Geochemical processes in Latosols on the geomorphic surfaces from Brazilian Central Plateau

Adriana Reatto[A], Ary Bruand[B], Luiz Roberto Guimarães Guilherme[C], Eder de Souza Martins[A], Euzebio Medrado[D], Michel Brossard[E] and Fabrice Muller[B]

[A]Empresa Brasileira de Pesquisa Agropecuária (Embrapa Cerrados), BR 020, km 18, 73310-970, Planaltina, Distrito Federal, Brazil, Email reatto@cpac.embrapa.br, eder@cpac.embrapa.br
[B]Institut des Sciences de la Terre d'Orléans (ISTO) UMR6113 CNRS/Université d'Orléans 1A, rue de la Férollerie 45071 Orléans, France Cedex 2, Email Ary.Bruand@univ-orleans.fr, Fabrice.Muller@univ-orleans.fr
[C] Universidade Federal de Lavras, Departamento de Ciência do Solo, Setor de Mineralogia e Química do Solo. Campus Universitário UFLA 37200-000 - Lavras, MG - Brasil - CP: 3037, Email guilherm@ufla.br
[D] Consultor Técnico, Brasília-Brasil, Email euzebio.medrado@gmail.com
[E] Institut de Recherche pour le Développement (IRD), Unité Valpédo, BP 64501, 34394 Montpellier Cedex 5, France, Email Michel.Brossard@ird.fr

Abstract

Latosols are deeply weathered soils characteristic of the most Tropics. These soils represent 1/3 of the Brazilian National Territory and occupy about 40% of the Brazilian Central Plateau. The objective of this study was to discuss the distribution of the Latosols on the geomorphic surfaces from Brazilian Central Plateau based on geochemical process. Ten Latosols (L) developed in different parent materials were selected along an approximately 350km long regional toposequence across the South American Surface (L1 to L4) and Velhas Surface (L5 to L10) from Brazilian Central Plateau. The main conclusion is that there is a close relation between the occurrence of gibbsite(Gb), kaolinite (K) and hydroxy-Al interlayered vermiculite (HIV) in the soil-solution phase versus their presence in the equilibrium soil-solid phase for these Latosols independently of the geomorphic surface. The presence of HIV is not consistent with the weathering process in the tropical areas where the tendency is the progressive loss of Si and the enrichment of Al consequently Gb.

Key Words

Oxisols, pedogenesis, clay mineralogy, soil solution equilibria, geomorphology.

Introduction

The Latosols represent 1/3 of the Brazilian National Territory and occupy about 40% of the Brazilian Central Plateau surface area. These soils correspond to the end of a geochemical sequence of weathering (Pédro 1968). Most Latosols in the Brazilian Taxonomy (Embrapa 2006) correspond to Oxisols in the Soil Taxonomy (Soil Survey Staff 2006) and Ferralsols in the World Reference Base (IUSS Working Group WRB 2006). The Latosols are defined in Brazilian Taxonomy by the presence of a diagnostic Bw horizon somewhere between the top surface and 200-cm depth (Embrapa 2006). The main geochemical process occurring in Latosols is hydrolysis (Melfi and Pédro 1977, 1978) causing a release of cations from the primary minerals thus resulting in the formation of minerals depleted of silica such as 1:1 clay minerals or without silica such as iron oxyhydroxides and aluminum hydroxide. Thus, the clay fraction of the Bw horizon is characterized by the presence of kaolinite, gibbsite, goethite, and hematite in variable proportions, according to the parental material, geomorphic position, and prevailing moisture conditions (Curi and Franzmeier 1984; Macedo and Bryant 1987; Ker 1998; Schaefer *et al.* 2008; Reatto *et al.* 2008). The objective of this study was to discuss the distribution of the Latosols on the geomorphic surfaces from Brazilian Central Plateau based on geochemical process, such as chemical and mineralogical characteristics of the solid phase (soil and parent material) and chemical composition of the soil-solution phase equilibrium.

Methods

Soil selection

Ten Latosols (L) were selected along an approximately 350-km long regional toposequence across the Brazilian Central Plateau, thus enabling to explore a large range of mineralogical soil composition. They were located either on the South American Surface (SAS), (Latosols L1 to L4) or on the Velhas Surface (VS) (Latosols L5 to L10) as shown in Figure 1.

Soil characterization

Samples were collected in the diagnostic horizon (Bw) for every Latosol selected in this study. Physico-

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

chemical analysis were performed on the air-dried <2-mm material according to the Brazilian standard procedures (Embrapa 1997) which in general follow the international procedures (Klute, 1986; Page *et al.* 1982). X-ray diffractions (XRD) patterns were performed using oriented samples of the < 2-µm fraction using Thermo Electron ARL`XTRA diffractometer. Oriented samples were studied after Mg^{2+} saturation (i) at room temperature, (ii) after heating at 110°C, 220°C, 350°C and 550°C, (iii) and at room temperature after glycerol solvatation (Robert and Tessier, 1974). X-ray diffractions patterns were also recorded as transmission for samples collected in the saprolite, which corresponds to the parent materials of the Latosols, using an INEL XR3000 diffractometer. Every sample was grinded and installed within a capillary tube 0.5-mm in diameter. Soil solution extracts were obtained in triplicate for every B*w* horizon following the saturation extract method (Embrapa 1997; Sparks 2003). The concentrations of Si, Al, Ca, Mg, Fe and K were determined using ICP-AES.

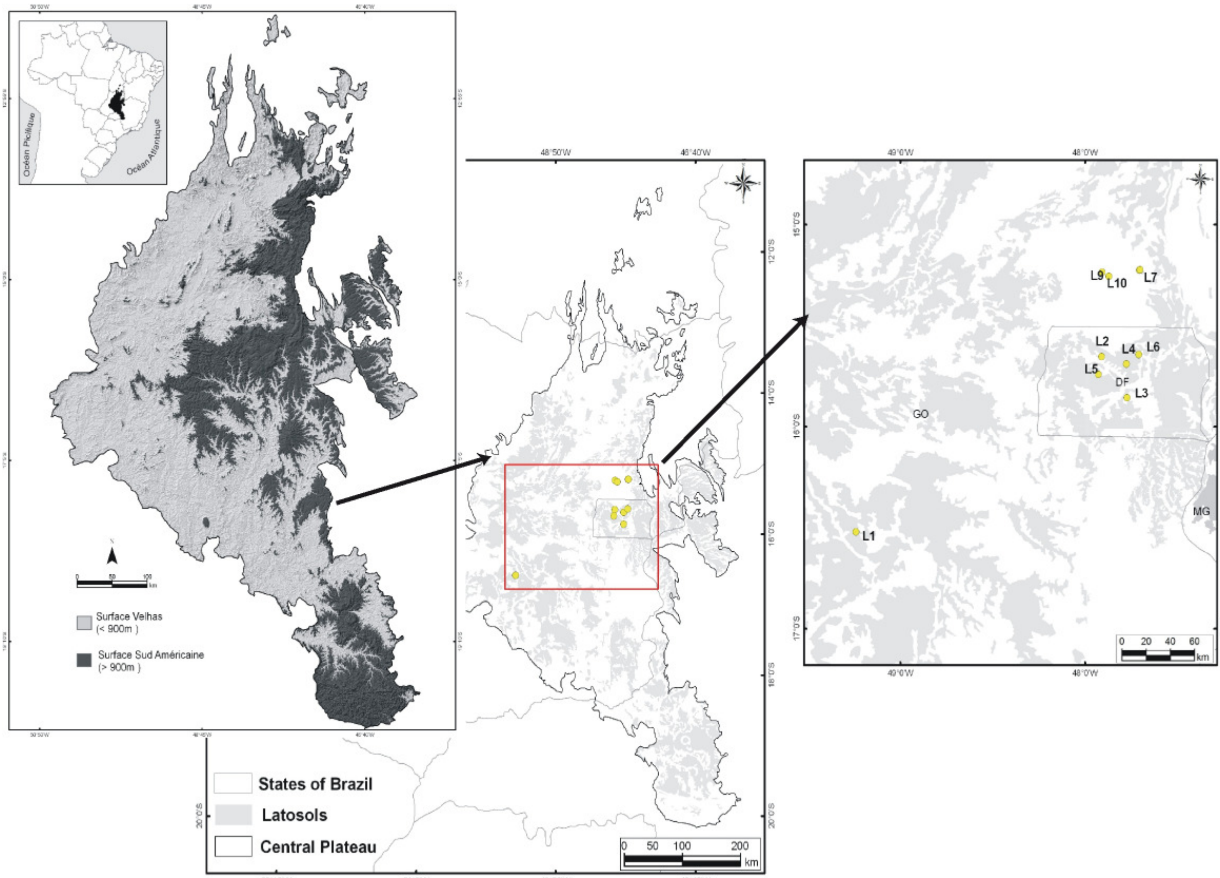

Figure 1. Spatial distribution of the Latosols (L) on the geomorphic surfaces from Brazilian Central Plateau: South American Surface (> 900-m high) represented by L1 to L4, and Velhas Surface (< 900-m high) represented by L5 to L10.

Results

General physical and chemical properties

The Bw horizons of the Latosols studied showed a variation of clay content ranging from 300 to 780 g/kg, smallest for L4 from quartzite parent material. The pH_w ranged from 4.8 to 5.3 and the pH_{KCl} from 4.00 to 6.20. The pH_w and pH_{KCl} of Latosols was greater on the SAS ($5.2 \leq pH_w \leq 5.3$ and $5.7 \leq pH_{KCl} \leq 6.2$) for the Latosols (L1, L2, L3, and L4) than on the VS ($4.8 \leq pH_w \leq 5.2$ and $4.0 \leq pH_{KCl} \leq 5.5$) for the Latosols (L5, L6, L7, L8, L9, and L10). The organic carbon content ranged from 0.01 to 0.62 g/kg. The cation exchange capacity (CEC) ranged from 1.73 to 10.60 $cmol_c$/kg and the high values of CEC were correlated with high ($H^+ + Al^{3+}$) content as observed in L2, L6, and L8. The Al_2O_3 content removable by H_2SO_4 in the Bw horizons was greater in the Latosols on the SAS (528 to 651 g/kg) than in those on the VS (440 to 514 g/kg). On the other hand, the SiO_2 content removable by H_2SO_4 in the Bw horizons was smaller in the Latosols on the SAS (112 to 239 g/kg) than in those on the VS (226 to 341 g/kg). In general the Fe_2O_3 and TiO_2 content removable by H_2SO_4 in the Bw horizons were greater in the Bw horizons on the SAS than in those on the VS with exceptions.

Mineralogical properties

The Table 1 summarizes the main minerals found in the Bw horizons (in different fractions; < 2 mm and < 2 µm) as well as in the saprolite-rocks of the Latosols investigated. In general, the minerals identified were kaolinite (K), gibbsite (Gb), goethite (Gt), and hematite (Hm) in all Bw horizons in the two soil-fractions analyzed, except for L4 concerning to Hm. Quartz (Q) was also found, except in the < 2 – µm fraction (oriented sample). Hydroxy-Al interlayered vermiculite (HIV) and muscovite (M) were observed respectively in the < 2 µm fraction (oriented sample) and the saprolite-rocks for Latosols L5, L7, L8, L9, and L10.

Table 1. Clay mineralogy of the Latosols (L) studied.

Latosol	Samples identification		Minerals identification						
			K	Gb	Gt	Hm	Q	HIV	M
L1	saprolite	granulite (powder)	x	-	-	-	x	-	-
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	-	-
L2	saprolite	sandy metarithimite (powder)	x	-	-	-	x	-	-
		lateritic crusts (powder)	x	x	x	x	x	-	-
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	-	-
L3	saprolite	sandy metarithimite (powder)	x	-	-	-	x	-	-
		lateritic crusts (powder)	x	x	x	x	x	-	-
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	-	-
L4	saprolite	quartzite (powder)	-	-	-	-	x	-	-
		lateritic crusts (powder)	x	x	x	x	x	-	-
	soil	< 2 – mm fraction (powder)	x	x	x	-	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	x	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	x	-
L5	saprolite	clayed metarithimite (powder)	x	-	-	-	x	-	x
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	x	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	x	-
L6	saprolite	metapelite (powder)	x	-	-	-	x	-	x
	soil	lateritic crusts (powder)	x	x	x	x	x	-	-
		< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	-	-
L7	saprolite	metapelite (powder)	x	-	-	-	x	-	x
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	x	-
L8	saprolite	metapelite (powder)	x	-	-	-	x	-	x
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	x	-
L9	saprolite	metapelite (powder)	x	-	-	x	x	-	x
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	x	-
L10	saprolite	limestone (powder)	-	-	-	x	x	-	x
	soil	< 2 – mm fraction (powder)	x	x	x	x	x	-	-
		< 2 – µm fraction (powder)[1/]	x	x	x	x	x	-	-
		< 2 – µm fraction (oriented)	x	x	x	x	-	x	-

[1/] Reatto *et al.* (2008), saprolite-rocks = parent material, soil = Bw horizon of the Latosols, (x) = presence of the minerals and (-) absence of the minerals, K = Kaolinite, Gb = Gibbsite, Gt = Goethite, Hm = Hematite, Q = Quartz, HIV = Hydroxy-Al interlayered vermiculite, M = Muscovite.

Soil-solution composition

The values of soil-solution pH (pHs-s) ranged from 4.28 to 6.42. These values of pHs-s for the Latosols on the SAS presented higher values (pH 5.16 to 6.42) than in those on the VS (4.28 to 4.84). The activities of the major ionic species (pCa, pMg, pK, pAl and pH_4SiO_4) in the soil-solution composition for these Latosols ranged from: 4.91 to 5.12 (pCa); 5.15 to 6.03 (pMg); 4.78 to 5.49 (pK); 6.14 to 6.55 (pFe); 5.34 to 5.71 (pAl) and 4.21 to 4.73 (pH_4SiO_4). The ion-activity product for the minerals gibbsite (pQ_{Gb}), kaolinite (pQ_K) and hydroxy-Al interlayered vermiculite (pQ_{HIV}) in the soil-solution composition for almost all Bw horizons investigated were more negative than the thermodynamic equilibrium constant of these minerals. These findings indicate supersaturation or precipitation conditions before equilibrium is reached, except for the L7, L9, and L10, in which undersaturation or dissolution condition prevailed.

Conclusions

There is close relation between the occurrence of Gb, K, and HIV in the soil-solution phase versus its presence the equilibrium soil-solid phase in a short-time scale for the Latosols studied. The presence of HIV in these Latosols is not consistent with the weathering process in the tropical areas where the tendency is the progressive loss of Si and the enrichment of Al, consequently Gb (pedogenesis time).

References

Curi N, Franzmeier D (1984) Topossequence of Oxisols from Central Plateau of Brazil. *Soil Sci. Soc. Am. J.* **48,** 341–346.

Embrapa (1997) ‘Manual de métodos de análise de solo’. 2ed. rev. atual. (Empresa Brasileira de Pesquisa Agropecuária: Rio de Janeiro-RJ).

Embrapa (2006) ‘Sistema Brasileiro de Classificação de Solos’. (Empresa Brasileira de Pesquisa Agropecuária: Rio de Janeiro-RJ).

IUSS Working Group WRB. (2006) ‘World Reference Base for Soil Resources 2006’. (FAO: Rome)

Ker JC (1998) Latossolos do Brasil: uma revisão. *Geonomos.* **5,** 17-40.

Klute A (1986) In ‘Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods’. (Ed A Klute) pp. 383–411. (American Society of Agronomy Inc.: Madison, WI)

Macedo J, Bryant RB (1987) Morphology, mineralogy, and genesis of a hydrosequence of Oxisols in Brazil. *Soil Sci. Soc. Am. J.* **51,** 690-698.

Melfi AJ, Pédro G (1977) Estudo geoquímico dos solos e formações superficiais do Brasil. Parte 1 – Caracterização e repartição dos principais tipos de evolução pedogeoquímica. *R. bras. Geociências.* **7,** 271 – 286.

Melfi AJ, Pédro G (1978) Estudo geoquímico dos solos e formações superficiais do Brasil. Parte 2 – Considerações sobre os mecanismos geoquímicos envolvidos na alteração superficial e sua repartição no Brasil. *R. bras. Geociências.* **8,** 11 – 22.

Page, A. L., Miller, R. H. and Keeney, D. R. (1982) *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties.* Amer. Soc. Agronomy and Soil Sci. Soc. Amer., Madison, Wisconsin, USA. 1159 pp.

Pédro G (1968) Distribution des principaux types d`altération chimique à la surface du globe. *Rev. Géogr. Phys. Géol. Dyn.* **X,** 457-470.

Reatto A, Bruand A, Martins ES, Muller F, Silva EM, Carvalho Jr OA, Brossard M (2008) Variation of the kaolinite and gibbsite content at regional and local scale in the Latosols of the Brazilian Central Plateau. *C. R. Geoscience* **340,** 741-748.

Robert M, Tessier D (1974) Méthode de préparation des argiles des sols pour des études minéralogiques. *Ann. Agron.* **25,** 859–882.

Schaefer CEGR, Fabris JD, Ker JC (2008) Minerals in the clay fraction of Brazilian latosols (Oxisols): a review. *Clay Minerals.* **43,** 1-18.

Soil Survey Staff (2006) ‘Keys to Soil Taxonomy.’ 10th edn. (USDA–Natural Resources Conservation Service: Washington, DC)

Sparks DL (2003) ‘Environmental Soil Chemistry’. (Academic Press: London).