Experimental determinations of filtration properties problems for non-conventional rocks

Team 4

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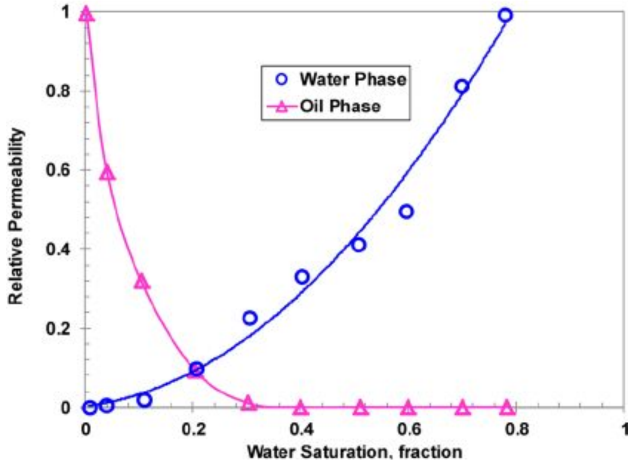
Filtration properties

- **Displacement coefficient** - is the ratio of the volume of oil displaced from the reservoir area occupied by the working agent (water, gas) to the initial oil content in the same area.

The **displacement coefficients** depend on:

- of the washing multiplicity (ratio of the volume of the pumped working agent to the pore volume),
- ratio of the viscosity of oil to the viscosity of the working agent,
- of the permeability coefficient,
- distribution of the pore size, the nature of the wettability of the formation rocks.



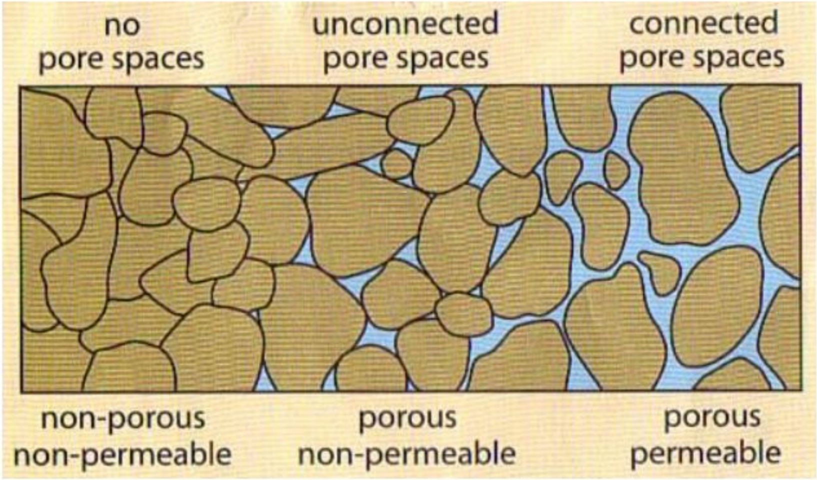
Permeability

- **Absolute permeability** - is the permeability of a porous medium for a homogeneous liquid and gas, m2.
- **Phase permeability** - is the permeability of a porous medium for a given liquid or gas in the presence of another phase (oil–water, oil–gas, gas —water), m2.
- **Relative phase permeability** - is the ratio of phase permeability to absolute (single–phase) permeability. Relative permeability is measured in fractions of a unit.

Does not apply to non-conventional rocks!

Types of non-conventional low permeable rocks

- **Shale-** Sedimentary rock, with high porosity but essentially no permeability.
- **Tight Oil-** Tight oil are classified as source rock (sedimentary rock with petroleum hydrocarbon production capacity).
- **Unfractured Granite-** Most granite blocks have porosity ratios that range between 0.4 and 1.5 percent.
- **Low permeability Carbonate-** Porosity and permeability is greatly reduced in ancient carbonate reservoir rocks due to compaction and cementation



Laboratory methods applied to porous media of the shale rocks

Conventional rocks

$$\emptyset = 1 - \frac{\rho_B}{\rho_G}$$

- using bulk density and grain density

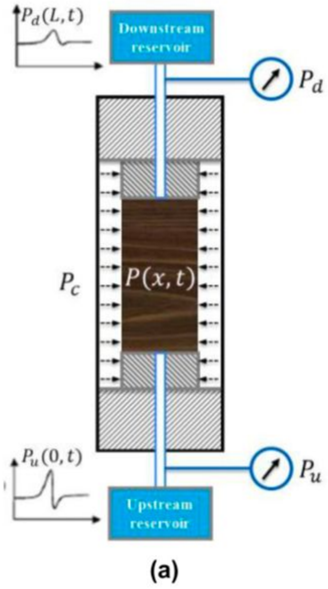
$$k = \frac{QL\mu}{A(P_1^2 - P_2^2)}$$

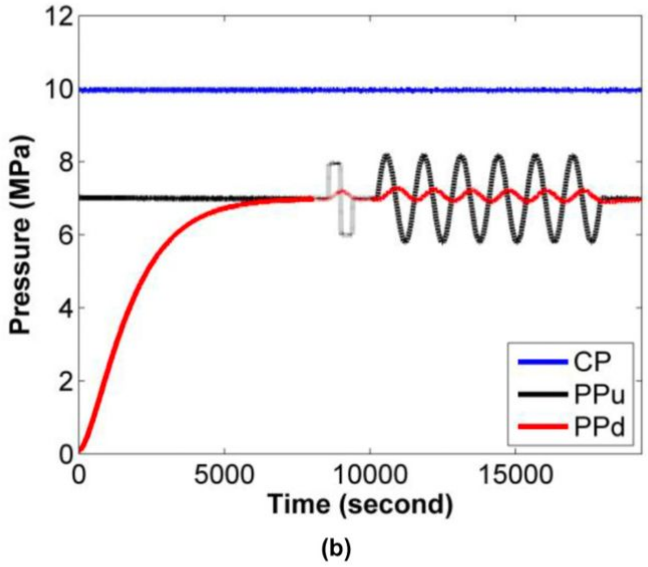
- Darcy's gas flow (mostly use helium)

Disadvantages using conventional methods for the shale rocks

- shales delaminating as core plugs are taken
- nm-scale so may be less accessible to methane than to helium
- methane adsorption may lead to the swelling of organic matter
- slippage, transitional flow or Knudsen diffusion gas flow mechanism in shale rocks
- Mixed wettability
- high injection pressures of approximately 400 MPa

Laboratory setup for measurement permeability rich-organic shale rocks and measurement results





Schematic diagram of the experimental setup for measuring the transient permeability of unconventional shales

Typical pore pressure profile during the permeability measurement of a plug under the confining pressure

3 methods for permeability measurement:

1.Pressure build-up methods

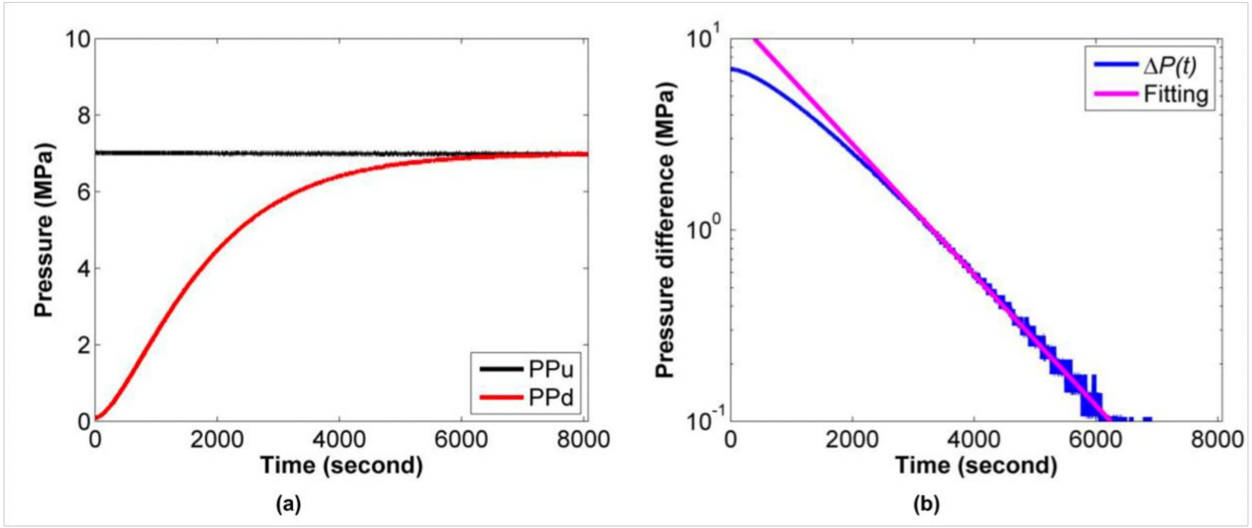
2.Pulse-decay method

3.The oscillating pulse method

PPu - the pressure change at the upstream side

PPd- at the downstream side

Pressure build-up method



$$\Delta P(t) = C_1 \Delta P(0) \exp\left(\frac{-\theta^2 k_{1a} t}{\beta \phi \eta L^2}\right)$$

$$C_1 = \frac{2\gamma\theta\left(\gamma^2 + \theta^2\right)^{1/2}}{\theta^4 + \theta^2\left(\gamma + \gamma^2\right)}$$

$$\gamma = \frac{V_p}{V_d}$$

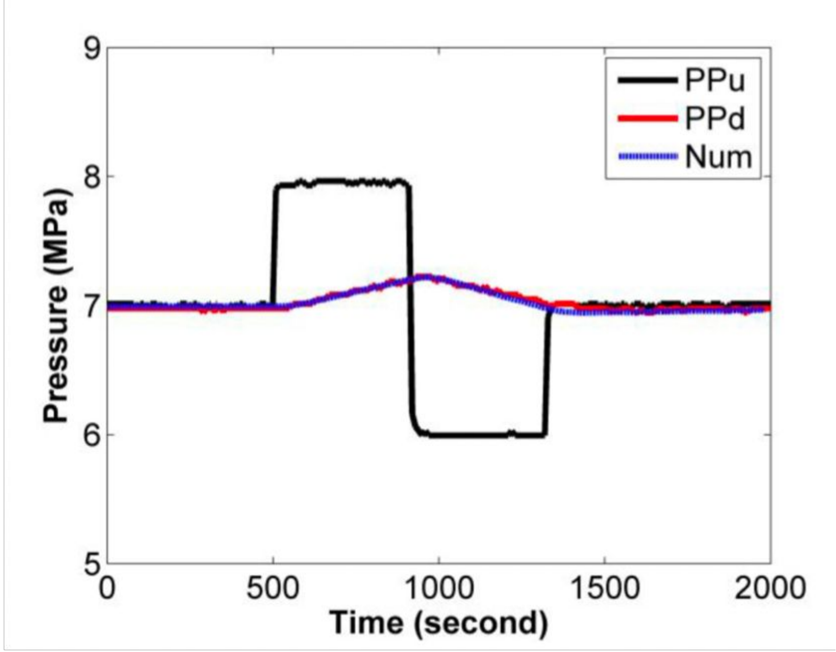
$$\tan\theta = \frac{\gamma}{\theta}$$

$$S = \frac{-\theta^2 k_{1a}}{\beta \phi \eta L^2}$$

Pressure profiles at the upstream and downstream sides during a pressure build-up test

Pressure difference d*P(t)* between the upstream and downstream sides as a function of time in a semi-logarithmic system

Pulse-decay method

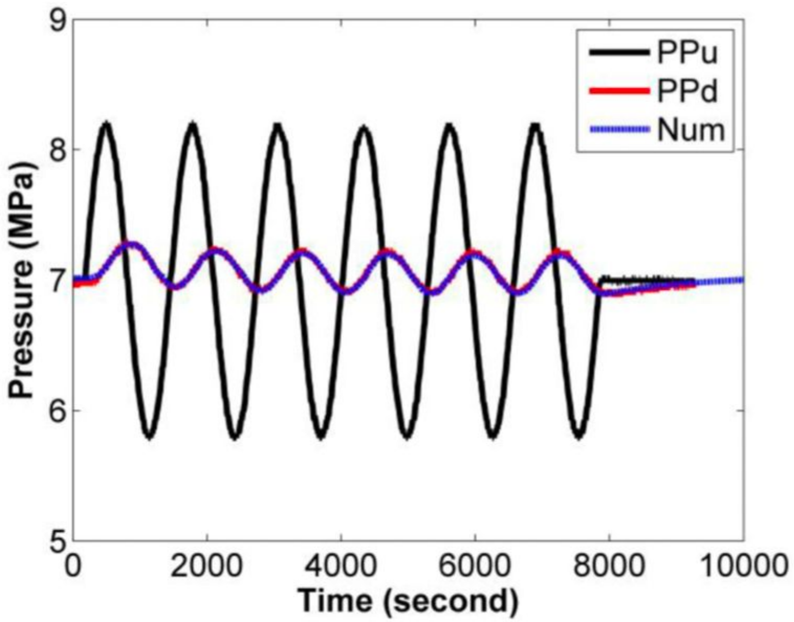


Multi pressure pulse (PPu, black curve) applied at the upstream side of the sample during the pressure pulse decay test. The resultant pressure response at the downstream end (PPd, red curve) is monitored

1) reservoir pressures and the sample pore pressure are initially in equilibrium at a constant value of P_0
2) a small pressure pulse is rapidly applied to the upstream side of the sample
3) the differential pressure enables gas flow
4) recording downstream pressure as a function time
5) numerical solving the equation to measure permeability

$$\Delta P(t) = C_1 \Delta P(0) \exp\left(\frac{-\theta^2 k_{1a} t}{\beta \phi \eta L^2} \right)$$

The oscillating pulse method



Upstream (PPu) and downstream (PPd) pressure profiles during an oscillating sinusoidal pulse test

1) reservoir pressures and the sample pore pressure are initially in equilibrium at a constant value of P_0
2) a small sinusoidal pressure wave with constant amplitude and frequency is generated in the upstream and propagates through a core plug
3) the pressure response at the downstream side is recorded
4) The amplitude attenuation and phase shift between the wave sent at the upstream side and the one recorded at the downstream side is used to calculate the permeability

Low-permeability sandstone

Low-permeability sandstone reservoirs have many different characteristics from conventional reservoirs. They are mainly distributed in the slope and syncline locations in basins without a definite trap boundary or caprock. Their reservoir rocks have low porosity and permeability or super low porosity and permeability (porosity less than 10% and permeability between 10-3 and 10-12 μm2).

In low-permeability sandstone reservoirs, Shanley et al. (2004) illustrated that both wetting and nonwetting phases can be immobile within a certain saturation range referred to as “permeability jail.”

Thanks! c: