Effects of Natural or Hydraulic Fractures on CO_2 Sequestration in Saline Formations

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Outline

- Background
- Methodology
- Case study
- Conclusions

Challenges in CO_2 Sequestration

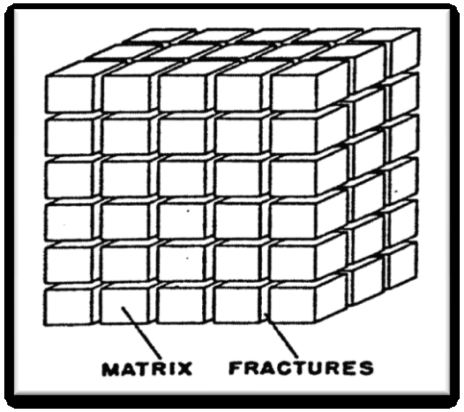
- Site selection: storage potential assessment with considering possible leakages
- Monitoring: scheme design to be capable of observing CO_2 transport and precaution of leakage through fractures/wells

- This work: to simulate CO_2 propagation in saline aquifer and leakage through fractures/wells

Models for Fracture Description

- Single porosity model
  - Accuracy
  - Large number of grids

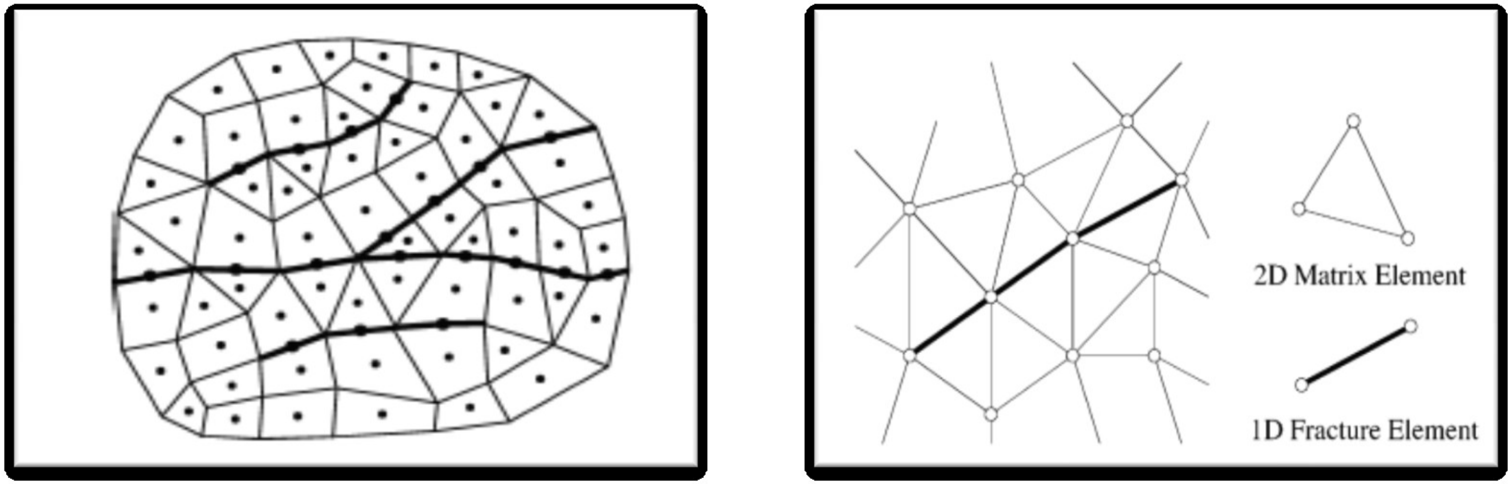
- Dual porosity model
  - Large-scale but sparse fractures
  - Transfer function
  - Scale-dependent heterogeneity



- Discrete fracture modeling

Discrete Fracture Modeling

- Fractures are discretized as explicit entities
- Fractures are represented individually
- Connection-list based simulation: fracture-fracture, matrix-fracture, matrix-matrix connections

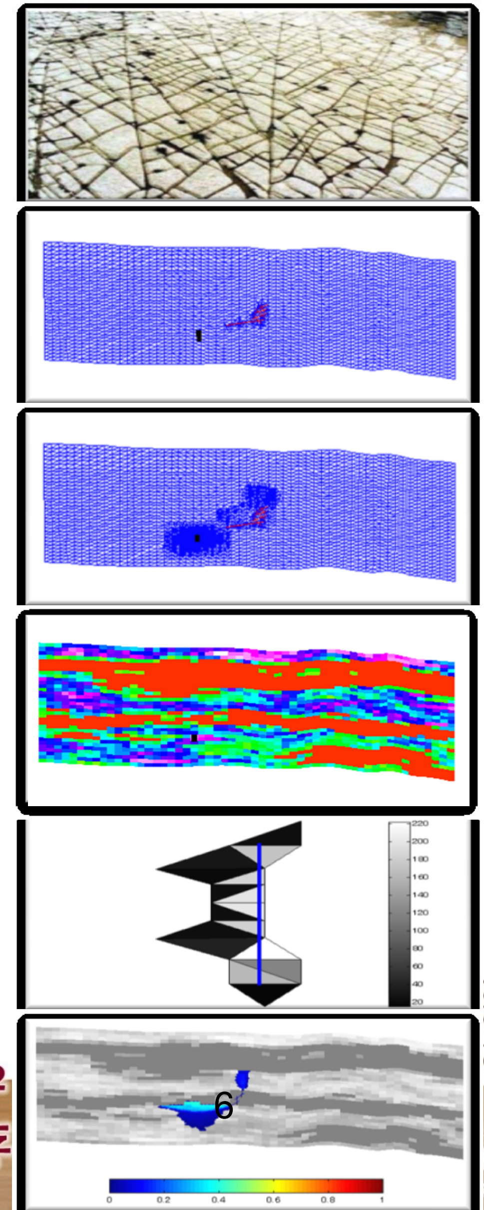


(Karimi-Fard, SPE 88812)

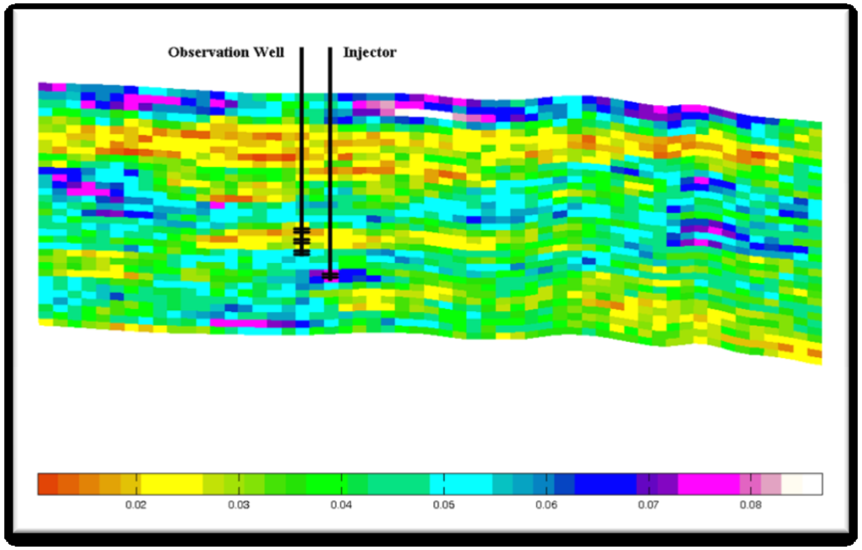
Applied DFM Workflow

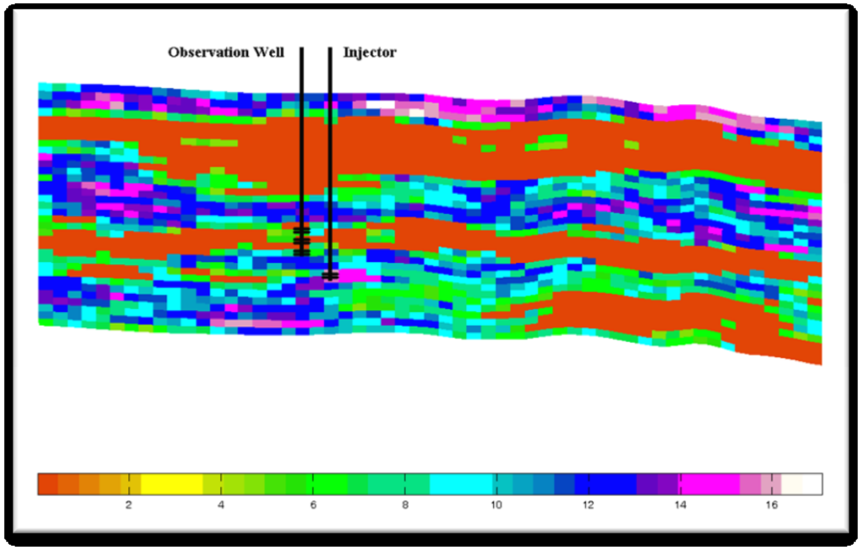
Geologic Model
↓
Unstructured Gridding
↓
Grid Refinement → Well Index Calculation
↓
Property Modeling → Well Index Calculation
↓
Transmissibility Calculation

Transmissibility Calculation + Well Index Calculation → Simulation



Simulation Setup



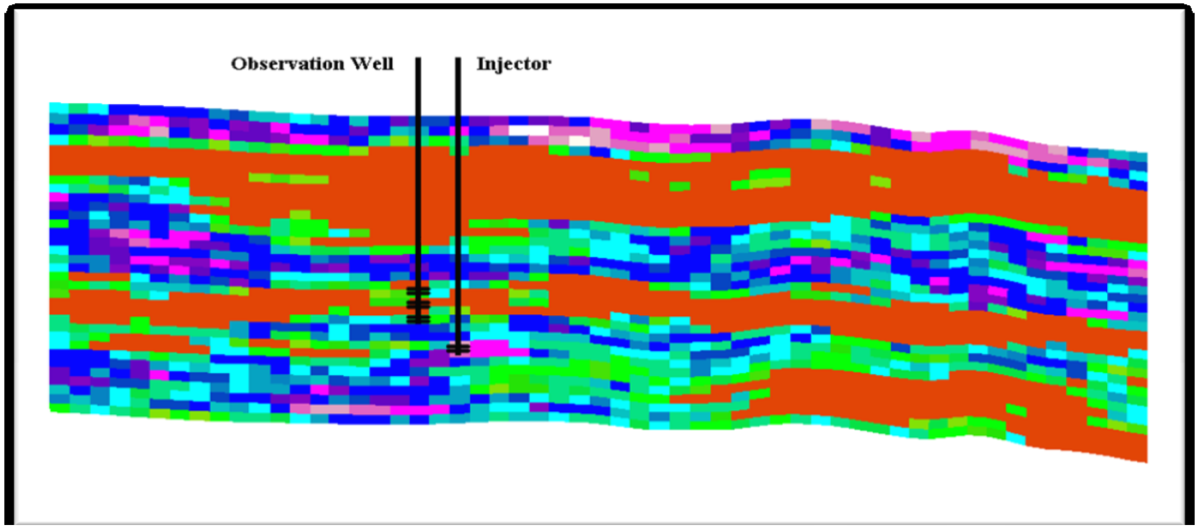


- Reservoir size: 17,209.3 ft × 2,589.99 ft
- Matrix porosity: 0.48% – 8.4%
- Matrix permeability: 0.0019mD – 11.7mD
- Fracture porosity: 100%
- Fracture permeability: 1,000,000mD
- Fracture aperture: 3.28 × 10^{-3} ft
- Two wells: one injector completed in target formation, one monitoring well completed below, in middle of, and above caprock

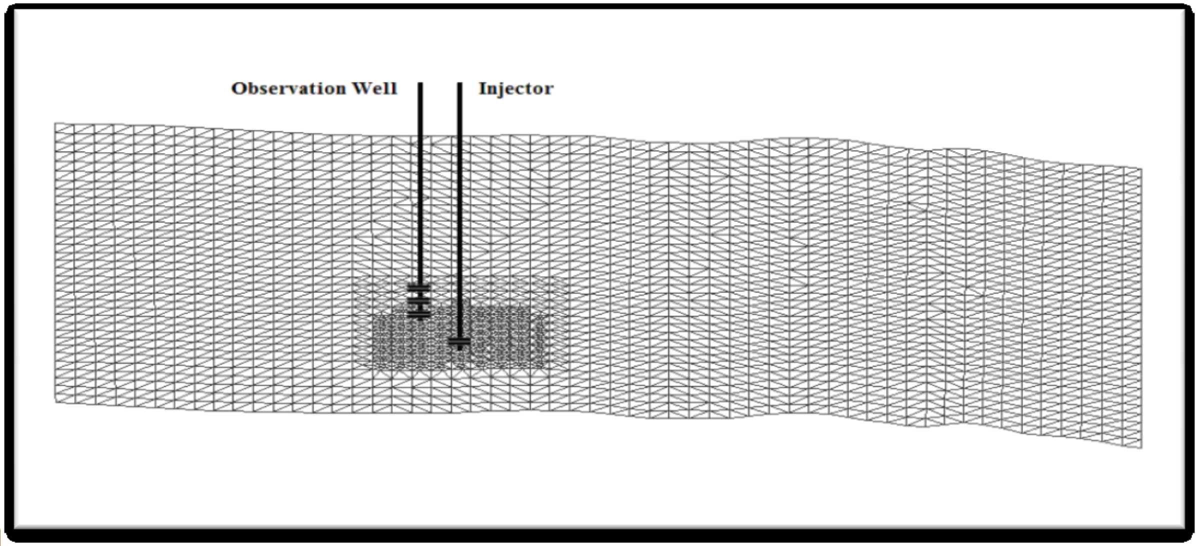
Case Description

Case 1	With no natural fractures
Case 2	With natural fractures
Case 3	Fractures close to injection location
Case 4	Fractures far from injection location
Case 5	Fracturing well: half length = 150 ft
Case 6	Fracturing well: half length = 450 ft

Case 1: with no natural fractures

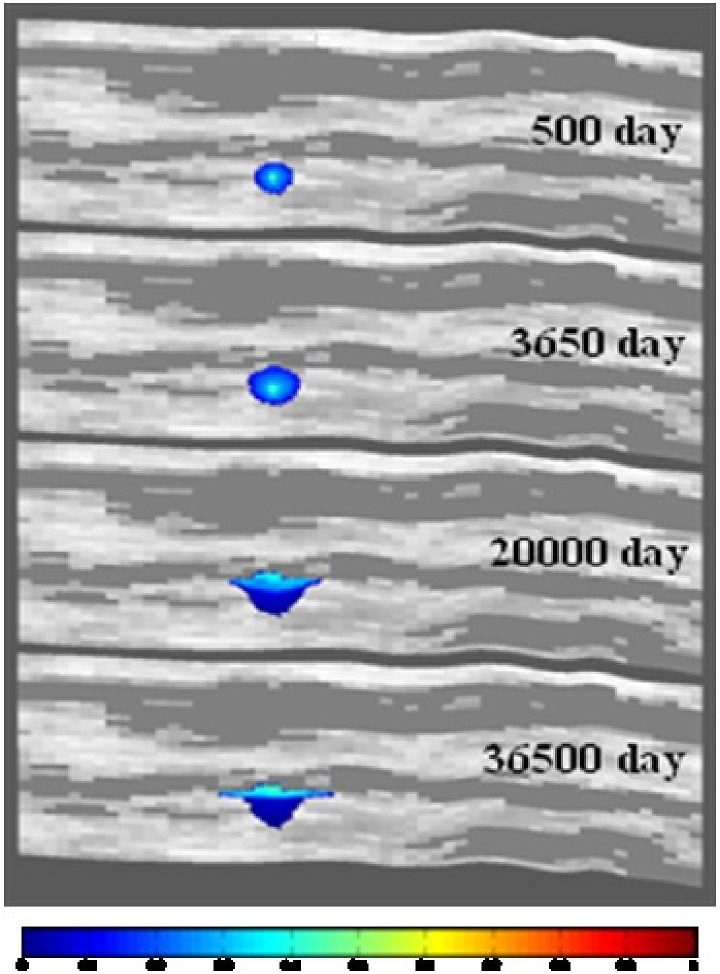


GeoModel

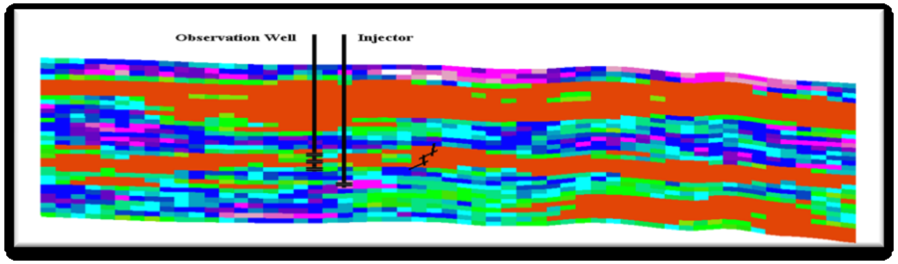


Gridding

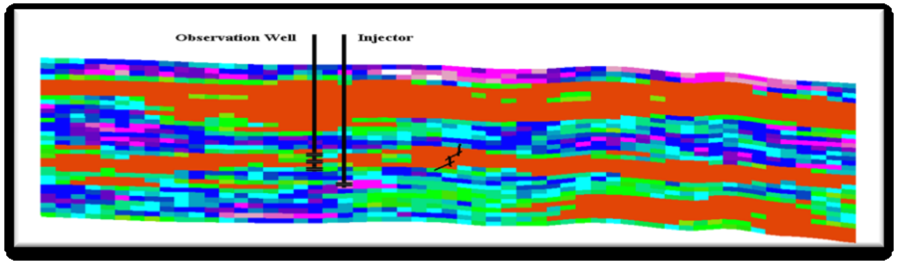
CO_2 saturation profiles



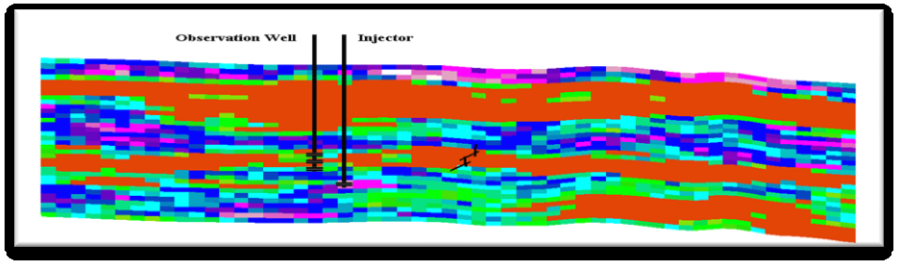
Case 2-4: with natural fractures



Fractures close to injection location

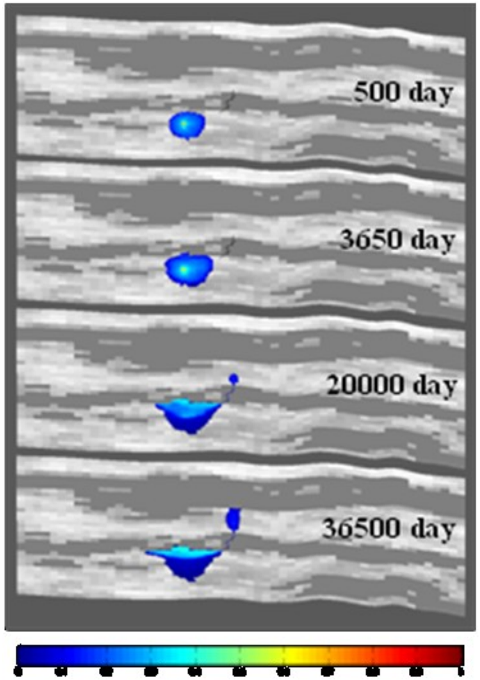


The distance between the fractures and the injection point are moderate

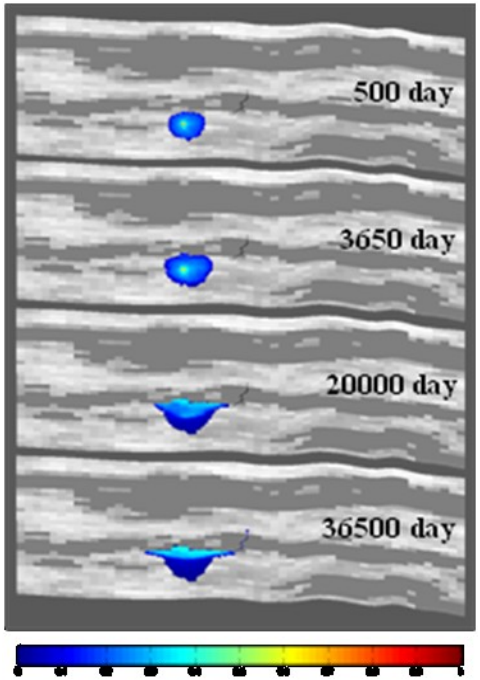


Fractures far from injection location

CO_2 saturation profiles



Fractures close to injection location



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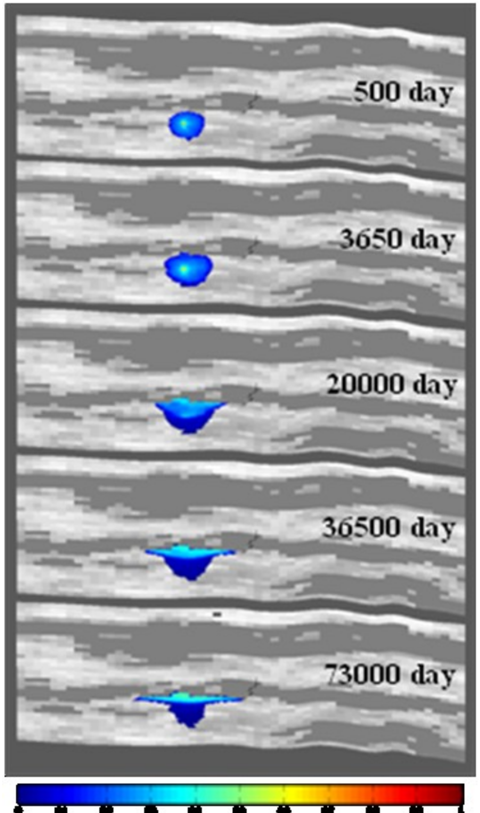
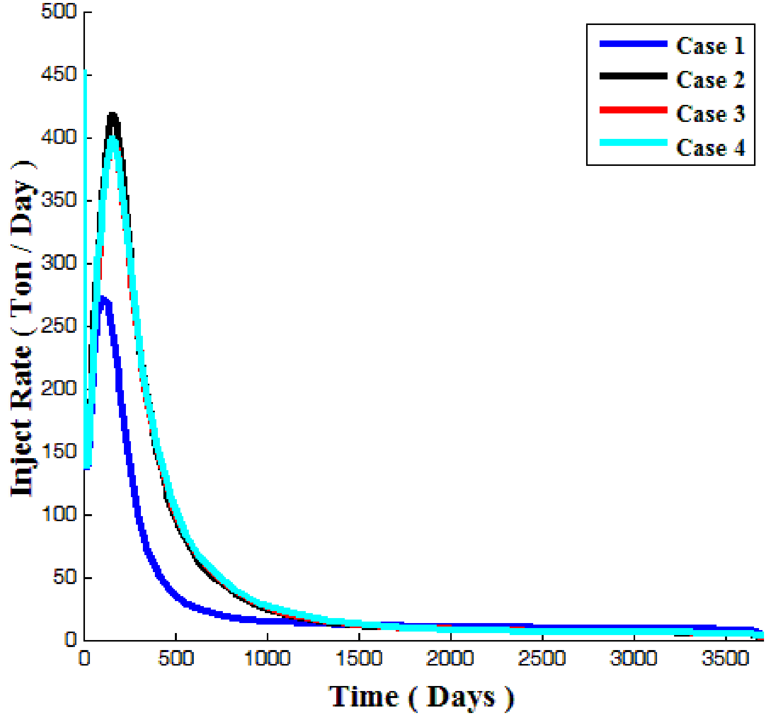
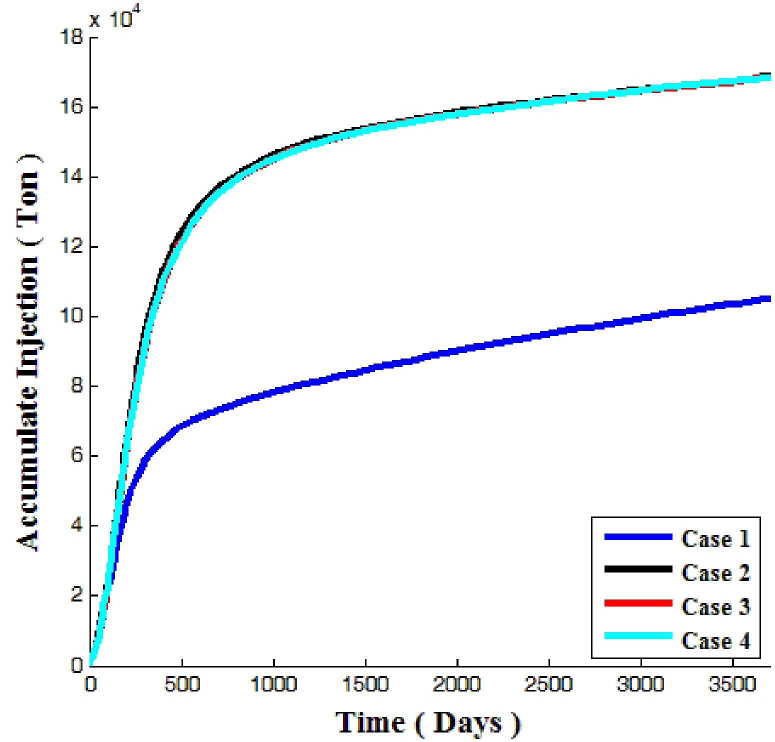


Fractures far from injection location

CO_2 storage rate and cumulatives

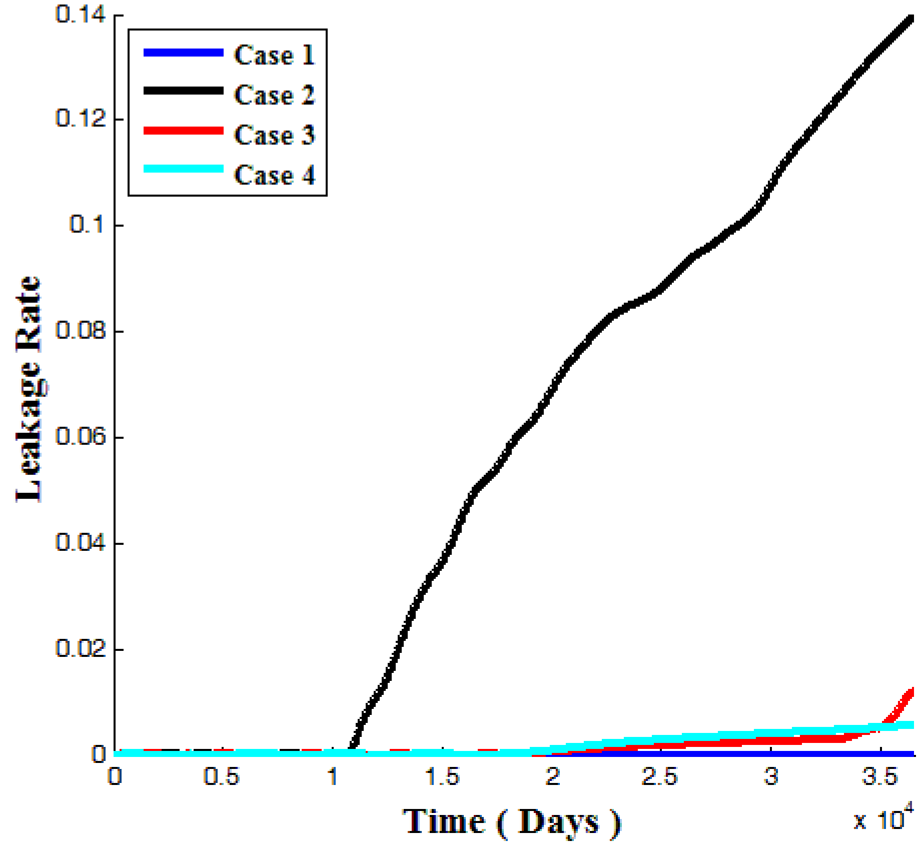


CO_2 injection rate for cases 1-4

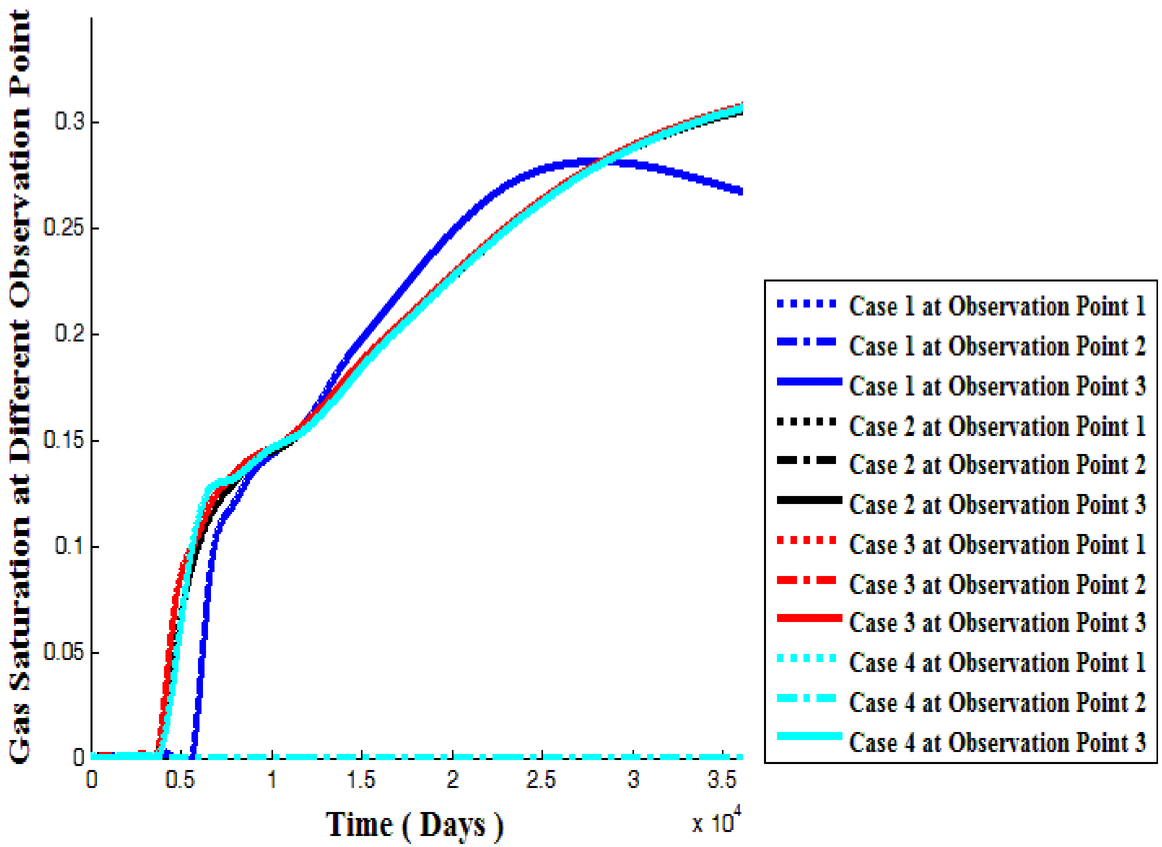


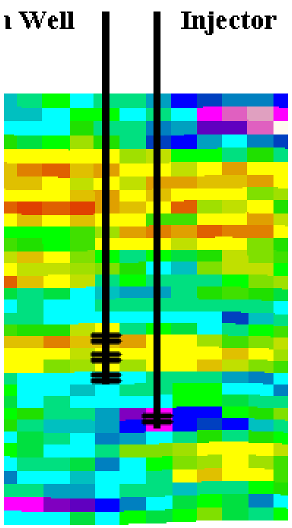
Cumulative CO_2 injection for cases 1-4

CO_2 leakage rate

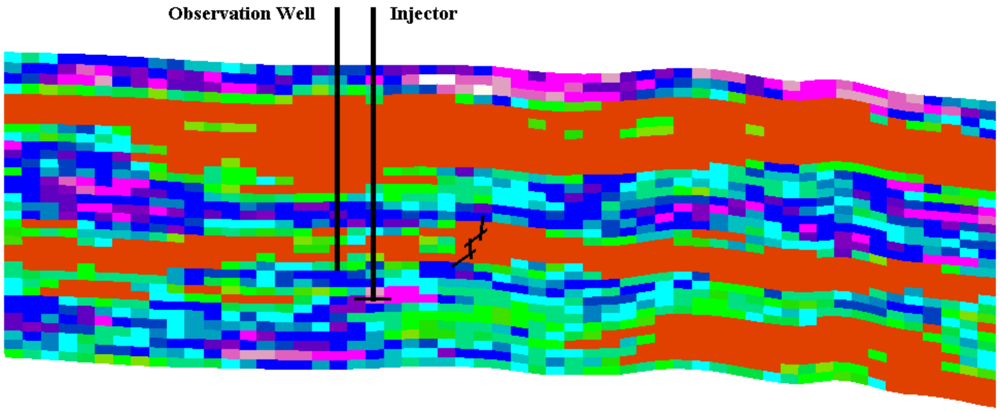


CO_2 concentration at observation well

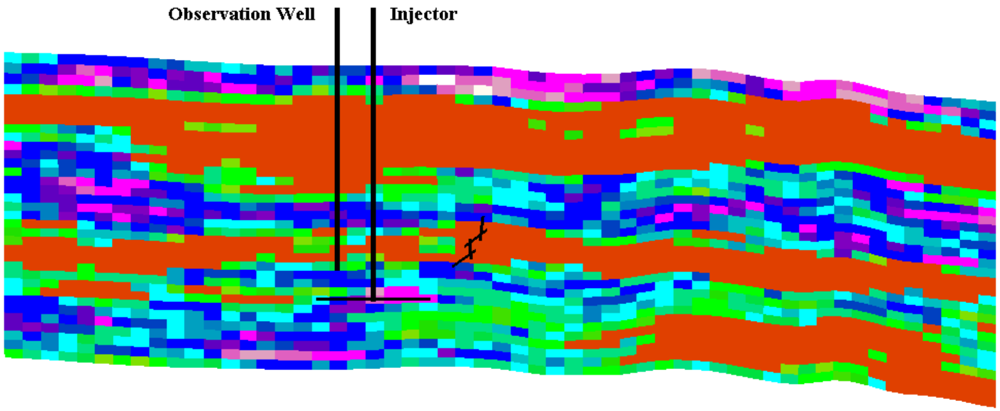




Case 5-6: with hydraulic fractures

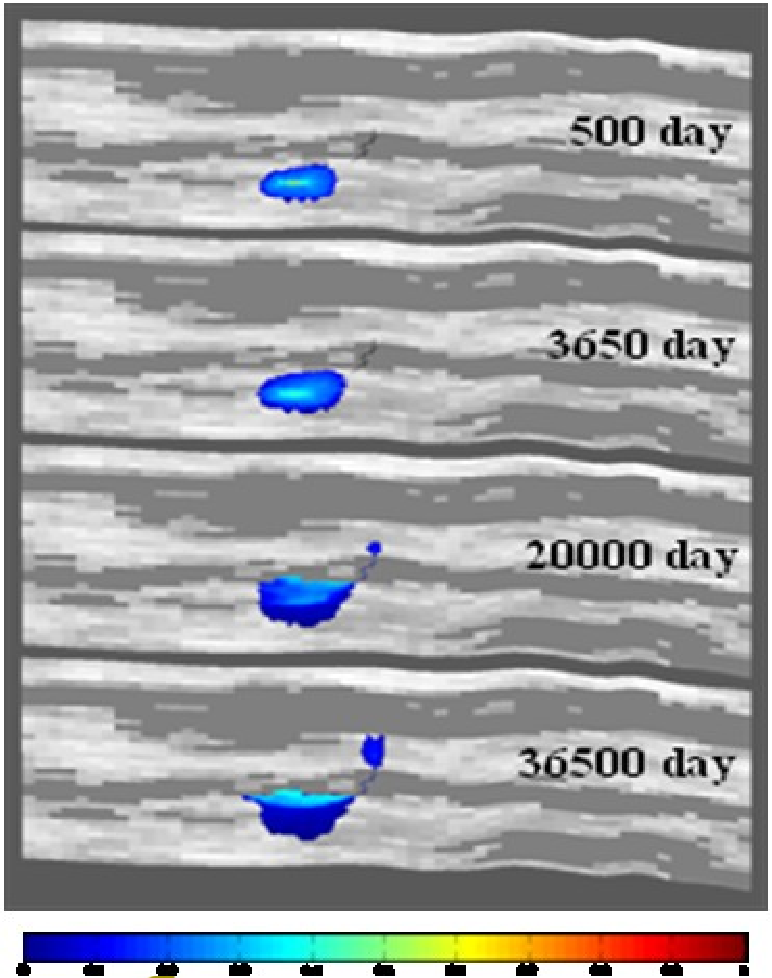


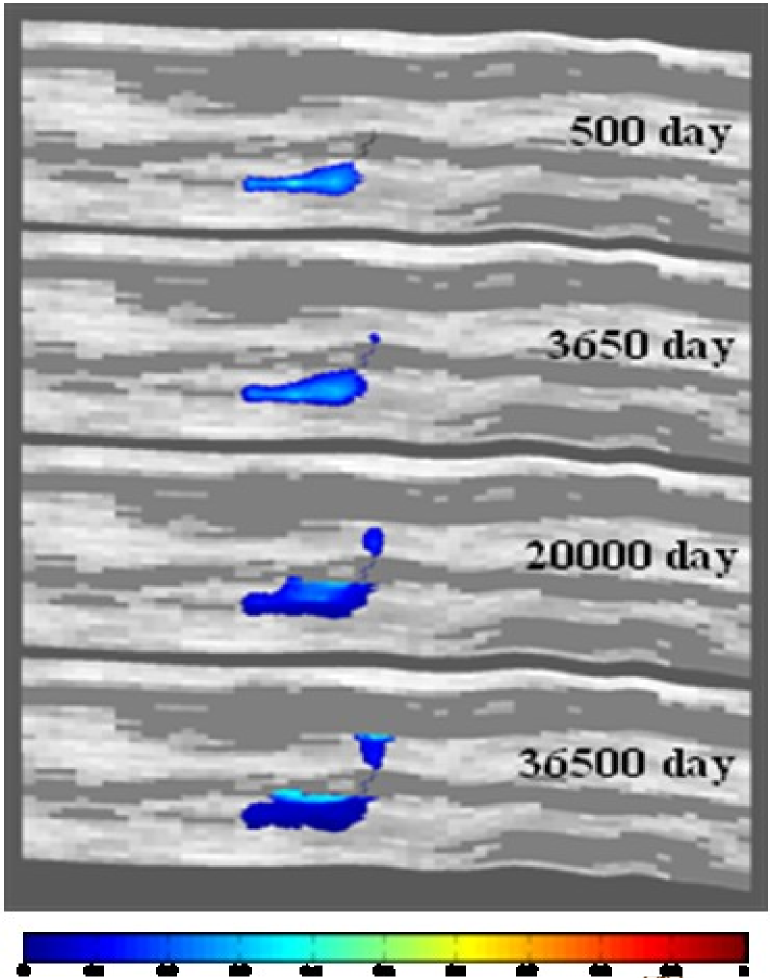
Hydraulic Fracture
length: 100m



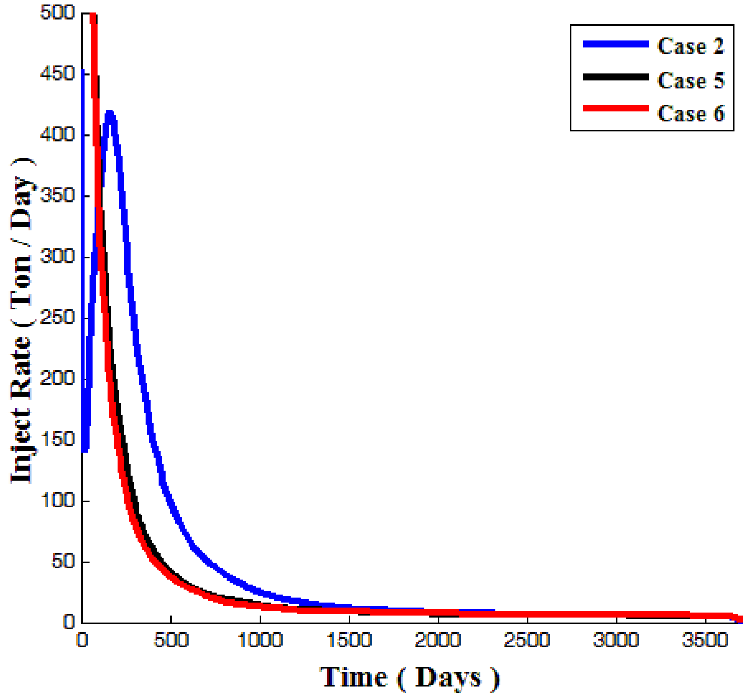
Hydraulic Fracture
length: 300m

CO_2 saturation profiles

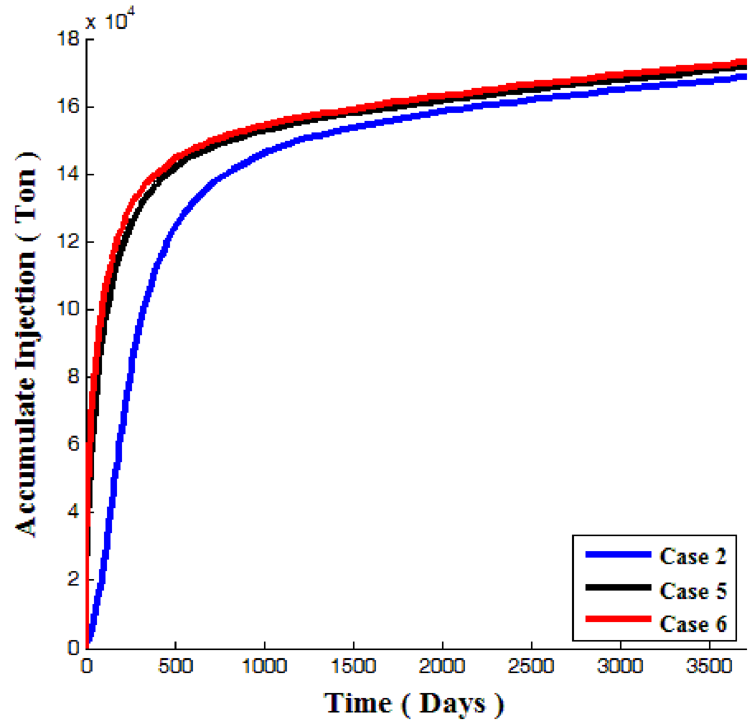




CO_2 storage rate and cum.

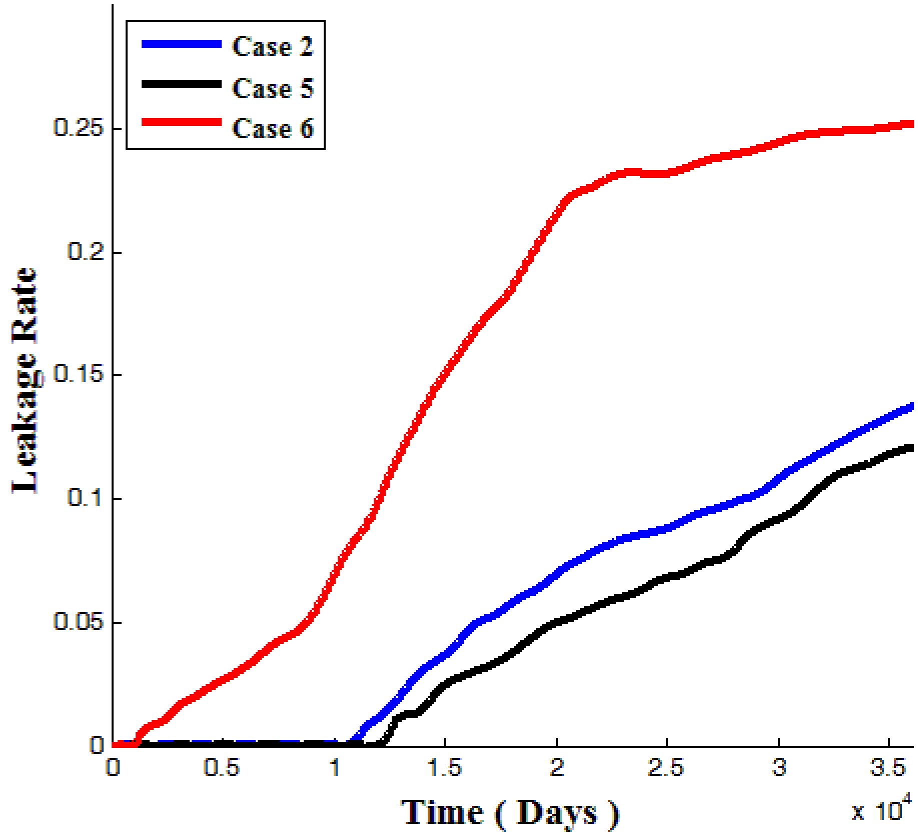


CO_2 injection rate for cases 2, 5, 6



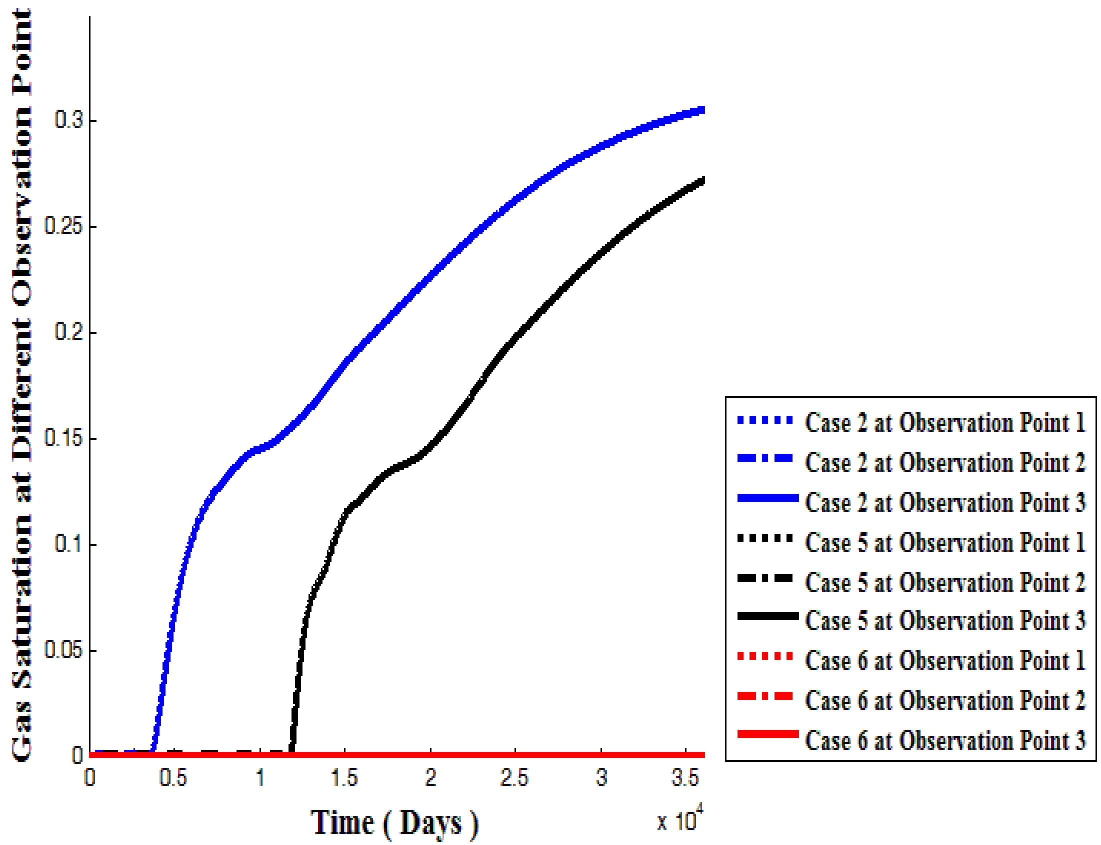
Cumulative CO_2 injection for cases 2, 5, 6

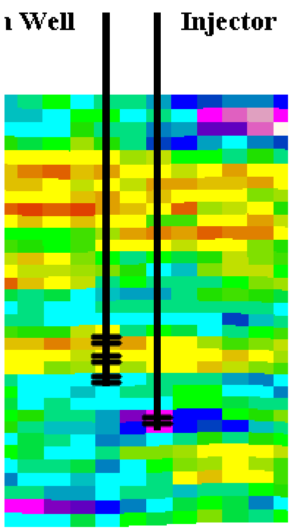
CO_2 leakage rate



CO_2 leakage rate for cases 2, 5, 6

CO_2 concentration at observation well





Conclusions

- The existence of caprock and mudstone layers could prevent injected CO_2 from leaking outside the saline aquifer when no fractures are present.
- Fractures intersecting with mudstone layers will cause significant leakage increase as the fractures form extremely preferential pathways for CO_2 transport.
- Fracturing will help CO_2 moving horizontally. The longer the hydraulic fracture, the more CO_2 will be retained in the target formation.
- Hydraulic fractures, if not communicate with natural fractures, will not only help improve injectivity but also mitigate the leakage risk; But if they are close enough to natural fractures up out of the target formation, it may cause severe CO_2 leakage.
- If the location of the injector is far enough from fractures in the caprock, the leakage risk is very limited and injectivity is significantly improved.

Acknowledgements

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Thank you!