Australian Government

Geoscience Australia

Carbon storage capacity analysis through the integrated reservoir modelling on Caswell Fan, Upper Campanian, Browse Basin, Australia

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Geoscience Australia

CO_2 Geological Storage and Technology
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Outline

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

1 Objective

➢ ***To assess the characterized and practical CO_2 storage capacity of Caswell Fan, Upper Campanian, Browse Basin, through static and dynamic reservoir modelling***

Stage 1:

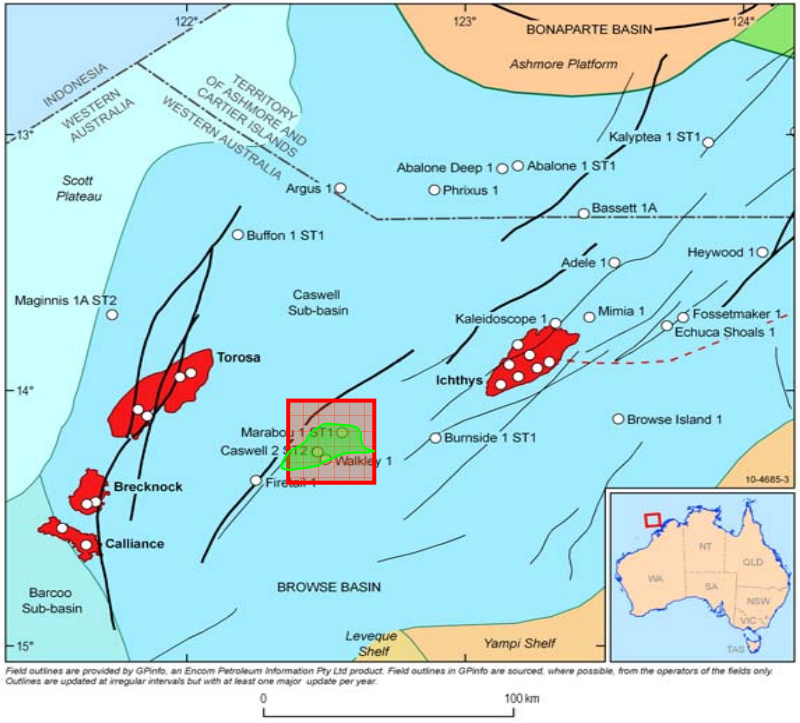
✓Characterized CO_2 Storage Capacity Assessment through Static Reservoir Modelling Using GOCAD™

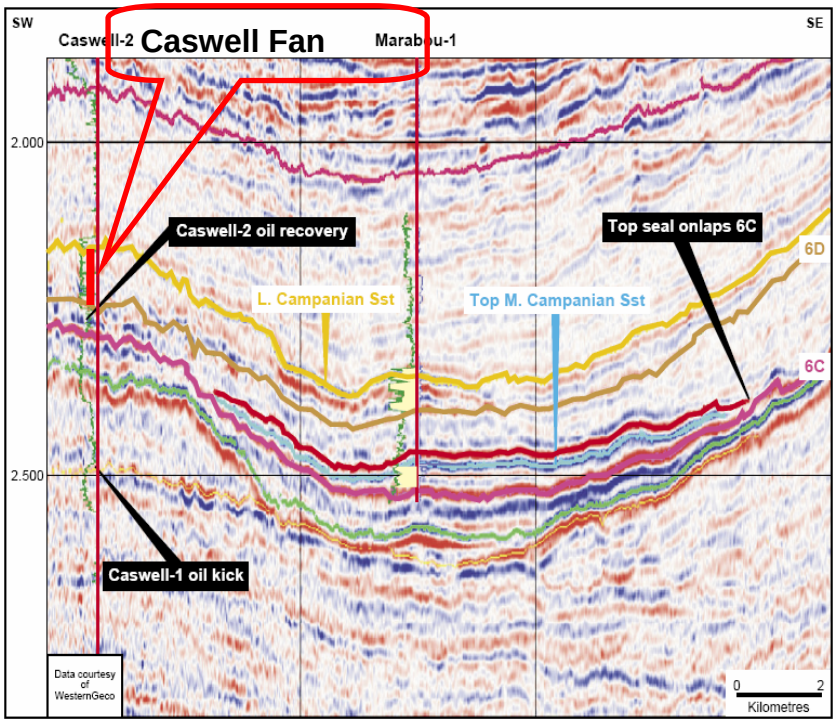
Stage 2:

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

2 Static Reservoir Modelling

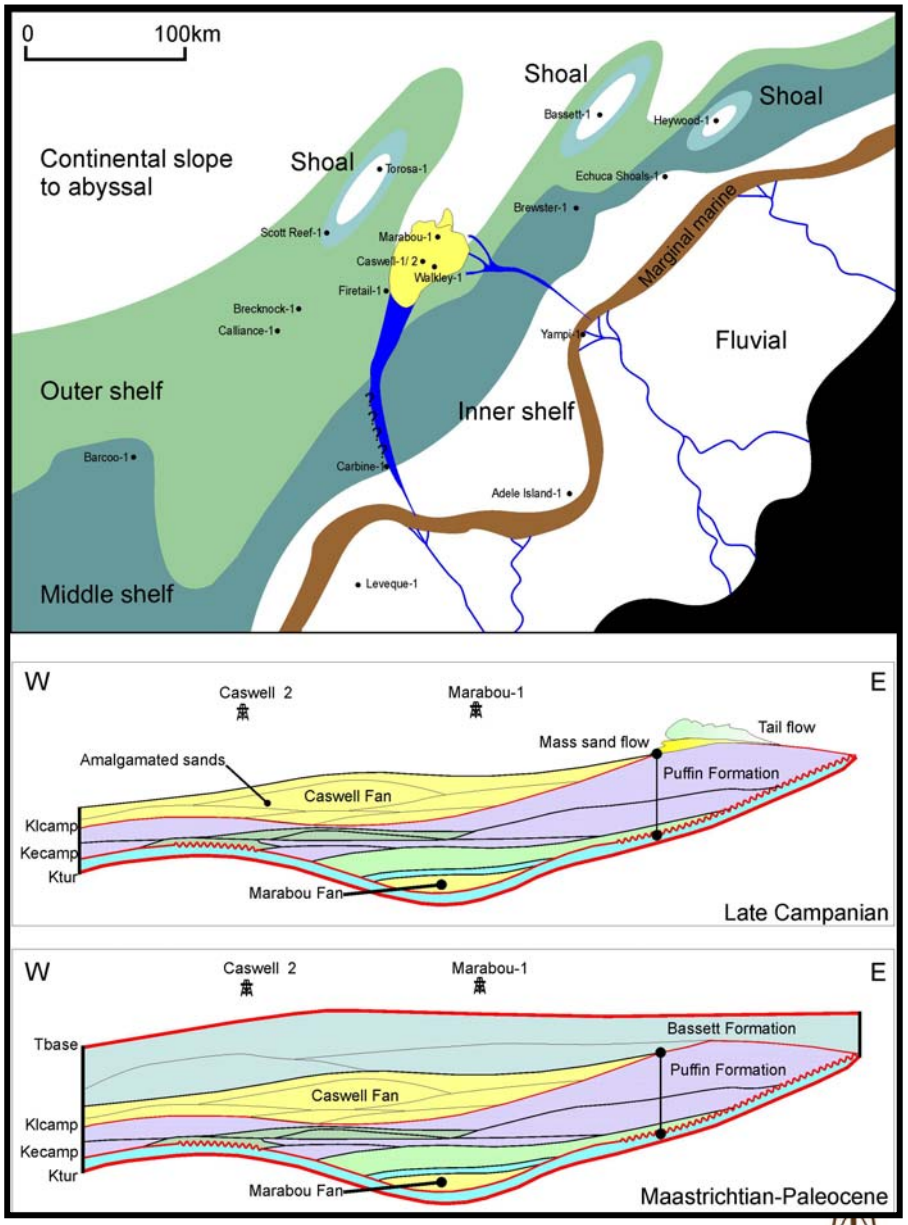
Location of Caswell Fan





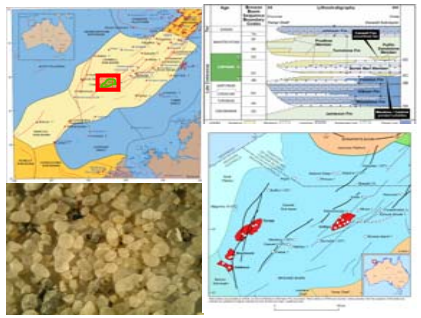
Paleogeography (Late Campanian sequence boundary) (Benson et al, 2004)

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

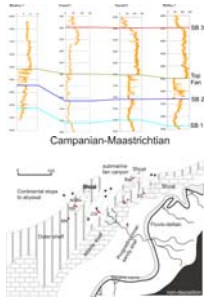


2 Static Reservoir Modelling

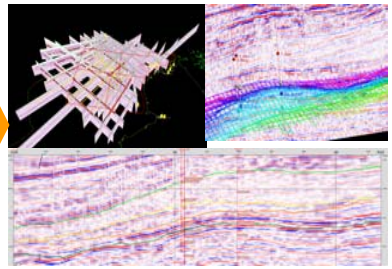
Workflow



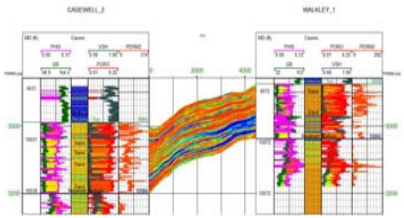
Basin Geology



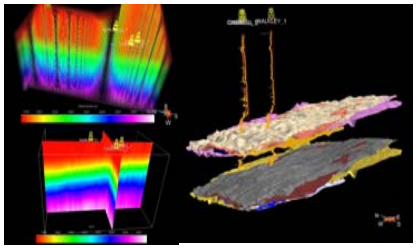
Sedimentology &
Sequence Stratigraphy



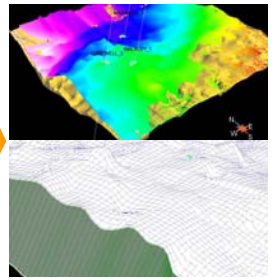
Seismic Interpretation



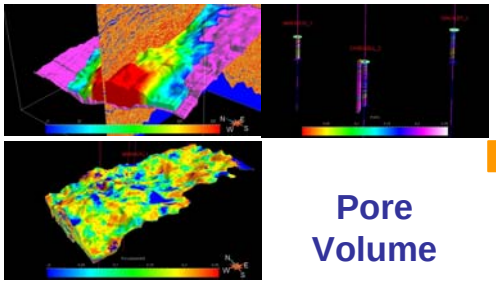
Well Log Interpretation



Velocity Modelling
& Time-Depth
Conversion

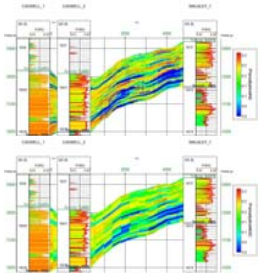


3D Grid
Construction



Pore Volume

Reservoir Modelling



Reservoir
Heterogeneity &
Upscaling

Characterized CO_2 Storage Capacity Potential

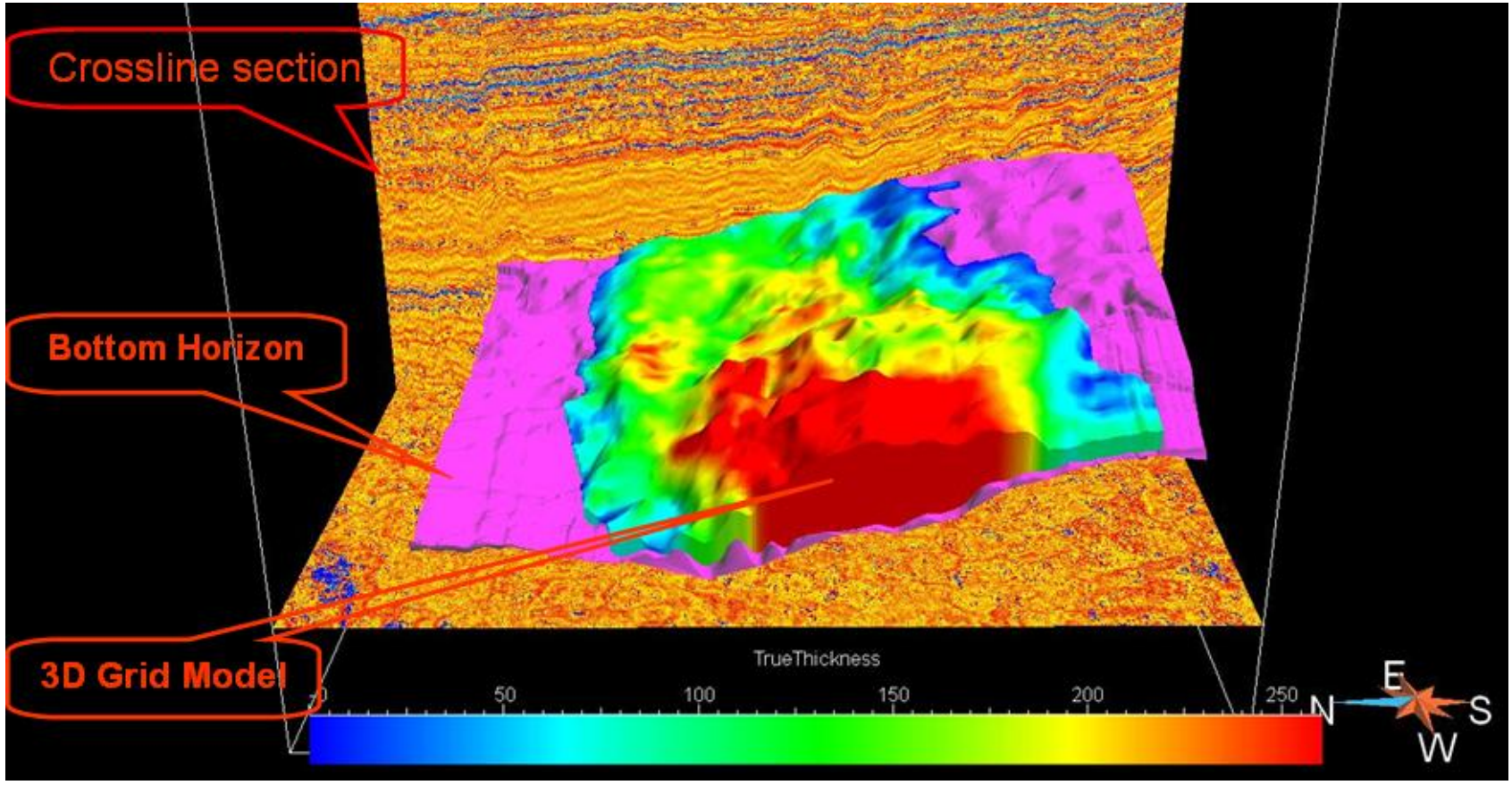
cags

China Australia Geological Storage of CO_2

中澳二氧化碳地质封存

2 Static Reservoir Modelling

Reservoir Model-Seismic-Bottom Horizon



True thickness of Caswell Fan: 0~260.53m

2 Static Reservoir Modelling

CO_2 Storage Potential in AOI-Caswell

➢**US DOE Methodology:**

$$G_{CO_2} = Ah_g \phi_{tot} \rho E$$

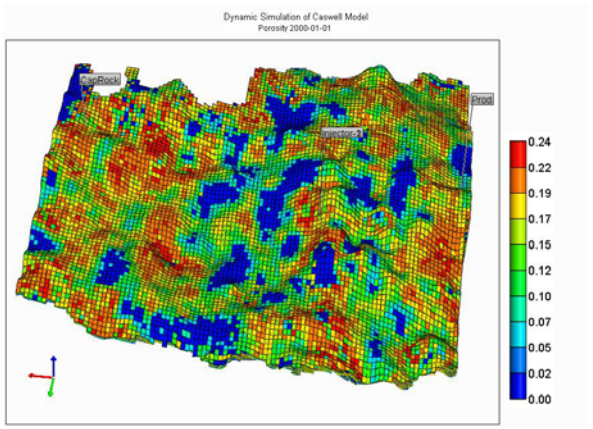
➢**Storage Coefficient for (in Clastic Formation) (IEAGHG Report: 2009/13):**

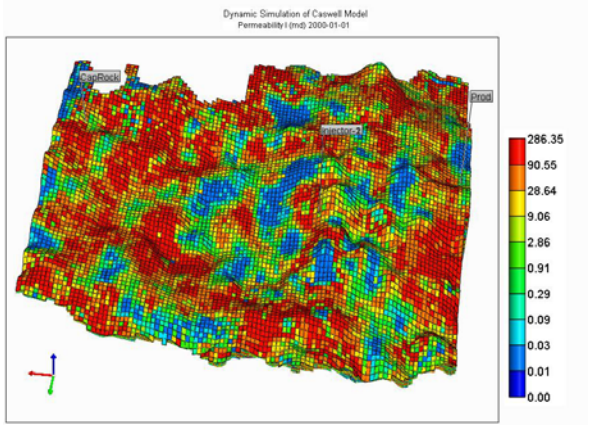
P10: 1.86%
P50: 2.70%
P90: 6.00%

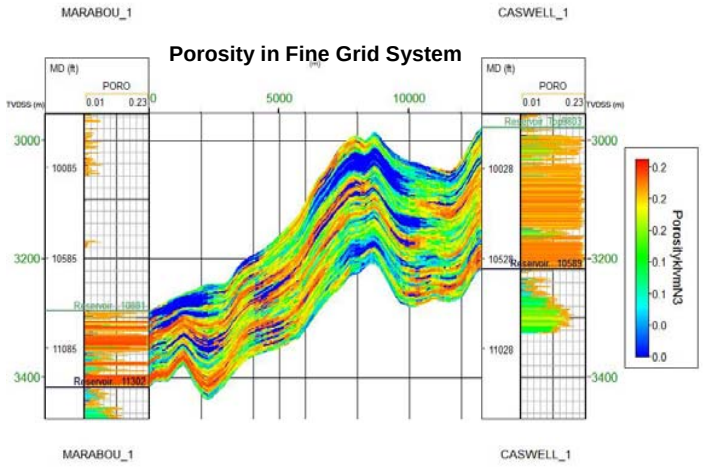
➢**Characterized Storage Potential (Assume CO_2 density: 0.65 g/cc, normal reservoir conditions):**

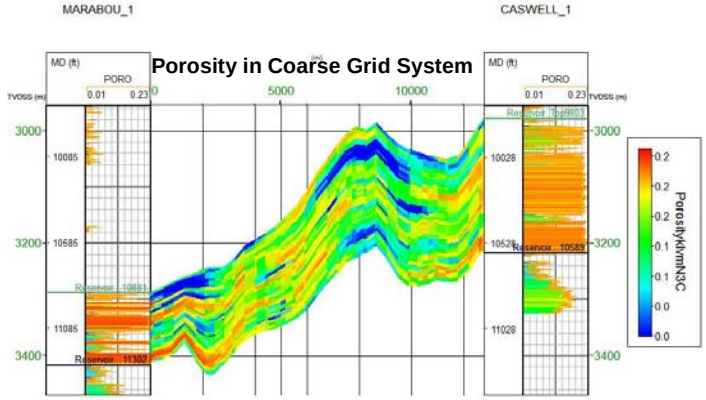
P10: 2.04 ×10^8 tonne
P50: 2.96 ×10^8 tonne
P90: 6.59 ×10^8 tonne

3 Upscaling of Static Reservoir Model









① Number of grid cells: From >7mllion to half million.

② RESCUE format from modelling tool to simulator.

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

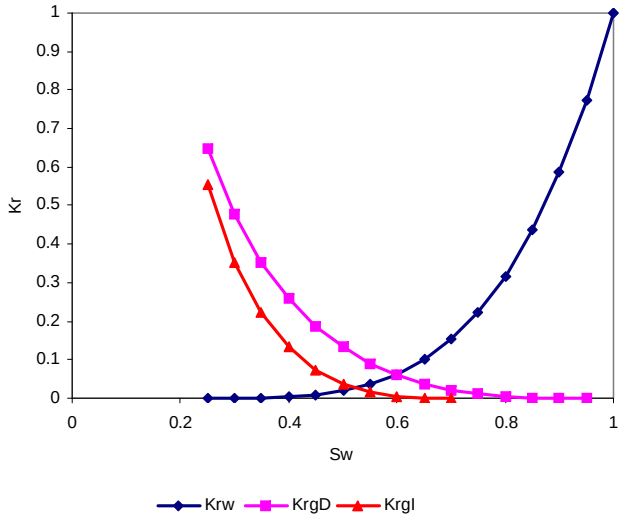
Critical Pressure (*atm*)	72.8
Critical Volume ($m^3/kmol$)	0.094
Critical Temperature (*K*)	304.2
Acentric factor (dimensionless)	0.225
Molecular Weight	44.01
EOS Ω_a parameter (Peng-Robinson's Model)	0.45724
EOS Ω_b parameter (Peng-Robinson's Model)	0.0778
Henry's Law Constant	771111
Reference Pressure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

5 Gas-Water Relative Permeability Hysteresis Model

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

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

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



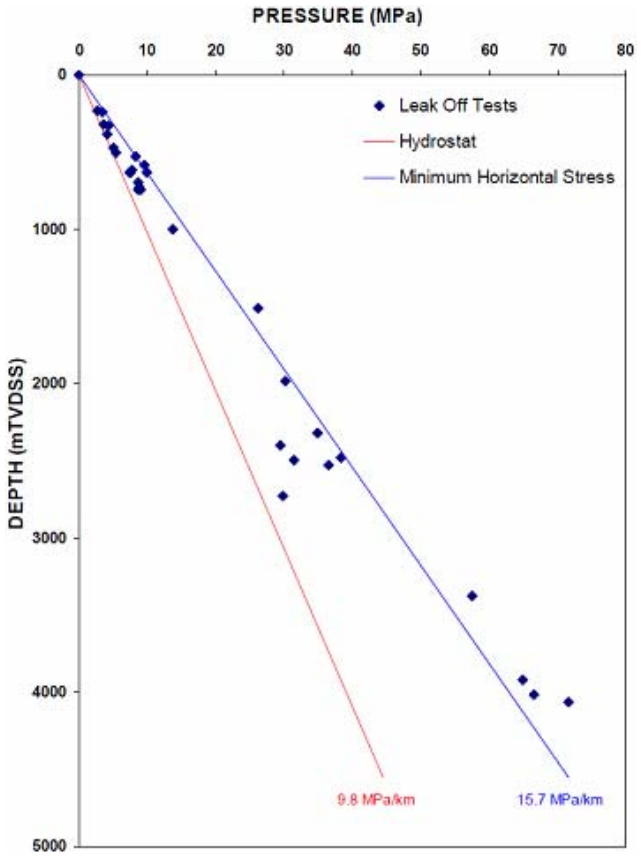
- CMG-GEM™ internal hysteresis model
  - Modified Land's equation:

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

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.



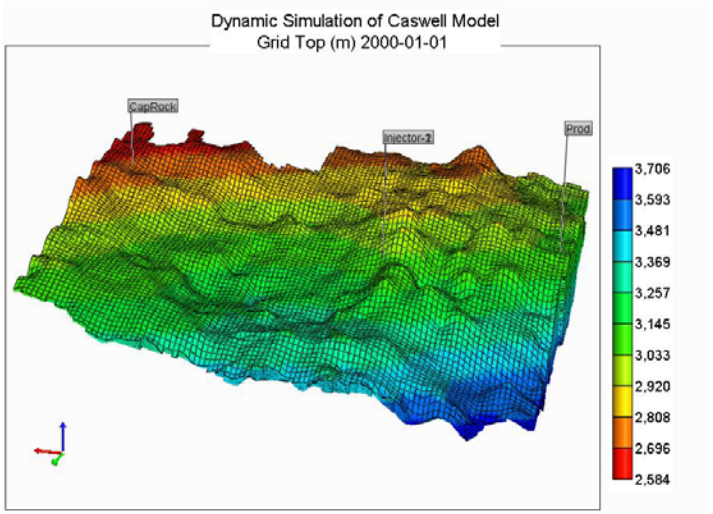
➢Maximum injection (STG surface gas) rate:
1.473×10^6 m^3/day

➢***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

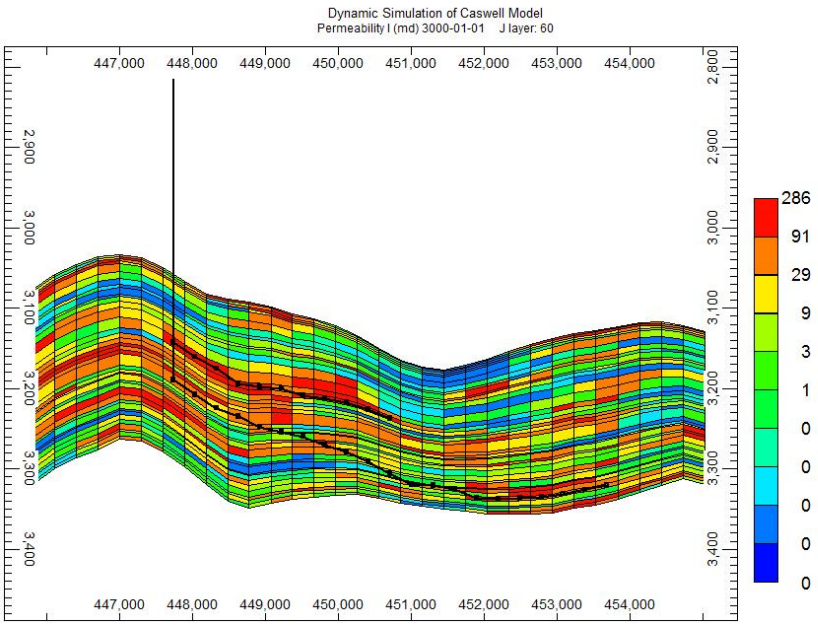


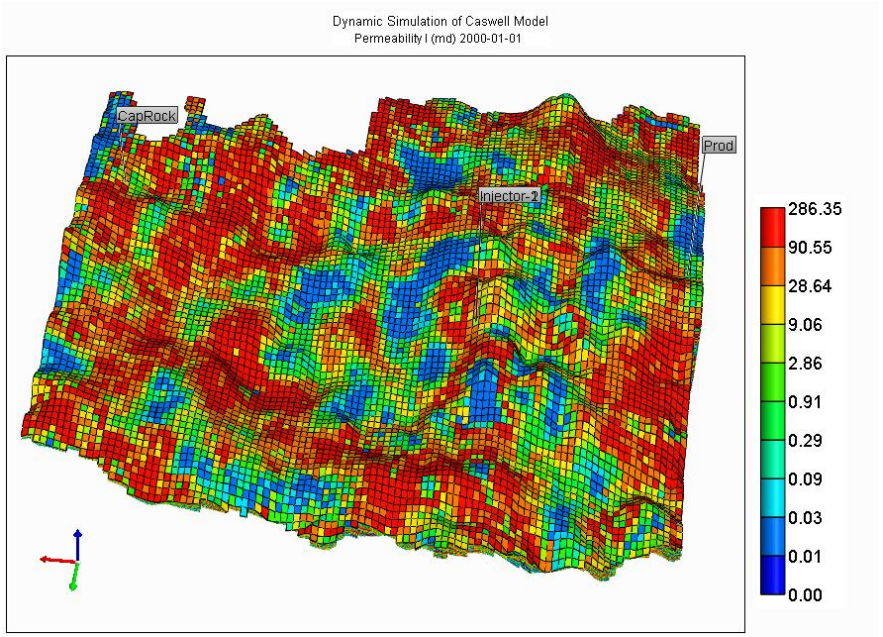
✓2 horizontal injection well (Injector-1 & 2)
✓1 production well (Prod)
✓1 Caprock well (CapRock)

✓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

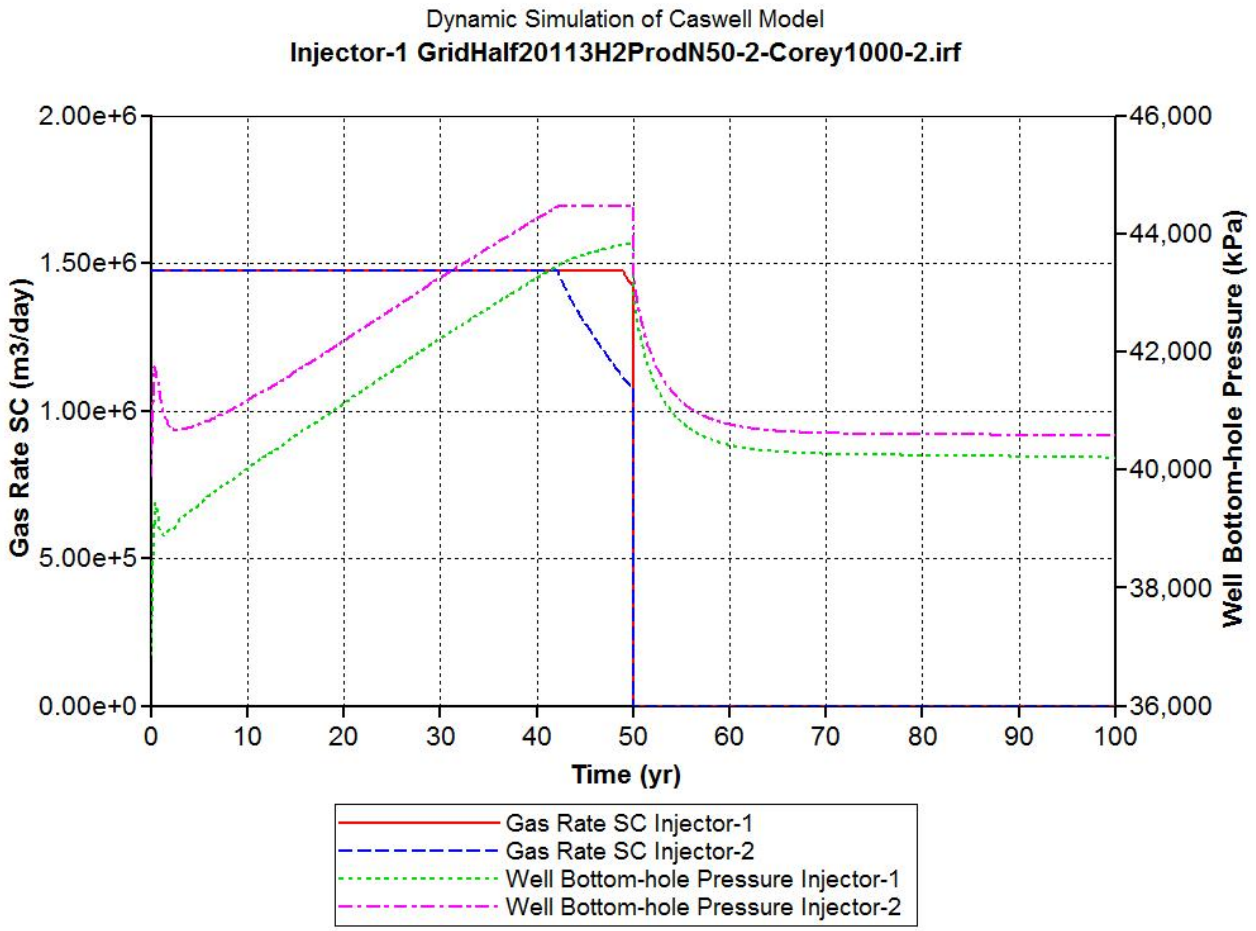
Perforation Interval





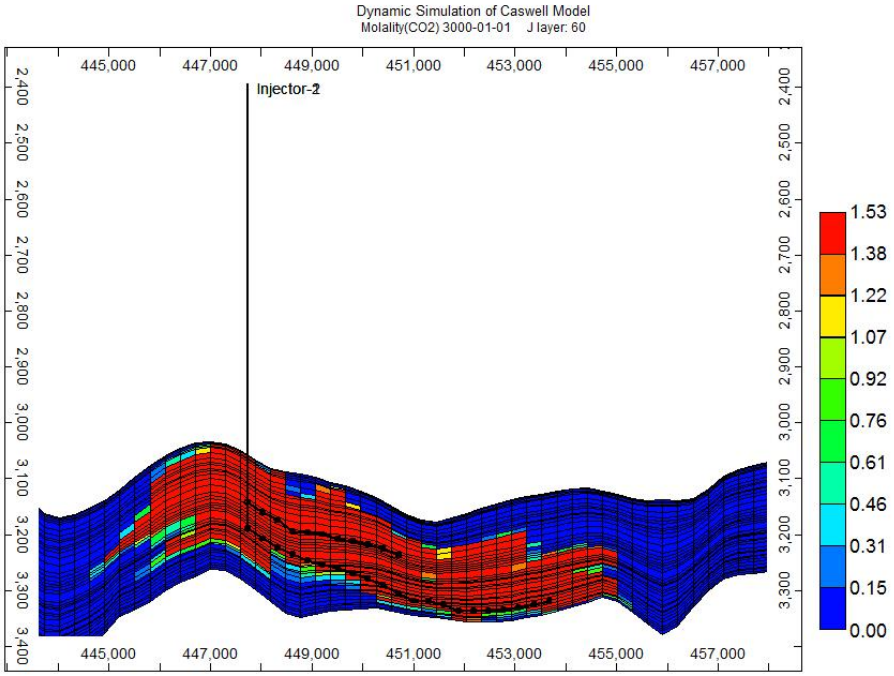
Simulation with Caswell Fan Model

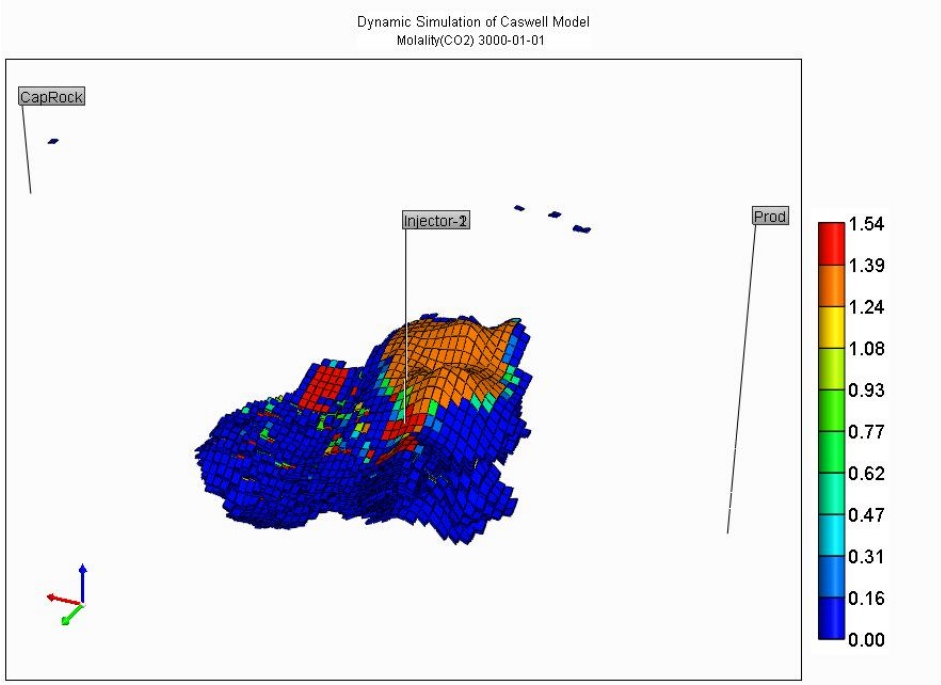
Gas Mass Rate & Bottom Hole Pressure (100 years)



Simulation with Caswell Fan Model

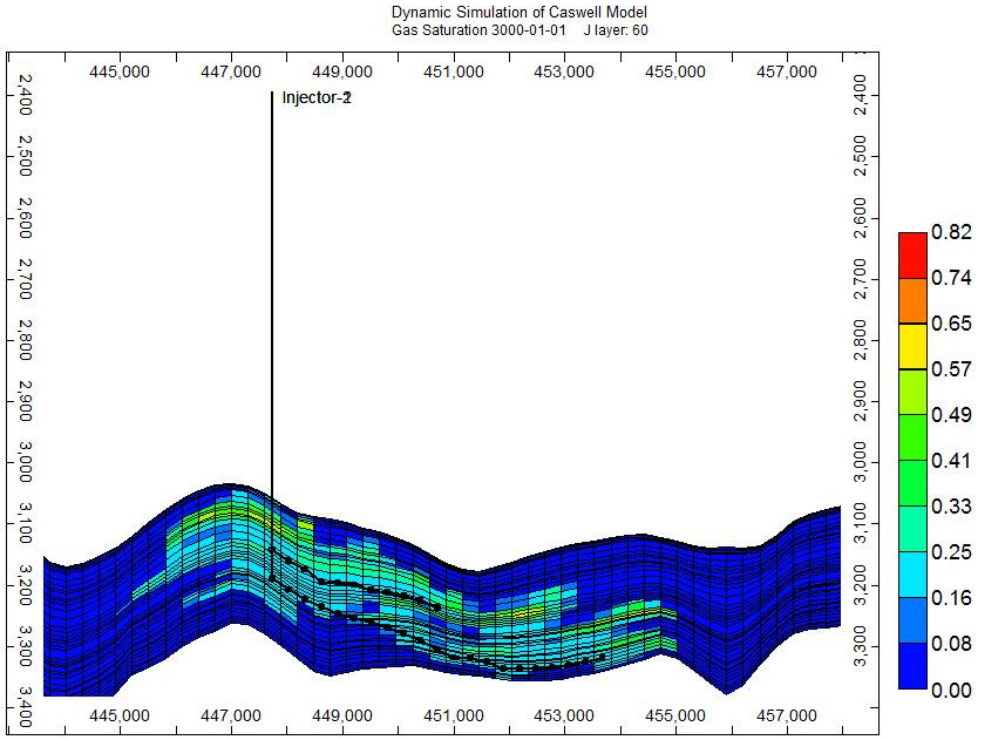
CO_2 Molality (1000yrs later)

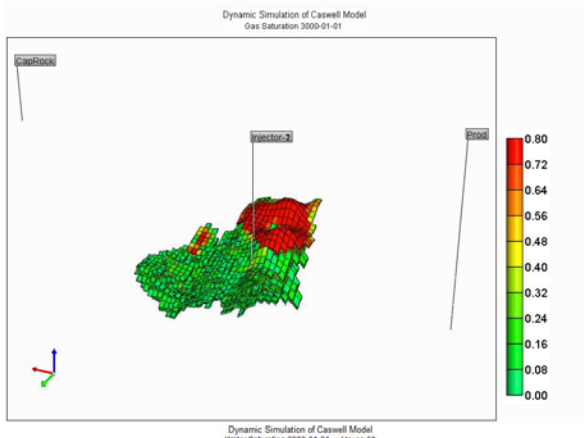


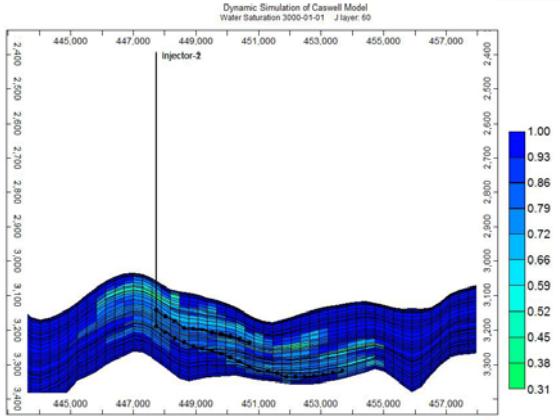


Simulation with Caswell Fan Model

Gas Saturation (1000yrs later)

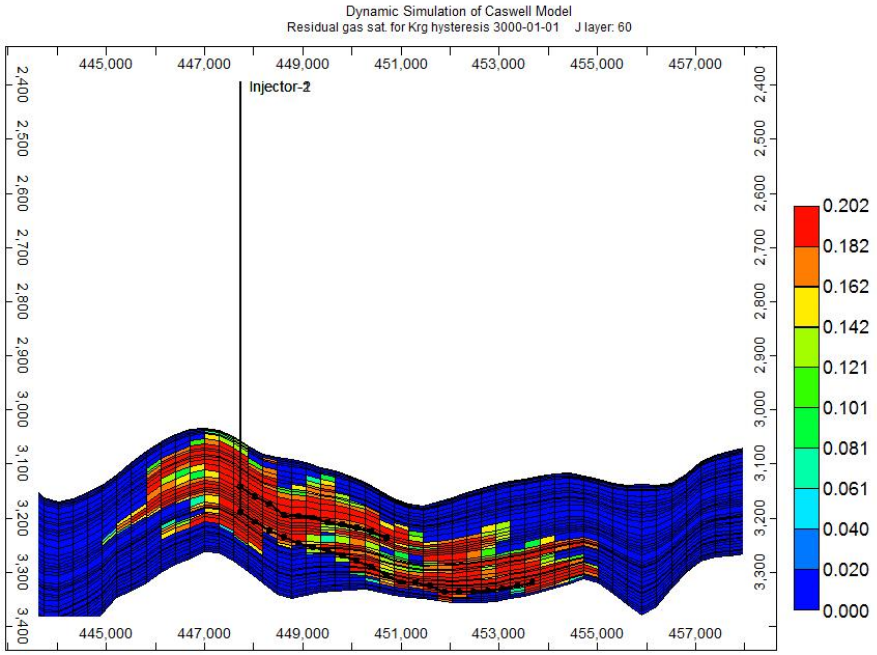


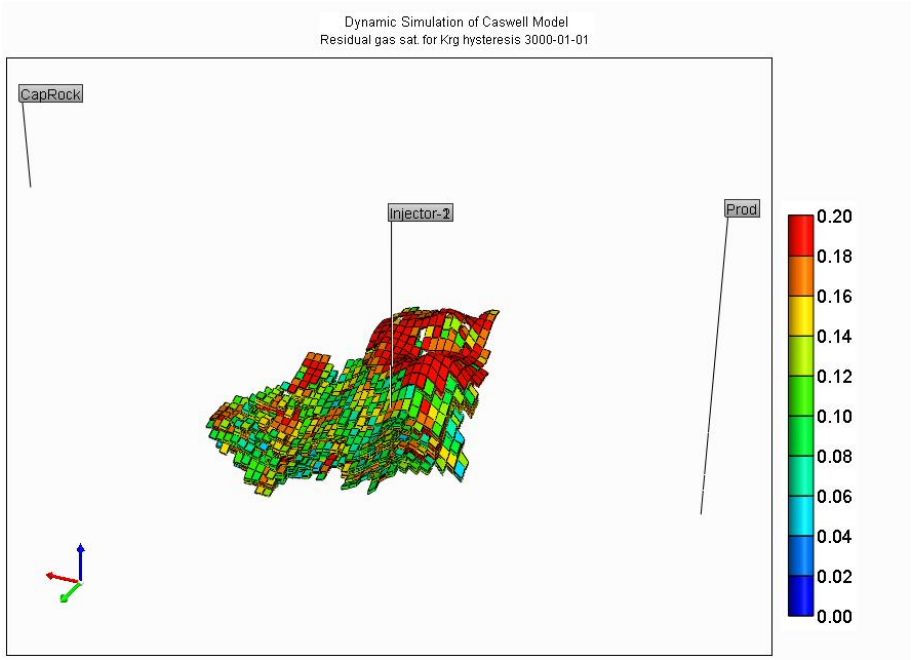




Simulation with Caswell Fan Model

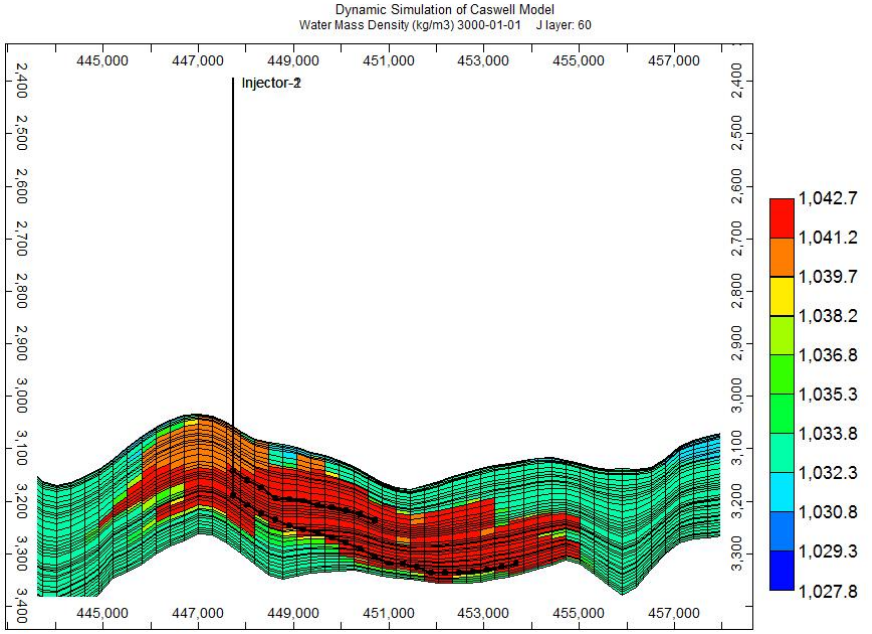
Residual Gas Saturation for Krg Hysteresis (1000yrs later)

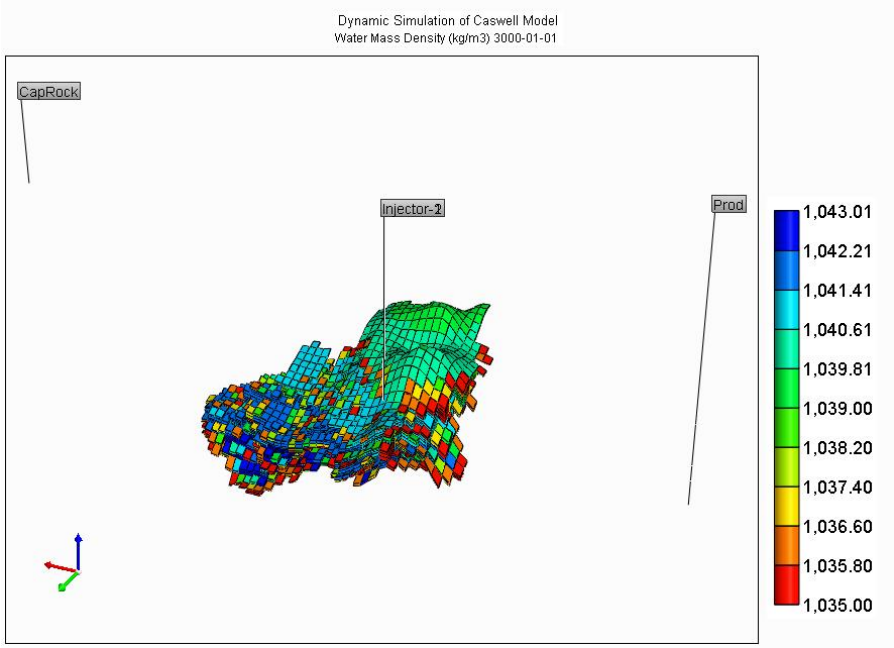




Simulation with Caswell Fan Model

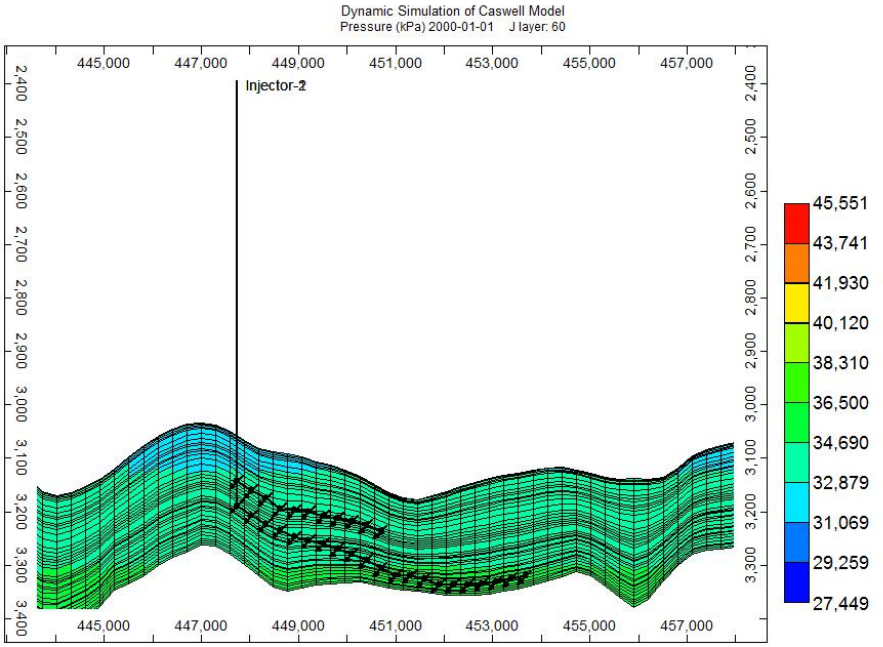
Water Mass Density (1000yrs later)



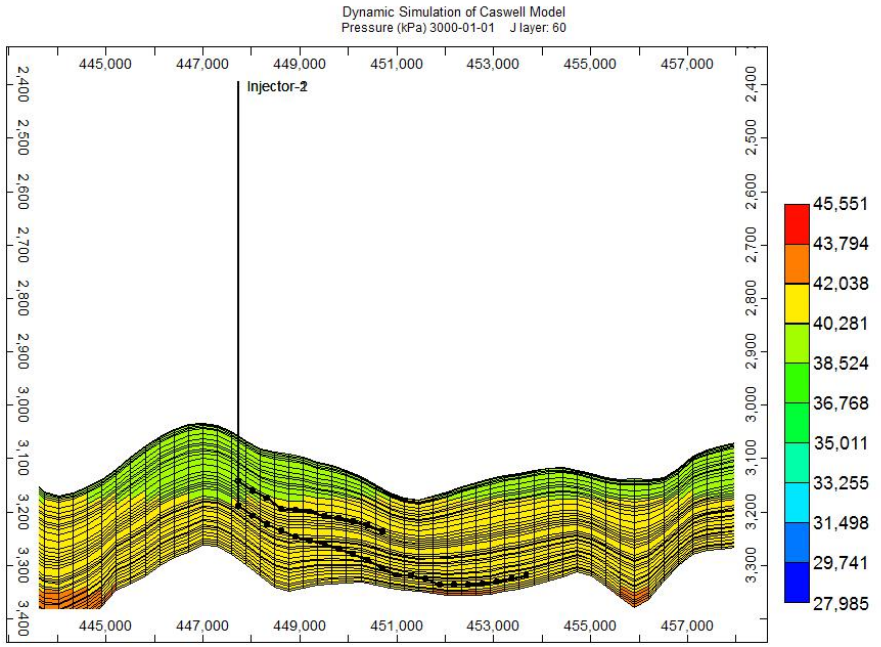


Simulation with Caswell Fan Model

Formation Pressure



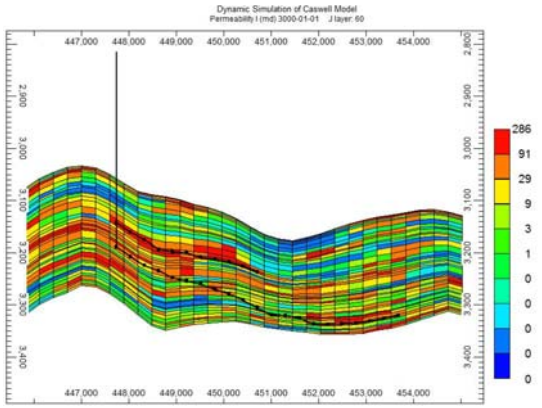
Before Injection

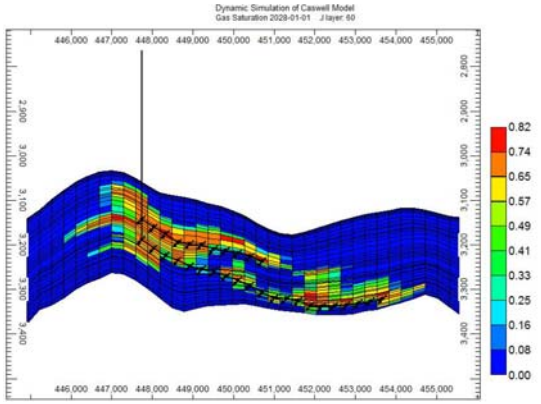


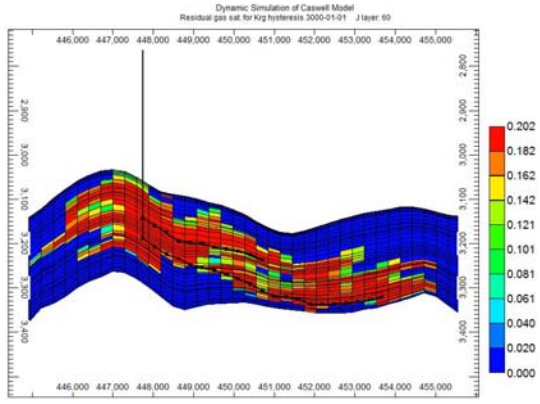
After Injection

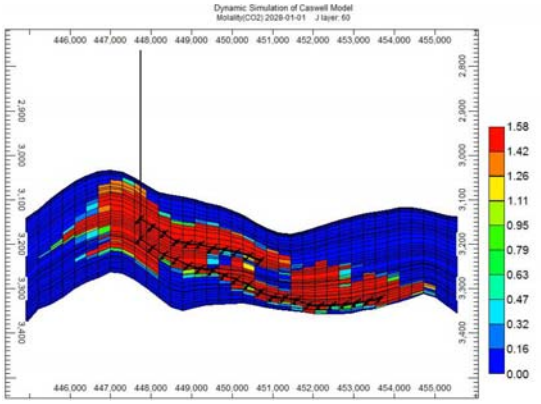
Simulation with Caswell Fan Model

Reservoir Heterogeneity (1)



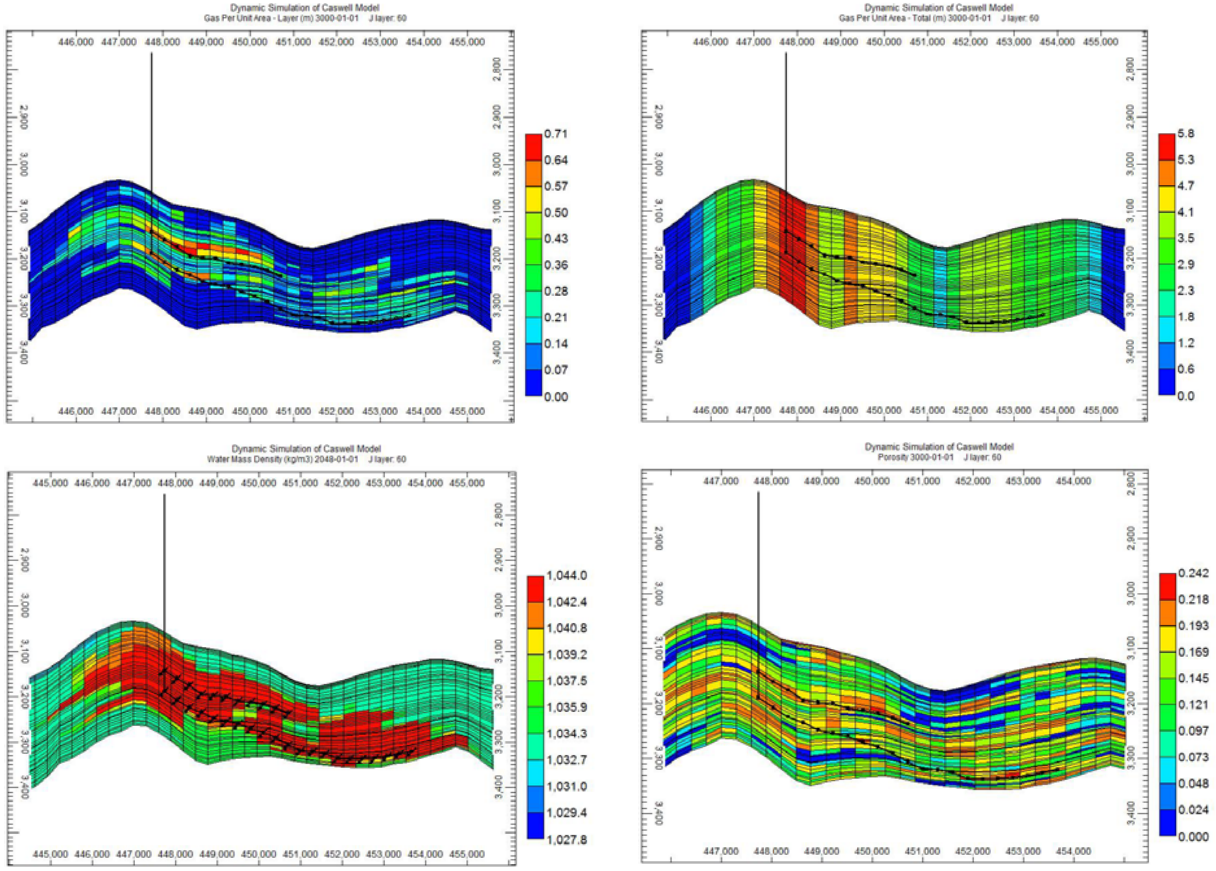






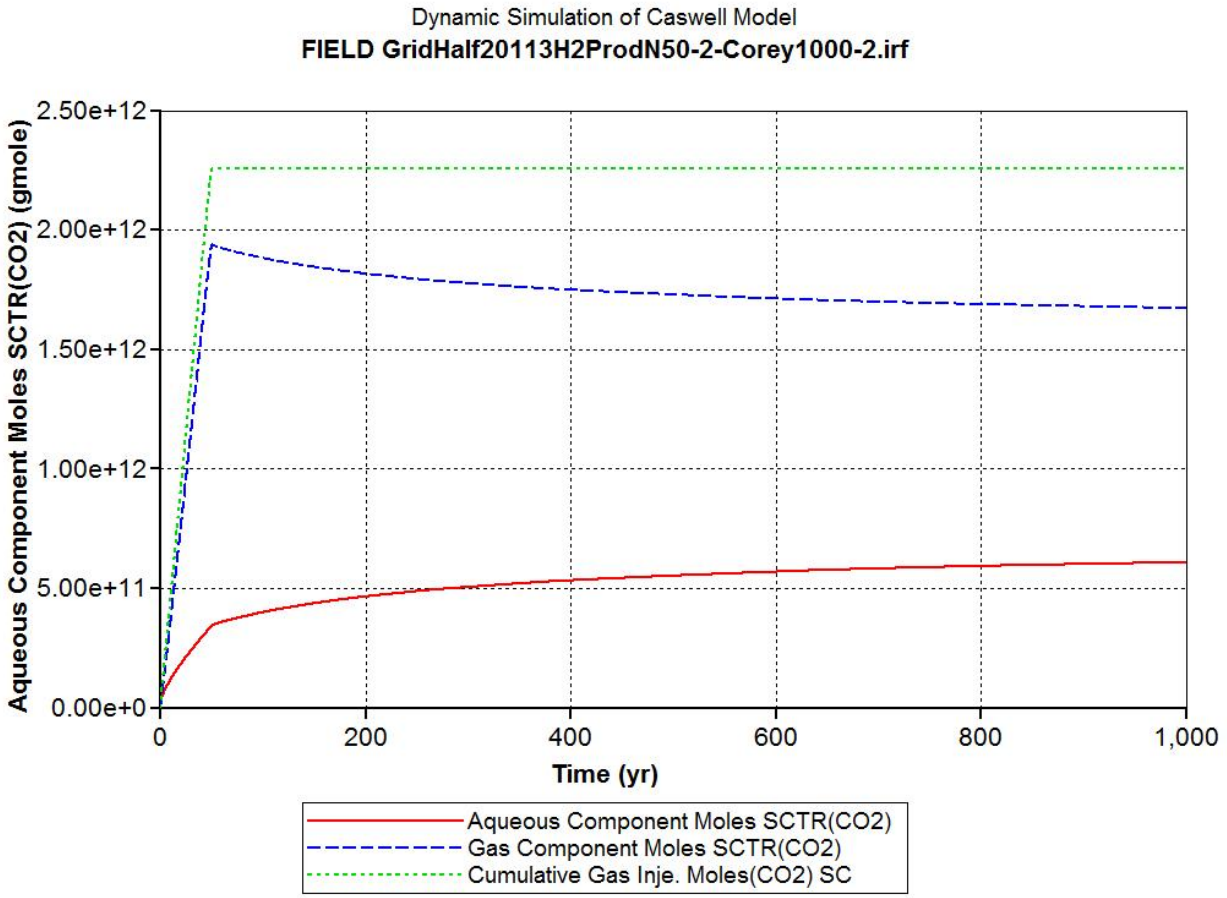
Simulation with Caswell Fan Model

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 (*gmole*)	2.25719×10^{12}
Supercritical Gas (*gmole*)	1.67332×10^{12}
Residual Trapped Gas (*gmole*)	8.40807×10^{11}
Dissolved in Water (*gmole*)	6.09251×10^{11}
Ratio of Dissolution	27%

7 Summary

- After the static reservoir modelling, the characterized CO_2 storage potential is 296 million tonnes.

- 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.