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Pedological Study of Soils Developed on Biotite-Hornblende-Gneiss in Akamkpa Local Government Area of Cross River State, Nigeria

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ABSTRACT

Morphological, physicochemical and mineralogical properties of soils derived from Biotite-Hornblende-Gneiss of Akamkpa, Cross River State, Nigeria were studied with a view to classifying the soil taxonomically, assessing their potentials and suggesting appropriate management strategies. Three profiles were dug on the landscapes of Nsan, Okomita and Old Netim. The micro-morphological properties of soil colour, soil structure, soil consistence, drainage and root abundance were determined in the field. The soils were characterized as follows: Deep profiles (>100 cm) with texture of gravelly sandy clay loam; hues of 10-5 YR; structure of subangular peds with sticky consistence (wet); bulk density values of 0.9-1.3 mg m^{-3}; total porosity of 52.6-64.7%; silt-clay ratios of 0.4-1. Others were soil reaction (pH 4.4-5.1) H_2O; organic carbon (0.8-14.56 g kg^{-1}); total nitrogen (0.56-1.40 g kg^{-1}); ECEC (1.46-4.40 cmol kg^{-1}); CEC (3.30-6.00 cmol kg^{-1}); available P (2.70-17.56 mg kg^{-1}); base saturation (45-47%) and minerals such as quartz (81.26%), kaolinite (11.97%) and microcline (6.77%). According to the criteria of the USDA Soil Taxonomy, the soils were classified as loamy skeletal, mixed isohyperthermic typic kandiudults. Equivalent FAO-World Reference Base for Soil Resources of the soils was Dystric Acrisol. Pedogenetic process of elluviation-illuviation reflecting the weathering process has been occurring in the soils under the humid tropical influence. The soils can be managed by planting acid tolerant crops liming and adopting appropriate cultural practices.

Key words: Pedological study, Biotite-Hornblende-Gneiss, typic kandiudults, elluviation, illuviation

INTRODUCTION

The soils of Akamkpa Local Government area are derived from basement complex rocks consisting of granite gneiss. Basement complex rocks are known to occur at Oban and Obudu areas in Cross River State of Nigeria. At Oban, it is known as Oban Massif which Nsan, Okomita and Old Netim are the integral parts occupying about 10,000 km^2 (Ekwueme, 2003; Amah *et al.*, 2012). The present study locations at Nsan, Okomita and Old Netim are underlain by basement complex rocks characterized as Biotite-Hornblende-Gneiss (Ekwueme, 2003; Amah *et al.*, 2012). The igneous and metamorphic rocks are crystalline and they weather easily and deeply under humid conditions to form deep soil (>100 cm) profiles (Olaniyan *et al.*, 2010). Studies have shown that Biotite-Hornblende-Gneiss undergoing weathering under humid tropical conditions can influence the morphological, physical and chemical as well as mineralogical properties of the soils

(Wilson, 1967; Velbel, 1989). The high rainfall of the study area (>3500 m) and high soil temperature (Isohyperthermic soil temperature) (>27-31°C) can enhance hydrolytic weathering by predisposing the metamorphosed rocks (gneiss) to ferralitic pedogenesis (Amusan, 2002; Akpan-Idiok, 2012). Biotitie-Gneiss can undergo weathering with resultant formation of interstratified minerals such as vermiculite/or montmorillonite which can decompose rapidly to kaolinite; also hornblende-gneiss can weather through a pedological process of dissolution-reprecipitation to form ferruginious and aluminous weathering products (goethite, gibbsite and kaolinite) (Velbel, 1989).

A modal profile developed on granite-gneiss of south western Nigeria was characterized by a hue range of 2.5-5-7.5 YR in most layers depicting a residual accumulation of Fe and Al with a dominant pedogenic process of ferralitic weathering (Tessens and Shamshuddin, 1982; Amusan, 2002). Soils formed on biotite-hornblende rocks of Aberdeen in United Kingdom were observed to have surface dark reddish brown (5 YR 3/2) fine sandy loam with moderate crumb structure over subsurface brown to dark brown (7.5 YR 4/2-4/4) fine sandy loam with weak subangular blocky structure. Soils developed on biotite-granite in Jos, Plateau, Nigeria are characterized by low nutrient status with chemical properties showing low to very low total nitrogen, phosphorus and basic cations (Olowolafe and Dung, 2002). Also, soils developed on Biotite-Hornblende Gneiss of Akamkpa are characterized by deep profiles, depending on the topography, coarse to fine sand-texture, low base status, acidic reaction and low activity clays, probably because of high amount of rainfall and high soil temperature among others (Bulktrade Investment Company Limited, 1989).

The soils developed on Biotite-Hornblende-Gneiss in Akamkpa support a lot of agricultural crops such as tree crop plantations (oil palm, rubber and gmelina trees) and food crop production such as cassava, yam, cocoyam, plantain and vegetables. Many industrial quarries have been established in the study area for mining granite for the production of rock aggregates that are used as sub base during road construction and as foundation materials (Amah *et al*., 2012). Industrialization drive of the Cross River State Government through establishment of agricultural plantations and increase in human population have exerted pressure on the soils derived from biotite-hornblende-gneiss which serves as suburbs to fast growing Calabar Metropolis. The nature of the parent material influences the properties of the soils; with the widespread intensive cultivation of the soils and the associated consequential land degradation problems, a pedological study consisting of morphological, physicochemical and mineralogical properties as well as soil classification was carried out with a view to suggesting appropriate land use management measures for the soils derived from Biotite-Hornblende-Gneiss in Akamkpa Local Government area, Cross River State, Nigeria.

MATERIALS AND METHODS

Description of the study area: Akamkpa Local Government Area (latitudes 5°00' and 5°57'N; longitudes 8°06 and 9°0 E) is located in southern Cross River State, Nigeria (Fig. 1). The climate of the area is characterized by tropical humid conditions with a mean annual rainfall of 2500-3000 mm, a mean annual temperature of 26-27°C and a mean relative humidity of 80-90% at the peak of the rainy season (Bulktrade Investment Company Limited, 1989; Akpan-Idiok, 2012).

The soils of the area are derived from the Basement Complex rocks predominantly granite and gneisses (Ekwueme, 2003; Amah *et al*., 2012). The present study locations at Nsan, Okomita and

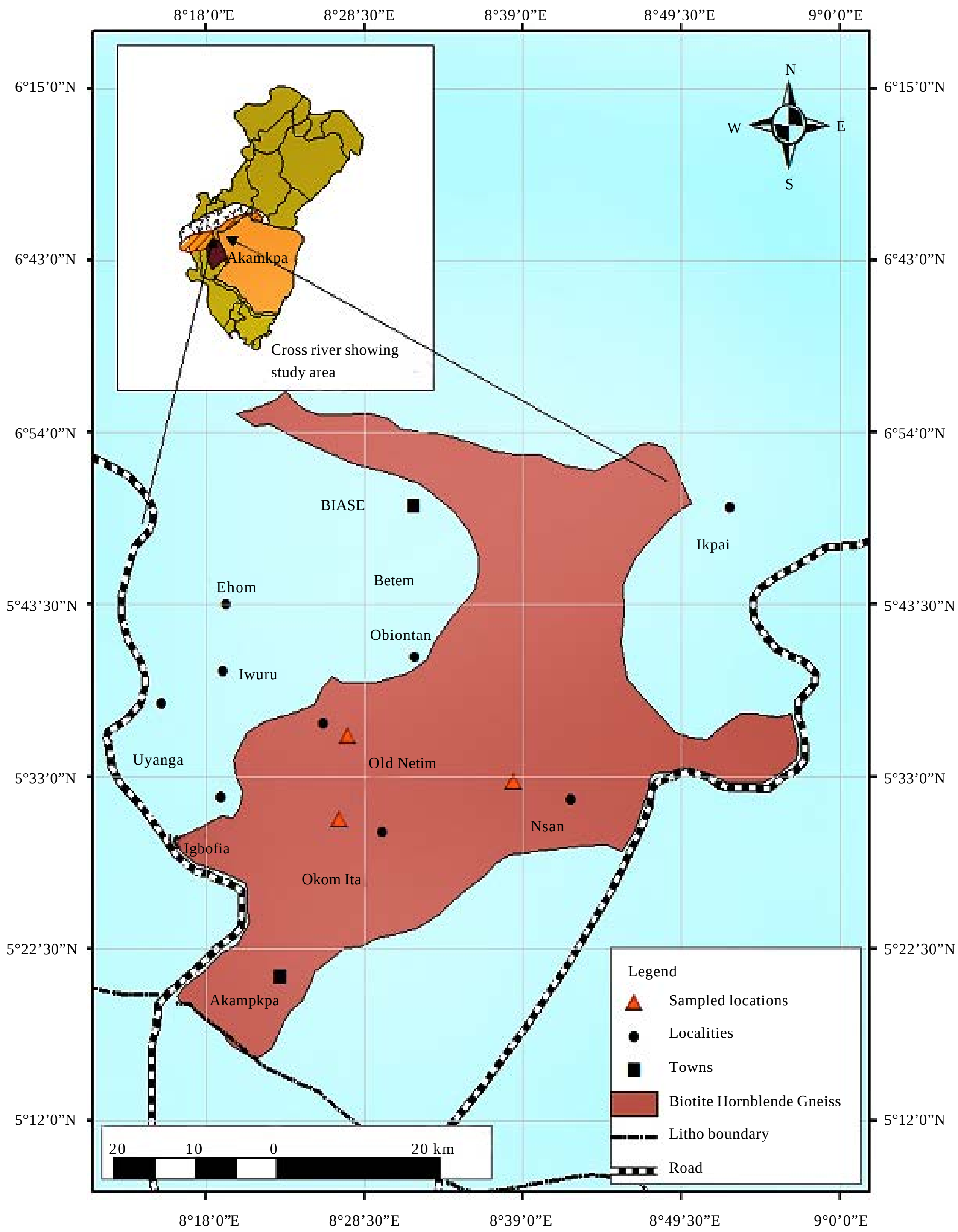

Fig. 1: Map of Akamkpa showing sampling points at Nsan, Okomita and Old Netim

Old Netim are underlain by Biotite Hornblende-Gneiss (Ekwueme, 2003). The landscape is gently to strongly undulating in some places. The original rainforest in the area has been tampered with by human activities.

Soil sampling: A total of three representative soil profile pits of depths 0-140, 0-144 and 0-145 cm were dug at Nsan (05°19'04" N; 008°21'33" E); Okomita (05°19'85" N, 008°19'94 E and Old Netim (05°21'10" N, 008o21'42 E) at elevations of 111, 106 and 96 m above a mean sea level, respectively. The coordinates and the altitudes of the three profile sites were obtained using Garmin Etrex 2000 GPS meter. Field characterization of the profiles was carried out and the soil samples obtained from the pedogenic horizons from the base of the profiles to avoid contamination; the samples were preserved in polythene bags and were taken to University of Calabar Soil laboratory for physicochemical analysis.

Laboratory analysis: Soil samples were air-dried and sieved through a 2 mm mesh. Particle size analysis was carried out by hydrometer method (Juo, 1979) using sodium hexametaphosphate (calgon) as the dispersant. Soil pH was determined in soil water ratio of 1:2.5 using a glass electrode pH meter. Organic carbon was determined by the Walkley and Black method (Juo, 1979) while total nitrogen was by the micro-Kjedahl digestion method (Juo, 1979). Available phosphorus was determined by the Bray and Kurtz (1945) No. 1 method. Exchangeable bases (Ca, Mg, K and Na) were extracted with 1 N NH_4OAc at pH 7. Exchangeable potassium and sodium were determined with a flame photometer while Ca and Mg were determined by the EDTA titration method (Black and Evans, 1965). Exchangeable acidity was determined by titration method using 1 N KCl extract (McLean, 1965). Effective cation exchange capacity was estimated by summing the exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity. Percent base saturation was obtained by dividing the total exchangeable bases (Ca, Mg, K, Na) by the effective cation exchange capacity. For X-ray analysis, particle size analysis was carried out on each sample to separate and prepare the clay fraction for the analysis. The sample was prepared for XRD analysis using a back loading preparation method. Ten percent internal standard (flourite) was added and the sample micronized. The micronized material was analysed by XRD utilizing a PANalytical Empyrean Diffractometer with PIXcel detector and fixed slits with Fe filtered Co-kα radiation. The phases were identified using X'Pert Highscore plus software. The XRD analysis was used to determine the crystalline mineral phases present in the sample. The abundance of each phase (weight percent) was determined by the Rietveld Refinement method. An orientation specimen was prepared from each of the samples, the head and the clay (<2 um) fraction. The glass slide was analysed by XRD to determine the mineralogy of the samples, the head and clay (<2 um) fraction. The slide was then glycolated and reanalyzed, heat treated and reanalyzed. The process of glycolation and heat treatment made it possible to identify and quantify, the various phyllosilicates that occur in the clay fraction.

RESULTS AND DISCUSSION

Morphological characteristics: The morphological characteristics of the three profiles representing soils derived from Biotite-Hornblende-Gneiss at Nsan, Okomita and Old Netim were studied (Table 1). The morphological features exhibit a range of hues-10 YR through 7.5-5 YR which typifies the soils with variation of colour such as very dark grayish brown, brown, strong brown, brownish yellow and yellowish red. This range of colours is associated with minerals such as goethite (alpha-FeOOH), maghemite (gama-Fe_2O_3), Hematite (alpha Fe_2O_3) and Gibbsite [Al (OH_3)] (Akpan-Idiok *et al*., 2013).

The hue of 10 YR and chroma of 2 in the surface (pedons 1 to 3) and the red mottles (10 R 4/8), dark red (2.5 YR 3/6) at the bottom (pedons 2 and 3) are associated with poor drainage in the

Table 1: Morphological properties of soils developed on Biotite-Hornblende-Gneiss in Akamkpa Local Government area, Cross River State

Location	Horizon designation	Depth (cm)	Munsell colour	Mottling	Texture	Structure	Consistence	Boundary	Other features
05°19'.035"N	Pedon 1 (Nsan)								
008°23'.323"E	AP	0-21	10 YR 3/2 (Very dark greyish brown)	-	gls	1 msbk	sssp	cs	Termite, many mica flakes, worm cast; many medium roots; macro and micro pores
	Bt_1	21-54	7.5 YR 4/4 (Brown)	-	gscl	2 msbk	sssp	gs	Common fine mica flakes; common fine and medium roots; clay skins in the peds
	BC	54-100	7.5 YR 4/6 (Strong brown)	-	gscl	2 msbk	sp	as	Many large quartzite, muscovite, biotite schistose; common medium and fine roots; common macro and fine pores
	Crt	100-140	7.5 YR 4/6 (Strong brown)	-	sgscl	2 msbk	sp		Many large quartzite, muscovite, biotite schistose and weathered rocks; common fine roots
05°19'.852"N	Pedon 2 (Okom Ita)								
008°19'.943"E	AP	0-15	10 YR 4/2 (Very dark greyish brown)	-	gls	1 msbk	sssp	sc	Earthworms cast, termite and ant activities; many fine roots; macro and micro pores
	Bt_1	15-29	10 YR 4/4 (Very yellowish brown)	-	gsl	1 msbk	sssp	cw	Many common mica flakes, termite activities; clay skins in the peds
	Bt_2	29-116	7.5 YR 5/6 (Strong brown)	-	gsc	2 fgr	sp	as	Many fine mica flakes, many meddium weathered rocks, fragments of quartzite schistose; clay skins in the peds
	Crt	116-144	5 YR 5/6 (Yellowish brown)	(10 R 4/8)	gscl	3 mcsbk	sp		Many mica, haemite termite activities

Table 1: Continue

Location	Horizon designation	Depth (cm)	Munsell colour	Mottling	Texture	Structure	Consistence	Boundary	Other features
05°21'.100''N	Pedon 3 (Old Netim)								
008°21'.415''E	AP	0-22	10 YR 3/2 (Very dark greyish brown)	-	gsl	1 msbk	sssp	cs	Termite, worm casts, human activities; many fine and medium roots; many macro and micro pores
	Bt_1	22-60	10 YR 6/8 (Brown yellow)	-	gscl	2 msbk	sssp	gs	Common fine roots; common macro and micro pores; many micas flakes; clay skins in the peds
	Bt_2	60-94	10 YR 6/8 (Brown yellow)	-	gscl	2 msbk	sp	as	Common fine roots; many micro pores; many mica flakes; clay skins in the peds
	Crt	94-154	10 YR 6/8 (Brown yellow)	2.5 YR 3/6 Dark red	gscl	2 msbk	sp		Large quartzitte, muscovite schist, biotite schist and weathered; common micro pores

gls: Gravelly loamy sand, gsl: Gravelly sandy loam, gscl: Gravelly sandy clay loam, gsc: Gravelly sandy clay, 1: Weak, 2: Moderate, 3: Strong, f: Fine, m: Medium, c: Coarse, sbk: Subangular blocky, gr: Granular, Consistency: sssp: Slightly sticky slightly plastic, sp: Sticky and plastic, Boundary: cs: Clear smooth, gs: Gradual smooth, gd: Gradual diffuse, cw: Clear wavy, as: Abrupt smooth pedo environment; this is an indication that the soils are either imperfectly drained or poorly drained during the rainy season in the study locations. The soils are well-developed with deep (>100 cm) profiles and are characterized by gravelly loamy or sandy clay loam subsurface; weak medium subangular structure; slightly sticky or sticky and slightly plastic or plastic under wet condition consistency; argillic or kandic horizons with clay skins in the peds at the depth of 21-154 cm; abundance of macro and micro pores; many fine and medium roots as well as animal activities with the presence of many termites, ants, earthworms; many fine mica flakes and fragments of quartzite, muscovite, biotite, schistose and weathered rocks; horizon delineation of clear smooth boundary occur in the surface to gradual smooth or diffuse smooth in the subsurface. Similar observations were reported for forest soils of Akamkpa (Bulktrade Investment Company Limited, 1989).

Physical characteristics: Particle size distribution data in the surface of the three profiles are sandy (>770 g kg^{-1}) with an overall texture of loamy sand overlying sandy clay loam texture with sand fraction greater than 647 g kg^{-1} in the subsurface (Table 2). Clay fractions (profiles 1-3) on the average are 143 and 270 g kg^{-1} for surface and subsurface soils, respectively. The soils are free draining but with the clay content exceeding 200 g kg^{-1} in the subsurface horizons, the soils can retain considerable amount of water for crop production and that the clay accumulation in the subsurface indicates the dominant pedogenic process of eluviation-illuviation in layers coded as the Bt horizons in the three profiles (Akpan-Idiok, 2012; Ogbaji *et al.*, 2013).

Bulk density values increase with soil depth with overall surface and subsurface means values of 1.00 mg m^{-3} and 1.20 mg m^{-3} which fall within the typical range (1.00-1.60 m gm^{-3}) for mineral soils (Wild, 1963; Akpan-Idiok *et al.*, 2012). The soils therefore have no mechanical impedance for plant roots and also have adequate aeration. The mean total porosity varies from 50.9-93.2% with overall mean values of 64.7 and 52.6% in surface and subsurface soils of the three profiles. This range of values typifies sandy material which can enhance easy movement of water in the soils. Soils with 50% total porosity are well granulated and may have high moisture retention for crop plants (Akpan-Idiok *et al.*, 2012). Silt/clay ratio refers to the relative amount of silt and clay in soils. Using silt/clay ratio of 0.15 (Van Wambeke, 1962) or 0.25 (Asamoa, 1973), the considerable silt/clay ratios averaging 1.0 and 0.4 in the surface and subsurface soils, respectively indicate the parent material (Biotite-Hornblende-Gneiss) as being under advanced level of weathering (Akpan-Idiok and Opuwaribo, 1992).

Chemical characteristics: The soils are generally very strongly acid in reaction with mean pH (H_2O) values of 4.9 and 4.8 in surface and subsurface soil, respectively (Table 3). The exchangeable acidity values (sum of $Al+H^{+}$) in the surface (1.0-1.6 cmol kg^{-1}) are considerable when compared with the threshold value of 0.5-2 cmol kg^{-1} for productive soils (Holland *et al.*, 1989). The ΔpH values (pH in KCl-pH in H_2O) are negative with mean values of -0.97 and -0.91 for surface and subsurface soils. This is an indication that the soils possess net negative charge for all horizons. The soils with net negative charge can retain basic cations and heavy metal pollutants. The drop in pH in the KCl solution arises from the hydrolysis of Al^{3+} displaced by the K (Mekaru and Uehara, 1972) and being strongly acidic soils, the dominant cation on the exchange complex might be exchangeable Al^{3+} (Esu *et al.*, 2008).

Organic cation content decreases with soil depth in the three profiles (Table 3) with the overall moderate mean values of 9.08 g kg^{-1} in the surface soils. Similarly, the surface total nitrogen

Table 2: Physical properties of soils developed on Biotite-Hornblende-Gneiss in Akamkpa Local Government area, Cross River State

			Particle size							
Location	Horizon/designations	Horizon depth (cm)	Sand ($g\ kg^{-1}$)	Silt ($g\ kg^{-1}$)	Clay ($g\ kg^{-1}$)	Gravel content (%)	Textural classes	Bulk density ($mg\ m^{-3}$)	Total porosity (%)	Silt/clay ratio
05°19'.035"N	Pedon 1 (Nsan)									
008°23'.323"E	Ap	0-21	870	60	70	5.7	gls	1.0	62.3	1.0
	Bt1	21-54	730	60	210	14.4	gscl	1.2	54.7	0.3
	Bt2	54-100	710	60	230	37.2	gscl	1.2	52.8	0.3
	Crt	100-140	750	40	210		gcl			0.2
05°19'.852"N	Pedon 2 (Okom Ita)									
008°19'.943"E	Ap	0-15	790	140	70	11.0	gls	1.0	62.3	2.0
	Bt	15-29	710	120	170	21.1	gsl	1.2	54.7	1.0
	Btr	29-116	530	120	350	66.1	gsc	1.2	54.7	0.3
	Crt	116-144	610	140	250		gcl			1.0
05°21'.100"N	Pedon 3 (Old Netim)									
008°21'.415"E	Ap	0-22	810	80	110	1.4	gsl	0.9	93.2	1.0
	Bt1	22-60	710	60	230	7.2	gscl	1.2	52.8	0.3
	Bt2	60-94	630	80	290	11.2	gscl	1.3	50.9	0.3
	Crt	94-154	650	60	290	67.7	gscl			0.2
Range			530-870	60-140	70-350	1.33-67.3		0.9-1.3	51.0-68.7	0.2-2.0
Surface mean			770	87	143	10.1		1.0	64.7	1.0
Sub surface mean			647	83	270	61.0		1.2	52.6	0.4

Table 3: Chemical properties of soils developed on Biotite-Hornblende-Gneiss in Akamkpa Local Government area, Cross River State

Location	Horizon designations	Horizon depth (cm)	pH (1:1) KCl	H_2O	ΔpH	carbon	Organic ($g\ kg^{-1}$)	T:N ($Mg\ kg^{-1}$)	Avail P Ca	Mg	K	Na ($Cmol\ kg^{-1}$)	TEB	H+Al	CEC	ECEC	Base saturation
05°19'.035"N	Pedon 1 (Nsan)																
008°23'.323"E	Ap	0-21	4.0	4.9	-0.9	10.77	1.26	2.9	1.8	0.4	0.05	0.01	2.26	1.2	3.8	3.43	65
	Bt1	21-54	4.3	5.1	-0.8	5.19	0.84	1.93	1.6	0.3	0.03	0.01	1.94	0.6	3.6	2.97	65
	Bt2	54-100	4.0	5.1	-1.1	4.19	-	-	1.0	0.3	0.03	0.05	1.38	0.8	3.2	1.46	95
	Crt	100-140	4.0	5.0	-1.0	3.19	-	-	1.6	0.6	0.04	0.03	2.27	0.8	3.5	2.35	97
05°19'.852"N	Pedon 2 (Okom Ita)																
008°19'.943"E	Ap	0-15	4.1	5.0	-0.9	17.56	1.4	4.04	1.2	0.3	0.08	0.01	1.59	1.6	4.3	3.19	50
	Bt	15-29	3.7	4.5	-0.8	7.80	0.84	2.89	1.2	0.4	0.07	0.01	1.68	2.2	6.0	3.88	43
	Btr	29-116	3.8	4.4	-0.6	3.19	-	-	1.8	0.5	0.05	0.05	2.4	2.0	5.2	4.40	55
	Crt	116-144	4.1	5.0	-0.9	3.79	-	-	1.2	0.4	0.11	0.05	1.86	1.8	5.8	3.56	49
05°21'.100"N	Pedon 3 (Old Netim)																
008°21'.415"E	Ap	0-22	3.7	4.8	-1.1	13.17	1.12	17.16	1.4	0.6	0.12	0.01	2.13	1.0	3.6	3.13	68
	Bt1	22-60	3.6	4.8	-1.2	4.19	0.56	8.18	1.0	0.4	0.03	0.05	1.48	2.6	5.2	4.08	36
	Bt2	60-94	3.7	4.7	-1.0	3.39	-	-	1.8	0.4	0.03	0.01	2.24	1.4	5.0	3.64	62
	Crt	94-154	4.2	5.0	-0.8	0.8	-	-	1.6	0.5	0.08	0.03	2.21	0.8	3.3	2.29	97
Range			4.3-4.2	4.4-5.1	-(0.6)-(1.27)	0.8-17.56	0.56-1.40	2.89-17.16	1.0-1.8	0.3-0.6	0.03-0.12	0.01-0.05	1.38-2.40	0.8-2.6	3.2-5.8	1.5-4.4	36-97
Surface mean			3.9	4.9	-0.97	9.08	1.26	8.0	1.37	0.40	0.05	0.01	1.99	1.5	4.4	3.45	48
Sub surface mean			4.0	4.8	-0.91	3.09	0.74	4.33	1.50	0.45	0.04	0.04	1.69	1.3	4.3	2.95	76

(1.13-1.4 g kg^{-1}) is rated medium in the soils while available P is generally low except for moderate value of 17.16 mg kg^{-1} in the Old Netim surface soils. Exchangeable Ca (1.00-1.8 cmol kg^{-1}), Mg (0.30-0.60 cmol kg^{-1}), K (0.03-0.12 cmol kg^{-1}) and Na (0.01-0.05 cmol kg^{-1}) are low when compared with their threshold values of 5, 1 0.3 and 0.3 cmol kg^{-1} (Holland *et al.*, 1989) for the respective cations. This is an indication that the soils are leached and under advanced level of weathering. The rapid leaching of basic cations has been reported for soils developed from Granite-Gneiss in south western Nigeria (Amusan, 2002). The Effective Cation Exchange Capacity (ECEC) (1.5-4.4 cmol kg^{-1}) and cation exchange capacity (CEC-NH_4OAc-pH7) (3.2-5.8 cmol kg^{-1}) are rated low as most values are less than 4.00 and 16 cmol kg^{-1}, respectively in most horizons (Table 3). With the mean percentage saturation of 48-76%, basic nutrients occur in available forms in soil solution for plant uptake in spite of the low cation reserves in the soils (Akpan-Idiok, 2012).

Mineralogical characteristics

Quartz: Quartz is one of the common minerals that occurs in highly weathered soils of humid tropical regions. It is an intrinsic part of sand sized grains and can persist in soil because it is chemically inert (Akpan-Idiok and Ukwang, 2012; Akpan-Idiok *et al.*, 2013). The X-ray diffraction analysis shows that quartz accounts for 81.26% in the clay fraction of the soils derived from Biotite-Hornblende-Gneiss (Fig. 2). The high percentage (81.26%) of quartz suggests that the soils are at advanced stage of weathering with low percentage (<10%) of weatherable minerals such as feldspars (Microcline) (Chikezie *et al.*, 2010; Miranda-Trevino and Coles, 2003; Akpan-Idiok and Ukwang, 2012). The findings are consistent with the earlier study by Wilson (1967) who reported quartz as a dominant mineral in clay fraction of soils derived from Biotite-Rich-Quartz-Gabbro in Aberdeen Shire in United Kingdom. Chemically, quartz mineral can hardly contribute to soil fertility or plant nutrition but its interaction with other soil elements improves structural stability, water permeability, biomass productivity, resistance to erosion, aeration among others (Akpan-Idiok and Ukwang, 2012). The X-ray diffractograms of the mineral are shown in Fig. 3.

Microcline: Microcline ($KAlSi_3O_8$) is one of the important igneous rock-forming tectosilicate minerals such as feldspars, biotite among others. Its formation arises from cooling of orthoclase and

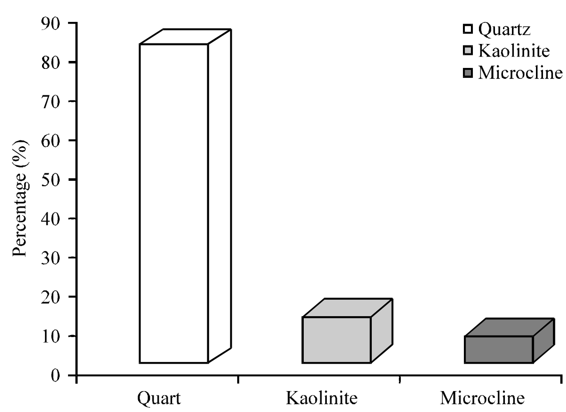

Fig. 2: Distribution of minerals in clay fraction of soils (depth 15-166 cm) derived from Biotite-Homblends-Gneiss in Akamkpa, Cross river state

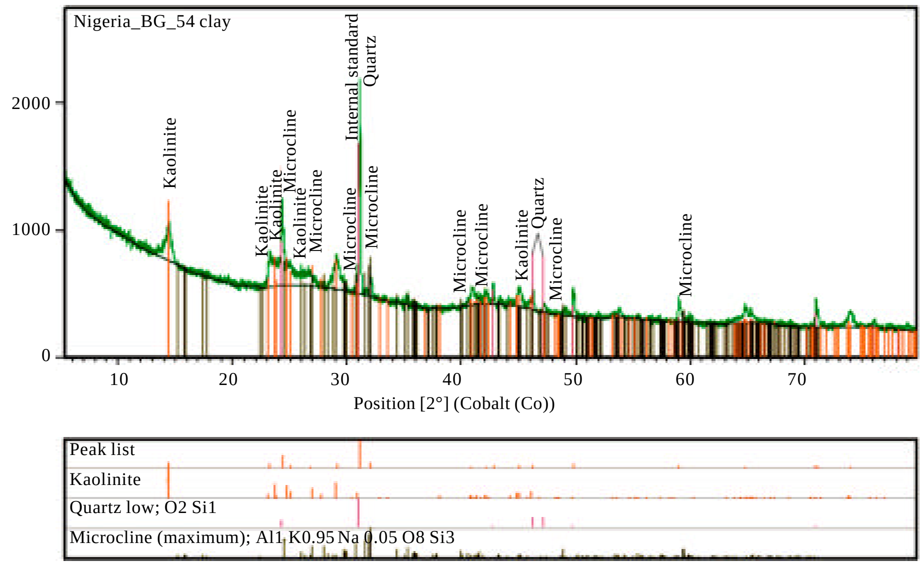

Fig. 3: X-ray diffractogramme of clay fractions of soils developed on Biotite-Hornblende-Gneiss in Akampka Local Government area, Cross River State, Nigeria

more stable at lower temperature than orthoclase; it can be transformed to sanidine as a polymorph of alkali feldspar under higher temperature. It is a common mineral in metamorphic regions such as Eastern Alps in Germany (Bernotat and Morteani, 1982). The X-ray diffraction data show microcline constitutes about 6.77% (Fig. 2) in the clay fraction of soils derived from Biotite-Hornblende-Gneiss of Akamkpa, Cross River State, Nigeria. Microcline is of agricultural importance because it releases the essential nutrient, potassium into soil solution for crop plant uptake. The x-ray diffractograms of the mineral are presented in Fig. 3.

Kaolinite: Kaolinite has been recognized as a natural weathering product of biotite (Fordham, 1990) and Hornblende through a process of a dissolution-reprecipitation under humid tropical conditions (Velbel, 1989). The X-ray diffraction data show that kaolinite constitutes about 11.97% in the soils formed on Biotite-Hornblende-Gneiss in Akamkpa, Cross River State, Nigeria (Fig. 2). In the present study, kaolinite is one of the end products of weathering sequence of Biotite-Hornblende-Gneiss. The implications of the identified minerals, quartz and kaolinite suggest that the soils have undergone advanced stage of weathering with low activity clay, low charged surface area, low cation reserve and low fertility status (Akpan-Idiok and Ukwang, 2012). Figure 3 presents the x-ray diffractogramms of the minerals.

Classification: On the basis of morphological, physicochemical and mineralogical properties, the soils are classified under USDA Soil Taxonomy and FAO-World Reference Base for Soil Resources. The three profiles have low base saturation (by summation of cations) of less than 35%, kandic horizons (ECEC<12 cmol kg^{-1} of clay or less), umbric epipedon (value of 3 or less, moist) for Nsan and Old Netim and Ochric epipedon (value of 4 or more, moist) for Okomita and are therefore fit into the Ultisols order of the USDA Soil Taxonomy (Soil Survey Staff, 2010). The profiles have udic soil moisture regime and brown/brownish yellow argillic or kandic horizons in humid tropical conditions and are therefore, fit into the suborder of Udults. With kandic horizon, increase in clay content with depth of 150 cm from the mineral soil surface and irregular decrease of organic carbon with depth, the three profiles are placed in the great group kandiudults and typic kandiudults at the subgroup level. With less than 35% of clay and rock fragments as well as mixed mineralogy of quartz, kaolinite and microcline (K-feldspars), the soils qualify as loamy skeletal, mixed isohyperthermic typic kandiudults.

CONCLUSION

The investigation highlights the morphological, physicochemical and mineralogical properties of soils derived from Biotite-Hornblende-Gneiss in Akamkpa, Cross River State, Nigiera. The soils are well-developed, well-drained with coarse textured materials. The soils are characterized by very strongly acid in reaction, moderate organic carbon and nitrogen but low in available P and basic cations. The soils have mixed mineralogy of quartz, kaolinite and microcline (K-feldspars) under the same geologic and climatic conditions and undergoing the same rate of weathering. Therefore, the soil fertility management should focus on reducing the leaching of basic nutrients from the soils through mulching, planting of cover crops, crop rotation, adoption of zero tillage as well as application of liming materials to reduce/ameliorate the strong acidity of the soils.

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