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Weathering Status and Some Pedogenic Activities of Soils Formed Over Falsebedded Sandstone In Southeasthern Nigeria

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Abstract

The study investigated weathering status and some pedogenic activities in soils formed over falsebedded sandstone in Imo State Nigeria. Three profile pits were sunk in three locations whose soils are derived from falsebedded sandstone. The profile pits were described in line with the FAO guidelines. Soil samples were prepared before laboratory tests. Silt-clay ratios indicated that Okigwe soils were younger (Si/Cl=0.9 to 2.3) than Lekwesi (Si/Cl= 0.3-1.2) , and Leru (Si/Cl =0.3 to 1.2) soils. Silica content in Okigwe pedons (8.16 to 19.12%) was higher than the values obtained at Lekwesi (9.92 to 16.26%) and Leru (6.32 to 8.84%). Silica-sesquioxides ratios were higher in Okigwe soil (1.34 to 1.85) compared with Lekwesi (0.36 to 0.44) and Leru (0.23 to 0.42). Potassium as index of weathering indicated that Okigwe soils were younger (1.32 to 1.55%) than Lekwesi (0.40 to0.62 %) and Leru (0.38 to 0.46%).Soils Silica- alumina ratios were higher in Okigwe (2.46 to 3.55) than Lekwesi (0.63 to 0.83%) and Leru (0.43 to 0.95). It was concluded that silication was the predominant pedogenic process in Okigwe while desilication has reached advanced stage in Lekwesi and Leru soils. The soils were classified as Inceptic Hapludult (Okigwe), Typic Paleudult (Lekwesi) and Typic Rhodudults (Leru).

Keywords: Weathering ,status, sandstone mineralogy

1.0 Introduction

Most tropical soils are highly to extremely weathered, implying that the crystal lattice structure of feldspars and other aluminosiilicates have been broken down to form kaolinites, oxides and hydroxides of aluminum. An increase in the concentration of organically bound, crystalline and poorly crystalline iron oxide in soils invariably corresponds with increased in situ weathering (Buol *et al.,* 1997), and its quantity in soils additionally provides an estimate of the degree of soil development since it represents total pedogenic iron (Birkeland, 1999). Sometimes, iron - clay ratios are used to determine the level of association between pedogenic iron and clay fraction (Rebertus and Buol, 1985) in boulder top soils. Oxalate extractable iron is a measure of poorly crystalline and organically bound iron in the soil (Parfitt and Childs, 1988), while pedogenic inorganic iron (iron sequestered in crystalline iron oxide) is estimated by the difference between the total pedogenic iron and organically bound iron (Birkeland, 1999). Laterization is a major pedogenic activity of highly weathered tropical soils, leading to the formation of laterite (ironstone). Laterite is formed by concentration of sesquioxides which are further oxidized to give indurated material (FAO, 1998) which makes digging difficult (Yakubu, 2006). Degree of weathering of soil can be estimated using silt- clay ratio (Van Wambeke, 1962), sesquioxide ratios (Sombroek and Zonneveld, 1971) and total potassium. In addition, ratios of sesquioxides provide information on the crystalline and amorphous components of clay fraction as values higher than 3.0 indicated predominance of montmorillonite, 2.0 - 3.0 show presence of both montmorillonite, illite and kaolinite, 1.6 – 2.0 indicate predominance of kaolinite and below 1.6 defines a good presence of gibbsite or aluminum oxides (Sombroek and Zonneveld, 1971). Buol *et al.(*2003), observed a predominance of kaolinte in acidic soils.However, Dixon(1989) reported similarly findings in moderately weathered soils.

Falsebedded sandstone (Ajalli formation) is a major lithologic material from which agricultural soils are derived in southeastern Nigeria.The body of the Falsebedded sandstone is thick,friable and poorly

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sorted; and sometimes white in colour (Orajaka,1975). This lithological material is exposed along the Ajalli river as well as at Nkpologu in the Nsukka area. A substantial volume of soils formed over falsebedded sandstone is destroyed in search of stones used in engineering and architectural ventures while these soils are of immense agricultural importance although characterized by an abundance of gravels and concretionary nodules. This study investigated weathering status and predominate pedogenetic activities in the study site.

2.0 Materials and Methods.

2.1 Study Area

The study was conducted in three selected hilly locations of Okigwe, Lekwesi and Leru situated between Latitudes $5^0 56^1 35^{11}$, $6^0 01^1 16^{11}$ and $5^0 55^1 27^{11}$ North and Longitudes $7^0 44^1 06^{11}$, $7^0 38^1 11^{11}$ and $7^0 40^1 42^{11}$ East. The soils were derived from Falsebedded Sandstone (Ajalli Formation). The study area lies within the humid tropics with a mean annual rainfall of about 1800 mm. Mean annual temperature ranges from 27^0C (min.) to 31^0C (max.). The soils were gravelly and found on gentle, undulating to steep slopes. Less dense rainforest characterized the vegetal type. The vegetation is dominated by shrubs and grasses with few trees interspersed in the area. The Ibu River with few tributaries and few springs govern the hydrology of the area. Socio economy is dominated by stone mining, quarrying and subsistence agriculture.

2.2 Field Studies

Geological maps assisted in indentifying the study and sampling sites, while Handheld Global Positioning System (GPS) Receiver was used to locate high points on which soil profile pits were dug. A soil profile pit was done on each point. These profile pits were described according to procedure of Schoeneberger *et al.,* (2002). Soil samples were collected based on horizon differentiation. Soil samples were air- dried and sieved using 2 mm sieve. Some particles were greater than 2 mm were weighed as gravel, and thereafter expressed as percentage of soil volume (Soil Survey Staff, 1996).

2.3 Laboratory Analysis

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Total aluminum (Al), potassium (K), iron (Fe) and silicon (Si) were estimated using the procedure of Liu, (2001). Fine earth samples (materials less than 2mm were examined with an x-ray diffractometer (Rigaku Miniflex type) and Ni-filtered Cu-Ka radiation generated at 40Kv and 30 mA. The XRD patterns ranging from 3-60^o(2ô) with a scanning speed of 20^o/min were recorded. The method of Brindley

Table 1.0.Soil Macromorphological Properties Under Moist Conditions.

Horizon	Depth (cm)	Colour matrix(moist)	Soil structure	Soil consistence	Roots	boundary
			Okigwe (Inceptic Hapludult)			
A	0-21	7.5YR 4/6	1fsbk	Fr	3co	C
Bt1	21-61	5yr 5/6	1csbk	Fr	1co	C
Bt2	61-150	2.5yr 4/6	1csbk	Fr	1fnr	G
BC	150-195	2.5yr 3/6	Om	Fr	-	-
			Lekwesi (Typic Paleudult)			
A	0-11	7.5yr 4/6	1fsbk	Fr	3co	C
E	11-33	7.5yr 5/6	1csbk	Fi	3fnr	A
Bt1	33-96	2,5yr 3/6	2csbk	Fi	1fnr	S
Bt2	96-170	2.5yr 4/6	2csbk	Fi	-	S
BC	170-200	2.5yr 3/6	OM	Fi	-	-
			Leru (Typic Rhodudult)			
A	0-25	7.5yr 4/6	1csbk	Lo	3co	C
AB	25-70	2.5yr 3/6	2csbk	Fr	2co	G
Bt1	70-99	2.5yr 4/6	3csbk	Fi	1fnr	S
Bt2	99-140	2.5yr 3/6	3csbk	Fi	1fnr	-

Structure: D=structureless, 1=weak, 2 = moderate, 3= strong, csbk = Coarse subangular blocky, m = massive.

Consistency: lo= loose, fr= friable, fi= firm,

Boundary: A=Abrupt, C= Clear, G = gradual, S = smooth.

Roots: 1= Few, 2 = moderate, 3= many, fnr= fine roots, co= coarse roots.

(1980) was used in the identification and determination of minerals based on differences in reflectance patterns from the air-dried samples. Bulk density was determined by core procedure (Grossman and Reinsch, 2002). Total carbon was determined by the method of Nelson and Sommers (1982). Cation exchange capacity was estimated in 1N NH_4OAc at a pH of 7.0 (Soil Survey Staff, 2003). Soil pH was determined using pH meter in a soil: solution ratio of 1:2.5 (Hendershot *et al.,* 1983).

3.0 Results and Discussion

Macro-morphology of soils is shown in Table 1. The soils were deep (>100 cm), well drained with topmost horizons indicating dark brown (7.5YR4/6) moist while deeper horizon were redder (2.5 YR3/6) moist. Brown colours of uppermost horizons indicated braunification while red colours showed ferrugination. Soils of Okigwe and Lekwesi had weak, fine subangular blocky structures at the epipedons (0-10cm). However, deeper horizons showed moderate to strong structures in all studied soils except Okigwe (150 - 195 cm depth) that was structurelesss and massive. Soils were friable in all horizons of Okigwe profile pit, while subsurface horizons in Lekwesi pedon showed firm consistence. Leru soil had loose consistence (0 - 25cm depth), friable consistence (25 - 70 cm depth) and a firm consistence in the argillic horizons (70 – 99 cm and 99 - 140 cm depths). There were many coarse roots in the A- horizons of the three soils while few fine roots were found in deeper horizons. However, many fine roots were observed in Bt_1 horizon of Lekwesi soil profile possibly due to abundant grass species associating with shrubs in the site. Strikingly, subangular blocky structures dominated throughout the three profile pits even at A- horizons. Foth, (1984) reported that subangular soil structures are characteristics of Bt (Argillic) horizons.

Particle size distribution(Table 2) indicated a dominance of sand in Okigwe soil(750-810 g kg^{-1}). Argillic horizons (21 – 150 cm) were weakly developed and silt- clay ratio indicated young soils (0.9 to 2.3). Of the three profiles soils of Lekwesi had the least sand content (380 – 780 g kg^{-1}), with silt –clay ratios ranging from 0.3 t0 1.2 thus showing advanced weathering. Similar findings were observed in Leru profile pit. Silt- clay ratios less than 1.2 , according to Van Wambeke, 1962) indicated high degree of weathering status.

Results of bulk density (Table 2) showed that it ranged from 1.21 to 1.55 Mg m^{-3} (Okigwe), 1.25 to 1.54 Mg m^{-3} (Lekwesi) and 1.19 to 1.50 Mg m^{-3} (Leru). Bulk density increased with depth in all the profile . Soil organic matter distribution indicated a decrease with depth in all the sites: 3.1 to 25 g kg^{-1} (Okigwe), 1.6 to 22.6 g kg^{-1} (Lekwesi) and 6.9 to 25 g kg^{-1} (Leru). Cation exchange capacity varied

Table 2. Some Physico – chemical Properties of Soils

Horizon	Depth(cm)	TS	Si	Cl	Si/Cl	BD (mg/m3)	OM g/kg	BS%	CEC cmol/kg	pH(water)
				Okigwe (Inceptic Hap;udult)						
A	0-21	810	90	100	0.9	1.21	25.0	45	9.5	5.8
Bt1	21-61	800	60	140	2.3	1.31	11.6	41	5.6	4.7
Bt2	61-150	750	100	150	1.5	1.37	5.7	39	8.2	5.1
BC	150-195	780	120	100	1.2	1.55	3.1	40	4.3	5.0
				Lekwesi (Typic Paleudult)						
A	0-11	780	120	100	1.2	1.25	22.6	30	7.2	5.5
E	11-33	750	70	170	0.4	1.29	10.2	26	5.8	5.0
Bt1	33-96	750	50	200	0.3	1.38	8.3	20	6.9	5.2
Bt2	96-176	380	270	350	0.9	1.48	3.8	19	5.2	5.1
C	170-200	450	220	330	0.7	1.54	1.6	17	4.4	4.9
				Leru (Typic Rhodudults)						
A	0-10	800	110	90	1.2	1.19	26.8	35	10.2	6.0
AB	10-70	790	90	120	0.8	1.26	11.4	28	7.1	5.1
Bt1	70-99	750	60	190	0.3	1.39	9.2	30	5.9	50
Bt2	99-140	700	90	210	0.4	1.50	6.9	16	5.5	5.2

Ts= Total sand, Si = silt, Cl = clay, Si/Cl = Silt-clay ratio, BD = bulk density, CEC= cation exchange capacity, B.S = base saturation.

among sites with highest value of 10 cmol kg^{-1} reported for 0-25 cm depth in Leru. Soils were slightly acidic using FDALR (1985) rankings. Soils of Lekwesi and Leru exhibited Ochric epipedons and well- defined argillic horizons as well as low base saturation . These attributes suggest that soils belong to the Ultisols of USDA Soil Taxonomy.

Total elemental composition and ratios in studied soils are shown on Table 3. The SiO_2 content ranged from 8.16 to 19.12 % (Okigwe), 9.92 to 16.26 % (Lekwesi), and 6.32 to 8.84 % (Leru). The Al_2O_3 values ranged from 2.6 to 7.76 % (Okigwe), 13.8 to 19.6 % (Lekwesi) and 7.8- 14.6 % (Leru)., while Fe_2O_3 ranged from 1.11 to 5.66 % (Okigwe), 11.96 to 17.82% (Lekwesi) and 11.34 to 12.36% (Leru). Potassium oxide composition varied from 1.32 to 1.55 % (Okigwe), 0.40 to 0.62% (Lekwesi) and 0.38 to 0.48 % (Leru). These results showed predominance of silica over sesquioxides in Okigwe pedon signifying less advanced weathering and a confirmation of higher silt- caly ratio relative to other studied soils. However, the sesquioxides (Al_2O_3 and Fe_2O_3) values were higher in Lekwesi and Leru soils, indicating advanced weathering status. The SiO_2/ Al_20_3 (silica/alumina) ratios were higher in Okigwe profile (2.46 to 3.55) when compared with values from Lekwesi (0.63 to 0.83) and Leru (0.43 to 0.95). On the other hand, Silica –sesquioxide ratios ($Si0_2/Al_2O_3 + Fe_20_3$) were higher in soils in Okigwe profile (1.34- 1.85) compared to 0.36 to 0.44 (Lekwesi) and 0.23 to 0.42 (Leru). Values of Silica –sesquioxide ratios suggest that the soils of Lekwesi and Leru are more advanced in weathering status than Okigwe soils, an indication that Okigwe soils have more mineral reserves than Lekwesi and Leru soils.. The ratio of silica –sesquioxide in Okigwe indicated a predominance of Kaolinite since Som-

Table 3: Total Elemental Composition And Ratios in Soils

Horizon	Depth(cm)	SiO_2	Al_2O_3	Fe_2O_3	K_2O	$SiO_2/Al_2O_3+Fe_2O_3$	$SiO_2+Al_2O_3$
		Okigwe (Inceptic Hapludult)					
A	0-21	8.16	3.3	1.11	1.55	1.85	2.47
Bt_1	21-61	19.12	7.76	2.84	1.32	1.80	2.46
Bt_2	61-150	14.80	4.8	5.66	1.38	1.41	3.0
BC	150-195	9.24	2.6	4.28	1.41	1.34	3.55
		Lekwesi (Typic Paleudult)					
A	0-11	9.92	13.8	13.62	0.62	0.36	0.71
E	11-33	11.62	18.2	12.32	0.44	0.38	0.63
Bt_1	33-96	12.18	18.8	11.96	0.40	0.40	0.64
Bt_2	96-170	16.26	19.6	17.82	0.48	0.44	0.83
BC	170-200	13.33	16.2	16.43	0.50	0.40	0.81
		Leru (Typic Rhodudults)					
A	0-25	6.32	14.6	12.36	0.48	0.23	0.43
AB	25-70	7.22	7.8	11.34	0.42	0.38	0.97
Bt_1	70-99	8.84	9.6	11.36	0.38	0.42	0.92
Bt_2	99-140	7.76	8.4	11.48	0.46	0.40	0.95

Table 4: Mineralogy of soils (2 mm separates) by X –ray diffraction.

Horizon	Depth (cm)	Kaolinite	Quartz	Feldspar
		Okigwe (Inceptic Hapludult)		
A	0-21	46	36	14
Bt_1	21-61	50	30	9
Bt_2	61-150	43	40	3
BC	150-155	36	56	-
		Lekwesi (Typic Paleudult)		
A	0-11	17	80	2
E	11-33	36	60	3
Bt_1	33-96	40	56	3
Bt_2	96-170	10	83	5
C	170-200	10	86	2
		Leru (Typic Rhodudults)		
A	0-25	20	66	10
AB	25-70	36	58	5
Bt_1	70-99	20	70	8
Bt_2	99-140	40	55	3

broek and Zonneveld (1971), postulated that values from 1.6 to 2.0 suggest abundance of kaolinite while below 1.6 is an indication of high content of gibbsite and aluminum oxides.

Mineralogy of soils showed a dominance of kaolinite in Okigwe soils and quartz in Lekwesi and Leru soils (see Table 4). Kaolinite ranged from 36 to 50 % (Okigwe), 10 to 40% (Lekwesi) and 20 to 40 % (Leru). Quartz values had a minimum of 30 % and a maximum of 56 % in Okigwe. In Lekwesi and Leru soils, quartz ranged from 56 to 86 % and 55 to 70 %, respectively. The dominance of kaolinite clays in the surface horizon(epipedon) in soils of Okigwe suggest formation of extremely stable soil aggregates since Foth, (1984) reported low plasticity in soils dominated by kaolinite. The relatively higher values of kaolinite than quartz and feldspar in Okigwe soils might have been favoured by acidic conditions (pH water = 4.7 – 5.8)(Buol *et al*.,2003). Futhermore,the high feldspar content of Okigwe soils may have resulted in the high values kaolinite associated with these soils since complete breakdown of feldspar result in the re-arrangement of the silicon – oxygen tetrahedra, into silica pentoxide sheets (Foth,1984).

4.0 Conclusions

The study revealed differences in weathering status of soils irrespective of similar lithological materials (Falsebedded sandstone). Soils at Okigwe were younger (Si/Cl=0.9 to 2.3) with predominance of silica (8.16 to 19.12 %) and higher silica – alumina ratios of 2.46 to 3.55 and silica- sesquioxide ratio of 1.34 to 1.85. Silication was a major pedogenic process in Okigwe while Lekwesi and Leru exhibited greater desilication. Quartz dominated the mineralogy of Lekwesi and Leru soils while kaolinte was common in soils of Okigwe.

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