Cullen College of Engineering
UNIVERSITY OF HOUSTON

DOCTORAL

DISSERTATION DEFENSE ANNOUNCEMENT

AT THE CULLEN COLLEGE OF ENGINEERING

Alteration of Kerogen Wettability Due to Compositional Change in Shale by Interaction with Fluid

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Location: Room104, ERP9

Teams Link: https://teams.microsoft.com/l/meetup-join/19%3ameeting_MmU2NzcxYzItMDQ1NC00NGRlLTljY2EtNDBkN2FkM2NiOWRm%40thread.v2/0?context=%7b%22Tid%22%3a%22170bbabd-a2f0-4c90-ad4b-0e8f0f0c4259%22%2c%22Oid%22%3a%229d7c142c-76e8-4a6b-98da-10de35bf835c%22%7d

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Abstract

In organic-rich shales, kerogen-associated pores and fractures serve as principal conduits for hydrocarbon flow, yet the influence of fluid-induced wettability alterations on this flow remains poorly understood. This study investigates the impact of fluid interactions on kerogen wettability alterations in organic-rich shales and their consequent effects on hydrocarbon flow behavior within shale. To address this, the study conducts experiments and develops models to understand and quantify the changes in kerogen properties and flow dynamics due to these interactions. The research involves three main tasks.

First, experiments are performed to quantify the impact of fluids on kerogen wettability alterations. To achieve this objective, kerogen isolates from various organic-rich shales with different types and maturities are mixed with various fluids, including hydraulic fracturing fluid, brine, and deionized water, at a temperature of 80 °C for 14 days. Approaches such as sessile drop method for contact angle measurement, Ion Chromatography (IC), Attenuated Total Reflectance Fourier-Transform Infrared spectroscopy (ATR-FTIR), and Rock-Eval pyrolysis are conducted to determine the alteration of kerogen wettability and geochemistry. This phase determines the mechanisms of kerogen wettability change.

Second, an empirical model is developed to capture the contact angle as a function of time. Furthermore, an analytical model is developed to describe gas-water flow behavior in shale, by employing fractal theory and quadratic Hagen-Poiseuille equation and considering time-varying contact angle incorporated into the boundary conditions. The impact of variables such as porosity, wetting phase thickness, wettability, and gas rarefaction on the flow behavior is discussed. This part provides a comprehensive understanding of gas and water flow behavior in shale formation, highlighting the importance of contact angle and wettability as its controlling factors.

Third, two numerical models at different scales are developed to explore the effects of wettability changes on the gas-water displacement flow. The centimeter-scale model incorporates time-varying contact angles obtained from experimental data as boundary conditions. Meanwhile, the micrometer-scale models, derived from SEM images of shale samples, set initial gas-water distributions according to the analytical model, i.e., gas occupying the center and water as a thin layer along the wall for hydrophilic conditions, and vice versa for hydrophobic conditions. Slip effects were included due to the small scale. In addition, wettability alterations were also taken into account. The simulations produce relative permeability curves, which are compared with the predictions from analytical models. Additionally, the effect of liquid-gas viscosity ratio and rate of contact angle change on the relative permeability was investigated.

As such, this dissertation encompasses a workflow that identifies the kerogen wettability alteration due to fluid interactions and their influence on gas-water flow in shales, utilizing experimental analysis, analytical modeling, and numerical modeling approaches. The study determines the mechanisms of kerogen wettability alteration, quantifies changes in wettability over time, proposes an analytical model for gas-water flow with time-varying boundary conditions, and simulates gas-water displacement in shale pores from SEM images. By incorporating these findings, this research provides crucial insights into the kerogen wettability alteration due to interaction with fluids and fluid flow behavior in shale pores, offering guidance for optimizing hydrocarbon recovery.