

# Geochemistry of a sedimentary lateritic kaolin deposit in Quadrilátero Ferrífero, Brazil

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Received 1 April 2005; accepted 19 August 2005

Available online 27 December 2005

## Abstract

The present study deals with the mineralogy and geochemistry of the clayey facies of the Água Limpa kaolin deposit, situated in the Moeda Syncline, Quadrilátero Ferrífero, Minas Gerais, Brazil. Kaolinite, quartz, oxides and iron hydroxides (hematite and goethite) represent the mineral assembly of the five facies of the deposit. White mica, rutile, anatase and gibbsite are heterogeneously distributed along the profile. Despite the variable behavior of the chemical elements along the profile, the geochemical patterns for major and rare earth elements enable to define the filiations generated by the laterization process that affected the sediments.

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*Keywords:* Kaolinite; REE; Major elements; Ferruginization; Deferruginization

## 1. Introduction

The Quadrilátero Ferrífero constitutes an important geologic province of the State of Minas Gerais, south-eastern Brazil. The geological structural pattern of the Quadrilátero Ferrífero results from a complex Paleoproterozoic tectonism that produced synclines and anticlines, such as the Moeda Syncline, west of the Quadrilátero Ferrífero. After the Precambrian deformation, Cenozoic graben zones were generated and filled during periods of reactivation and increased erosion under arid/sub-arid climatic conditions (Santos and Varajão, 2004; Santos et al., 2004a,b) resultant from

the paleoclimatic evolution throughout the Tertiary and Quaternary (Tardy et al., 1991). An important amount of sediment was formed in these structures and the Água Limpa kaolin deposit exemplifies this regional depositional event in the Moeda syncline. The deposit is composed of laterized Cenozoic sediments that occur in unconformity upon Paleoproterozoic Fecho do Funil Formation phyllites (Piracicaba Group). Studies based on sedimentologic, pedologic and microstructural investigations (Santos, 2003) defined five main lithofacies in this deposit, from bottom to top: cohesive sandstone (Cs), white diamictite (Dw), red diamictite (Dr), nodular (N), and conglomerate (C). The present study aims at tracing the geochemical evolution of these facies by means of mineral analyses by X-ray diffractometry (Jobin-Yvon Sigma 2080 diffractometer/CoK $\alpha$  radiation), chemical analyses of major and minor elements (Jobin-Yvon emission spectrometer), trace and rare earth elements (ELAN 5000

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Perkin-Elmer ICP-MS) and statistical data treatment by principal component analysis (Stad Box program).

## 2. Results and discussion

The X-ray diffraction analyses show that kaolinite, quartz, iron oxides and hydroxides (hematite and goethite) are the predominant minerals in the five facies of the deposit. Minerals of minor abundance as white mica, rutile, anatase and gibbsite are heterogeneously distributed. Micromorphological (Santos et al., 2002) and crystallochemical (Santos et al., 2004b) studies shows that the post-deposition pedogenetic process in this basin produced the obliteration of the primary structures and the superposition of secondary microstructure features. For these authors, the sediments source area is the ferruginous soil developed on the Piracicaba Group. The basal facies (cohesive sandstone-Sc and white diamictite-Dw) have been deferruginized, since the matrix is free of iron minerals and only part of the quartz grains present a relictal iron coating. The red diamictite (Dr) facies represents the transition zone of the deferruginization processes showing heterogeneous distribution of iron minerals in the matrix. In the nodular (N) and conglomerate (C) facies, iron nodules appear in a completely ferruginized matrix. This actual pile represents a classical lateritic profile developed above the sediments (Fig. 1A). The geochemical analysis shows at the base of the profile high  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  concentrations (Fig. 1B), related to the predominance of kaolinite and quartz. The top

facies presents an increase of  $\text{Fe}_2\text{O}_3$  and a decrease of  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  values, due to the enrichment in iron oxides and hydroxides (hematite and goethite) in the matrix and the ferruginous nodules (Fig. 1B). Additionally the deferruginized facies contain higher  $\text{TiO}_2$  and trace elements (Y, Nd, Sr) concentrations in comparison to the ferruginous facies that, to the contrary, presents higher Cr concentrations than the preceding facies.

The behavior of rare earth elements normalized to the chondrite (C1) shows that the five facies present the same filiation (Fig. 2A) and is similar to that of phyllites of the deposit substrate (Fig. 2B). This corroborates previous studies (Santos, 2003). There is an LREE enrichment in relation to HREE, a more significant negative Eu anomaly in the deferruginized facies, and a gradual REE enrichment in the facies in comparison with the substrate REE contents. Inversely, the concentration of REE in the ferruginous facies is lower than that of the deferruginized facies.

The present information, together with the results of the statistical treatment of the chemical data by means of principal component analysis (Lebart et al., 1979), show that there is a direct correlation between LREE and  $\text{Al}_2\text{O}_3$ , and a direct correlation between HREE and titanium minerals.

## 3. Conclusion

The geochemical patterns of the major elements of the Água Limpa lateritized sedimentary profile is similar to those of the classic lateritic profiles developed in situ

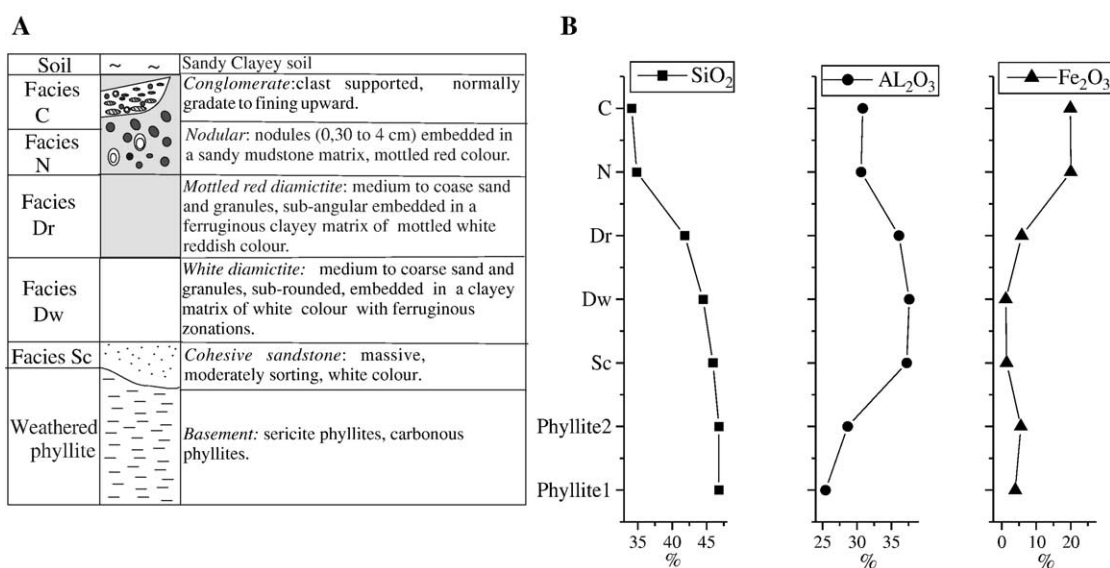


Fig. 1. (A) Schematic profile with textural description of the facies and pedogenetic interpretation. (B) Geochemical distribution of the major elements  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$  and  $\text{Fe}_2\text{O}_3$  in the facies.

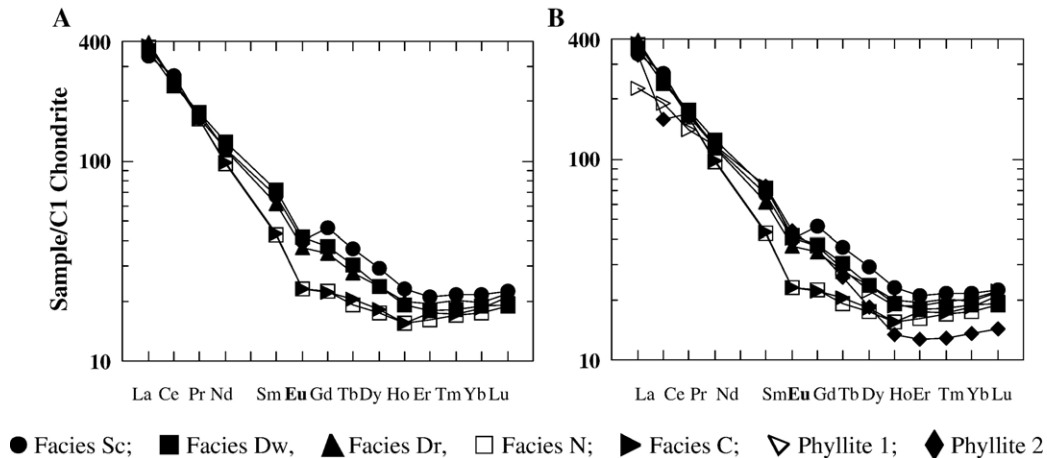


Fig. 2. (A) Chondrite (C1) normalized REE distribution for representative samples of the Agua Limpa deposit facies. (B) Chondrite (C1) normalized REE distribution for representative samples of the Agua Limpa deposit facies and for the basement rock (phyllite).

on granitic and gneissic rocks (Tardy, 1969; Tardy and Nahon, 1985; Nahon, 1986; Tardy, 1993). In other words, Al is concentrated at the bottom and Fe at the top of the profiles, in general covered by an iron duricrust which is enriched in LREE and depleted in HREE. However, in the classic profiles, Fe, Mn, Ni, and Cr enrichments are mainly attributed to the superficial affinities (trapping in the specific surface) and to the Fe-oxyhydroxides (Fleet, 1984). In this study, it is suggested that the REE geochemical affinity is linked to the accessory minerals associated to rutile and anatase, and that the REE distribution pattern is correlated to Al concentration due to deferruginization mechanisms of the basal facies.

### Acknowledgments

The authors thank CAPES/COFECUB and CNPq for financial support. We are grateful to Magnesita S.A. for the support given during the fieldwork.

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