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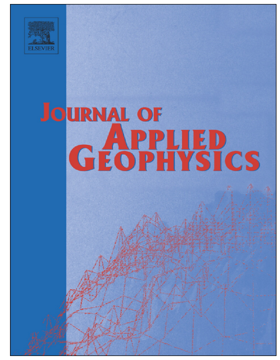

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Exploring a carbonate reef reservoir – Nuclear Magnetic Resonance and Computed Microtomography confronted with narrow channel and fracture porosity

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ABSTRACT

The complexity of hydrocarbon reservoirs, comprising numerous moulds, vugs, fractures and channel porosity, requires a specific set of methods to be used in order to obtain plausible petrophysical information. Both Computed Microtomography (μCT) and Nuclear Magnetic Resonance (NMR) are nowadays commonly utilized in pore space investigation. The principal aim of this paper is to propose an alternative, quick and easily executable approach, enabling a thorough understanding of the complicated interiors of the carbonate hydrocarbon reservoir rocks. Highly porous and fractured Zechstein bioclastic packstones from the Brońsko Reef, located in West Poland were studied. Having examined 20 thin sections coming from two different well bores, 10 corresponding core samples were subjected to both μCT and NMR experiments. After a preliminary μCT-based image analysis, 9.4 [T] high-field Zero Echo Time (ZTE) imaging, using a very short repetition time (RT) of 2 [μs] was conducted. Taking into consideration the risk of internal gradients' generation, the reliability of ZTE was verified by 0.6 [T] Single Point Imaging (SPI), during which such a phenomenon is much less probable. Both narrow channels and fractures of different apertures appeared to be common within the studied rocks. Their detailed description was therefore undertaken based on an additional tool – the spatially-resolved 0.05 [T] T2 profiling. According to the obtained results, ZTE seems to be especially suitable for studying porous and fractured carbonate rocks, as little disturbance to the signal appears. This can be confirmed by the SPI, indicating the negligible impact of the internal gradients on the registered ZTE images. Both NMR imaging and μCT allowed for locating the most porous intervals including well-developed mouldic porosity, as well as the contrasting impermeable structures, such as the stylolites and anhydrite veins. The 3D low-field profiling, in turn, showed the fracture aperture variations and contributed to the recognition of pore geometry. Analogously, the authors believe that such a spatially-resolved profiling could also be successfully implemented to study unconventional reservoirs. Finally, it has been concluded that although it is possible to investigate the connectivity of a given pore space solely using μCT, a detailed labeling process might turn out to be too time consuming and require a sound experience in that field. Therefore it is proposed to follow a preliminary μCT modeling by the direct and non-invasive set of NMR experiments.

Keywords: ZTE imaging; Nuclear Magnetic Resonance relaxometry; computed microtomography; carbonate reservoir; fracture modeling; channel porosity.

1 INTRODUCTION

1.1 Main concept

Natural fractures have always been a valid component of any pore network. Even if they occupy a relatively small volume of a hydrocarbon reservoir rock, they often turn out to substantially ameliorate its connectivity (Tiab and Donaldson, 1996; Odling et al., 1999; Spence et al., 2017). Besides the typical fracturing events observed in many reservoir rocks, additional pore space diversification can be expected in carbonate reservoirs (Choquette and Pray, 1970; Halley and Schmoker, 1983; Moore, 1984; Ahr et al., 2005; Ali et al., 2010; Reijers, 2012). Taking into consideration the wealth of fossils they represent, combined with the weak stability of the minerals they are built from, the carbonates