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Effect of kaolinite as a key factor controlling the petrophysical properties of the Nubia sandstone in central Eastern Desert, Egypt

Mohamed A. Kassab [a], Mohamed F. Abu Hashish [b], Bassem S. Nabawy [c, *], Osama M. Elnaggar [a]

[a] Egyptian Petroleum Research Institute, Nasr City, 11727, Cairo, Egypt
[b] Faculty of Science, Menoufia University, Shebin El-Kom, 32511, Egypt
[c] Department of Geophysical Sciences, National Research Centre, Cairo, Egypt

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ABSTRACT

This paper presents the results of a comprehensive petrographical and petrophysical investigation for the Late Cretaceous Nubia sandstone from Wadi Kareem in central Eastern Desert to measure their fluid flow properties and to investigate the effect of kaolinite on their petrophysical characteristics.

From the petrographical analyses, scanning electron microscope 'SEM' and the X-ray diffraction 'XRD' analysis, it is shown that the studied sandstone samples are quite homogeneous in mineralogy and can be distinguished into four sedimentary microfacies: quartz arenite as a clean sandstone as well as three kaolinitic microfacies; namely they are kaolinitic quartz arenite, kaolinitic subarkose, and calcareous to kaolinitc quartz arenite. The main recognized diagenetic processes that prevailed during the post-depositional history of the Nubia sandstone are; compaction, cementation, alteration and dissolution of feldspar into kaolinite.

The petrophysical potentiality of the studied sandstones was studied using the helium pycnometer, gas permeability and mercury injection confining pressure 'MICP' techniques. The investigated sandstones can be classified into three petrophysical facies with varying reservoir performances. The petrophysical behaviour of these facies is dependent mostly on their kaolinite content and its impact on porosity, permeability, irreducible water saturation, R35 (pore aperture corresponding to mercury saturation of 35% pore volume), R50 (median pore-throat radius), and MHR (the mean hydraulic radius). Therefore, the studied petrophysical facies are comparable to the distinguished petrographical facies.

1. Introduction

The term "Nubia Sandstone" is used to describe the non-marine sandstone sequence which lies unconformably on the Precambrian rocks and underlies the Late Cretaceous marine shale (Quseir Variegated Shale) and the phosphatic Duwi Formation. The Nubia sandstone is of great importance due to its economic potential as oil, gas, and groundwater resources.

The Nubia sandstone is assigned to the Late Cretaceous age. The petrophysical properties of its type section in El Nuba area to the south of Egypt were measured extensively by Nabawy et al. (2009a, 2009b, 2010) as well as Nabawy and Géraud (2016) who described a sequence of 250 m of the Nubia sandstones from south Egypt and separated them into four formations; Adindan, Abu Simbil, Abu Ballas and Kesieba formations.

The present study concerns with characterizing the petrophysical and fluid flow properties of the Nubia sandstone outcrops in Wadi Kareem (Lat. 25°40′–26°00′ N & Long. 32°30′, 34°00′ E) in the central Eastern Desert of Egypt (Fig. 1), that comprises 55.0 m of massive sandstone beds unconformably overlying the basement rocks. It is described as yellowish, cross- and convolute-bedded, as well as rarely fossiliferous sandstone, with occasional clay intervals (Abu Hashish, 2004). A general lithostratigraphic column of the present Nubia sandstone was constructed accompanied with their primary sedimentary structures as shown in Fig. 2.

The quality of a reservoir is characterized by porosity and permeability to a large extent and the relationships between both of them were handled by many authors (e.g. Levorsen, 1967; El Sayed, 1995; Tiab and Donaldson, 2004; Díaz-Viera et al., 2006;

* Corresponding author.
E-mail address: bsnabawy@yahoo.co.uk (B.S. Nabawy).

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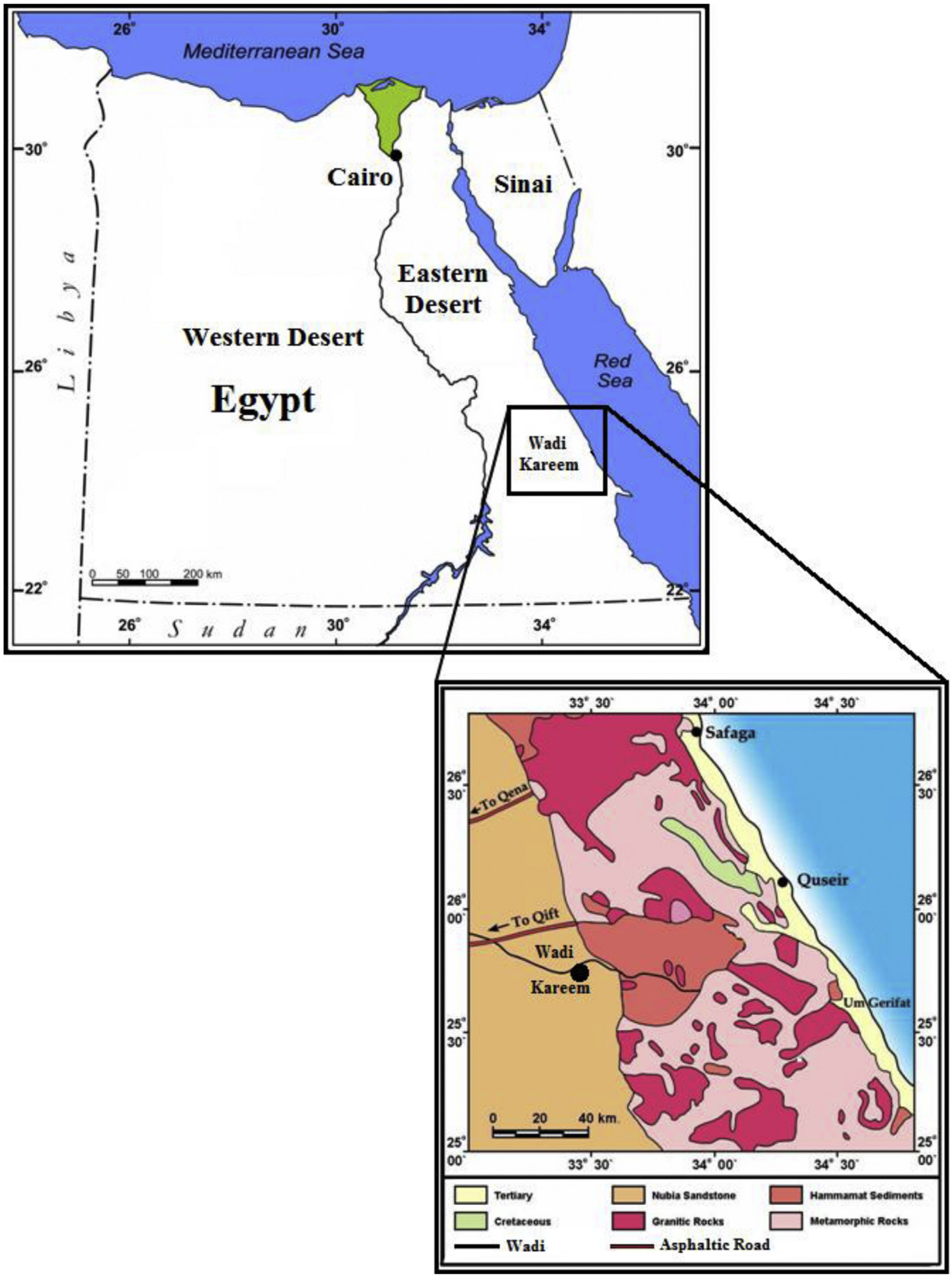

Fig. 1. Location and geological map of the study area.

Erdely and Díaz-Viera, 2009, Nabway and Kassab, 2014; Nabawy and Al-Azazi, 2015).

The mineral composition in the reservoir, especially the clay content of the reservoir rocks can play an effective reducing impact on the petrophysical reservoir properties that are used to evaluate the reservoir quality (e.g., Moll, 2001; Jiang, 2012).

The presence of clay minerals, that are generally very fine, reduces the effective porosity and permeability and therefore may have direct consequences on the reservoir properties (Said et al., 2003).

Some of the reservoir pores have no direct contribution to the fluid flow, such as dead end pores between the flakes of the clay content. These kinds of pores may complicate the relationship between porosity and permeability (Kassab et al., 2013). The higher content of kaolinite is an indicator for a higher micro and nano pore sizes which can be explained by the fact that matrix porosity was created when the feldspars were dissolved by water to produce kaolinite (Jiang et al., 2010).

It is a routine procedure for geologists, petrophysicists and petroleum engineers to evaluate the reservoir rock quality, net pay