C. R. Geoscience xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Comptes Rendus Geoscience

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Hydrology, Environment

The building stone of the Roman city of Dougga (Tunisia): Provenance, petrophysical characterisation and durability

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ARTICLE INFO

Article history:
Received 8 August 2017
Accepted after revision 21 September 2017
Available online xxx

Handled by François Chabaux

Keywords:
Nummilitic limestone
Building stone
Dougga
Petrophysics
Durability

ABSTRACT

Preservation of the architectural integrity of archaeological sites requires detailed information about the properties of the building materials and their decay processes. This study investigates the petrophysical properties of the Eocene nummulitic limestone rock used in the construction of the Roman City of Dougga (Tunisia) and its resistance to various factors of decay. The petrographical study is carried out using standard microscope techniques and the petrophysical behaviour by a combination of techniques focusing on hydric and mechanical properties. The pore network is studied by fluorescence microscopy and mercury intrusion porosimetry. Durability was assessed by ice crystallization and SO_2 attack ageing tests. The results allowed the identification of four main building lithotypes and their exact stratigraphic point of mining in the ancient quarries. The petrographic variations between lithotypes correlate well with their physical properties. In addition, the four lithotypes show high resistance to ageing tests, confirming the excellent characteristics of the studied nummulitic limestones as a building rock.

1. Introduction

Nummilitic limestones have been extensively used as building rocks in the Mediterranean basin since the first constructions made by humans. This is the case of important archaeological sites like the ancient Corinth (Greece), several monuments in Cairo (Egypt) such as temples and pyramids (Fitzner et al., 2002), and the cathedral of Girona in Spain (Esbert et al., 1989), among others. The use of these limestones was, and still it is, facilitated by (*i*) the abundant exposures located in the circum-Mediterranean countries, and (*ii*) the common easy extraction and shaping process of limestones compared to harder rock types.

Nummulitic limestones, Eocene (Ypresian–Lutetian) in age, belonging to the El Garia Fm (Metlaoui Group) (Fournié, 1978; Moody and Grant, 1989; Perthuisot, 1974, 1979; Tlig et al., 2010) (Fig. 1 and Fig. S1), are the most common building rock used in the Roman City of Dougga (Thugga). Dougga is located in the north-central part of Tunisia, in the Béja Governorate, at around 100 km southwest of Tunis. Dougga has a warm-temperature Mediterranean climate, with a hot and dry summer, which

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https://doi.org/10.1016/j.crte.2017.09.017
1631-0713/

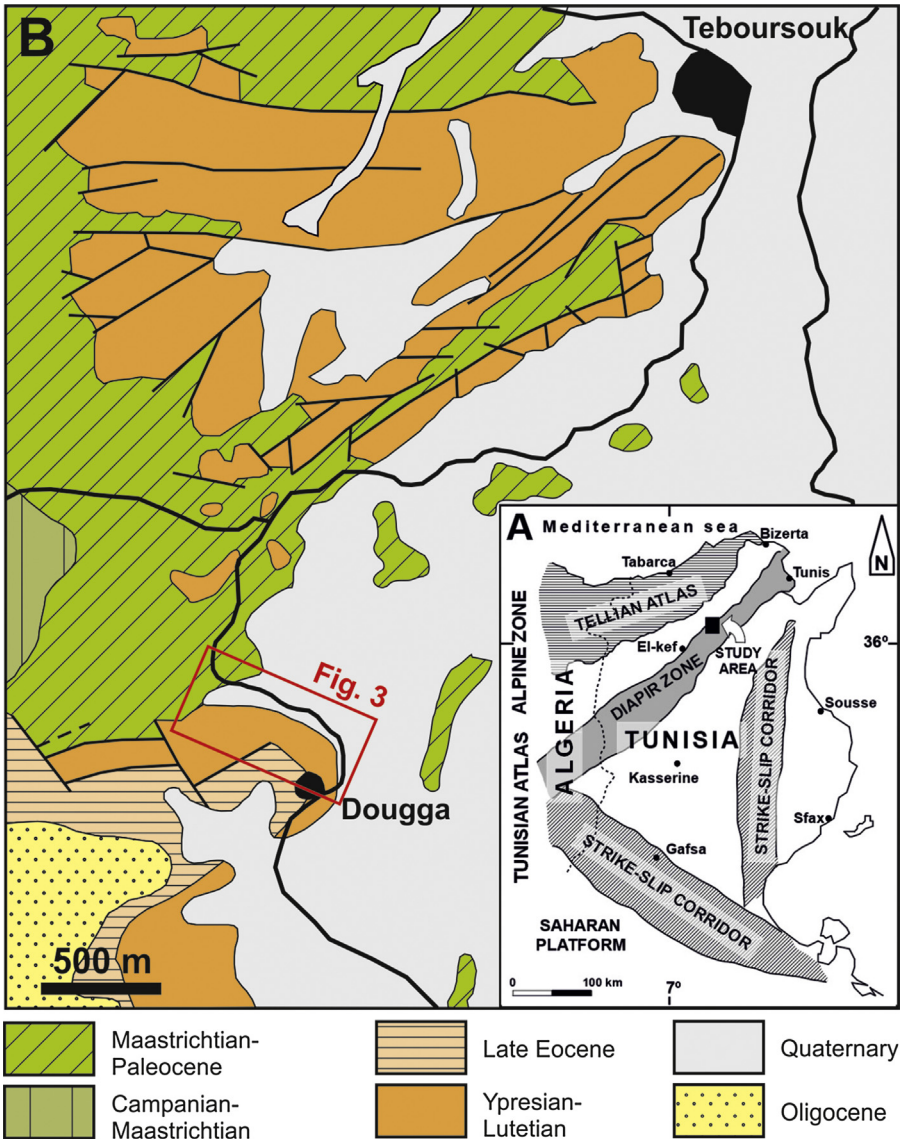

Fig. 1. A. Location of Dougga in Diapir Zone of the north-central part of Tunisia. B. Simplified geological map of the Teboursouk region, showing the age of the rocks cropping out in the area of Dougga (based on Perthuisot, 1979).

is classified as Csa according to the Köppen–Geiger climate system (Kottek et al., 2006). The average annual temperature is 18 °C, with a minimum average value of 11.4 °C and a maximum average value of 24.7 °C, the annual precipitation is 504 mm, and the mean month insulation is 211 h (National Institute of Meteorology of Tunisia).

This archaeological site covers an area of approximately 75 ha, although only one third of them have been excavated. The building rock was extracted from local quarries that are still located and perfectly recognized in the vicinity of the city (Fig. S2). The ruins of Dougga represent a complete city with all its components, testimony of more than 15 centuries of history (Khanoussi, 1989, 2003). They are an extraordinary illustration representing the synthesis between several cultures, including Numidian, Roman, Punic and Byzantine ones.

The city of Dougga possesses a remarkable group of public buildings dating back, for the most part, to the 2nd and 3rd centuries A.D. (Fig. 2). It conserves traces of the different periods of the Antique city with all its components: the monumental centre (capitol, forum, market, Rose of the winds square, etc.), entertainment buildings (theatre, circus), and public baths. Dougga is considered the best-preserved example of an Africo-Roman city in North Africa (Ennabli, 2000), and so was inscribed on the World Heritage List of UNESCO in 1997.

Despite the overall good state of preservation of Dougga compared to other Roman cities of Tunisia such as Carthage, some buildings have been partially destroyed,

Please cite this article in press as: Zoghlami K, et al. The building stone of the Roman city of Dougga (Tunisia): Provenance, petrophysical characterisation and durability. C. R. Geoscience (2017), https://doi.org/10.1016/j.crte.2017.09.017