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Abstract

Organic-rich shale formations consist of multi-scale pore structure, which includes pores with sizes down to nano-scale, contributing to the storage of hydrocarbons. We show that the hydrocarbons in the formation partition into fluids with significantly varying physical properties across the nanopore size distribution of shale. This partitioning is a consequence of multi-component hydrocarbon mixture stored in nanopores showing a significant compositional variation with the pore size. The smaller the pore is, the heavier and the more viscous the hydrocarbon mixture becomes. During the production and pressure depletion, primarily the lighter hydrocarbons of the mixture are released from the nanopores. Hence, the composition of the remaining hydrocarbons inside the pores becomes progressively heavier. The viscosity and apparent molecular weight of the hydrocarbon mixture left behind increase significantly during the depletion. The kinetic mean-free path length of the mixture does not increase, however, as anticipated from the kinetic theory of gases. Further, the length may decrease drastically in small nanopores as an indication of capillary condensation and trapping of the hydrocarbon mixture. These effects significantly limit the release of hydrocarbons from nanopores, in particular those pores with sizes smaller than 10nm.

In the light of these microscopic scale observations, the concept of composition redistribution of the produced fluids is introduced and a new volumetric method is presented honoring the compositional variability in nanopores for an improved accuracy in predicting hydrocarbons in-place in presence of adsorption and nano-confinement effects. The method allows us to differentiate mobile bulk hydrocarbon fluids from the fluids under confinement effects and from the trapped hydrocarbon fluid dissolved in the organic material. Hence, it also reduces the uncertainties in predicting the reserve. The application of the method is presented using produced hydrocarbon fluid composition for dry gas and wet-gas formations and using reservoir flow simulation of production from a multi-stage fractured single horizontal well. We showed that liquids production is mainly due to flow of bulk fluid in large-pore volume.