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Investigating the Capillary Systems in Complex Carbonates by integrating Formation Evaluation Data and MICP Core Data Analysis

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Abstract

Understanding the hydraulic properties of reservoir rocks is crucial for estimating reserves or managing storage and production of a reservoir. In reservoirs containing complex carbonates, rock-typing methodologies that recognize multimodal porosity have been widely used. A new petrophysical rock typing workflow based on Thomeer buoyancy modelling has been applied to wellbores in a Middle East carbonate reservoir in which multimodal porosity was observed.

Porosity reflects the total pore volume of the rock, while the fluid transport within a porous rock unit is dominated by the fractional pore volume connected to the largest pore throat system. Mercury intrusion capillary pressure (MICP) measurements uniquely provide insight into the connected porosity and permeability volumes and establish the relationship between the vertical saturation profile of the wetting and non-wetting fluid phases. A workflow that captures the buoyancy of the formation fluids (saturation-height) together with this pore volume complexity can then provide insight into the pore geometry, saturation distribution and permeability of the investigated reservoir volume.

This new workflow is distinctive as it integrates reservoir physics with new analytic approaches that include a routine conversion of properties from ambient to reservoir conditions, a fully automated Thomeer deconvolution of MICP experiments and a Thomeer-buoyancy analytical solver for properties estimation in the log domain.

Rock typing is performed through the relationship of bulk property logs, such as the NMR porosity and T2 distribution, and the characterized Thomeer plug database in the context of the buoyancy model. The ‘rock type’ log generated defines the probability of the defined rock types occurring for that depth in the well. The probabilities combined into a single discrete rock type, provide a traditional ‘reservoir facies’ descriptor that links the porosity, saturation and permeability of any point within the reservoir space.

The solutions provided comprise continuous magnitude and category estimations of permeability at reservoir conditions and Thomeer coefficients, statistical uncertainties of the previous and continuous scalar results in the hydrocarbon column including reservoir capillary pressure, bulk volume oil and water saturation as well as probabilistic pore geometry grouping.

Two case studies are presented to demonstrate the application to wellbores within the investigated Middle Eastern carbonate reservoirs.