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Mineralogical, crystallographic and morphological characteristics of natural kaolins from the Ivory Coast (West Africa)

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Abstract

Thirteen clay samples from four deposits in the Ivory Coast (West Africa) were studied using X-ray diffraction, thermogravimetric analysis and chemical analysis. Mineralogical, crystallographic and morphological characteristics of these samples are given. Kaolinite is the principal mineral but other minerals are present in small quantities: illite, quartz, anatase and iron oxides (oxides and oxyhydroxides). The crystallographic, morphological and surface characteristics are influenced by the presence of these impurities. In particular, the presence of iron oxides was associated with reduced structural ordering and thermal stability of kaolinite and increased specific surface area. These clays could be used in the ceramics industry to make tiles and bricks, and also in agronomy as supports for chemical fertilizers or for environmental protection by immobilising potentially toxic waste products.

Keywords: Kaolin; Metakaolinite; Iron oxide; XRD; DTA; Structural disorder

1. Introduction

Geological surveys carried out between 1964 and 1968 by the "Société pour le Développement Minier" (SODEMI) in the Ivory Coast identified many clay deposits mostly dominated by kaolinites. The exploitation of these deposits for industrial and craft activities has considerable potential to promote the economical and social development of the country (Emeroua, 1993). Kaolins form a large family of minerals ranging from perfectly ordered, defect-free minerals (Géode kaolinite) to highly disordered minerals also called "fire clays". Between these two extremes, there is a quasi-continuous series of intermediates (Tchoubar et al., 1982). Fialips et al. (1999) show that crystallographical and chemical characteristics of kaolinites are very variable, and depend on their genesis. Sedimentary kaolinites, formed by weathering of parent material (feldspars, micas), like those studied here, are particularly prone to contamination by other minerals, including clays. They are associated with minor components which, depending on their nature and abundance, confer different properties and colours. A detailed investigation including the appreciation of the crystallographic and morphological properties is needed to identify possible industrial applications and this requires an integrated approach combining several methods of mineralogical analysis (Liétard, 1977; Cases et al., 1982; Delon et al., 1982; Yvon et al., 1982; Singh and Gilkes, 1992).

In the present study, we (i) analysed some samples from various deposits with the aim to determine the nature and

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the abundance of their mineral components; (ii) determined some of their physicochemical and structural properties; and finally (iii) attempted to class them according to possible applications.

2. Deposits and their geological environments

The geology of the Ivory Coast is characterized by two chronologically distinct entities: the insular shelf of Precambrian age and the sedimentary basin developed between the Mesozoic and the Quartery on the Atlantic coast (Fig. 1). Deposits of Adattié (ADA), Grand-Bassam (GB), Nieki (NIE) and Nigui-Saff (NS), the objects of our study, are situated in the sedimentary basin, near Abidjan (Digbehi et al., 2001). The sedimentary basin, which includes sandy and clayey formations, is made up of a zone of tablelands with altitude between 40 and 100 m, terminating in slopes on lagoons and a littoral zone near sea level (Tastet, 1979).

The Adattié and Nieki deposits, approximately 30 km north-west of Abidjan, are in a plateau area. In the North they lie on the Precambrian shelf, and in the South on formations of the early Tertiary. It is assumed that these formations resulted from sedimentation of alluvial products eroded from the uppermost layer of the Precambrian shelf, at that time exposed to chemical weathering under a semi-arid climate (Le Bourdiec, 1958). The plateaux are delimited in the North by a valley at the limit between the Precambrian shelf and Tertiary continental deposits (Continental terminal in French geological classification) and in the East and West by deep N–S oriented river valleys. In the South they fall steeply towards the coastal lagoons. A schematic N–S profile after Dorthe (1964) is shown in Fig. 2. Dorthe (1964) has distinguished three formations composed by sands, clays, and ferruginous material, distinguished by their mean grain sizes. The deepest formation (S1) consists of conglomerates and feldspathic micaceous sands. Above lies a formation of clays (S2) covered by coloured clayey sands and sandy clays (S3). There

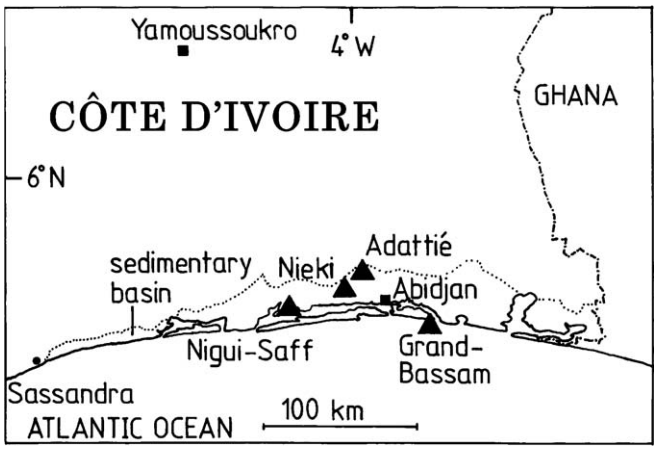

Fig. 1. Map of the Ivory Coast showing the location of the four deposits in the sedimentary basin (redrawn from Digbehi et al., 2001).

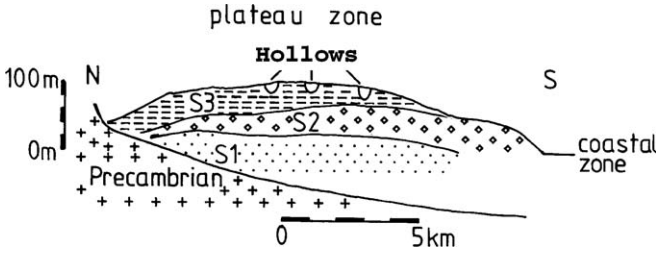

Fig. 2. Schematic N–S profile of the plateau and coastal zone near Abidjan (redrawn from Dorthe, 1964).

is no surface water on the plateaux, but they have considerable stocks of groundwater, often only a few meters below the surface. Water seeping through the ground has locally created circular or oval depressions, 3–5 m deep, with diameters between 100 and 500 m. Some of these hollows are filled with water during the rainy season due to the rising groundwater level. The hollows are covered by sparse vegetation characteristic of hydromorphous soils. Deposits of white clays lie beneath the soil cover and occur as flat lens- or cone-shaped accumulations. On their borders the colour of the clay changes progressively from white, yellow and orange to the red-brown of the surrounding S3 sediment. The studied samples were taken from such hollows approximately 3 m below the surface, above the groundwater level.

Deposits of Grand-Bassam and Nigui-Saff are situated in the littoral zone, approximately 50 km East and West of Abidjan, respectively. Sediments are supposed to have the same origin as those on the plateau zone. Sediments consist principally of kaolinitic clays, ferruginous residues of quartz, sand and iron oxides (Madon, 1969; Bacchiana, 1981).

3. Methods

The size fraction less than 2 μm, was obtained by sedimentation then saturated with magnesium. Part of this fraction was treated with dithionite citrate-bicarbonate (DCB) to remove iron oxides (Mehra and Jackson, 1960) before saturation with Mg. Several experimental techniques have been used and compared in this study.

3.1. X-ray diffraction

X-ray diffraction (XRD) patterns were recorded on a Philips diffractometer (CuKα radiation with $\lambda = 1.5418$ Å). Both random and oriented powder samples were investigated. The latter was obtained by the sedimentation of the clay suspension on a slide support allowing the (0 0 1) reflection intensities of the various clay minerals to be amplified in order to ease their identification. We have estimated crystallinity of samples from the apparent coherent scattering thickness of crystallites of kaolinite (L_{001} and L_{002}) and by using Scherrer formula (Guinier, 1956).