CHARACTERIZATION AND CLASSIFICATION OF TWO SOILS DERIVED FROM BASIC ROCKS IN PERNAMBUCO STATE COAST, NORTHEAST BRAZIL

Lindomário Barros de Oliveira[1*]; Maria da Graça de Vasconcelos Xavier Ferreira[2]; Flávio Adriano Marques[1]

[1]*UFRPE - Depto. de Agronomia, R. Dom Manuel de Medeiros s/n, Dois Irmãos - 52171-900 - Recife, PE - Brasil.*
[2]*UNICAP - Depto. de Engenharia, R. do Príncipe, 526, Boa Vista - 50050-900 - Recife, PE - Brasil.*
**Corresponding author <lbdeoliveira@yahoo.com.br>*

ABSTRACT: Geomorphic surfaces that present soils derived from basic rocks under warm and humid climate are unique scenarios for studying tropical soils. This paper aimed to characterize and classify two pedons derived from basalt at the Atlantic Forest Zone, Pernambuco State, Northeastern coast of Brazil. Two representative pedons (P1 and P2) were selected on a hillslope at the Cabo de Santo Agostinho municipality. Field macromorphological descriptions were carried out and soil horizon were sampled for physical, chemical, mineralogical and micromorphological characterization. The soils were classified, according to the Brazilian System of Soil Classification (and US Soil Taxonomy) as: "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox) (P1) and "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult) (P2). Pedon 1 differs from Pedon 2 in some aspects. For instance, P1 presents more yellowish colors, absence of clay illuviation, more friable consistence and the prismatic structure undergoes transformation to angular and subangular blocks. Pedon 2 presents ferri-argilans and leptocutans which indicate that vertical and lateral illuviation of clay is an active process in their formation. These chemically poor and mineralogically uniform soils are a result of the high temperature and rainfall of the studied area.
Key words: Red Nitisol, Red-Yellow Latosol, Cabo de Santo Agostinho, tropical soils

CARACTERIZAÇÃO E CLASSIFICAÇÃO DE DOIS SOLOS DESENVOLVIDOS DE ROCHA BÁSICA NA ZONA DA MATA ÚMIDA DE PERNAMBUCO, BRASIL

RESUMO: Superfícies geomórficas nas quais há ocorrência de solos derivados de rochas básicas sob condições de clima quente e úmido são cenários ímpares para estudos de solos tropicais. O presente trabalho objetivou caracterizar e classificar solos derivados de basalto na Zona da Mata Sul do Estado de Pernambuco. Dois pedons representativos foram selecionados no município do Cabo de Santo Agostinho. Após a descrição morfológica, foram coletadas amostras de seus horizontes para caracterização física, química, mineralógica e micromorfológica. Os solos foram classificados, de acordo com o Sistema Brasileiro de Classificação de Solos (e com o "Soil Taxonomy"), como: Latossolo Vermelho-Amarelo distroférrico argissólico ("Typic Hapludox") (P1) e Nitossolo Vermelho distroférrico típico (Rhodic Paleudult") (P2). O Latossolo difere do Nitossolo por apresentar cores mais amareladas (centradas no matiz 5YR), pela ausência de pedofeições que indiquem argiluviação, maior friabilidade e pela transformação da estrutura prismática em blocos angulares e sub angulares. Ferri-argilãs e leptorrevestimentos (leptocutãs) indicam que iluviação, vertical e lateral de argila, é um processo ativo na formação do Nitossolo estudado. Na encosta estudada as elevadas precipitações pluviais, associadas à temperaturas também elevadas durante todo o ano, conduzem à formação de solos quimicamente muito pobres e mineralogicamente uniformes.
Palavras-chave: Nitossolo Vermelho, Latossolo Vermelho-Amarelo, Cabo de Santo Agostinho, solos tropicais

INTRODUCTION

Climate conditions at the Atlantic Forest Zone of the Pernambuco State (Brazil) are warm and humid. In the geological viewpoint it is a sedimentary basin, named the Cabo Basin, filled out with lithic materials of different origins (igneous, metamorphic, and sedimentary rocks). These rocks appear in different forms and weathering stages, and form a thick mantle above the bedrock (Nóbrega, 1995). The various rock types outcropping in the area produced different soils when submitted to a specific bioclimatic condition and on several landscape positions. However, the soils formed are all acidic, dystrophic and dominantly aluminum saturated, and the clay fraction is essentially compound by kaolinite and Fe-Al oxides (Ferreira et al., 2000).

The occurrence of basic rocks such as basalt and andesite in warm and humid condition during the all year is not common in Brazilian territory. Thus, the region of the Southern Forest Zone of Pernambuco State is a unique site for studying the genesis and characterization of tropical soils developed on basic lithology. In this site, soils named (EMBRAPA, 1999) as Nitosol (Utisol), Latosol (Oxisols), and Cambisols (Inceptisols) are the more commonly formed soils (Jacomine et al., 1973).

The objective of this work is to characterize and classify two pedons derived from basalt at the Southern Forest Zone of Pernambuco State, Brazil, in an attempt to contribute to the understanding of tropical soil formation and the improvement of the Brazilian System of Soil Classification.

MATERIAL AND METHODS

Location and description of sample site

The Cabo Basin, a coastal sedimentary basin dated from the Cretaceous, runs along all Southern coastal area of Pernambuco State. Its surficial part is a narrow strip elongated in the North-South direction, measuring 100 by 12 km (Nóbrega, 1995). It is implanted over pre-cambrian terrain limited by the Sergipe-Alagoas Basin, through the Maragogi High in the south, and by the Pernambuco-Paraíba Basin, through the Pernambuco Linearly, on the north. In the west, it is limited by the Maciço Pernambuco-Alagoas (Figure 1).

A sedimentary sequence cut, covered by volcanic rocks, fills the Cabo Basin (Gomes, 2001). The volcanic rocks (Ipojuca Formation) are represented by traquites, andesite, rhyolite occurring as dike, plugs, sill and laccolites besides igneous breccia, tuff and basalt flows (Sial et al., 1987 apud Gomes, 2001). The more basic materials are basalts and andesite, which occur as aphanitic and holocrystalline mass with rare olivine fenocrystals (Borba, 1975).

The topography ranges from gently undulating to hilly; the slope ranges in 10 to 25% (Jacomine et al., 1973). The climate is tropical humid and classified as *Ams'* by Köppen and *3dTh* by Gaussen (Jacomine et al., 1973). The annual mean temperature is 24ºC (± 2.6ºC) and the mean annual rainfall is 2,140 mm. Although irregularly distributed, the rain is concentrated between March and July and the monthly mean is higher than 40 mm even in the drier months (October to December) (SUDENE, 1990). The original native vegetation was a semi-evergreen tropical forest, composed of a dense forest formation with tall trees and great species diversity (Andrade-Lima, 1960). This vegetal formation, however, has been replaced almost entirely by sugarcane plantations.

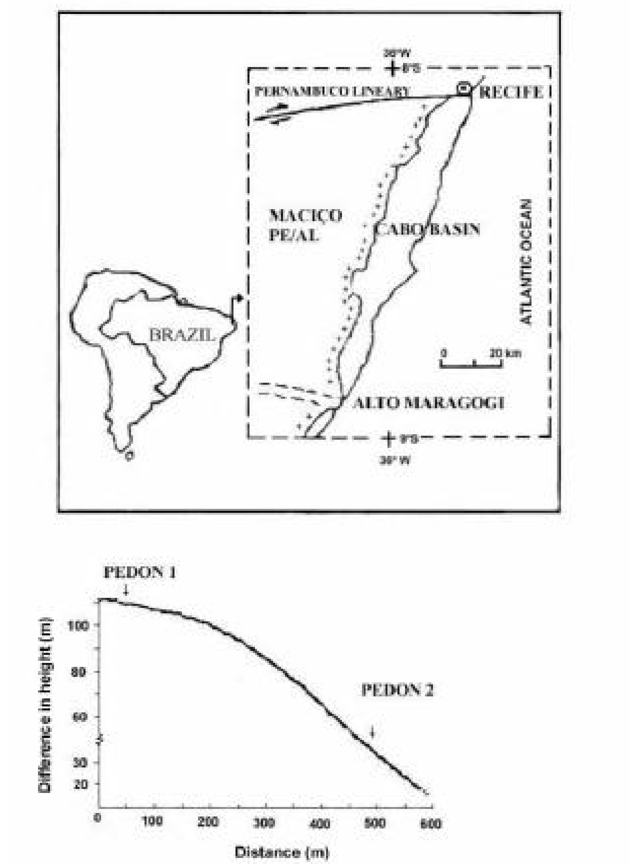

Figure 1 - Schematic location of the Cabo Basin (adapted from Nóbrega, 1995).

Methods

Two pedons were chosen: Pedon 1 on hill summit and Pedon 2 on hill backslope. They are located at Engenho Rosário in Cabo de Santo Agostinho municipality (08º18'S and 34º59'W). These pedons occur 420 m from each other, and the summit differs 60 m in height. Macromorphological profile description and soil sampling were carried out according to standard procedures (Lemos & Santos, 1996). Bulk soil samples of all horizons were collected from each pedon, air dried, ground to pass a 2 mm sieve, and used for physical, chemical, and mineralogical analyses.

Physical and chemical analyses were carried out according to EMBRAPA (1997). Particle-size analysis was performed by the hydrometer method after dispersion with 0.35 mol L^{-1} hexametaphosphate and 0.08 mol L^{-1} sodium carbonate, combined with strong mechanical shaking for 15 min. The determination of dispersed clay in water followed the same procedure but without adding chemical dispersant. Bulk density was determined by oven drying the core samples at 105ºC overnight. Particle density analysis was carried out by the pycnometer method. Moisture retention at 0.034 and 1.52 MPa was determined using a pressure plate extractor.

Soil pH was measured in water and 1 mol L^{-1} KCl using a soil:solution ratio of 1:2.5. Exchangeable Ca, Mg and acidity were displaced with 1 mol L^{-1} KCl. Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrophotometry, whereas exchangeable acidity was determined by titration with 0.25 mol L^{-1} NaOH and expressed as Al^{3+}. Exchangeable Na and K were displaced with Mehlich-1 solution and determined by flame photometry. Potential acidity was extracted using 0.5 mol L^{-1} pH 7.0 buffered calcium acetate, and determined by titration with 0.0606 mol L^{-1} NaOH. Available P was extracted using Mehlich-1 solution and determined by colorimetric method. Organic C was determined following the Walkley-Black method. Total clay contents of Al, Fe, and Ti in soil were estimated by dissolution with sulfuric acid and Si by NaOH on the residue. Determination was by atomic absorption spectrometry and data was expressed as Al_2O_3, SiO_2, Fe_2O_3, and TiO_2. Silt:clay ratio, total porosity, available water, sum of bases, cation exchange capacity, base saturation, aluminum saturation, exchangeable sodium percentage, Ki [SiO_2/Al_2O_3], and Kr [$SiO_2/(Al_2O_3 + Fe_2O_3)$] were calculated according to EMBRAPA (1997).

The coarse (2-0.2 mm) and fine (0.2-0.05 mm) sand fractions were examined by means of stereomicroscope. Mineral contents percentages were estimated by point counting, after successively quartering the soil samples. About 300 grains were counted for each fraction, considering: color, shine, form and rounding degree. For mineral identification of those fractions, chemical tests with 30% hydrogen peroxide, magnetic attraction with pocket magnet, and petrographic analysis of thin sections also were performed.

Silt and clay fractions were analyzed by X-ray diffractiometry. Those fractions were separated from sand by wet sieving, after removal of cementing agents. Clay and silt fractions were separated by sedimentation. Exchangeable cations, organic matter and free iron oxides were removed using 1 mol L^{-1} sodium acetate (pH 5.0), 30% H_2O_2, and citrate-bicarbonate-dithionite solutions, respectively (Jackson, 1975). Clay Samples were saturated with K^+ and irradiated at 25º and after heating for two hours at 550ºC. A second sample Mg^{2+} saturated and glycerol treated was also irradiated at 25ºC.

The diffractograms were obtained using a diffractometer operating at: 40Kv tension, 20 mA current with Cu radiation tube and Ni filter. The 2θ interval ranged from 2 to 40º for the clay, and from 2 to 60º for the silt samples Interpretation was performed as a function of the basal spacing and peak form and symmetry according to Grim (1968), Jackson (1975), Dixon & Weed (1989) and Moore & Reynolds Jr. (1989).

Vertically-oriented thin sections (5.0 × 8.0 cm large and 30 μm thick) were prepared for micromorphological examination (Jongerius and Heintzberger, 1975). The thin sections were examined by petrographic microscope according to criteria and terminology proposed by Bullock et al. (1985) or Brewer (1976).

RESULTS AND DISCUSSION

Soil classification and morphological characteristics

Soils were classified, according to the Portuguese criteria and terminology of the recent Brazilian Soil Classification System (EMBRAPA, 1999) and their U.S. Soil Taxonomy nearest equivalent (in brackets). Two classes were identified: Pedon 1 – "Latossolo Vermelho-Amarelo distroférrico argissólico textura muito argilosa A moderado fase floresta subperenifólia relevo suave ondulado" (Very-fine, Ferruginous, Isohyperthermic Typic Hapludox) and Pedon 2 – "Nitossolo Vermelho distroférrico típico textura muita argilosa A moderado fase floresta subperenifólia relevo ondulado" (Very-fine, Kaolinitic, Isohyperthermic Rhodic Paleudult).

Pedon 1 presents predominant colors in the 5YR hue, with value between 3 and 4, and chrome between 4 and 6. The Ap horizon structure is strong, fine to medium, and granular. The B horizon structure is weak, medium, prismatic formed by moderate, fine, angular and subangular blocky. Very few and faint clay skins were observed during field examination, but (ferri-)argilans were not found in the thin sections of the soil's horizons (Tables 1 and 6).

The Pedon 2 had colors in the 2.5YR hue, with values from 2.5 to 3, and chrome between 2 and 4. The Ap horizon structure is strong, fine, and subangular blocky. The structure is moderate, coarse, prismatic formed by moderate, very fine and fine, and subangular blocky in the BA, Bt1 and Bt2 horizons. The Bt3 horizon structure is strong, coarse, and prismatic parting to strong, small, subangular and angular blocky. The clay skins in the BA horizon were faint and common. Clay skins were distinct and common in Bt1, Bt2, Bt3 and BC horizons (Table 1).

The very strong pedogenesis in the Pedon 1 promoted soil xanthization, the transformation of prismatic structure to angular and subangular blocky, and turned the soil more friable (Table 1). Although prismatic structure is not common in the Latosols, it has been observed in the "Latossolos Brunos" (Brown Latosols) also derived from basic rocks in Rio Grande do Sul, subtropical Brazil (Oliveira et al., 1992). Other soil characteristics typically observed in the latosolic B horizon, including lack of expressive clay skins and high friability (Bennema, 1966), were present in this Latosol pedon.

As the "Latossolo" profile showed intermediate characteristics to "Nitossolo", it was necessary to use a terminology of the soil classification system that suggested this philogenetic relationship. The term 'nitisolic', which expresses the intermediate nature between Latosol and Nitisol pedons, should be used in the 4º categori-

Table 1 - Morphology of two soil profiles developed from basic rock of Pernambuco State.

Horizon	Depth	Color	Texture	Structure	Clay skins	Consistence†	Boundary
	cm	moist					
Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)							
Ap	0-15	Dark reddish brown (5YR 3/4)	Clayey	Strong fine to medium granular		Slightly hard; firm; very plastic and sticky	Clear and smooth
AB	15-40	reddish brown (5YR 4/4)	Clayey	Weak medium prismatic parting to moderate fine angular e subangular blocky		Slightly hard; friable; plastic and sticky	Gradual and smooth
BA	40-60	reddish brown (2.5YR 4/5)	Clayey	Weak medium prismatic parting to moderate fine angular e subangular blocky	very few and faint	Hard; friable; plastic and sticky	Diffuse and smooth
Bo1	60-130	yellowish red (5YR 4/6)	Clayey	Weak medium prismatic parting to moderate fine angular e subangular blocky	very few and faint	Hard; friable; plastic and sticky	Diffuse and smooth
Bo2	130-190+	yellowish red (5YR 4/6)	Clayey	Weak medium prismatic parting to moderate fine angular e subangular blocky	very few and faint	Slightly hard; friable; plastic and sticky	
Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)							
Ap	0-14	very dusky red (2.5YR 5/3)	clayey	Strong fine subangular blocky		Very hard; very firm; plastic and sticky	Clear and smooth
BA	14-30	dark reddish brown (2.5YR 3/4)	clayey	Moderate coarse prismatic parting to moderate very fine to fine subangular blocky	common and faint	Very hard; firm; plastic and sticky	Gradual and smooth
Bt1	30-56	dark reddish brown (2.5YR 3/4)	clayey	Moderate coarse prismatic parting to moderate very fine to fine subangular blocky	common and distinct	Hard; firm; plastic and sticky	Diffuse and smooth
Bt2	56-105	dark reddish brown (2.5YR 3/4)	clayey	Moderate coarse prismatic parting to moderate very fine to fine subangular blocky	common and distinct	Hard; firm; plastic and sticky	Diffuse and smooth
Bt3	105-160	dark reddish brown (2.5YR 3/5)	clayey	Strong coarse prismatic parting to strong fine subangular and angular blocky	common and distinct	Hard; firm; plastic and sticky	Gradual and wavy (41-61cm)‡
BC	160-200+	dusky red (2.5YR 3/2)	clayey	Moderate fine subangular and angular blocky	common and distinct	Firm; slightly plastic and sticky	

†dry, humid and wet, respectively. ‡Up and down limits.

cal level to express this transitional behavior, as used for Chernosol and some Latosol Classes (Dystrophic Red Latosol and Distroferic Red Latosol) in the Brazilian System of Soil Classification. The 'argisolic' term means soils with intermediate characteristics to "Argissolos", and the distinctive characteristic for this soil class is an expressive clay accumulation in the B horizon, i.e., presence of a textural B horizon.

Table 2 - Particle size distribution analysis, water-dispersed clay, flocculation index and silt:clay ratio of soils developed of basic rocks of Pernambuco State.

Horizon	Depth	Gravel	Fine Earth	Coarse sand	Fine sand	Silt	Clay	WDC*	Flocculation index	Silt/clay ratio
	cm	---------------------------- g kg-1 de solo						----------------------------	%	
Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)										
Ap	0-15	0	1000	30	37	167	766	46	94	0.22
AB	15-40	0	1000	20	26	128	826	66	92	0.15
BA	40-60	0	1000	19	27	108	846	56	93	0.13
Bo1	60-130	0	1000	20	25	109	846	46	94	0.13
Bo2	130-190	0	1000	23	26	105	846	66	92	0.12
Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)										
Ap	0-14	4	996	67	53	213	667	539	19	0.32
BA	14-30	3	997	43	34	123	800	79	90	0.15
Bt1	30-56	2	998	33	37	100	830	79	90	0.12
Bt2	56-105	0	1000	20	70	153	757	79	89	0.20
Bt3	105-160	0	1000	12	62	236	690	79	88	0.34
BC	160-200	0	1000	08	82	320	590	79	86	0.54

*Water- dispersed clay

Table 3 - Bulk and particle densities, porosity, and water content of soils developed from basic rocks of Pernambuco State.

Horizon	Depth	Density		Porosity	Water content		
		Bulk	Particle		U[1] -0.034MPa	U[1] -1.52MPa	Avail. water[2]
	cm	Mg m-3		%	----------------------	%	----------------------
Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)							
Ap	0-15	1.08	2.90	62	36.9	27.3	9.6
AB	15-40	0.97	2.90	67	40.6	30.8	9.8
BA	40-60	0.95	2.90	69	40.1	30.6	9.5
Bo1	60-130	0.97	3.00	68	42.9	29.8	13.1
Bo2	130-160	0.98	3.00	67	42.9	30.3	12.6
Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic paleudult)							
Ap	0-14	1.46	2.86	49	38.0	26.6	11.4
BA	14-30	1.34	2.90	54	41.6	30.6	11.1
Bt1	30-56	1.29	2.86	55	46.3	33.4	12.9
Bt2	56-105	1.38	2.86	52	45.3	31.9	13.5
Bt3	105-160	1.47	2.98	51	45.7	30.1	15.6
BC	160-200	1.44	2.98	52	44.6	28.5	16.1

1. U = moisture (w/w); 2. Avail. = available

Physical characteristics

The two pedons did not present expressive amount of coarse fractions (larger that 2 mm). Total sand content was very small as well. The values ranged from 70 to 120 g kg^{-1} in the Pedon 2, and 45 to 67 g kg^{-1} in the Pedon 1 (Table 2). This trend results form the low content of resistant primary minerals and the aphanitic texture of the parent material (Buol et al., 1980).

The silt content ranged from 105 to 167 g kg^{-1} in the Pedon 1, and 100 to 320 g kg^{-1} in the Pedon 2. The clay content ranged from 766 to g kg^{-1} in the Pedon 1, and from 846 590 to 830 g kg^{-1} in the Pedon 2. Clay contents larger than 500 g kg^{-1} are common in soils developed from basaltic rocks (Lima, 1979; Rauen, 1980; Rocha, 1990). It was observed clay accumulation in the nitic B horizon, but not enough to characterize textural gradient according to the criteria used by the Brazilian Taxonomy (EMBRAPA, 1999). More clay accumulation in the Pedon 2 B horizon than in the Pedon 1 is compatible with the soil profiles identification and selection during field work (Bennema, 1966). Higher silt content in the Ap horizon of Pedon 2 was probably due to preferential removal of clay in this soil horizon. Low values of silt:clay ratio and high contents of clay in the “Latossolo” indicated that it is in a more advanced weathering stage than the “Nitossolo”.

Table 4 - Chemical characteristics of soils developed from basic rocks de Pernambuco State.

Horizon	pH		Ca^{2+}	Mg^{2+}	K^+	Na^+	Base sum	Al^{3+}	H^+	CEC	Base Sat.	Al sat	ESP	C	P
	H_2O	KCl	---------------------- $cmol_c$ kg^{-1} of soil							----------------------	---------- %	----------		$g\ kg^{-1}$	$mg\ kg^{-1}$
Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)															
Ap	4.9	4.2	5.5	3.0	0.12	0.10	8.7	0.7	10.2	19.6	44	7	<1	2.43	1
AB	4.9	4.2	0.3	1.2	0.03	0.05	1.6	1.0	7.3	9.9	16	38	<1	1.14	1
BA	4.8	4.2	0.2	1.0	0.03	0.06	1.3	0.9	7.3	9.5	14	41	<1	1.01	4
Bo1	4.8	4.4	0.1	0.9	0.02	0.04	1.1	0.8	7.2	9.0	12	42	<1	0.65	4
Bo2	4.8	4.3	0.1	0.8	0.01	0.03	0.9	0.8	7.1	8.8	10	47	<1	0.61	5
Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)															
Ap	4.9	4.2	1.0	0.5	0.16	0.15	1.8	0.6	7.1	9.5	19	25	2	2.62	1
BA	4.7	4.0	0.5	0.4	0.06	0.07	1.0	1.5	5.0	7.5	13	60	1	1.41	1
Bt1	4.7	4.0	0.4	0.3	0.04	0.08	0.8	1.6	4.7	7.1	11	67	1	0.95	1
Bt2	4.6	3.9	0.4	0.2	0.03	0.07	0.7	1.9	3.2	5.8	12	73	1	0.49	1
Bt3	4.6	3.9	0.4	0.4	0.03	0.08	0.9	3.6	2.6	7.1	13	80	1	0.27	1
BC	4.5	3.8	0.2	0.4	0.03	0.08	0.7	5.3	2.0	8.0	9	88	1	0.23	1

Table 5 - Elemental composition as access by dissolution by sulfuric acid of soils developed from basic rocks from Pernambuco State.

Horz.	Depth	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Sum	Ki	Kr
	cm	-------------		$g\ kg^{-1}$		-------------		
Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)								
Ap	0-15	186	163	234	64	647	1.94	1.01
BA	40-60	192	178	237	59	666	1.83	0.99
Bo2	130-160	205	188	233	57	683	1.85	1.03
Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)								
Ap	0-14	147	162	203	69	581	1.54	0.86
Bt2	56-105	204	209	198	42	653	1.66	1.03
BC	160-200	201	204	218	51	174	1.67	0.99

The water-dispersed clay content was very low for both pedons, except in the Ap horizon of the pedon 2 (539 g kg^{-1}). As a result, the flocculation index was very high, in general higher than 85%. One can speculate that the high proportion of water-dispersed clay in the Ap horizon of the Pedon 2 results from decreased participation of di and trivalent cations (Ca^{2+}, Mg^{2+} and Al^{3+}) in the exchange complex.

The bulk density ranged from 1.29 to 1.47 Mg m^{-3} for the "Nitossolo", and 0.95 to 1.08 Mg m^{-3} for the "Latossolo". These values are within the range for clayey soils, as mentioned by Prevedello (1996). The lowest values of bulk density for the "Latossolo" are probably due to its expressive microporosity, which results from the large clay content and smaller structure, as pointed out by the micromorphological descriptions (Table 2 and Figure 5IV). The particle density of both soils presented high values (2.86-3.00 Mg m^{-3}), due to high amounts of iron bearing minerals, as shown by the sand and silt fractions mineralogical analyses.

The water content at various tensions is high. Even in the permanent wilting point (moisture at -1.52 MPa), these soils exhibited values above 26% (Table 3).

Chemical characteristics

The soil reaction was acidic, with pH in H_2O ranging from 4.5 to 4.9, and pH in KCl from 3.8 to 4.4. The pH in KCl was consistently lower than the pH in H_2O, an indication of negative net charges (Table 4). Organic carbon and exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) were higher in the surficial horizon, decreasing with depth. Amount of basic cations were considered low ranging from 0.7 and 2.0 $cmol_c$ kg^{-1}. However, the Ap horizon of the Pedon 1 had values as high as 8.7 $cmol_c$ kg^{-1} of soil, as a result of liming and fertilizes additions. Exchangeable aluminum was higher values in the Pedon 2 than Pedon 1, especially in subsurface (5.3 $cmol_c$ kg^{-1}), resulting in a high Al saturation (ranged from 25 to 88%). The exchangeable aluminum content in the Pedon 1 ($\leq$ 1.0 $cmol_c$ kg^{-1} of soil) was lower than in the Pedon 2, and Al saturation ranged from 7 to 47%. CEC was low and usually < 10.0 $cmol_c$ kg^{-1}. Clay activity was low in both soils and ranged from 7.7 to 25.6 $cmol_c$ kg^{-1}, which results from the kaolinitic and oxidic composition.

Large differences were observed between these two studied soils and the basic rock-derived soils from Southern of Brazil, which usually have higher CEC and are dominantly eutrophic (Lemos, 1975). Similar soils in São Paulo State, but dystrophic, are not rich in Al, and its Al saturation is lower than 18% (Oliveira & Menk, 1984).

The ferric term in the Brazilian soil classification means high content of Fe_2O_3 (198 – 237 g kg^{-1}). In the Pedon 2 Ki values, from 1.54 to 1.67, suggested the pres-

Table 6 - Syntheses of micromorphological description of soils derived from basic rocks from Pernambuco State, Brazil.

Horizon	RDP[†]	b-fabric[‡]	Microstructure	Voids	Pedofeature
Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)					
Ap	Porphyric	Undifferentiated	Subangular and angular blocky peds	Compound packing voids, planes, vughs and root channels	
BA	Porphyric	Stipple-speckled	Subangular and angular blocky peds and some parts prims	Compound packing voids, planes and vughs	
Bo2	Porphyric	Stipple-speckled	Subangular and angular blocky peds and some parts prims	Compound packing voids, planes and vughs	
Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)					
Ap	Porphyric	Undifferentiated	Subangular and angular blocky peds	Vughs, compound packing voids and root channels	Ferri-argilans coat peds surface; hematans
Bt2	Porphyric	Stipple-speckled	Prims and subangular blocky peds	Planes, vughs and channels	Leptocutans
BC	Porphyric	Stipple-speckled	Prims and subangular blocky peds	Planes, vughs and channels	Ferri-arglans, argilans and papules

[†]Related Distribution Pattern; [‡]birefringence fabric.

ence of gibbsite, as indicated by Verdade (1975). However, such trend was not confirmed by the soil mineralogical results. On the other hand, Ki values for Pedon 1, from 1.83 to 1.94, indicated the presence of minerals of the kaolinite group (Table 5).

The lowest values of Ki for Pedon 2 suggested that it is more weathered than the Pedon 1, although other evidences (silt:clay ratio, clay content, and landscape position) indicated a contrary trend. The treatment with sulfuric acid may not be effective in the whole clay fraction, since it will also attack particles of other fractions if the analysis is carried out using samples of fine earth Verdade (1975). This can generate misunderstandings in the interpretation of the results. The sum of the oxides, obtained of dissolution by sulfuric acid method, should be approximately equal to the clay content Resende (1983). For the studied soils, the sum of the oxides is always smaller than the clay content, except for the BC horizon, which may indicate that the dissolution was not effective in breaking up the whole clay fraction.

Mineralogy and micromorphology

Mineral on coarse and fine sand fractions were mostly quartz, opaques (rock fragments composed of magnetite and/or ilmenite), and hematite. These components were present in varying proportions in both pedons. Quartz grains amounts decrease with depth and pedon 1 has higher amounts of hematite than pedon 2 (Figure 2).

The quartz grains are colorless and coated with iron oxides films. They are sub-angular to subrounded in shape. The hematite grains are subrounded and rounded, with intense red color. The opaque minerals are subrounded, black, and are probably composed of magnetite and/or ilmenite. Ilmenite identification in thin sections is based at tendency to form grain clusters (FitzPatrick, 1984). Such behavior was not evident in thin sections analyses. However, the presence of ilmenite was observed in the silt fraction X-ray diffracograms. It is thus possible that ilmenite also occurs in the sand fraction of these soils.

The opaque minerals were most probably inherited from the parent material and their large content in the pedon 2 suggests that this soil is in an early weathering stage as compared to the pedon 1. This is also supported by the color gradation between opaque minerals and hematite, which seemingly starts with a loss of the metallic shine. In addition they present larger degree of roundness in the Pedon 1. It is thus believed that most of the hematite, whose larger percentage is found in pedon 2, has been produced by magnetite alteration, as suggested by Schwertmann & Taylor (1989). The hematite grains were also altered, exhibiting yellowish-colored rings, which suggests goethite neoformation. The yellow bodies alteration, identified as hematite pseudomorph in thin sections, reinforces this finding (Figure 6I and 6II). The X-ray diffractograms of the silt fraction, for both soils, presented peaks that allow the identification of quartz (0.334 and 0.197 nm), hematite (0.251 and 0.169 nm), ilmenite (0.274 and 0.172 nm), and no philosilicate (Figure 3).

The peaks of 0.720 and 0.357 nm in the diffractograms of the clay samples saturated with K (25ºC) and Mg-glicerol, and its disappearence when the clay samples were saturated with K and heated at 550ºC, allowed the identification of kaolinite as the dominant philosilicate in the clay fraction (Figure 4). This kaolinite is well crystallized, as observed by the basal symmetry and peak intensity. Despite the removal of free iron, the clay fraction diffractograms of the Pedon 1 showed a small goethite peak of 0.418 nm (Figure 4). The citrate-bicarbonate-dithionite method is not very efficient in the removal of goethite with high isomorphic substitution by aluminum (Jeanroy et at., 1991; Möller & Lourenço, 1994).

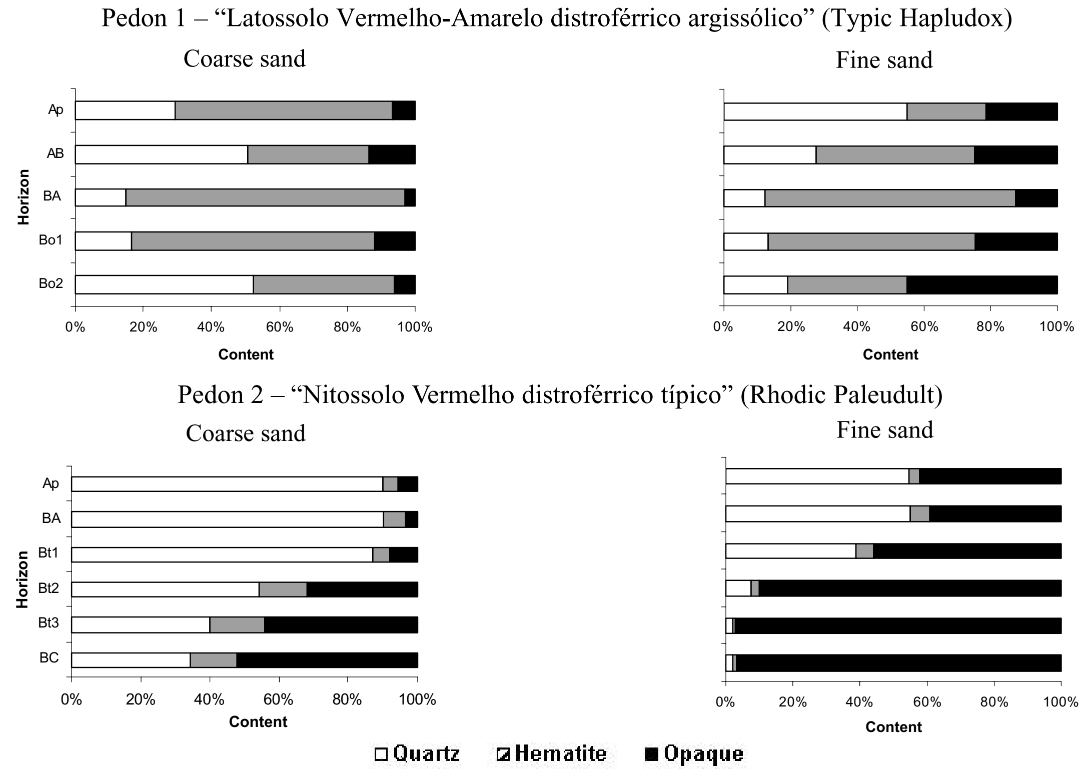

Figure 2 - Mineralogical composition of coarse and fine sand of the two pedons derived form basic rocks from Pernambuco State, Brazil.

Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)

Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)

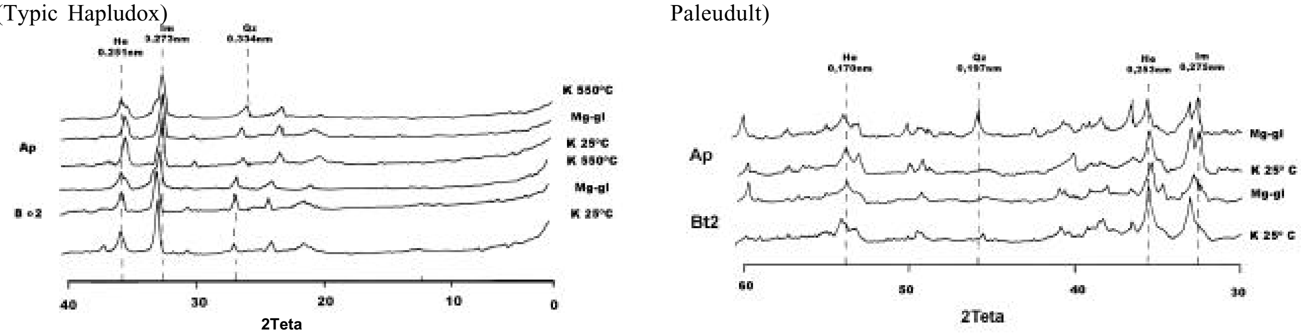

Figure 3 - X-ray diffractograms of the silt fraction of selected horizons of two pedons derived from basic rocks from Pernambuco State, Brazil. Hematite (He), quartz (Qz) e ilmenite (Im). K 25ºC, Mg-gl and K 550ºC are the treatments: saturation with K, with Mg-glycerol and with K and heating to 550ºC, respectively.

Pedon 1 - "Latossolo Vermelho-Amarelo distroférrico argissólico" (Typic Hapludox)

Pedon 2 - "Nitossolo Vermelho distroférrico típico" (Rhodic Paleudult)

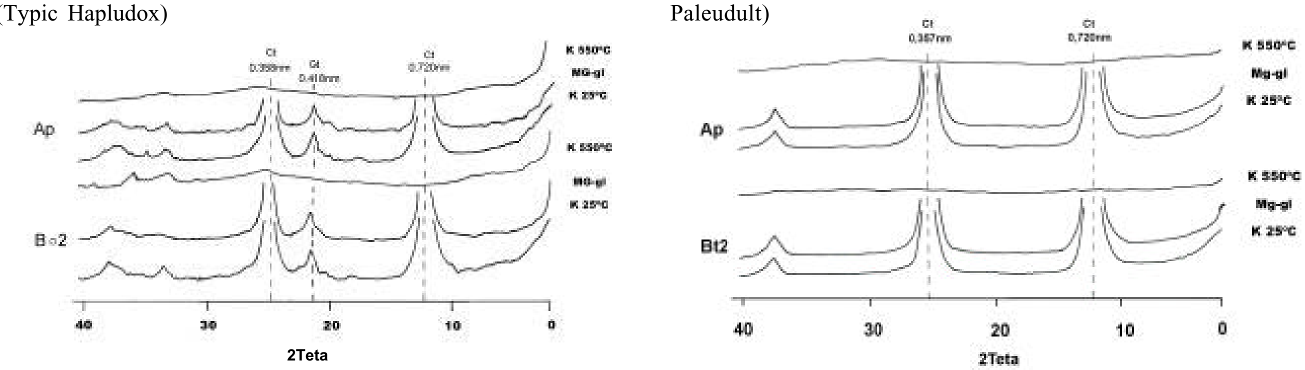

Figure 4 - X-ray diffractograms of clay fraction of selected horizons of two pedons derived from basic rocks from Pernambuco State, Northeast, Brazil. Kaolinite (Ct) and goethite (Gt). K 25ºC, Mg-gl and K 550ºC represent the treatments: saturation with K, with Mg-glycerol and with K and heating to 550ºC, respectively.

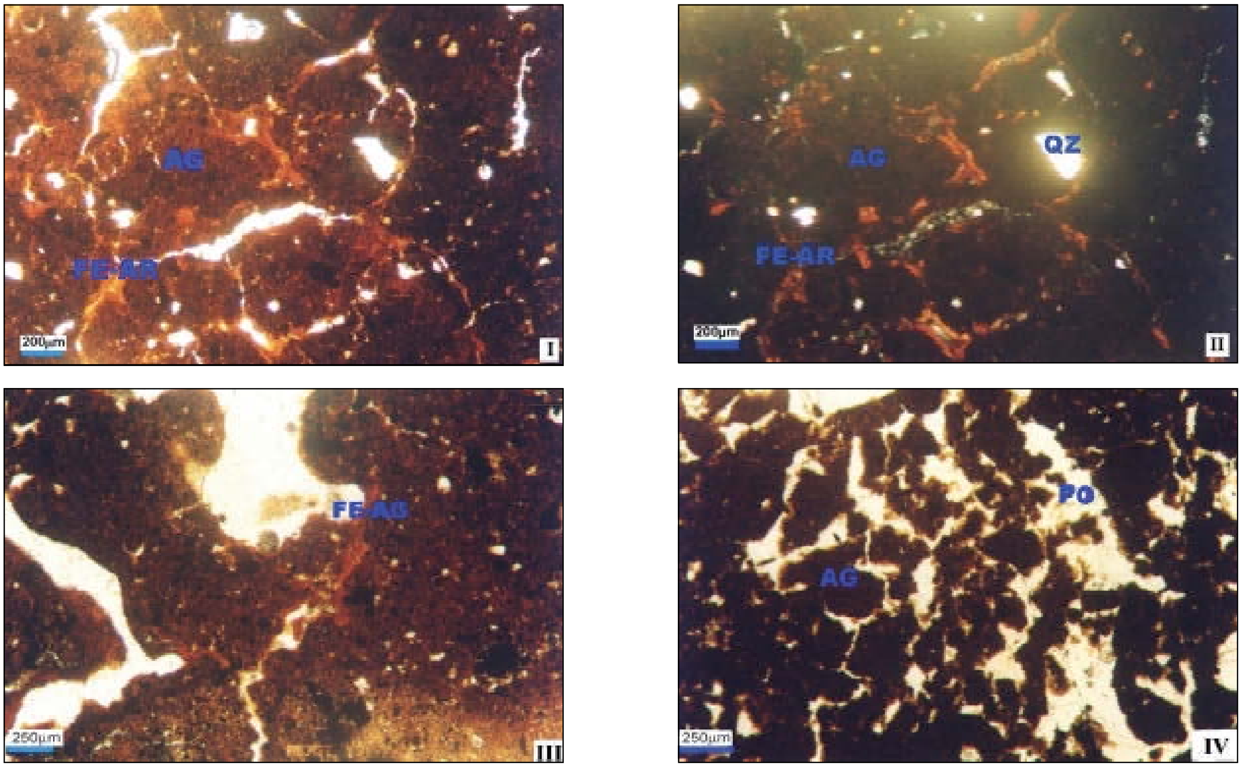

Figure 5 - Photomicrographs of the thin sectons of selected soil horizon. I – many ferri-argilans in Ap horizon of the Pedon 2 (Rhodic Paleudult),em PPL. II – equal, XPL. III - Ferri-argilan and part of prismatic structure of the Pedon 2 Bt2 horizon. IV – Blocky structure of the Pedon 1 Bo_2 horizon. FE-AR, AG, PO e QZ mean ferri-argilans, aggregates, voids and quartz, respectively.

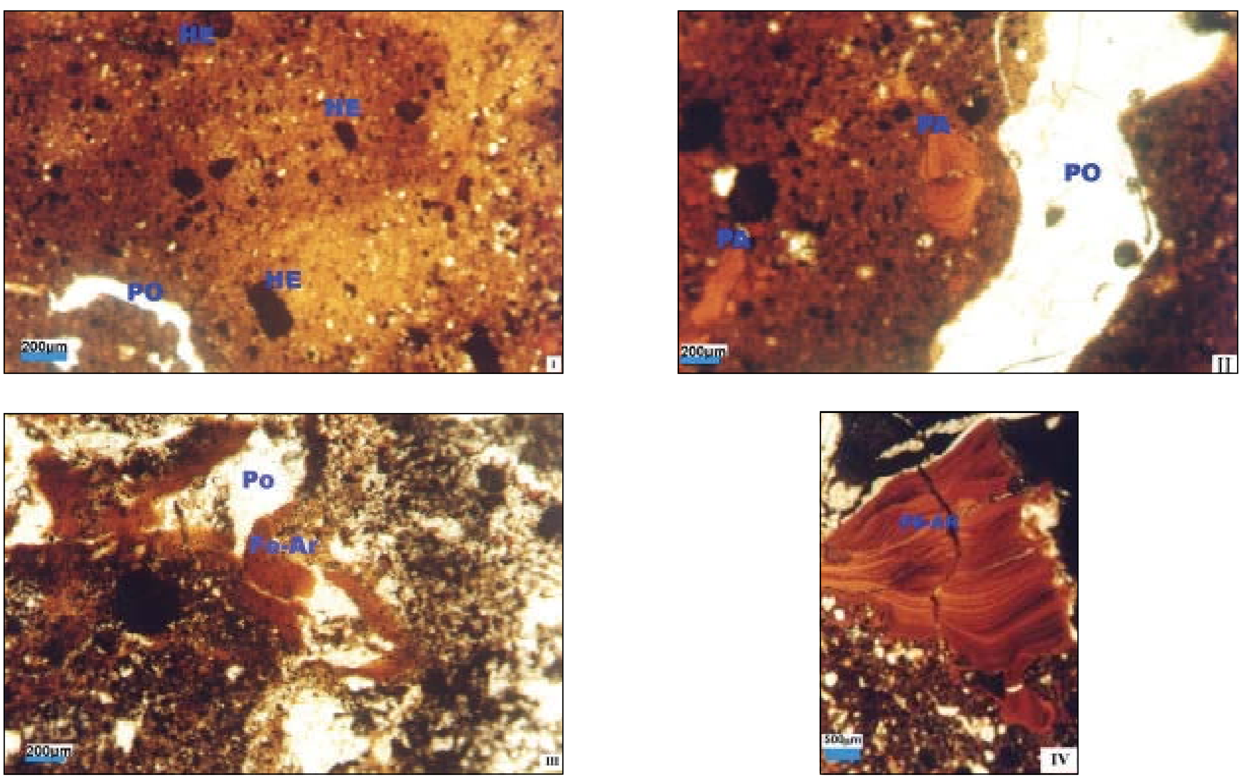

Figure 6 - Photomicrographs of thin sections of selected horizons of soils. I – Hematite grains of sand fraction of the Bt2 horizon of the Pedon 2 (Rhodic Paleudult), PPL. II - Papules formed by hematite pseudomorphic, the same horizon, PPL. III e IV – Thick ferri-argilans in BC 'horizon of the Pedon 2, PPL. HE, FE-AR, PA e PO mean, respective, hematita grains, ferri-argilans, papules e voids.

The mineralogical composition of these soils differs from the soils developed from similar parental material in the South and Southeast of Brazil. The soils from Southern Brazil present mixed-layered chlorite-vermiculite-montmorillonite, gibbsite, and kaolinite (Lemos, 1975). Hydroxy-interlayered vermiculite has also been found in soils from this Brazilian region (Gomes et al., 2001).

The related distribution pattern of soils was porphyric, i.e., the coarser particles occur in a groundmass of finer material (Bullock et al., 1985). The Ap horizon of Pedon 2 appears granular and subangular blocky microstructure. In the Bt2 and BC horizons, the microstructure is predominantly prismatic and seldom subangular blocky (Table 6). The surface horizon of the Pedon 1 showed same microstructure as the surface horizon of Pedon 2; however it was angular and subangular blocky, with few areas, where it was prismatic composed of subangular blocky in BA and Bo2 horizons.

The "Latossolo" microstructure probably resulted from the destruction of prismatic structure, which tends to form smaller aggregates. This new structural framework led to higher porosity, although it has not been quantified micromorphologically. This is also corroborated by the total porosity values of the "Latossolo", which are about 10% higher than in "Nitossolo" (Table 3).

On the other hand, the absence of microgranular structure, which is common in Latosols derived from basic rocks of the South and Southeast Region of Brazil (Rauen, 1980; Oliveira & Menk, 1984; Rocha, 1990), may be due to the gibbsite absence, as Schaefer (2001) has reported. Although gibbsite is not responsible directly for the development of the micrograular structure, it leads to the persistence of such structure. Schaefer (2001) advocated that the different kinds of micrograular structure, present in Brazilian Latosols, were a long-term biotic product, and soil termites are among the major organisms involved in their genesis. The stability and preservation of the microaggregates, formed as a result of the mesofauna activity, are primarily favored by gibbsite, and secondarily by iron oxides.

Coatings (ferri-argilans in the Brewer's terminology) are common in the Ap horizon of Pedon 2 and suggest high clay mobility, which should be related to the low degree of clay flocculation, as shown by the physical analyses. In the Bt horizon, the ferri-argilans, that are coating ped surfaces, are usually very thin and may be named leptocoatings (leptocutans), as suggested by Creutzberg & Sombroek (1987). However, better preserved ferri-argilans were observed as well (Figure 5).

The iron oxides from the cutans masks their anisotropy and, due also to their finesses, made their identification more difficult. Perhaps, due to this reason, Eswaran (1978) did not mention such pedofeature when analyzed thin sections of similar soil to the pedon 2.

The thicker ferri-argilans and argilans of the studied soils, which occured as infillings, were observed in the BC horizon of the Pedon 2 (Figure 6). Great papules were present in this horizon as well. According to Buol & Hole (1961), the decrease of pedoturbation with depth allows features of such nature to be relatively undisturbed.

It was not observed features that indicated clay movement in the Pedon 1, and, thus, argilluviation was not either an expressive process in its formation or its subsequent processes masked its effects. That is, the haplodization destroyed the possible features generated by horizonation.

FINAL REMARKS

The soils developed from basalt, in warm and humid climate in the Southern Forest Zone of the Pernambuco State, are chemically very poor, and kaolinite and oxides are the dominant minerals in the clay fraction. It is suggest the inclusion, in the Brazilian System of Soil Classification, of a *nitisolic* subgroup in the class of Dystrophic Red-Yellow Latosol, to include the soils of this class that present intermediate characteristics with Nitisols

ACKNOWLEDGMENTS

To Paulo Kinger Tito Jacomine and Mateus Rosas Ribeiro (UFRPE) for help in soil description, and to Carmem Sueze Miranda Masutti (UFPE) for translation of the original Portuguese version.

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Received November 29, 2002
Accepted September 16, 2004