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Characteristics and Classification of some Upper Slope Soils in Savanna Ecosystems of South Western Nigeria

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Abstract

Some upper slope soils of the savanna ecosystems of south-western Nigeria were studied with a view to broaden their data base and pave the way for a better classification of the soils.

The three profiles used were obtained from Shaki, Igbeti and Baba-Ode in the northern part of Oyo State. The soils were subjected to physical, chemical, mineralogical and micromorphological analyses.

Generally, it was observed that the morphological and chemical characteristics of the soils studied have been affected considerably by the interaction of climate, parent material, relief, vegetation, time and biological factors. The physical, chemical and mineralogical data do not show any well-defined sequence in the profiles. These analytical data indicate that the surface horizons may be developed in transported material, while the subsurface horizons may be derived from the underlying rock. These indicate the complexity of the profiles and also confirm the non-uniformity of the parent materials. Clay mineralogy indicates that Kaolinite is dominant in the soils, with considerable amounts of smectite and mica. Cutans were associated with both Inceptisols and Alfisols in the soils studied. Thus, cutans may not be a good diagnostic feature for argillic horizons in south western Nigeria.

Introduction

In south-western Nigeria, the primary objective of soil studies was to solve the problems posed by poor cocoa yields (Vine, 1951). Later, with the growing government interest in natural resources, efforts were made to examine individual profiles. These were grouped together on the basis of environmental characteristics and profile morphology. The soils were grouped at the lower category of classification, such as the 'series' and the 'associations'. At the higher level, D'Hoore (1964) grouped the soils of the area of study as Tropical Ferruginous soils.

There is very little known about the genesis of the soils in south western Nigeria. But some soil scientists and geomorphologists have indicated that soil-formation in the area had been considerably influenced by past climatic condition; especially the three erosional phases. Superficial deposits on the pediments have been described in detail by Nye (1954, 1955); Smyth and Montgomery (1962); Folster and Ladeinde (1967); Folster (1969); Ojanuga *et al* (1976) and Murdoch *et a.* (1976). They revealed that stratified slope deposits are present, which could not have been laid down under the present climatic conditions. De Swardt (1953); Folster (1969) and Burke and Durotoye (1970) described three distinct erosional surfaces in south-western Nigeria. These indicated that the post-African landscapes have been modified by periodic denudational processes during Pleistocene-holocene period. It is concluded that periods of humid and arid climates have alternated in the area.

Generally, the soil studies in the area have been geared towards the immediate needs of agricultural development and fundamental pedological research has been minimal. Therefore, this investigation was undertaken to collect more information on mineralogical and micromorphological characteristics, for a better grouping of the soils.

Materials and Methods

Field Sampling

Three modal profile-pits were sampled on horizon basis for laboratory analyses. Undisturbed bulk samples were collected with Kubiena tins for micromorphological studies (Fig. 1).

Laboratory Methods

All analyses were made on material which had been air dried and passed through a 2mm sieve. Particle size distribution was determined by the pipette method. pH was measured with a glass electrode using a 1:1 soild water ratio. Organic carbon was determined by the Walkley-Black dichromate titration method and nitrogen by a modified kjeldahl procedure.

Cation exchange capacity was determined by direct distillation of absorbed ammonia; Exchangeable cations by leaching with normal ammonium acetate at pH7 and available phosphorus, by the Bray No. 2 method.

For sand mineralogy, the 50–100 micron fractions were investigated. The heavy and the light fractions were separated using the specific gravity of the minerals as compared to Bormoform (S.G. 2.89). Representative grains of each fraction were mouted in Canada Balsam and inspected under a petrological microscope. The technique used in coun-

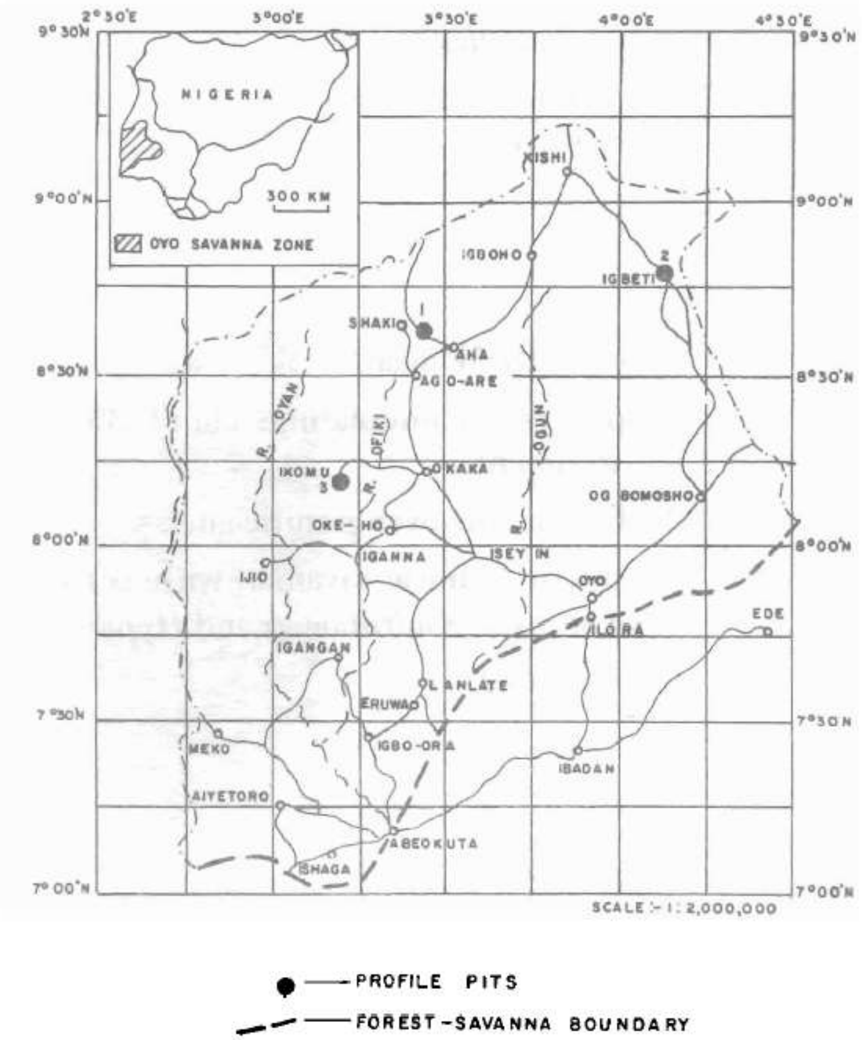

Fig. 1: Location Map of the studied profiles.

ting, was a single line count, and in each case about 1,000 grains were counted. Identification was made according to their optical properties as summarised by Milner (1962). The clay fractions (less than 2 um equivalent spherical diameter) of the soils studied were obtained by sedimentation, Na-saturated and dried. Suitable quantities of the Na-saturated samples were separately Mg-and K-saturated. Oriented mounts were obtained on glass slided from the suspensions and analysed by X-ray diffraction methods using an automatic "Philips" diffractometer and Ni-filtered Cu K o radiation.

Thin-sectioning

The thin sections of the undisturbed samples were made using Araldite impregnating resin as adapted by Fitzpatrick (1971) from the method of Wells (1961). For the description of the slides, the terminology of Brewer (1964) was used.

Results and Discussion .

Morphology and site characteristics

Descriptions of the profiles were made usually following the FAO specifications. These are provided along with the site characteristics as follows:

SITE 1

Location	Block 118/5F near Shaki town 8° 38′ N, 3° 23′E.
Land-form	Upper slope, undulating; about 3% slope. stony environment.
Parent material	Pedisediments over granitic-gneiss.
Vegetation	Northern Guinea savanna with scattered *Isoberlinia* spp and *Andropogon* and *Hyparrhenia* grasses.
Drainage	Well-drained.

Soil Description

Profile 1

0 – 5cm –	A 1	Dark reddish brown (10 YR 4/2) moist; loamy sand; very weak, fine, subangular blocky; loose dry; friable moist, and non-sticky wet; many, medium, interstitial pores; few small, angular, quartz stones; many, fine, fibrious roots; clear, smooth boundary.
5 – 20 cm –		Brown (7.5 YR 4/4) moist; loamy sand weak, fine, subangular blocky; loose dry; friable moist and non-sticky wet; many, fine interstitial pores; few. small, angular, quartz stones; few, small, irregular, moderately hard concretions; few, fine, fibrous roots and few, medium, woody roots; clear, smooth boundary.
20 – 50 cm –	B1	Brown (7.5 YR 5/4) moist; loamy sand; weak, medium, subangular blocky; loose dry; friable moist and non-sticky wet; common, fine, interstitial pores; many, small, angular, quartz stones; few, small, irregular, hard concretions; few, fine, fibrous roots and few, medium, woody roots, clear, smooth boundary.
50 – 103 cm –		Yellowish red (5 YR 4/6) moist; with few, faint, diffuse, light reddish brown (5 YR 6/4) mosttles,

	pores; many, fine, fibrous roots and many, medium, woody roots; clear, smooth boundary.
44 – 80 cm – B1	Yellowish red (5 YR 5/6) dry; sand; structureless; loose dry; loose and friable moist and non-sticky wet; common, medium, interstitial pores; common, fine, fibrous roots and common, medium, woody roots; clear, wavy boundary.
80 – 144 cm – B31	Yellowish red (5 YR 4/8) dry; sand; structureless; loose dry; loose and friable moist and non-sticky wet; common, fine and medium interstitial pores; abundant, medium and coarse, spherical and irregular, hard and very hard concretions; many, weathered. feldspathic patches; fine, few fibrous roots and few; medium, woody roots; clear, wavy boundary.
144 – 180cm -- B32	Yellowish brown (10 YR 5/4) dry; with many, faint brown (7.5 YR 5/4) mottles; loamy sand; weak, medium, subangular blocky; loose dry; loose and friable moist and non-sticky wet; few, fine, interstitial pores; common, medium, spherical and irregular, hard and very hard concretions.

SITE 3

Location	Block 295 / 5F; near Baba Ode 8° 10'N, 3° 12'E.
Landform	Gentle upper slope, undulating with 5% slope, stony environment.
Parent material	Pedisediments over Porphyritic granite.
Vegetation	Southern Guinea Savanna with scattered *Daniella oliveri* and *Andropogon* and *Hyparrhenia* grasses.
Drainage	Well-drained.

Soil Description

Profile 3

0 – 15 cm – Ap	Black (10 YR 2/1) moist; loamy sand, structureless; loose, friable moist and non-sticky wet; many, medium, interstitial pores; many, small, angular, quartz stones; many fine, fibrous roots and common, medium, woody roots; clear, smooth boundary.
15 – 33 cm – A3	Dark yellowish brown (10 YR 3/4) moist; sandy loam; weak, medium, sub-angular blocky, loose dry; friable moist and non-sticky wet; many, medium and fine, interstitial pores; many, small,

	angular, quartz stones and mica flakes; common, fine, fibrous roots and few, medium woody roots; clear, smooth boundary.
33 – 48 cm – B1	Dark brown (7.5 YR 3/2) moist; sandy loam, weak medium, sub-angular blocky; loose dry, friable moist and non-sticky wet; common, fine, interstitial pores; many, small, angular, quartz stones; many, fine, mica flakes; few, fine, fibrous roots; clear, smooth boundary.
48 – 80 cm – B2	Dark reddish brown (5 YR 3/2) moist; sandy loam; weak, medium, sub-angular blocky, loose dry, friable moist and non-sticky wet; common, fine and medium, interstitial pores; no detectable cutans; abundant, small, angular, feldspar and quartz fragments; abundant, fine, mica flakes and white, medium, weathered patches; few, fine, fibrous roots; clear, smooth boundary.
80 – 108 cm – B31	Dark red (2.5 YR 3/2) moist; loamy sand; weak, medium, sub-angular blocky; loose dry; friable moist non-sticky wet; common, fine, interstitial pores; abundant, small angular, feldspar and quartz fragments; abundant, fine, mica flakes and white, medium, weathered patches; clear, smooth boundary.
108 – 150 cm – B32	Dark red (2.5 YR 3/2) moist; with common, faint, fine, dark reddish-brown (2.5 YR 3/4) mottles; sandy loam, moderately strong, medium, angular, blocky, loose dry; friable moist and non-sticky wet; few, fine interstitial pores; abundant, small, angular, feldspar and quartz fragments; abundant, fine, mica flakes and grey and white, coarse, weathered patches; clear smooth boundary.
150 – 180 cm – C	Dark red (2.5 YR 3/2) moist; with common, faint, fine, dark reddish brown (2.5 YR 3/4) mottles, sandy loam; strong, medium, angular blocky, loose dry; friable, moist and non-sticky wet, few, fine interstitial pores; abundant, small, angular, feldspar and quartz fragments; abundant, fine mica flakes and white, coarse, weathered patches.

Micromorphology of profiles

This was studied for some horizons using thin sections and the results are presented in Table 1.

In profile 1, horizons A1 (10 – 5cm), B31 (63 – 67 cm) and B32 (112 – 116 cm) were studied. This was a stony variation: A1 was characterised by few faintly developed micropeds, while B31 and B32 had common, fairly developed micropeds. The related distribution of plasma with reference to the skeleton grains was agglomeroplasmic with some intertextic patches in A2. IN B31, the arrangement was agglomeroplasmic, intergrading into intertextic and porphyroskelic, while in B32 it was porphyroskelic with some agglomeroplasmic patches. The plasmic fabric in A1 was isotic, while in B31 and B32 isotic aggregates were still dominant but part of the plasma had flecked orientation patterns referred to as Vosepic.

TABLE 1: MICROMOPHOLOGICAL DESCRIPTION OF THE PROFILES OF SOME UPPER SLOPE SOILS IN THE SAVANNA ECOSYSTEMS OF SOUTHWESTERN NIGERIA

Profile No.	Classification	Horizon	Depth (cm)	Peds	Related Distribution of Plasma with Reference to Skeleton grains	Plasmic Fabric	Voids	Pedological Features	Remarks
1.	Typic Haplustalf	A1	0 – 5	Few, faintly developed micropeds	Agglomeroplasmic with some intertextic	Isotic	Common, simple packing voids	Common, discrete loosely adhesive subspherical unoriented sesquioxide nodules.	Some big-sized quartz grains are fractured with plasma deposits along cracks.
		B1	63 – 67	Common fairly developed micropeds	Agglomeroplasmic intergrading into intertextic and Porphyroskelic	Isotic with Skel-Vosepic	Simple packing voids and intrapedalvugh metavughs.	Simple embedded grain cutans and occasional cutans.	Root remains in voids. The S-matrix is dominantly skeletal and most big size grains are fractured with thick plasma deposits at the surfaces.
		B32	112–116	Common fairly developed micropeds	Porphyroskelic with some agglomeroplasmic	Isotic with some Skel-Vosepic	Interconnecting vughs, intrapedal metavughs and simple packing voids.	Some simple embedded grains cutans and occasional vugh cutans	S-matrix is domidominantly skeletal but at advance stage of weathering.

TABLE 1 CONTD.

Profile No.	Classification	Horizon	Depth (cm)	Peds	Related Distribution of Plasma with Reference to Skeleton grains	Plasmic Fabric	Voids	Pedological Features	Remarks
2	Typic Ustropept	B1	61—65	Few, faintly developed micropeds	Agglomeroplasmic	Argillasepic with some isotic.	Simple packing voids	Common, discrete weakly adhesive, subspherical unoriented sesquioxinic nodules.	Many fractured quartz grains.
3	Typic Ustropept	A2	0 – 4	Common, weakly developed micropeds.	Agglomeroplasmic with some Intertextic.	Isotic	Simple packing voids.	Common, discrete weakly adhesive, subspherical unoriented nodules.	Many fractured quartz grains.
		B3	82—86	Common, weakly developed micro and macropeds.	Intertextic intergrading into Porphyroskelic with Agglomeroplasmic patches.	Isotic with some Skel-Vosepic	Interconnecting vugh and intrapedal vughs	Simple embedded grains cutans and occasional vugh cutans.	S-matrix is dominantly skeletal, but heavily weathered with plasma along cracks.

Common, simple, packing voids were present in the A1 horizon. Also, Spv (skeleton-plasma-voids) ratio was 5:1:1:4, indicating the dominance of skeleton grains and voids, Simple packing voids were dominant in B31, but some intrapedal metavughs were present. Spv ratio was 2:2:6 showing the dominance of voids. B32 was characterised by common interconnecting vughs; intrapedal metavughs and simple packing voids. Spv ratio was 4:4:2; indicating more plasma than the upper layers.

In this profile, glaebules (pedorelicts) were restricted to the A1 horizon, with common, discrete, loosely adhesive, subspherical unoriented sesquioxide nodules. The pedological features in the B31 and B32 horizons were mainly simple grain cutans and occasional vugh cutans. Generally, the s-matrix was dominantly skeletal and most coarse grains were fractured, with thick plasma deposits along the cracks. The indicates the immature nature of the profile.

In profile 2, only the B1 (61 – 65 cm) horizon was examined. It was a sandy variation. The pedality was few, faintly developed micropeds; with an agglomeroplasmic arrangement. The plasmic fabric was argillasepic with some isotic aggregates.

Simple packing voids were present with Spv ratio of 5:1:4, indicating that skeleton grains and voids dominate the s-matrix. No cutans were present. Common, discrete, loosely adhesive, unoriented, subspherical, sesquioxide nodules were the only pedological features present.

Generally, most quartz grains were fractured with plasma deposits along cracks.

In profile 3, a typic Ustropept, horizons Ap (0–4cm) and B31 (82–86cm) were examined. This profile was sandy and stony. The pedality of the Ap horizon was described as weakly developed micropeds, while in the B31 horizon, the peds were weakly developed micro and macropeds. The related distribution of plasma with reference to skeleton grains was agglomeroplasmic with some intertextic patches in Ap. The arrangement in B31 was intertextic intergrading intoporphyroskelic, with agglomeroplasmic patches. The plasmic fabrics in Ap was isotic. Isotic aggregates were common in B31 and part of the plasma had flecked orientation patterns referred to as skel-Vosepic.

Simple packing voids with root remains in parts, dominated the AP horizon, Spv ratio was 5 : 1 : 4, indicating the dominance of skeleton grains and voids. In B31, the voids were mainly interconnecting vughs and intrapedal vughs. Spv ratio was 2 : 4 : 4 indicating more plasma deposits in the horizon.

The dominant pedological features in the Ap horizon were the nodules. These were discrete, weakly adhesive, subspherical unoriented, sesquioxide nodules. The pedological features in the B31 horizon were mainly simple embedded grain cutans and occasional vugh cutans.

Throughout, the s-matrix was dominantly skeletal and most coarse grains were fractured, with plasma deposits along the cracks. This indicated the immature nature of the profile.

Analytical Characteristics

The soils investigated were slightly acid to neutral with pH ranging from 5.6 to 7.5. Profile 3 appeared more alkaline than profiles 1 and 2. The highest values of pH were restricted to the surface horizons and decreased down the profile, with increases again in the bottom horizons. The high values in the surface horizons may be due to higher basic cation contents of the ash, which has resulted from annual burnings in the area. Ca and Mg were the dominant exchangeable cations in the soils, followed by K and occasionally Na. The neutral condition of the C horizon in profile 3, indicates probable derivation from base-rich parent material.

Cation exchange capacities were low (1.8 – 18.2 meq/100g). Highest values occurred in the surface horizons in conformity with organic matter distribution. The values then decrease and increase again in close association with the percent clay. Base saturation percentages were high (between 72–100%) and exhibited no well-defined sequence down the profiles. Available phosphorus values were low in profiles 1 and 2 but high in profile 3, with a range of 209 to 795 ppm. This might probably be ascribed to the presence of phosphorus bearing minerals in the detrital analysis. Organic carbon and Nitrogen values were low and concentrated in the surface few centimetres of the soils. The values 0.68% and 2.41% decreased progressively down the profiles.

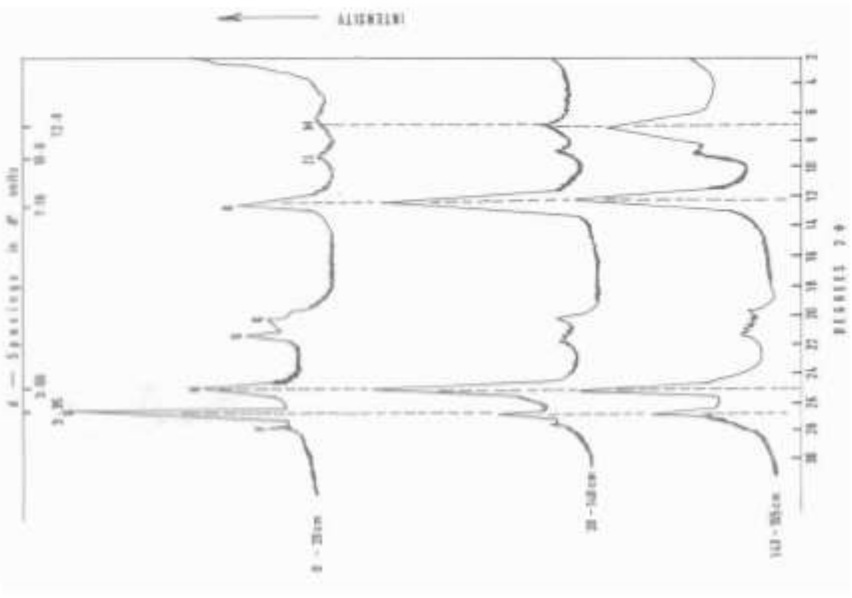

Fig. 2: X-ray dilfractograms for K--Saturated oriented soil clay profile 1 (K = Kaolinite, 11 -- Illite, A = Quartz. G = Geothite, M = Montmovillonite and F = feldspan).

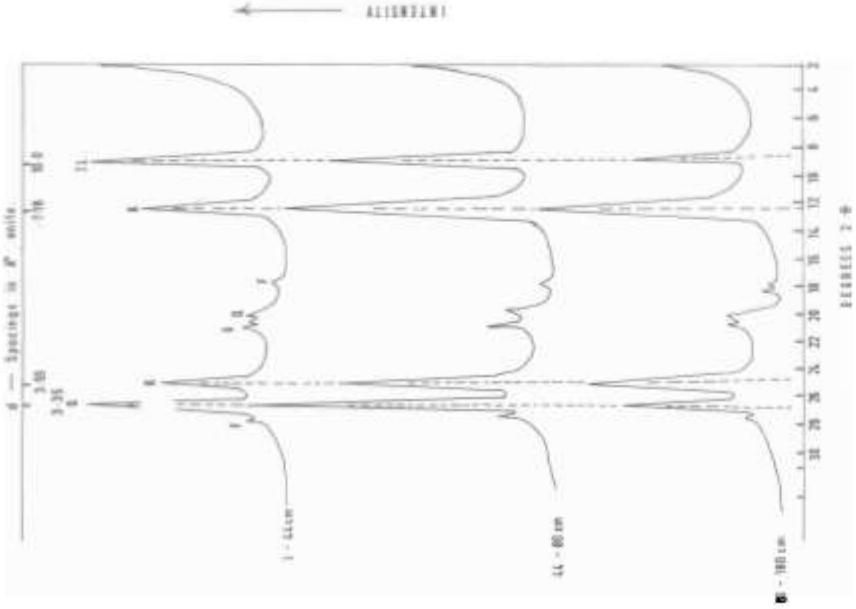

Fig. 3. X-Ray Diffractogram for K--Staturated Oriented Soil clay Profile 2 (K = Kaolinite, 11 = Illite, Q = Quartz, G = Geothite and F = Feldspan).

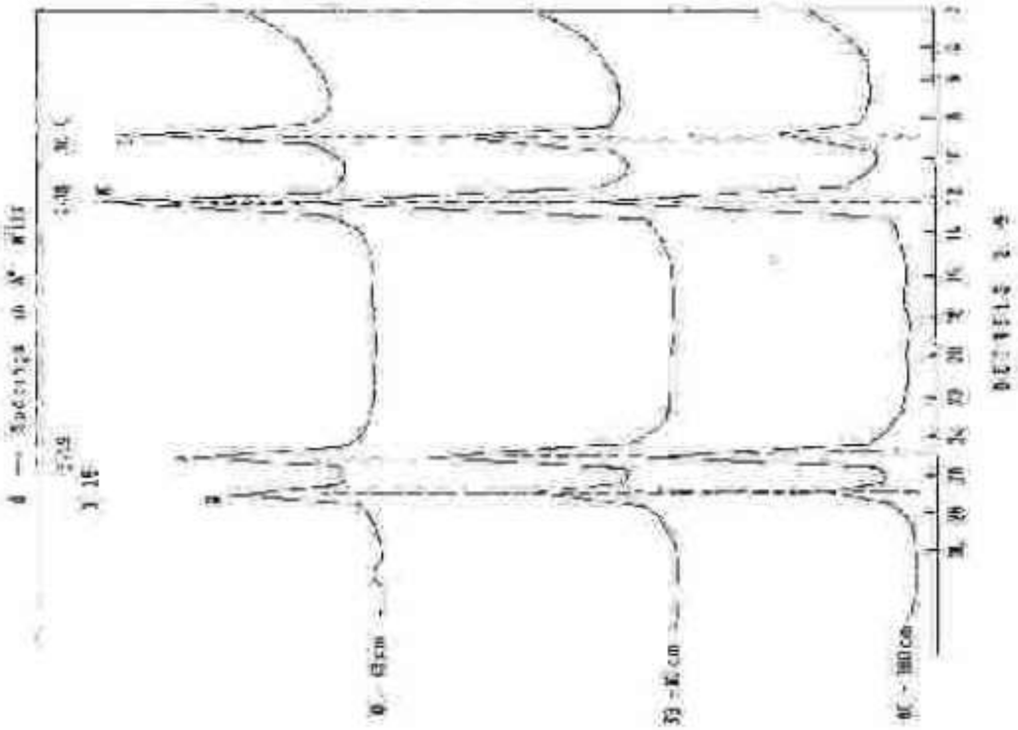

Fig. 4: X-ray diffractograms for K−Saturated oriented soil clay profile 3 (K−Kaolinite, 11 = Illite, and Q= Quartz.

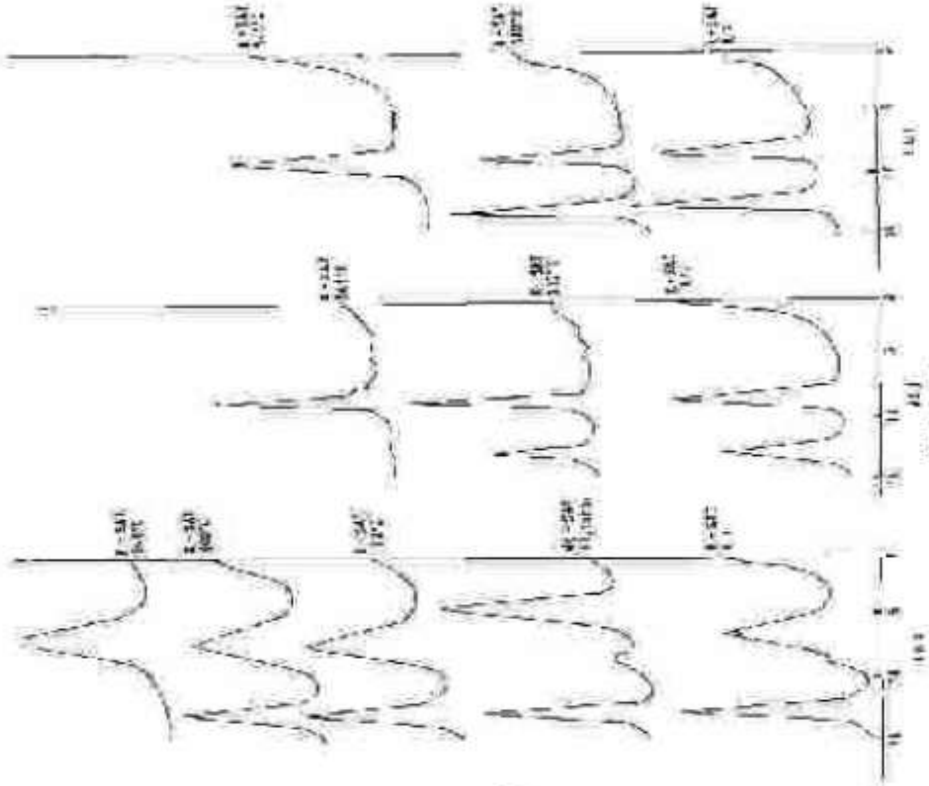

Fig. 5: X-ray diffractogram of treated soil clays.

(a) Profile 1 140 − 195 cm.
(b) Profile 2 44 − 80 cm
(c) Profile 3 , 0−0−33 cm R.T. = Room Temperature

TABLE 2: PHYSICAL AND CHEMICAL PROPERTIES OF SOME UPPER SLOPE SOILS OF SAVANNA ECOSYSTEM IN SOUTHWESTERN NIGERIA

Profile No.	Horizon	Depth (cm)	Mechanical Analysis: Coarse Sand 2000–200u	Fine Sand 200u–20u	Silt 20u–2u	Clay 2u	% P.H 1:1 Water	Extractable bases: Na	K	Mg	Ca	T.e.b. meq/100g	C.e.c. meq/100g	% Base Sat.	Available P ppm	% Total N o.d.s	% Org. C O.d.s.
1	A1	0 – 5	59.0	31.0	5.0	5.0	6.7	T	0.2	1.1	3.4	5.2	5.6	93	11.4	0.06	0.95
	A3	5 – 20	58.0	31.0	5.0	6.0	6.6	NIL	0.2	0.7	2.5	3.4	4.1	83	4.5	0.04	0.56
	B1	20 – 50	72.0	16.0	5.0	7.0	6.5	NIL	0.1	0.6	1.8	2.5	3.8	66	2.6	0.02	0.32
	B31	50 – 103	55.0	15.0	5.0	25.0	6.2	T	0.2	1.7	3.6	5.5	6.9	80	5.0	0.03	0.26
	B32	103 – 140	61.0	13.0	7.0	19.0	6.3	T	0.2	3.3	4.4	7.9	8.7	91	4.3	0.02	0.11
	C1	140 – 168	50.0	19.0	8.0	23.0	6.4	T	0.2	5.0	5.6	10.8	11.5	94	3.2	0.03	0.09
	C2	168 – 195	55.0	19.0	6.0	20.0	6.5	T	0.2	5.1	5.6	10.9	11.0	99	3.0	0.02	0.09
2	AP	0 – 6	53.9	35.2	7.0	3.9	6.9	0.2	0.4	0.1	5.3	6.1	6.3	97	12.5	0.16	0.65
	A3	6 – 44	68.3	25.6	2.6	3.6	5.9	0.3	0.1	0.1	1.0	1.5	1.8	93	1.5	0.02	0.28
	B1	44 – 80	55.3	35.5	3.5	5.6	5.6	NIL	0.2	0.01	1.7	1.9	1.8	100	1.7	0.02	0.11
	B31	80 – 144	71.2	19.8	1.9	7.1	5.8	0.2	0.1	0.02	1.7	2.0	2.8	72	1.3	0.01	0.14
	B32	144 – 180	61.4	31.7	6.4	10.6	6.1	0.3	0.2	0.02	2.3	2.9	8.9	33	1.1	NIL	0.11
3	AP	0 – 15	55.0	23.0	9.0	13.0	7.5	T	1.0	2.4	19.5	22.9	18.2	100	493.1	0.16	2.41
	A3	15 – 33	51.0	25.0	10.0	14.0	7.3	T	0.4	0.7	6.0	7.1	6.3	100	209.1	0.04	0.58
	B1	33 – 48	56.0	19.0	7.0	18.0	6.8	T	0.4	0.5	6.0	6.9	6.7	100	358.9	0.05	0.55
	B2	48 – 80	57.0	18.0	7.0	18.0	6.6	T	0.4	0.8	6.2	7.4	7.9	94	408.0	0.03	0.30
	B31	80 – 108	71.0	14.0	4.0	11.0	6.9	T	0.3	0.5	5.2	6.0	6.0	100	324.4	0.02	0.20
	B32	108 – 150	57.0	16.0	8.0	19.0	6.9	T	0.3	0.6	4.8	5.7	5.8	98	795.6	0.03	0.24
	C	150 – 180	65.0	10.0	5.0	19.0	7.0	T	0.2	0.4	3.7	4.3	4.1	100	379.8	0.02	0.10

T = Trace.

Detrital Analysis

The results of the specific gravity analysis showed small differences in the distribution of the heavy and light fractions with depth, especially in profile 1 (Table 3). This indicates the non-uniformity profile 1, which could be ascribed to hill-creep. This is in conformity with the recognition of pedisediments in south-western Nigeria by Folster and Ladeinde (1967), Folster (1969), Burke and Durotoye (1970) and Ojanuga *et al* (1976).

In terms of heavy minerals, (Table 4) profile 1 was characterised by the dominance of the opaques (mainly haematite) and hypersthene. Biotite, Diopside and Epidote occurred as traces. The presence of hypersthene, diopside and epidote indicates the influence of intermediate or basis rocks with the profile. Profiles 2 and 3 were characterised by the dominance of the opaques and Zircon Staurolite, Epidote, Biotite, Hypersthene, Augite, Enstatite and Olivine occurred in subordinate amounts.

TABLE 3: PERCENTAGE HEAVY AND LIGHT MINERALS IN THE FINE SAND FRACTION (100 – 50u)

Profile No.	**Depth (cm)**	**% Light fraction (SG.<2.90)**	**% Heavy fraction (SG>2.90)**	**% Experimental Error**
1	0 – 5	96	2	–2
	20 – 50	86	12	–2
	103 – 140	88	10	–2
	168 – 195	75	24	–1
2	0 – 6	99	1	–
	44 – 80	99	1	–
	144 – 180	99	1	–
3	0 – 15	98	1	–1
	33 – 48	99	1	–
	80 – 108	99	1	–
	150 – 180	99	1	–

TABLE 4: MINERAL COMPOSITION OF HEAVY FRACTION (S.G. 2.90). PERCENTAGE OF TOTAL COUNTS

Depth	0—5	Profile 1 20 — 50	103—140	168—195	Profile 2 0 — 6	44 — 80	144—180	Profile 3 0 — 15	33 — 48	80 — 103	150 — 180
Kyanite	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	—	—	—	—	—	—	—	—	1	—	1
Ziron	—	—	—	—	14	6	5	41	33	20	33
Opaque	50	72	49	31	71	80	73	46	60	61	55
Garnet	—	—	—	—	Rare	—	Rate	—	—	—	—
Rutile	—	—	—	—	—	—	—	—	—	—	—
Titanite	—	—	—	—	—	—	—	—	— —	—	—
Staurolite	—	—	—	—	—	Rare	—	1	Rare	1	2
Tremolite											
Actinolite	—	—	—	—	—	—	—	—	—	—	—
Epidote	1	—	—	—	1	—	1	1	—	—	1
Hornblende	—	—	—	—	—	—	—	Rare	—	—	Rare
Biotite	—	1	—	4	7	Rare	1	2	4	16	4
Chlorite	—	—	—	—	—	—	—	—	—	—	
Clinozoisite	—	—	—	—	—	—	—	—	—	—	—
Hypersthene	44	26	9	63	2	7	Rare	6	—	1	2
Diopside	1	—	1	—		Rare	—	—	—	—	—
Apatite	—	—	—	—		—	—	—	Rare	—	—
Augite	—	—	—	—	Rare	Rare	3	Rare	Rare	—	—
Enstatite	—	—	—	Rare	—	Rare	—	—	Rare	Rare	—
Olivine	—	—	—	—	1	Rare	2	—	—	—	Rare
Sillimanite	—	—	—	—	—	—	—	—	—	—	—
Weathered	4	1	1	2	3	5	14	3	1	—	1

TABLE 5: MINERAL COMPOSITION OF LIGHT FRACTION
PERCENTAGE OF TOTAL COUNTS

Profile No.	Depth (cm)	Quartz	Orthoclase	Plagioclase	Muscovite	Biotite	Chlorite	Microcline	Weathered
1	0 — 5cm	94	Rare	1	2	—	—	—	2
	20 — 50cm	69	—	Rare	6	1	—	—	6
	103 — 140cm	68	Rare	1	2	23	—	Rare	5
	168 — 195cm	84	Rare	Rare	1	13	—	Rare	1
2	0 — 6cm	82	Rare	3	Rare	12	—	—	2
	44 — 80cm	83	Rare	Rare	16	—	—	—	1
	144 — 180cm	67	—	1	27	4	—	—	1
3	0 — 15cm	66	—	10	17	7	—	—	3
	33 — 48cm	60	1	2	11	26	—	—	1
	80 — 108cm	91	1	1	4	2	—	—	1
	150 — 180cm	93	Rare	1	1	4	—	Rare	1

The presence of Hypersthene, Augite, Olivine, Enstatite and Epidote indicates the influence of basic rocks in the development of the profiles. The minerals are mainly ferro-magnesian, occurring widely in igneous and metamorphic rocks. The presence of Garnet in profile 2, proves the influence of metamorphosed granitic rock and further indicates the nearness of gneisses and schists.

The original rock composition is well reflected in heavy minerals observed in the investigated sand fraction. Hypersthene, Diopside, Enstatite, Augite, Olivine and Epidote are mainly derived from ferromagnesian rocks, occurring widely in the igneous and metamorphic rocks.

The heavy mineral suites showed no definite sequence down the profiles. This indicates non-uniformity of the parent materials, which could be ascribed to the admixture of other minerals. This is in conformity with the three erosional cycles recorded in the area by Swardt (1953) and Burke and Durotoye (1970).

The results on the light minerals complement those obtained on the heavy mineral suites (Table 4). Quartz was the dominant mineral. Orthoclase, PLagioclase, Muscovite, Biotite and Microcline occurred in surbordinate amounts. The presence of Plagioclase in the profiles further confirms the influence of intermediate or basic rocks. Also, the distribution of the minerals suites shows no regular sequence, thus confirming non-uniformity of the profiles.

Clay mineralogy

Kaolimite was present in the three soil profile studies. It is characterized by the strong reflections at 7.18A° and 3.59A° (Figs 2–5). The broadness of the peaks and their disappearence below 550° C indicate disordered kaolinite (Grim, 1968 Carroll, 1970). The occurrence of this phyllosilicate is indicative of the prevailing weathering conditions in the tropics.

The position and size of the 10A° reflection was not affected by temperature changes up to 100° C. This eliminates the presence of hydrated kaolinite (Halloysite). At higher temperature, the 10A° reflections become more intense for all the samples. In the three samples from Profile 1, the collapse of the expanding clay (smectite) enhanced the 10A° reflections at temperatures from 300° C. No distinction is here made between the members of the mica group of minerals.

TABLE 6: QUANTITATIVE ESTIMATES OF PHYLLOSILICATES IN THE SOIL CLAY FRACTIONS

Profile No.	Depth (cm)	Kaolinite	Illite	Montrmorillonite
1	0 – 20	60	20	20
	20 – 140	60	10	10
	140 – 195	30	20	50
2	0 – 44	40	60	Nil
	44 – 80	50	50	Nil
	80 – 180	80	20	Nil
3	0 – 33	60	40	Nil
	33 – 80	60	40	Nil
	80 – 180	80	20	Nil

*Weighted percentages based on the method of Avery and Bullock (1977).

The 15A° reflection in the Mg-saturated samples of profile 1 moved up to 17A° after treatment with glycerol. The inability of potassium to collapse the structure to 10A° (12.8A° recorded) eliminates vermiculite (Pawluk and Brewer, 1975a and b). The 17A° d-spacing was permanently collapsed to 10A° at a temperature below 550° C, thus confirming the presence of smectite as the expanding clay since vermiculite regains its interlayer water rapidly at temperatures up to 550° C (Barshad, 1950) and does not completely lose its ability to rehydrate below 700° C (Walker, 1951).

Quartz was present in all samples of the three profiles studies, though its abundance varied within each profile. Feldspars were present in profiles 1 and 2 but not in profile 3. Although all the samples were pretreated by the dithionite citrate – $NaHCO_3$ (DCB) method to remove sesquioxides the presence of goethite was recorded in profiles 1 and 2.

Quantitative estimation of the phyllosillicate minerals and weighted estimates of the clay minerals present in the soils studied were obtained using the method of Avery and Bullock (1977). The proportion of mica was directly related to the area beneath the 10A° reflections of the untreated sample. Kaolinite was weighted relative to mica by dividing the area of its 7.18A° reflection by a factor of two. Smectite was weighted relative to using the 17A° reflection of the glycerated sample.

Soil Classification (Soil Taxonomy)

Profile 1 is a mineral soil, with an ochric epipedon low in organic matter and high in values and chromas. The profile has an argillic horizon with distinct, recognizable cutans (clay skins) in the B3 horizon. Base saturation was high, (ranges between 80% nd 99%) and kaolinite was prominent in the clay fraction. These criteria place the profile in the order of Alfisols.

Below the argillic horizon, there is a horizon of transition to the C horizon in which there has been weathering and alteration. The alteration of this transitional horizon is comparable to that of a cambic horizon. But, USDA (1975) stated that because there is an overlying argillic, a transitional horizon of this kind is not considered a cambic horizon. So profile 1 can be classified as an Alfisol, grouped as 'Ustalfs' because of its present moisture regime. On the Great Group level, the soil is classified as Haplustalf. At the sub-group level, the Typic Haplustalk is recognized.

Profiles 2 and 3 are mineral soils with altered horizons, that lack argillic (illuvial) horizons, but retain weatherable minerals. Profile 2 has an ochric epipedon, while profile 3 has a mollic epipedon. Base saturation is high, but kaolinite is a dominant clay mineral even though considerable amounts of 2:1 clay types do occur. These criteria have placed the soils in the order of Inceptisols.

The Inceptisols are classified as Tropepts on the basis of soil temperature regime. At the Great Group level, the soils are classified as Ustropept because of their present soil moisutre regime. At the sub-group level, the soils will classify as typic subgroup. The soils are well-drained with cambic horizons that have formed from country rocks viz syenite and Porphyritic granite. They do not have shallow lithic contact.

Summary and Conclusion

The characteristics of the soils studied have been affected considerably by the interaction of climate, parent material, relief, vegetation, time and biological factors. Their influence is reflected in the morphological properties of the soils.

As a result of the field observations, supported by analytical data, it appears that the surface horizons may be developed in transported material, while the subsurface horizons may be derived from the underlying rock. The physical, chemical and mineralogical data do not show any well-defined sequence in the profiles. These indicate the complexity of the profiles, especially profile 1 with both argillic and cambic horizons. These also confirm the non-uniformity of the parent materials. Folster and Ladeinde (1967), Folster (1969), Burke and Durotoye (1970) and Ojanuga *et al* (1976) reported that most of south-western Nigeria has been subjected to three erosional phases, which have influenced the present day relief and resulted in formation of secondary deposits (pedisediments). These pedisediments have subsequently become soil parent materials.

The soils have been subjected to weathering in this sequence. Profile 1 is more intensely weathered than profiles 2 and 3. Clay mineralogy indicated that kaolinite is conspicuously present in the solis. considerable amount of smectitte and mica were also recorded. In the B3 horizons of the soils, some minerals have not been completely destroyed. Feldspar minerals and easily weatherable minerals such as biotite, pryroxenes and amphiboles have been observed to the partly weathered. These indicate the incipient nature of weathering in the profiles.

Generally, it was observed that cutans (clay skins) may not be a good diagnostic feature for argillic horizons in south-western Nigeria. As a result of micromorphological studies of the soils, cutans have been observed to be associated with both inceptisols and Alfisols. Profiles 1 and 3, have been classified as Alfisol and Inceptisol respectively. They have cutans in the B3 horizons. However, USDA (1975) indicated that a cambic horizon may have a few clay skins, but that evidences of clay illuviation are not adequate for recognition of an argillic horizon.

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