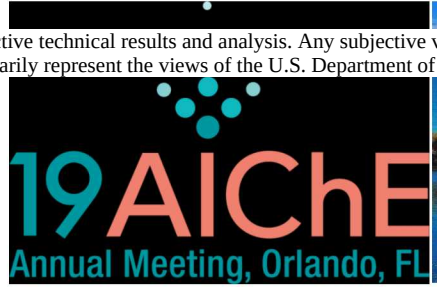
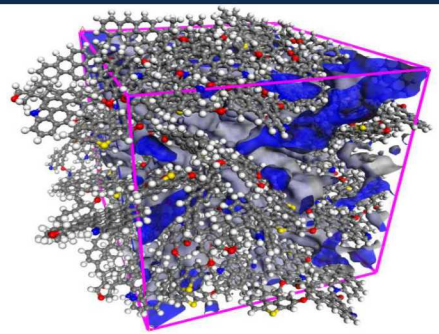
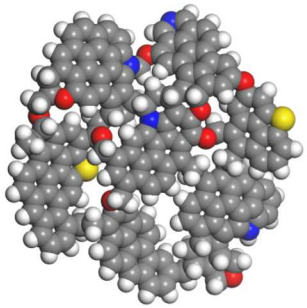
SAND2019-13603C

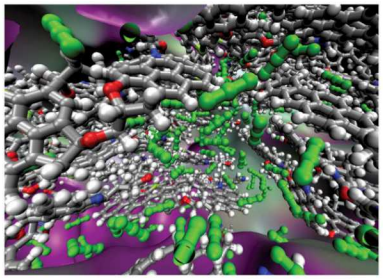






Fluid Transport in Shale Nanopores

Tuan A. Ho and Yifeng Wang
Sandia National Laboratories



Highlighting shale gas research from the Geoscience Group, Sandia National Laboratories, NM, USA. This work was conducted by Dr Tuan Ho, thanks to funding granted to Dr Yifeng Wang by the DOE National Energy Technology Laboratory.

Chemo-mechanical coupling in kerogen gas adsorption/desorption

We use an integrated experimental and modeling approach to fundamentally understand the interaction of gas and fluid with kerogen and clay under reservoir conditions. Specifically, nanostructural properties of subsurface porous media, gas adsorption and release from the kerogen network, deformation of shale associated with adsorption and lithostatic stress, and wettability of inorganic and organic matter.

As featured in:

See Tuan Anh Ho et al., Phys. Chem. Chem. Phys., 2018, 20, 12590.

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U.S. DEPARTMENT OF ENERGY

NNSA
National Nuclear Security Administration

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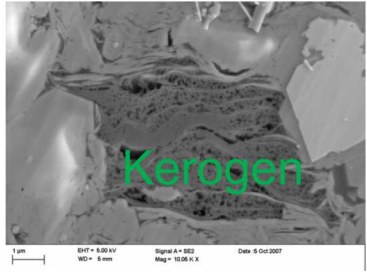
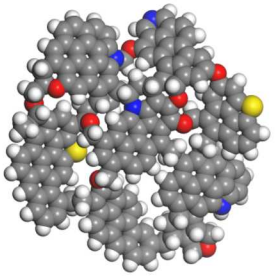
Introduction

Shale - Kerogen



- Insoluble organic matter found in sedimentary rocks (geochemistry)
- Cracks into petroleum products (kerogen maturation, petroleum generation)

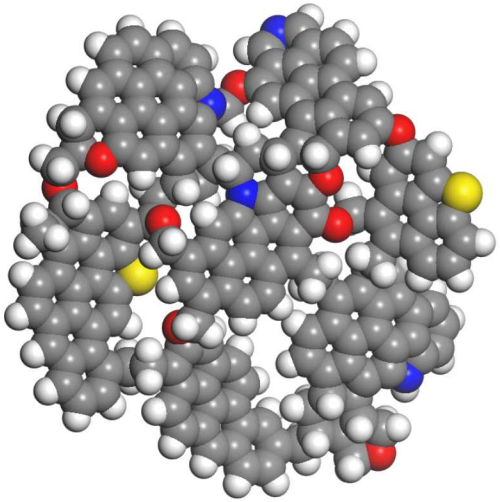


Ungerer et al., Energ Fuel 29, 91-105

- **Hosts pore space responsible for petroleum storage and transport**

Formation of condensed kerogen

Sandia National Laboratories



$C_{175}H_{102}O_9N_4S_2$

Energy Fuels 2015, 29, 91-105

24 Kerogens in 10x10x10nm^3 box, 1000K

NVT

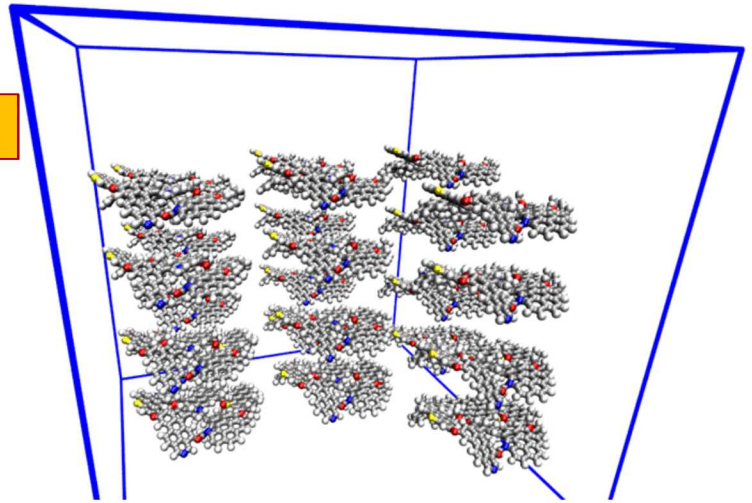
9 snapshots

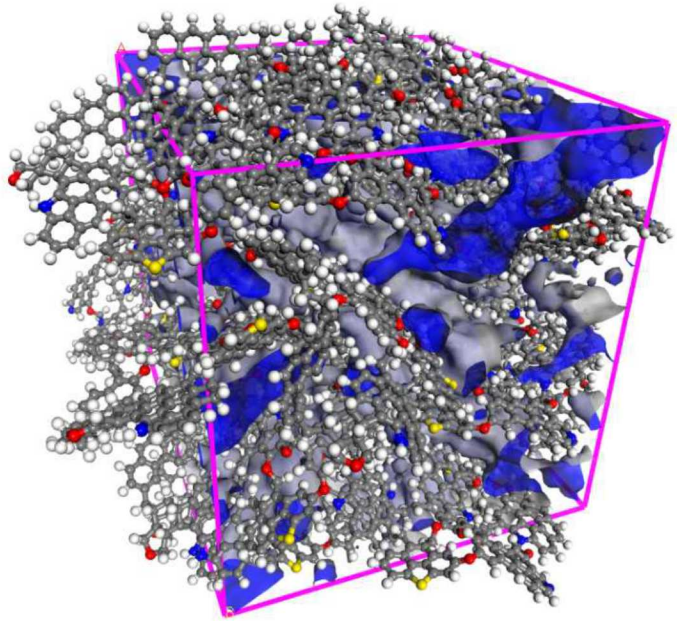
NPT, 100at, 900K to 300K

300K and 100atm

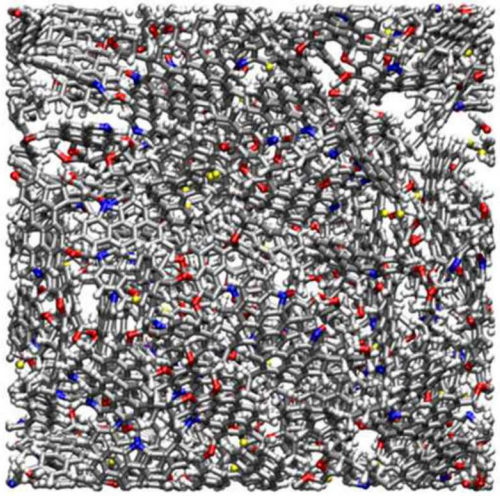
NPT, 1atm, 300K

9 samples at 300K and 1atm





Characterization



Density

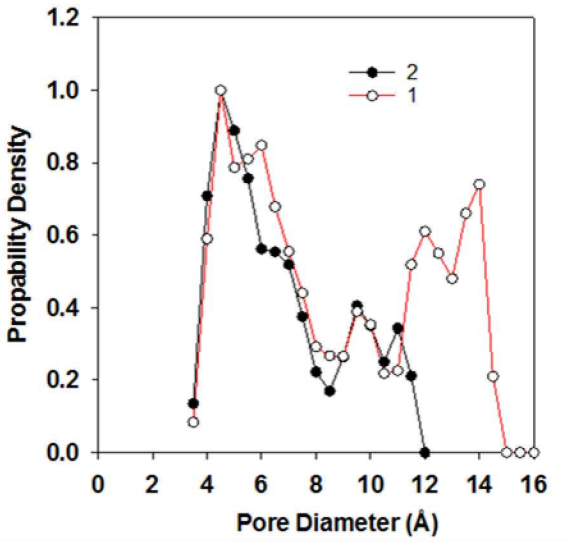
Average :1.22±0.04 g/cm^3

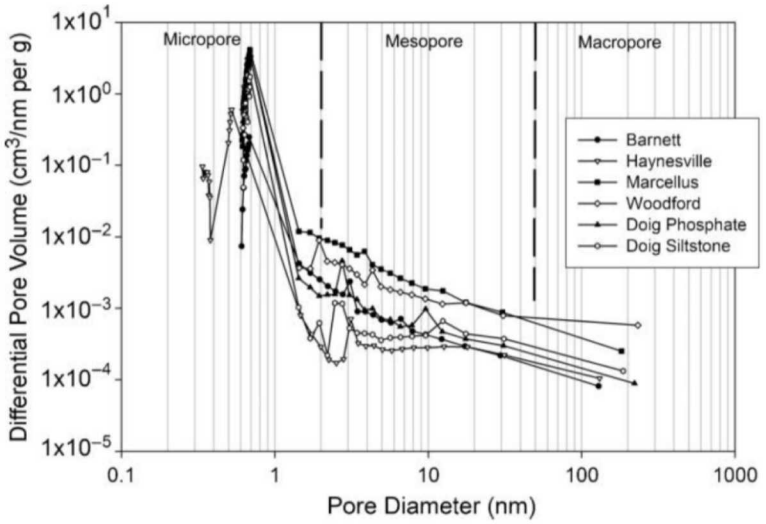
Experiment: 1.28±0.3g/cm^3

Stankiewicz A, *et al.* (2015) Kerogen density revisited – lessons from the Duvernay Shale. *In: Paper URTeC 2157904 at the Unconventional Resources Technology Conference, San Antonio, Texas, July 2015*

(Scientific Reports 6, 28053, 2017)

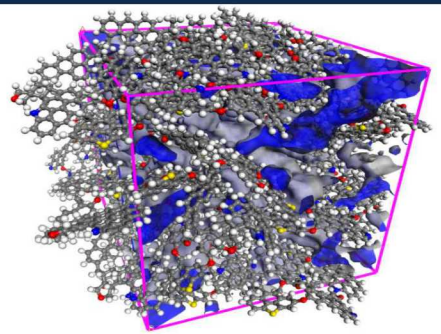
Pore size distribution

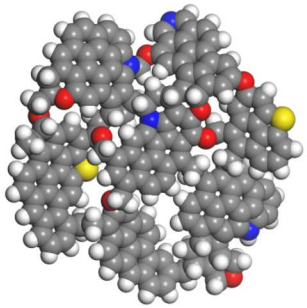




AAPG 96 (2012), 1099-1119

Fluid Transport in Shale Nanopores





Outline:

1. Gas adsorption and kerogen swelling

Fuel 220, 1-7, 2018
Scientific Reports 6, 28053, 2017
PCCP 20, 11390, 2018

2. Transport in shale nanopores

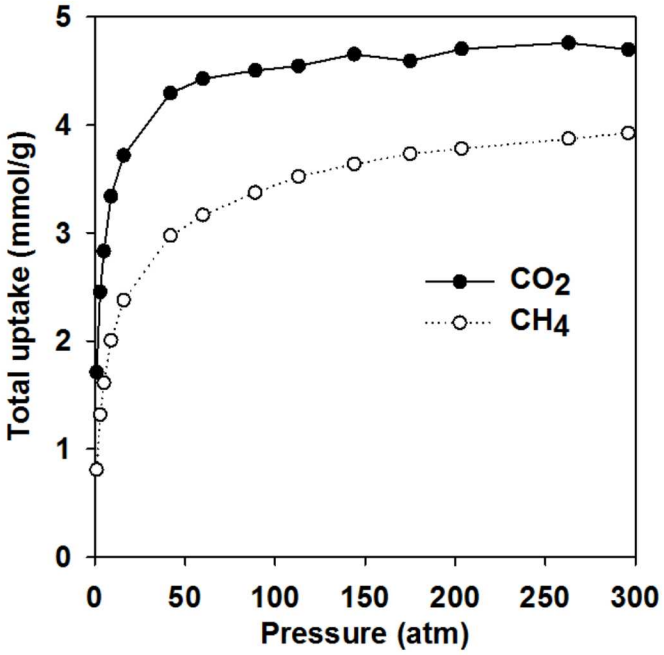
Nanoscale 10, 19957, 2018
PCCP 21, 12777, 2019

Differential retention and release of CO_2 and CH_4 in kerogen nanopores (Fuel 220, 1-7, 2018)

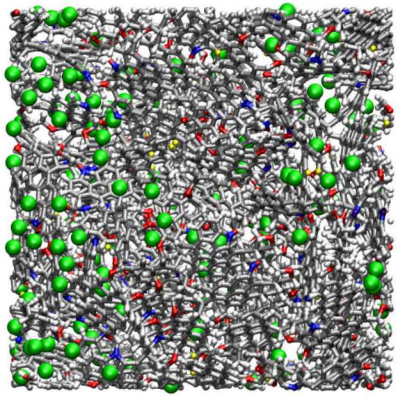
Sandia National Laboratories

Implications for gas enhanced recovery and carbon sequestration

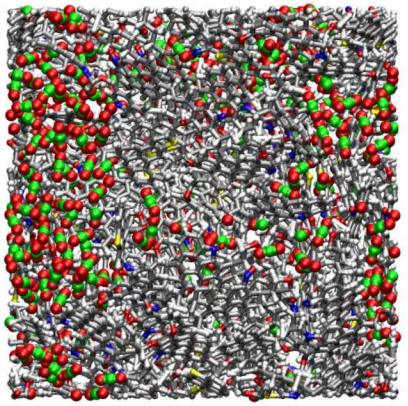
Pure gas adsorption



CH_4



CO_2

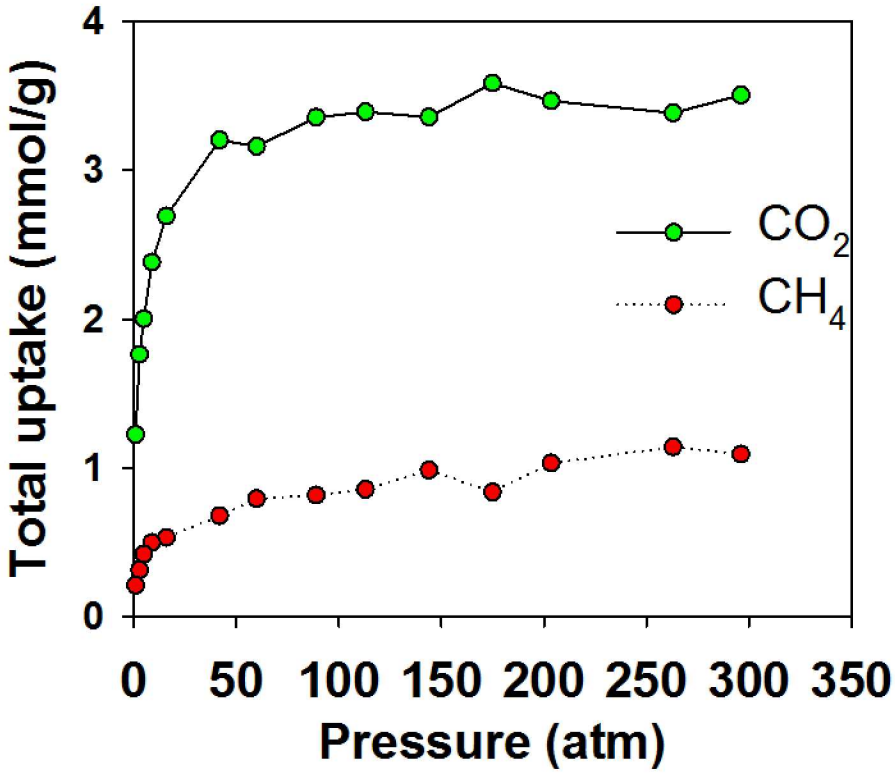


Differential retention and release of CO_2 and CH_4 in kerogen nanopores (Fuel 220, 1-7, 2018)

Sandia National Laboratories

Implications for gas enhanced recovery and carbon sequestration

1:1 binary gas adsorption



Kerogen preferentially retains CO_2 over CH_4

Kerogen swelling (PCCP 20, 11390, 2018)

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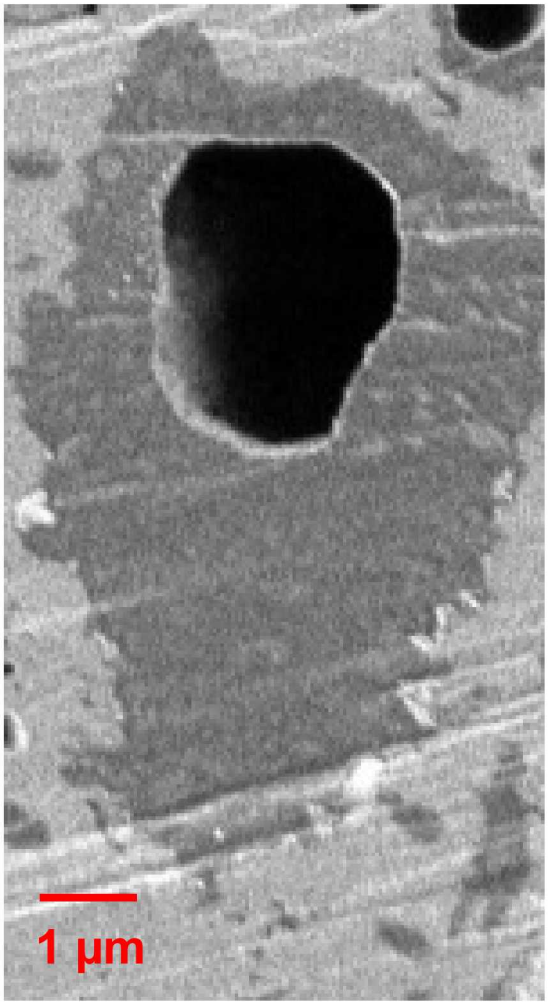
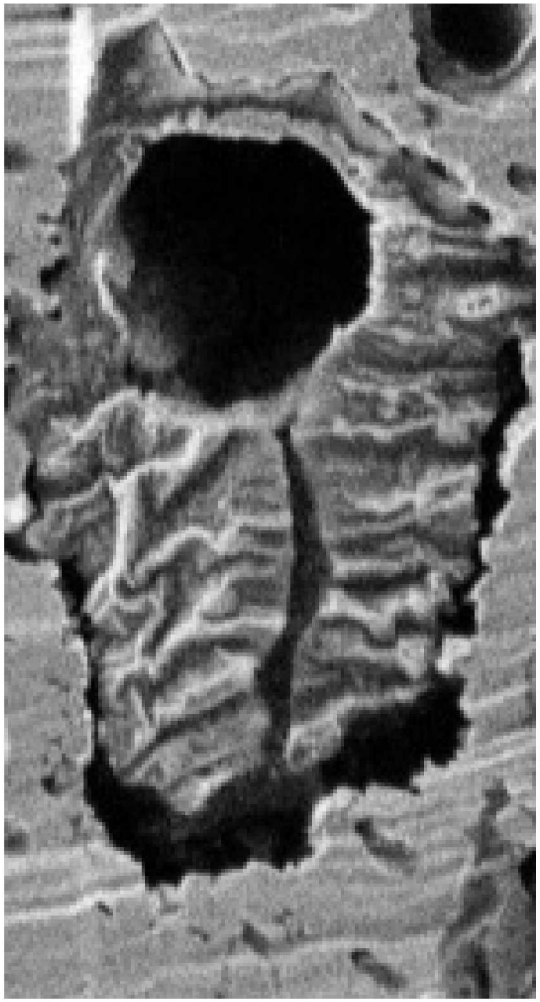
Rubber swelling in oil

Drew Pomerantz, Schlumberger

Will kerogen swell upon gas adsorption?



Intact shale with swollen kerogen



Bitumen-extracted shale with collapsed kerogen

Chemo-mechanical coupling in kerogen gas adsorption (PCCP 20, 11390, 2018)

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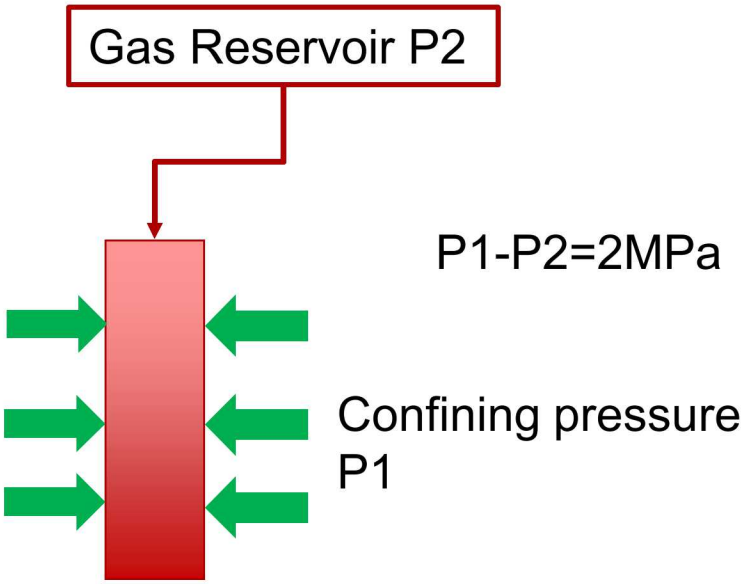
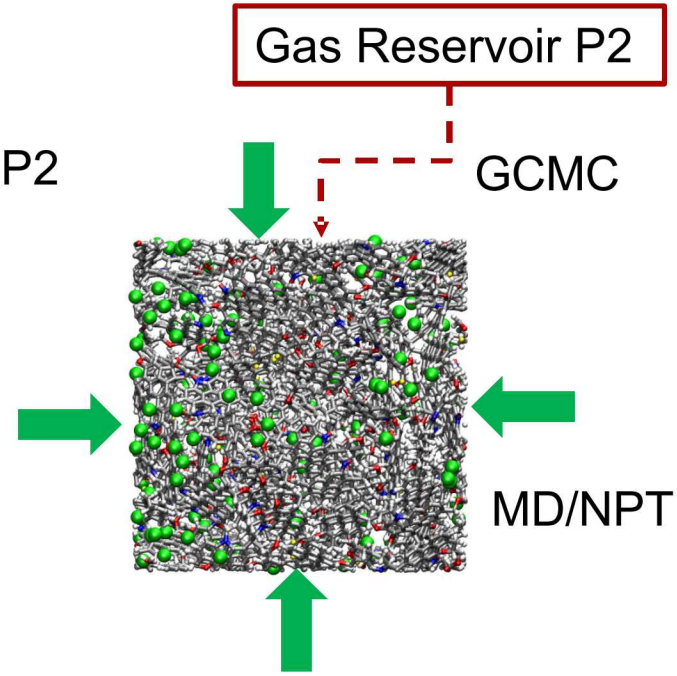
Experimental setup

(J. Unconv. Oil Gas Resour., 2014)



Simulation: Hybrid MD/MC

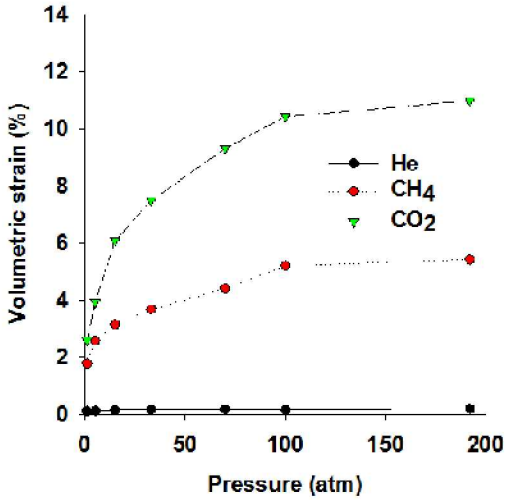


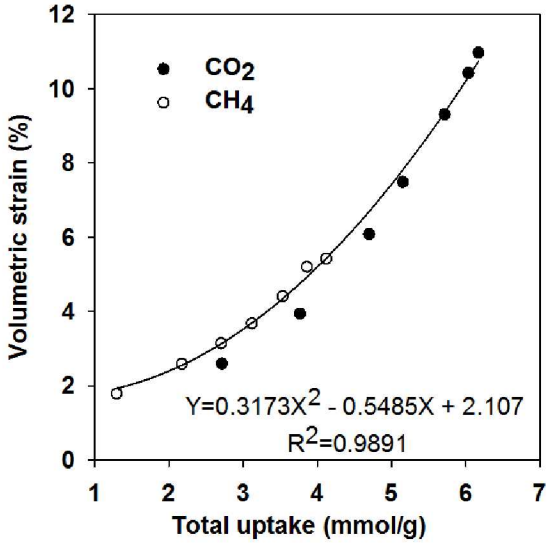
$$Volumetric\ strain = \frac{V - V_o}{V_o}$$

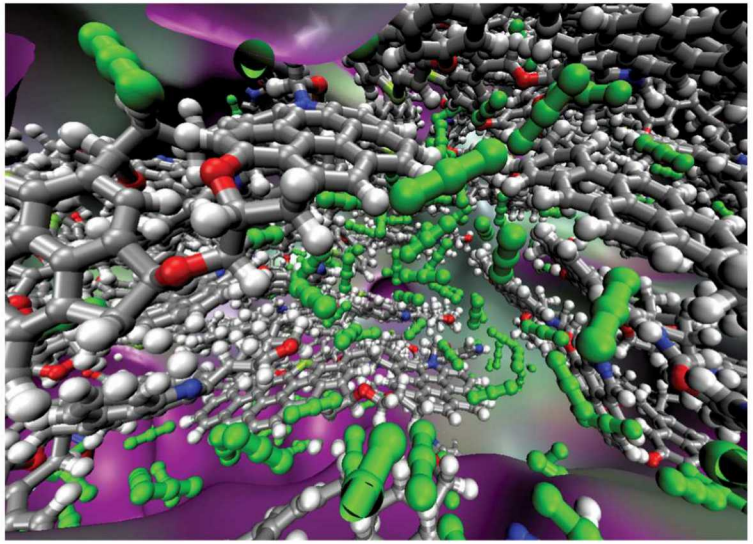
V: kerogen volume after gas adsorption

V_o: kerogen volume before gas adsorption

Chemo-mechanical coupling in kerogen gas adsorption (PCCP 20, 11390, 2018)







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Upon shale gas extraction kerogen shrinks

Kerogen swelling with gas (PCCP 20, 11390, 2018)

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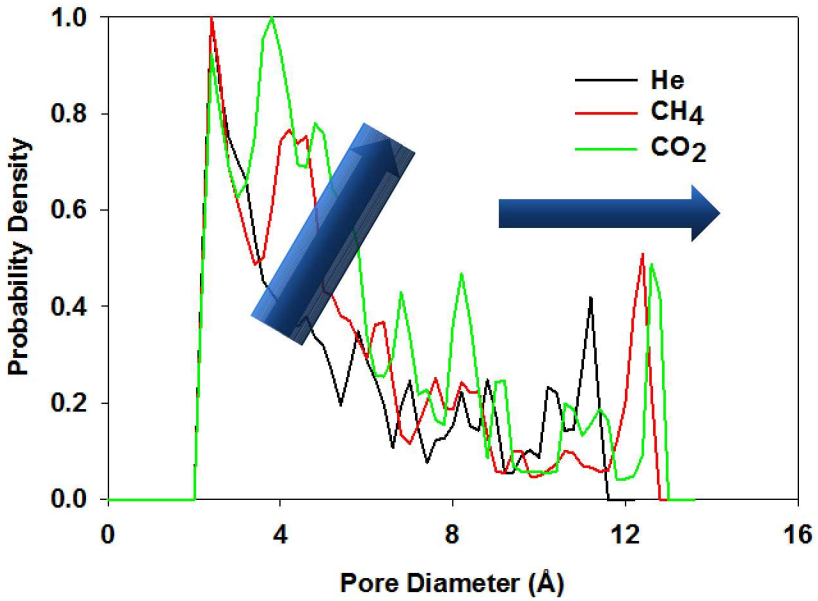
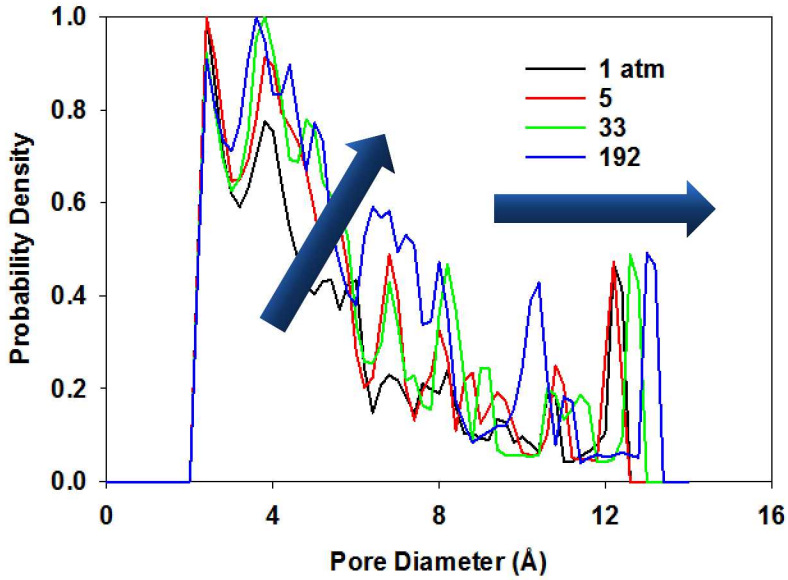
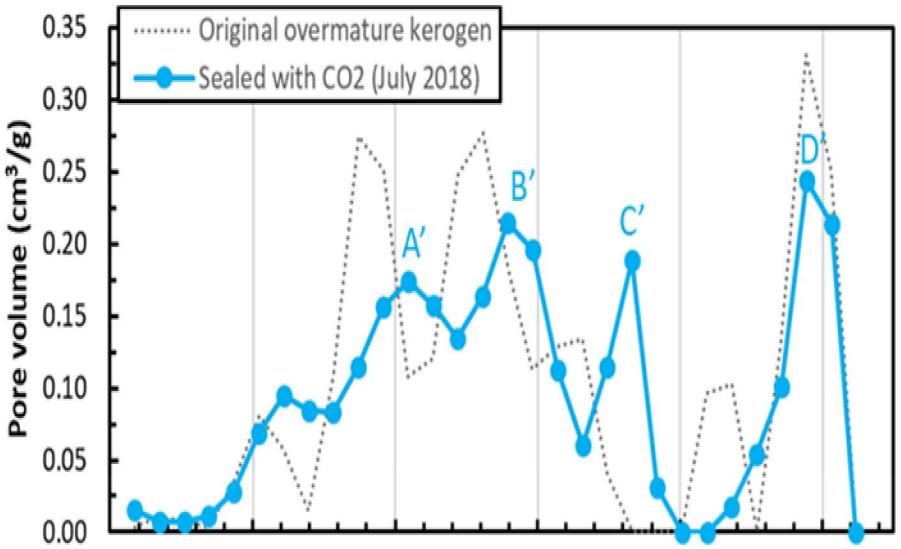
Effects of kerogen swelling on pore size distribution

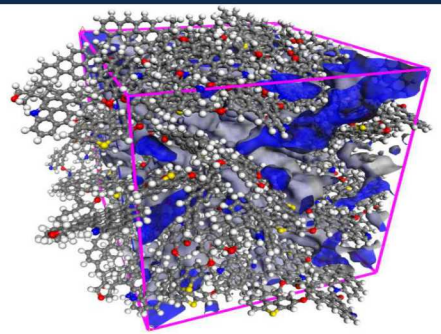


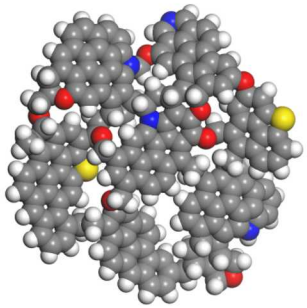




From Guangping Xu SNL

Fluid Transport in Shale Nanopores





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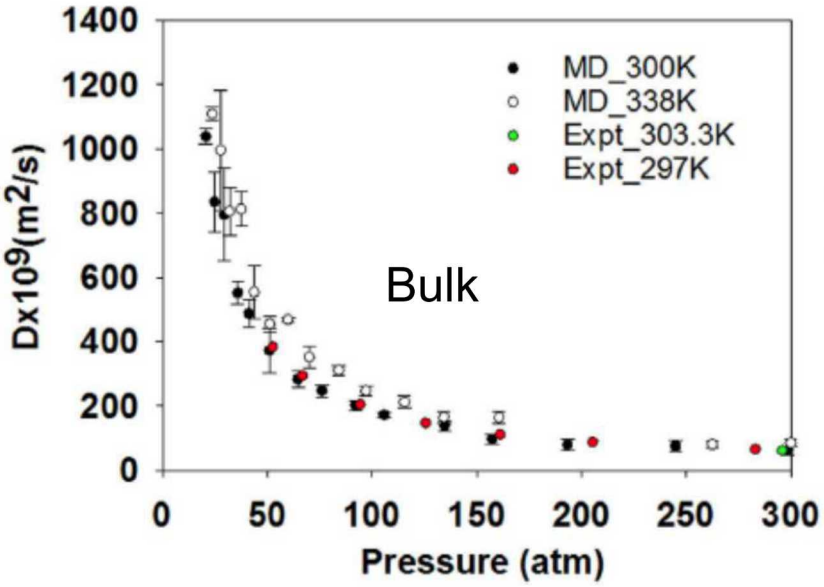
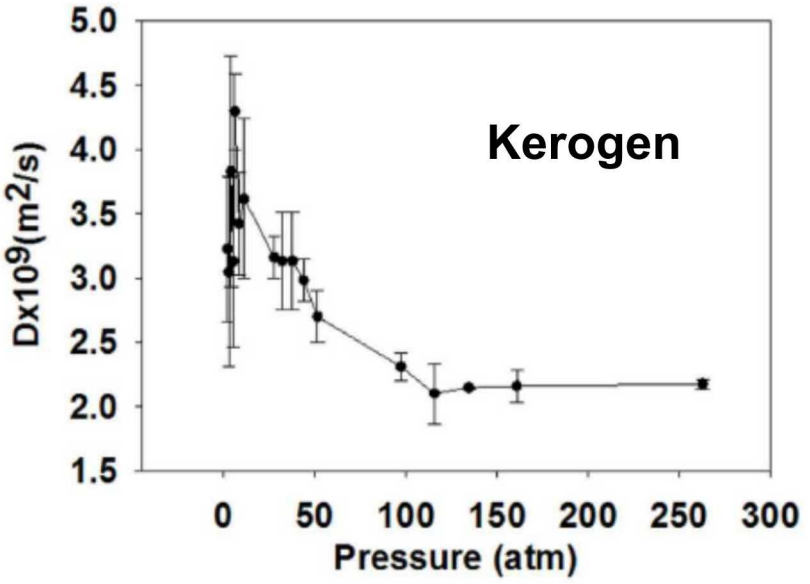
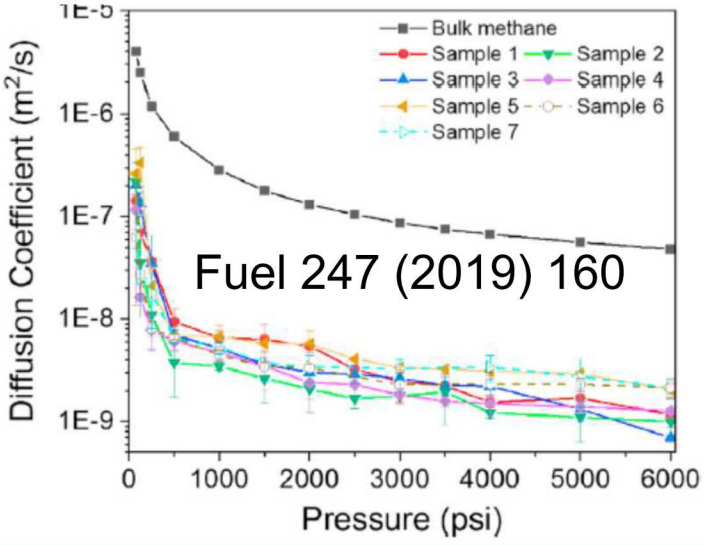
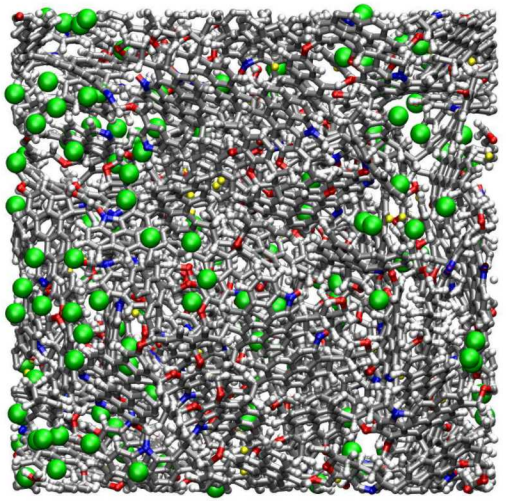
Methane diffusion in kerogen

(Scientific Reports 6, 28053, 2017)



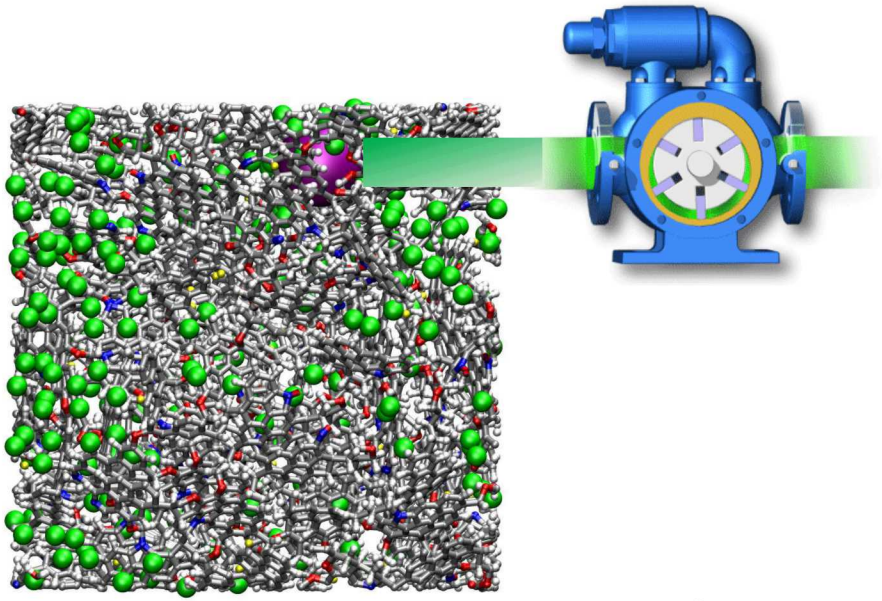


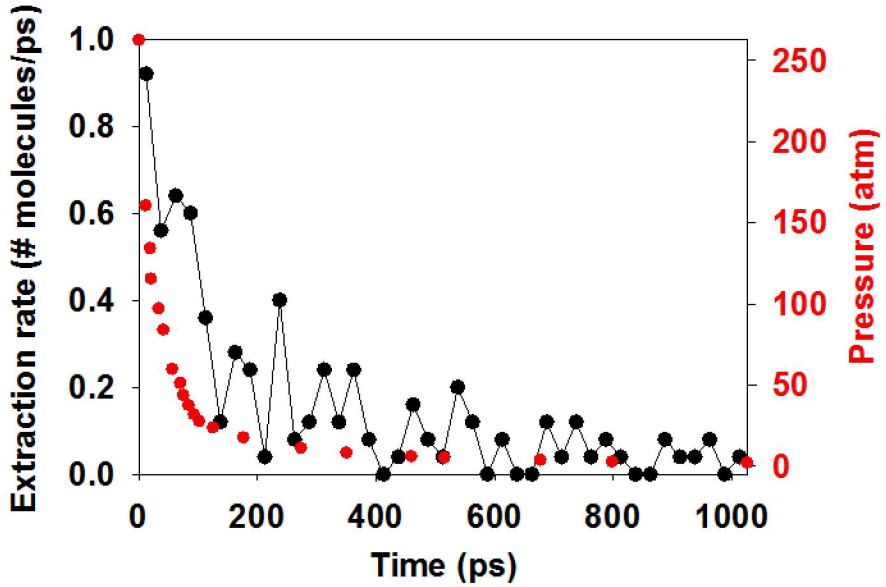


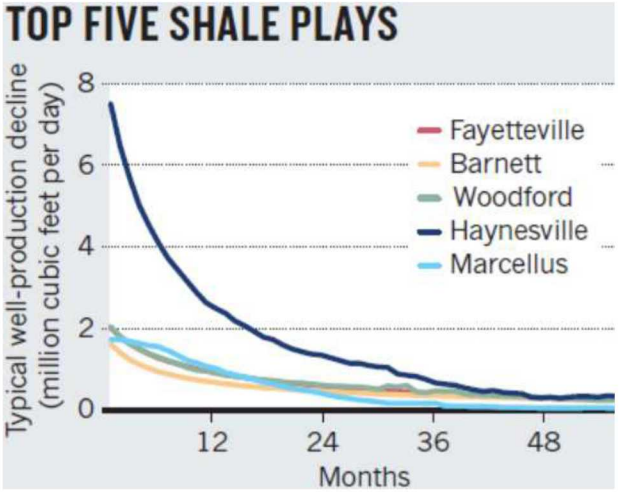


Methane extraction from kerogen

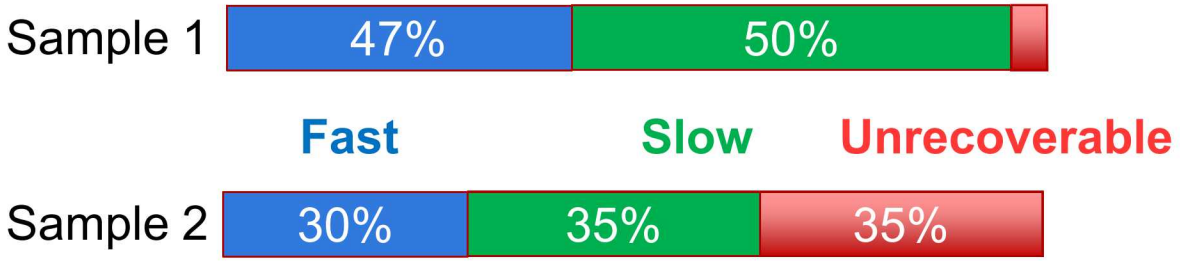
(Scientific Reports 6, 28053, 2017)





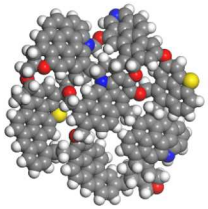


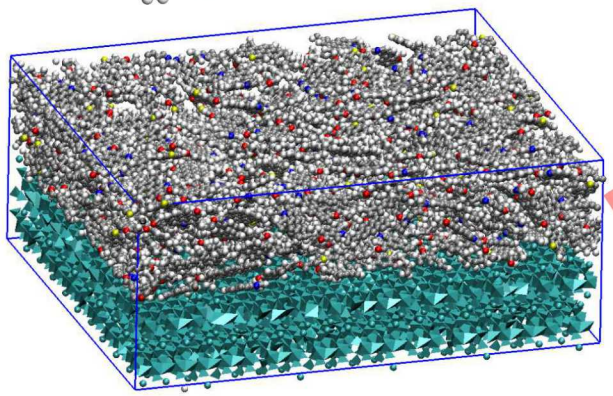
Nature 494, 307 (2013)

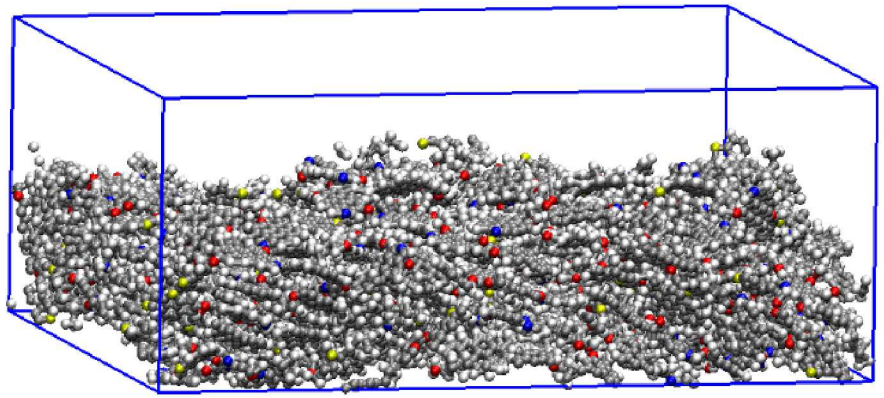


Kerogen wettability and fluid flow (Nanoscale 10, 19957, 2018)

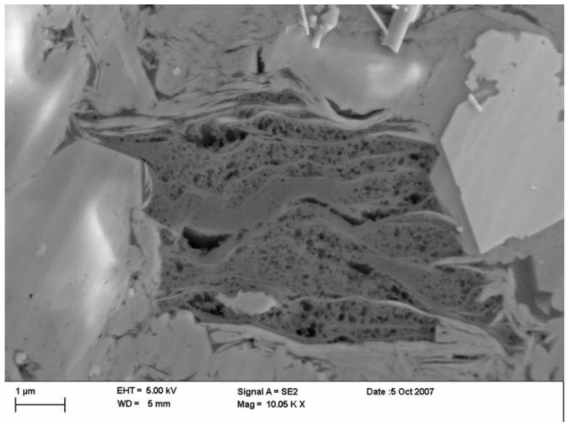
Sandia National Laboratories

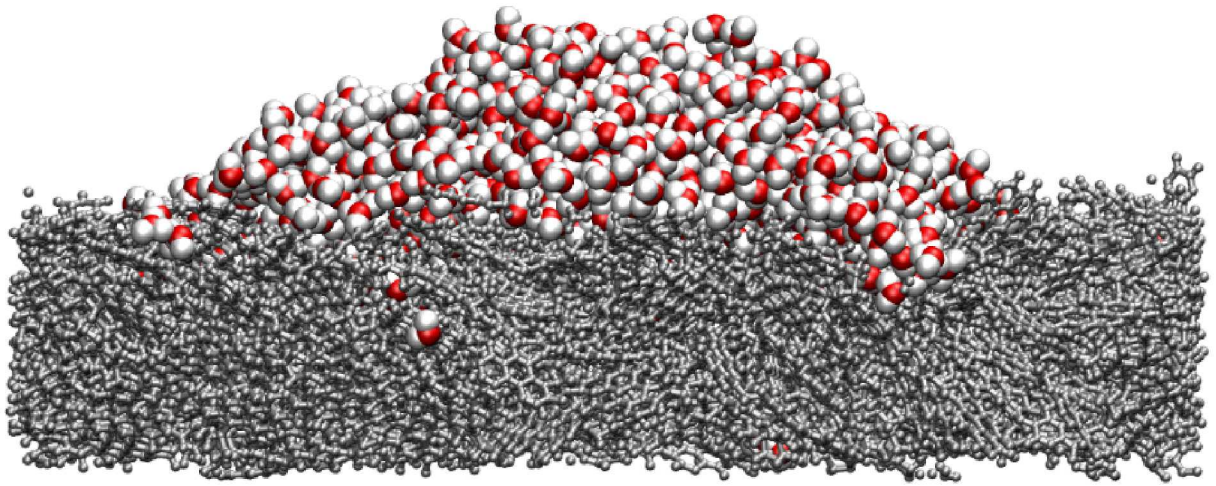






42.8°±6.5°

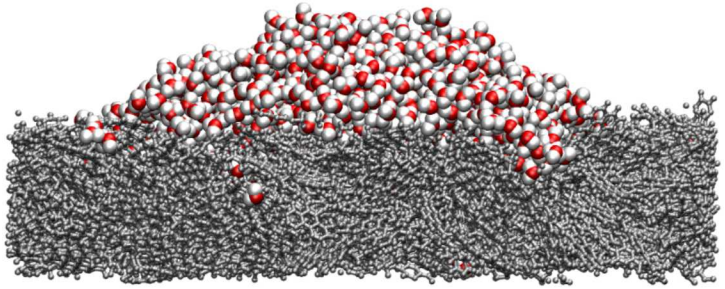


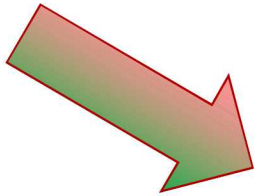


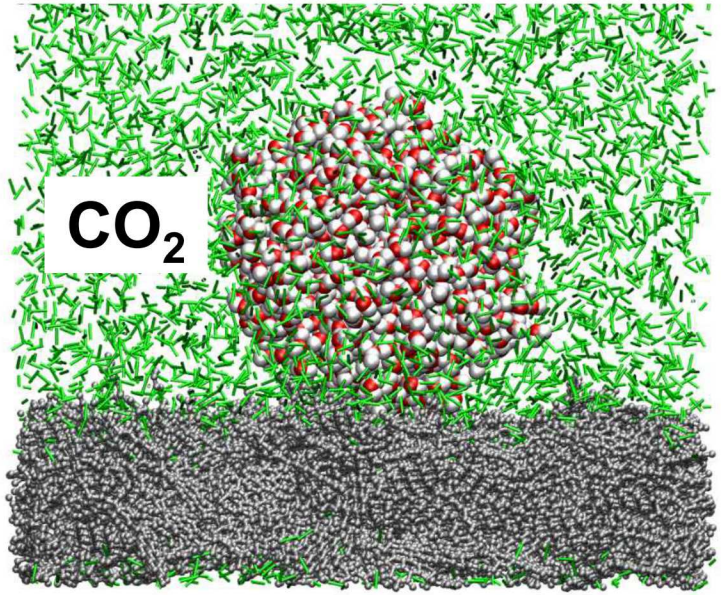
Kerogen wettability and fluid flow

Sandia National Laboratories

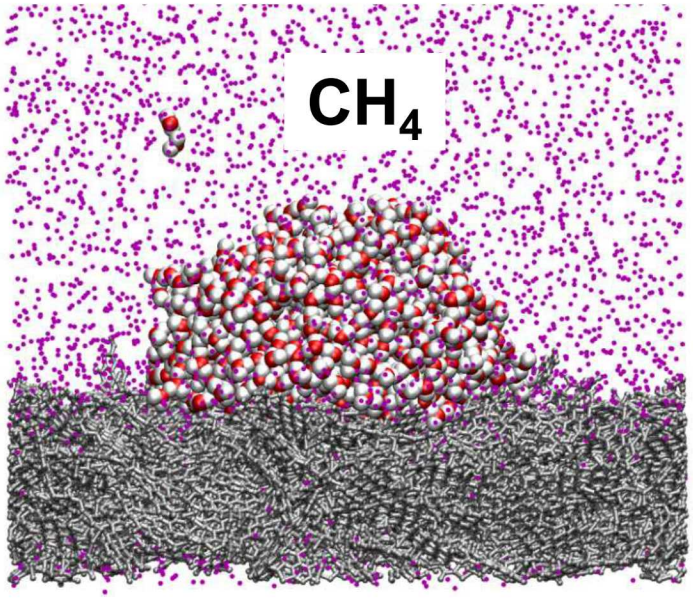
42.8°±6.5°







79.18°±1.97°

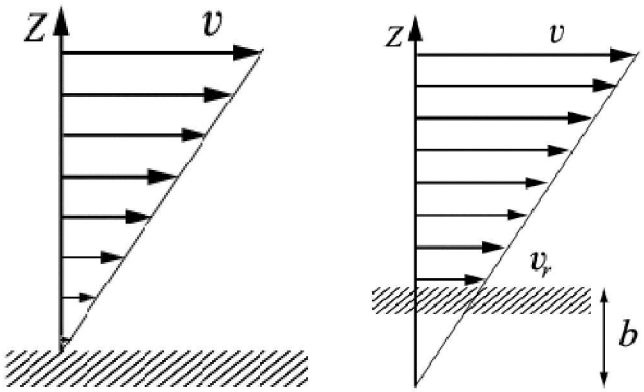


Wetting → Non-wetting behavior

Kerogen wettability and fluid flow

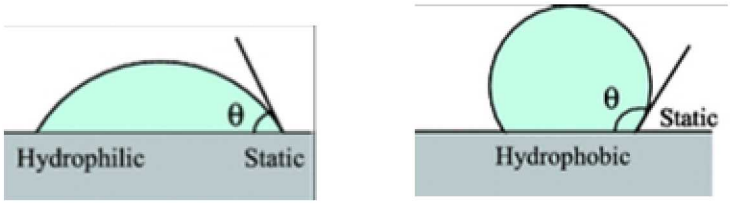
Sandia National Laboratories

Wetting to non-wetting transition → Stick to slip flow transition

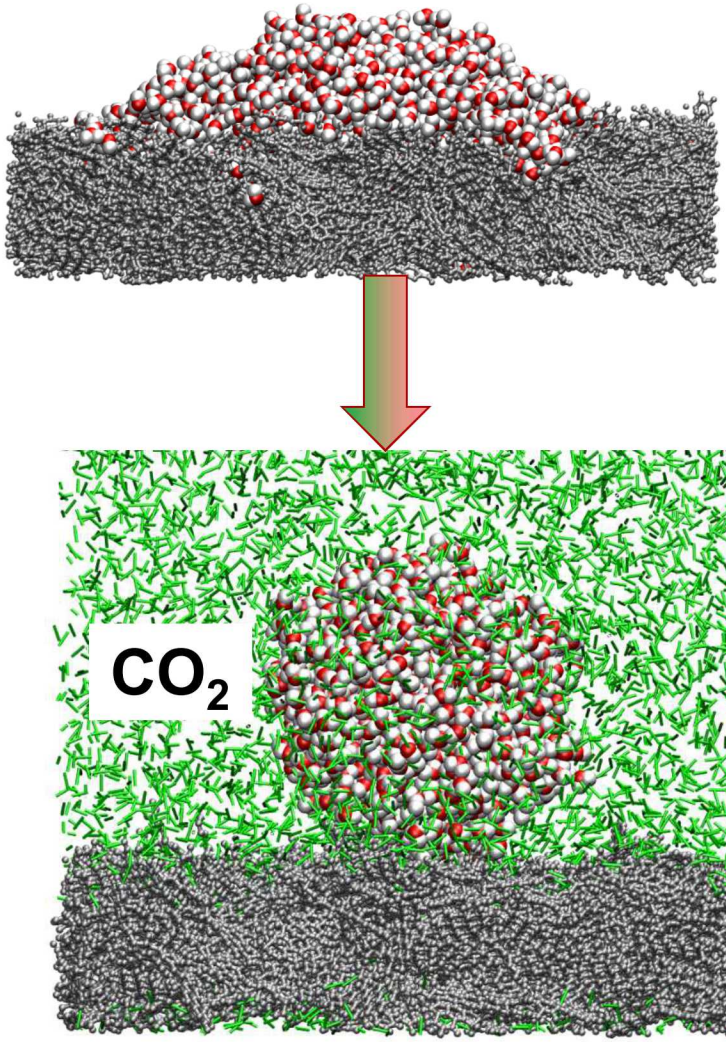


No slip

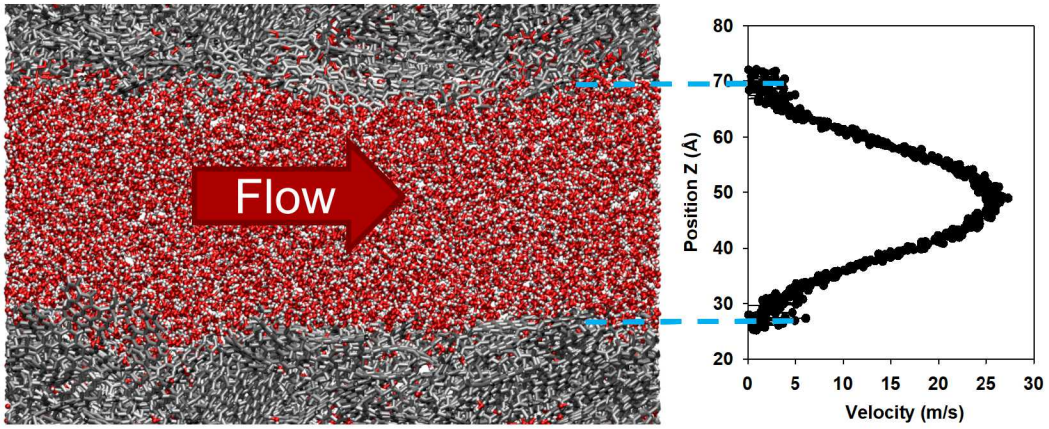
Slip



42.8°±6.5°

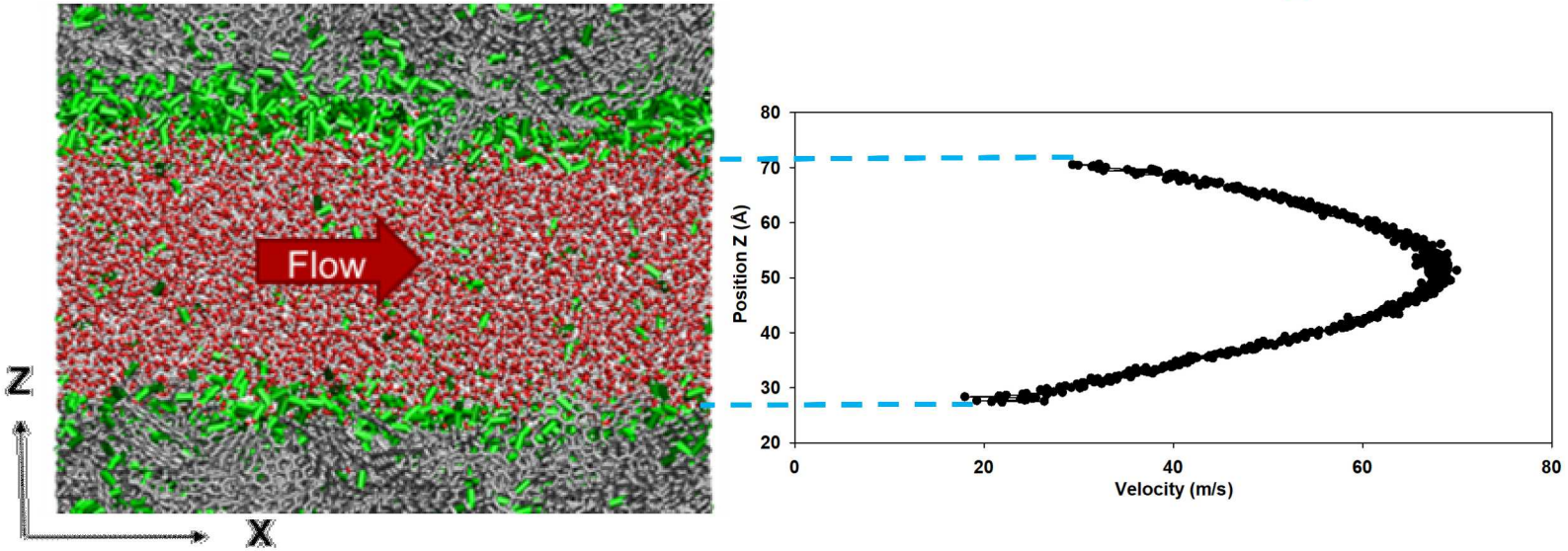


Kerogen wettability and fluid flow



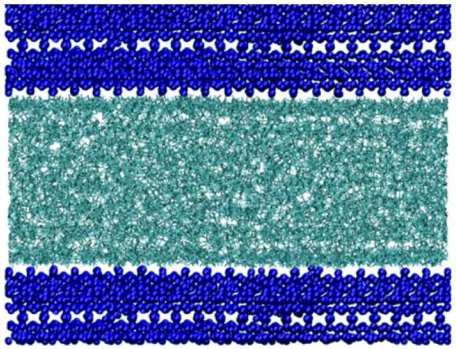
$$\frac{\text{Flow Rate (w } CO_2\text{)}}{\text{Flow Rate (w/o } CO_2\text{)}} \sim 4$$

CO_2 thin layer → Lubricant

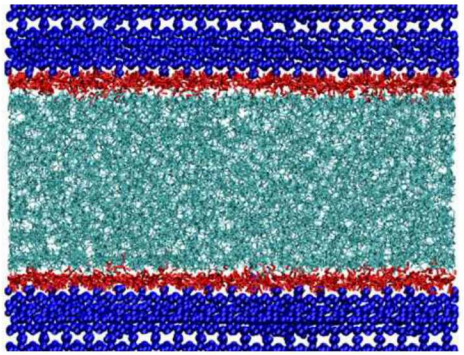


Enhancement of oil flow in shale nanopores

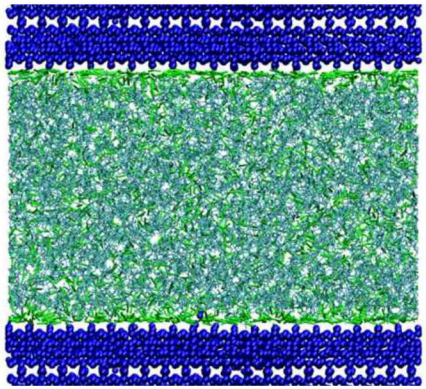
PCCP 21, 12777, 2019



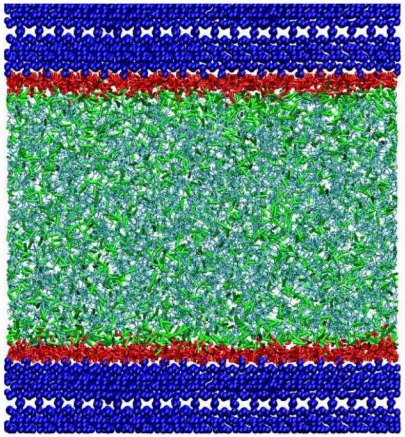
M_O
(Muscovite and Octane)



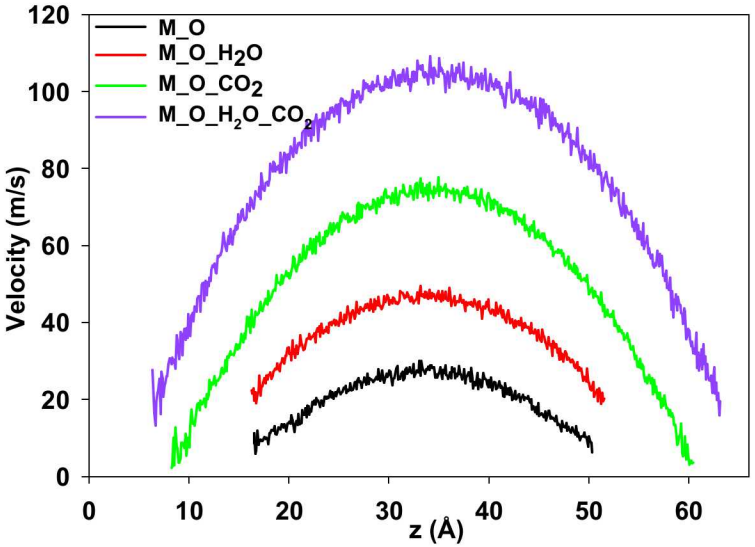
M_O_H_2O



M_O_CO2

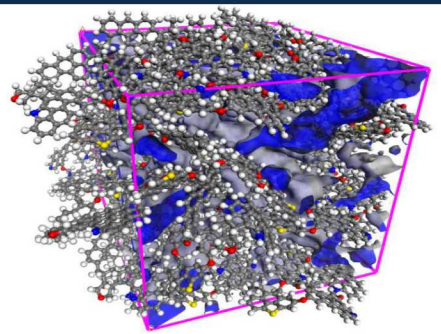


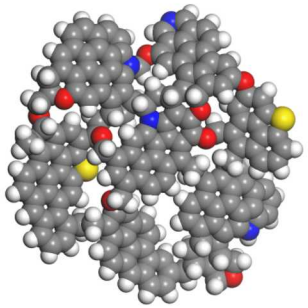
M_O_CO2_H2O



Effect of viscosity and friction coefficient on oil flow

Fluid Transport in Shale Nanopores

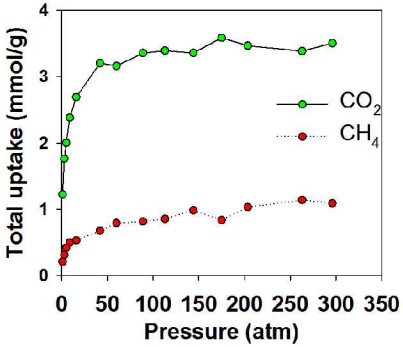


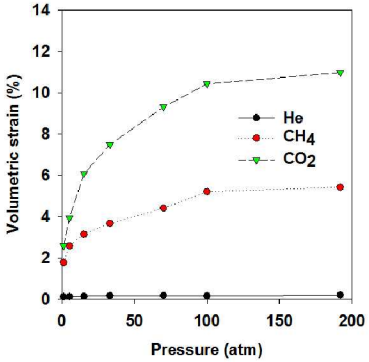


Summary

1. Gas adsorption and kerogen swelling

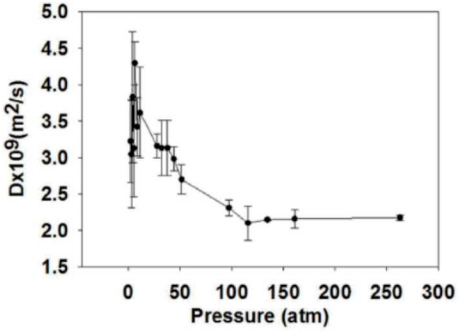
Fuel 220, 1-7, 2018
PCCP 20, 11390, 2018

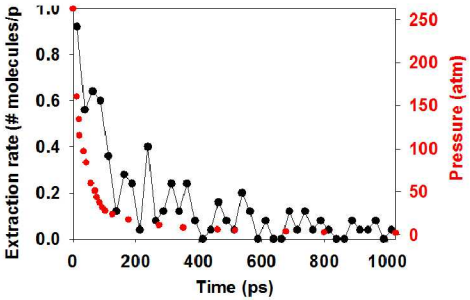


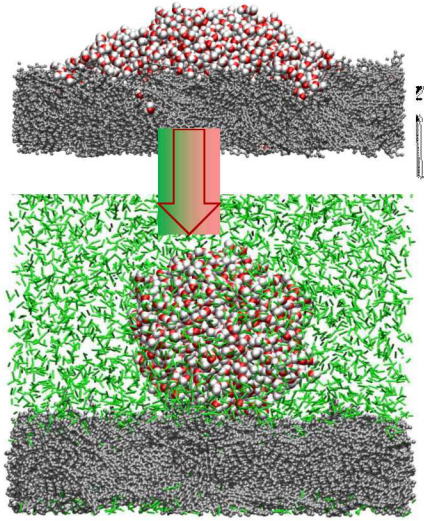


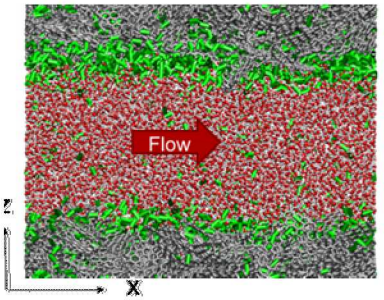
2. Transport in shale nanopores

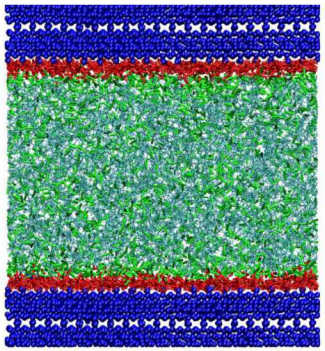
Scientific Reports 6, 28053, 2017
Nanoscale 10, 19957, 2018
PCCP 21, 12777, 2019



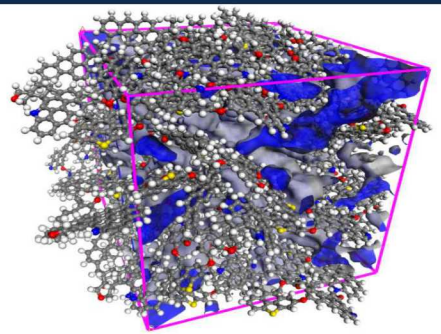


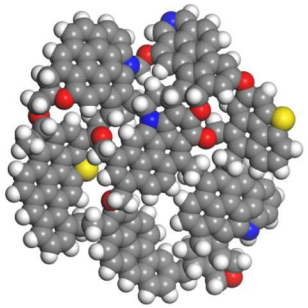






Fluid Transport in Shale Nanopores





Tuan A. Ho and Yifeng Wang

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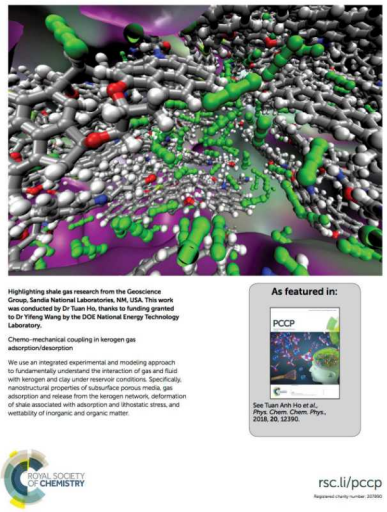

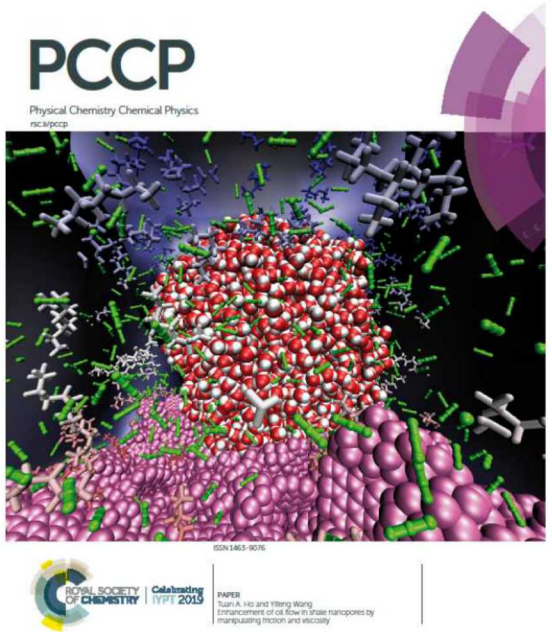

Funding: NETL