PETROPHYSICS

Absolute Permeability

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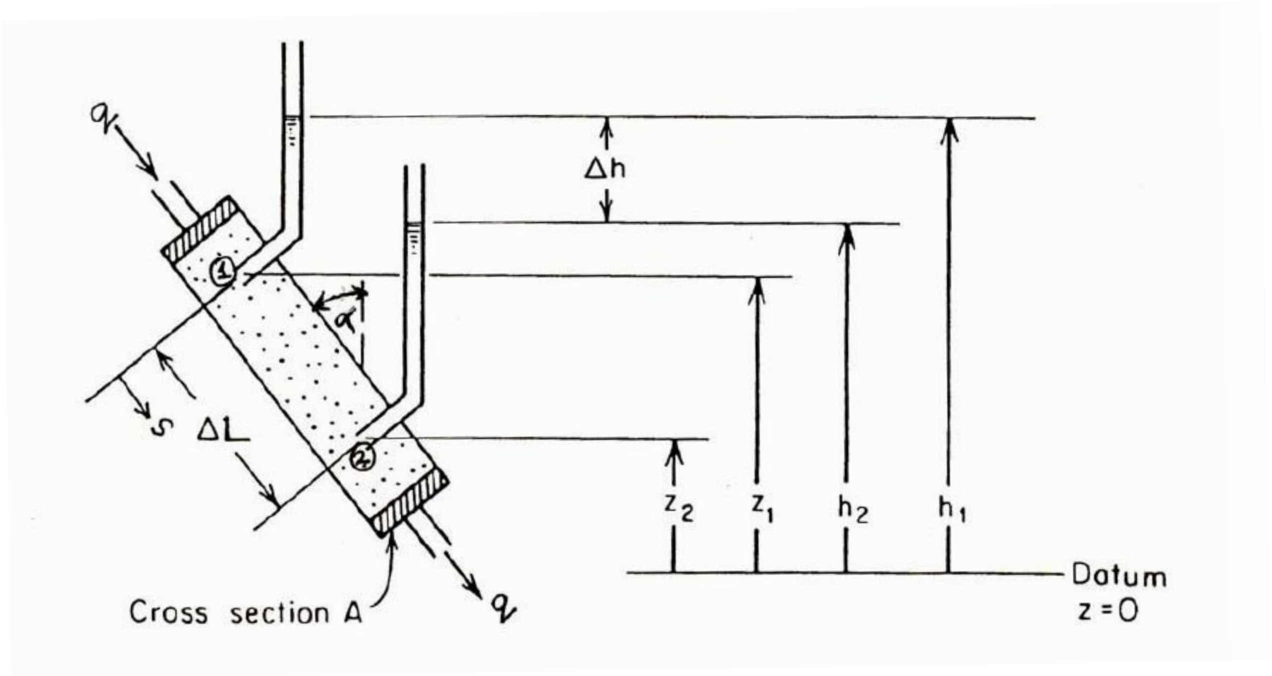
Absolute Permeability

- Definition of Permeability
- Factors affecting Permeability
- Typical Reservoir Permeability Values
- Laboratory Determination of Permeability
  - Steady-State Measurements
  - Unsteady-State Measurements
- Measurement of Transverse Permeability

Permeability Definition

- Permeability is the ability of the rock to flow fluids.



Henry Philibert Gaspard Darcy: *Les fontaines publiques de la ville de Dijon*, 1856

Darcy found:

$$q \propto A$$

$$q \propto \Delta h$$

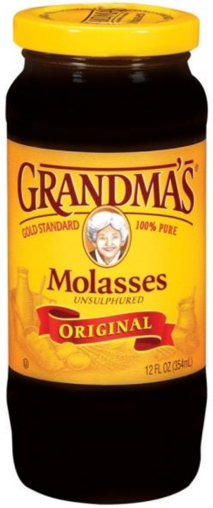
$$q \propto \frac{1}{\Delta L}$$

$$\longrightarrow \boxed{q = -KA\frac{\Delta h}{\Delta L}}$$

Permeability Definition

$$K \propto \frac{1}{\mu}$$

or



or

$$K \propto d^2$$

Keep A, Δh, ΔL constant.
Which has higher q?

or

20wt% brine

$$K \propto \rho g$$

M. King Hubbert: Darcy's law and the field equations of the flow of underground fluids. AIME Petroleum Transactions, 1956.

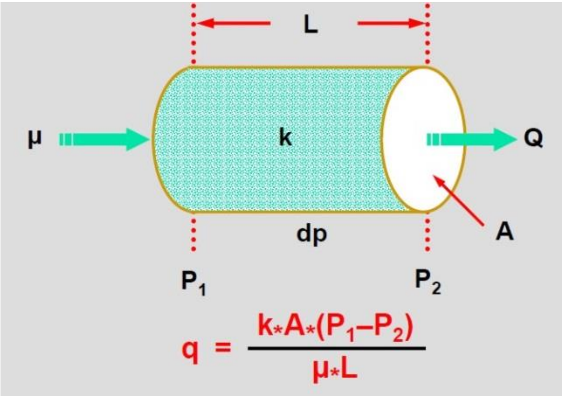
Permeability Units

1 Darcy = the permeability of a medium that permits a flow rate of
1 cm³/s of a fluid of viscosity 1 cp under a pressure gradient of
-1 atm/cm acting on an area of 1 cm².

	SI	Darcy
Pressure	Pa	atm
Viscosity	Pa.s	cp
Flow Rate	m^3/s	cm^3/s
Permeability	m^2	D

$$q = -\frac{kA}{\mu}\frac{dP}{dx}$$

$$1\ \mathrm{Darcy} = 9.869 \times 10^{-9}\mathrm{cm}^2$$



$$[k] = \frac{[q][\mu][L]}{[A]][\Delta P]}$$

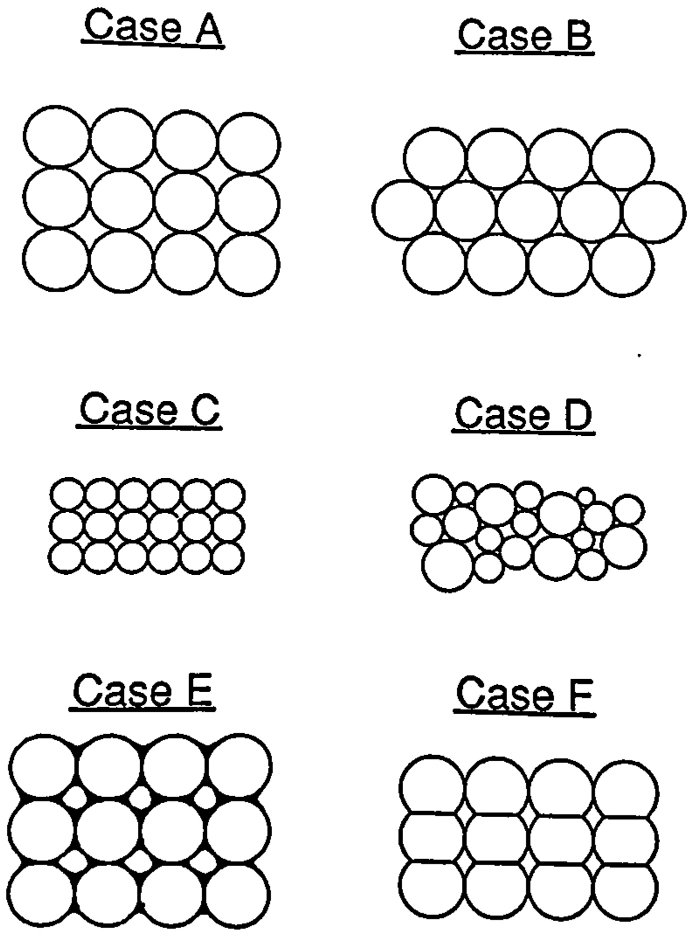
Conversion:
1 Pa = 9.86923267 x 10^{-6} atm
1 Pa.s = 1000 cp
1 m = 100 cm

1 D = [(1 cm^3/s)*(1 cm)*(1 cp)]/[(1 atm)*(1 cm^2)]
= [(10^{-6} m^3/s)*(0.01 m)*(0.001 Pa.s)]/[(101325 Pa)*(0.0001 m^2)]
= 9.86923267 x 10^{-13} m^2

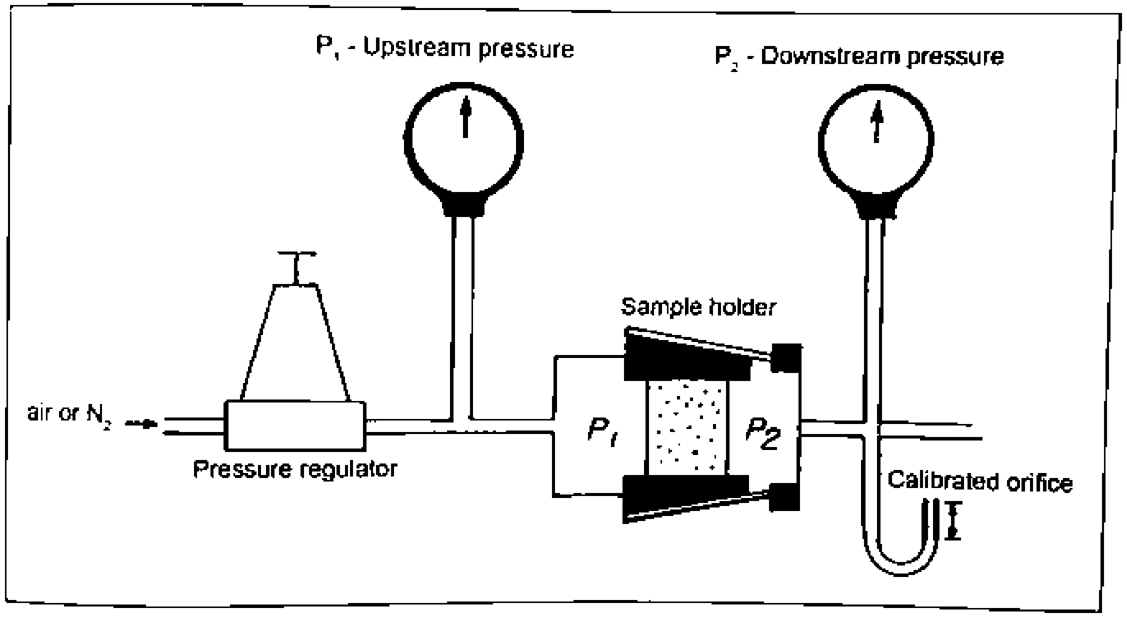
$$\boxed{0.001\ \mathrm{mD} < k < 4000\ \mathrm{mD}}$$

Permeability Affecting Factors

- Pore size: Although porosity is not dependent on grain size, permeability decreases with the decrease in the grain size.
- Compaction: As a result of compaction, the permeability of rocks tends to decrease with depth of burial.
- Sorting
- Cementation
- Layering: permeability changes in different directions of flow.
- Shale swelling



Laboratory Measurements - Klingenberg



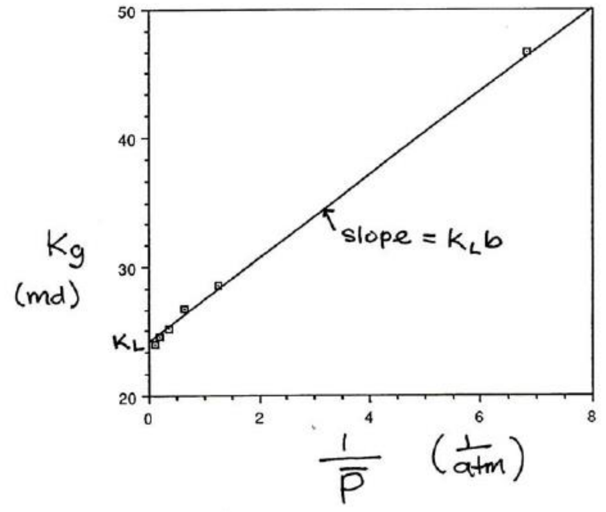
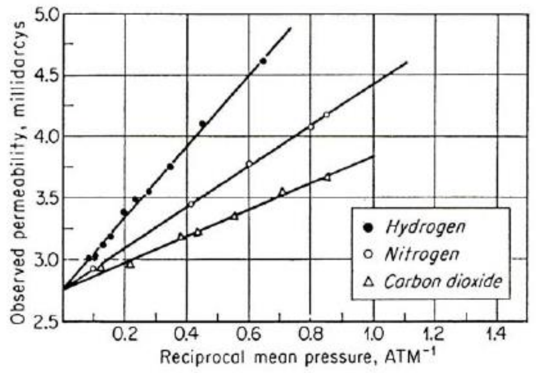
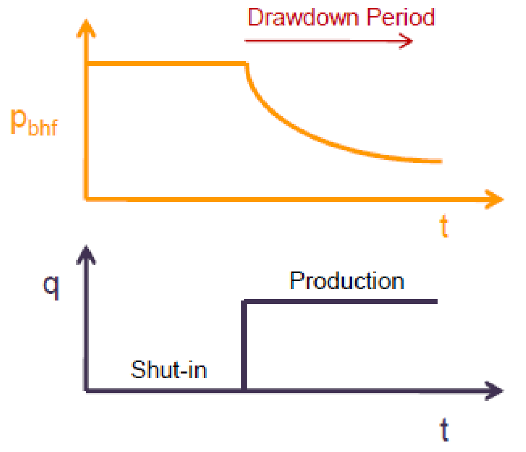


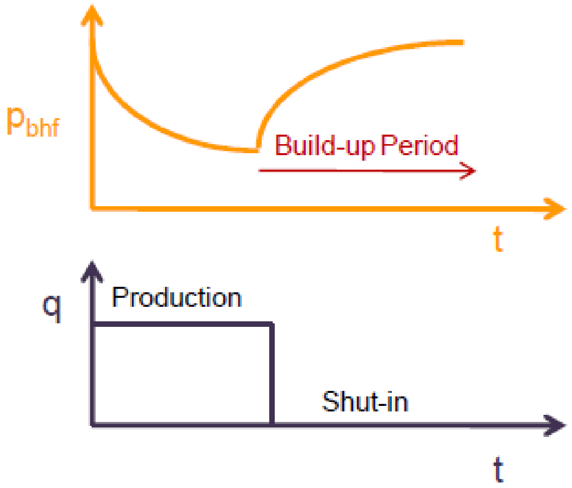
Figure 3.4. Klinkenberg permeability correction.

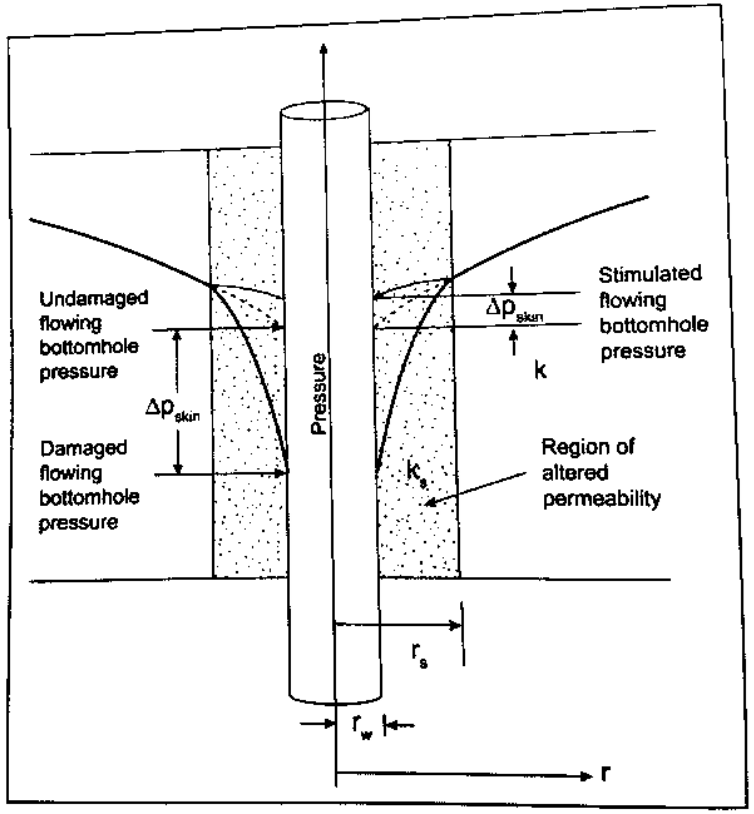


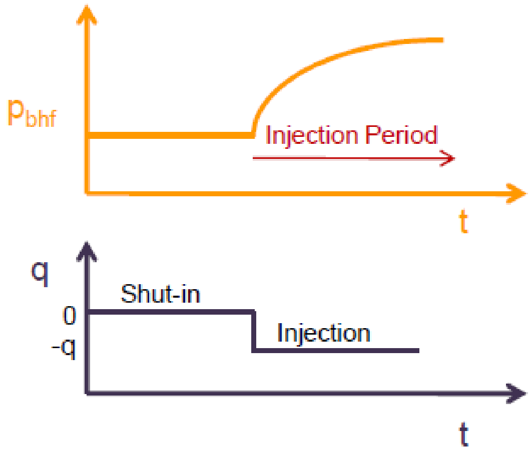
$$k_g = k_L\left(1 + \frac{b}{\bar{P}}\right) \qquad \bar{P} = \frac{P_1 + P_2}{2}$$

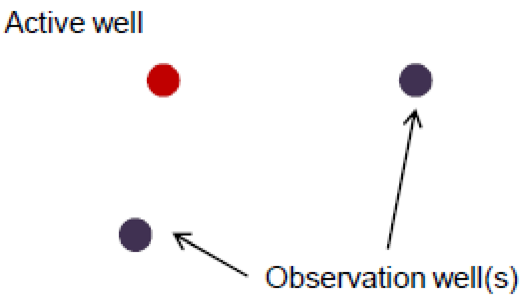
Field Measurements – Well Testing











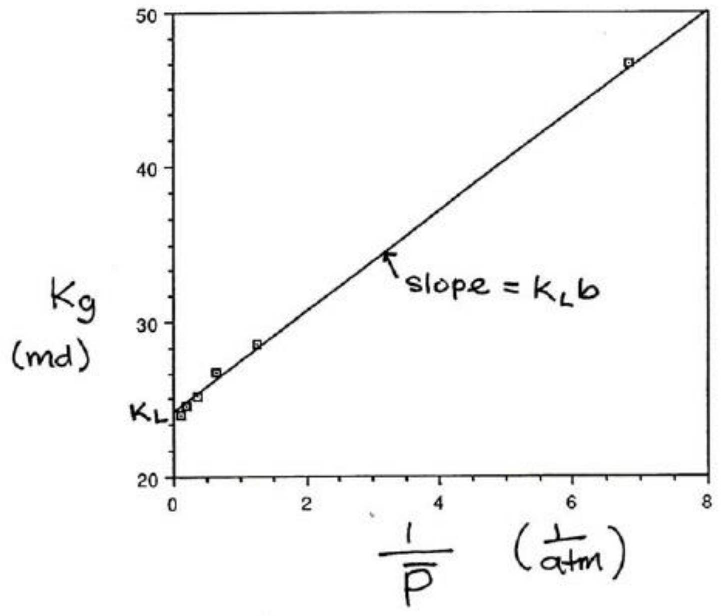


Figure 3.4. Klinkenberg permeability correction.

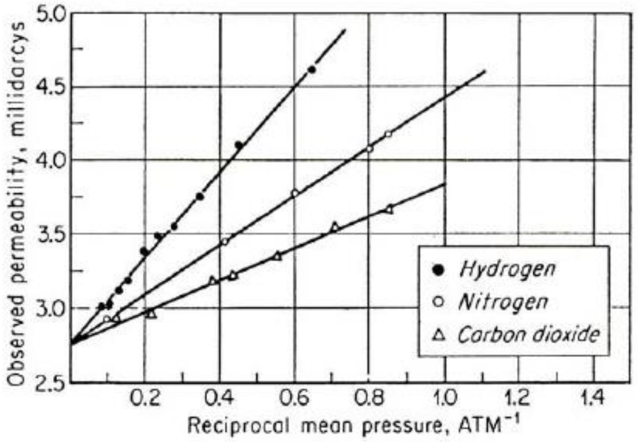
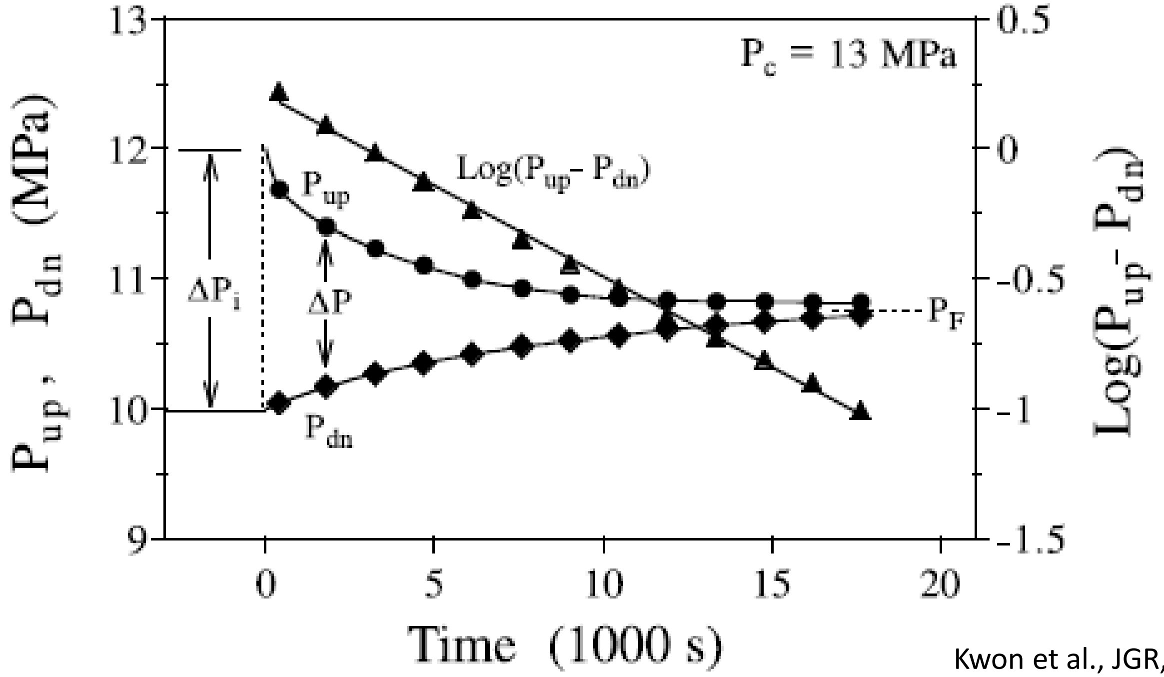


Figure 3.5. Permeability of a core sample to hydrogen, nitrogen and carbon dioxide. Absolute permeability of the core to isooctane = 2.55 md (from Klinkenberg, 1941).

$$k_{app} = k\left(1 + \frac{b}{\overline{P}}\right)$$

$$\overline{P} = \frac{P_1 + P_2}{2}$$



Kwon et al., JGR, 2004

Method of solution:

$$P_{up} - P_{down} = \Delta P_0 \exp\left(-\theta t\right)$$

where

$$\theta = \frac{kA}{\mu\beta L}\left(\frac{1}{V_{up}} + \frac{1}{V_{down}}\right)$$

See also Brace et al., JGR, 1968