A laboratory apparatus for measuring the frequency-dependent streaming potential coupling coefficient of porous rock samples

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Summary

I. Introduction to the electrokinetic phenomena in porous rocks

II. DC measurements apparatus

III. AC measurements apparatus

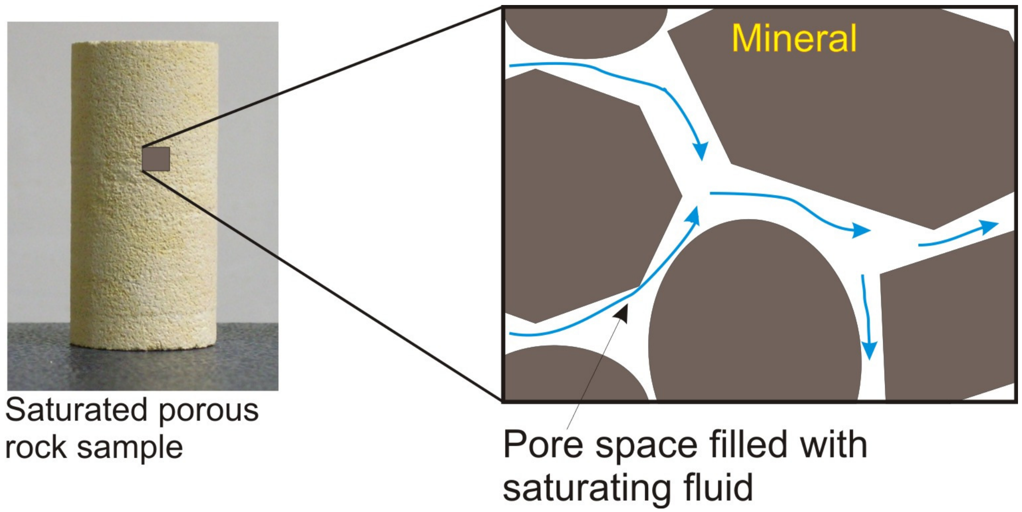
I. Introduction to the electrokinetic phenomena in porous rocks

Rock-fluid interface

Saturated porous rock sample

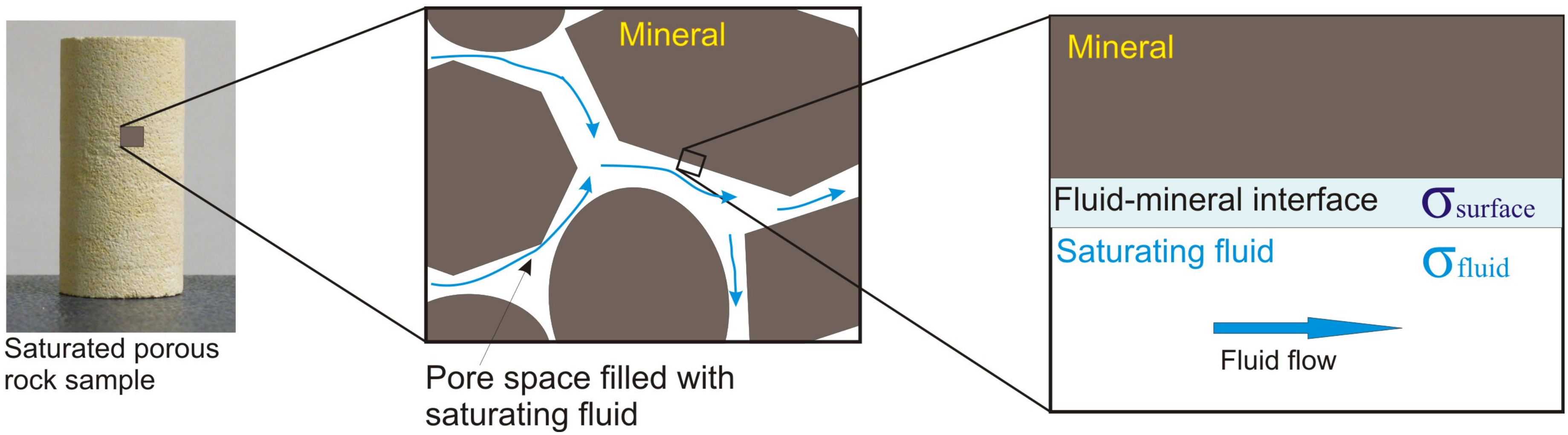
- Fluid flow and rock-fluid interface
- Electrokinetic or Streaming potential

Rock-fluid interface



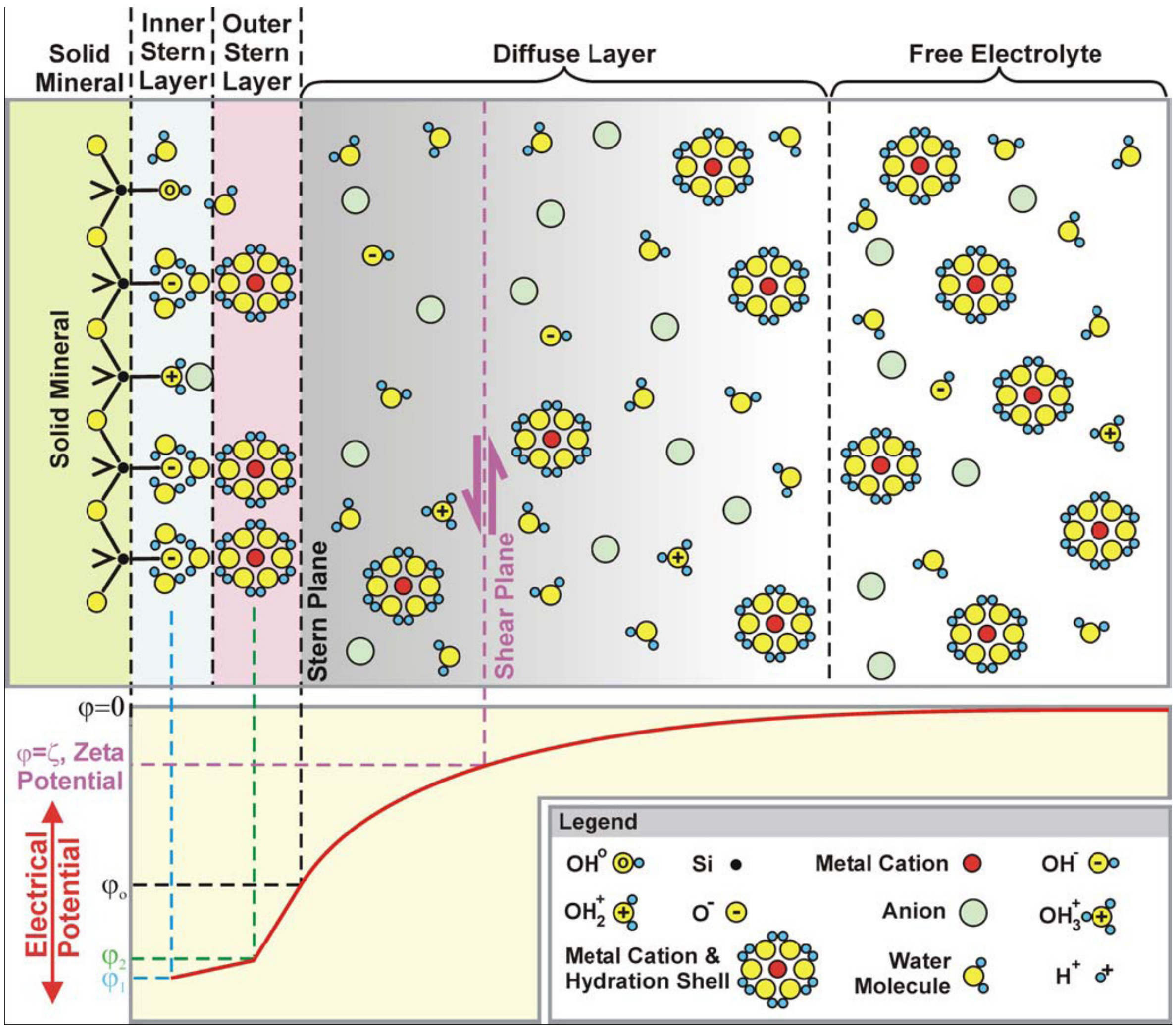
- Fluid flow and rock-fluid interface
- Electrokinetic or Streaming potential

Rock-fluid interface



- 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)

σ_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

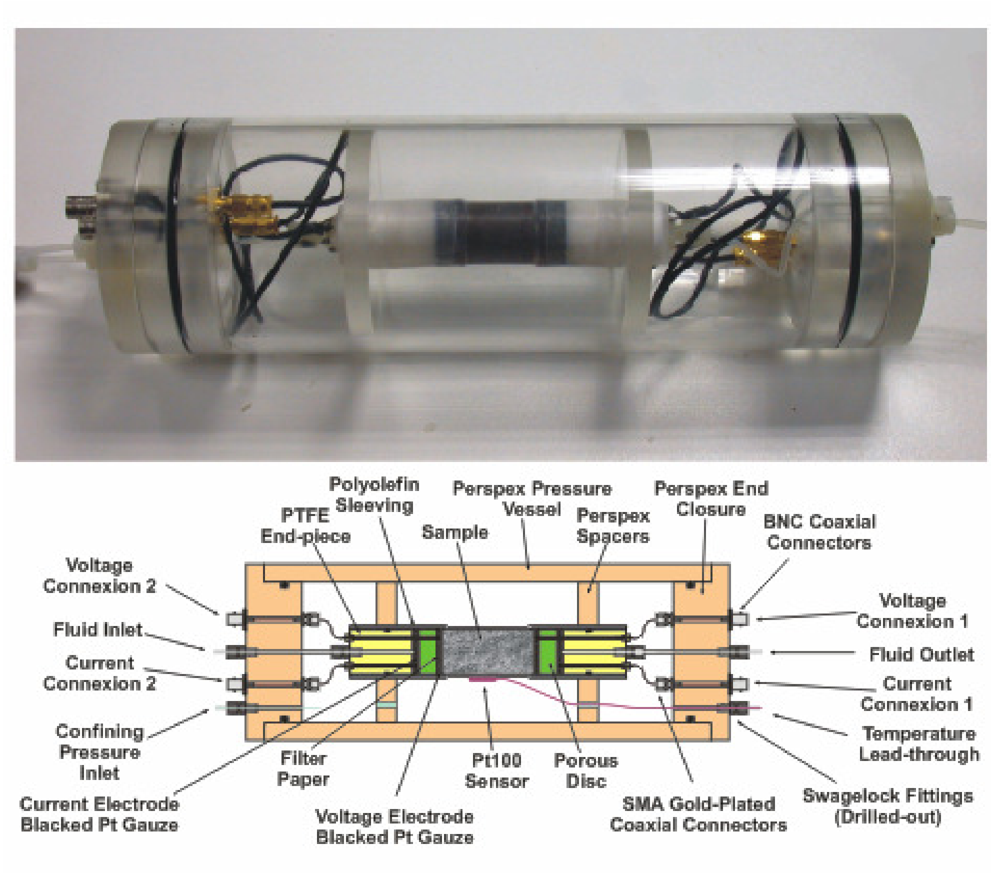
- Electrokinetic phenomena in the AC regime for capillaries : *Packard (1953)*

✓ OK for capillaries ✘ No existing theory for rocks

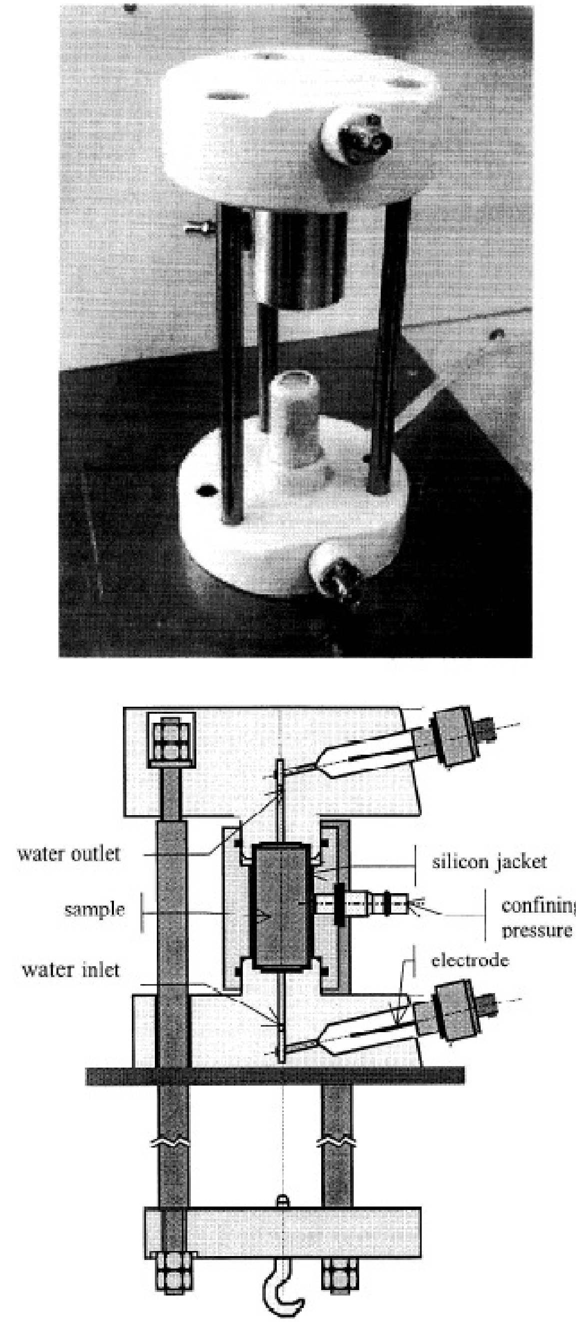
II. DC measurements apparatus

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

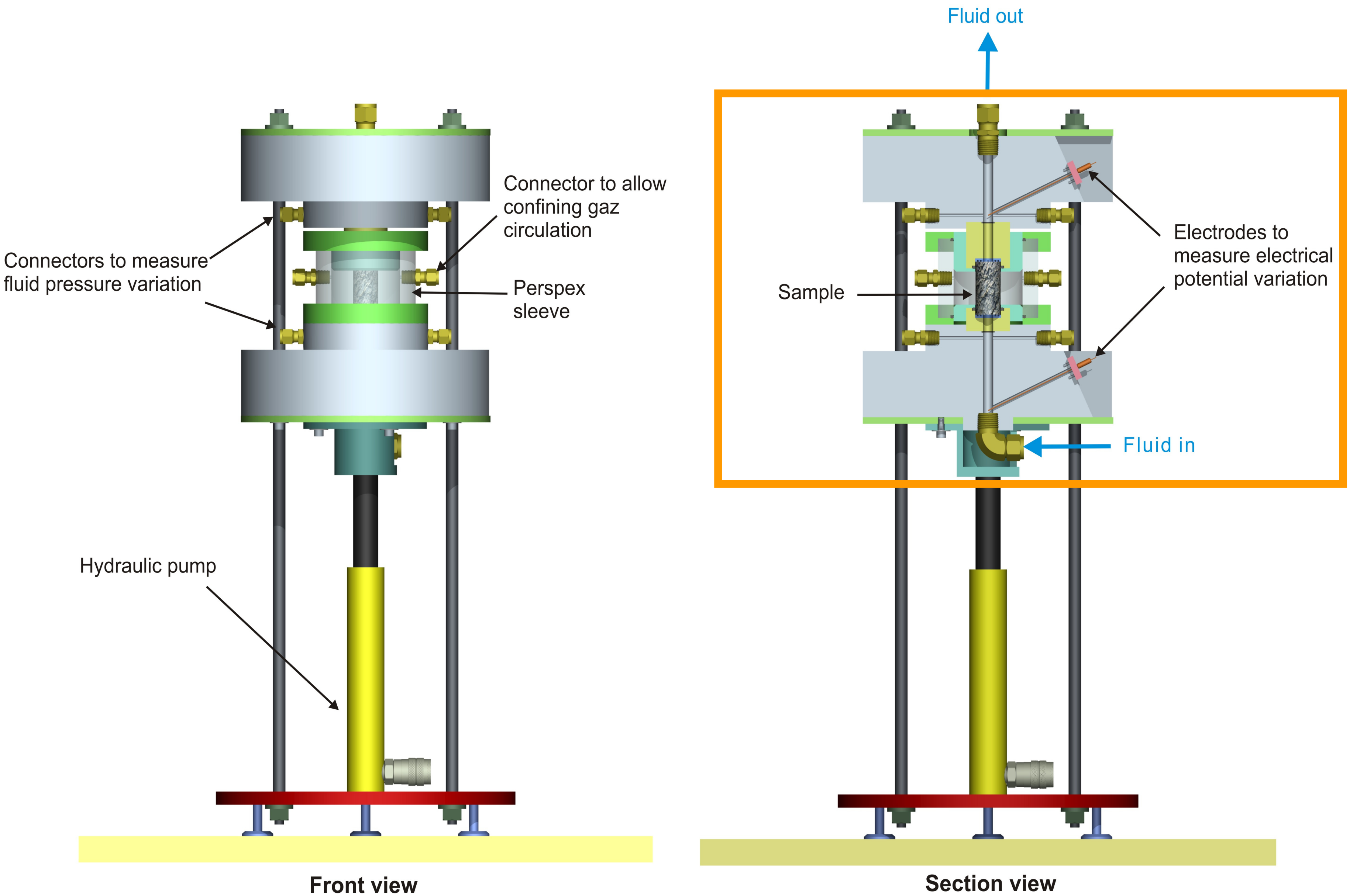
➔New cell designed and constructed

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

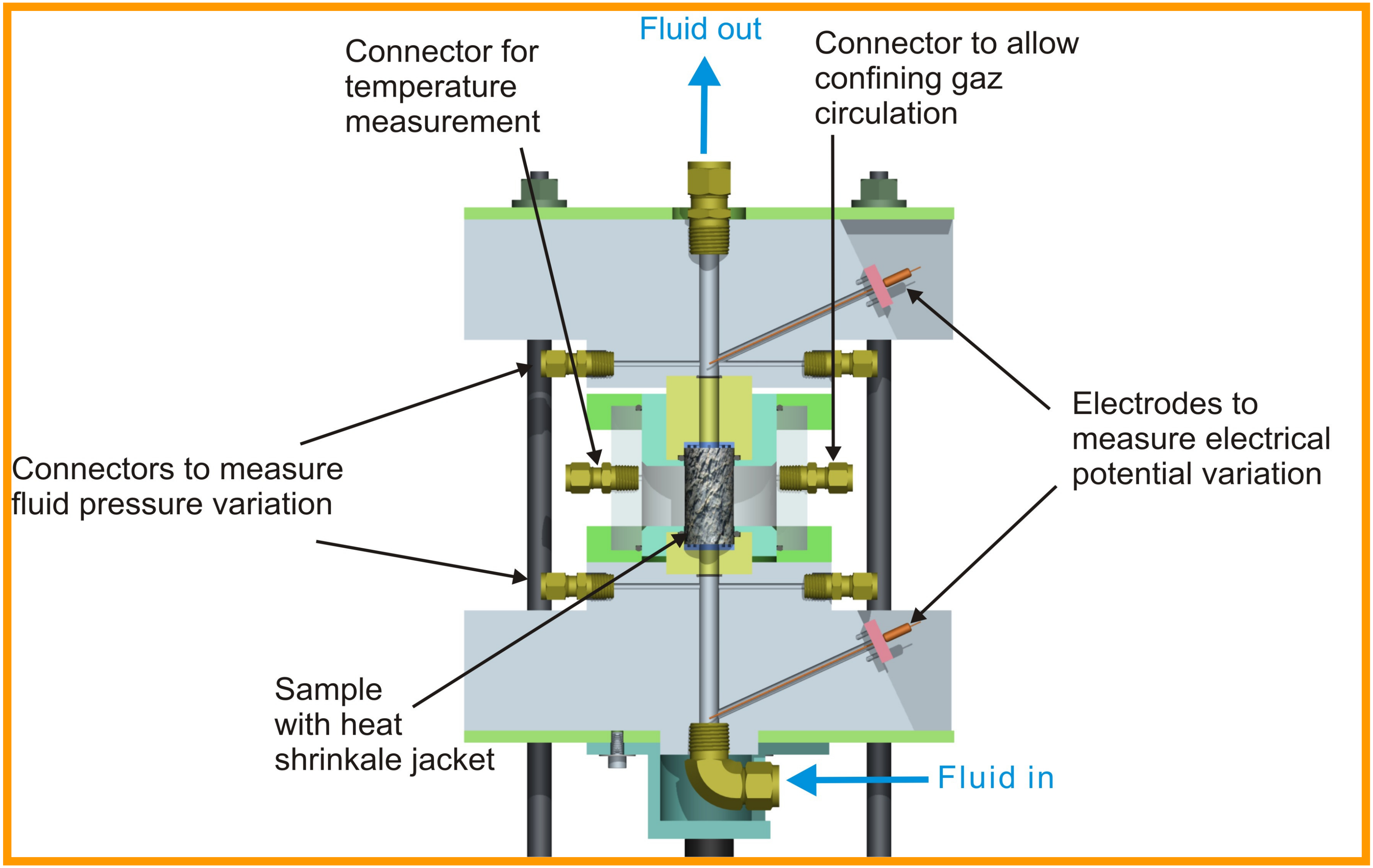
DC measurement cell.

Laboratory of Petrophysics,
Département de géologie,
Université Laval.

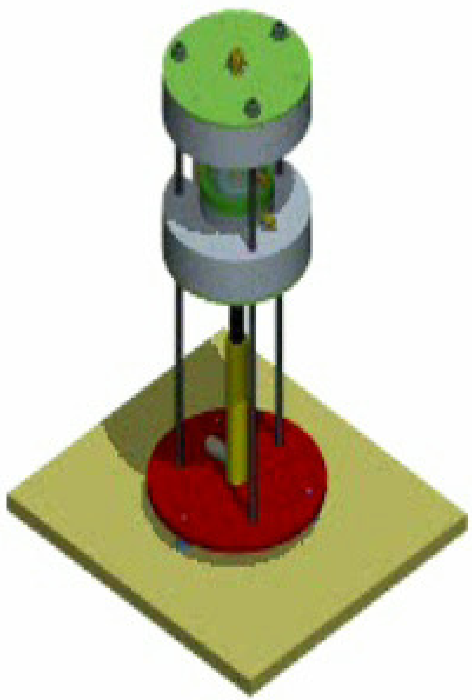
Laboratory apparatus for measuring the DC streaming potential of porous rock samples



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

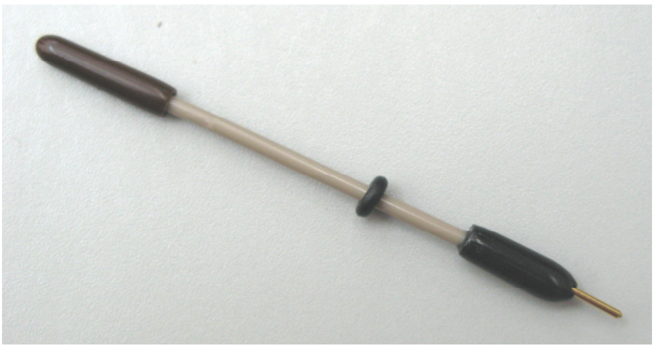


Laboratory apparatus for measuring the DC streaming potential of porous rock samples



Vidéo: Guillaume Lalande, 2008

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



- **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

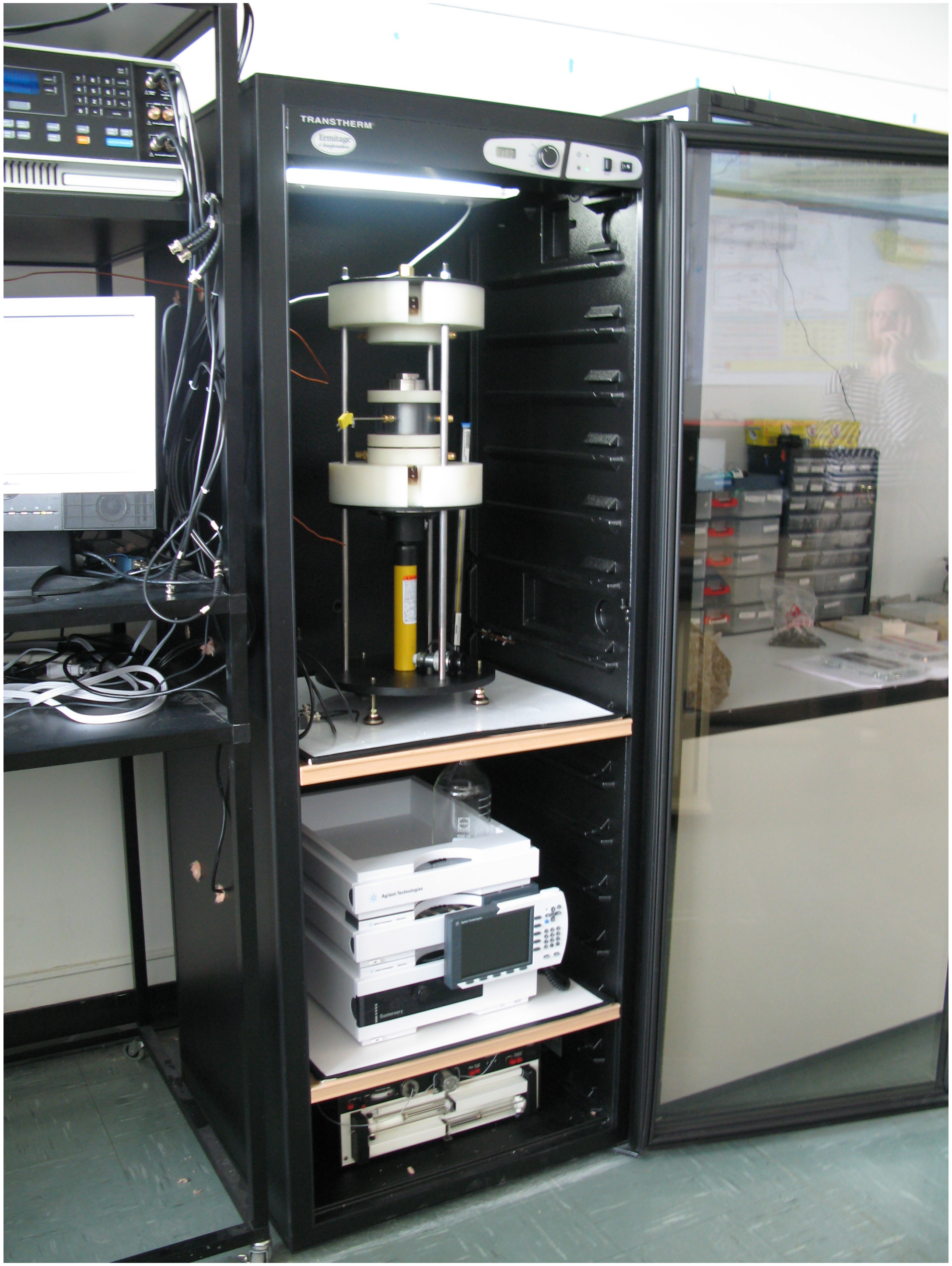
- **Fluid flow** *Agilent quaternary pump*
  - →4 fluids
  - →Flow from 0.06 to 300 cm³/h.

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*)



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

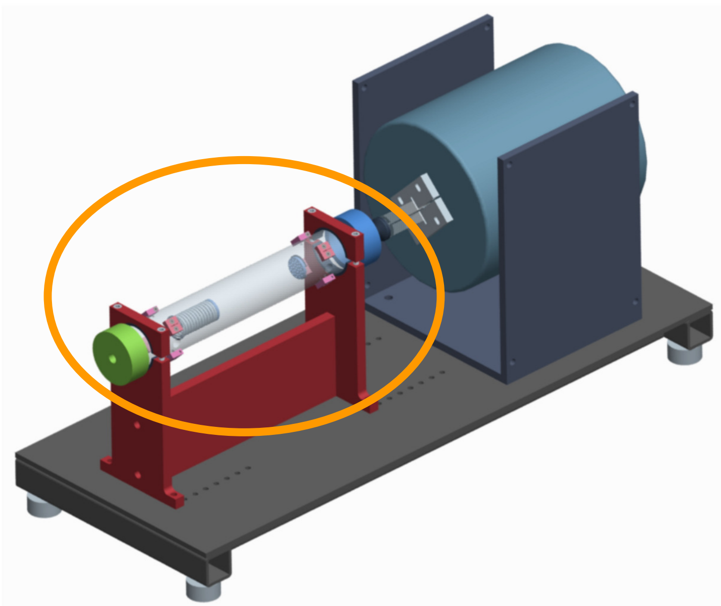
- Testing
  - Glass beads samples → known theory
  - Fluid samples
  - Samples previously tested
  - Sensibility and precision of the set up?

- Measurements:
  - Pressure variation
  - Electrokinetic potential

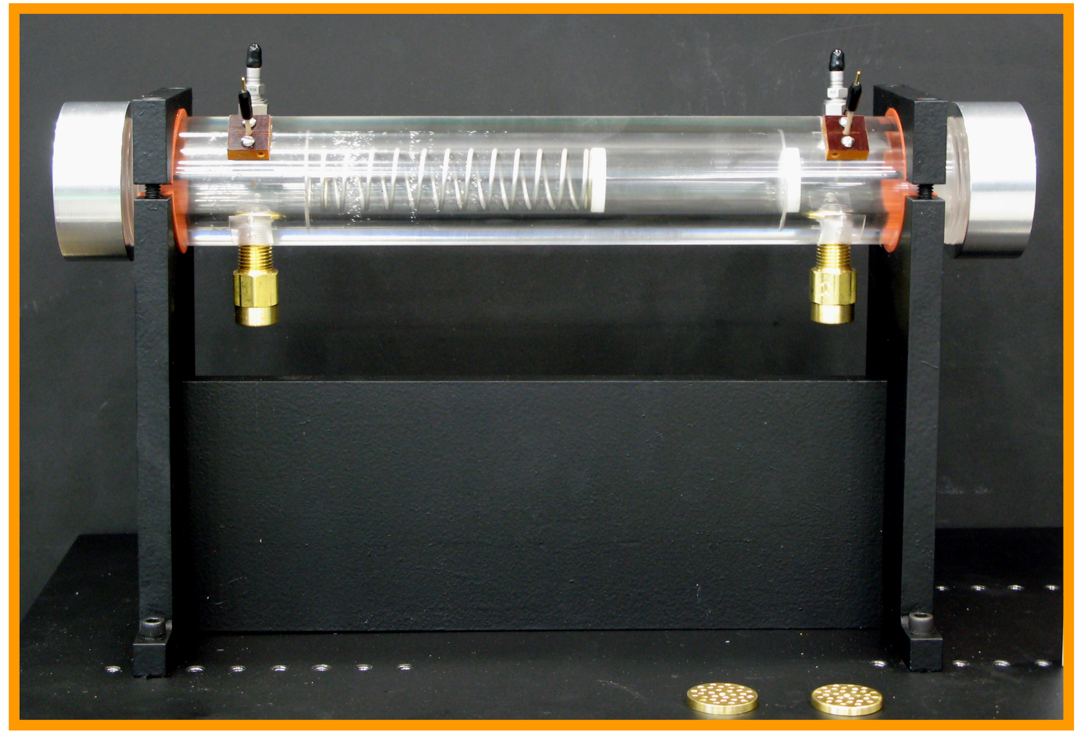
- Experiments:
  - For different rocks
  - For different fluid pH → pH=2 to pH=10
  - For different fluid concentration → 2 M. to 10^{-5} M.
  - For different saturation
  - For different controlled temperature
  - For different fluid flow rate

III. AC measurements apparatus

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



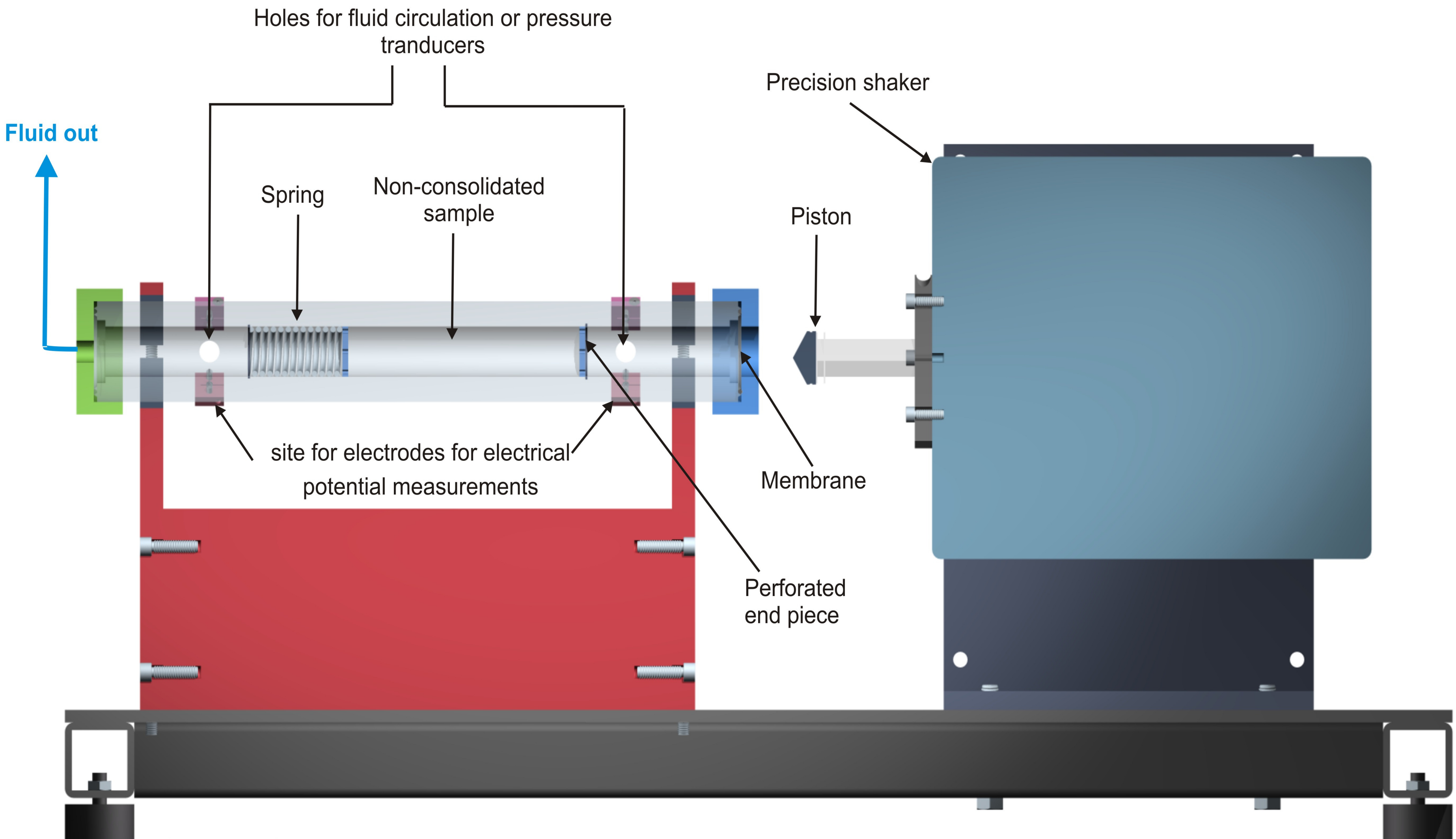
Drawing: G. Lalande & M. Bergeron



AC measurement cell.

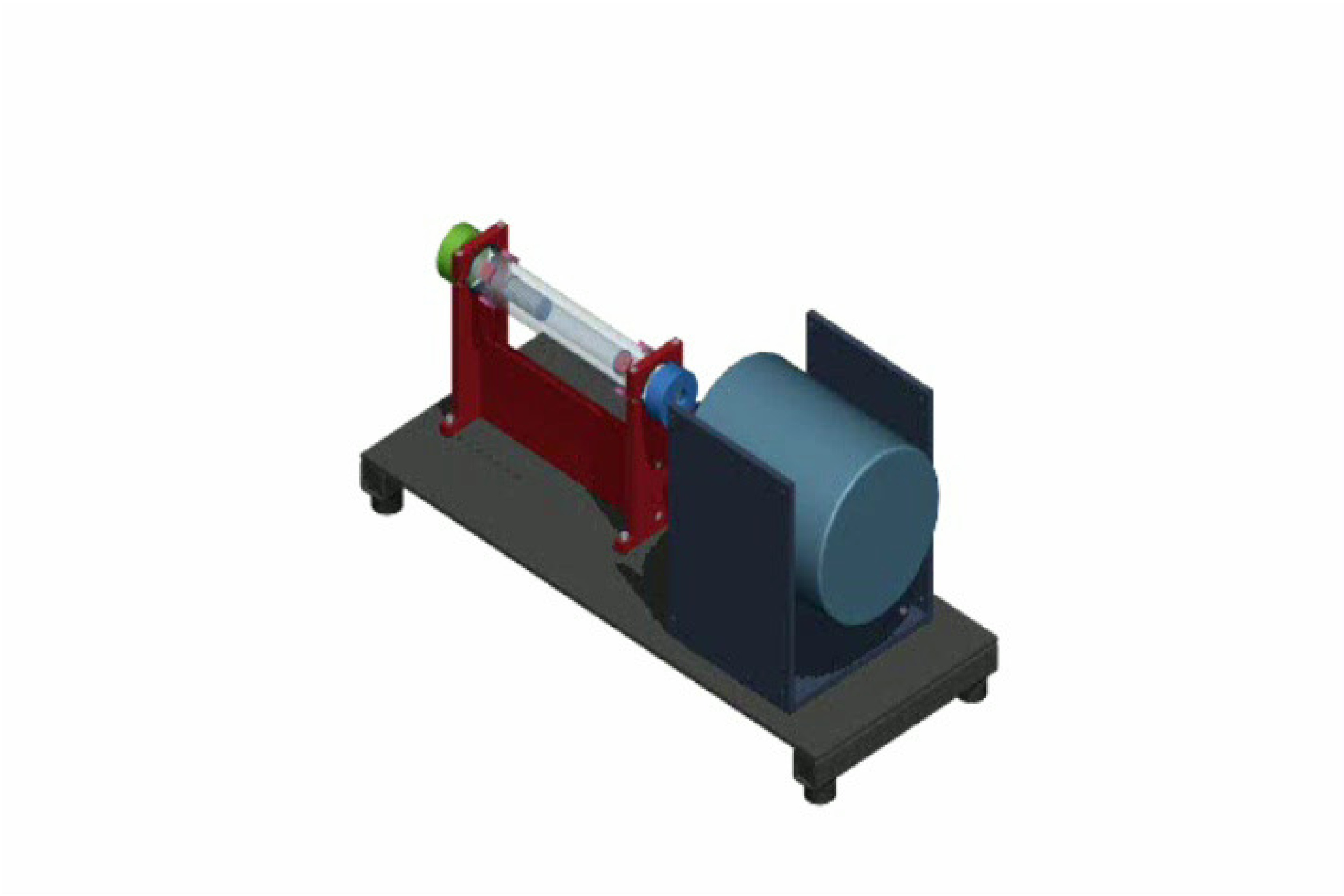
Laboratory of Petrophysics, Département de géologie, Université Laval.

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

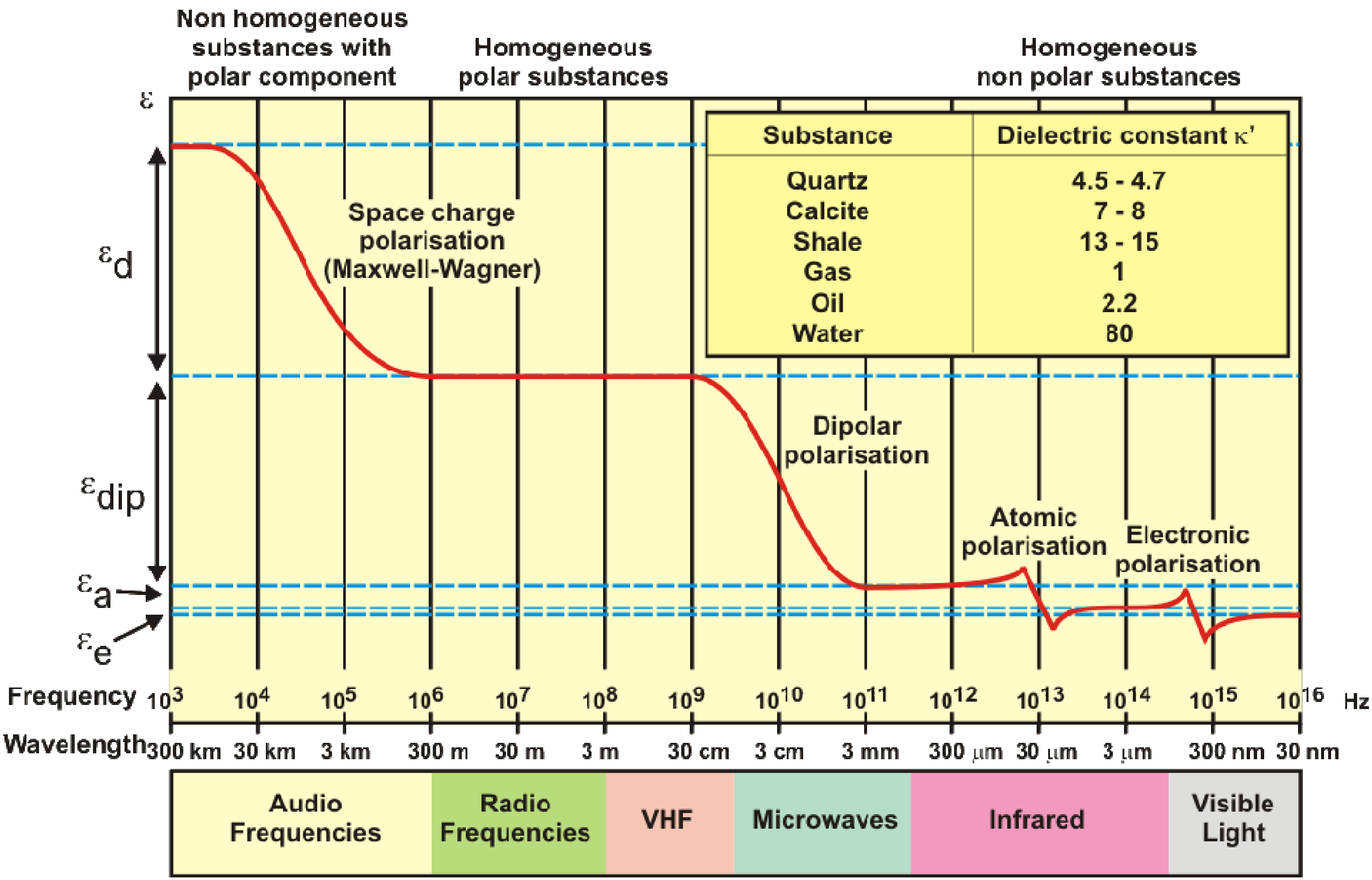
Applications

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

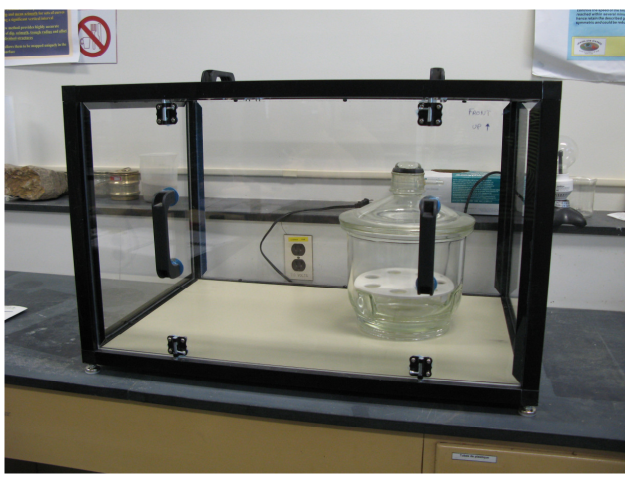
Thank you for your attention.

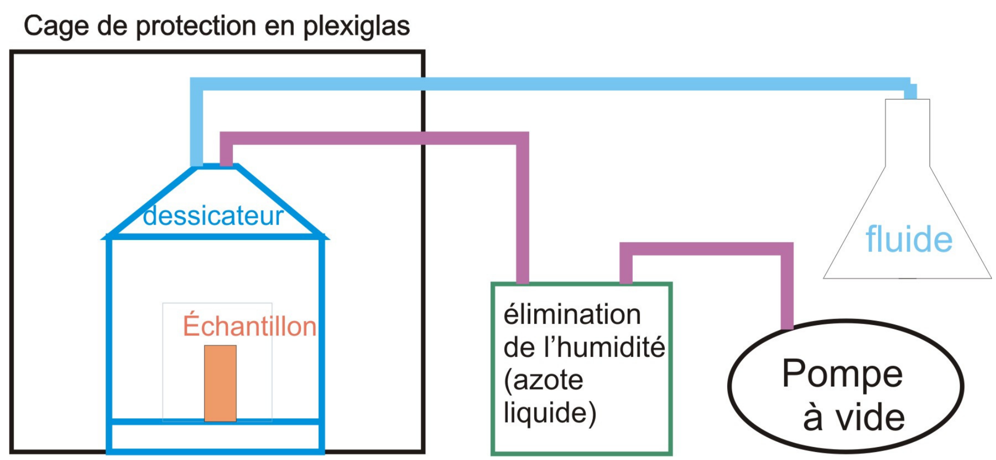
Polarisation vs. frequency



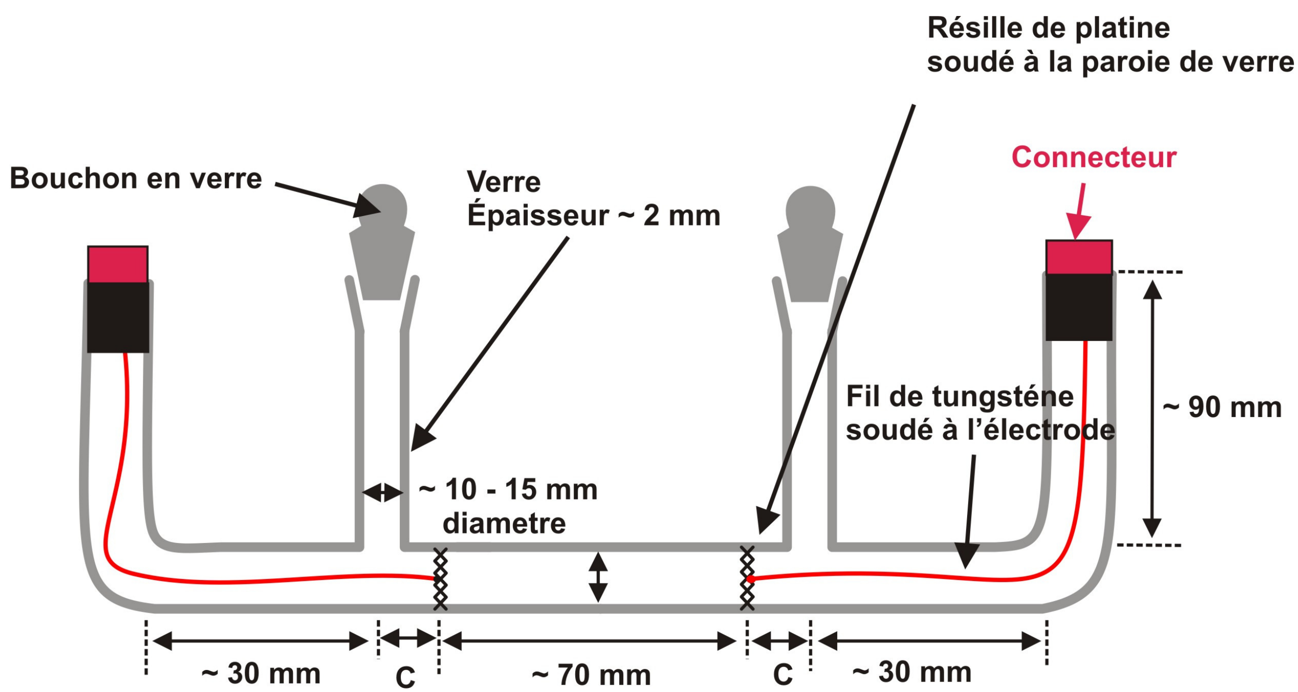
Rocks saturation

- Cylindre diametre: 1'' à 1.5''. Length: 2'' à 3''
- Dried then vacuum saturated.
- Polyefin jacket heat shrinkable

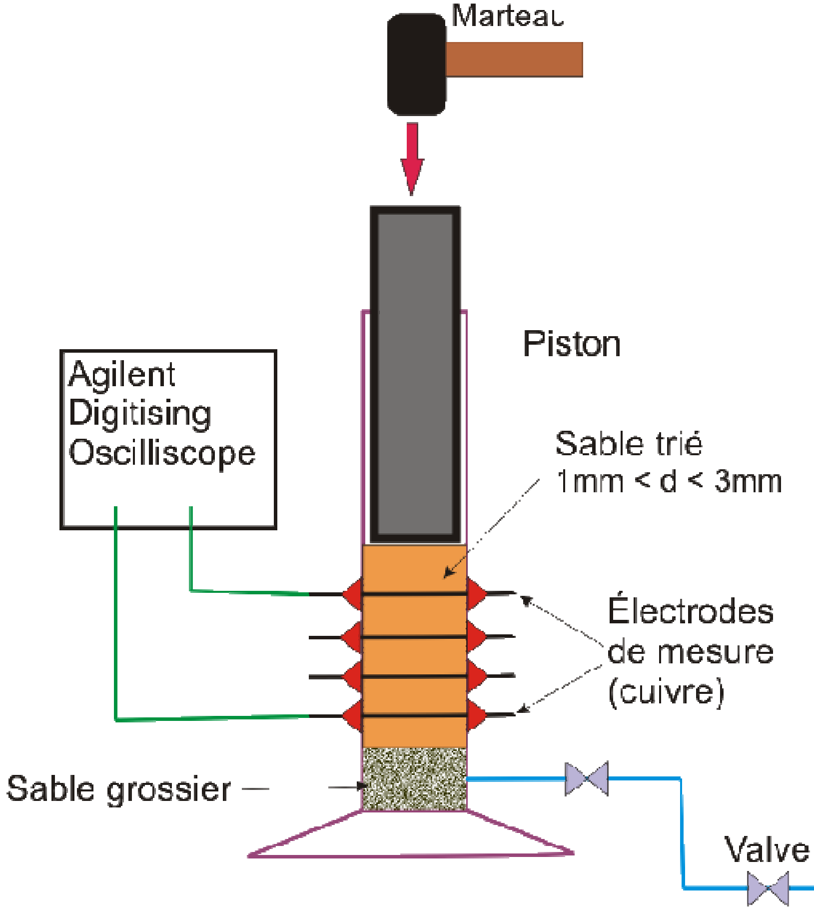


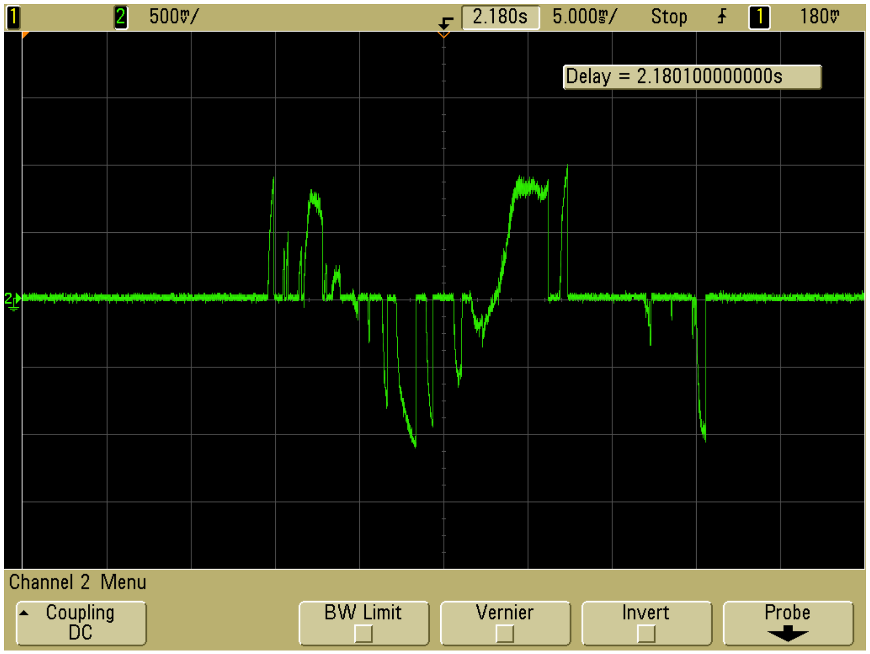


Fluid conductivity measurement



Electrical potential from a fluid pulse : The « Hammer test » *(Glover, 2007)*





échantillon de sable ordinaire,
0.1mm<diamètre des grains<1mm,
Saturé avec un fluide à 0.1M de NaCl.
Échelle verticale: 1 carré = 1V.
Échelle horizontale: 1 carré = 5ms.

(*Glover, 2007, communication personnelle*)