Textural and diagenetic assessment of the Zechstein carbonates in the scope of Nuclear Magnetic Resonance and supplementary methods

Abstract

Despite the efforts undertaken to date in the field of the Nuclear Magnetic Resonance (NMR), little has been done to evaluate the detailed parameters of carbonate hydrocarbon reservoir rocks. In particular, rock texture, pore geometry and related diagenesis, to some extent remain unsolved using NMR as a leading method. These features have a dramatic impact on reservoir quality. The existence of such a gap and a poor petrophysical recognition of the Polish Zechstein Limestone strata (Ca1, the Polish Lowlands, Wolsztyn Ridge), gave a direction of this work towards NMR-based texture and pore geometry typing. The Ca1 material was ideal for the NMR tests, regarding its rich diagenetic and sedimentological history, producing pore space diversification. A new procedure of carbonate texture typing was brought into use through the interpretation of the following low-field (0.05 T) NMR-derived parameters: (1) the amount of free water (Free Fluid Index, FFI), (2) capillary water content (Bulk Volume Irreducible, BVI), (3) the amount of Clay-Bound Water (CBW), (4) the degree of fluctuation of the transverse relaxation (T_2) curve; and (5) the width of the main peak, being the first T_2 peak located within FFI, whose average amplitude observably exceeds that found either within the CBW or BVI system. Because vuggy porosity represents relatively large, albeit incoherently-sized voids of various diameters, small differences in T_2 time specifics were utilized to distinguish this kind of pores from other voids, by means of the NMR. In other words, vugs could have been identified based on significant width of the main peak, since it records the pore diameter variations, encoded in different T_2 times. The evaluation of spatially-resolved T_2 plots was also used to accurately locate fractures and dissolution channels within a sample, both of which frequently give either isolated or dual peaks on the T_2 curves. A new approach including the integration of the high-field NMR (Zero Echo Time Imaging, ZTE at 9.4 T*)* and X-ray microtomography (μCT) data, aiming at channel porosity assessment, was proposed. Hence, both pore geometry and the patterns of distribution of water within a sample were yielded.

The research and experiments conducted allowed at least six Dunham's carbonate facies to be identified using NMR. The guidelines for the recognition and characterization of vuggy and channel porosity were also proposed. It was moreover shown that under the presence of stylolites, both CBW and BVI components tend to relatively high, and that cementation frequently causes the T_2 plot to fluctuate. It is noteworthy that the petrographical analyzes were crucial in the verification of the results obtained, and enabled resolving the origin of pores. The caverns and large moulds were mainly connected with the dissolved shells of brachiopods. The channels, in turn, originated through the dissolution of the shells of encrusting foraminifers and ostracods.

It was concluded that both high- and low-field NMR research enable carbonate texture recognition and allow for pore geometry and diagenetic information to be deciphered. The procedures developed can be successfully applied in carbonate hydrocarbon reservoir rock characterization, including various reservoirs worldwide. However, in the case of complex diagenesis, numerous attenuations of the T_2 curve may appear, and therefore petrography should never be entirely neglected.

Keywords

Nuclear Magnetic Resonance (NMR), carbonates, Permian, channel porosity, vugs, facies, reefs