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Pore-scale Flow Simulation of CO2 Sequestration in Deep Shale Based on Thermal-hydro-mechanical Coupled Model

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The technology of sequestering CO2 in deep shale has shown great potential due to the low permeability of shale and the high adsorption of CO2 by organic-rich characteristics. Deep shale is characterized by high-temperature and high-pressure with a significant hydro-mechanical coupling effect. The Darcy-Brinkman-Stokes method was integrated with heat transfer equations to simulate thermal-hydro-mechanical coupled single-phase steady-state flow, combined with multiphase flow equations to simulate hydro-mechanical coupled transient flow under high-temperature conditions. This study aims to reveal the effect of temperature difference between CO2 and reservoir, Reynolds number, and formation pressure on the flow process of CO2 geological storage in deep shale based on the constructed real core structure consisting of organic pore, organic matter, and inorganic matter. The results indicate that low-temperature CO2 is conducive to giving full play to the role of convection heat transfer, improving the CO2 saturation and the swept volume of organic pores. Reynolds number has a negligible impact on the transition of convective and conduction heat transfer. At higher Reynolds numbers, CO2 flows extensively and deeply, and CO2 clusters occupy a higher proportion in organic pores. The Nusselt number is higher, and convective heat transfer is more dominant under lower confining pressure. Shallower reservoirs are favorable conditions for adsorption trapping, as their cores are subjected to slightly lower confining pressure, resulting in higher CO2 saturation in the organic matter and higher sweep rate of organic pores. Our main finding is that low-temperature CO2, a higher Reynolds number and shallower buried depth favor carbon sequestration.

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Primary author: LIU, Ziwei (China University of Petroleum, East China)

Co-authors: Prof. YANG, Yongfei (China University of Petroleum (East China)); YAO, Jun (China University of Petroleum)

Presenter: LIU, Ziwei (China University of Petroleum, East China)

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