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HYDROMOPHIC SOILS OF TWO INLAND VALLEY SWAMPS IN THE RAIN FOREST ZONE OF NIGERIA. II CLAY MINERALOGY AND PEDOGENIC PROCESSES.

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ABSTRACT

The Clay mineralogy and pedogenic processes in soil of two inland valley swamps were investigated. Both field morphologic observations and particle size distribution indicate lithologic discontinues in only two (pedons AB-2 and AB-5) of the nine pedons studied. Clay mineralogy was predominantly kaolinitic except in pedons BD-1 and BD-2 which contained some degraded mica minerals. Ferrolysis was well demonstrated in pedons BD-1 and BD-2. Decomposition processes of minerals led to the formation of some degraded mica.

Keywords: clay, ferrolysis, kaolinite

INTRODUCTION

Properties of two inland valley swamps have been described in the first article of this two-article series. It was found that the particle size distribution, exchangeable bases and acidity fractions of the CEC vary significantly between the pedons. Although the geology is nearly the same, the mineralogy of clay separates and its properties may vary appreciably because mineralogy of the clay-size fraction is generally influenced by both pedogenesis and nature of parent material.

Investigations have shown that scarcity of information on the mineralogy of soils of rain forest zone of Nigeria has made classification of the family level of soil taxonomy (Soil Survey Staff, 1992) impossible. This has created impediment on the understanding of the genesis of the soils as a tool in the agro-technological transfer. The primary mineral composition of hydromorphic soils would generally seldom show a noticeable change induced by rice cultivation during a few hundred years, except for biotite which has been found to weather rapidly in seasonally flooded plough layers of rice soils (Kawaguchi and Kyuma, 1977). In a study of changes in clay mineralogy in a chronosequence of paddy soils in Japan, Wakatsuki *et al* (1984) reported that prolonged paddy cultivation (150 and 265 years) brought some modification in the clay mineralogy of AP horizons, whereas the mineralogical changes were not evident in the profiles less than 75 years of age. This was characterized by changes in smectite to chlorite.

The primary objective of the investigation is to improve understanding of the origin of wetland soils in Nigeria. This paper presents the clay mineralogy of the soils and tentative hypothesis as to their origin are proposed.

MATERIALS AND METHODS

Sand and clay fractions were separated from the soils for mineralogical analyses. Particle size distribution was calculated on clay-free basis in order to remove the effect of possible translocated clay (Smith and Wilding, 1972; Barrios *et al.*, 1996a). Separation of the fine sand fraction into light and heavy minerals was by the use of bromoform (s.g = 2.89). The fine sand was added to bromoform and thoroughly stirred.

After 3 hours, the heavy grains (s.g > 2.89) were obtained by running the sample plus bromoform through a filter paper under suction in a filter funnel over a Buchner flask. The grains were then washed with acetone and dried.The light minerals (s.g < 2.89) were also collected in the same way. Clay mineralogical composition of clay fractions (less than 0.002mm) was determined by X-ray diffraction analysis (XRD) using Fe/ radiation from $2^0 2\Theta$ to $2^0 38\Theta$. Oriented clay specimens for x-ray diffraction study were prepared on glass slides.

Some samples were Mg-saturated and glycol solvated, while others were K-saturated and heated at temperatures up to 110^0C, 300^0C and 550^0C. From the relative peak height ratios on the differactogram for the sample slide specimens, clay mineralogical composition was semi-quantitatively assessed. Samples of the very fine sand fraction (0.5-2.0mm) were mounted on a glass slide under a cover slip with 1.54 index of refraction oil (Canada basalm) for petrographic examination.

RESULTS AND DISCUSSION

Particle size distribution (clay-free basis) data are shown in Table 1. The essence of particle size distribution calculated on clay-free basis is to remove any possible eluvia/illuvia processes on data interpretation. The fine sand and the very fine sand proportions were used to indicate lithologic discontinuities within individual pedons because these two size fractions dominate the sand fraction of soils of Abaliki site, and are made up of mainly quartz. In soils of Bende, however, all profiles examined seem to have homogenous type of parent materials. Both field morphologic properties and particle size distribution (fine sand and very fine sand fractions) indicate lithologic breaks at 47-74cm depth and at both 50-76cm and 95-135 depths of pedons AB-2 and AB-5 respectively. The clay-free analysis would not support the idea of multiparent materials sources for pedons AB-1, AB-3 and AB-4.

Results of the fine sand fraction (0.25-0.10) mineralogical analysis are shown in table2. Petrographic studies revealed that quartz comprises 85 to 95 percent of the minerals counted. Other minerals, such as muscovite and feldspars were in small amounts. Heavy minerals (s.g > 2.89) detected were zircon, biotite, and tourmaline. Prolonged water saturation in the pedons led to loss of Fe from the soils resulting in the light gray dominant colour of the grains.

X-ray patterns of Mg-saturated clays showed that pedons were characterized by distinct and sharp peaks at about 1.0nm, 0.79nm, indicating the presence of mica, metahalloysite and kaolinite as the dominant minerals However, the presence of 1.4nm diffraction peaks in Mg-saturated clay samples of pedons AB-2, AB-3, BD-1 and BD-2 suggests that they contain some 2:1 minerals. The persistence of the 1.0nm peak after glysol solvation confirms the presence of mica.

Heating of k-saturated clays at 110^{0}C increased the intensity of the 1.0nm peak indicating the collapse of smectite associated with K-saturation in a mechanism similar to those reported by Parfitt and Childs (1983) for vermiculite. The 300^{0}C heat treatment led to complete dehydration of geothite (disappearance of the 0.42nm peak) The 1.0 nm peak obtained after 300^{0}C heat treatment in pedon BD-1 K-saturated clay sample may indicate the presence of some interstratified minerals, possibly chlorite or vermiculite. The 0.70nm diffraction peak disappeared after heating the K-saturated samples at 550^{0}C which implies a destruction of kaolinite at this temperature (Berry, 1974). The metahalloysite peak (0.79nm) was also destroyed by heating at 55^{0}C. XRD patterns of Mg-saturated clays showed that the 1.70nm peak shifted slightly to about 1.80nm upon glycolation (Fig.2).

The intensity of 1.40 nm peak which appeared after glycolation decreased progressively with increasing soil depth in pedon BD-1. This might be due to partial chloritization of smectite as a result of incorporation of iron, and possibly some aluminum interlayer by the mechanism referred to as ferrolysis (Brinkman, 1978). The 1.40 nm peak which remained after glycolation implies the existence of some quantities of some degraded mica minerals. The chloritization process can be associated with partial dissolution of exchangeable bases and of the Si-tetrahedral sheet (partial decomposition of mica). Both mechanisms (partial chloritization and decomposition) may lead to the formation of some degraded mica minerals. The process of minerals decomposition may imply that exchangeable bases are leached and A1 (or Fe)- octahedral sheets are formed at interlayer positions of the smectite, in which a degraded mica layer could be considered as equivalent of two (2) units of kaolinite layers.

Formation of argillic horizons was not noticeable in any of the pedons examined which suggested that the rate of clay translocation was not much, or at least not great enough so that assemblage could not be masked by pedogenic alteration of the translocated clays, i.e lessivage was not significant. A continuos alternating wet/dry soil moisture regime destroyed the clay minerals in situ without significant clay movement. Seasonal fluctuation of water table with the accompanied pedoturbation at least with respect to clay size particles would greatly affect pedogenetic interpretation of mineral assemblage in the soils. In all pedons studied it appears that a high water table and/or saturated moisture conditions have slowed the weathering processes such that biotite, tourmaline, smectite and other weatherable secondary minerals still persist.

CONCLUSION

Both field morphologic observations and particle size distribution (fine sand and very fine sand fractions) indicate lithologic discontinuities at 47-74cm depth and at both 50-76cm and 95-135cm depth of pedons AB-2 and AB-5 respectively. The clay –free particle size analysis would not support the idea of multi-parent material sources for the remaining pedons. The mineralogy of the clays was predominantly kaolinitic except in pedons BD-1 and BD-2 which contained significant amounts of some degraded mica minerals. Ferrolysis was well demonstrated in pedons BD-1 and BD-2. Mineral decomposition led to the formation of some degraded mica minerals. Lessivage was not significant and high water table and/or saturated moisture conditions have slowed the weathering processes such that smectite and other weatherable minerals still persist.

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TABLE 1: Particle size distribution (Clay free basis)

Horizon	Depth (cm)	V.coarse Sand	Coarse Sand	Medium Sand	Fine Sand	V. Fine Sand	Total Sand	Silt.
					$g\ kg^{-1}$			
Pedon AB-1								
Ap	0 – 28	-	26	45	96	57	224	776
A$_2$	20-40	16	36	62	141	61	36	684
Bwg^1	40-81	26	29	45	171	176	447	553
Bwg^2	81 – 111	-	35	51	103	98	287	713
Bwg^3	111-170	-	35	42	111	99	287	713
Bcg	170 – 194	-	15	46	67	94	222	778
Pedon AB-2								
Ag	0-28	-	31	47	68	69	215	785
A2g	28-47	3.7	46	52	221	113	469	531
2Bwg	47-74	-	41	31	52	65	189	811
2Bg	74-109	7.8	80	52	71	52	333	667
2Bcg	109-158	-	32	48	70	70	220	780
Pedon AB-3								
Apg	0-28	-	16	22	45	24	107	893
A2feg	28-54	49	45	77	138	141	450	550
B1g	54-100	28	34	95	178	191	526	474
B2g	100-158	65	64	77	233	138	577	423
Pedon AB-4								
Apg	0-30	64	92	125	228	116	625	375
Bwg1	30-50	-	39	50	79	47	215	785
Bwg2	50-98	-	39	57	94	70	260	740
Bcg	98-148	-	35	44	144	63	286	714
Pedon AB-5								
Ap	0-20	-	76	79	55	81	291	709
AB	20-50	-	94	61	72	66	293	707
2Ew	50-76	61	62	211	142	146	622	378
2Bwfeg	76-95	103	116	60	135	100	514	486
3BCg	95-135	126	182	233	212	154	907	93
3Cg	135-170	146	165	250	170	165	896	104

Pedon BD-1

Ap	0 – 21	146	182	170	264	179	941	59
BW1	21-50	138	173	73	157	93	634	366
Bwg2	50-85	-	109	148	191	117	565	435
Bwg3	85 – 100	-	143	152	221	98	614	386
Bcg	100-158	135	141	81	171	113	641	359

Pedon BD-2

Ap1	0-20	83	96	166	247	145	737	263
Apg2	20-52	78	123	119	327	125	772	228
Bwg1	52-89	185	129	96	215	167	792	208
Bwg2	89-120	140	243	100	137	85	705	295
BCg	120-165	115	146	233	283	120	897	103

Pedon BD-3

Ap	0-20	75	121	175	262	198	831	169
Bw1	20-73	50	178	141	347	112	828	172
Bw2	73-100	65	164	120	275	287	911	89
BCg	100-152	80	173	134	363	175	925	75

Pedon BD-4

Ap	0-18	166	186	368	105	121	946	54
Bw1	18-30	105	172	322	211	111	921	79
Bw2	30-75	133	192	275	172	168	940	60
BC	75-144	88	144	374	187	163	956	44

Table 2: Fine sand fraction (0.25 – 10mm) mineral compostition

Horizon	Depth (cm)	Fieldspar	Muscovite	Quartz	Zircon	Biotite	Tourmaline	opaque
Pedon AB-1								
A2	20-40	X	X	XXXX	X	-	-	-
Bwg2	81 – 111	-	X	XXXX	-	-	-	-
Bcg	170 – 194	-	X	XXXX	-	X	-	-
Pedon AB-2								
Ag	0-26	XX	-	XXX	-	-	-	-
2Bwg	47-74	X	-	XXXX	-	XX	-	X
2Bcg	109-150	-	-	XXXX	-	XX	-	-
Pedon AB-5								
AB	0-20	-	X	XXXX	-	-	-	-
2Bwfeg	76-95	-	X	XXXX	-	X	X	X
3BCg	95-135	-	X	XXXX	-	-	-	-
Pedon BC-1								
Ap1	0 – 21	X	-	XXXX	X	-	-	-
Bwg2	50-85	X	XX	XXX	X	XX	-	X
Bcg	100-158	X	XX	XXX	-	XX	-	-
Pedon BD-3								
Ap	0-20	X	X	XXXX	X	-	-	-
Bw1	20-73	-	X	XXXX	-	-	-	-
Bc	100-152	-	X	XXXX	-	-	-	-

*Assessment of fine sand minerals (numbers of grains); X, very few (0-99); X,X, few (100-499)); XXX many (500-1000); XXXX Abundant greater than 1000