CO₂ storage in aquifers is one of many methods by which CO₂ 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 CO₂ becoming immobilized via residual trapping. Three parameters are varied in order to investigate the trapping phenomenon. First, CO₂ 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 CO₂ varies with the dip angle of the aquifer. Last, an alternative injection scheme is proposed to encourage the immobilization of CO₂.

**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: $N_{gv} = \frac{k L \Delta \rho g}{H \mu t}$
- 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.

**Simulation approach** | **Results**

**Motivation:**
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**Saturation profiles for high and low $N_{gv}$:**
- Without $P_c$
- With $P_c$

- 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:**
- Tiling the reservoir enhances trapping efficiency (amount and rate)

**Injection schemes and its effects:**
- No Additional Brine Injection
- Brine Injection from top with $hr$

**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 CO₂ trapping efficiency
- Carefully engineered injection schemes can increase trapping
- Other injection schemes besides those considered in this study must be explored.