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PEDOGENESIS, WEATHERING STATUS AND MINERALOGY OF THE SOILS ON IRONSTONE PLATEAUX (LATERITES), SOKOTO NIGERIA

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ABSTRACT
Soils on four ironstone plateau near kalalawa, Adarawa, Bissalam and Tureta in Sokoto State were studied with the aim of a ascertaining their genesis, weathering status and soil mineral content. Morphological studies, total elemental analysis and X-ray diffraction were conducted for this purpose. The soils were found to have formed on weathered geological materials overlain by indurated ironstone crust. The geological weathered materials are Gwandu/kalambaina, Gwandu, Dange/Wurno and Gundumi formation on kalambaina, Adarawa, Bissalam and Tureta ironstone plateau respectively. The soils have good structural development and pronounced textural differentiation. The soils are well developed in terms of pedogenic processes (humification, mineralization, lessivation, homogenization and leaching) that have operated and are still operating to form the soils. Result of the silt/clay ratio, sesquioxide ratio and total Potassium, revealed a low weathering potential of the soils making them moderately weathered soils. The dominant mineral identified in the soils is quartz with kaolinite, feldspar and chlorite in trace amounts.

Keywords: Pedogenesis, Weathering, Mineralogy, Ironstone, Laterite and Plateau

INTRODUCTION

Tropical soils can be extremely weathered. This means that the crystal lattice structure of feldspars, other alumino-silicates, even the mica-like soil clays are broken down finally to kaoline or hydroxides and oxide of Al and Fe. The minerals responsible for cation exchange properties in most temperate soils are thereby eliminated (Jack, 1974). Tropical soils represent the most heavily weathered soils on earth, because the temperatures are high, the rainfall is high, so weathering is rapid. They are mainly red because of the high oxidized content and are known as laterites or Oxisols (oxidized soils). Nigeria being in the tropics, the soils are often regarded as highly weathered and deficient of weatherable minerals.

Laterite is a pedogenic and highly weathered natural material formed by the concentration of hydrated oxides of iron and aluminium, further oxidized to form an insoluble precipitate of fine particles. Further concentration and dehydration and subsequent cementation forms hard concretionary nodules (IFG, 2006). Laterite is also known by the following names: brickstone or iron clay (India), plinthite (USA), mantle rock (Ghana) and ironstone (Nigeria). Ironstone is a continuous indurated material in which iron is an important cementing agent and in which organic matter is in traces (FAO, 1998). It is hard and makes digging difficult (Yakubu, 2006). Ironstone is formed when plinthite material harden irreversibly and the hardening is often the result of a lowered ground water table e.g. during a geological upheaval of the terrain or if land is artificially drained (Buringh, 1979).

The *Hausa* plain of northern Nigeria dominates the topography of Sokoto State and the vast *Fadama* land of the Sokoto-Rima river dissects the plain and provides the rich alluvial soil for varieties of crops. There are also isolated ironstone plateaux (hills) and surfaces scattered all over the State (Anon, 2003). The residual tabular ironstone hills (laterite) and scarp of various resistant materials capped by indurated petroplinthite were believed to have formed at a period of relatively stable and imperfect drainage of the land (Sombroek, 1971).

The ironstone hills are so scattered all over the different geological formations within the State such that they occupied a substantial part (5 %) of the land in the State. However, they have remained underutilized and in some cases unutilized, because of possible difficulty in cultivation and inadequate pedological information. It is in realization of the importance of these kinds of surfaces (ironstone plateaux) for agricultural purpose and the limited agricultural land in the state, that this study was conducted to determine their weathering status, mineralogy and postulate their genesis.

MATERIALS AND METHODS

Study Area

The study was conducted in four selected ironstone plateau (hills) in different geologic formations in Sokoto State. The areas include *Kalalawa, Adarawa, Bissalam*, and *Tureta* lying on *Kalambaina, Gwandu, Wurno* and *Gundumi* geologic formations respectively. The dominant underlying geology is Cretaceous and Tertiary sediments.

The Cretaceous sediments are composed of the Wurno-Taloka (fine grained sandstone, mudstone and siltstone), and Gundumi (sorted basal conglomerates, tough clays), formations, while the Tertiary sediments are composed of Dange (bluish-grey shale) Kalambaina (white marine clayey limestone and shale) and Gwandu (massive clay, clayey grits and sandstones) formations (Kogbe, 1976). Sokoto State is situated between latitude11^0 30^1 to 13^0 50^1 N and longitude 4^0 to 6^0E. The climate is hot, semi-arid tropical or type Aw in Koppen's climatic classification (Sombroek and Zonneveld, 1971) supporting Sudan savanna vegetation (Deleeuw, 1966). The mean annual rainfall is about 600 mm falling between June and September, the rest of the year being characterized by pronounced dry season (Kowal and Knabe, 1972).

Field study

Topographic and geologic maps (FAO, 1969; Falconer, 1911) were used to identity ironstone plateaux on different geologic formations. Highest point (contour lines) on the topographic maps were marked as ironstone plateau and followed by ground truthing (a field visit or reconnoiter to confirm the ironstone plateaux points identified on the maps). After the identification of the ironstone plateaux, four profile pits (pedons) were dug on four different ironstone plateaux (one for each of the ironstone plateau) and designated P 1, P 2, P3 and P 4. Profile descriptions were done according to the profile description manual of Schoeneberger *et al.,* (2002). Soil samples were collected from pedogenic horizons for laboratory analyses.

Sample preparation and Laboratory Analyses

The soil samples were air-dried and passed through a 2 mm sieve. Particles larger than 2 mm were weighed as gravel content in the sample and expressed as percentage (Soil Survey Staff, 1996). The fine-earth (≤2mm) separate was used for the physical and chemical analyses.

Particle size analysis was undertaken with the Bouyoucos hydrometer method as described by (Gee and Bauder, 1986). Total K, Al, Fe and Si were determined using the method of Liu (2001).

The fine-earth air-dried samples were examined with an X-ray diffractometer (Rigaku Miniflex type) and Ni-filtered Cu- Kα radiation generated at 40 KV and 30 mA. The XRD patterns were recorded ranging from 3- 60^o (2θ) with a scanning speed of 20^o/min. The identification and semi-quantitative determination of the mineral are based on the differences of reflection patterns from the air-dried samples (Johns *et al*., 1954; Brindley, 1980).

RESULTS AND DISCUSSION

Morphological properties of the soils

The summary of the morphological properties of soils of the studied ironstone plateau are presented in Table 1.

Pedon P 1 is on the surface identified as Gwandu surface. The parent materials are thin aeolian sandy deposits overlying indurated stones and ironstone boulders over decomposed (weathered) Kalambaina formation. Large fragments of the indurated materials and smaller fragments (stones and gravels) are found in the upper layers of the soils and also in the subsurface. The soils are well drained and are typically red (2.5YR Hue) in the subsoil and dark brown (7.5YR 4/4) in the surface horizon. The redder colour suggests that the soils might contain more iron as coatings, separations and concretions inherited from earlier pedogenesis. Bigham *et al*., (1978) also reported that increase in the proportion of hematite to goethite is responsible for redder hues in soils. Single-grained structure is common in the A horizon and well developed subangular blocky structure and strutureless massive in the subsoil. Consistency of the soil is loose to friable in the surface and subsurface and very friable in the subsoil (B horizon) and firm in horizon 2Bt2. Clay skins on ped faces were observed in the B horizons qualifying the horizons as argillic.

Pedon P 2 was formed on weathered Gwandu formation that underlies thin colluvial materials. Morphologically, the soil is well drained, shallow due to continuous layer of ironstone crust, dark brown (7.5YR 4/4) in the surface and yellowish red (5YR 5/6) in the subsoil. The soil has a weak fine subangular blocky structure in the surface horizon and weak coarse subangular blocky in the subsoil. Soil consistency is loose in the surface horizons and friable in the subsoil. An impermeable layer of indurated ironstone that makes digging impossible was observed within 100 cm of the profile.

Pedon P 3, which is on Bissalam ironstone plateau is formed on Dange surface overlying Wurno formation. The soils are well- drained, deep and highly permeable. Soil colour is strong brown (2.5YR 4/6) in the surface and changes to dark brown (5YR 4/6) and brown (5YR 5/6 and 10YR 6/2) in the subsoil. Structurally, the soil is strong coarse subangular blocky in both the surface and subsoil. The strong subangular blocky structure may be due to good drainage, moulding actions of wetting and drying cycles as suggested by Ojanuga (1980) for soils of Kaduna-Zaria area. The consistency is firm in the surface and slightly firm in the subsoil. Clay skin was identified in the B horizons given rise to an argillic horizon (Bt).

In pedon P 4, the soils have been identified to have formed from weathered Gundumi formation (Late cretaceous age) (Sombroek and Zonneveld, 1971). The colour of the soil is strong brown (7.5YR 5/6) at the surface, grading to red (2.5YR 5/6 and /or 2.5YR 4/6) in the subsurface and subsoil. The soils are generally well-drained and highly permeable with well developed and marked Bt horizons. Single-grained structure is common in the surface and changes to moderate coarse subangular blocky and massive in the subsoil and C horizon respectively. Structural grade was also observed to be stronger with increasing depth of pedon. The change in structural grade from weak to strong in the subsurface to subsoil could be attributed to the increase in clay content within the pedon. Weak structural development in the surface horizons is common in the soils.

It is an important fact that must be taken into consideration in the management of the soil. Consistency of the soil is loose in the surface and firm in the subsurface and subsoil. Krotovina (channels/holes created by soil organisms) and few large natural channels were observed at a depth of 74-100 cm which is an indication of activities of soil organisms. Pisiolites (iron concretions/nodules) were identified in the C horizon which made up of about 20 % by volume of the materials in 2C2 horizon.

Table 1. Morphological properties of the soils

Pedon	Horizon	Depth (cm)	Colour*	Structure*	Consistence*	Other Features	Boundary	Particle size distribution <-------%-----------→			
P 1				***Lithic Rhodustults***				Sand	Silt	Clay	Silt/clay ratio
	A	0-30	7.5YR 4/4	0Sg	Lo	1cor, Fe,	AW	75	21	4	5.3
	Bt1	30-54	2.5YR 3/6	2fsbk	Fr	3fnr, ch	CS	75	15	10	1.5
	2Bt2	54-74	2.5YR 3/6	1csbk	Vfr	3fnr,ch, sh	CS	67	12	21	0.6
	2Bt3	74-150	2.5YR 4/6	1csbk	Vfr	3cor, sh,	CS	70	13	17	0.8
	2Bt4	150-192	2.5YR 4/6	1csbk	Vfr	3cor, sh	CS	68	12	20	0.6
	2Bt5	192-210	2.5YR 4/6	0m	Fi	Ch		67	11	22	0.5
P 2				***Petroferric Haplustults***							
	A	0-30	7.5YR 4/4	1fsbk	Fr	1fnr, 1cor, ch, Fe	AW	75	13	12	1.1
	2Bt1	30-70	5YR 5/6	1csbk	Fr	3fnr,	AS	55	7	37	0.2
	2Bt2	70-80	5YR 5/8	1csbk	Fr	1fnr, Fe		55	9	36	0.3
		80+		Ironstone crust							
P 3				***Kanhaplic Haplustults***							
	A	0-10	2.5YR 4/6	3csbk	Fi	3cor,1fnr,Fe	GW	66	11	23	0.5
	2Bt1	10-60	5YR 4/6	3csbk	Fi	1cor, cs	GW	49	16	35	0.5
	2Bt2	60-150	5YR 5/6	2csbk	Fi	Cs,	CW	49	25	26	0.9
	2Bt3	150-210	10YR 6/2	3csbk	Fi	Cs	CW	39	21	40	0.5
P 4				***Kanhaplic Haplustults***							
	A	0-30	7.5YR 5/6	0Sg	Lo	3fnr,3cor,ch,	AS	81	10	9	1.1
	2Bt1	30-55	2.5YR 6/6	2csbk	Fi	3fnr,3cor,ch	AS	53	20	27	0.7
	2Bt2	55-74	2.5YR 5/6	2csbk	Fi	1fnr,kr,ch	CI	42	27	31	0.9
	2Bt3	74-100	2.5YR 4/6	2csbk	Fi	ch, pi	CS	42	26	32	0.8
	2Bt4	100-130	2.5YR 3/6	3csbk	Fi	ch, pi		38	27	35	0.8
	2C	130-220	2.5YR 3/6	3csbk	Fi	-		42	25	33	0.8

*****= Determined at natural moisture condition, **Note:** symbols/code according to **Schoeneberger, *et al.,* 2002**
Structure: 0= structureless, 1 =weak, 2= moderate, 3= strong, sg=single grain, csbk=coarse subangular blocky, fsbk, fine subangular blocky, m=massive,; **Consistence:** lo=loose,fr=friable, vfr=very friable; **Roots:**1=few,2=moderate,3=many,fnr=fine roots, co=coarse roots; sh=shale, ch=channel Fe=ironstone crust, Fec=iron concretion;
Boundary; A=abrupt, **C**= clear, **G**=gradual, **S**=smooth, **W**=wavy, **I**=irregular

Pedogenesis of the soils

Pedogenic processes observed to have operated and differentiated the soils of the different ironstone plateau include humification, and mineralization of organic matter, leaching, lessivation, aggregation and homogenization. The consistently low organic matter of the soils is presumed to be a result of rapid humification and mineralization as conditioned by high radiation in the area and Sokoto environment in general.

The low exchangeable bases and the predominance of exchangeable acidity on the exchange complex in all the soils, is an indication of leaching process. The increase in clay content with depth in the soils and the presence of clay skins evidently infers the process of lessivation. Lessivation process was also observed to have occurred in pedons with marked clay break materials thereby giving rise to argillic (Bt) horizon. The Bt horizons in pedon P 1 as indicated by thin to moderate clay skins observed on the ped faces in the field is a result of lessivation. Alternate wet and dry seasons, the prevalent climatic conditions in this area, have been reported to favour lessivation (Ojanuga, 1980).

Weathering State of the Soils

Weathering state of soils can be inferred from the kinds and arrangement of horizons in the profiles, and their weathering potentials. The weathering potential could also be deduced from the result of silt/clay ratio, silica/sesquioxide ratio, total K and the clay mineralogy of the soils (Nwaka, 1990; Ayolagha, 2001). The results of these parameters are presented in Table 2, 3 and 4.

Kinds and arrangement of horizons

Kinds and arrangement of horizons are expressed in terms of the diagnostic horizons within pedons. The arrangements of diagnostic horizons in pedons help to understand soil development and hence its weathering status. In this study, the soils are observed to be well developed with an ochric horizon in the surface overlying strongly developed argillic B horizon. In this situation, the saprolite must have been weathered to some extent to allow the formation of the argillic horizon. In the soils, ironstone underlies an ochric epipedon and an argillic B horizons. Buringh, (1979) reported that many ironstone hardpans at or near the soil surface are old. He further opined that the most extensive areas with ironstone pans in Africa are mainly in older landscape. From this assertion, it could therefore be deduced that soils with ironstone are relatively older and thus may have low weathering intensity.

Weathering potentials

Weathering potential of the soils could be assessed based on the silt/clay ratio, total K, and silica/sesquioxide ratio.

Silt/clay ratio as index of weathering

Silt/clay ratios P 1 ranged from 0.5 to 5.3, In P 2, the range is between 0.2 and 1.1, In P 3 the range is from 0.5 to 0.9 while Pedon P 4 have a silt/clay range of 0.7 to 1.1 (Table 1). Silt/clay ratio is an important criterion used in the classification of tropical soils. It is also used in the evaluation of clay migration, stage of weathering and age of parent material and soils (Nwaka, 1989-90). The more highly weathered a soil is, the lower the silt fraction. Therefore, soils with silt/clay ratio of less than 0.15 are regarded as highly weathered (Van Wambeke, 1962).

Table 3. Total elemental composition of the soils

Pedon	Horizon	Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	K_2O	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$
		----→	←------------------%-------					
					Lithic Rhodustults			
P 1	A	0-30	7.62	3.5	3.21	0.63	2.18	1.14
	2Bt2	54-74	15.24	15.7	2.95	0.20	0.97	0.82
	2C	192-210	12.39	13.3	4.08	0.34	0.93	0.71
					Petroferric Haplustults			
P 2	A	0-30	10.24	6.9	4.28	0.34	1.48	0.91
	2B1	30-70	12.15	10.3	2.41	0.19	1.18	0.96
	2B2	70-100	14.53	13.9	2.53	0.26	1.05	0.88
					Kanhaplic Haplustults			
P 3	A	0-30	18.34	8.6	2.34	0.46	2.13	1.68
	2Bt1	30-60	14.05	12.4	1.98	0.34	1.13	0.98
	2Bt3	150-210	15.75	13.7	1.45	0.43	1.15	1.04
					Kanhaplic Haplustults			
P 4	A	0-30	5.24	3.5	3.21	0.63	1.50	0.78
	2Bw2	55-74	9.29	15.7	2.95	0.20	0.59	0.50
	2C2	130-220	8.34	13.3	4.08	0.34	0.63	0.48

Silt/clay ratios are relatively higher in the surface and subsurface horizons and decrease with increase in pedon depth. Ayolagha (2001) obtained similar results from meander belt soils of the Niger Delta region of Nigeria. Ashaye (1969) also reported similar results with highest values in the surface horizons for well drained soils. A decrease in silt/clay ratio is apparent in pedons with lithologic discontinuity (pedons P 1, P 2) which indicates changes in parent materials.

Van Wambeke (1962) reported that "old" parent materials usually have a silt/clay ratio below 0.15 while silt/clay ratios above 0.15 are indicative of "young" parent materials. FAO (1990) on the other hand reported that soils with silt/clay ratios of less than 0.20 indicate a low degree of weathering. Results of this study show that, all the soils have silt/clay ratio above 0.15 or 0.25 indicating that the soils are relatively young with high degree of weathering potential. With the results obtained the soils could be said to be moderately weathered. The decrease in silt/clay ratio with depth is an indication that subsoils horizons are more weathered than surface horizons. Nwokocha *et al.*, (2003) reported that decreasing silt/clay ratio with depth suggest increased weathering of silt to clay with depth. They further opined that this phenomenon in addition to illuviation explained the increase in clay with depth of profiles. However, Esu (1987) attributed increase in clay content with depth in humid climate, occasioned by pronounced weathering.

Total K as index of weathering

The total K content of a soil gives an indication or estimate of the weathering status of soils. Soils with low total K are regarded as highly weathered and have low mineral reserve, while those with high total K content are considered not highly weathered and have high mineral reserve. In P1, Total K (Table 3) ranged from 0.20 to 0.63 % In P2 it ranged between 0.19 and 0.26 % In P 3 the total K content ranged from 0.34 to 0.46 % while in P 4 it ranged from 0.20 to 0.63 %. From the data presented, the values are generally low and this means that the former is less weathered than the latter. With these values, the soils on both the younger and older surface could be regarded as moderately weathered soils. Higher values of Total K are obtained in the surface horizon than in the subsoil horizons (B horizon) and unconsolidated material (C horizon) meaning that surface soils are less weathered than the subsoil. There is a clear decrease in total K content from horizons A to B and C in pedons P 1, and P 3.

Sesquioxide ratios as index of weathering

Results of sesquioxide ratios are presented in Table 3. Sesquioxides are oxides and hydroxides of iron, aluminium, manganese or silicon and the content of different forms in tropical soils increases as the soil ages due to the influence of weathering. Sesquioxides in P 1 ranged from 7.62 % to 15.25 % (SiO_2), 3.5 % to 15.7 % (Al_2O_3), and 2.95 % to 4.08 % (Fe_2O_3), In P 2, the range is from 10.24 to 14.53 ((SiO_2), 6.9 to 13.9 % (Al_2O_3), 2.41 to 4.28 % (Fe_2O_3) on. In P 3, the range is 14.05 to 18.34 % (SiO_2), 8.6 to 13.7 % (Al_2O_3), and 1.45 to 2.34 % (Fe_2O_3) In P 4, sesquioxide range from 5.24 to 9.29 % (SiO_2), 3.5 to 15.7 % (Al_2O_3), and 2.95 to 4.08 % (Fe_2O_3), (Table 16).

From the result, the silica content in the soil is higher than the iron and aluminium oxides indicating that the soils are not highly weathered. Buringh (op cit) reported that, with progressive weathering and weathering intensity more oxides of iron and aluminium (Fe_2O_3 and Al_2O_3) tend to accumulate in soil while silica (SiO_2) is leached out. This has further confirmed the results of the silt/ clay ratio which indicate lower weathering potential of the soils. The sesquioxides values within the profiles were observed to be higher in the subsurface and subsoil than the surface indicating that soils below are more weathered than those on the surface.

The silica/alumina (SiO_2/Al_2O_3) ratios in the soils are generally moderate and ranged from 0.59 to 2.18. The silica/sesquioxide ratio ($SiO_2/ Fe_2O_3 + Al_2O_3$) on the other hand are moderate too and ranged from 0.48 to 1.68. Silica/sesquioxide ratio determines the relative degree of weathering of materials. High ratio means that the material is less weathered and therefore has some mineral reserve.

Low ratio means intensively weathered materials with no or little mineral reserve. With the moderate ratios obtained in the soils and with the identification of some weatherable minerals as indicated in the X-ray diffraction result, it could be concluded that the soils of Sokoto environment are moderately weathered.

The ratios of sesquioxides also provide information on both the crystalline and amorphous components of the clay fraction which in turn gives information on the weathering state of the soil (Sombroek and Zonneveld, 1971). Values higher than 3.0 indicate a predominance of montmorillonite/illite; 2.0-3.0 the presence of both montmorillonite/illite and kaolinite; 1.6-2.0 indicate the predominance of kaolinite and values below 1.6 indicate the presence of considerable percentages of gibbsite, or aluminum oxides (Sombroek and Zonneveld, 1971). The ratios in the soils are generally less than 2.0 and indicating the presence of kaolinite and ferromagnesian mineral in the soils. Kaolinite as elaborated by Buol *et al.,* (2003) is the most common clay mineral in acid, moderately weathered soils (Dixon, 1989).

Mineralogy of the Soils

X-ray diffraction analysis was only conducted for some soil horizons in pedons P 1 and P 4. Result of the mineralogy of the air-dried fine- earth fraction of soils is summarized in Table 4 and peaks are shown in figure 1 and 2.

In horizons A, 2Bt2 and 2C of pedon P 1, the predominance of quartz is indicated by a peak of between 3.34nm and 4.46 nm. Kaolinite (7.19 nm) is present in the three horizons but more clearly identified in the B (argillic) horizon than in A and C horizons (Figures 1). The quartz mineral ranges from 50 to 95 % and kaolinite ranges from 3 to 49 %.

In pedon P 4, quartz also remains the dominant mineral with peaks at 3.34nm and 4.46 nm in A, B and C (Figure 2). Kaolinite indicated by peaks at 7.15 nm and 7.17 nm, is identified in the 3 horizons and more in the subsoil (27-28 %) than in the surface horizon. A trace of chlorite mineral with a peak of 3.48 nm was identified in B horizon.

Quartz ranges from 69 to 93 % in the soils while chlorite is between 2 and 3 %. Quartz is the dominant mineral in the fine-earth fractions. Raji *et al*., (1997) reported similar results in a study conducted on sand dunes around Sokoto-Rima basin. The predominance of kaolinite as a clay mineral suggests that the prevailing dry and wet moisture conditions coupled with the low base saturation and low pH in the soils preclude the conditions conducive to formation of montmorillonite. Kaolinite may have also been in part inherited from the parent materials.

Table 4. Mineralogical composition by X-ray diffraction of the fine-earth samples (< 2mm) of pedons P 1, and P 4.

Pedon	Horizon	Depth (cm)	Qz	Kao	Fld	Chl
P 1	A	0-30	95	3	-	-
	2Bt2	74-150	50	49	-	-
	2C	192-210	79	20	-	-
P 4	A	0-30	93	6	-	-
	2Bt2	55-74	69	27	-	3
	2C	130-220	71	28	-	-

Qz= Quartz, **Kao=** Kaolinite**, Chl=** Chlorite**, Fld=** Feldspar, **tr**=traces

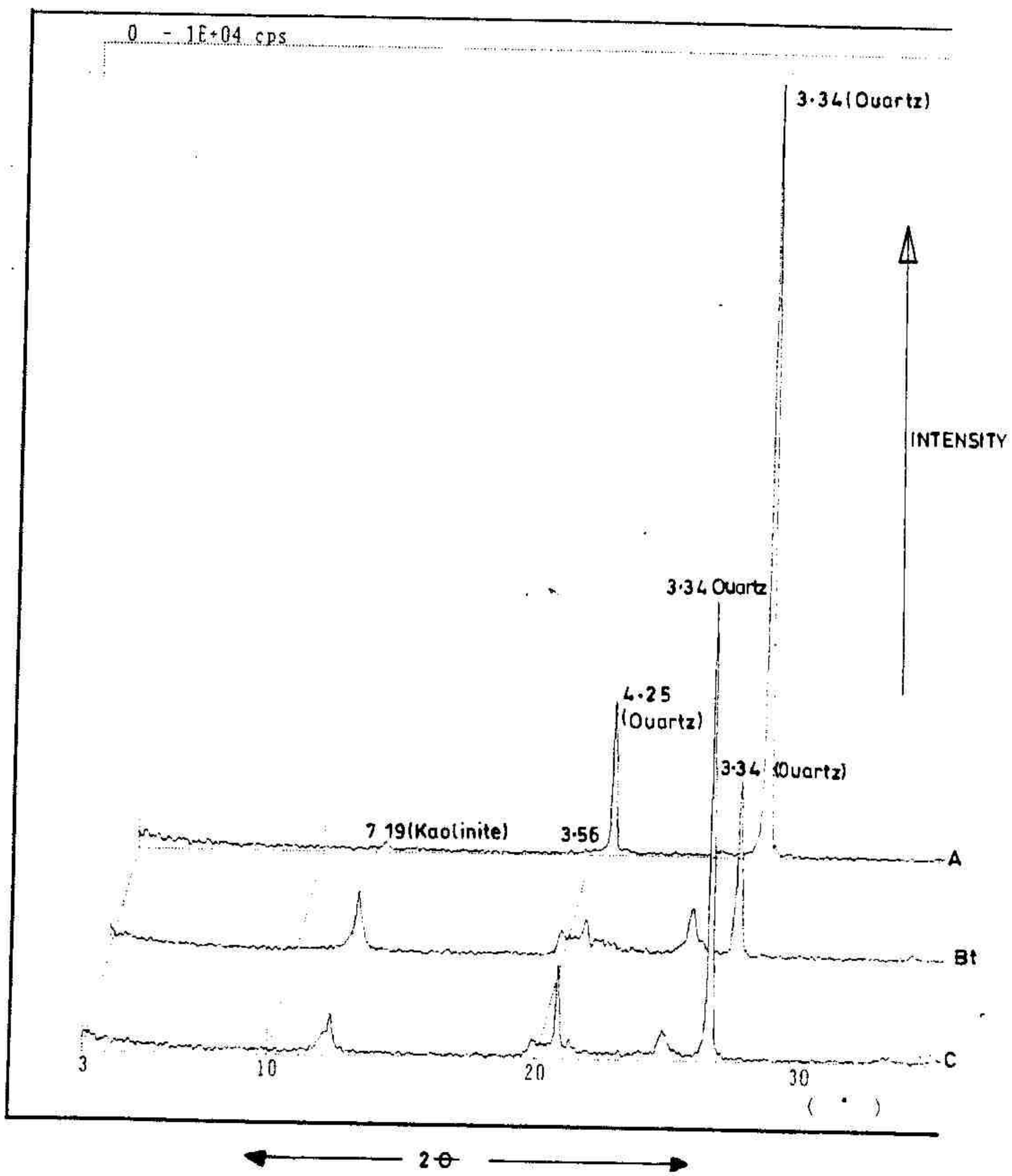

Figure 1: X-ray diffraction pattern of the fine-earth fraction of horizons in pedon P 1

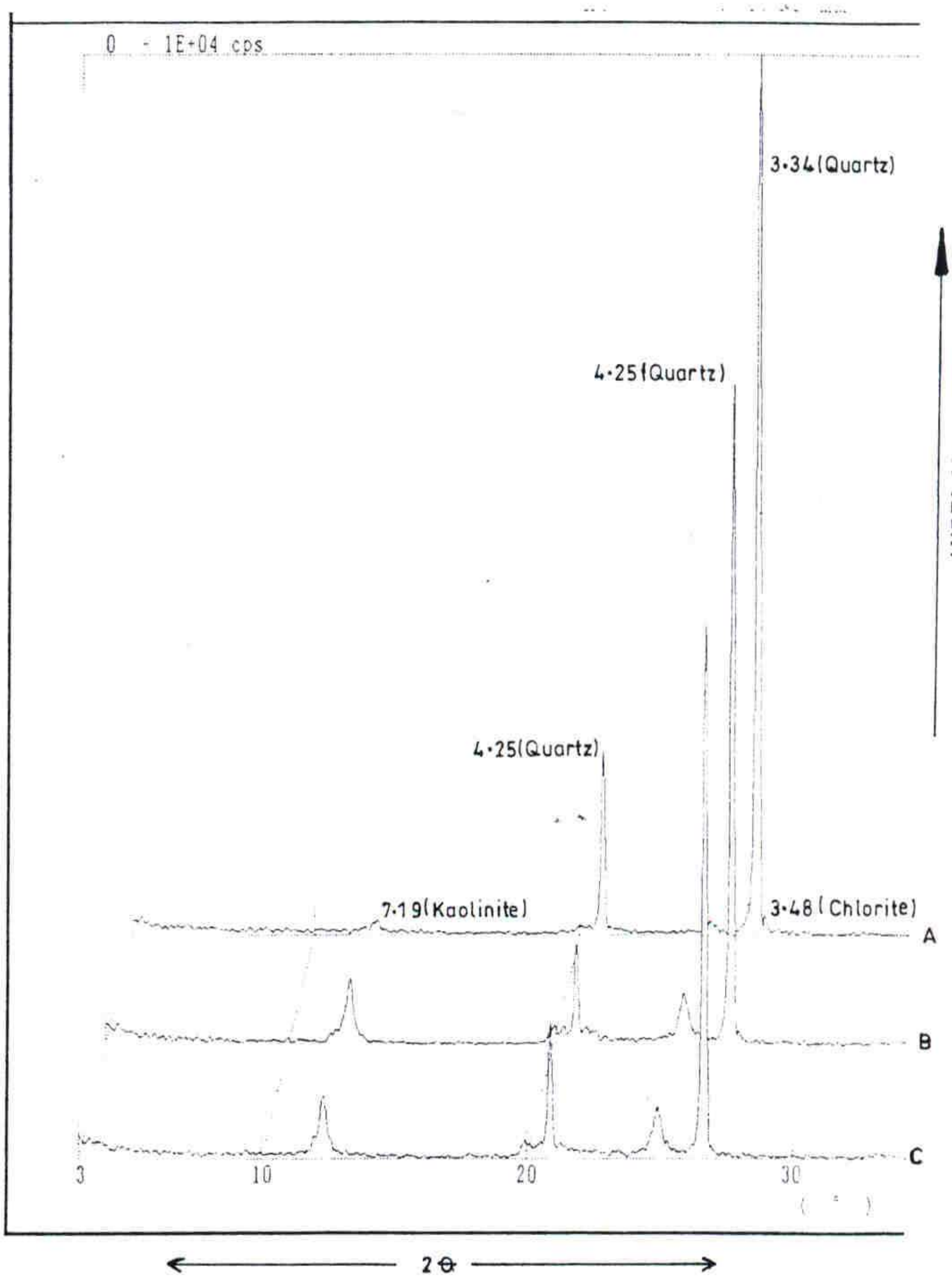

Figure 2: X-ray diffraction pattern of the fine-earth fraction of horizons in pedon P 4

CONCLUSION

The soils were found to have been formed on weathered geological materials overlain by indurated ironstone crust. The geological weathered materials are *Gwandu/kalambaina, Gwandu, Dange/Wurno* and *Gundumi* formation on *kalambina, Adarawa, Bissalam* and *Tureta* ironstone plateaux respectively. The soils have good structural development and pronounced textural differentiation. The soils are well developed in terms of pedogenic processes (humification mineralization, lessivation, homogenization and leaching) that have operated and are still operating to form the soils. Result of the silt/clay ratio, sesquioxide, ratio and total K, revealed a low weathering potential of the soils making them moderately weathered. The dominant mineral identified in the soils is quartz with kaolinite, feldspar and chlorite in trace amounts

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