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Asphaltene Precipitation and Deposition during Nitrogen Gas Cyclic Miscible and Immiscible Injection in Eagle Ford Shale and Its Impact on Oil Recovery

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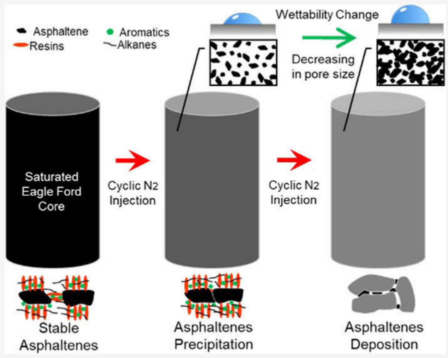
ABSTRACT: Cyclic gas injection methods have been shown to improve oil recovery in conventional reservoirs. Even though similar technologies have been used in unconventional reservoirs with some success stories in shale resources, cyclic gas injection enhanced oil recovery (EOR) is still a little-understood subject in boosting oil recovery from unconventional reservoirs. During gas injection, asphaltenes start to deposit and precipitate, which causes pore plugging and reduces oil recovery. Studies of asphaltene deposition challenges during cyclic nitrogen (N_2) gas injection and oil production in unconventional reservoirs are yet relatively limited. Therefore, a comprehensive experimental study was conducted using 12 Eagle Ford shale cores (dynamic mode), and filter paper membranes (static mode) were used to evaluate whether miscible and immiscible huff-n-puff (cyclic) N_2 injection increases oil recovery and aggravates asphaltene precipitation. To ensure that miscibility can be examined in cyclic experiments, N_2 minimum miscibility pressure (MMP) was determined using a slim tube technique. The factors studied included the injection pressure, number of cycles, production time, and injection cyclic mode, all conducted at 70 °C. The findings showed that a high asphaltene weight percent was calculated during static experiments (i.e., using filter membranes), and this increase was severe on smaller pore size structures. Dynamic tests (i.e., using shale cores) showed that miscibility increased oil recovery, but a stronger intermediate-wet system was observed when measuring the wettability of cores after N_2 cyclic tests. When starting with shorter soaking times, more oil recovery could be achieved. Oil recovery reduction and asphaltene depositions were observed at later cycles. Microscopy and scanning electron microscopy (SEM) imaging of the Eagle Ford cores showed asphaltene clusters inside the cores after cyclic tests. A mercury porosimeter emphasized the degree of pore plugging after cyclic tests, and the findings revealed a smaller pore size distribution after N_2 tests due to the asphaltene deposition process when compared to cores that had not been pressured. This extensive study focuses on the effects of asphaltene deposition on oil recovery under cyclic N_2-miscible and immiscible conditions in shale resources.



1. INTRODUCTION

Gas injection has been a widely used technology for increasing oil production in unconventional shale plays in the United States, and it may be the most efficient approach for unlocking the remaining oil percentage. Unconventional resources, like shale reservoirs, are widely recognized for their extremely low permeability and porosity.[1] Despite the fact that multistage hydraulic fracturing and horizontal well drilling techniques are used to extract the remaining oil from such reservoirs, only 4–6% of the trapped oil can be extracted, and the oil production drops after a few months, attributing to the ultralow permeability.[2−19] Water injection is also one of the suitable strategies for increasing oil recovery from conventional reservoirs; nevertheless, due to weak injectivity, insufficient sweep potency, and clay swelling concerns, this approach is not the ideal solution for tight reservoirs.[20,21] Cyclic gas injection outperforms gas flooding methods in terms of enhancing oil recovery, mainly in ultratight reservoirs.[22,23] The total organic carbon (TOC) is the most important influencing parameter on gas injection in tight reservoirs because kerogen makes the surface of the pore oil-wet, making the oil inside challenging to extract.[24] Due to the combination of multiphase fluids (i.e., gas, oil, condensate, and water) and scales, multiphase flow production can create a number of challenges including wax and asphaltene deposition, hydrate formation, slugging, and emulsions.[25] Organic hydrocarbon particles settling in oil and gas reservoirs might create many flow assurance problems throughout the extraction process. These materials may increase flow resistance, causing production reduction or even pipeline plugging.[26,27] Crude oil is a complicated composition of hydrocarbons with different molecular weights

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