2. Reservoir Engineering

- Reservoir engineering explores the engineering operations for developing and production of oil and gas reservoirs. It involves analyzing the production behavior of oil and gas wells.
- In petroleum engineering, a reservoir is the place where the hydrocarbon resides.
- Our job as petroleum engineering is to access reservoirs and extract the hydrocarbons in an economical and environmentally safe manner.

2.1. Types of Petroleum Reservoirs

- Petroleum reservoirs are generally classified according to their **geologic structure** and their **production (drive) mechanism**.
- Petroleum reservoirs are broadly classified as **oil** or **gas** reservoirs. These broad classifications are further subdivided depending on:
  - The composition of the reservoir hydrocarbon mixture.
  - Initial reservoir pressure and temperature.
  - Pressure and temperature of the surface production.
- Reservoirs can be classified as:

1. **Oil reservoirs**: If the reservoir temperature is less than the critical temperature (T_c) of the reservoir fluid, the reservoir is classified as an oil reservoir.
2. **Gas reservoirs**: If the reservoir temperature is greater than the critical temperature of the hydrocarbon fluid, the reservoir is considered a gas reservoir.

- Reservoirs can be classified Depending upon **initial reservoir pressure** oil into the following categories:

1. **Undersaturated oil reservoir**. If the initial reservoir pressure is greater than the bubble-point pressure p_b of the reservoir fluid, the reservoir is labeled an under saturated.
2. **Saturated oil reservoir**. When the initial reservoir pressure is equal to the bubble-point pressure of the reservoir fluid, the reservoir is called a saturated oil reservoir.

3. **Gas-cap reservoir**. If the initial reservoir pressure is below the bubble point pressure of the reservoir fluid. the reservoir is termed a gas-cap or two-phase reservoir, in which the gas or vapor phase is underlain by an oil phase.

❖ **For Gas Reservoirs** natural gases can be classified into four categories.

1. Retrograde gas-condensate

2. Wet gas

3. Dry gas

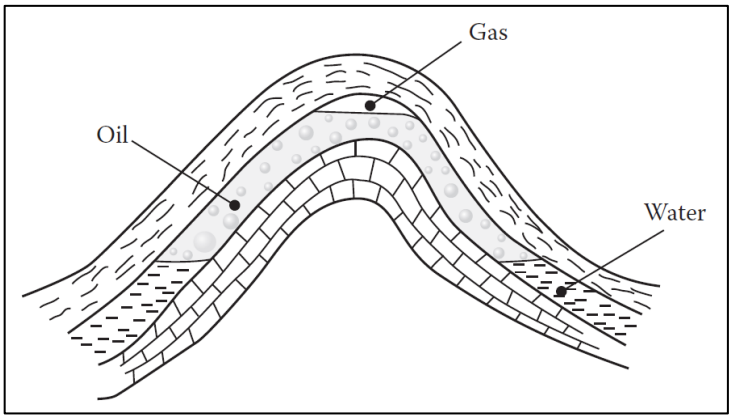
Important definition

1. **The gas solubility (Rs):** is defined as the number of standard cubic feet of gas that will dissolve in one stock-tank barrel of crude oil at certain pressure and temperature
2. **The bubble-point pressure**: is defined as the highest pressure at which a bubble of gas is first liberated from the oil.
3. **Critical point**: The critical point for a multicomponent mixture is referred to as the state of pressure and temperature at which all intensive properties of the gas and liquid phases are equal.

2.1.1. Geologic Classification of Petroleum Reservoirs

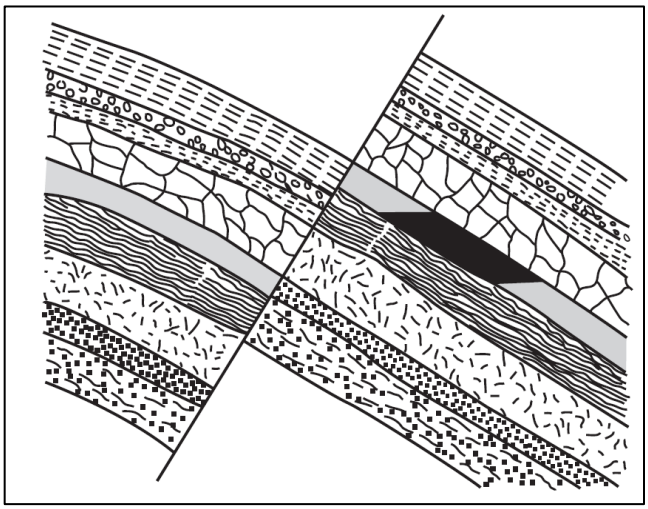
Petroleum reservoirs exist in many different sizes and shapes of geologic structures.

1. Dome-shaped and anticline reservoirs: These reservoirs are formed by the folding of the rock layers as shown in Figure below. The dome is circular in outline, and the anticline is long and narrow.



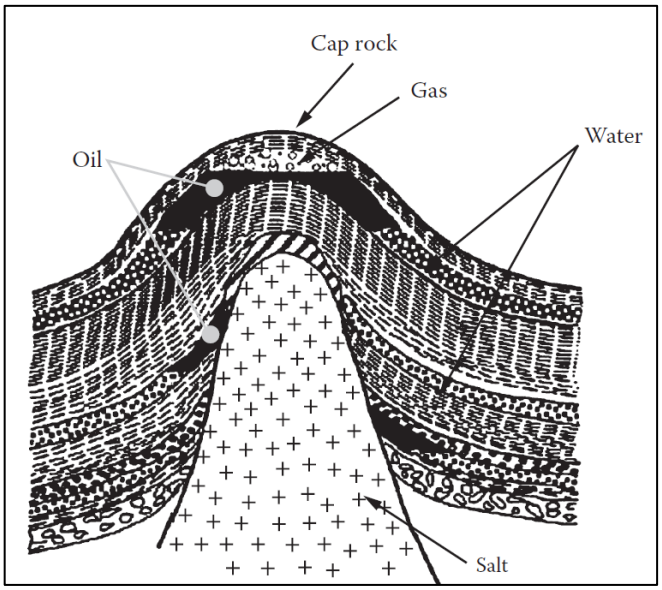
A reservoir formed by folding of rock layers.

2. Faulted reservoirs: These reservoirs are formed by shearing and offsetting of the strata (faulting), as shown in Figure below.



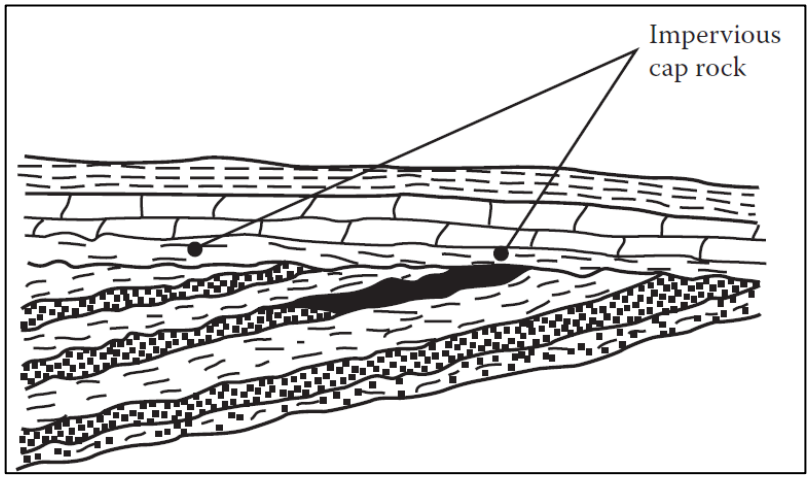
A cross section of faulted reservoir

3. Salt-dome reservoirs: This type of reservoir structure, which takes the shape of a dome as shown in Figure below.



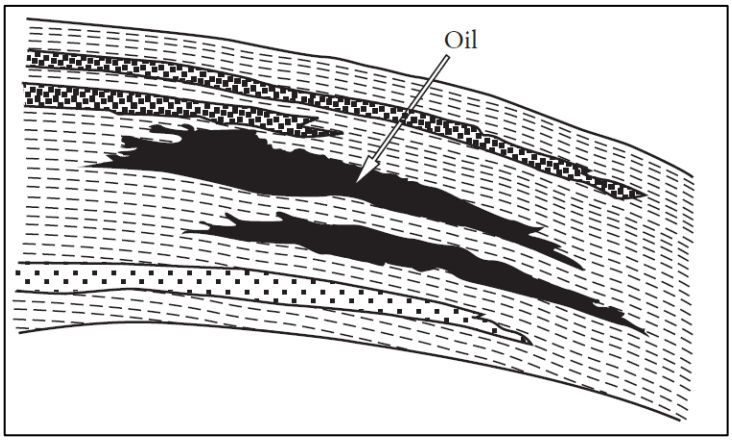
Section in a salt dome reservoir

4. Unconformities: This type of reservoir structure, shown in Figure below.



A reservoir formed by unconformity

5. Lense-type reservoirs: An example of this type of reservoir is shown in Figure below.



An example of a sandstone lense- type reservoir

6. Combination reservoirs: In this case, combinations of folding, faulting, abrupt changes in porosity, or other conditions create the trap from this common type of reservoir.

2.1.2. Classification of Petroleum Reservoirs according to Reservoir Drive Mechanisms

The reservoir drive is the energy that moves crude oil and natural gas from subsurface rock to the production well. Types of reservoir drive mechanism.

1. **Natural drive mechanisms**. Hydrocarbons produced by reservoir original drive energy are referred to as primary production.
2. **Dissolved gas drive**: Natural gas is dissolved with oil in its liquid state under high reservoir pressures, and when production begins from the reservoir through the production well; The reservoir pressure begins to decrease, which leads to the expansion of the dissolved gas and pushes the oil into the production well. Recovery factor (recovery efficiency) reach to 30%.
3. **Gas cup drive**: Due to the lightness of the gas density relative to the oil, it separates and accumulates in the upper region of the reservoir. With the start of production, the pressure decreases, and the gas expands in the gas cap, leading to pushing the oil towards the production well. Recovery efficiency reach to 40%.
4. **Water drive**: Because water is heavier than oil and gas, it collects in the lower region of the reservoir, and with the start of production, the reservoir pressure decreases, so the water

pushes the oil from the bottom to the top and the water tries to occupy the place of the oil produced in the porous medium. Recovery efficiency reaches to (35% - 60 %).

5. **Combination drive**: It combines two or more types of drive mechanisms. Recovery efficiency reaches to 20% - 65 %.

2.2. Distribution of hydrocarbons

In general, there are two forces affecting the distribution of hydrocarbon in the porous rocks of the reservoir, which are:

1. **Gravity force (gravitational):** this force causes the less dense (light) fluids to seek the higher positions in the trap. The gravity force makes water run downhill.
2. **Capillary force:** tends to make a wetting fluid to rise into pore space containing a non-wetting fluid. Capillary tends to counteract the force of gravity in segregating the fluid.

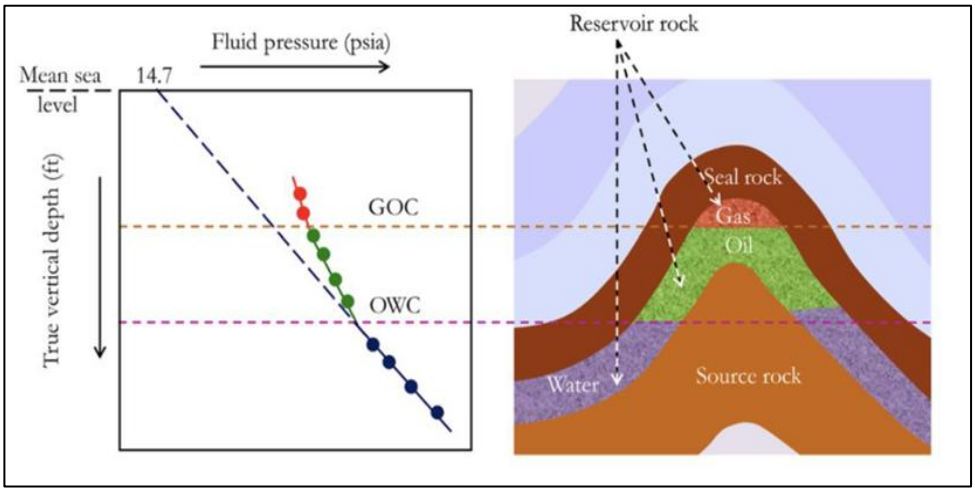
Note:

- In general water is wetting fluid with respect to oil and gas.
- Before oil production, an equilibrium exists between the capillary and gravitational forces.

Oil water contact: The contact surface between water and oil. The deepest level of oil production.

Gas oil contact: The contact surface between gas and oil. Lowest level of oil production.

It is necessary to determine these two surfaces accurately before calculating the oil and natural gas reserves in the reservoir and estimating the production rate.

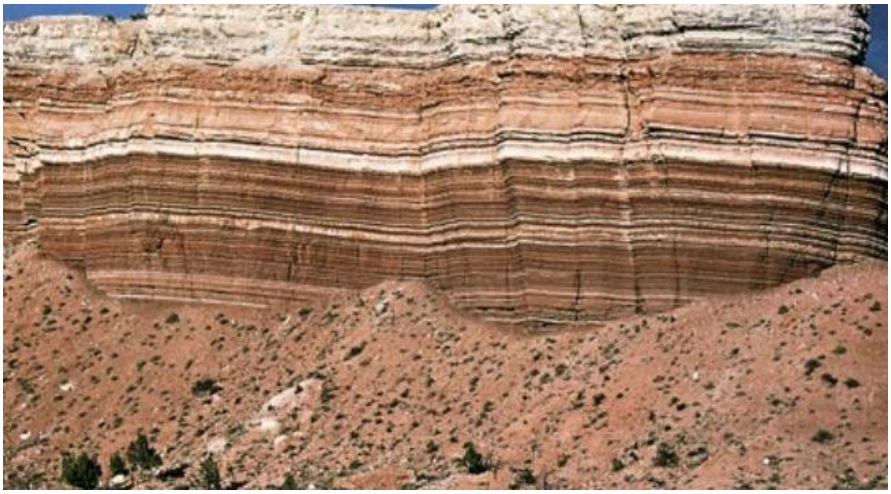


2.3. Reservoir rocks

- Rocks are divided into three main types; **Igneous rocks**, **Sedimentary rocks**, and **Metamorphic rocks**.
- There is a relationship between these types of rocks, as rocks are transformed from one species to another as a result of the continuous physical and chemical processes in nature such as weathering, erosion, pressure, heat and melting.

1. **Igneous rocks.**

Sedimentary rocks: They are originally Igneous rocks, but under the weathering, and erosion they turned into sedimentary rocks. The hydrocarbons are found only in sedimentary rocks.



2. **Metamorphic rocks:** originally sedimentary rocks, have been transformed under the influence of pressure and heat factors over time.

2.3.1. properties of sedimentary rocks

The most important properties of sedimentary rocks:

1. Stratification, they exist in nature in the form of successive layers according to the time of their formation, and these layers differ in color, thickness and composition.
2. Sedimentary rocks usually contain the remains of organisms.
3. Sedimentary rocks are characterized by the pores between the grains that make them up, so they are considered natural reservoirs for groundwater and natural gas.
4. Sedimentary rocks can resist weathering to a lesser extent than igneous rocks.