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Mineralogical characteristics of Cretaceous-Tertiary kaolins of the Douala Sub-Basin, Cameroon

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ABSTRACT

As a step in evaluating the quality of Cretaceous-Tertiary kaolins of the Douala Sub-Basin, their mineralogical characteristics were determined. The X-ray diffractometry technique was used to identify and quantify the mineral phases present in bulk and <2 µm fractions. Scanning electron microscopy was used to determine the micromorphology of <2 µm fractions kaolins. Thermal analyses (derivative thermal gravimetric analysis, thermal gravimetric analysis, and heat flow) were conducted to further characterise the kaolins. The main mineral phases present in the studied Cretaceous-Tertiary kaolins of the Douala Sub-Basin were kaolinite > smectite > illite, with mean values of 33.01 > 11.20 > 4.41 wt %; and 72.23 > 10.69 > 4.69 wt %, in bulk and <2 µm fractions, respectively. The kaolins, micromorphologically, consisted of pseudo-hexagonal and thin platy particles; swirl-textured particles; and books or stacks of kaolinite particles. Three main reactions occurred during heating of the kaolins: a low temperature endothermic reaction, observed between 48 and 109 °C; a second low temperature peak, observed between 223 and 285 °C; and a third endothermic peak was found between 469 and 531 °C. In addition, an exothermic reaction also occurred between 943 and 988 °C in some of the samples. The absence of primary minerals such as feldspars and micas in most of these kaolins is an indication of intensive weathering, probably due to the humid tropical climate of the region. The different morphologies suggested that these kaolins might have been transported. Therefore, a humid tropical climate was responsible for the formation of Cretaceous-Tertiary kaolins of the Douala Sub-Basin through intense weathering of surrounding volcanic and metamorphic rocks.

1. Introduction

Kaolin exploitation is a financially sustainable profit-making mining industry that contributes positively to national economies of the world (Ekosse, 2010). The physical, mineralogical and chemical properties of kaolins are important in establishing their proper utilisation in various industrial applications; and help to identify impurities, such as Fe-bearing minerals that impart the undesired red colouration to kaolin and considerably decrease its industrial value (Prasad et al., 1991; Murray and Kogel, 2005; Siddiqui and Ahmed, 2008).

With increasing new industrial applications of kaolins, any promising deposit is worth exploiting, particularly in developing countries (Nyakairu and Koeberl, 2001; Njoya et al., 2006). Moreover, Ekosse (2010) recommended that any exploration of kaolins in Africa should focus on Cretaceous-Tertiary kaolins, because world-known and most exploited kaolins, namely, the Cornwall (England), Capim River (Brazil), Georgia (USA) and Cape York Peninsula (Australia) kaolins, are found in Cretaceous-Tertiary Formations (Harvey and Murray, 1997).

The Douala Sub-Basin, a sub-basin of the Douala-Kribi-Campo Basin, stretches on the south coast of Cameroon, covering a total surface area of 19 000 km^2 (Mbesse et al., 2012). It is made up of Cretaceous-Recent Formations. This Sub-Basin is mainly known for hosting hydrocarbons (Brownfield and Charpentier, 2006; Ntamak-Nida et al., 2008; Chavom et al., 2014; Effoudou-Priso et al., 2014; Ngaha, 2005). Though the kaolin industry could be a profitable one, few studies have been carried out on those in this Sub-Basin (Ngon Ngon et al., 2012; Diko and Ekosse, 2012, 2013; Logmo et al., 2013; Ngon Ngon et al., 2014; Diko et al., 2016).

Four minerals constitute the kaolin group, namely; kaolinite ($Al_2Si_2O_5(OH)_4$), halloysite ($Al_4Si_4O_{10}(OH)_8.8H_2O$), nacrite

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($Al_2Si_2O_5(OH)_4$) and dickite ($Al_2Si_2O_3(OH)_4$) (Kearey, 2001; Obaje et al., 2013). Halloysite is a fairly common mineral that develops in tropical and moderate-temperature soils and weathering crusts, particularly on basalts; and through a range of hydrothermal alterations that affect particularly volcaniclastic formations (Melka et al., 2000). Nacrite is believed to either be primarily hydrothermal or associated to elevated temperature environments (Chen et al., 2001). Dickite is an uncommon mineral, usually associated with hydrothermal alteration zones and veins of ore minerals, while kaolinite can form over a wide temperature range, as a result of weathering, diagenesis, or hydrothermal deposition and alteration (Schroeder and Hayes, 1968).

The presence of some accessory minerals (such as iron-bearing minerals or quartz) in a kaolin deposit could reduce its quality for some industrial applications e.g. in plastic and rubber industries (Ekosse, 2000); though for other applications such as for ceramics, these accessory minerals enhance the kaolin's quality (Andji et al., 2009; Soro et al., 2003). Therefore understanding the mineralogy of a kaolin deposit could be a first step in evaluating its quality. The objective of this paper is to present a mineralogical characterisation of Cretaceous-Tertiary kaolins of the Douala Sub-Basin.

2. Geology of the Douala Sub-Basin

The studied kaolins are found in the Douala Sub-Basin (SNH/UD, 2005) (Fig. 1). This Sub-Basin is part of the West-Central Coastal Province, delineated by Brownfield and Charpentier (2006), which also includes the Kribi-Campo, Rio Muni, Gabon, Congo, Kwanza, Benguela, and Namibe Basins, which together form the Aptian salt basins of equatorial West Africa.

Kenfack et al. (2012a, b) described five tectonic events which contributed to the formation of this Sub-Basin:

- Pre-rift phase (Jurassic): Characterised by Jurassic continental sediments, which were deposited in an Afro-Brazilian depression that extended over this sub-basin.
- Rifting phase (Jurassic-Barremian): Characterised by a stratigraphic sequence controlled by listric faulting and associated roll over anticlines.
- Syn-rift phase: Characterised by an intensive erosion activity of the highlands and deposition in the previously formed graben.
- Rift-drift transition phase (Mid-Late Aptian): Marked by salt deposition and the transform direction resulting in a series of cross-faults which have segmented the rift structure.
- Post-rift phase (Albian-Present): Whose sedimentation was dominated by marginal clastic sedimentation with sparodic build ups between the Albian and Paleocene.

Stratigraphically, the Douala Sub-Basin is subdivided into seven Formations, ranging from Cretaceous to Recent (Fig. 2).

These Formations, as described by Nguene et al. (1992), Ngon Ngon et al. (2012) and Effoudou-Priso et al. (2014), consist of:

- The Barremian-Albian Mundeck Formation made up of sandstones;
- The Cenomanian-Campanian Logbadjeck Formation made up of sandstones, limestones and microconglomerates;

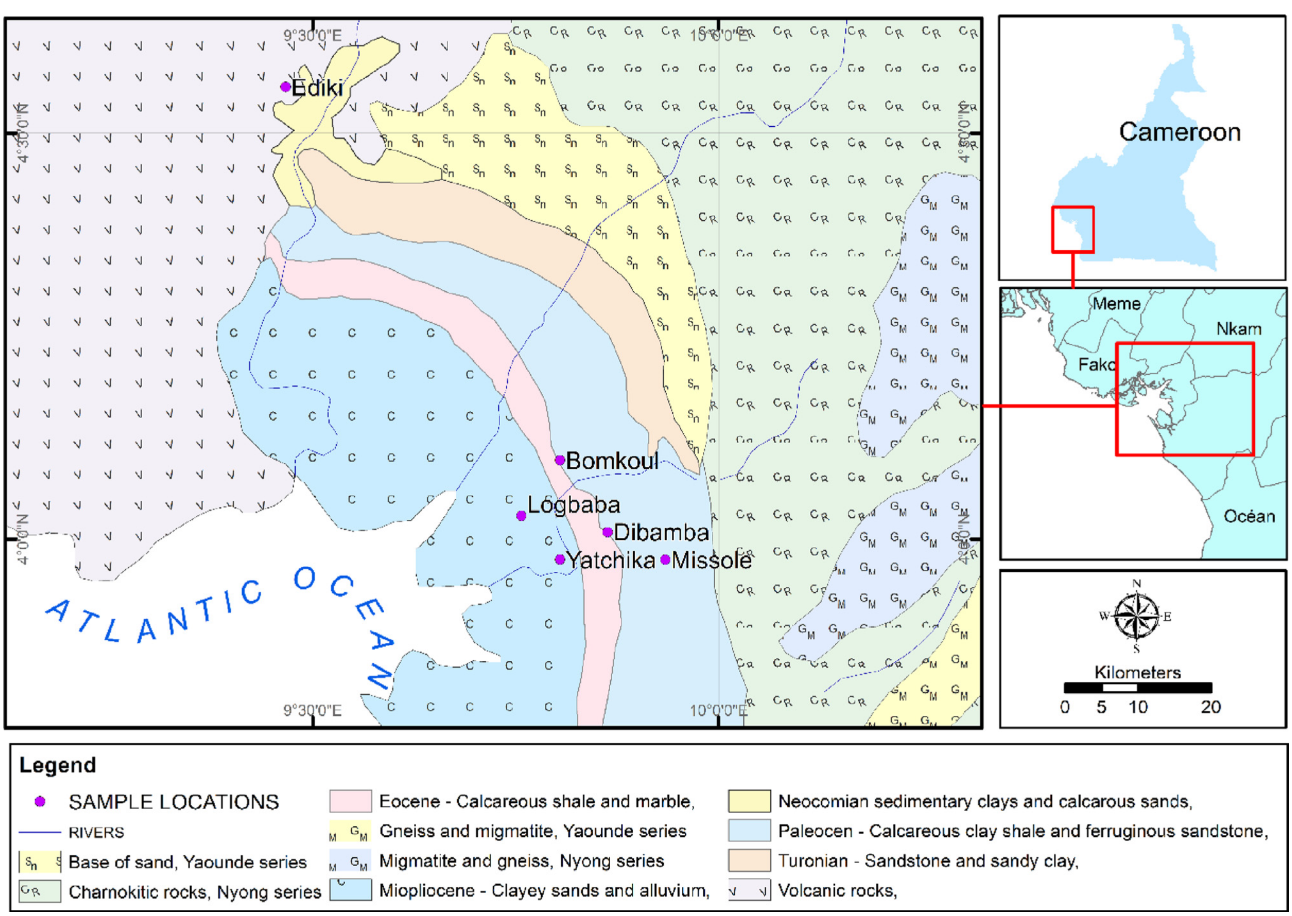

Fig. 1. Geologic map of the Douala Sub-Basin (Modified from SNH/UD, 2005).