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Comparative Analysis of CO_2 Enhanced Oil Productivity and Carbon Sequestration Performance in Continental Shale Oil Reservoirs

Authors : Chenqi Ge, Dongqi Ji, Yiquan Yan, Zhewei Chen, Zhengdong Lei, Zhangxing Chen, Gang Hui

Abstract : CO_2 injection has emerged as a promising technique to enhance oil recovery in continental shale reservoirs by addressing challenges such as low sweep efficiency caused by micro-to-nano-scale heterogeneities and rapid production decline due to low reservoir pressure. This study evaluates the potential of CO_2 injection for improving shale oil productivity and sequestration efficiency through numerical simulations that incorporate nano-confined phase behavior, oil displacement mechanisms, water-oil imbibition, cross-scale flow characteristics, and dynamic fracture properties. Two major continental shale oil reservoirs in China, Gulong (pure shale deposition) and Jimsar (mixed deposition), are analyzed to assess the feasibility of CO_2-enhanced oil recovery. The study models spatially dependent fluid phase behavior by differentiating between matrix and fractures, while multiscale fluid flow, ranging from nanopores to fractures and wellbores, is simulated using a hybrid multiple-interacting-continua and discrete fracture network approach. Model validation is achieved through comparison with historical production data, achieving over 85% agreement in production rates. The effects of cross-scale oil flow and CO_2 channeling on sequestration and oil production efficiency are investigated for both reservoirs. The comparative analysis reveals distinct mechanisms governing CO_2-enhanced oil recovery in the two reservoirs. In the Gulong shale, CO_2 injection at high pressure expands bedding fractures, enhancing connectivity between the nano-scale matrix and fractures. Additionally, slow CO_2 diffusion into the tight matrix promotes oil displacement and long-term sequestration. Conversely, in the Jimsar shale, CO_2 injection primarily enhances oil mobility by reducing viscosity from 50 cp to below 5 cp. The relatively larger matrix pore structure and lower minimum miscibility pressure in Jimsar lead to higher sweep efficiency during CO_2 displacement. Simulation results also indicate that CO_2 utilization efficiency in Jimsar surpasses that in Gulong. This study introduces an integrated numerical simulation approach that combines spatially dependent phase behavior with multiscale flow modeling to evaluate the interplay between oil productivity and CO_2 sequestration in shale reservoirs. The findings provide insights into optimizing CO_2 injection strategies for different shale reservoir types, offering a pathway for sustainable CO_2 utilization in enhanced oil recovery operations.

Keywords : shale oil, CO_2 displacement, CO_2 sequestration, enhanced oil recovery
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