A New Workflow for Assessment of Fluid Components and Pore Volumes From 2D NMR Measurements in Formations With Complex Mineralogy and Pore Structure

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Abstract:

It is challenging to reliably identify fluid components and to estimate their saturations in formations with complex lithology, complex pore structure, or varying wettability conditions. Common practices for assessing fluid saturations rely on the interpretation of resistivity measurements. These techniques require model calibration, which is time consuming/expensive and can only differentiate conductive and nonconductive fluids. Interpretation of 2D NMR maps provides a viable alternative for identifying fluid components and fluid volumes. However, conventional techniques for the interpretation of 2D NMR rely on cutoffs in the T1-T2 or D-T2 maps. The application of cutoffs is prone to inaccuracies when fluid-component relaxation responses overlap. To address these shortcomings, we introduce a new workflow for identifying/tracking fluid components and estimating their volumes from the interpretation of 2D NMR measurements.

We developed an algorithm that approximates 2D NMR maps with a superposition of 2D Gaussian distributions. The algorithm automatically determines the optimum number of Gaussian distributions and their corresponding properties (i.e., amplitudes, variances, and means). Next, a clustering technique is implemented to the data space containing the Gaussian distributions parameters obtained for the entire logged interval. Each Gaussian is assigned to a cluster corresponding to different fluid/pore components. We then calculate the volumes under the Gaussian distributions corresponding to each cluster at each depth. The volumes associated with each cluster translate directly into the pore volumes corresponding to the different fluid components (e.g., heavy/light hydrocarbon, bound/free water) at each depth.

We successfully verified the reliability and robustness of the new workflow for enhancing petrophysical interpretation in two organic-rich mudrock formations with complex mineralogy and pore structure. The fluid volumes estimated by the introduced algorithm were compared against fluid volumes obtained from resistivity-based methods, laboratory measurements, and production data in both formations. The introduced 2D NMR workflow significantly improved the reliability of pore/fluid typing and assessment of fluid volumes in dozens of wells covering over 100,000 ft of log data in unconventional plays. Additionally, this work enabled the identification of the presence of light hydrocarbon in an interval where other interpretation methods have not been able to detect it.

A highlighted contribution of this work is that, in contrast to the alternative petrophysical interpretation techniques for fluid characterization, the introduced workflow does not require calibration efforts, user-defined cutoffs, or proprietary data sets. Furthermore, approximating 2D NMR data with a superposition of Gaussian distributions improves the accuracy of estimated pore volumes of fluid components with overlapping NMR responses. The clustering using the Gaussian distributions parameters as inputs enables depth tracking of different fluid components without making use of user-defined 2D cutoffs. Finally, the multidimensional nature of the introduced clustering provides the unique capability of identifying different fluid components with 2D NMR response located in the same range of coordinates in a T1-T2 map.

Bio:

Artur Posenato Garcia works as a research petrophysicist for Chevron CTC in Houston, TX. He earned his PhD in Petroleum Engineering from The University of Texas at Austin and the outcomes of his research resulted in 60+ journal and conference publications. Artur was designated an SPWLA Distinguished Speaker in 2017-2018 and 2018-2019 and he served as the president of the student chapter of SPWLA at The University of Texas at Austin (2018-2019). He continues to serve the petrophysics community as the VP Downtown of the SPWLA Houston chapter, as an associate editor for the SPE Journal, and as a technical reviewer for SPE REE, Geophysics Journal, Journal of Applied Geophysics, etc. Furthermore, Artur is currently pursuing an MSc in Computer Science at UT Austin.