# A method for measuring the AC and DC streaming potential coupling coefficient of porous rock samples in the laboratory

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# Summary

I. Introduction to the electrokinetic phenomena in porous rocks

II. DC measurements apparatus

III. AC measurements apparatus

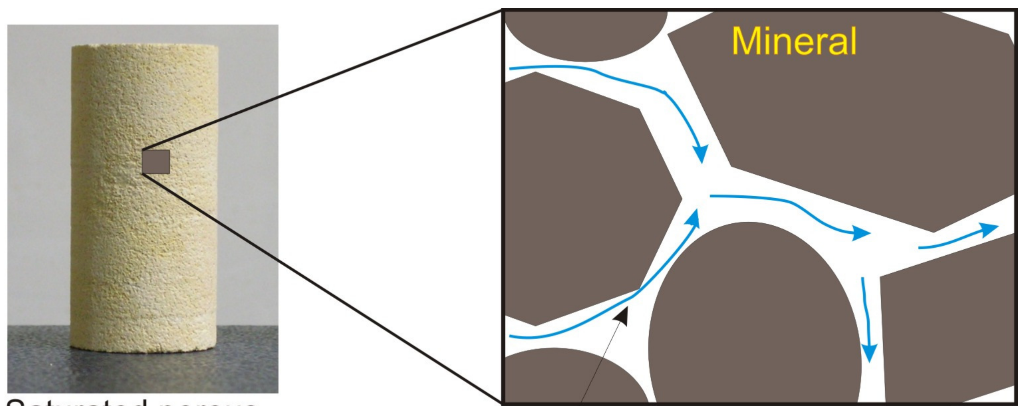
# I. Introduction to the electrokinetic phenomena in porous rocks

# Rock-fluid interface

Saturated porous
rock sample

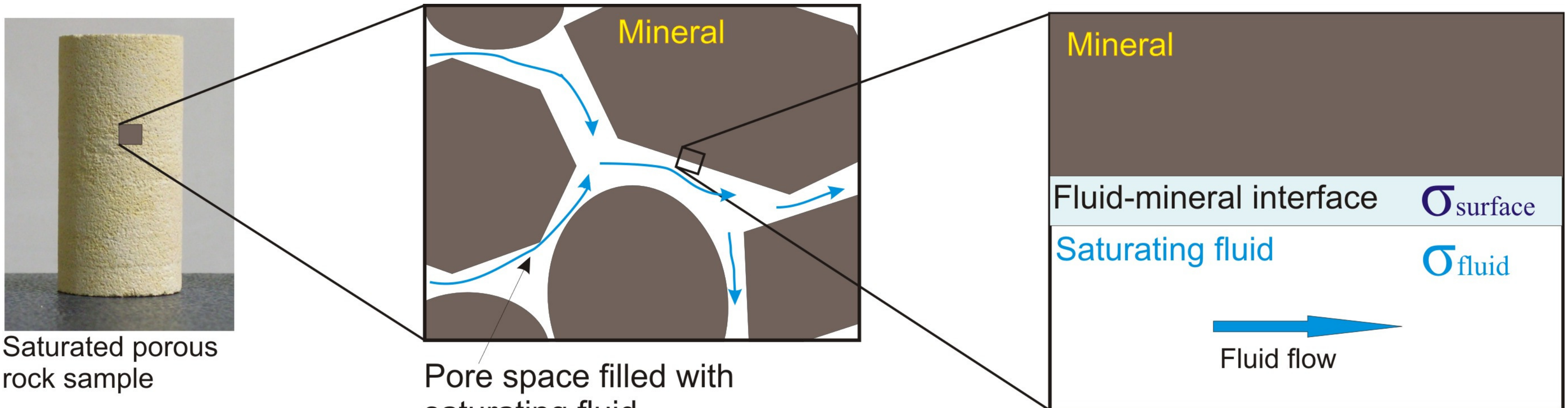
- Fluid flow and rock-fluid interface
- Electrokinetic or Streaming potential

# Rock-fluid interface




- Fluid flow and rock-fluid interface
- Electrokinetic or Streaming potential

# Rock-fluid interface

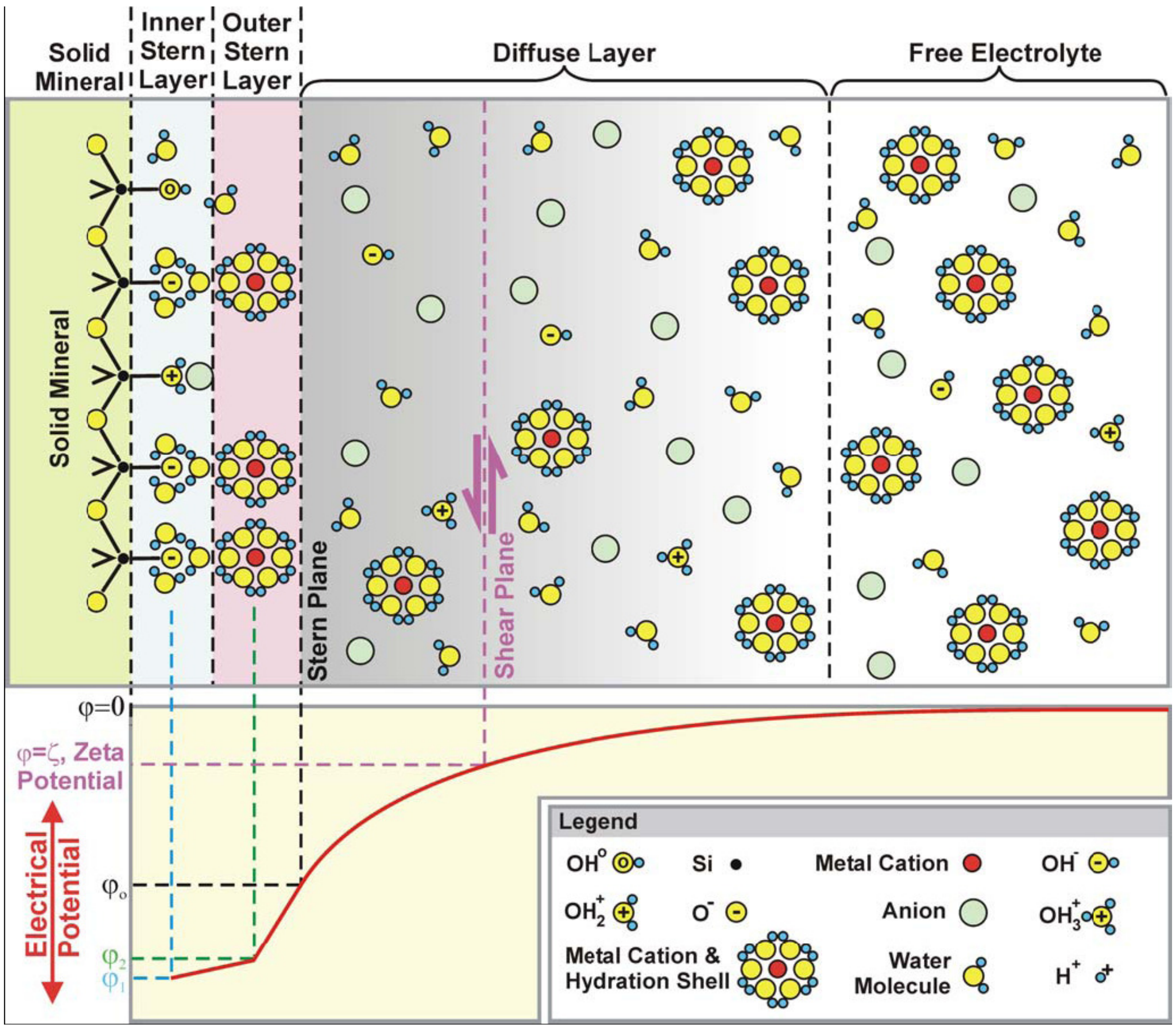



Saturated porous rock sample

Pore space filled with saturating fluid

- Fluid flow and rock-fluid interface
- Electrokinetic or Streaming potential

# Electrical double layer




(Glover & Ransford, 2007)

- *Gouy*, *Chapman* and *Stern* model

    Free electrolyte

    Diffuse layer

    Outer Stern layer

    Inner Stern layer

- Shear plane

- Thickness of the layer

# Electrokinetic phenomena : Theory

- Electrokinetic phenomena in the DC regime

Darcy's law, $L_{11} = k/\eta$

$$\begin{bmatrix} Q \\ J \end{bmatrix} = -\begin{bmatrix} L_{11} & L_{12} \\ L_{21} & L_{22} \end{bmatrix} \begin{bmatrix} \nabla P \\ \nabla \varphi \end{bmatrix}$$

Electrokinetic phenomena

$L_{21} = L_{12} = \varepsilon\zeta/\eta$,

Ohm's law, $L_{22} = \sigma_f$

**k**: permeability of the medium (D)

**$\sigma_f$** : fluid conductivity (S/m)

**ε** : fluid dielectric constant

**ζ** :zeta potential (V)

**η** : fluid viscosity (Pa.s)

**P**: fluid pressure (Pa)

**φ** : electrical potential (V)

**Q** : fluid flow (L/m²),

**J** : electrical current density (A/m²)

$$C_s = \frac{\Delta V}{\Delta P} = \frac{\varepsilon\, \zeta}{\eta\, \sigma}$$

**$C_s$**: Electrokinetic coupling coefficient

✓ OK for capillaries ✘ To be verified for rocks

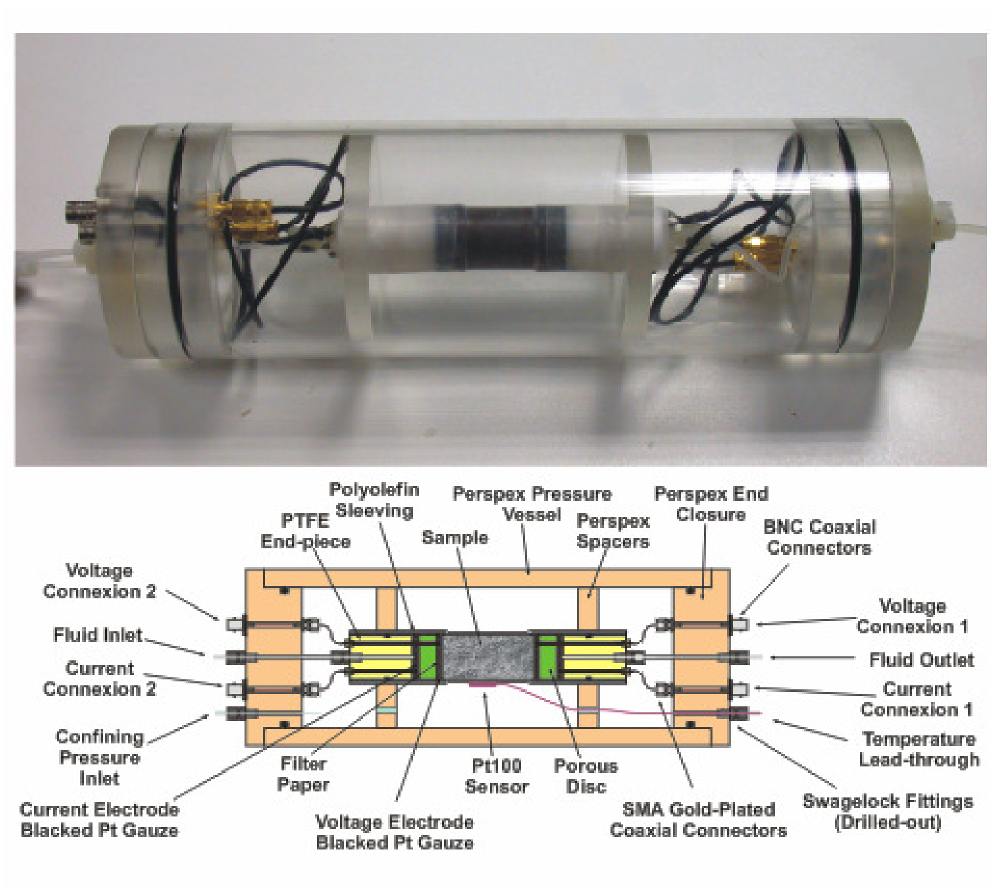
- Electrokinetic phenomena in the AC regime for capillaries : *Packard (1953)*

✓ OK for capillaries ✘ No existing theory for rocks

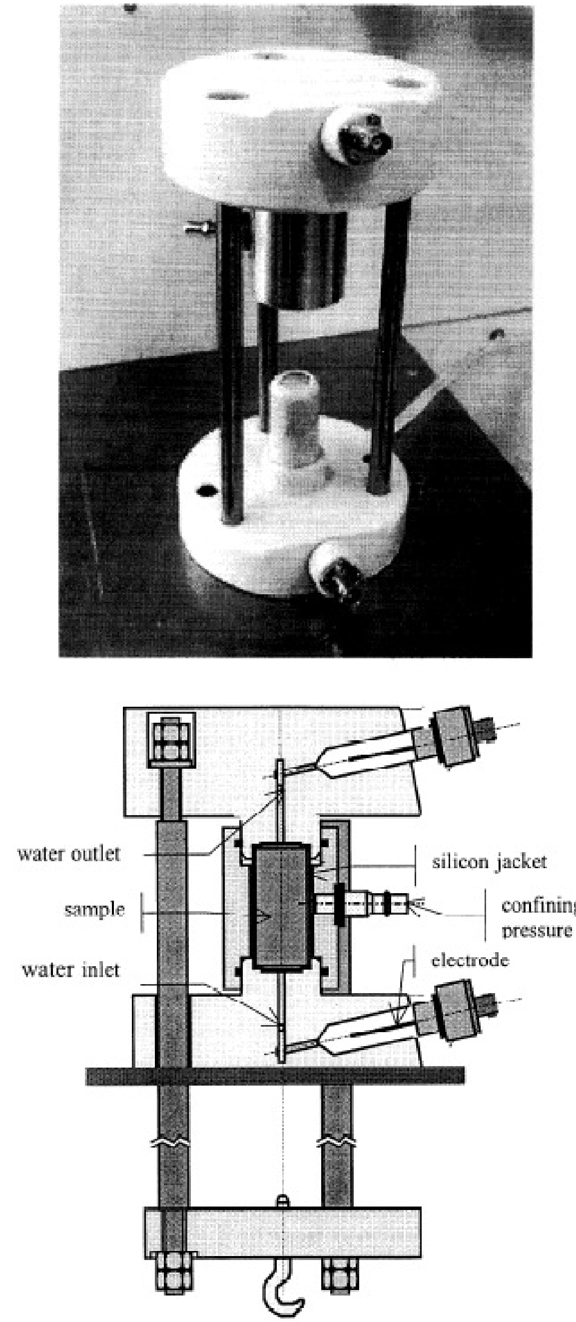
# II. DC measurements apparatus

# Development of a laboratory apparatus for measuring the DC streaming potential of porous rock samples

- From two existing cells:
  - → *Jouniaux et al. (2000)*
  - → *Glover (2001)*




(*Glover, 2001*)




*(Jouniaux et al., 2000)*


# Laboratory apparatus for measuring the DC streaming potential of porous rock samples

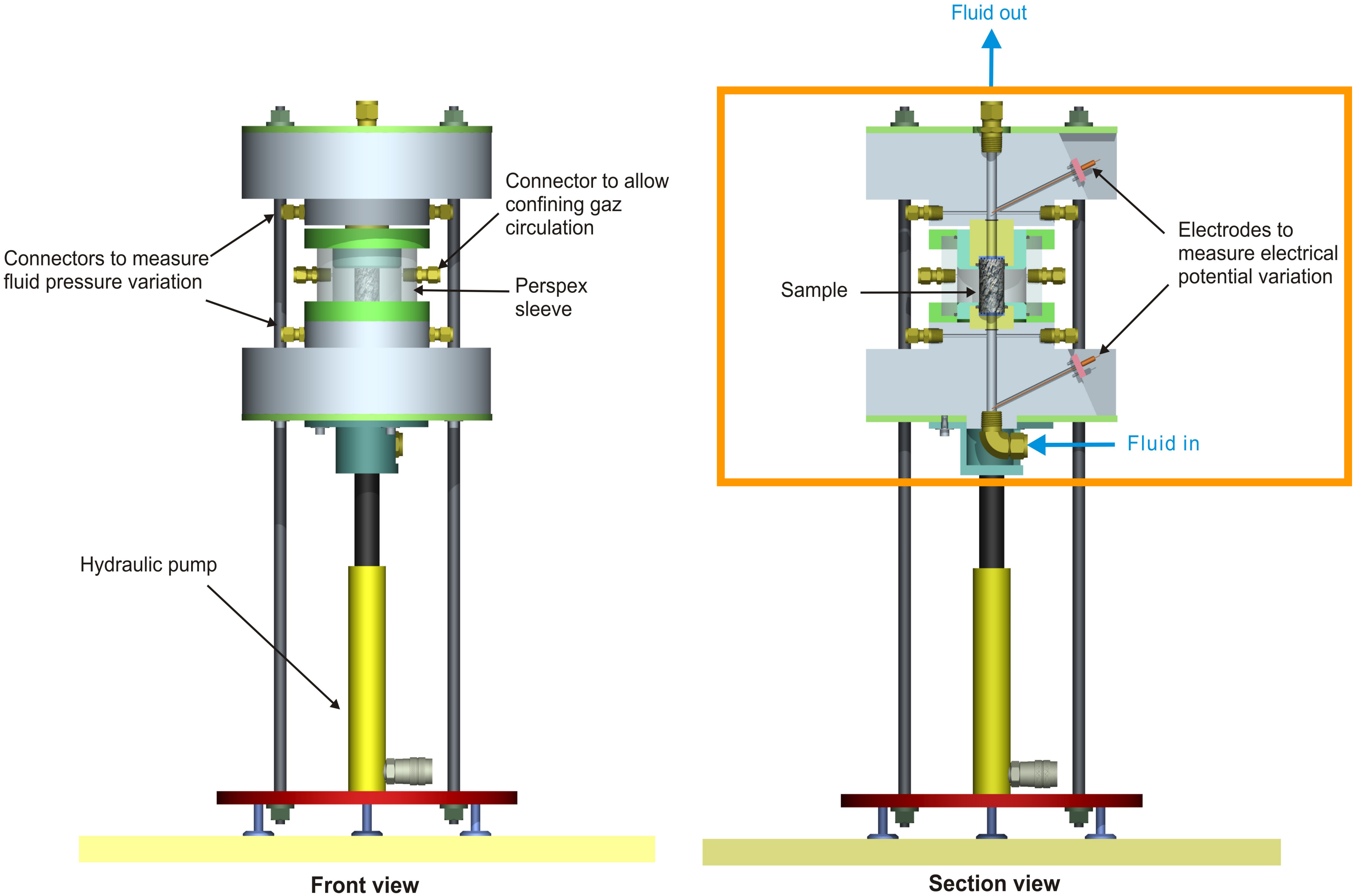
➔New cell designed and constructed

(Collaboration with the departement of mechanical engineering, Université Laval, Canada)

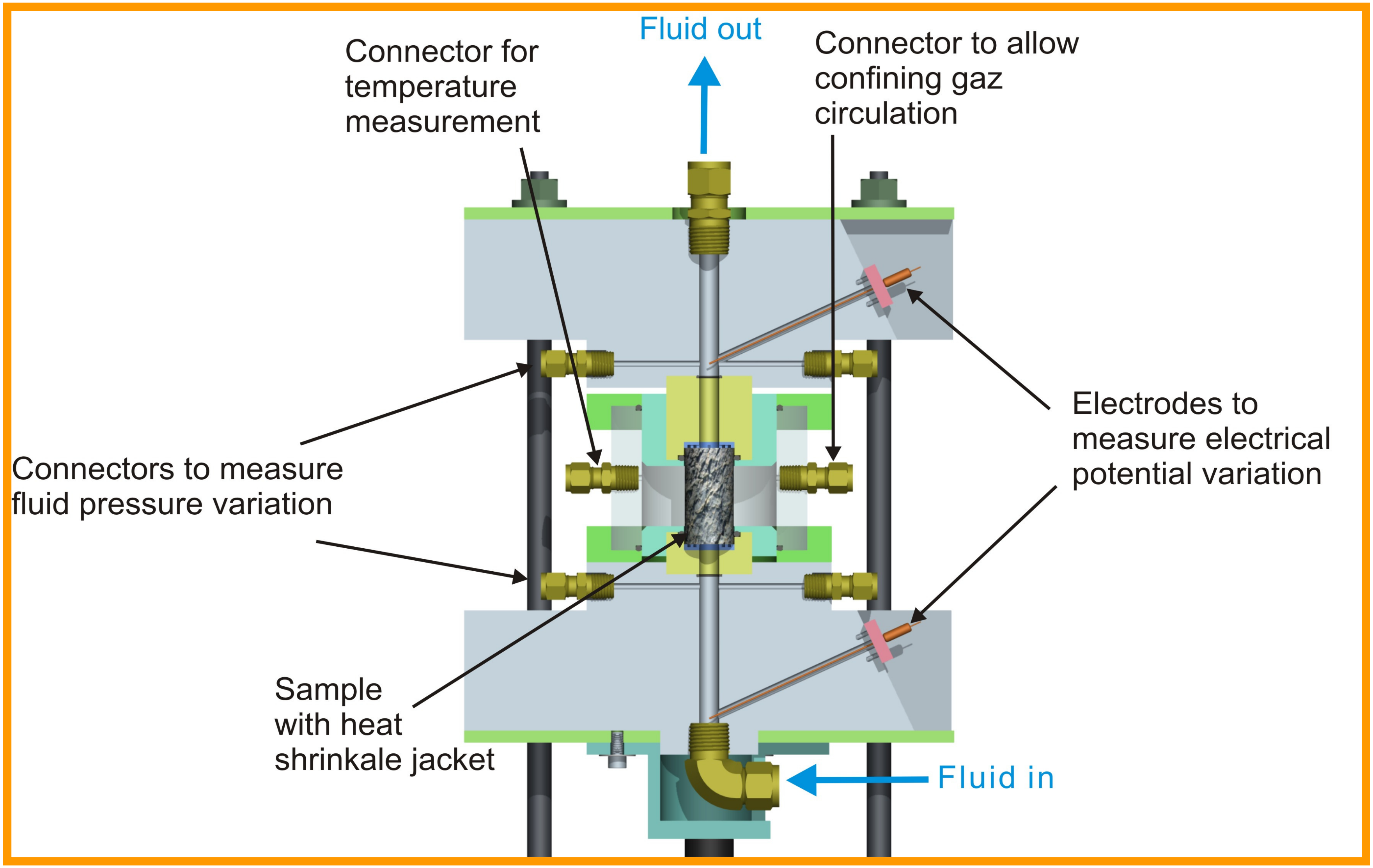
DC measurement cell.

Laboratory of Petrophysics,
Département de géologie,
Université Laval.

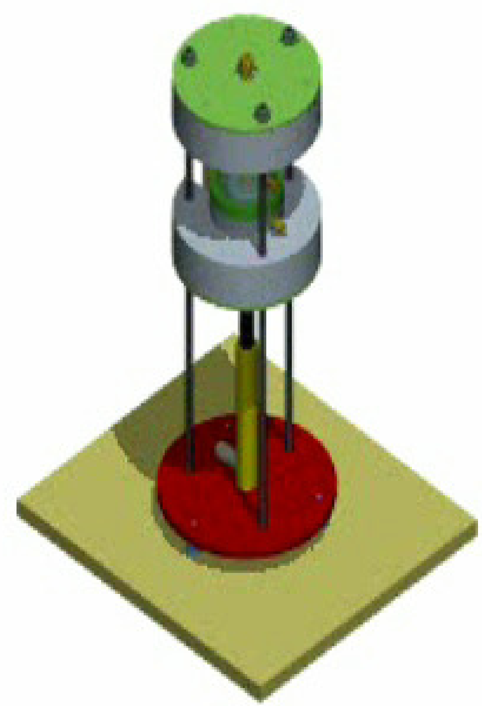
# Laboratory apparatus for measuring the DC streaming potential of porous rock samples



# Laboratory apparatus for measuring the DC streaming potential of porous rock samples

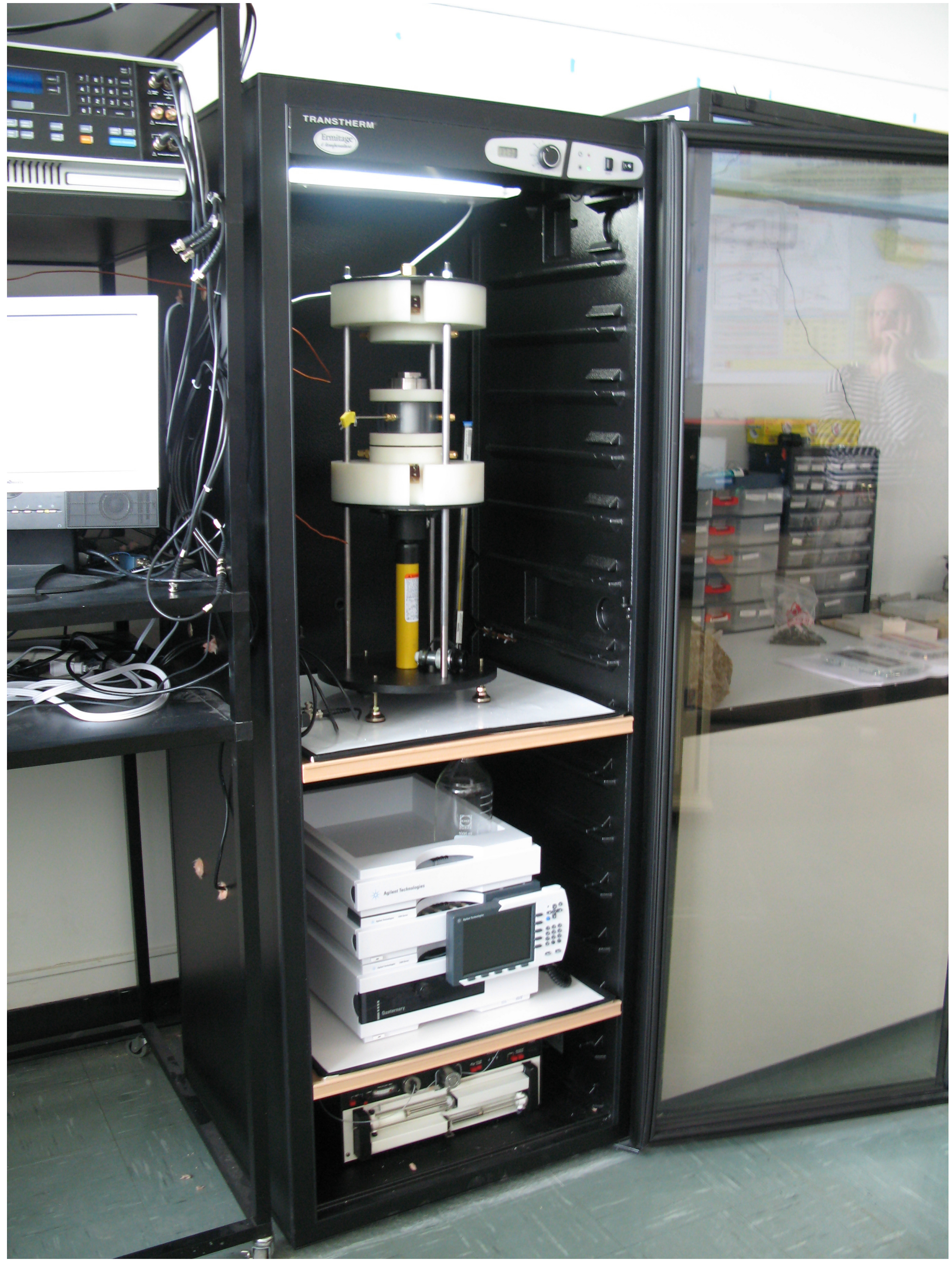


# Laboratory apparatus for measuring the DC streaming potential of porous rock samples



*Vidéo: Guillaume Lalande, 2008*

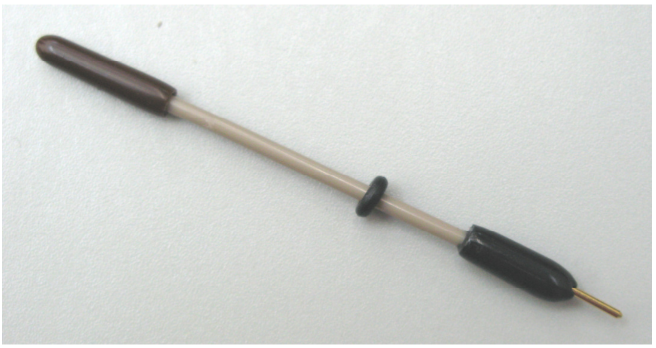
# Laboratory apparatus for measuring the DC streaming potential of porous rock samples




- <u>Temperature control</u>
  ➔ cell in a cellar with temperature control

(*Transtherm, Ermitage, 1 temperature*)

# Laboratory apparatus for measuring the DC streaming potential of porous rock samples



- **Streaming potential electrodes measurements**
  - →Non polarisable, Ag/AgCl
  - →Fluid saturated

(Oméga)

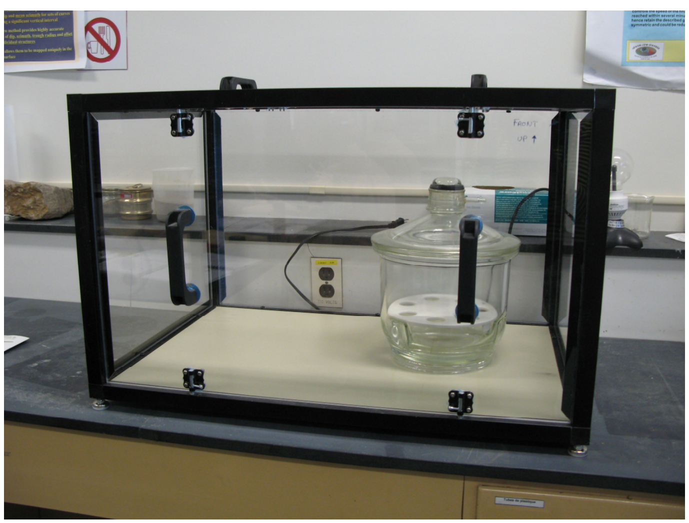
- **Dynamic pressure sensor**
  - → Oméga DPX101-250
  - → For high frequency measurements
  - → Answering time: 1 µs
  - → Pression to 35 MPa

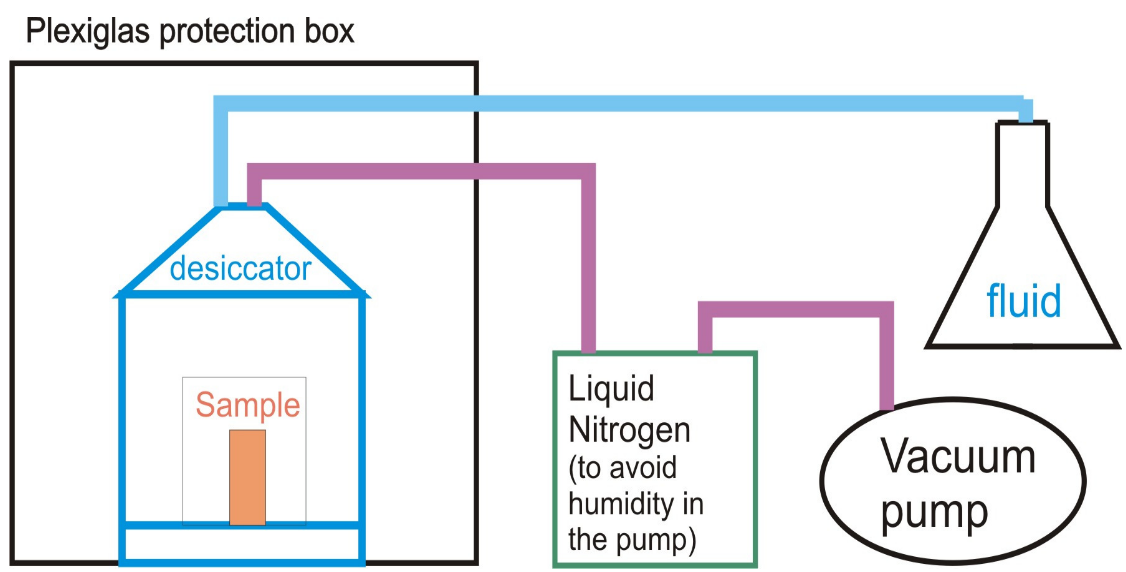
- **Fluid flow** *Agilent quaternary pump*
  - →4 fluids
  - →Flow from 0.06 to 300 $cm^3/h$.

# Laboratory apparatus for measuring the DC streaming potential of porous rock samples

## Rock samples and saturation


- Cylindre diametre: 1’’ to 1.5’’. Length: 2’’ to 3’’
- Dried then vacuum saturated.
- Heat shrinkable Polyefin jacket

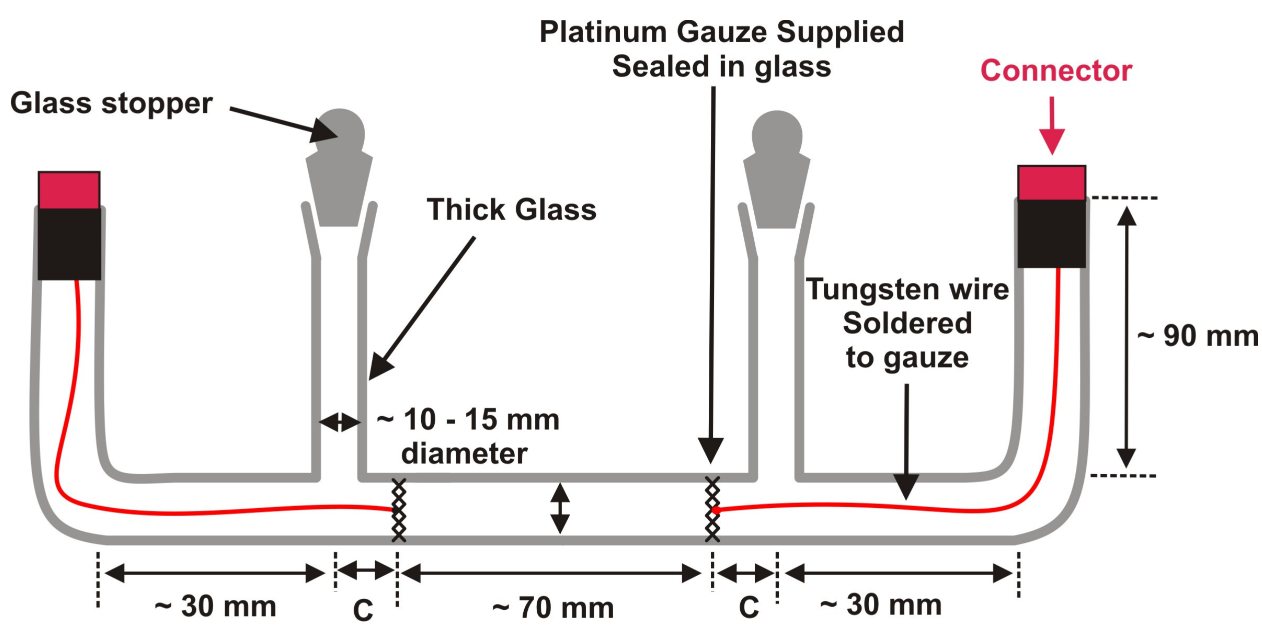




# Laboratory apparatus for measuring the DC streaming potential of porous rock samples

## Fluid conductivity measurement

- Measurement cell for fluid conductivity, build with François Dion, from *Glover (2007)*.




- Set up needing modifications after first tests

# Set of data on electrokinetic properties of porous rock samples in the DC regime

- Testing
  - Glass beads samples → known theory
  - Fluid samples
  - Samples previously tested
  - Sensibility and precision of the set up?

- Measurements:
  - Pressure variation
  - Electrokinetic potential

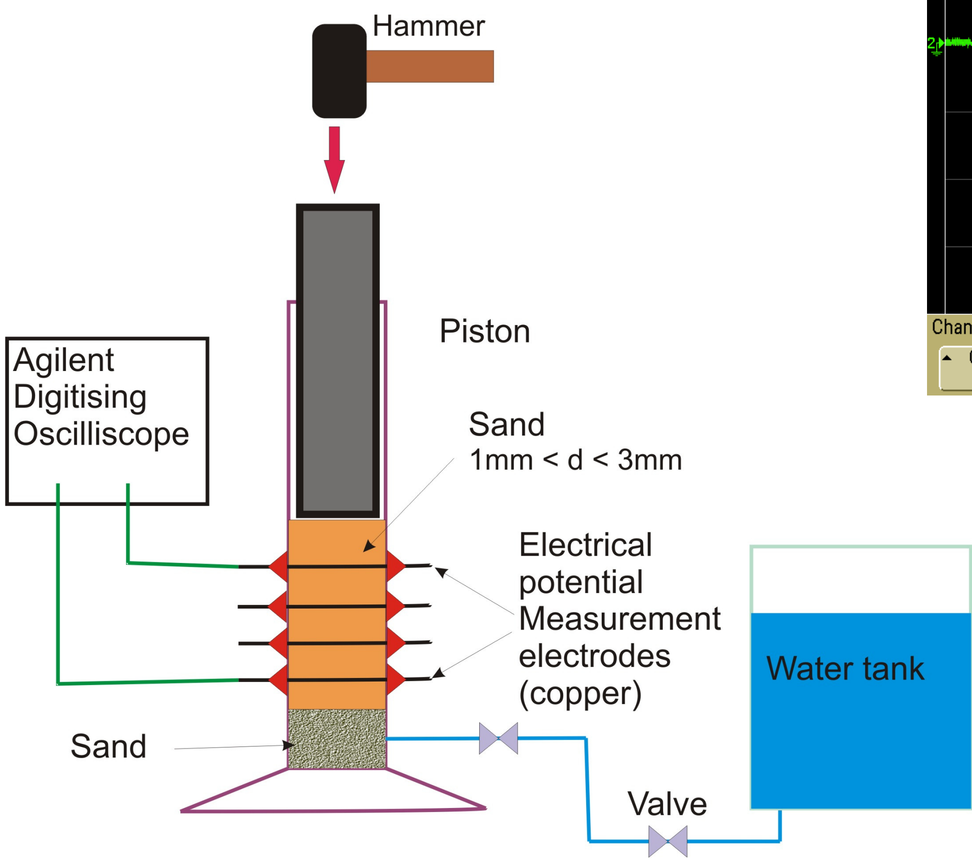
- Experiments:
  - For different rocks
  - For different fluid pH → pH=2 to pH=10
  - For different fluid concentration → 2 M. to $10^{-5}$ M.
  - For different saturation
  - For different controlled temperature
  - For different fluid flow rate

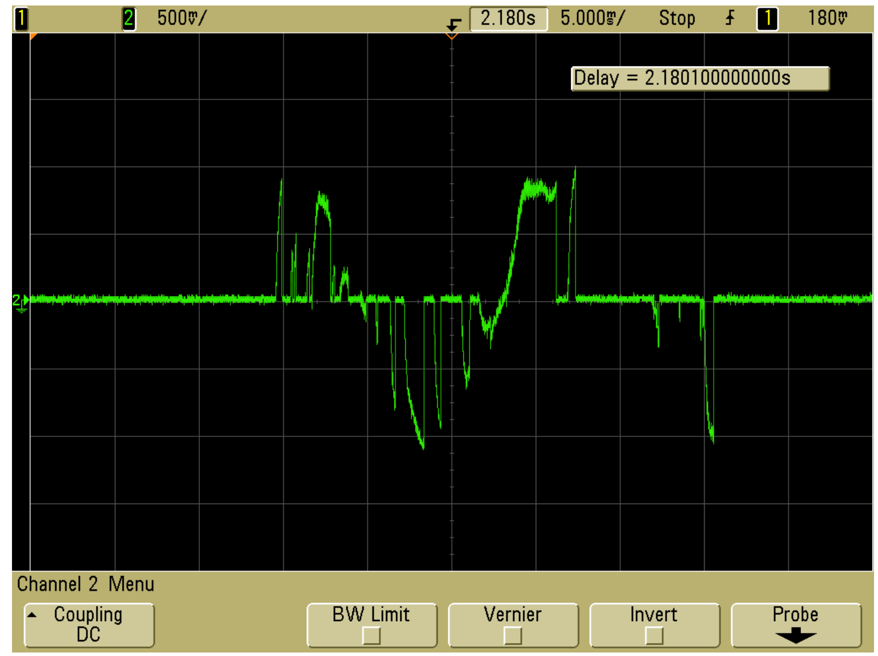
# III. AC measurements apparatus

# Can we measure an electrical potential from a fluid pulse ?

## The « Hammer test » *(Glover, 2007)*

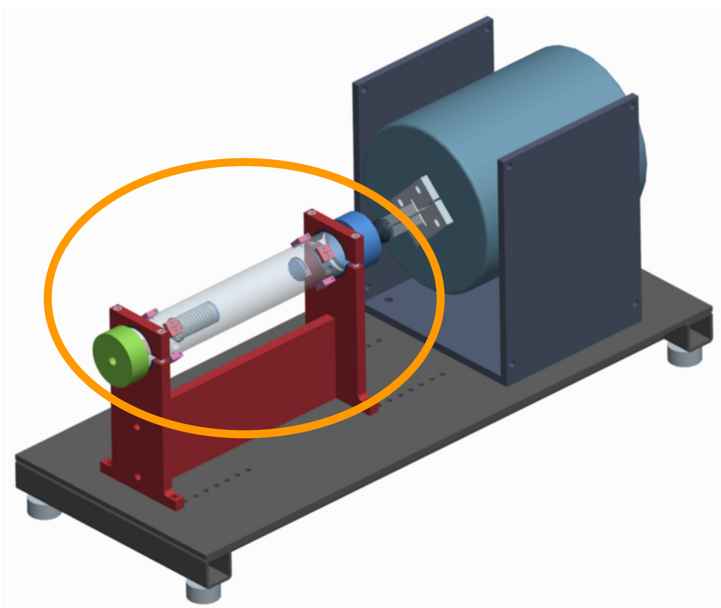
→ Measurement of electrical potential linked to a frequency change in natural materials.



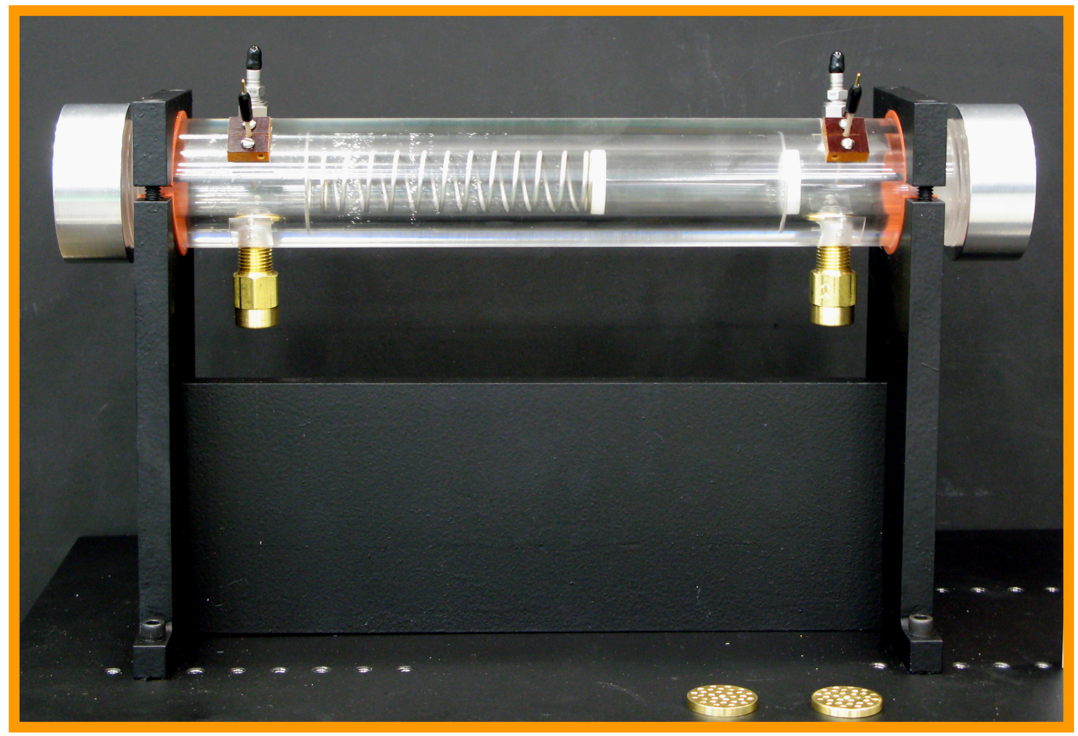




Sample of ordinary sand,
0.1mm < grains diameter < 1mm,
Fluid saturated (NaCl 0.1M).
Vertical scale: 1 square = 1V.
Horizontal scale: 1 square= 5ms.

# Laboratory apparatus for measuring the AC streaming potential of porous rock samples



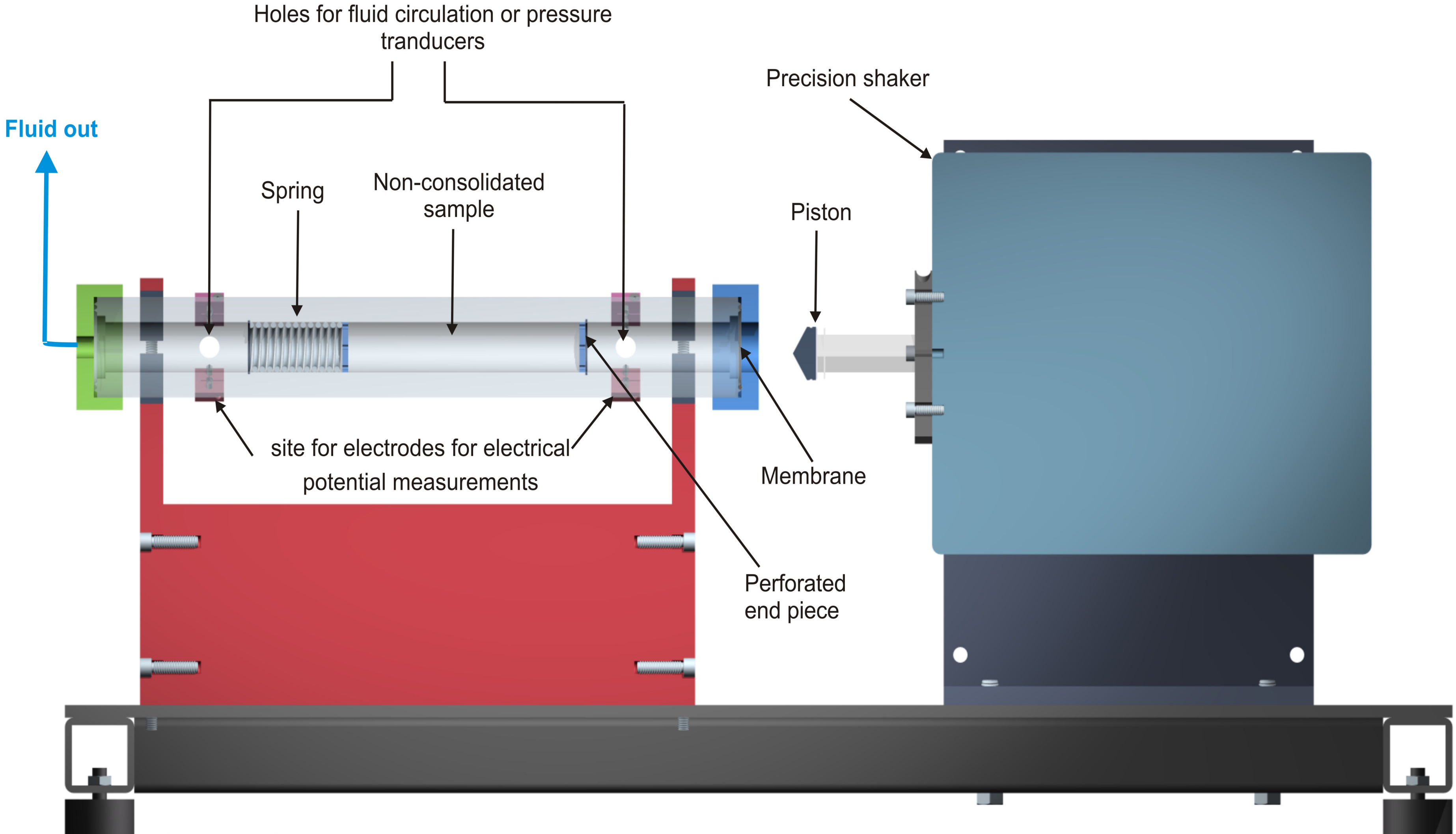
*Drawing: G. Lalande & M. Bergeron*



AC measurement cell.

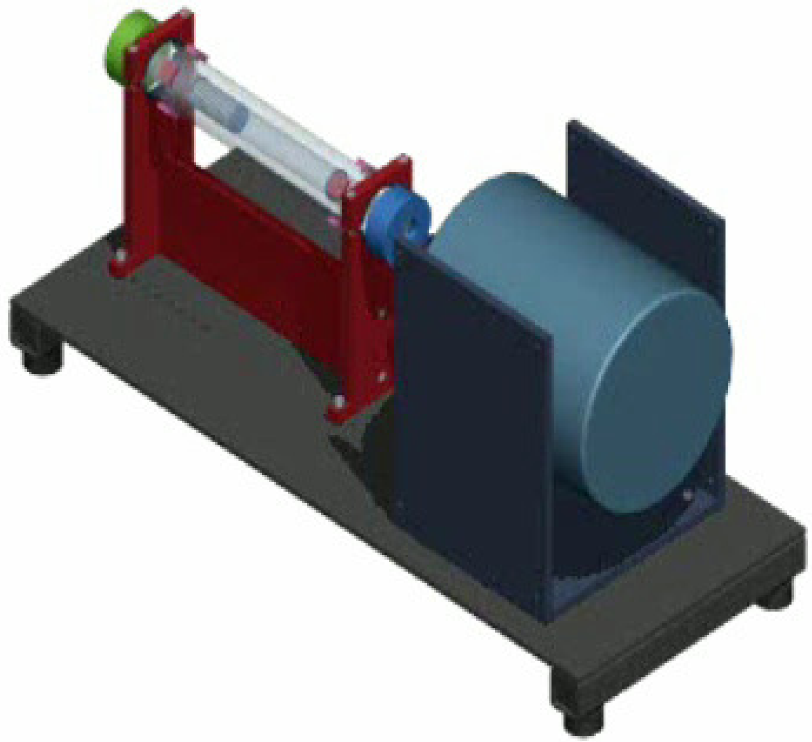
Laboratory of Petrophysics, Département de géologie, Université Laval.

# Laboratory apparatus for measuring the AC streaming potential of porous rock samples




**Section of the set-up**

# Laboratory apparatus for measuring the AC streaming potential of porous rock samples



*Vidéo: Guillaume Lalande, 2008*

# Set of data on electrokinetic properties of porous rock samples as a function of frequency

- Testing phase

- Measurements:
  - Pressure variation
  - Electrokinetic potential
  - Frequency of fluid injection

- Experiments:
  - For different rocks
  - For different fluid pH → pH=2 to pH=10
  - For different fluid conductivities

# Applications

What if we can develop and understand electrokinetic theories in porous rocks, with a set of specialised data ?

- ✓ Application to hydrocarbons prospection and reservoir management.
- ✓ Management of water reservoirs.
- ✓ Monitoring and survey of polluted areas.
- ✓ Earthquakes stimulation.
- ✓ Monitoring of earthquake zones.
- ✓ Monitoring of volcanic zones.
- ✓ Monitoring of permafrost melt.
- ✓ Acid mine drainage.

Thank you for your attention.

# Polarisation vs. frequency