

# Time Scales for Migration and Trapping of CO<sub>2</sub> in Saline Aquifers

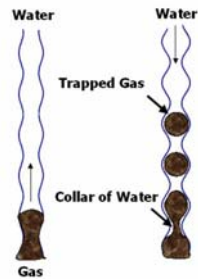
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## Simulation approach

## Results

### Motivation:

CO<sub>2</sub> storage in aquifers is one of many methods by which CO<sub>2</sub> emissions may be reduced. In this study, we investigate how aquifer properties and different injection schemes impact both the quantity and the rate of injected CO<sub>2</sub> becoming immobilized via residual trapping. Three parameters are varied in order to investigate the trapping phenomenon. First, CO<sub>2</sub> is injected into aquifers under varying ratios of gravity to viscous forces ( $N_{gv}$ ). Second, we study how the rate and the amount of the injected CO<sub>2</sub> varies with the dip angle of the aquifer. Last, an alternative injection scheme is proposed to encourage the immobilization of CO<sub>2</sub>.

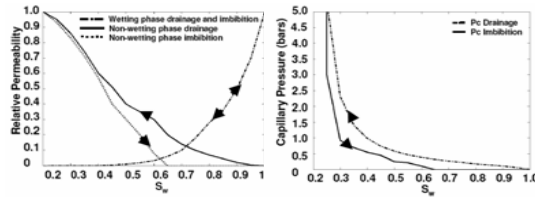


### Physics of Capillary Trapping:

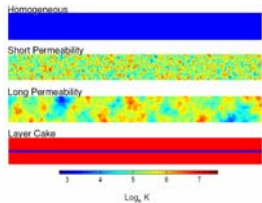
- Hysteresis effects are observed in both relative permeability and capillary pressure ( $P_c$ ).
- Trapping occurs when gas saturations decline.
- The amount trapped depends on the maximum gas saturation before the saturation begins to decline.
- Once the injected gas is snapped off, the trapped gas cannot move unless:
  - A significant viscous force displaces the trapped gas
  - The gas is reconnected
- The trapped gas can dissolve in the surrounding brine leading to permanent storage.

### Simulation Approach:

Define relative permeability curves and  $P_c$  curves



Define permeability distributions:



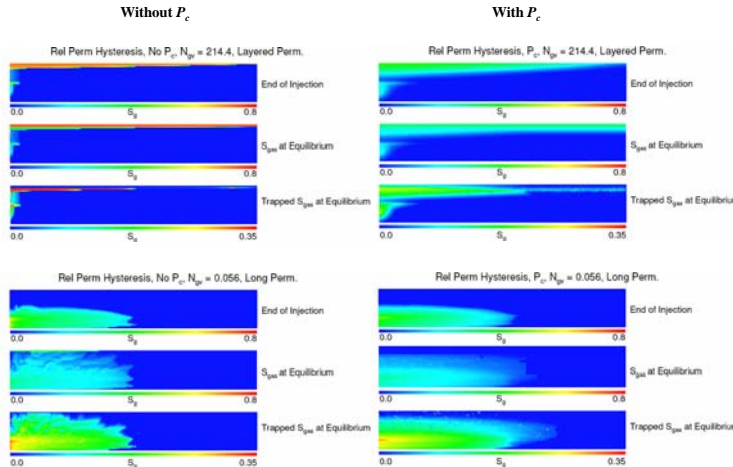
Aquifer setting:

$$N_{gv} = \frac{k_v L \Delta \rho g}{H \mu \mu}$$

Each aquifer model is associated with a gravity number,  $N_{gv}$ , as defined in the equation above.

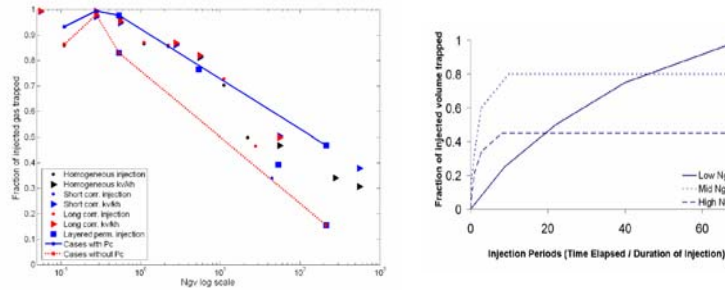
$N_{gv}$  was varied by altering injection rates and  $k_v/k_h$  ratios.

### Saturation profiles for high and low $N_{gv}$ :

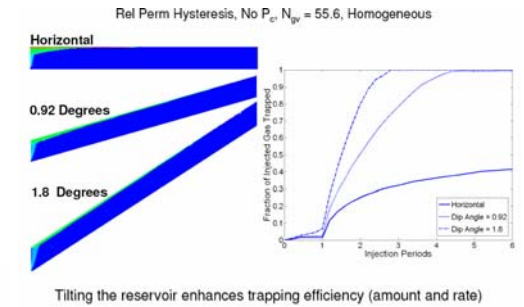


### Fraction of injected gas trapped vs. $N_{gv}$ :

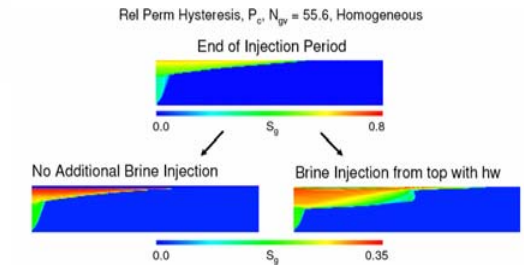
- Fraction of injected gas trapped decreases as the gravity number of the system increases.
- As seen in the saturation profiles above, systems with high gravity numbers lead to the formation of strong gravity tongues.
- In the absence of any dip, the saturations in the gravity tongue cannot be reduced, and thus remain mobile.
- The addition of capillary pressure shows that a greater volume of aquifer is contacted before flow reversal, leading to a higher trapped saturation amount.
- High gravity number systems trap less of the injected gas, but do so more quickly, compared to low gravity number systems that trap more but over a longer time scale.



### Dip angle and its effects:



### Injection schemes and its effects:



### Conclusion and future work:

- High ratio of gravity to viscous forces causes a gravity tongue to form, which limits trapping
- The presence of capillary pressure effects enhances trapping
- High gravity number systems trap less, but do so relatively quickly
- Low gravity number systems trap more, but more slowly
- Larger dip angles enhance CO<sub>2</sub> trapping efficiency
- Carefully engineered injection schemes can increase trapping
- Other injection schemes besides those considered in this study must be explored.