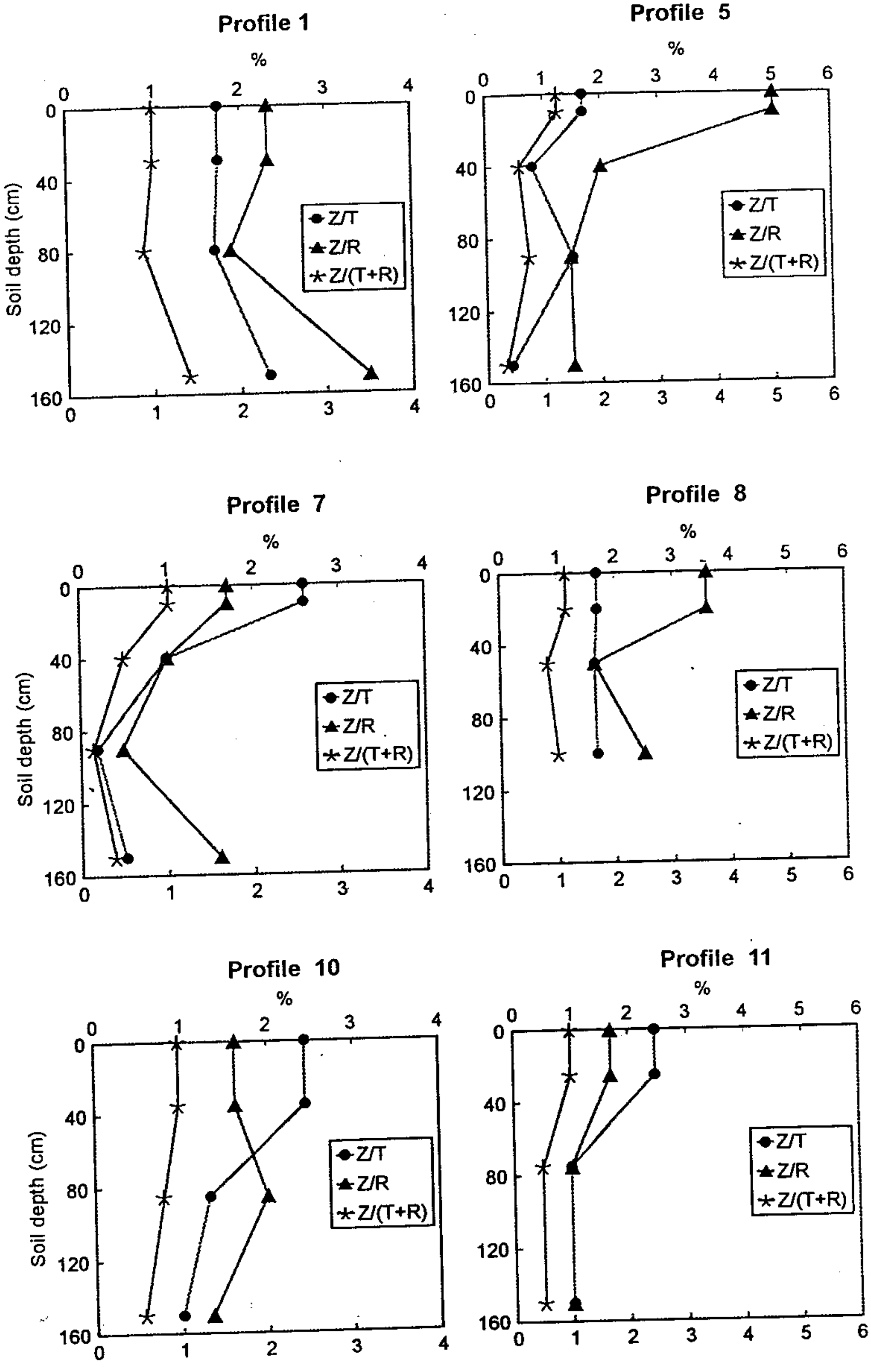
Location	Geom-orphic Unit	Prof. No.	Depth (cm)	Uniformity ratios			Weathering ratios		
				Z / T	Z / R	Z/(T+R)	Wr_1	Wr_2	Wr_3
El- Tina plain	El-Tina	1	5-30	1.75	2.33	1.0	6.3	1.8	0.24
			30-80	1.7	1.88	0.89	6.8	1.9	0.23
			80-150	2.33	3.5	1.4	5.8	1.5	0.30
		5	0-10	1.7	5.0	1.25	8.7	2.12	0.11
			10-40	0.81	2.0	0.58	10.7	2.8	0.33
			40-90	1.5	1.47	0.73	17.9	4.1	0.40
			90-150	0.41	1.5	0.33	11.5	2.5	0.19
		7	0-10	2.6	1.70	1.03	13.04	2.60	0.28
			10-40	1.0	1.00	0.50	18.5	5.03	1.00
			40-90	0.19	0.48	0.14	9.0	1.51	0.33
			90-150	0.51	1.60	0.39	7.6	1.57	0.42
		8	0-20	1.7	3.6	1.16	7.4	1.82	0.37
			20-50	1.65	1.65	0.83	11.6	3.13	1.25
			50-100	1.68	2.5	1.00	8.6	2.28	0.26
		10	0-35	2.45	1.63	0.98	8.8	2.61	0.29
			35-85	1.33	2.0	0.8	14.6	4.3	0.29
			85-150	1.00	1.35	0.57	10.9	3.66	0.13
		11	0-25	2.47	1.7	1.0	13.13	3.6	0.13
			25-75	1.00	1.0	0.50	11.70	3.3	0.33
			75-150	1.00	1.00	0.50	19.10	5.00	2.27
	Elevated sand dunes	12	0-30	2.8	0.52	0.44	5.7	2.78	0.09
			30-70	1.7	0.69	0.49	2.8	1.14	0.09
			70-150	1.5	0.67	0.46	3.1	0.66	0.05
		14	0-20	1.2	2.1	0.74	4.8	1.69	0.26
			20-70	1.2	2.7	0.83	4.0	1.72	0.19
			70-150	2.3	2.3	1.20	8.7	3.85	0.30

Z = Zircon
T = Tourmaline
R = Rulite
Wr_1 = Pyroxene+ Amphibole/ Zircon + Tourmaline
Wr_2 = Hornblende / Zircon + Tourmaline
Wr_3 = Biotite / Zircon + Tourmaline

Table (21) cont.

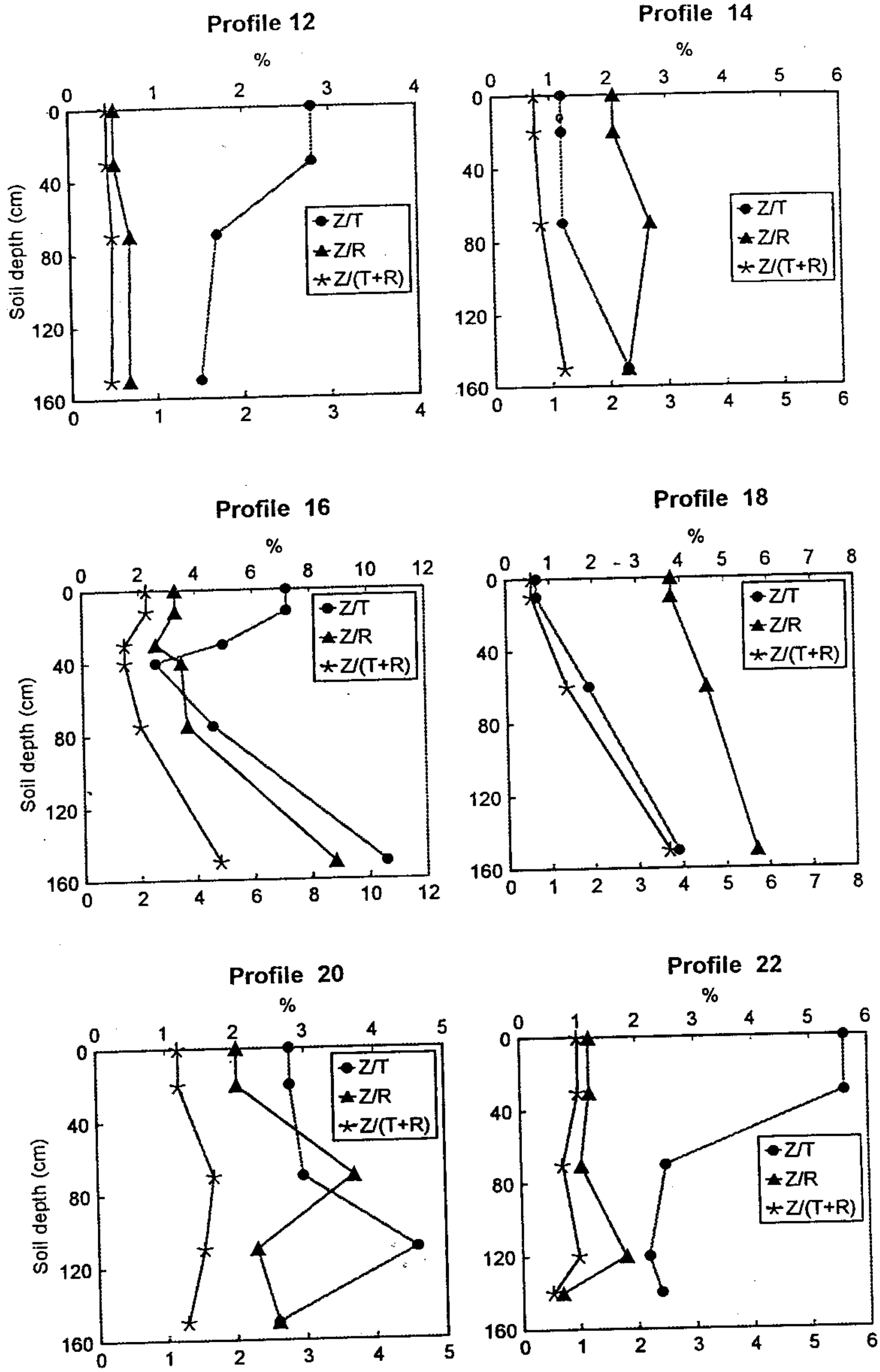
Location	Geomorphic Unit	Prof. No.	Depth (cm)	Uniformity ratios			Weathering ratios		
				Z / T	Z / R	Z/(T+R)	Wr_1	Wr_2	Wr_3
El-Qaa plain	Wadis	16	0-12	7.2	3.30	2.30	2.90	0.53	0.017
			12-30	4.96	2.60	1.50	3.40	0.70	0.130
			30-40	2.6	3.50	1.50	2.80	0.46	0.096
			40-75	4.6	3.70	2.04	3.00	0.29	0.126
			75-150	10.6	8.80	4.80	3.40	0.49	0.068
		18	0-10	0.71	3.80	0.60	6.10	3.26	0.049
			10-60	1.90	4.60	1.40	16.90	10.20	0.143
			60-150	3.90	57.00	3.70	4.90	2.71	0.014
	Alluvial fan	20	0-20	2.80	2.04	1.20	0.63	0.79	0.094
			20-70	2.98	3.70	1.70	0.45	0.46	0.089
			70-110	4.60	2.30	1.55	0.53	0.56	0.063
			110-150	2.60	2.60	1.30	0.55	0.83	0.085
	Coastal plain	22	0-30	5.60	1.20	1.04	0.84	0.55	0.147
			30-70	2.50	1.04	0.73	0.97	0.99	0.034
			70-120	2.20	1.80	0.99	0.83	0.44	2.060
			120-140	2.40	0.69	0.53	1.32	1.03	0.260

Z = Zircon
T = Tourmaline
R = Rulite
Wr_1 = Pyroxene+ Amphibole/ Zircon + Tourmaline
Wr_2 = Hornblende / Zircon + Tourmaline
Wr_3 = Biotite / Zircon + Tourmaline



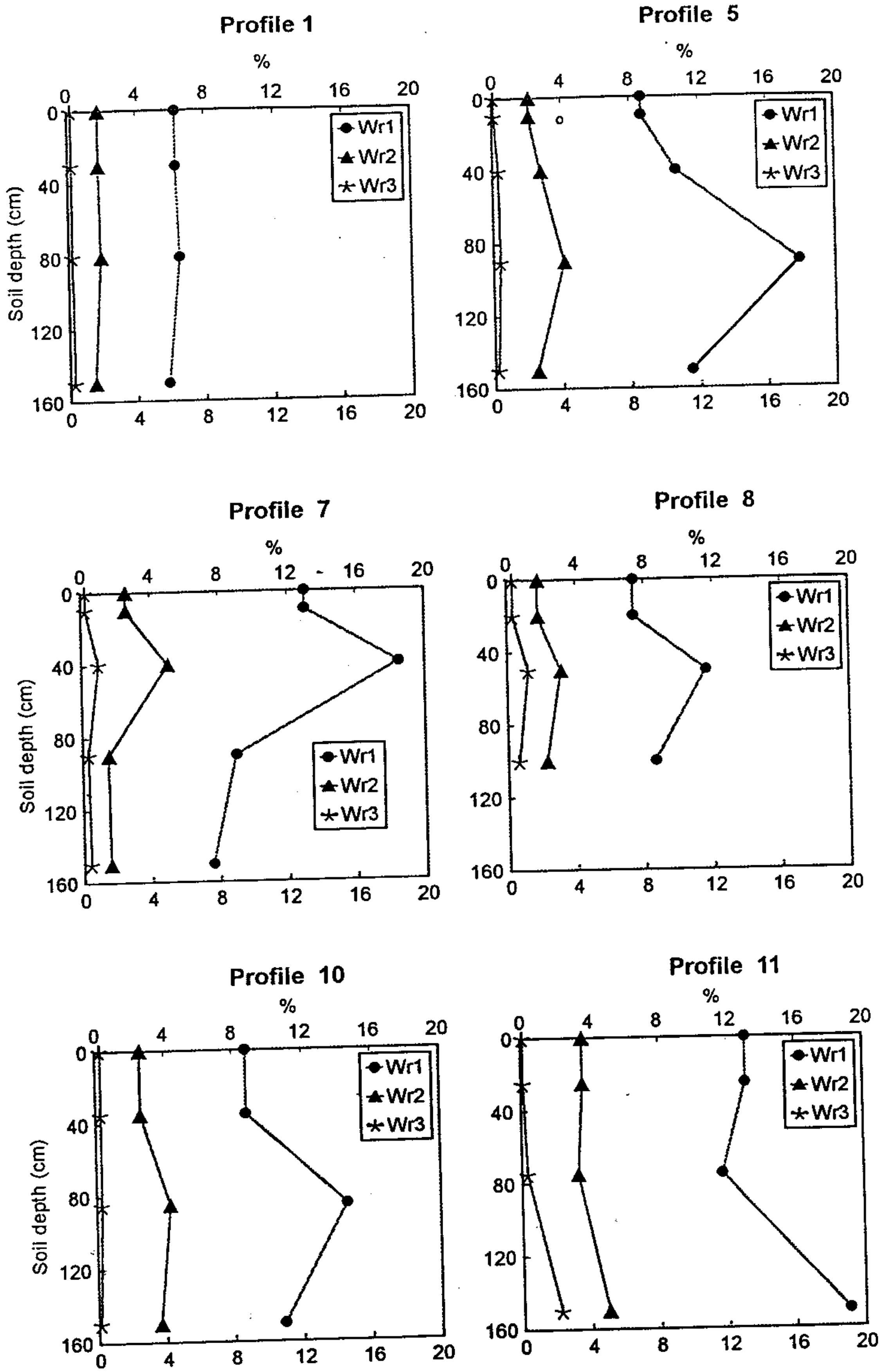
Z = Zircon, T = Tourmaline and R = Rutile

Fig. (12) Depthwise distribution of the most resistant minerals in the studied soils.



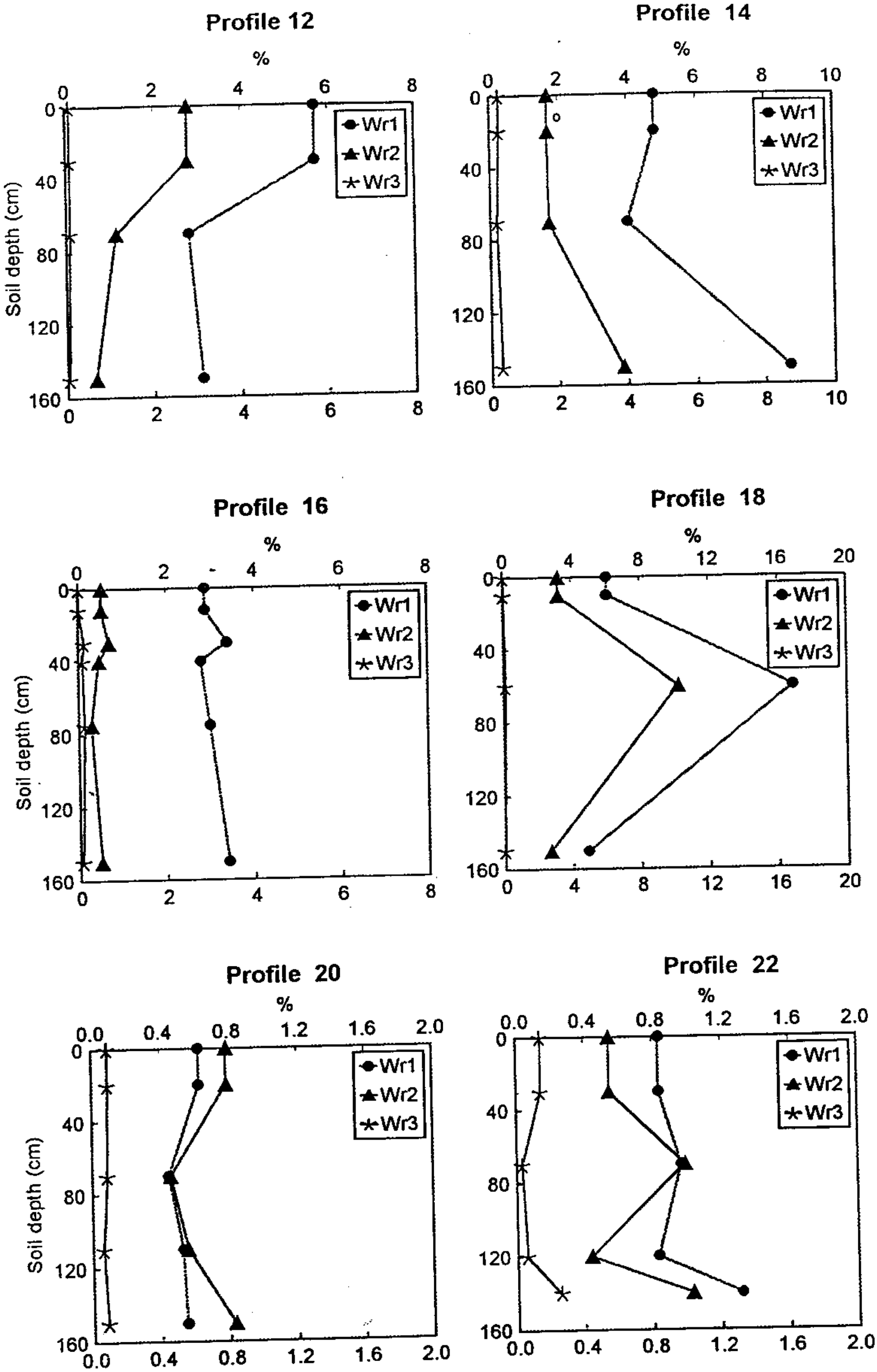
Z = Zircon, T = Tourmaline and R = Rutile

Fig. (12) Depthwise distribution of the most resistant minerals in the studied soils.



Wr1 = (Pyroxene+Amphibole) / (Zircon+Tourmaline)
Wr2 = (Hornblend) / (Zircon+Tourmaline)
Wr1 = (Biotite) / (Zircon+Tourmaline)

Fig. (13) Depthwise distribution of weathering ratios in the studied soils.



Wr1 = (Pyroxene+Amphibole) / (Zircon+Tourmaline)
Wr2 = (Hornblend) / (Zircon+Tourmaline)
Wr1 = (Biotite) / (Zircon+Tourmaline)

Fig. (13)Depthwise distribution of weathering ratios in the studied soils.

5) Concerning the soils of coastal plain (profile 22) data given in Table (21) show marked variations throughout the profile layers which reflect heterogeneity of soil materials and /or multi depositional regime.

In conclusion, the data of frequency distribution of resistant minerals and weathering ratios lead to the conclusion that the soils of each profile are heterogeneous, most probably due to the sedimentation course. However, some minute variations within profile layers, may be attributed to the natural variation within the parent material of each profile, and not due to the intermixing of variable parent materials. The studied soils are considered young from the pedological view point.

4.6- Mineralogical analysis of the clay fraction

Clay minerals content and distribution in soils are considered as a criterion for soil origin, genesis and prevailing environmental conditions involved in soil formation. The type of clay minerals and their contents are of paramount importance as they control most soil properties. For instance, they affect shrinkage, swelling, plasticity, moisture holding properties, permeability, ion exchange, absorption, fixation and release of nutritive elements and weathering ability. Clay minerals data are used for differentiating soil families in the comprehensive soil classification system " Soil taxonomy"

X-ray diffraction technique is one of the most effective tools for the identification of clay minerals. It is based on the presence of diagnostic diffraction maximum for each mineral. The intensity and sharpness of these maximum are affected by particle size, chemical composition, crystal orientation, crystal imperfection, amorphous materials content and the presence of a mixture of clay minerals.

Identification of clay minerals present in the studied profiles was made according to the basis outlined by Brown (1961), Jackson (1965) and Dixon et al. (1977) as follows.

a) Semectite minerals are identified by the expansion of the basal reflection (001) from 14 A° in the Mg- saturated sample to 18 A° upon glycerol solvation and its collapse to about 10 A° in K-saturated,heated to 550 °C for 4 hours.

b) Kaolinite is detected by its strong characteristic diffraction maxima at 7.13 A° and 3.57 A°, that disappear upon heating at 550 °C, but stays unaffected by glycerol solvation.

c) Illite "hydrous mica" minerals are identified by the presence of the basal maximum 10 A° peaks upon Mg-saturation, which remains constant throughout the different treatments.

d) Palygorskite minerals is identified from the basal reflection (001) of strong intensity at spacing ranges from 10.2 A° to 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, 4.50, 3.68, 3.24 and 2.15 A°, confirms its occurrence.

e) Vermiculite is identified by the presence of the 14 A° peak which contracts to 10 A° in the K-saturated and heating to 550 °C treatment for four hours.

f) Chlorite is identified by the presence of basal diffraction peaks at 13.6-14.3 A° (first order) and 7.07-7.2 A° (second order) which remain constant throughout the different treatments; the presence of a third order reflection at 4.7-4.8 A° further confirms chlorite presence.

g) Interstratified 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.

h) Quartz usually gives two fairly strong peaks at 3.35 A° and 4.26 A°; the former is more than twice as intense as the latter.

i) Feldspars, calcite and dolomite are identified by their characteristic diffraction peaks at 3.1-3.25, 3.03 and 3.89 A°, respectively.

For further differentiation, a semi-quantitative estimation of minerals is performed on basis of the relative frequencies indicated by the peak area, Jackson (1976).

Out of the studied profiles in the whole areas, only nineteen soil samples were chosen for clay separation and identification. These samples represent the soils of El-Tina plain, elevated sand dunes, wadis, alluvial fan and coastal plain. The mineralogical composition of the clay fraction in the studied soils, is presented below.

4.6.1.-Soils of El-Tina Plain

1-Clay mineralogy of El-Tina plain.

The X-ray diffraction pattern of the clay fractions separated from the fine- textured layers of profiles 1, 5, 7, 8, 10 and 11 (which represent soils of El-Tina plain) are shown in Figs. 14 to 25 and Table 22. These soils are highly saline and have considerably low amounts of calcium carbonate.

The diffraction pattern reveals that the clay fractions of these soils are dominated by montmorillanite followed by kaolinite. Montmorillonite dominates in all layers except for the 40—90cm layer of profile 5 which has moderate amount of it. Interstratified minerals are usually detected in traceable amounts except in the 40-90 cm depth of profile 5 and 35—85 layer of profile 10 which have few of them. Kaolinite constitutes moderate to common amounts of the mineralogical composition. Illite is found in traces to few amounts in all profile layers. Chlorite is detected in traceable amounts, and disappears entirely in the subsurface layers of profiles

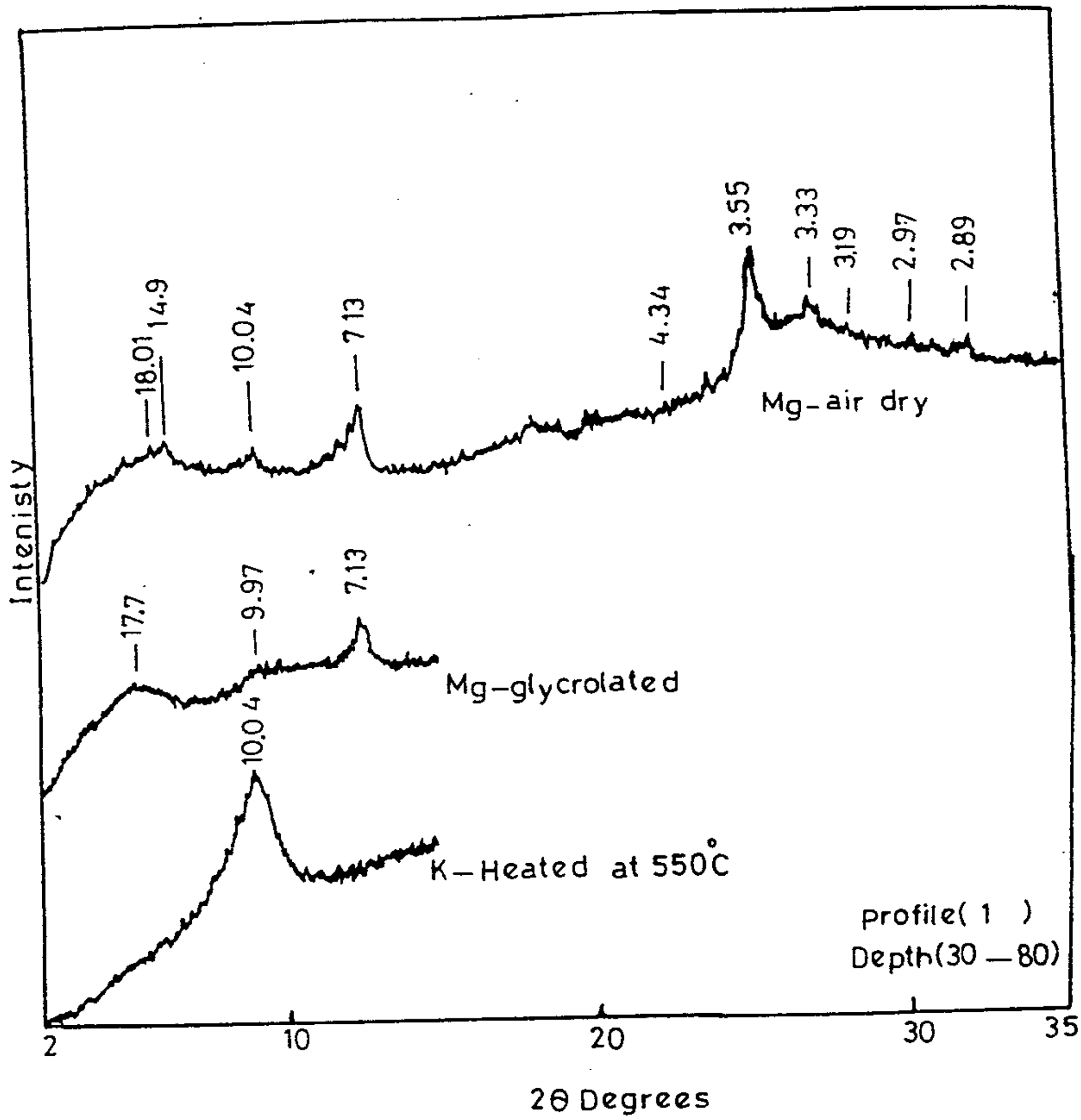


Fig. (14): X-ray diffraction pattern of the clay fraction separated from the 30-80 cm layer of profiles (1). (El-Tina plain)

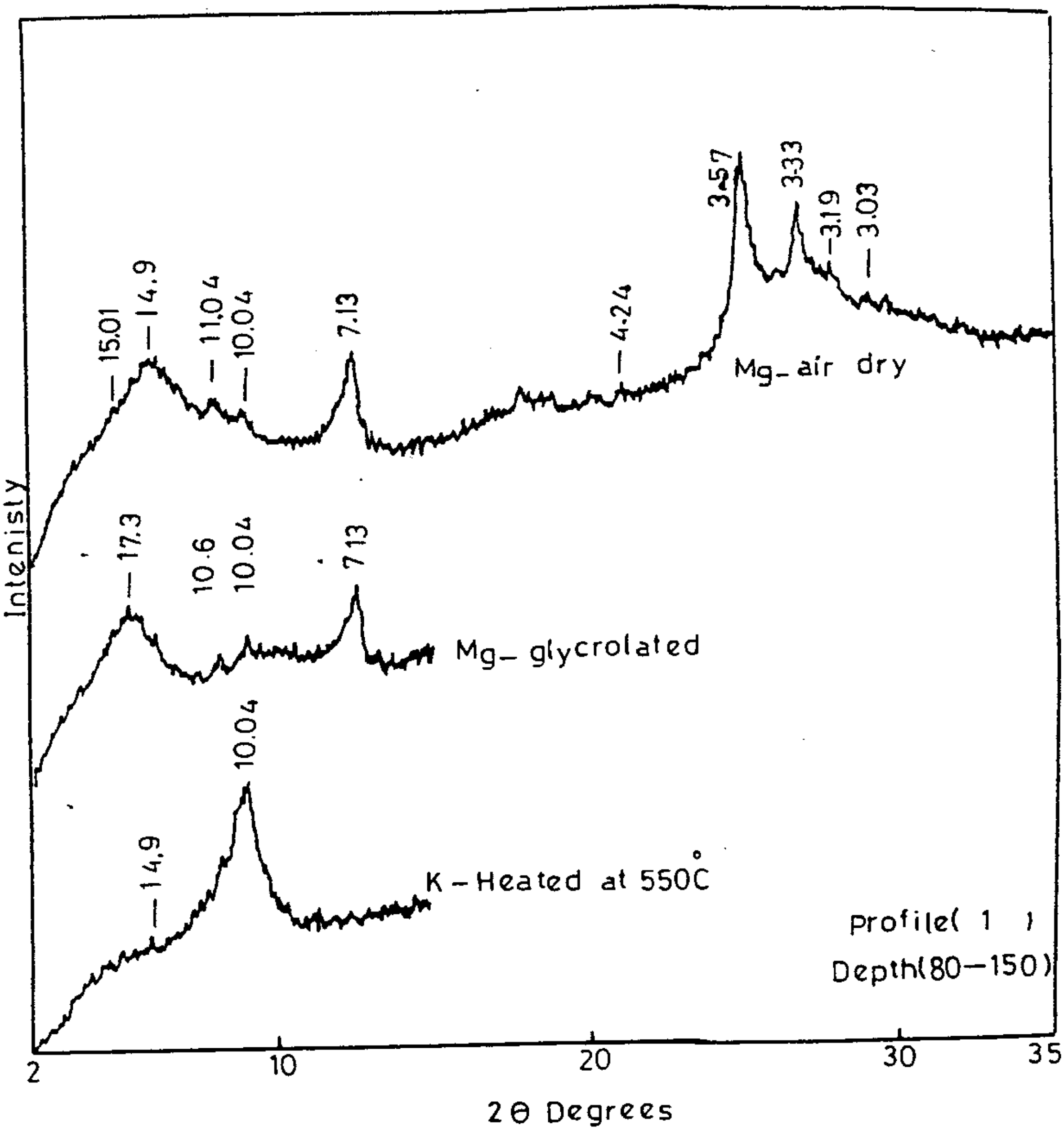


Fig.(15): X-ray diffraction pattern of the clay fraction separated from 80-150 cm. layer of profile (1). (El-Tina plain).

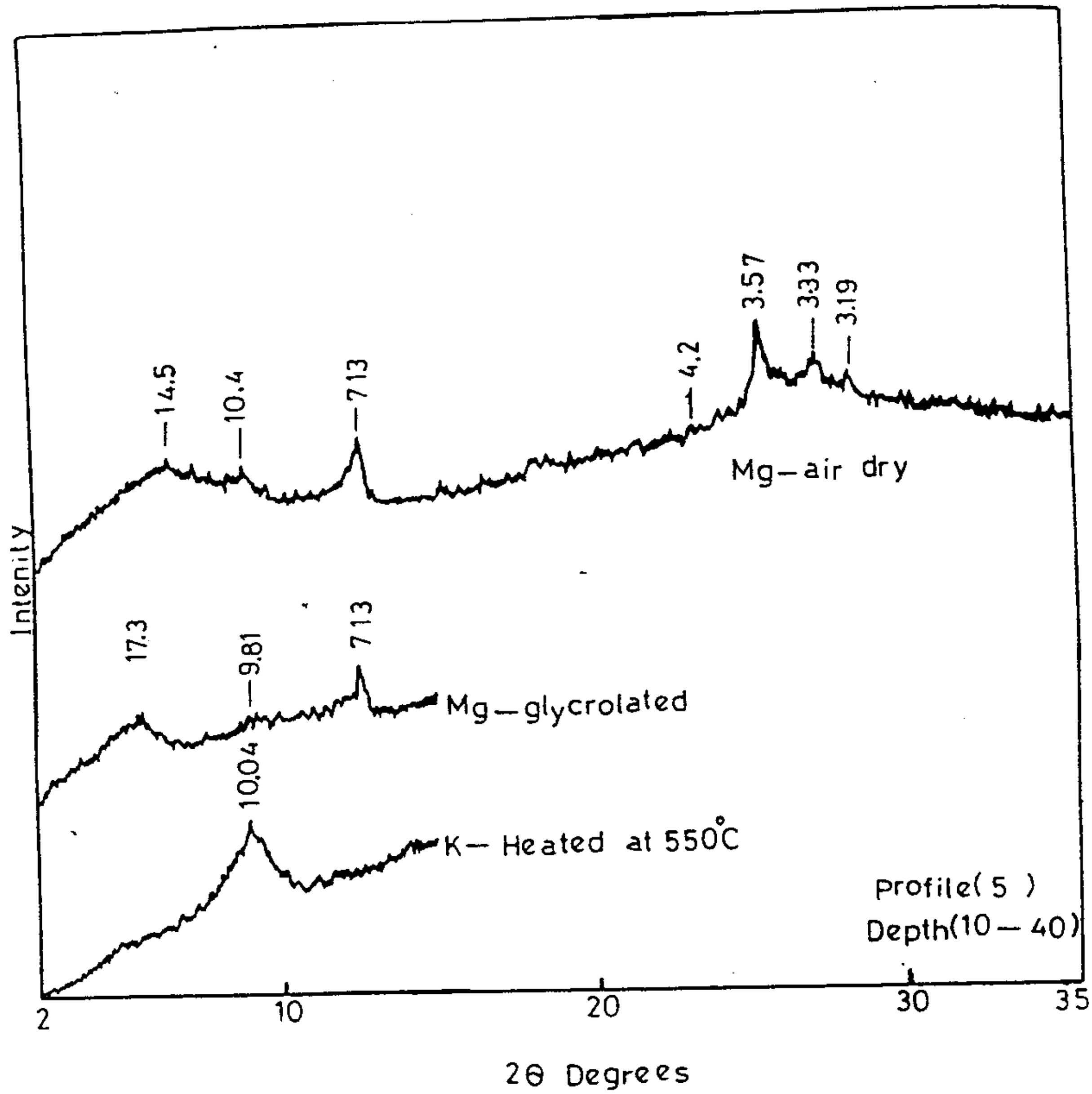


Fig.(16): X-ray diffraction pattern of the clay fraction separated from 10-40 cm.layer of profile (5) (El-Tina plain).

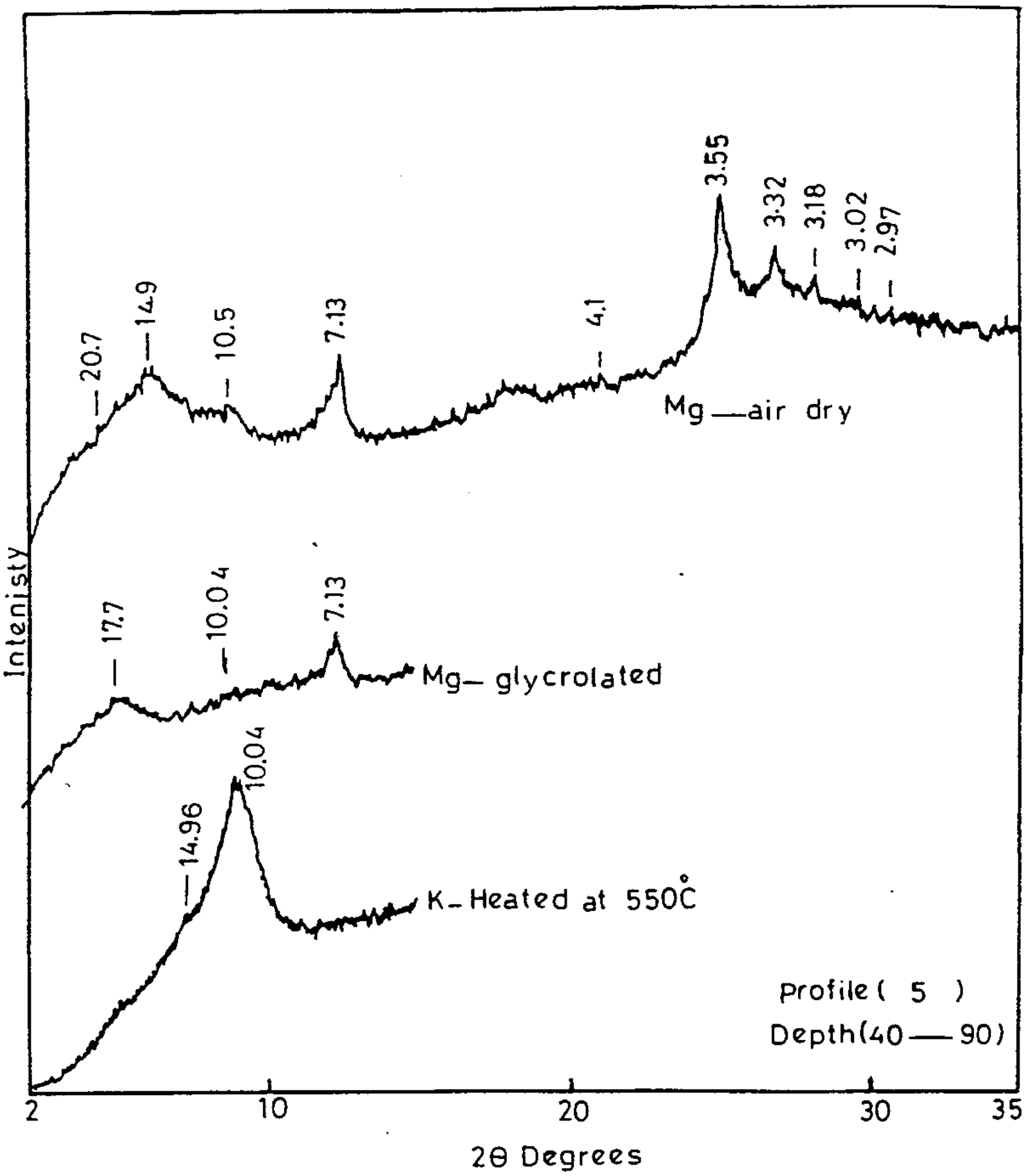


Fig.(17):X-ray diffraction pattern of the clay fraction separated from the 40-90 cm.layer of profile(5) (El-Tina plain).

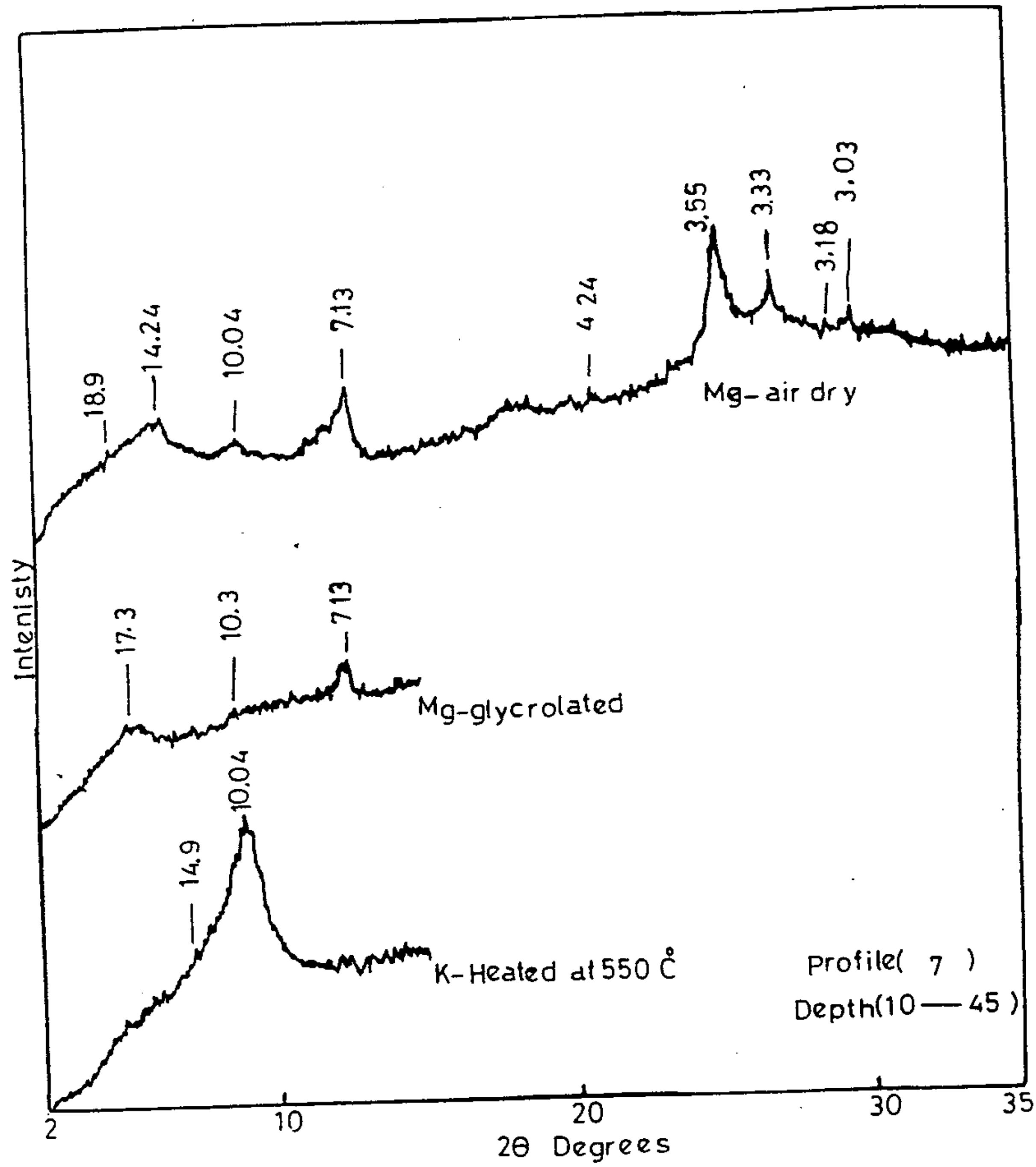


Fig.(18): X-ray diffraction pattern of the clay fraction separated from 10-45 cm.layer of profile (7) (El-Tina plain).

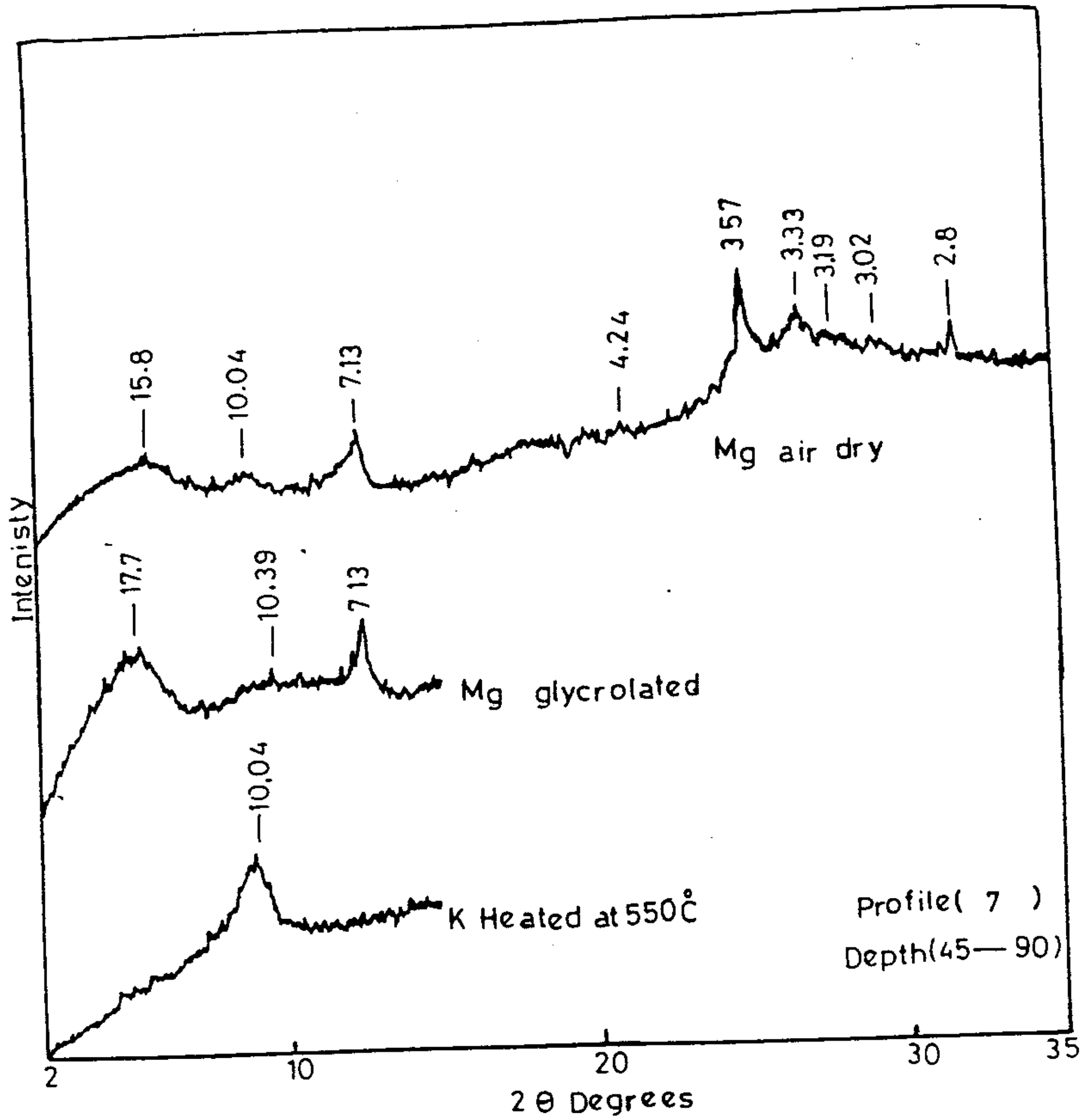


Fig.(19): X-ray diffraction pattern of the clay fraction separated from 45-90 cm. layer of profile (7) (El-Tina plain).

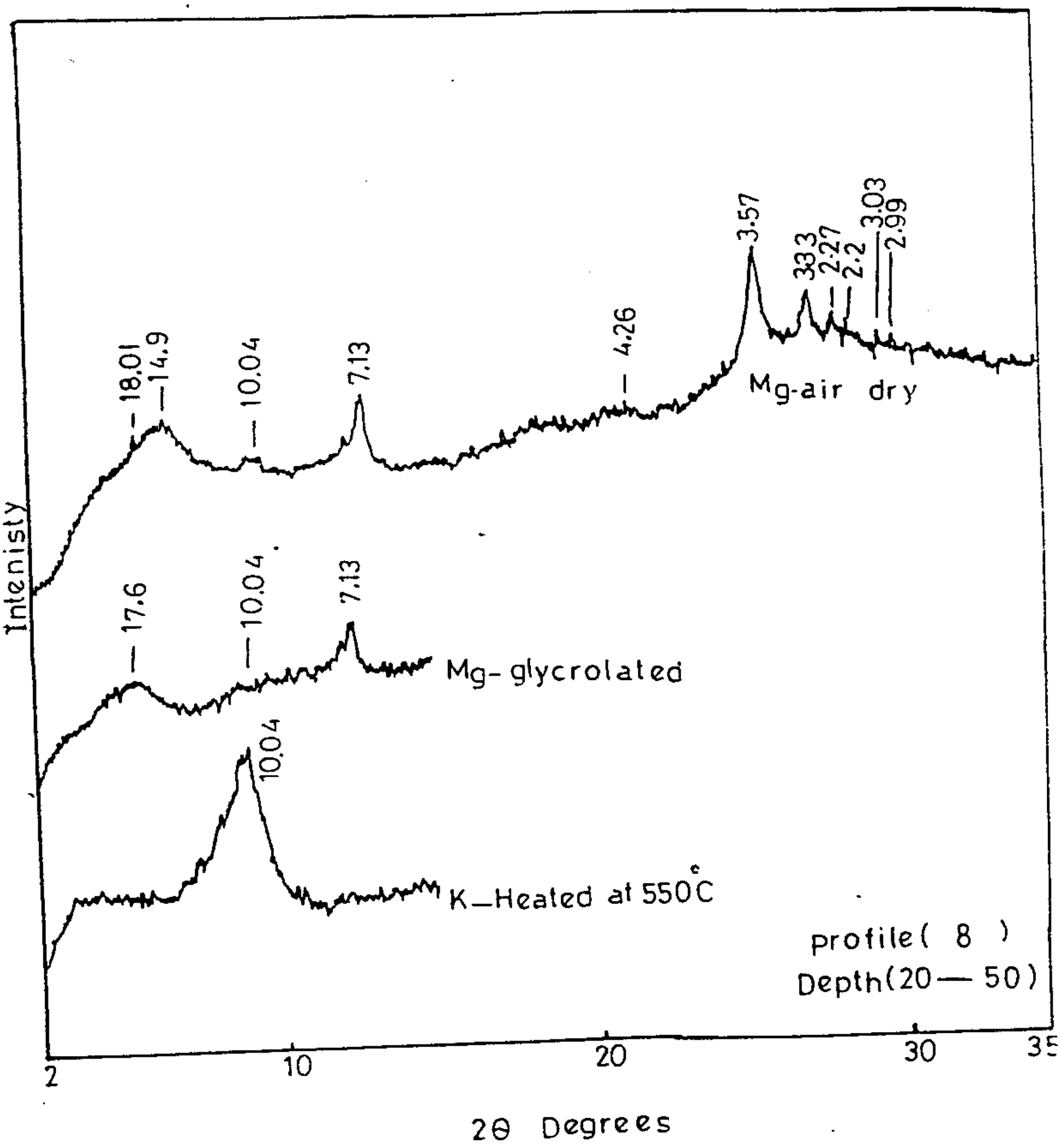


Fig.(20): X-ray diffraction pattern of the clay fraction separated from 20-50 cm. layer of profile(8) (El-Tina plain).

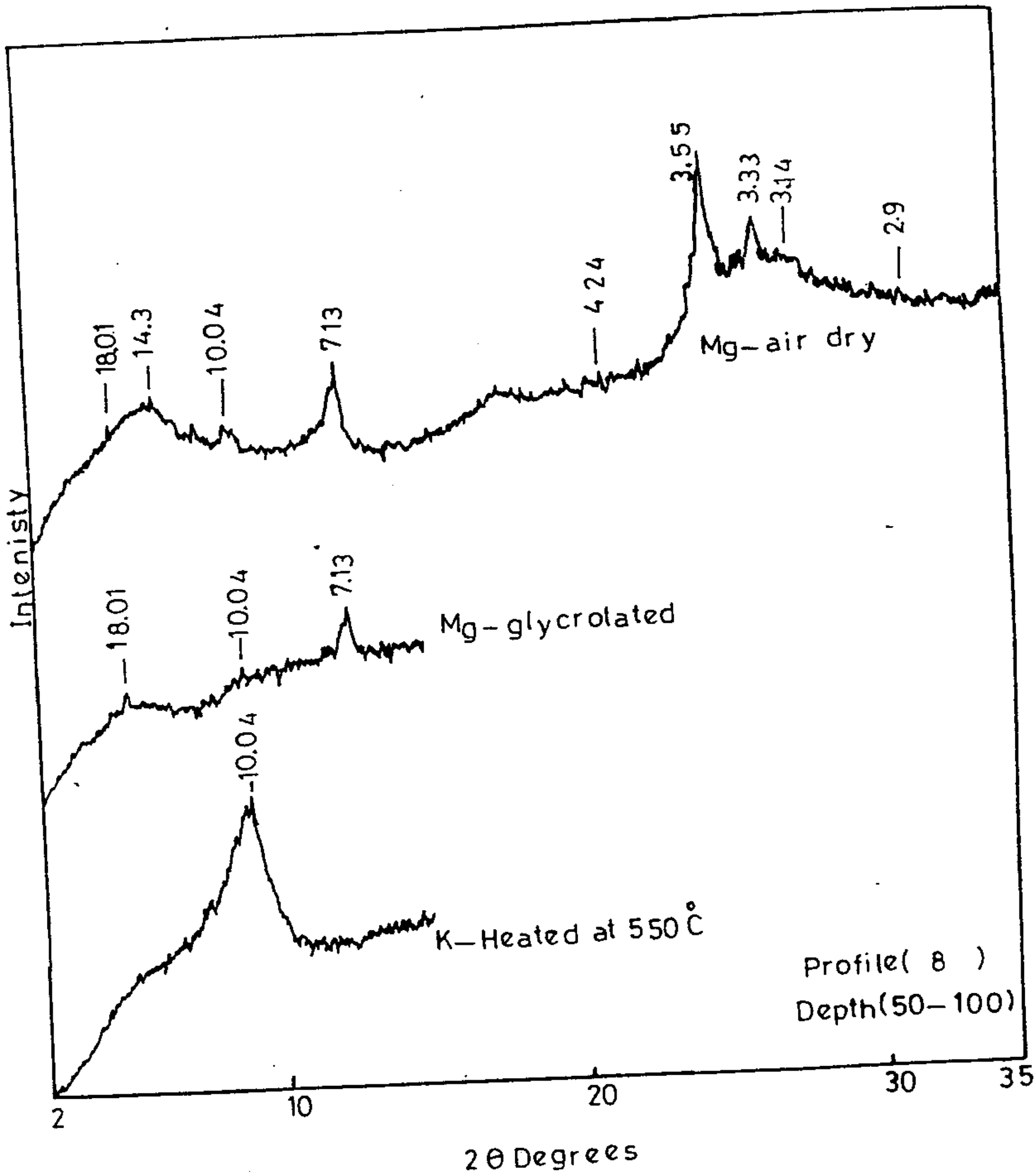


Fig.(21); X-ray diffraction pattern of the clay fraction separated from 50-100 cm. layer of profile(8) (El-Tina plain).

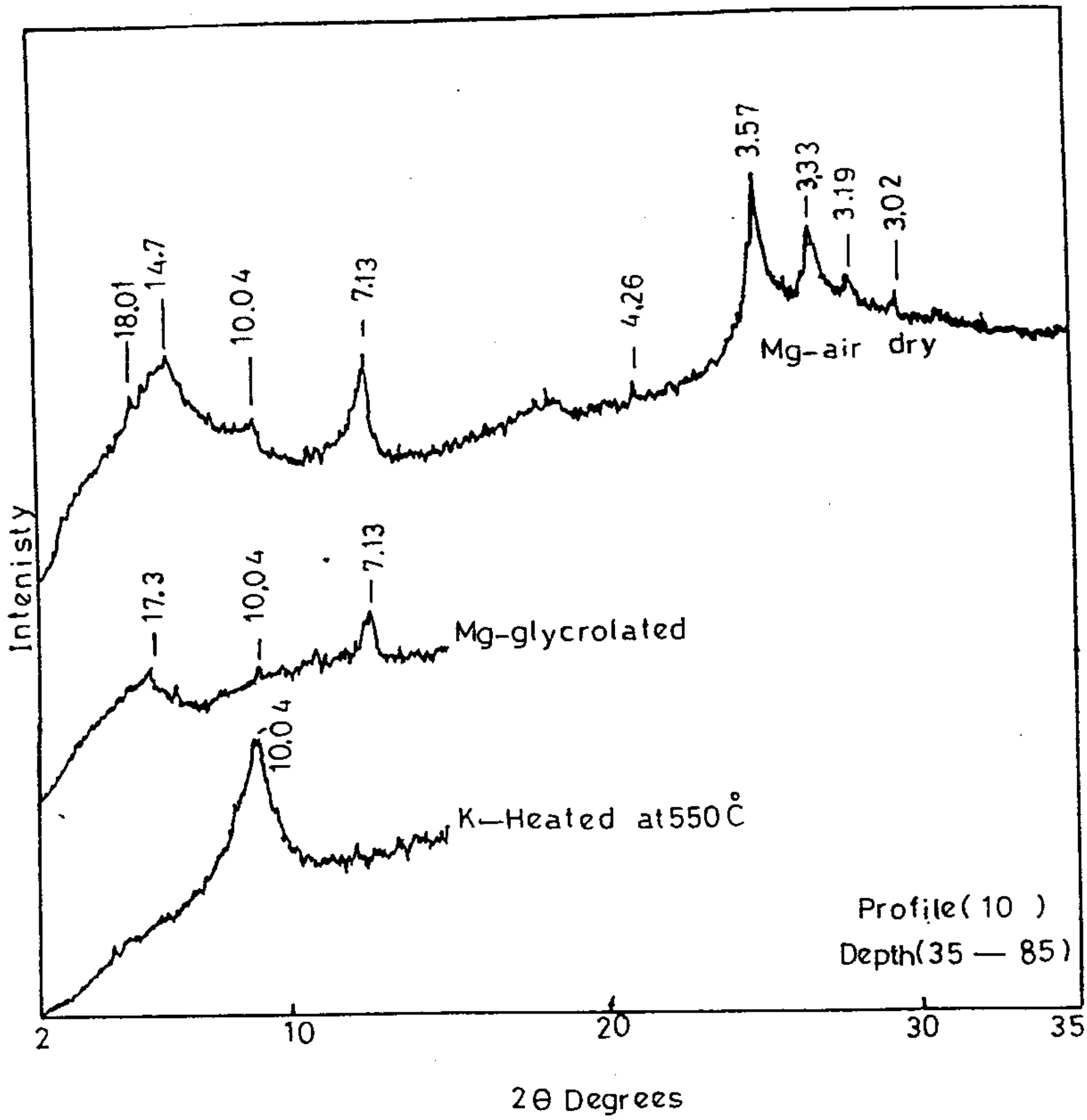


Fig. (22): X-ray diffraction pattern of the clay fraction separated from 35-85 cm. layer of profile 10. (El-Tina plain).

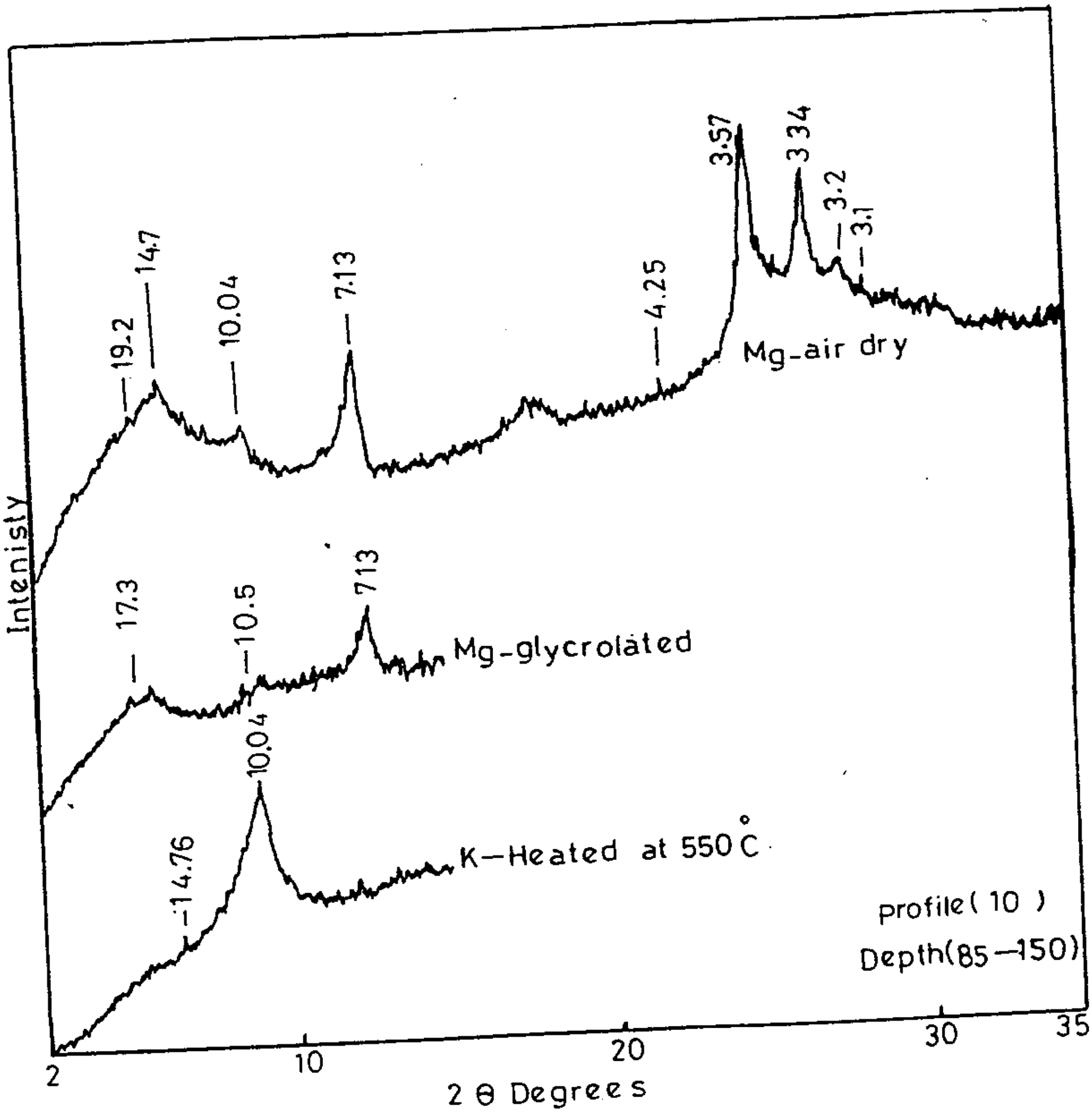


Fig. (23): X-ray diffraction pattern of the clay fraction separated from 85-150 cm. layer of profile 10. (El-Tina plain).

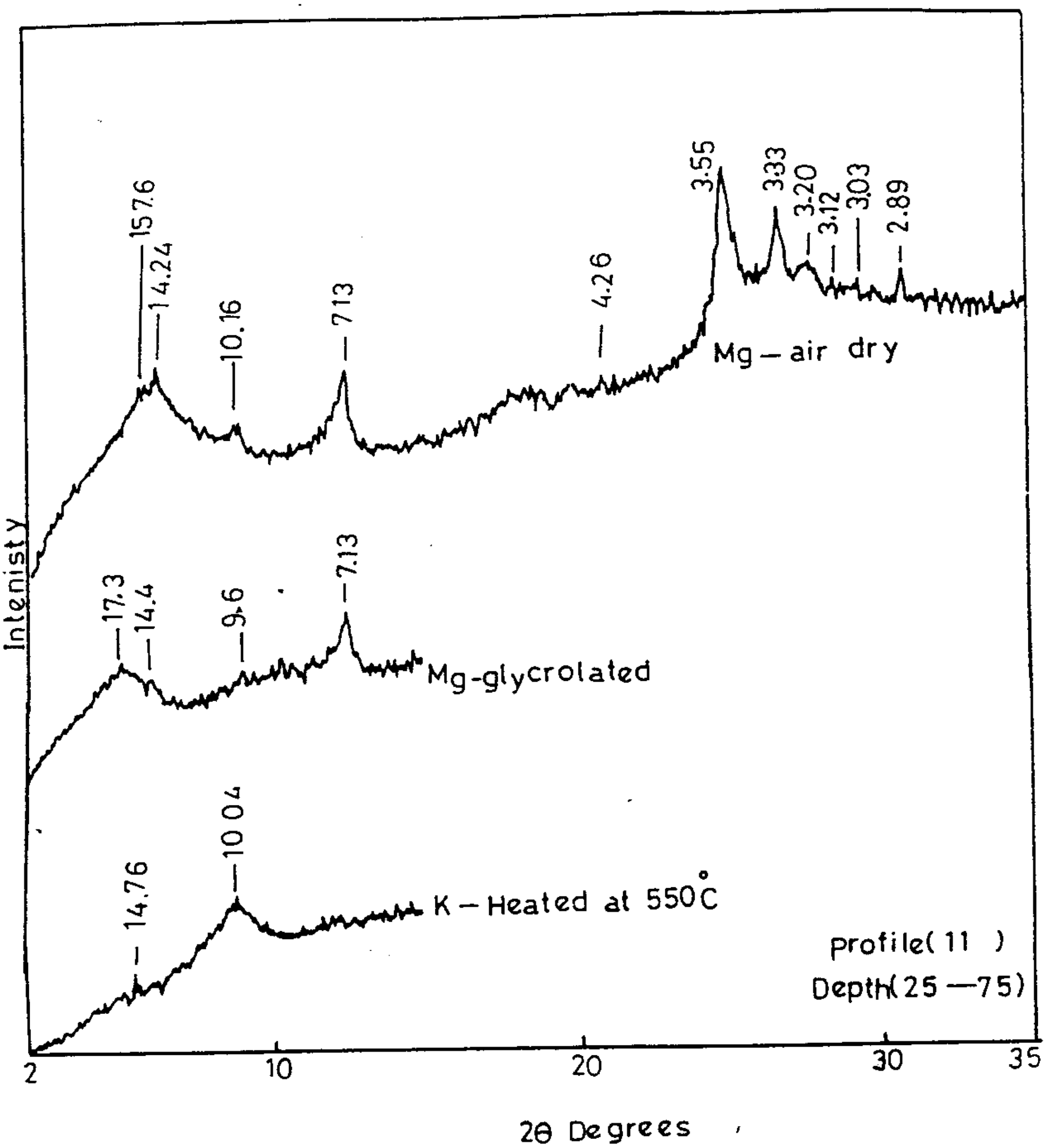


Fig. (24): X-ray diffraction pattern of the clay fraction separated from 25-75 cm. layer of profile 11. El-Tina plain.

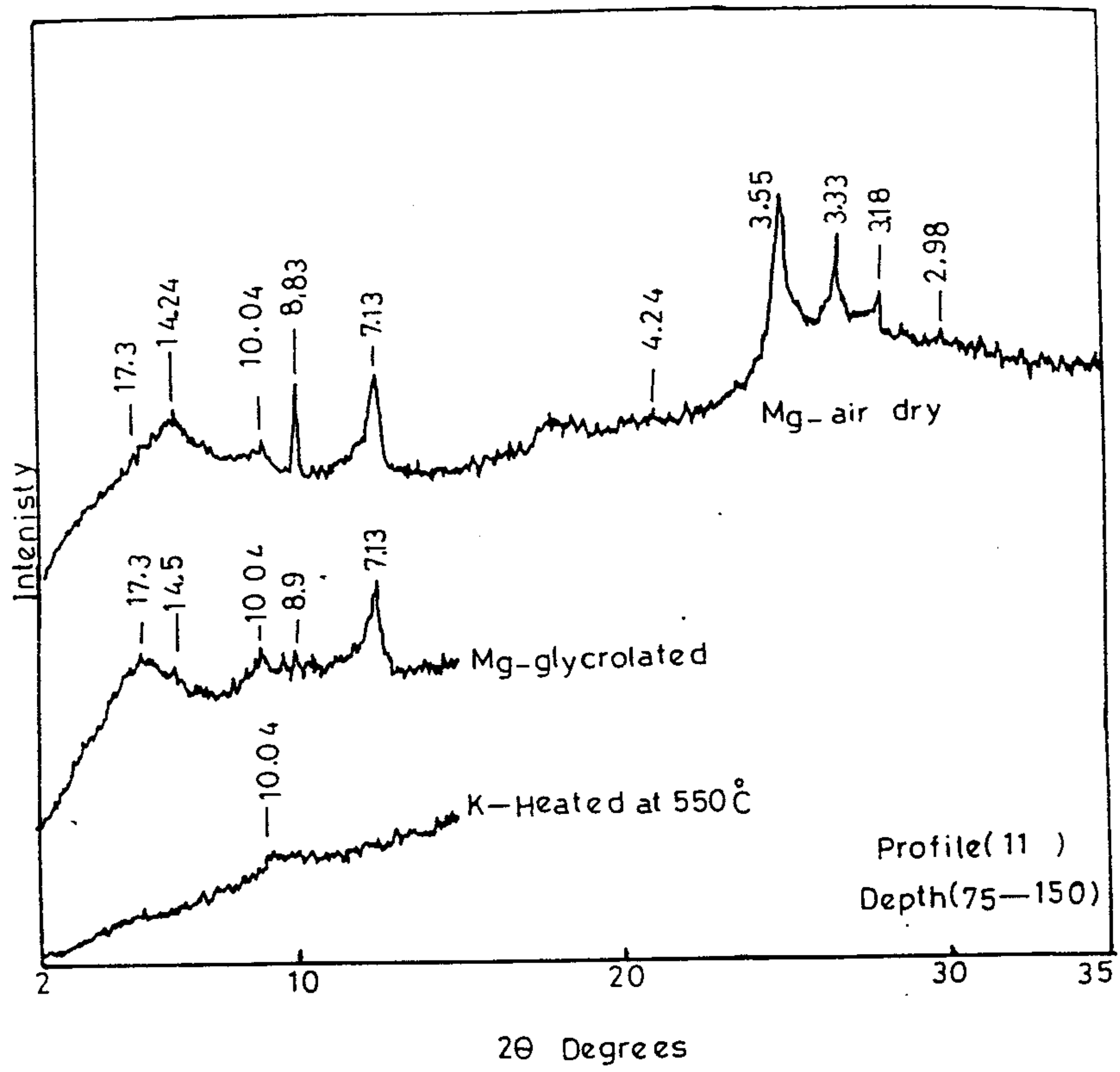


Fig.(25): X-ray diffraction pattern of the clay fraction separated from 75-150 cm. layer of profile 11. (El-Tina plain).

Table(22). Semi – quantitive analysis of clay mineral composition of the studied soil profiles.

Location	Geomo-Rphic units	Prf. No.	Depth (cm)	Interstr-tified minerals	Clay minerals						Accessory minerals			
					Kaolinite	Montm-orllonite	Illite	Chlorite	Vermi-culite	Playgo-rskite	Quartz	Feldspars	Calcite	Delomite
El-Tina plain	El-Tina plain	1	30-80	Tr.	Mod	Dom	Few	--	--	--	Few	Tr.	-	Tr.
			80-150	Tr.	Mod	Com	Tr.	Tr.	Mod	--	Few	Tr.	Tr.	--
		5	10-40	--	Com	Com	Few	--	Few	--	Few	--	--	--
			40-90	few	Com	Mod	Few	Tr.	Few	--	Few	Tr.	--	--
		7	10-45	Tr.	Mod	Com	Tr.	Tr.	Few	--	Few	Tr.	Few	--
			45-90	--	Mod	Com	Tr.	--	--	--	Few	Tr.	Tra	--
		8	20-50	Tr.	Mod	Mod	Tr.	--	--	--	Few	Tr.	Tr.	--
			50-100	Tr.	Com	Dom	Few	--	--	--	Few	Tr.	--	--
		10	35-85	Few	Mod	Com	Tr.	--	--	--	Mod	Few	Tr.	--
			85-150	Tr.	Com	Dom	Tr.	Tr.	Few	--	Few	Few	--	--
		11	25-75	--	Mod	Dom	Tr.	Tr.	Few	--	Few	Few	Tr.	Tr.
			75-150	Tr.	Com	Dom	Tr.	--	--	--	Few	Tr.	--	--
	Elevated sand dunes	14	20-70	Few	Mod	Com	Few	--	--	--	Com	Few	Few	Tr.
			70-150	--	Few	Few	Tr.	--	--	--	Com	Com	Tr.	Tr.
El-Qaa plan	Wadis	17	40-80	Com.	Few	Dom	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	--	--
			80-120	Com.	Few	Com	Tr.	Few	--	--	Tr.	Tr.	--	--
	Alluvial fan	20	20-70	Mod	Mod	Com	Tr.	Tr.	Few	Tr.	Tr.	Tr.	--	--
			70-110	Com	Few	Com	Tr.	--	Tr.	Tr.	Tr.	Tr.	--	--
	Coastal plain	22	70-120	Dom	Few	Com	Tr.	Tr.	Few --	Tr.	Tr.	Tr.	--	--

Dom = Dominant > 40%
Mod = Moderate 15—25%
Tra = Trace < 5%

Com = Common 25—40%
Few = Few 5—15%
Absent = --

1, 5, 10 and in all layers of profile 8. Vermiculite is found in moderate amounts in the 80—150cm layer of profile 1 and few amounts in the other layers, while disappears in all layers of profile 8 and the deepest layer of profiles 7 and 11.

The identified accessory minerals are mainly dominated by quartz followed by feldspars, calcite and dolomite.

The obtained results are in agreement with those obtained by Farag (1981), Hamra (1982), and Khalil (1985) as they found that clay minerals in soils of of El-Tina plain are dominated by smecitite (montmorillonite) and Kandite (Kaolinite) with less pronounced occurrence of interstratified minerals.

2-Clay mineralogy of soils of elevated sand dunes.

Soils of this geomorphic unit are represented by profile 14. The x-ray differactograms of this profile are depicted in Figs. 26 and 27. The data in Table 22 show that smectite (montmorillonite) predominates the clay minerals followed by kaolinite . Interstratified minerals are detected in few amounts in the subsurface layer and disapper in the deepest layer. Illite is detected in few amounts except for the deepest layer where the mineral is found in traceable amounts.

The identified accessory minerals are mainly dominated by quartz followed by feldspars calcite and dolomite. The obtained results are in agreement with those obtained by Abdel-Hady (1981), Farag (1981), Abdel-Reheim (1982) and Hassona (1989) who found that the clay fraction in soils of the elevated sand dunes was mainly dominated by smectite and kandite. Other associated clay minerals were of the interstratified forms, vermiculite, chlorite and occasionally hydrous mica.

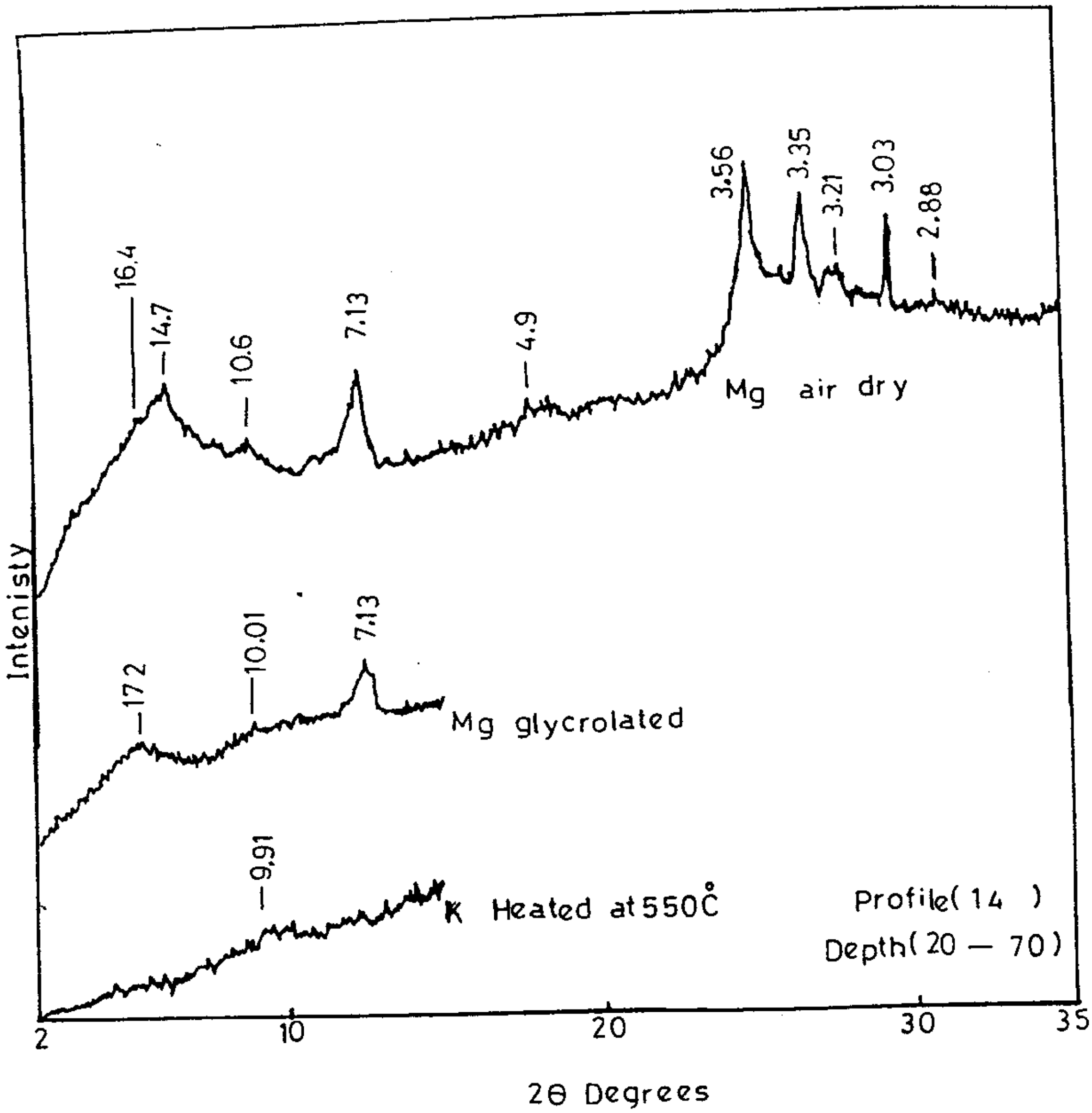


Fig. (26): X-ray diffraction pattern of the clay fraction separated from 20-70 cm.layer of profile (14) (Elevaled sand dunes).

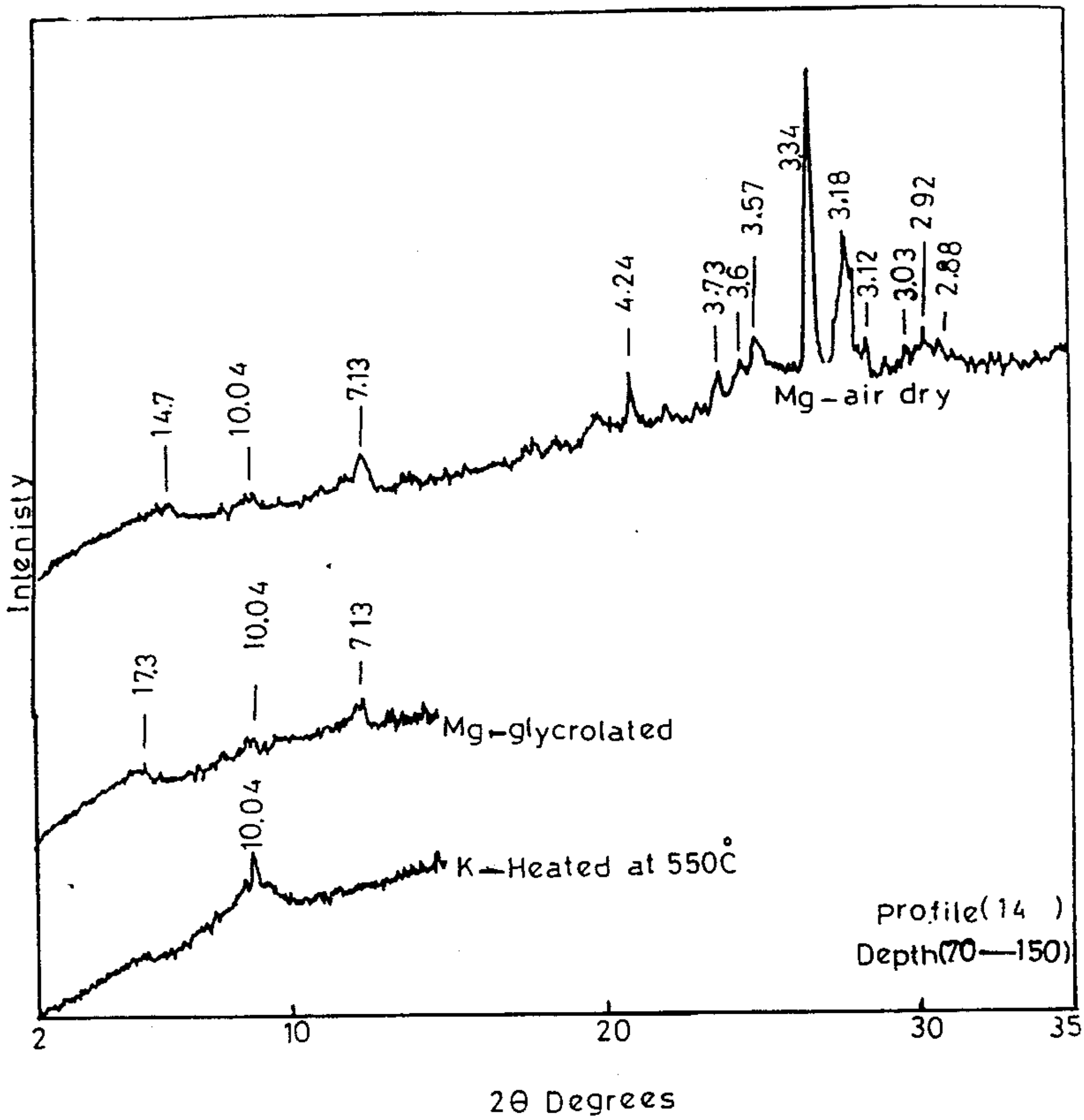


Fig. (27); X-ray diffraction pattern of the clay fraction separated from 70-150 cm. layer of profile 14. (Elev ated sand dunes).

4.6.2-Soils of El – Qaa plain

1) Clay mineralogy of the wadis

The clay mineral assemblage of profile 17 (which represents the wadis soils) is characterized by the dominance of smectite (montmorillonite) followed by interstratified minerals (Figs. 28and 29). Kaolinite and chlorite are found in few amounts, while chlorite is in traces in the 80—120cm layer. Illite is also found in traces in all profile layers. Vermiculite and palygorskite minerals are also in traces in the subsurface layers, and are absent in the deepest layers. The associated non-clay minerals are mainly represented by quartz and feldspars.

2-Clay mineralogy of the alluvial fan

Profile 20, which represents the alluvial fan soils is characterized by the dominance of smectite (montmorillonite) minerals followed by the iterstratified minerals Figs. 30 and 31. Kaolinite is detected in moderate amounts in the subsurface and decreased into few amounts in the deepest layer. Illite, palygorskite and chlorite are in traceable amounts or absent in the deepest layer. Vermiculite is detected in few amounts, decreasing into traces with depth. With regard to the accessory minerals, quartz is the dominant, followed by feldspars.

3- Clay mineralogy of the coastal plain

The clay mineralogy of profile 22, representing the soils of the coastal plain is generally dominated by smectite and / or interstratified minerals, Fig. 32. The second abundant minerals are kaolinite and vermiculite in few amounts, while illite , chlorite and palygorskite are

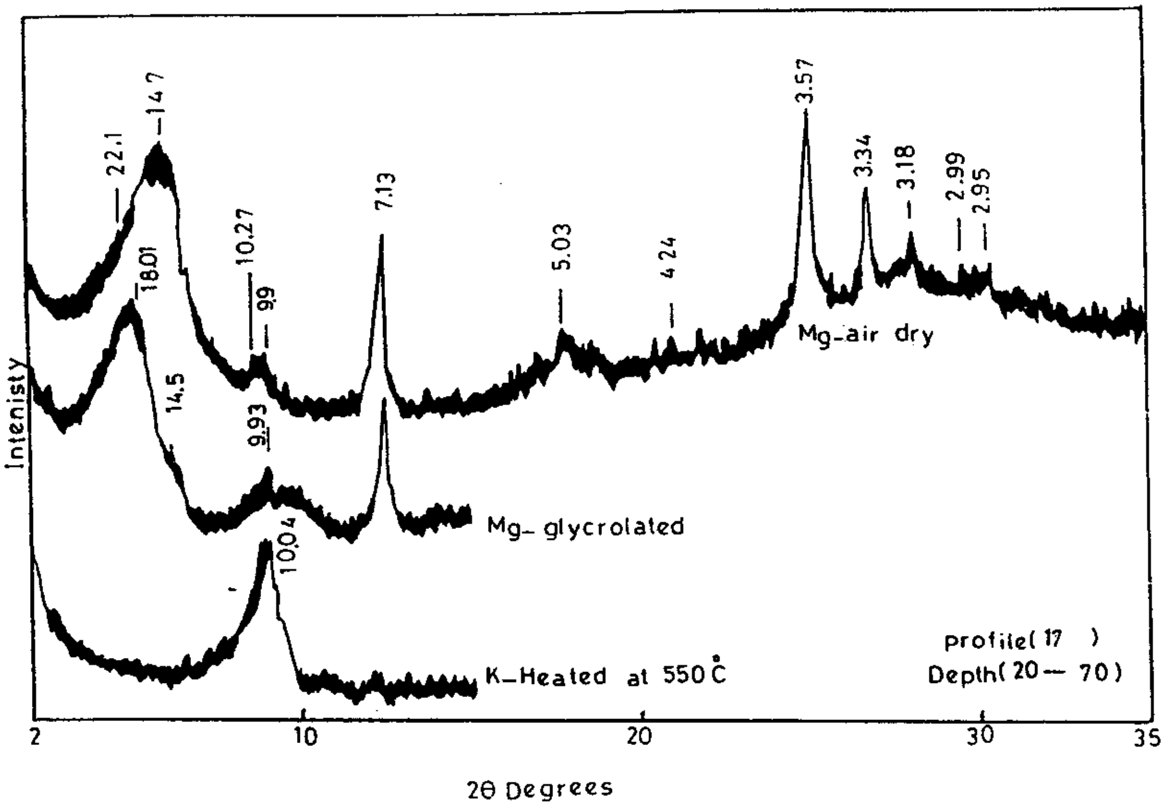


Fig. (28): X-ray diffraction pattern of the clay fraction separated from 20-70 cm. layer of profile 17. (Wadis).

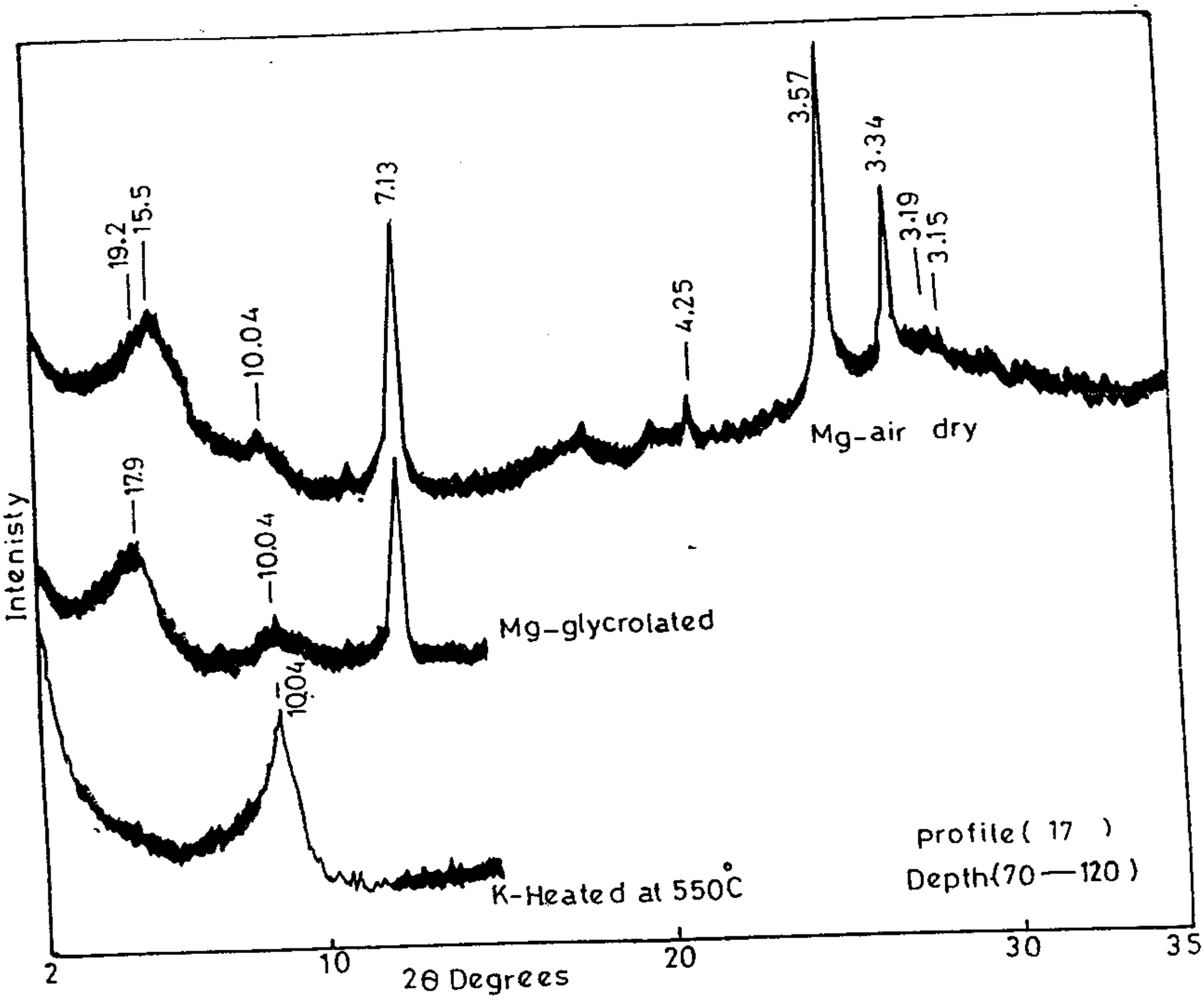


Fig. (29): X-ray diffraction pattern of the clay fraction separated from 70-120 cm. layer of profile 17 (Wadis).

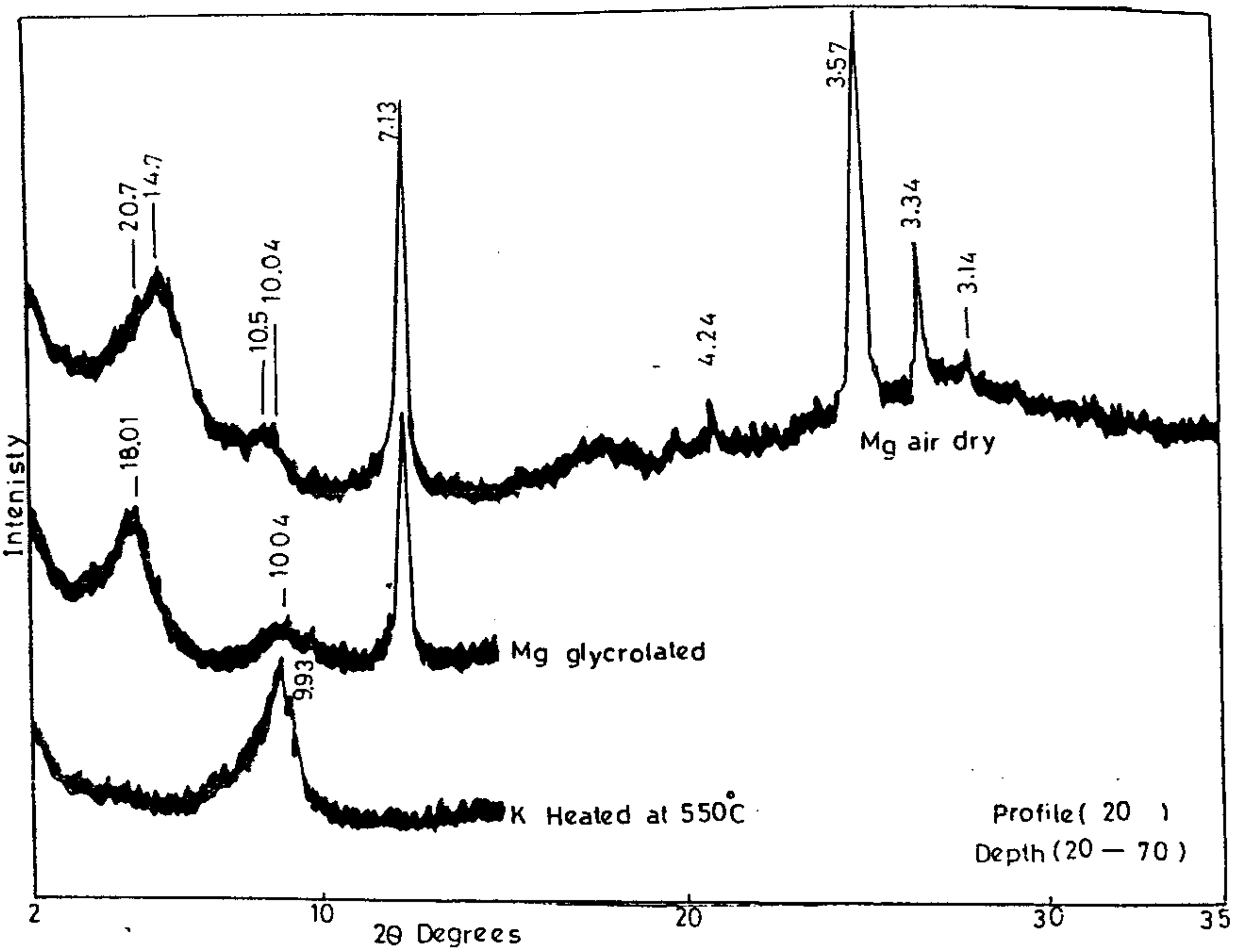


Fig.(30): X-ray diffraction pattern of the clay fraction separated from 20-70 cm layer of profile 20. (Alluvial fou.).

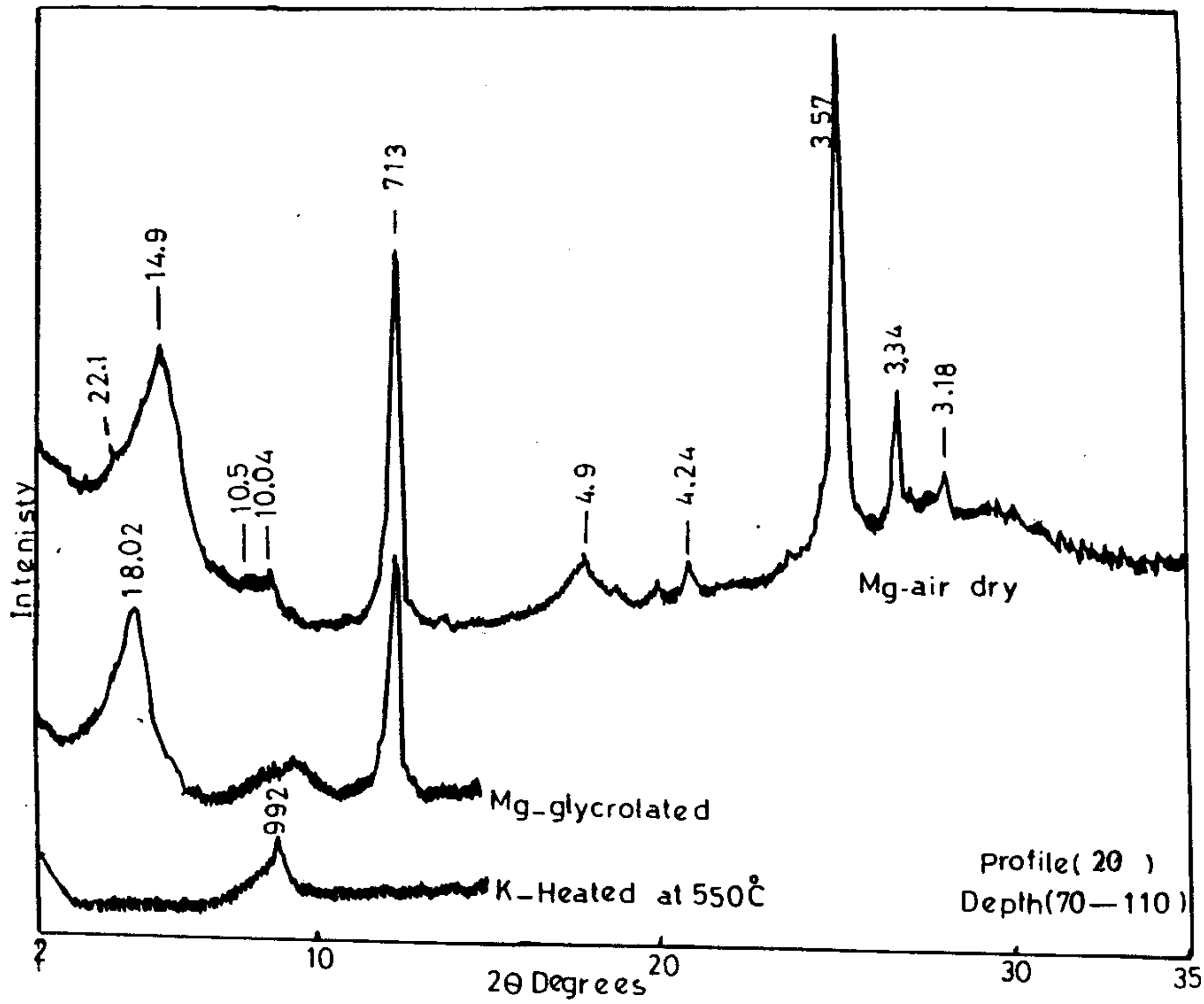


Fig.(31): X-ray diffraction pattern of the clay fraction separated from 70 - 110 cm. layer of profile 20 (Alluvial faw.).

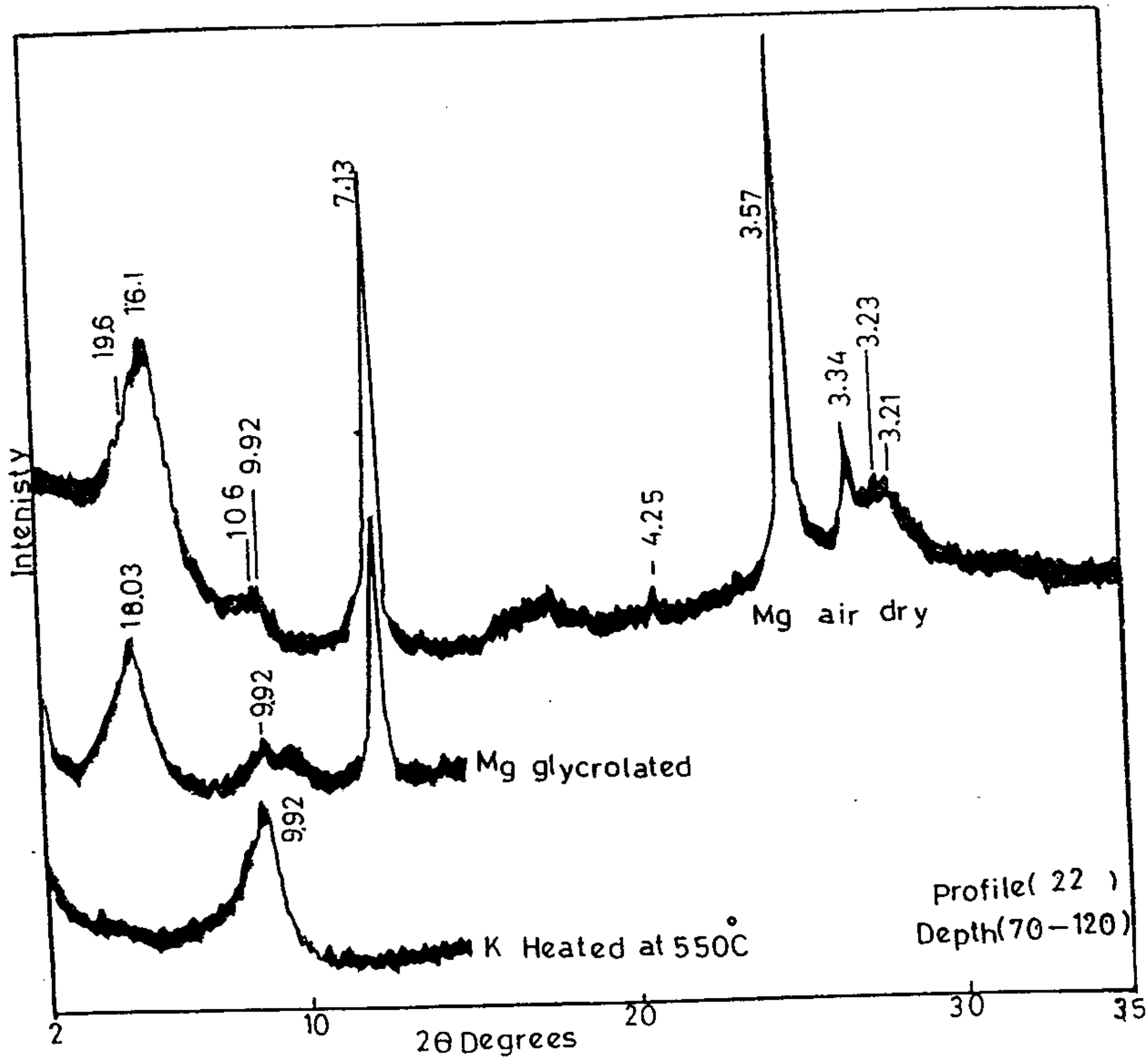


Fig.(32): X-ray diffraction pattern of the clay fraction separated from 70-120 cm. layer of profile 22 (Coastal plain).

present in traces. Traces of quartz and feldspars are present as accessory minerals.

From the previous discussion on the mineralogy of the clay fraction of the soils of El-Tina and El-Qaa plain in the Sinai Peninsula, one can conclude that most of these minerals are inherited from the parent materials. The variation of the clay mineral assemblages with depth reflect multi-origin nature of these soils or the multi-environments during soil formation. The soils derived from alluvium and fluvio marine materials representing the soils of El-Tina plain are mostly characterized by smectite, kaolinite, and interstratified clay minerals, hydrous mica and chlorite with vermiculite in a decreasing order, soils derived from limestone, igneous rocks, and metamorphic rocks representing El-Qaa plain have smectite, interstratified minerals and kaolinite as the major components of their clay fraction.

4.7- Surface area of the clay fraction

The term " specific surface" or " surface area" refers to the area per unit weight of clay. It is usually expressed in square meters per gram (m^2 /gm). Clay minerals differ in their surface area. Non swelling clay minerals, such as kaolinite and illite have an external surface only, while swelling clay minerals, such as smectite and vermiculite have internal surfaces between their expanded layers, as well as external surface.

Table (23) shows that surface area values of the clay fractions separated from some selected layers of the studied soil profiles. Data indicate that specific surface area of the clay fractions ranges from 96 to 508 m^2 /g. The lowest values is in the deepest layer of profile 14 representing the soils of elevated sand dunes where kaolinite is the

Table (23) Surface area and cation exchange capacity "CEC" of the clay fraction of the studied soil profiles .

Location	Geomorphic units	Prof. No.	Depth (cm)	Surface area m^2/g	CEC me/100g clay
El- Tina plain	El- Tina plain	1	0-30	313	46.4
			30-150	246	44.5
		5	10-40	236	42.0
			40-90	508	52.2
		7	10-45	501	47.6
			45-90	420	46.0
		8	20-50	276	49.0
			50-100	239	42.5
		10	35-85	377	42.0
			85-150	347	43.5
		11	25-75	259	40.2
			75-150	259	43.1
	Elevated sand dunes	14	20-70	122	20.2
			70-150	96	18.7
El- Qaa plain	Wadis	17	40-80	159	26.3
			80-120	195	28.9
	Alluvial fan	20	20-70	185	25.9
			70-110	148	24.2
	Coastal plain	22	70-120	159	22.2

dominant clay mineral, while the highest is in the 40—90 cm layer of profile 5 representing the soils of El-Tina plain where montmorillonite is dominant mineral. Soil profiles representing El-Qaa plain are characterized by their relatively moderate values of surface area.

Thus specific surface area of the studied soils follow the following order: El-Tina plain > El-Qaa plain > elevated sand dunes plain. These findings show that the type of clay mineral which predominates in the clay fraction is the major important factor determining their surface area. The variations, encountered within or between the groups of profiles, may be ascribed to the particle size and shape of the dominant clay minerals, the presence of inorganic mixed gels and the occurrence of non-clay minerals.

4.8-Cation exchange capacity "CEC" of the clay fraction.

The actual exchange of cations is dependent on the structure and chemical composition of clay concerned in the cation exchange reaction and on the environment in which the exchange takes place. Therefore, the cation exchange capacity is of great importance in the identification of clay minerals.

Grim (1953), mentioned three causes of the cation exchange capacity of clay minerals:

1) Broken bonds around the edges of the silica-alumina units would give to unsatisfied charges, which would be balanced by adsorbed cations,
2) Substitution within the lattice structure of the trivalent aluminum ion for the quadrivalent silicon ions in the tetrahedral sheet. Also

substitution of lower valence ions (particularly magnesium) for the trivalent aluminum ion in the structural units of some clay minerals,

3) The hydrogen of exposed hydroxyls may be replaced by a cation which would be exchangeable. The following range of CEC(me/100g) are suggsted by Grim (1953): kaolinite (3—15), smectite (80—150), illite (10—100); vermiculite (100—150); chlorite (10—40) and palygorskite (20—30).

It is evident from Table (23) that the CEC of the examined clay samples shows a maximum of 52.2 me / 100g. in the 40—90 cm layer of profile 5 representing the soils of El-Tina plain, whereas, the minimum of 18.7me/100g. is in the deepest layer of profile 14 representing the soils of elevated sand dunes. The high CEC values of the clay fraction in the soils of El-Tina plain compared with these of elevated sand dunes of El-Qaa plain are possibly related to the high montmorillonite contents in the former soils. This is verified by the x-ray analysis.

By comparing results obtained from El-Tina with those of El-Qaa plains it can be concluded that since the range of capacities in the current soils is between 19 and 52 me/100g which is lower than that of pure smectite, this may be due to smectite in these soils is associated with some kaolinites (3—15 meq /100g) as revealed by the results of the x-ray investigation.

Generally, it can be concluded that the obtained CEC values are in fairly good agreement with the results reached from the x-ray examination, surface areas and the determined values of amorphous materials.

4.9.- Taxonomy of the soils

The studied soil profiles are classified according to "SOIL TAXONOMY" system of soil classification, of USDA(1975), which takes in account soil morphology, physical, chemical and mineralogical properties in addition to the climatic environmental conditions.

On these bases, the investigated soil profiles may be classified in to two orders, namely ***Aridisols*** and ***Entisols***. Table 24 gives a summary of taxonomy of soil of the study area.

Soil belonging to the order ***Aridisols***

Aridisols are defined as having ochric epipedons and one or more of the following subsurface horizons: argillic, cambic, natric,gypsic, calcic, petrocalcic or duripan. They are dry or have a saturated paste extract conductivity of more than 2 dS/m in the 18-50cm layer or above a lithic or paralithic whichever is shallower. The presence of salic and calcic horizons is used as a criterion for diving this order into two suborders; salids and calcids. Based on the analytical data of the studied profiles, soil, of El Tina plain (profiles 1 to 11), are salids. Soils of the wadis "of El-Qaa" (profiles 16,17,and 18) and soils of the coastal plain "of El-Qaa" (profiles 21and 22) are calcids The families are types recognized from further classification of this order as follows:-

1- ***Typic Aquisalids*** fine loamy, mixed, thermic (profiles2and6)
2- ***Gypsic Aquisalids*** clayey, mixed, orthic (profiles 1and 3)
3- ***Gypsic Aquisalids*** fine loamy, mixed, thermic(profiles 5 and 8)
4- ***Gypsic Aquisalids*** coarse loamy, mixed, thermic (profile 4)

Table (24). Classification of the studied soil profiles (according to Soil Taxonomy 1998).

Location	Geomorphic units	Prof. No.	Soil order	Sub group	Soil family
El-Tina plain	Clay flats	2,6	*Aridisols*	*Typic Aquisalids*	Fine-loamy, mixed, thrmic.
		1,3		*Gypsic Aquisalids*	Clayey, mixed, thermic.
		5,8		*Gypsic Aquisalids*	Fine-loamy, mixed, thermic.
		4		*Gypsic Aquisalids*	Coarse-loamy, mixed, thermic.
		7		*Typic Haplosalids*	Fine-loamy, mixed , thermic.
		10,11		*Gypsic Haplosalids*	Clayey, mexed, thermic.
		9		*Gypsic Haplosalids*	Fine-loamy, mixed, thermic.
	Elevated sand dunes	12,13	*Entisols*	*Typic Torripsamments*	Siliceous, thermic.
		14,15		*Typic Torripasamments*	Mixed, thermic.
El- Qaa plain	Wadi plans	16	*Aridisols*	*Typic Haplocalcids*	Sandy, mixed, thermic.
		18		*Typic Haplocalcids*	Sandy, mixed, thermic; saline phase.
		17		*Typic Haplocalcids*	Sandy, mixed, thermic; saline and loamy surface layer phase.
	Alluvial fan	19,20	*Entisols*	*Typic Torriorthents*	Sandy, mixed, thermic.
	Coastal plain	22	*Aridisols*	*Typic Haplocalcids*	Sandy, mixed, thermic.
		21		*Typic Haplocalcids*	Sandy , mixed, thermic; loamy surface layer phase.

5- ***Typic Haplosalids*** fine loamy, mixed, thermic (profile 7)

6- ***Gypsic Haplosalids*** clayey, mixed, thermic (profiles 10 and 11)

7- ***Gypsic Haplosalids*** fine loamy, mixed, themic (profile 9)

8- ***Typic Hoplpcalcids*** sandy , mixed, thermic (profiles 16 and 22)

9- ***Typic Hoplpcalcids*** sandy, mixed, thermic, saline phase (profile 18)

10- ***Typic Hoplpcalcids*** sandy, mixed, thermic,saline and loamy surface layer phase (profile 17)

11- ***Typic Hoplpcalcids*** sandy, mixed thermic, loamy surface layer phase (profile 21).

2-<u>Soils belonging to the order ***Entisols***</u>

Entisols include soils having little or no evidence of pedogenic horizons due to the continual addition of soil materials or to the siliceous nature of soils which resist the prevailing limited weathering.

The sandy soils of the elevated sand dunes plain "El-Tina" (profiles 12,13,14 and 15) and the soils of the alluvial fan "El-Qaa" (profiles 19 and 20) are deep sandy soils devoid of fragments of any diagnostic horizon and are usually dry in most of the year within one meter of the surface. These soils are suggested to be placed to the suborders ***Psamments*** and ***Orthents*** and great groups of ***Torripsamments*** and ***Torriorthents*** owing to prevailing torric moisture regime. Further classifications of this order are as follows:

1-***Typic Torripsamments*** , siliceous, thermic (profiles 12 and 13)

2-***Typic Torripsamments*** , mixed, thermic (profiles 14 and 15)

3-***Typic Torriorthents,*** sandy, mixed, thermic (profiles 19 and 20)

4.10- Land Capability Evaluation :

From the agricultural point of view, classification of soils for evaluating their capability for irrigation utilization aims at assessing the degree of limitation or suitability for agriculture use on the basis of their permanent properties. In this respect a number of systems have been suggested to evaluate the agricultural limitations, affecting land capability, the system proposed by Sys and Verheye (1978) which was further elaborated by Sys (1991), and which took in account certain systems such as that of Storie (1964) has gained acceptability and is proposed for use by the food and the 6 grades or classes concerning land capability agriculture organization (FAO) of the United Nation.

It is based on computing score points from 0 to 100% such overall rating score is compiled by equations from sub-rating regarding a number of properties and conditions of the soils.

Table 25 shows the 6 classes for land capability evaluation and the overall rating scores for each grades Table 26 shows the soil properties and the grades for limitations concerning each with the score associated with each.

The overall rating score for a soil is the product of multiplication of those factors from A to J expressed in terms of decimal figures.i.e.

Overall grades =

$$A/100 \times B/100 \times O/100 \times E/100 \times F/100 \times G/100 \times I/100 \times J/100.$$

Table (25) shows each grade and the score or rating limits for each class (Storie 1964 and Sys 1991)

Grad or class of land capability	Overall Rating
(I) Excellent soils	100—80
(II) Good soils	79—60
(III) Fair soils	59—40
(IV) Poor soils	39—20
(V) Very poor soils	19—10
(VI) Non agricultural soils	less than 10

Applying the land classification system of Sys and Verheye (1978) and Sys (1991); to the soils of the study area, table (25) reveals that these soils can be placed at the following orders, classes and subclasses.

Order S: suitable land for irrigation, the soils related to this order can be further distinguished into

Class S_2: recognized in the moderately suitable soil with texture limitation represented by soils of elevated sand dunes (profile 15) and coastal plain (profile 21).

Class S_3: represents the marginally suitable soils with severe limitation due to salinity and moderate limitations, due texture class, wetness and $CaCO_3$ represented by the soils of El-Tina plain and soils of wadis (profiles 17 and 18).

Table (25): Soil properties rating

Factor	Soil properties	Rating
A	**Availability and quality of irrigation water**	
	Nile water	100
	Mixed Nile and drains water 1000 ppm	90
	Mixed Nile and drains water < 2000 ppm	80
	Mixed Nile and drains water 2000 –4000 ppm	60
	Mixed Nile and drains water 4000- 5000 ppm	40
	Mixed Nile and drains water > 5000 ppm	20
B	**Texture grade**	
	L, SiL, SCL, SiCL, CL,	100
	Si	95-90
	LS, SC	85-80
	FS, Ms, SiC	75-60
	CS	55-40
	Texture / SiGr / Gr / VGr	
	Rating %	
	L, SiL, CL: 80 / 70 / 60	
	SL: 70 / 60 / 50	
	LS: 60 / 50 / 40	
	S: 50 / 40 / 30	
C	**Soil profile depth cm**	
	> 120	100
	120-90	100-90
	90-60	90-70
	60-30	70-40
	< 30	< 40
D	**Wetness (drainage conditions)**	
	Well drained	100
	Moderately drained	95-85
	Imperfectly drained	85-75
	Poorly drained	75-45
	Very poorly drained	45-25
E	**Salinity level (dS/m)**	
	< 4	100
	4-8	95-85
	8-16	85-45
	> 16	< 45

Table (25): Cont.

Factor	Soil properties	Rating
F	**Sodicity (ESP) %**	
	< 10	100
	10-15	95-85
	15-30	85-75
	30-50	75-55
	> 50	< 50
G	**Carbonate as $CaCO_3$ content %**	
	< 5	100
	5-10	95-90
	10-20	90-75
	20-50	75-40
	> 50	< 40
H	**Gypsum ($CaSO_4 . 2H_2O$) content %**	
	< 3	100
	3-10	95
	10-15	85
	15-25	75
I	**Slope %**	
	Flat or almost flat (0-2 %)	100
	Undulating (2-8%)	95-90
	Rolling (8-10 %)	90-85
	Hilly (16-30%)	85-70
	Steep (30-45%)	70-35
	Very Steep (> 45%)	< 35
J	**Erosion**	
	Wind erosion	
	Non	100
	Slightly	95-90
	Moderately	90-75
	Severe	75-20
	Water erosion	
	Non	100
	Slightly	95-90
	Moderately	90-75
	Severe	75-40
	Very severe	40-10

Table (26) Evaluation of the soil of the different geomorphic units in the studied soil profiles (According to Sys 1991).

Location	Geomo-rphic unit	Prof. No.	Topo-graphy (t)	Wetness (w)	Soil physical condition(S)				Salinity and alkalinty (n)	Suitability index (Ci)	Suitability index Class
					Texture (S_1)	Soil depth (S_2)	$CaCO_3$ (S_4)	Gypsum (S_4)			
El-Tina plain	El-Tina plain	1	100	90	89.6	100	95	100	40	30.6	S_3
		2	100	90	85.0	100	95	100	40	29.1	S_3
		3	100	90	83.3	100	95	100	40	28.5	S_3
		4	100	90	87.7	100	85	100	58	38.9	S_3
		5	100	90	87.5	100	85	100	40	26.8	S_3
		6	100	90	86.7	100	95	100	40	26.7	S_3
		7	100	90	76.5	100	95	100	58	37.9	S_3
		8	100	90	83.3	100	85	100	40	25.5	S_3
		9	100	100	90.4	100	95	100	58	49.8	S_3
		10	100	95	82.4	100	85	100	40	26.6	S_3
		11	100	95	89.0	100	85	100	40	28.7	S_3
	Elevated sand dunes	12	90	100	30.0	100	95	90	100	23.1	N_1
		13	90	100	30.0	100	95	90	100	23.1	N_1
		14	100	100	30.0	100	95	90	100	25.7	S_3
		15	95	100	75.0	100	95	90	100	60.9	S_2
El_Qaa plain	wadis	16	95	100	30.0	100	95	90	100	24.4	N_1
		17	95	100	65.2	100	90	90	85	47.4	S_3
		18	90	100	40.4	100	100	100	85	30.9	S_3
	Alluvial fan	19	95	100	55.0	100	95	90	100	44.7	S_3
		20	100	100	30.0	100	95	90	100	25.7	S_3
	Coastal plain	21	95	100	73.4	100	90	90	90	50.8	S_2
		22	95	100	30.0	100	95	90	90	21.9	N_1

S_3: represents the marginally suitable soils with severe limitation due to texture and moderate limitation due to gypsum, represented by the soils of elevated sand dunes (profile 14) and soils of alluvial fan (profiles 19 and 20).

The non suitable land for cultivation (N) are those units having one severe limitation that excludes the use of the land or more than one severe limitation land index normally less than 25. One class is reported in this order N_1.

The non suitable land for cultivation (N_1) are those units with severe limitation that can be corrected. Elevated sand dunes (profiles 12 and 13), soils of wadis (profile.16) and soils of coastal plain (profile.22), occur in this class. Limitation numbers of these soils are present in Table (26).