# Mineralogical assemblage and iron oxides of soils of the Pantanal biome, Brazil

**Ricardo Simão Diniz Dalmolin**[A], Deborah Pinheiro Dick[B], Egon Klamt[C], Eduardo Guimarães Couto[D] and Alessandro Samuel-Rosa[A]

[A]Universidade Federal de Santa Maria, Santa Maria, RS, Brazil. Email dalmolinrsd@gmail.com, alessandrosamuel@yahoo.com.br
[B]Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil. Email debby.dick@gmail.com
[C]UFRGS, Porto Alegre, RS, Brazil. Email egonklamt@yahoo.com.br
[D]Universidade Federal do Mato Grosso, Cuiabá, Mato Grosso, Brazil. Email couto@ufmt.br

**Abstract**
The Pantanal biome is the largest wetland area of the world. Located in the centre of South American continent, it is being affected by the expansion of agricultural use. The effect of this occupation on environmental components of this complex biome such as flooding, sedimentations, vegetation and the characteristics of soils can not be evaluated due to scarce scientific information related to these factors. This study aimed to obtain information related to the forms of iron oxides features and mineralogical assemblage of the predominant soil classes found in this environment, once these characteristics reflect changes introduced by modifications in drainage conditions, flooding and sedimentation processes. The Gleysols present higher clay content than the Planosols and Plinthosols studied, probably related to deposition of clay in the lower position of the landscape, where they occur. The Plithosols, in spite of their lower clay content, showed the largest increase in $Fe_d$ and $Fe_d - Fe_o$ content, which must be related to the better oxidation conditions of this soil found on low ridges and mounds. The uniform mineralogical assemblage of the studied soils indicates that the origin and composition of the sediments and/or the pedogenic processes were similar in these soils.

**Key Words**
Pantanal biome, agricultural expansion, sedimentation processes, pedogenetic processes.

## Introduction
The Pantanal biome, located in the middle of the South American continent (16° - 20°S and 58° - 50°W), predominantly in Brazil, is considered the world's largest wetland, occupying an area of about 200,000 km$^2$ (Por 1995). The landscape is characterized by a mosaic of landforms, such as permanent and temporary rivers and lagoons, vast extensions of floodplains and non-flooded mounds and ridges usually covered with woody vegetation (Haase 1999). The distinct areas have received different types of sediments resulting in a different behavior of water dynamics in the soil profile, which determines the occurrence of different pedogenetic process (Couto and Oliveira 2009). Hydromorphism is the predominant acting pedogenetic process where the redistribution of iron and the development of grey soil colors and reddish mottling (gleying) is the most viewable consequence. In non-flooded landforms podzolization and laterization are the main acting pedogenetic processes. At the Barão de Melgaço region, located in Northern Mato Grosso State, Brazil, three main soil classes are identified: Gleysols (exchangeable aluminum-rich) in seasonally flooded areas, Planosols (sodium-saturated with eutric character) and Plintosols (low cation exchange capacity and base saturation) in slightly more elevated landforms (Couto and Oliveira 2009).

The environmental impact of the increasing land use in this biome is not assessed yet. This is related to the existence of poor scientific environmental information about the relationship between landforms, vegetation and distribution of soils. In order to improve the understanding of the environmental responses to the anthropogenic influence, this study aimed to collect information about mineralogical assemblage and iron oxides features of the main soil classes of Pantanal biome in Northern Mato Grosso State, Brazil.

## Methods
The study was developed at RPPN-SESC Pantanal at Barão de Melgaço sub region located between Cuiabá and São Lourenço Rivers, 145 km away from Cuiabá, capital of Mato Grosso State. The landscape is plain to gently sloping with elevations ranging from 80 to 150 m. Local climate is classified as Aw, with mean annual temperature ranging from 22 to 32 °C, with a well defined dry season from May to September and a rainy season from October to April. The total annual precipitation is around 1000 to 1200 mm. Data of three modal soil profiles was obtained from SBCS (2002): Umbric Gleysol (GLum), Haplic Planosol (PLha) and Haplic Plinthosol (PTha).

The pipette method was used for granulometrical analysis after sample dispersion with 1.0 mol/L NaOH solution. Total iron oxides (oxides, hydroxides and oxi-hydroxides) ($Fe_d$) were estimated by the dithionite-citrate-bicarbonate method and iron from poorly crystalline oxides ($Fe_o$) were extracted with 0.2 mol/L $NH_4$ oxalate (pH 3.0). Air-dried, K-saturated (subjected to successive heat treatments), Mg-saturated and glycolated samples of clay fraction were analyzed by X-ray diffraction (XRD).

**Results**

*Clay and iron oxides features*

Among the studied soils, the greatest clay contents were found in the Glum soil. All samples showed an increase of clay content with soil depth (Figure 1a), and this behavior was also observed for $Fe_d$ and $Fe_d$ - $Fe_o$ contents (Figure 1b and d). PTha soil showed the largest increase in $Fe_d$ and $Fe_d$ - $Fe_o$ contents with depth in spite of its lower clay content (Figure 1b and d) and this result was related to the occurrence of $Fe^{3+}$-rich nodules and mottles formed in aerated soil pores during reductive conditions.

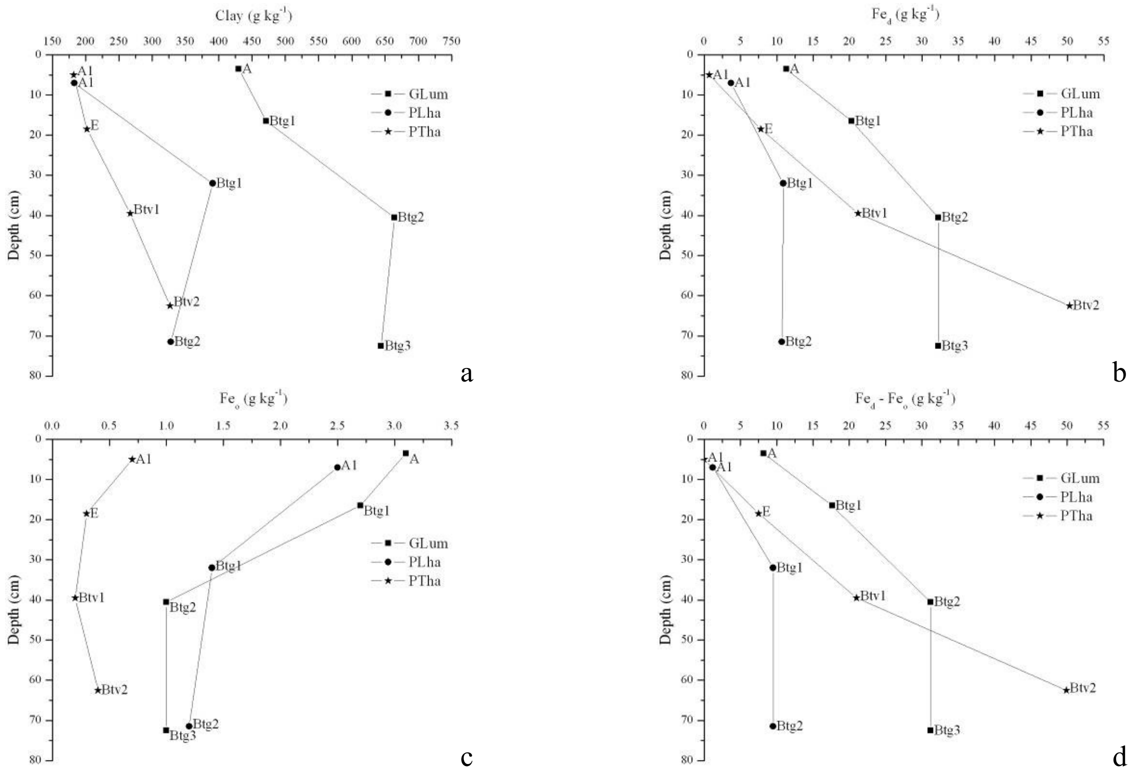


**Figure 1. Clay and iron oxides contents in three modal soil profiles of Pantanal biome, Mato Grosso, Brazil.**

$Fe_o$ content in GLum and PLha soils were high in surface layers and decreased considerably with depth, while in PTha the contents were low and relatively uniform along the profile (Figure 1c). Greater contents of $Fe_o$ on upper horizons can be assigned to the complex formation with soil organic matter, which hinders the crystallization of amorphous Fe oxides forms (ferrihidrite and lepidocrocite) into more stable ones (hematite and goethite) (Dalmolin *et al*. 2007). Consequently, the ratio $Fe_o/Fe_d$ was higher in upper horizons and decreased with depth (Figure 2a). Values of $Fe_o/Fe_d$ below 0.20, recorded for deeper horizons (< 0.30 m) suggest that translocation of Fe oxides in these soil profiles is not relevant. The extremely low value of $Fe_o/Fe_d$ in PTha (< 0.05) is coherent for plintic horizons (Daugherty and Arnold 1982). This behavior demonstrates that crystallization degree of Fe oxides increases when a mottled horizon turns into a plintic one during pedogenetic evolution.

The increase of crystalline Fe forms with depth, indicated by a reduction of $Fe_o/Fe_d$, suggests that in deeper horizons crystalline rather than amorphous Fe forms may be dissolved preferentially by acting as terminal electron acceptors during bacterial anaerobic respiration (Munch and Ottow 1980). The high variability in Fe oxides features observed in the present study indicates a different dynamics regarding the total reducible Fe content (van Bodegom *et al*. 2003). The highest $Fe_d$/Clay values in deeper layers observed in the PTha soil (Figure 2b) (0.00 to 0.15) can be attributed to a segregation of Fe oxides from soil matrix during plinthite genesis. According to Blume and Schwertmann (1969) the occurrence of uniform $Fe_d$/Clay values along soil profile, as shown by GLum and PLha might indicate that Fe oxides and clay are being mobilized together.



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

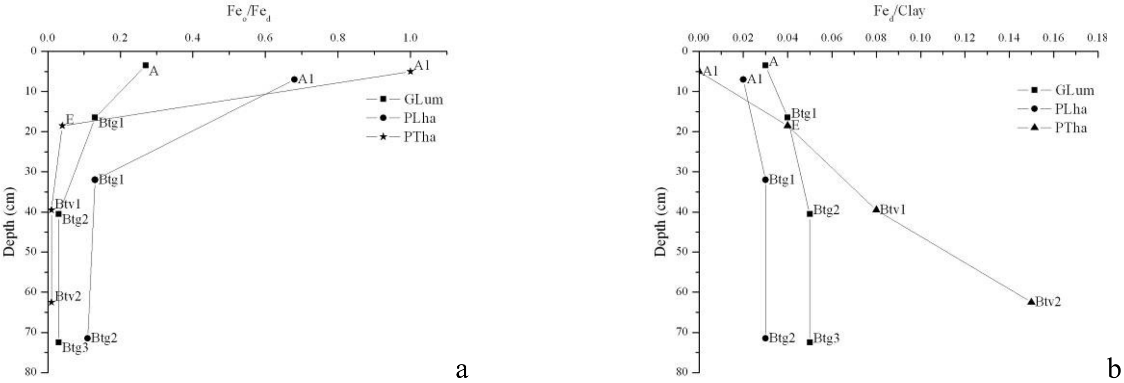


**Figure 2. Fe$_o$ to Fe$_d$ (a) and Fe$_d$ to clay (b) ratios in three modal soil profiles of Pantanal biome, Mato Grosso, Brazil.**

*Mineralogical assemblage*

The XRD difractograms of clay fraction showed a very similar pattern in the studied soil evidencing a low diversity in its mineralogical composition (Figure 3). Occurrence of micaceous minerals was indicated by peaks around 0.5, 0.445 and 0.255 nm. Furthermore, the peaks at 1.0 e 0.33 nm (illite) were not altered after saturation and heating treatments, confirming this assumption. According to Kämpf and Curi (2003) high contents of micaceous minerals may be found in soils originated from sandstone, which is one of the most important sources of sediments for Pantanal (Buchas *et al*. 2000).

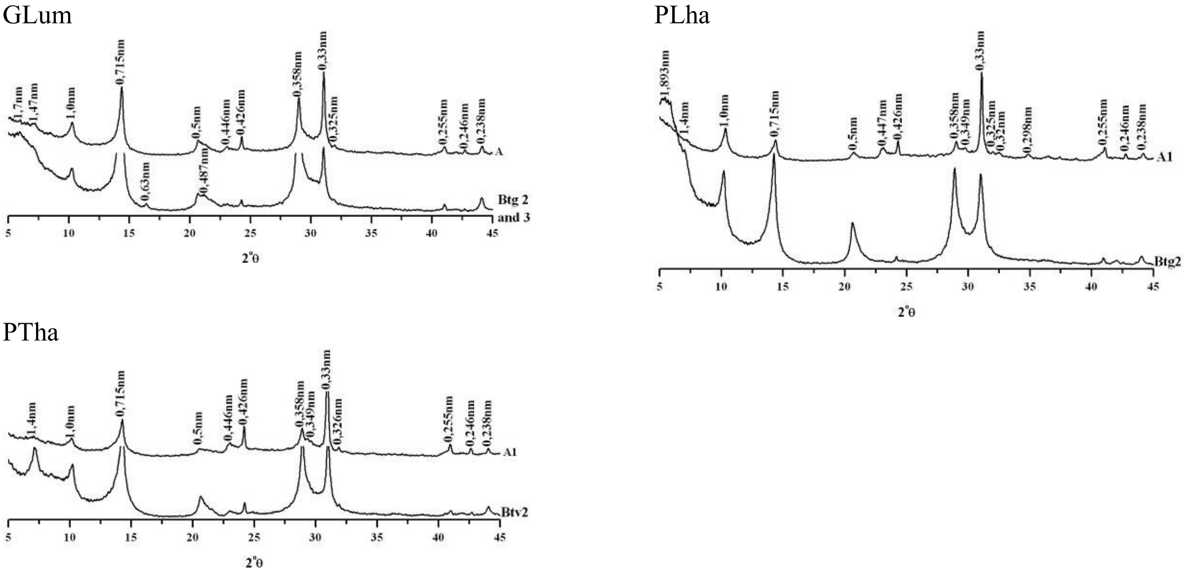


**Figure 3. XRD patterns of the clay fraction in three modal soil profiles of Pantanal biome, Mato Grosso, Brazil.**

Occurrence of kaolinite was identified in all soil horizons due to highest intensity of diffraction peaks at 0.715 e 0.357 nm which disappear after heating at 550 °C. Probably, due to adverse pedogenic conditions (alkalinity and high base saturation) kaolinite has an exogenous origin, coming mainly from well-drained sites outside Pantanal (Furquim *et al.* 2009). Under reductive (alkaline) medium dissolution of these minerals may occur with consequent liberation of Si, Al and Fe into solution (Huertas *et al.* 1999). Diffraction peaks at 0.426, 0.33 and 0.246 nm indicate the occurrence of quartz, while diffraction peaks around 0.299, 0.322, 0.324 and 0.348 nm indicate the occurrence of feldspar in all soil horizons.

GLha soil also showed diffraction peaks at 0.63 nm assigned to the presence of lepidocrocite in B horizons as a result of the precipitation of Fe oxides in mottles and nodules. Hydroxy-Al interlayered vermiculite (HIV) was identified after partial collapse of diffraction peak around 1.4 nm in K-saturated and heated samples. Occurrence of hydroxy-Al increases vermiculite stability and allows its coexistence with gibbsite assigned to the diffraction peak around 0.487 in GLha. HIV was also identified in PLha and PTha. Abundance of micaceous minerals in Pantanal soils indicates that the formation of HIV may follow the ordinary weathering sequence: feldspar – mica – illite – vermiculite – HIV (Barnhisel and Bertsch 1989).

## Conclusion

GLum soil present the highest clay contents when compared to the other soil classes. PTha showed the largest increase in $Fe_d$ and $Fe_d$ - $Fe_o$ contents with depth in spite of its lower clay content. $Fe_o$ content in GLum and PTha decreased considerably with depth while small variation occurs in PTha. Higher contents of $Fe_o$ on upper horizons indicate that transformation of amorphous Fe oxides forms into more stable ones is being retarded. The high variability in Fe oxides features results in differences among soils which is related mainly to C contents and drainage conditions. The mineralogical characteristics were not good parameters for distinguishing Pantanal soils. In spite of their sedimentary origin that resulted in remarkable lithological discontinuities and poor drainage environments, affecting sensitively soil granulometry and Fe oxides features, mineralogy has shown a great uniformity.

## References


Barnhisel RI, Bertsch PM (1989) Chlorites and hidroxy-interlayred vermiculite and smectitte. In 'Minerals in soil environments'. (Eds JB Dixon, SB Weed) pp.729-779. (Soil Science Society of America, Madison)

Blume HP, Schwertmann U (1969) Genetic evaluation of distribution of aluminum, iron, and manganese oxides. *Soil Science Society of America Proceedings* **33,** 438-444.

Buchas H, Irion G, Nunes da Cunha C, da Silva CJ, Kasbohm J, Junk WJ (2000) Sedimentological, Geochemical and Geomorphological Studies of Sediment Deposits in the Pantanal/Brazil. In 'Neotropical ecosystems, Proceedings of the German-Brazilian Workshop'. (Eds R Lieberei, HK Bianchi, V Boehm, C Reisdorff) p.737-741. (Hamburg).

Couto EG, de Oliveira VA (2008) The Soil Diversity of the Pantanal. In 'The Pantanal of Mato Grosso: Ecology, biodiviersity and sustainable management of a large neotropical seasonall wetland'. (Eds Junk WJ, CJ da Silva, CN da Cunha, KM Wantzen) pp.40-64. (in press) (Sofia: Pensoft).

Dalmolin RSD, Dick DP, Knicker H, Klamt E, Couto EM (2007) Organic matter in lowly weathered soils from Pantanal region, Brazil. In: International Symposium on Organic Matter Dynamics in Agro-Ecosystems, 2007, Poitiers. Organic matter dynamics in agro-systems. Poitiers: Inra. v. 1. p. 175-177.

Daugherty LA, Arnold RW (1982) Mineralogy and iron characterization of plinthitic soils on alluvial landforms in Venezuela. *Soil Science Society of American Journal* **46**, 1244-1252.

Furquim SAC, Graham RC, Barbiero L, Queiroz Neto JP, Vidal-Torrado P (2009) Soil mineral genesis and distribution in a saline lake landscape of the Pantanal Wetland, Brazil. *Geoderma*. (available online)

Haase R (1999) Litterfall and nutrient return in seasonally flooded and non-flooded forest of the Pantanal, Mato Grosso, Brazil. *Forest Ecology and Management* **117**, 129-147.

Huertas FJ, Chou L, Wollast R (1999) Mechanism of kaolinite dissolution at room temperature and pressure. Part II - kinetic study. *Geochimica et Cosmochimica Acta* **63**, 3261-3275.

Kämpf N, Curi N (2003) Argilominerais em solos brasileiros. In 'Tópicos em ciência do solo'. (Eds N Curi, JJ Marques, LRG Guilherme, JM Lima, AS Lopes, V Alvarez). Vol **3**, pp.1-54. (Viçosa: SBCS).

Munch JC, Ottow JCG (1980) Preferential reduction of amorphous to crystalline iron oxides by bacterial activity. *Soil Science* **129**, 15-21.

Por FD (1995) *The Pantanal of Mato Grosso (Brazil). World's largest wetlands.* Monographiae Biologicae, vol. 73. Kluwer Academic Publisher, Dordrecht.

SBCS (2002) Guia de excursão de estudos no Estado de Mato Grosso. In: Couto EG, Jacomine PKT, Cunha CN, Vechiatto AB (org) *Reunião Brasileira de Manejo e Conservação do Solo e da Água*, 14. Cuiabá: UFMT, 2002. 58p.

van Bodegom PM, van Reeven J, Denier van der Gon HAC (2003) Prediction of reducible soil iron content from iron extraction data. *Biogeochemistry* **64,** 231-245.