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Geochemical evolution of the Capim River kaolin, Northern Brazil

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Abstract

The Capim River kaolin, located in the eastern Brazilian Amazon, constitutes one of the most important kaolin deposits in the world. Known for its high whiteness, its noble application is in the paper industry. Studies were carried out on samples from the six facies of the deposit (sand kaolin, soft kaolin, lower transition facies, ferruginous crust, upper transition facies and flint kaolin) in order to trace its geochemical evolution. The kaolin developed at the expense of Cretaceous sandy–clayey sediments of the Ipixuna Formation. Intense lateritic processes characterized by ferruginization and deferruginization mechanisms led to the distinction of the different facies.

Keywords: Kaolinite; Ferruginization process; Deferruginization process; REE

1. Introduction

The Capim River kaolin, located in northern Brazil, in the Amazon region, is known worldwide for the high whiteness of its kaolin reserves. The whole production is used in paper coating industry. Due to its economic importance, the scientific interest for the Capim River kaolin has increased since the 70s. The studies encompass both general works on geology and genesis (Hurst and Bósio, 1975; Monteiro, 1977) and specific works, involving mineralogical, geochemical and faciologic aspects (Costa and Moraes, 1992, 1998; Kotschoubey et al., 1996; Sousa, 2000; Barbosa et al., 2004).

The kaolin is embedded in the Ipixuna Formation (Late Cretaceous/Early Tertiary) and its representative profile is constituted, from bottom to top, by 6 facies: sand kaolin, soft kaolin, lower transition facies, ferruginous crust, upper transition facies and flint kaolin.

Despite the great number of works involving the Capim River kaolin, genetic studies that emphasize the evolution of facies are scarce and do not attempt any correlations taking mineralogical, micromorphologic and geochemical aspects into consideration at the outcrop level. The objective of this work is to characterize the geochemical evolution of the kaolin facies, emphasizing lateritic processes based on mineralogical and chemical studies.

The representative whole rock samples of the six kaolin facies previously defined, were analyzed for mineralogical (Bruker AXS-D8 Advance diffractometer with monochromatic CoKα radiation) and major, trace and rare-earth elements (REE) identification. The major elements were analyzed by inductively coupled plasma spectrometry (ICP–AES) and the trace and rare-earth elements by ICP–MS.

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2. Results and discussion

The predominant mineral of the representative samples of the Capim River kaolin facies is kaolinite except for the samples from the transition facies and ferruginous crust that show the dominant presence of hematite and goethite and the samples from the sand facies where quartz is the predominant mineral. Additionally all the facies show the same assemblage of heavy minerals such as zircon, tourmaline, rutile, staurolite, and kyanite. Phosphates of the crandalite–goyazite series were identified at the top of the soft facies and in the lower transition facies.

The chemical composition shows the predominance of SiO_2 and Al_2O_3, except for the lower transition facies and ferruginous crust, where the predominant oxide is Fe_2O_3. The average values of the SiO_2/Al_2O_3 ratio range from 1.19 and 1.21 and are confirmed by the conspicuous presence of kaolinic plasma and minor amounts of quartz. The high SiO_2/Al_2O_3 ratio obtained for the sandy kaolin sample is attributed to the high concentration of quartz in this facies.

The triangular diagram (Fig. 1) with SiO_2, Al_2O_3 and $Fe_2O_3+TiO_2+MgO+CaO+Na_2O+K_2O$ values, including examples from Nyakairu et al. (2001) for the Latium kaolin deposits (Itália), Buwamdo (Uganda), Saxony and Bavaria (Germany), Devon and St. Austell (UK), Bretagne (France), Georgia (USA) and Jarí (northern Brazil), show that the Capim River kaolin plots together with those deposits that contain the lowest chromophores and alkali contents. This fact indicates that the sandy–clayey sediments of the Ipixuna Formation underwent intense leaching processes and that a high grade of maturation was reached. The high values refer to the change from the soft facies to the ferruginous crust facies. Also in this interval and mainly at the top of the flint facies the highest TiO_2 values occur. These values correspond to the relative anatase enrichment due the deferruginization process.

P_2O_5 values, in the 0.04% and 0.15% interval, indicate that residual lateritic processes also took place. The highest values are concentrated in the least evolved portions (lower transition facies) where features of the ferruginization process are still recognizable and where the minerals of the continuous crandallite–goyazite series and xenotime nodules were detected. In the deferruginized facies (flint facies) and mainly in the most evolved flint facies, P_2O_5 contents are the lowest.

Ti, Nb, Ta and Zr, considered as refractory elements, are typically immobile. Ti was used in the Nb vs. Ta

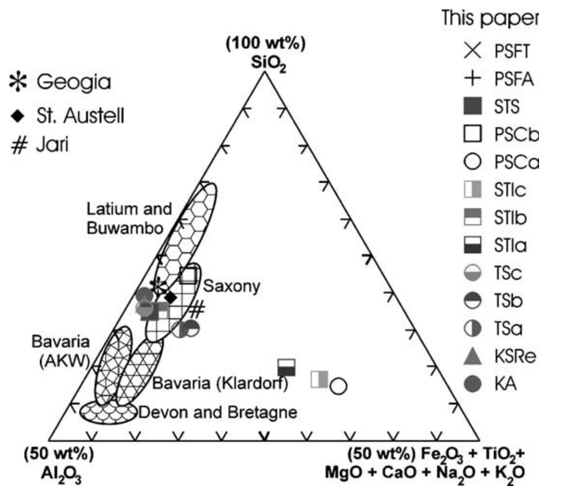

Fig. 1. Triangular diagram showing the chemical characteristics of the Capim River kaolin facies compared to other kaolin occurrences of different origins (after Nyakairu et al., 2001). Sand kaolin (KA), soft kaolin (TSa, TSb, TSc), lower transition facies (STIa, STIb, STIc), ferruginous crust (PSCa, PSCb), upper transition facies (STS) and flint kaolin (PSFA, PSFT).

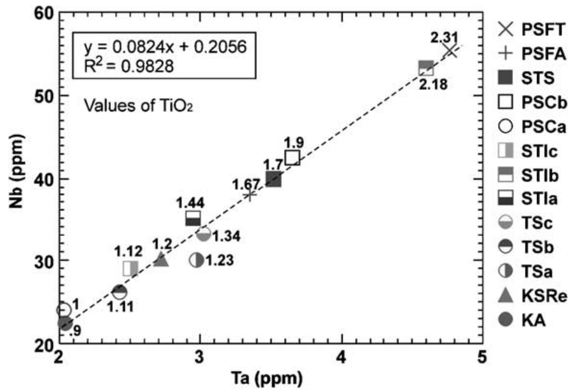

Fig. 2. Graph showing the correlation between Nb, Ta and Ti for the Capim River Kaolin facies (see Fig. 1).

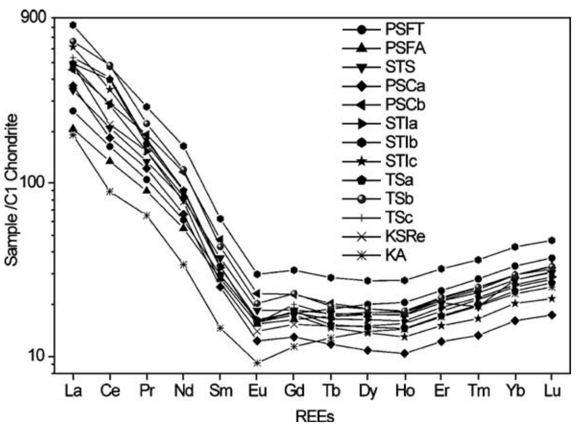

Fig. 3. C1 Chondrite-normalized REE distribution for the Capim River kaolin facies (see Fig. 1).

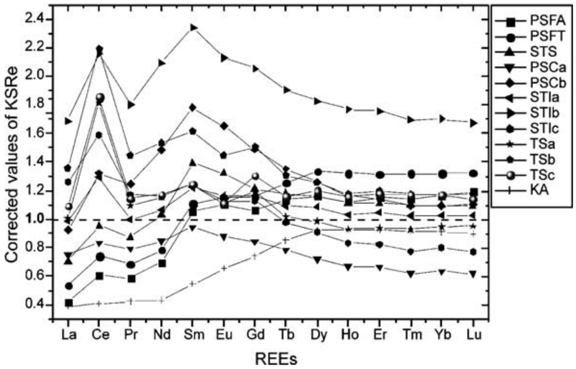

Fig. 4. REE distribution for the Capim River kaolin facies (see Fig. 1). REE normalized to the soft kaolin (KSRe/value = 1).

correlation diagram (Fig. 2) illustrating the good correlation between different Capim River kaolin facies, suggesting that they originate from the same sediments.

The REE distribution patterns normalized to chondrite (Fig. 3) are similar for all facies and are characterized by LREE enrichment, a slight HREE depletion and a strong negative Eu anomaly. However, the REE distribution patterns normalized to the soft and least evolved facies (KSRe), whose characteristics are similar to those of the protolith of the alteration profile, show that anomalous Ce and Sm values are frequent in all facies (Fig. 4). Additionally, other differences are depicted: strong LREE depletion and HREE enrichment occur in the most evolved facies (upper transition and flint facies) that underwent ferruginization followed by deferruginization processes. The least evolved facies (soft and lower transition) that preserve relicts of the original sediment are the most LREE enriched. This is confirmed by the low P_2O_5 values found in the most evolved facies, where LREE were removed and transported by phosphates of the crandallite–goyazite series. Additionally, residual zircon concentrations in the most evolved facies corroborate a stronger HREE enrichment.

3. Conclusion

The chemical analyses corroborate the role played by the lateritic processes, characterized by the ferruginization and deferruginization mechanisms that generated distinct facies (Sousa, 2000; Barbosa et al., 2004). These mechanisms are well represented by the REE distribution patterns normalized to the soft kaolin (KSRe), which show strong LREE depletion and HREE enrichment in the most evolved facies (upper transition and flint facies), and LREE enrichment in the least evolved facies (soft and lower transition). This is confirmed by low P_2O_5 contents in the most evolved facies, where LREE were removed and transported by phosphates of the crandallite–goyazite series. Additionally, residual zircon concentrations in the most evolved facies corroborate HREE enrichment. Ti, Nb and Ta, considered immobile elements during alteration processes, show a good correlation for all facies, evidencing evolution from a common source.

Even if ferruginization and deferruginization mechanisms led to the individualization of different Capim River kaolin facies, the same heavy mineral assembly persists in all facies, evidencing that these minerals originated from the same basal sediments.

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