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Research Paper

Characterization, firing behavior and ceramic application of clays from the Gabes region in South Tunisia

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ABSTRACT

In this study, a part of paper has been conducted on geological survey of Gabes clays and their surroundings; so we can focus on the highest thicknesses of clay sediments, for subsequent investigation or exploration. The greatest part of work focuses on the mineralogical, chemical, physical, and geotechnical tests carried out on Creatceous clays collected from the Zimlet El Beida in Gabes area (South-eastern Tunisia). Firing behavior and ceramic application are also conducted for these clay materials. The mineralogy study shows illitic clays; however, other clay minerals, such as kaolinite, mixed-layer I/Sm and chlorite are also present. The mineralogical phases during the firing process were recorded at 300, 600, 800, 1000 and 1150 °C for 3 h with heating rate of 10 °C/min. The main transformations were observed at 1000 °C with the appearance of new crystalline phases, such as diopsite, cristobalite, mullite and spinel. The chemical analysis indicates that these clays are notably siliceous. The alkali content ($K_2O + Na_2O$) is high (~ 4.13%), thus explaining why these clays can be fired at relatively low temperatures. The amount of alumina and iron oxide, with an average of 16.42 and 7.07% respectively, is variable. The tests show that these clays have medium plasticity values (PI = 14–20%). The firing shrinkage and the expansion are limited. A lower firing and drying temperature can be translated into significant energy savings. Technical tests show that the properties fall within the ceramic International Standards (ISO). Ceramic tiles made of these clays have appropriate characteristics without defects and can be classified in group BIII and BIIb according to the European Standard NF EN 159 (1991).

1. Introduction

A study conducted by Clarke and Washington (1924) on the composition of the earth's crust was based on 5920 geochemical analyses. The work included averages grouped by geographical areas as well as figures for the crust of the earth as a whole. Averages of analyses grouped on a geographical basis were found to agree fairly well from one area to another, provided the areas chosen were large enough to eliminate local variations. Clays are substances found throughout the earth's surface, as they are the main component of sedimentary rocks and they constitute >70% of sedimentary rocks (Clarke and Washington 1924). Because of their frequency of occurrence, they are used by man as raw materials in many industries such as ceramic, paper, petroleum industry, pharmaceutical formulations, medical treatment, catalysis, clarification of various effluents, paint, rubber, etc. (Chang Luke, 2002). The suitability of different clays in different applications is strongly dependent on its mineralogical and chemical compositions, physical properties, structure, plastic, and thermal behavior (Grim, 1962, 1968; Mandour et al. 1989; Gualtieri et al. 2010; Dondi et al. 2014). For most of the cases, clays have been used to produce bricks and earthenware tiles in Tunisia. Today, there is an increase in construction activity. The industries cannot meet the ever-increasing market demand for the construction materials needed.

The study area, named Zimlet El Beida (Gabes, south-east Tunisia), is selected for this exploration and considered as: potential deposits for the following reasons; (i) Few studies have been carried out of the clays or of raw materials used for traditional ceramic, especially in South Tunisia. (ii) The study sector is easily accessible by road and by footpaths from nearby towns like Gabes, Gafsa, Ouedref, El hamma, and Menzel El Habib. (iii) The extent of the clayey outcrops and the location are near to energy sources (water, gas and electricity).

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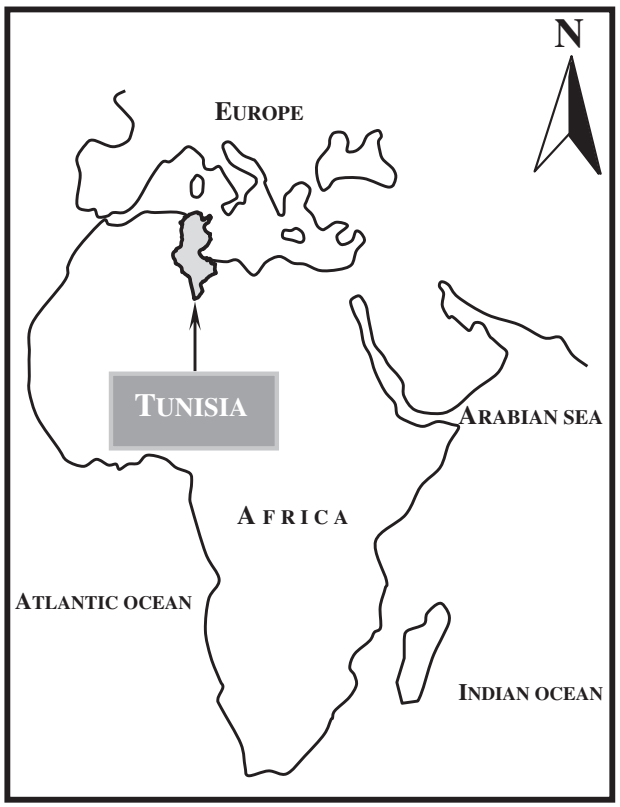

Fig. 1. The geographic location of the studied sector.

The principal aim of this study is the characterization and the assessment of potential use of clay deposit in the ceramic industry which will encourage businessmen to invest in this region.

2. Materials and methods

2.1. Sampling and samples

The present study was carried out in red and green colour clay series. They were collected from the base of the Bouhedma formation in the Lower Cretaceous (Hauterivian-Barremian) outcroppings, widely exposed in the Jebel Zimlet El Beida. We collected ten samples of clays named from the base ZEB1 to top ZEB10 (five samples from the red clays: ZEB1 to ZEB5 and five samples from the green clays ZEB6 to ZEB10).

No < 50 kg of clay sediments were sampled by digging a pit or using a hand auger and they were blended and quartered into 5 kg aliquot to ensure a representative sample for laboratory assessment including identification of clay properties and industrial tests. After homogenization, they were initially dried at 105 °C until a constant weight was obtained, and then they were powdered for 30 min to pass through a 100 μm sieve prior to laboratory analysis.

To prepare the oriented aggregates, the raw material was completely decarbonated by adding a small amount of 1 N HCl, and treated with H_2O_2 to eliminate any organic matter. The material was washed five times with 1 N NaCl and excess salt was removed by dialysis. The fraction <2 μm was separated in a centrifuge and the suspension was dried at 60 °C (Grim, 1962; Środoń, 1981; Bergaya et al., 2006).

Specimen tiles 100 × 50 × 5 mm^3 were prepared using 60 g of green material per test piece by pressing (6–7% water), kept at room temperature for a day, then oven-dried 24 h at 105 °C (standard ISO 13006, 1998).

2.2. Methods

The mineralogical composition of bulk samples and on the oriented aggregates (natural (N) and treated with ethylene glycol (EG) and heated to 550 °C for 2 h (H)) were recorded on a Philips X'Pert diffractometer using CuKα radiation (1.5418 Å). The accelerating voltage and filament current were maintained at 40 kV and 40 mA, respectively. The powder samples were mounted on the sample holder with very little pressure. Oriented samples were prepared by depositng the clay suspension on to a glass slide as discussed by Środoń et al. (1986). Samples were scanned from 2° 2θ to 70° 2θ for bulk and <2 μm fraction. The percentages of the different mineral phases were estimated by measuring the areas of representative peaks, using X'Pert HighScore Plus software and PDF-4 (JCPDS-ICDD data base). The standard deviation was ± 5%.

The chemical compositions were determined by atomic absorption spectroscopy. The loss-on-ignition was evaluated from the weight difference between samples heated at 100 °C and 1000 °C for 2 h. The results are expressed in concentration percent of oxides.

The specific surface area was determined with the methylene blue index method. A suspension of 10 g of powdered clay and 100 ml of

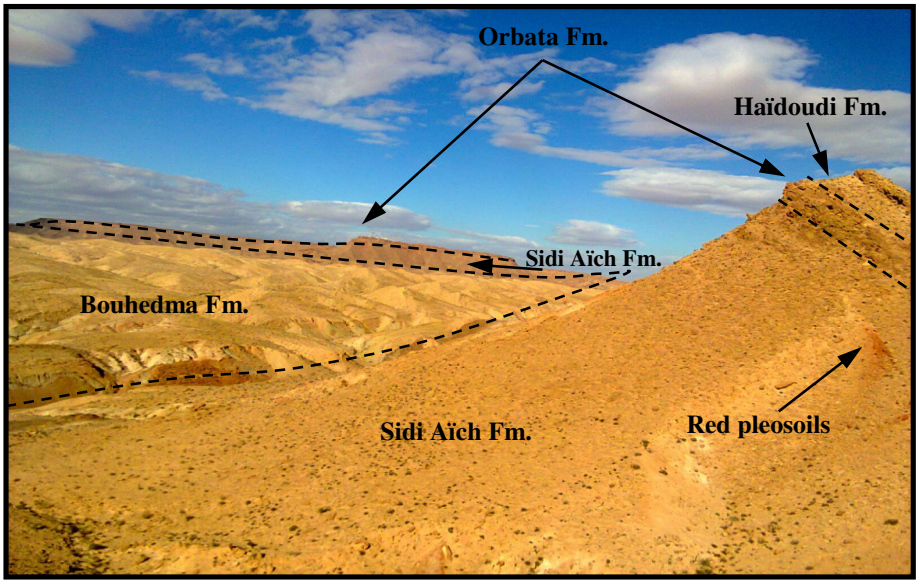

Fig. 2. Panoramic view of the studied sector.

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