Clay Mineralogy Investigation In The Soils Of Arid Almanaqil Ridge, Gezira State, Sudan, Using Xrd Diffractograms

Elhag A.M.H, Ibrahim M.M.M, Ibrahim S.I, Dafalla M.S

Abstract: Clay mineralogy was studied in the soils of Arid Almanaqil Ridge. The soils are classified according to the American System (Keys to Soil Taxonomy, 2010) in the fallowing families: Fine loamy, mixed, isohyperthermic, TypicHaplustepts (unit1, sample A1 and A2), Fine, mont, superactive, Isohyperthermic, VerticHaplocambids (unit2, sample A3) and Fine, mont, superactive, isohyperthermic, TypicHaploustert (unit3, sample A4). Representative soil samples were collected from these units. These samples were samples A1 and A2 for unit1, sample A3 for unit 2 and sample A4 for uint3 respectively. Those samples were compared with samples from outside the study area from north of the study area (sample A5 and A6) and from the alluvium of the Blue Nile (sample A7), according to their lithology, topographic position, soil types and soil mapping units. Clay mineralogy of the samples was studied using X-ray diffractograms (XRD) techniques. The XRD diffractograms indicated the presence of smectite, chlorite, illite, and kaolinite as the major clay minerals in the soil of the study area and outside of the study area. The major clay minerals in these soils, Chlorite, illite and kaolinite could have originated from parent material. Smectite, showed an increasing trend in samples A7 (outside of study area) and sample A4 (unit 3). The CEC of clay minerals in unit 1 and 2 were less than 50 Cmol+/kg , which indicated that minerals with low CEC were dominant this result conformed with the XRD results that showed dominance of Chlorite, illite, and Kaolinite. Higher CEC values (more than 50 Cmol+/kg) of the clay were encountered in soils samples from unit3 (A4) and those from outside study area (Sample A7), XRD results showed that the samples were dominated by smectite. Moreover, the CEC values of clay minerals were consistent with results of XRD. The X-ray mineralogy indicated that the Vertisols and Aridisols of the study area had the same origin as that of the Gezira soils.

Keywords: Arid soils, Clay mineralogy, Vertisols and X-ray diffractograms.

---

1 INTRODUCTION

It has been recognized that the minerals in the clay (< 2 1m) fraction of soils play a crucial role in determining their major physical and chemical properties, and inevitably. Questions concerning the origin and formation of these minerals have assumed prominence in soil research (Wilson, 1999). Palygorskite, smectite, chlorite, illite, kaolinite and vermiculite are the main clay minerals in soils of arid and semi-arid regions (Abtahi, 1980; Gharaee, and Mahjoory, 1984; Khormali, and Abtahi. 2003; Wliaie, *et al.,* 2006). Millot (1970) distinguished three principal processes to account for the genesis of clay minerals: Inheritance from parent materials (Abtahi, 1977); and transformation from other clay minerals (Abtahi, 1980), and neoformation from soil solution (Abtahi, A., and F. Khormali. 2001). Illite and chlorite are two commonly observed clay minerals occurring in steep areas and are believed to be inherited largely from parent rocks (Wilson, 1999). Interstratified minerals primarily represent intermediate transformation products, mainly involving mica, chlorite and an expansible phase, either smectite or vermiculite (Sawhney, 1989), although there are many examples of interstratified minerals in soils originating by inheritance. This study aims at investigated clay mineralogy using XRD in the Soils of arid Almanaqil Ridge, Gezira State, Sudan.

2 STUDY AREA

This study was conducted in Almanaqil ridge, Gezira State located in south west of Gezira State, Sudan. The ridge is approximately midway between the Blue Nile in the east and White Nile in the west, (latitude 14° 04´ to 14° 29´ N and longitude 33° 97´ to 33° 19´ E). It covers an area of about 220,000 Acers (Fig. 1). The elevation of the area varies between 380 to 470 m above sea level. The soils of the study area were classified, according to the American System of the Soil Classification (Keys to Soil Taxonomy, 2010), into 3 families, namely; Fine loamy, mixed, isohyperthermic, TypicHaplustepts (unit1), Fine, mont, superactive, Isohyperthermic, VerticHaplocambids (unit2) and Fine, mont, superactive, isohyperthermic, TypicHaploustert (unit3) which represents 26.08%, 38.27% and 35.65% of the total area, respectively. The classification was based on the morphology of the soil in the field together with the results of laboratory analysis (Ibrahim, 2013).

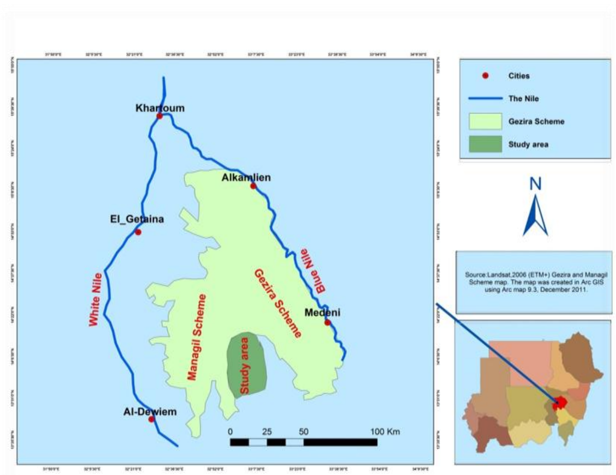

Fig.1: *Location map of study area*

Physically the study area, which is part of the Gezira State, is a plain surface intermitted by dispersed hills. The topography of the study area includes three major units. Namely: highlands and isolated mountains in the southeast, plain area characterized by clayey and sandy soil either along flat or gently sloping areas and valleys (*Wadis*) areas including depositional areas formed of sediment brought down by the Blue Nile from Ethiopian high land. Most of the area is underlain by Basement Complex or Tertiary Basalts both of which provide little ground water, except in the detrital material around the occasional hills together with limited supplies found along joints in the rock (Davies, 1964). Two distinctive climatic belts are found in the study area. The first one is semi-arid climate found in the north and northeast and characterized by summer rains during July to October. The second one is the dry monsoon climate found in the eastern and southern parts of the state with average rainfall of 250 to 450 mm/ year and maximum mean annual temperature of 47°C, (Meteorology Office-Gezira, 1994). According to the American system of soil classification (Keys to Soil Taxonomy, 2010) the soils of the study are characterized by two moisture regimes; ustic moisture regime that has a dry monsoon climate with either one or two dry seasons which is located in the southern parts of the study area; and aridic moisture regime. In which soils lack available water most of the time when the soil temperature is suitable for plant growth.

3 Materials and Methods

In this study, topographic maps and satellite images were used in addition to several field visit. Then accordingly, seven representative samples were collected for the study. Four soil samples from the study area were compared with three samples from outside the area. The onsite samples were collected from the three taxonomic units. Sample A4 represented unit3, while sample A3 represented unit2 and Sample A1 and A2 represented unit1. The outside samples were collected from an area north of the study area (sample A5 and A6) and from Blue Nile alluvium (sample A7). The preparation of XRD diffractograms followed the method of Kittrick and Hope (1963). X-ray diffraction analysis was (XRD) conducted using a Siemens D-5000 instrument with CuKá radiation. The cation exchange capacity (CEC) was determined by the ammonium acetate-ethanol-sodium acetate method using flame photometry. Exchangeable sodium was measured by determining the total extractable sodium using 1N NH4OAc and measuring sodium by flame photometry and then subtracting the water-soluble sodium, obtain the exchangeable sodium (Page *et al.,* 1982).

4 RESULTS AND DISCUSSIONS

The X-ray diffractogram, indicated presence of smectite, chlorite, illite, and kaolinite as the major clay minerals in the soil of the study area. Table 1 summarizes the results. Smectite identified at diffraction peak of 2θ=5.4. Diffraction peaks of semectite in unit 3, unit 2 and unit 1 are shown in Fig. 2, Fig. 3, 4 and Fig. 5 respectively. Its proportion in unit 3, unit 2 and unit 1 was 51.31%, 11.47% and 0.59%, respectively. Semectite showed high values (51.31%) in unit 3 compared to unit 2 and unit 1. This could indicate that the montmrillonite had the same origin as those of the Gezira, i.e. weathering of basic volcanic rocks in the headwaters of the Blue Nile and to deposition in the Pleistocene age. This result was in line with the findings of Hag Abdulla (1983) and El-Attar and Jackson (1973). Moreover, the poorly drained semi-arid conditions encouraged the concentration of smectite through neoformation. Kaolinite encountered in unit 3, unit 2 and unit 1 was 8.45%, 70.85% and 97.74%, respectively. Diffraction peaks of Kaolinite (2θ=12.5) of unit 3, unit 2 and unit 1 as shown in Fig. 2, Fig. 3, 4 and Fig. 5 respectively. The higher values of kaolinite in unit 2 and unit1 might indicate advanced weathering of the parent material (Senkayi *et al.,* 1983). Illite was represented in unit 3, unit 2 and unit 1 as 35.22%, 16.62% and 5.13 % respectively. Diffraction peaks of Illite at (2θ=8.8) of unit 3, unit 2 and unit 1 as shown in Fig 2, Fig. 3, 4 and Fig. 5 respectively. In general, diageneticillitic clay, are thought to be neoformed materials resulting from the dissolution of K-feldspar and/or kaolinite, whereas illitic clays are thought to have been transformed from smectite (Altaner *et al.,* 1984). 1Ilite and chlorite, however, indicate the dry and arid climate where physical disintegration of parent rocks dominates. Their presence suggests direct - rock weathering and an early stage of soil development. This confirmed by Osman *et al.,* (Egypt, 1996). Smectite, showed an increasing trend in samples A7 (outside study area) and A1 (unit 3). The CEC of clay minerals in unit 1 and 2 are less than 50 Cmol+/kg (Table 1), which indicates that minerals with low CEC are dominant and confirmed with the XRD results, that showed dominance by Chlorite, illite, and Kaolinite. The higher CEC values (more than 50 Cmol+/kg) of the clay are observed in soils samples unit3 and out of study area (Sample A7), XRD results showed that they were dominated by smectite. Moreover, the CEC values of clay minerals were in consistent with obtained results of clay mineralogy.

Table 1
Results of XRD Analysis

Units	Sample Code	Location	Kaolinite 2θ=12.3	Smectite 2θ=5.4	Illite 2θ=8.8	Chlorite 2θ=12.3 (Heat550)	Smectite/Illite 2θ=13.14	CEC (Cmol+kg-1)
1	A1	East of study area	97.74	0.29	1.26	0.43	0.29	19
1	A2	North of study area	87.59	0.59	5.13	6.10	0.59	22
2	A3	Mideast of study area	70.85	11.47	16.62	0.63	0.42	30
3	A4	South of study area	8.45	51.31	35.22	2.99	2.03	52

WN	A5	White Nile	1.34	0.57	97.25	0.63	0.21	36
NS	A6	Almanagil north	90.13	0.81	7.05	1.20	0.81	20
BN	A7	Blue Nile alluvium	58.49	30.28	2.62	8.00	0.60	46

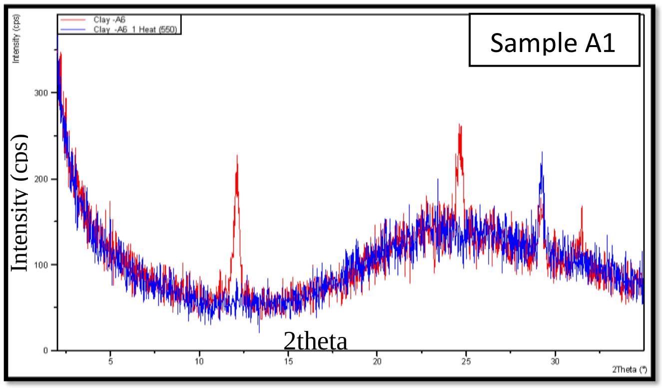

Fig.5: *XRD patterns of clay fractions (<0.002 mm) of sample A1.*

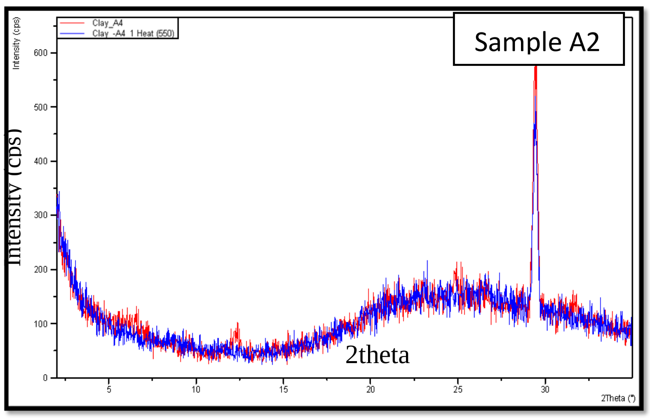

Fig.4: *XRD patterns of clay fractions (<0.002 mm) of sample A2.*

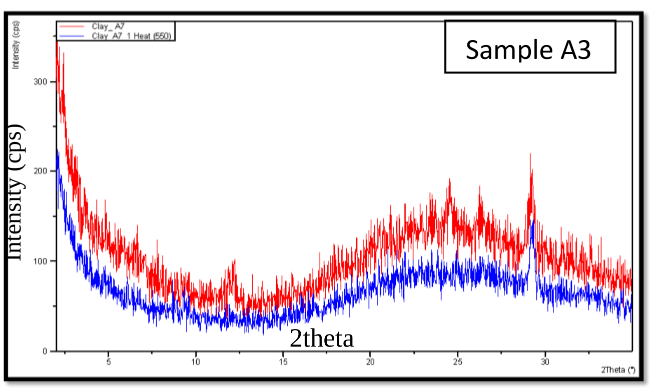

Fig. 3: XRD patterns of clay fractions (<0.002 mm) of sample A3.

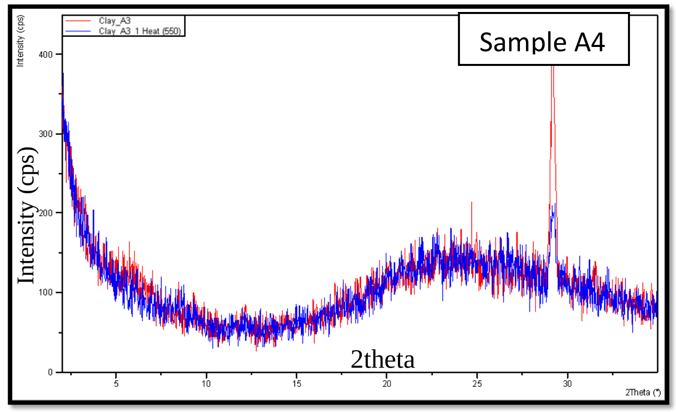

Fig. 2: *XRD patterns of clay fractions (<0.002 mm) of sample A4.*

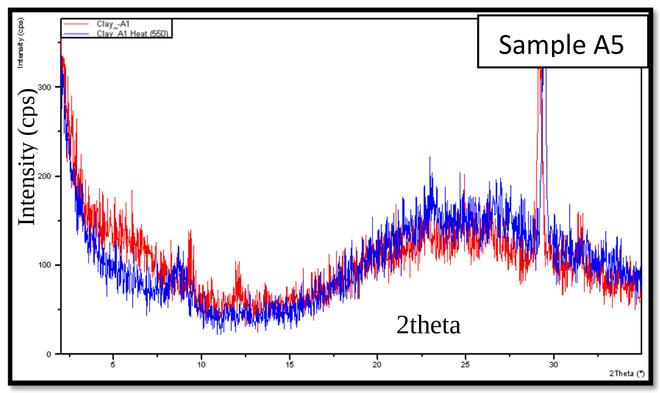

Fig.6: XRD patterns of clay fractions (<0.002 mm) of sample A5.

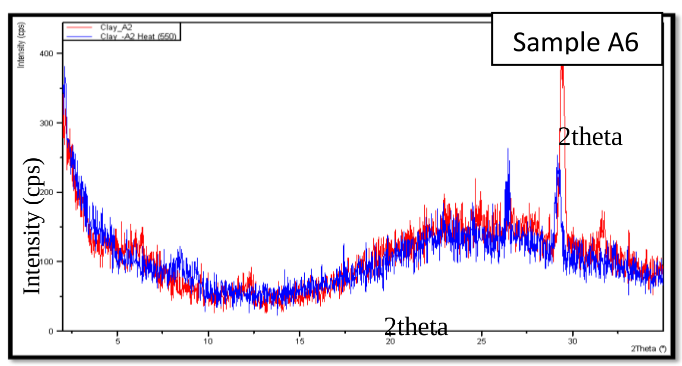

Fig. 7: *XRD patterns of clay fractions (<0.002 mm) of sample A6.*

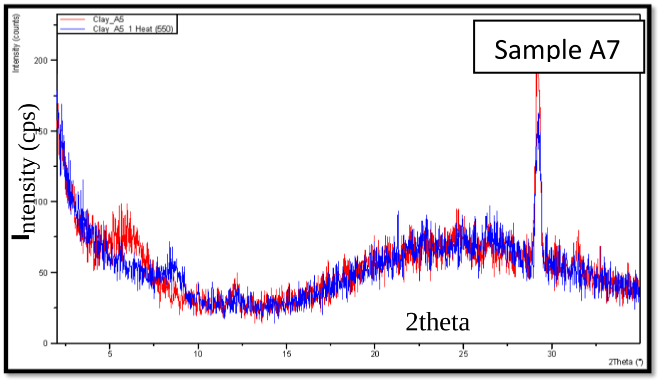

Fig. 8: *XRD patterns of clay fractions (<0.002 mm) of sample A7.*

5 CONCLUSIONS

From a comprehensive study of the soils (field observations, clay mineralogy), it draw the following conclusions:

- Smectite, chlorite, illite, and kaolinite are the major clay minerals in the soils in decreasing order.
- Chlorite, illite and kaolinite can be originated from parent material. Probable due to the low clay mica content of the parent materials and with less probability simple transformation of illite to other clay minerals (mainly smectite) may play a major role in decrease of illite content in the studied samples of the soils.

REFERENCES

[1] Wilson, M. J. 1999. The origin and formation of clay minerals in soils: past, present and future perspectives. Clay Miner. 34: 7-24.

[2] Abtahi, A. 1980. Soil genesis as affected by topography and time in calcareous parent materials. J.Soil Sci. Soc. Am. 44: 329 -336.

[3] Gharaee, H. A., and R. A. Mahjoory. 1984.Characteristica and geomorphic relationships of some representative Aridisols in southern Iran. Soil Sci. Soc. Am. J. 48: 115 -119.

[4] Khormali, F., and A. Abtahi. 2003. Origin and distribution of clay minerals in calcareous arid and semi-arid soils of Fars province. Clay Miner. 38: 511 -527.

[5] Wliaie, H. R., A. Abtahi, and R. J. Heck. 2006. Pedogenesis and clay mineralogical investigation of soils formed on gypsiferous and calcareous materials, on a transect, southwestern Iran. Geoderma 134: 62-81.

[6] Millot, G. 1970. Geology of clays. Masson et Cie., Paris.

[7] Abtahi, A. 1977.Effect of a saline and alkaline ground water on soil genesis in semiarid southern Iran.J.Soil Sci. Soc. Am. 41: 583-588.

[8] Abtahi, A., and F. Khormali. 2001. Genesis and morphological characteristics of Mollisols formed in a catena under water table influence in southern Iran. Commun. Soil Plant. 32: 1643-1658a.

[9] Sawhney, B. L. 1989. Interstratification in layer silicates. In: J. B., Dixon, and S. B. Weed, (eds.), Minerals in Soil Environment. Soil Sci. Soc. America, Madison, WI, pp. 789-828.

[10] Keys to Soil Taxonomy (2010).Soil Survey Staff.a basic system of soil classification for making and interpreting soil surveys, 11 edition. Agricultural Handbook 436, Natural Resources Conservation Service, USDA, Washington DC, USA, pp. 869.

[11] Ibrahim,M.M.M (2013). Spatial Variability and Land Evaluation of the Soils of Almanaqil Ridge, Gezira State, Sudan (Thesis, PhD) submitted to University of Khartoum, Khartoum, Sudan.

[12] Davies HRJ (1964). An agricultural revolution in the African tropics, the development of mechanized agriculture on the clay plains of the Republic of Sudan.Tijdshriftvoor econ.Ensoc.Geografie, pp. 101- 108.

[13] Meteorology Office-Gezara (1994). Rainfall records 1922-1994.

[14] Kittrick J.A. and E.W. Hope, 1963.A procedure for the particle size separation of soils for X-ray diffraction analysis. Soil Sci., 96: 312 -325.

[15] Page, A. L.;Miller, R. H. and Ceaney, D. R. (1982). Methods of Soil Analysis.Part 2. Chemical and Microbiological Properties, 2nd edition, American Society of Agronomy, Inc., Soil Science Society of America, Inc., Wisconsin, USA.

[16] Hag Abdulla, H. (1983).Profile development in arid and semi-arid tropical environment.Annual Report of the Gezira Research Station and Substations, ARC, Medani, Sudan.

[17] El-Attar, A. and Jackson, M. (1973). Montmorillonite soils developed in Nile River sediments. Soil Science 116,191-201.

[18] Senkayi, A. L.; Dixon, J. B.; Massner, L. R. and Viani, B. E. (1983). Mineralogical transformations during weathering of lignite overburden in East Texas. Clay and Clay Minerals 31(1), 49-56.

[19] Altaner SP, Hower J, Whitney G, Aronson JL. (1984). Modelfor K-bentonite formation: Evidence from zoned K-benton-ites in the disturbed belt, Montana. Geology 12:412-415.

[20] Osman, M.R., 1996. Recent to Quaternary river Nile sediments: A sedimentological characterization on samples from Aswan to Naga-Hamadi, Egypt. Ph.D. Thesis, University of Vienna, Austria, pp: 301.