Ife Journal of Agric. Vol. 6 Nos. 1 & 2 (1984)

Micromorphology and soil formation of some savanna alfisols in South Western Nigeria

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Abstract

The relationship between micromorphology and soil formation in some well-drained soils in the savanna ecosystem of south-Western Nigeria was studied. Arrangements of soil constituents were evaluated in nineteen (75 x 25mm) thin sections made from undisturbed samples.

Thin section studies show that the related distribution of plasma and skeleton grains is usually agglomeroplasmic with some intertextic patches in the surfacial horizons of the soils. The sub-surfacial horizons of the soils are characterized by a porphyroskelic related distribution.

Pedological features are glaebules and cutans. Pedorelicts and Lithorelicts were recognized. The sub-rounded shape of the pedorelicts indicates that they have been transported and the presence of the nodules in the surfacial horizons of most profiles probably shows former soil process.

Introduction

Very few micromorphological studies have been made of Nigerian soils. The main exceptions are Ojanuga (1971) and Ashaye (1975). The former studied the micromorphology of three toposequences of soils at Ife and Asejire in South-Western Nigeria. He concluded that the soils exhibited characteriatics derived from former soils (e.g. pedorelicts or concretions, iron stained quartz grains, earthy ironstones or fragments of former crusts). Ashaye studied the micromorphology of four representative soils derived from diorite in south-western Nigeria. He noted redistribution of sesquioxides in the soils to form nodules, concretions and diffuse sesquioxidic patches.

The aim of the present study was to provide micromorphological information about eight Alfisols from south-western Nigeria. Particular emphasis was placed on the pedogenic organisation of the constituents of these soils and provide a basis for interpreting their genesis and the environmental conditions under which they formed.

The Present soil environment:

The study area is situated within Oyo State, between latitudes 7° 30'N and 9° 15'N and longitudes 2° 40' and 4° 30'E (Fig. 1). It has a periodically dry savanna climate belonging to the Guinea Savanna group (Papadakis, 1965). Annual rainfall ranges from 1000 to 1500mm occurring mainly in six months.

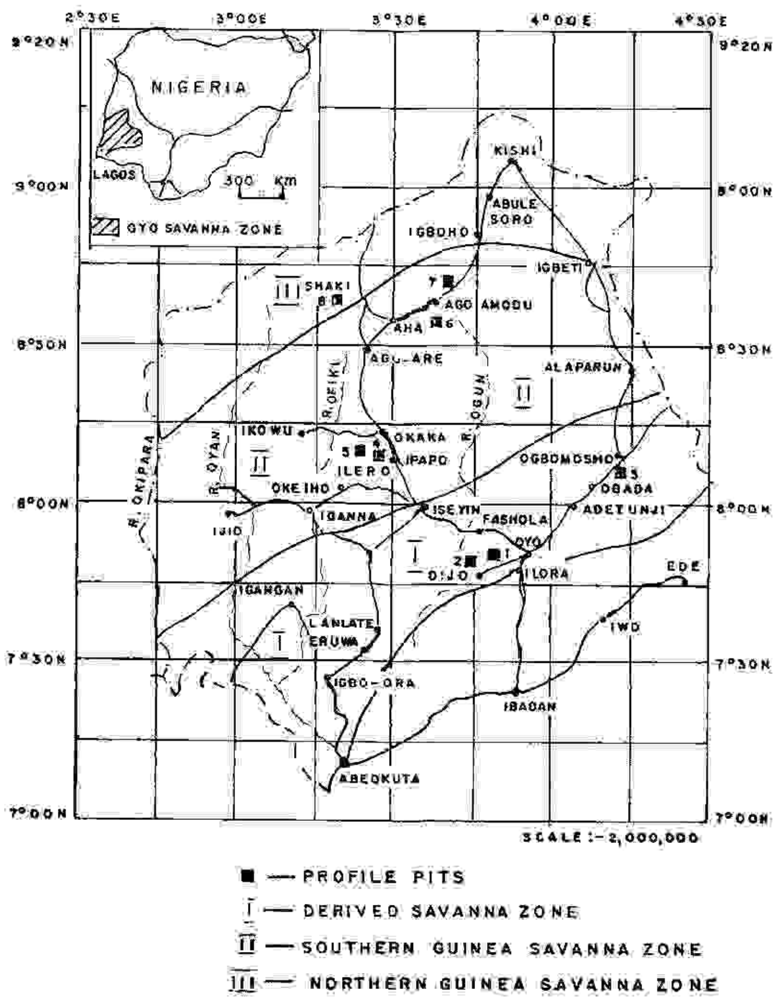

Fig. 1: Location Map of the investigated profiles.

The land surface is old; according to King (1967, the main surface is Post-African of late Ceinozoic age. Thee erosional periods are presumed to have taken place on the basis of which De Swardt (1953) concluded that periods of humid and arid climates alternated in the area. Studies of some pediments (Folster and Ladeinde, 1967; Burke and Durotoye, 1970 and Ojanuga *et al*, 1976) revealed the presence of stratified slope deposits which could not have been laid down under the present climatic conditions. Various processes have played a role in transporting and mixing soil materials, and this is reflected in the complexity of the soils.

Methods

The arrangement of soil constituents in eight *Alfisol* profiles was studied in 19 thin sections (75 x 25mm) made from undisturbed samples. Five of the soils were classified as *Haplustalfs* (Profiles 1,3,5,7 and 8), two as *Paleustalfs* (4 and 6) and one as a *Plinthustalf* (Profile 2). Several horizons were sampled in some profiles whereas for others only one sample was taken to represent a particular phenomenon such as clay illuviation or induration. The samples were impregnated with Araldite. The terminology of Brewer (1964) with some modifications was used to describe the sections.

The summaries of environmental characteristics, profile descriptions and analytical data of the soils are given in Appendix 1 – Tables 1–3.

Results and Discussion

(a) Microstructure:-

The summary of micromorphological descriptions is shown in Appendix 11 – Table 4.

The surface horizons of the profiles are characterised by weakly developed, subangular micropeds arising from a combination of ploughing, soil creep and faunal activity. Between the peds are vughs and some simple packing voids. Distinct subangular to angular meso and macropeds dominate the subsurface horizons. Skew planes, vughs and channels are the dominant forms of voids. The planar voids relate to shrinking and swelling of the clayey subsurface horizons during the periodicially wet and dry seasons characteristic of the area. Although faunal activity is most common in the surface horizons, the channels in the sub-surface horizons originate as root, eathworm, and termite and ant burrows.

(b) Pedological Features

The most striking pedological features are the glaebules and cutans. The glaebules have an undifferentiated internal fabric and hence are nodules rather than concretions. Two types of nodules are present viz: nodules with soil fabric, called pedorelicts, and nodules with rock fragment, termed lithorelicts (Plates 1 & 2).

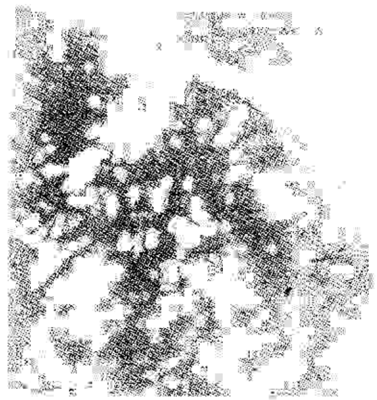

PLATE 1: Portion of sequioxide nodule (Pedorelict) having sharp boundary with the S-matrix of profile 8 (B_2t horizon) Typic Haplustalf. (Note the undifferentiated internal fabric of the nodule). Thin section under plain light.

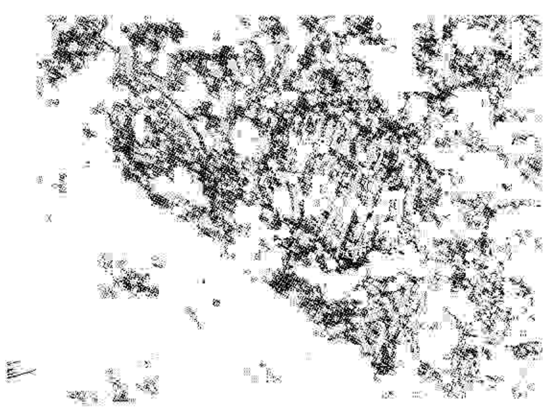

PLATE 2: Portion of an irregular Nodule with rock fabric (Lithorelict) in Profile 4 ($B_1/B_{21}t$ horizon) Typic Paleustalf. Thin section under plain light. (Note the feldspar crystals)

The pedorelicts in thin section vary in colour from very dark brown, dark brown, reddish brown to yellowish brown between crossed polarisers. Their colour often suggests high iron and/or managanese contents and this has been confirmed by elemental analysis (ojo-Atere, 1978). Lithorelicts are similarly high in iron and/or managanese.

The smooth rounded form of the pedorelicts suggest that they have been transported whereas the lithorelicts have a more irregular, angular form consistent with in situe formation.

The pedorelicts in the surface layers may be interpreted as remnants of old soil horizons since they have features in common with B horizons. The dating of these pedorelicts is speculative at this stage but it is assumed that they were formed prior to the three erosional phases reported for this area.

Void and grain argillans are mainly restricted to the B2t and B3 horizons. Both simple and compound types are present. (Plates 3 and 4). They are strongly oriented. They are, however, discontinuous and occupy only a very small proportion of the total plasma. They are mainly ferriargillans judging by their dark brown colours. A few ferrans and mangans are also present.

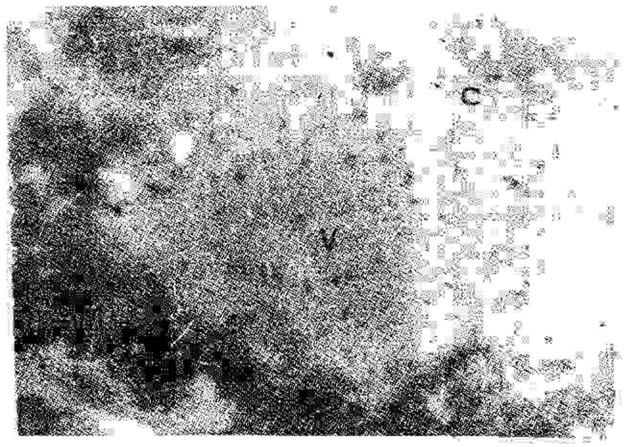

PLATE 3: Simple vugh cutan with strong continuous parellel orientation in profile 5 (B_3 horizon) Typic Haplustalf. Thin section under plain light. The central portion (V) is a vugh. The broad zone (C) surrounding the vugh is cutan (SM = S-Matrix).

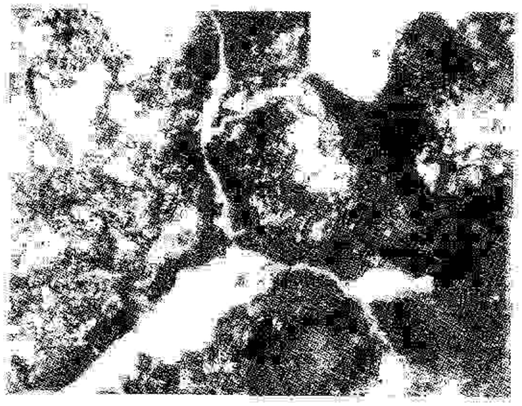

PLATE 4: Graded compound cutan (C) in Profile 5 (B_3 horizon). Typic Halplustalf Thin section under plain light.

(c) Plasmic fabric and Related Distributions:

The surface horizons have a generally isotic plasmic fabric, presumably related to the presence of organic matter and the levels of iron oxides. The related distribution of plasma and skeleton grains in the surface layer is agglomeroplasmic with a few intertextic pockets (Plate 5).

The surbsurface horizons are characterised by more plasma separation leading to complex plasmic fabrics with ma – skel – vo-latti-sepic entities all represented. The related distribution is porphyroskelic (Plate 6).

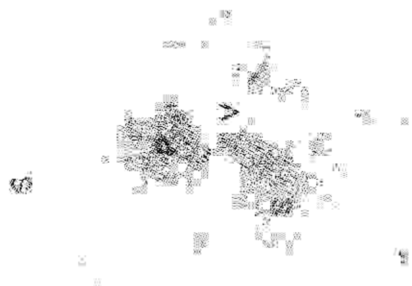

PLATE 5: Agglomeroplasmic arrangement in Profile 7 (A_1) – Typic Haplustalf. Thin section under plain light. (S = Skeletal grain; V = Void; P = Pasma).

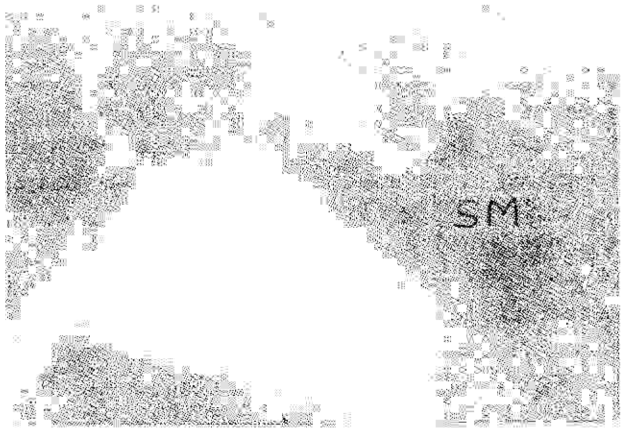

PLATE 6: Porphyroskelic type of arrangement in the B_{32} horizon of profile 8 – typic Haplustalf. Thin section under plain light, (Note the occurrence of oriented cutans around voids and skeleton grains (Skel-Vo-Sepic plasmic fabric). Also, note the isotic patches in the S-matrix.

Soil formation:

The size and shape of the peds are probably inherited from the parent material. But the peds in the surfacial horizons have been considerally modified probaly by the disturbance of the soil material by ploughing, faunal activities and soil creep.

The smooth subrounded shapes of the pedorelicts indicate that they have been transported, while the rough and angular forms of the lithorelicts indicate that they have probably been formed in-situ. The presence of pedorelicts with porphyroskelic arrangements in the surfacial horizons might be interpreted as remnants of an old soil borizon. This is strongly supported by the similarity between the internal fabric of the superficial pedorelicts and those of the subsurfacial horizons. Also, the presence of these pedorelicts in the surfacial horizons indicates the probable admixture of foreign materials in the soil and/or former soil processes leading to their formation. It is assumed that these pedorelicts were formed prior to the three erosional phases, which had been reported in the area. The lithorelicts were probably formed as a result of sesquioxide accumulations on weathered fragments of the underlying rock. The enclosed feldsper crystals in the lithorelicts, indicate probable formation of the glaebules in areas which are most susceptible to weathering in the parent rock. They are stable after their formation and highly subjected to ferruginization.

Cutans lining skeletal grains and voids, lend support to translocation of clay or sesquioxides from the upper horizons and subsequent accumulation in the B_2t horizons. The translocated sesquioxides form coatings of oriented pattern on the voids through which or into which water moves or in which it stands. The formation of these cutans suggests that the soils dry from time to time, as a result of which the soil solution is forced to retire in a more concentrated form to the surfaces of the mineral grains or voids. The presence of compound cutans indicates mass illuviation. The ustic moisture regime of the area of study, implies that sufficient moisture is available during a part of the year to induce the mass transport of colloidal soil material.

A possible cause of unoriented domains (asepic fabrics) in the surfacial horizons is probably due to the disturbance of the soil by soil fauna, tillage and soil creep. The unoriented domains in the subsurfacial horizons may be due to the normal weathering of parent rock.

The oriented patterns of plasma separations are probably due to the effects of pressures and tensions created as a result of wetting and drying. The periodic dry and wet seasons in the area favour this process.

The simple packing voids result from the normal packing of plasma and skeleton grains. The vughs are probably formed by differential weathering of mineral skeleton grains and complete removal of the weathering products by leaching. The formation of channels is probably by the activity of soil fauna or plant root systems. The planes originate from shrinking and swelling during wetting and drying, which is in conformity with the periodic wet and dry seasons operative in the area.

APPENDIX I TABLE 1 – ENVIRONMENTAL CHARACTERISTICS OF THE PROFILES

Profile No.	Soil Name	Location	Elevation	Physiographic Position	Surrounding Landform	% Slope	Vegetation	Parent Material	Drainage	Moisture Conditions	Surface Stone or Rock-Out Crop	Evidence of Erosion	Human Influence
1	OXIC HAPLUSTALF (Woro-	Ilora Farm Settlement	223m.	On slope near summit of rise	Undulating	3%	Cultivated Field under Maize	Granitic-gneiss	Well-drained	Slightly moist throughout	Stony	Slight sheet erosion	Cultivation with digging of surface soil
2.	PLINTHUSTALF (no-sub group) (Temidire series)	Ilora Farm Settlement	220m	Gentle lower slope	Undulating	3%	Cassia siamea plantation	Granitic gneiss	Well-drained	Slightly moist	Fairly stony	None	Established trees
3	TYPIC HAPLUSTALF (Iwo series)	Ogbomoso Farm Settlement	335m	Gentle Upper slope	Undulating	3%	Teak plantation	Granitic gneiss	Well-drained	Slightly moist throughout	Fairly stony	None	Under Teak plantation
4	TYPIC PALEUSTALF (Igboho series)	Block 272/56 near Okaka town	305m	Gentle Upper Slope	Undulating	3%	Bush regrowth	Granitic gneiss	Well drained	Slightly moist throughout	Fairly stony	None	Previously Cultivated

Appendix Table 1 Contd.

5	TYPIC HAPLUSTALF (Olorunda series)	Block 272/4c near Okaka town	305m	Gentle Upper slope	Undulating	3%	Bush regrowth	Gneiss	Well-drained	Slightly moist throughout	Fairly stony	None	Previously cultivated
6	TYPIC PALEUSTALF (Amodu series)	On the outskirts of Ago-Amodu	320m	Gentle Upper slope	Undulating	4%	Bush regrowth	Basic gneiss	Well-drained	Slightly moist throughout	Very few stones	None	Previously cultivated
7	TYPIC HAPLUSTALF (Aporu series)	Mile post 31/23, on Igboho/Shepeteri road	396m	Gentle lower slope	Undulating	2%	Bush regrowth	Granitic gneiss	Fairly well-drained	Moist throughout	Fairly stony	None	Previously cultivated
8	TYPIC HAPLUSTALF (Shepeteri Series	Block 118/4h near Shaki	472m	Gentle Upper slope	Undulating	2%	Bush regrowth	Grainite	Well-drained	Slightly moist throughout	Fairly stony	None	Previously cultivated

APPENDIX I TABLE 2 — MORPHOLOGICAL CHARACTERISTICS OF THE SOILS

Profile	Soil Name	Depth (CM)	Horizons	Colour	Texture	Structure	Consistence	Inclusions
1		0–18	Apcn	10YR4/2	LS	vwfsb	ld;fm1;msw	fcn
	OXIC	18–30	A_{31cn}	10YR4/2	LS	vwmsb	ld;fm_1;msw	mcn
	HAPLU. STALF	30–68	A_{32cn}	7.5YR5/4	Sl	wfsb	ld;fm_1;ssw	mcn;fqz.
		68–95	B_{1cn}	5YR4/4	SL	wmsb	ld;fm_1;ssw	acn;fqz
		95–168	B_{2cn}	5YR4/6	SCL	msmab	shd;fm_2;sw	fqz;acn
		168–180	B_{3cm}	5YR4/8	SCL	msmab	shd;fm_2;sw	fqz;acn.
2		0–10	A_1	7.5YR3/2	LS	wfsb	ld;lm;msw	–
		10–33	A_{31}	7.5YR3/2	LS	wfsb	ld;fm_1;msw	–
	PLINTHU-STALF	33–55	A_{32}	10YR3/4	S	Sl.	ld;lm;msw	–
		55–88	B_1	7.5YR5/4	S	Sl	ld;lm;msw	–
		88–130	B_{2cn}	7.5YR5/8	SL	wmsb	ld;fm_1;msw.	acn;aqz
		130–160	B_{31cn}	5YR5/8	SL	wmsb	ld;fm_1;msw	aqz;acn.
		160–180	B_{32}	(2.5YR6/4 (7.5YR5/8	SCL	msmab	hd;fm_2;sw.	aqz. wp
3		0–10	A_1	10YR2/2	SL	wfsb	ld;fm_1;msw	fqz;
	TYPIC	10–20	A_{3cn}	10YR2/2	SL	wmsb	ld;fm_1;msw	cqz;ccn.
	HAPLU-STALF	20–38	B_1	5YR3/2	SCL	msmab	hd;fm_2;sw	mqz;mcn
		38–85	B_{21}tcn	5YR4/4	C	scab	hd;vfm_2;sw	fqz.ccn

LEGEND

Texture:-

S – Sand

LS – Loamy sand

SL – Sandy loam

SCL – Sandy clay loam

SC – Sandy clay

C – Clay

STUCTURE:

vwfsb – very weak, fine, subangular blocky

vwmsb – very weak, medium subangular blocky.

wfsb – weak, fine, subangular blocky.

wmsb – weak, medium subangular blocky.

msmab – moderately strong, medium angular blocky.

Appendix Table 2 Contd.

	85–103	$B_{22}t$	(5YR4/6 (10YR5/8	C	Scab	hd;vfm$_2$;sw	fqz:	scab–	strong coarse, angular blocky
	103–140	B_{31}	(5YR4/6	SC	Scab	hd;fm$_2$;sw.	–	smab–	strong, medium, angular blocky.
	140–180	B_{32}	(5YR4/6 (10YR5/8	SC	Smab	hd:fm$_2$;sw	wp	msfab–	moderately strong, fine angular blocky
								St –	Structureless
4 TYPIC PALEU-STALF	0–13	Ap	5YR2/3	SCL	wfsb	hd sfm$_2$;	–	CONSISTENCE	
	13–25	B_{1cn}	5YR4/3	SCL	wmsb	hd;fm$_2$;sw$_{SW}$	fqz;ccn	ld – Loose dry	
	25–43	B_{21t}	(5YR4/3	SCL	msmab	hd:fm$_2$;sw	cqz;ccn	shd–	Lightly hard dry
			(5YR4/6						
			(5YR4/6					hd –	hard dry
	43–70	B_{22t}	(2.5YR4/4					fm_1 –	friable moist
			(5YR4/6					Sfm_2 –	Slightly firm moist
	70–100	$B_{23}t$	(5YR4&8						
			(7.5YR7/6	SC	Smab	hd;fm$_2$;sw	fqz.	fm_2 –	firm moist
	100–155	B_{31}	(2.5YR4/8; 7.5YR7/6,					vfm_2 –	very firm moist
			5YR4/8	SCL	msmab	hd;fm$_2$;sw.	—	nsw –	Non-sticky wet
	155–195	B_{32}	(10YR4/8;					ssw –	Slightly sticky wet.
			(7.5YR7/6	SCL	msmab	shd;fm$_2$;sw	–	sw –	Sticky wet.
	0–10	A_1	10YR2/1	SL	vwfsb	ld;fm$_1$;nsw	–		
5 TYPIC	10–23	A_3	10YR3/1	SL	wfsb	ld;fm$_1$;nsw	fcn		
HAPLUSTALF	23–38	B_{1cn}	5YR3/3	SL	waeb	ld;fm$_1$;nsw	fqz.ccn	Cn –	Accumulation of concretions
	38–53	$B_{21}t$cn	5YR3/3	SC	msmab	hd;fm$_2$;sw	fqz.ccn		
	53–103	$B_{22}t$	(2.5YR3/4					qz	Accumulation of quartz gravels
			(10YR6/4	SC	smab	hd;fm2;sw	fqz;fcn		
	103–145	$B_{23}t$	(10YR5/6; 5YR3/3						
			(2.5YR3/6	C	smcab	hd;fm$_2$;sw	fcn	wp –	Weathered

Appendix Table 2 Contd.

		145–180	B3	10YR4/8; 10YR7/4	SC	smab	hd;fm$_2$sw	wp
6		0–20	A_1	5YR3/3	SL	wfsb	ld,fm$_1$;nsw	—
	TYPIC	20–35	B_1	2.5 YR3/4	SCL	msmsb	shd;fm$_2$;sw	—
	PALEUSTALF	35–53	$B_{21}{}^t$	2.5YR3/6	SC	msmab	hd;fm$_2$;sw	–
		53–105	$B_{22}{}^t$	2.5YR3/7	SC	smab	hd;fm$_2$sw	–
		105–180	B_3	2.5YR3/8	SC	smab	hd,fm$_2$sw	fcn;fqz
7		0–18	A_1	10YR3/2	S	S	ld;fm$_1$nsw	—
	TYPIC HAPLUSTALF	18–35	A_3	7.5YR4/4	S	S	ld;fm$_1$;nsw	—
		35–53	B_{11}	7.5YR5/4	S	S	ld;fm$_1$;nsw	—
		53–105	B_{12cn}	10YR7/4	S	S	ld;fm$_1$;nsw	fcn, flpr
		105–143	$B_{21}{}^t{}_{cn}$	7.5YR5/4				
		143–180	$B_{22}{}^t{}_{cn}$	2.5YR3/6 10YR6/2 2.5YR4/6	SCL	msab	shd;fm$_2$;sw	mcn;
				10YR5/8	SCL	msab	hd;fm$_2$;sw	fcn
8	TYPIC HAPLUSTALF	0–5	A_{1cn}	10YR4/3	LS	vwfsb	ld;fm$_1$;nsw	fqz
		5–18	A_{3cn}	10YR3/4	LS	wfsb	ld;fm$_1$;nsw	mqz mcn
		18–23	B_{1cn}	7.5YR5/4	SCL	msfab	shd;fm$_2$;sw	acn,mqz
		33–90	$B_2{}^t{}_{cn}$	(2.5YR5/6 (5YR4/8	C	smab	hd;vfm^2;sw	aqz;wp
		90–145	B_{3cn}	10YR6/8;7 5YR5/8				
		145–185	C	(2.5YR3/6 10YR6/? 5YR4/6	SC	scab	hd;fm$_2$;sw	ccn;wp
				(7.5YR6/4	SC	smab	hd;fm$_2$;sw	awp

patches

fcn – fewqconcretions

mcn – man concretions.

ccn – Common concretions

acn – abundant concretions

fqz – few quartz gravels.

cqz common quartz gravels.

mqz – many quartz gravels.

aqz – abundant quartz gravels

flpr – few Iron-pan nubbles

APPENDIX 1

TABLE 3 – PHYSICAL AND CHEMICAL DATA OF THE SOILS

PROFILE NO	HORIZON	DEPTH (CM)	MECHANICAL ANALYSIS COARSE SAND	FINE SAND	SILT	CLAY	PH 1:1 H_2O	EXCHANGEABLE CATIONS (meq) Na	K	Mg	Ca	TEB Meq/ 100gms	CEC Meq/ 100gms	% Base SATH	AVAIL-ABLE P (ppm)	% TOTAL N	% ORGANIC C
1	Ap	0–18	72.1	20.3	3.9	8.8	6.0	T	0.3	0.6	2.4	3.3	2.9	100	7.9	0.03	0.42
	A_{31}	18–30	70.7	20.0	4.0	5.4	6.9	T	0.2	0.3	1.0	1.5	1.7	88	2.6	0.02	0.21
	A_{32}	30–68	84.4	6.4	2.7	6.5	5.8	0.1	0.1	0.4	1.5	2.1	2.0	100	3.1	0.02	0.24
	Bt	68–95	70.1	10.2	4.6	15.2	7.0	0.1	0.2	0.9	2.1	3.3	3.7	89	3.6	0.02	0.18
	B_2	95–168	59.2	6.9	5.1	28.7	6.8	0.1	0.3	1.2	3.3	4.9	6.2	79	4.3	0.02	0.15
	B_3	168–180	43.7	8.67	2.4	45.3	6.8	0.1	0.2	2.2	4.3	6.8	8.8	77	4.6	0.02	0.15
2	A_1	0–10	26.4	56.8	9.6	7.2	7.3	NIL	0.3	1.9	11.0	13.8	10.9	100	24.9	0.13	1.90
	A_{31}	10–33	66.4	25.3	4.6	3.7	5.7	T	0.1	0.8	2.1	3.0	2.4	100	2.9	0.02	0.52
	A_{32}	33–55	62.7	28.2	4.8	4.4	6.8	NIL	0.1	0.5	1.0	1.6	1.7	94	2.4	0.02	0.25
	B_1	55–88	70.1	19.5	5.2	5.3	5.3	NIL	T	0.3	0.5	0.8	1.3	62	2.4	0.01	0.16
	B_2	88–130	66.5	14.3	5.2	14.0	6.7	T	0.1	0.7	1.6	2.4	4.8	50	2.1	0.02	0.22
	B_{31}	130–160	65.4	16.3	6.4	22.0	6.4	T	0.1	0.8	1.5	2.4	4.0	60	3.1	0.01	0.19
	B_{32}	160–180	49.7	12.8	12.0	20.0	6.3	0.2	0.1	2.3	3.8	6.5	6.6	99	3.2	0.01	0.16

Appendix Table 3 Contd.

3.	A_1	0–10	29.4	43.0	11.1	16.5	6.3	NIL	0.6	2.0	7.9	10.5	10.01	1001	10.8	0.13	1.94
	A_3	10–20	56.9	22.7	6.8	13.6	6.5	T	0.3	1.1	5.0	6.4	7.0	91	5.5	0.06	1.03
	B_1	20–38	47.2	18.5	8.5	25.8	6.5	T	0.3	1.1	4.2	5.6	5.6	100	4.2	0.06	0.74
	$B_{21}t$	38–85	30.0	11.4	6.4	52.2	6.0	T	0.3	1.2	2.9	4.4	5.6	69	3.6	0.05	0.42
	$B_{22}t$	85–103	26.8	12.7	9.1	51.3	5.9	T	0.3	1.1	3.0	4.4	5.6	79	4.2	0.04	0.29
	B_{31}	103–140	24.5	16.1	12.7	46.8	5.9	T	0.3	0.8	2.7	3.8	4.7	81	3.4	0.02	0.18
	B_{32}	140–180	25.8	15.9	13.0	45.3	5.9	0.1	0.3	0.8	3.2	4.4	5.0	88	4.1	0.02	0.15
4	Ap	0–13	34.8	31.0	12.7	21.5	7.0	T	0.6	2.5	15.6	18.7	16.0	100	49.5	0.16	2.20
	B_1	13–25	34.9	24.5	10.3	30.3	6.8	NIL	0.6	1.7	6.9	9.2	9.1	100	4.9	0.66	0.82
	$B_{21}t$	25–43	42.5	17.1	8.6	31.8	6.7	NIL	0.5	1.4	4.4	6.3	6.7	94	4.5	0.05	0.50
	$B_{22}t$	43–70	25.2	13.4	15.3	44.1	6.6	NIL	0.5	1.6	3.3	5.4	6.0	90	3.9	0.05	0.43
	$B_{23}t$	70–100	39.5	14.3	16.7	39.5	6.7	NIL	0.7	0.9	2.4	4.0	5.1	78	3.3	0.03	0.27
	B_{31}	100–155	29.8	17.0	21.4	31.8	6.8	T	0.3	0.9	2.4	3.6	4.4	82	2.5	0.03	0.20
	B_{32}	155–195	24.6	21.5	24.7	29.2	6.1	T	0.3	1.0	3.2	4.5	4.8	94	2.5	0.03	0.21
5	A_1	0–10	45.3	30.8	9.9	14.0	6.9	0.1	0.7	2.6	9.0	12.4	13.3	93	7.1	0.14	1.72
	A_3	10–23	57.2	22.5	7.9	12.4	6.7	T	0.4	1.1	3.8	5.3	7.2	74	4.4	0.07	0.86
	B_1	23–38	60.7	13.9	7.7	17.7	6.1	T	0.2	0.9	2.6	3.7	5.1	73	4.2	0.05	0.44
	$B_{21}t$	38–53	42.9	14.7	6.0	26.8	6.0	T	0.2	1.1	2.4	3.7	5.7	65	3.8	0.05	0.46
	$B_{22}t$	53–103	34.9	10.8	8.6	45.7	5.9	0.2	0.3	1.1	2.6	4.2	6.1	69	3.9	0.05	0.43
	$B_{23}t$	103–145	18.3	12.0	12.5	57.2	6.2	T	0.2	1.4	3.4	5.0	6.7	75	3.6	0.03	0.25
	B_3	145–180	28.7	9.1	16.0	44.2	6.9	0.1	0.2	1.1	3.6	5.0	5.1	98	3.1	0.03	0.18

Appendix Table 3 Contd.

6	A_1	0–20	46.6	39.0	4.5	10.5	6.4	T	0.2	1.3	3.6	5.1	6.0	85	7.3	0.06	0.90
	B_1	20–35	35.8	26.4	3.0	34.9	5.7	T	0.1	1.2	1.6	2.9	5.4	54	3.5	0.05	0.53
	$B_{21}t$	35–53	31.2	22.1	3.3	44.5	5.3	0.1	0.1	0.9	1.7	2.8	6.0	47	3.5	0.05	0.46
	$B_{22}t$	53–105	30.0	22.7	2.4	44.9	5.4	T	0.1	0.9	1.7	2.7	5.2	52	3.1	0.04	0.37
	B_3	105–180	27.9	24.4	3.7	44.0	5.8	0.1	0.1	1.0	2.2	3.4	5.0	68	3.1	0.03	0.23
7	A_1	0–18	9.8	76.7	7.1	6.4	6.2	T	0.3	0.9	2.5	3.7	3.7	100	7.8	0.04	0.65
	A_3	18–35	9.1	77.6	7.6	5.8	6.2	T	0.1	0.6	0.6	1.3	1.3	100	2.1	0.02	0.21
	B_{11}	35–53	10.2	77.2	7.5	5.2	6.3	T	0.1	0.5	0.5	1.2	1.2	100	2.6	0.01	0.16
	B_{12}	53–105	11.2	75.9	6.8	6.2	6.4	T	0.1	0.5	0.5	1.1	1.1	100	2.3	0.01	0.12
	$B_{21}t$	105–143	14.6	9.0	9.0	27.0	5.5	T	0.1	1.0	1.4	2.5	3.7	68	2.7	0.02	0.21
	$B_{22}t$	143–180	12.9	56.1	9.01	22.0	6.0	T	0.1	1.2	1.0	2.3	2.7	85	2.4	0.01	0.12
8	A_1	0–5	22.0	48.0	16.0	14.0	6.3	T	0.4	2.0	8.3	10.7	11.3	95	9.9	0.12	1.92
	A_3	5–18	43.0	33.0	12.0	12.0	6.2	T	0.2	1.3	5.2	6.7	8.2	82	5.5	0.08	1.33
	B_1	18–33	44.0	25.0	11.0	20.0	6.0	T	0.2	1.2	2.8	4.2	5.9	71	4.3	0.04	0.73
	$B_{2t}t$	33–90	29.0	10.0	7.0	54.0	5.4	T	0.2	1.2	2.9	4.3	8.2	52	4.5	0.03	0.35
	B_3	90–145	35.0	16.0	8.0	41.0	5.7	T	0.2	1.1	2.2	3.5	7.3	48	3.0	0.02	0.22
	C	145–185	24.0	21.0	12.0	42.0	5.7	T	0.2	1.2	2.6	4.0	6.8	59	3.0	0.02	0.15

T Trace

APPENDIX II – TABLE 4 SUMARRY OF MICROMORPHIOLOGICAL DESCRIPTIONS

No.	Classification	Horizon	Depth in CM	Peds	Related distribution of Plasma with reference to skeleton grains	Plasmic fabric	Voids	Pedological features	Remarks
1	OXIC	A_2	0–4	Few weak micro	Agglomeroplasmic with some intertextic patches	Isotic	Simple and Compound packing voids SPV – 4:2 4	Few discrete weakly adhesive random, subspher-subspherical sesquioxide nodules	Some root remains in voids and fractures & the surface of some quartz grains
	HAPLUSTALF	B_1	84-87	Few weak random micropeds	Agglomeroplasmic with some intertextic patches	Agillasepic with some Isotic	– do – SPV = 3:1:6	Abundant, discrete weakly adhesive, random subspherical sesquioxide nodules	Large angular quartz grains exhibit fracture along which black isotic plasma are deposited
		B_2	151–155	Fairly distinct moderate peds	Intertextic with Agglomeroplasmic patches.	Insepic with Isotic	Common Skew-Planes joint planes & some some packing voids. SPV = 1:6:4	Many, discrete, oriented, weakly adhesive random sub-spherical sesquioxide nodules	Skeletal grains are mainly quartz grains and altered Biotite.

Appendix Table 4 Contd.

2	PLINTHU-STALF	A_2	0–4	Few weak micro-peds	Agglomeroplasmic with some intertextic	Isotic	Simple compound packing voids. SPV = 5:1:4	Few, discrete sub-angular angular sesquiozde nodules	The colour of the s-matrix is masked by organic matter
		B_1 B_1/B_{21} t	58–62 40–45	Few weak micro- Common, distinct Subangular meso	– do Porphyroskelic	Argill–asepic with some Isoltic	Simple & compound packing voids. SPV 6:0:4	Some discrete sub-rounded sesquiozide nodules	Skeletal grains are mainly quartz by some Magnetite identified.
		B_2	104–108	Few faint, weakly developed micro-peds	Porphyroskelic	Skel-Vosepic with some Isotic	Skew planes & equant to prolate vughs. SPV 4:5:1.	Abundant discrete sub-rounded sesquioxide nodules	Nodules are closely packed, spaces vary from 25ml – 62ml
		B_{32}	180–184	Fairly distinct moderate peds	Intertextic intergrading into Porphyroskelic	Skel-vo-latti sepic with some Maseic and Isotic	Inter-connec- vughs skew planes and intra-pedal vughs.	Few, discrete sub-angular sesquioxide nodule. Some skew plane, vugh and grain cutans.	Large & medium fractured quartz grains with plasma concentrations along the cracks.
3	TYPIC	B_{22} t	98–102	Common, distinct subangular meso	Porphyroskelic	Skel-Vo-sepic with some omnise-	Some inter-pedal skew planes and	Some skew and channel ferri-argillans. Occasional neostrians	Skeletal grains dominantly quartz, typersthene.

Appendix Table 4 Contd.

						pic and and Isotic.	channels & common equant to prolate intrapedal	& Embeded grain cutans	
4		B_1/B_{21}[1]	40–45	Common, distinct, angular meso and macropeds	Porphyroskelic	Skel-vo-Latti-Sepic with Isotic. & in-sepic.	Some ortho & meta skew planes & common equant to prolate meta & Ortho vughs. APV = O:7:3	Common, discrete unoriented Lithorelit. Some skew embeded grain cutans	The Glaebules are composed or rocks.
	TYPIC PALEUSTALF	B_{31}	108–112	Common, distinct angular meso and macropeds.	–do –	Vo-insepic with, some omini sepic & Isotic.	Some ortho & meta skew planes and common meta & ortho vughs. SPV = 0:9:1	Many, discrete unoriented lithorelicts. Some simple & compound skew plane (ferriargillans) Cutans	The Lithorelicts composed mainly Felsparthic materials (Plagioclase)
5	TYPIC HAPLUSTALF	A_1	0–4	Common, weakly developed subangular meso and micropeds.	Agglomeroplasmic intergrading into intertextic	Isotic	Simple & compound packing	Many, discrete, unoriented sesqui-	Many fractured quartz grains with plasma deposit.

Appendix Table 4 Contd.

							voids. SPV ratio 4:3:3	oxide nodules	
		B_1	29–33	Common distinct subangular meso & micropeds.	Intertextic with some Agglomeroplasmic and prophyroskelic.	Isotic with some insepic and argillasepic.	Simple & Compound packing voids & interconnected ortho vughs. SPV = 2:3:5.	Many, discrete, loosely adhesive subrounded unoriented sesquioxide nodules	The plasma is dominantly isotic.
		B_3	147–151	Common distinct angular mesopeds.	Porphyroskelic	Ominisepic with some Isotic & skel-Volattisepic.	Ortho and meta-joint & skew planes & common ortho & metavughs SPV = 0:8:2	Some simple & compound plane cutans common vugh cutans	Many fractured macro Skeletal grains with plasma deposits
6	TYPIC PALEUSTALF	A_1/B_1	17–21	Common distinct sub-angular micro- and macropeds.	Porphyroskelic	Insepic with some isotic	Common Ortho-skew planes & ortho and meta vughs, & some interconnected vughs. SPV = 4:4:2	Common vugh cutans	Skeletal grains are commonly quartz, Tourma-line Hypersthene & Hornblende.
		B3							

Appendix Table 4 Contd.

		B_3	133–137	Common distince subangular micro and macropeds.	Porphyroskelic	Insepic with some Isotic.	Ortho-Skew plane Inter-connected vughs and Intrapedal ortho and meta vughs SPV = 1:7:2	Simple grain and vugh cutans. Few discrete, unoriented Lithorelict.	The Lithorelict is dominated by clusters of prismatic Felspartnic materials and some quartz grains.
7	TYPIC HAPLUSTALF	AP	0–4	Common weakly developed subangular micropeds	Agglomeroplasmic with some intertextic.	Isotic	Simple and compound packing voids SPV = 0:2:8	Few, discrete, loosely adhesive subspherical unoriented sesquioxide nodule	Root remains are present in some voids. Plasma masked by Organic matter.
		B_2	127–131	Common, fairly developed micro- and macropeds	Intertextix Intergrading into Porphyroskelic	Isotic	Interconnecting ortho and intrapedal prolate to equant meta vughs SPV = 1:8:1	Many, discrete, loosely adhesive subsepherical unoriented sesquioxide nodules Common vugh cutans.	Skeletal grains are mainly evensized quartz, and occasional Magnetite and masked tourmaline.
8	TYPIC HAPLUSTALF	$B_{2}t$	50–54	Common, fairly developed micropeds.	Porphyroskelic	Insepic with some Isotic.	Some joint & skew planes & intra pedal equant to prolate	Abundant discrete loosely adhesive unoriented subspherical sesquioxide nodule	The nodules are closely packed in the s-matrix; distances between the nodules vary from 28–70U.

Appendix Table 4 Contd.

						vughs. SPV = 0:6:4.		
B_{32}	1 56 - 160	Some distinct subangular micro- & macropeds.	Porphyroskelic		Vomasepic with some Isotic	Some craze planes some joint & skew planes and intra-pedal equant to prolate vughs SPV = 0:8:2.	Many, discrete weakly adhesive black, un-oriented sesquioxide nodules. Occasional vugh cutans.	S-matrix is dominantly crisscrossed by crazeplane.

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