An Evaluation of CO$_2$ Sequestration in Organic-rich Shales Using COMSOL

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Presentation Outline

• Introduction
• Objective
• Method
• Results
• Discussion
• Summary
Carbon dioxide (CO$_2$) sequestration

- Involves separation and capture of CO$_2$ prior to atmospheric release
- Geologic storage include:
  - organic-rich shales
- Benefits of CO$_2$ sequestration:
  - Mitigate GHG emissions
  - Increased oil/gas recovery

[Image of the sequestration process]

http://www.canada.com/technology/Players+bail+showcase+carbon+capture+project+Alberta/6526185/story.html
Introduction

Objective

Method

Results & Discussion

Summary

Organic-rich shales

- Consist of organic matter (OM) and mineral matrix
- Organic matter (OM) produces hydrocarbons (oil & gas)
- Degenerated organic matter leaves behind nano-pores
- OM preferentially adsorbs CO₂ over methane (CH₄)
- Ultra-tight nature minimizes leakage
Objective

- To understand the underlying mechanism(s) of CO₂ sequestration in organic-rich shales at varying pressure and temperature using COMSOL
Flow regimes

(a) Continuum flow
(b) Slip flow
(c) Transition flow
(d) Free molecular flow

Schematic diagram of flow regimes (Moghaddam & Jamiolahmady, 2016)
Knudsen layer

- Non-equilibrium region, where wall collision is considered
- Covers less than 20% of characteristic length in slip flow
- Slip effects are more pronounced as Knudsen number increases

Schematic diagram of Knudsen layer
(Moghaddam & Jamiolahmady, 2016)
Slip flow module - COMSOL

• Navier-Stokes applies but slip boundary condition is required.

• Maxwell first order slip boundary condition

\[ U_{\text{slip}} = \frac{2-\sigma_v}{\sigma_v} \lambda \frac{\partial U}{\partial y} \]

\[ U_{\text{slip}} = U_{\text{fluid}} - U_{\text{wall}} \]

where, \( \sigma_v \) = tangential momentum accommodation coefficient
Simulation

- Fluid domain within the pore-slit driven by pressure gradient
- Fluid domain: CO$_2$ and CH$_4$ gases
- Pressures vary from 250 psi to 500 psi
- Temperature vary from 298 K to 320 K
- TMAC varied from 0.9 to 0.7
Results

Velocity magnitude of CH$_4$ at 250 psi, 298.15 K, and TMAC = 0.9

Velocity magnitude of CO$_2$ at 250 psi, 298.15 K and TMAC = 0.9
Results

Velocity magnitude of CH₄ at 500 psi, 320 K and TMAC = 0.7

Velocity magnitude of CO₂ at 500 psi, 320 K and TMAC = 0.7
Results

Mean free path of CH$_4$ at P=500 psi, T=298.15K, and TMAC=0.9

Mean free path of CO$_2$ at P=500 psi, T=298.15K, and TMAC=0.9
Discussion

• At the same prevailing conditions, CH$_4$ recorded higher slip velocity and mean free path than CO$_2$

• Decrease in TMAC from 0.9 to 0.7 slightly caused an increase in slip velocity and mean free path in both cases

• Increase in temperature from 298.15 K to 320 K also saw an increase in the slip velocity and mean free path in both cases

• Increase in pressure from 250 psi to 500 psi resulted in a decrease in the mean free path

• Knudsen number ranged from 0.06 to 0.1
Summary

• Carbon dioxide (CO₂) is more susceptible to adsorption than methane (CH₄) in the same pore geometry and under similar conditions.
• TMAC plays an important role in gas slip models
• Slip velocity is due to pore wall interactions and therefore depends on the type of reflection gas molecules experience at the walls
Acknowledgements
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QUESTIONS ??