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Porosity and permeability of tight carbonate reservoir rocks in the north of Iraq

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ABSTRACT

The distribution of reservoir quality in tight carbonates depends primarily upon how diagenetic processes have modified the rock microstructure, leading to significant heterogeneity and anisotropy. The size and connectivity of the pore network may be enhanced by dissolution or reduced by cementation and compaction. In this paper we have examined the factors which affect the distribution of porosity, permeability and reservoir quality in the Turonian–Campanian Kometan Formation, which is a prospective low permeability carbonate reservoir rock in northern Iraq. Our data includes regional stratigraphy, outcrop sections, well logs and core material from 8 wells as well as a large suite of laboratory petrophysical measurements. These data have allowed us to classify the Kometan Formation into three lithological units, two microfacies and three petrofacies. Petrofacies A is characterized by dense and compacted and cemented wackstone/packstone with nanometer size intercrystalline pores and stylolites and presents a poor reservoir quality (porosity range 0.005 ± 0.01 to 0.099 ± 0.01, permeability range 65 nD–51 μD). Occasional open fractures in Petrofacies A improve reservoir quality resulting in a 2–3 order of magnitude increase in permeability (up to 9.75 mD). Petrofacies B is a dissolved wackstone/packstone that contains moldic and vuggy pores (porosity range 0.197 ± 0.01 to 0.293 ± 0.01; permeability range 0.087–4.1 mD), with both presenting good reservoir quality, while Petrofacies C is a carbonate mudstone that has undergone dissolution and possibly some dolomitization (porosity range 0.123 ± 0.01 to 0.255 ± 0.01; permeability range 0.065–5 mD). All three petrofacies can be distinguished from wireline log data using porosity and NMR measurements. A poroperm plot of all of the data is fitted by a power law of the form $k\,(\mathrm{mD}) = a\phi^b$ with $a=28.044$ and $b=2.6504$ with coefficient of determination, $R^2=0.703$. When the permeability is predicted with the RGPZ model of the form $k\,(\mathrm{mD}) = d^2\phi^{3m}/4am^2$ with mean grain diameter $d=10$ μm, and mean cementation exponent $m=1.5$ and $a=8/3$ a better fit is possible with $R^2=0.82$.

1. Introduction

The Middle Turonian to Lower Campanian rock succession in the central part of Iraq is represented by the Khasib, Tanuma and Sa'di Formations (Aqrawi, 1996). These formations host producing fields including the East Baghdad fields in an important reservoir-seal system, which contains an estimated 9 billion barrels of oil in-place (Al-Sakini, 1992; Aqrawi, 1996). The equivalent of the Middle Turonian to Lower Campanian rock succession in North Iraq is the Kometan Formation, which may also be productive where it is sufficiently fractured (Jassim and Goff, 2006). Fig. 1 shows the palaeogeography map of the Kometan Formation and its equivalent rocks in Iraq, while Fig. 2 shows the positions of the various geological structures, major faults, fields and wells referred to in this paper.

The Kometan Formation is a fractured reservoir unit that produces commercial oil in some oil fields in the north of Iraq (Aqrawi, 1996). The Taq Taq oil field, for example, is a fractured Cretaceous reservoir that includes the Kometan Formation and produces light oil (41 API) with estimated recoverable reserves of 700–750 million barrels. It has been predicted that the field will produce 200,000–250,000 barrels per day when it is fully developed (TTOPCO, 2007).

In the Kirkuk embayment, the Kometan Formation is recognized as a productive formation in the oil reservoirs at the Avanah and Baba Domes of the Kirkuk structure and in the Bai Hassan field, as well as producing gas in the Jambur oil field (Aqrawi et al., 2010).

The equivalent formations in the central and southern parts of Iraq, which are characterized by the chalky units of the Khasib and Sa'di Formations with intercalation of shale and marl of the

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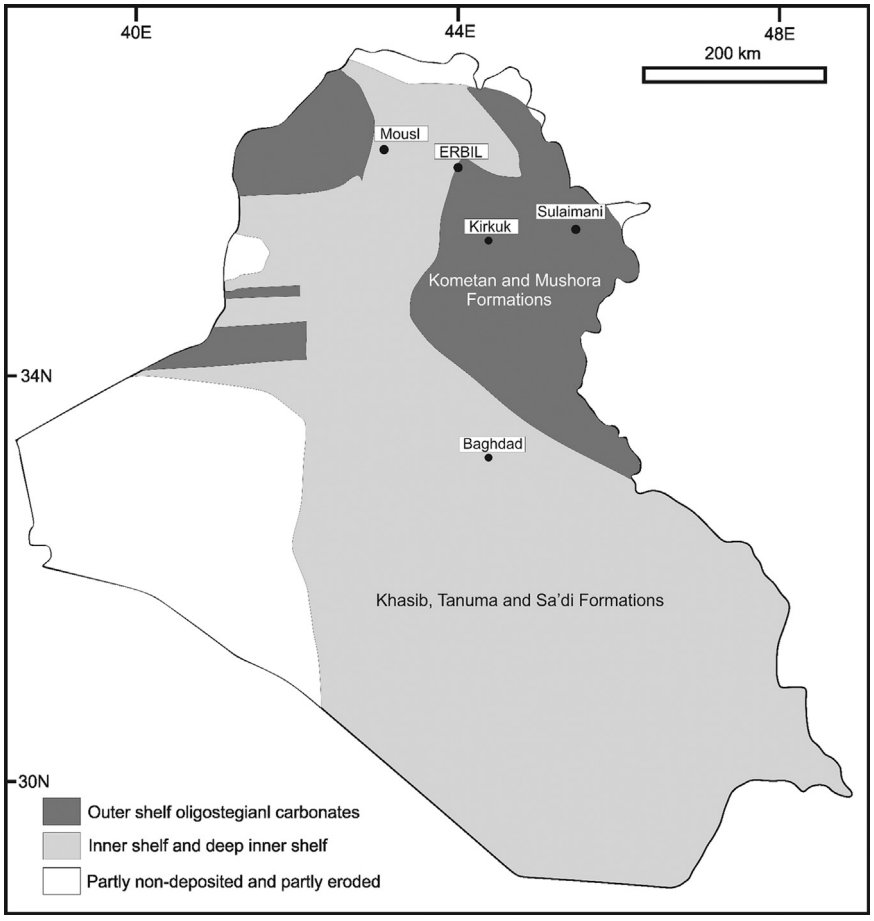

Fig. 1. Palaeogeographical map of the Kometan Formation and its equivalent formation in Iraq (Jassim and Goff, 2006).

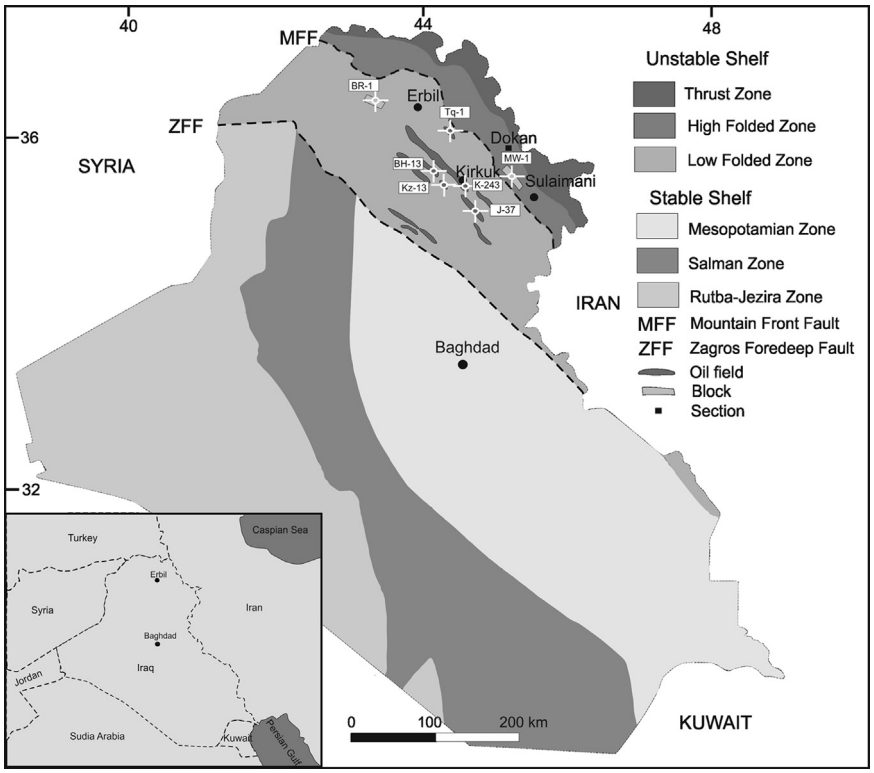

Fig. 2. Tectonic division of Iraq (after Aqrawi et al., 2010), showing the investigation area and including the wells used in this work as well as the position of the Dokan out-crop section.