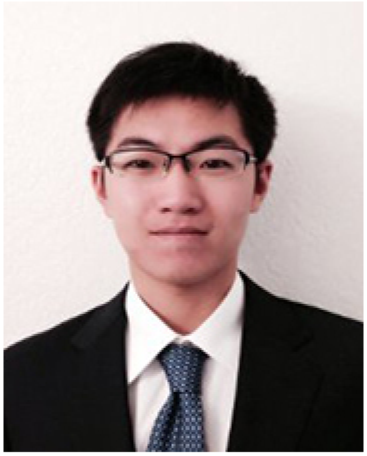

DI CHAI

FINAL PH.D. DEFENSE

PETROLEUM ENGINEERING

Date:

Wednesday, August 19, 2020

Time:

Starts @ 9:30AM

Zoom Meeting Details:

https://kansas.zoom.us/j/93156183536

Meeting ID: 931 5618 3536

Password: 738096

Committee Chair:

Assistant Professor Xiaoli Li

Comprehensive characterization of shale gas seepage in nanoscale organic-rich shales

Unlike conventional gas reservoirs, the shale gas resources are widely distributed in organic-rich shale formations with most pore sizes down to nanoscale. Such nanoscale confinement has invalidated the conventional gas transport mechanisms which are characterized by the Navier-Stokes equations. This research work aims to bridge the gap in scientific understanding of the shale gas transport across the hierarchical structures of organic-rich matrix by developing different analytical and numerical models which incorporate various mechanisms in shale formations. More specifically, this work explores the qualitative and quantitative influences of the rarefaction effect, real gas effect, multilayer adsorption, surface diffusion, nano-confinement effect, and pore-structure heterogeneity on the shale gas flow.

First, a new unified gas transport model is developed by modifying Bravo's model to describe the rarefaction which is commonly present in nanopores. Particularly, a straight capillary tube is characterized by a conceptual layered model consisting of a viscous flow zone, a Knudsen diffusion zone, and a surface diffusion zone. To specify the contributions of the viscous flow and the Knudsen diffusion, the virtual boundary between the viscous flow and Knudsen diffusion zones is firstly determined based on Kennard's analytical kinetics approach. Then, the model considers the real gas effect, multilayer adsorption and nano-confinement effect to quantify the density oscillation and phase behavior in confined nanopores. Meanwhile, the apparent permeability (AP) model is analytically derived and numerically simulated at core-scale. In addition, the field scale production rate is numerically calculated by coupling the nanoscale mechanisms. Furthermore, the pore-structure heterogeneity impact on production rate is studied by the fuzzy statistical method in which the Monte Carlo simulation is implemented for the sensitivity analyses of the structural parameters in the fractal model. One of the advantages of the new unified gas transport model is its great flexibility which is capable to cover the full flow regimes. It is found that the increase of real gas viscosity can reduce the total molar flux in the inorganic pores up to 66.0%. In addition, it is observed that the pore confinement effect is of importance when the pore size is smaller than 50 nm. The apparent permeability is found to increase greatly as the adsorption layer number increases, implying that the application of Langmuir model in existing gas transport models may substantially underestimate it. Compared with the flow mechanisms in the nanopores, it is found that the fractal dimension of the tortuosity has the largest impact on the production rate than the pore size and the fractal dimension of pore size distribution. In addition, the fuzzy statistical method can quantify the confidence interval within which the satisfactory flow rate results can be acquired. The fuzzy statistical method enables more flexibility to predict the realistic production profile with significant data fluctuations.