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MORPHOLOGICAL, PHYSICOCHEMICAL AND MINERALOGICAL PROPERTIES OF SOILS DEVELOPED FROM BASALT ATIKOM, CROSS RIVER STATE, NIGERIA

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ABSTRACT

Soils developed from basalt were studied along a toposequenceof a deeply excavated basaltic quarry site at Ikom, Cross River State, Nigeria. The soils were very deep and occupy gently sloping plains of 0 – 8% gradients. Each pedon examined, had four distinct layers, the Ap, BA, Bt and Crtg horizons. The Ap horizons have dark reddish grey (5YR 4/2) to dark reddish brown (5YR 3/4) colours while the Bt horizons have mostly red (2.5 YR 4/6) colour with friable consistence. The Crtg horizons have dominantly grey (2.5Y 5/0) to greyish brown (2.5Y 5/2) matrix colours and contain many, medium, distinct dark grey (2.5YR 4/0) to weak red (2.5YR 4/2) mottles and many rotten basaltic fragments. Soil texture was uniformly clay with Bt horizon values of 61 to 67% clay. The soils were well aerated with macroporosity, which ranged from 4.8 to 18.8% in all the horizons studied. The soils were extremely to strongly acid in reaction with pH (H2O) ranging from 4.4 to 5.2 in all horizons of the three pedons examined. Organic carbon content was low with values which varied from 6.22 to 8.78 gkg^{-1}in the Ap horizons. Total N, available P, and exchangeable cations were all low to very low indicating that the soils are impoverished of plant nutrient elements. Cation exchange capacity (pH 7.0) values were low to very low with values ranging from 4.0 to 7.10 $cmolkg^{-1}$ with a mean of 4.8 cmolkg-1in all the three pedons studied. X-ray diffraction studies of the whole soils indicated that kaolinite constitute 71 to 78% of the mineralogy of the soils while only very resistant minerals such as quartz, anatase (TiO2), hematite (Fe2O3) and goethite (αFeOOH) were detected in the soils. The properties of the soilsindicate that they are highly leached, highly weathered, nutrient-poor, sesquioxidicand kaolinitictropical soils.

Keywords: Basaltic soil, humid tropics, morphology, physicochemical properties and mineralogy

INTRODUCTION

Soils formed on basalticparent material usually have tremendous agricultural potential (Kparmwang, 1993). This is because according to Hatch et al. (1972), basalts are composed predominantly of ferromagnesian minerals, mainly plagioclase feldspars and pyroxenes. These minerals readily decompose into clay and free iron oxides releasing a lot of bases in the process (Singer, 1966). The bases so released, make the basaltic soils initially quite fertile.

Basaltic soils are, however, prone to two main problems that can limit their agricultural potentialities. First, under high rainfall conditions such as we have in Ikom area (MAR = 2700mm), the bases can easily be lost through leaching. The second problem that basaltic soils are prone to is plinthizationdue to the preponderanceof free iron and aluminium oxides released during weathering. Plinthization is said to be formed by alternating wetting and drying conditions, a condition that is quite pronounced in the Ikom area of Nigeria. Althoughplinthite is initially formed below the soil surface and remains soft, it is often exposed to the surface through erosion and hardens irreversibility to ironpan making the land quite unusable for agriculture (Sivarajasinghamet al., 1962; Esu, 2010).

In order to have adequateknowledge of the properties and thus adequately manage basaltic soils, anywhere they occur, it is necessary to possess a full understanding of the morphological, physical, chemical and mineralogical properties of the soils. According to Eshett (1987), early studies of the environment and soils of eastern Nigeria by Jungerius (1964) and Floyd (1969) identified the red clayey soils derived from tertiarybasalt around Ikom and Obubra areas of Cross River State. The soils were described as the best soil type in the region (Jungerius, 1964) and has been used over the years for large plantations of cocoa (Theobromacacoa) and Gmelina(Gmelinaarborea) as well as for the cultivation of food crops such as yams, cassava, maize and pineapple. Regrettably, all the documented studies of the soils by Eshett (1987), Egbe (1972), Wessel (1966) and Jungerius (1964) have involved only limited physicochemical and morphological properties, while no single mineralogical characterization of the soils have been carried out.

The objective of the present study was therefore, to truly extend the earlier limited contributions by various soil scientists to include a comprehensive characteristics of the morphological, physicochemical and mineralogical properties of very deep pedonsof basaltic soils exposed along a toposequence at a quarry site in Ikom.

MATERIALS AND METHODS

StudyArea

The project site was located within the CCECC Basalt Quarry site in Ikom, which lies within longitude 08o 43’ E and latitude 06o 13’ N (Figure 1) at an elevation of 20m above mean sea level. The area consists of gently sloping plains of 0 – 4% gradient. It has an udic soil moisture regime with a mean total annual rainfall of 2700mm and an isohyperthermic soil temperature regime with mean annual temperature minimum of 25oC and maximum of 32oC (Table 1). Ikom lies within the typical tropical rainforest zone of Nigeria.

FieldStudies

Three soil profile pits were dug at the summit, backslope and footslope positions along a gently slopingtoposequence lying adjacent to a very deeply excavated basalt quarry site. The morphological properties of the soils were described following the procedure specified in the “Field book for describing and sampling soils, version 3.0” (Schoenenbergeretal., 2012). Undisturbed core samples were also collected in duplicates from the genetic horizons of representative profiles for bulk density, water content, total porosity and macroporosity determinations.

LaboratoryStudies

Soil samples collected from the field were air-dried, ground and sieved to remove mate-

Table 1: Monthly and total annual rainfall and other climatic data for Ikom in 2013

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean maximum temp. (°C)	34.3	34.7	34.1	33.1	32.2	30.8	29.1	28.4	29.9	31.1	32.1	31.5
Mean minimum temp. (°C)	21.5	22.8	23.6	23.3	23.2	22.5	22.5	22.4	22.6	22.5	22.7	22.2
Mean relative humidity (%)	72	71	76	78	80	92	87	87	85	83	80	82
Mean sunshine (hrs)	5.5	5.6	5.2	5.2	6.0	5.5	3.2	22.6	3.8	6.4	6.6	
Monthly total rainfall (mm)	23.6	63.5	76.1	216.4	303.6	524.4	207.7	363.0	367.2	393.0	77.6	81.1
Mean wind velocity (knots)	12.65	23.41	24.63	20.40	17.47	07.84	06.75	11.82	11.85	12.75	11.31	

rials greater than 2mm fraction. The samples were then analyzed for their physical, chemical and fertility properties. Particle size distribution was determined by the hydrometer method using sodium hexametaphosphate (calgon) as the dispersant (Gee and Bauder, 1986). Bulk density was determined by the undisturbed core method of Blake and Hartge (1986). Soil pH was determined in a 1:1 soil/water and 1NKCl ratios with a glass electrode pH meter. Exchangeable acidity was determined by the 1NKCl method, while exchangeable bases (Ca, Mg, K and Na) were determined using NH4OAc saturation method and the Ca and Mg in solution were determined using AAS, while K and Na were determined on a Flame Photometer (IITA, 1979). Organic carbon was determined by the Walkley and Black dichromate wet oxidation method (Nelson and Sommers, 1982). Total nitrogen was determined by the micro-Kjeldahl technique (Bremner and Mulvaney, 1982). Cation exchange capacity (CEC) was determined by the 1N NH4OAC pH 7.0 saturation method and the effective CEC by summation of exchangeable bases and exchangeable Al3+ (Soil Survey Laboratory Staff, 2004). Percentage base saturation was calculated as the sum of all base forming cations divided by CEC and multiplied by 100. Available forms of micronutrient elements (Cu, Mn, Zn and Fe) were determined by the diethylenetriamine-penta-acetic acid (DTPA) extraction method (Udoetal., 2009).

The mineralogical studies were carried out in the Geodata Services Limited Laboratory in Ghana. Two samples, one from the Bt horizon and the other from the Crtg horizons of Pedon 1 were subjected to X-ray diffraction analysis. The samples were prepared for XRD analysis using a back loading preparation method, which involved the addition of 10% internal stand-

Table 2: Morphological properties of the pedons studied[+]

Horizon	Depth (cm)	Munsell colour (moist)	Texture	Mottling	Structure	Consistence (moist)	Boundary	Other features
Pedon 1: On the Summit Position								
Ap	0 – 11	5YR 4/2	C	-	1f &msbk	vfr	cs	Many medium and coarse roots; common ant holes and earthworm casts
BA	11 – 90	2.5 YR 4/4	C	-	2msbk	mfr	gw	Few thin clay cutans on ped faces; common medium pores; common medium roots; few ant holes
Bt1	90 – 210	2.5 YR 4/6	C	-	2m &csbk	mfr to mfi	gi	Medium thick clay cutans on ped/faces; many medium pores; common medium roots; common ant holes.
Bt2	210 – 315	2.5 YR 4/6	C	-	2m &csbk	mfr to mfi	as	Medium moderate thick clay cutans on ped faces; many medium pores; common medium roots; common ant holes.
Crtg	315 – 390	2.5Y 5/0	vgr-c	m2d; 2.5YR 4/0	2msbk	mfi	-	Common moderately tick cutans on faces; many rotten basaltic frgrants; few medium and coarse roots.
Pedon 2: On the Backslope Position								
Ap	0 – 20	7.5YR 3/2	C	-	2msbk	mfr	cs	Common fine pores; many very fine and medium roots; many worm casts and ant holes; many charcoal.
BA	20 – 82	2.5YR 4/4	C	-	2m &csbk	mfr to mfi	gs	Common moderately thick clay cutans on ped faces; many fine pores; many very fine coarse roots; many ant holes.
Bt	82 – 158	2.5YR 4/6	C	-	2m &csbk	mfr to mfi	aw	Continuous moderately thick clay cutans on ped faces. Many fine medium roots; many large ant holes; few pottery pieces.
Crtg	158 – 243	2.5Y 5/0	vgr-c	m2d; 2.5YR 4/0	smsbk	-	-	Many medium weathered basaltic fragrants; many thick clay cutans on ped faces.
Pedon 3: On footslope position								
Ap	0 – 7	5YR 3/4	C	-	1msbk	mfr	cs	Many very fine medium roots
BA	7 – 23	2.5YR 4/4	C	-	2mcr &sbk	mfr	Cs	Many fine roots
Bt	23 – 52	2.5YR 4/6	C	-	wm&csbk	fr	Aw	Many fine roots; common ant holes
Crtg	52 – 190	2.5Y 5/1	vgr-c	m2d; 2.5Y 4/2	2msbk	mfi	-	Few fine roots.

+ Symbols used according to abbreviations given in "Soil Survey Manual", USDA Handbook 18, p 139 – 140, 1951 as modified in Schoeneberger et al., 2012. "Fieldbook for describing and sampling soils", version 3.0 – profile/pedon description.

ard (flourite) and the sample micronized. The micronized material was then analysed by XRD utilizing a PAN Analytical Empyrean Diffractometer with pixceldetector and fixed slits with Fe filtered Co-k∝ radiation. The phases were identified using X'pertHighscore Plus software. The XRD analysis was used to determine the crystalline mineral phases present in the sample. The abundance of each phase (weight %) was determined by the Rietveld Refinement method.

RESULTS AND DISCUSSION

MorphologicalProperties

Table 2 presents the morphological properties of the three pedons studied on the summit, backslope and footslope positions along a toposequence. The soils occur on gently sloping plains of 0 to 4% slopes at the summit,and gradually merge into gradients of 4 – 8% towards to the backslope to footslope landscape positions. The footslope also grades into existing stream valleys without any pronounced toeslope. The soils have very deep solum with the Crtg horizons (saprolite) occurring at 315cm, 160cm and 50cm at the summit, backslope and footslope positions respectively. Solid basalt rock which was being quarried often occurred within 1000cm to 400cm from the summit to the footslope position.

A typical soil profile representing the soils consisted of well drained, dark reddish brown (5YR 3/4) to dark brown (7.5YR 3/2) clay to reddish brown (2.5YR 4/4) to mostly red (2.5YR 4/6) clay subsoils. The C horizons were strongly gleyed (2.5Y 5/0) and dark grey (2.5Y 4/0) matrix with many medium distinct dark grey (2.5YR 4/0) to weak red (2.5YR 4/2) mottles. The soils had weak to moderate medium subangular blocky structure and generally had friable moist consistence especially within the soil solum (A and B horizons). Horizon boundary characteristics were clear smooth from the Ap to the transitional BA horizons, but gradual wavyand irregular within the Bt horizons and abrupt smooth to the Crtg horizons particularly because of the higher organic matter content in the Ap horizons and the abrupt change in colour from red in the Bt to grey in the Crtg horizons. Clay and Fe-oxyhydroxidecutans were quite obvious on ped faces and in pores, an indication that eluviation-illuviation process was active in the soils. Common ant holes and worm casts were also within the soil solum, indicating that faunal pedoturbation is also an active process in the soils.

Table 3: Physical properties of the pedons studied

Horizon	Depth (cm)	Bulk density (Mgm^{-3})	Gravimetric water (ew)g/g	Volumetric water (ev)g/g	Total porosity (f) %	Macroporosity (fa) %	% Gravel	Particle size distribution (%)			Soil texture
								Sand	Silt	Clay	
Pedon 1: On the Summit Position											
Ap	0 – 11	0.88	0.55	0.48	66.80	18.80	3.70	37	16	47	Clay
BA	11 – 90	1.02	0.52	0.53	61.50	8.50	5.70	29	8	63	Clay
Bt1	90 – 210	1.00	0.54	0.54	62.30	8.30	4.10	27	6	67	Clay
Bt2	20 – 315	1.07	0.50	0.54	59.30	5.60	36.20	33	4	63	Clay
Crtg	315 – 390	1.29	0.40	0.52	51.30	(0.70)		31	10	59	Clay
Pedon 2: On the backslope position											
Ap	0 – 20	0.92	0.57	0.53	65.30	12.80	5.50	45	12	43	Clay
BA	20 – 82	1.05	0.51	0.54	60.40	6.48	20.60	41	14	45	Clay
Bt	82 – 158	0.97	0.52	0.50	63.40	13.40	10.40	29	8	63	Clay
Crtg	158 – 243	1.18	0.40	0.47	55.50	8.67	58.30	37	4	59	Clay
Pedon 3: On Footslope Position											
Ap	0 – 7	1.13	0.43	0.49	57.40	8.36	7.00	45	14	41	Clay
BA	7 – 23	1.00	0.50	0.50	62.30	12.36	14.70	25	24	51	Clay
Bt	23 – 52	1.07	0.51	0.55	59.60	4.82	17.10	29	10	61	Clay
Crtg	52 – 190	0.93	0.57	0.53	64.90	12.00	19.10	31	8	61	Clay

Physicochemical Properties of the Soils

Table 3 contains the physical properties of the soils. Particle-size distribution analysis indicates that the soils have uniformly clay texture from the Ap to the Crtg horizons. However, clay content increased from about 41 to 47% in the Ap to 61 to 67% in the Bt horizons and then decreased slightly towards the Crtg horizons; indicating the exsistence of a definite clay bulge which suggests the occurrence of ar-

Table 4: Chemical properties of the pedons studied

Horizon	Depth (cm)	PH H₂O	PH KCl	ΔpH	OC(%)	N (%)	C/N	Avail P (mg/kg)	Ca	Mg	K	Na	TEB	Exch. Al	CEC (pH 7.0) (cmolkg^{-1})	ECEC	CEC/Clay (pH 7.0)	CEC/Clay (ECEC)	Base saturation (%) pH 7.0	Base saturation (%) ECEC
Pedon 1: On the summit position																				
Ap	0 – 11	5.00	4.30	-0.7	0.67	0.10	6.70	2.63	2.40	0.80	0.19	0.18	3.57	1.00	5.60	4.57	11.90	9.7	64	78
BA	11 – 90	4.90	4.10	0.8	0.37	0.08	4.63	2.45	1.80	0.60	0.08	0.09	2.57	1.60	4.30	4.14	6.80	6.6	60	62
Bt1	90 – 210	4.80	4.10	-0.7	0.37	0.04	9.25	2.63	1.80	0.50	0.07	0.08	2.45	1.80	5.80	4.25	8.65	6.3	42	58
BT2	20 – 315	5.00	4.00	-1.0	0.38	0.04	9.50	2.45	1.40	0.45	0.08	0.17	2.1	2.40	5.80	4.50	9.20	7.1	36	47
Crtg	315 – 390	5.20	4.40	-0.8	0.21	0.07	3.00	4.03	1.60	0.40	0.07	0.17	2.24	1.00	4.50	3.24	7.60	5.5	50	69
Pedon 2: On the backslope position																				
Ap	0 – 20	4.80	4.20	-0.5	0.88	0.13	6.80	4.2	2.40	0.70	0.09	0.10	3.29	1.00	5.80	4.29	13.50	9.9	57	77
BA	20 – 82	4.40	3.90	-0.9	0.61	0.1	6.10	4.03	2.20	0.60	0.07	0.12	2.59	2.00	7.10	4.90	15.80	10.9	36	53
Bt	82 – 158	4.90	4.00	-0.9	0.97	0.06	16.20	4.38	1.20	0.40	0.07	0.18	1.65	1.80	4.30	3.65	6.8	5.8	38	45
Crtg	158 – 243	5.20	4.30	-0.9	0.32	0.03	10.70	3.85	1.20	0.35	0.08	0.15	1.58	1.15	4.00	2.78	6.8	4.7	36	57
Pedon 3: On footslope position																				
Ap	0 – 7	4.90	4.10	-0.9	0.62	0.13	4.77	4.38	2.00	0.65	0.11	0.10	2.66	1.40	5.10	4.26	12.40	10.4	52	62
BA	7 – 23	4.90	4.00	-0.9	0.42	0.13	3.23	5.08	1.80	0.50	0.08	0.10	2.58	2.00	5.50	4.48	10.8	8.8	47	57
Bt	23 – 52	4.90	4.00	-0.9	0.40	0.06	6.67	4.03	1.60	0.55	0.08	0.12	2.55	2.00	6.20	4.35	10.20	7.4	41	59
Crtg	52 – 190	5.00	4.10	-0.9	0.21	0.04	5.25	4.2	1.00	0.30	0.06	0.04	1.40	1.80	5.40	3.20	8.90	5.2	26	44

gillic or kandicdiagnostic horizon in the soils (Fig.3). Silt content was the lowest of the three size-fractions, with the lowest values of 4 – 10% in the Bt horizons. This low silt content is completely at variance with the results obtained for the same soils by Eshett (1987), but compares favourably with values obtained for basaltic soils in the Nigerian savanna region by Kparmwang (1993) and for basalt derived soils in Northern Ireland (McAleese and McConaghy, 1957). Basaltic soils especially in regions with high rainfall and temperature regimes often weather readily to the clay fraction but are strongly aggregated because of high Fe-oxide content and so improper dispersion during analysis could result in grossly exaggerated values of silt and sand separates such as those obtained by Eshett (1987). The sand fraction varied conversely with the clay fraction, with values varying from 37 – 45% in the Ap horizons to 27 – 33% in the Bt horizons. The Crtg horizons were very gravelly to cobblydue to the abundance of weathered basalt fragments.

Bulk density was generally low with values ranging from 0.88 – 1.29 Mgm-3 in all the horizons of the three pedons studied. These low value is an indication that the soils are porous and non-compacted as corroborated by the high total porosity which ranged from 51.3 – 66.8%. However, air-filled porosity decreasedsharply towards the strongly gleyedCrtg horizons, but averaged a very satisfactory value of 13.32% in the Ap horizons. Thus, the soils are well aerated within the soil solum.

Chemical and Fertility Properties of the Soils

The chemical and fertility properties of the soils are presented in Tables 4 and 5. Soil pH (H20) varied from 4.8 to 5.2 while pH (KCl) varied from 3.9 to 4.4 throughout all the horizons in the three pedons studied and indicates that the soil profiles are uniformly, very strongly to strongly acid in reaction (Schoenebergeretal., 2012). Exchangeable Al3+also varied from 1.0 to 2.4 cmolkg-1, an indication that exchangeable Al3+ is a major contributor to the acidity of the soils.

Exchangeable Ca, Mg and K are low but are within the threshold of critical limits for deficiencies and likely response to fertilization (Habyetal., 1990 and Obigbesan, 2009). Also, Mg/K ratio varied from 4.2 to 8.5 and averaged 6.7 in the plough layer (Ap and BA horizons) of the soils. According to Lombin (1974), deficiency of Mg in maize was observed in Southwestern Nigeria only when the Mg/K ratio fell below 2 and when exch. Mg2+ was below 0.28 cmolkg-1.Exchangeable Ca varied from 2.0 to2.4 cmolkg-1.Mg ranged from0.50 to 0.80 cmolkg-1 and exchangeable K varied from 0.08 to 0.19 cmolkg-1 within the plough layers of the pedons studied. These values represent moderate levels of the plant nutrients in the soils.

Organic carbon, total N, available P and cation exchange capacity were generally low to very low in the soils according to the ratings of Enwezoretal (1989), Sims (2002), Obigbesan (2009) and Esuetal. (2009). The soils would therefore require the application of liberal doses of N and P fertilizers to maintain adequate soil fertility. The application of dolomitic limestone would also increase soil pH, release fixed phosphorus and boost the levels of Ca and Mg in the soils.

Percentage base saturation by NH4OAc (pH 7.0) ranged from 36 to 64% and averaged 53% in the Ap and BA surface soil horizons but decreased sharply to a range of 36 – 42% with an average of 39 % in the Bt subsoil horizons. Similarly, the CEC per 100g of clay for the Bt horizons ranged from 6.8 to 10.2 cmolkg-1and averaged 8.7 cmolkg-1 (by NH4OAc pH 7.0 CEC) and ranged from 5.8 to 7.4 cmolkg-1 with a mean of 6.7 cmolkg-1 by ECEC. These values all indicate that the soils are highly weathered and highly leached to the oxic state as the values are below the 16 cmolkg-1 and 12 cmolkg-1respectively for the identification of oxic or kandic diagnostic subsurface horizons in soils (Soil Survey Staff, 1999).

Table 5: Available micronutrient elements in the soils

Horizon	Depth (cm)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
Pedon 1: On the summit position					
Ap	0 – 11	2.97	4.74	35.54	26.66
BA	11 – 90	1.09	5.73	20.94	34.22
Bt1	90 – 210	0.85	10.56	12.43	38.17
BT2	20 – 315	0.19	4.23	8.91	32.05
Crtg	315 – 390	0.44	4.66	5.51	41.37
Pedon 2: On the backslope position					
Ap	0 – 20	2.92	4.5	33.11	24.67
BA	20 – 82	3.29	5.39	20.37	29.98
Bt	82 – 158	0.94	4.65	8.54	37.83
Crtg	158 – 243	1.45	4.26	8.27	52.97
Pedon 3: On footslope position					
Ap	0 – 7	4.27	6.46	24.17	35.79
BA	7 – 23	2.81	4.86	12.56	32.1
Bt	23 – 52	1.45	5.78	8.93	35.24
Crtg	52 – 190	1.23	5.35	44.16	41.14

Surprisingly, despite the highly leached and highly weathered conditions of the soils, they appear tocontain sufficient levels of micronutrient Cu, Zn, Mn and Fe (Table 5). All the values obtained for each of the DTPA extractable micronutrients are above the critical limits for their responses to fertilization (Sims and Johnson, 1991; Esuetal., 2009). Cottenieetal. (1981) reported that Nigerian soils derived from basic rocks such as basalt and amphiboles are richer in micronutrients than those derived from acid granites and sandstones.

Mineralogical Properties of the Soils

X-ray diffraction analysis of whole soil within the Bt and Crtg horizons reveal that kaolinite, quartz, goethite, anatase and hematite in that order, are the dominant crystalline minerals present in the soils (Figure 2). Kaolinite accounted for 71 to 78%, while quartz accounted for 7.95 to 15.52% and goethite accounted for 6.3 to 8.28% in both the Bt and Crtg horizons. The highly resistant minerals Anatase, accounted for 2.47 to 2.77% in the soils (Table 6). According to the "stability series" of the resistance of minerals to weathering proposed by Goldrich (1938) and Jackson etal., (1984), kaolinite, hematite, goethite and anatase represent the 10th, 12th and 13th most resistant minerals in soils in a series ranked from 1 – 13. This means that, the basaltic soils of Ikom are so highly weathered to the extent that they no longer possess any further weathering potential. They have indeed, reached the oxic state of weathering.

Table 6: Whole soil mineralogy of the soils

Horizon/Minerals	Formula	% mass
Bt-Horizon		
Minerals		
Quartz	SiO_2	15.52
Kaolinite	$Al_2SiO_5 (OH)_4$	71
Anatase	Tio_2	4.4
Goethite	FeO.OH	6.3
Hematite	Fe_2O_3	2.77
Crtg Horizon		
Quartz	SiO_2	7.95
Kaolinite	$Al_2Si_2O_5' (OH)_4$	77.7
Anatase	Tio_2	3.6
Goethite	FeO.OH	8.28
Hematite	Fe_2O_3	2.47

CONCLUSION

The basaltic soils of Ikom occur within the tropical rain forest zone of Cross River State, Nigeria with total annual rainfall of 2700mm, mean annual temperature of 28oC and relative humidity of 82%. The soils, therefore, have udic soil moisture and isohyperthermic soil temperature regimes. The soils lie on gently sloping plains of 0 – 8% gradients from the summit to the toeslope of the landscape. The soils are very deep with clayey, very fine particle-size class and are reddish in colour. They also have well definedkandic horizons with oxic properties and are well drained with friable consistence.

Chemically, they are very strongly acid in reaction, low to moderate in exchangeable bases, but deficient in total N and available P. They are however, quite sufficient in micronutrient elements, especially Cu, Zn, Mn and Fe. X-ray diffraction analysis indicates that the dominant minerals in the soils are mainly kaolinite, quartz, hematite, goethite and the titanium oxide, anatase. The dominance of these highly resistant minerals in the soils indicate that the soils are highly weathered. The most dominant soil-forming process in the soils appear to be leaching, eluviation-illuviation, laterization,braunification and faunal pedoturbation. Soil weathering appears to have attained the oxic state to the extent that the soils virtually have zero weathering potential.

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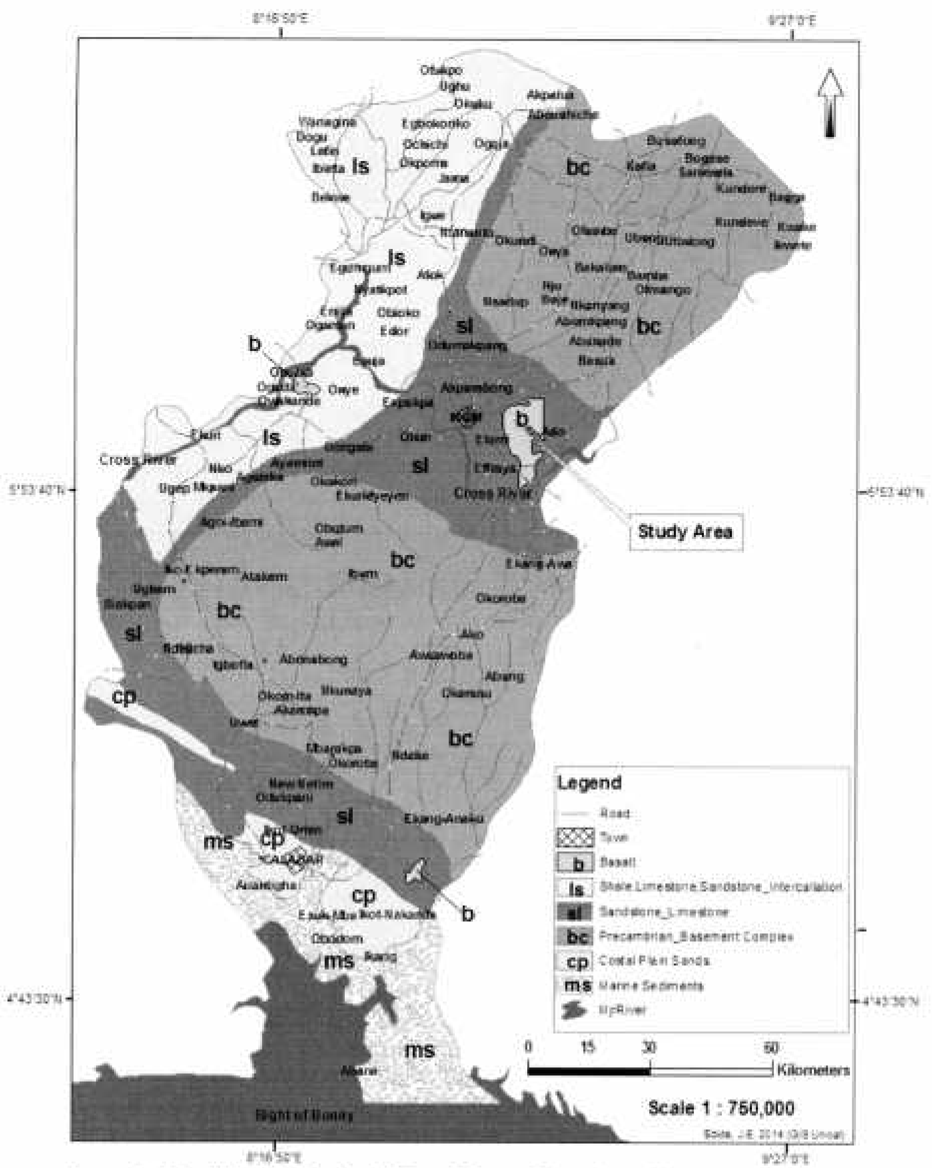

Figure 1: Simplified Geological Map of Cross River State Showing Location of Study Area at Ikom

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