Tikrit University

The College of Petroleum Processes Engineering

Petroleum and Gas Refining Engineering Department

An Introduction to Petroleum Technology

First Class

Lecture (3)

By

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3-1 Rock properties:

Rock properties are essential for reservoir engineering calculation as they directly affect both the quantity and he distribution of hydrocarbons and when combined with fluid properties. Control the flow of the existing phases (gas, oil, water) within the reservoir.

Rock properties are determined by performing laboratory analysis on cores from the reservoir to be evaluated.

The most important rock properties are porosity, permeability, saturation and capillary pressure.

3-1-1 Porosity Φ:

The rocks fluid storage capacity or is the ability of the rock to store fluids.

Porosity is of two types:

1- Absolute or total porosity (Φa) : is the ratio of all the pore spaces in a rock to the bulk volume.

$$\Phi a = \frac{VP}{Vb} = \frac{pore\ volume}{Bulk\ volume} \quad ..3\text{-}1$$

Pore volume (Vp) = bulk volume – grain volume .. 3-2

2- Effective porosity (Φe) : is the ratio of the interconnected pore spaces in a rock to the bulk volume.

$$\Phi e = \frac{interconnected\ pore\ spaces\ volume}{Bulk\ volume} \quad ..3\text{-}3$$

Not : Only effective porosity contains fluids that can be produced.

0-5% negligible

5-10% poor or low.

10-20% good.

Φe ≥ 20% very good.

3- Residual porosity (Φr) : It is the unconnected (isolated) porosity in which fluids cannot collects.

$$\Phi r = \Phi a - \Phi e \quad ..3\text{-}4$$

3-1-2 Porosity may be classified according to its origin to:

1- Primary porosity (original porosity) : It occurs during the formation of the rock by the sedimentation process.
2- Secondary porosity: is porosity formed within a reservoir after a deposition due to impact: Reservoir fluid activity or tectonic movements.

3-1-3 Factors on which porosity depends:

1- Grain size: as the grain size decrease the porosity of the rock will decrease.
2- Heterogeneity of grain.
3- Degree of Cementation: deposition of cement material such as silt , clay around the rock grains will reduced pore space

between grains will reduced pore space between grains (porosity)

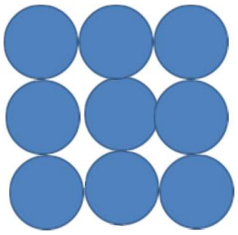
4- Packing of grains.

Packing of grains: It may be regular or it may be irregular.

The highest porosity ratio is when the packing is regular.

The porosity in cubic packing = 48%, prove it?

Cubic packing



Cubic volume = (Length of the side)^3

Length of the side = 2r + 2r + 2r = 6r

V_b (bulk volume) = $(6r)^3$

Since the grain is spherical:

Ball volume = $\frac{4}{3}$ л r^3

V_G (volume of grain) = 27 ($\frac{4}{3}$ лr^3)

Φ = $\frac{Vb-VG}{Vb}$ = $\frac{(6r)^3-(\ 27(\frac{4}{3}\text{л r}^3)}{(6r)^3}$ x 100% = 48%

3-1-4 The methods to determine porosity:

1- Direct method or laboratory measurement or core analysis.
   This method depends on taking a rock core from the formation, and samples are usually taken for some depths of the formation, and not taken for all depths of the formation, because it requires a very high cost.
   This is the best method for calculating porosity and permeability.
   But it is not sufficient alone because the models taken are for some depths and not for all depth of composition.

2- In direct methods : such as:
   - Well logging
   - Well testing.

Type of well logging from which porosity and permeability are calculated:

1- Sonic log: to determine effective porosity.
2- Neutron log: to determine effective porosity.
3- Density log: to determine effective porosity.
4- Resistivity log: to determine water and hydrocarbon saturation.

After calculating the saturation and effective porosity from well logging, the permeability is calculated using the following equation:

$$K=a\ \frac{\Phi e^{b}}{Sw^{c}} \qquad \ldots 3\text{-}5$$

Where:

K: permeability, md

a,b and c constant (given).

Sw : calculate from resistivity log.

Equation (5-4) to calculate the permeability by well logging.

3-1-5 Average of porosity (Φavg):

Reservoir rocks are characterized by the presence of variation in their petrophysical characteristics, whether in the vertical or horizontal direction. The vertical variation is greater than the horizontal one.

The porosity changes greatly in the vertical direction due to compaction.

The porosity average in the reservoir can be calculated in several ways:

1- Arithmetic average :

$$\Phi_{avg} = \frac{\sum_{i=1}^{n} \Phi i}{n} \qquad ..3\text{-}6$$

2- Thickness weighted average :

$$\Phi_{avg} = \frac{\sum_{i=1}^{n} \Phi i \; hi}{\sum_{i=1}^{n} hi} \qquad ..3\text{-}7$$

3- Areal weighted average :

$$\Phi_{avg} = \frac{\sum_{i=1}^{n} \Phi i \, Ai}{\sum_{i=1}^{n} Ai} \qquad ..3\text{-}8$$

4- Volumetric weighted average :

$$\Phi_{avg} = \frac{\sum_{i=1}^{n} \Phi i \, Vi}{\sum_{i=1}^{n} Vi} \qquad ..3\text{-}9$$

Where :

n: total number of samples.

Φi: porosity of the sample (i)

hi: thickness of the sample (i)

Ai: area of the sample (i)

Vi: volume of the sample (i)

Note : The most accurate method is: volumetric weighted then Areal weighted and The least accurate Arithmetic average.