# MINERALOGICAL CHARACTERIZATION OF SOILS REPRESENTING THE CLAY PLAIN OF SUDAN

## Deng, P.K.[1], and Marchelo-d'Ragga, P.W.[2*]

[1]Pio Kur **Deng**, Assistant Professor, Faculty of Agriculture, Upper Nile University, Juba, South Sudan.

[2*] Philip Wani **Marchelo-d'Ragga**, Professor, Department of Agricultural Sciences, College of Natural Resources and Environmental Studies, P.O. Box 82 Juba, South Sudan, Email: drwani49@gmail.com

## ABSTRACT

Soil profiles were dug in the clay plains of Sudan and six profiles were selected in a transect from East of Rahad River, across Gezira, and west of the White Nile. The objectives of this study were to investigate the clay mineralogical characteristics of these soils, mineralogical forms and soil samples according to genetic horizons. Twenty four soil samples and four genetic horizons were selected from the six soil profiles; and were selected for identification of clay mineralogy by X-ray diffraction technique (clay fraction method). The analysis of clay minerals was performed in two steps; the first step was the separation of less than 2μ clay size fraction and the second step was the X-ray technique itself. Results on mineralogical investigations for the primary clay revealed high content of quartz, and muscovite which were also observed in the clay fraction of the soils. Proportions of smectite, kaolinite with relatively higher values of smectite especially in the sub-soils were recorded, Illite and chlorite was lower. Part of the White Nile and the remaining soils have been derived from the Ethiopian plateau which is dominated by basic and ultra basic rocks; these rocks are dominant in smectite clays. Quartz, Muscovite and Illite are the main primary minerals in the studied soils with minor amounts of Zeolite, Pyroxene and Calcite minerals. The clay minerals showed Smectite, Kaolinite, Illite and Chlorite in variable amounts. From the above results, we can conclude that the identified clay minerals in the studied soils are detrital and originated from the Ethiopian Plateau and later on have mixed with limestone material during transportation.

**Keywords: Clay plain, Clay minerals, X-ray diffraction.**

## 1. INTRODUCTION

The Vertisols in Sudan comprise of mainly the central clay plains in addition to the southern clay plains and Nuba Mountain clays. The deposit is mostly clay that is high in montmorillonite (smectite) and shows some colour and/or textural variation between strata. The Gezira area is part of this clay plain. Clay content may reach 60% or more throughout the soil profile. The dominant clay minerals are smectites (Adam *et al.,* 1983; Blokhuis, *et al.,* 1993, Fadl, 1971). It covers all the area between the White and Blue Niles. Therefore, it is expected that these soils of Gezira may have different origin sources of clay and mineralogical composition from those of Rahad, Butana and the White Nile Soil. Mineralogical studies are generally carried out to determine the mineralogical homogeneity of the soil profile, identify soil forming processes used in the soil classification and assess the status of soil fertility. One type of soil mineralogical investigation is that concerned with residual mineral in the soil, i.e. mineral with minimum alteration. A mineral usually has a definite chemical composition which on weathering releases its constituent elements that may provide nutrients to growing plants, e.g. hornblende, a common green or bluish green to black; amphibole mineral that contains Ca, Na, Mg, Fe, Al, Ti and Si.

Soil mineralogy has strong influence on soil behaviour, its use in soil classification, and its relevance to soil genetic processes. Soils commonly contain primary minerals, which are formed from magma and provide an insight look into their characteristics such parent material provenance, uniformity and weathering rate. Soils also contain secondary minerals which are formed from weathering processes and may have crystallographic characteristics that strongly influence the physical and chemical properties of soil.

The clay fraction, which contains mineral materials, has great influence on the development of soil physical and physico-chemical properties. The mineral part of the clay fraction consists of layer alumino-silicates, oxides and hydroxides of iron, aluminum and manganese. In most soil, properties of water retention, hydraulic conductivity, swelling and shrinking and cation exchange are largely controlled by mineralogical composition. Identification and characterization of clay minerals are one of the basic requirements for classifying soils as well as for better understanding of soil genesis. Agronomic practices to great extent depend on mineralogical properties of clay in soil for which soil belong to its inherent fertility status. Therefore, understanding the mechanism responsible for ion exchange, fixations etc. are vital for developing soil fertility management strategies to maximize the efficiency of nutrient uptake from soil and fertilizers. The study areas are from the most important agricultural regions in Sudan. Thus the objective is to investigate the clay mineral characterization. It is expected that these soils may have different mineralogical compositions.

## 2. MATERIALS AND METHODS

### 2.1. Location

The soil samples were collected from soil profiles in the clay plains of Sudan in a transect from East of Rahad River, across Gezira, and West of the White Nile. The studied profiles were selected to represent the Rahad (profiles R-1 and R-2), Gezira (profiles G-1 and G-2), and White Nile (profiles W-1and W-2). GPS (Geographical Positioning System) readings were also taken for reference purposes.

Table 1. Location, GPS readings of soil sampling sites and soil taxonomy.

| Location | Soil profile | GPS E | GPS N | Soil taxonomy: (Soil survey, 1999) |
|---|---|---|---|---|
| Rahad | R-1 | 0598235 | 1580487 | Typic Haplotorrerts, Very fine, smectitic, isoheperthrmic |
|  | R-2 | 0643104 | 1590775 | Chromic Haplotorrerts, Very fine, Smectitic, isoheperthrmic |
| Gezira | G-1 | 0531909 | 1575275 | Typic Haplotorrerts, Fine, smectitic, isoheperthrmic |
|  | G-2 | 0556520 | 1581936 | Chromic Haplotorrerts, Very fine, smectitic, isoheperthrmic |
| White Nile | W-1 | 0418121 | 1545061 | Chromic Haplotorrerts, Very fine, smectitic, isoheperthrmic |
|  | W-2 | 0435851 | 1547331 | Sodic Haplocambids, Fine clay, mixed, superactive, isoheperthrmic. |

## 2.2. Soils

Six soil profiles from different location in clay plain of Sudan were selected a transect from east of Rahad River, across Gezira, and west of the White Nile for study. GPS (The GPS Garmin 12 Model) was utilized in the study while profiles was located using Adindan Sudan, UTM system was used to locate the position of the sites from where the soil profile samples were taken. The soil samples were collected according to genetic horizons and classified following the USDA Soil Survey Protocols (1999).

## 2.3. Analysis of clay minerals

Twelve soil samples from two genetic horizons from the six soil profiles, and were selected for identification of clay mineralogy by X-ray diffraction techniques (clay fraction method). The analysis of clay minerals was performed in two steps; the first step was the separation of less than 2μ clay size fraction and the second step was the X-ray technique itself.

## 2.4. Separation of < 2μ fraction

In order to extract the fraction of the clay (< 2μ) from the samples, the following preparation methods were adopted. Each soil sample was carefully washed with distilled water for several

times in order to remove the filling, mud and contamination substances. The samples were then put in plastic bottles, submersed with distilled water which was added till hydraulic conductivities of about <50-60 µS (micro Siemens) were reached. The samples were carefully and gently disaggregated without any grinding in the presence of distilled water; then left for a short time for settlement of coarse particles. Thereafter, the fine suspension was poured into a bucket. This step was repeated several times resulting in a bucket full of water and fine particles. The suspension was then centrifuged for two minutes at 2000 rpm. The finer silt particles would settle down whereas the clay particles ($< 2\mu$) remained in suspension. The $<2\mu$ clay fraction was filtered through a ceramic filter using a suction pump. The filtrate was collected in dishes and kept in oven at 50˚C for subsequent analyses. From the wet clay fraction ($<2\mu$) oriented mounts were prepared on glass slides to obtain basal reflections of the clay. The prepared glass slides were kept in desiccators for 24 hours to dry and then taken for air–dry measurements.

## 2.5. X-ray diffraction b (XRD)

The x-ray diffraction technique was used to identify the different clay minerals and semi-quantitatively proportion of each clay mineral with respect to the other clay minerals present in the studied samples. Moore and Reynolds (1997) gave comprehensive treatment of the theoretical and practical aspects of the XRD technique and Tucker (1988) provided a concise summary about the application and interpretation aspects. The XRD analyses were carried out using the X-Pert Philips 00186 diffractometer under the following conditions:-

-Generator setting: 40KV and 50 MA.

-Cu Ka1, 2 wave length: 1.54060, 1.4439 Å

-Step size, sample time: 0.02 deg, 0.805, 40.0 /deg

-Primary monochromatic filter was used

-Divergence slit: automatic (specimen length 12.5 mm)

-Angle range from 0° to 40°

The clay minerals were identified from their basal reflections determined from the XRD pattern after the following steps:-

-After air-drying (normal)

-And lastly heating to 550°C for two hours

Then the four runs were analysed through two computer programmes Philips X Pert Organiser and X pert plus. The net area of the peaks of the basal reflection (001) of the clay minerals were calculated above the background and considered as the proportion of each mineral in the samples. The total association were taken to be equal to 100%. Then the relative proportions were deduced semi-quantitatively by using the factors cited in Schwertmann and Niederbudde (1993). Mineral percentage evaluation of the bulk sediment and clay fraction were based on peak areas measured on X-ray diagrams using computer programmes Philips X Pert Organiser and X pert plus.

## 3. RESULTS AND DISCUSSION

### 3.1 Soil mineralogy: primary mineralogy

The study of primary clay minerals has involved analytical techniques, X-ray diffraction (XRD). The results of primary mineralogy are shown in Table (2). In addition the XRD graphical charts are shown in Figs 1-3 which are largely dominated by quartz, muscovite and illite in association with minor amounts of pyroxene, albite, anorthite, zeolite, vermiculite and calcite.

Table 2. Primary Minerals of the studied Soils.

| Site | Depth | Primary minerals % | | | | | | | | |
|------|-------|------|-------|--------|--------|--------|-----------|---------|--------|---------|
|      |       | Qtz  | Pyrox | Muscov | Illite | Albite | Anorthite | Zeolite | Vermic | Calcite |
| R -1 | 0-40   | 13.5 | 0.0  | 59.5 | 0.0  | 0.0 | 0.0     | 27.0 | 0.1 | 0.0 |
|      | 40-80  | 25.5 | 0.0  | 74.3 | 0.0  | 0.0 | 0.0     | 0.0  | 0.2 | 0.0 |
| R-2  | 0-35   | 19.7 | 0.0  | 31.4 | 41.4 | 2.5 | 5.0     | 0.0  | 0.0 | 0.0 |
|      | 35-100 | 23.6 | 0.0  | 73.6 | 1.0  | 0.0 | 1.9     | 0.0  | 0.0 | 0.0 |
| G -1 | 0-50   | 25.4 | 6.1  | 32.4 | 28.0 | 0.0 | 1.0/6.7 | 0.0  | 0.0 | 0.0 |
|      | 50-120 | 24.3 | 11.5 | 57.4 | 1.8  | 0.0 | 0.0     | 0.0  | 0.6 | 4.4 |
| G -2 | 0-55   | 18.9 | 5.7  | 37.7 | 33.1 | 2.3 | 2.2     | 0.0  | 0.0 | 0.0 |
|      | 55-120 | 15.8 | 0.0  | 12.0 | 51.9 | 1.8 | 6.0     | 12.5 | 0.0 | 0.0 |
| W -1 | 0-35   | 29.1 | 0.0  | 67.3 | 2.2  | 1.4 | 0.0     | 0.0  | 0.0 | 0.0 |
|      | 35-55  | 25.0 | 0.0  | 46.5 | 22.2 | 5.3 | 0.0     | 0.0  | 0.0 | 0.0 |
| W -2 | 0-55   | 35.8 | 0.0  | 32.1 | 1.1  | 0.0 | 24.1    | 0.0  | 0.0 | 7.0 |
|      | 55-100 | 24.6 | 23.4 | 2.2  | 37.7 | 7.1 | 0.0     | 0.0  | 0.0 | 5.0 |

**3.1.1 Quartz** is an essential constituent of granite and other felaic igneous rocks. It is very common in sedimentary rocks such as sandstone and shale schist, gneiss and other metamorphic rocks. Because of its resistance to weathering it is found in all soils studied (Table 2, Figs.1-3. Its distribution in the soils horizons is decrease with depth. They are nearly the same range (13.5-25.5) in Rahad and Gezira soils. White Nile soils have the highest amount of quartz (35.8%), this indicates its more resistance to weathering. Samples W-1 contains quartz, muscovite and illite.

**3.1.2 Muscovite** is a phyllosilicate mineral of aluminium and potassium. Muscovite is the most common mica, found in granites, gneisses, and schists, either as a contact metamorphic rock or as a secondary mineral resulting from the alteration of feldspar, kyanite, etc. Muscovite is found in all the studied soils with variable amounts ranging from (31.4 -74.3), (12-57.4) and (2.2-67.3)

in Rahad, Gezira and White Nile soils, respectively. In the profiles R-1,R-2and G-1 it increases with depth up to 80, 100 and 150 cm depth, respectively and with a decrease inW-1 and W-2. Its non-uniform distribution in the other profiles indicates irregular time of weathering and formation (Table 2, Figs 1-3).

**3.1.3 Illite** is the result of the muscovite weathering (Table 2, Figs 1-3) where the weathered muscovite is 57.4% to 12.0% as compared to 1.8 to 51.9% illite, respectively. This showed that an increase of illite following decreasing of muscovite, where Illite has structure similar to muscovite. Reaction of muscovite with solution to form illite has been reported in experimental studies (Yate and Rosenberg, 1987) and in nature (McDowell and Elders, 1980).

**3.1.4 The pyroxene** is almost not found in all soils (Table 2, Figs 1-3) except in few horizons as shown in Table 2 e.g. in  horizon in G-1 and G-2 (0-50) ,(50-120) ( 6.1% and 11.5%)  and in upper horizon in G-2 (5.7) and (35-55) in W-2 (23.4%).

**3.1.5 Vermiculite** is originated from weathering and low temperature hydrothermal alteration of basic igneous rock. It is most common in humid temperature and mountainous regions (de Visser, 1991). Vermiculite is most often reported to be transformed from muscovite, biotite or chlorite (Douglas, 1989).It is almost found in minor amount or absent in all the studied soils expect in Rahad soil ranging from  0.1-0.2 and in Gezira it is found in the second layer of G-1in minor amount (Table 2, Fig 1-3).

**3.1.6 Calcium carbonate** is one of the most amazing minerals found on Earth. Minor of amount of calcite is found in the lower depth of the Gezira soils as well and in the upper horizon of W-2 (Table 2, Figs 1-3). Indicative to the parent material at lower depth, calcium carbonate

concentration has formed in situ. Larger soft aggregates mark the beginning of C-horizon in Rahad Soils which is different from Gezira and White Nile soils. Calcite can be formed in many different geologic environments and it is a significant part of all three rock types; the common colour of calcite found in the studied soils was white.

**3.1.7 Zeolite** is found in relatively high amount 27% in R-1and 12.5 in G-2 (Table 2, Figs 1-3), naturally occurring zeolite is rarely pure and contaminated to varying degrees by other minerals. Suddenly the other primary minerals of albite, and anorthite are absent in almost all the soils except in the few horizons shown in Table 2 and figures 1-3.

**3.1.8 Albite** is plagioclase feldspar mineral. It occurs in granitic and pegmatite masses in some hydrothermal vein deposits forming part of the typical green shist metamorphic facies for basaltic composition.

**3.1.9 Anorthite** is a rare compositional variety of plagioclase. It occurs in mafic igneous rock, it also occurs in granulite facies metamorphic rocks, in metamorphosed carbonate rocks and corundum deposited.
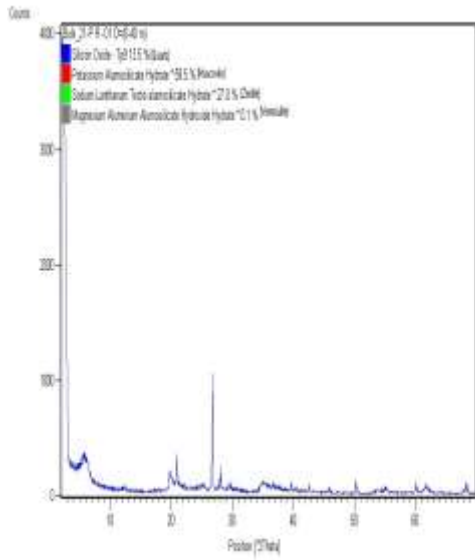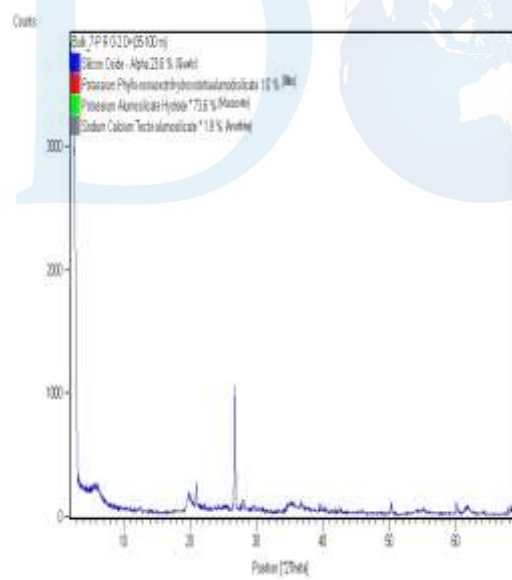
a)  Profile, R-1, 0- 40 cm depth
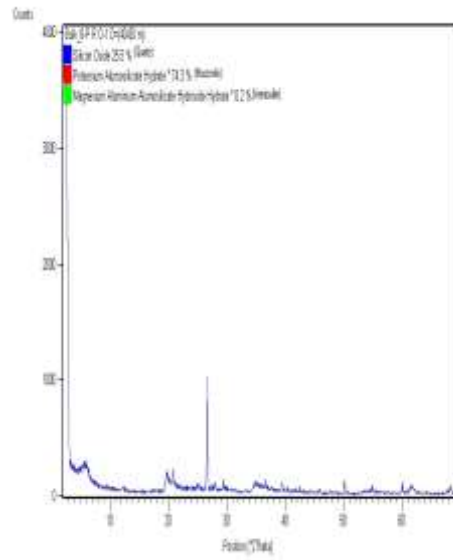
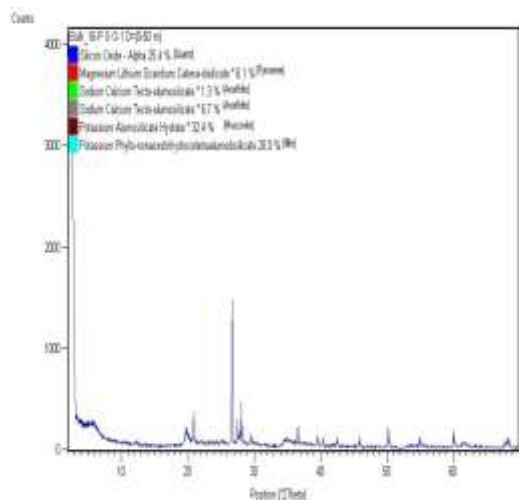b) Profile, R-1, 40- 80 cm depth
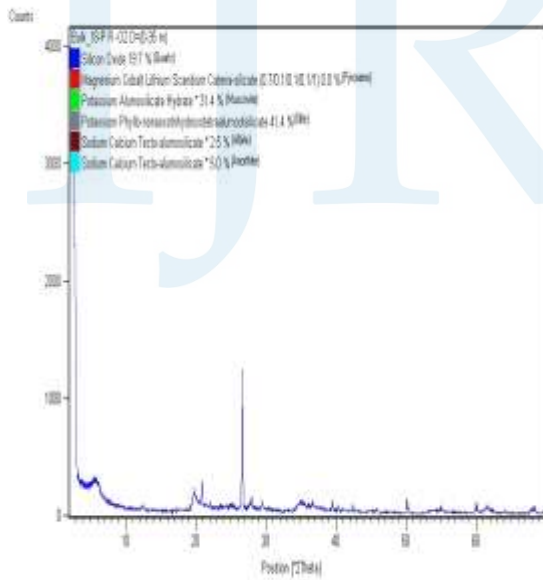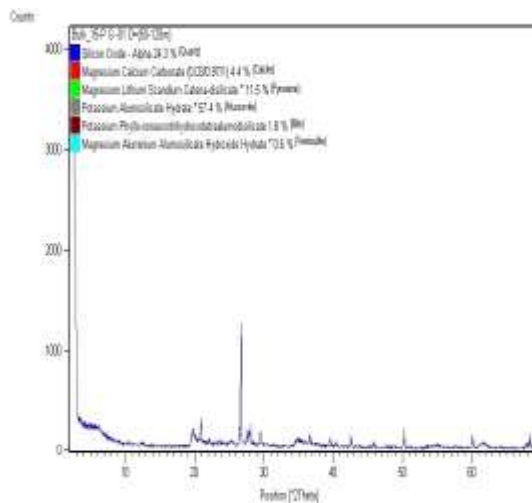
c)  Profile, R-2, 0- 35 cm depth

d) Profile, R-2, 35-100 cm depth
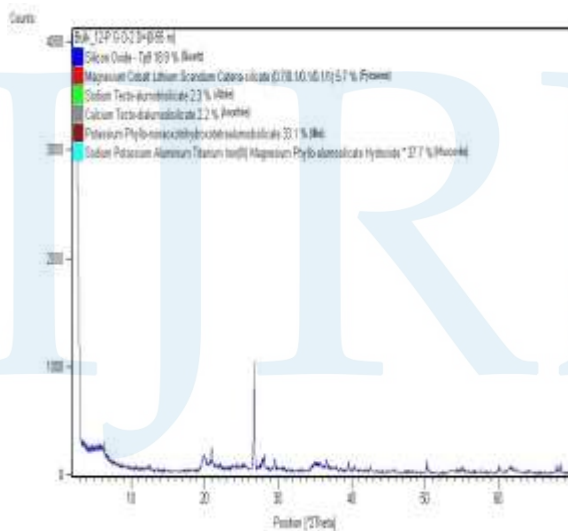
Fig. 1. X-ray diffraction patterns of Primary clay minerals of Rahad soils.
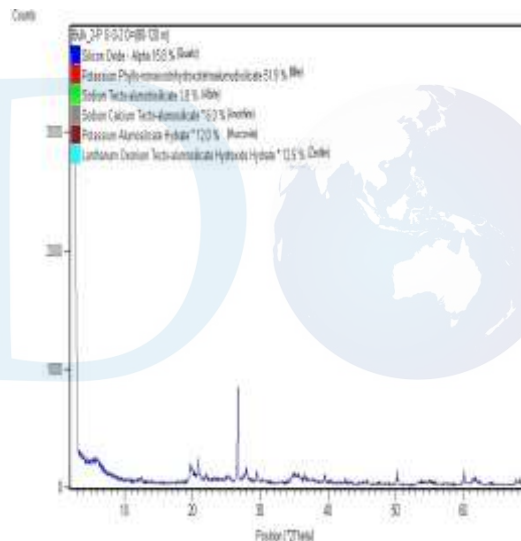
a)   Profile, G-1, 0- 50 cm depth                    b) Profile, G-1, 50- 120 cm depth
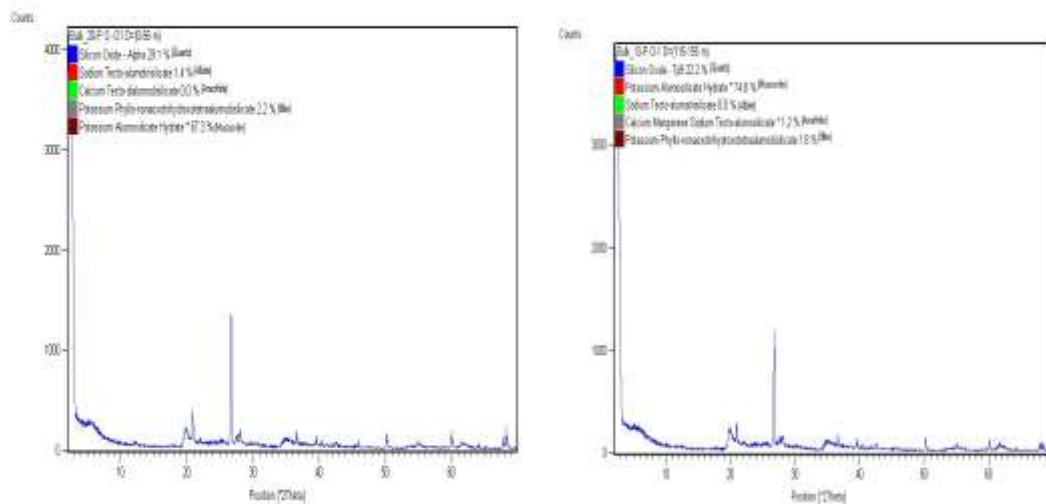


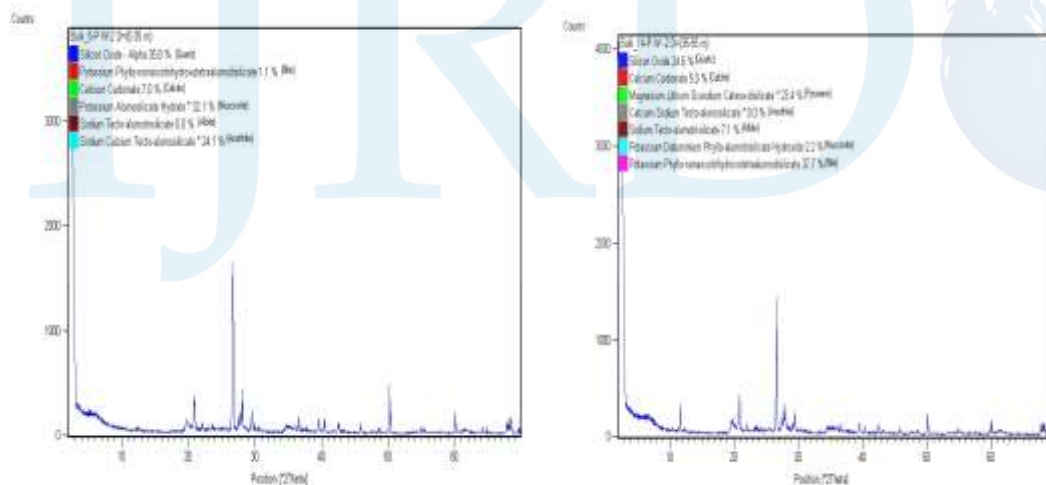c) Profile, G-2, 0- 55 cm depth                    d) Profile, G-2, 55- 120 cm depth

Fig. 2 X-ray diffraction patterns of Primary minerals of Gezira soils

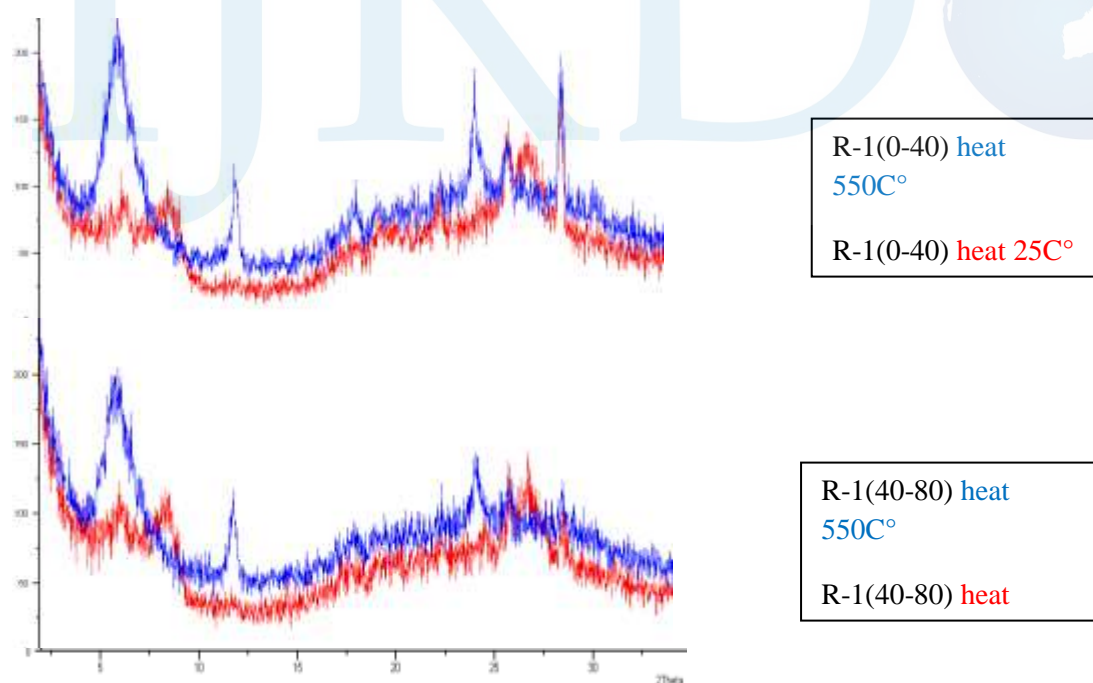a)  Profile W-1, 0-35 cm depth            b) Profile W-1, 35-55 cm depth

b)  Profile, W-2, 0- 55 cm depth            d) Profile, W-2, 55-100 cm depth

Fig. 3 X-ray diffraction patterns of Primary minerals of White Nile soils.

## 3.2. Clay minerals

The twenty four soil samples collected from the six locations were analysed with XRD technique. Five clay minerals were identified, viz. smectite, kaolinite, illite, chlorite and smectite/ illite mixed layer (Table 3). Following $CEC_c$ results of the studied soils, after being amended for $CEC_c$, all the seven soils dominantly contain smectite. These, finding are more or less consistent with previous investigations on some soils of the central clay plain (Blockhuis, 1993). In addition, Figs 4 to 6 show the X-Ray diffractograms of the clay fraction of the r soil, g soil and w soils; in order to give a general idea about the degree of variability clay minerals. The relative abundances of clay minerals were determined semi-quantitatively by comparison of intensity peak readings of each clay mineral type with those of pure standard clay minerals according to the methods of Moore and Reynolds (1989).



R-1(0-40) heat 550C°

R-1(0-40) heat 25C°

R-1(40-80) heat 550C°

R-1(40-80) heat

R-2(0-35) heat 550C°

R-2(0-35) heat 25C°

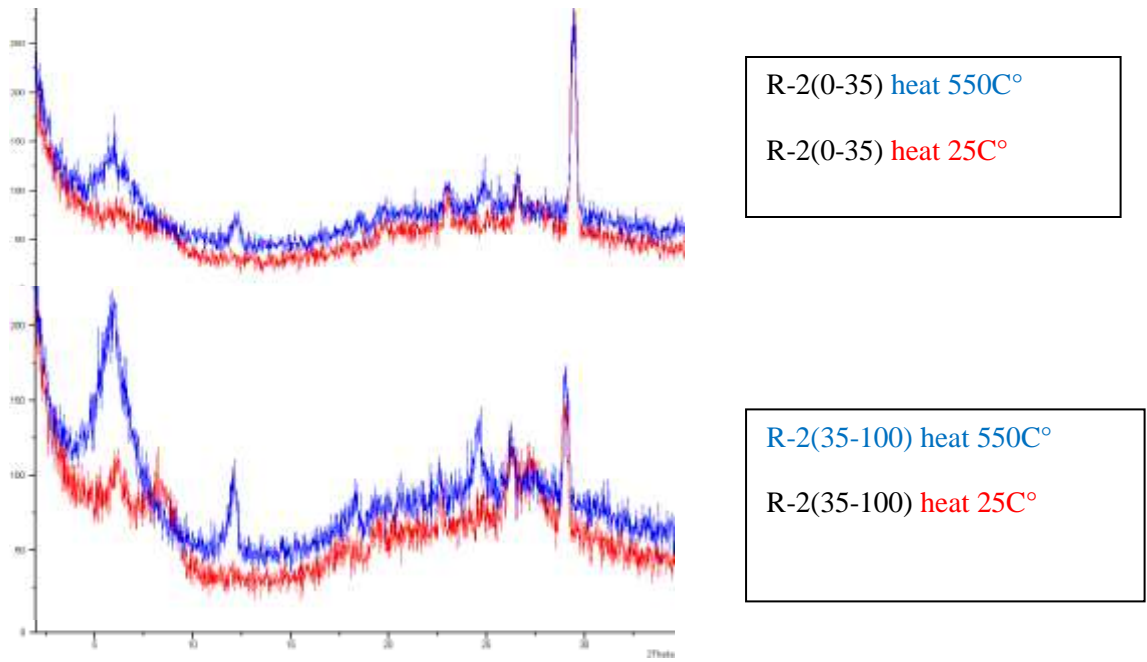R-2(35-100) heat 550C°

R-2(35-100) heat 25C°

Fig. 4 X-Ray diffractograms of the clay fraction of Clay minerals of Rahad soils.



G-1 (0-50) heat 550C°

G-1(0-50) 25C°

G-1 (50-120) heat 550C°

G-2(0-55) heat 550C°

G-2(0-55) heat 25C°

G-2(55-120)heat 550C°

G-2(55-120) heat 25C°
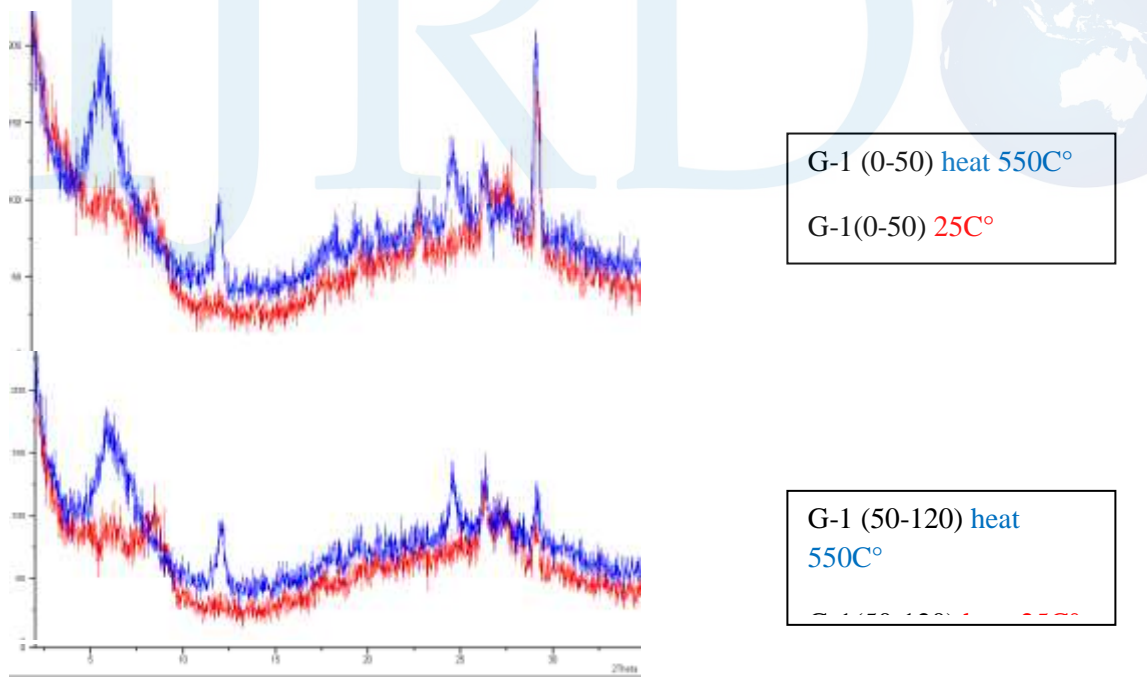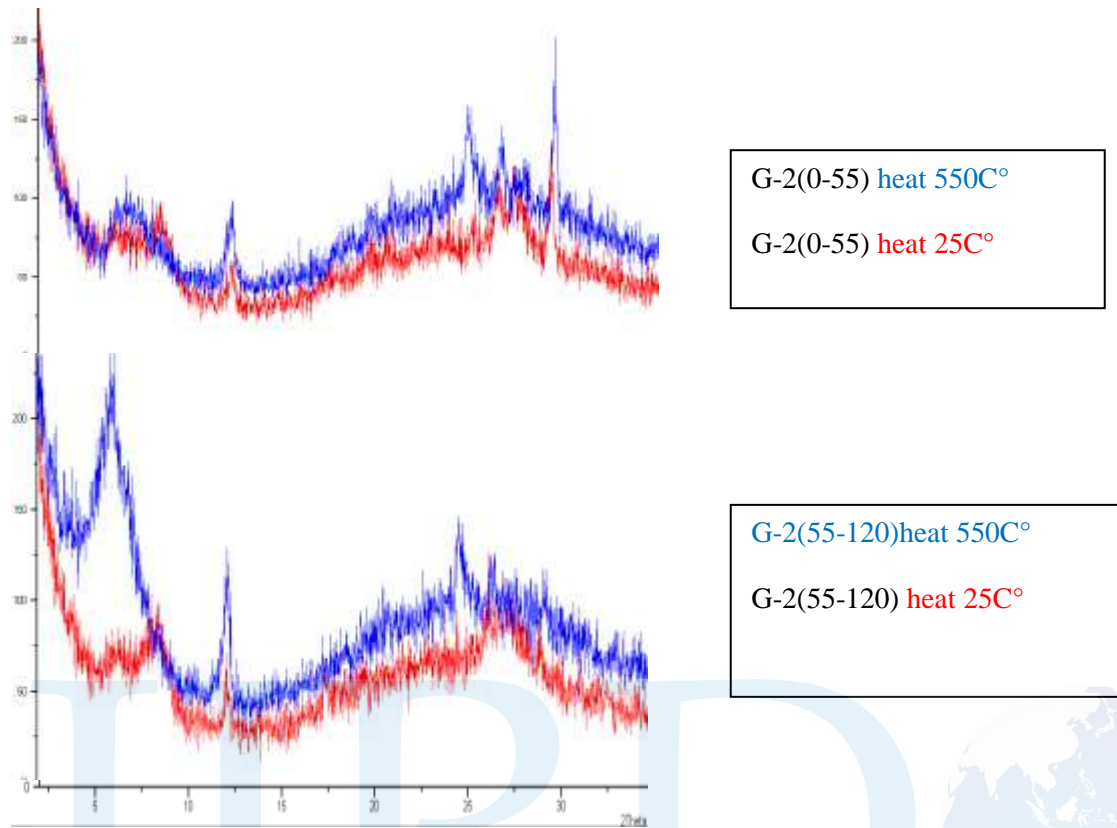
Fig. 5 X-Ray diffractograms of the clay fraction of Clay minerals of Gezira soils.



W-1 (0-35)heat 550C°

W-1(0-35) heat 25C°

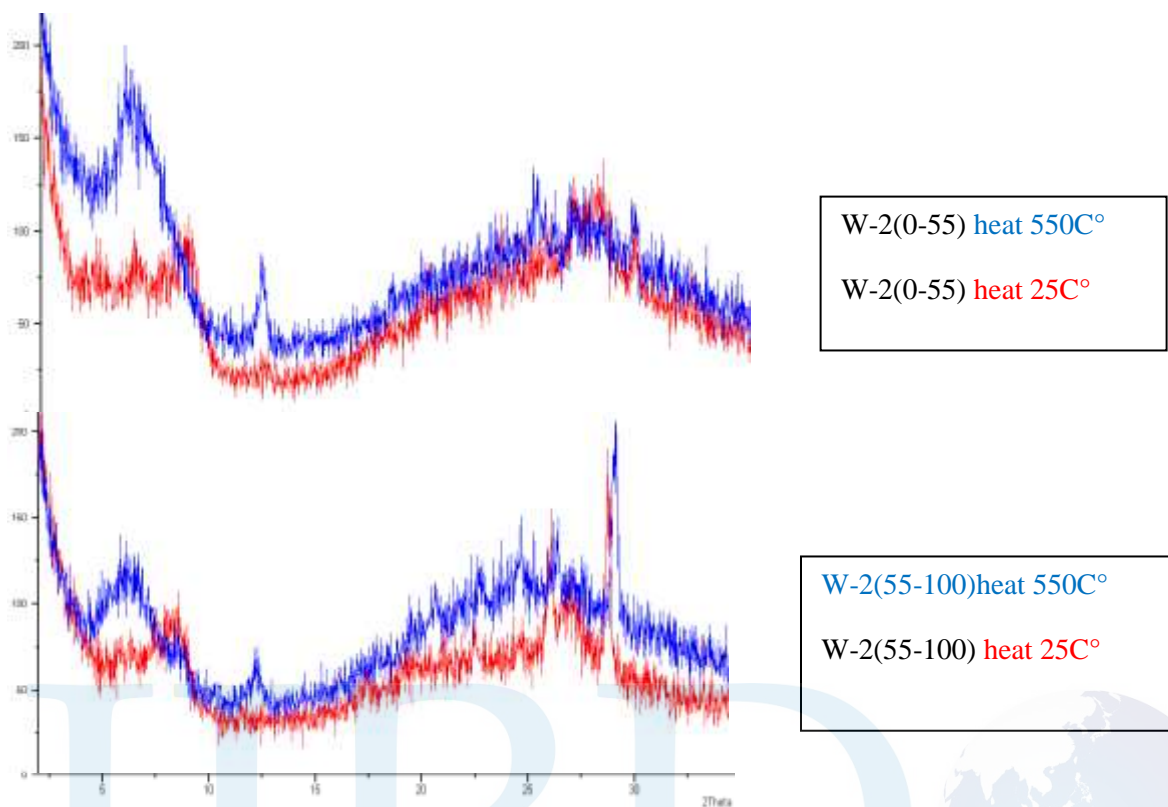W-1(35-55)heat 550C°

W-1(35-55) heat 25C°
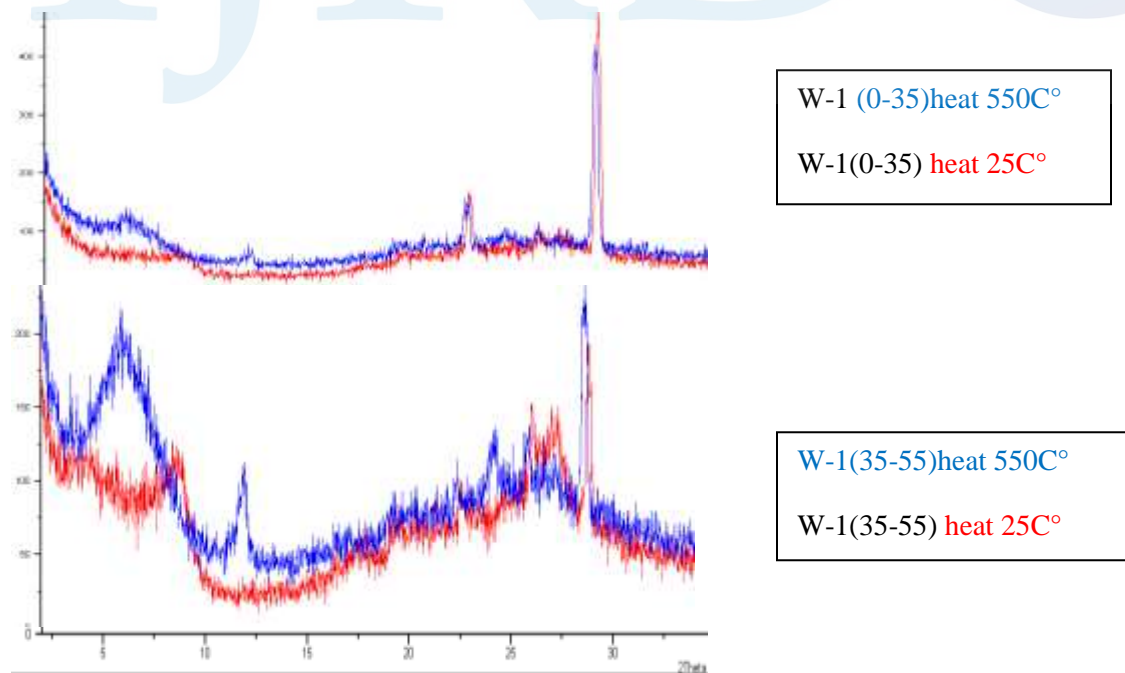
Fig. 6 X-Ray diffractograms of the clay fraction of Clay minerals of White Nile soils (W-2)

**3.2.1 Smectite** is present in all the studied soils is with range amounts being relatively more in R-2, G-1 with a content of 74.5 to 84.4% and 62.4 to 71.9%, respectively. It is usually higher in the second horizons of R-1, R-2, G-1, G-2, with a content of 79.3, 84.4,71,9, and 62.2 respectively. Still the distribution of this mineral through the profiles is irregular in W-1 and W-2 (Table 3). According to above mentioned findings smecitie was dominate in all soils except W-1,W-2, G-2 as well as in the top -soils of G-2 Smectite is a group of clay minerals (montmorillonite, nontronite, saponite, etc) that have very high cation exchange capacities and have the ability to expand (swell). This means that heavy metals and organic molecules can be incorporated between the expandable layers of smectite lattice (absorption), in addition to adsorption on surface faces. The smectite were confirmed after heating to 550°C when the original 14 Å d-spacing reduced to 10 Å d-spacing. The peaks are not sharp and indicate that the

minerals might be polycrystalline which implies the detrital origin (Figs. 4 to 6). Most of smectite minerals have a hydrothermal origin and then may also form by alteration of volcanic materials and basic igneous rocks. Weaver (1989) stated that the climate and topographic condition necessary for the formation of smectite are basically the opposite of those that favour the formation of kaolinite, i.e. low relief, rainfall, water flux and low temperature. Moreover, smectite normally develops from weathering.

The most common smectite is montmorillonite, derived by weathering of volcanic ash. Smectite formation in soil takes place when the following factors come together: base-rich parent rock, poor drainage, low-lying topography, high pH, high silica activities, and abundance of basic cations (Borchardt, 1977). These conditions can occur under different climates (temperate, cold, or even tropical) when leaching is limited.

**3.2.2 Kaolinite** is identified by its 7.1 Å and 3.58 Å peaks in dried X-ray diffraction patterns which are destroyed after heating to 550°C (Figs 4 to 6) (Chamley, 1989; Moore and Reynolds, 1997). The kaolinite clay minerals show relatively higher values in G-2, W-1 and 2 with a content of 21.7 to 51.9. 28.6, to 65.7, and 43.7 to 87.7 respectively (Table 3). Kaolinite is only dominant in the top soil of G-2 and the sub-soils of G-1, W-1 and W-2. In non-clay plain sites, scattering within the central clay plain, there is usually less CEC (40-70 cmol (+) kg$^{-1}$), corresponding with more kaolinite compared to smectite. Also it may be formed by the alteration of K-feldspars in acid organic rich waters (Tucker, 1991). Moreover, hydrothermal alteration of alumosilicates, especially of feldspars, may also form kaolinite (Moore and Reynolds, 1997). Kaolinite is derived from nearly all types of igneous, metamorphic and sedimentary rocks if rainfall is frequent and water flow and hydrolysis are sufficiently strong under tropical to

subtropical climate (de Visser, 1991). It is generally accepted that most kaolinite is formed by acid leaching of alkaline rocks primarily the feldspars and micas. These latter two primary minerals have been identified in these soil samples. Also any silicate rocks or silicate minerals will alter to kaolinite if leaching conditions are suitable. Kaolinite can be a neoformed, transformed or inherited minerals in soil .as already mentioned, high rainfall and a temperate climate can transform muscovite and biotite into kaolinite together with some illite. Al-(hydo) oxides liberated by extensive leaching can react with silica to produce kaolinite under slightly acidic condition and when silica activity is moderate and the concentration of basic cation is low. Like kaolinite that derives from weathering, soil kaolinite is usually highly disordered and may contain $Fe^{+3}$ from isomorphous substitution. In some cases, it is also interstratified with smectites (Dixon, 1989).

The two dominant minerals in all the studied soils are smectite and kaolinite where their sum values exceeds 90% of the total minerals in more than half of the soil horizons (Table 3).

Table 3. Percentage of clay minerals present in all soils.

| Site | Depth | Clay minerals % | | | | |
|------|-------|-----------|----------|-------|----------|-----------------|
|      | cm    | Kaolinite | Smectite | Illite | Chlorite | Smectite/Illite |
| R-1 | 0-40 | 20.5 | 75.9 | 1.9 | 0.8 | 0.8 |
| R-1 | 40-80 | 19.9 | 79.3 | 0.3 | 0.1 | 0.4 |
| R-2 | 0-35 | 20.2 | 74.5 | 5.0 | 0.2 | 0.1 |
| R-2 | 35-100 | 14.2 | 84.4 | 0.5 | 0.2 | 0.8 |
| G-1 | 0-50 | 21.9 | 62.4 | 12.9 | 2.2 | 0.5 |
| G-1 | 50-120 | 23.4 | 71.9 | 3.2 | 0.1 | 1.4 |
| G-2 | 0-55 | 51.9 | 0.9 | 11.8 | 33.2 | 2.2 |
| G-2 | 55-120 | 21.7 | 62.2 | 8.1 | 7.4 | 0.6 |
| W-1 | 0-35 | 28.6 | 66.8 | 2.5 | 0.2 | 1.9 |
| W-1 | 35-55 | 65.7 | 31.2 | 1.4 | 1.4 | 0.3 |
| W-2 | 0-55 | 43.7 | 49.1 | 1.7 | 1.2 | 4.4 |
| W-2 | 55-100 | 87.7 | 2.2 | 9.1 | 0.7 | 0.4 |

**3.2.3 Illite** was identified by their basal diffraction about 10 Å which is neither affected by ethylene glycol nor by heating (Figs. 1-3). Illite occurs in most of the analysed samples with a concentration ranges between 1.4 to 2.5 % in W1; 1.7 to 9.1 %.in W2; 3.2 to 12.9 % in G1; 8.1 to 11.8 % in G2; 0.3 to 1.9 % in R 1; 0.5 to 5.0 in R2 Table (3).  Illite mineral content decreases with depth in Gezira soils (G-1, G-2), but its distribution is irregular with depth in all other soils. Values are relatively low with less than 5% in Rahad, and White Nile surface soils. The highest amount (more than 10%) are found in Gezira soil (G-2) (Table 3). According to Moore and Reynolds (1989) illite is considered to have more Si, Mg and $H_2O$ but less Al tetrahedral layer and less K-interlayer than muscovite. The peak of the illite is not sharp in XRD charts; this indicates that part of the illite is polycrystalline.

**3.2.4 The chlorite**  characterizing basal spacing for the structural unite of the clay mineral chlorites is close to 14 Å. Swelling chlorite or pseudo-chlorite expand like smectite when immersed in water or ethylene glycol, but resist heating where the d-spacing is kept constant  at 14 Å (Figs 4 to 6). The concentration of the chlorite in the examined samples relatively low in almost all the soils studied (< 8%) except in G-2 where the content is 33.2, the value of 33.2 % is in surface layer 0-55cm show in Table (3). From the above-mentioned results, it is concluded that the identified clay minerals in the studied soils are detrital and are originated from the Ethiopian Plateau and later on they have mixed with limestone material during transportation. This conclusion is in full agreement with that reported by Said (1981).


## 4. CONCLUSION

This study indicated that part of the White Nile and the remaining soils have been derived from the Ethiopian plateau which is dominated by basic and ultra basic rocks; these rocks give rise the

dominance of smectites clays. Quartz, Muscovite and Illite are the main primary minerals in studied soils with minor's amount of Zeolite, Pyroxene and Calcite minerals. The clay minerals showed Smectite, Kaolinite, Illite and Chlorite in variable amounts. Form the above-mentioned results, it is concluded that the identified clay minerals in the studied soils are detrital and are originated from the Ethiopian Plateau and later on they have mixed with limestone material during transportation.

## 5. ACKNOWLEDGEMENTS

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