

# The Impact of Geologic Heterogeneity on CO<sub>2</sub> Injection with Simultaneous Brine Extraction and Economic Uncertainty for Large-Scale CO<sub>2</sub> Sequestration

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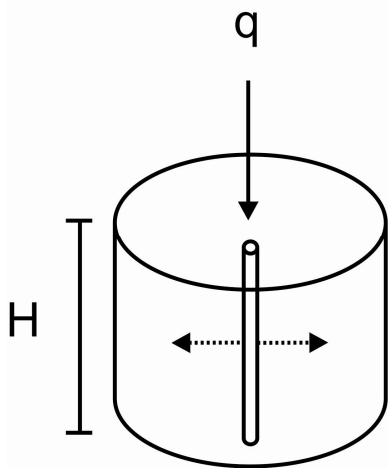
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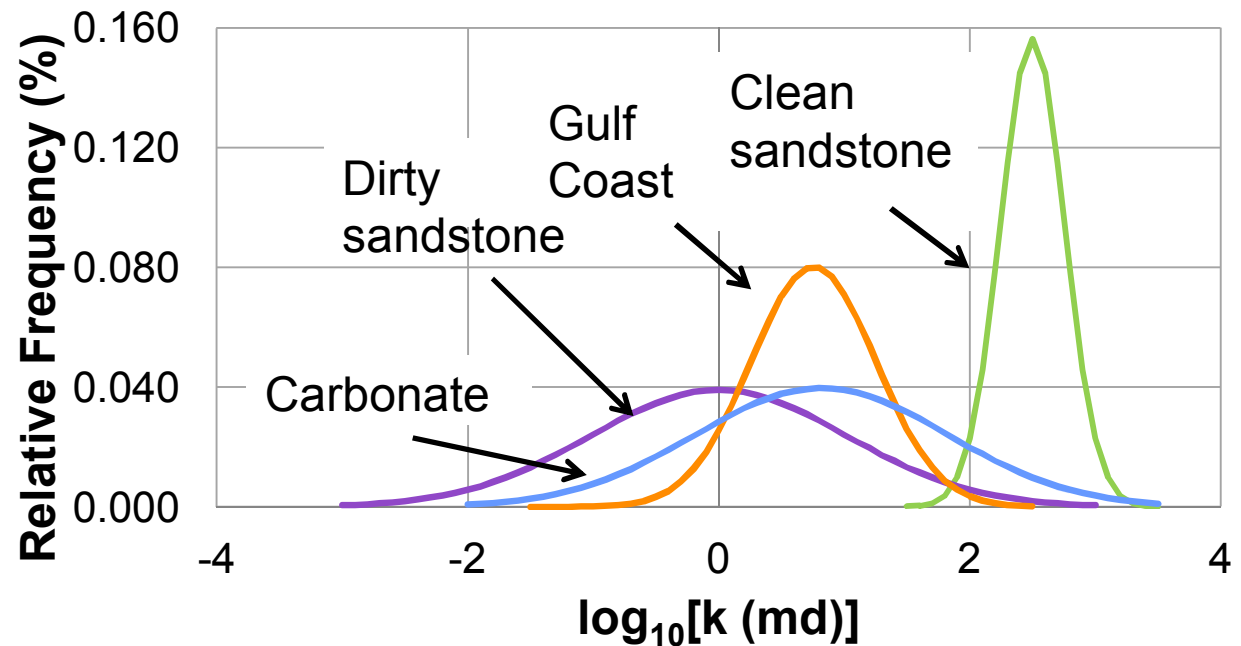
# CO<sub>2</sub> Injectivity and Large Scale Economic and Storage Assessment

$$I \equiv \frac{q}{\Delta P}$$



Reservoir volume

Radial flow from the well

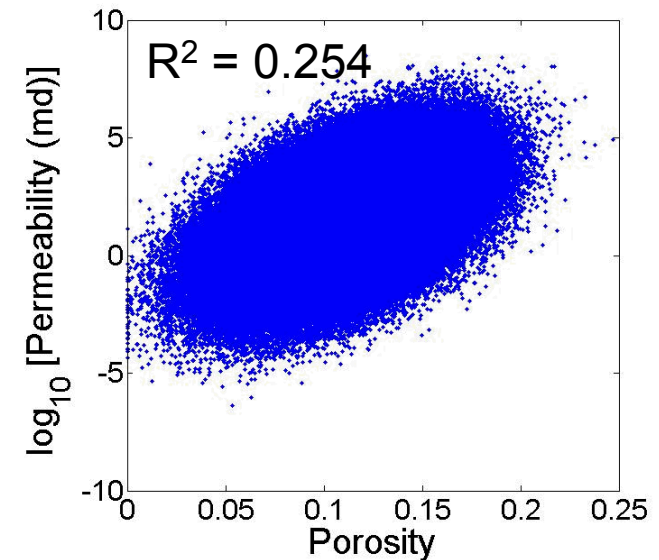


(Kobos et al., 2011)

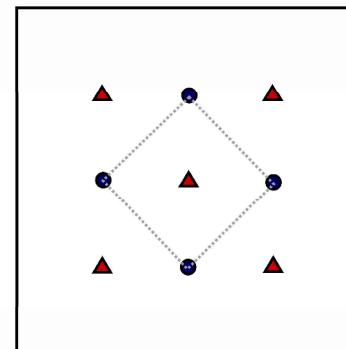
**Examples:** Eccles et al., 2012; Keating et al., 2011; Cinar et al., 2008; Stauffer et al., 2009; Zakrisson et al., 2008; and many others

# Digging into Common Assumptions

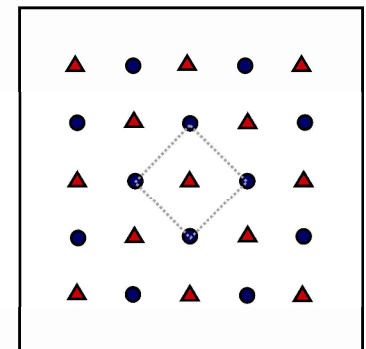
1. How does correlation between permeability and porosity affect injectivity?
2. How different in terms of injection rates are the homogeneous versus heterogeneous cases?
3. How does heterogeneity impact well numbers and associated costs?



- ▲ CO<sub>2</sub> injector
- Brine extractor



16 km



16 km

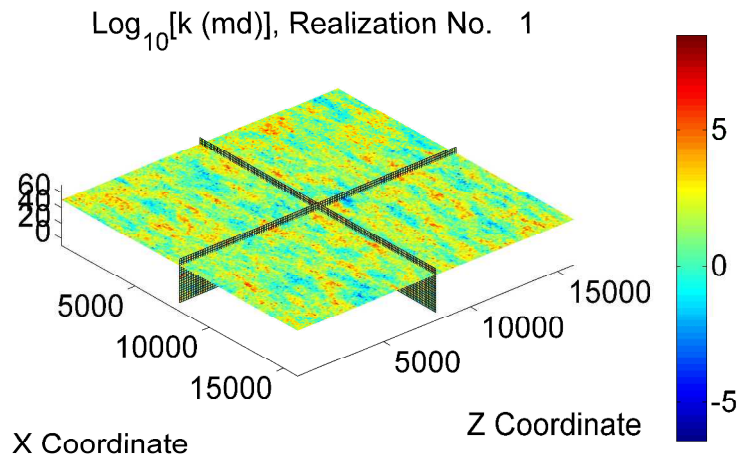
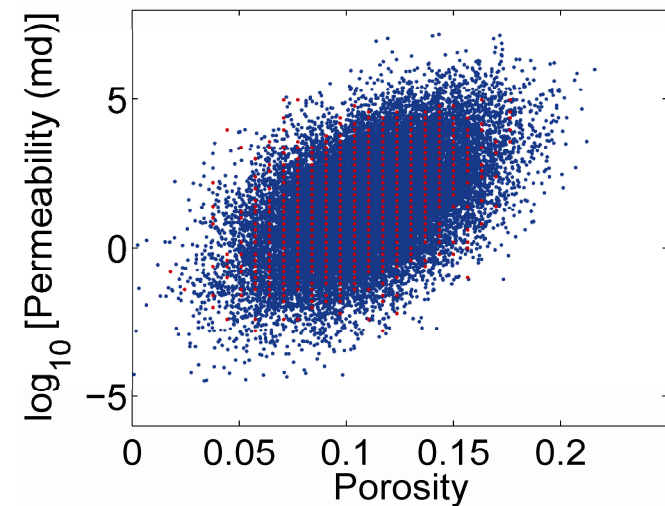
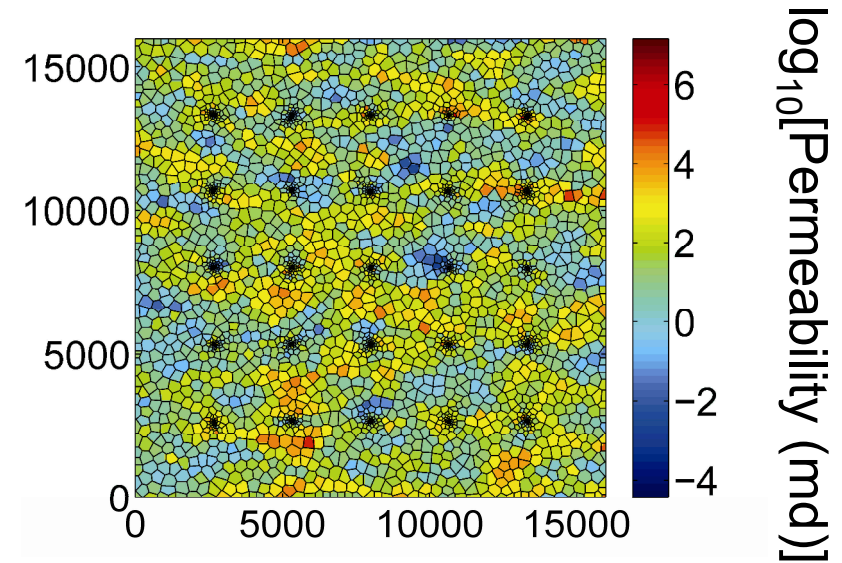
# Methods

## 2. Multiphase Flow: TOUGH2-ECO2N

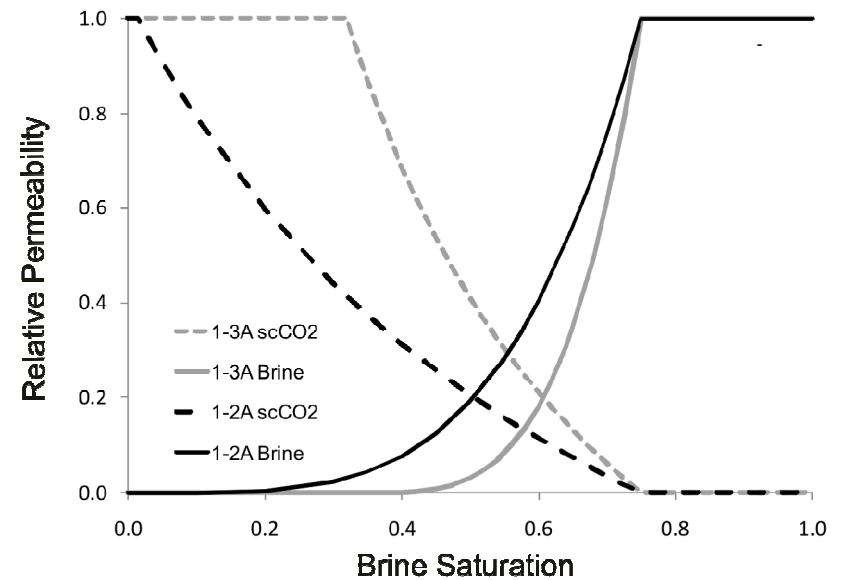
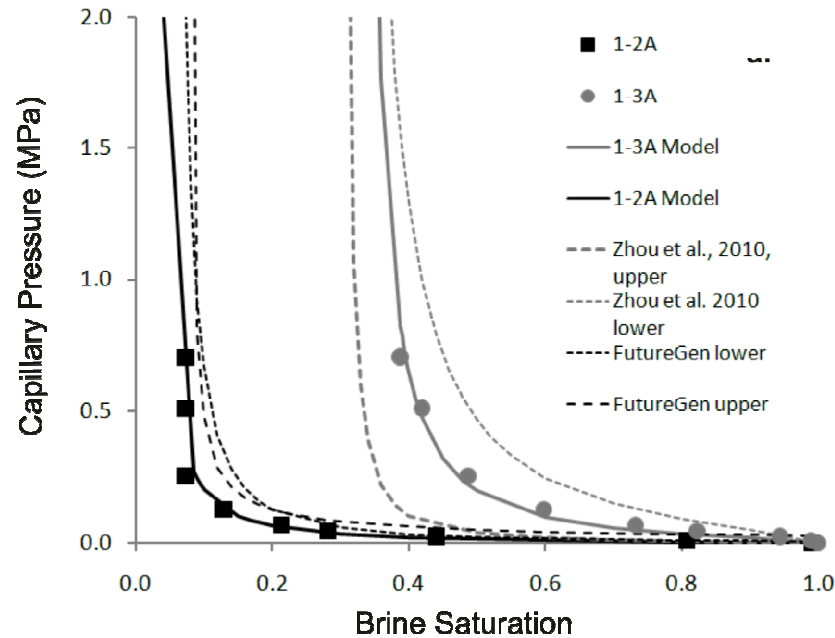
### 1. Geostatistics:

Coregionalization and SGSIM  
(Rautman and McKenna, 1997;  
Deutsch and Journel 1992)

$$r^2 = \underline{0.25} \text{ or } 0.75$$



# Relative Permeability & Capillary Pressure

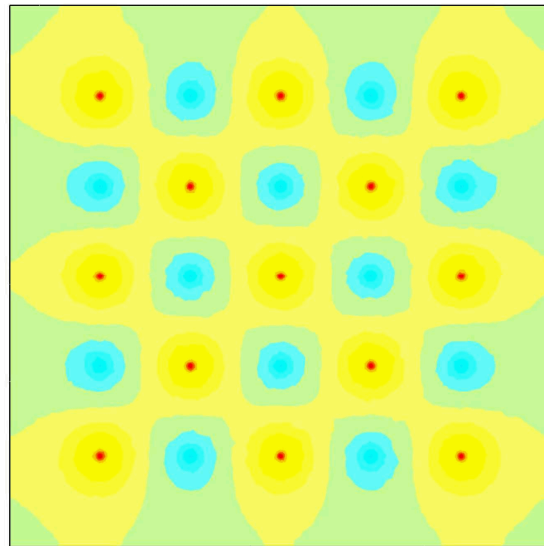


(Heath et al., 2012)

# Methods: Base Cases

Time = 36 days

## Injection and Extraction



16 km

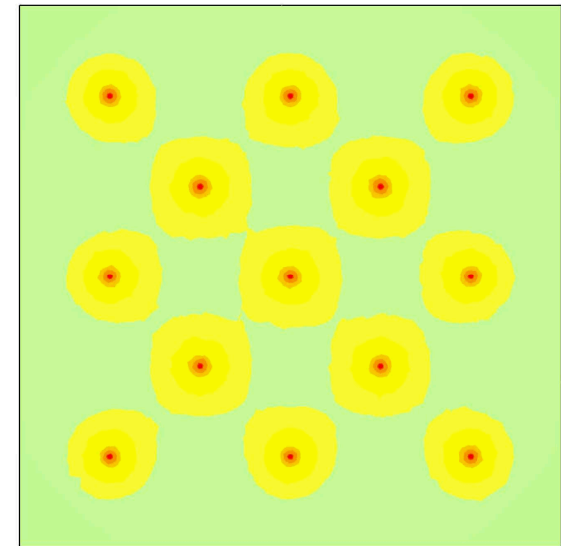
Press. (Mpa)

2.83e7



1.44e7

## Injection only



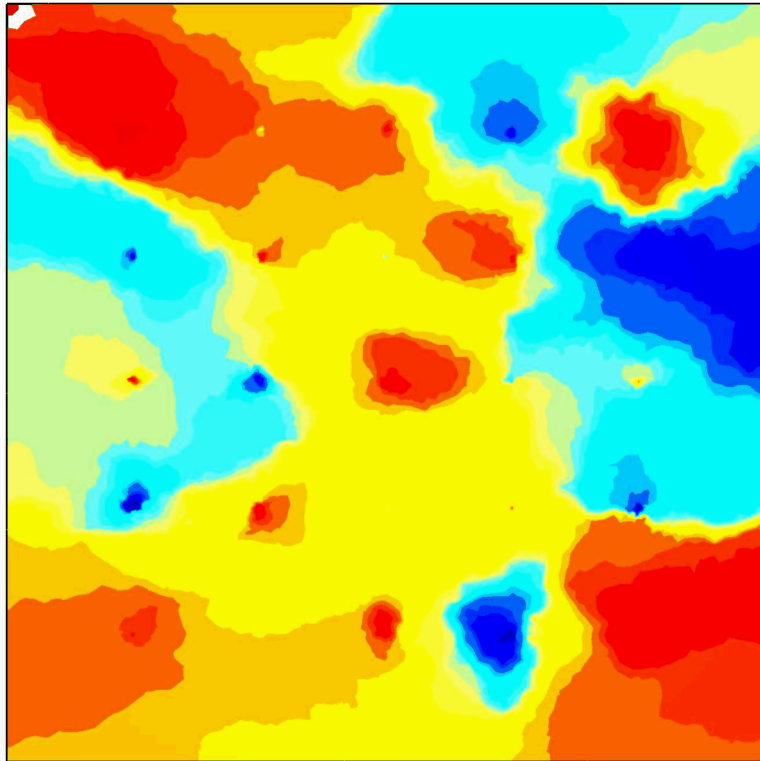
16 km

- Permeability = 29.7 md; porosity = 11.1 % (Finley, 2005)
- CO<sub>2</sub> injection with or without brine extraction
- Maximize flow rates: constant pressure at wells
- Closed reservoir
- Homogenous and heterogeneous cases

# Heterogeneous Example

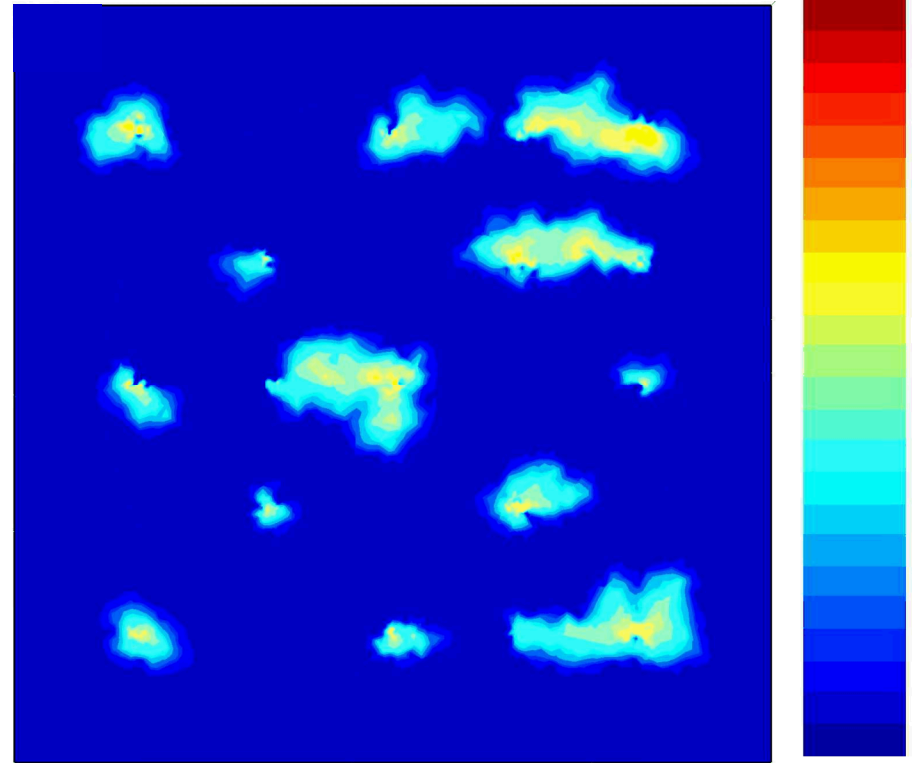
Time = 6 years

Press. (MPa)  
2.83e7

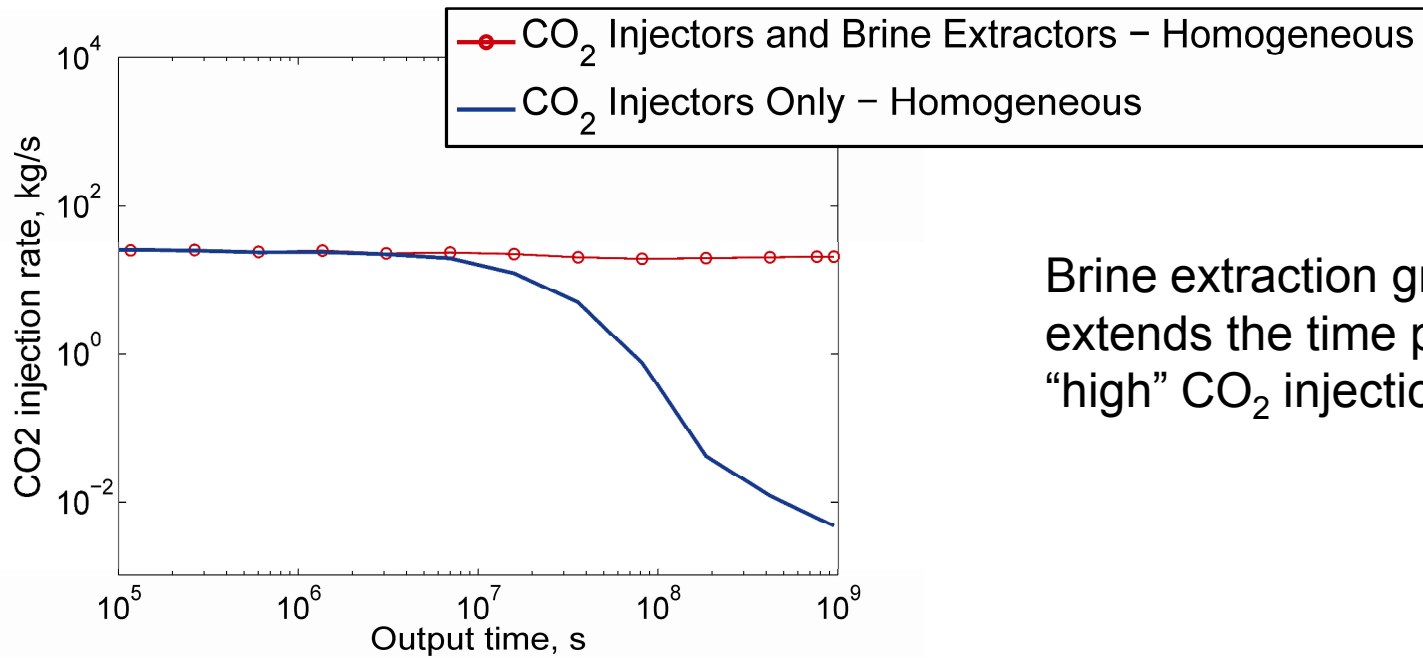


1.44e7

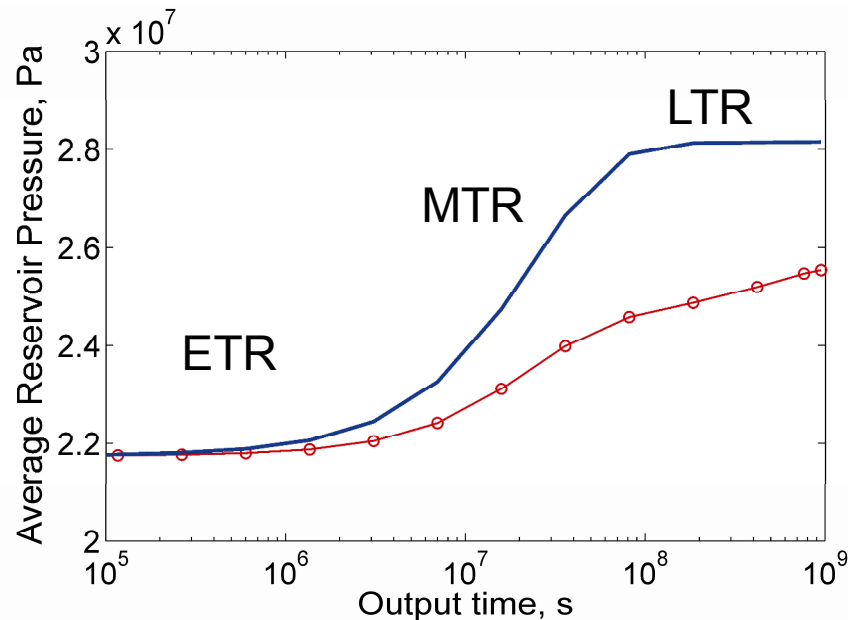
$S_{CO2}$   
1



0

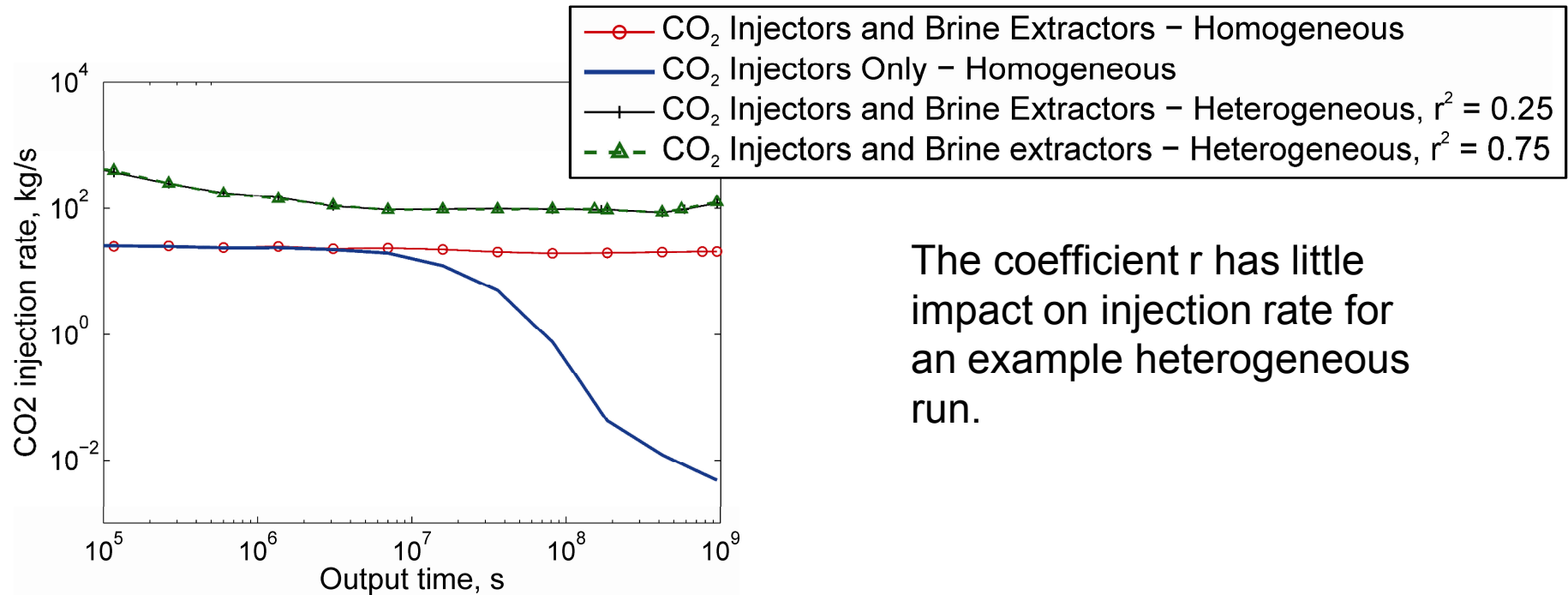


Brine extraction greatly extends the time period of “high” CO<sub>2</sub> injection rates.

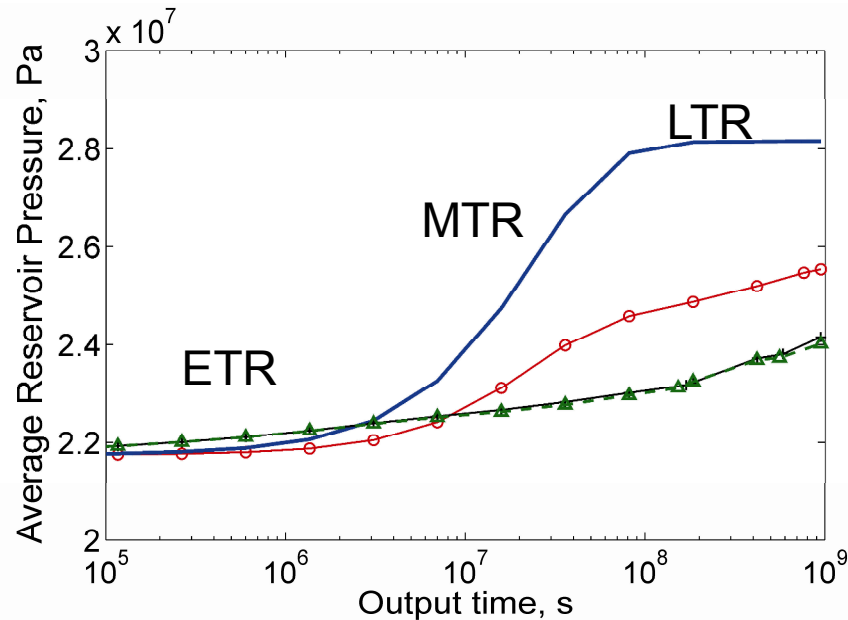


Clear early, middle, and late time regions occur during CO<sub>2</sub>-only-homogeneous case

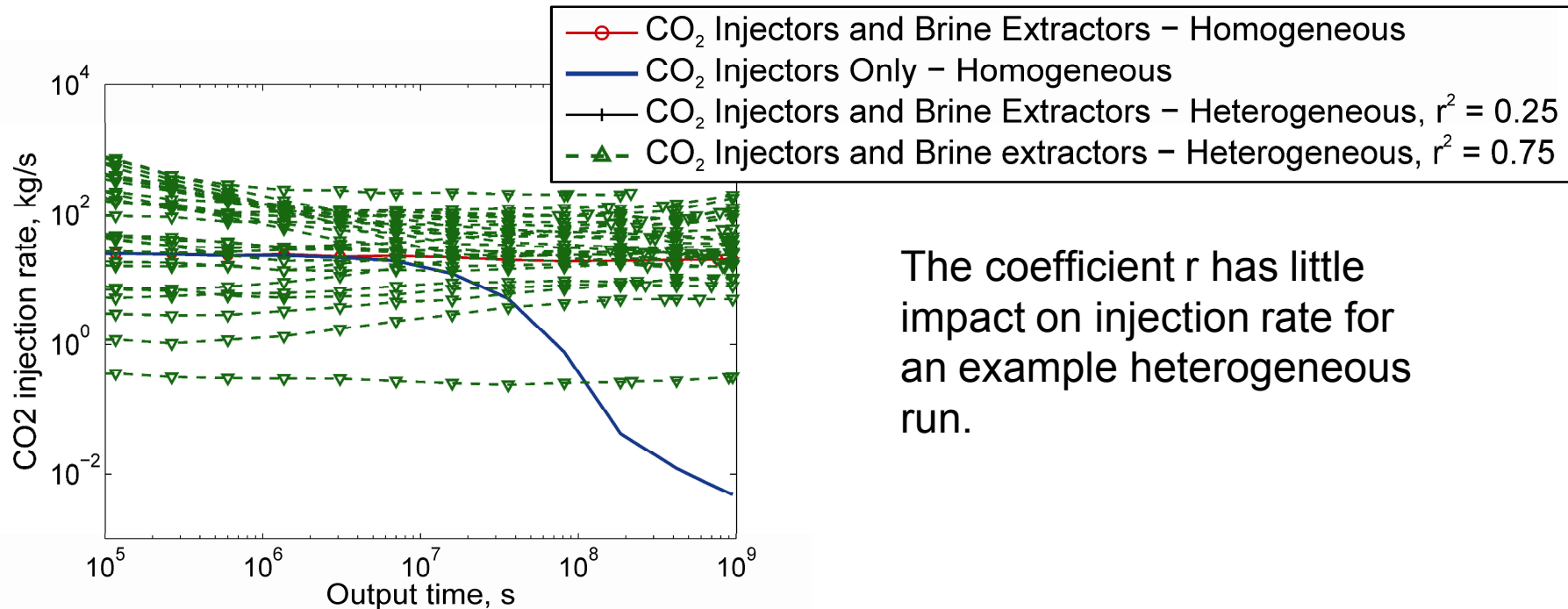




The coefficient  $r$  has little impact on injection rate for an example heterogeneous run.



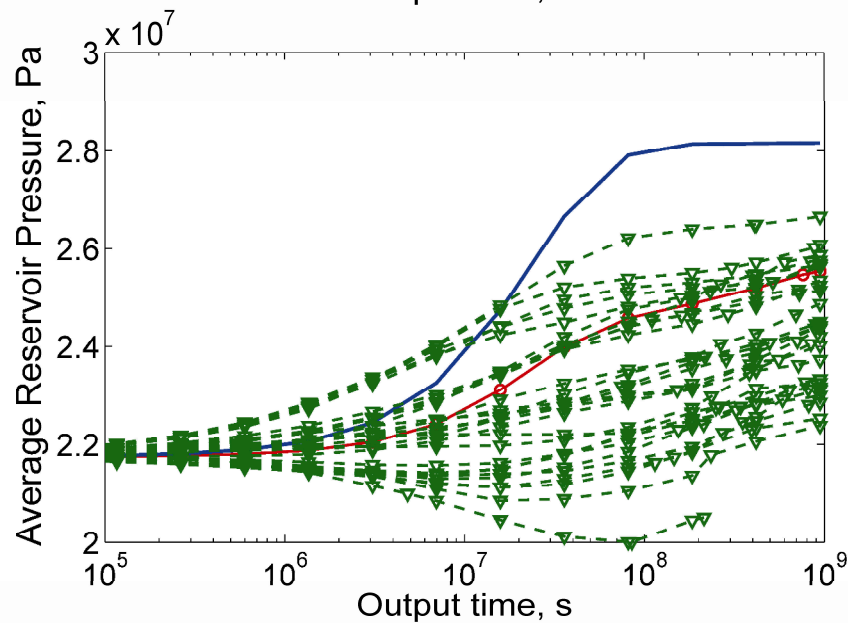
The heterogeneous case differs in behavior from the injection-extraction homogeneous case.



The coefficient  $r$  has little impact on injection rate for an example heterogeneous run.

Heterogeneous cases display a range of behaviors.

**30 geostatistical realizations**

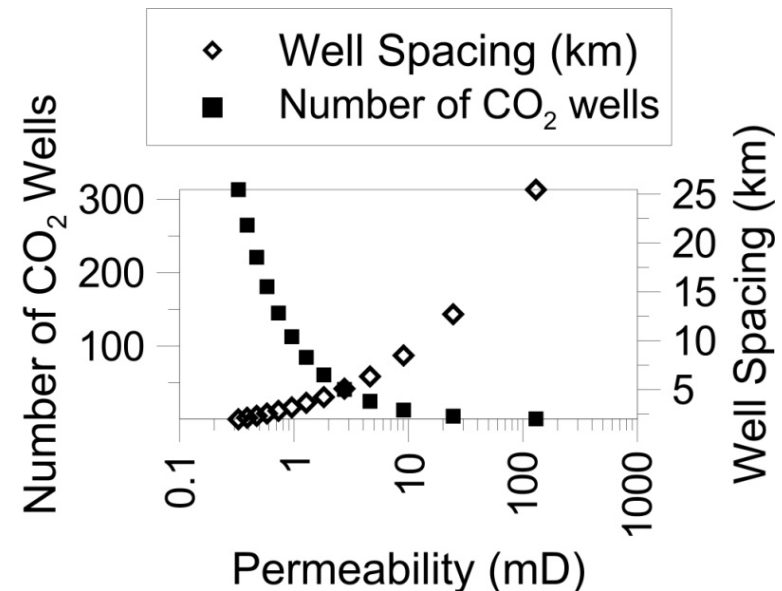


# Conclusions

Brine extraction greatly extends the time period of high injectivity in closed reservoirs

Brine extraction, however, may be limited by breakthrough for higher permeability cases

Heterogeneity provides a mix of high and low injectivity wells, thus making simple analytical solutions difficult



# Ongoing Work

Investigating impact of permeability-porosity coefficient  $r$  on:

- Sweep efficiency
- Breakthrough
- Storage capacity (probably most import here?)

## Acknowledgements

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