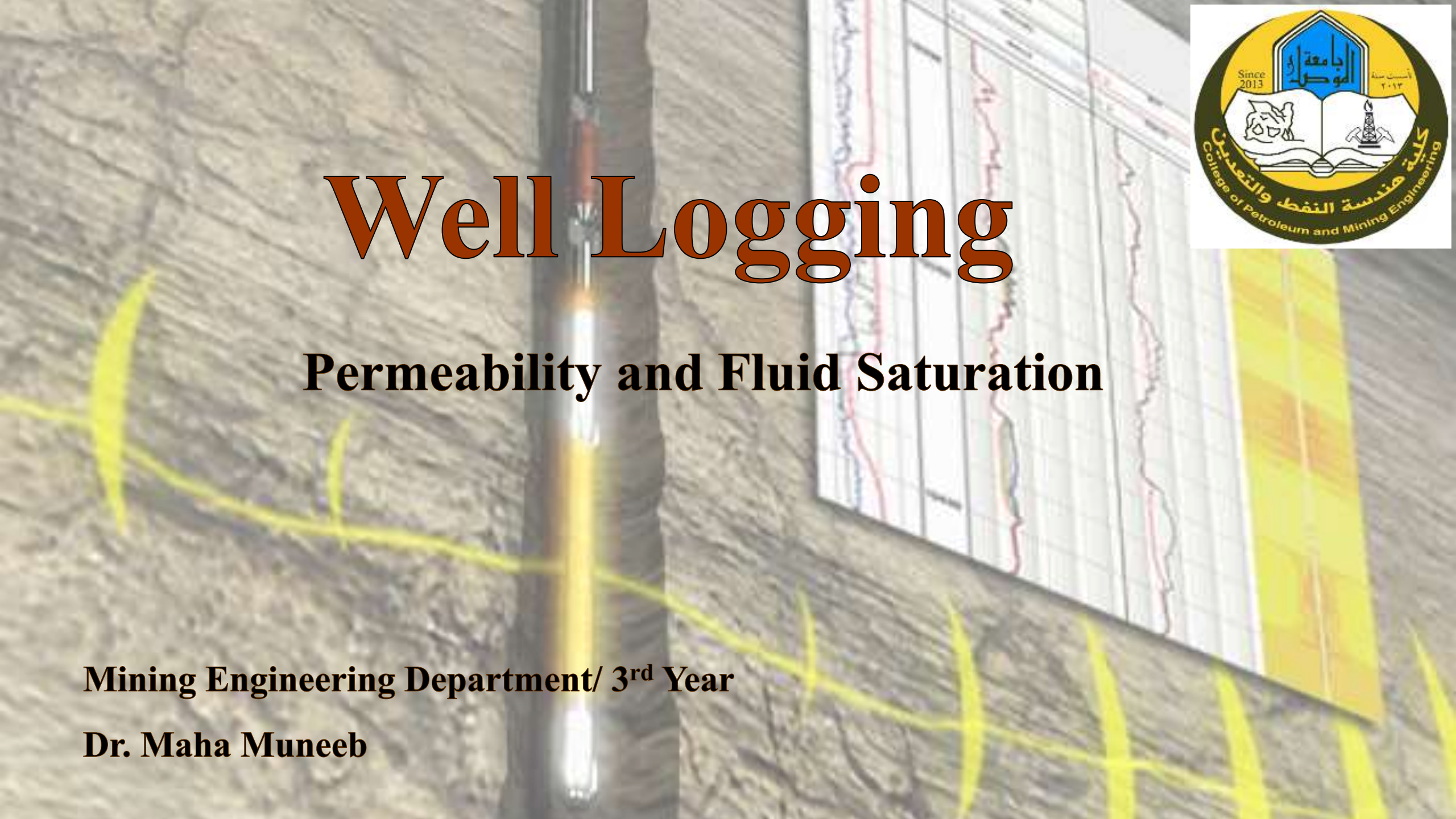


Well Logging

Permeability and Fluid Saturation

Mining Engineering Department/ 3rd Year

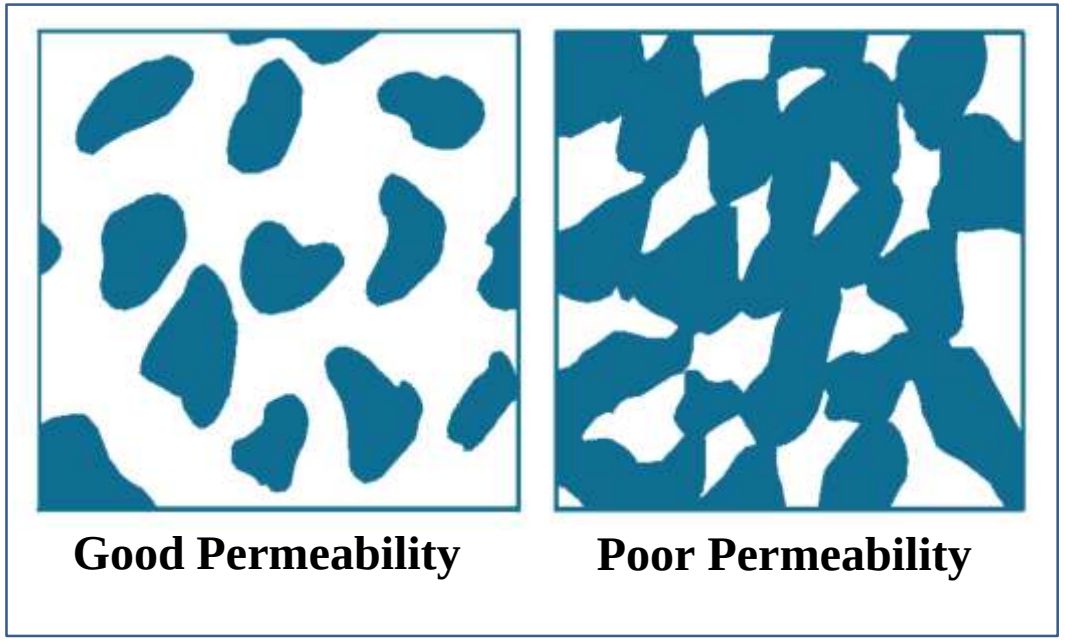
Dr. Maha Muneeb

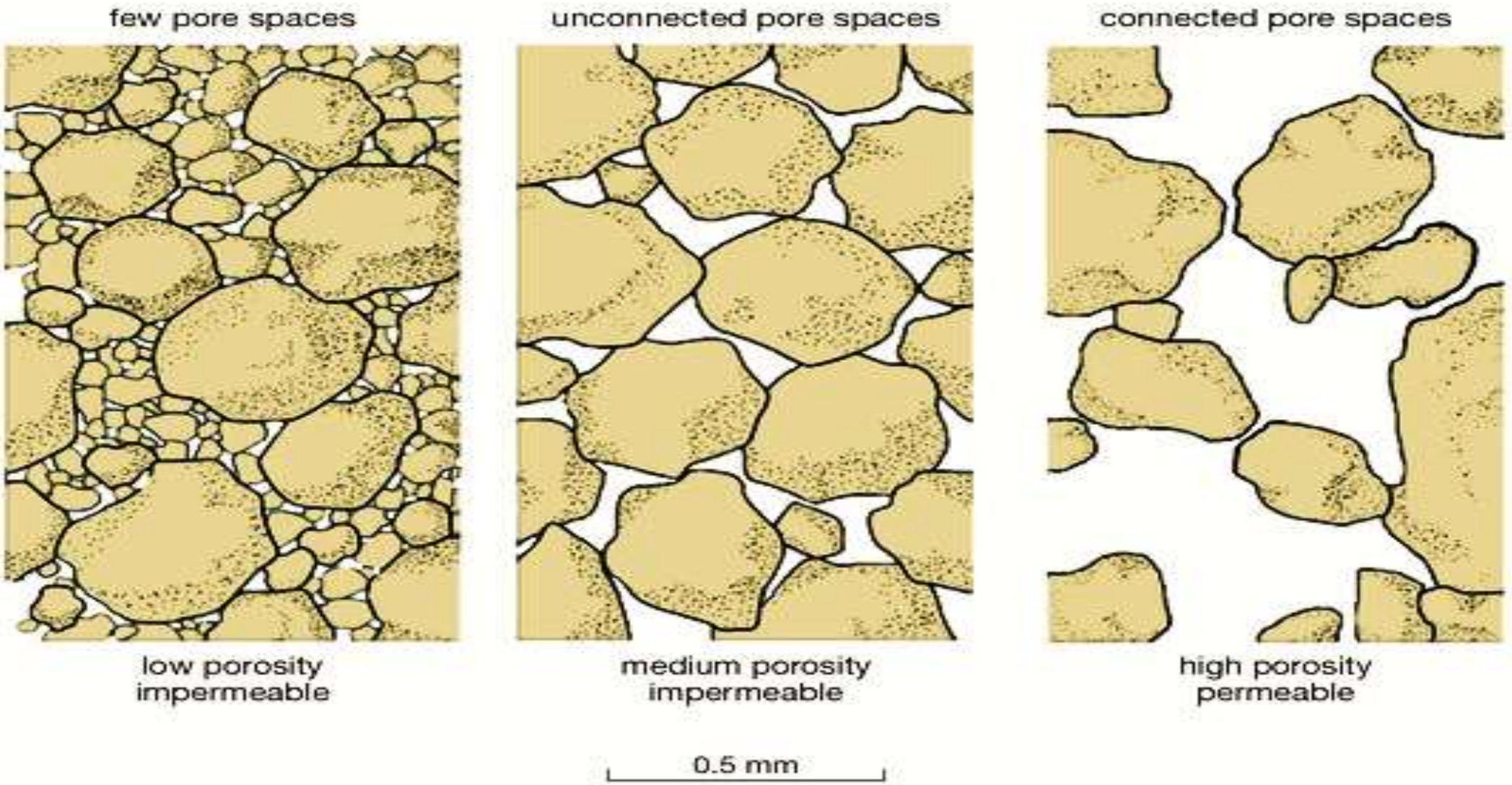
Permeability

Permeability (k): is a measure of the ability of a rock to transmit a fluid. It is depends on:

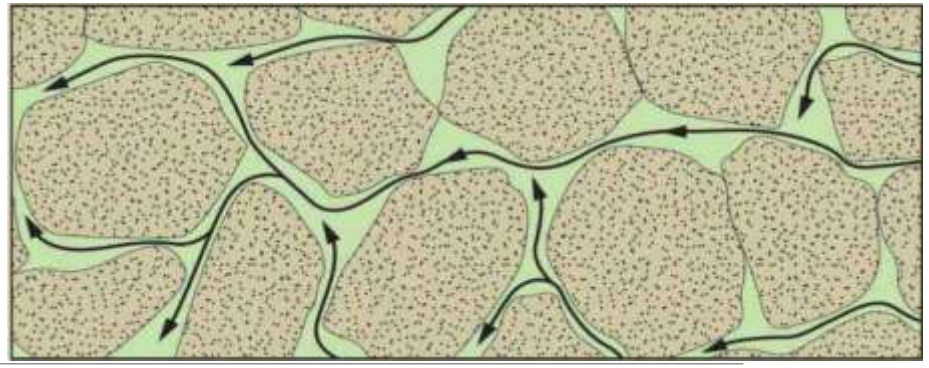
- ✓ ***Interconnected pores with each other***
- ✓ ***The size of the connecting passages***

The unit of permeability is the **darcy**, which is very large; so the thousandth part is generally used**:** ***the millidarcy (mD)***




few pore spaces
unconnected pore spaces
connected pore spaces
low porosity
impermeable
medium porosity
impermeable
high porosity
permeable
0.5 mm

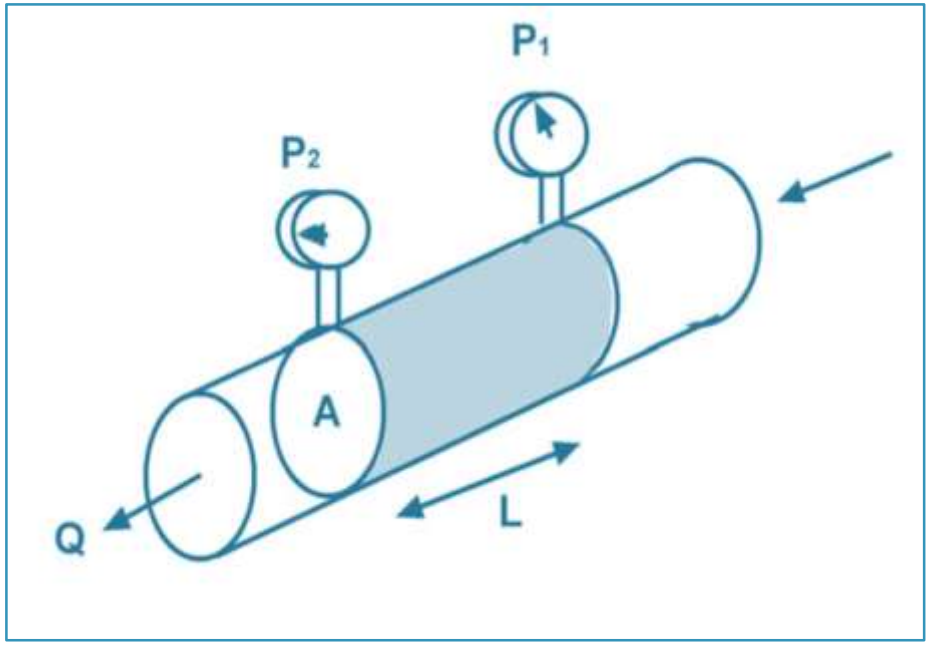
Permeability is expressed by Darcy's Law:



$$Q = A\left(\frac{k}{\mu}\right)\left(\frac{\Delta P}{L}\right) \quad \textbf{So} \quad k = \frac{Q\,\mu\,L}{A\,\Delta P}$$

Where: ***Q*** is rate of flow, ***k*** is permeability, **μ** is fluid viscosity, ***A*** is the cross-sectional area of the sample, Δ***P*** pressure differential, and ***L*** length of sample.

Darcy's Law measured permeability at 100% saturation of a single fluid, such as oil, gas or water, is called the ***Absolute Permeability*** of the rock.



Darcy's parameters for permeability

- ***Effective Permeability***: is flow of one fluid in the presence of another fluid (presence of two fluids in a rock).

- ***Relative Permeability***: is the ratio between effective permeability of a fluid at partial saturation and the permeability at 100% saturation. (**ratio of effective to absolute permeability).**

Permeability Measure Methods

Direct Method

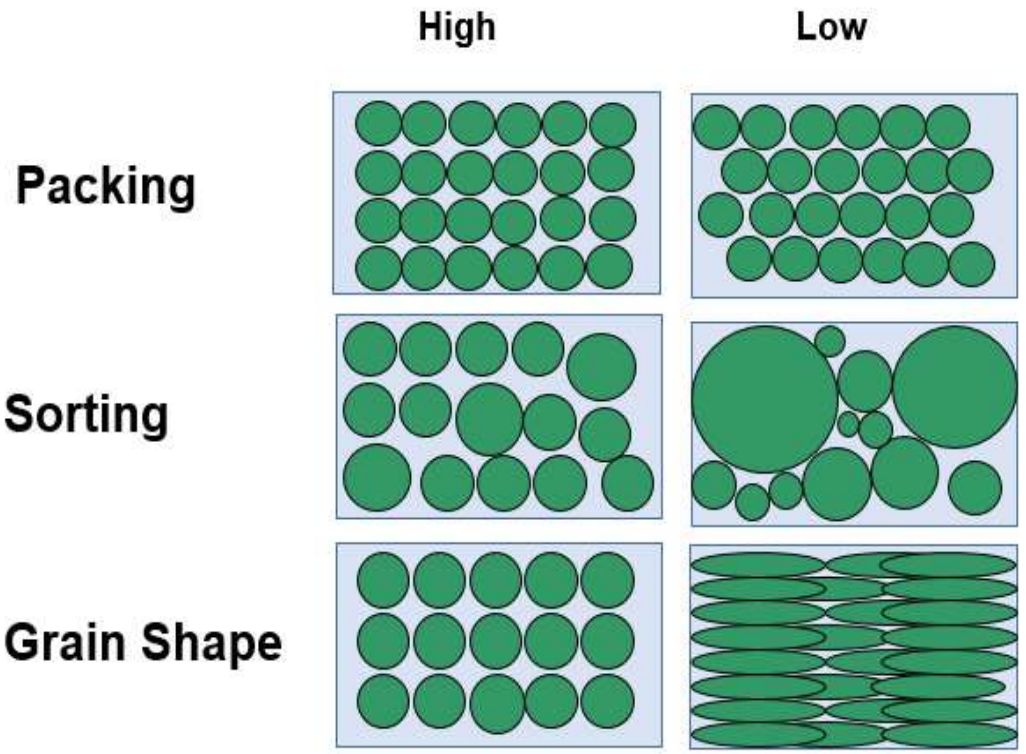
From Core and Plug samples and Well Testing

Indirect Method

Well logs, from Water Saturation and Phi relation

Factors Affect on the Amount of Permeability

- ✓ Effective porosity (connected pores)
- ✓ Pore and grains size
- ✓ Shape of grains
- ✓ Packing of grains
- ✓ Amount, distribution, and type of clays
- ✓ Type and amount of secondary porosity, especially fractures.



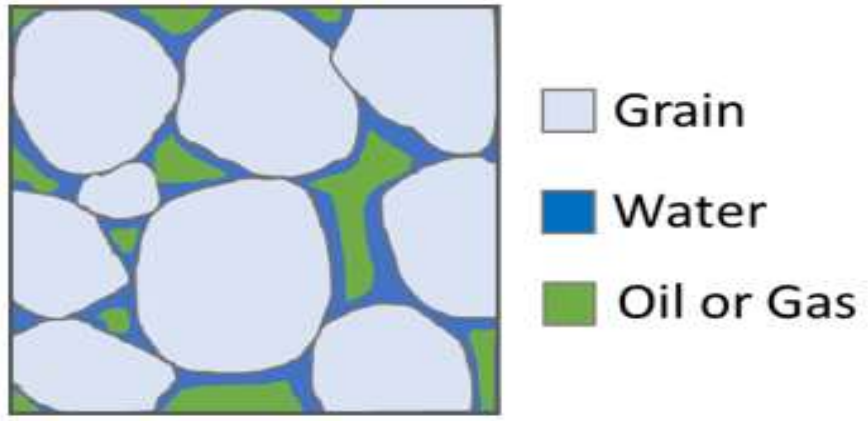
Fluid Saturation

Saturation (S_i): is the volume fraction of a fluid i in a porous rock.

$$\textbf{Fluid Saturation} = \frac{\textbf{total volume of the fluid}}{\textbf{pore volume}}$$

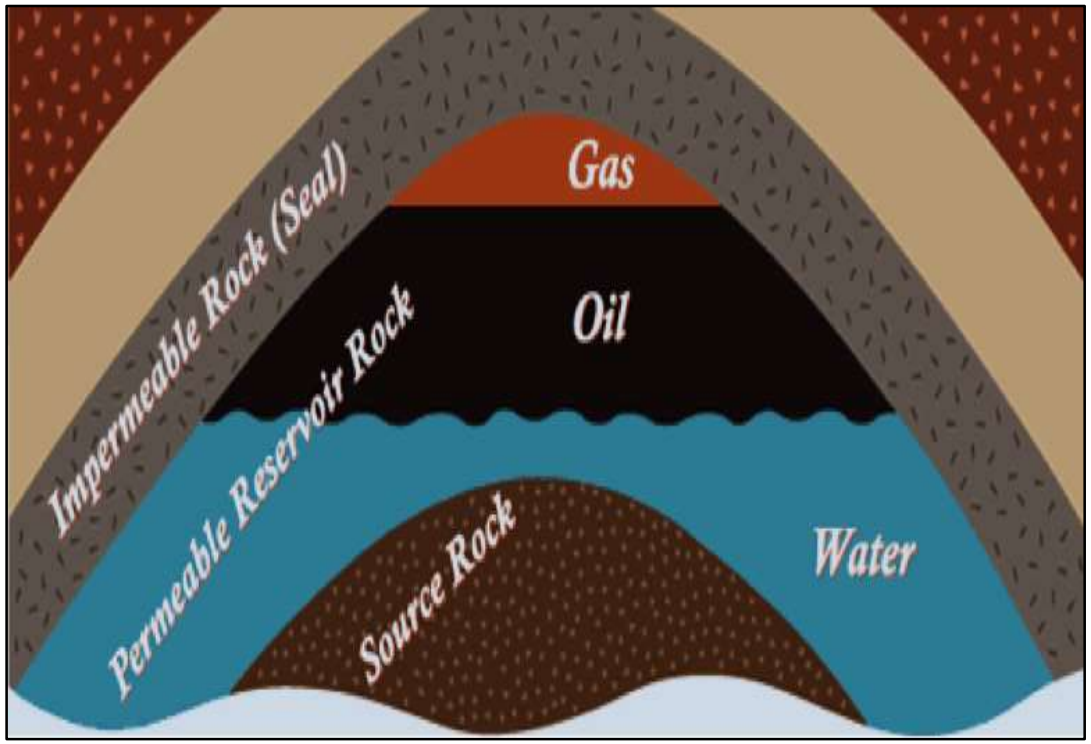
- ***Water Saturation (S_w)***: is the measure of pore volume filled with water. $S_w = \frac{V_w}{V_p}$
- ***Oil or Gas Saturation (S_o or S_g)***: is the fraction of the pore volume that contains oil or gas. $S_o = \frac{V_o}{V_p}$, $S_g = \frac{V_g}{V_p}$

$$S_w + S_o + S_g = 1 \qquad S_h = 1 - S_w$$



The Fluid in the Reservoir

The fluids tend to separate *according to their densities*. If all *three fluids* should be present, the hydrocarbons will tend to migrate upward, with the gas accumulating above the oil and the salt water below the oil.



Saturation Measure Methods

Direct Method

From Core and Plug samples

Indirect Method

Well logs (Resistivity Logs)

Resistivity

The electrical resistivity (R): *is the ability to impede the flow of electrical current through the substance*. The unit used is ohm – m^2/m as illustrate bellow:

$$R = \frac{r\ A}{L}$$

R = resistivity, ohms m^2/m

r = resistance, ohms

A = cross-sectional area, meters/

L = length of material, meters

Resistivity is a basic measurement of a ***reservoir's fluid saturation*** and is function of ***porosity***, ***type of fluid***, and ***type of rock***.

What does the formation's resistivity depended on?

The resistivity of a formation depends on:

- The resistivity of the formation water,
- The amount of water present (Ø, S_w),
- The temperature,
- The distribution of the pores, clay and conductive minerals

Some Concepts In log Interpretation:

- ***Hydrocarbons***, the ***rock***, and ***fresh water*** all act as ***insulators*** and are, therefore ***non-conductive and highly resistive*** to electric flow.
- ***Saltwater*** is ***conductor*** and has a ***low resistivity*** for it contains dissolved salt.

Why Salt Water is Conductor?

The salt water contains ***cations*** (Na^{+},Ca^{++}) and ***anions*** (Cl^{-} , SO_4^{--}). Under the influence of an electrical field ***these ions move***, carrying an electrical current through the solution

Practical Part

1- A brine is used to measure the absolute permeability of a core plug. The rock sample is 4cm long and 3cm2 in cross section. The brine has viscosity (1.0 cp) and is flowing a constant rate (0.5cm3/sec) under (2.0 atm) pressure differential. Calculate the absolute permeability.

2- Core sample has bulk volume (70 cm^3) and matrix volume (50 cm^3). Calculate the **absolute porosity and** estimate **all saturation** of these sample if you knowing it contain water (V_w =7$cm^{3)}$ and oil (V_O = 12 cm^3).


Thank
You!