Lecture one: Hydrocarbon Traps

1.1. Introduction to Reservoir engineering:

Reservoir engineering is the application of engineering principles for evaluating and managing reservoirs. The primary functions of reservoir engineering are the estimation of hydrocarbons in place, the calculation of a recovery factor and the attachment of a time scale to the recovery.

The accuracy of the determination of oil in place depends largely on the accuracy of calculating the petrophysical properties of the reservoir and the properties of the reservoir fluids.

Reservoir engineer responsibilities:

Reservoir Engineering covers a large range of complex functions critical to petroleum industry including:

- Using advanced numerical simulation techniques to forecast oil and gas production from both new and existing hydrocarbon fields
- Collaborating with other technical professionals in design economically viable development plans for oil and gas accumulations
- Optimizing recovery plans, including new well locations or projects involving enhanced recovery methods
- Managing the day-to-day operation of oil and gas fields
- Developing and executing data-gathering plans and using the results to develop projects to increase recovery efficiency

1.2. Rock Classification

Rocks are broadly classified into three groups:

1. Igneous.

Igneous rocks comprise 95% of the earth's crust. They originate from the solidification of molten material emanating from below the earth's surface.

2. Sedimentary.

Sedimentary rocks are formed from the materials of older up-lifted formations which have broken down by erosion and transported by the elements to lower elevations where they are deposited. Consolidation of sands, silts, pebbles and clays by pressure of many thousands of feet of overlying sediments, and cementation by precipitates from percolating waters act to convert these materials into sandstones, siltstones and conglomerates.

Sedimentary rocks are classified into two groups;

- Clastic (the rocks of detrital origin or debris from older rocks) such as sandstone, siltstone and shales.
- Non-clastic (rocks of biochemical or chemical precipitate origin) such as limestone, dolomite and clays.

Clastic Rock - Formed From Debris of Older

Rock Type	Particular	Diameter
Conglomerate	Pebbles	- 2 to 64 mm
Sandstone	Sand	- 0.06 to 2 mm
Siltstone	Silt	- 0.003 to 0.06
Shale	Clay	- Less than 0.00

Fig. 1-1a Sedimentary rock classification.

Nonclastic - Mostly of Chemical or Biochemica

Rock Type	Composition	
Limestone	Calcite	- $CaCO_3$
Dolomite	Dolomite	- $CaMg(CO_3)_2$
Salt	Halite	- NaCI
Gypsum	Gypsum	- $CaSO_4.2H_2O$
Chert	Silica	- SiO_2
Coal	Chiefly Carbon	

Fig. 1-1b Sedimentary rock classification.

3. Metamorphic.

Metamorphic rocks are formed from other sedimentary deposits by alteration under great heat and/or pressure. Examples of metamorphic rocks are;

- Marble - metamorphosized limestone.
- Hornfeld - converted from shale or tuff.
- Gneiss - similar to granite but metamorphically consolidated.

Oil and gas are not usually found in igneous or metamorphic rocks as both are so non-porous that hydrocarbons cannot accumulate or be extracted from them. The few exceptions are when hydrocarbons have seeped from near-by sedimentary formations through cracks and fractures.

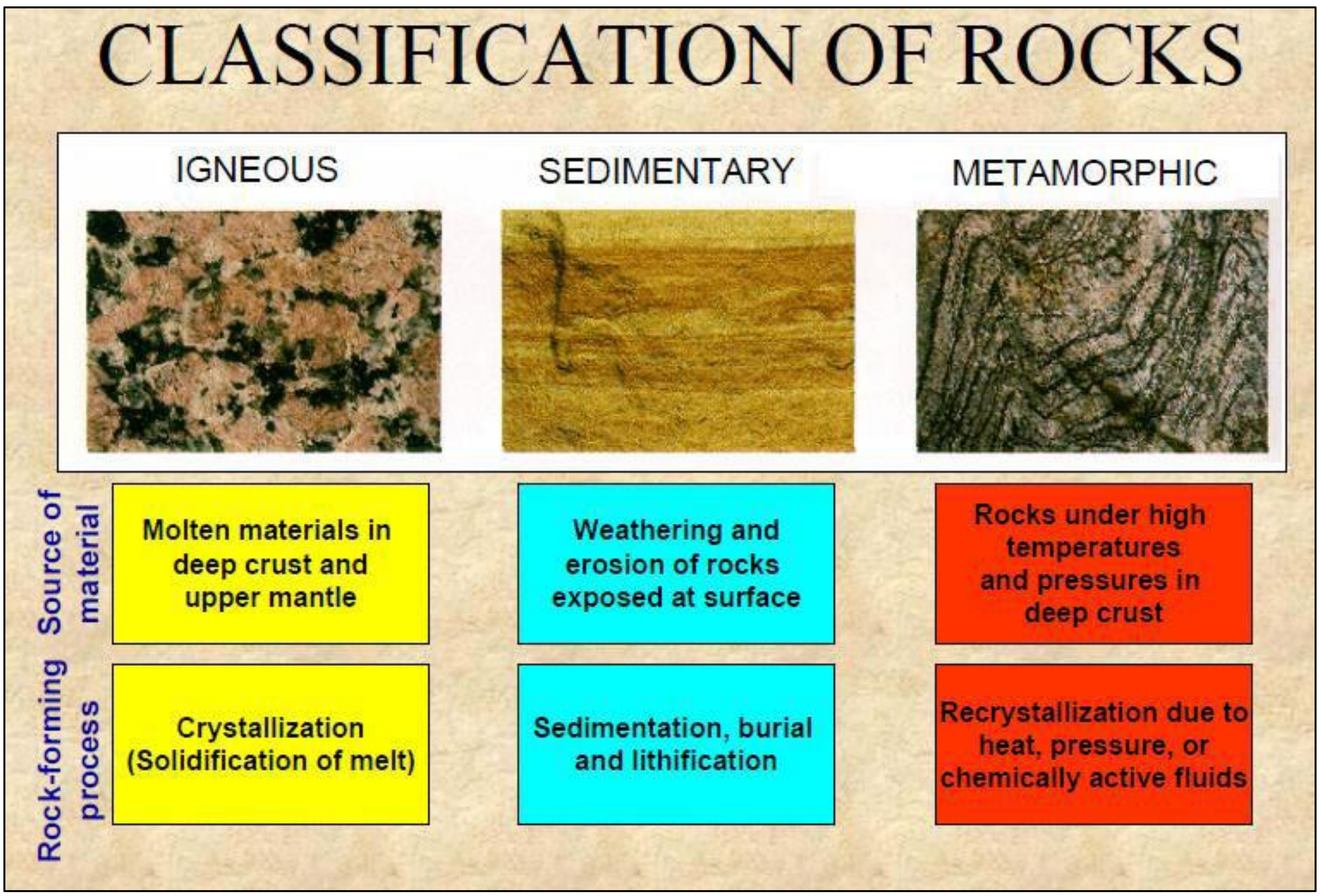

Fig. 1-2 Classification of rocks.

1.3. Hydrocarbon Accumulations

Petroleum deposits will be found only in those areas where geological conditions combine to form and trap them. Hydrocarbons, being less dense than water, migrate upwards from the source beds until they escape at surface or an impervious barrier is encountered. The principle classifications of petroleum reservoir forming traps are as follows.

To form a commercial reservoir of hydrocarbons, a geological formation must possess three essential characteristics;

1. Sufficient void space to contain hydrocarbons (porosity).

2. Adequate connectivity of these pore spaces to allow transportation over large distances (permeability).

3. A capacity to trap sufficient quantities of hydrocarbon to prevent upward migration from the source beds.

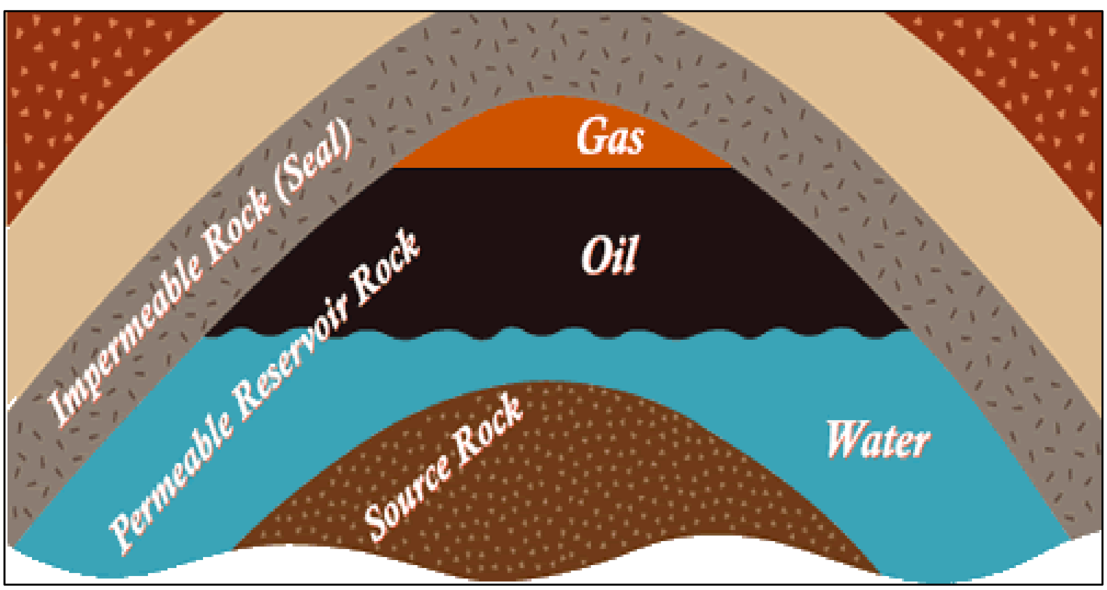

Fig. 1-3 Accumulation of oil and gas into a reservoir.

Hydrocarbon Traps Types

1.3.1. Structural traps

Structural traps are caused by structural features. They are usually formed as a result of tectonics.

1- Domes and Anticlines

Domes and anticlines are formed by uplifting and folding of the strata. When viewed from above the dome is circular in shape, whereas the anticline is an elongated fold. Oil and gas migrate upward from source beds until trapped by the impermeable cap rock.

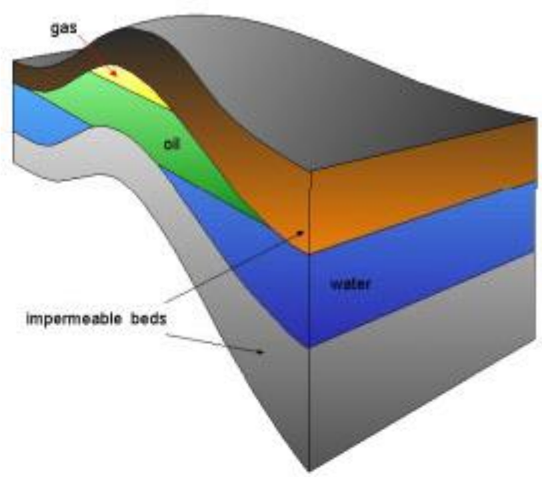

Fig. 1-4a Dome structure.

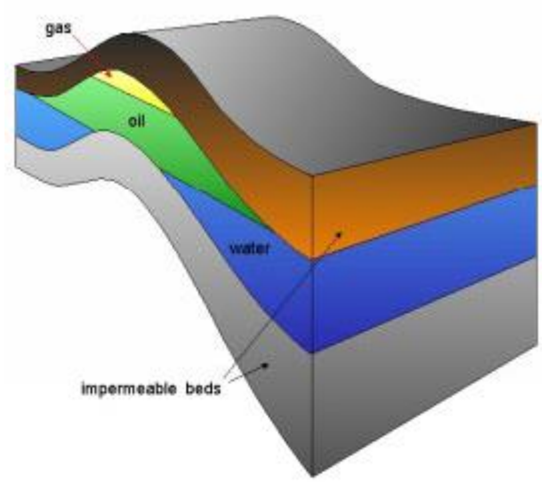

Fig. 1-4b Oil and gas accumulation in an anticline.

2- Salt Domes and Plug Structures

This commonly occurring geological structure is caused by the intrusion from below of a salt mass or volcanic material. In pushing or piercing through the overlying strata, the intrusion may cause the formation of numerous traps in which petroleum may accumulate.

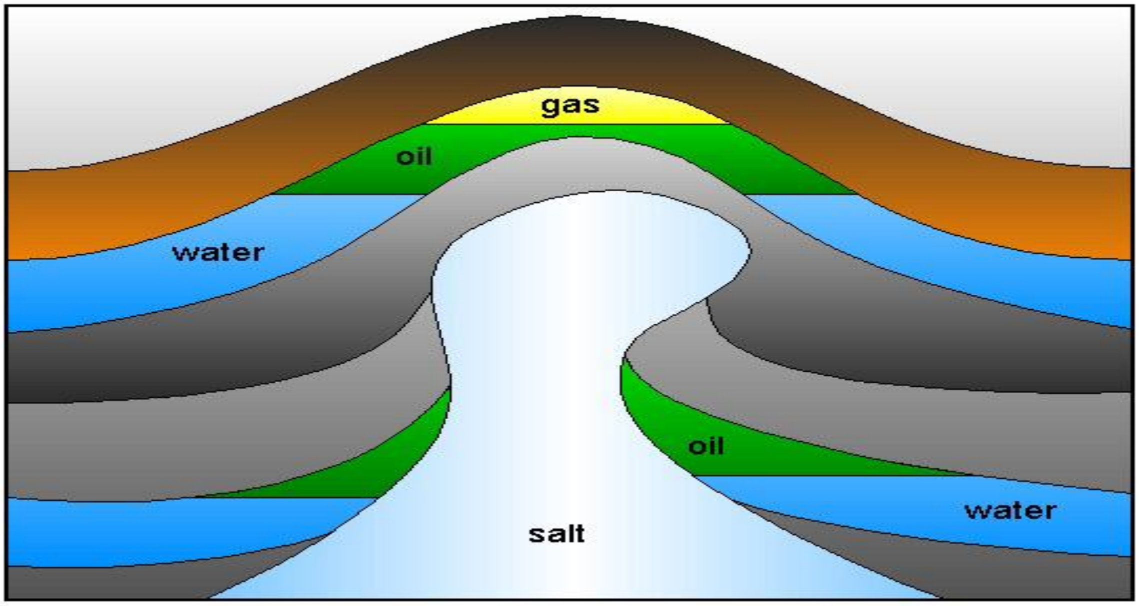

Fig. 1-5 Hydrocarbon accumulation associated with a piercement salt dome

3- Faults

Reservoirs may be formed along the fault plane where the shearing action has caused an impermeable bed to block the migration of oil and gas through a permeable bed.

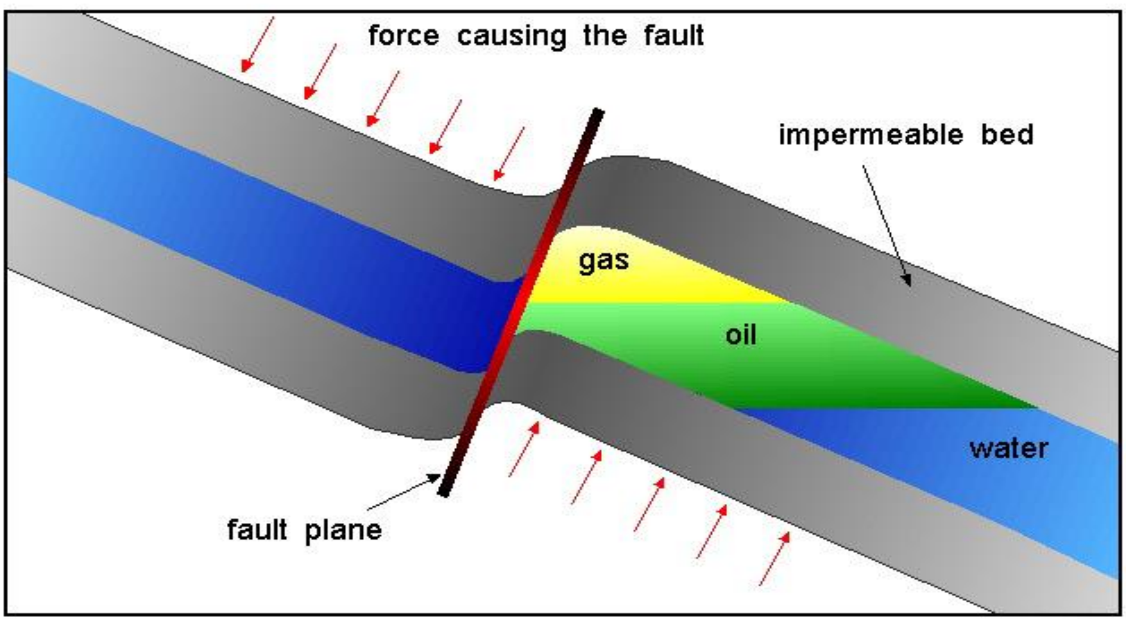

Fig. 1-6 Trap formed by a fault.

1.3.2. Stratigraphic traps

Stratigraphic hydrocarbon traps occur where reservoir facies pinch into impervious rock such as shale, or where they have been truncated by erosion and capped by impervious layers above an unconformity.

1- Unconformity

This type of structure can be formed where more recent beds cover older, inclined formations that have been planned off by erosion. A reservoir may be formed where oil and gas is trapped by an impermeable overlying layer.

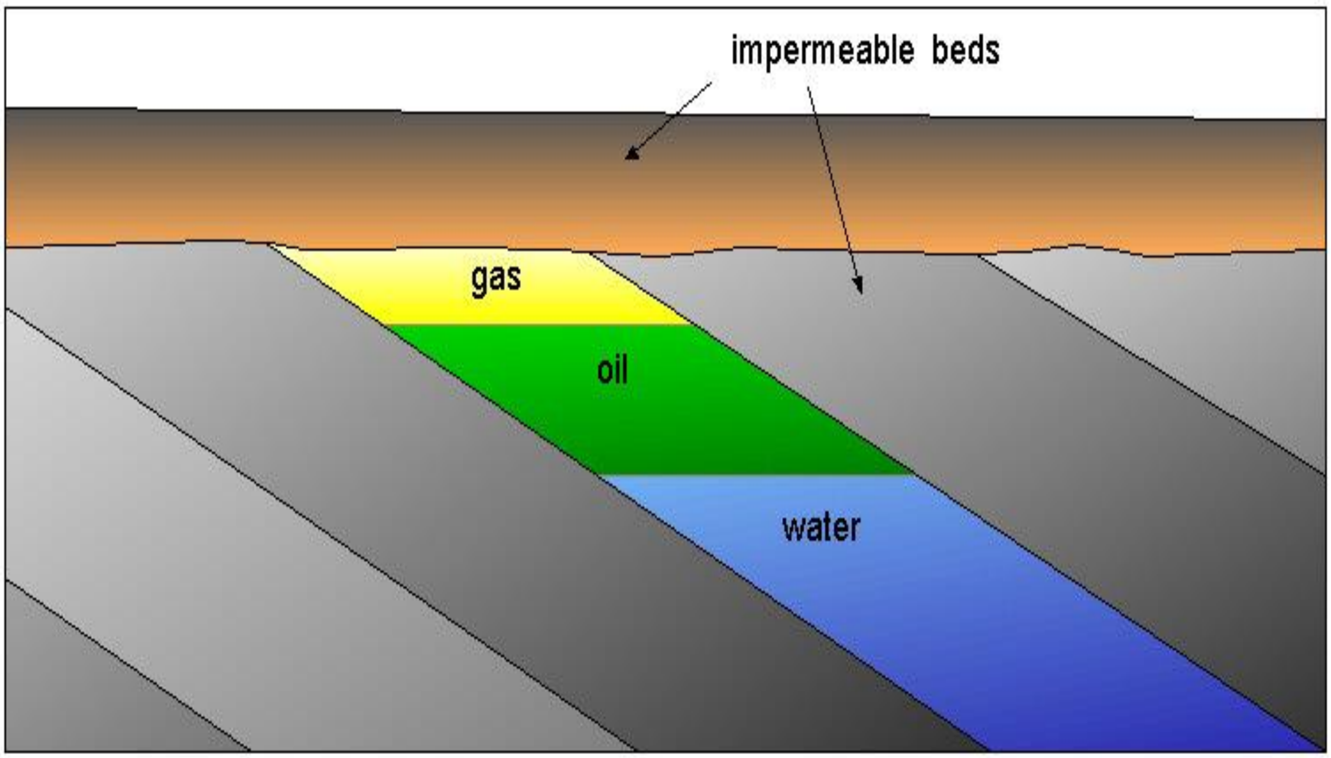

Fig. 1-7 Oil and gas trapped under an unconformity.

2- Lenticular Reservoirs

Oil and gas may accumulate in pockets of porous permeable beds or traps formed by pinch-outs of the porous beds within an impermeable bed. Lens type reservoirs are formed where sand was deposited along an irregular coastline or by filling in an ancient river bed or delta. Similar productive zones occur in various porous sections in thick impermeable limestone beds. Pinch-outs may occur near the edge of a basin where the sand progressively "shales out" as the edge of the basin is approached. In river deposited sand bars, shale-out frequently occurs within a few hundred feet.

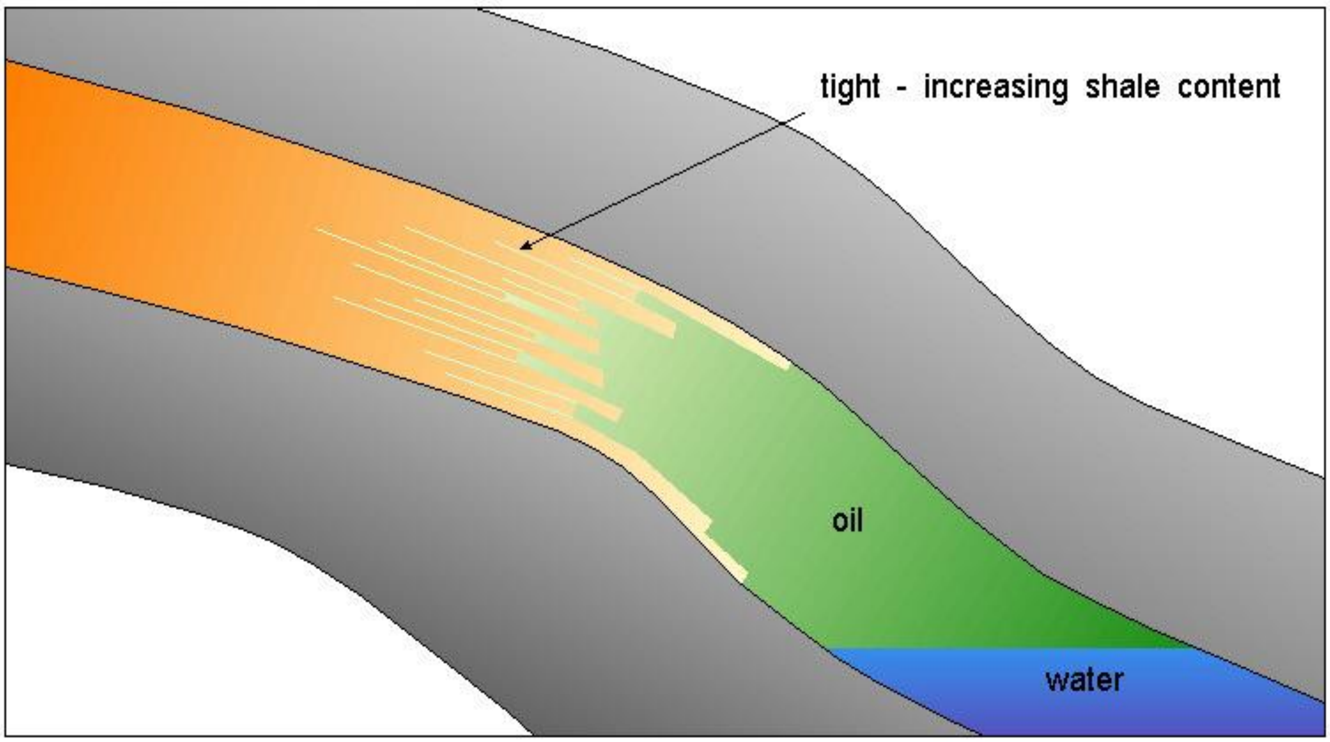

Fig. 1-8 Upper bounds of the reservoir formed by change in permeability of sand.

1.3.3. Combination traps

Combination traps that combine more than one type of trap are common in petroleum reservoirs.

Other types of traps (such as hydrodynamic traps) are usually less common. In hydrodynamic traps, the hydrocarbon is trapped by the action of water movements. Tilted contacts are common in this case. The water usually comes from a source such as Oil rain falls or rivers.