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Reservoir Simulation using synthetic data for CO2 Sequestration in saline aquifers using CMG simulator

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Introduction

CO_2 sequestration in saline aquifers is a promising solution for mitigating greenhouse gas emissions. These deep geological formations offer vast storage capacities for securely trapping CO_2 through multiple mechanisms: structural trapping (CO_2 is contained beneath impermeable cap rock layers), residual trapping (Capillary forces immobilize CO_2 in pore spaces), solubility trapping (CO_2 dissolves into formation brine), mineral trapping (CO_2 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 CO_2 in long term storage.

Method

CMG builder was used to develop a basic 3D reservoir model, the parameter input are as below mentioned in table. 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 CO_2 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).

The permeability of the model varies horizontally with each subsequent four-layer present.

Parameter	**Value**
Length, ft	53000
Width, ft	53000
Thickness, ft	1000
Depth at top of formation at injection well, ft	5500
Temperature, °F	150
Initial pressure, psia	2265
Constant boundary pressure, psia	2265
Salinity, ppm	150000
Porosity	0.30
Permeability distribution	layered
Vertical to horizontal permeability ratio(K_v/K_h)	0.01

Horizontal permeability of each layer, md	
Layers 1-4	95
Layers 5-8	70
Layers 9-12	35
Layers 13-16	20
Layers 17-20	10
Layers 21-24	180
Layers 25-28	215
Layers 29-32	335
Layers 33-36	950
Layers 37-40	585

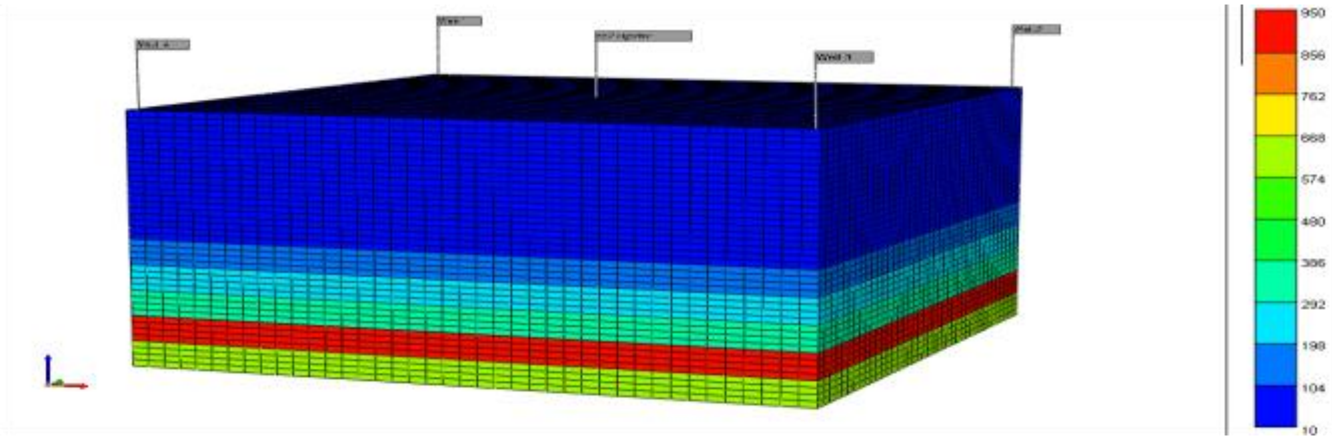

Figure *3D view of aquifer model permeability in CMG Builder* .

Table 2 *parameter values for sensitivity analysis*

Aquifer Parameter	**Variation**
Formation Porosity	0.25, 0.30, 0.35
Formation thickness, ft	15, 25, 35
Reservoir intial pressure, psi	2065, 2265, 2465
Injection rate of well, MMScf/day	25, 50, 100
Vertical to horizontal permeability ratio (K_v/K_h)	0.01, 0.05, 0.1

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 CO_2 and favoring 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 CO_2 storage. The permeability ratio further affects trapping efficiency, where increased horizontal permeability enhances CO_2 retention. Overall, the study suggests that optimizing aquifer selection, pressure conditions, and injection rates can maximize CO_2 storage efficiency, with residual trapping playing a dominant role in long-term sequestration.

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