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Reservoir Simulation Using Synthetic Data for CO₂ Sequestration in Saline Aquifers Using CMG Simulator

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Abstract

Introduction

CO₂ sequestration in saline aquifers is a promising solution for mitigating greenhouse gas emissions. These deep geological formations offer vast storage capacities for securely trapping CO₂ through multiple mechanisms: Structural Trapping (CO₂ is contained beneath impermeable cap rock layers), Residual Trapping (Capillary forces immobilize CO₂ in pore spaces), Solubility Trapping (CO₂ dissolves into formation brine), Mineral Trapping (CO₂ reacts with minerals form stable carbonate components). Understanding these mechanisms and their interactions is critical for optimizing storage efficiency and ensuring long-term security. The objective of the study is to do extensive sensitivity analysis on model of layered permeability using commercial simulator CMG, to analyse the influence of geological parameters (porosity, pressure, permeability, thickness) and other factor such as injection rate on the trapping mechanisms. These are done to determine which of the trapping mechanism is more likely effective to hold CO₂ in long term storage.

Method

CMG builder was used to develop a basic 3D reservoir model, the parameter input are as below mentioned. A 5-spot pattern well is considered in the current study. A well is placed at the centre of model to act as injection well with well-being perforated throughout the model at each layer, it allows us to study the CO₂ plume migration in all directions. Four production wells are placed at edges to simulate pressure management, preventing excessive pressure build up in the aquifer. The aquifer dimensions are 53000x53000x1000ft, with layered permeability is taken. The aquifer model is structured in a 40x40x40 grid arrangement (64000 blocks).

Conclusions

Based on the study, solubility trapping is dominant during the injection phase, whereas residual trapping overtakes it post-injection, particularly in high-pressure, high-permeability, and highly porous aquifers. The thickness of the aquifer plays a crucial role, with larger layers storing more CO₂ and favouring residual trapping over solubility trapping. Injection rate variations also impact the trapping mechanisms, where higher rates enhance residual trapping but reduce solubility trapping efficiency. Higher porosity facilitates solubility trapping initially, while residual trapping strengthens over time. Pressure variations significantly influence residual trapping, making high-pressure environments more effective for long term CO₂ storage. The permeability ratio further affects trapping efficiency, where increased horizontal permeability enhances CO₂ retention. Overall, the study suggests that optimizing aquifer selection, pressure conditions, and injection rates can maximize CO₂ storage efficiency, with residual trapping playing a dominant role in long-term sequestration.