Chemie der Erde 74 (2014) 195–203

Contents lists available at ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Geochemistry and origin of the Cretaceous sedimentary kaolin deposits, Red Sea, Egypt

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ARTICLE INFO

Article history:
Received 21 January 2013
Accepted 28 June 2013
Editorial handling - Prof. Dr. K. Heide

Keywords:
Sedimentary kaolin deposits
Red Sea
Mineralogy
Geochemistry
Source

ABSTRACT

This work reports, for the first time, the mineralogical and geochemical characteristics of the Cretaceous sedimentary kaolin deposits in the Red Sea area, Egypt and sheds the light on their source. Mineralogical and geochemical analyses of both bulk deposits and the sand and clay fractions of these deposits indicated that they are composed of kaolinite (average of 75 wt.%) and quartz (average of 22 wt.%). Traces of anatase (average of 1 wt.%) were identified in all kaolin samples, while traces of halite (average of 2 wt.%) and hematite (average of 1 wt.%) were reported in the majority of the analyzed samples. The clay fractions show relatively high contents of TiO_2 (average of 2.1%), Ni (average of 103 ppm), Nb (average of 98 ppm), Y (average of 67 ppm), and Zr (average of 630 ppm). Sum of the rare earth elements (ΣREE) in the clay fractions varies between 193 and 352 ppm. Chondrite-normalized REE patterns show enrichment of the light REE relative to the heavy REE ($(La/Yb)_N = 9$) and negative Eu anomaly ($Eu^*/Eu = 0.67$).

Major, trace, and rare earth elements geochemistry of the clay fractions from the studied kaolin deposits suggested that these deposits were derived from a mixture of more than source rocks probably a mixture of mafic, granitic, and alkaline rocks. The contribution of granitic rocks was proposed based on the REE pattern and negative Eu anomaly as well as the high Zr and Y contents, while the contribution of mafic rocks to the source was suggested based on the relatively high TiO_2 and Ni contents. The abnormally high Nb contents in the clay fractions of the Red Sea kaolin deposits indicated a contribution of alkaline rocks to the source of these deposits. Igneous and metamorphic rocks of different composition belonging to the Arabian-Nubian Shield are located very close to the studied deposits.

The monomineralic nature of the Red Sea kaolin deposits as kaolinite, abundance of organic matter, and absence of any marine fossils suggested a non-marine depositional environment of these deposits. Occurrence of halite in the studied deposit is probably due to sea breezes since the studied deposits are located close to the Gulf of Suez.

1. Introduction

Sedimentary kaolin deposits are usually drawn from the deposition of kaolinite formed elsewhere (e.g. Schroeder and Shiflet, 2000; Schroeder et al., 2004; Murray, 1988; Piper et al., 2008). Kaolin deposits occur in a wide range of lithologies (e.g. laterites, bauxites, and altered igneous and metamorphic rocks) and form in various depositional environments (e.g. tropical soils, flood plain deposits) (Dill et al., 1997). The geochemistry of sedimentary kaolin deposits are controlled by many factors including: (1) the detrital minerals such as quartz, feldspars, zircon, rutile, and leucoxene that reflect the source area composition, (2) the newly formed minerals during weathering including kaolinite and non-clay minerals such as anatase, and (3) postdepositional alterations including diagenesis and weathering. Some attempts have been postulated to examine the source of kaolin deposits and their origin based on their geochemistry. For example, Dombrowski (1982) and Dombrowski and Murray (1984) used the Th and Co concentrations in the Georgia sedimentary kaolin deposits to distinguish kaolin deposits derived from granites and gneiss from those derived from phyllite and schist. Dill et al. (1997) used the P/S, Zr/Ti, (Cr + Nb)/(Ti + Fe) and (Cr + Y + La)/(Ba + Sr) ratios to discriminate between hypogenic and supergenic kaolinitization processes. Piper et al. (2008) used major, trace and rare earth elements geochemistry to identify provenance of clastic sediment.

Sedimentary kaolin deposits are widely distributed in many parts of Egypt (e.g. Aswan, Red Sea, and Sinai) of different ages (e.g. Carboniferous and Cretaceous). Baioumy and Gilg (2011) and Baioumy et al. (2012) studied the mineralogy and geochemistry of sedimentary flint kaolin from Aswan area and Carboniferous and Cretaceous kaolin deposits in Sinai region, respectively. In these studies, the mineralogy and geochemistry of these deposits were

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0009-2819/$ – see front matter
http://dx.doi.org/10.1016/j.chemer.2013.06.008

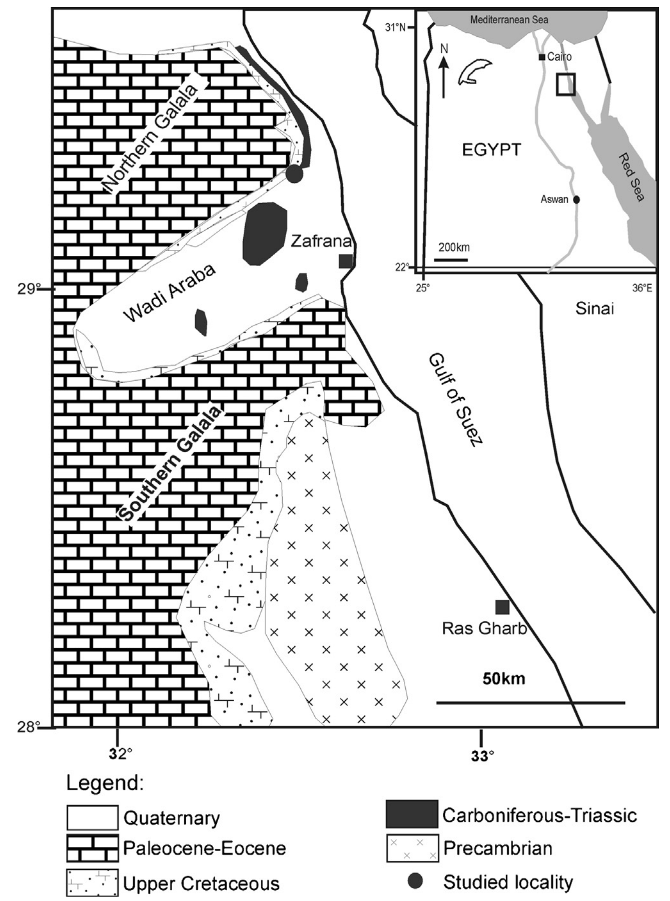

Fig. 1. Location and geological map of the Abu Darag area (from Scheibner et al., 2003).

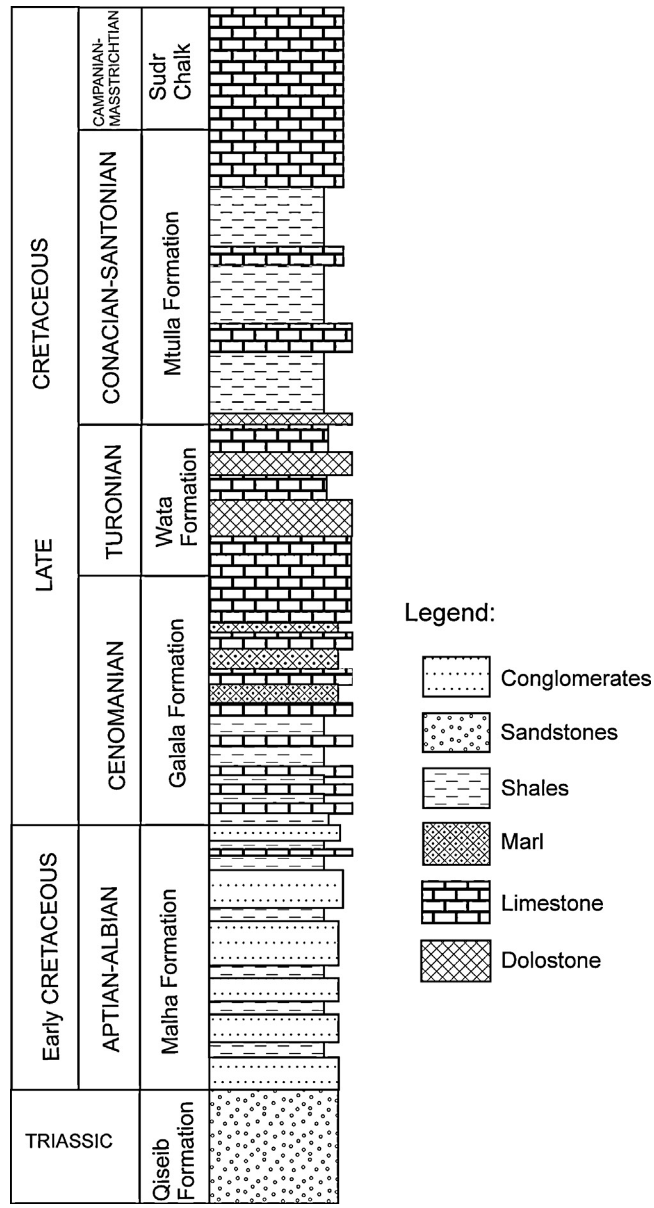

Fig. 2. Lithostratigraphy of the sedimentary sequence at the Abu Darag area (from Abd El-Azeam and Metwally, 1998).

used to discuss their source rock compositions. Although the lower Cretaceous sedimentary kaolin deposits in the Red Sea region have some economic significance and are exploited for domestic industrial applications in Egypt (e.g. for refractories, ceramics, and white concrete industries), nothing has been published on their mineralogical geochemical characteristics as well as their source and origin. This work presents, for the first time, the mineralogy as well as the geochemistry of major, trace and rare earth elements of the bulk deposits and clay fractions from the Cretaceous deposits from the Red Sea area. Unlike many of the previous investigations that used the geochemistry of bulk sediments, the current study included the geochemistry of clay fractions along with the bulk kaolin deposit.

2. Location and geology

The lower Cretaceous sedimentary kaolin deposit in the Red Sea region occurs at the Abu Darag area that is located approximately 85 km south of Suez City (Fig. 1) at latitude 29°20′70″ N and longitude 32°29′17″ E. It belongs to the Nubian Sandstone sequence that outcrops on both sides of Wadi Araba, which is bounded in the north and south by the Galala plateaus and in the east by the Gulf of Suez (Fig. 1; Said, 1990).

The kaolin bed is approximately 17.8 m thick and occurs as part of the lower Cretaceous Malha Formation (Fig. 2) of Albian age (Abdallah et al., 1963). Lithologically, the Malha Formation consists of sandstones, siltstones, claystones, kaolin, and some carbonates. Some of the claystone and siltstone beds in the lower part are richly fossiliferous with plant remains and Albian foraminifera, whereas the claystone beds of the upper 10 m contain early Cenomanian foraminifers (Awad and Abdallah, 1966). Bachmann et al. (2003) described the Cretaceous kaolin-bearing formation (Malha Formation) as delta-dominated facies and Abdallah et al. (1963) considered the Malha Formation as continental sandstone. The Malha Formation is overlain conformably by the Galala Formation in all of its exposures in the Northern and the Southern Galala Plateaus. The Galala Formation is the most obvious unit in the Northern Galala scarp, characterized by its yellowish-green color and its content of macrofossils. It is also distinguished by its transitional character between the Lower Cretaceous-Jurassic-Paleozoic clastic sequence below and the Upper Cretaceous-Tertiary carbonate succession above. Lithologically, the Galala Formation was subdivided into a thick lower part consisting of shales and marls with minor limestone and dolostone interbeds and an upper part consisting collectively of limestone and dolostone beds (Atta, 1992). It is overlain conformably by the Adabiya Formation through the Northern Galala and Gabal Ataqa, while to the south of Wadi Qiseib at Abu Darag area and in the entire scarp of the Southern