STANFORD UNIVERSITY

The Effect of CO_2 Adsorption on Permeability Anisotropy in the Eagle Ford Shale

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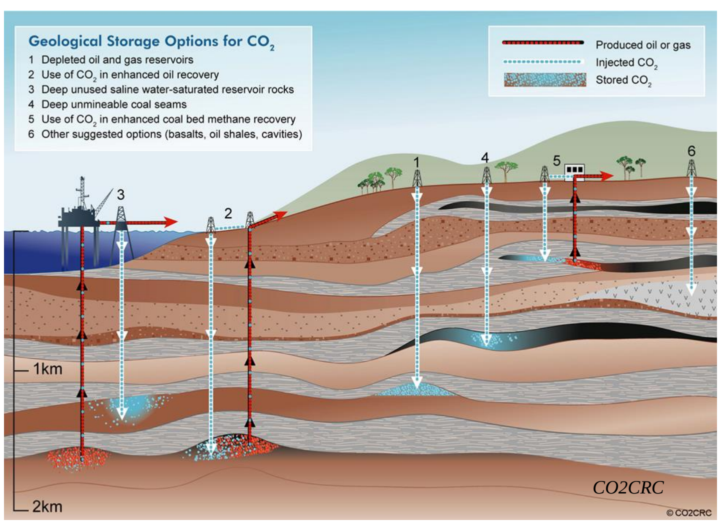
May 21, 2014

Motivation



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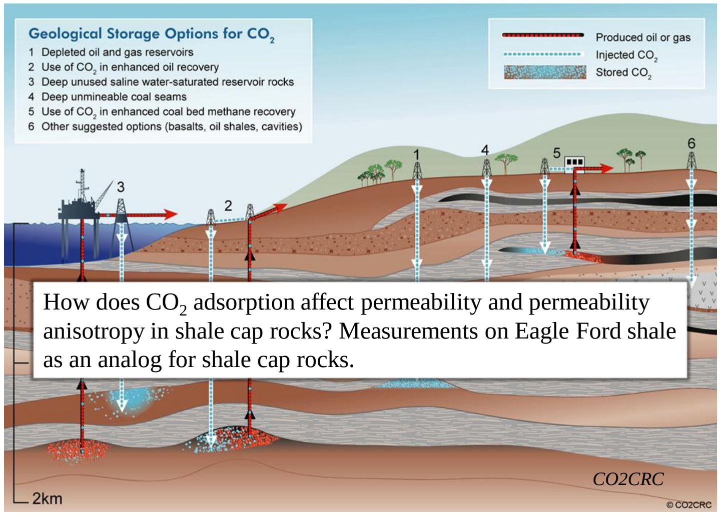
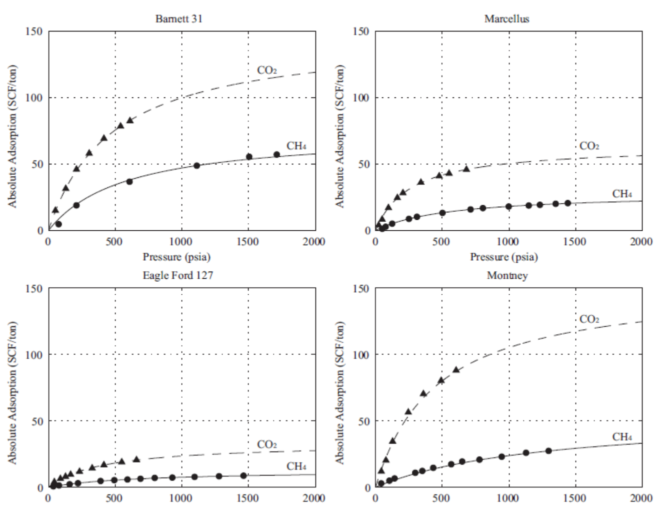
Motivation



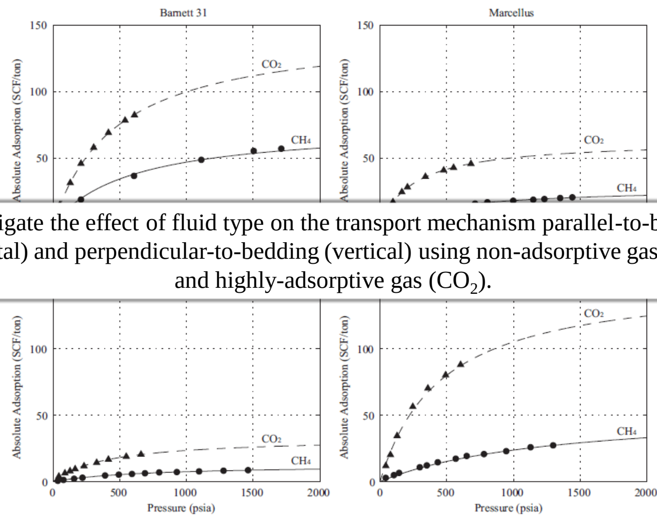
How does CO_2 adsorption affect permeability and permeability anisotropy in shale cap rocks? Measurements on Eagle Ford shale as an analog for shale cap rocks.

Objectives



Heller and Zoback (in press)

Objectives



Investigate the effect of fluid type on the transport mechanism parallel-to-bedding (horizontal) and perpendicular-to-bedding (vertical) using non-adsorptive gas (Helium) and highly-adsorptive gas (CO_2).

Heller and Zoback (in press)

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Outline

- Study approach
- Mean free path
- Experimental setup
- Methodology
- Results:
  - Vertical sample
  - Horizontal sample
- Discussion
- Conclusions
- Acknowledgments

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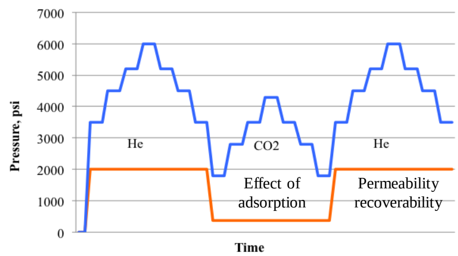
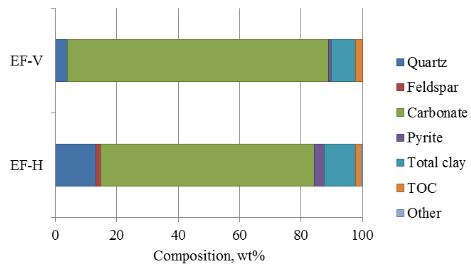
Study Approach

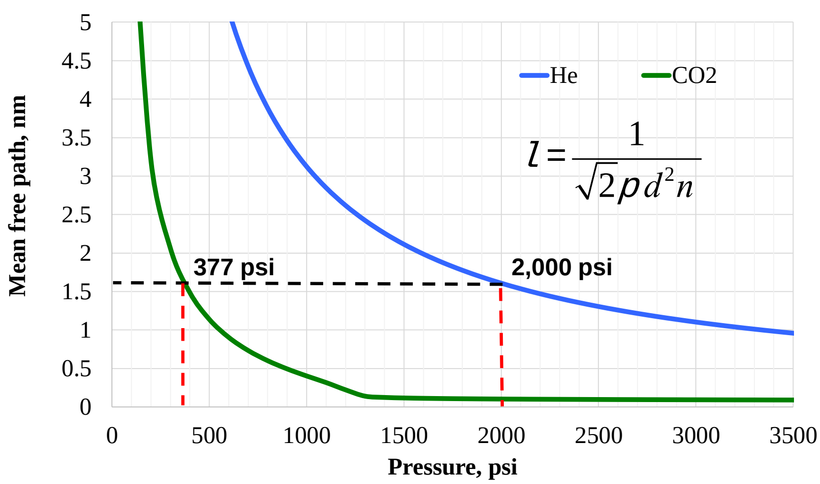
- Permeability cycles:
  - Cycle 1: Helium
  - Cycle 2: CO_2
  - Cycle 3: Helium



- Eagle Ford shale samples:
  - Vertical: EF-V
  - Horizontal: EF-H



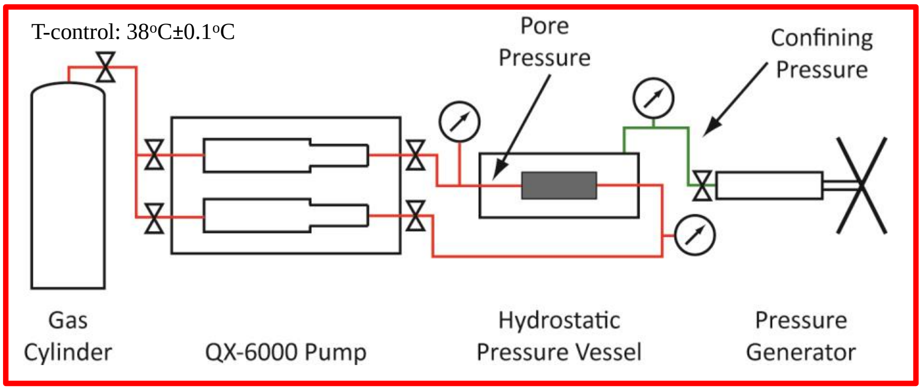
Mean Free Path



d	Molecular diameter
n	Number of gas molecules/unit volume

Experimental Setup

The hydrostatic permeability system inside a thermal isolation chamber



Modified from Heller (2013)

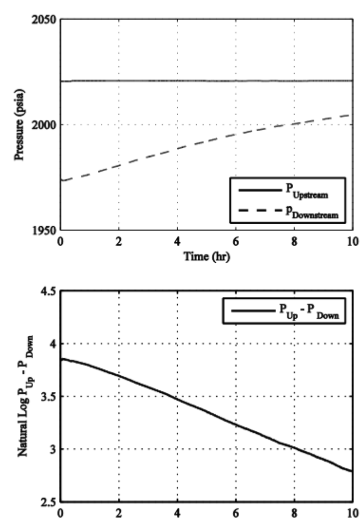
Methodology

- <u>Method 1:</u> Pressure pulse decay technique (Brace, 1968):

$$\boldsymbol{\Delta p(t) = \Delta p_o e^{-\alpha t}}$$

$$\boldsymbol{\alpha = \frac{k_g\, A}{\beta\, V_{down}\, L\, \mu}}$$

α	Slope of the line
k_g	Gas permeability
A	Sample cross-sectional area
β	Gas compressibility
V_{down}	Downstream volume
L	Sample length
μ	Gas viscosity



Heller et al. (2014)

Methodology

- Method 2: Steady-state Darcy flow technique (Scheidegger, 1974):

$$k_g = \frac{2\,\mu\,p_{DS}\,q\,L}{A\,(p_{US}^2 - p_{DS}^2)}$$

k_g	Gas permeability
μ	Gas viscosity
p_{DS}	Downstream pressure
p_{US}	Upstream pressure
q	Gas flowrate
L	Sample length
A	Sample cross-sectional area

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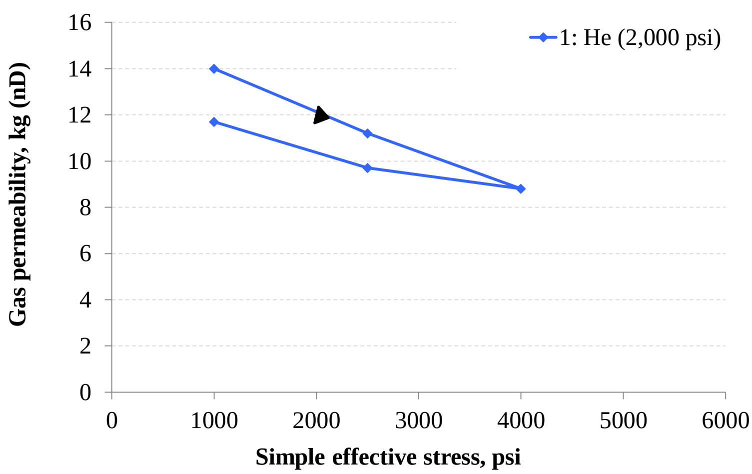
Vertical Sample

1st cycle with Helium at 2,000 psi pore pressure



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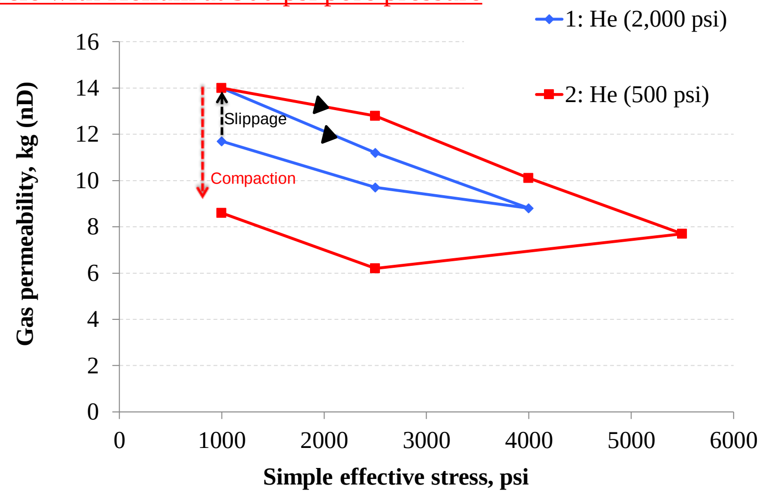
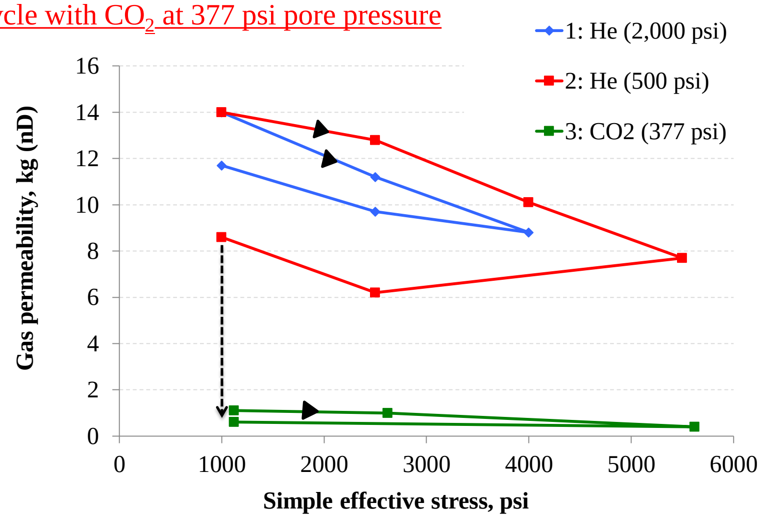
Vertical Sample

2nd cycle with Helium at 500 psi pore pressure



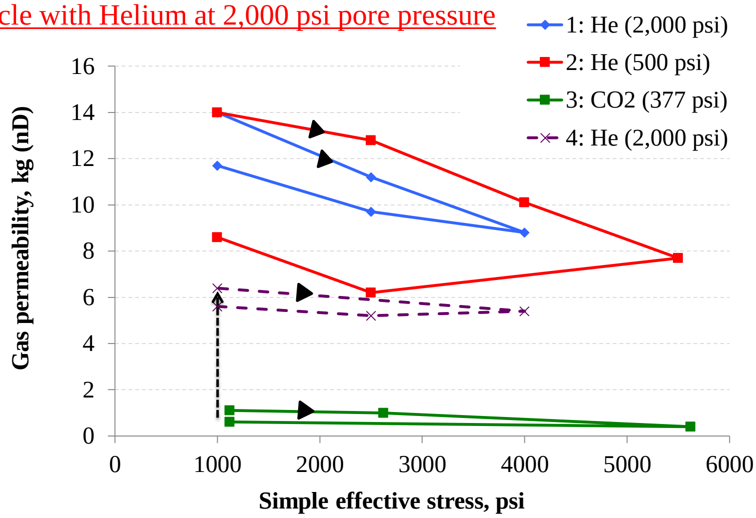
Vertical Sample

3rd cycle with CO_2 at 377 psi pore pressure

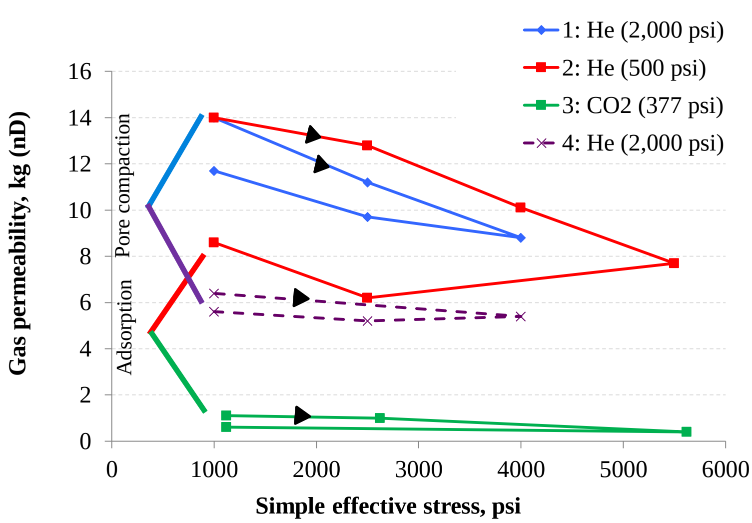


Vertical Sample

4th cycle with Helium at 2,000 psi pore pressure

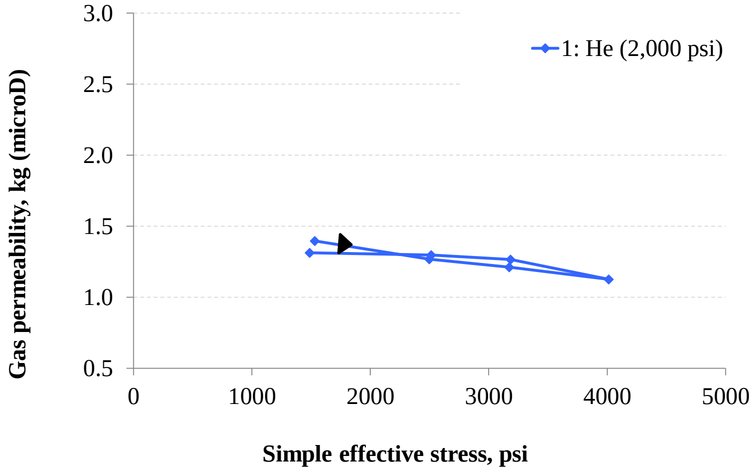


Vertical Sample



Horizontal Sample

1st cycle with Helium at 2,000 psi pore pressure



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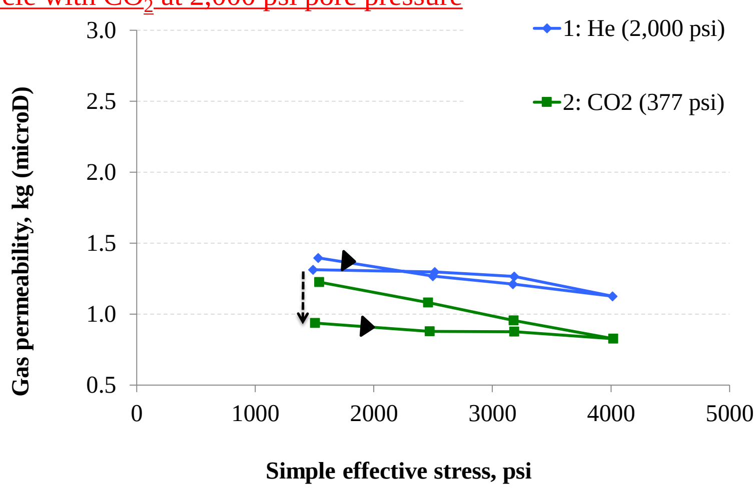
Horizontal Sample

2nd cycle with CO_2 at 2,000 psi pore pressure



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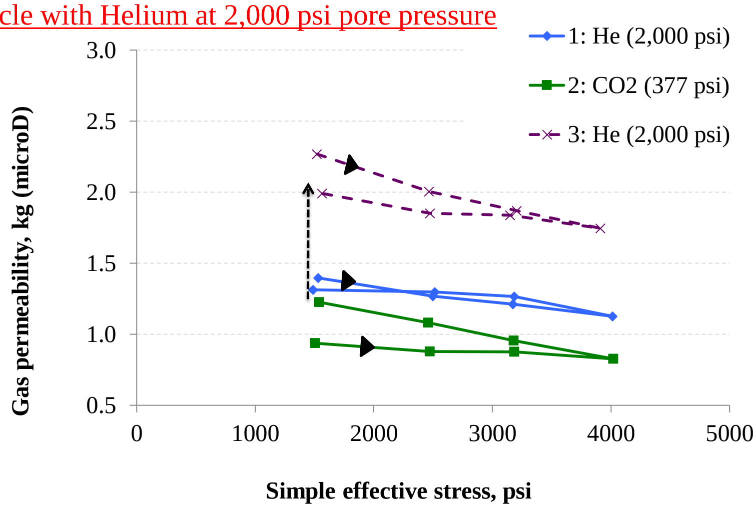
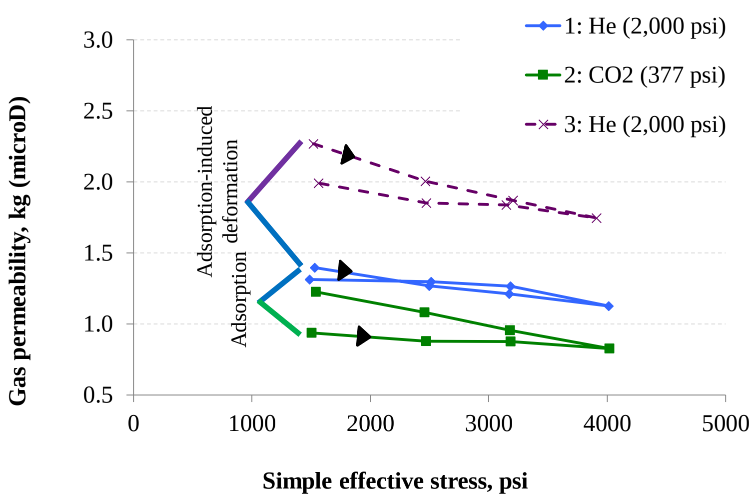
Horizontal Sample

3rd cycle with Helium at 2,000 psi pore pressure

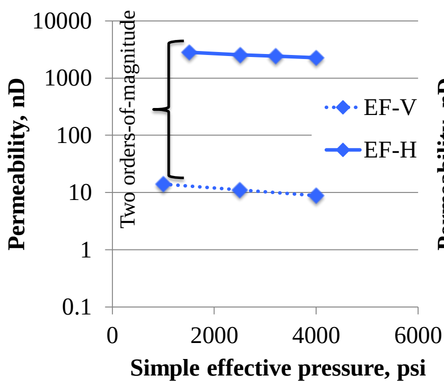


Horizontal Sample

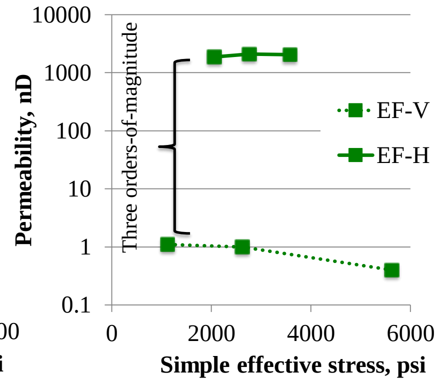


Permeability Anisotropy

He



CO_2



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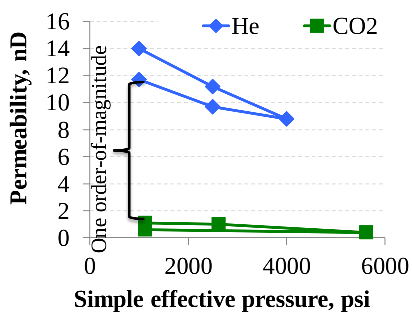
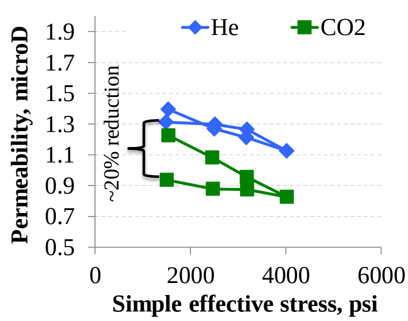
Effect of CO_2 Adsorption

Vertical



Horizontal



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Conclusions

- Permeability anisotropy:
  - Vertical permeability is 2 orders of magnitude lower than horizontal permeability (~10 nD vs. ~ 1μD)
  - Vertical Flow through extremely small (~100 nm) interconnected pores in kerogen whereas horizontal flow also occurs through microcracks in the planes of bedding
- Effect of adsorption:
  - Reduction of vertical permeability by an order of magnitude due to adsorption in extremely small pores
  - However, no significant change in horizontal permeability as the size of the microcracks is large enough that the adsorption does not impact flow significantly

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Acknowledgements

- ConocoPhillips for providing the samples
- SCCS for financial support
- Saudi Aramco for graduate fellowship

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