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# NMR Imaging Elucidates Fluid Flow in Ultra low Permeability Unconventional Reservoir Rocks

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## ABSTRACT

In typical hydraulic frac jobs of unconventional source rocks, up to 85% of the frac fluids are lost to the reservoirs and are not produced. In the published literature mixed results are reported and it is not clear what the impact of the retained frac fluids is on the hydrocarbon production. One of the main reasons is that the fluid flow in source rocks or unconventional shales is extremely complex and not well understood. The pores in kerogen and pores in inorganic matrix may have different wettability and the majority of the pores are in the nanometer range (<= 100 nm) and the pore throats are even smaller. Consequently, the flow of hydrocarbons or water-based fluids may take completely independent different paths through these rocks and the conventional flow models may no longer be adequate. In addition, the potential existence of micro-fractures in source rocks further complicates the flow process. In this paper, we address some of these challenges using NMR imaging and spectroscopy methods to investigate the imbibition of different fluids into source rocks. Specifically, we present the following: —Laboratory NMR imaging methods for imbibition of fluids in conventional and source rocks. In addition, NMR spectroscopy methods are used to track oil and water flowing in specific pore system in source rock samples. —A new fluid flow model is proposed based on the acquired NMR imaging data. The NMR imaging results show non-Darcy flow behavior for all of our shale samples, in stark contrast to the rigorous Darcy flow observed in Berea Sandstone. —Imbibition data revealed different flow regimes including dual-continuum behavior in some source rocks. —The impact of imbibition of frac fluids into source rocks on hydrocarbon flow by imaging the spontaneous imbibition of different fluids sequentially into the sources rocks.