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CO2 Storage and Enhanced Oil Recovery in Tight Oil Formations: Insights from Laboratory Investigations and Field-Scale Simulations

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Unconventional plays like the Bakken petroleum system (BPS) are the main reason behind the U.S. oil and gas industry renaissance during the last decade. In that period, more than 10,000 wells have been drilled in the Bakken alone, most of them targeting low or ultralow permeability strata. While the hydrocarbon in-place estimates are in the order of hundreds of billions of barrels, most recovery factor estimations range in the single digits. Thus enhanced oil recovery (EOR) has emerged as an area of interest attracting attention from governmental agencies, operators, and academic institutions.

Recently, the Energy & Environmental Research Center (EERC) conducted a comprehensive set of Bakken-centered EOR research activities, including lab experiments, reservoir characterization studies, modeling and simulation exercises, and a field test. Key findings indicate that tight oil formations such as the Bakken may be suitable targets for CO2 EOR opportunities. The use of CO2 serves a twofold purpose: CO2 is an excellent hydrocarbon extraction solvent, and CO2 sequestration contributes to mitigating greenhouse emissions.

This work presents a systematic modeling and simulation study that incorporates freshly acquired laboratory and field data sets from the Bakken Formation. The goal of these efforts was to better understand the implications of injecting CO2, CO2 storage efficiency, oil mobilization and sweep efficiency, and the potential for incremental oil recovery through various schemes.

Core plug-scale measurements were used to calibrate physicochemical parameters of the organic shale members of the BPS. Simulations replicating hydrocarbon extraction experiments using supercritical CO2 allowed the assessment of mass transfer mechanisms at work. The results indicated molecular diffusion and CO2 adsorption had significant effects on fluid flowing behavior in these tight rocks.

Operational observations were used to inform drill spacing unit models. Field data included petrophysical properties, reservoir pressure, temperature, fluid saturations, fluid composition, and primary production records. 3D heterogeneous models were built to investigate different injection strategies with two contiguous, hydraulically fractured, horizontal wells. Sensitivity studies were performed to quantify the effects of key parameters. Several scenarios were examined in detail, including varied well configurations (vertical or horizontal), well schedules, and targeted injection/production rates. Simulation results obtained with the geo-cellular models revealed natural fracture networks could result in more favorable CO2 storage and oil sweep efficiency in tight oil reservoirs. The natural fractures may significantly increase the contact area between the formation and the (artificially) stimulated region, leading to more favorable conditions for the recovery process. Consequently, reservoir characterization emerged as a critical element to understand the effectiveness of CO2 storage and enhanced recovery for tight oil formations.

This work improves the understanding of the physical and chemical mechanisms occurring in tight oil reservoirs undergoing CO2 EOR. The simulation models and results provide critical assistance for planning and optimizing both oil production and CO2 storage in future efforts.

References

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