1-INTRODUCTION

Reclamation and utilization of sandy soils are the main hope for horizontal expansion of the cultivated lands to meet the over increasing population in Egypt, hence the vertical expansion of the land production is limited.

If such soils are to be cultivated, plans and techniques for increasing their retention of water and plant nutrients are quite essential.

Sandy soils are considered as the most important newly reclaimed soils. Many reclamation projects face several problems .A better insight has been obtained to solve such problems by execution the different physical, chemical and pedagogical studies for these soils at first.

To cover these problems, five traverses included most of the reclamed sandy soils projects in Egypt were selected for the current study. The main morphological, chemical and mineralogical properties of these soils and the factors affecting their properties were studied in this work for the sake of tentative evaluation of these soils.

2- REVIEW OF LITERATURE

2.1. Sandstone's and sands:

Sandstone's constitute an important class of sediments. Excluding carbonate and volcanic sands, they form roughly one-fourth of the total sedimentary record. Many sands and sandstone's are economic resources-as abrasives; as rows materials in the chemical, glass, and metallurgical industries. Sands constitute important reservoirs for natural gas, oil, and artesian water. Some placer sands are a source of ore minerals and gems. Sand erosion and deposition are of engineering importance on beaches, in rivers and in dune areas. Sandstone contribute to our understanding of geological history. Their composition is a clue to provenance, *Pettijohn (1957)*.

Sands may be divided into three major groups, i.e., terrigenous, carbonate and pyroclastic. Terrigenous sands are those produced by weathering and breakdown of preexisting rocks. They are transported, sorted, and modified by moving threw air and water fluids-and derived from external sources to the basin of deposition.

carbonate sands are for the most part marine, and are primarily skeletal grains, oolites and locally derived detrital carbonate intraclasts (interafomational particles). These constituents are produced `within the basin of deposition and are not the debris formed by breakdown of preexisting rocks. An exception are those sands rich in carbonate particles shed by very rapid

erosion of thick carbonate sequences of organic chains. Such carbonate sands are in fact terrigenous sand derived from preexisting limestone's and dolomites.

Pyroclastic sands are produced by volcanic explosions. They may be deposited in divers environments-in air or in water. The term volcaniclastic is also applied to some sands, rich in volcanic debris, which may be either truly pyroclastic or terrignous (if derived from an older volcanic terrane).

The distinction between several types of sands becomes blurred where materials of several different origins are deposited together. Pyroclastic materials may be mixed in all proportions with normal terrigenous sands.

In general, there is no geomorphic area of the earth where sand is not found. (*Pettijohn, 1984*).

2.2. Environments of sandy deposition

Sediments of sand are deposited most abundantly in shallow water and continental environments and reach deep water only in exceptional circumstances.

According to *Hatch, et al., (1938)* sea sand forms the lower portion of a normal beach, and a similar deposit extends far below-water mark. The chief exception to this is off the mouths of large rivers, or in some partially enclosed seas, where mud is dominant. Under ordinary conditions, the further material forms the land of finer grains. Since sea-sand undergoes considerable movement on beaches, the present amount, at any given time, depends on a

large extent on the weather of the previous periods. Most sands disappears during storms and accumulates in fair weather.

Recent sea-sands usually contain abundant shells and other organic remains, while, the older rocks formed from sea-sands are so often wholly unfossiliferous; the explanation is probably that the calcareous shells are dissolved and calcium carbonate is either removed or redistributed forming cement of calcite between quartz-grains. On shores exposed to prevailing wind, much sand is carried in land to form sand-dunes. They added that, fresh-water sands are found forming the beaches of the larger fresh-water lake, although there is a strong tendency for the shore to be bordered by a fringe of vegetation, especially if it is at all sheltered from the winds, it is chiefly in exposed places where purely fragmental beach deposits accumulate. If the organic constituents be left out of account, these lake lake-sands do not differ in any important respect from those of the sea. River-sands are abundant, and tend to accumulate where the current is weak. They are often deposited over considerable areas during floods. Sands of deltaic origin are common and naturally show a close resemblance to river-sands.

According to the same authors, terrestrial sand are as a rule almost wholly due to wind action. Sand dunes are formed along many of the coastlines of temperate regions. The sand is formed in the first place by the sea, and carried in land by the winds. Consequently, the sand-grains are often angular or subangular, and rarely show the high degree of rounding characteristic of the desert sands. The constituent materials are, in most cases, the same as those of the adjacent beach-sands, through a certain amount of gravitational sorting has usually take place. The size of dune sand grain is

much more uniform than sea-sand one and considered the magnitude to be a function of the wind-pressure, and the normal diameter of the grains is about 0.2 mm. Quartz is the predominant mineral, constituting about 85 percent of the whole. The most abundant of the rest are garnet, augite, staurolit, magnetite, zircon, rutile, tourmaline, and epidote; while orthoclase, hornblende, ilmenite, apatite, and calcite are presented in less quantity. Much more rare are plagioclase, microcline, cordierite, sphene, sillimanite, olivine, kyanite, corundum and spinel, but no mica was observed in any sample.

They stated also that, the most characteristic of all terrestrial sand deposits are those formed in true desert regions, where the action of running water is entirely excluded, except under very special circumstances. The disintegration of rocks is affected by the so-called "dry weathering" and the only agent of transport is the wind. A note worthy feature is the conspicuous rounding of desert sands, as compared with sands laid down in water: firstly, the rolling motion is predominant under wind-action, while saltation and suspension are less frequent than in water, secondly, since the sand grains move in air, their whole weight is effective in producing friction, whereas in water only a part comes into play.

2.3. Sandy soils in Egypt:

In Egypt, the properties of sandy soils vary according to the origin and formation conditions of those soils. Sandy soils dominating in the western desert are mainly quartz and formed from weathering of sandstone after exposure of this area to tectonic movements that resulted in the formation of the Quattara depression. In the northern coast of this region, sandy soils are of marine origin and characterize by oolitic limestone with calcium

carbonate content up to 98%. On the other hand, sandy soils predominant in the eastern desert and the north of Sinai are composed of quartz developed from sediments carried by Nile water over the ages; this has been confirmed by the similarity of the heavy mineral composition of the Nile mud, the delta and the valley soils. On the contrary, sandy soils on the other parts Sinai originated from geologic formation found in El-Tih plateau. (*F.A.O., 1975*).

The two main landforms are the desert plateau and Nile valley and delta. In the late Tertiary period the Nile valley was covered by a sea gulf filled gradually with marine and terrestrial deposits during Pleistocene and recent times. The desert plateau ranges in age from Cretaceous to Pliocene with formations of sandstone s (Nubian), shales and limestone s interspersed with gravel, rubble and sand deposits in various stages of consolidation. The Western Desert plateau region is predominantly calcareous. According to geomorphological features,*Veenenbos (1966)* suggested the following seven landform groupings: (i) rubble terraces; (ii) river terraces;(iii) deltaic stages of river terraces. (iv) wadies; (v) alluvial fans and outwash plains; (vi) plain lands; and (vii) wind-blown. In Nile Delta, the main landforms were fluvio-marine marsh lands; lagoon lakes with swamps; sandy coastal barrier plain and shifting sand dunes.

The soils of rubble terraces, where gravel and sandy loam predominate, were subdivided into five soil associations corresponding to the five terrace levels. In delta soils, sands predominate and gravel content is low. The differentiation of two soil associations was in the presence or absence of loamy sand topsoils. The soils of alluvial fans and outwash plains, which contain high fractions, are differented by the gravel and sand textural

components. The textural groupings of gravel, cobble and sand differentiated the soil associations of the wadi. Wind-blown, marine lacustrine and residual soils are the subdivision of the plain soils. In the cultivated zones of Nile Valley and Delta, two distinct sandy soil areas are exist as a result of torrenteal depositions in the Pleistocene period. (Eastern Province and Arab El-Raml).

2.4 Factors affecting the formation of sandy soils in Egypt:

According to *Fitzpatrick (1986)*, climate is the principal factor governing the rate and type of soil formation as well as being the main agent determining the distribution of vegetation and the type of geomorphological processes.

The meteorological data presented in Tables (1 to 5). The average monthly values of the climatic parameters were collected from eight stations, i.e., Damietta, Ganakleas, Zagazig, Helwan, Fayoum, Beni-Seuf, Minya, and Kom Ombo.

According to *Fitzpatrick (1986)*, atmospheric and soil temperature variations are the most important manifestations of the solar energy reaching the surface of the earth. The main effect of temperature on soils is its influene on the rate of reactions. The principal reaction in soil is the hydrolysis of primary silicates. The rate of chemical and biological activities will vary during the year. Development of vegetation can also be affected by soil temperature.
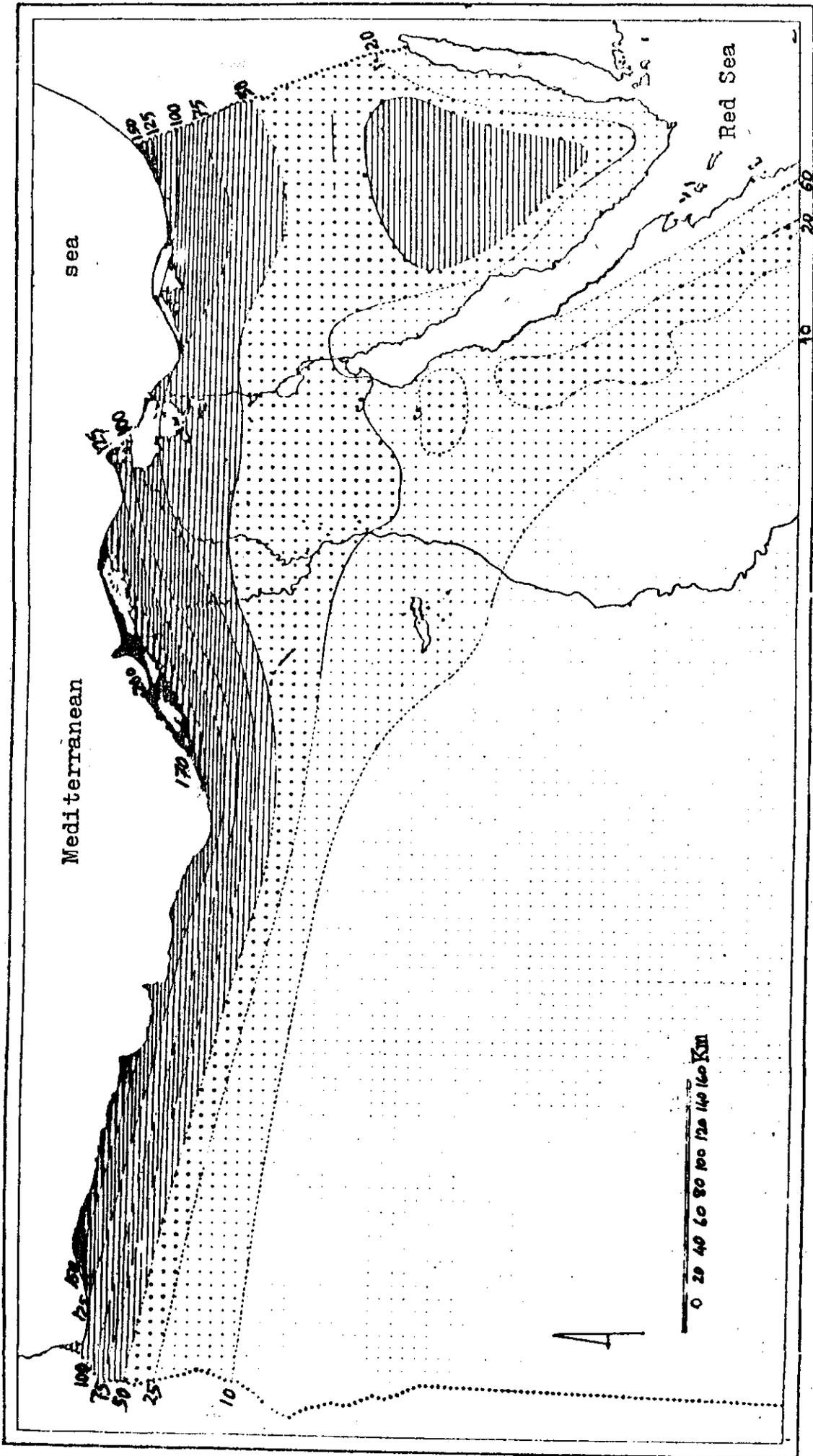
Fig.(1):The average annual rainfall in Egypt.

Table (1): Mean monthly , maximum and minimum of air temperature (°C)

Station		J	F	M	A	M	J	J	A	S	O	N	D	Mean
Damietta	Max.	18.30	18.60	20.50	23.10	26.60	29.20	30.60	31.00	29.40	27.40	23.90	19.80	24.87
	Min.	8.40	8.80	11.10	13.60	16.80	19.80	21.20	21.40	20.00	18.40	15.20	10.60	15.44
	Mean	13.35	13.70	15.80	18.35	21.70	24.50	25.90	26.20	24.70	22.90	19.55	15.20	20.16
Ganakleas	Max.	18.40	20.50	23.00	26.20	29.70	31.30	33.10	32.60	31.60	28.50	23.60	19.40	26.49
	Min.	7.70	7.70	9.90	12.20	15.00	18.10	19.80	20.00	18.70	15.90	12.30	8.90	13.85
	Mean	13.05	14.10	16.45	19.20	22.35	24.70	26.45	26.30	25.15	22.20	17.95	14.15	20.17
Zagazig	Max.	19.70	21.00	23.60	27.60	31.40	34.00	34.40	34.20	32.50	30.20	25.70	21.20	27.96
	Min.	6.60	7.10	9.20	12.00	15.50	18.60	20.20	20.40	18.60	16.60	13.00	8.60	13.87
	Mean	13.15	14.05	16.40	19.80	23.45	26.30	27.30	27.30	25.55	23.40	19.35	14.90	20.92
Helwan	Max.	18.90	20.50	23.90	28.40	32.40	34.70	35.20	34.80	32.40	30.00	24.70	20.20	28.01
	Min.	8.40	9.30	11.30	14.20	17.70	19.80	21.40	21.60	20.10	18.40	14.50	10.40	15.59
	Mean	13.65	14.90	17.60	21.30	25.05	27.25	28.30	28.20	26.25	24.20	19.60	15.30	21.80
Fayoum	Max.	20.30	22.20	25.40	29.90	33.80	36.10	36.80	36.50	33.90	31.60	26.40	21.80	29.56
	Min.	5.90	7.30	9.80	13.20	17.10	19.80	21.20	21.40	19.60	17.10	13.00	8.40	14.48
	Mean	13.10	14.75	17.60	21.55	25.45	27.95	29.00	28.95	26.75	24.35	19.70	15.10	22.02
Beni Suef	Max.	19.70	22.30	25.40	30.20	33.90	37.00	36.90	36.60	34.90	31.20	25.40	21.00	29.54
	Min.	5.50	7.00	9.90	13.80	17.40	20.30	20.10	21.50	20.20	16.60	12.30	7.50	14.34
	Mean	12.60	14.65	17.65	22.00	25.65	28.65	28.50	29.05	27.55	23.90	18.85	14.25	21.94
El Minya	Max.	20.20	22.50	25.80	30.80	34.80	36.50	36.70	36.30	33.60	31.40	26.50	21.80	29.74
	Min.	3.90	5.30	8.00	12.10	16.40	19.00	20.20	20.40	18.50	15.50	11.30	6.50	13.09
	Mean	12.05	13.90	16.90	21.45	25.60	27.75	28.45	28.35	26.05	23.45	18.90	14.15	21.42
Kom Ombo	Max.	23.70	25.80	30.10	35.00	39.00	40.80	40.50	40.40	38.40	36.00	29.40	24.70	33.65
	Min.	7.00	7.90	11.40	15.70	19.70	22.10	22.50	22.40	20.30	17.80	13.20	8.70	15.73
	Mean	15.35	16.85	20.75	25.35	29.45	31.45	31.50	31.40	29.35	26.90	21.30	16.70	24.69

Table (2): Average monthly and annual rainfall (mms) .

Station	Month												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
Damietta	25.5	17.2	10.7	3.7	1.9	0.1	Tr.	Tr.	0.5	7.1	15.4	24.6	106.7
Ganakieas	20.0	0.6	4.0	3.6	0.4	0.0	0.0	0.0	0.0	5.4	12.5	19.3	65.8
Zagazig	6.7	5.6	3.8	2.0	2.6	Tr.	0.0	0.0	Tr.	1.8	4.3	6.1	35.9
Helwan	3.7	3.6	2.1	1.0	2.6	Tr.	0.0	0.0	Tr.	1.1	3.2	6.0	23.3
Fayoum	1.0	1.4	1.2	0.6	1.0	Tr.	Tr.	0.0	Tr.	0.7	0.9	4.0	10.8
Benisuef	2.0	0.9	0.7	0.2	0.1	0.0	0.0	0.0	0.0	Tr.	2.5	1.4	7.8
Minya	0.5	1.5	0.3	0.3	0.4	Tr.	0.0	Tr.	Tr.	0.4	0.1	0.5	4.0
Kom Ombo	Tr.	0.1	0.2	0.2	0.3	Tr.	0.0	0.0	0.1	0.2	0.1	0.0	1.2

Table (3): The mean monthly of relative humidity (%) .

Station	Month												Mean
	J	F	M	A	M	J	J	A	S	O	N	D	
Damietta	75	72	70	69	68	70	70	76	75	74	75	74	72.33
Ganakieas	71	63	60	59	57	60	65	66	67	57	69	69	66.08
Zagazig	77	73	69	62	55	57	63	69	73	75	77	78	69.00
Helwan	55	48	42	37	36	39	50	52	52	52	58	56	48.08
Fayoum	62	52	49	43	39	40	47	51	52	54	62	64	51.25
Benisuef	56	48	41	36	35	36	43	47	47	49	57	57	46.00
Minya	58	53	48	40	35	39	45	51	54	54	60	62	49.92
Kom Ombo	43	32	26	21	20	19	26	29	30	32	42	48	30.67

Table (4): Mean monthly of evaporation perday (mms)

Station	Month												Mean
	J	F	M	A	M	J	J	A	S	O	N	D	
Damietta	2.8	3.3	4.1	4.6	5.1	5.4	4.9	4.6	4.4	4.2	3.5	2.8	4.14
Ganakieas	3.9	5.6	7.0	8.5	8.9	8.9	8.1	7.6	6.9	6.2	4.4	4.4	6.70
Zagazig	2.6	3.2	4.0	5.6	6.7	7.0	5.8	4.8	4.3	4.1	3.0	2.4	4.46
Helwan	6.0	7.6	10.2	13.0	15.6	16.2	14.0	13.4	12.3	10.9	7.5	6.2	11.08
Fayoum	3.2	4.4	6.0	8.4	9.0	10.0	11.0	9.6	8.2	6.7	4.4	3.2	7.01
Benisuef	5.5	7.6	10.9	15.7	18.4	20.1	17.7	16.0	15.6	11.8	7.9	5.7	12.74
Minya	4.6	5.9	8.0	10.8	14.6	15.9	14.0	11.9	10.0	8.7	6.1	4.6	9.59
Kom Ombo	5.6	7.0	10.0	12.8	15.0	16.1	14.6	14.1	13.0	10.2	7.4	5.4	10.93

Table (5): Mean of monthly of wind speed (knots)

Station	Month												Mean
	J	F	M	A	M	J	J	A	S	O	N	D	
Damietta	5.5	6.0	7.2	6.9	6.1	6.1	5.4	4.8	4.4	4.8	4.8	5.6	5.63
Ganakieas	6.0	6.2	7.0	7.3	5.7	5.2	5.1	5.0	4.6	4.6	4.0	5.4	5.51
Zagazig	3.4	3.5	3.9	4.2	4.1	3.8	3.1	2.4	2.5	3.1	2.6	3.1	3.28
Helwan	5.5	6.7	8.3	9.2	9.2	9.1	9.9	7.5	8.2	8.6	7.6	6.1	7.99
Fayoum	3.6	4.0	4.9	5.0	5.4	5.4	4.9	4.8	5.1	4.5	4.3	3.9	4.20
Benisuef	6.0	7.7	9.4	10.6	11.5	12.4	12.4	11.3	11.8	9.7	8.4	5.8	9.75
Minya	5.0	5.9	7.9	8.0	8.7	9.2	7.8	6.6	7.4	6.6	6.0	4.9	7.00
Kom Ombo	3.6	3.8	4.5	4.0	4.1	4.2	4.1	3.7	4.1	3.5	3.3	3.2	3.44

According to the classification of soil temperature regimes by the US Taxonomy *(USDA, 1975)*, stations of Damietta, Ganaklese, Zagazige, Helwan, Beni-Suef and El-Minya have the mean annual soil temperature from 15 to 22°C and the difference between the mean of both and summer and winter soil temperature is >5°C so, the soil of the area would be categorized as "thermic temperature regime", while, the stations of El-Fayoum and Kom Ombo have mean annual soil temperature higher than 22°C and the difference between mean of both summer and winter temperatures is >5°C, so, they would be categorized as " Hypethermic temperature regime".

On the basis of modified Lang's factor *(Reifenberg, 1936)*:

$$\text{Lang's factor} = \frac{\text{annual rainfall (mm)}}{\text{mean temperature (°C)}}$$

Lang's factor varied between 0.05 to 5.3.

So, the areas would be categorized as "Arid"

On the basis of the degree of aridity "Q" *(Emberger, (1939)*:

$$Q = \frac{P}{(M+m)\,(M-m)} \times 100$$

where:

P = annual rainfall (mm).

M= mean of maximum temperature in °C for the wormiest month.

m= mean of minimum temperature in °C for the coldest month.

The degree of aridity for these areas varied between 0.07 and 11.98. So, the areas would be categorized as "Arid".

Generally, the meteorological data show that temperature and evaporation tend to increase from north of Egypt to south, while rainfall and relative humidity show an opposite trend. These parameters may be explain decreasing sand areas from north to south. This phenomenon may be explain too by the effect of Nile Delta.

According to *Kadry (1975)*, the soil climate is extreme. Soils are very dry and hot. Wind erosion is dominant. Chemical weathering and soil formation are extremely slow and physical weathering predominate in response to the extreme variations in temperature. This is attributed to the long periods of dryness since in winter, rainfalls in short heavy showers, but it does not percolate through the upper layer which becomes moist for short periods in the desert zone. The lower part of the sandy soils is always dry and is called the "dead" horizon. In the arid zones, the dead horizon is just below the surface, but in the semi-arid zones, it is deeper. Absence of vegetation cover results in an extremely low production of organic matter, the extreme climate, sparse vegetation and low chemical and biological activity cause very slow soil formation processes to occur. With increasing rainfall and little percolation of water through the upper part of the sandy soil, carbonate, gypsum and salts may become soluble and accumulate at some depths. Redistribution of carbonates and gypsum are the main processes in most sandy soils. In less dry sandy soil of semi-arid regions, some transport of fire clay causes a weak argillic horizon. All sandy soils are weakly developed. However, some old soils may exhibit profile horizon formations. The A horizon is weakly developed and can hardly be seen in a desert sandy soil, but becomes more distinct in the semi-arid sandy soils. Organic matter is almost lacking. Soil structure is weak and very unstable. The B horizon is

almost absent except where they are very old and have formed in a pluvial period of the Pleistocene with a wetter climate than the present. In sandy soils of the semi-arid region, a cambic or argillic B horizon, often weakly developed, can be recognized. According to the same author, the processes of calcification and gypsification are the main ones, eventually leading to the formation of calcic and gypsic horizons. Many sandy soils, especially in the desert, have a thin and brittle surface crust, formed by rain showers. This crusty surface restricts and delays infiltration of water, causing much runoff during the incidence of rainfall thus promoting sheet, rill and finally gully erosion. In some sandy soils, lime or gypsum crusts occur. These are hardened layers of carbonate or gypsum accumulation. The strong winds promote sand and dust storms. Depending on the topography, the upper layer is therefore either blown off or is covered with aeolian deposits. Sand dunes and loess occur locally and regionally. Sandy soils containing gravel have a surface gravel layer, that is left behind when the finer soil particles have been blown off.

Sawy et al (1990) found that the soil texture of the eastern area of the River Nile is mainly affected by the distance from the main River course, slope and relief and landform Soils located at relatively high levels are coarser than those located at relatively low levels, and the soils adjacent to the River course are coarser than those far from it. The desertic soils differ in their texture due to the differences in their parent materials. $CaCO_3$ content increases gradually with distance from the Nile course to the Eastern desert border due to the effect of Cretaceous and Eocene limestone deposits. The $CaCO_3$ is mainly due to the secondary from $CaCO_3$ in alluvial soils and the finer transported particles in the interference zone, while the latter is due

to the products of the physical disintegration of the desertic deposits which are rich in CaCO₃ content.

Sadek (1990) found that the northern part of the eastern desert are characterized by relatively coarse texture soils, with a dominance of medium and fine sand fractions. The CaCO₃ content shows a low to moderate amounts. The pH values show the highest value is found in non-saline and the lowest value is found in saline one. The soils are non-saline to slightly saline except some sites which are characterized by geological inherited salinity. The same author showed that the statistical size parameters of the studied sediments reveal that the sorting coefficients indicate that the coarse sediments are of a poorly to very poorly sorted nature and most likely transported in aqueous media as the environments of deposition. However, the relatively fine sediments show moderately well sorted indicating that the aqueous and aeolian media are considered the major agents for transportation. In general, He concluded that the mechanism of transportation for the sediment grains under consideration is attributed to their textural grades.

According to *Abdel-Aal et al (1990)*, the soil northern littoral of Western Desert, had a relative coarse texture with high content of carbonates mainly in the form of calcite. Upon cultivation, texture became fine and total CaCO₃ level being minimized that associated with the dominance of dolomite due to the partial dissolution of the lower stable calcic portion. Contrarily, active carbonate fraction increased upon land use and had a positive correlation whether with silt or clay contents.

Gouda et al., (1990) showed that the cultivation of sandy soils during many years resulted in a significant increase in soil moisture characteristics. This effect is most pronounced in the surface layer. The statistical analyses show water stable aggregates have a major direct effect on the soil moisture characteristics. Also, sandy the cultivation of soil over many years increased significantly the total pore space and micropores and significantly decreased the macropores.

According to Omar et al., (1990), soil aggregation values (in sandy soils which were selected to represent different cultivation periods, i.e., 0, 5, 10, 15 and 30 years were) significantly increased with the increase of cultivation period. The relations between soil aggregation and active fractions are positive and highly significant, while those with coarse fractions and calcium carbonate are negative and highly significant. Statistical analyses indicate that coarse sand, silt and organic matter contents are the factors which have the major direct effect on macro-aggregates, while coarse sand, silt and clay are affected on micro-aggregates.

2.5 Characteristics of sandy soils:

In general, sandy soils refereed as coarse textured soils. Most of sandy soils are noncoherent and remain as single grains, especially in the absence of organic matter or other binding compounds. The grade of their structure is thus termed "structureless". They are non sticky, non plastic under wet conditions and they have a loose consistency under dry conditions (Massoud, 1975). The high apparent specific gravity of these soils (1.55-1.80) is reflected on their low total porosity (32-42%), Israelsen and Hansen (1962). The relative distribution of pore size, which is more important than the total

porosity, show that sands have a high number of large pores which are responsible for good aeration, rapid drainage and low moisture-holding capacity *(Baudelaire, 1975)*. According to *Fitzpatrick (1986)*, soils of coarse sand are loose and without well formed aggregates and the individual units may have only a few points of contact but generally are surrounded by a continuous pore phase.

Coarse-textured soils have a low-moisture retention and high permeability *(Richards, 1954)*. Their available water range is rather narrow (4-6%), *Rivers and Shipp (1972)*. *Ibrahim (1990)* found that the available water range between 2 and 10% by volume for sandy soils.

The infiltration rate of sandy soils (2.5-25.0 cm/hr) could be 250 times more than that of clay soils (0.01-0.10 cm/hr) due to their large pore space and high saturated hydraulic conductivity values. They move more slowly under unsaturated flow conditions *(Bouma and Dinning, 1972)*. *Ibrahim (1990)*, found that the infiltration rate showed that the values are high in clay soil than in sandy soils, in Northern Delta soils, probably to cracks or to the fluffy top soil. The permeability values indicated that fine textured soil had a permeability between 58 to 81, while sandy soil permeability was between 21 and 36. These soils have too much aeration due to adequate water holding capacity. Air permeability was found to decrease by decreasing particle size and increasing bulk density *(El-Gabaly and El-Ghamry, 1970)*.

The fertility of sandy soils controlled by clay and organic matter contents so, they tend to be poor in nutrient elements. The nutrients applied to raise their low fertility level remain in solution and subjected to be loosed by

leaching, *Davies et al.* *(1977)*. According to *Isbell and Gillman (1973)*, the deep sandy soils overlying granitic rocks are characterized in the surface 10 cm layer by uniformity very low levels of organic C, N, P, K, S, Cu, Zn and exchangeable cations. Evidence is presented that some of the soils are weakly podzolized and have a low clay and organic matter contents. *Teixeira et al. (1980)* studied the properties of sandy soils in south Portugale and found that they characterized by deep profiles (> 1 m), acidic reaction (pH 5.4), 92% sand, very poor in silt, clay and organic carbon contents. Their exchangeable capacities are very low (2.27 me/100g) with a very low levels of K, P and N. These soils are poor in their contents of molybdenum (0.016 ppm mean extractable Mo), Cobalt (0.05 ppm) copper (0.16 ppm) manganese (0.8 ppm) zinc (0.2 ppm) and occasionally, boron (0.3 ppm). Leaching is extremely high as affected by low exchangeable capacity, clay and organic matter percentages and moisture retention, and high permeability. On the other hand, *Donahue et al. (1977)*, mentioned that sandy soils have many advantages: they are easily tilled under any moisture conditions without the hazard of destroying structure; many sands do not compact seriously and they easily support tillage equipment; they are well aerated; and they absorb water easily and rapidly and release a major percentage of it to plant roots.

2.6. Classification of sandy soils:

Sandy soils were classified according to the US soil Taxonomy *(USDA, 1975)* in Aridisols and Entisols orders. Soils in the order Aridisols are characterized by the presence of an ochric epipedon and the absence of an oxic or spodic horizon. They are usually dry and have feature of arid and semi-arid regions such as calcic, petrocalcic or gypsic horizons, or a duripan. In semi-arid regions, the better developed soil often have an argillic horizon

(the suborder Argids) or they have a cambic horizon often with a calcic, petrocalcic or gypsic horizon or duripan (the suborder Orthids). In the suborder Orthids the following great groups are distinguished:

- Camborthids: Orthids has a cambic horizon, often with redistribution of lime and gypsum.

- Calciorthids: Orthids with a calcic or gypsic horizon within one meter of the soil surface.

- Paleorthids: Orthids with a petrocalcic horizon within one meter of the soil surface.

- Salorthids: Orthids with a salic horizon within 75 Cm of the soil surface.

- Durorthids: Orthids with a duripan within one meter of the soil surface.
  Soils order Entisols are have no diagnostic horizon. Sandy soils were laid in suborder Psamments. Psamments are the Entisols that:

- Have below the bottom of the Ap horizon or a depth of 25 cm, whichever is deeper, a sandy particle size class in all subhorizons, either to a depth of 1m or to a lithic, paralithic or petroferric contact.

- Have < 35 % (by volume) of gravel or coarser fragments in all subhorizons.

- Do not have fragments of diagnostic horizons.

- Are not permanently saturated with water and do not have the characteristics associated with wetness.

2.7 Trace elements in sandy soils:

According to *Vinogradov (1959)*, the information about trace elements concentrations in the genetic horizons may be useful in estimating the degree of leaching and weathering in a profile. *Swaine and Mitchell (1960)* found that trace elements contents of the Scottish soils was more influenced by

parent rocks than by any other pedogenic factor. *Tiller (1963)*, on the other hand, concluded that trace elements in some Australian soils are not closely related to their concentrations in parent rocks except in places where weathering is slight. *Mitchell (1964)* and *Krauskopf (1972)* stated that trace elements contents in soils depend on the parent rocks from which these soils are derived by isomorphous substitution in soil materials. According to *Jenkins and Jones (1980)*, in sedimentary rocks Mn is more abundant in limestone, while the other trace elements are conspicuously abundant in shales. Sandstones, on the other hand, are relatively poor except in Ti and B. According to *Fetzpatrick (1986)*, it is necessary to determine the total amount of each element in the soil. Where soil formation has proceeded for a long period and where there has been a considerable amount of hydrolysis and solution it is usual to perform a partial ultimate analysis to estimate the dominant elements in each horizon as well as in the underlying parent material, in order to determine the predominant chemical changes that have taken place during soil formation. The mode of occurrence and distribution of trace elements in igneous rocks, and their behavior during crystallization of magma, are now fairly well known, but much less is known about their distribution in soil.

a) Iron:

Krauskopf (1967) stated that iron in soils can be divided into the iron presents in primary minerals and that in secondary ones. Exclusive of that in primary minerals, iron is found in soils in the form of various hydrated oxides. Ferric hydroxides are the most important form and iron solubility is largely controlled by solubility of these hydroxides. *Vesudevaro and Chartterjee (1972)* studied the contents of iron and other trace elements in three soils of

India. They reported that iron had a strong tendency to be concentrated in clay minerals especially in hydrous mica, montmorillonite and illite minerals. *Dress and Wilding (1978)* reported that much of iron concentration in light minerals, occurs as micro inclusion of accessory minerals within primary host minerals such as quartz and feldspars.

Total iron content was positively correlated with either clay and clay + silt contents *(Abd Allah, 1977)*. *Abd El-Hamid (1981)*, stated that the contribution of soil variables to total iron in the studied soils was interpreted in terms of statistical evaluation as follows: clay > $CaCO_3$ = clay + $CaCO_3$ > clay + silt > silt > silt + $CaCO_3$. *El-Shazly (1983)* mentioned that, soil texture, mineral composition and $CaCO_3$ content are most important factors that correlate total and available contents of iron. The total content of iron is significant positively correlated with the percents of heavy minerals and some of pyroxenes, amphiboles and epidotes. Likewise, total iron content is significantly correlated with montmorillonite percent. He suggested that the possible presence of these minerals is due to the isomorphous substitution or the coincidence of trace elements with smectite during soil formation.

El-Gala and Hendawy (1972) showed that total iron content is about 0.5% in the sandy soils. *Malewar and Randhwa (1977)* stated that maximum (7.3%) and minimum (4.1%) average values of total iron were recorded for calcareous forest and shallow black soil, respectively. *Deixon and Weed (1977)* found that sedimentary rocks (limestone, sandstone and shale) contain 1700, 29000 and 48000 ppm Fe, respectively. *El-Falaky (1981)* found that total iron content in Egypt ranged from 0.96 to 1.68% in the desertic soils and 0.64 to 1.9% in the calcareous soils. *Rabie et al. (1989)* found that total iron

content ranged between 1716 to 41077 ppm with lowest value in sandy soils of siliceous nature and highest value in the Nile flood plain soils. The non-calcareous coarse aeolian sandy soils demonstrated the low averages. Total iron has a negative correlation with sand %. Available iron (DTPA-extracted) was 0.7 and 0.36 for sandy noncalcareous and sandy calcareous soil, respectively. *Hafez et al., (1992)* found that extractable Fe is mainly governed by clay, silt, clay + silt and calcium carbonate in clay and sand size fractions.

b) Manganese:

Manganese is found in parent materials containing ilmenite, magnetite, hornblende, epidote, garnet and sphene in the heavy minerals, *Gladilovich and Sergeeva (1971)*. *Krauskopf (1972)* stated that. manganese exists in limestone. Bentonite and illite fixed significant quantities of manganese under wetting and drying processes. Kadinite fixed relatively small amount of manganese as compared to bentonite and illite, *Reddy and Perkins (1976)*.

Ismail (1968 a) found that all forms of manganese were positively and significantly correlated with clay either as clay fraction content or as clay mineral, but they positively and insignificantly correlated with silt. On the other hand, a negative and significant correlation was found between $CaCO_3$ content and different forms of manganese. *Ismail (1968 b)* found a positive relationships between total manganese content and percentage of each of fine sand, silt, clay and organic carbon. However, the relationship between total manganese content and percentage of each of coarse sand and calcium carbonate were negative and high significant. *Sequeira (1981)* stated that total manganese was positively correlated with pH and exchangeable Ca, Mg and K, and negatively correlated with sampling depth. *El-Shazly (1983)*

reported that the total content of soil manganese is significantly and positively correlated with heavy minerals content.

Ghanim et al. (1971) stated that the sandy soils show the lowest total manganese content (116 to 223 ppm), while calcareous soils are containing from 400 to 533 ppm. *Metwally et al.* (1971) found that total Mn ranged between 250 and 325 ppm. *Kishk et al.* (1979) found that total Mn ranged between 111 to 2287 the highest values being in the fine textured alluvial soils and the lowest values in the sandy and calcareous ones, in soils of Middle and Upper Egypt, and reported values from 1.1 to 57.4 ppm for the DTPA-extractable Mn. According to *Rabie et al., (1989)*, total Mn content ranged between 28.30 and 864.16 ppm with lowest value in sandy soils of siliceous nature and highest value in the Nile flood plain soils. The non-calcareous, coarse aeolian sandy soils demonstrated the low averages. Total Mn has a negative correlation with sand %. Available Mn (DTPA-extracted) was 1.12 and 0.23 ppm for sandy non-calcareous and sand calcareous soils respectively. According to Hafez et al. (1992), extractable Mn is mainly controlled by silt, clay + silt and calcium carbonate in sand $CaCO_3$ which is major soil component (8-58%).

c) Zinc:

Chartterjee and Das (1964) found a simple relationship between mineralogical composition of clay and the amount of available zinc. However, extractable zinc was much more abundant in soils where illite was the predominate clay mineral than in soils predominated with montmorillonite. *Abd El-Hamid (1981)* stated that the total content of zinc was highly significantly and positively correlated with $CaCO_3$ content *El-Shazly (1983)*

reported that soil texture, mineral composition and $CaCO_3$ content are the most important factors that correlated with total content of zinc. The total content of zinc is significantly correlated with the percent of heavy minerals and some of pyroxenes, amphiboles and epidotes. *Rashad (1986)* found that the main factors influencing total zinc content in the soil of Egypt are the contents of clay fraction, organic matter and $CaCO_3$.

EL-Kady (1970) found that total amount of Zn, ranged from 18 to 156 ppm the highest values were achieved in the heavy alluvial soils of Egypt, while the sandy soils had the lowest values and the calcareous soils were in the intermediate. According to *Rabie et al., (1989)*, total zinc contents demonstrate the highest value (125.9 ppm) in soils which have relatively high contents of clay and silt and low carbonates, while aeolian sand soil contained the low value (15.41 ppm). Regarding the DTPA- extractable Zn, the highest content was present in fluviomarine sample (8.34 ppm) and the lowest one (5.05 ppm) in the aeolian sandy samples.

d) Copper:

Copper occur as a trace constituent in olivine, hornblende, augite, biotite, anorthite, andesine, oligoclase, albaite and orthoclase. In montmorillonite and hydrous mica structure, AL can be replaced by small amounts of copper, *Mitchell (1964). Abd EL- Hamid (1981)* stated that the contribution of clay, silt and $CaCO_3$ contents to total soil copper content followed the order: $CaCO_3$ > silt > clay + silt > clay. According to *EL-Shazly (1983)*, soil texture, mineral composition and $CaCO_3$ content are the important factors that correlated with total and available contents of copper.

EL- Gibaly et al., (1970) found that total copper in the desert sand soils contain 2-10 ppm. *Rabie et al., (1989)* found that total copper demonstrated the highest value (53.87 ppm) in the Nile flood plain sample and the lowest (5.05 ppm) in the aeolian sandy one. DTPA-extractable Cu reveals that the highest value (3-10 ppm) was that of deltaic flood plain sample and the lowest (0.10 ppm) in aeolian sandy one.

e) Boron:

Mathur et al., (1964) found a positive and significant relationships between $CaCO_3$ percent and total boron content in the soils of Rajasthan irrigated with high boron water. According to *Cornillon (1970)*, soils differ widely in their total boron content according to rock   parent material from which they were drived. The highest proportion of total boron is, generally, occurred in the fine clay fraction which contains up to 60% of the total boron content. On the other hand, sand fraction contains less than 7.0% of the total B amount except in the andosol and the lithosol where boron was similarity distribution in the clay, silt and sand fractions. *Hassona (1989)* Found that total boron is a high significantly and positively correlated with both fine sand and silt contents, whileahigh significant and negative correlation was found concerning the content of organic matter. On the other hand, total boron is insignificantly correlated with clay and $CaCO_3$.

Sequeira (1980) Found that sandy soils from Mio-Plio- Pleistocenic sands characterized by having 170 ppm total B. *Teixeira et al., (1980)* showed that sandy soils are deficient in boron (0.3ppm). According to *EL-Gundy (1988)*   the total boron in sandy soils ranged between 2.9 and

28.9 ppm. On the other hand, *Hassona (1989)* showed that total boron content in sandy soils ranged from 15.3 to 38.3 ppm .

2.8 Grain size parameters:

According to *Folk (1961)*, for evaluation of sets of samples it is probably best to compare the curves directly by eye as only in that way can the entire character of the sediment curves be revealed. But this is inconvenient and furthermore not very quantitative: it is often difficult to decide whether curve A represents a better sorted or finer sample than curve B, or how great the differences are. To solve this problem one resorts to various statistical measures with describe quantitatively certain features of the curves; these values can then be tabulated and, it is hoped, certain combinations of values may be indicative of different sedimentary environments.

Folk and Ward (1957) suggested the following parameters which calculated from the cumulative curves:

A- Mean size (Mz) :

Mz is measure used for determining overall size and it is much superior to the median because it bases on three points and gives a better overall picture. It considered as a standard measure of grain size *(Folk, 1961)*

B- Sorting (σI):

σI is a measurement of sorting values. The following verbal classification scale for sorting were suggested by *Folk and Ward (1957)* and *FolK (1961)* :

Limits of sorting (σI)	Correlation
under 0.35 φ	very well sorted
0.35 - 0.50 φ	well sorted
0.50 - 0.71 φ	moderately well sorted
0.71 - 1.00 φ	moderately sorted
1.00 - 2.00 φ	poorly sorted
2.00 - 4.00 φ	very poorly sorted
over 4.00 φ	extremely poorly sorted

Inman (1949) concluded that sorting is a sinusoidal function of mean size, hence the sediments falling in the "well sorted" category would be the medium and fine sands, and all clays, silt and most gravels would be poorly sorted. *Inman (1952)* pointed out that sediments transported by wind are usually well-sorted, while that transported by water or weathered in situ are usually poorly sorted. Accordingly, all aeolian materials should be sandy, or at least of a sand diameter. *Folk and Ward (1957)* stated that sorting increase with transport in many suites simply due to the fact that, the mean size of a sediment changes with transport and the improvement in sorting is dependent only on the decreasing mean size not the distance.

C-SKewness (SKI):

Inman (1952) suggested two measures of skewness; one to determine the asymmetry of the central part of the distribution curve and the other; to measure the asymmetry of the extremes. A better measure of over-all

skewness may be averaging these two values by the formula of *Folk and Ward (1957)*.

This measure is geometrically independent of sorting. Perfectly a symmetrical curves have $SK_I = 0.00$, and the absolute mathematical limits are -1.00 to + 1.00. Very few curves have SK_1 beyond - 0.80 or + 0.80 .Positive values of SK_1 indicate that the samples have a "tail" of fine grains; negative values indicate a " tail " of coarse grains. The following verbal limits were suggested by *Folk* and *Ward (1957)*.

Limits of skewness (SK_I)	Correlation
- 1.00 to - 0.30	Very negatively skewed
- 0.30 to - 0.10	Negatively skewed
- 0.10 to + 0.10	Nearly symmetrical
+ 0.10 to + 0.30	Positively skewed
+ 0.30 to + 1.00	Very positively skewed

D-Kurtosis: (KG)

Kurtosis measures the ratio of sorting in the extremes of the distribution compared with the sorting in the central part and as such is a sensitive and valuable test of the normality of a distribution. A normal curves have KG = 1.00; leptokurtic curves have KG over 1.00; and platykurtic curves have KG under 1.00. The following verbal limits have been suggested by *Folk and Ward (1957)*.

Limits of kurtosis (KG)	Correlation
under 0.67	Very platykurtic
0.67 - 0.90	Platykurtic
0.90 - 1.11	Mesokurtic
1.11 - 1.50	Leptokurtic
1.50 - 3.00	Very leptokurtic
over 3.00	Extremely leptokurtic

2.9. Uniformity, maturity and source rocks:

According to *Folk (1961)*; heavy minerals are generally studied classified to four groups:

1- Opaque minerals: These minerals generally have high specific gravity because of their iron content. These minerals are:

a- Magnetite and ilmenite, which considered moderately stable and more stable under oxidizing conditions but are dissolved readily in a reducing environment.

b- Pyrite.

c- Hematite and limonite

d- leucoxene is an aggregate of extremely fine-grained sphene, rutile or anatase, and forms as an alteration product usually after ilmenite.

2- Micas: Percentages unreliable because they do not always sink in bromoform. Commonly not counted in heavy mineral studies because of their widely different shape, hence different. hydraulic behavior.

3- Ultra-stable group: Zircon, tourmaline and futile; because the first two are very hard and inert (even more then quartz) they can survive many reworking. When older sediments are reworked to form younger ones, zircon and tourmaline are about the only ones that can survive. An abundance of tourmaline and zircon in a heavy suite then means either (1) prolonged abrasion and/or chemical attack has occurred or (2) the minerals are being reworked from older sediments.

4- Metastable group:

a. Olivine is very rare in sediments, occurring only under climatic conditions and rapid erosion.

b- Apatite is moderately stable,

c- Hornblende and pyroxene are moderately unstable. Pyroxenes are etched and dissolved rapidly by solution after deposition, hence are rare in porous sands.

d- Garnet: Rapidly dissolved in many porous sands, stability variable, depending on the variety.

e- Epidote, clinozoisite and zoisite are moderately stable.

f- Kyanite, sillimanite, andalusite and staurolite are moderately sable, but usually rather soft.

Some experiments have been made to determine the resistance of mineral grains to wear. *Friese (1931)* determined the durability of a

considerable number of minerals. Taking crystalline hematite as 100, he assigned a numerical value to the abrasion resistance of each mineral studied as follow, hematite (100), monazite (117), orthoclase (150), diopside (160), andalusite (220), kyanite (260), apatite (275), common olivine (290), epidote (320), ilmenite (325), garnet (378), magnetite (380), topaz (390), common augite (420), staurolite (420), cordierite (480), pyrite (500), and tourmaline (817).

Order of persistence, was based on published records of minerals in sediments of all ages and places. For each species the frequency of occurrence (ratio of reported occurrences of the species in question to number of investigated formations) in recent sediments and the average frequency of occurrence in ancient sediments were determined. The ratio of these two frequencies is taken as a measure of the survival ability of each species investigated, a subject explored by *Pettijohn (1941)* as follow: (-3) anatase, (-2) muscovite (-1) rutile, (1) zircon (2) tourmaline (3) monazite (4) garnet (5) biotite (6) apatite (7) ilmenite (8) magnetite (9) staurolite (10) Kyanite (11) epidote (12) hornblende (13) andalusite (14) topaz (15) sphene (16) zoisite (17) augite (18) sillimanite (19) hypersene (20) diopside (21) Actinolite (22) olivine. A negative sign indicates the mineral to be more abundant in the ancient than in modern sediments.

Marshall (1940), Marshall and Hasman (1943), Brewer (1964) used zircon, tourmaline and rutile as indices of weathering conditions and soil development:

According to *Brewer (1964)*, uniformity and development of soil parent material can easily be delineated in soil profiles derived from a uniform parent material rather than profiles originated from heterogeneous parent material. In the former case, weathering sequence and translocation or migration of dynamic components are only rendered to pedological factors. Such materials which are capable of being transported, are termed "plasma", while immobile soil fractions are stable with minor or no change during soil formation processes. In this connection, it is accepted that the establishment of homogeneity or discontinuity within parent material is based on the assumption that the content of an index minerals remains constant during weathering sequence accompanying soil development.

Marshall and Hasman (1943), and Barshad (1964) cleared that, the constancy of a trend of index minerals throughout the profile layers or horizons, indicated by their percentage of the ratios between two index minerals, suggests uniformity of parent material, whereas the inconstancy in such a trend marks the heterogeneity or discontinuity of parent materials. Moreover, amphiboles and pyroxenes are readily susceptible to weathering and decay, thus, their frequencies give indications of the presence or absence of recent deposition and/or degree of soil development.

Heavy minerals have been found exceptionally useful as clues to the nature of source rocks *(Boswell, 1933)*. According to *Folk (1961)*, olivine, chiefly from basic igneous rocks. Apatite commonly it occurs sporadically (abundant in a few specimens, sparse in others) then indicates a volcanic source. Otherwise, it can occur in basic to acid plutonic rocks. Hornblende and pyroxene, may come from either igneous or metamorphic rocks, but when

present in abundance indicate metamorphics, such as hornblende schist. Glaucophane and tremolite are other less common amphiboles, indicating almost certainly a metamorphic source. Pyroxenes are etched and dissolved rapidly by after deposition, hence are rare in porous sands. Garnet may come from plautonic rocks, pegmatite, or metamorphics but in abundance indicate a metamorphic source. Epidote, clinozoisite and zoisite indicate a metamorphic or hydrothermal source. Kyanite, sillimanite, andalusite and staurolite are highly diagnostic of a metamorphic source. According to *Pettijohn (1984)*, glauconite, rutile, rounded tourmaline and rounded zircon indicate reworked sediments.

The most common mineral of sand is, quartz, most efforts, therefore, have been conducted to determine the relation between kinds of quartz and source rock. The elongation has been used as a criterion of provenance, the quartz of metamorphic rocks is more elongated than that of igneous origin. The extinction of quartz varies from sharp to wavy. Quartz which has been subjected to considerable pressure shows "strain shadow" or "undulatory extinction" observed under crossed nicols. In general, therefore, quartz of metamorphic rocks was presumed to show a marked wavy extinction, whereas that of igneous rocks was not.

2.10 Mineralogy of clay fraction

There are seven important types of clay minerals in soils, namely; kaolinite, halloysite, montmorillonite, hydrous mica (illite), vermiculite, chlorite and allophane, the first six clays minerals are crystalline and composed of silicon tetrahedral, aluminum hydroxide and magnesium

hydroxide sheets in varies combinations, while allophane is not crystalline *(Fitzpatrick, 1986).*

X-ray diffraction technique is one of the most effective tools for clay minerals identification. Interpretation of the X-ray diffraction patterns was based on the presence of diffraction peaks characteristic of the crystalline species present in the sample. The diagnostic diffraction peaks used for the identification of clay and accessory minerals are those reported by *Brown (1961), and Jackson (1969)* as follows:

(1) Smectite:

Smectite gives a diagnostic peak (001) at about 14.0-14.5 A° for Mg-saturated air dried sample which expands to 17.8 A° upon glycerol solvating and shifts to 10.0 A° after K saturation and heating at 550°C for four hours.

(2) Vermiculite:

It gives a diffraction spacing at 14.0-15.8A° on Mg-saturation and ethylene glycolation which contracts to 10.2-10.7A° upon K-saturation and heating to 550°C.

(3) Chlorite:

Chlorite gives a basal diffraction spacing of 14.0-14.3 A°, which remains constant throughout the different treatments besides a strong second order peak at 7.1A° which becomes weaker on heating at 550°C.

(4) Hydrous mica "illite":

It exhibits a basal reflection at 9.96-10.28 A° in the Mg-saturated air-dried sample which remains constant in the other treatments.

(5) Kaolinite:

Kaolinite gives a strong spacings at 7.16 A° and 3.57 A° in the Mg-saturated air-dried samples which remain constant in the other treatments and disappear upon heating at 550°C for four hours.

(6) Palygorskite:

It is distinguished by the spacing of 14.40-10.53, 6.40-6.48, 4.45-4.55, 3.20-3.25 and 2.56-2.58 A° in all treatments.

(7) Sepiolite:

It is identified by the presence of diffraction peaks at 12.05-12.30, 7.40-7.70, 9.49-4.50, 4.29-4.31, 3.73-3.75, 3.33-3.67 and 2.66-2.69 A° in all treatments.

(8) Interstratified minerals:

Interstratified layer silicates of soil clays, often result in registration of more complicated X-ray diagrams. Making use of the suggestions provided by *Jackson (1965), Kodama et al. (1968), Gradusov (1968)*, Horn and *Chapman (1968) and Mac-Ewan (1968)*, the individual members are resolved.

a) Regularly interstratified: smectits-chlorite are identified by the presence of 19.19-31.50 A° in the glycerol solvated sample, mica-smectite displays

24.00 A° peak in the Mg-saturated air-dried sample, which is shifted to 26.8 after glycerolation and collapse to 10 A° after K-saturation and heating and mica-vermiculite is detected by a 25.00 A° peak on Mg-saturation and glycerolation and 20.53 A° on K-saturation air-drying.

b) Irregularly interstratified minerals are identified as follows:

1- Smectite-chlorite has a 15.78 A° peak on Mg-saturation air-drying which is shifted to 16.10 A° glycerolation and 10.70 A° on K-saturation.

2- Vermiculite-chlorite has a 15.5 A° peak which persists in the Mg-saturated, glycerolated and K-saturated samples.

3- Smectite-vermiculite gives 15.5 A° which is shifted to 16.0 A° in the Mg-saturated glycerol solvated sample.

(9) Quartz:-

Usually quartz gives two fairly strong peaks at 3.35 A° and 4.26 A° the former being over twice intense as the latter.

(10) Gypsum, feldspars, calcite and dolomite:

They are identified by their characteristic diffraction peaks at (4.40-4.60), 4.05, (3.10-3.25) and 2.89 A° respectively.