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Research paper

Ti-bearing minerals in sedimentary kaolin deposits of Egypt

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ABSTRACT

Titanium (Ti) is a major impurity in the economic Carboniferous and Cretaceous sedimentary kaolin deposits in Egypt. The current study clarifies the distribution of Ti and its modes of occurrence in these deposits through petrographic, mineralogical, and geochemical investigations. It is found that Ti is present as an independent mineral phase rather than in the crystal structure of kaolinite. Ti occurs mainly as uniform very fine-grained and rounded anatase crystals in pockets within the kaolin mass of all deposits. Traces of rutile, leucoxene and ilmenite are present in the sand fractions. Average anatase content ranges between 1.4% and 3%. Cretaceous kaolin deposits show a homogeneous distribution of anatase regardless of the location (1.8 and 2.8%), while Carboniferous deposits are heterogeneous with the highest anatase content in the Abu Natash deposit (3%) and the lowest (1.4%) in the Khaboba deposit. The positive correlations between TiO_2 and some trace elements such Cr, Nb and Zr in the clay fractions, where anatase is the only Ti-bearing mineral, suggest the occurrence of most of such elements in the anatase structure.

The occurrence of anatase as uniform very fine-grained crystals as pockets within the kaolin mass, together with the presence of ilmenite and/or leucoxene in the sand fractions of the studied kaolin samples suggests an authigenic origin for the anatase as a result of post-depositional alteration of ilmenite precursor to leucoxene. The positive correlations between TiO_2 and trace element contents probably support this assumption. The higher trace element contents in the anatase from different deposits compared to the associated leucoxene and ilmenite are considered to result from relative enrichment of the immobile trace elements during the alteration of ilmenite and leucoxene to anatase.

1. Introduction

Titanium occurs in most soils and siliceous igneous, metamorphic, and sedimentary rocks, as structural Ti^{4+} in silicates and as free oxides. The amount of Ti varies from less than 0.5% in little weathered soils of temperate regions to as much as 25% in the highly weathered ferruginous latosols of Hawaii (Sherman, 1952). Much of the Ti in the finer particles occurs in secondary minerals such as leucoxene (TiO_2–nH_2O) and anatase (TiO_2). In coarse silt and very fine sand Ti mainly resides in primary minerals such as rutile and brookite (TiO_2), sphene (CaSiTiOs) and ilmenite ($FeTiO_3$) (Sayin and Jackson, 1975).

In some commercial kaolin deposits, Ti content can amount to several percent by weight (Murad and Koster, 1999). "Part of the Ti may be incorporated in the kaolinite structure, but significant proportions are often bound in accessory titaniferous minerals. Ancillary minerals whose association with kaolinites has been frequently reported are the TiO_2 polymorph anatase, rutile and brookite. Leucoxene, a grayish white alteration product of ilmenite that usually consists of aggregates of fine-grained anatase and/or rutile, often associated with Fe-bearing phases such as pseudorutile ($Fe_2^{3+}TiO_9$) and Fe oxides, is another common accessory. Many of these minerals contain iron either as an essential or a minor constituent and may, therefore, reduce kaolin whiteness. Titanium and Fe furthermore affect the color of porcelain, so that the presence of titanium minerals can have a notable effect on the economic value of commercial kaolin deposits" (Murad and Koster, 1999). As the Ti-bearing phases, particularly anatase, are essential constituents in sedimentary kaolin deposits, source and origin of anatase have been widely considered (e.g. Grey and Reid, 1975; Force, 1991; Schroeder and Shiflet, 2000; Schroeder et al., 2004). However, the source of Ti and origin of anatase are still a controversy (e.g. Schroeder and Shiflet, 2000; Schroeder et al., 2004).

According to Baioumy and Gilg (2011) and Baioumy et al. (2012), sedimentary kaolin deposits of predominantly Carboniferous or Cretaceous age are widely distributed in Egypt in various localities in the Sinai and Aswan areas, and include different kaolin lithologies (flint, pisolitic and plastic kaolin deposits). These deposits are exploited for domestic, industrial applications in Egypt such as ceramics, tiles and chemicals (e.g. Youssef, 1993, 1994, 1996; Abdel-Khalek et al., 1996; Youssef et al., 1997). No systematic work has been published on the distribution and modes of occurrence of Ti in these kaolin deposits as one of the factors that determine their economic value and industrial

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application. Bulk kaolin samples, clay fractions (<2 μm), and sand fractions (>63 μm) from selected sedimentary kaolin deposits in Egypt were examined by petrographic, mineralogical, and geochemical methods in order to clarify the distribution of Ti in these deposits and to specify the modes of occurrence of the Ti-bearing phases. The results provide information on the possible source(s) of anatase in the sedimentary kaolin in Egypt and its genesis. This finding has implications for development of kaolin deposits in Egypt where the sources of titanium and the significance of anatase in kaolin deposits remain controversial (e.g. Abdel-Khalek et al., 1996; Youssef et al., 1997).

2. Geology of sedimentary kaolin deposits in Egypt

Carboniferous and Lower Cretaceous sedimentary kaolin deposits of Egypt are widely distributed in Aswan and Sinai areas (e.g. Baioumy and Gilg, 2011; Baioumy et al., 2012; Baioumy, 2013). The Aswan deposits are located approximately 105 km southwest of Aswan at Wadi Kalabsha area covering an area of about 7 km^2. Said and Mansour (1971) distinguished three lithological units at Wadi Kalabsha area with a total thickness of nearly 28 m (Fig. 1A, from Baioumy and Gilg, 2011). The Lower and the Upper Sand Members enclose the Wadi

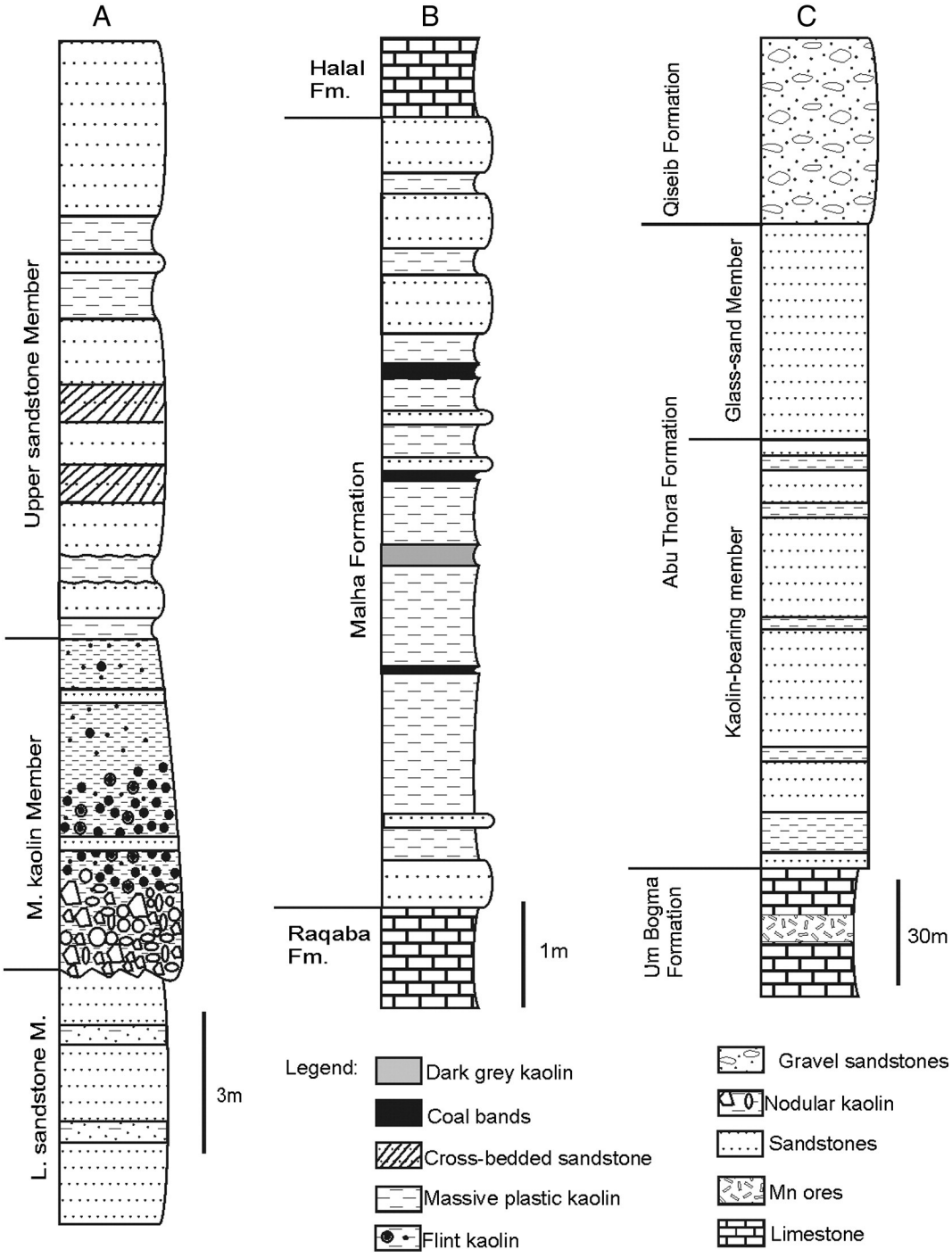

Fig. 1. A) Lithostratigraphy of the kaolin deposits in the Aswan area. B) Lithostratigraphy of the Lower Cretaceous kaolin-bearing Malha Formation in the Sinai Peninsula. C) Lithostratigraphy of the Carboniferous kaolin-bearing Abu Thora Formation in the Sinai Peninsula.

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