Characterization of Heavy Mineral Composition in Some Soils Representing Clay Plains of the Sudan

1Pio Kur Deng
2Philip Wani Marchelod'Ragga

piokowr12@gmail.com
drwani49@gmail.com

1Department of Soil Sciences, Faculty of Agriculture, Upper Nile University, Juba, South Sudan,

2 Department of Agricultural Sciences, School of Natural Resources and Environmental Studies, (SNRES)University of Juba, P.O. Box 82 Juba, South Sudan

RECEIVED AT :02/02/2019
PUBLISHED AT :02/02/2019

ABSTRACT

The current study has been conducted in seven soil profiles in clay plains of the Sudan, sites were selected in a transect from East of Rahad River, across Gezira, West of the White Nile and Malakal. The objectives of this study were to characterize the heavy mineralogical composition of thee soils according to genetic horizons. The heavy minerals of sand fraction of these soil samples were separated and identified using a petrography microscope. The results for textural class showed that the studied samples belong clay with the higher clay content (>40%). A petrography microscope of heavy minerals indicates the presence of Zircon, Andalusite, Silimanite, Kyanite, Staurolite, Rutile, Garnet, Epidote, Hormblende and Tourmaline. The variations in the percentages of these minerals throughout the soils depth and the distance between the White Nile, Blue Nile and Rahad River indicate multi sedimentation regimes. The heavy minerals are dominated by Staurolite, followed by Rutile and Epidote. All samples comprised a heterogeneous population of zircon and rutile grains with diverse physico-chemical properties, expressed by large differences in colour. White Nile soils (W-2) had higher maturity Index (ZTR, 28.0-38.2%) followed by Rahad soil (R-2), (ZTR, 22.0-36.4%) and Malakal soil (M-1) (ZTR, 16.1-29.5%). The characteristics between and among the studied profiles even in the coupled –sites, indicate variances incorporated in sedimentation with effects of the location from the sandstone during transportation and precipitation.

Keywords: Soil type, heavy mineralogy, maturity index, clay plains, Sudan.

INRODUCTION

The Central Clay Plain of Sudan consists of a very large deposit, more than 1000 km2 of relatively uniform materials. The Gezira area is part of this clay plain. It covered all the area between the White Nile and Blue Nile. So that it is expected that this soil of Gezira may have different origin sources of heavy mineralogical composition from those of Malakal, Rahad (Butana) and the White Nile Soil. Heavy minerals are defined as high density minerals, which have specific gravities greater than 2.9 g cm 3[1], [2]. They are deposited and sorted according to differences in size, shape and density [3], [4].Heavy minerals help in understanding the transport history and give clue to processes and environment of deposition. Morphological character and color of heavy minerals has sometimes been used to locate the source rocks more categorically. The distribution pattern and mineral assemblages can also help in understanding the transport and direction of dispersal.

Heavy minerals are derived from the weathering and erosion of pre-existing rocks. These minerals vary in their resistance to chemical weathering and physical erosion. The physical stability is related to grain properties, hydrodynamic condition in sedimentary environment, and distance from the source rocks. Although mechanical abrasion during transportation of heavy minerals from their source may decrease the concentration of heavy minerals, there is no proof that heavy minerals are lost from assemblages during transportation [5].

To assess the mineralogical maturity of sediments, it is important to calculate the percentage of zircon, tourmaline and rutile in the opaque heavy mineral suit. Reference [6] provided an index, which represents a combined percentage of ultra-stabile heavy mineral zircon, tourmaline and rutile; and in the non-opaque heavy mineral suite excluding mica and concentration of ultra-stable heavy mineral reflects the most mature mineral composition. The sediments become immature as the proportion of unstable mineral in or ease weather [7].

Physical stability patterns of various heavy minerals were introduced to rank heavy minerals according to their mechanical resistance during transportation. Reference [8] used only shape and roundness as indicators of resistance to abrasion, and [9] included weight loss in their experiments. The chemical stability of heavy minerals is related to dissolution processes and intractable dissolution, which alter the original assemblage by removing soluble minerals and converting minerals species by chemical replacement (e.g. metastability minerals) in both the source rock and /or the sedimentary environment. Thus, the interpretation of source rock can be vague [10]. Therefore, the objective of this study is to characterize their heavy mineralogical composition according to genetic horizons. It is expected that these soils may have different heavy mineralogical characteristic and composition.

II. MATERIALS AND METHODS

A. LOCATION

The study area is located in the clay plain of Sudan and the soil profiles were selected in a transect from east of Rahad River, across Gezira, west of the White Nile and further south in Malakal.The locations of the studied profiles are shown in Figure 1.

B. SOIL SAMPLING

The Global Position System (GPS) was used for location of the soil samples site. A total of twenty-one- soil samples were collected from the seven soil profiles Fig. 1, and Table l. indicate GPS coordinate, Landform and surface cracks for sample site profiles from White Nile west and

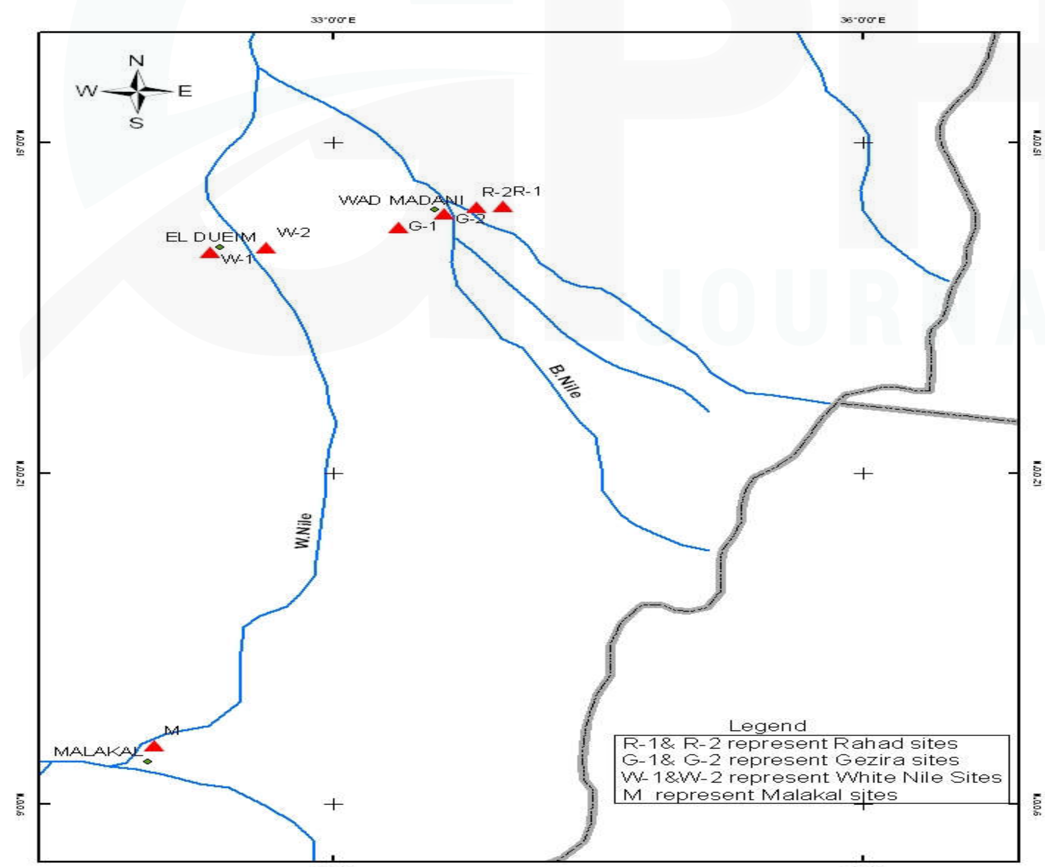

FIGURE 1. LOCATION OF STUDIES SOILS

TABLE I. GPS COORDINATE, LANDFORM AND SURFACE CRACKS FOR SAMPLE SITE.

Samples site	GPS Coordinate		Landform	Surface cracks (mm)
	E	N		
Rahad (R-1)	0598235	1580487	Plain	75 mm
Rahad (R-2)	0643104	1590775	Plain	77 mm
Gezira (G-1)	0531909	1575275	Plain	80 mm
Gezira (G-2)	0556520	1581936	Plain	80 mm
White Nile (W-1)	0418121	1545061	Plain	70 mm
White Nile (W-2)	0435851	1547331	Plain	none
Malakal (M-1)	0359225	1065365	Plain	70 mm

East banks, two soil profiles in Gezira, two profiles in Rahad and one profile in Malakal. The soil samples were saved at room temperature and subjected to laboratory analyses. The heavy mineralogical studies were performed in the Central Petroleum Laboratory (CPL) of the Ministry of Energy and Mining, Khartoum, Sudan. The methodology for heavy mineral analysis involves: -

C. SAMPLE PREPARATION AND ANALYSIS

In the laboratory, soil samples were spread to air dry at room temperature, ground using wood pestles and mortars and sieved to pass 2 mm sieves.

(1). PRACTICLE ANALYSIS

The particle size distribution was determined following the pipette methods of [11].

(2). DISAGGREGATION

The samples were submerged in distilled water for one to two days, using one liter plastic bottles and shaken for 10 to 12 hours. The same samples were then treated ultrasonically to remove iron staining and kaolin tic coatings, which were expected to cover the surfaces of the mineral grains.

(3). WET SIEVING

About one gram of each of the twenty-one soil samples was wet sieved. The agitating wet sieve (DIN 4188) to obtain thesand fractionsize range from 0.045 to 0.25 mm since it represents the size range in which most amounts all important heavy minerals are concentrated. The samples were taken for drying in an oven at 60°C.

(4). MEGNETIC SEPARATION

The fractions size ranges from 0.045 to 0.25 mm were subjected to magnetic separation (e.g. magnetite). They were separated by using the horseshoe magnet and the isodynamic separator was used to separate electromagnetic minerals such as haematite. This process was repeated several times to ensure the complete removal of the electromagnetic particles. The remaining fraction which contained both light and heavy minerals was subject to density separation.

(5). DENSITY SEPARATION (HEAVY LIQUID SEPARATION)

The heavy liquid separation of a sample into heavy and light minerals depends on the difference between the densities of the heavy liquid and those of the minerals. The bromoform with density of 2.89 g/cm3 was used to separate light fraction minerals from the heavy fraction minerals. When a sample is poured in this liquid, the heavy minerals (density > 2.89 g/cm3) will sink down whereas the light ones (density < 2.89 g/cm3) will float in this liquid. Aliquots of 2 to 5 g of the non-magnetic portion, of each sample were poured into a separating funnel, stirred and then left to settle for about 15 minutes. The settled heavy minerals in the filtrate were collected, washed by acetone to remove bromoform and then left to dry at room temperature. The fraction which contains the heavy mineral grains was mounted onto a glass slide using Canada balsam.

(6). IDENTIFICATION AND COUNTING OF THE HEAVY MINERALS:-

The heavy minerals were identified using a polarizing microscope. Their identification is based on the optical properties of these heavy minerals, such as: colour, cleavages, form and relief.Counting minerals for quantitative utilization was made along ribbon-e-traverse already drawn on the slide to facilitate the counting process. In this study, the slides were examined under the petrographic (polarized) microscope. All the amountof the heavy minerals was calculated to obtain their relative percentage.All these procedures were carried out according to [2].

(D). 2.4 ZIRCON, TOURMALINE AND RUTILE INDEX (ZTR INDEX)

The Zircon, Tourmaline and Rutile index (TZR index) which is a quantitative definition of mineral assemblage was calculated using the percentage of combined Zircon, Tourmaline and Rutile grain for each sample to determining the degree of maturity weathering were used for the evaluation of soil profile maturity. From the calculated percentage, ZTR < 75% implies immature to sub-mature sediments; ZTR > 75% indicates mineralogical matured sediments, [2], [6].

III. RESULTS AND DISCUSSION

A. PARTICLE SIZE DISTRIBUTION AND TEXTURAL CLASS

Table2. Indicated that the total samples were dominated by clay. Clay values ranged from 42-72%, with an average of 59.8%, silt values were ranged from 18-29%, with an average of 24%. Whereas; sand was found to be only in 15.90% of total samples and values ranged between 4-34 % with clay textural class. The results of particle size of the Gezira soil samples indicate that the total clay content increases slightly with depth as found by [12]. The increase of clay with depth is probably due to in-situ clay synthesis (weathering). In the

White Nile samples (W-1) the clay content increases with depth, while silt decreases with depth. Grain size (particle size in soil) distribution is one of the most important characteristics of sediment. This is true because grain size is a powerful tool for describing a site's geomorphic setting, interpreting the geomorphic significance of fluid dynamics in the natural environment, and distinguishing local versus regional sediment transport mechanisms as well because grain size is a dominant controlling factor in sediment geochemistry.

TABLE 2. PARTICLE SIZE DISTRIBUTION PERCENTAGES AND TEXTURAL CLASS

Soil sample Location	Depth cm	Particle size distribution percentage			Textural class
		Sand	Silt	Clay	
Rahad soil (R- 1)	0 – 40	7	21	72	Clay
	40- 80	6	22	72	Clay
	80 - 125	7	23	70	Clay
Rahad soil (R-2)	0 – 35	6	27	67	Clay
	35 – 100	6	28	66	Clay
	100 - 130	4	24	72	Clay
Gezira soil (G-1)	0 – 50	27	22	51	Clay
	50 – 120	25	20	55	Clay
	120 - 150	16	26	58	Clay
Gezira soil (G-2)	0 – 55	11	24	64	Clay
	55 – 180	9	28	63	Clay
	180 – 160	6	25	69	Clay
White Nile Soil(W-1)	0 – 55	8	29	63	Clay
	55 – 90	8	26	66	Clay
	90 – 115	6	23	71	Clay
White Nile Soil(W-2)	0 – 35	34	24	42	Clay
	35 – 55	30	25	45	Clay
	55 - 100	33	18	49	Clay
Malakal Soil (M-1)	0 – 25	27	25	48	Clay
	25 – 65	31	24	45	Clay
	65 - 103	27	25	48	Clay

(B). THE HEAVY MINERALS

The microscopic inspection of the studied soils samplesindicates presence of the following heavy mineral; Zircon, Andalusite, Silimanite, Kyanite, Staurolite, Rutile, Garnet, Epidote, Hormblende and Tourmalin; for twenty-one soils samples represent the site. The values of these minerals showed high variability between them and within some of them Table.3.

(1). STAUROLITE

Generally,staurolite has the highest average content in almost all the studied soils followed by Rutile and epidote. Hormblendesilimanite, Andalusite and garnet come next while Kyanite, zircon and tourmaline content the lowers value Table.2.Staurolite the most abundant minerals throughout the different samples with a range of 3.50-57.5% of the total heavy fractions (Table 2).Staurolite has highest proportion in G-1 in the surface and subsurface 56.2% and 57.5%,respectively.The lower content 3.5% in sub-soil of W-2 in sub soil. Staurolite is a metamorphic metastable heavy mineral. It occurs as angular to sub-angular grains with corroded edges. It is grain was identified by their golden and yellowish orange, brown, colorless and yellow green strong pleochroism (Plate 1). The occurrence of staurolite could be attributed to the weathering from the basement complex rocks. Also, Reference [13] elucidated that staurolite is commonly derived from schist, phyllites and gneiss.

Plate 1. Microscope photomicrography of some heavy minerals represented of the studies soils (Staurolite goldish yellow, colourless and yellow)

(2). ZIRCON

The relatively high resistant minerals including sphene, rutile, garnet and zircon are found in most the studied soil samples as relatively moderate amounts (0.20-31.6%, 0.00-16.6%, and 0.0-23.5%, respectively), with irregular distribution throughout the entire depth. The soil of W-1 profile has high value in sub soil 23.5% and lower in W-2 profile soil (Table 2). The concentration of zircon can be attributed to its ability to resist weathering and high specific gravity [14]. Zircon is one of the most extremely stable heavy minerals be resistant during weathering. Many types of zircon have been recognized based on color, shape and inclusion that it has. Zircon occurs as sub-rounded to round a hedral and irregular sub-hedral grains which reflect multiple sediment sources it appears commonly colorless (Plate 2). Presents of rounded and sub rounded zircon may indicate a relatively long distance of transport as well relatively strong reworking and probably most coming from igneous or metamorphic rocks derived from the Ethiopian plateau. These findings were in agreement with [15]. It characterized by high relief which distinguished it from apatite and stronger birefringence [13].

Because of its durability it is often found in far from its source in sedimentary rocks and alluvial heavy mineral sand. It is mostly absent in basalts and very rare in mafic rocks [16]. The rocks source can be igneous, metamorphic or sedimentary.

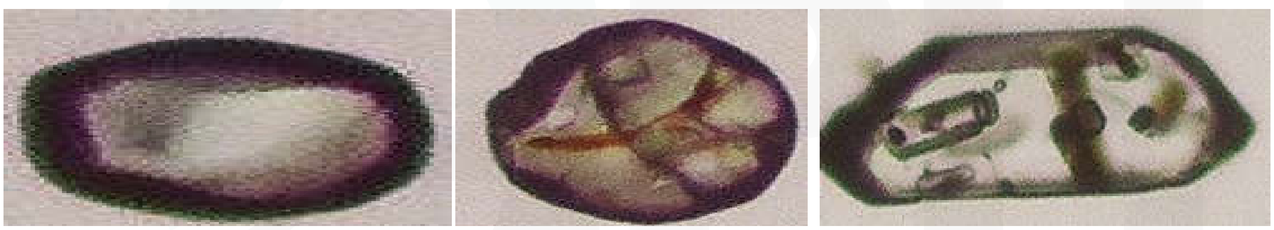

Plate 2. Microscope photomicrography of some heavy minerals represented of the studies soils (Zircon Angular, Zircon rounded and colorless with inclusion angular)

(3). ANDALUSITE

Table 2. Show value of andalusite found in all the studied soil samples range between 2.80 and 34.3% in W-1and W-2 range between 2.90-34.3%, with lower value in G-2 3.20%) as shown in (Table 2). It was identified in the most of the soils examined. It is colour less and sometime with very faint shadows of bluish colour. The combination of perfect cleavage and parting together with a large extinction angle and the good interference figure provide an easy diagnosis. Moreover, it is non-pleochroic. It occurs as elongated tubular grain with strongly corroded edges (Plate 3). The presence of the andalusite may

indicate reworked sediments and most probably derived from argillaceous rocks subjected to contact metamorphism around igneous intrusions [17].

TABLE 3. THE PROPORTION OF HEAVY MINERALS IN EACH SOIL SAMPLES OF THE STUDY AREA

Sample site	Depth (cm)	Z	Ad	Si	K	St	R	Ga	Ep	Ho	T	ZTR index%
R1-1	0-40	4.40	2.80	12.8	4.40	36.7	10.0	10.6	12.2	2.80	3.30	17.7
R1-2	40-80	5.90	7.50	14.4	4.30	21.9	11.8	16.6	5.40	10.7	1.60	19.3
R1-3	80-125	2.70	14.8	22.2	10.1	24.1	5.40	6.00	7.40	1.30	6.00	14.1
R2-1	0-35	3.00	10.0	10.0	0.00	16.8	26.7	0.00	26.8	0.00	6.70	36.4
R2-2	35-100	4.00	26.0	4.00	4.00	32.0	20.0	0.00	8.00	2.00	0	24.0
R2-3	100-130	2.00	16.0	8.00	2.00	32.0	18.0	8.00	6.00	6.00	2.00	22.0
G1-1	0-50	2.50	15.2	3.60	3.60	56.2	2.50	6.30	0.00	10.1	0	5.00
G1-2	50-120	2.20	9.90	8.50	3.00	57.5	3.40	2.60	1.30	11.6	0	5.60
G1-3	120-150	4.30	13.0	14.0	3.40	32.2	6.30	5.60	8.70	8.20	4.30	14.9
G2-1	0-55	3.50	4.60	10.4	3.50	39.1	10.4	2.30	11.5	10.7	3.50	17.5
G2-2	80-120	1.60	3.20	8.10	7.30	33.9	8.10	12.1	23.4	0.00	2.30	12.0
G2-3	160-180	1.60	6.60	9.90	2.50	38.0	26.5	3.30	8.30	2.50	0.80	28.9
W1-1	0-55	14.0	5.30	8.80	7.00	21.1	10.5	15.8	10.5	3.50	3.50	4.40
W1-2	55-90	0.00	5.30	11.8	1.30	25.0	31.6	7.90	6.60	4.00	6.60	2.00
W1-3	115-155	23.5	34.2	0.00	3.50	25.9	3.50	0.00	5.90	0.00	3.50	9.30
W2-1	0-35	0.00	34.3	0.00	0.00	8.70	4.40	4.40	17.4	30.4	0.00	28.0
W2-2	35-55	0.00	6.20	0.00	4.40	11.5	0.20	8.90	40.0	27.4	1.80	38.2
W2-3	55-100	0.00	2.90	0.00	0.60	3.50	5.80	5.80	52.9	25.0	3.50	30.5
M1-1	0-28	2.00	3.40	20.1	4.70	43.0	5.40	5.40	0.00	7.40	8.70	16.1
M1-2	65-103	8.10	18.1	11.4	8.10	26.2	15.4	0.00	4.70	2.00	6.00	29.5
M1-3	103-140	5.10	16.2	10.6	5.40	40.1	11.3	1.40	4.20	1.40	4.30	20.7

Where: Zircon (Z), Andalusite (Ad), Silimanite(Si), Kyanite(K), Staurolite (St), Rutile (R), Garnet (Ga), Epidote (Ep), Hornblende (Ho)and Tourmaline (T).

Plate 3. Microscope photomicrography of some heavy minerals represented of the studies soils (Andalusite prismatic Angular).

(4). SILIMANITE

Silimanitein Malakal and Rahad soils show high value 10.6- 20.1%, 0.00-22.2% respectively and lower value in W-2 (Table 2). [2] Showed that the presence of sillimanite in small amount might be sourced by metamorphic rocks or granite and genesis complex which contains significant amounts of sillimanite.Silimanite is metastable heavy clay a mineral which is commonly occurs as long slender prisms, short stout prismatic fragments. Prismatic grain is colour less although some grains show brown colour which is mainly due to iron staining. Silimanite was identified in the soil samples as Colourless striate with cleavage, fibrous style. It crystallizes in high temperature metamorphic rocks. It is also present in granulite facies rocks, high grade regional metamorphism of politic rocks (Plate 4).

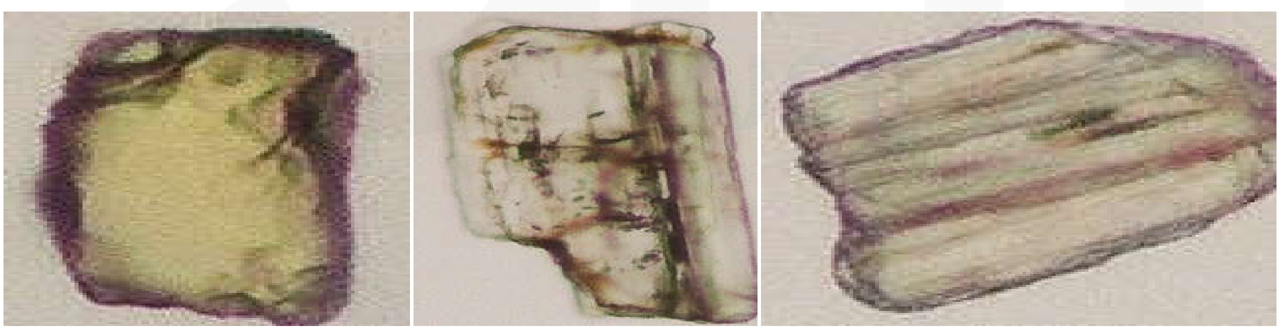

Plate 4. Microscope photomicrography of some heavy minerals represented of the studies soils (Silimanite striate and Silimanite colour less).

(5). RUTILE

Rutile is next to staurolite and relatively abundant in most soils, (Table 2). It's found in all the studied soil samples as relatively moderate amounts (0.20-31.6%). It is occurring as sub-angular prismatic or angular grains sub rounded, rounded (plate: 5); its colour varies from golden, yellow, red, reddish brown, brownish red or dark brown. It is characterized by high relief, strong birefringence, pleochroic and with parallel extinction.

The present of rutile reflect change in weathering, transportation and diagenetic states rather than different in the source rocks. Generally, rutile is usually found in various metamorphic rocks and sometimes it is found among some igneous rocks, so basement complex at the upper reaches of the Blue Nile might be the source area. Present of rutile is characteristic of a provenance of metamorphosed argillaceous sediments of high grade schists [18]. The occurrence of zircon and rutile heavy minerals is with the predominance of quartz is indication of chemical weathering in the profile.

Plate 5. Microscope photomicrography of some heavy minerals represented of the studies soils (Rutile Red rounded and Rutile Yellow Sub-Rounded).

(6). GARNET

Rahad soils scoured high value of garnet 0.00-16.6 % with low value in Malakal 0.00-5.40% in the studies soils Table (3). Garnet was found as sharp irregular fragment and sub-round to round grains. Its colour varies fromdark green, brown and green. Garnet is unstable heavy mineral, are characterized by their relative fresh and un-weathered appearance as in (Plate 6). Garnet is commonly in variety of metamorphic rocks and also present in igneous rocks. Garnets form in a variety of geologic settings, depending on the garnet species.

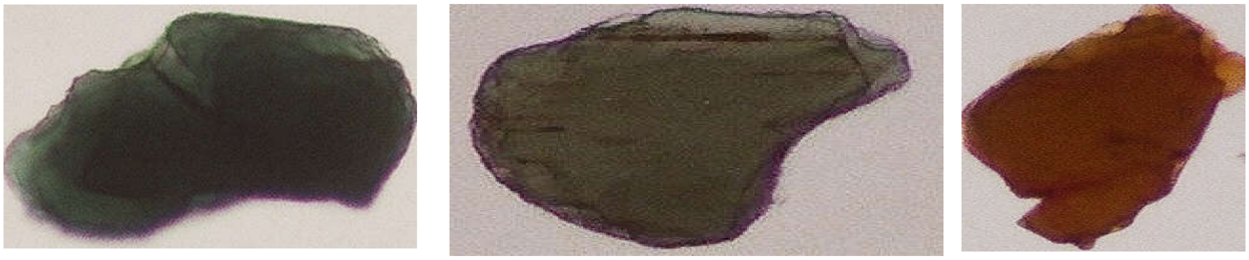

Plate 6. Microscope photomicrography of some heavy minerals represented of the studies soils (Garnetgreen, dark green andbrown).

(7). EPIDOTE

Epidotes are the second most abundant group of non-opaques with a range between 0.00-52.9%. Most of the soils show high value of epidote more than 5 % and lower value in G-1 and M-1 top soils (Table 3). Epidote is identified by its yellowish green colour, green plate,green high relief, short prismatic habit, very weak pleochroism, moderate birefringence, contrasting anomalous interference colors and parallel extinction. The intensity of its color is very much fluctuating between faint and deep green (Plate7). It is widely derived from a mixed source area and that might explain the present result. It is equally common in igneous and metamorphic rocks. In igneous rocks, it is late magmatic mineral, [13]. Hence, its source may be mixture of igneous and metamorphic rocks.

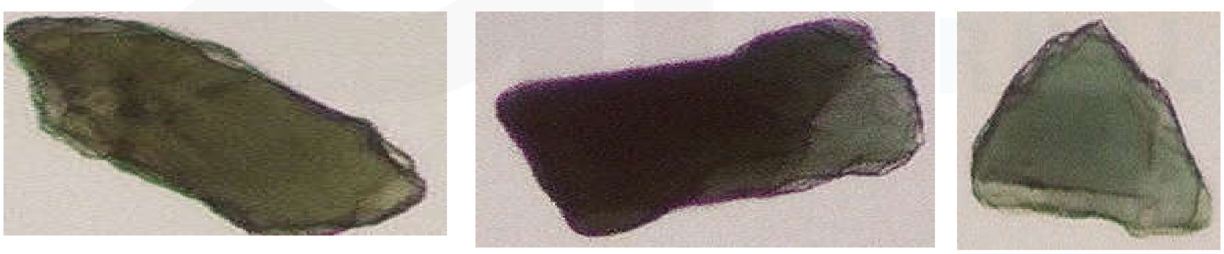

Plate 7. Microscope photomicrography of some heavy minerals represented of the studies soils (Epidote Green).

(8). HORNBLENDE

Hormblende found in all the studied soil samples range from (0.00-30.4% in total soils). Hormblende also showed moderate value in W-2 (7.40-30.4%) and lower value in R-2, G-2, and W-1. (2.00-6.00%; 0.00-10.7% and 0.00-4.00%)

respectively, (Table3). It occurs as sub-angular to sub-rounded grains (Plate 8) the shapes of hornblende may be due to the short distance of transportation as well as to less intensive weathering conditions in the source area. Generally, hornblende forms in a large variety of igneous and metamorphic rocks. It is characterized by high relief, moderate birefringence and strong pleochroism, its colour ranges from green, deep green, green to dark pate green, blue, light brown and light green. It is fundamentally derived from metamorphic rocks and wide variety of igneous rocks.

Plate 8. Microscope photomicrography of some heavy minerals represented of the studies soils (Hornblende prismatic dark green and petro chromic Green to pale green).

(3.2.9). TOURMALINE

Tourmaline found in Malakal andGezira range from (4.30-8.70% and (0.00-4.30%) respectively, (Table 2). Tourmaline is present in most samples of the studied soils with small to very small amounts. Tourmaline comes after zircon with valuerange from (0.00-8.70%). Four different colored varieties were observed brown-green-blue green, green, colorless and brown varieties, (Plate 9). The main source rock of tourmaline is the acid igneous rock and to some extent metamorphic rocks, like schist, gneisses and phyllites. This may suggest relatively long distance of transport and most probably igneous or metamorphic particularly, gneisses and schist source rocks which could be derived from the Ethiopian plateau. Similar findings were obtained by [19]. Tourmaline is part of the ZTR index for highly-weathered sediments.

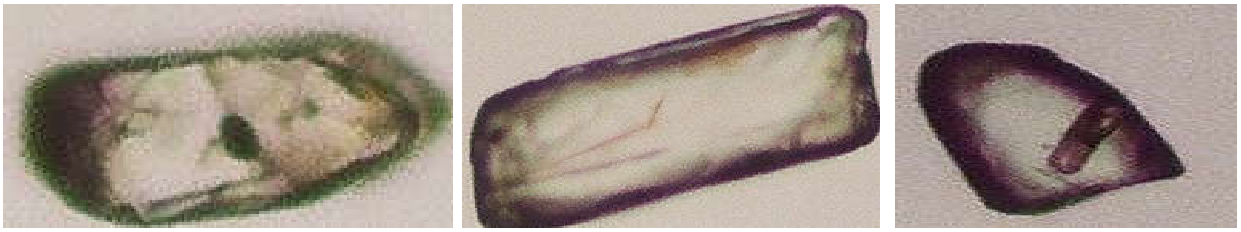

Plate 9. Microscope photomicrography of some heavy minerals represented of the studies soils (Tourmaline colourless Sub angle and angalur)

(10). KYANITE

Table 2. Kyanite gave more values in Malakal soil (4.70-8.10%) and in R-2, (0.0-10.1). Kyanite is found in association with its polymorphs, (Plate 10). Kyanite was identified in the soil samples, it has different colour, colourless, white, gray, green and deep green.Kyanite is typically the result of regional metamorphism of pelitic rocks and is associated with corundum, garnet, and staurolite. The availability of minerals such as garnet, kyanite, epidote, hornblende, staurolite, in sediments also indicates erosion in the source area which is rapid in its deposition [20]. Garnet, kyanite, epidote, staurolite and some sillimanite are suggestive of metamorphic [21].

Plate 10. Microscope photomicrography of some heavy minerals represented of the studies soils (Kyanite Green and Kyanitecolourless)

C. ZIRCON, TOURMALINE, RUTILE (ZTR) INDEX (%)

The Zircon, Tourmaline, Rutile (ZTR) percentage index calculated for each sample is included in Table 3. Results show some variations between the profile layers of the studied soils profile sites (irregular, decreased and increased). This indicates that the soil materials forming at different time of deposition with effect of the location of the studies soils samples. Since the ZTR index relates to the degree of maturity of soils, it seems that part of the White Nile soils is more mature (ZTR index, 2.00-38.2) than the other soils studied, probably due to its direct effect by the highly intensive weathering of southern clay plain, especially in the subsoil (35-55 cm) with a ZTR index of 38,.2%.The soil of Rahad (R-2) is relative maturity decreasing with depth (ZTR 22.00–36.4%).This maturity may be related to the neighboring high weathering associated with co-alluviation by Gallabat-Gedaref ridge. The soils of Rahad (R-1) show lower maturity than Rahad-2(ZTR 14.1-19.3%). The maturity index (ZTR) of Malakal soil ranges from (16.1 -29.5% with an irregular pattern mostly relate to high weathering conditions affected by river deposition.Gezira soils (G-2) has a higher subsoil maturity index (ZTR -29%) while the surface horizons ZTR index less than 17.5%, thus indicating a recent surface deposition.The other Gezira profile (G-1) has the same trend of deposition but with lower maturity index giving a ZTR of 5.0% in the surface soil and a ZTR of 5.00-14.9% in subsoil. The White Nile soil (W-1) is the least mature soil (ZTR 2.0-9.3%) with irregular pattern of very recent deposition. Irregular, increased and decreased distribution of these minerals throughout the entire depth and the distance from the eastern of Rahad River to western of the White Nile and Malakal. This indicates that the soil materials forming at the different time with effects of location of the studies site.

CONCLUSION

The present study showed that soils in the Central Clay Plainsof the Sudan are characterized and composed by the following:

1. The physical property (particle size) distributions of the studied soil are more or less similar. The results for textural class showed that the studied samples belong clay with the higher clay content (>42%).

2. The heavy minerals investigated in the studied soils indicate presence of Zircon, Andalusite, Silimanite, Kyanite, Staurolite, Rutile, Garnet, Epidote, Hormblende and Tourmaline. The variations in the percentages of these minerals throughout the soils depth and the distance between the White Nile, Blue Nile and Rahad River indicate multi sedimentation regimes.

3. The heavy minerals are dominated by Staurolite, followed by Rutile and Epidote.All samples comprised of a heterogeneous population of zircon and rutile grains with diverse physico-chemical properties, expressed by large differences in colour.

4. A White Nile soil (W-1) has higher maturity Index (ZTR, 15.8-38.2%) followed by Rahad soil (R-2), (ZTR, 21.9-36.4%) and Malakal soil (M-1) (ZTR, 12-29.8%).

5. It seems that characteristic between and among the studied profiles even in the coupled –sites, indicated the variances incorporated in sedimentation with effects of the location from the parent material during the transportation and precipitation.

ACKNOWLEDGEMENTS

We acknowledge Dr. Elseir, Director of Land and Water Research Centre for financial support and the Agricultural ResearchCorporation for this work. Also, the supervisory roles of Dr. Fawzi Mohamed Salih and Dr. Mohamed Aliof Central Petroleum Laboratory (CPL), Ministry of Energy and Mining, Khartoum, Sudan is greatly acknowledged.

References

[1] R.G. Rothwell, "Minerals and Mineraloids in Marine Sediments an Optical Identification Guide," Elsevier Applied Science Publishers Ltd, London, pp. 1989.

[2] M.A. Mange, and H.F.W. Maurer, "Heavy Minerals in Colour," Chapman and Hall, London, pp. 147, 1992.

[3] D. Padmalal, K.K. Ramachandran, and P. Scralathan, "Significance of heavy minerals suitc in riverine and estuarine sediments in the southern west coast of India- a case study," Indian Journal of Marine Sciences, vol. 27, pp. 185-189, 1998.

[4] P.D. Komar, "The entrainment, transport and sorting of heavy mineral by weaves and current," In: Mange, M.A. and Wright, D.T. Ed. Heavy Minerals in Use, Developments Sedimentology, Elsevier. Amsterdam. vol. 58, pp. 3-48, 2007.

[5] A.C. Morton, and C. Hallsworth, "Stability of detrital heavy minerals during burial diagenesis," In: Mange, M.A. and Wright, D.T. Ed., Heavy Minerals in Use Developments in Sedimentology, vol. 58, pp. 215-245, 2007.

[6] A. Hubert, "The geology of part of Southwestern Nigeria." Geological Survey of Nigeria, Bulletin 3, 1962.

[7] E. Garzanti, and S. Ando´, "Heavy mineral concentration in modern sands: implications for provenance interpretation." In: Developments in Sedimentology, vol. 58, pp. 517-545, 2007.

[8] V. Dietz, "Experiments on the influence of transport on shape and roundness of heavy minerals". Contribution to Sedimentology, vol. 1, pp. 103-1225, 1973.

[9] G.A. Thiel, "Mechanical effects of stream transportation in mineral grains of sand size," Geological Society of America Bulletin, vol. 56, pp. 1207, 1945.

[10] A.C. Morton, and C. Hallsworth, "Processes controlling the composition of heavy mineral assemblages in sandstones," Sedimentary Geology, vol. 124, no. 1-4, pp. 3-29, 1999.

[11] M.L. Jackson, Soil Chemical analyses. Prentice Hall. Inc. Engle Wool Cliffs, N.J., U.S.A, pp. 87, 1958.

[12] M.B. Said, "Distribution of Phosphorus in the Sudan Gezira soils," Trop. Agric. (Trinidad), vol. 52, pp. 269-274, 1975.

[13] P.F. Kerr, "Optical Mineralogy," McGraw-Hill Book Company, 1977.

[14] T.E.Garnar Jr, "Mineralogical methods used in the heavy mineral industry" In Applied Mineralogy. Proceedings of the Second International Congress on Applied Mineralogy in Minerals Industry, Metallurgical Society of the AIME, pp. 297-312, 1984.

[15] Y. Samy, and E. Abou El-Anwar, "Textural and Mineralogical Characters of the Sand Fraction of Some Quaternary Sediments on Giza-Fayium District, Western side of the Nile Valley, Egypt," Australian Journal of Basic and Applied Sciences, vol. 7, pp. 770-779, 2013.

[16] R.J. Finch, and J.M. Hanchar, "Structure and chemistry of zircon and zircon-group minerals", In: Hanchar, J.M., and Hoskin, P.W.O, Eds. Reviews in Mineralogy and Geochemistry, vol. 53, pp. 1-25, 2003.

[17] W.A. Deer, R.A. Howie, and J. Zussman, "An Introduction to the Rock –Forming Minerals" 2nd Edition, Prentice Hall, Harlow, 1992.

[18] R.L. Folk, "The Provenance of Rutile". Journal of Sedimentary Research, vol. 50, pp. 485-488, 1980.

[19] R.A. Haredy, "Distribution and Provenance of Heavy Minerals in Surficial Sediments of Minnmurra and Bass Point New South Wales, Australia," Research Thesis, School of Geosciences, University of Wollongong, Wollongong, 2003.

[20] B.P. Duarah, P.K. Das, and D.C. Goswami, "Heavy Mineral Study from Modern Sediments of a Point Bar in the Puthimari River near Puthimari Village, Kamrup District, Assam". Journal of the Indian Academy of Geoscience, vol. 41, pp. 47-52, 1998.

[21] R.S. Chaudhri, and G.T.S. Gill, "Heavy Mineral Assemblage of the Siwalik Group of Nepal Himalayas". Journal of the Geological Society, vol. 22, pp. 220-226, 1980.