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STUDIES OF A LATOSOL ROXO *(Eutrustox)* IN BRAZIL: DESCRIPTION, SETTING AND CHARACTERIZATION*

W. Moura Filho
S. W. Buol**

1. INTRODUCTION

Latosol Roxo is a soil developed from mafic rocks on gently undulating topography under tropical seasonal rainforest. It has high porosity, low bulk density and very stable granular structure. It contains many heavy minerals, has a high iron content, and only slight color variation is observed throughout the soil profile (3). The color is not diagnostic for the identification of the boundaries between subhorizons. The Brazilian Soil Commission found that the soil color changes from a dusky red (10R 3/4) to a yellowish red (5YR 5/8) when samples were crushed. Further, the ground material is attracted by a magnet.

BRAMAO and LEMOS (2) referred to Latosol Roxo as being similar to some Low Humic Latosols described and studied in Hawaii (5, 16). The Balmoral series, in South Africa, is cited by de VILLIERS (8) as equivalent to the Terra Roxa Legitima - the former name for the Latosol Roxo in Brazil - but a close comparison reveals that the description of the Balmoral series (7), describes better horizonation, lower pH, lower

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base saturation, shallower solum, and slightly different in color than the Brazilian equivalent. Latosol Roxo soils correspond to the Ferralsols Roxo soils of the FAO system as presented by WRIGHT and BENNEMA (20) and to the Rhodic Ferralsols of the latest presentation of that System by DUDAL (9). In that paper Dudal referred to Latosol Roxo as equivalent to Hygro-xeroferralsols and Hygro-xeroferrisols found in the Congo; to Sols ferralitiques faiblement a moyennement desatures of the French Soil Classification System used in some areas of Africa; and to the Orthox, Torrox, and Ustox of the USDA System (17). Some of the Krasnozems of Australia are like the Latosol Roxo soils*.

The objective of this work was to compare two Latosol Roxo profiles in the Triangulo of Minas Gerais, Brazil and determine changes in soil properties after 15 years of cultivation.

2. SETTING

Two sites were selected for these studies. The approximate coordinates of the sites are 18° 52' south and 48° 51' W. Grw., in Minas Gerais, between São Paulo and Brazilia. Both sites are in the middle of a long, 2% convex slope at 480 m elevation. The original vegetation of both sites is a tropical seasonal rain-forest (18). The soils are developed from mafic rocks of the Triassic and Cretaceous Age.

The area receives 1,600 mm mean annual rainfall and has a 21°C mean annual temperature. The maximum rainfall occurs during the warm season and the cold season is dry. In the nearby stations, evaporation exceeds precipitation from May through September. Insolation is about 2,588 hours per year.

The soil profiles were described and initially sampled in January, 1967 (Table 1). Infiltration studies were made in July, 1968.

* Smith, Guy D. 1965. Impressions on Soils of Brazil. A speech given to the Ministry of Agriculture, in Rio de Janeiro, Brazil.

TABLE 1 - Profile Descriptions by Mr. Cliff Spies, Mr.Mauro Resende and Mr. Bairon Fernandes

Profile Description Site I

A1	0-35 cm	Dusky red [10R 3/4 (m)] dark red [2.5YR 3/6 (d)] and yellowish red [5YR 5/8 (ground dry)]; clay; moderate, coarse, granular broken into strong, very fine, granular; friable, slightly sticky; abundant roots; gradual and diffuse boundary.
A3	35-70 cm	Dusky red [10R 3/4]; weak, medium, sub-angular, broken into strong, very fine, granular; friable, slightly plastic, slightly sticky; abundant roots; diffuse boundary.
B21	70-96 cm	Dusky red [10R 3/4]; clay; massive or weak, coarse, sub-angular, both broken into strong, very fine, granular; very friable, slightly plastic, slightly sticky; abundant roots; diffuse boundary.
B22	96-150cm	Dusky red [10R 3/4]; clay; massive or weak; medium, sub-angular broken into strong, very fine, granular; friable, slightly plastic, slightly sticky; few roots.

Profile Description Site II

A1	0-20 cm	Dusky red [10R 3/4 (m)]; dark red [2.5YR 3/6 (d)] and yellowish red [5YR 5/8 (ground dry)]; clay; weak, medium to coarse, sub-angular; firm, slightly plastic, slightly sticky; few roots; abrupt and smooth boundary.
A3	20-40 cm	Dusky red [10R 3/4 (m)]; clay; the peds tend to be coarse with relatively well defined plane of weakness, (in the upper part of the peds tend to be broken horizontally), broken into strong, very fine, granular; firm, slightly plastic, slightly sticky; very few roots; gradual and wavey boundary.
B2	40-150cm+	Dusky red [10R 3/4 (m)]; clay, massive broken into strong, very fine, granular; very friable, slightly plastic, slightly sticky; rarely roots.

Site I was cleared of natural forest two months before initial sampling. Only manual tools and fire were used. Rice and cotton were planted in a primitive way the next two growing seasons. Machinery, lime, and fertilizers were not used prior to the infiltration studies. Site II is across a fence line about 50 m north of site I. It was cleared 15 years before sampling in about the same way as was site I. Chronologically the cropping history includes 10 years annual crops, 4 years bananna trees, 1 year legume. Machinery was used but lime and fertilizers had never been applied prior to initial sampling. During the last 2 years the area was plowed twice a year with large disc plows to turn over the upper 15 cm layer, and twice a year with small discs to break up the clods. The surface soil is cloddy and a "hardpan" formation is present at about 15 to 20 cm depth. Fire has been used in both sites to clear the areas and control weeds after each growing season.

3. MATERIALS AND METHODS

Representative bulk soil samples and undisturbed samples were taken from each soil profile. Since horizon boundaries are generally diffuse and the samples were usually taken at arbitrary depth limits.

Soil samples were dispersed with sodium - hexametaphosphate (calgon), sand was separated by wet sieving, clay and silt were determined by sedimentation using the pipette method (13). Particle size distribution was also determined in organic matter and iron free samples using JACKSON (12) procedure as modified by KITTRICK and HOPE (14). Five extractions were necessary to remove all free-iron and from 35-45 centrifugations were necessary to separate the smaller than 0.2μ fraction. Soil samples were stirred in H_2O for 15 minutes with a malted milk mixer prior to determination of water-dispersible clay by the pipette method (13). Free iron was extracted by citrate-dithionite method and iron determined with a Perkin-Elmer 303 atomic absorption spectrophotometer and expressed as Fe_2O_3.

Undisturbed cores were saturated and subjected to various tensions on the tension table to determine

pore size distribution (19). Pressure equipment was used for the 15-bar, 0.2-bar, and 1-bar extractions. The bulk density was determined on oven dry cores of known volume.

Field measurements of infiltration were conducted in July, 1968. Double ring infiltrometers were used on three subsequent days in the pre-wet infiltration measurements, and a single ring infiltrometer was used in the dry infiltration studies.

The double ring infiltrometers were composed of two cylinders of different diameters. The smaller ring had a 20 cm internal diameter and the ouside ring had about a 40 cm internal diameter. Both cylinders were pushed 20 cm into the soil. After initial wetting in both rings, the infiltration was measured in the internal ring.

The single ring infiltrometer was a cylinder with a 11.2 cm internal diameter.

The pre-wet treatment was used in sites I and II in duplicate, and in a natural forest adjacent to both sides and at the top of the same landscape without replication.

In sites I and II, two measurements of the infiltration were made on the surface and after the upper 12 cm (plow layer) was removed, this 12 cm was the position of the "hardpan" formation as found in site II.

In the forest only the infiltration at the surface was determined. A 10 cm head of water was used but the equipment available did not allow maintenance of a constant head thus, a constant interval time was used to reestablish the head. This time interval was 15 minutes for site II, and 2 minutes for both site I and for the forest site.

The volume of water used to re-establish the head was recorded and the infiltration rate was calculated in cm/hour.

The dry infiltration procedure was used in sites I and II without replication. The cylinder was pushed 30 cm into the soil. All the measurements were of surface infiltration. A 6 ± 0.5 cm head was used. The time required for 100 ml to infiltrate was recorded at several consecutive times and the infiltration rate was calculated in cm/hour.

Soil reaction was measured by means of a pH meter equipped with a glass electrode in 1:1 soil-water and 1:1 soil-N KCl. Exchangeable H and exchangeable

Al were determined by titration of the N KCl leachates using methyl orange and phenolphthalein as indicators (6). Extractable bases were determined on soil samples as described by CHAPMAN (4), and calculated on the amount of clay dispersed by Calgon. The samples were allowed to remain in the N NH_4OAc for 24 hours before extraction. The base retention was the sum of extractab. bases plus exchangeable Al. The organic carbon was determined as outlined by ALLISON (1) and the total N was determined by Kjeldahl procedure with KEL- PAC No. 1 as a catalyst. Silicon was extracted and determined as described by FOX *et al* (10).

4. RESULTS AND DISCUSSION

The particle size distribution analysis (Table 2) revealed that sand and silt contents were considerably reduced after free iron removal. It is apparent that dispersion with calgon was incomplete and that silt and sand sized, iron cemented aggregates of clay remained throughout both profiles. After free iron removal, more than 70 percent of the particles were less than 0.2μ in diameter in the upper 50 cm, except for the first layer sampled in both sites.

The water-dispersible clay content decreased with depth, being minimum in the oxic horizon. Distribution of the H_2O dispersible clay with depth at site II suggested clay translocation after 15 years of cultivation (figura 1), but illuvial argillans were not observed in thin section (15). Possibly they had been destroyed by turbation under the monsoon nature of the climate. The free iron oxide contents varied from 19.6 to 24.4% and were slightly higher in site II. There was a limited available water holding capacity (%H_2O at 0.2 bar - %H_2O at 15 bars) despite the high value for %H_2O at 0.2 bars.

The pore size distribution with depth are represented in Figures 2 and 3. The total porosity was high for both sites but site II was less porous than site I. The amount of pores smaller than 0.05 mm was reasonably constant with depth. The volume of larger pores was extremely reduced upon cultivation, principally in the upper 30 cm. This suggested that

TABLE 2 - Some physical and chemical properties

	Depth	Without Iron Removal			On Iron Free Basis					Fe_2O_3	H_2O dispersible clay	Air dry H_2O	H_2O at 15 bars	Vol. H_2O at 0.2 bars
		Sand 2mm-50μ	Silt 50μ-2μ	Clay <2μ	Sand 2mm-50μ	Coarse Silt 50μ-20μ	Fine Silt 20 μ-2μ	Coarse Clay 2μ-0.2μ	Fine Clay <0.2μ					
	cm	%	%	%	%	%	%	%	%	%	%	%	%	%
Site I	0-10	24.0	33.1	40.2	7.8	8.6	0.1	9.4	74.0	19.6	13.2	2.6	24.5	29.0
	20-30	22.0	27.3	48.1	6.6	22.1	0.2	0.5	70.6	19.6	3.9	2.2	24.4	27.5
	40-50	16.4	28.8	52.9	6.4	21.8	0.0	0.4	71.3	20.2	0.5	1.9	25.1	
	80-90	24.5	24.7	48.6	6.7	27.7	0.0	0.4	65.2	19.5	0.3	2.0	25.0	25.7
	100-110	18.0	23.0	56.1	6.4	24.9	0.0	0.5	68.2	20.8	1.2	1.8	25.5	
	120-130	20.2	17.9	60.1	6.7	28.2	0.1	0.5	64.6	21.0	1.3	1.9	25.2	
	140-170	21.9	20.1	56.1	7.8	28.5	0.0	0.3	63.4	21.4	3.2	2.1	25.5	
Site II	5-15	22.8	39.9	36.0	5.6	15.2	0.3	7.6	71.3	22.6	7.3	2.1	23.5	27.7
	20-30	17.5	31.9	48.4	4.2	19.4	0.1	4.4	71.9	23.1	4.1	2.2	24.8	27.9
	40-50	13.5	28.8	56.2	2.1	25.1	0.2	3.9	68.7	23.3	7.4	2.2	24.7	26.6
	60-70	22.4	22.8	51.9	2.7	25.4	0.1	1.8	70.0	22.9	0.2	1.9	24.7	
	70-80	20.7	37.5	39.8	2.8	33.4	0.1	3.1	60.5	23.8	3.7	2.0	25.0	
	135	18.9	15.6	62.8	3.1	32.1	0.1	3.0	61.7	24.4	3.5	1.8	25.6	
	200	22.1	24.1	51.6	6.4	31.5	0.1	0.8	61.2	23.7	6.7	1.9	25.3	
	350+	17.8	25.5	54.1	5.4	29.5	0.5	0.7	63.9	23.7	7.3	1.7	24.9	

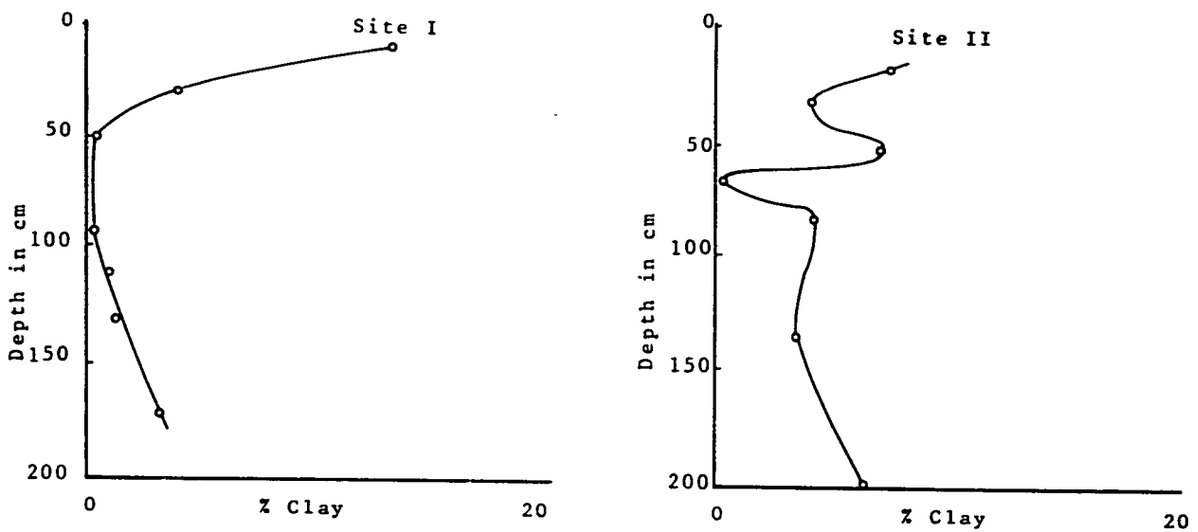

FIGURE 1 - Relative distribution of water dispersible clay (<2μ) throughout both profiles I and II.

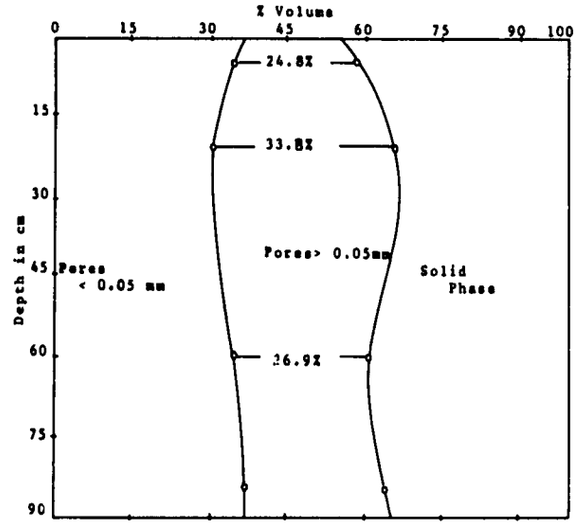

FIGURA 2 - Pore size distribution with depth - Site I

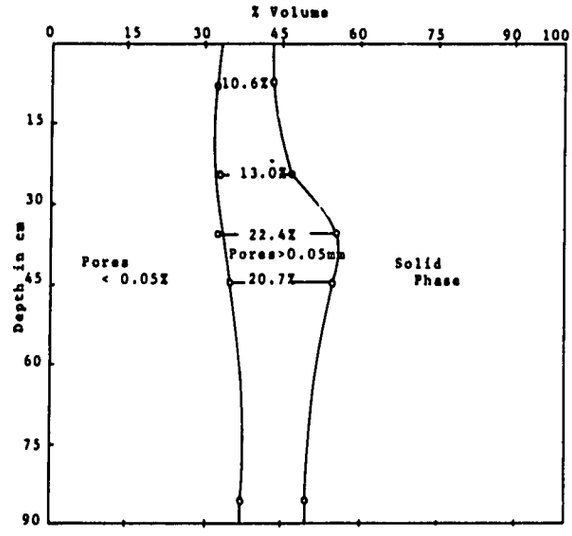

FIGURE 3 - Pore size distribution with depth - Site II

cultivation affects the total porosity by reduction in the non-capillary (<0.05mm) pores, decreasing the soil permeability. Bulk density was measured at about 1.00 g/cm^3 throughout both profiles.

There was a considerable difference in infiltration rates between the cultivated and non-cultivated sites (Table 3). The forest site had a high infiltration rate, but somewhat less than site I, suggesting that the clearing itself was not responsible for the decrease in the infiltration. The use of machinery in the cultivation practices for 15 years did show a marked effect. Infiltration differences are in agreement with what would be predicted from the pore size distribution data. At both sites, the infiltration rate was higher when the top 12 cm layer was removed than when the infiltration was carried out on the natural soil surface; indicating that the plow layer is in some way limiting infiltration The dry infiltration rate in site I was 5.5 times that of site II in the first day and 7.8 times in the second day (Table 4).

TABLE 3 - Results of pre-wet treatments of field infiltration studies

	Site I		Forest	Site II	
	at 12 cm	on surface	on surface	on surface	at 12 cm
	Av. rate	in cm/hr.	Av. rate in cm/hr	Av. rate	in cm/hr
1st day	107.9	82.0	62.0	12.0	16.0
2nd	125.0	60.1	67.0	10.0	11.7
3rd	-----	51.6	----	8.1	----
Total time	52 min.	72 min.	52 min.	9 hr.15min.	4 hr.15 min.

TABLE 4 - Results of dry-infiltration studies

	Site I	Site II
	Average rate in cm/hr	
First day	25.6	4.6
Second day	20.5	2.6

Considering the setting and the advanced weathering of the clay mineral suite, the base saturation showed surprisingly high values for all samples from both profiles. The pH values were also high for this climatic condition (Table 5). The extractable silicon contents were slightly higher near the surface in site II (Table 6).

5. CONCLUSIONS

The amount of clay (<2μ) varies from 61.9% to 83.5% of the sample after "free" iron removal, and the fine clay content (<0.2μ) varies from 60.5% to 74.0% on the same basis. Sodium-hexamethphosphate-calgon-was not satisfactory for dispersion particularly for the upper 50 cm. The clay content calculated by 2.5X $\%H_2O$ at 15 bars as recommended by the Soil Survey Staff was only about 10% lower than percent clay on iron free basis. The free iron oxide content is high throughout both profiles and varies from 19.5 to 24.5 percent.

The high amount of particles of less than 0.2μ and the dominance of kaolinite and gibbsite in this fraction (15) suggest a high degree of weathering, stages 10-12 in the weathering sequence (11). However, base retention and pH values were much higher than expected in the highly weathered soils.

TABLE 5 - Some chemical data without iron removal

	Depth cm	pH H_2O	pH KCl	Organic Carbon	Total Nitrogen	C/N	O.M	Ex.Al	Extractable Bases	CEC	Base Saturation
		1:1	1:1	%	%	ratio	%		meq/100g clay		%
Site I	0-10	5.9	5.5	2.80	0.25	11.2	4.8	0.23	19.3	19.5	98.8
	20-30	5.2	4.9	1.30	0.15	8.7	2.2	0.85	12.2	13.0	93.5
	40-50	4.9	5.1	1.02	0.11	9.3	1.7	0.55	10.2	10.7	94.9
	80-90	5.6	6.3	0.63	0.07	9.0	1.0	0.43	9.8	10.2	95.8
	100-110	5.8	5.3	0.63	0.05	12.6	1.0	0.34	8.7	9.0	96.2
	120-130	6.1	5.1	0.63	0.05	12.6	1.0	0.37	8.3	8.7	95.7
	140-170	6.0	5.5	0.35	0.04	8.7	0.6	0.35	8.7	9.1	96.1
Site II	5-15	6.1	5.7	1.49	0.15	9.9	2.5	0.22	17.0	17.2	98.7
	20-30	6.2	6.0	1.00	0.10	10.0	1.7	0.16	16.4	16.5	99.0
	40-50	6.6	6.3	0.86	0.08	10.7	1.5	0.10	13.1	13.2	99.2
	60-70	5.4	5.1	0.55	0.08	6.8	0.9	0.44	7.8	8.2	94.6
	70-80	6.5	6.3	0.55	0.06	9.2	0.9	0.18	13.2	13.4	98.6
	135	5.5	5.7	0.47	0.04	11.7	0.8	0.17	9.3	9.5	98.2
	200	5.5	5.8	0.32	0.04	8.0	0.5	0.19	11.1	11.3	98.3
	350	5.9	6.2	0.29	0.03	9.7	0.5	0.17	9.6	9.8	98.2

TABLE 6 - Extractable Silicon

	Depth	Water extract 1.10*	Water extract Saturation*	Phosphorus extract **
	cm	ppm	ppm	ppm
Site I	0-10	1.81	5.05	92
	20-30	1.67	4.40	81
	40-50	1.70	3.78	120
	80-90	1.65	3.08	180
	100-110	1.54	2.51	171
	120-130	1.70	2.70	192
	140-170	1.73	2.24	214
Site II	5-15	2.94	5.94	144
	20-30	2.28	5.29	154
	40-50	1.67	2.40	182
	60-70	1.73	3.20	138
	70-80	1.24	1.90	189
	135	1.22	2.05	200
	200	1.13	2.00	208
	350	0.92	1.13	248

* Content of Si in extract.

** Content of Si on a soil wt. basis.

The water dispersible clay distribution in the profiles suggests there is water-dispersible clay translocation after clearing the forest but argillans were not detected in thin sections, except in cracks

in the charcoal material. Absence of argillans was interpreted to be caused by pedoturbation upon wetting and drying.

The soil is classified as *Typic eutrustox;* clayey, kaolinite, thermic family. The oxic horizon was not structureless as defined for the typic subgroup but is massive in place breaking into a strong, very fine granular structure.

The data available suggested that the exposure and the cultivation them-selves were not responsible for the compaction or "hardpan" formation. There was slight indication of Si cementation. Indications are that the use of machinery in the cultivation practices has reduced the capillary pores in the upper parts of the solum and this reduction has served to decrease infiltration.

6. ABSTRACT

Latosol Roxo *(Eutrustox)* pedons from a recently cleared site and an adjacent site after 15 years cultivation were studied in Brazil. An oxic horizon was identified at about 70 cm in the profiles. The bulk density of surface horizons increased and infiltration rate was reduced by cultivation. The upper 50 cm of both soils contained 19.6-23.3% Fe_2O_3 and over 70% fine clay (<0.2μ) on an iron free basis. Content of exchangeable bases and pH values were much higher than expected in highly weathered soils.

7. RESUMO

Foram estudados dois *pedons* classificados como Latosol Roxo *(Eutrustox)*, no Triângulo Mineiro. Um deles em derrubada recente, e o outro após 15 anos de cultivo.

Seus horizontes apresentaram de 19,6 - 23,3% de Fe_2O_3, mais de 70% de argila fina (<0,2μ), elevada saturação de bases, altos valores de pH e reduzida disponibilidade d'água.

O perfil da distribuição da argila natural sugeriu a translocação de argila, durante os 15 anos de cultivo.

O cultivo reduziu o volume ocupado pelos poros não capilares, aumentando a densidade aparente dos horizontes superficiais e reduzindo a velocidade de infiltração.

O teor de bases permutáveis e o pH foram bem mais elevados do que os esperados para os solos altamente intemperizados, mostrando assim, haver necessidade de estudos para esclarecer esses desvios.

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STUDIES OF A LATOSOL ROXO *(Eutrustox)* IN BRAZIL: CLAY MINERALOGY*

W. Moura Filho
S. W. Buol**

1. INTRODUCTION

An Oxisol located in the Triangulo area of Minas Gerais, Brazil, was sampled for this study. The soil is developed from mafic rocks, under tropical seasonal rainforest, with a pronunced dry season. It was characterized and classified as *Typic Eutrustox* by MOURA FILHO (14).

The clay (<2μ) fraction of the Oxisols is ordinarily regarded as composed of sesquioxides mixed with varying amounts of 1:1 lattice silicate clays (19).

MONIZ (13), working with soils similar to the one reported in this study, found that the air-dry soil had 17-25% Fe_2O_3 and the clay (<2μ) fraction was composed of about 40% kaolinite, 40% gibbsite, 7-18% amorphous materials determined by selective dissolution analysis, 0.5-7.7% vermiculite, and less than 2.6% clay mica.

In earlier work (14) it was reported that over 90% of the clay (<2μ) fraction of this soil is composed of fine clay (<0.2μ).

Water-dispersible clay (<2μ) is significant in the definition of the upper boundary of the oxic horizon (20). The oxic horizon is defined as containing

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less than 1% water-dispersible clay. The surface horizons of Oxisols usually have a somewhat higher water-dispersible clay content than the oxic horizon. The soil used in this study was found to contain 13% water-dispersible clay in the upper 10 cm and 4% in the 20-30 cm depth (14). The upper boundary of the oxic horizon was determined to be at 70 cm.

Both water-dispersible and water-stable (dispersible in NaOH) clays (<2μ) were used in this study in an attempt to determine if any mineralogical differences exist between these clays differing in water dispersibility and to characterize the nature of the clays present.

2. MATERIALS AND METHODS

Site I characterized by MOURA FILHO (14) was described and sampled from the 0-20 cm depth. The clay (<2μ) samples were separated and treated according to the following flow sheet (Figure 1).

Eight clay (<2μ) samples of the following designations are thus reported:

A. Water-dispersible
   1. Total clay
   2. Fe-free clay
   3. X-amorphous-free clay
   4. 400° C-treated clay

B. Water-stable
   1. Total clay
   2. Fe-free clay
   3. X-amorphous-free clay
   4. 400° C-treated clay

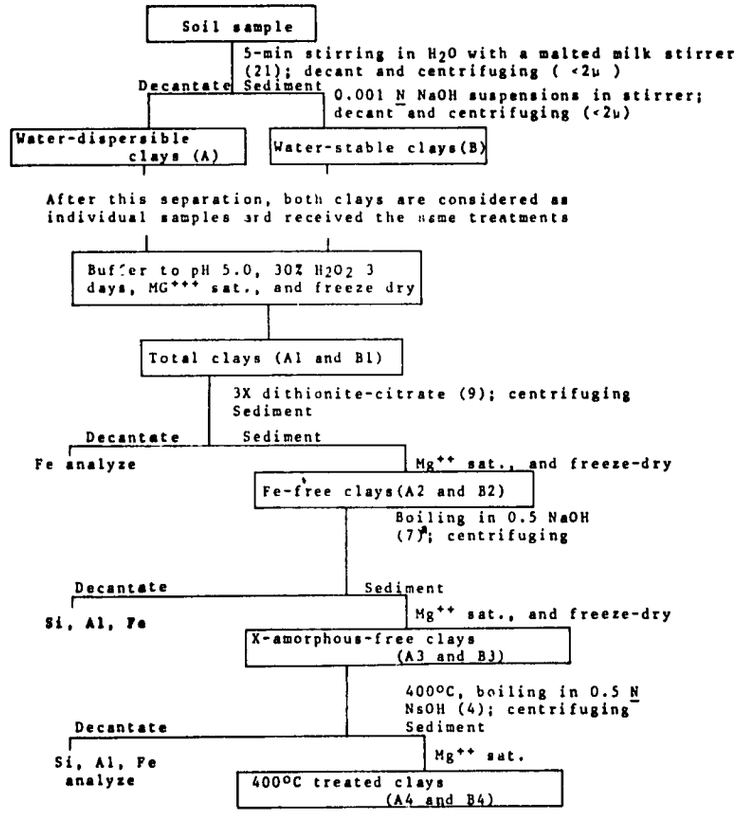
All chemical analyses were conducted in triplicate unless otherwise specified. Free-Fe was obtained by dithionite-citrate procedure (9).

Total dissolution of the clay (<2μ) samples was carried out as described by SHAPIRO and BRANNOCK (18). A Perkin-Elmer 303 atomic absorption spectro-photometer was used to determine Si, Al, Fe, Mn, Ti, Mg, and K in all chemical analyses.

The molybdate-vandate method described by OLSEN and DEAN (16) was used to determine P.

The weight loss upon heating from 110°C to 900°C was calculated as the percent loss on ignition.

Kaolinite and gibbsite were estimated by DTA



[a]A condenser was used to prevent evaporation from the NaOH solution and quick cooling in ice water immediately followed the boiling.

FIGURE 1 - Flow wheet of clay (<2μ) samples preparation

using calibration curves prepared with mixtures of different proportions of Georgia kaolinite (API No. 4) and gibbsite both specimens were obtained from Wards*. The content of intergradational materials was calculated using a percent K_2O to intergradational materials conversion factor of 10 (9). The amount of material removed by boiling in NaOH, less the gibbsite as estimated by DTA, was recorded as X-amorphous materials.

The Walkley-Black method as outlined by ALLISON (1) was used to determine the organic carbon.

Oriented glass slides of each clay (<2μ) sample were prepared. Mounting, solvation, and heating followed the methods described by JACKSON (9). Also, random-oriented specimens were formed into spindles with Duco cement and mounted in a powder camera.

For DTA analysis 20 mg of Mg-saturated clay (<2μ) equilibrated with a slurry of $Mg(NO_3)_2$ was heated in a Dupont 900 differential thermal analyzer at a temperature rate of 15°C per minute in a flowing N_2 atmosphere**.

Infrared absorption spectra were recorded from pellets containing 0.25% clay (<2μ) in KBr using a Perkin Elmer 457 grating infrared spectrophotometer.

Surface area was determined by the adsorption of ethylene glycol monoethyl ether (EGME) (8). The samples were oven-dried to constant weight rather than over P_2O_5 (17).

For CEC determinations, the clay (<2μ) samples were buffered with pH 5.0 Na-acetate, Mg-saturated, washed free of salts, and freeze-dried. Duplicate 100-mg samples were then treated with 1 N Ca-acetate, pH 7.0, shaken, centrifuged, and the supernatant collected. Three extractions were used to accumulate the Mg^{++}. The Mg displaced was determined by atomic absorption.

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* Wards Natural Science Establishment, Inc., P.O. Box 1712, Rochester, N. Y. 14603.

** Appreciation is expressed to W. E. Pearce, N. C. State Bureau of Investigation, Raleigh, N. C., for DTA determinations.

3. RESULTS AND DISCUSSION

The results of the total dissolution are reported in Table 1. There is no apparent difference in elemental composition between the water-dispersible and water-stable clays.

The removal of the free Fe also removed P. With the free Fe removed, the relative amounts of Ti, Al, and Si showed an apparent increase. The Al content increased less than Si which is reflected in the slight increase of the SiO_2:Al_2O_3 molecular ratios.

The 0.5 N NaOH dissolution (7) increased the relative amounts of Si and decreased those of Al, thereby increasing the SiO_2:Al_2O_3 molecular ratio. This is due to the removal of gibbsite as will be discussed later. The apparent Ti content was almost doubled and K content was observed to increase by a factor of 3.0-3.5. The loss on ignition values of the X-amorphous-free samples are lower than other reported kaolinite values (9), but the presence of Ti oxides and intergradational materials may account for this observation.

The composition of the materials removed by 0.5 N NaOH dissolution was approximately 73% Al_2O_3, 25% SiO_2 and less than 1.5% Fe_2O_3 (15). The procedure gave good reproducibility for these soil clays (<2μ) and no alteration of the kaolinite was observed in X-ray diffractograms.

The mineralogical composition is reported in Table 2. The water-dispersible and water-stable clays had about the same mineralogical composition. Kaolinite, free-Fe, and gibbsite comprised more than 70% of the total clays. Removal of the free-Fe reduced the amounts of X-amorphous present, probably by solution of the Si combined with Fe (3). As a result of the free-Fe removal, kaolinite, gibbsite, and Ti contents reflected a relative increase. The removal of the X-amorphous materials also removed gibbsite, concentrating kaolinite, intergradational materials, and Ti. The Fe-free clays still contained small amounts of Fe not removed by the dithionite-citrate extraction. This iron was probably in ilmenite and/or magnetite (9). Contents of iron were relatively increased by boiling in 0.5 N NaOH.

The mineralogical summation of the clays did not equal 100% probably indicating slightly inaccurate

TABLE 1 - Total elemental analysis of clays

Clays	K_2O	SiO_2	Al_2O_3	Fe_2O_3	MnO	TiO_2	$\frac{SiO_2}{Al_2O_3}$	P_2O_5	Loss on ignition
	%	%	%	%	%	%	ratio	%	%
					Water-dispersible				
Total	0.60	18.94	34.78	25.66	0.11	6.49	0.93	.58	14.65
Fe-free	0.60	27.99	47.00	1.95	0.02	7.82	1.01	zero	16.40
X-amorphous-free	1.80	35.95	37.60	3.83	0.04	11.53	1.65	zero	12.78
					Water-stable				
Total	0.49	19.15	34.83	25.67	0.11	6.18	0.93	.66	14.01
Fe-free	0.83	27.99	47.94	2.18	0.03	7.31	0.99	trace	15.26
X-amorphous-free	1.73	35.48	37.58	3.72	0.03	12.45	1.61	zero	12.36

TABLE 2 - Mineralogical data of the clays

Clays	Mineralogical composition								Surface area	CEC
	Fe_2O_3	Gibbsite	Kaolinite	X-amorphous	O.M.	TiO_2	Intergradational materials	Totals		
	%	%	%	%	%	%	%	%	m^2/g	meq/100g clay
					H_2O-dispersible					
Total	24.1	13	41	20	0.3	6.5	6	110.9	90.9	21.87
Fe-free	2.0	19	47	14	---	7.8	6	95.8	76.7	21.04
X-amorphous-free	3.8	--	67	--	---	11.5	18	100.3	117.0	25.00
					H_2O-stable					
Total	21.0	13	41	21	0.3	6.2	--	107.1	81.0	22.29
Fe-free	2.2	22	51	12	---	7.3	8	102.5	58.5	21.26
X-amorphous-free	3.7	--	65	--	---	12.5	17	98.2	93.5	25.00

estimations of gibbsite and kaolinite, and/or the K_2O to intergradational materials conversion factor not being equal to 10.

Boiling the X-amorphous-free clays in 0.5 N NaOH after heating to 400°C for four hours showed the water-stable clay to be more resistant than the water-dispersible clay (Table 3). It is suspected that this is due to a larger particle size. The composition of the materials removed from the water-stable clay by the 0.5 N NaOH boiling contained more Si, less Al, and a greater $SiO_2:Al_2O_3$ molecular ratio than that removed from the water-dispersible clay.

TABLE 3 - Results of dissolution of clays preheated to 400°C

Sample of X-amorphous-free clay	Material removed	Composition of material removed			Fe_2O_3(free)
		SiO_2	Al_2O_3	SiO_2/Al_2O_3	
		%	%	ratio	%
H_2O-dimspersible	39.19	34.61	63.48	0.93	1.91
H_2O-stable	27.80	40.13	58.75	1.16	1.12

The total clays, both water-stable and water-dispersible, presented weak but definable X-ray peaks of kaolinite, gibbsite, TiO_2, and hematite (Figure 2). The latter was also confirmed in the random-oriented sample giving strong reflection lines of the 102, 104, 110, and 116 planes. The Fe-free clays (Figure 2) gave stronger and sharper X-ray basal peaks for kaolinite, gibbsite and TiO_2. A weak 14.47 A° peak appeared but the 2.69 A° (hematite 104) peak was destroyed. Boiling of the Fe-free clays in NaOH enhanced the intensity of the 14.47 A° peak (Figures 3 and 4). This peak did not expand on solvation, but

collapsed upon 350°C heating (15), suggesting the presence of an aluminum interlayered 2:1 lattice silicate clay. Gibbsite was absent. The 7.24 A° peak was removed by heating at 550°C but the 3.51 A° TiO_2 peak remained at a lower intensity due to removal of the reinforcing second-order kaolinite peak.

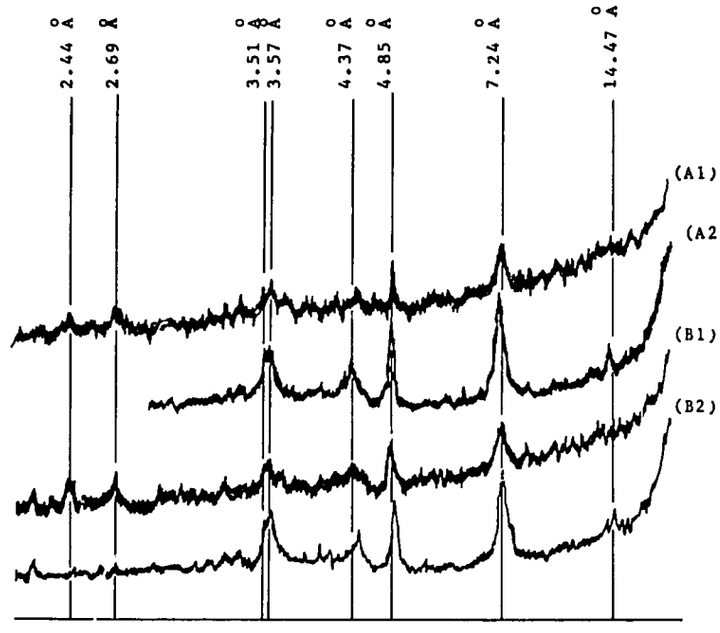

FIGURE 2 - X-ray diffractograms of Mg-saturated water-dispersible clays (<2μ) [(A1) total clay, (A2) Fe-free clay] and water-stable clays (<2μ) [(B1) total clay, and (B2) Fe-free clay] (air temperature and 500 cps).

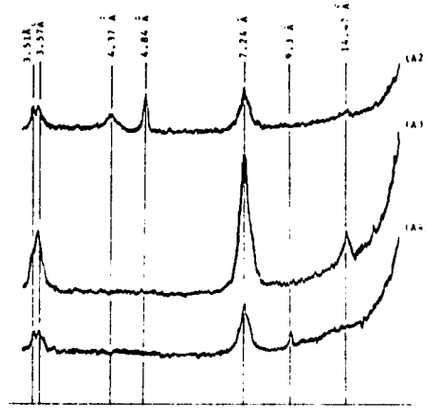

FIGURE 3 - X-ray diffractograms of Mg-saturated water-dispersible clays (<2μ): (A2) Fe-free, (A3) X-amorphous-free, and (A4) 400°C-treated clays (air temperature and 1,000 cps).

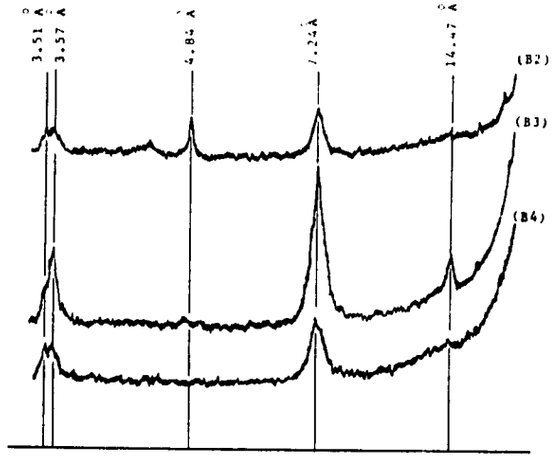

FIGURE 4 - X-ray diffractograms of Mg-saturated water-stable clays: (B2) Fe-free, (B3) X-amorphous-free, and (B4) 400°C-treated clays (air temperature and 1,000 cps).

Heating the X-amorphous-free clays to 400°C and boiling in NaOH decreased the intensity of the kaolinite peak, maintained the TiO_2 peak and destroyed the 14.47 A° peak (Figures 3 and 4). After this treatment the water-dispersible clay presented a small but distinct basal peak at 9.3 A° (Figure 3) that did not expand on solvation and did not collapse at 550°C. It is suggested that the removal of the interlayered materials caused a collapse of the 14 A° material to a pyrophyllite-like material. This peak was not distinguishable in the water-stable clay (Figure 4).

Figure 5 presents the thermograms for the clay (<2μ) samples. Characteristic kaolinite and gibbsite endotherms were detected. Boiling the samples in 0.5 N NaOH destroyed the gibbsite. It is noted that there was no exothermic peak in the 250-500°C range suggested by MACKENZIE (10, 11) and by GREITH (5) for amorphous iron oxides and hydroxides. The removal of free-Fe did not affect the shape or position of the endotherms indicating that most of the iron removed was probably in the hematite form, as detected by X-ray, which does not have DTA peaks from 0-100°C (11). No difference was observed between the thermograms for water-dispersible and water-stable clays (<2μ).

The infrared absorption spectra are recorded in Figure 6. The water-dispersible and water-stable clays (<2μ) were almost identical. These data further substantiate that boiling in 0.5 N NaOH did not affect kaolinite but did remove gibbsite. The removal of free-Fe did not affect the IR spectra, except for slightly increasing the steepness of the curve in the 3.0-3.5μ band, possibly indicating a slight decrease in amorphous material.

Table 2 contains the data for specific surface area determinations. The water-dispersible clays (<2μ) had a larger specific surface area than the water-stable clays (<2μ). The removal of the free-Fe decreased the specific surface area of both water-dispersible and water-stable clays, indicating that the material removed had higher specific surface area and consequently a smaller particle size than the remaining material. Similar results were reported by DESHPANDE *et al* (3). Probably most of the free-Fe removed was as finely divided discrete hematite particles. This is in agreement with the results of

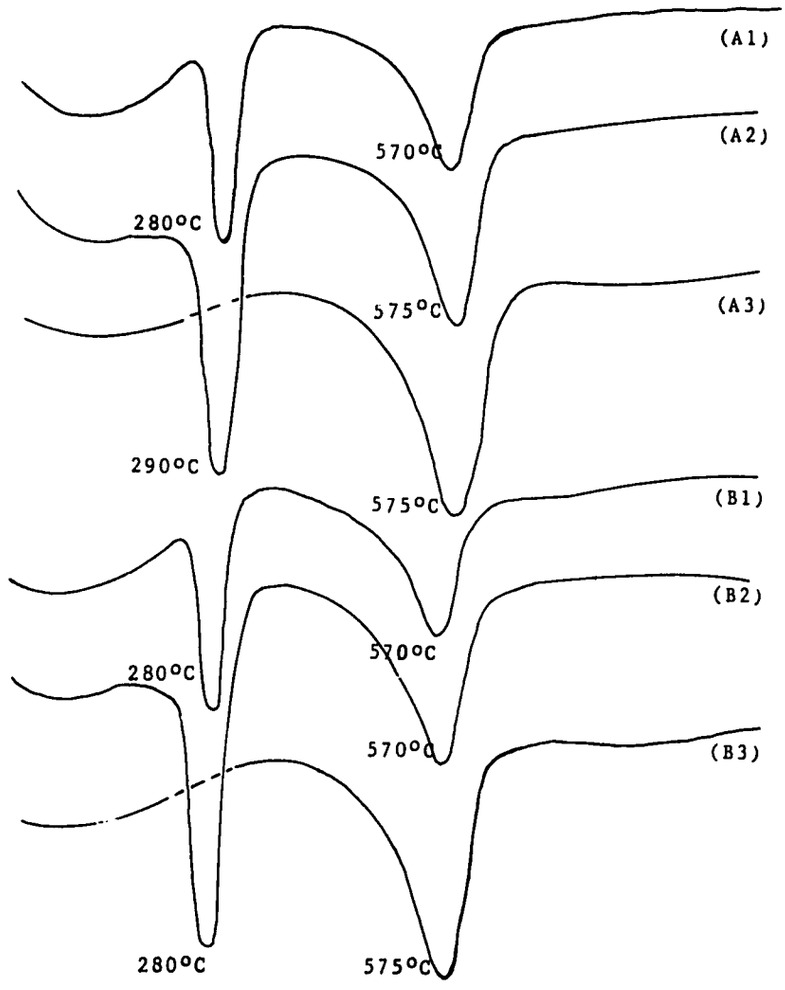

FIGURE 5 - Thermograms of clay (<2μ) samples. Water-dispersible: (A1) total, (A2) Fe-free, and (A3) X-amorphous-free; water-stable: (B1) total, (B2) Fe-free, and (B3) X-amorphous-free.

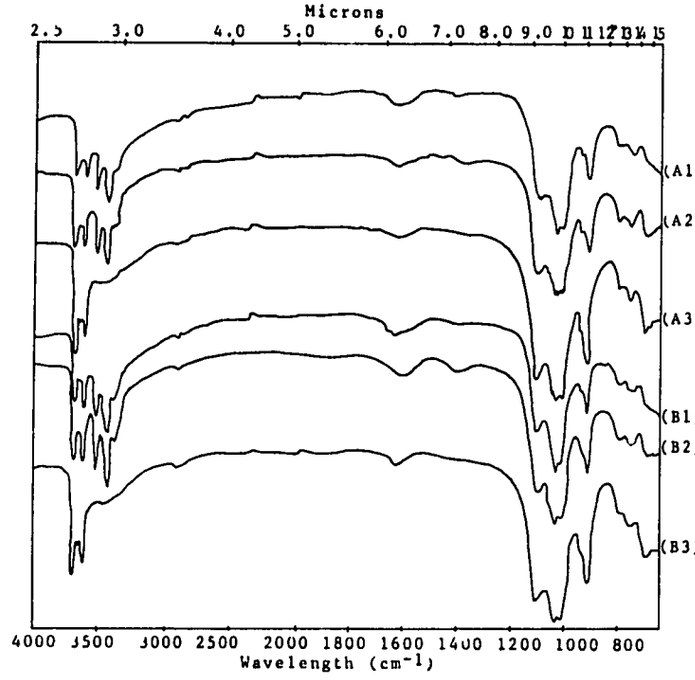

FIGURE 6 - Infrared absorption spectra of clay (<2μ) samples. Water-dispersible: (A1) total, (A2) Fe-free, and (A3) X-amorphous-free; water-stable: (B1) total, (B2) Fe-free, and (B3) X-amorphous-free.

work done by MACKENZIE and MELDAU (12) and GREENLAND *et al* (6). The X-amorphous-free clays (<2μ) had considerably higher specific surface area than the clays (<2μ) with only the free-Fe removed suggesting that the boiling in 0.5 N NaOH removed materials of smaller specific surface area and/or dispersed small aggregates. The CEC values (Table 2) were higher than normal for kaolinite. The presence of the 2:1 clay (<2μ) can account for some of the increase in charge. The removal of the free-Fe did not affect the charge, suggesting that the free-Fe was not blocking charge sites, or that the negative charge developed on the surface of the iron particles, as suggested by

DESHPANDE *et al*, (2) was enough to balance the blocked charge sites. Removal of the X-amorphous materials led to a 20% increase of the CEC probably due to relative enrichment of the more active clay minerals as a result of the gibbsite removal.

4. CONCLUSIONS

The mineralogy of both water-dispersible and water-stable clays (<2μ) from this soil is composed of 41% kaolinite, 21-24% iron oxides, 20-21.5% X-amorphous, 13% gibbsite, 6% intergradational materials and 6.5% TiO_2.

Only slight chemical and mineralogical differences were found between the water-dispersible and water-stable clays (<2μ). The water-dispersible clay has higher specific surface area and is more subject to dissolution at 400°C than the water-stable clay. Also, the silica in the water-dispersible clay appears more soluble in the 400°C dissolution. This data is indicative of a smaller kaolinite particle size in the water-dispersible clay. Crystallinity, as determined from X-ray patterns, does not appear to be a factor.

The data suggest that most of free-iron is present as small discrete particles of hematite.

The dissolution described by HASHIMOTO and JACKSON (7) has good reproducibility and proved to be useful for removal of gibbsite without affecting the crystallinity of other minerals present in the samples.

It is concluded that no mineralogical differentiation is caused by water dispersion of *Eutrustox* soil material. It appears that the finest particles are preferentially dispersed by water. The natural occurrence of more frequent wetting and drying of the surface soil material is suggested as the mechanism responsible for the occurrence of more water-dispersible clay in the upper horizons than in the oxic horizon of these soils (14). It is unclear why the water-dispersible "fine clay" is not observed in the subsoil as argillans. Evidence of translocated clay has been noted on pieces of charcoal in the subsoil, indicating some translocation of clay (14) but lessivage is apparently minimal in these soils.

5. ABSTRACT

Water-dispersible and water-stable clays (<2μ) were separated from the 0-20 cm depth of a *Eutrustox*. Both clays (<2μ) were dominated by kaolinite 41%, iron oxides 21-24%, X-amorphous 20-21.5%, gibbsite 13%, TiO_2 6.5%, and intergradational materials 6%. No mineralogical preference is affected by water dispersion. The natural occurrence of more frequent wetting and drying of the surface soil material is suggested as the mechanism responsible for the occurrence of more water-dispersible clay in the upper horizons than in the oxic horizon of this soil.

6. RESUMO

Um Latosol Roxo *(Eustrustox)* foi selecionado e amostrado no Triângulo Mineiro.

A argila (<2μ) natural foi separada da argila estável n'água. Numa e noutra dominaram: caolinita, óxidos de ferro, materiais amorfos, gibsita, óxidos de titânio e material intergradacional. Não houve preferência mineralógica relacionada com a dispersibilidade n'água. Entretanto, a argila dispersa n'água apresentou maior superfície específica.

Os dados sugerem que o ferro livre estava presente sob a forma de pequenos cristais individuais de hematita.

A ocorrência natural de ciclos de seca e umidecimento, mais freqüentes à superfície, é sugerida como provável mecanismo responsável pelo maior teor de argila dispersa n'água nos horizontes superficiais.

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STUDIES OF A LATOSOL ROXO *(Eutrustox)* IN BRAZIL: PHOSPHATE REACTIONS*

W. Moura Filho
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E. J. Kamprath**

1. INTRODUCTION

Previous studies revealed that eight successive extractions with dilute acid (0.05 N HCl + 0.025 N H_2SO_4) in a leaching column removed about 100 ppm of P from *Eutrustox* soil material. Phosphorus removal was nearly constant at about 16 ppm per extraction and seemed independent of aggregate size (8).

The degree of chemical weathering which a soil has undergone may be estimated by measuring the distribution of the soil inorganic P in the following sequence: Ca-P, Al-P, Fe-P, and occluded-P (2, 14). This sequency may hold for dilute acid extracts as well, leading to the impression that the dilute acid-extractable P in soils comes primarily from the adsorbed P and the easily weathered Ca-P form.

It was postulated that basic cations may accumulate and be protected from leaching by occlusion within the fine, firm, granular peds of the *Eutrustox* (8). The activity of basic cations is one of the soil factors apparently related to the formation of discrete chemical forms of inorganic P (2). With this consideration it is then possible to hypothesize that any mechanism responsible for retention of Ca would also be responsible for a relative increase in Ca-P.

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The soil material used is composed of about 60% fine clay less than 0.2μ and consisting of 41% kaolinite, 21-24% iron oxides, 20-21.5% amorphous, 13% gibbsite, and 6% mica, and 6.5% titanium oxide (7). Most of the iron probably is present as minute but discrete particles of hematite. In general, amorphous compounds have high phosphate sorption capacity and low degree of availability, and crystalline materials have a reverse relation (13, 3).

This study was conducted in an attempt to (1) evaluate the effect of aggregate size and structure on the sorption and availability of added P, (2) evaluate the sorption of added P by various fractions of the clay present, and (3) study the fractionation of the inorganic P as related to aggregate size.

2. MATERIALS AND METHODS

An *Eutrustox* in Minas Gerais, Brazil (8) was sampled from 0-20 cm depth. Thin sections were prepared from oven-dried (110°C) samples, impregnated as described by BUOL and FADNESS (1) and mounted on polished carbon discs with epoxy resin. After polishing with 0.3μ alumina, they were carbon-shadowed and analyzed with an electron micro-probe X-ray analyzer*.

Aggregate fractions of 2-0.5 mm, 0.5-0.25 mm, and smaller than 0.25 mm, and the whole soil are thus reported both in their "natural" structural condition and after the structure was mechanically destroyed. Water-dispersible clays and water-stable clays were obtained (8).

Total P was determined after total dissolution (12). The organic P was extracted as described by OLSEN and DEAN (10). The inorganic P was fractionated by the modified CHANG and JACKSON procedure as outlined by PETTERSON and COREY (11). The P content in the extracts was determined according to the procedure described by MURPHY and RILEY (9).

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P sorption was measured on 2.5-g samples of each aggregate fraction in a 1:20 soil-P solution ratio. Portions of pH 6.0, 0.1 M KCl to give a final concentration of 200, 400, 600, 800, 1,000, 1,5000, and 2,000 µg P as KH_2PO_4 per gram of soil were transferred into 100 ml polypropylene centrifuge tubes and agitated at room temperature on a horizontal-action shaker for 24 hours, centrifuged, and the P content of the supernatant determined. Sorbed P was calculated as follows:

$$\text{Sorbed P} = \text{total added P} - \text{total P in the supernatant} \quad (1)$$

The volume of the entrapped solution was estimated by weight difference. Then, the tubes corresponding to 200, 400, 600, 800, and 1,000 µg P were incubated for 20 days at 100% relative humidity and at room temperature, then the P was extracted by dilute acid (0.05 N HCl + 0.025 N H_2SO_4) and determined. The availability of the sorbed P was estimated by the formula:

$$P_{av} = P - (P_E + P_C) \quad (2)$$

where: P_{av} = available sorbed P

P = P extracted

P_E = entrapped P (calculated from P content and amount of entrapped solution)

P_C = dilute acid-extractable P contained in the check.

The sorption of P by the clays was measured on 100-mg clay samples by the same method described for the soil samples, using 20 ml of a solution containing 10 ppm of P. The sorbed P was calculated using formula (1).

3. RESULTS AND DISCUSSION

Analyzing 1-cubic micron volumes in traverses of the thin section surface with the electron microprobe X-ray analyzer showed that P was associated with Fe and Ca. No P was observed to be associated with Al (Figure 1).

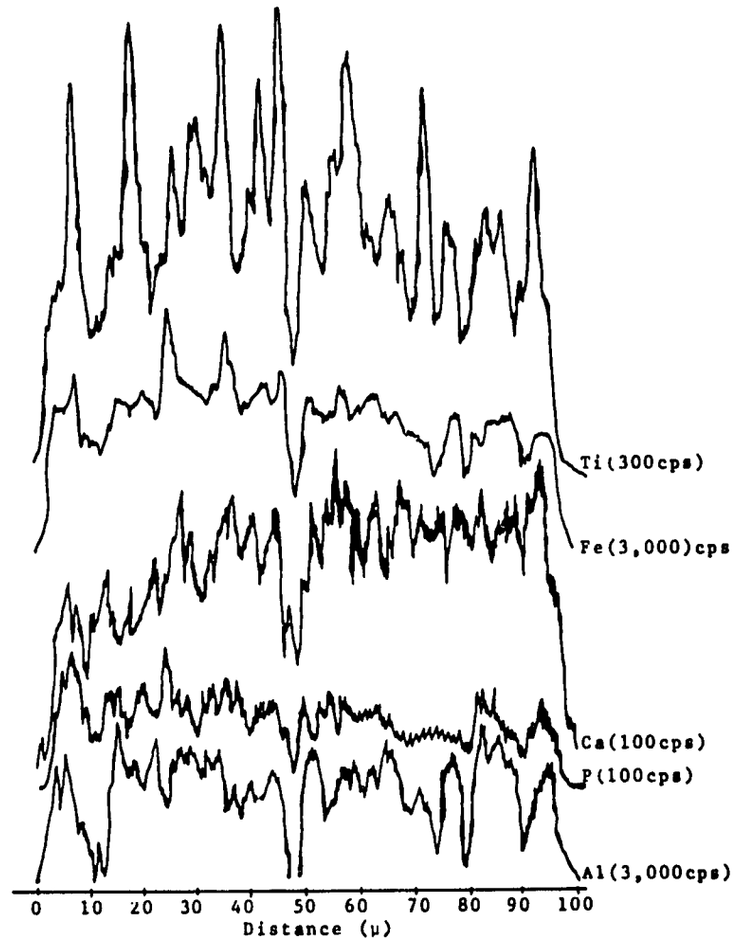

FIGURE 1 - Electron microprobe X-ray analyzer line scan of a traverse of a thin section surface through the center of a ped.

The P fractionation data are reported in Table 1. The total P content was 3,260 ppm in all aggregate fractions except the 0.5-0.25-mm fraction which contained 3,310 ppm. The organic P content was relatively low, comprising only about 2.5% of the total P content. There was only slight variation in the distribution of various P species among the various aggregate size fractions and the mechanical alteration of the structure, as expected, did not show any effect in this distribution. About 75% of the total P was determined to be reductant-P. No Al-P was detected. The Fe-P comprised about 9% of the inorganic P, Ca-P was less than 5%, occluded Fe-P higher than 5% and occluded Al-P was about 0.5%. It is believed that such a small percentage of occluded Al-P could easily be overlooked in the small sample represented in the electron probe X-ray analysis. A rather high amount, 6-8% of the P was reported as residual-P. Five extractions were required to remove all of the free-iron in this soil which contains 25% free iron (7). Since only one extraction was used in the extraction of reductant P, it is believed that the relatively high value for residual-P was due to the incomplete extraction of the reductant-P.

Approximately 60-90% of the P added as KH_2PO_4 was sorbed by the soil samples (Table 2). Percentage-wise, sorption was greater from diluted solutions, and remained about the same in concentrations greater than 400 μg/g. The high P sorption capacity of this soil is probably due to the high content of clay-sized materials of which 60% consisted of sesquioxides and X-amorphous materials. Apparently, the aggregate size did not affect the P sorption capacity of this soil. The crushed samples sorbed more P than their correspondent natural aggregates at concentrations above about 600 and 800 μg/g, but the natural aggregates sorbed more P than their crushed counterparts at lower concentrations.

The availability of the sorbed P, as measured by the dilute acid extraction, was consistently high for all samples (Tables 2 and 3), suggesting that the most probable P reaction in this soil material is adsorption on the surface of the clay-sized materials (5). The high availability of the sorbed phosphate suggests that the P was not bound very tightly by the soil materials. This may be due to a high degree of crystallinity of the sesquioxides in this soil. The availability of sorbed P varied from 60-95%, increased

TABLE 1 - Phosphorus fractionation data

Samples		Total P	Organic P	Al-P	Fe-P	Reductant P	Ca-P	Occluded Al-P	Occluded FeP	Residual P
		PPM of P								
Whole soil	Natural	3260	82	--	275	2364	150	25	185	179
	Crushed	3260	82	--	231	2362	150	24	185	226
2-0.5 mm	Natural	3260	82	--	231	2356	150	27	185	229
	Crushed	3260	82	--	231	2364	150	22	185	226
0.5-0.25 mm	Natural	3310	82	--	231	2361	166	29	185	256
	Crushed	3310	82	--	231	2360	166	30	185	256
< 0.25 mm	Natural	3260	82	--	249	2364	150	26	185	204
	Crushed	3260	82	--	279	2364	150	25	185	175

TABLE 2 - P sorption capacity and availability of added P related to aggregate size and structure

Samples			P added (µg/g soil)						
			200	400	600	800	1,000	1,500	2,000
			Sorbed and available added P						
			µg/g soil						
Whole soil	Natural	Sorbed	180	330	420	580	660	1,060	1,400
		Available	113	231	281	390	469	---	---
	Crushed	Sorbed	170	330	480	620	820	1,260	1,480
		Available	150	303	455	578	778	---	---
2-0.5 mm	Natural	Sorbed	170	370	480	540	600	1,180	1,400
		Available	150	235	262	354	530	---	---
	Crushed	Sorbed	170	330	480	580	660	1,220	1,480
		Available	161	298	453	534	581	---	---
0.5-0.25 mm	Natural	Sorbed	180	330	480	600	700	1,180	1,400
		Available	163	222	278	385	582	---	---
	Crushed	Sorbed	170	340	560	640	740	1,340	1,600
		Available	163	301	450	556	633	---	---
< 0.25 mm	Natural	Sorbed	170	340	420	540	700	1,180	1,400
		Available	165	327	389	477	575	---	---
	Crushed	Sorbed	170	370	560	640	740	1,260	1,560
		Available	163	352	534	610	699	---	---

TABLE 3 - Percent of added P sorbed and percent of sorbed P extracted by dilute acid, calculated from Table 2

Samples			P added (μg/g soil)						
			200	400	600	800	1,000	1,500	2,000
			% of added P sorbed and % sorbed P available						
Whole soil	Natural	Sorbed	90	82	70	72	66	70	70
		Available	63	70	67	67	71	--	--
	Crushed	Sorbed	85	82	80	77	82	84	74
		Available	88	92	95	93	95	--	--
2-0.5 mm	Natural	Sorbed	85	92	80	67	60	78	70
		Available	88	63	55	66	88	--	--
	Crushed	Sorbed	85	82	80	72	66	81	74
		Available	94	90	94	92	88	--	--
0.5-0.25 mm	Natural	Sorbed	90	82	80	75	70	78	70
		Available	90	67	58	87	83	--	--
	Crushed	Sorbed	85	85	70	67	70	89	80
		Available	96	88	80	87	85	--	--
< 0.25 mm	Natural	Sorbed	85	85	70	66	70	78	70
		Available	97	96	92	88	82	--	--
	Crushed	Sorbed	85	92	93	80	74	84	78
		Available	96	95	95	95	94	--	--

with decreasing aggregate size, and was greater for crushed samples than for their corresponding natural aggregates. These results substantiate the hypothesis that structure may play a considerable role in controlling P extractable by short-term soil extraction procedures.

Sorption of added P by the clays (<2μ) is presented in Table 4. The total clays, both water-dispersible and water-stable, had the same P sorption capacity (60% of the added P). Removal of the free-Fe showed a drastic decrease in the P sorption capacity. This reduction corresponded to a reduction in the surface area of the clays but was not proportional to the reduction in the reactivity. These data indicate clearly that free-Fe probably as finely divided hematite is the major clay component involved in the reaction with the added P. The reduction in reactivity after free-Fe removal was much greater for the water-stable than that for the water-dispersible clay. This difference can in part be explained by differences in suface area. Crystallinity does not appear to be a factor (8).

The boiling in NaOH (4) substantially increased both the surface area and the P sorption capacity of the clays, but again there was no proportionality between variations in surface area values and P sorption capacity. The Al:Al + Si ratio (Table 4) decreased with this treatment and may be one of the factors involved in decreasing P sorption as shown by CLOOS *et al* (3) in pure silico-alumina systems.

All these data indicate that the P sorption capacity of the clays was an adsorption reaction. But there was no direct surface area to adsorption proportionality ratio apparent, suggesting that some differences in surface reactivity exist among the clay components and clay samples.

TABLE 4 - Phosphate sorbed, surface area and Al:Al + Si ratio of clays

Samples	Water-dispersible clays			Water-stable clays		
	P sorbed[a]	Surface area	Al/Al+Si	P sorbed[a]	Surface area	Al/Al+Si
	µg/g	m^2/g	ratio	µg/g	m^2/g	ratio
Total clays	1,125	90.9	0.675	1,125	81.0	0.674
Fe-free clays	500	76.7	0.656	125	58.5	0.660
X-amorphous-free clays	1,000	117	0.543	625	93.5	0.546

[a]A rate of 2,000 µg P/g clay was added.

4. CONCLUSIONS

Aggregate structure and size are seen to be factors affecting the P sorption capacity and availability of sorbed P in the *Eutrustox* soil material studied. Smaller agrregates and crushed samples were found to have higher P sorption and higher availability of the sorbed P. Inorganic P species distribution did not change with aggregate size fractions.

Free-Fe oxides apper to be the major clay component responsible for P sorption by the clays. Some P was found to also be associated with Ca but no P was found to be associated with Al except in the occluded fraction.

The main reaction of this soil material with added P appears to be an adsorption reaction. It is suggested that there is a great potential for research on the availability of P using large initial applications of fertilizer P as reported by KAMPRATH (6) in Georgeville soils.

5. ABSTRACT

Aggregate fractions of whole soil and clay samples of a *Eutrustox* were submitted to P sorption release and fractionation studies. Three-fourths of the P was present in reductant soluble form. Smaller aggregates and crushed samples have higher P sorption and higher availability of sorbed P than larger sized aggregates. The removal of free-Fe drastically reduced the P sorption by the clays.

6. RESUMO

Um Latosol Roxo *(Eutrustox)* foi amostrado no Triângulo Mineiro, a uma profundidade de 0-20 cm.

Os agregados foram fracionados em três classes de diâmetro (2-0,5 mm, 0,5-0,25 mm, e menores que 0,25 mm). Parte de cada uma dessas frações teve sua estrutura destruída mecanicamente.

As análises no electron microprobe X-ray

analyzer mostraram fósforo associado ao ferro e ao cálcio, porém não foi observado fósforo associado ao alumínio.

Não houve diferenças em composição química entre as diversas classes de agregados.

Estudos de retenção e disponibilidade de P mostraram que os agregados menores e o material moído apresentaram maior poder de retenção de P e maior disponibilidade do P retido.

A remoção do ferro reduziu drasticamente a capacidade de retenção de P pela fração argila (<2μ), indicando que o ferro livre, provavelmente como cristais individuais de hematita, é o componente mais envolvido nas reações com o fósforo adicionado.

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