CO_2 storage capacity study through dynamic simulation on Caswell Fan, Upper Campanian, Browse Basin, Australia

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Outline

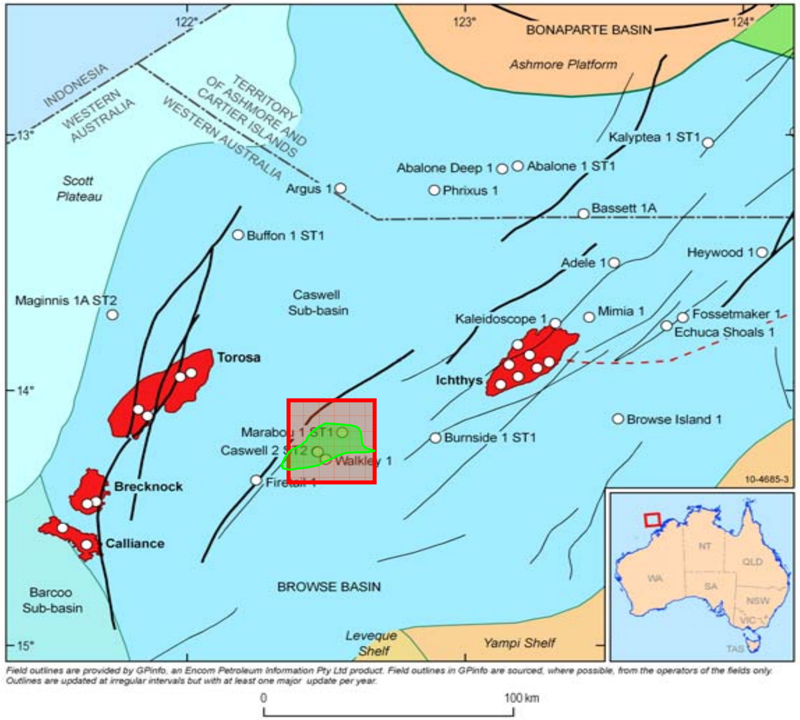
- Objective
- Introduction
- Preparation of Static Reservoir Model
- Initial Reservoir Condition
- Fluid Property and Relative Permeability
- Injectivity Analysis
- Simulation result and analysis
- Summary

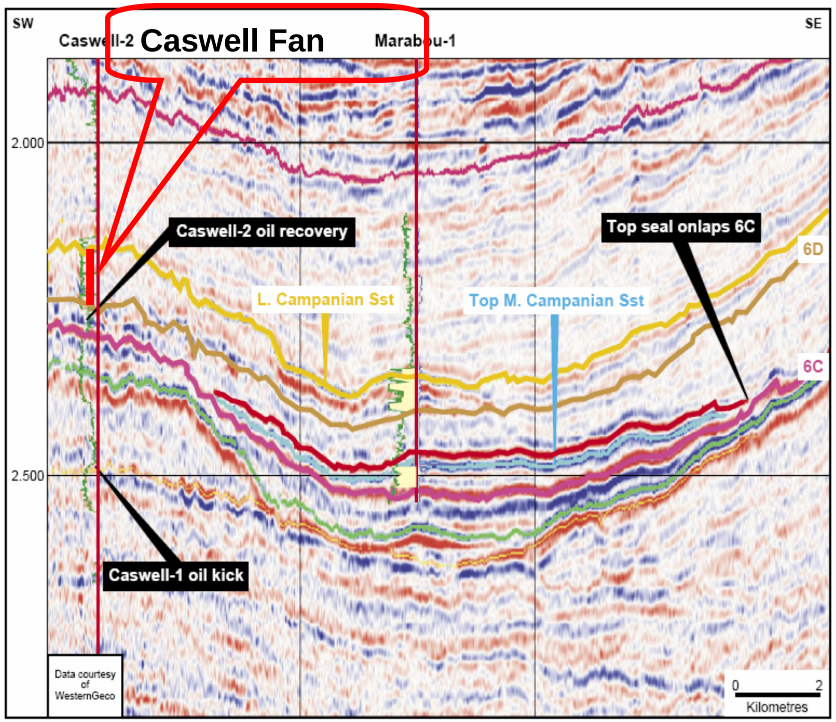
1 Objective

- To assess Practical CO_2 Storage Capacity Analysis through Dynamic Reservoir Simulation Using CMG-GEM™

2 Introduction

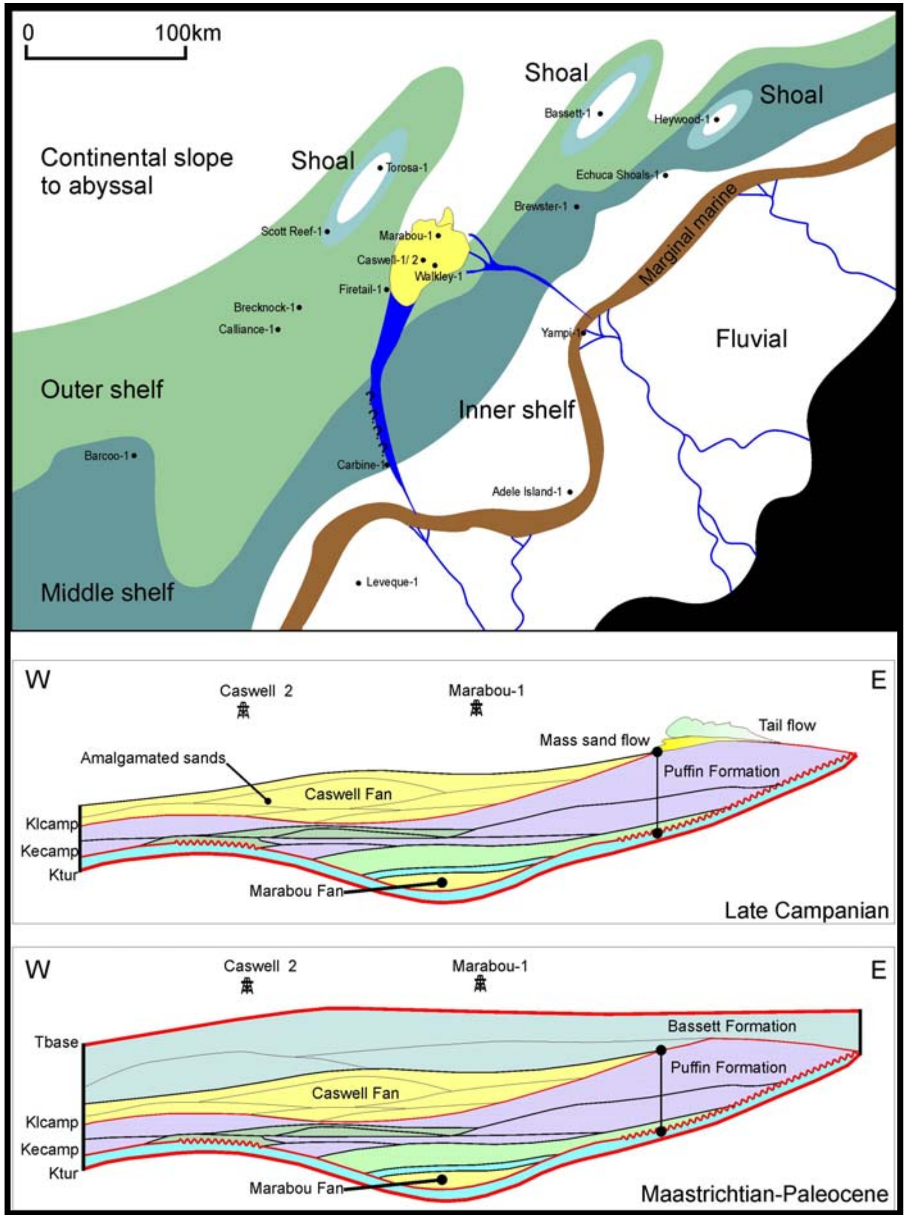
Location of Caswell Fan



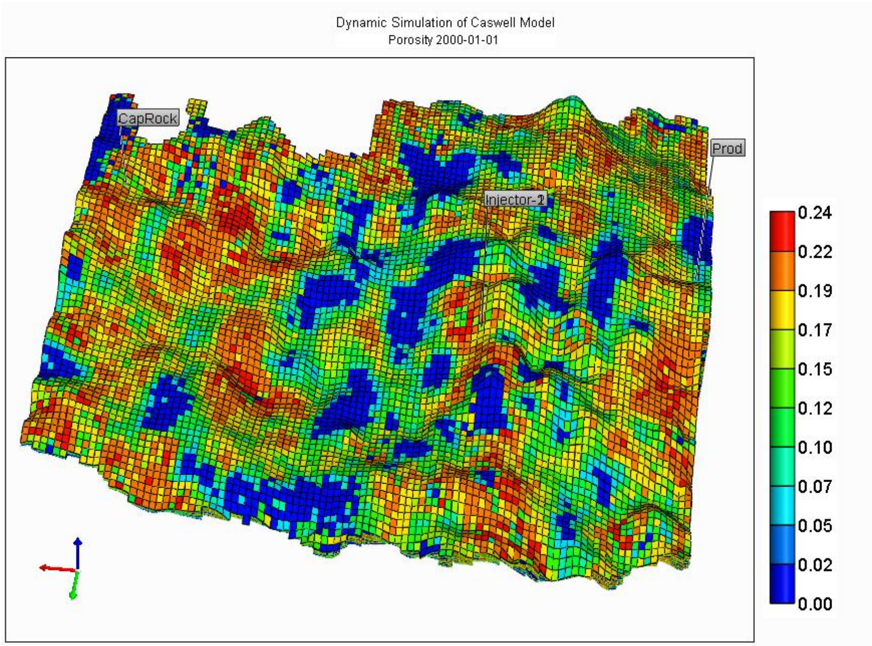


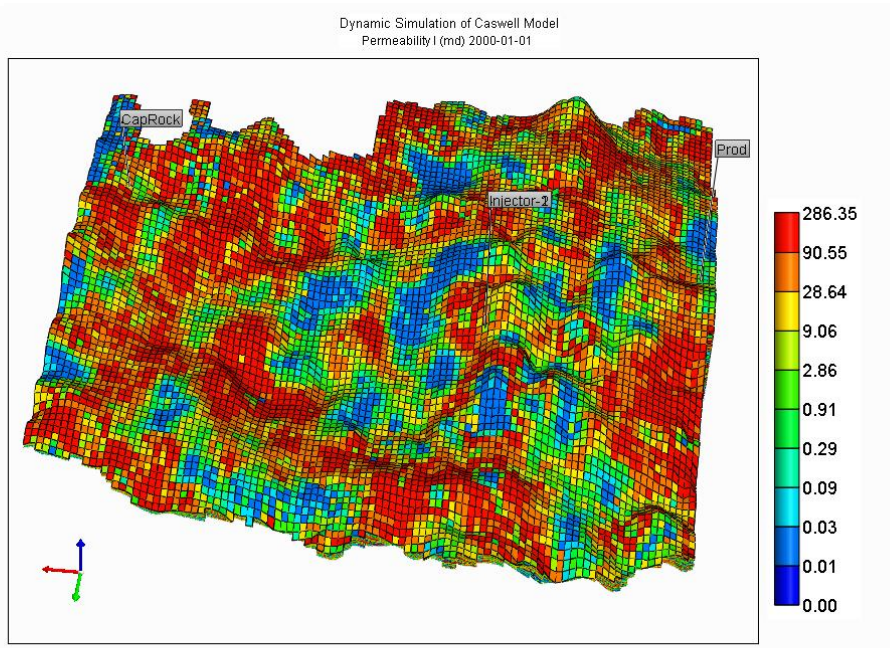
Paleogeography (Late Campanian sequence boundary) (Benson et al, 2004)

Late Campanian palaeogeography (After Stephenson and Cadman, 1994 and Benson et al., 2004).



3 Static Geological Model





- The mean CO_2 storage potential in AOI-Caswell Fan after static reservoir modelling is 296 million tonnes.

4 Initial Reservoir Condition

- The formation pressure gradient at Caswell_1 well is about 0.465 psi/ft. The regional thermal gradient is 33ºC/km, and the temperature at the seabed is 17.7ºC.

- At the reservoir condition (3300 mKB, T=118ºC, Formation pressure=34.75 MPa), the physical properties of CO_2:

CO_2 mass density (kg/m^3)	650.11
CO_2 viscosity (cp)	0.05319
CO_2 Compressibility factor	0.7234

5 Fluid Properties
Gas Solubility in Aqueous Phase

- Gas solubility from Henry's law

$$f_{CO_2,g} = f_{CO_2,w} = y_{CO_2,w} \cdot H_{CO_2}$$

- Gas phase: $f_{CO_2,g}$ calculated from Peng-Robinson's EOS

- Henry's law constant, H_{CO_2} is a function of pressure, temperature and salinity:

  - ✓Increase in solubility with increase in P
  - ✓Decrease in solubility with increase in T and salinity
  - ✓Increase in aqueous phase density with CO_2 solubility

5 Fluid Properties

Chemical Properties of CO_2

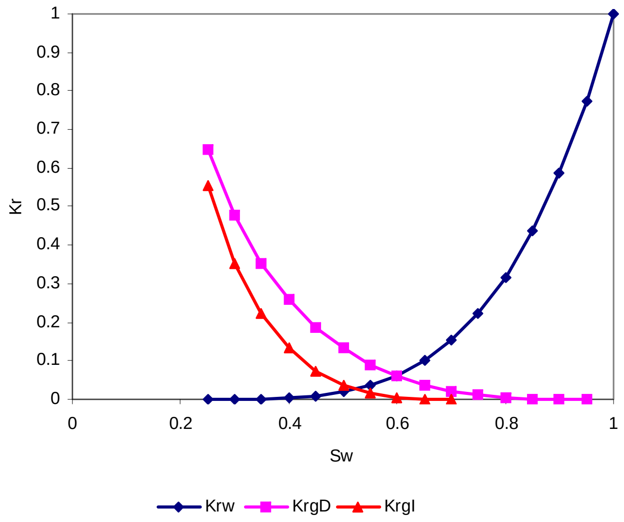
Critical Pressure (*atm*)	72.8
Critical Volume ($m^3/kmol$)	0.094
Critical Temperature (K)	304.2
Acentric factor (dimensionless)	0.225
Molecular Weight	44.01
EOS Ω_a parameter (Peng-Robinson’s Model)	0.45724
EOS Ω_b parameter (Peng-Robinson’s Model)	0.0778
Henry's Law Constant	771111
Reference Pressure (*MPa*)	34.75
Molar volume at infinite dilution ($m^3/kmol$)	0.03648

5 Gas-Water Relative Permeability Hysteresis Model

- **Corey's Model (1976):**

$$K_{rw} = (S^*)^4 \qquad S^* = \frac{S - S_{wr}}{1 - S_{wr}}$$

$$K_{rg} = (1-\hat{S})^2(1-\hat{S}^{0.5}) \qquad \hat{S} = \frac{S - S_{wr}}{1 - S_{wr} - S_{gr}}$$



- CMG-GEM™ internal hysteresis model
  - Modified Land's equation:

$$\frac{1}{S_{gr}^{\max}} - \frac{1}{S_g^{\max}} = \frac{1}{S_{gh}} - \frac{1}{S_{grh}}$$

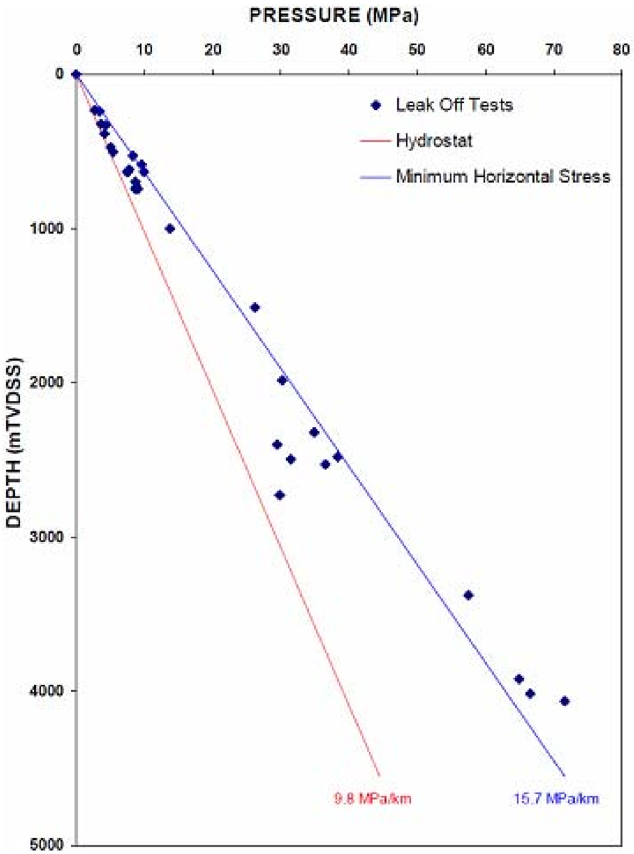
6 Injectivity Analysis

➢According to Tenthorey and Ruth (2007), the approximated fracture pressure gradient in Browse Basin was estimated to be 15.7MPa/km.

➢The maximum injection rate and the maximum bottom hole pressure are set as the limits for injection.

➢Maximum injection (STG surface gas) rate:
1.473×10^6 m^3/day

➢***BHP_{max}=Fracture Pressure × 0.9***

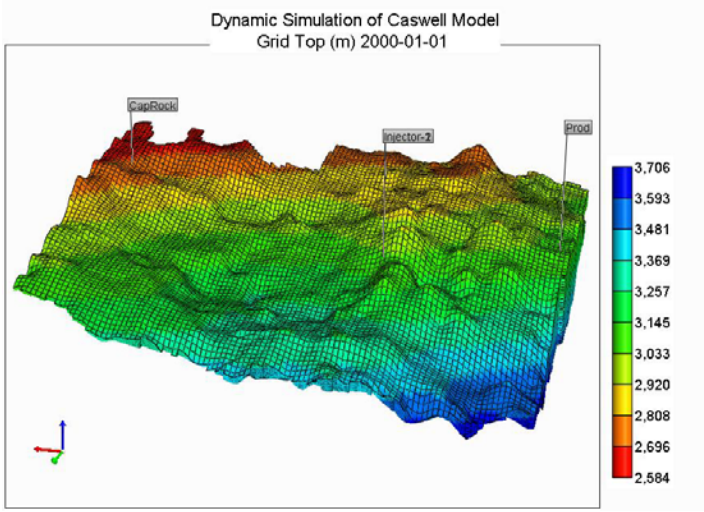


7 Simulation with Caswell Fan Model

✓Static Model: Model 1
✓100% implicit algarithm

✓Sgrm = 0.2
✓Kv/Kh = 0.1
✓Relative permeability: Corey's model

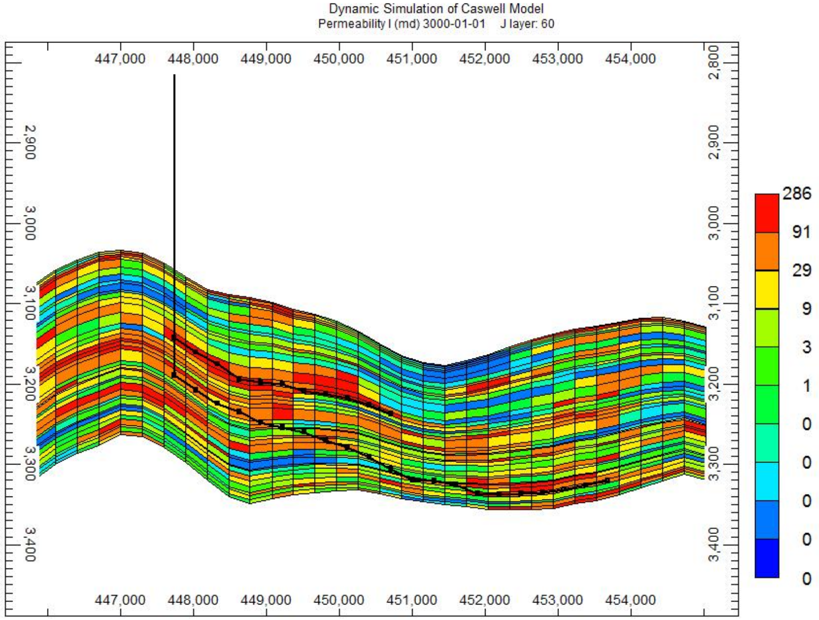
✓2 horizontal injection well (Injector-1 & 2)
✓1 production well (Prod)
✓1 Caprock well (CapRock)

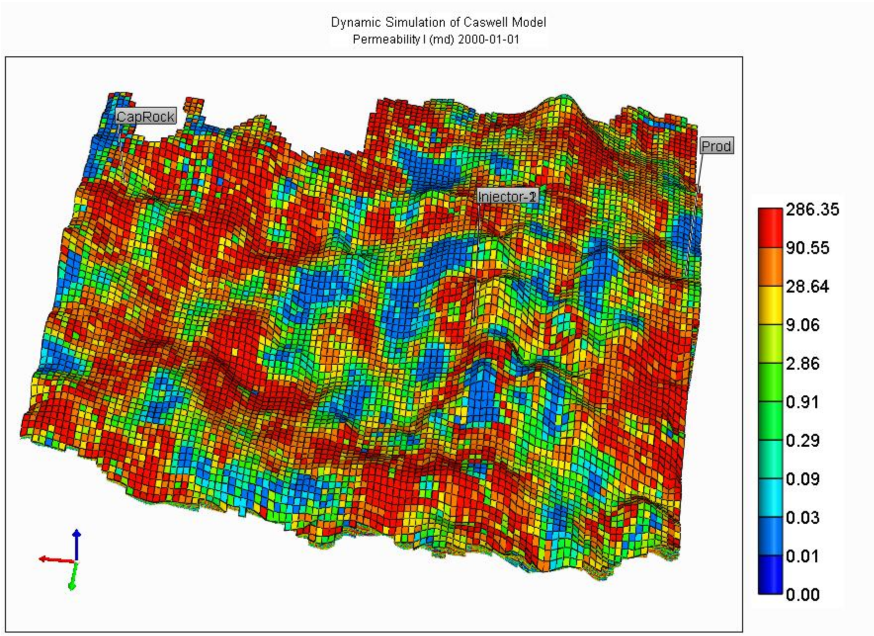


✓Injection time: 50 years
✓Injection rate: 1.473×10^6 m^3/day (STG surface gas rate)
✓Simulation period: 2000-01-01 to 3000-01-01

Simulation with Caswell Fan Model

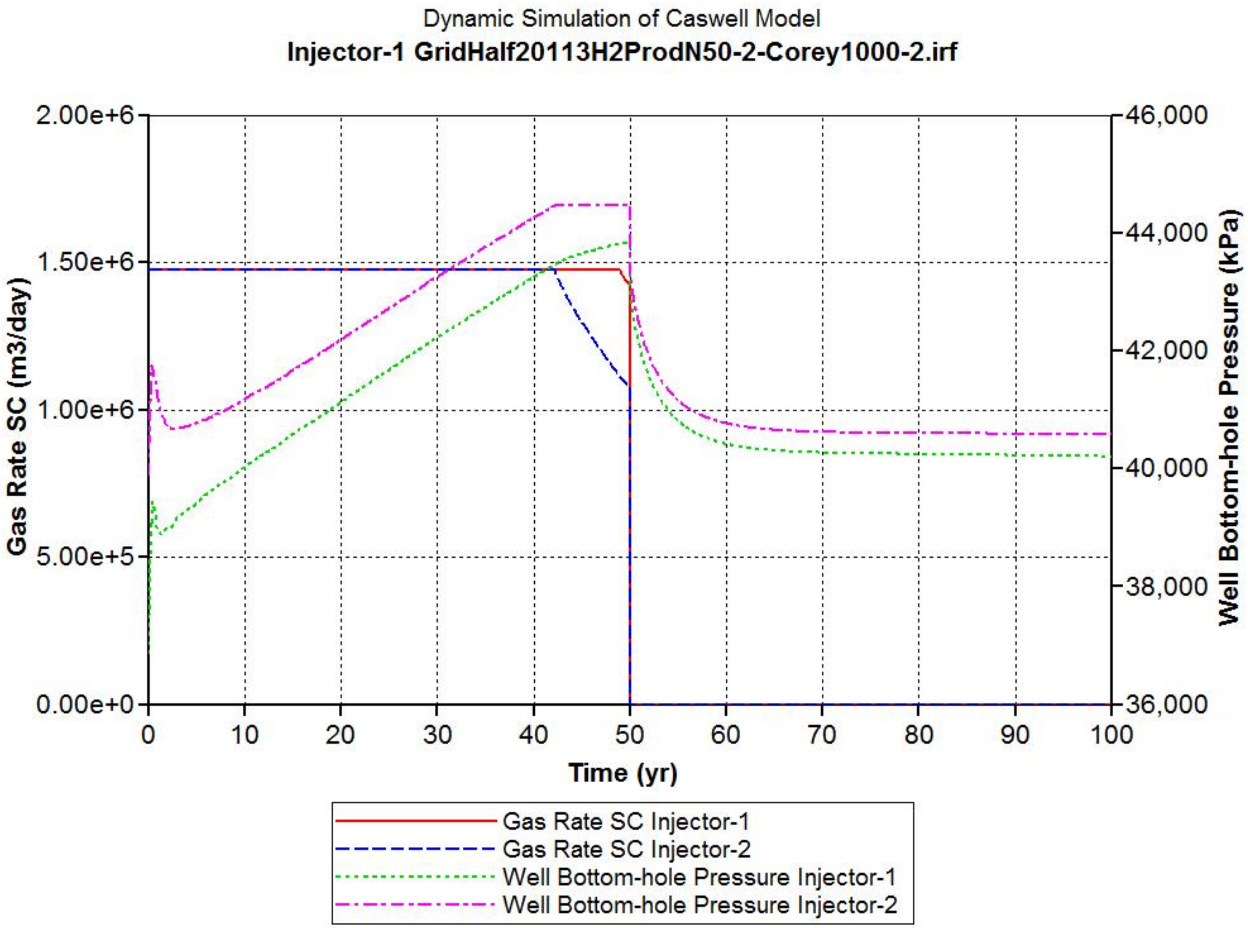
Perforation Interval





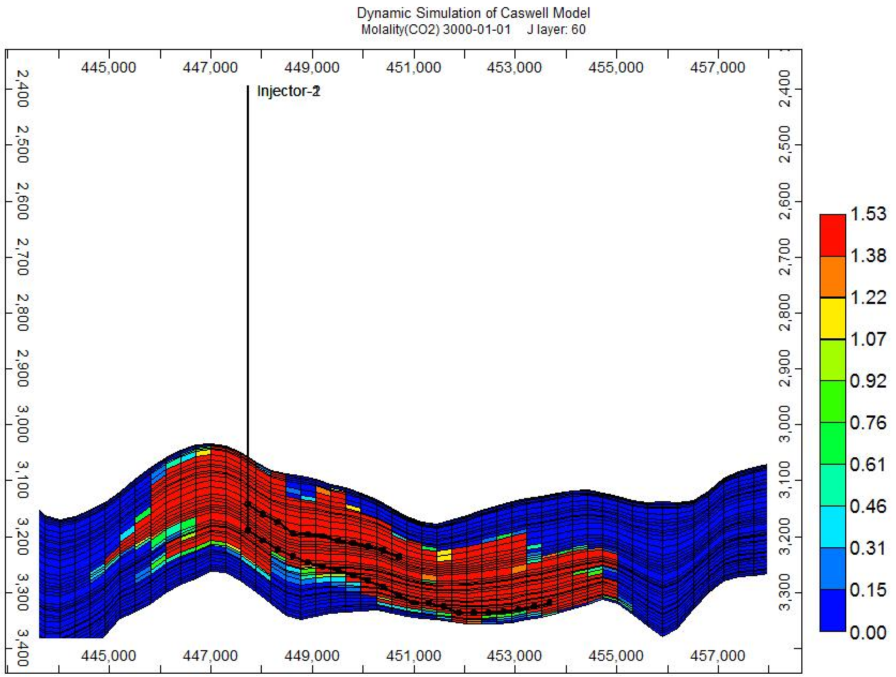
Simulation with Caswell Fan Model

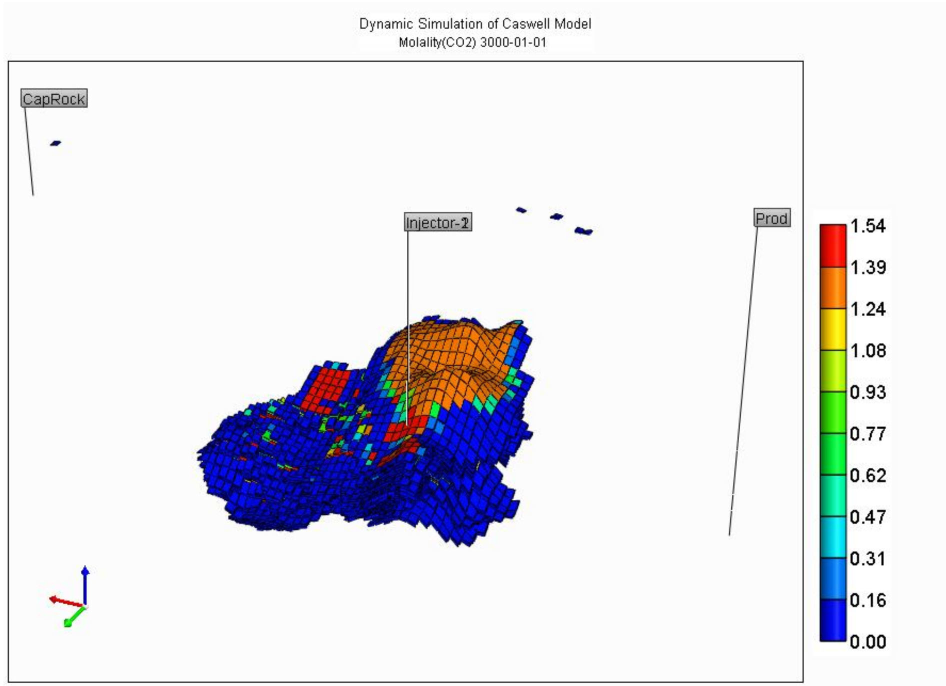
Gas Mass Rate & Bottom Hole Pressure (100 years)



Simulation with Caswell Fan Model

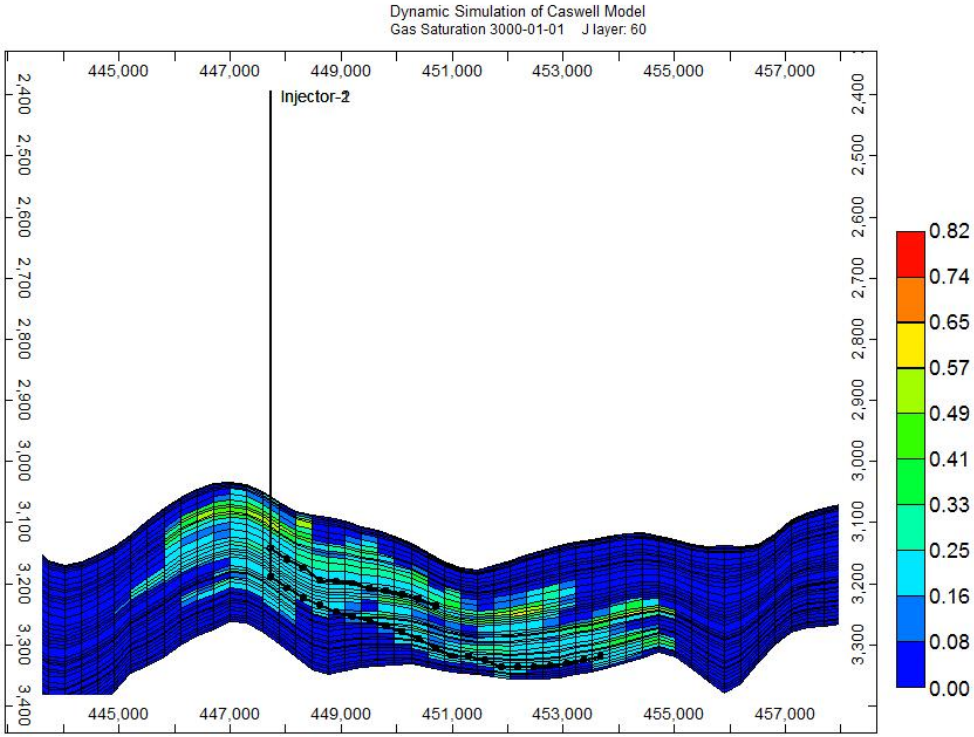
CO_2 Molality (1000yrs later)

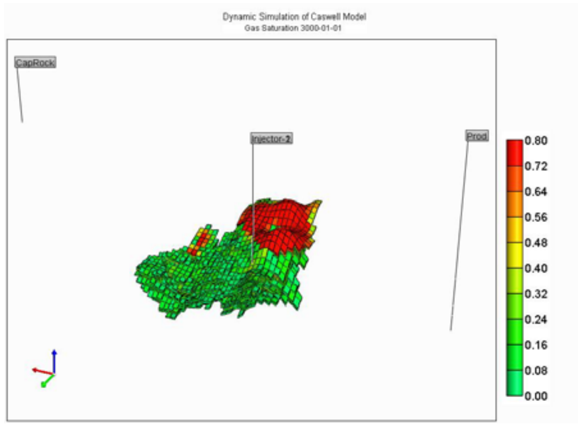


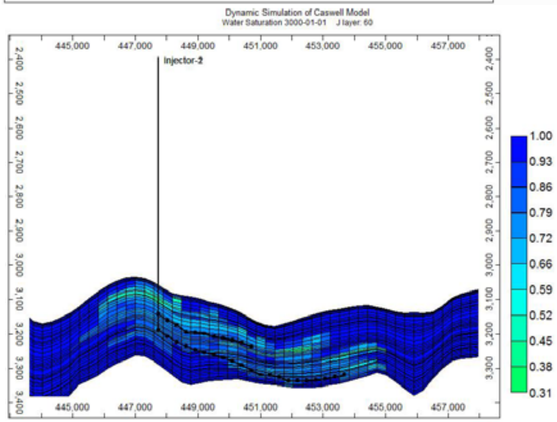


Simulation with Caswell Fan Model

Gas Saturation (1000yrs later)

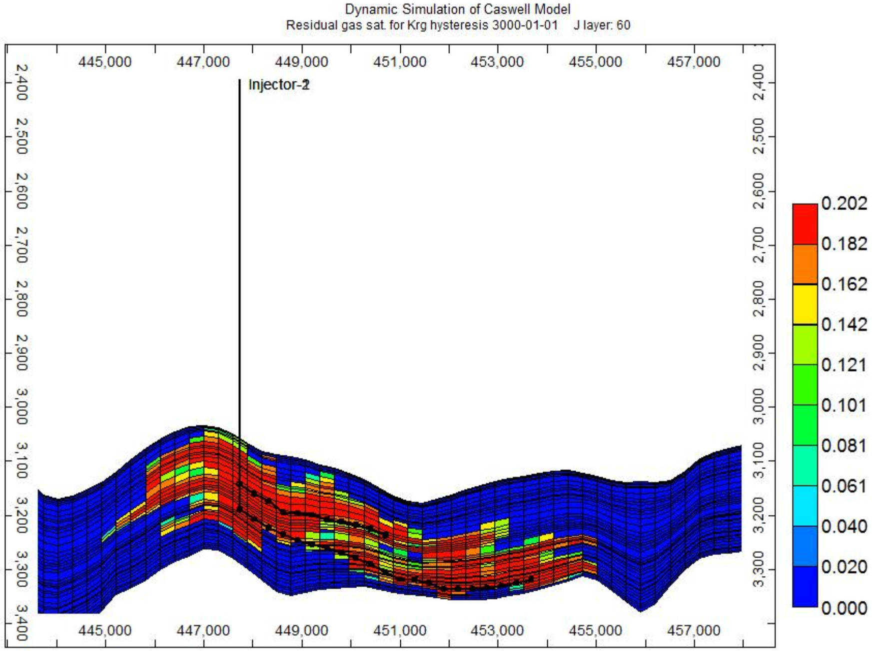


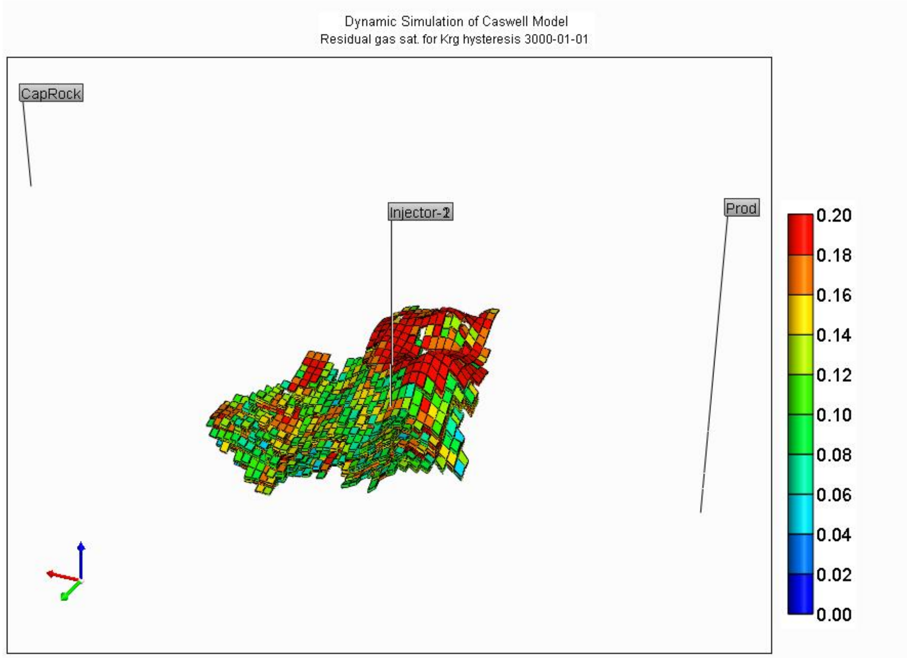




Simulation with Caswell Fan Model

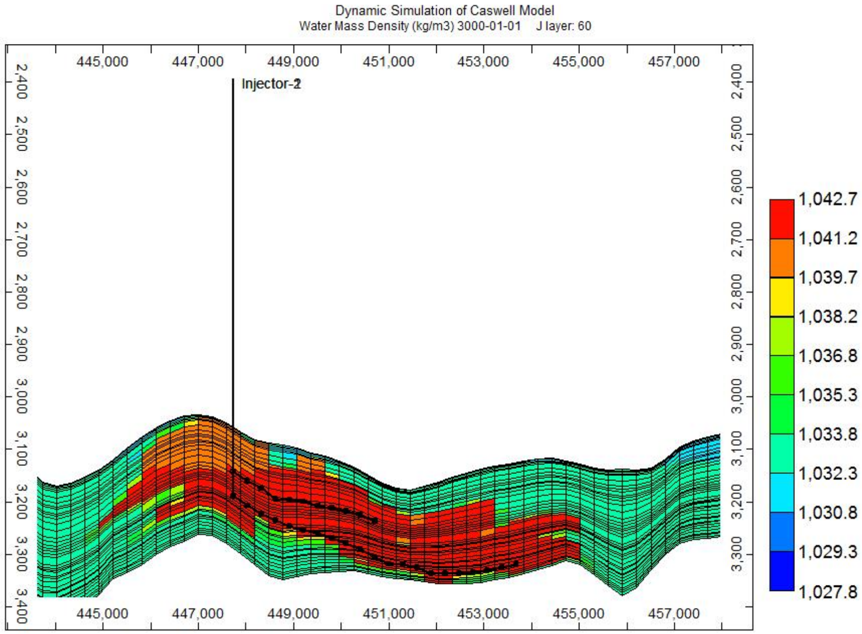
Residual Gas Saturation for Krg Hysteresis (1000yrs later)

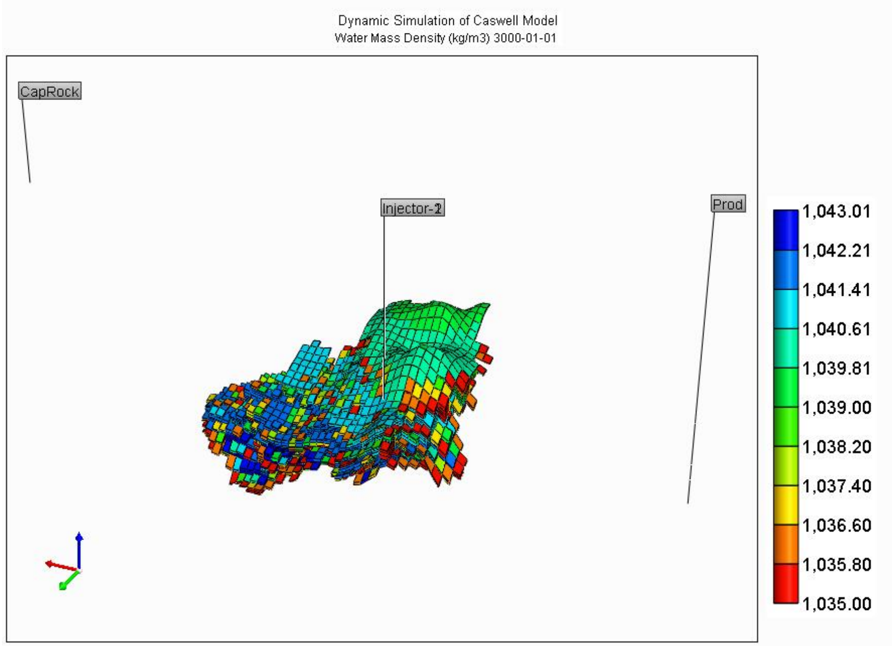




Simulation with Caswell Fan Model

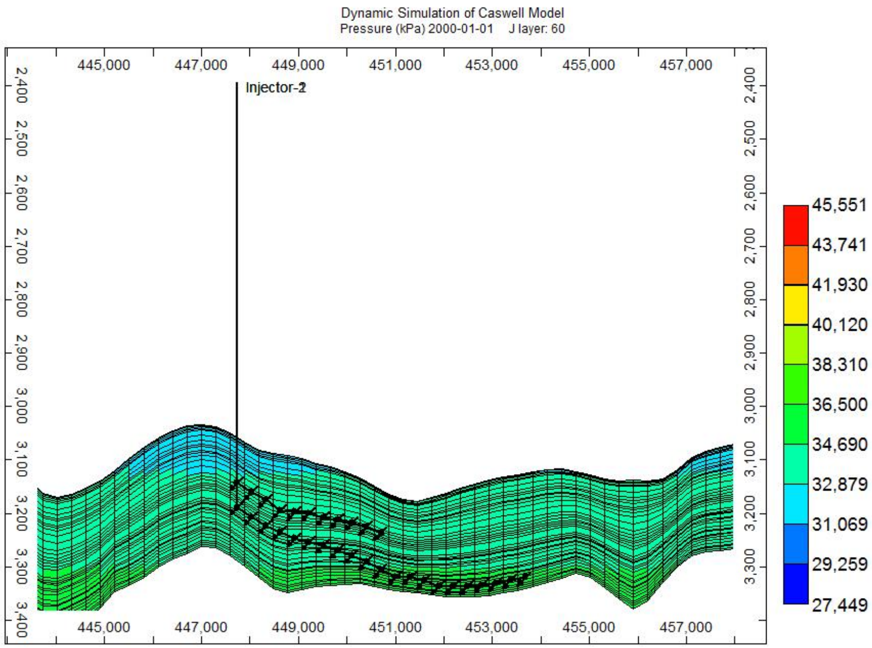
Water Mass Density (1000yrs later)



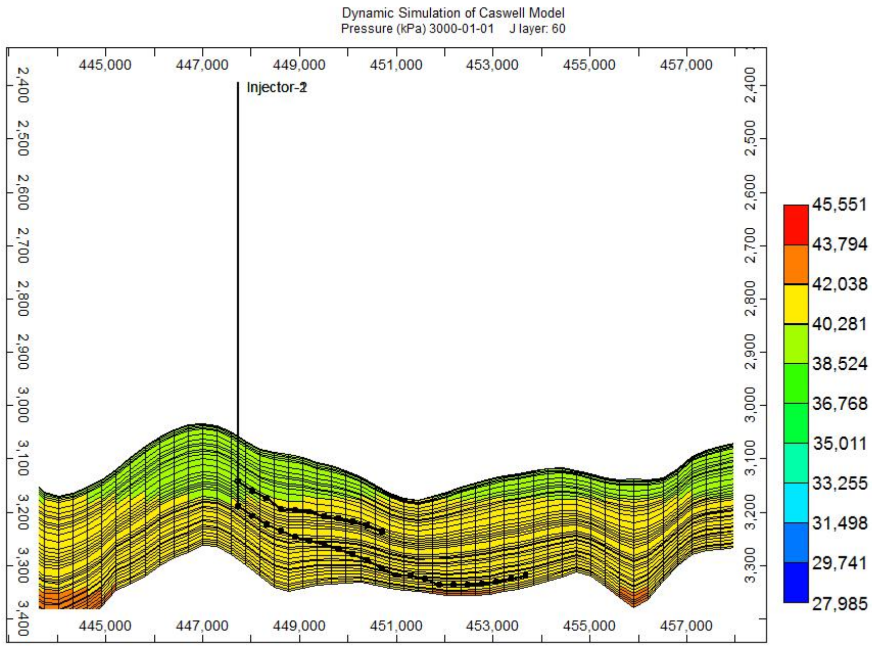


Simulation with Caswell Fan Model

Formation Pressure



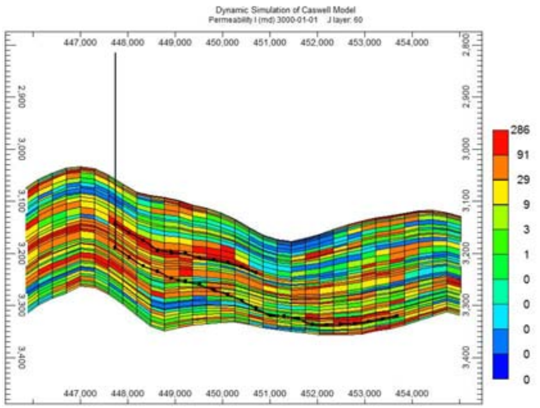
Before Injection

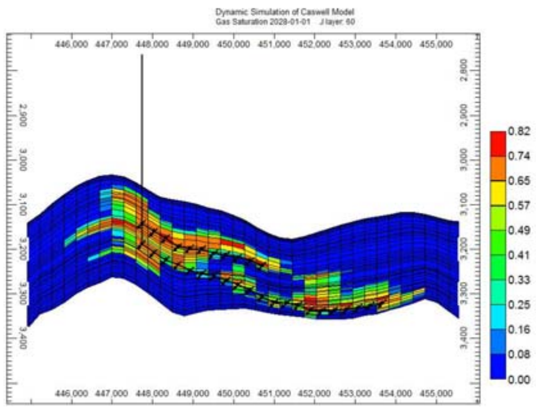


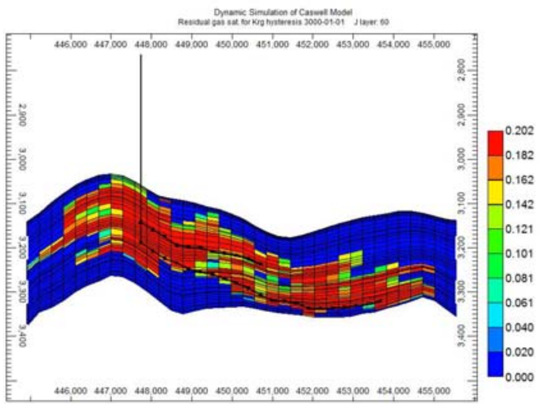
After Injection

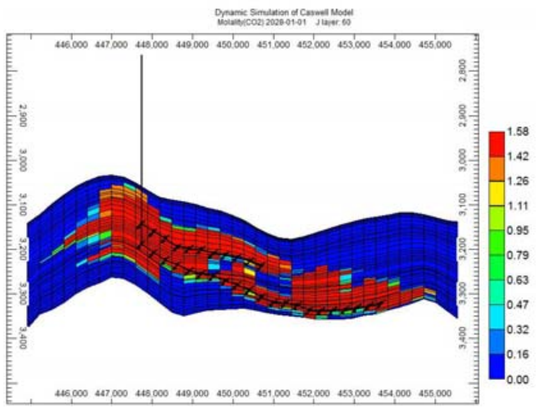
Simulation with Caswell Fan Model

Reservoir Heterogeneity (1)



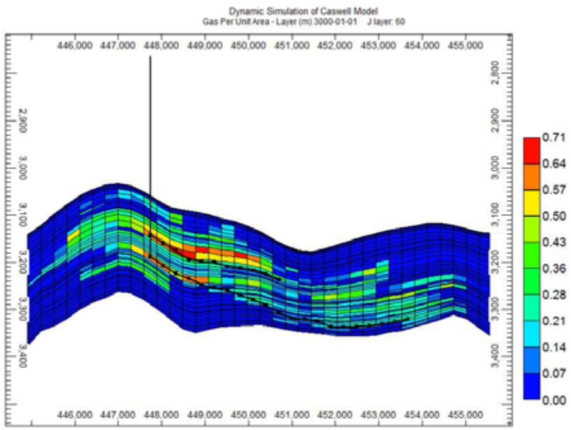


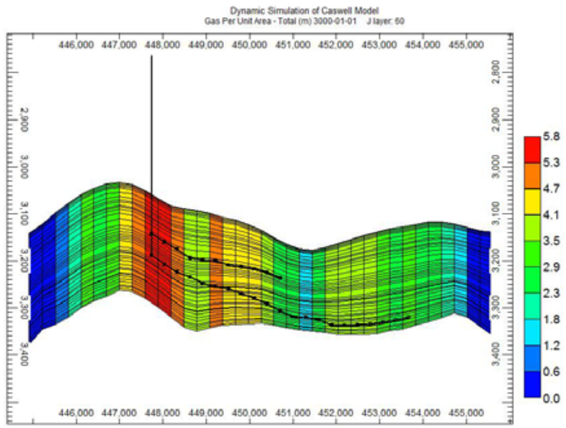


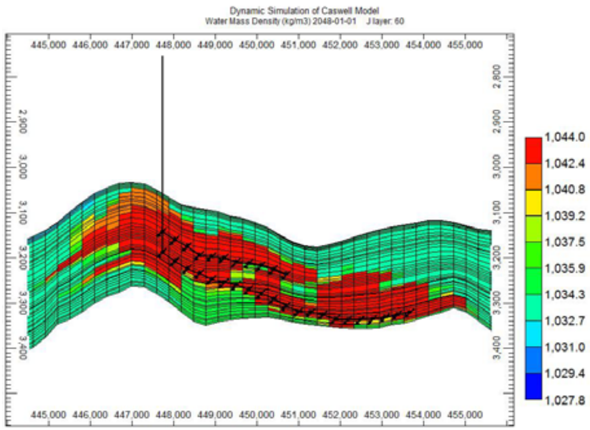


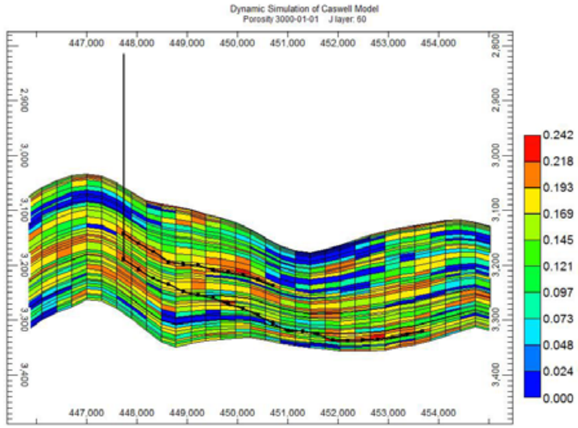
Simulation with Caswell Fan Model

Reservoir Heterogeneity (2)



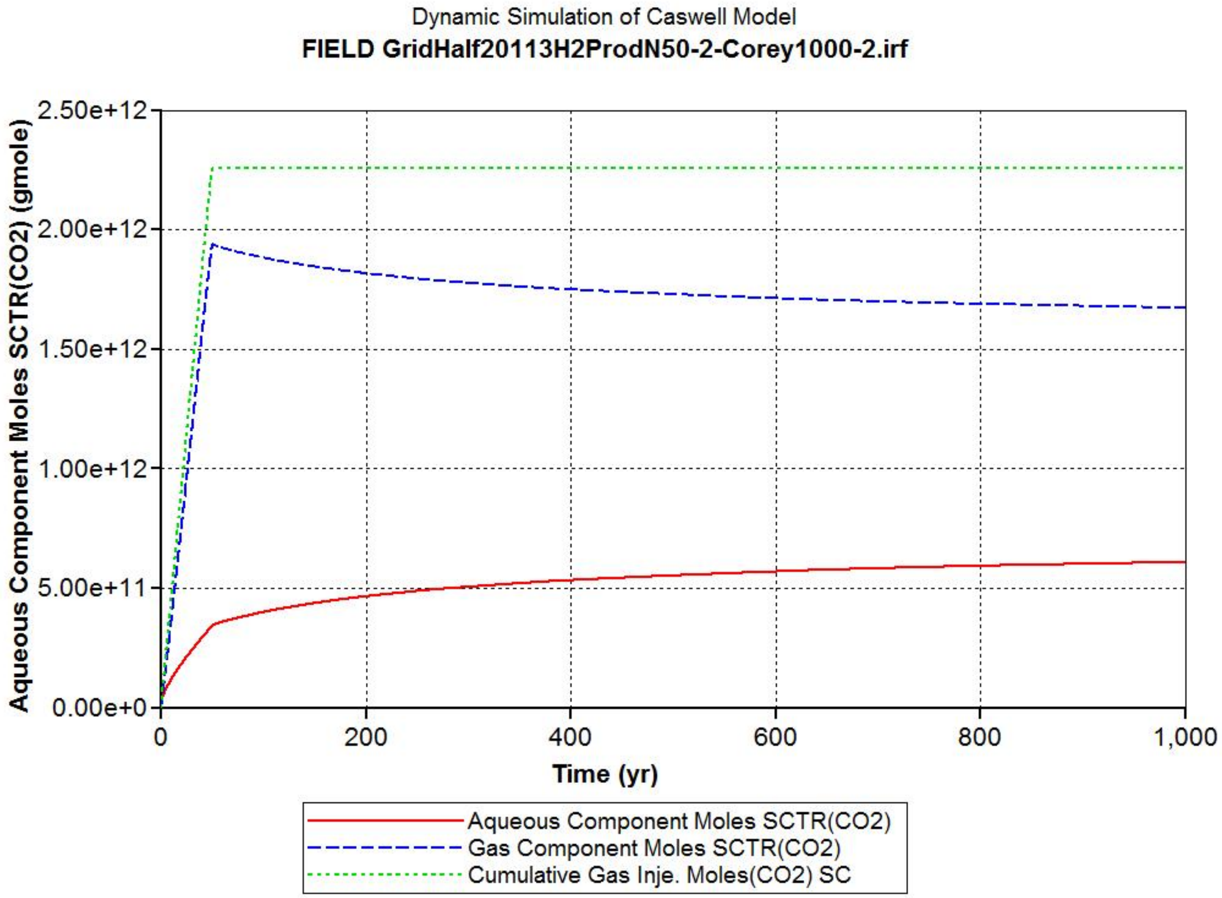






Simulation with Caswell Fan Model

CO_2 Profiles (1000 years)



Simulation with Caswell Fan Model

CO_2 Profiles (1000 years)

Total Injection	2.25719×10^{12}
Supercritical Gas	1.67332×10^{12}
Residual Trapped Gas	8.40807×10^{11}
Dissolved in Water	6.09251×10^{11}
Ratio of Dissolution	27%

7 Summary

- The compositional simulator, CMG-GEM, is suitable to carry out the full-physics dynamic simulation of CO_2 migration and storage.

- The solubility of CO_2 is controlled by the reservoir conditions, including reservoir pressure, temperature and formation water salinity through changing Henry's law constant. The brine water saturated with CO_2 has higher mass density, and tends to move downward or sink.

- The CO_2 injectivity is controlled by reservoir petrophysical properties, such as reservoir porosity, absolute and relative permeability, ratio of Kv/Kh, and perforation.

- Reservoir heterogeneity clearly controls the migration of CO_2 plume and accumulation of CO_2.

- The practical storage capacity of Caswell Fan is more than 99.3387 million tonnes for two horizontal wells.