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Geological and Mineralogical Study of the Clays of Boumaiza Northeast of Algeria

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Abstract: This study concerns with clay deposits, occurring at Boumaiza Northeast of Algeria, due to the significance of clay in manufacture. To meet the objectives of the study, data from both field and laboratory are collected the field data includes geological investigations and samples collection, whereas the laboratory data consists of several analytical techniques (XRD, infrared absorption spectroscopy, chemical analysis, determination of the humidity, determination of the loss on ignition, porosity and granulometric analysis). The geological results show that these clays are associated with the Numidian flysch of the Edough complex and the laboratory results reveal that the illite is the dominant clay mineral, quartz, kaolinite, montmorillonite are also present, the size of clay particules is between 2 and 10 μm, the samples contain a low content of carbonates and show an important vacuum. These clays could be used for the fabrication of various ceramics especially, bricks and tiles, it may also be used in environmental protection by immobilizing polluants.

Key words: Clays, illite, numidian flysch, Edough complex, Algeria

INTRODUCTION

Boumaiza is situated in the Northeast of Algeria, at 10 km far away from the village of Berrahal, in the South the terrain is limited by the national road 44, the railroad (Annaba-Constantine) (Fig. 1). The climate of the region is wet Mediterranean type, with tepid wintry season (average temperature 12°C) and rainy (700 mm year^{-1}) and of warm and dry summer (diurnal temperature 26-38°C) (Bouasla, 2005).

The clays of Boumaiza are now worked in the Boumaiza quarry for the manufacture of the renowned Boumaiza red bricks and tiles (Bouasla, 2005).

The aim of this study, was to reveal the geological context and the physicochemical properties of these clays.

Geological setting: Geologically Boumaiza belongs to the Edough Massif. The Edough Massif is the eastern most metamorphic complex of the Algerian coast and has been subjected of several geological studies (Gleizes *et al*., 1988; Hammor and Lancelot, 1998; Hily, 1962; Marignac, 1985; Marignac and Zimmermann, 1983; Villa, 1970). The core complex of the Edough is composed of a variety of Neoproterozoic and Palaeozoic metamorphic rocks, distributed in a NE-striking antiform (Fig. 2), the Gneisses which form the core are cal-alkaline rocks (Ahmed-Said and Leak, 1997). The metapelites overlying the gneisses consist of two units: Garnet-or, more commonly, Kyanite-mica schiste alterning with metric slabs and layers of marble and skarns and a Paleozoic upper unit (Ilavsky and Snopkova, 1987) comprising andalousite-bearing aluminous schists alternating with feldspathic quartzites, these rocks have undergone a polycyclic metamorphism, from HP-HT conditions (cycle 1) to medium P-T conditions (cycle 2) and finally to LP-HT (cycle 3) conditions (Hammor, 1992), the Edough is part of the internal zone of the north African Alpine Belt, whose current position is believed to be a consequence of Oligo-Miocene subduction and collision in the western Mediterranean between the African and European plates (Auzende *et al*., 1975; Bouillin, 1978, 1986; Cohen, 1980; Carminati *et al*., 1998).

Sedimentary nappes covering some parts of the Edough metamorphic complex consist of Upper Cretaceous Maestrichtian; Marignac and Zmmermann (1983) and Numidian Oligo-Miocene; Lahondère *et al*. (1979) flysch. The clays of Boumaiza are within this

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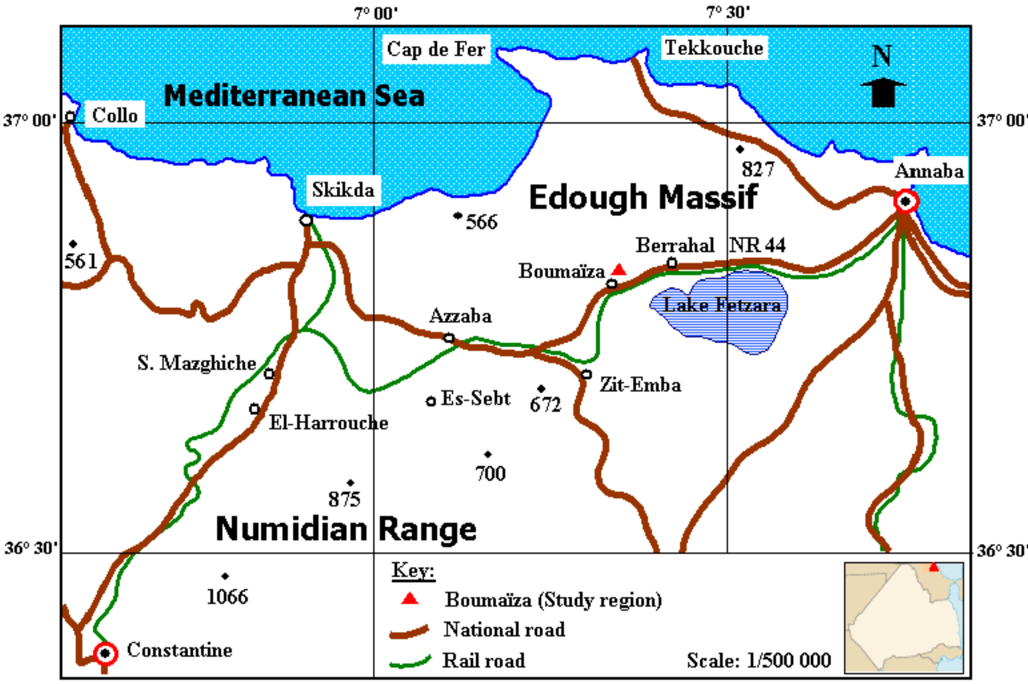

Fig. 1: Geographic situation of the region of Boumaiza

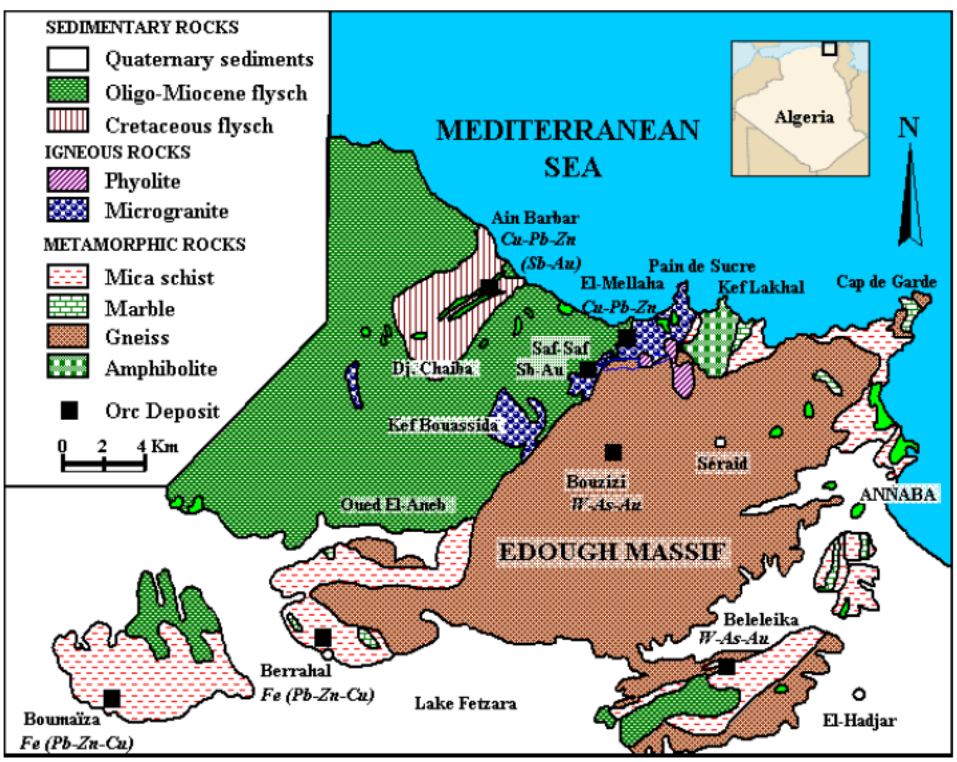

Fig. 2: Geological map of the Edough massif, Annaba modified after (Hilly, 1962)

Numidian flysch (Hilly, 1962; Villa, 1970), the numidian flysch contains from the bottom to the top.

The numidian clays: This term is a classical geological term used in Algeria which includes diverse sort of clays

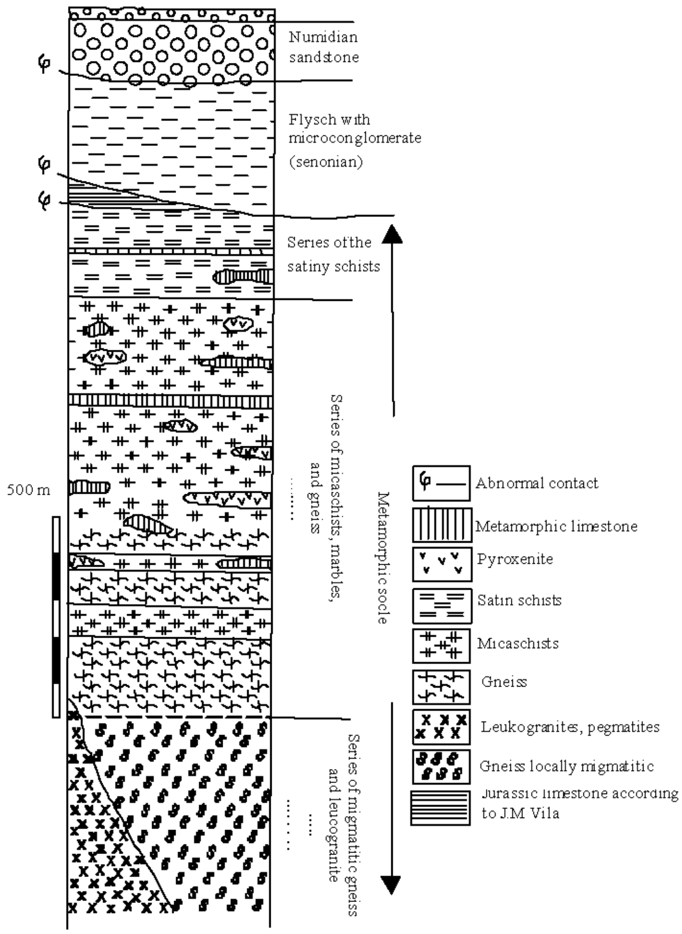

Fig. 3: Lithostratigraphic column of the Edough massif (Aissa, 1985)

and argillites, the tint and the aspect of these clays are very changeable: grey, blue grey, black, greenish, reddish… etc. they can be looses or very hard to split in plaques in prisms or in baguettes this numidian clays admit a little thick benches of quartzites and sandstone (Hilly, 1962).

Numidian sandstone: Of aquitanian to lower burdigalian.

Clear marl, silexites: Of Burdigalian age (Fig. 3).

MATERIALS AND METHODS

Several samples were taken from the study area; the most significant due to the aim of study were studied in details.

X-ray diffraction: X-Ray Diffraction (XRD) data were obtained using a philips® PW 1710 diffractometer equipped with CU Ká radiation source and operated at 40 kV/40 mA, all XRD data were collected under the same experimental conditions, in the angular range $3° \le 2 \le 45°$ with counting time 47 m 37 s, to identify clay mineral associations and Brown (1980) and Velde (1992).

Infrared absorption spectroscopy: To provide adequate characterization of a clay mineral by infrared spectroscopy, the spectrum should be recorded over the range 4000-250 cm^{-1} and if it is possible to 200 cm^{-1}, for it 2 samples were tested the kaolinite resulting from KPLC (Kaolinite, Porcelain, Ceramic of limoges) as well as the natural clay of Boumaiza, 1 mg of every clay is palletized in 200 mg of potassium bromide (Yariv, 1975). The spectrums were registred between 4000-600 cm^{-1} by means of spectrometer Perkelin Elmer 297 (Wilson, 1987).

Chemical analysis: The samples were mixed with double carbonate of Na and K for chemical analysis. The ignition loss was measured by calcinations at 1000°C (Mallem, 1997).

Determination of the humidity: The humidity was determined by difference in weight of an empty watch glass and its increased weight by 1 g of clay, after stoving between 100±2°C during 24 h.

Porosity: The porosity is in close relationship with two characteristic values D_r and D_a which are respectively the real density and the apparent density. D_r could be measured with precision using a pycnometer of comparison D_a could be measured with a mercury porosimeter. The porosity p was given by the following formula:

$$P = \frac{D_r - D_a}{D_r} \times 100$$

(Marc and Jacques, 2006).

Granulometric analysis: It has been determined by using a Mastersizer Malvern particle size analyser.

RESULTS AND DISCUSSION

X-ray diffraction: The obtained diffractogram (Fig. 4) represents peaks of variable intensities; the most intense peaks correspond to a given mineralogy, the comparison of these rays with those of clays standards shows that our clay is a mixture consisting mainly of: Quartz, illite, kaolinite, montmorillonite (Table 1) (Bouchet *et al*., 2000).

This mineralogy was explained as a result of a detrital sedimentation without alteration of minerals (Hilly, 1962). The high percentage of quartz is a serious probleme in the manufacture of red brick, because on one hand the quartz is very hard, so it exerts an intense abrasive action on the machinery of preparation and mouling, on the other hand during baking the quartz performs an important variations of volume very different from those of clay, this causes a significant reduction in the resistance of the baked brick (Ferdand and Lietti, 2004; Bergaya *et al*., 2006).

Infrared spectroscopy: The characteristic bands of the mineral elements are situated towards low wave lengths (Fig. 5) for the kaolinite coming from KPLC, spectra (a) we obtain the following characteristics: The bands of absorption situated in 3694, 3620 and 3440 cm^{-1} correspond to hydroxides according to their places in the crystal lattice: the bands 3694 cm^{-1} corresponds to OH the least connected to the structure. The band 3620 cm^{-1} corresponds to OH which is between tetrahedral layers Si_2O_5 and octahedral layers $Al(OH)_6$, the band 3440 cm^{-1} would correspond partly to the vibration of OH valence located in the defects of the crystalline structure, the bands of absorption situated in 1000 cm^{-1} correspond to SiO (the quartz is characterized by the bands of absorption of 1000-470 cm^{-1}).

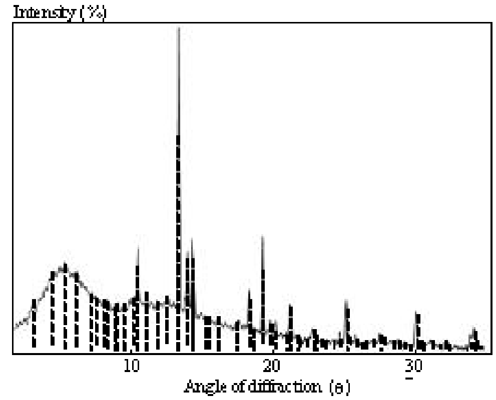

Fig. 4: Diffractogram of the clay of Boumaiza

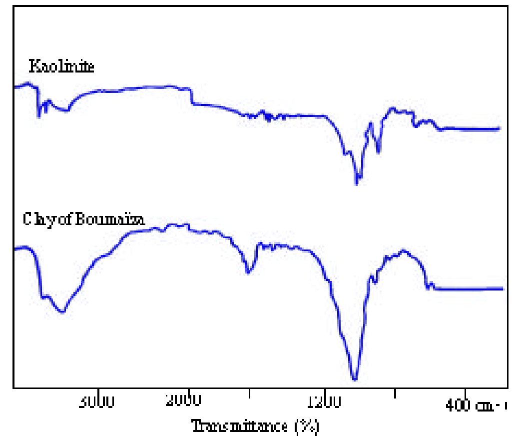

Fig. 5: Spectre of infrared absorption

Table 1: X-ray diagram, principles rays

θ (°)	d (A°)	Intensity (%)	Possible confusion with
10.24	4.33	36	Illite-montmorillonite
13.40	3.32	100	Illite-montmorillonite, Illite 2 M, 1 Quartz
19.30	2.33	40	Kaolinite-Montmorillonite Kaolinite 1 Md and 1 A
20.20	2.23	15	Illite 1 M

For Boumaiza, spectra (b), we obtain the following characteristics the bands of absorption situated between 3200-3800 cm^{-1} correspond to the grouping hydroxides with a protuberance in 3635 cm^{-1} the band which is situated towards 1630 cm^{-1} corresponds to the vibrations of deformations H-OH due to the adsorbed water molecules. At 961 cm^{-1} we can observe the vibrations (Al-OH) the resolution of the device being weak we cannot have a representative spectre of our clay, for example in 550 cm^{-1}, we do not observe the vibrations of deformations corresponding in Si-O-Al. (Wilson, 1987).

Chemical analysis: The calculated results are grouped in (Table 2). As can be seen from this Table 2 the most

Table 2: Chemical composition of the clay of Boumaiza

Elements	(%)
SiO_2	60.4±2.50
Al_2O_3	25.5±1.50
CaO	1.7±0.10
Fe_2O_3	5.9±0.90
C	0.9±0.10
S	0.04±0.01
MgO	Traces
MnO	Traces

important percentages are those of SiO_2 and Al_2O_3 dominating elements of a clay soil this in addition specifies the argillaceous nature of the ground of Boumaiza besides percentages in carbonates are weaks sign of absence or weak presence of humic substances. The value of the loss on ignitionis equal to 7.2% (±0.2), this value shows the existence of volatile organic matters why not dissociable carbonates in the form of carbonic gas (Mallem, 1997).

Humidity and porosity: The results indicated that the humidity is equal to 1.89% (±0.09), this value of humidity is a weak water residual value, taking into account the possibility of swelling of the clay.

The porosity is equal to 32.04% this value indicates that there is an important vacuum.

Granulometry: The results of this method are shown in Fig. 6. This Fig. 6 shows 2 types of curves: The granulometric and cumulative curve. The granulometric curve presents a histogram whose envelope is a bell-shaped curve of Gauss; it shows that the major part of particles have a size between 2 and 10 μm. the cumulative curve, presented like the first one in semi-logarithmic diagram allows to calculate two principal granulometric parameters: The characteristic diameter d_x and the coefficient of uniformity U. The characteristic parameter d_x in μm, is measured by the value read in x-coordinates corresponding to a percentage in total weights, arbitrarily chosen in ordinates. The most used is the effective diameter d_{10}, obtained by the value 10%. From Fig. 6, $d_{10} \approx$ 1.5 μm.

This diameter expresses the weight of the granulometric phase equal to 10% of the total weight of the sample. The value d_{10} was fixed conventionally by studies in laboratory, by considering just the fine grains pulled by water in movement block the pores thus reducing their dimensions. Other characteristic diameters can be calculated as the diameter d_{60}, from which we can estimate the coefficient of uniformity U which attributes a numerical value to the slope of the curve, it is calculated by the formula $U = d_{60}/d_{10}$.

By convention if U lies between 1 and 2, the granulometry is known as uniform. If it is higher than

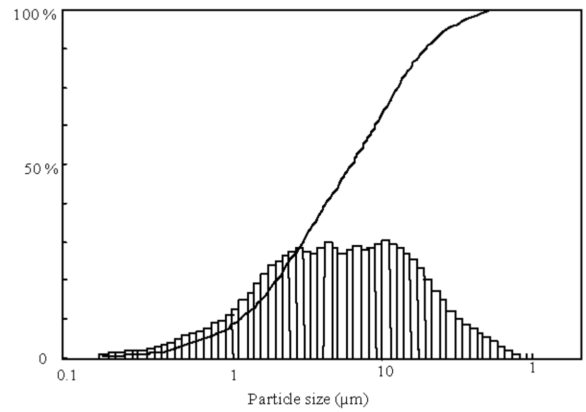

Fig. 6: Percentage of the sizes of particles

2 it is varied. For our case and according to the Fig. 5, U = 6, what implies that the granulometrie is varied.

CONCLUSION

The study showed that: Geologically the clays of Boumaiza are considered as Numidian clays, associated with the Numidian flysch of the Edough massif. The mineralogy of these clays is predominated by quartz and illite. In an industrial point of view, this clays could be used for fabricating red bricks and tiles (Ferdand and Leietti, 2004). These clays may be used in environmental protection (Mallem, 1997).

RECOMMENDATION

Finally, we recommend finer studies as regards, the evaluation of reserves of these clays, it would also be necessary to prceed to ceramic attempts for the improvement of lower qualities.

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REFERENCES

Ahmed-Said, Y. and B.E. Leake, 1997. The petrogenesis of the Edough amphibolites, Annaba, NE Algeria: Two unrelated basic magmas and the Iherzolite-harzburgite residue of a possible magma source. Mineral. Petrol., 59 (3-4): 207-237.

Aissa, D.E., 1985. Studies of the indexes and metalliferous deposits of the massif of the massif of Edough, Ph. D Thesis, USTBH, Algiers, pp: 134.

Auzende, J.M., J. Bonnin and J.L. Olivet, 1975. The northern African margin considered as an active margin. Bull. Geolog. Soc. France, 7 (4): 486-495. Accession No: 1976-044714.

Bergaya, F., B.K.G. Thend and G. Lagaly, 2006. Clays in industry. Handbook of clay Science. Development in Clay Sciences, Elsevier Ltd, 1: 10. DOI: 10.1016/S1572-4352(05)01015-9.

Bouasla, S., 2005. Contribution to the study of the clays of Boumaiza, State engineering dissertation. University of Badji Mokhtar Annaba, Algeria, pp: 83.

Bouchet, A., A. Meunier and P. Sardini, 2000. Clay minerals: Crystalline structure, identification by X-ray diffraction. Book Review. Clays Clay Minerals, 50 (2): 294-295.

Bouillin, J.P., 1978. The Collo-El Milia transverse (Lesser Kabylia), a key region for the interpretation of the Alpine tectonics of the littoral chain of Algeria. Bull. Geolog. Soc. France, 57 (135): 84. Accession No: 1980-014612.

Bouillin, J.P., 1986. The maghrebin basin: A former limit between Europe and Africa to the West of the Alps. Bull. Geolog. Soc. France, 2 (4): 547-558. Accession No: 1988-002426.

Carminati, E., M.J.R. Wortel, W. Spakman and R. Sabadini, 1998. The role of slab detachement processes in the opening of the western central Mediterranean basins: Some geological and geophysical evidence. Earth Planetary Sci. Lett., 160 (3-4): 651-665. PIIS: 0012-821X(98)00118-6.DOI:10.1016/S0012-821X(98)00118-6.

Cohen, C.R., 1980. Plate tectonic model for the Oligo-Miocene evolution of the Western Mediterranean. Tectonophysics, 68 (3-4): 283-311. DOI: 10.1016/0040-1951(80)90180-8.

Ferdand, S.A. and Leietti, 2004. Guide for ceramics, standards and technical characteristics. Soin and Monthey, pp: 11.

Gleizes, G., J. Bouloton, G. Bossière and P. Collomb, 1988. New lithological and petro-structural data on the Edough metamorphic massif (Eastern Algeria). Reports of the Academy of Sciences. Paris, 306 (14) (serie II): 1001-1008. Accession No: 1990-071066.

Hammor, D. and J. Lancelot, 1998. Miocene metamorphism of Pan-African granites in the massif of Edough (North-East of Algeria). Reports of the Academy of Sciences, Paris. Earth and Planetary Sci., 327 (6 serie IIA): 391-396. DOI: 10.1016/1251-8050(99)80015-9.

Hammor, D., 1992. From the pan-African to the Miocene: 600 My of polycyclic evolution in the massif of Edough (North-Eastern Algeria) recalled by petrology, tectonics and geochronology (U/Pb, Rb/Sr, Sm/Nd, 39Ar/40Ar). New thesis, University of Montpellier II, France (Unpublished).

Hilly, J., 1962. Geological study of the massif of Edough and Cap de fer (East-Constantinois). Publications of the Service of the Geological Map of Algeria (new series), 19: 408.

Ilavsky, J. and P. Snopkova, 1987. Discovery of Paleozoic Acritarchs in metamorphic rocks of the Edough massif (Wilaya of Annaba, Eastern Algeria). Reports of the Academy of Sciences, Paris, 305 (10 serieII): 881-884. Accession Number: 1991-055533.

Lahandère, J.C., H. Feinberg and B.U. Haq, 1979. Dating of the Numidian sandstones of Eastern Algeria: Structural consequences. Reports of the Academy of Sciences, Paris, 289 (4 serie D): 383-386. Accession No: 1980-037870.

Mallem, N., 1997. Study of the fixing of some mineral and organic compounds on a clay of Boumaiza. Msc. thesis. University of Badji Mokhtar Annaba. Algeria.

Marc, P. and G. Jacques, 2006. Handbook of soil analysis, mineralogical, organic and inorganic methods. Springer, Berlin New York, pp: 995. Library of Congress Control Number: 2005938390. ISBN: 10 3-540-31210-2

Marignac, C. and J.L. Zimmermann, 1983. Ages K-Ar of the hydrothermal event and the intrusions associated with the mineralized Miocene district of Ain Barbar (East Constantinois, Algeria). Mineralium Deposita, 18 (3): 457-467. Accession number: 1987-041101.

Marignac, C., 1985. Dike mineralisations of Ain Barbar (Algeria) a complexe of hydrothermalism related to the Alpine geothermic activiy in North Africa. Ph. D. Thesis (2 volumes), I.N.P. Lorraine, Nancy, France.

Velde, B., 1992. Introduction to clay minerals. Chapman and Hall. 1st Edn. ISBN: 0412370301.

Villa, J.M., 1970. The Edough massif, an external massif of the northeast of barbary. Bull. Geolog. Soc. France, 12 (5): 805-812. Accession number: 1972-037783.

Wilson, M.J., 1987. Determinative Methods in Clay Mineralogy. Chapman and Hall, New York. 1st Edn. ISBN: 0-412-00901-3, QE471.3.H36 1987.

Yariv, S., 1975. Some effects of grinding kaolinite with potassium bromide. Clays and Clay Minerals, 23 (1): 80-82. Accession No: 1976-044473.