SAND2016-11947C

Task F - Fluid Inclusion and Movement in Tight Rocks

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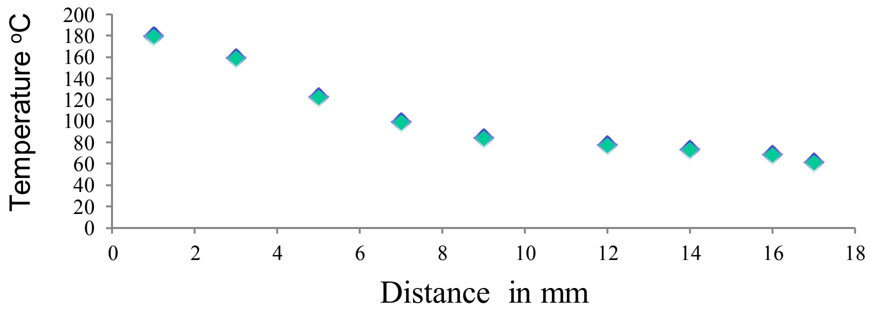
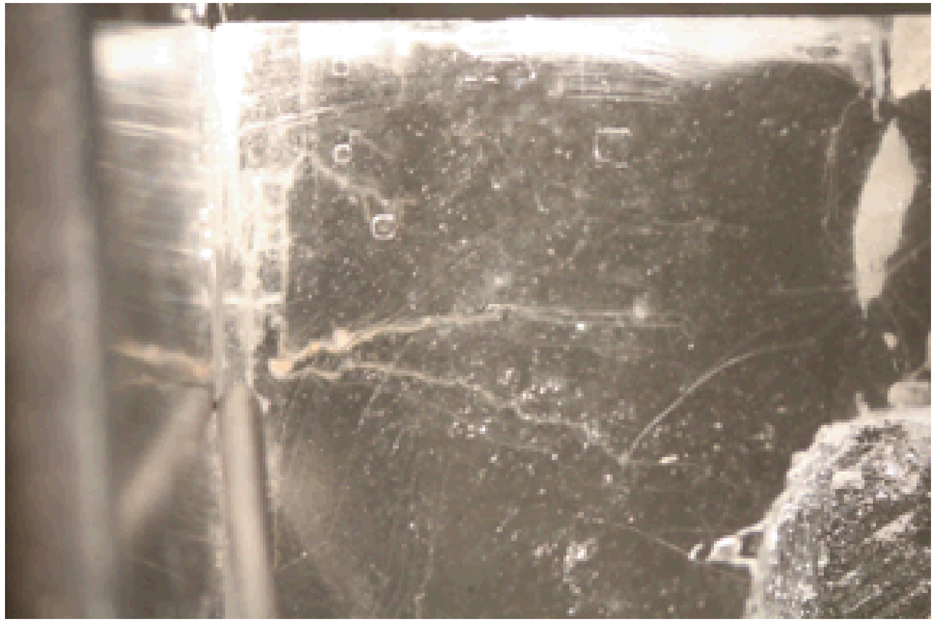
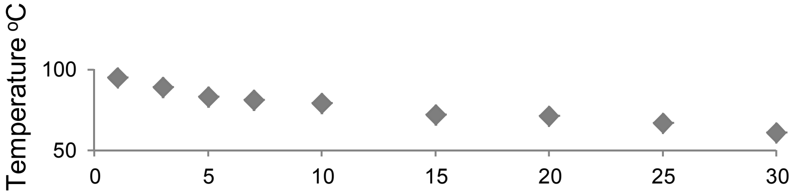
Sandia National Laboratories

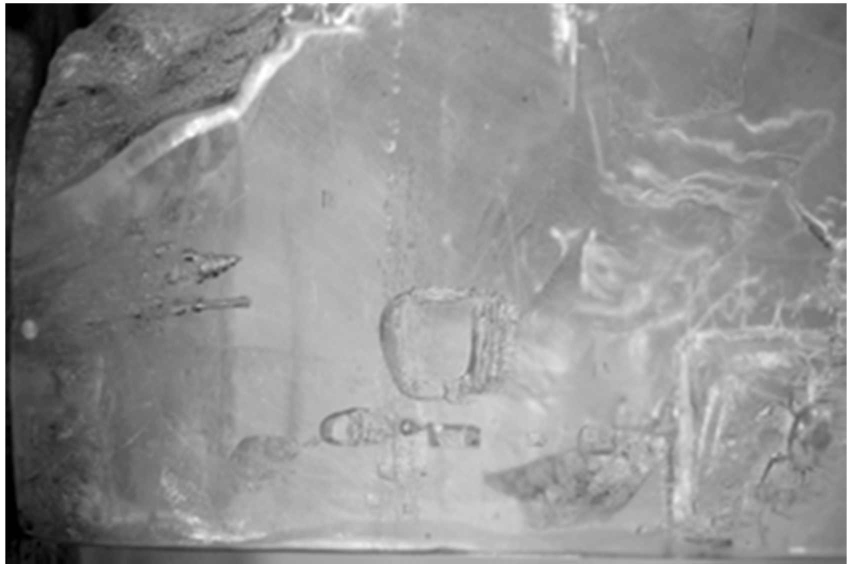
Observations: Temperature effect

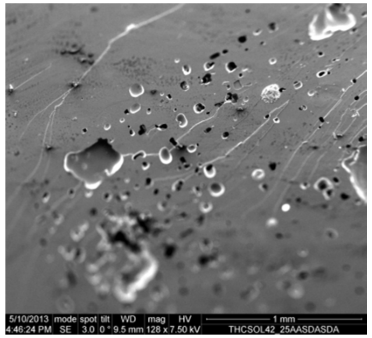


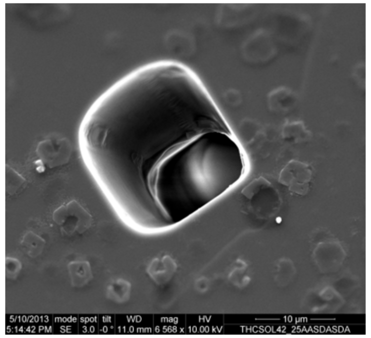


Caporuscio et al. (per. Comm.)



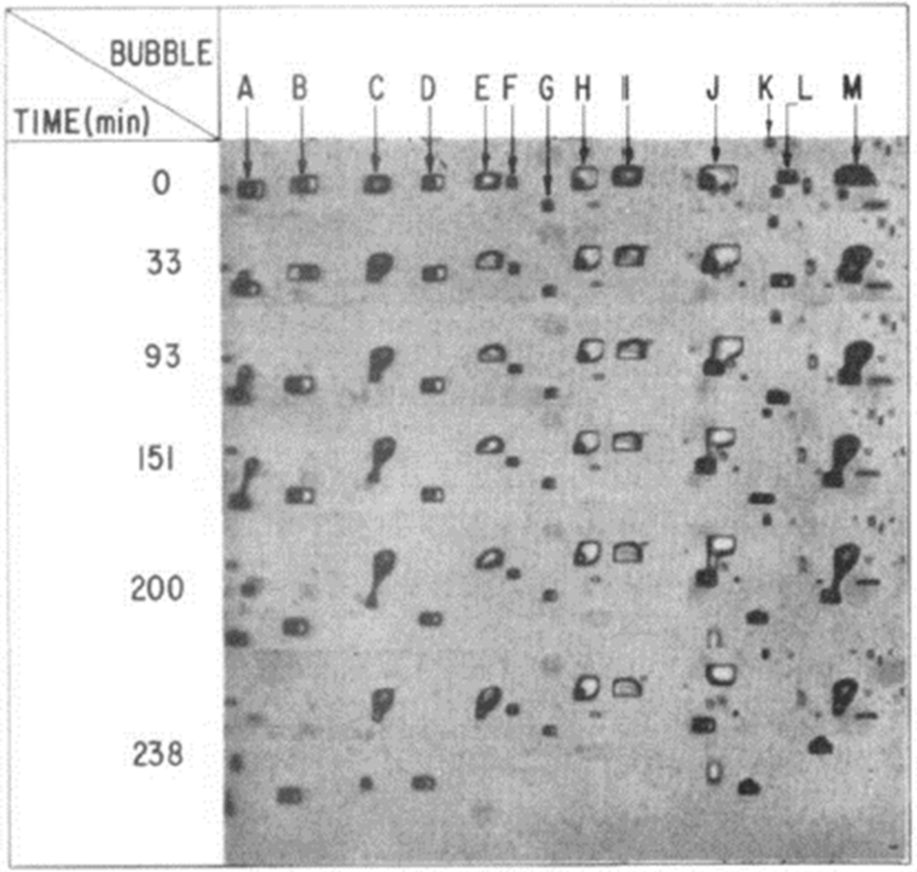


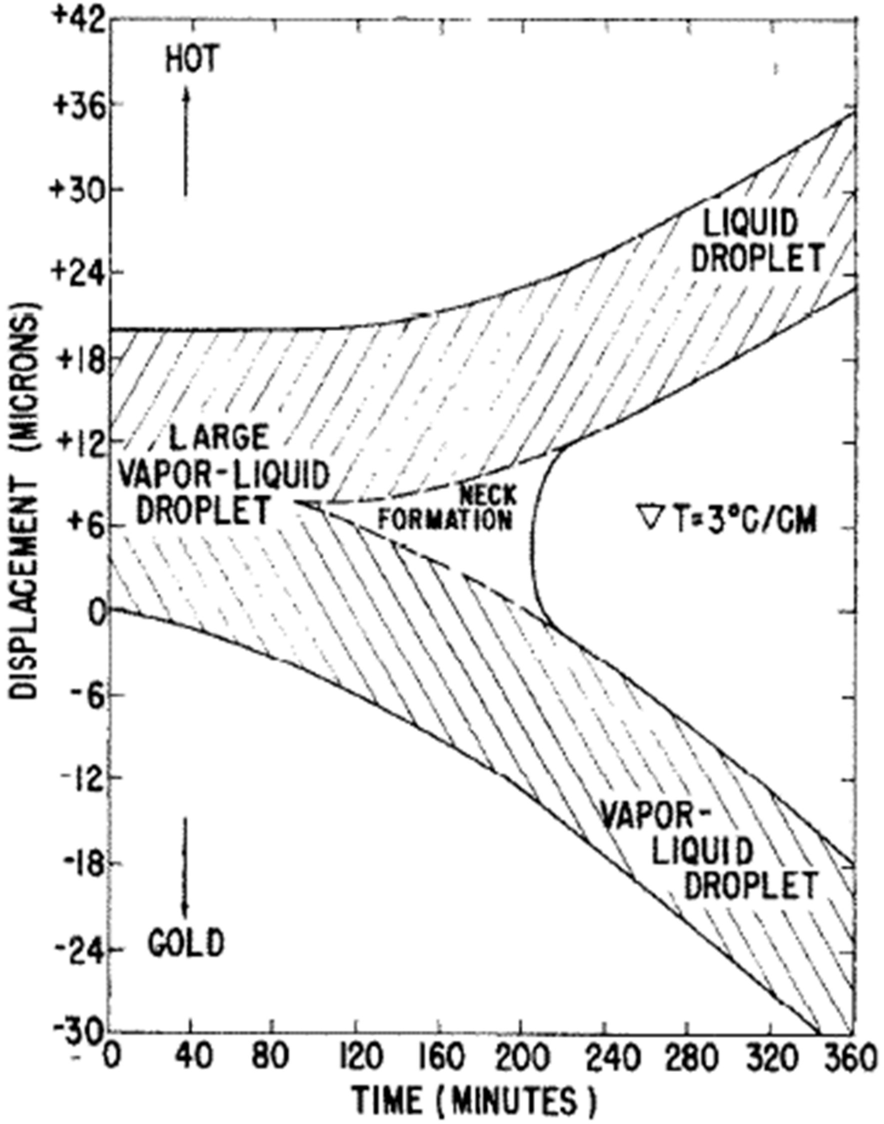




Interface instability and channeling

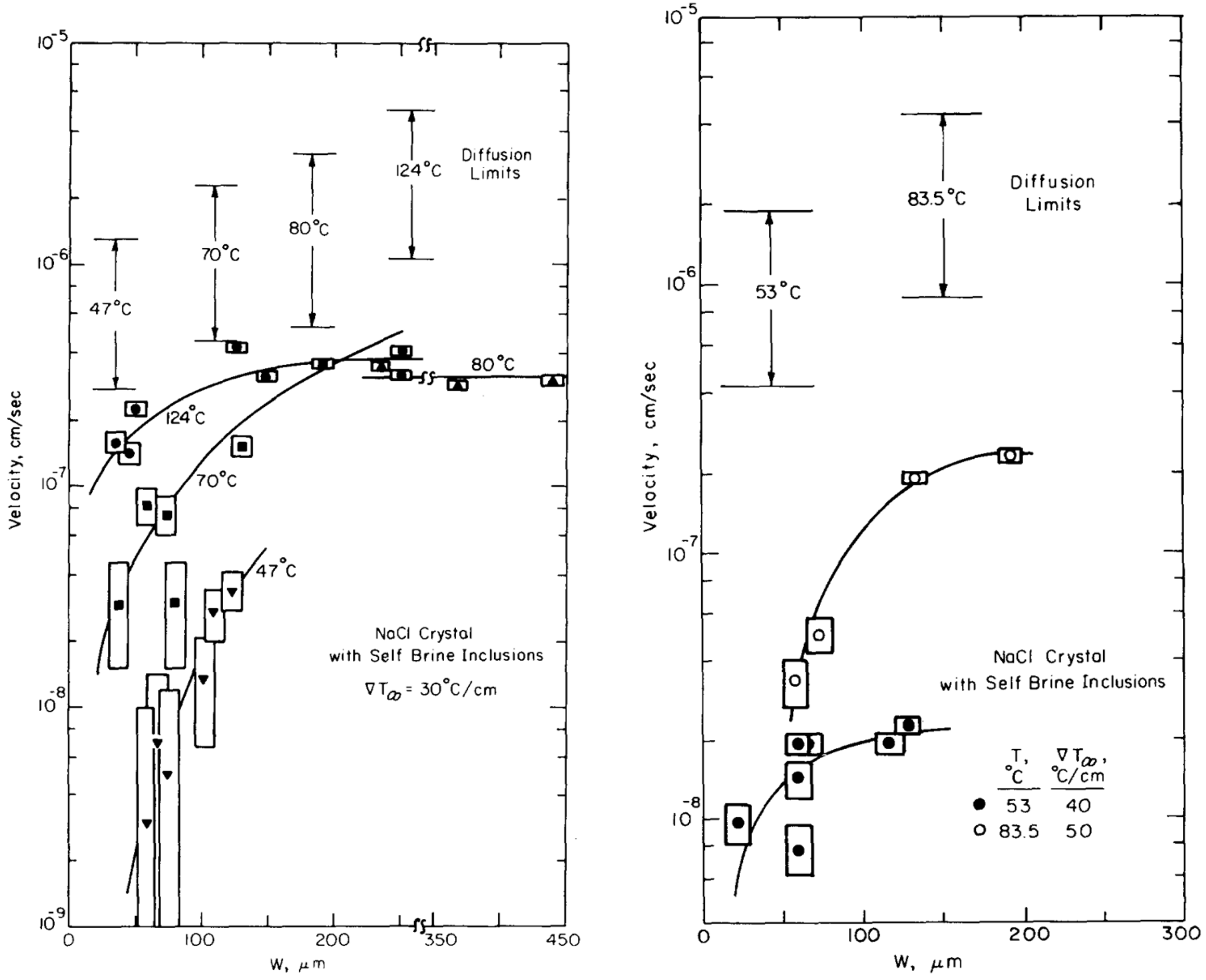
Observations: Biphase inclusions





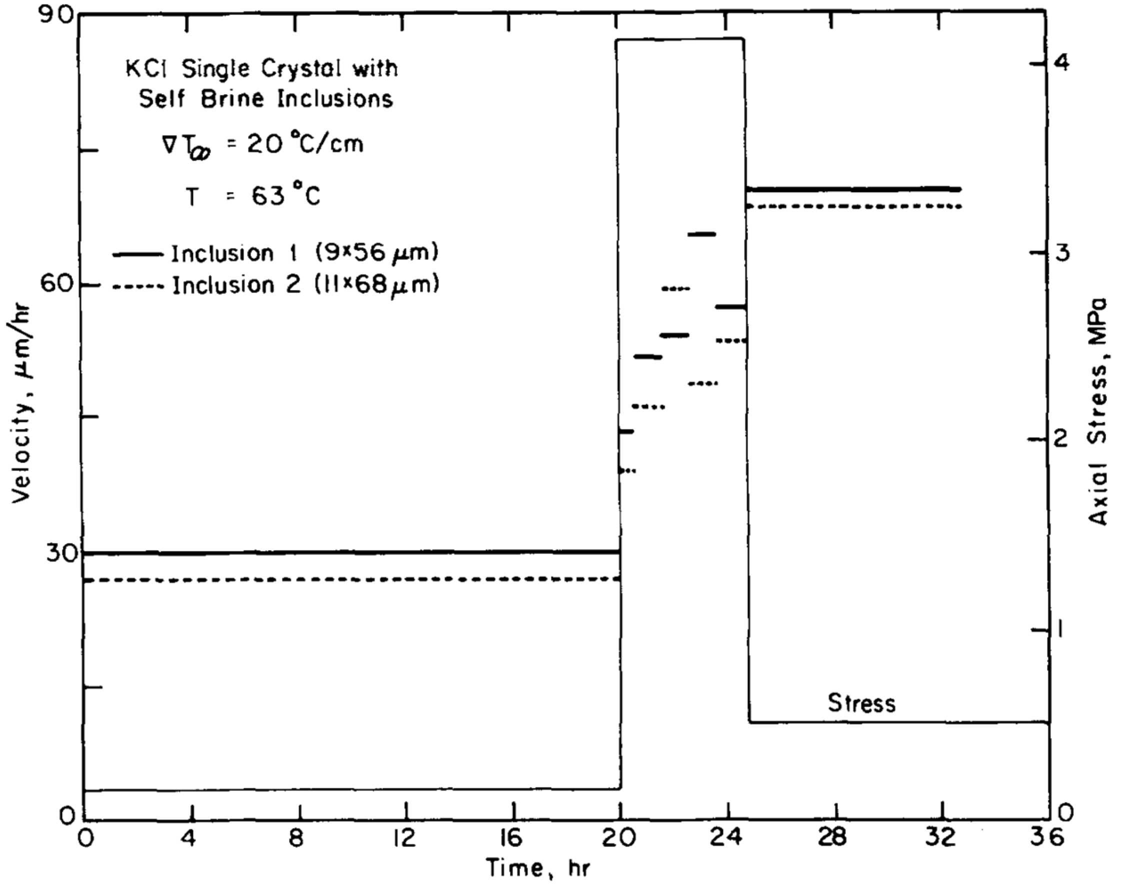
Anthony & Cline (1972)

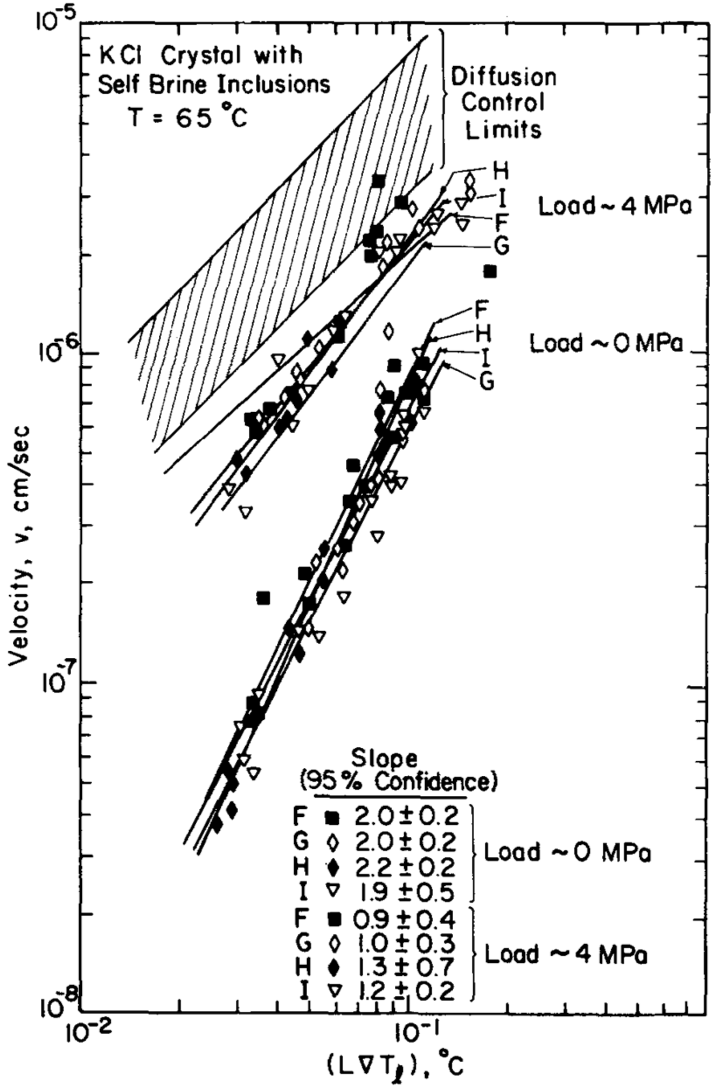
Observations: Size dependence



Olander et al. (1982)

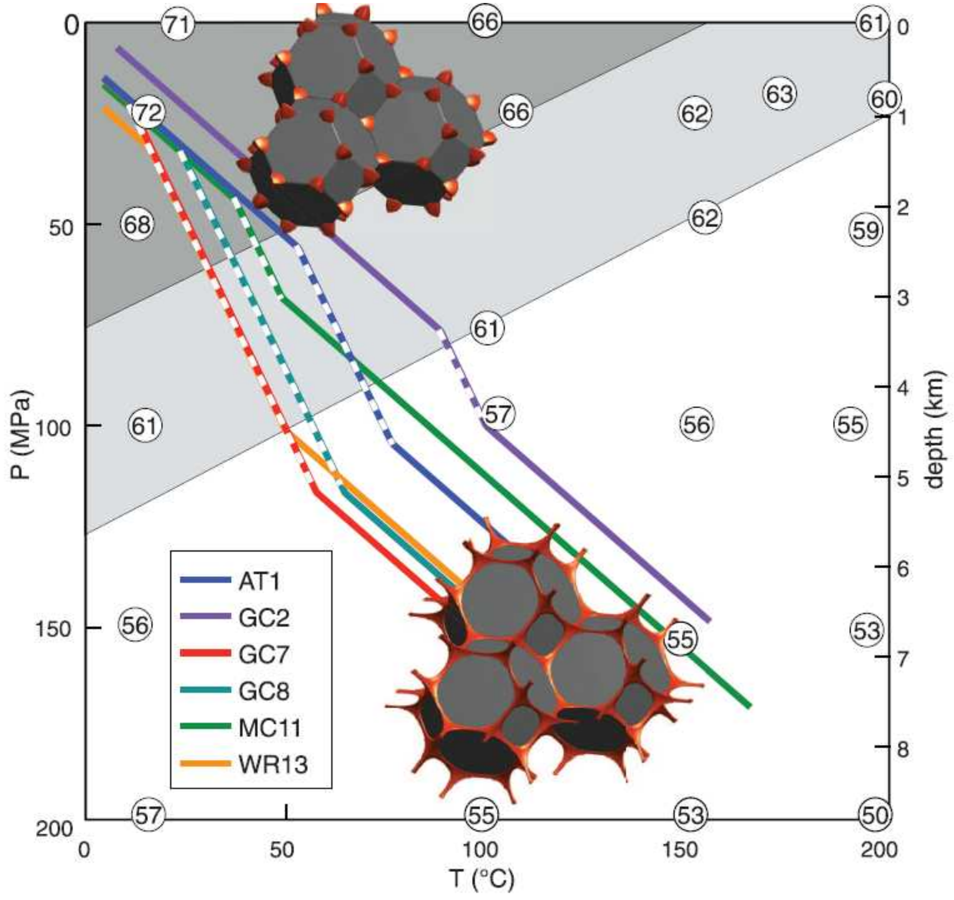
Observations: Effect of stress



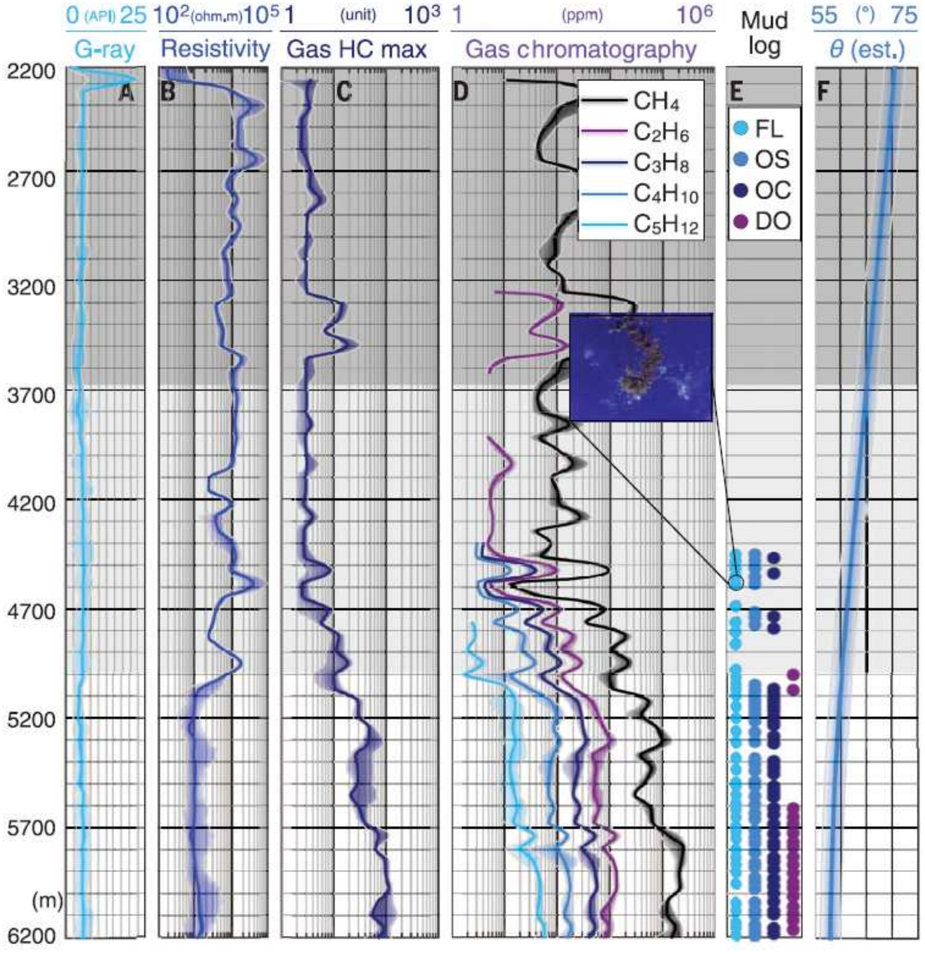


Olander et al. (1982)

Static and dynamic wetting

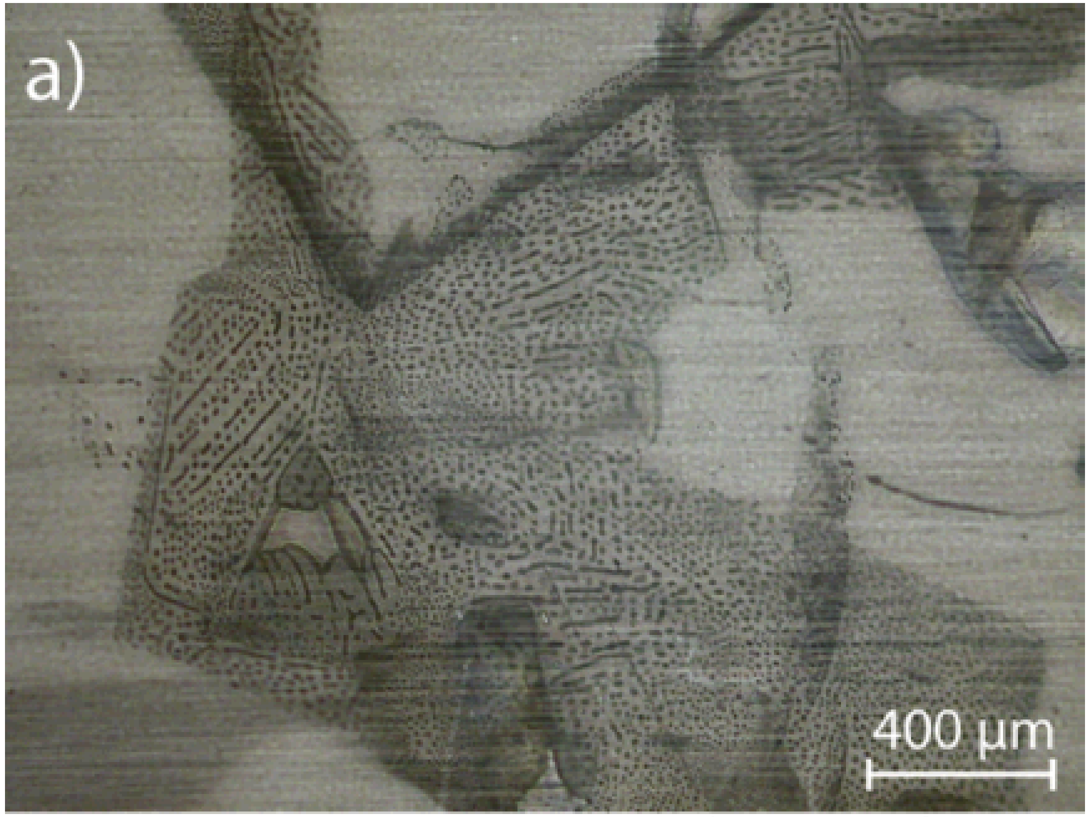


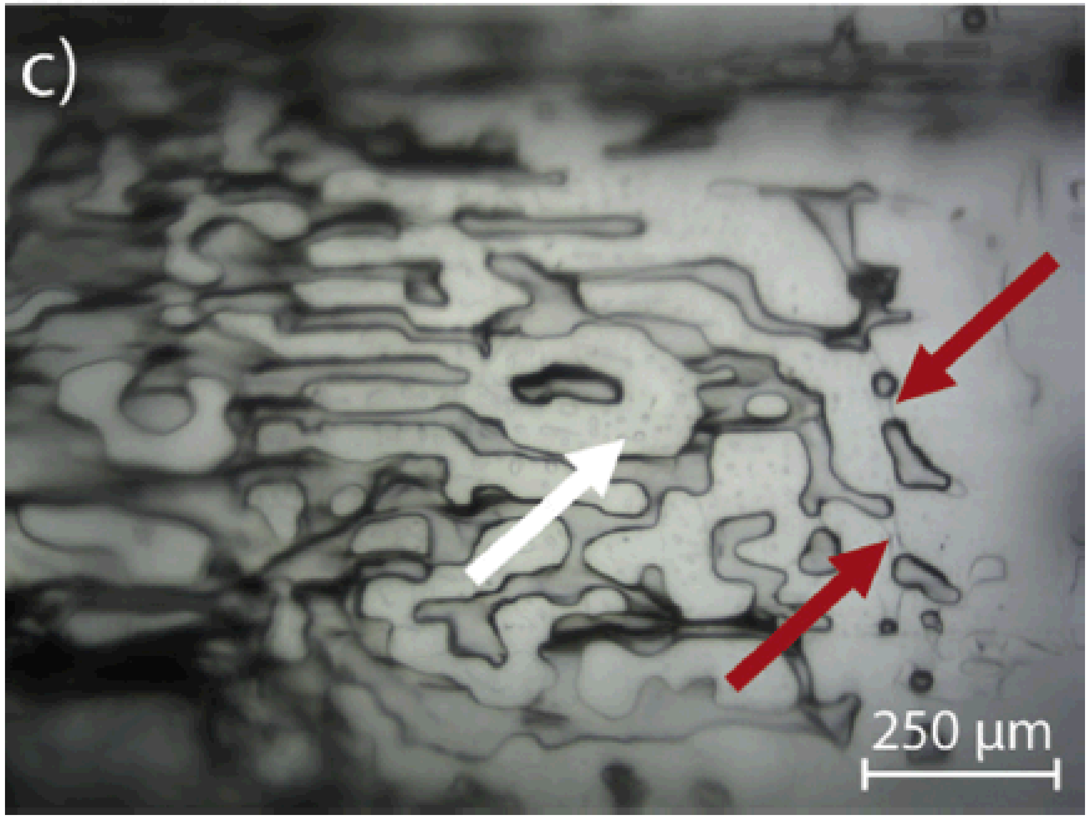
$$\theta = 2\cos^{-1}[\gamma_{ss}/(2\gamma_{sl})]$$



Ghanbarzadeh et al. (2015)

Fluid inclusion patterns along grain boundaries

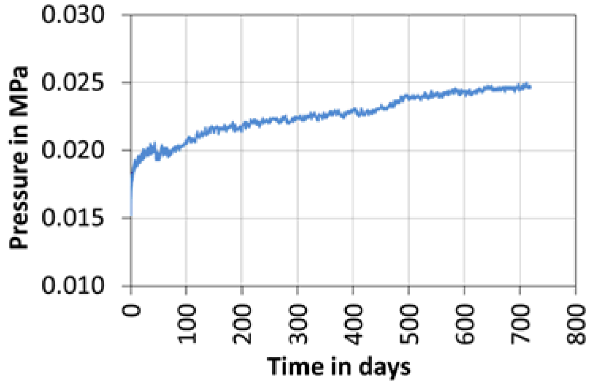




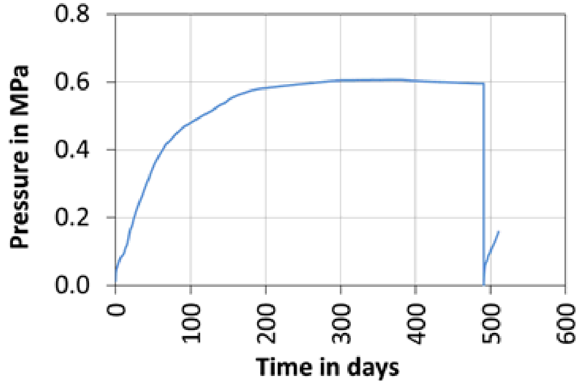
Thiemeyer et al. (2015)

Classification & Quantification

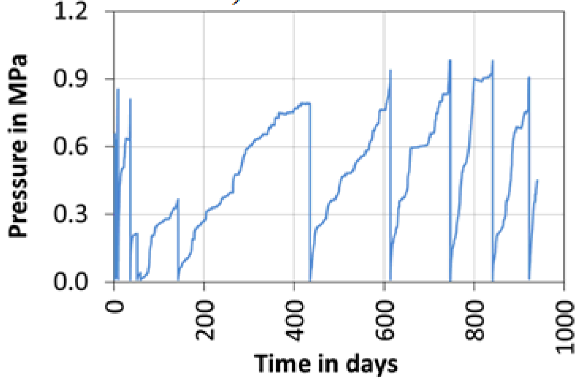
Category 1: Almost no pressure build up
(< 0.03 MPa; no pressure release needed)



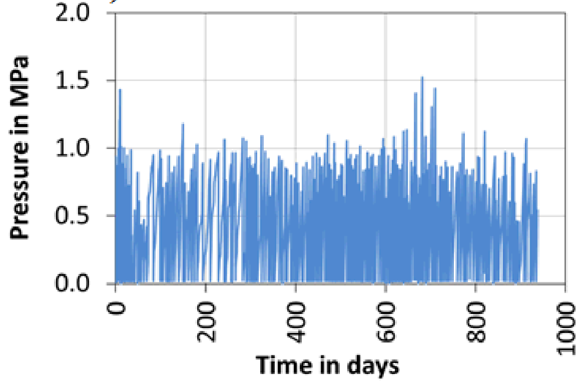
Category 2: Low pressure build up
(< 1 MPa; no pressure release needed)



Category 3: Intensive pressure build up
(initially frequent pressure build up;
pressure release needed)



Category 4: Very intensive pressure build up
(permanent pressure build up; pressure release
needed)



(Paul et al. 2014)

Schedule

	1. year		2. year		3. year	
	1. workshop	2. workshop	3. workshop	4. workshop	5. workshop	6. workshop
WP - 1						
Literature recherche						
Process definition/description						
Conceptuel modeling						
WP - 2						
Upscalling study (microscale - macroscale)						
Mathematical formulation						
Programm developement						
WP - 3						
Modelling against observation						

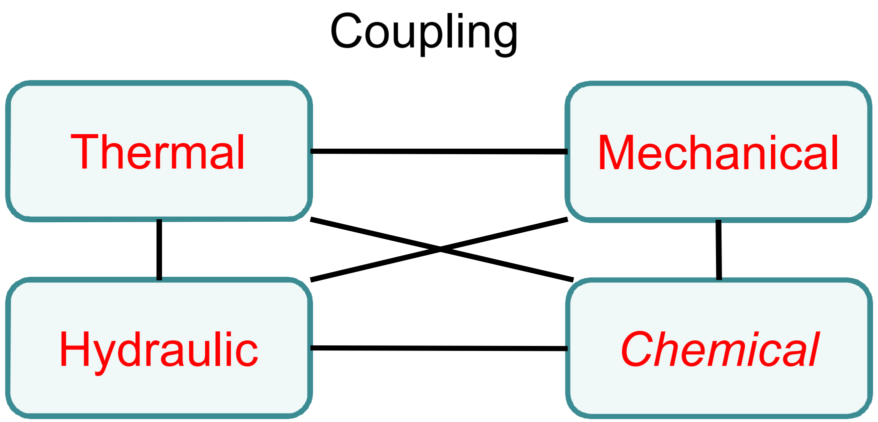
Technically challenging …

Significance to understanding the geological disposal processes

- **Migration of inclusion in a thermal/hydraulic/stress gradient**
- ***Fully coupled THMC processes***
- ***Upscaling from an individual inclusion scale to a continuum scale***

Thermal load
Thermal gradient

Thermal expansion of liquids
Vaporization
Pressure increase
Hydraulic gradient



Solid expansion

Opening/closure of flowpath

Cause the host to break or decrepitation

Next steps: (1) Formulate migration of an individual inclusion; (2) develop a conceptual model for fluid inclusion migration on a continuum scale.

TASK A: modEIliNg Gas INjection ExpERiments (ENGINEER)

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Sandia National Laboratories

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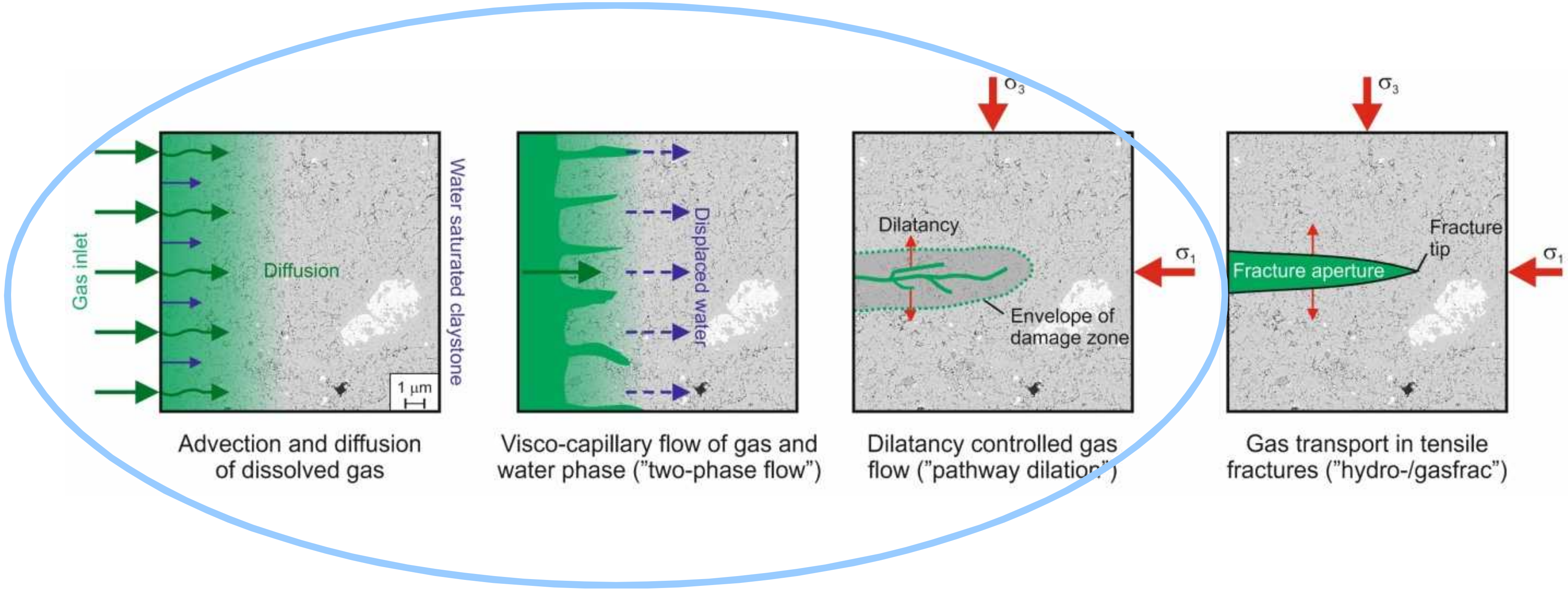
Background: Conceptual models

Movement of gas will occur by the combined processes diffusion and bulk advection



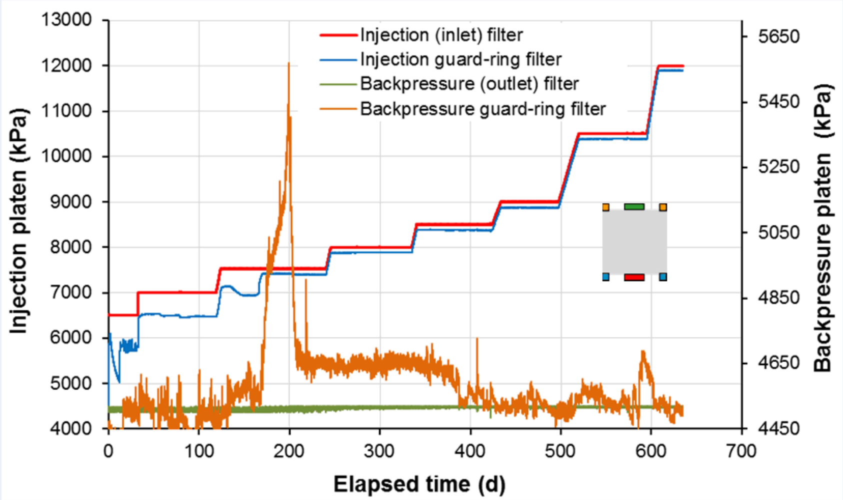
Choice of conceptual model(s) will dictate the predicted behaviour of the system

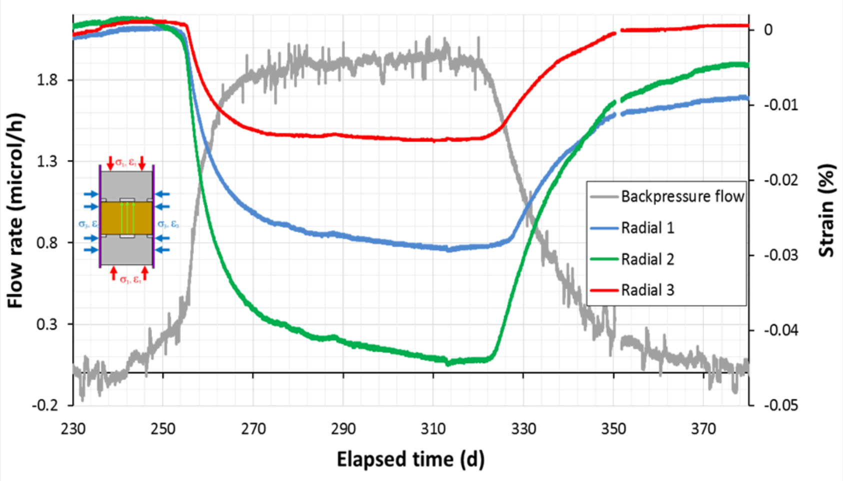
In clay-rich system considerable evidence exists suggesting gas flow is accompanied by the creation of preferential pathways and dilation of the clay

Harrington & Tamayo (2016)

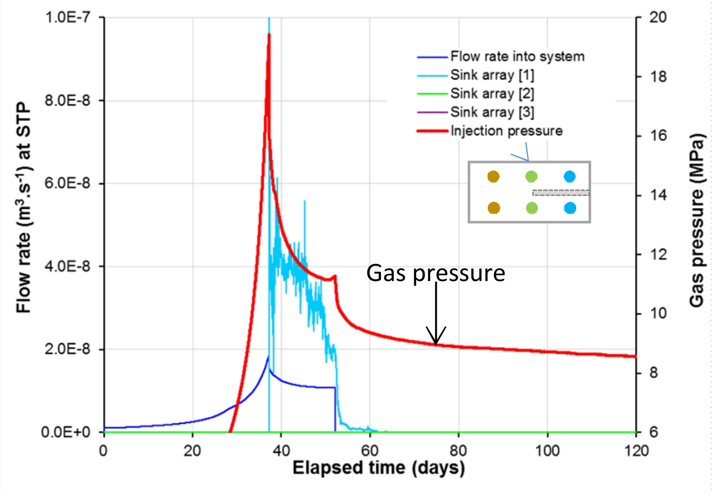
How stable are gas pathways?

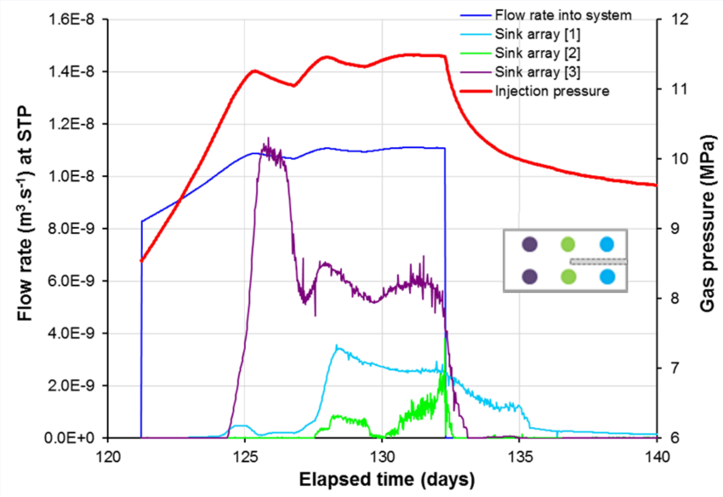
Callovo-Oxfordian claystone





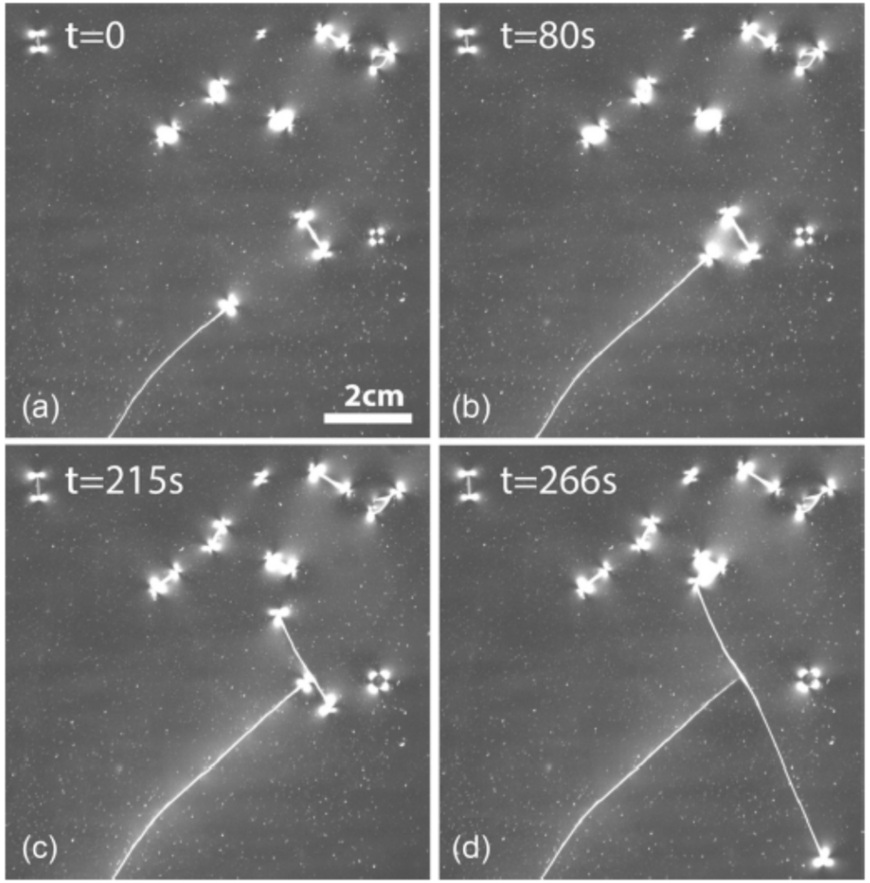
Compact bentonite

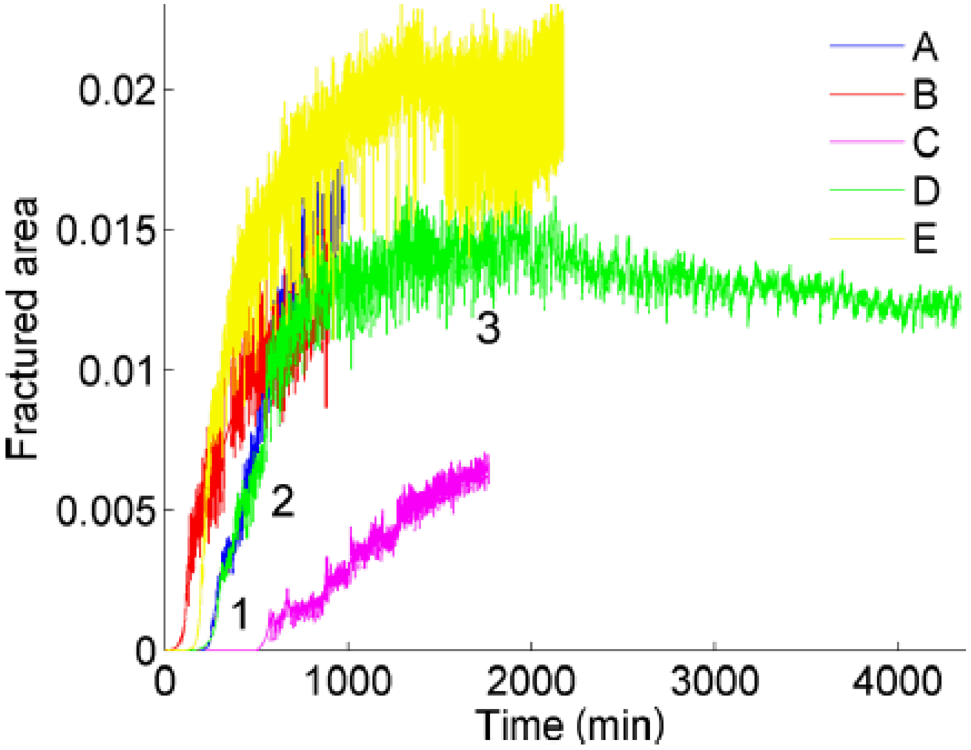




Harrington & Tamayo (2016)

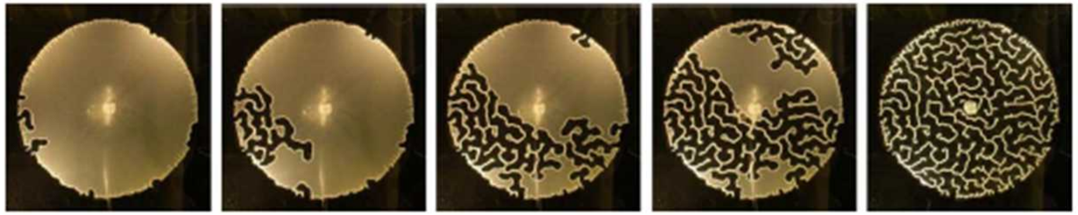
Chaotic behavior of fracture development

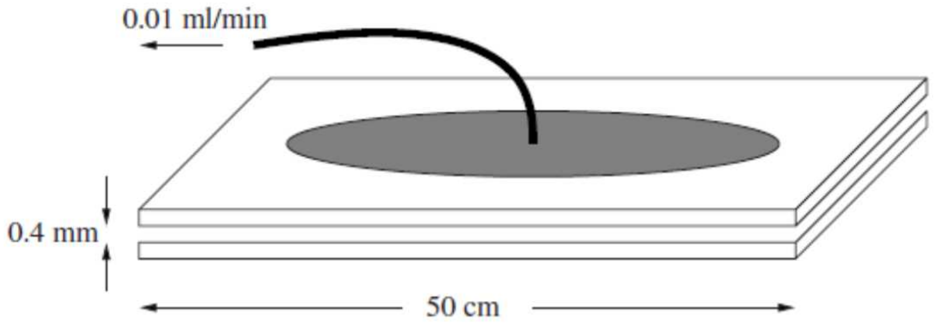


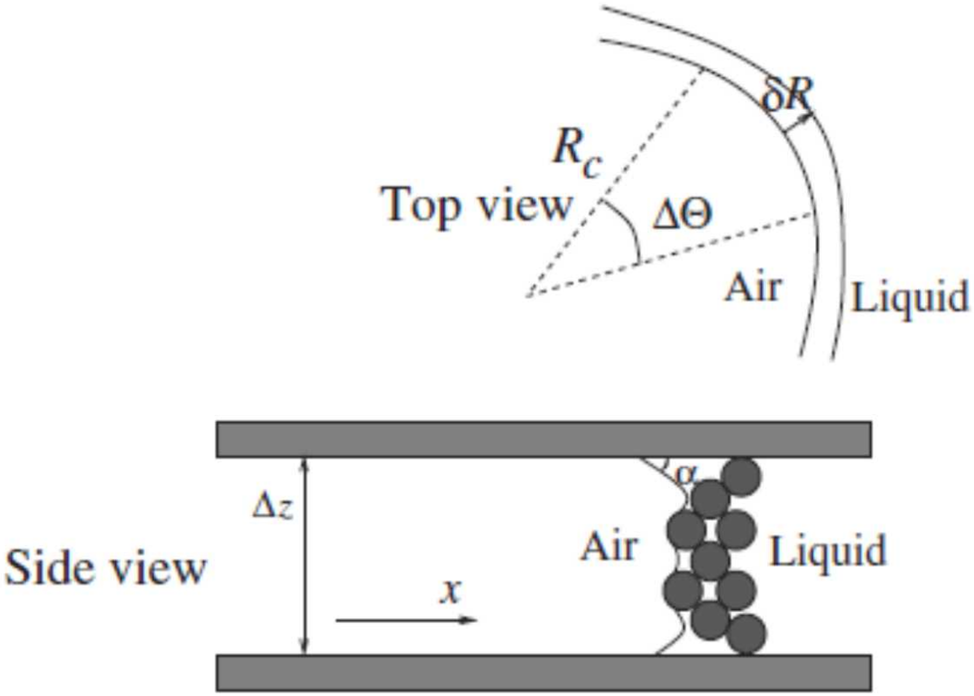


Kobchenko et al. (2014)

Pattern formation in water-saturated granular materials during gas injection





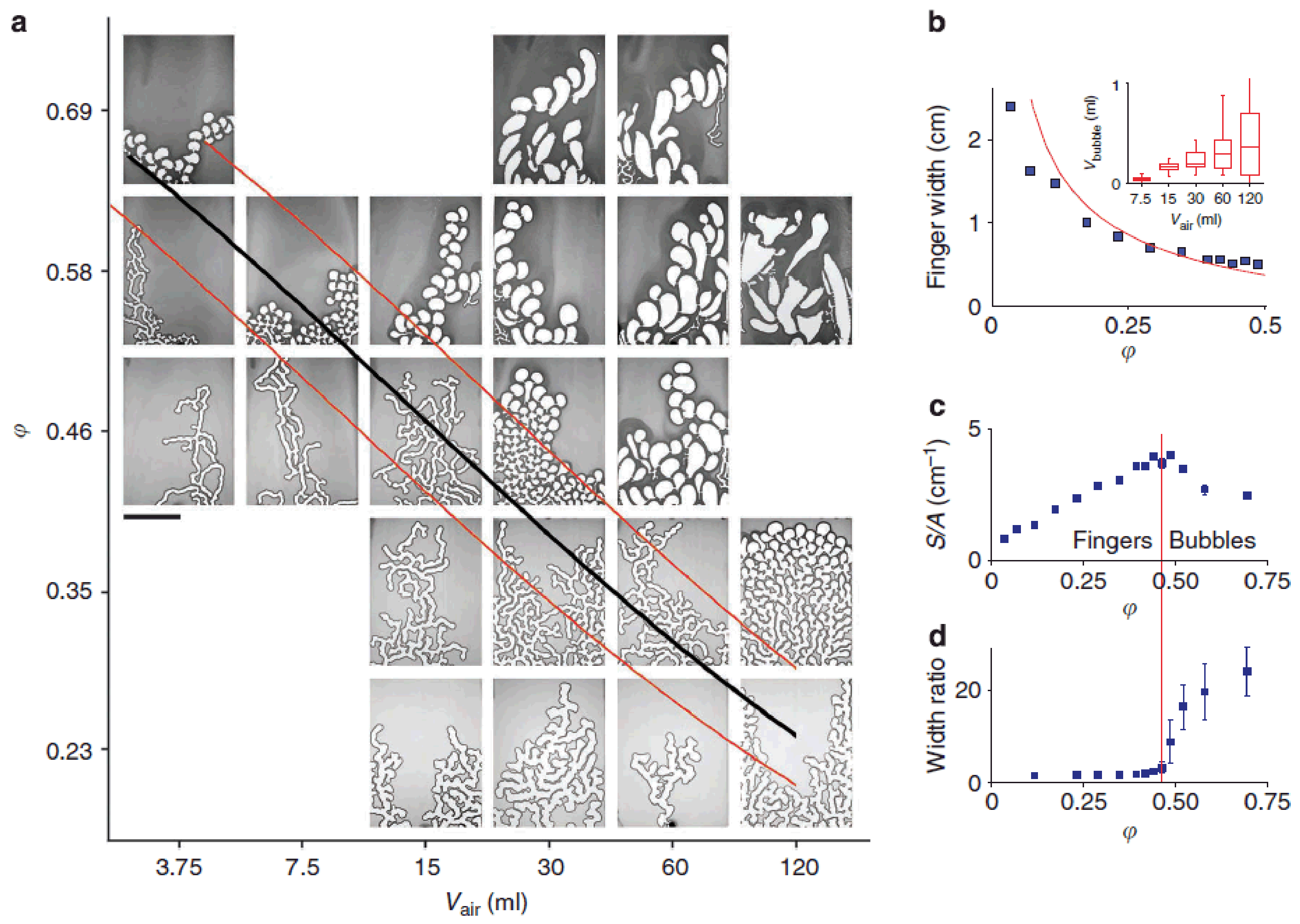


$$\Delta P = \frac{(a + a_p \cos \alpha_p)\gamma}{R_c} + \sigma + \frac{2\Delta \gamma_w}{\Delta z}$$

$$\sigma(x) = \frac{g\rho\Delta z}{2\kappa}\left[\left\{\frac{\kappa\mu}{\tan\theta} + 1\right\}\exp\left(\frac{2\mu\kappa[L-x]}{\Delta z}\right) - 1\right].$$

Knudsen et al. (2008)

Friction-capillary model



Sandnes et al. (2011)

Background: An age old problem…

"The displacement of an oil or gas phase from the centre of a finely grained argillaceous matrix goes against the laws of capillarity and is in principle impossible. The barrier can, however, be broken in one way. The pressure within the fluids formed in the pores of the source-rock increases constantly as products of the evolution of kerogene are formed. If this pressure comes to exceed the mechanical resistance of the rock, microfissures will be produced which are many orders of size greater than the natural (pore) channel of the rock, and will permit the escape of an oil or gas phase, until the pressure has fallen below the threshold which allows the fissures to be filled and a new cycle commences."

Tissot, B., Pellet, R. (1971)

Mandl and Harkness (1987) suggest hydrocarbon migration can only occur through thick, continuous water-wet rocks of low permeability through the process of fracturing, forming what they refer to as 'dykelets'

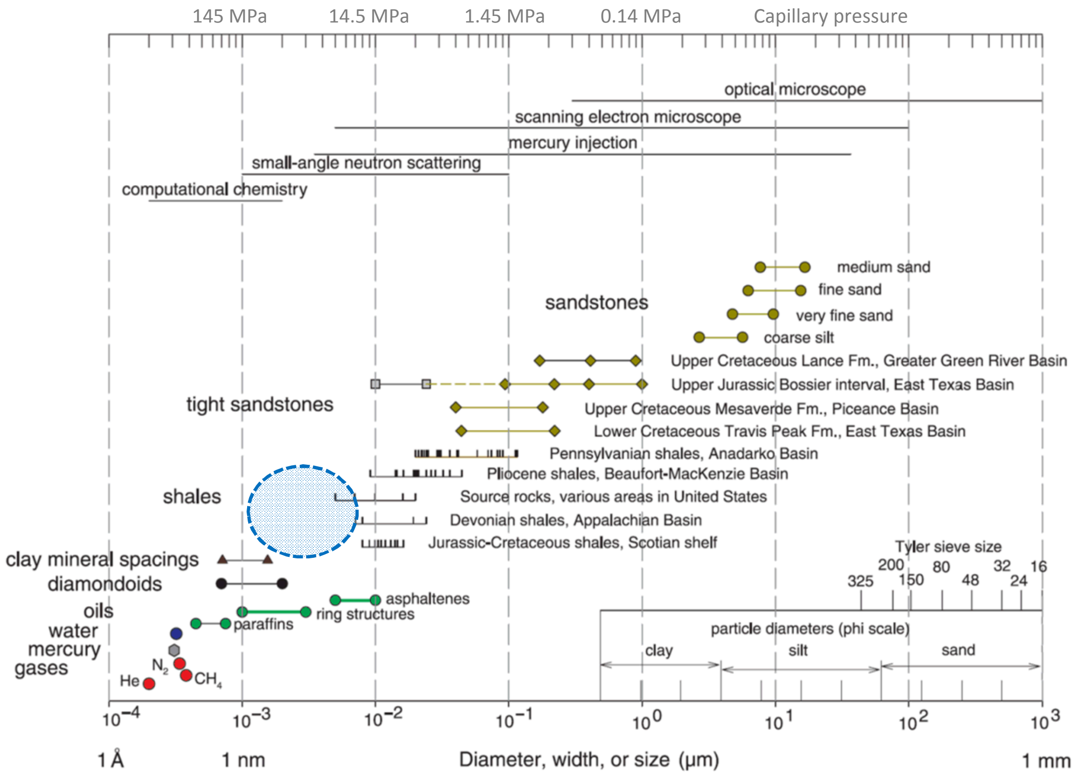


Figure 2. Sizes of molecules and pore throats in siliciclastic rocks on a logarithmic scale covering seven orders of magnitude. Measurement methods are shown at the top of the graph, and scales used for solid particles are shown at the lower right. The symbols show pore-throat sizes for four sandstones, four tight sandstones, and five shales. Ranges of clay mineral spacings, diamondoids, and three oils, and molecular diameters of water, mercury, and three gases are also shown. The sources of data and measurement methods for each sample set are discussed in the text.

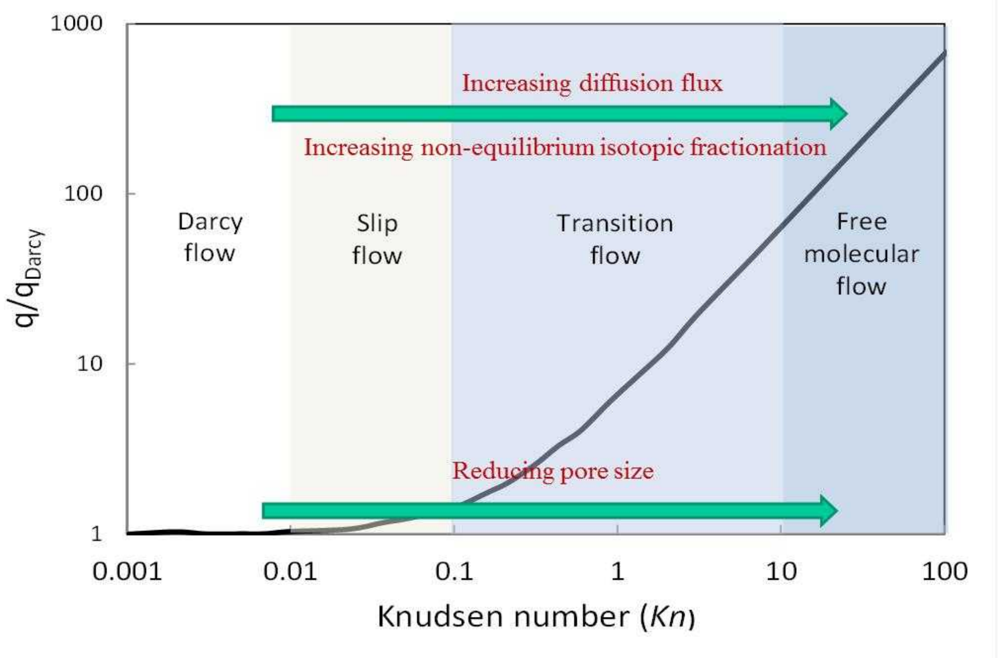
Nelson, P.H. (2009).

Harrington & Tamayo (2016)

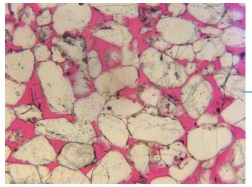
Nanoconfinement & emergent properties

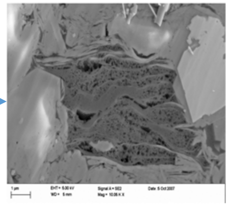
- Slip flow
- Knudsen diffusion

$$k_{app} = \frac{2r}{3RT}\left(\frac{8RT}{\pi M}\right)^{1/2} + \left[1 + \left(\frac{8\pi RT}{M}\right)^{1/2}\frac{\mu}{pr}\left(\frac{2}{\alpha} - 1\right)\right]\frac{cr^2}{8\mu}$$



Conventional reservoir

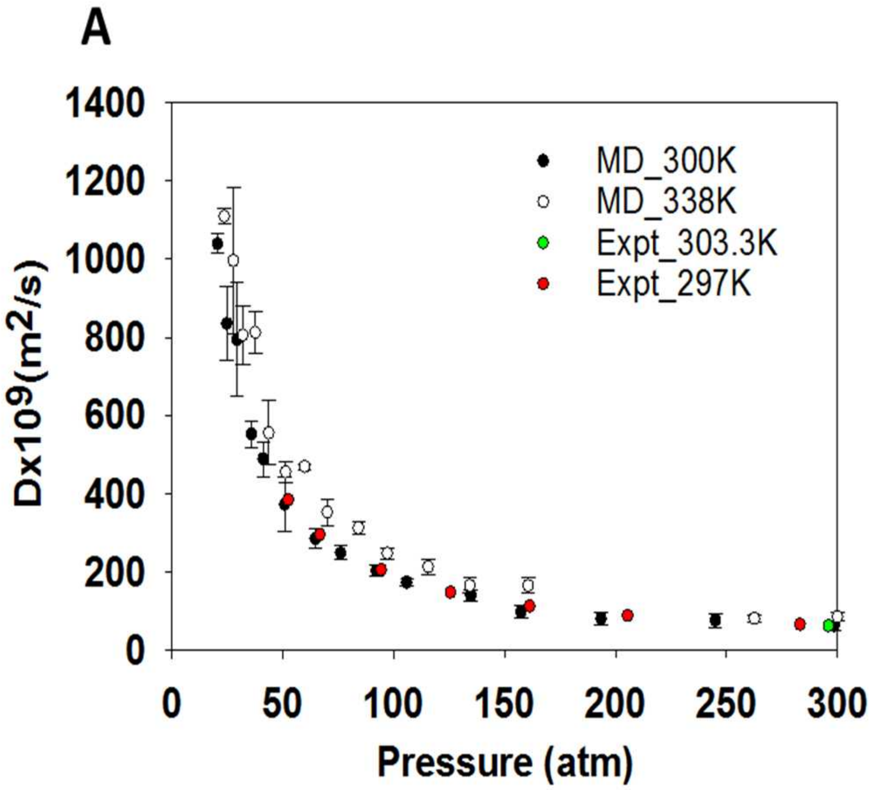


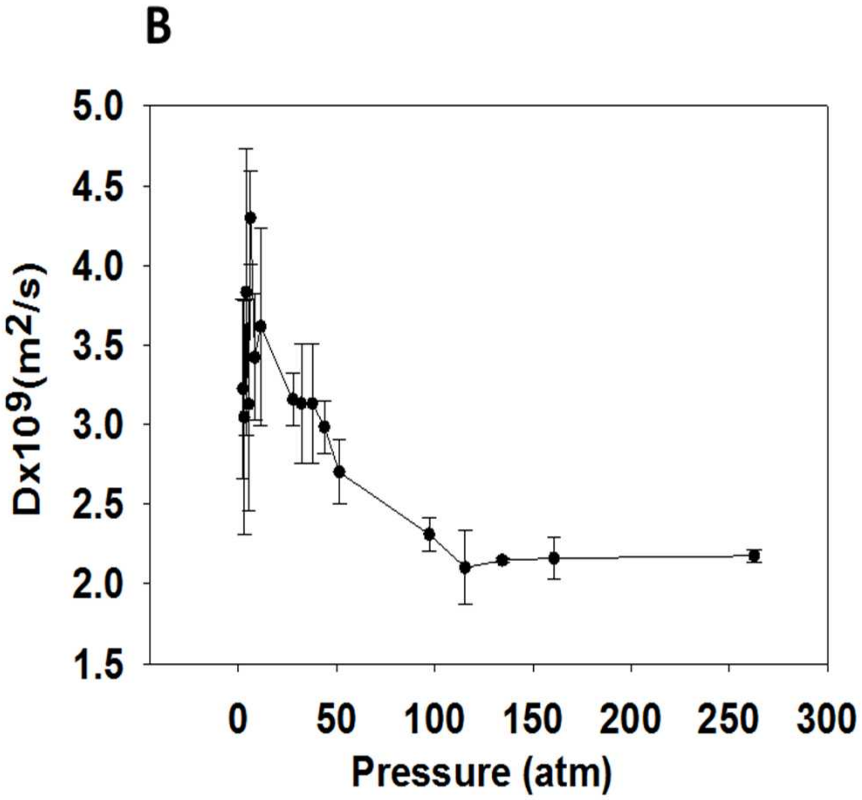


Shale formation

SPE 124253 (2009)

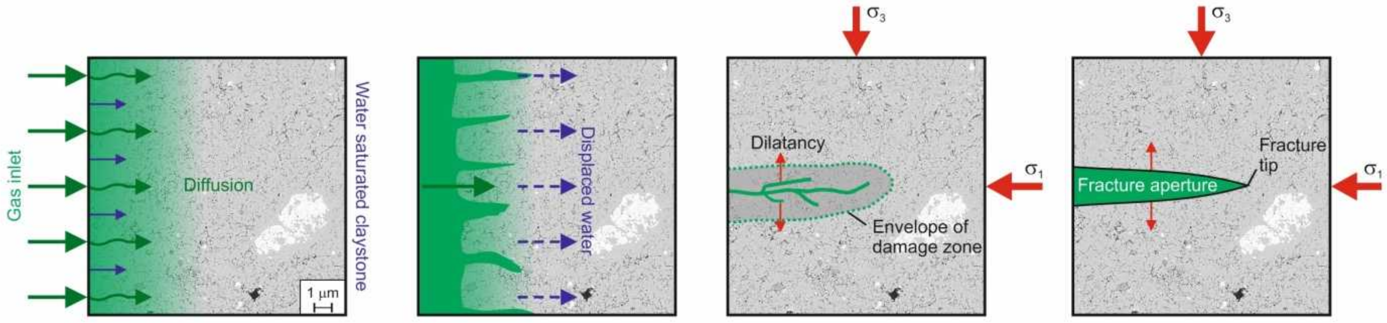
Diffusion in Kerogen





Schedule

Activity	Spring 2016	Autumn2016	Spring 2017	Autumn 2017	Spring 2018	Autumn 2018	Spring 2019	Autumn 2019
Stage1: 1D flow (laboratory)	Wksp 1	Wksp 2						
Stage 2: Spherical flow (laboratory)			Wksp 3	Wksp 4				
Interim reporting								
Stage 3: Field scale flow					Wksp 5	Wksp 6		
Stage 4: Gas flow in natural clay							Wksp 7	Wksp 8
Final Reporting								



Advection and diffusion of dissolved gas

Visco-capillary flow of gas and water phase ("two-phase flow")

Dilatancy controlled gas flow ("pathway dilation")

Gas transport in tensile fractures ("hydro-/gasfrac")