LABORATOIRE DE THERMOCINETIQUE DE NANTES
UMR 6607

Transport éruptif de l'eau dans les couches de diffusion de gaz des piles à combustible

De l'oscillateur capillaire à la modification de la saturation

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Equipe transport dans les milieux poreux au LTN

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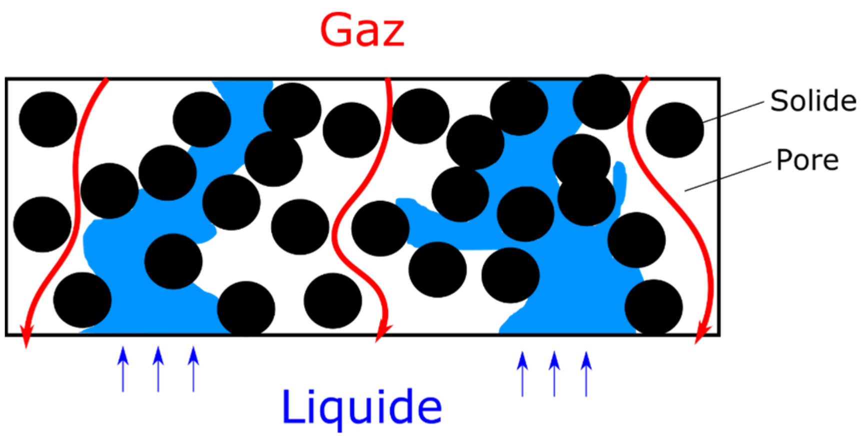
- Prof. J. Bellettre
- Dr. C. Josset (MdC)
- S. Chevalier (Postdoc Marie Curie fellow (Incoming))

Ces travaux s'inscrivent dans la suite de la thèse de G. Flipo

Objets d'étude
Transport diphasique à micro-échelle



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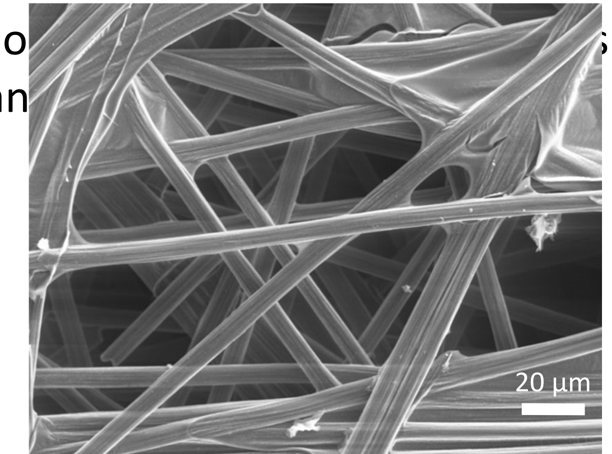
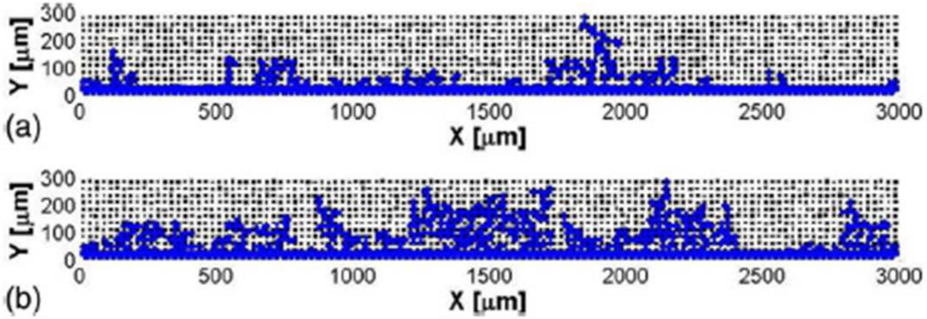


Introduction – Motivations (1/2)

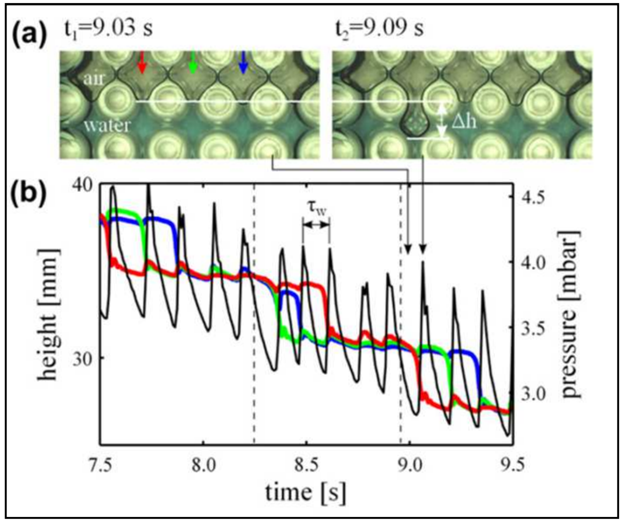
- Liquid water invasion in the GDL is well modelized by the Invasion Percolation mechanism.



Water distribution for two pore networks, Medici and Allen (2011 ECS Trans.)

- What about the liquid water discharge from the pore to pore?

Keywords: Dynamic breakthrough, eruptive transport

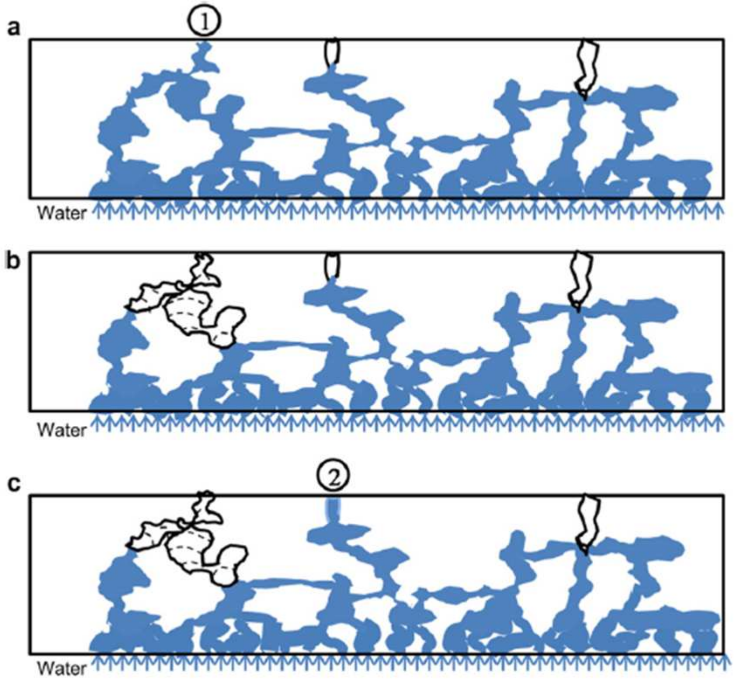


Interfacial Jumps and pressure bursts during fluid displacement, Moebius and Or (2012 J. Col. Int. Sc.)

Inertial effect (*Haynes jump*)?
Viscous effect?

Introduction – Motivations (2/2)

• As water emerges from the porous medium, it creates a partial flushing ⇒ Potential modification of the preferential paths.



Water drainage process of a model capillary system as water emerges from the GDL surface,
Lu et al. (2010 Int. J. Hydrogen Energy)

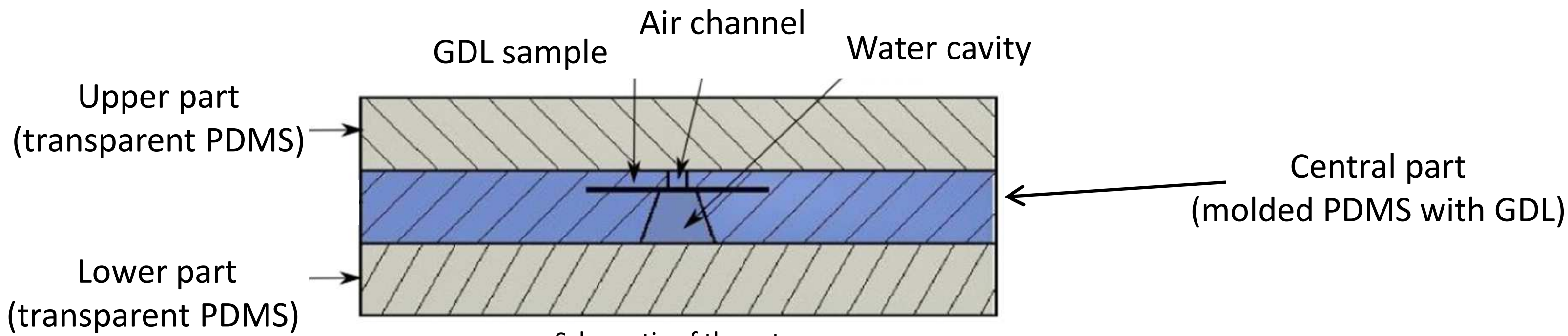
Motivations for the present work:

• How the eruptive nature of liquid water transport modifies the PN saturation?

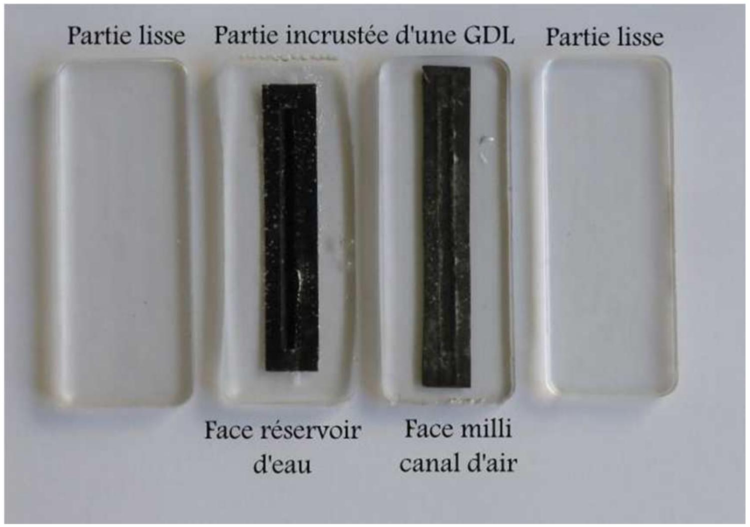
• Is the eruptive phenomenon significant enough to be taken into account in pore-network simulations?

- **Motivation:** Evidence of change in preferential breakthrough points

Experimental set-up: molded PDMS with embedded GDL (SGL 35 BC)

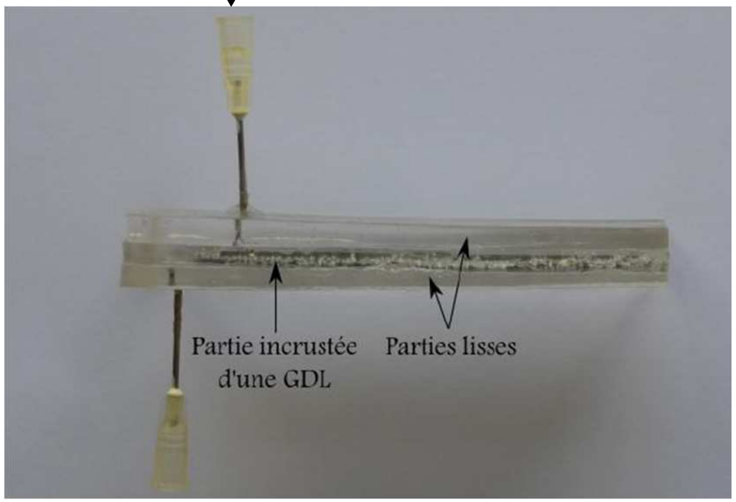


Schematic of the set-up



Pictures of the 3 parts of the set-up

Inlet air flow controlled by a mass flow controller

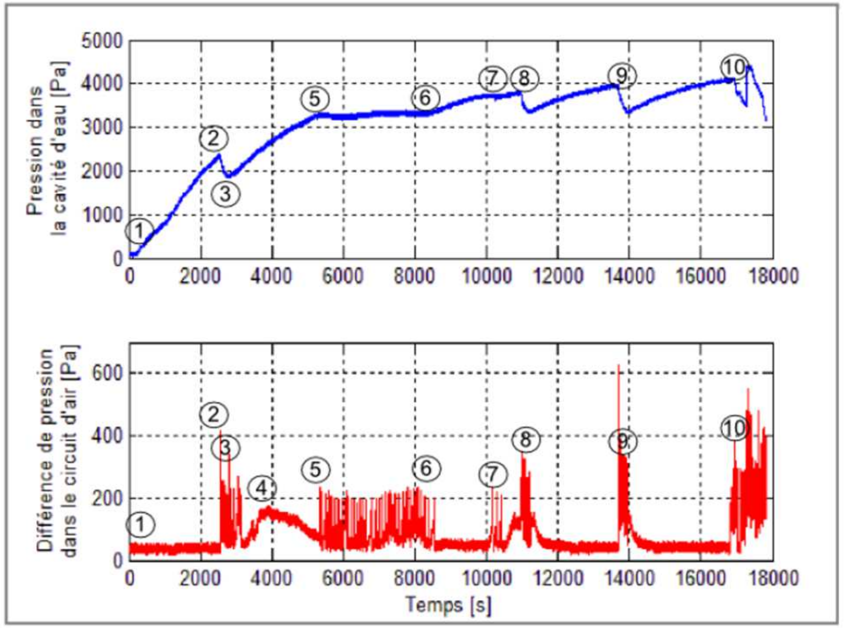


Final set-up

Inlet liquid water flow controlled by a syringe pump

First Part: embedded GDL experiments

- Experimental conditions: SGL 35 BC (with MPL); water flow: 10.5 µl/min; air flow:43 cm^3/min



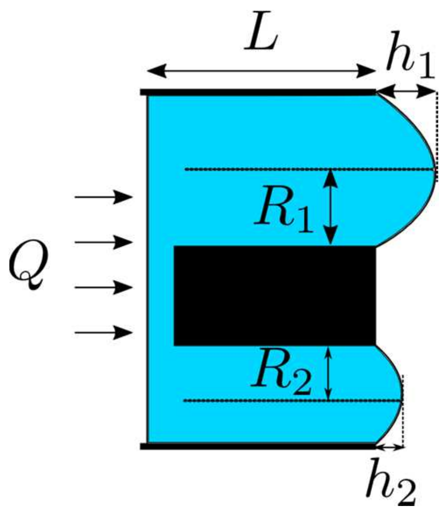
Pressure signals in the water cavity (up) and the air channels (down)

- Evidence of changes in the preferential paths

Another possible explanation: may the eruptivity affect the liquid distribution in PN?

- **Motivation:** clarify the interaction between two neighbooring pores

Two connected cylindrical pores



Poiseuille flow — Laplace-Young law

$$\begin{cases} p_i = \underbrace{\frac{8\mu L}{\pi . R_i^2} . \dot{V}_i}_{\text{Poiseuille flow}} + \underbrace{\frac{4\gamma \cos\theta}{R_i}}_{\text{Laplace-Young law}} + p_0 \\ p_1 = p_2 \\ Q = \dot{V}_1 + \dot{V}_2 \end{cases}$$

Hyp: constant water flow, spherical meniscus/drop

Once written with *h* (meniscus height) and non-dimensionalized, it becomes:

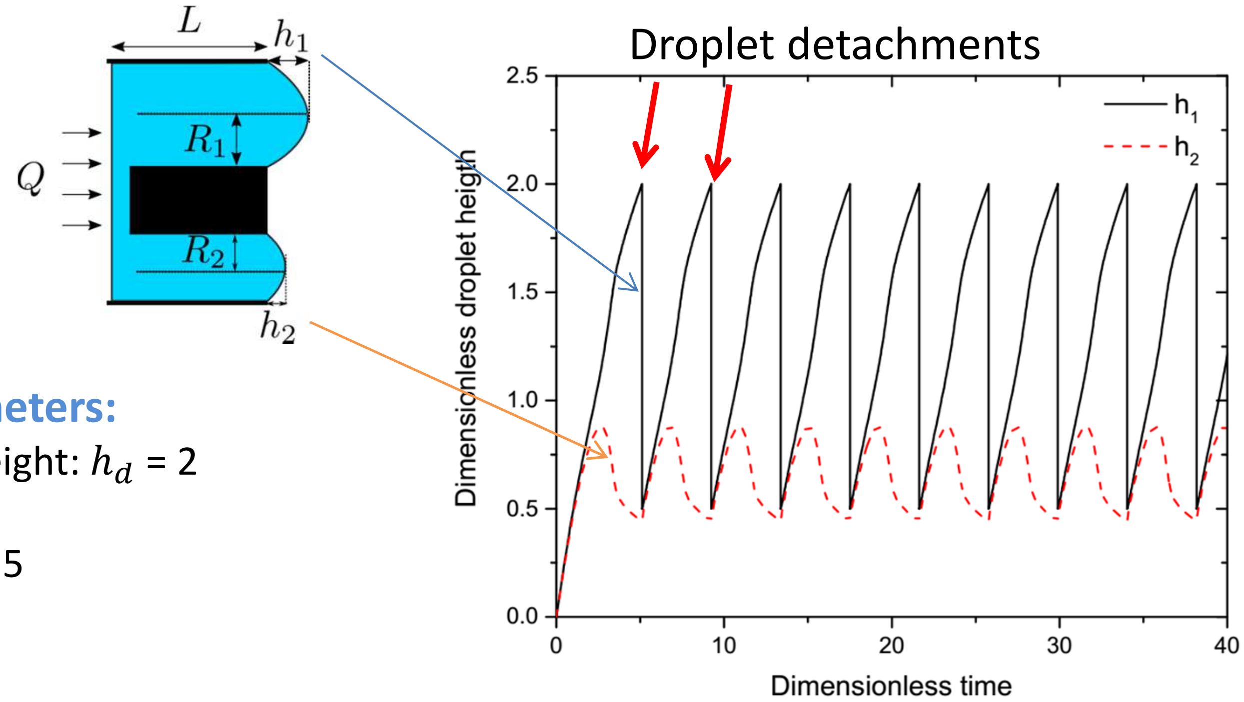
$$\begin{cases} f\left[\dot{h}_1(h_1^2+1) - R\dot{h}_2(h_2^2+1)\right] = \frac{1}{Ca}\left[R\frac{h_2}{h_2^2+1} - \frac{h_1}{h_1^2+1}\right] \\ \dot{h}_1(h_1^2+1) + \frac{1}{R^3}\dot{h}_2(h_2^2+1) = 1 \end{cases}$$

Problem driven by ***3 parameters***:

- $f = L/R_1$, pore aspect ratio
- $R = R_1/R_2$, pore radii ratio
- $C_a = \frac{U_0 . \mu}{\gamma}$, capillary number

• **First result of the model:** ***capillary regime***

i.e. low value of the product (Ca.f)



Model parameters:

Detachment height: h_d = 2

R = 1,03

$\log(Ca.f)$ = -1,5

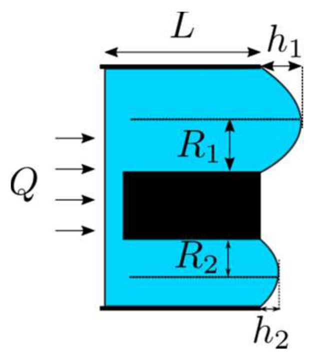
• Periodic emission of water drops from the larger tube

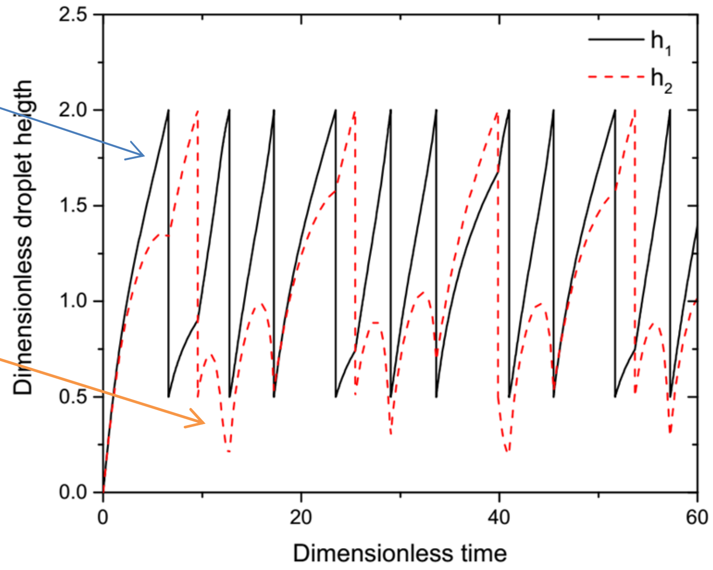
• inflation/deflation of the meniscus in the smaller tube.

The meniscus/drop growth in the bigger pore does act upon the meniscus in the neighbooring pore

- **Second result of the model: *mixed viscous/capillary regime***

i.e. intermediate value of the product (Ca.f)





Model parameters:

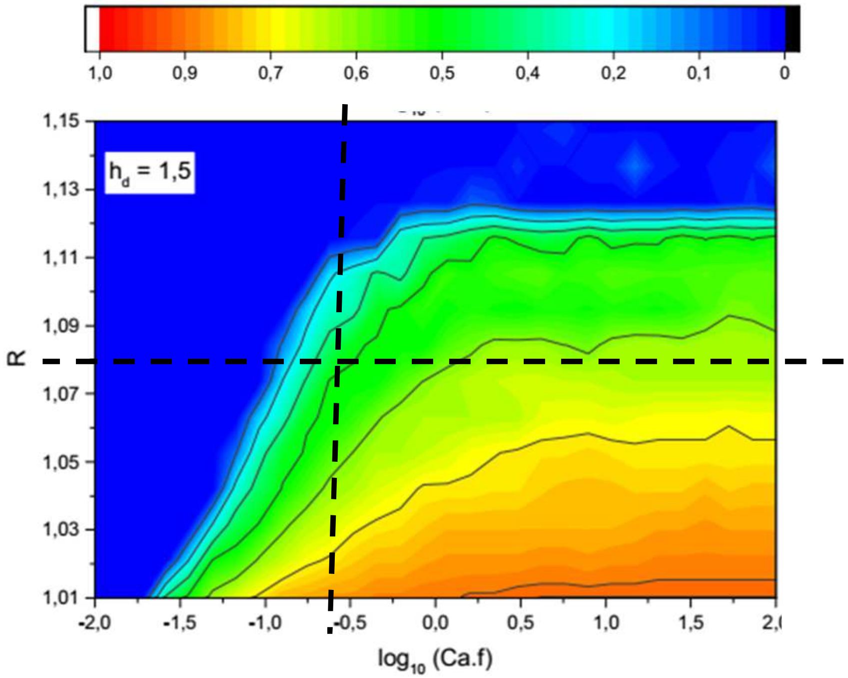
Detachment height: h_d = 2
R = 1,03
$\log(Ca.f)$ = -0,5

- Periodic emission of water drops in both tubes
- It has been called «capillary oscillator» characterized by a ***duty cycle, λ,*** being the ratio

$$\lambda = \frac{\text{drop numbers emitted from the smaller tube}}{\text{drop numbers emitted from the larger tube}}$$

As the viscous effects get more important, a change of « preferential path » appears

• **Third result of the model:** ***transition from the capillary to the mixed regime***



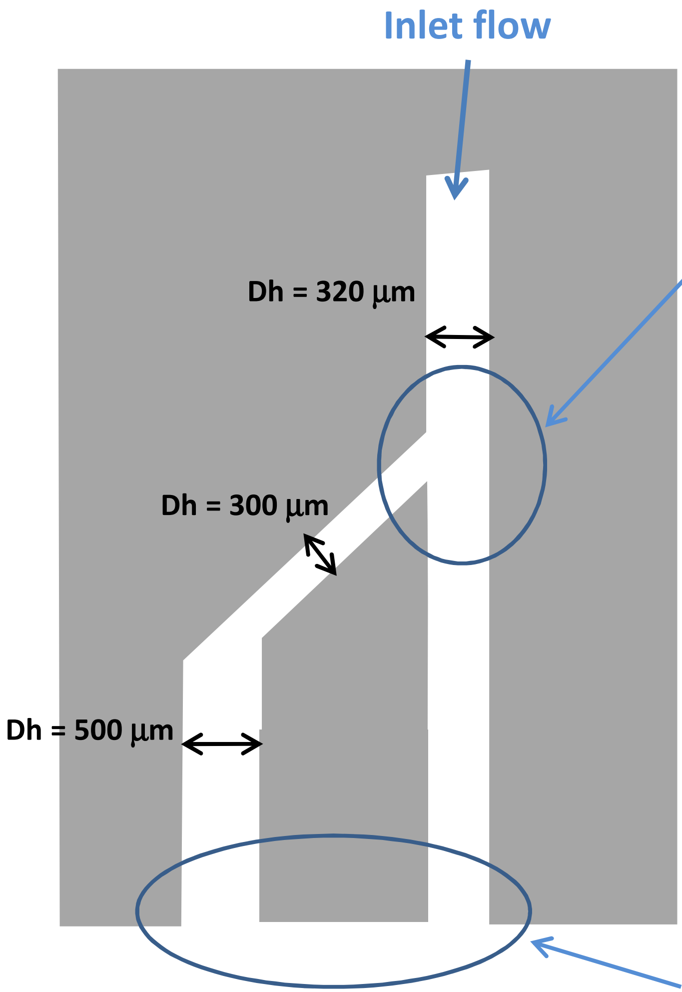
2D map of the duty cycle

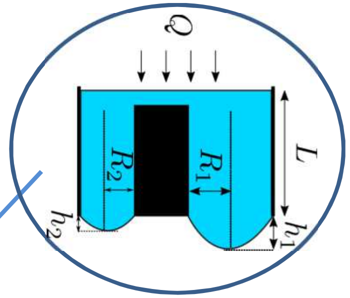
• Higher the pore radius ratio, lower the duty cycle i.e. less drops are emitted from the smaller pore,
• Higher the viscous effects, higher the duty cycle.

Without inertial effects, the « two drops » model predicts that the location of the breakthrough pores change as the viscous effects get more important.

Third Part: the "inverted Y" network

- **Motivation:** highlighting the change in preferential paths in a simple capillary network

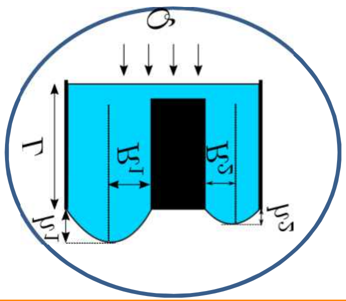




Experimental conditions:

Machined channels in teflon block
Upper side in PDMS (for visualization)
Inlet water flow rate: 50 µl/min
FPS: 30
R = 1,07 (hydraulic diameter ratio)
Ca = 1.6 10^{-4}

Check out the movie!

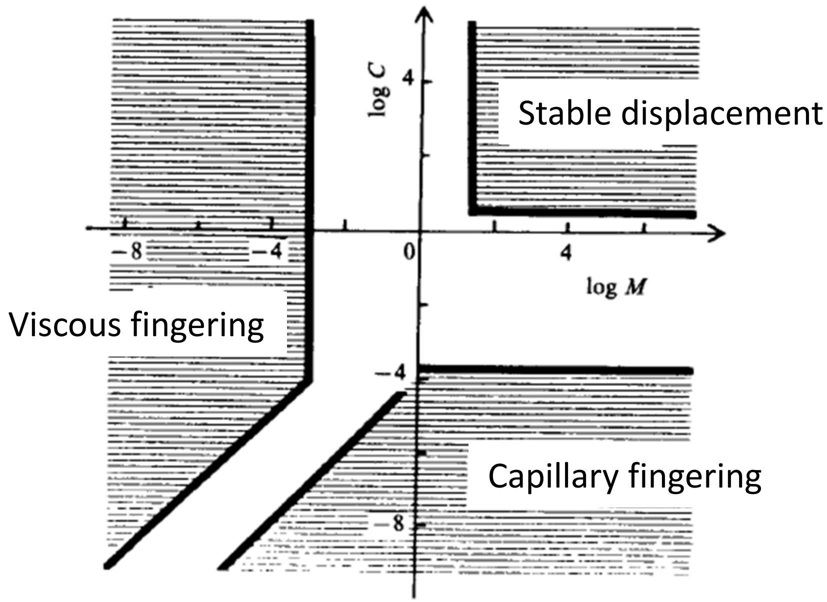


Conclusion:

- Dynamic breakthrough is evidenced using relatively « simple » models and experiments
- The dynamic nature of the pore to pore transport may alter the invaded pattern

Open questions:

- Specify the limits of validity of the Invasion Percolation model for the liquid water transport in porous media



Drainage phase diagram, Lenormand et al. (1988 J Fluid Mech.)

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Droplet condition detachment