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CLAY MINERALOGY IN RELATION TO GEOMORPHIC ASPECTS IN WADI EL-NATROUN DEPRESSION SOILS, WESTERN DESERTS, EGYPT

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ABSTRACT: **The aim of the current work is to identify the mineralogy of the clay fraction of some soils representing Wadi El-Natroun Depression (W.N.D), Western Desert of Egypt using X-ray (XRD), Cation exchange Capacity (CEC), and surface area (SA) in an attempt to throw light on the interrelation of clay minerals to lithology and depositional environments of the areas.**

The obtained results indicate that, the studied soils are dominated by smectite (montmorillonite) mineral followed by Kaolinite and palygorskite. Also, hydrous mica (illite) and layer silicate (inter stratified clay minerals) are present yet in variable frequency depending on the geomorphic unit on which these soil are occurred. CEC and surface area of the clay fraction varied from 33.42 to 48.23 Cmol/Kg and 447 to 652 m^2/g clay, respectively. The relatively Low content of CEC and surface areas in the studied clay samples is attributed to that, smectite (montmorillonite) is associated with the occurrence of Kaolinite, palygorskite and illite.

The mineral assemblage are interpreted in terms of lithology and depositional environments. The mode of formation to the pre-wet climate conditions in contrast to the present aridity.

Key words: **Geomorphic units, X-ray (XRD), Surface area (SA), cation exchange capacity (CEC).**

INTRODUCTION

The clay fraction plays an important role in determining the physical and phiso-chemical properties and the reactions that occur in soils. The influence of the clay fraction is very pronounced in desertic regions of Egypt, particularly in those region having low content of particle less of <2 um equivalent spherical diameter.

Assessment of the particle importance of clay minerals in soils by pedolgists, agronomists and civil engineers rests largely upon a Knowledge of the structure of these hydrous aluminosiliates. Lithology and the prevailing environmental conditions may be the main factors controlling the end-product of clay minerals and their suite.

Wadi EL-Natroun depression (WND) is one of the prominent depression in the Western Desert (WD) that could situated just West of Cairo - Alexandria Desert Road nearly at its middle. It is located in the northeast corner of the Western Desert between longitudes 30^o $00^\backslash$ and 30^o $30^\backslash$ East and latitudes 30^o $15^\backslash$ and and 30^o $00^\backslash$ North (Fig 1). Wadi El-Natroun Depression (W.N.D) has an oval shape with about 50 km. in length and its width ranges from 15 to 20 Km. The total area of the depression that lies below sea level (0-23 m.a.s.l) is about 5oo Km^2 (120.000 feddans).

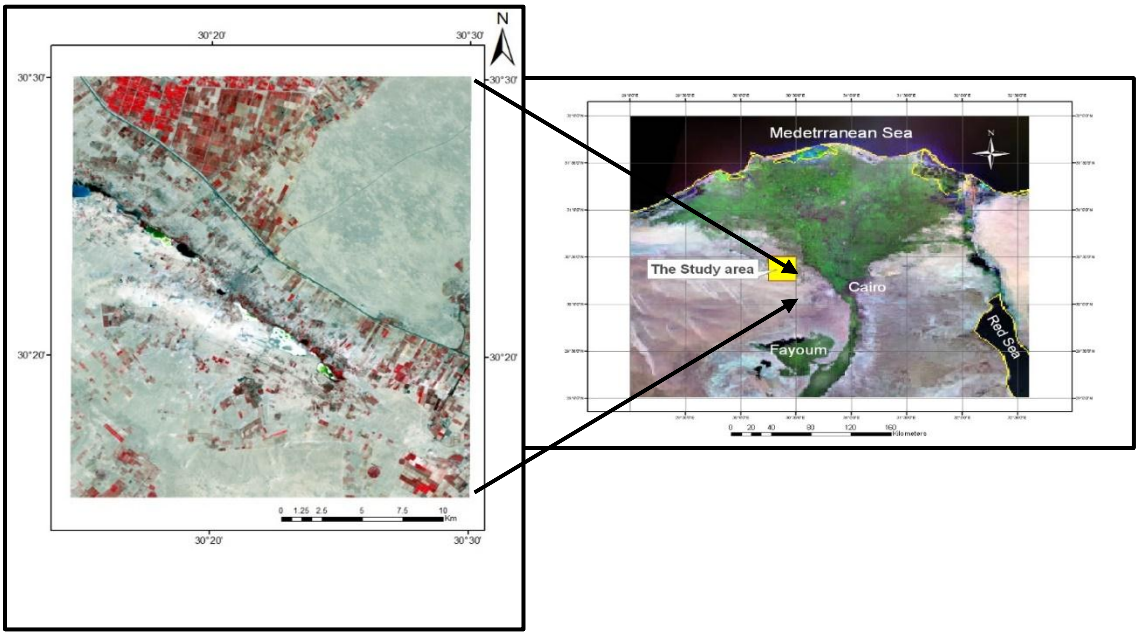

Fig (1). Location of the study area (Wadi El-Natroun, Egypt).

Lithologically, the surface of W.N.D, is underlain by both Tertiary and Quaternary sediments with local outcrops of basalt and diorite. The Quaternary sediments include the Pleistocene prenile sediments, aeolian sand accumulation and stabilized dunes, (the lacustrine deposits, the salt lakes and Sabkhas) and the gravelly deposits of the Nile and calcareous crust (Said, 1999).

The clay fraction content of the soil is quite important in the field of agriculture land use. It constitutes the most active part in soil as well as controls the majority of the physical and chemical properties. Dixon (1991) reported that, the term clay fraction refers to all particles less than 0.002 mm in diameter. Thus it includes layers silicates, oxides and other minerals. Clay are the source of many of the chemical and physical properties of soils that make them a useful medium for the growth of the plants and for the less common uses such as a medium for the disposal of waters. Clay and much of the diversity is found in soils and the behavior of soil clays is influenced also by the associated minerals in the coarse fractions.

Concerning the previous mineralogical studies on W.N.D, the soils have attracted the attention of many scientists, i.e Elwan (1975), Attiay et al (1979), El-Sayed et al (2013) and Abdel EL. Khalek (2015).

In studies on mineralogical composition of the clay fraction of W.N.D soils El Sayed et al, (2013) recorded the presence of illite with biotite, mascovite and montmorillonite or Kaolinite in Miocene aquifer. West of W.N.D is an indication of typical fluviomarine and marine environment which reflects high water salinity. In contrast, the disappearance of illite with biotite and muscovite in both Pleistocene and Pliocene aquifers at east of W.N.D. reflect continental condition and low water quality.

Dixon (1991) reported that the importantce of layer silicate clays to the properties of soils is best illustrated by their cation - exchange capacity (CEC). The presence of permanent negative sites in certain clay minerals accounts for the ability of many soils to hold cations against leaching in a available form for plant uptake. Smectite and vermiculite are the group of minerals that have the highest CEC capacity in soils. Their charge is predominantly due to ionic substitution in structural positions. Smectite are the most common and , owing to their small porticle size and high charge, are the most chemically and physically active minerals in soils.

The objective of the current work is study the detailed the clay mineralogy of some soil in WND. Also, aimed to predict the role of environment in the formation of the different clay minerals.

MATERIALS AND METHODS

Fifteen soil profiles were selected to represent the different geomorphic units and landforms of W.N.D. (Abu Sleem, 2010). Their locations are shown in Fig (2).

The profiles were dug deep up to 150 cm from the surface unless rocky substrate were encountered. Soil samples were collected representing the morphological variations throughout the entire depths of each profile. The soil samples were air dried, ground, sieved through a 2 mm sieve and subjected to mineralogical analysis according to the methods described by Page et al (1982).

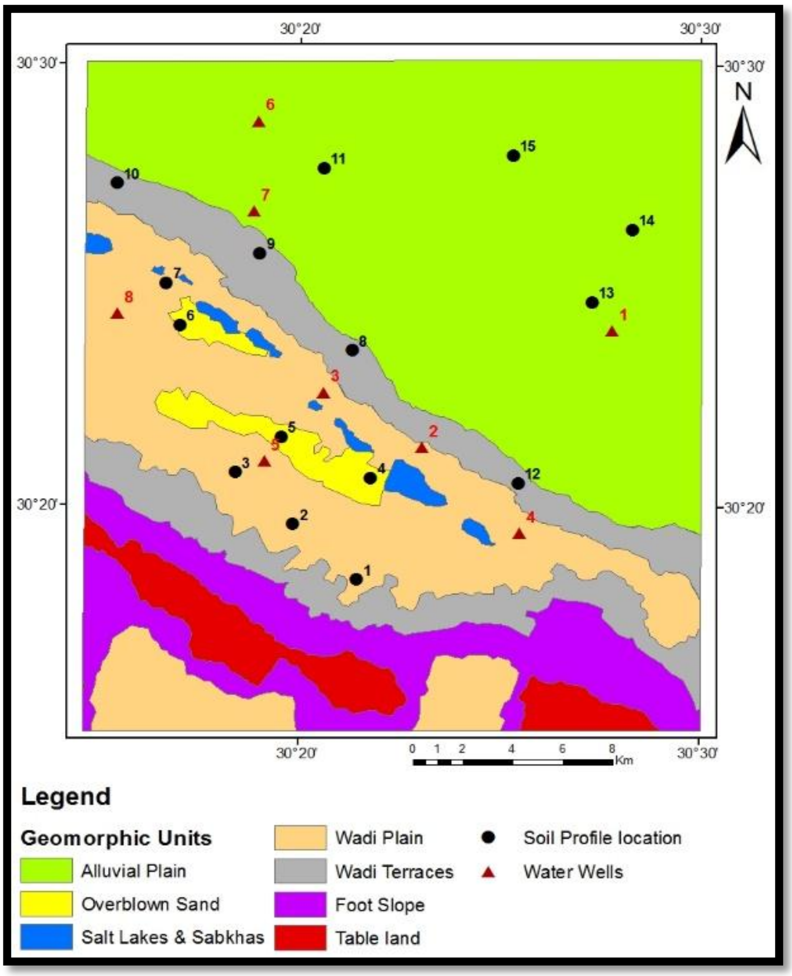

Fig. (2): Geomorphological units and location of soil profiles and water wells in Wadi El-Natroun area.

The mineralogical analysis of clay fraction (< 2u) was carried out on ten representative soil samples to declare the clay mineralogy of soils representing of different geomorphic units of WND. Clay fractions (< 2u) was separated by method reported by Folk (1980). The, separated clay samples were slightly crushed and representative portion was disintegrated and dispersed by soaking in distilled water and stirring. The natural separated clay fraction was water precipitate on to glass slides to produce preferred orientations of the clay samples. Oriented clay slides were prepared and examined as follows: Mg-saturated air dried, Mg-saturated glycerol solvated, and K saturated and heated to 500^{o} C for 4 hours.

The X-Ray diffraction analyses (XRD) was carried out using Scintag, Inc. U.S.A.X1. Advanced Diffraction System with Cu-radiating and Ni filter. The XRD data were interpreted using ASTM Cards together with data published by Dixon and Weed (1977). and Moore & Reynolds, 1989)

Semi- quantitative of clay minerals identified were estimated by measuring the peak areas of the first order basal reflection (001) and calculating the percentages of frequency according to methods outlined by Weaver (1961), Biscays (1965), Gjems(1967) and Ven Katarathinam and Ryan (1971).

Cation Exchang Capacity of the clay fractions (CEC), was carried out on clay fraction using sodium acetate pH=7 and ammonium acetate pH=8.2 according the method described by Page et al (1982), Ca^{++} and Mg^{++} were determined by titration with versenate, while Na^{+} and K^{+} by flame photometers.

Total Surfaces area (SA) of the clay fraction was determined according the procedure described by Lawrie (1961), using orthophenanathroline for adsorptions. The amount of orthophenanethroline, adsorbed on the clay surface is determined from the difference of concentrations between the initial and final solutions. The surface are occupied by orthophenanathroline is given by the relation.

A = M x 3.61 m^2/g of Clay

Where M= The amount of orthophenanathroline absorbed in m mol/100 g. of clay. A= The area in square meters per 100 g of clay.

RESULTS AND DISCUSSION

1-Identification of clay minerals:

Clay minerals identification in the present study is essentially based upon the X-ray diffraction analysis (XRD) of the oriented clay samples treated with the different treatments.

X.R.D pattern is based on the presence of diffraction peaks characteristic for each of crystalline species present in a sample. The intensity of the sharpness of these peaks are dependent not only on the number and the corresponding diffraction planes present in the examined sample but also on the particle size, chemical composition and pre-treatments during clay separation (Whittig, 1965).

The identification of clay minerals using XRD analysis (Figs. 3 to 12) was carried out following the essential principles established by Whittig and Jackson (1955), Brown (1961), Patterson (1963), Black (1965), Jackson (1969) and Dixon and Weeds (1977) as follows:

1- **Smectite** minerals are identified by the expansion of the basal reflection (001) from 14-15.8 A^o in the Mg-saturated to about 18.0 A^o upon glycerolated salvation and collapsed to about 10 A^o in K-heated treatment when heated to 550 °C for four hours.

1- **Kaolinite** mineral is identified by the presence of very sharp peaks at about 7.18 to 7.25 A^o (001) and 3.58 to 3.60 A° (002) in the Mg-saturated samples. These peaks are not affected by glycerol salvation and they disappear upon K-saturated and heating to 550 °C for four hours.

2- Palygorskite mineral is identified by basal reflection ranges from 10.3 to 10.6Ao which is not affected by the glycerol treatment while it disappears at 550 °C for two hours.

3- Hydrous mica (illite) minerals are detected by the presence of basal reflections at about 9.96 to 10.28 A^o peak upon Mg-saturation which remains constant throughout the different treatments such as glycerol salvation and K-saturation and heating to 550 °C for four hours.

4- Mixed layer (Illite-smectite) have d-spacing of basal reflections (001) range from 11.0 to 13.0 A^o which moves to about 12.0 and 14.0 A^o after glycerol treatments. Heating at 550 °C leads to complete collapse to about 10 A^o.

Non clay minerals:

Quartz and-feldspars are detected from the existence of 3:37-3.34 A^o and 3.31-3.18A^o respectively throughout the different treatments. Calcite-is identified by their characteristic diffraction peaks at 3.08-3.02 A^o and 2.89-2.81 A^o respectively.

Clay minerals of the studied Soils:

Data in Table (1) and Figs (3 to 12) show that, the clay minerals of the studied soils are mainly consists of smectite with variable quantities between abundance (>60%) and dominant (40-60%). However, kaolinite occurs as a few amounts (10-20%) in most of the studied samples. On the other hand, palygorskite occurs in moderate amount (21-40%) in profile No. 14 (Alluvial plain unit) and profile No.8 (Wadi terraces unit). Illite and mixed layer detected in some samples in a few (10-20%) and trace (3-10 %.) amounts.

In conclusion, gradient variation in the different clay minerals may reflect multi-origin (different source rocks) and multi-environments during the formation of these soils. This is supported, in general as previously discussion that, the sediments of the study area were not inherited in situe but they were derived from many sources and transported to the sedimentary basins.

Cations exchange capacity of the clay fraction

The cation exchange capacity (CEC) in the mean of the individual particles of the clay minerals and also the inorganic amorphous present in the clay fraction owing to the alteration and weathering of the soil in organic components (Grim, 1968). The values of CEC for the clay fractions of the studied soils of W.N.D varied between 33.42 and 48.23Cmol/kg (Table 1) in the alluvial plain and wadi terraces soils, respectively.

Comparing of the present CEC values with the scale given by Grim (1968), it can be concluded that the present, CEC values (33.42 - 48.23 Cmol kg^{-1} are somewhat lower than that of the pure montmorllonite (80-150 cm). This may be attributed to that montmorllonite is associated with Kaolinite which has CEC values range from 3 to 15 Cmol. This makes values of the studied clays dominated with montmorllonite are lower than values of pure montmorllonite (Dixon, 1991).

Surface area of the clay fraction (SA)

Lawrie, (196l) and Grim, (1968) reported that the term "Specific surface" or " Surface area" refers to the area per weight unit of soil or clay and is usually expressed in square meters per gram (m^2 /g)). The specific area (SA) of clay minerals ranged from 10 to 30 m^2/g for kaolinite, 67 to 290 m^2/g for illite, 770 m^2/g. For vermiculite and from 760 to 810 m^2/ g for montmorllonite.

The estimated specific area (SA) for the separated clay samples of the studied geomorphic units are given in Table (1) Data indicate that, specific (SA) of the clay fractions varied from 447 to 652 m^2/g. The highest value is obtained in the 0-10 cm layer of profile 15 representing the alluvial plain soils. Whereas the lowest value is recorded in the (40-60 cm) layer of profile 8 representing the Wadi terraces soils.

Generally, the type of clay minerals influences the values of (SA) greatly. In other words, the type of existence clay minerals controlled with long extents of the values of (SA). Where none-swelling minerals such as kaolinite hove low values because they constitute only external surfaces. While the swelling minerals of montmorllonite as well as vermiculite have comprised internal and external surfaces

The high content of montmorllonite in most of the clay samples as detected by XRD played a vital role for increasing the value of (SA). These values ranged from 447 to 652 m2/g. clay in the studied samples corresponding to the values obtained by Lawrie (1961). In his study on montmorllonite clays collected from different localities which are 480 ,660, 675 and 770 m^2/ g clay for Marchagree (West Australiana), New Castel C.N.S.W acid treated Wyoming (U.S.A.) and natural Wyoming montmorllonite, respectively.

Furthermore, the lower values of (SA) in the studied samples is attributed to the predominat montmorllonite with considerable amounts of kaolinite in these clay samples. This leads to lowering the values of surface area than the values recorded by Lawrie (1961).

Table (1): Semi-quantitative mineralogical composition, CEC and surface area of the clay fraction separated from some layers of the studied soil profiles.

Geomorphic unit	Prof. No.	Depth (cm)	Clay Minerals					Non clay mineral	CEC Cmol/ cm	Surface area m2/g
			Smectite	Koalinite	illite	Mixed Layer	Palygorskite			
Wadi Alluvial Deposits	3	(15-55)	Abundance	Few	Few	Few	-	Quartz, feldspar	39.37	527
Wadi Aeolian Deposits	5	(15-50)	Abundance	Few	Few	-	Few	Quartz, feldspar	36.29	572
		(50-90)	Abundance	Few	terace	-	Few	Quartz, feldspar	45.18	650
Wadi Terraces	8	(6-110)	Dominant	Few	terace	-	Few	Quartz, feldspar	36.22	447
	12	(25-55)	Abundance	Few	-	-	-	Quartz, feldspar	48.23	612
Alluvial Plain	13	(0-20)	Dominant	Few	terace	terace	Few	Quartz, feldspar,	42.15	578
		(20-65)	Dominant	Moderate	terace	terace	Few	Quartz, feldspar,	33.42	451
	14	(0-20)	Dominant	terace	-	-	Moderate	Quartz, feldspar,	36.04	568

								calcite		
		(20-60)	Dominant	-	-		Moderate	Quartz, feldspar, calcite	39.19	560
	15	(0-10)	Abundance	Few	-	Few	Few	Quartz, feldspar , calcite	45.14	652

Abundance > 60% - Dominant - 40-60% - Moderate - 21-40% - Few-10-20% - Trace = 3 -10%

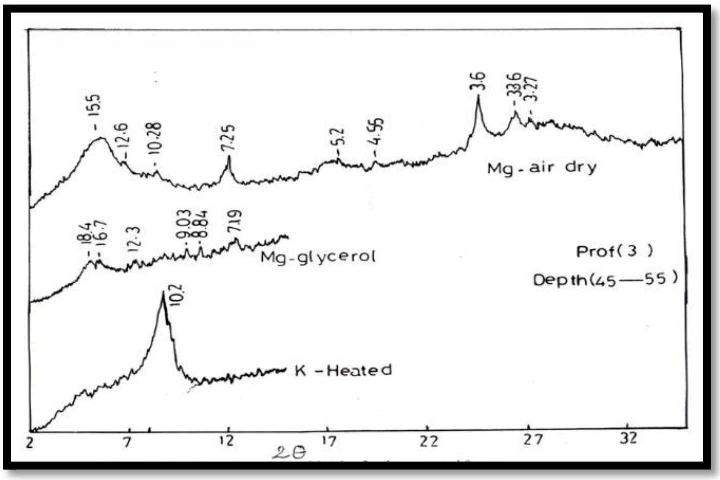

Fig. (3): X-ray diffraction pattern of the clay fraction separated from 45-55 cm depth of profile No.3.

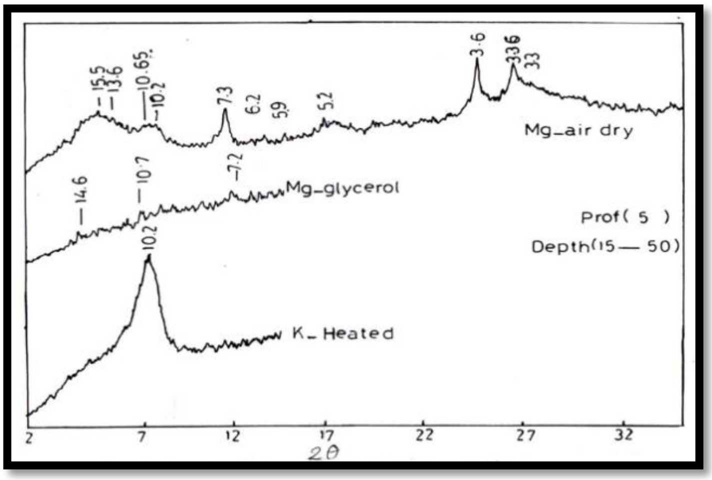

Fig. (4): X-ray diffraction pattern of the clay fraction separated from 15-50 cm depth of profile No.5.

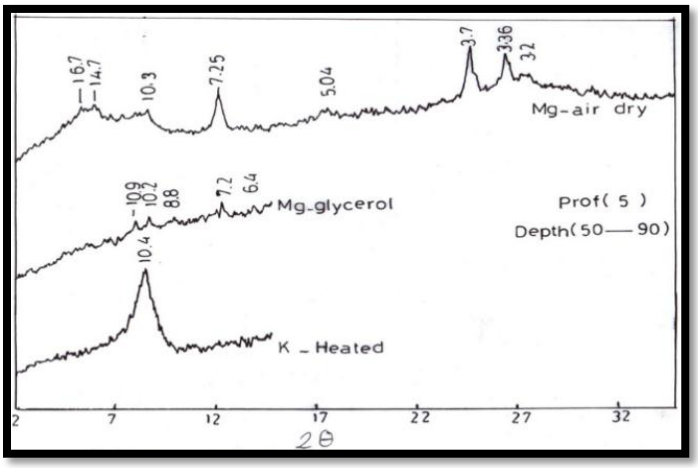

Fig. (5): X-ray diffraction pattern of the clay fraction separated from 50-90cm depth of profile No.5.

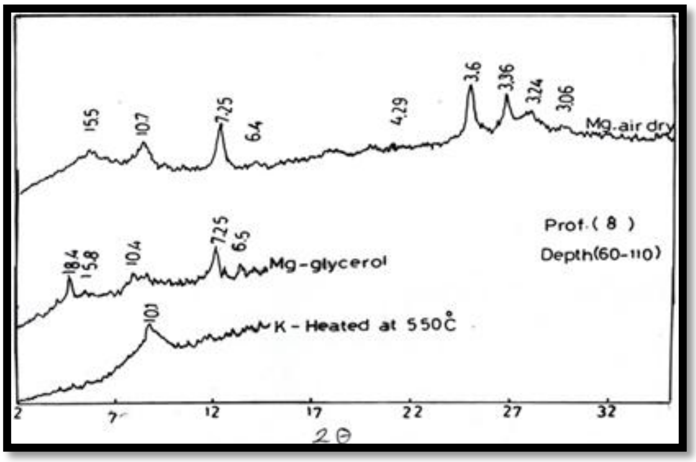

Fig. (6): X-ray diffraction pattern of the clay fraction separated from 60-110 cm depth of profile No.8.

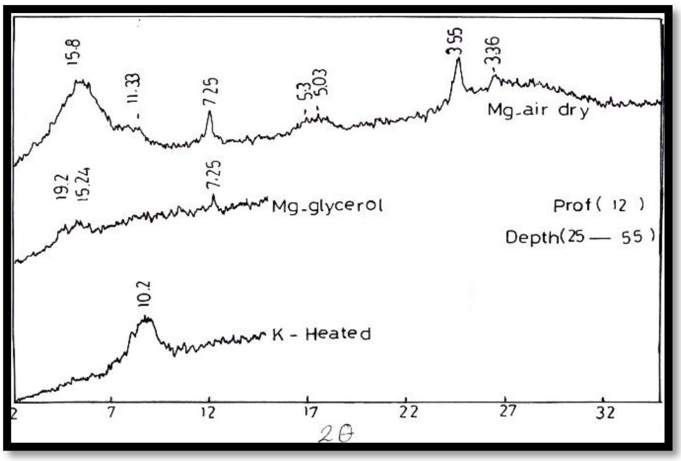

Fig. (7): X-ray diffraction pattern of the clay fraction separated from 25-55 cm depth of profile No.12.

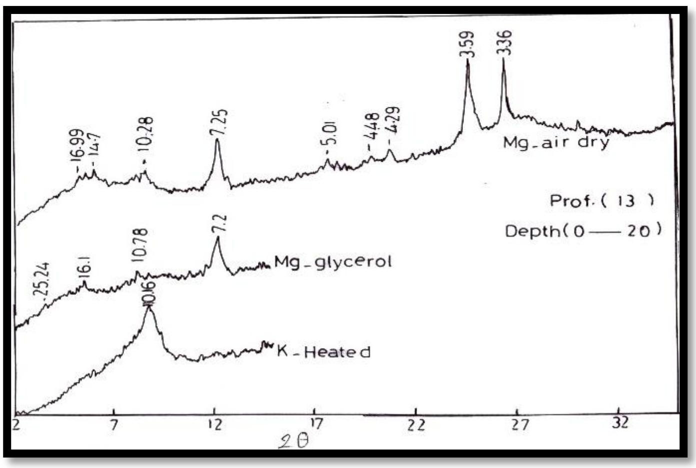

Fig. (8): X-ray diffraction pattern of the clay fraction separated from 0-20 cm depth of profile No.13.

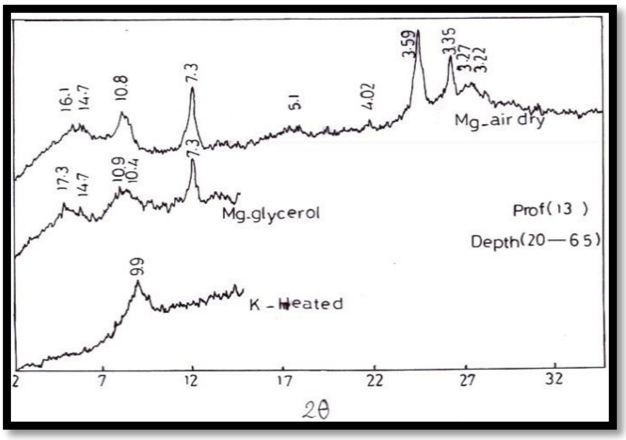

Fig. (9): X-ray diffraction pattern of the clay fraction separated from 20-65 cm depth of profile No.13.

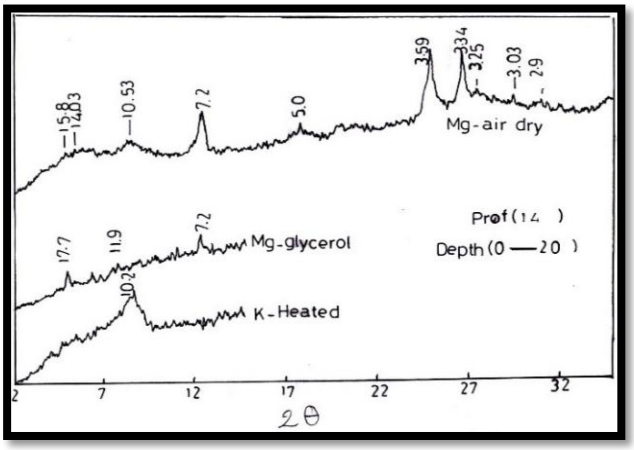

Fig. (10): X-ray diffraction pattern of the clay fraction separated from 0-20 cm depth of profile No.14.

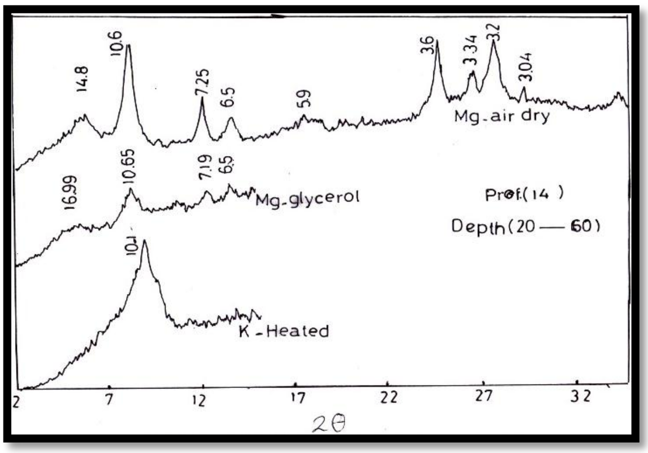

Fig. (11): X-ray diffraction pattern of the clay fraction separated from 20-60 cm depth of profile No14.

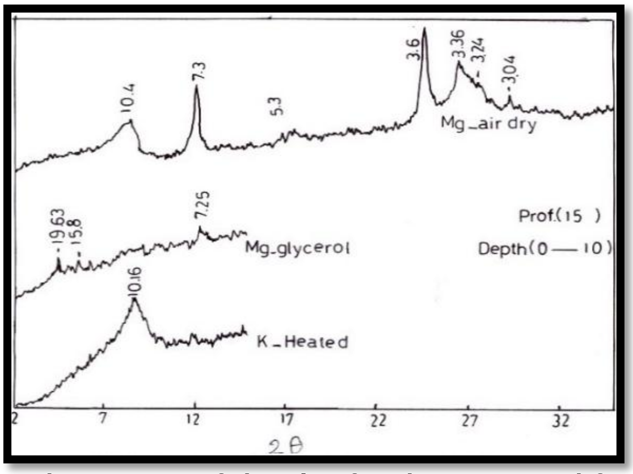

Fig. (12): X-ray diffraction pattern of the clay fraction separated from 0-10 cm depth of profile No.15.

Origin and genesis of clay minerals:

Clay minerals are not the same in both the chemical and structure compositions because of they were formed by several ways. The distribution and genesis of the recognized clay minerals can be discussed as follows:

1-Smectite is suggested to be derived from volcanic source of basement rocks under arid climatic conditions where evaporation exceeds rainfall and leaching process is limited and in turn the alkaline conditions is prevailing. This finding is similar to the conclusion of Greensmith (1985).

2- Differences in kaolinite contents of the studied soils are most probably related to the nature of parent material and the content of silica in the source areas. Kaolinite may be formed in source areas by hydrogenation (decomposition) or by selective leaching of alkali feldspars under well aerated conditions and abundant rainfalls (Grim 1968 and Millot, 1970). The considerable well crystalline kaolinite may also indicate a prolonged intensively weathered product in the source area.

3- Illite is a common detrital mineral inherited from very numerous sediments (Weaver, 1989). The majority of illite in the investigated soil is inherited in a degraded state from muscovite rich sedimentary rocks in the source area.

4- Palygorskite is usually associated with saline media in the highly calcareous soil. It is believed to be pedogenic (diagenitc) in origin (Millot, 1970). However, the occurrence of palygorskite in the study soils with few amounts may be due to that, these soils are recent and poorly developed from the pedogenic point of view.

Furher, the genesis of exited non-clay minerals can be briefed as follows:

1. **Quartz is inherited mostly from parent materials and transported to the basins of deposition either by streams or wind.**
2. **Feldspars may be derived from slightly weathered soil developed from highly feldspathic parent materials in the source area. It is worth to mention that, the presence of feldspars may support the suggestion of immaturity, poorly developed and relatively young age of the studied soils.**
3. **Calcite may be inherited from the limestone parent material in immature soil profiles developed on young geomorphic surfaces.**

In conclusion, it is well known that, the clay minerals could be present as a result of inheritance from parent material by alteration, degradation of primary minerals, synthesizing and addition. For the present study, the chemical decay is somewhat limited due to the prevalence of aridity, while the mechanical weathering contributes to a great extent. The variation in the relative content of the present clay minerals may be attributed mainly to sedimentation regime varieties and/or to the nature of the source rocks.

Significance of clay minerals occurrences:

The clay content has active effect on chemical, physical and morphological properties of soils as briefed in the following:

1. **The differences of clay minerals contents contribute to the quality of the soil, so that soils contain simple mineral suite, probable tend to need high levels of management.**
2. **The relative high clay content (particularly the smectite clay) improves to a great extent the soil water holding capacity and nutrients availability. Furthermore, the clay content give the soils most of their cohesive and adhesive properties. However, the clay content of the study soils is very limited.**
3. **Soil swelling (by wetting) and shrinkage (by drying) are mainly clay mineral types and contents dependent. Few of polygonal cracks and clay flakes can be detected in some surfaces of the dry alluvial plain unit.**
4. **The shrinking of soils is credited with forming pressure faces that contribute the boundary of soil structural units (aggregates). The soil structure development is important for aeration improvement. The minute amount of smectite in the study soils hardly can lead to shrinking and sweling damage (destruction effects) as the majority of the soil bulk in the study area is sand. But smectite effect is magnified with the fine soil texture prevalence.**

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التركيب المعدني للطين وعلاقته بالظواهر الجيومورفولوجية في أراضي منخفض وادي النطرون، بالصحراء الغربية – مصر

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الملخص العربى

يهدف هذا البحث إلى تحديد التركيب المنرالوجي للطين المفصول من بعض الوحدات الجيومورفولوجية لأراضي منخفض وادي النطرون بالصحراء الغربية بمصر وذلك كمحاولة لإلقاء الضوء على الإرتباط بين معادن الطين الموجودة وكل من مادة الأصل وظروف الترسيب وذلك بإستخدام الـ X–Ray والسعة التبادلية الكاتيونية للطين وكذلك مساحة السطح النوعي للطين.

وقد أوضحت نتائج الدراسة بإستخدام جهاز حيود الأشعة X–Ray، سيادة معدن طين المونتورريللونيت مع وجود معادن الكاؤولينيت والباليجورسكيت والأليت ولكن بكميات متفاوتة وقليلة.

وكذلك أوضحت النتائج أن السعة التبادلية الكاتيونية ومساحة السطح النوعي للطين المفصول ما بين 33.42 إلى 48.32 سمول ، 447 إلى 652 م^2/جم طين على الترتيب، وقد إتضح أن المحتوى المنخفض من السعة التبادلية الكاتيونية ومساحة السطح النوعي راجع إلى تواجد معادن الكاؤولينيت والباليجورسكيت والأيليت

وقد فسر تواجد معادن الطين على أساس مادة الأصل وكذلك نظام وبيئة الترسيب، وقد نوقشت كذلك نشأة المعادن وبتركيز خاص على ظروف الغمر والإبتلال التي كانت سائدة قبل ظروف الجفاف الحالية.

الكلمات الدالة :– الوحدات الجيومورفولوجية، X–ray (XRD) مساحة السطح النوعي (SA) السعة التبادلية الكاتيونية (CEC)

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