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Genesis and Classification of Soils on a Toposequence Underlain by Mica Schist in Ife Area, Southwestern Nigeria

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Genesis and Classification of Soils on a Toposequence Underlain by Mica Schist in Ife Area, Southwestern Nigeria

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Abstract- The study was conducted to establish the morphological, physical and chemical properties of soils on a toposequence underlain by mica schist in Ife Area, identify the pedogenic processes that produced the soils and establish the taxonomic and fertility capability classes of the soils. The toposequence was delineated into five physiographic units and soil profile pits were established, described and sampled at each unit. The soil samples collected from each of the genetic horizon were subjected to routine analyses following the procedures in methods of soil analysis. Taxonomic and fertility capability classification of the soils were carried out.

The colour and texture of the soils change in response to changes in slope position and drainage condition along the toposequence. The soil's colour ranged from reddish brown to dusky red (5YR 3/2- 2.5YR 3/2) in the surface and yellowish red (5YR 4/8) to reddish yellow (7.5YR 6/6) in the subsoil at the higher position of the toposequence while it range from dark brown (7.5YR 4/2) to dusky red (2.5YR 3/2) in the surface and red (2.5YR 4/ 6) to reddish yellow (7.5YR 6/6) in the subsoil at the lower position. Texturally, the soils varied from sandy clay loam in the surface to sandy clay in the subsoil all through the pedons sampled. The soils were moderately acidic to neutral (pH 5.2 – 6.7) at the surface and strongly acidic to moderately acidic (pH 4.4 - 5.7) in the subsurface. They were characterized by low exchangeable bases which were in the order Ca > Mg > K > Na irrespective of slope position with low to moderate organic matter content. The soils were classified as Typic Kanhaplustults and Aquic Haplustults (USDA soil taxonomy) Plinthic Luvisols, Gleyic Luvisols and Eutric Luvisols (FAO-UNESCO). The agronomic constraints of the soils were acidic reactions, low nutrient reserve and gleying, hence dominant FCC unit of soils in the study area was SC *keh*.

The soils studied were highly-weathered, low in inherent fertility and with acidic solum. Therefore, sustainable use of the soils requires careful management to prevent rapid physical and chemical degradation.

Keywords: genesis, classification, toposequence, mica schist.

1. INTRODUCTION

Nigerian agriculture and indeed African agriculture has not succeeded in meeting the continuously changing needs of the citizenry (Chukwu *et al.*,

2013). Persistent food insecurity and failure of agriculture to supply adequate quantities of raw materials to industries are stark realities. These are attributed to many factors, among which is soil resource illiteracy (Wang *et al.*, 2001).

Researchers have identified poor knowledge of soil as a major problem hindering agricultural development in some parts of Nigeria (Chukwu *et al.*, 2013). This is not a surprise as similar observations had been made in most parts of Africa (Ololade *et al.*, 2010). Some of the reasons for this situation are related to lack of soil survey reports of most rural communities and Local Government Areas (LGAs) where food and fibre production take place. Further, the scales of most national soil surveys are so coarse (at reconnaissance level) that pedological information about rural communities where majority of the agricultural produce are coming from is virtually non-existent (Lawal *et al.*, 2010).

Soils vary considerably in their physical, chemical and mineralogical characteristics which are related to their geological history. The continued lack of required knowledge on the nutrient management as related to available pedological information of nutrient depleted soils are not only exacerbating soil degradation, but also jeopardizing agricultural sustainability in these regions (Ayoub, 1999; Sheldrick *et al.*, 2002). Similarly, in these communities, soils where most agricultural research and production take place are not characterized. All these reasons and perhaps more contribute to the widespread problems of soil resource illiteracy which in turn hinders effective agricultural development between areas with similar and/or different soils (Chukwu *et al.*, 2013).

Soil is a product of interaction between climate, parent material, relief and organisms over a period of time. While climate (Maynard *et al.*, 2004) and organisms (Quideau *et al.*, 2001) actively influence soil formation, topography indirectly affects the rate of pedogenesis and distribution of soils (Wang *et al.*, 2001). The effect of topography on soil genesis had long been recognized (Pregitzer *et al.*, 2000). It had been established that soils vary in vertical and lateral directions and that such variations follow systematic changes (Wilding and Dress, 1983). Graham *et al.* (1990) proposed a conceptual model relating slope

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processes to pedogenesis in which transported parent material interrupts the orderly progression of soil development in residual parent material. It was then suggested that genesis and distribution of soils are best understood when studied in landscape context rather than at the level of individual pedons or classification units (Graham *et al.*, 1990). Nye (1966), Smyth and Montgomery (1962), Murdoch and Ojo-Atere (1976) and Ojanuga (1979) had earlier noted that the study of soil distribution along slope was the corner stone of most soil classification in the basement complex area of SW Nigeria.

However, most pedological soil studies in Ife Area had been restricted to the granite gneiss bedrock areas while studies on the pedogenesis in mica schist predominant zones have not received the desired research attention. Yet, the two rock types cover well above 70% of the basement complex area in Ife Area. Therefore, characterization and classification of soils in the land forms of mica schist bedrock are necessary to generate baseline data on the soils with particular reference to Ife area of SW Nigeria. The specific objectives of this study were to establish the morphological, physical and chemical properties of soils on a toposequence underlain by mica schist in Ife area and establish the taxonomic and fertility capability classes of the various soil types along the toposequence.

II. MATERIALS AND METHOD

a) The study area

The study area is located approximately between latitudes 7° 32' N and 7° 33' N and longitudes 4° 39' E and 4° 40' E, which is about 2.5 km away from Kajola village, a suburb of the Obafemi Awolowo University (O.A.U.) Teaching and Research Farm (T&R-F) Ile-Ife and is located within the schist belt of southwestern Nigeria (Rahaman, 1988).

b) Climate

Kajola area is in the same ecological zone (tropical rainforest) as Ile-Ife with hot, humid tropical climate having distinct dry and bimodal rainy seasons. The mean annual rainfall is about 1,527mm and the mean monthly air temperature is approximately 31°C. The wet season starts from mid-March to late October, and the bimodal rainfall pattern has peak periods in June/July and September/October. The dry season runs from early November to early March. The influence of the north-east trade wind, which loses all its moisture as it passes over the Sahara desert towards the equator, is felt in the study area as 'harmattan' (cold dry wind) between late December and early January (FMANR, 1990).

Atmospheric temperature is moderately high throughout the year, with a low range between the monthly mean minimum and maximum temperatures.

The peak of the maximum is usually between February and March (34.3- 33.8°C) just before the onset of rains while the lowest minimum temperatures are between July and August (27.1 - 27.9°C) during the peak periods of rainfall. The area also records the following average monthly data: humidity 73.8%, and sunshine 6.6 hours. The wind speed was 114.6 km d⁻¹ while potential evaporation is 4.36 mm d⁻¹ (Meteorological data bank, T&R-F, O.A.U., Ile-Ife, 2010). The mean monthly soil temperature at 50 cm depth in Ile-Ife, for June, July and August is 27.7°C and for December, January and February is 29.4°C. Since these differ by less than 5°C, the soil temperature regime in the study area is isohyperthermic (Soil Survey Staff, 2006).

c) Vegetation and land use

The native vegetation of the study area was originally rainforest characterized by very tall, big trees and thick shrubs. However, as a result of human interferences, the vegetation now consists of admixture of bush regrowth, arable crop farms and tree crop plantations. The crest (summit) and the shoulder are presently being used for arable crop cultivation (cassava (*Manihot spp.*); yam (*Discorea spp.*); maize (*Zea mays*) and scattered banana/ plantain (*Musa spp.*). The upper slope area was cultivated to cocoa (*Theobroma cacao*), but was unkept and gradually transforming into secondary forest. The mid slope area was under bush fallow with mostly *Chromolaena odorata* and scattered oil palm (*Elaeis guinensis*). The lower slope supported cocoa plantation inter-planted with cassava (*Manihot spp.*) and banana/plantain (*Musa spp.*), while plantain/banana (*Musa spp.*) and cocoa (*Theobroma cacao*) were grown in the valley bottom area.

d) Field study

Guided by the geological map of the study area produced by the Department of Geology, O.A.U. Ile-Ife, a toposequence underlain by mica schist was selected for the study. The toposequence is slightly undulating with relatively flat top and is approximately 2.5 km southeast of Kajola village. The toposequence is approximately 500 m long from the valley bottom to the crest with an elevation of 295.9 m above mean sea level (amsl) at the crest and 268.6 m amsl at the valley bottom. The other physiographic positions were clearly identified and the upper slope, sedentary and hill-wash areas were 293.6 m, 283.5 m and 276.9 m amsl respectively.

Five soil profile pits were established along the toposequence at different physiographic positions. All the pedons were described following the procedures in the guidelines for soil profile description (FAO, 2001) and horizon designations of the Soil Survey Staff (2006). Soil samples were collected from each of the identified genetic horizons for physical and chemical analyses in the laboratory. Undisturbed core soil samples were collected and used for bulk density determination.

e) *Laboratory analyses*

The soil samples were air dried, gently crushed in ceramic mortar with pestle and passed through 2mm sieve to separate materials that were greater than 2mm. The fraction that was less than 2mm was used for the laboratory analyses other than the bulk density determination.

f) *Physical analyses*

The bulk density was determined by the core method. The particle size distribution was evaluated by the modified Bouyoucos hydrometer method (Bouyoucos, 1951) using 5% w/v sodium hexameta-phosphate (calgon) as the dispersing agent. Particle fractionation into very coarse sand (VCS), coarse sand (CS), medium sand (MS), fine sand (FS) and very fine sand (VFS) was carried out with the use of a set of sieves (1.0, 0.5, 0.25, 0.100 and 0.05 mm) representing 1000, 500, 250, 100 and 50 μ m respectively arranged in decreasing order of sieve sizes as listed (Buol *et al.*, 1997). Each of the sand fractions was weighed and preserved.

g) *Chemical analyses*

The soil pH was determined both in distilled water and 1.0 M KCl (1:1 soil: solution ratio) using glass electrode pH meter (Kent model 720) (Thomas, 1982) and was also carried out in duplicate. Delta pH computed is defined as the difference between pH in KCl and H₂O. The exchangeable bases (Ca, Mg, K and Na) were extracted with 1.0 M ammonium acetate (NH₄OAC) solution at pH 7.0 (Thomas and Throp, 1985). Calcium, Ca²⁺, sodium, Na⁺, and potassium, K⁺ ions in the extract were determined with the use of flame photometer (Gallenkamp Model FH 500), while magnesium (Mg²⁺) ion in the extract was determined by titration which was carried out by extracting the soil with neutral ammonium acetate solution (Soil Survey Staff, 2006).

The exchangeable acidity was determined by extraction with 1.0 M KCl solution and titrated with NaOH and HCl solutions to measure total acidity (Al³⁺ and H⁺) concentrations respectively (McLean, 1965). Effective cation exchange capacity (ECEC) was computed as the summation of NH₄OAC extractable bases (Ca²⁺, Mg²⁺, Na⁺ and K⁺) and KCl extractable aluminium (Al³⁺) (Soil Survey Staff, 2006). The organic carbon was determined by the Walkley Black method (Allison, 1965), and the available phosphorous by Bray No. 1 method.

h) *Fertility capability classification (FCC)*

The results of the laboratory analyses and field morphological properties of the pedons identified in the study area were used for fertility capability classification. The conversion data used in evaluating the soils are as outlined by Sanchez (2002), which consists of three categorical levels, 'type' (texture of plough layer or top

20 cm), 'substrata type' (texture of sub soils), and 'modifiers' (soil properties or conditions which act as constraints to crop performance). Class designations from the three categorical levels were combined to form FCC unit. Thus the soils were classified according to whether a characteristic was present or not.

i) *Statistical analyses*

Correlation coefficients and simple regression analysis between the selected soil properties were calculated. All statistical analyses were carried out using SAS 9.1 version (2002-2004) software programme.

III. RESULTS AND DISCUSSION

a) *Soil morphology and landform relationship*

Locational map showing the topographical sequence of the soil series identified in the study area is presented in Figure 1 and the summary of the important morphological characteristics of the soil types identified on the landscape positions on the toposequence is presented in Table 1. The soils along the toposequence are derived from fined-grained biotite gneisses and schist and are very extensive in southwestern Nigeria, the parent rocks are very easily weathered and give rise to very deep soils. The colour and texture of the soils change in response to changes in slope position and drainage condition down to the valley bottom. The bright yellowish and dark brown to red colours of soils in the higher topographical sites was an indication of good drainage (Periaswamy and Ashaye, 1982).

b) *Physical properties of the soils*

Table 2 shows the particle size distribution and bulk density data of the soils along the toposequence under study. The gravel content varied from 8 to 68 $\pm$ 17.38%, with Pedons from the summit, upper and middle slopes having relatively high values of 22 to 68 $\pm$ 14.94% while the lower slope and valley bottom Pedons have lower values, 8 to 32 $\pm$ 7.26%. The gravel content generally increased from the A-horizon to B-horizon and then decreased significantly from B to C-horizon, except at the lithologic break. However, in pedons at the lower slope position, there were no particular patterns of gravel distribution. This gravel accumulation had been found to be a characteristic property of soils formed in the upland portion of the landscapes derived from granitic gneiss metamorphic rock complex of central western Nigeria (Smyth and Montgomery, 1962; Okusami and Oyediran, 1985). These have not constituted an obstacle to root proliferation since roots are found beyond the gravel horizons.

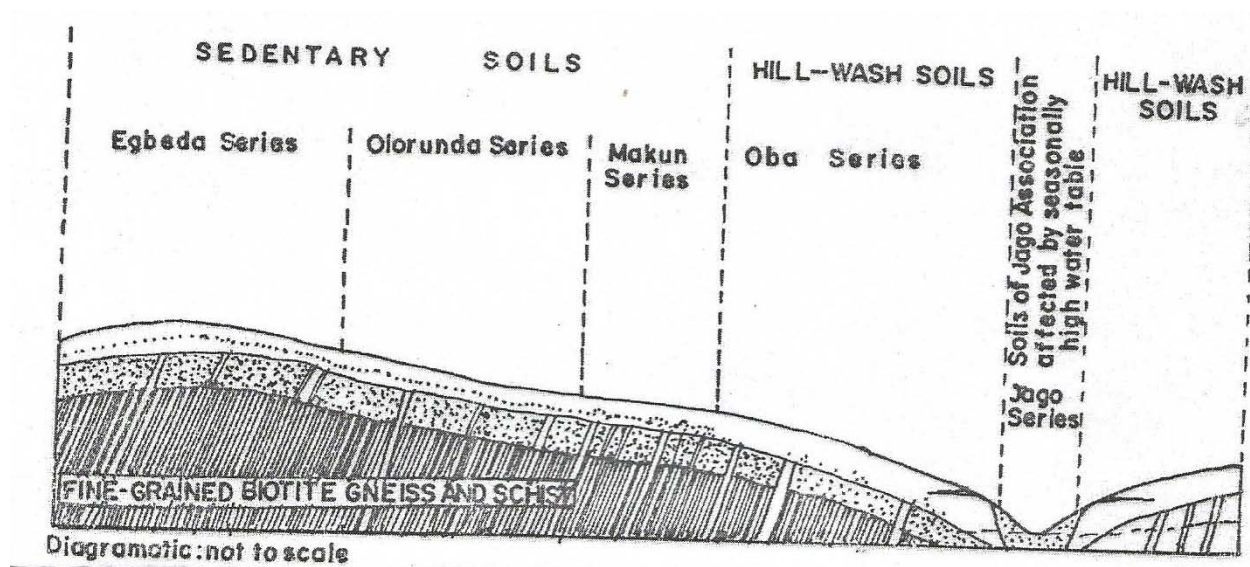


Fig. 1 : Topographical Sequence of soil Series in the Study Area (After Smyth and Montgomery, 1962)

Table 2 : Field morphological discription of the soils studied

Horizon	Depth (cm)	Colour Moist	Texture ¹	Structure ^x	Consistence ^y	Concretions ^b	Boundary ^z	Notes
Ap	0-18	5YR 3/2	SL	2mcsbk	Nstnplvfr	Profile 01 Egbeda series	cs	Abundant very fine, fine, and few medium roots
AB	18-24	10YR 4/4	SCL	2msbk	Nplfrnst		cs	Abundant fine and medium roots
B	24-51	2.5YR 4/4	SC	2msbk	Sstfrspl		gw	Few fine and medium roots
BC	51-70	5YR 4/8	SC	3psbk	Sstsplfr		cs	Very few fine roots
Ap	0-18	5YR 3/3	SCL	cmsbk	Sstsplfr	Profile 02 Olorunda series	cs	Abundant fine, medium to coarse roots
AB	18-28	2.5YR 4/4	SCL	2mcr	Sstsplfr		ds	Common fine and very fine and few medium roots
B21	28-72	2.5YR 4/8	SC	1msbk	Nstnplfr		s	Frequent fine roots
B22	72-132	2.5YR 4/4	SC	2msbk	Sstspl		cs	Few gravels
BC1	132-185	5YR 4/6	SC	3csbk	Fmstpl	Profile 03 Makun series	ds	Thick cutans of clay and iron oxides on ped
BC2	185-210	5YR 6/6	SC	3msbk	Vfr		-	Few mottles, frequent pieces of weathered rock, devoid of roots.
Ap	0-18	5YR 4/2	SCL	2msbk	Nstnplfr		cs	Common coarse fine to medium roots
BA	18-33	2.5YR 4/2, (5YR 5/6)	CL	2mlsbk	Sstspl		ds	Abundant very fine and few coarse and medium roots
B21	33-65	2.5YR 4/6	SC	2msbk	Frstpl	Profile 04 Oba series	Ds	Common medium and coarse roots
B22	65-120	(5YR 5/6)	SC	2msbk	Sstsplfr		Ds	Medium to fine prominent mottles, Weathered quartz stones with few patchy cutans
BC	120-200	5YR 4/6	SC	2msbk	Sstsplfr		-	Frequent quartz materials. Devoid of roots
Ap	0-20	7.5YR 4/2	SCL	2fcr	Vfrnstnpl		cs	Common medium frequent fine and few coarse roots
BA	20-40	5YR 4/6	SCL	2msbk	Frststpl	Profile 05 Jago series	cs	Few medium, common fine and few very fine roots
B1	40-71	2.5YR 4/6	SC	2msbk	Frststpl		ds	Few patchy cutans, common fine and medium roots
2BtC1	71-115	2.5YR 4/8	SC	2msbk	Vstpl		gs	Few patchy cutans with stonelines, few medium to fine roots
2BC2	115-170	5YR 5/8	SC	2msbk	Frstpl		-	Few roots with frequent black hard concretions present.
Ap	0-18	2.5YR 3/2	SCL	2mcr	Sstnp	Profile 05 Jago series	gw	Common medium frequent fine roots
AB	18-40	2.5YR 4/4, (5YR 6/1)	SC	2msbk	Sstspl		gw	Common medium frequent fine roots
B	40-60	2.5YR 4/6	SC	1msbk	Fmstpl		gw	Frequent medium and few fine roots
Btg	60-75	7.5YR 6/6	SC	2f	Fmstvpl		-	Common medium roots merging into a water saturated layers

Texture: SC= Sandy Clay, SL= Sandy Loam, SCL=Sandy Clay Loam, L= Loamy, LS= Loamy Sand, C=clay, CL= Clay Loam;

^x Structure: 1 = weak, 2 = moderate, 3 = strong, cr = crumb, sbk = subangular blocky, abk = angular blocky, p= platy, vf= very fine, f= fine, m = medium, c = coarse;

^y Consistence: m = moist, w = wet, vfr = very friable, fr = friable, fm = firm, vfm = very firm, nst = non sticky, sst = slightly sticky, vst = very sticky, st =

The soil texture varied from sandy loam to sandy clay loam for surface horizons except in Pedon 05 which has clay texture. The B and C-horizons have clay loam texture except in Pedons 03 and 04 that were more clayey in the B and BC horizons. The sand content ranged from 29 to 67 $\pm$ 12.83% and decreased with increasing depth except at certain depths where the BC-horizon contained more of sand as in Pedons 03 and 04. An outstanding feature of these soils irrespective of their location on the topography is their low to moderate silt content at the surface. The silt content ranged from 11 to 25 $\pm$ 3.31%, although the value fluctuated within all the pedons with increasing depth. Generally, the silt content is low, a characteristic which the soils shared with most Nigerian soils (Ojanuga *et al.*, 1981).

The clay values ranged from 18 to 59 $\pm$ 13.98% in the Bt horizons. The clay content increased generally

with increasing depth to a maximum (probably due to illuviation/ eluviation interplay or possibly clay migration) and then decreased in the BC horizons. Similar trend was observed by Ojanuga (1978) in soils of Ife and Ondo areas of southwestern Nigeria. Generally, soils in the middle and lower slope positions have higher clay content than those of the valley bottom position. For Pedons 02, 03, and 04, the particle size distribution of the sub-soil horizon of the soils suggests that the B-horizons were influenced more by eluviation – illuviation processes. The high clay content in the deeper horizons of some of the soils coupled with some morphological properties such as the colour, texture, consistence and plasticity in the profile description formed the basis for the recognition of argillic horizons in some of the soils (Fasina *et al.*, 2005).

Table 2 : Physical properties of the soils along the toposequence

Horizon	Depth (cm)	>2000mm (% of the whole soil)	Very coarse sand (1000- 2000 μ m)	coarse sand(500- 1000 μ m)	Medium Sand (250- 500 μ m)	Fine Sand (50- 100 μ m)	Very fine sand (0.05-0.50 μ m)	Total sand	Silt	Clay	Bulk density g/cm ³	Textural class
← % →												
Profile 01 Egbeda series												
Ap	0-18	35	10	13	10	9	7	49	21	30	1.06	Sandy loam
AB	18-24	61	10	12	10	8	7	47	25	28	1.54	Sandy clay loam
B	24-51	68	7	8	7	5	4	31	11	58	1.62	Sandy clay
BC	51-70	50	7	7	6	5	4	29	13	58	1.59	Sandy clay
Profile 02 Olorunda series												
Ap	0-18	41	10	13	12	10	10	55	17	28	1.01	Sandy clay loam
AB	18-28	68	10	12	11	10	8	51	11	38	1.57	Sandy clay loam
B21	28-72	64	10	8	7	7	6	39	13	48	1.63	sandy clay
B22	72-132	56	11	4	7	7	5	33	13	54	1.68	sandy clay
BC1	132-185	33	9	7	7	7	6	35	17	48	1.73	Sandy clay
BC2	185-210	22	9	9	9	8	8	43	15	42	1.48	Sandy clay
Profile 03 Makun series												
Ap	0-18	43	12	13	11	11	9	55	17	28	1.34	Sandy clay loam
BA	18-33	42	11	12	10	10	8	51	15	34	1.42	Clay loam
B21	33-65	39	12	8	7	4	3	34	13	53	1.45	Sandy clay
B22	65-120	47	12	6	6	4	2	30	11	59	1.65	Sandy clay
BC	120-200	23	11	8	10	5	5	39	15	46	1.40	Sandy clay
Profile 04 Oba series												
Ap	0-20	8	11	15	13	11	8	57	15	28	1.54	Sandy clay loam
BA	20-40	32	10	12	7	7	2	39	13	48	1.48	Sandy clay loam
B1	40-71	25	8	11	5	5	3	31	11	58	1.30	Sandy Clay
2BtC1	71-115	27	8	11	4	5	3	31	13	56	1.71	Sandy Clay
2BC2	115-170	15	10	13	7	7	2	39	13	48	1.40	Sandy clay
Profile 05 Jago series												
Ap	0-18	26	16	15	14	13	10	67	15	18	0.74	
AB	18-40	19	14	13	13	13	12	65	13	22	1.21	Sandy clay
B	40-60	18	14	17	15	12	10	67	11	22	1.31	Sandy clay
Btg	60-75	24	13	14	13	13	12	65	15	20	1.13	Sandy clay

The bulk density ranged from 0.74 g cm^{-3} in the Ap horizons to 1.7 g cm^{-3} in the Bt horizons. Generally, the bulk density value increased with increasing depth to a maximum and then decline with increasing soil depth. The exception to this trend was observed in Pedon 04 with their values fluctuating. However the higher values at depth have not created any hindrance to plant root penetration as evidenced by deep rooting of plants into greater depth in Pedon 02. A positive correlation exists between bulk density and clay that indicated the contribution of clay to soil bulk density with increasing depth.

c) Chemical properties of the soils

Tables 3 show the chemical properties of the pedons studied. The soils studied fall within the neutral to very strongly acid class (Ojanuga, 1978; Landon, 1991; Soil Survey Staff, 2003), with pH (H_2O) values ranging from 5.6 to 7.0. The pH decreased with soil depth except in Pedon 03. The pH (1M KCl) ranged from 4.4 to 5.7. The value also decreased with soil depth except in Pedon 03 where no definite pattern was observed. Generally, the surface horizons of the pedons were medium to slightly acid (pH 5.2 - 5.7), while B and C-horizon were strong to very strong acid with pH values ranging from 4.4 - 5.7. The acid nature of the soil can be ascribed to high rate of leaching of bases which is prevalent in the humid tropics, and the acidic nature of the parent rock (granite-gneiss). The higher pH values observed at the soil surface horizons according to Fasina *et al.* (2005) might be due to liming effect of bush burning and bio cycling of nutrients. The pH in 1M KCl was lower than the pH in water (H_2O), thus the difference in soil pH values between the pH in KCl and H_2O (as expressed by $\Delta\text{pH} = \text{pH}(\text{KCl}) - \text{pH}(\text{H}_2\text{O})$) were all negative ranging from -0.9 to -1.5. This suggests the dominance of silicate clay minerals over oxides (Van Raij and Michael, 1972).

Generally, there was higher accumulation of bases in the surface horizons $6.59 - 12.57 \text{ cmol}(+)\text{kg}^{-1}$ of the soil, and the total exchangeable bases decreased with soil depth except in some cases owing to nutrient biocycling (Ajiboye and Ogunwale, 2010), and could also be due to differential weathering that had taken place or as a result of plant uptake and leaching losses. Like in most tropical soils, the exchangeable sites of the soils studied were dominated by exchangeable calcium and magnesium. Exchangeable sodium (Na^+) and potassium (K^+) are low (Table 3) with values ranging from 0.08 to $0.26 \text{ cmol}(+)\text{kg}^{-1}$ and 0.15 to $0.30 \text{ cmol}(+)\text{kg}^{-1}$ soil for Na^+ and K^+ respectively. These low values indicated that the soils under investigation developed from materials that are either low in K^+ and Na^+ content or have been exhausted by plant uptake or leaching due to their mobility within the soil. The higher values obtained at the surface horizon of the pedons could be attributed to higher organic matter content

(Ano, 1991). However, the values fluctuated irregularly down the soil profile. Exchangeable acidity values ranged from 0.3 to $1.0 \text{ cmol}(+) \text{ kg}^{-1}$ soil (Table 3). All the pedons examined showed little variation in the exchangeable acidity (Al^{3+} and H^+) and the values were almost uniform with soil depth. Exchangeable Al^{3+} accounted for a greater percentage (54.14%) of the total acidity. Effective cations exchange capacity (CEC) was generally low with values ranging from 3.73 to $14.26 \text{ cmol}(+) \text{ kg}^{-1}$ soil. There were higher values in the surface horizons of all the soils examined than in the sub-soil, probably due to the influence of organic carbon on the exchange sites of the soils. However, in those profiles where higher values were noticed in the sub-soil as in Pedons 02 (B22) and 03 (BC) with more of clay content (Table 2), this could be due to the process of pedoturbation either by fauna or flora.



Table 3 : Chemical properties of the soils

Horizon	Depth (cm)	pH (H ₂ O)	pH KCl	ΔpH	OM %	P Ppm	Ca ²⁺	Mg ²⁺	Exchangeable Bases			Exchangeable Acidity		Sum of Bases	ECEC	Base saturation (%)	Aluminium Sat. (%)
									Na ⁺	K ⁺	Al ³⁺	H ⁺					
Profile 01 Egbeda series																	
Ap	0-18	6.9	6.0	-0.9	2.55	11.2	7.2	4.86		0.21	0.30	0.4	0.2	12.57	12.97	97	3
AB	18-24	6.8	5.4	-1.4	1.61	7.4	6.6	4.86		0.26	0.26	0.2	0.3	11.98	12.18	98	2
B	24-51	6.5	5.0	-1.5	1.21	3.4	6.7	4.10		0.25	0.30	0.3	0.3	11.30	11.60	97	3
BC	51-70	6.0	4.6	-1.4	1.07	3.2	5.8	3.20		0.20	0.24	0.7	0.3	9.44	10.10	93	7
Profile 02 Olorunda series																	
Ap	0-18	6.5	5.3	-1.2	1.68	6.3	5.3	4.86		0.19	0.24	0.4	0.2	10.58	10.98	96	4
AB	18-28	6.4	5.0	-1.4	1.14	8.2	4.9	4.05		0.19	0.22	0.4	0.3	9.35	9.75	96	4
B21	28-72	6.2	5.0	-1.2	0.87	4.1	5.5	1.62		0.21	0.28	0.1	0.4	7.69	7.79	99	1
B22	72-132	6.1	5.0	-1.1	0.67	3.3	5.3	5.67		0.19	0.26	0.4	0.3	11.42	11.82	97	3
BC1	132-185	5.9	4.9	-1.0	0.60	3.0	5.3	4.05		0.20	0.26	0.1	0.3	9.81	9.91	99	1
BC2	185-210	5.6	4.8	-0.8	0.07	2.6	5.0	4.86		0.17	0.26	0.2	0.2	10.29	10.49	98	2
Profile 03 Makun series																	
Ap	0-18	6.8	5.6	-1.2	1.54	8.4	4.0	7.29		0.14	0.22	0.4	0.3	11.64	12.04	97	3
BA	18-33	6.7	5.5	-1.2	0.94	10.5	4.9	4.05		0.19	0.24	0.3	0.3	9.38	9.68	97	3
B21	33-65	6.6	5.5	-1.1	0.94	7.0	5.3	1.62		0.21	0.30	0.2	0.2	7.44	7.64	97	3
B22	65-120	6.4	5.5	-0.9	0.87	5.8	4.1	6.48		0.14	0.20	0.2	0.3	10.91	11.11	98	2
BC	120-200	6.7	5.7	-1.0	0.40	3.2	3.1	10.53		0.11	0.22	0.3	0.2	13.96	14.26	95	2
Profile 04 Oba series																	
Ap	0-20	6.4	5.2	-1.2	1.74	7.7	4.7	4.05		0.23	0.24	0.2	9.22	0.9	9.92	93	7
BA	20-40	6.2	4.8	-1.4	0.93	8.4	3.2	5.67		0.12	0.22	0.2	9.21	0.3	9.31	99	1
BC1	40-71	6.0	4.8	-1.2	0.67	5.8	2.2	5.67		0.08	0.24	0.2	8.19	0.3	8.29	99	1
2BtC1	71-115	5.8	4.6	-1.2	0.60	6.2	2.1	4.05		0.10	0.24	0.3	6.49	0.4	6.59	99	2
2BC2	115-170	5.6	4.4	-1.2	0.40	4.5	2.8	3.24		0.16	0.26	0.2	6.46	0.3	6.56	99	2
Profile 05 Jago series																	
Ap	0-18	7.0	6.7	-1.3	1.74	6.9	1.5	4.86		0.08	0.15	0.2	6.59	0.6	6.99	94	6
AB	18-40	6.6	5.2	-1.4	0.74	8.9	1.9	4.86		0.08	0.24	0.3	7.08	0.6	7.38	96	4
B	40-60	6.5	5.0	-1.5	0.40	5.4	0.6	2.43		0.08	0.22	0.2	3.33	0.6	3.73	89	11
Btg	60-75	6.3	5.0	-1.3	0.13	5.2	1.5	2.43		0.08	0.21	0.2	4.22	0.6	4.62	91	9

The organic matter content of the surface horizons of the pedons ranged from 1.54 to 2.55% (Table 3) and decreased with soil depth. The sub-surface horizons were generally lower in organic matter than the surface horizons of all the pedons examined. The reasons for this may be due to the fact that the surface horizons are the points where decomposition and humification of organic materials take place. The organic matter content of the entire soils studied was generally low, mostly less than 2% except in the surface horizon of Pedon 01. The low organic matter obtained may be partly due to the effect of high temperature and relative humidity which favour rapid mineralization of organic matter (Fashina *et al.*, 2005). It might also not be unconnected with the degradative effect of cultivation and other land use and management activities. Available phosphorous content of the soils varied from 2.6 to 11.2 ppm in all the horizons in the profiles with the highest values at the surface horizons. The relatively high concentration of the available P and organic carbon in the surface horizons may imply significant organic or biocycled P in the soils and also an indication that organic matter contributes significantly to the available phosphorus in these soils. The available P values are considered low at some horizons as they were below or only slightly above the 10 ppm critical limit recommended for most commonly cultivated crops in the area (Uponi and Adeoye, 2000; Aduayi *et al.*, 2002; Obigbesan, 2009). The values generally decreased with depth, though the pattern is irregular in all the pedons examined. The low value of available P might be due to the fixation of phosphorus by iron and aluminum sesquioxides under well drained and acidic conditions of the soils (Onyekwere *et al.*, 2001). Further, Jubrin *et al.* (2000) noted that deficiency of P may occur in soils due to its strong adsorption by the soil colloids. Pedons 04 and 05 exhibit an unusually high concentration of available P in the sub surface horizons 8.4 and 8.9 ppm respectively (Table 3). This could probably be due to the effect of farming activities especially decomposed cocoa pod residue because the pedons are located within a cocoa farm or deposition of P in the valley bottom soils of the toposequence through erosion.

d) Classification of the soils studied

i. Local system

The following factors were taken into considerations in the classification of the soils under examination; nature of the bedrock, the form of parent material, physiographic position, soil colour, presence or absence of mottles, soil texture and general profile morphology. Pedon 01 of the toposequence is confined to the hill top and is formed over hard rock material. The pedon is dark reddish brown to yellowish red in colour with clayey texture, frequent ironstone concretions. The fine texture contains appreciable number of rounded

edge gravels with sub angular blocky structure. They were therefore, classified as Egbeda series. Pedon 02 is confined to the upper slope position of the toposequence. The soils were dark reddish brown to reddish yellow in colour with gravelly clay texture. They contain variable content of iron stones and fragments of iron pan in some horizon together with few continuous thick cutans probably of clay and iron oxides on peds. It was therefore, classified as Olorunda series.

Pedon 03 occupied the middle slope at intermediate to low levels in the topography. The soils are dark reddish grey to yellowish red in colour and have a sandy clayey texture close to the soil surface and mostly structureless. They are majorly devoid of mottles and consist of few gravel size iron concretions at some points within the profile. In view of its position on the toposequence, they were classified as Makun series (Smyth and Montgomery, 1962).

Pedon 04 occupied gently sloping section of the lower slope area of the toposequence. The soils were dark brown to yellowish red in colour and clayey textured close to the surface with almost uniform morphology. The profile is well drained with evidence of lithologic break at a portion in the pit. This suggests that colluvial materials were washed from higher sites. They are essentially devoid of stones and gravels to a certain depth. The residual materials are gravelly clay in texture with moderate medium subangular blocky structure. The colour ranges from (2.5YR 4/8 moist) red to yellowish red (5YR 5/8 moist). They were therefore, classified as Oba series (Smyth and Montgomery, 1962). Pedon 05 was at the valley bottom of the toposequence, the soils are poorly drained with gravelly clay loam texture and dusky red to reddish yellow colour. The profile was saturated at 75-cm from the soil surface. The pedon contained gley mottles and were therefore classified as Jago series.

ii. Taxonomic classification

All the pedons observed showed increasing trend in clay content with soil depth to a certain level, a kind of trend that was indicative of argillic horizon. Low level of fertility as observed from the organic matter content and other soil mineral composition to the extent that they cannot be used to grow crops economically unless fertilizers are used to supply nutrients (Soil Survey Staff, 2003). These are the two most important differentiating characteristics of the Ultisols. The pedons studied are mineral soils with ochric epipedon, low in organic matter, high in colour values and chromas. The soils are dry for more than 90 cumulative days but less than 180 (Table 1). The upland soils of southwestern Nigeria is primarily under ustic moisture regime (Periaswamy and Ashaye, 1982), therefore, the soils are in Ustults suborder. Pedon 05 qualifies as Aquults because of the hydromorphic properties right from the soil surface and the gleyed subsurface horizons. The

presence of Kandic horizons are established in most pedons because they meet the following requirements: coarse textured surface horizon over vertically continuous sub-surface horizons; ECEC values within the sub-surface B-horizons that are less than 12cmol(+)/kgclay (Table 3); a regular decrease in organic carbon contents with increasing soil depth (Table 3) (Soil Survey Staff, 2003).

Soils of Pedons 01, 02, 03 and 04 have no evidence of hydromorphic properties within 150 cm of the mineral soil surface but have clay distribution such that the percentage clay decreased from its maximum by 20% or more within 150 cm of the mineral soil surface. These soils therefore, classify as Typic Kanhaplustults, they have ECEC of less than 12 cmol/kg soil. Soils of pedon 05 show evidence of redox depletion within 75 cm of the mineral soil surface and therefore, qualify as Aquic Haplustults. In the FAO-UNESCO soil legend, all the pedons under consideration qualify as Luvisols because of the presence of argillic horizon and humus surface horizon that is separated from the mineral horizon (Bruand *et al.*, 2004), a horizon eluviated of clay minerals and a horizon of at least 5 cm thick with

illuvial clays (Bruand *et al.*, 2004). The soils of pedon 03 and 04 classify as Plinthic Luvisols because of the presence of indurated coherent plinthite within 100 cm of the soil mineral surface. Soil of pedon 05 classifies as Gleyic Luvisols because of evidence of gleyic properties within 100 cm of the soil surface. The soils of pedon 01 and 02 classify as Eutric Luvisols because of the high base saturation (IUSS, 2006).

e) Fertility capability classes of the soils

The fertility capability classification (FCC) is a technical system for grouping soils which have similar agronomic limitations and management problems in terms of the nutrient supply capacity of the soils (Buol *et al.*, 1997; Sanchez, 2002). The result (Table 6) showed that the dominant FCC unit of soils in the study area was SC *keh*, that is sandy clay texture with low nutrient reserve, low cations exchange capacity and acidic soils. However, they all have similar agronomic constraints. The study revealed that the general fertility constraints of the soils were acidic reaction (h), low potassium reserve (k) and gleying (g) at the valley bottom area.

Table 6 : Fertility capability classification (FCC) units of the soils studied

Pedon	Top soil	Sub soil	Condition Modifier				FCC Units
			g	K	E	h	
1	S	C	-	+	+	+	SCkeh
2	S	C	-	+	+	+	SCkeh
3	S	C	-	+	+	+	SCkeh
4	S	C	-	+	+	+	SCkeh
5	S	C	+	+	+	+	SCgkeh

Keys:

S = Sandy, C = Clayey, h = acidic reaction, e = low cations exchange, k=low nutrient reserve, g = gleying, + = present, and - = absent

IV. CONCLUSION

The study was designed to examine the morphological, physical and chemical properties of the soils formed in mica schist in the study area along a given Toposequence with a view to classifying them. The toposequence was delineated into different physiographic units namely the crest, the upper slope, mid-slope/ sedentary, hillwash and valley bottom and soil profiles were established, described and sampled at each unit. The soil samples were subjected to routine analyses. The morphology, physical and chemical characteristics alongside the taxonomic and fertility capability classifications of the soils were determined to generate valuable information about the soils' properties, understand their mode of formation/ genesis, their management requirements and agronomic constraints.

In conclusion, topography invariably influenced the pedogenetic processes leading to formation of

different soil types on the landscape. This study, therefore, provided evidence for the need to adopt different management practices to suit each soil type at the different physiographic positions as evidenced by the taxonomic and fertility capability classes.

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