LEC1.

Petroleum engineering: focuses on the production, exploration and extraction of oil and natural gas from reservoirs, wells and other locations where oil or gas is naturally found. This sector of engineering evolved from mining engineering and has developed as the energy needs of the world have changed.

What does a petroleum engineer do? Petroleum engineers focus on studying and assessing gas and oil reservoirs to analyze their profitability. They may examine maps of these reservoirs to determine the best and most efficient ways to access these energy resources and where to place wells. Their primary goal is to ensure the most economical production from a reservoir while also adhering to safety and environmental standards. Many petroleum engineers use computer technology to analyze potential production rates and flow from a well. Duties that a petroleum engineer may perform include:

- Designing equipment that will be used to extract gas or oil

- Developing plans to extract natural energy sources

- Supervision of operating machinery used to drill or recover gas or oil

- Studying reservoir maps to determine the most efficient placement of wells

- Performing technical consultations to resolve problems during the drilling process

- Designing surface collections

- Developing new techniques for recovering natural gases and oil

Branches of petroleum engineering

Several areas of specialization have been recognized within the petroleum engineering field. Many petroleum engineers choose to specialize in one of the following branches of this industry:

1. Drilling engineering
   Drilling engineers are responsible for all aspects of the drilling process in the oil field. They may design and implement the techniques used to drill into the earth as well as select the equipment used and oversee the drilling process. Drilling engineers must coordinate with various companies, governments and communities when planning and implementing a drilling project.
2. Production and surface facilities engineering
   This branch of petroleum engineering is in charge of overseeing production after the completion of a well. These engineers prepare equipment which used to extract crude oil or gas from the well and may also measure and control the fluids produced.

3. Reservoir engineering
   A reservoir engineer is focused on how gas and oil flow through porous rock as well as the distribution process of these energy sources. They may establish well-drainage patterns, estimate the performance of a reservoir and create new methods to increase production.

4. Petro physical engineering
   This sector of petroleum engineering is concerned with creating tools and techniques used to analyze the characteristics of energy sources. These engineers help all other petroleum engineers better understand the reservoir rock-fluid system.
5. Well logging
   A well log is a record of the formations and any events that are encountered in the drilling process. It basically tells you what you pass through as you are drilling deeper and deeper. It is also referred to as borehole logging. Well logs are used to determine formations.

Drilling engineering

Production and surface facilities engineering

Reservoir engineering

Petro physical engineering

I Petroleum geology

Origin of petroleum

Petroleum is a Latin word of (Petra ‘’rock’’ + Oleum ‘’ oil ‘’). The origin of petroleum still has uncertainties despite the tremendous researches and studies devoted to it rather than any other natural substance. There are two different theories for the origin of petroleum; Organic and Inorganic origin. Millions of years ago, the earth was populated with plants and animals. Much of that life was located in or adjacent to ancient rivers, lakes, and sea. As plants and animals died, their remains settled to the bottom of these bodies of water. Ancient seas carried mud sediments that buried the organic material. As layers of organic material continued to build up, the oxygen supply to the lower layers eventually was cut off and decomposition slowed down. The thickness of such layers grew to 100s of feet over the time.

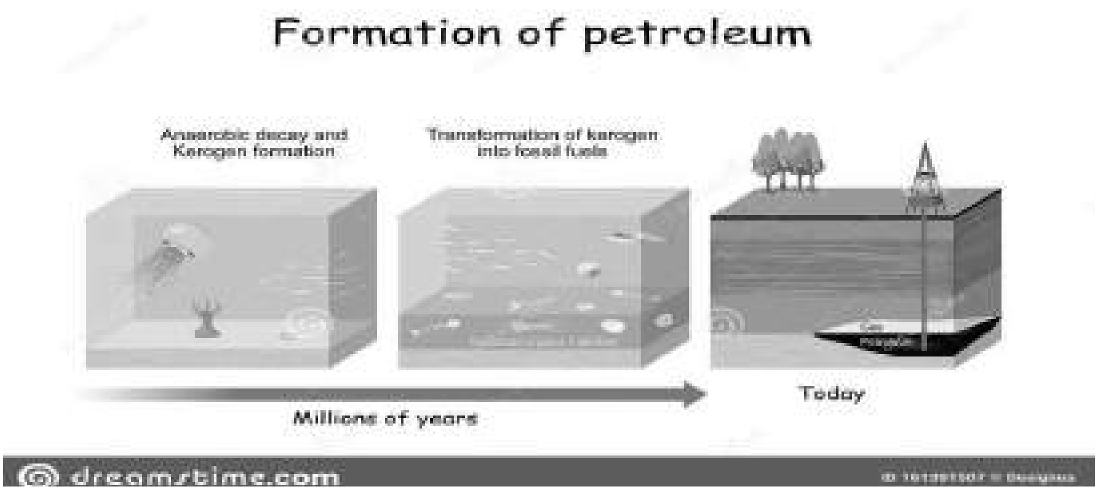
- **Inorganic or Abiotic origin**

  States that hydrogen and carbon came together under great temperature and pressure, far below the earth's surface and formed oil and gas where chemical reactions have occurred. There are some different theories that describe the inorganic origin of petroleum which include: Volcanic theory, Earthquake and Serpentinization theory .

- Organic origin

It is the most widely accepted. The oil and gas are formed from remains of prehistoric plants and animals. Remains of plants have been transformed to coal and animals to oil and gas. settled into seas and accumulated at the seas floor and buried under several kilometers of sediments.

The increase in pressure and temperature with the absence of oxygen changed the mud, sand, slit or sediments into rock and organic matter into Kerogen. After further burial and heating, the kerogen transformed via cracking into petroleum and natural gas.



Overwhelming evidences for organic origin of petroleum

1. Presence of brine (sea water) with petroleum.
2. Petroleum is found only in association with sedimentary rocks. There is no petroleum associated with igneous or metamorphic rocks.
3. Polarized light passing through all petroleum resources undergoes a rotation that is similar to all organic oils.
4. Molecules in hydrocarbons are thought to be similar to that of the organic matter.

5. The organic carbon found in plants is depleted into C_{13} due to photosynthesis process. In dead organic matter, it is further depleted due to radioactive decaying. The same depletion was found in petroleum and natural gas.

LEC2.

Petroleum system

The petroleum system is a unifying concept that encompasses all of the disparate elements and processes of petroleum geology, including: the essential elements (source, reservoir, seal, and overburden pressure) and processes (trap formation, generation-migration-accumulation) . Practical application of petroleum systems can be used in exploration, resource evaluation, and research.

What is a petroleum system?

A petroleum system encompasses a pod of active source rock and all genetically related oil and gas accumulations. It includes all the geologic elements and processes that are essential if an oil and gas accumulation is to exist. Petroleum describes a compound that includes high concentrations of any of the following substances:

-Thermal and biological hydrocarbon gas found in conventional reservoirs as well as in tight reservoirs, fractured shale, and coal

-Condensates

-Crude oils

-Natural bitumen in reservoirs, generally in siliciclastic and carbonate rocks

Elements and processes

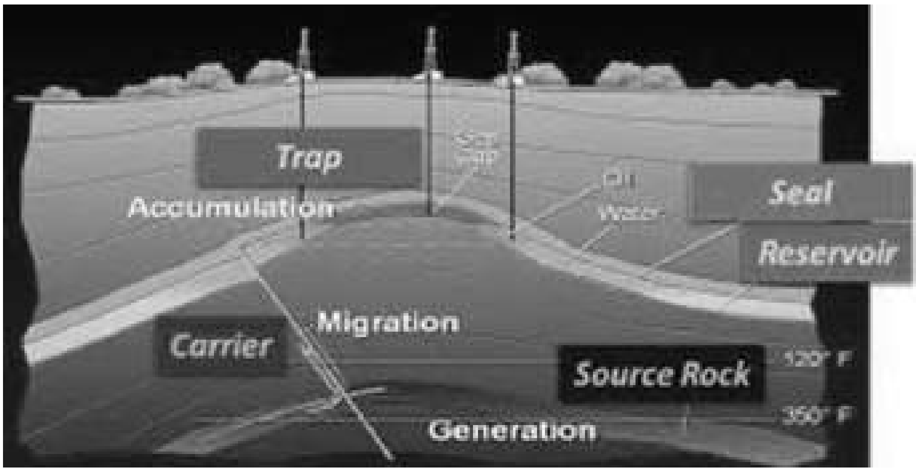
The essential elements of a petroleum system include the following (Fig. 1):

1. **Source rock**
   A source rock is a rock that is capable of generating or that has generated movable quantities of hydrocarbons:
   Potential source rock Rock which contains organic matter in sufficient quantity to generate and expel hydrocarbons if subjected to increased.
   Effective source rock Rock which contains organic matter and is presently generating and/or expelling hydrocarbons to form commercial accumulations.
   Relic effective source rock: An effective source rock which has ceased generating and expelling hydrocarbons due to a thermal cooling event such as uplift or erosion before exhausting its organic matter supply.
   Spent source rock: An active source rock which has exhausted its ability to generate and expel hydrocarbons either through lack of sufficient organic matter or due to reaching an overmature state.

Characterizing source rocks

To be a source rock, a rock must have three features:

1. High Quantity of organic matter
2. Quality capable of yielding moveable hydrocarbons
3. Thermal maturity



(Fig. 1): petroleum system

2. Reservoir rock

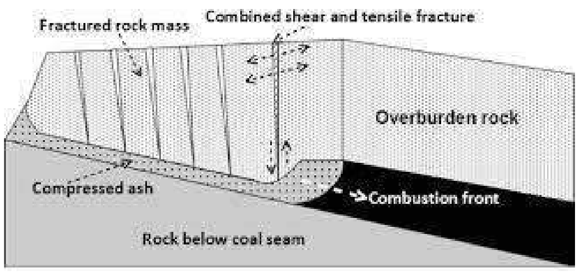
Reservoir rocks are rocks that have the ability to store fluids inside their pores, so that the fluids (water, oil, and gas) can be accumulated. In petroleum geology, reservoir is one of the elements of petroleum system that can accumulate hydrocarbons (oil or gas). Reservoir rock must have good porosity and permeability to accumulate and drain oil in economical quantities(Fig. 1).

3. Seal rock:

A relatively impermeable rock, commonly shale, anhydrite, or salt, that forms a barrier or seal above and around reservoir rock so that fluids cannot migrate beyond the reservoir(Fig. 1). It is often found atop a salt dome.

4. Overburden rock:

Overburden rock is the total stratigraphic section above the source rock. The thickness and age of overburden rock provides a history of the rate of burial of a source rock toward and through the increasing temperature domains of the basin. This includes the range of temperatures necessary for cracking kerogens into hydrocarbons(Fig. 2).



(Fig. 2): overburden rocks

Petroleum systems have two processes:

- Trap formation
- Generation–expulsion–migration–accumulation of hydrocarbons

Generation of hydrocarbon

Most people know the source of petroleum is plants and animals that died millions of years ago. During this period, this high carbon content matter (plants and animals) was exposed to high pressure and temperature that caused them to become mature and generate petroleum. However, the processes that lead to the generation of petroleum are still not clear enough. Therefore, it is interesting to know these processes and how petroleum was generated and how did it move(migrates) in the subsurface until it accumulated waiting for mankind to produce it and make use of it in all fields of life. The petroleum may be liquid or gas and our mission is to get it. Therefore, this article covers how it is generated, how it migrates and how it accumulates.

Maturation occurs through millions of years in which diagenesis and catagenesis processes take place. About 10 to 20% of petroleum is formed during diagenesis. Most petroleum is formed during the catagenesis and metagenesis of the residual biogenic organic matter. Converting biomolecules into petroleum is called maturation.

Diagenesis

In geology: the physical, chemical or biological alteration of sediments into sedimentary rock at relatively low temperatures and pressures that can result in changes to the rock's original mineralogy and texture. After deposition, sediments are compacted as they are buried beneath successive layers of sediment and cemented by minerals that precipitate from solution. Grains of sediment, rock fragments and fossils can be replaced by other minerals during diagenesis. Porosity usually decreases during diagenesis, except in rare cases such as dissolution of minerals and dolomitization (Fig.3).

In petroleum : The initial stage of alteration of sediments and maturation of kerogen that occurs at temperatures less than 50°C [122°F]. The type of hydrocarbon generated depends on the type of organic matter in the kerogen, the amount of time that passes, and the ambient temperature and pressure. During early diagenesis, microbial activity is a key contributor to the breakdown of organic matter and generally results in production of biogenic gas. Longer exposure to higher temperatures during diagenesis, catagenesis, and metagenesis generally results in transformation of the kerogen into liquid hydrocarbons and hydrocarbon gases.

Maturation: he process of a source rock becoming capable of generating oil or gas when exposed to appropriate pressures and temperatures. As a source rock begins to mature, it generates hydrocarbons.

Kerogen : The naturally occurring, solid, insoluble organic matter that occurs in source rocks and can yield oil upon heating. Kerogen is the portion of naturally occurring organic matter that is nonextractable using organic solvents. Typical organic constituents of kerogen are algae and woody plant material. Kerogens have a high molecular weight relative to bitumen, or soluble organic matter. Bitumen forms from kerogen during petroleum generation(Fig.4).

1-Catagenesis

The physical and chemical alteration of sediments and pore fluids at temperatures and pressures higher than those of diagenesis. Catagenesis involves heating in the range of 50 to 150 degC [122 to 302 degF]. At these temperatures, chemical bonds break down in kerogen and clays within shale, generating liquid hydrocarbons. At the high end of this temperature range, second ary cracking of oil molecules can generate gas molecules (Fig.3).

2-Metagenesis

The last stage of maturation and conversion of organic matter to hydrocarbons. Metagenesis occurs at temperatures of 150 to 200 degC [302 to 392 degF]. At the end of metagenesis, methane, or dry gas, is evolved along with nonhydrocarbon gases such as CO_2, N_2, and H_2S, as oil molecules are cracked into smaller gas molecules.

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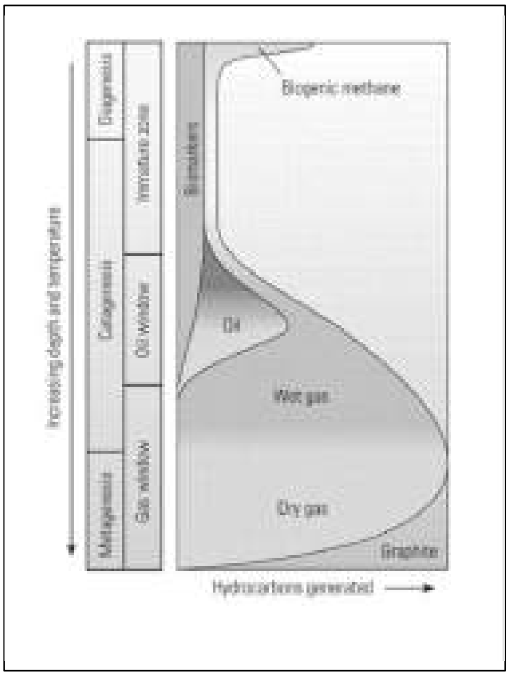


Fig.3 : Hydrocarbons generation

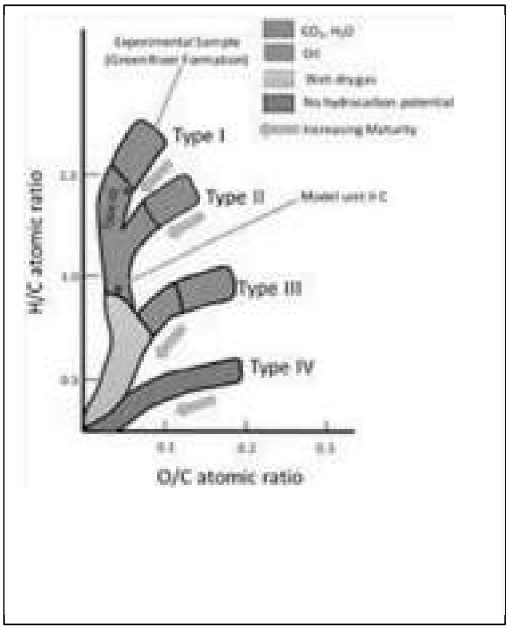


Fig. 4 : kerogen types

Petroleum migration and accumulation

Primary migration

Primary migration takes place within the source rock after fracturing due to pressure increase that happens due to the generation of oil and gas. Since gases and liquids are less dense than solids, they take up more volume causing pressure increase. So, it is important for a productive source rock to be easily fractured to let the fluids move through it. During primary migration, gas and oil travel together as a single liquid phase due to the high pressures in the source rock as these pressures usually become higher than the bubble point pressure at which gases start to be liberated from liquid. Expulsion from the source rock may be occur in pulses due to the closure of pores and fractures after some time from the first expulsion. With time, petroleum creates enough pressure to reopen fractures and pores causing to a second expulsion, and the pulses continue to happen as long as the petroleum can rebuild enough pressure to reopen its path out of the source rock. After migration the pressure decreases and the fractures and pores close. Finally, petroleum migrates out of the source rock, pressures decline, especially if the petroleum migrates vertically(Fig. 5).

Secondary migration

Secondary migration refers to the subsequent movement of hydrocarbons within reservoir rock. During secondary migration, the gas and oil separate with the gas traveling ahead of oil. The largest petroleum deposits are the result of lateral migration because this provides a larger drainage volume of source rock than does vertical migration. In most cases, differences in permeability between adjacent stratigraphic layers inhibit migration. This causes petroleum to flow within geologic units. For petroleum to accumulate in a trap, it must encounter a cap rock or seal such as evaporate which make the best seals due to their low permeability. They are found in deeply buried sediments as vertical pillars called diapirs (Fig. 5).

Tertiary migration

This migration occurs towards the surface through fractures.

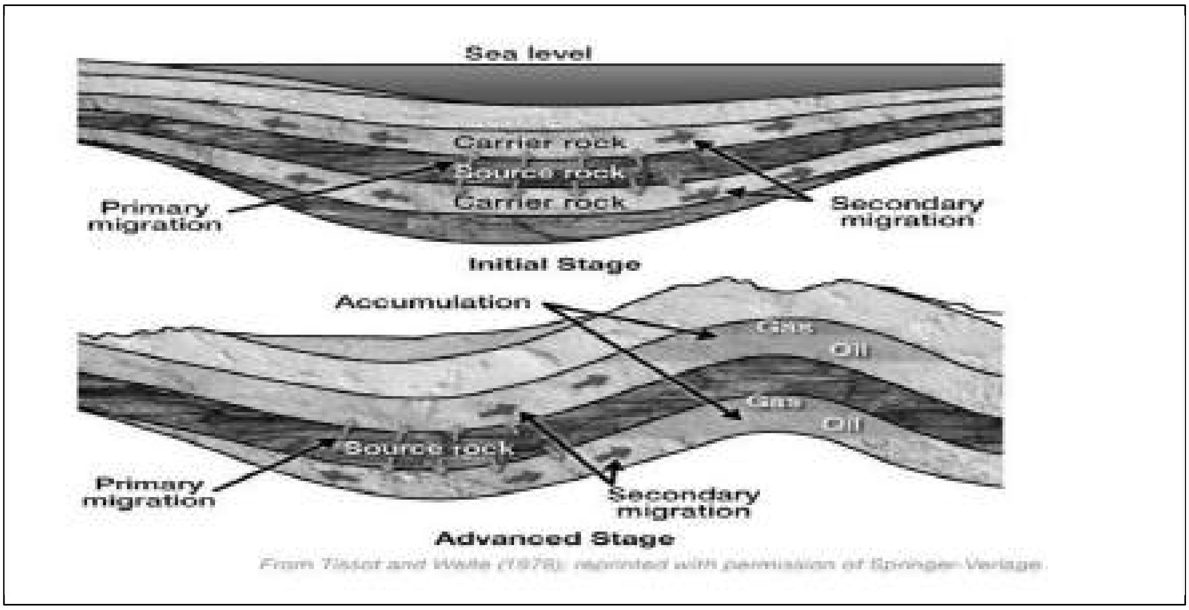


Fig. 5: Migration of hydrocarbon

Requirements for Favorable Petroleum Accumulations

1. High organic content of the source rock
2. Rapid burial or a reducing environment
3. Enough overburden pressure that helps in maturation process
4. Movement easiness from source rock to reservoir rock

5. Porous and permeable reservoir rock
6. Presence of accumulation traps (structural or stratigraphic)
7. Cap rocks presence to prevent the escape of petroleum fluids

Lec3. II Petroleum reservoir

reservoir :A subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum system (Fig . 6) .

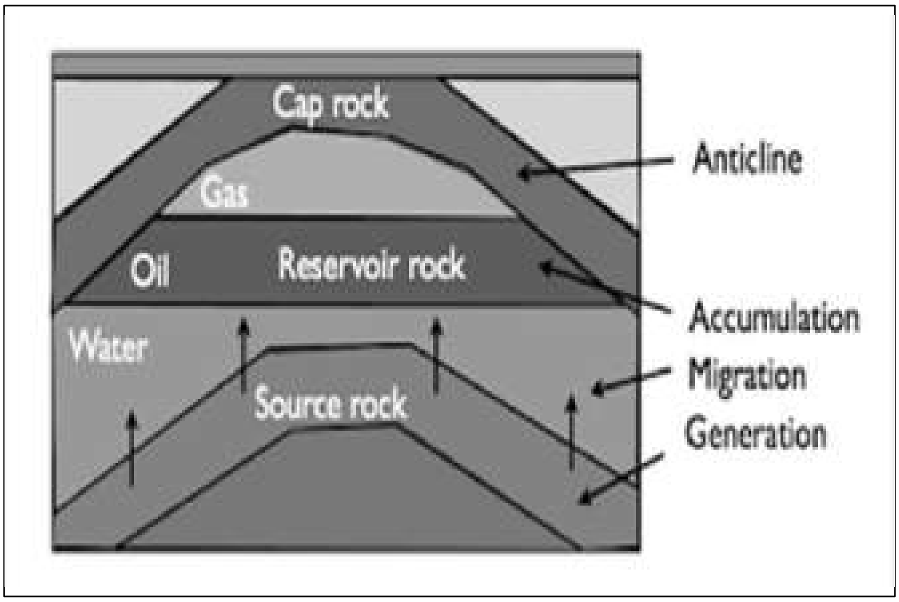


Fig . 6: Petroleum system

Lithology of Petroleum Reservoirs

Lithology is the study of the general physical characteristics of a rock. Reservoir rocks can be divided into two lithological types, namely, sandstone. and carbonates. Sandstones are formed from grains that have undergone: sedimentation, compaction, and cementation. Carbonates are principally formed on carbonate platforms by a combination of biogenic and non-biogenic processes. The major characteristics of both sandstone and carbonate rocks are shown in table. The lithologic symbols showed in Fig. 7.

Sandstone	Carbonate
• Usually composed of silica grains (mainly quartz and some feldspar).	Two major types are limestone ($CaCO3$) and dolomite $CaMg(CO3)_2$
• Consolidated (the rock is combined as one unit) or loosely consolidated	• Pore space consists of inter- or intragranular porosity as well as areas of dissolution (vugs) and fractures
• May contain swelling clays (clays have negative impact on reservoir quality).	Low contain of clays

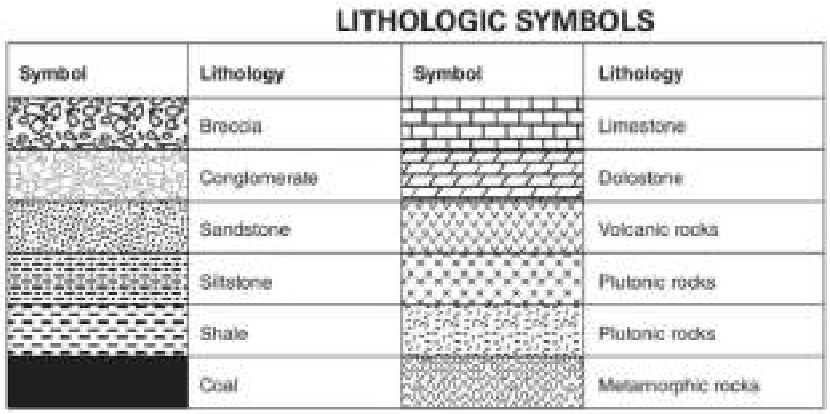


Fig. 7: Lithologic symbols

Properties of reservoir rocks

The reservoir rock properties that are of most interest to geologists and reservoir engineers . Properties of reservoir rocks includes: Porosity, Permeability , saturation, Compressibility, capillary pressure, wettability, and surface interfacial tension. We can study the reservoir properties from : 1- Reservoir rocks properties 2- Reservoir fluids properties

1. Porosity :

Porosity is a rock property that defines the fraction of the rock volume that is occupied by the pore volume(Fig.8). As previously mentioned, porosity, φ, is the fraction of the Bulk Rock Volume, vb , that is occupied by the Pore Volume, vp. Mathematically, it is defined as:

$$\varphi=\frac{vp}{\mathrm{vb}}$$

the bulk volume, Vb, can also be defined as the sum of the volumes of the two constituents of the rock, pore volume and Grain Volume, Vg. That is:

$$vb = vp + vg$$

From these two expressions, we can develop several equivalent definitions for porosity:

$$\varphi=\frac{vp}{\mathrm{vb}} = \varphi=\frac{vb\_vg}{\mathrm{vb}}\text{x}100$$

Note that the fractional porosity value is often multiplied by 100 to make it a percentage

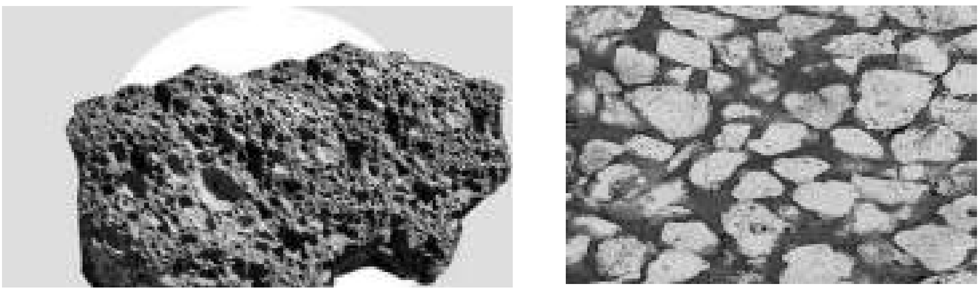


Fig.8: Porosity

Example:

A core sample has a total volume of 24.5 cm3 and a matrix volume of 18.9 cm3(a) What is the pore volume of this sample? (b) What is the porosity of this sample?

Vb=vp+vg

24.5= vp+ 18.9

Vp= 24.5 – 18.9

Vp= 5.6

$\varphi=\frac{vp}{\mathrm{vb}}$

Vp= 0.229 ⟶ 22.9%

Classification of Porosity

Porosity has two types of classifications: geological and engineering.

A: Geological Classification of Porosity

In terms of geological classification, porosity is classified into two subdivisions: primary and secondary. Primary porosity is the original porosity that develops during the deposition of the material. Primary porosity can be either intergranular or intragranular(Fig. 9) . Intergranular porosity is the porosity between grains, while intragranular porosity is the porosity within the grain itself. Intergranular porosity forms the majority of the porosity of the rock. Secondary (induced) porosity is developed after deposition by geological processes which result in vugs and fractures (Fig. 10).

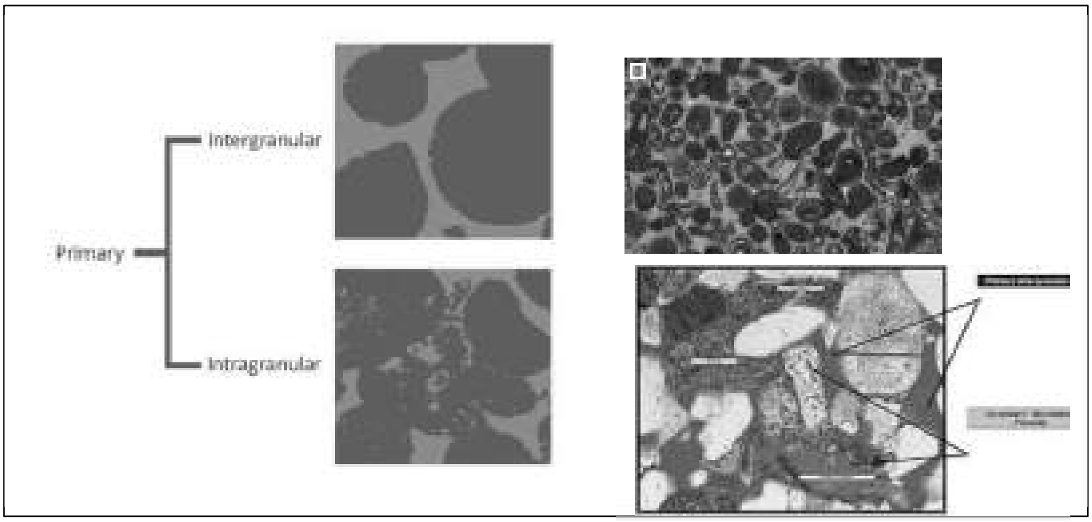
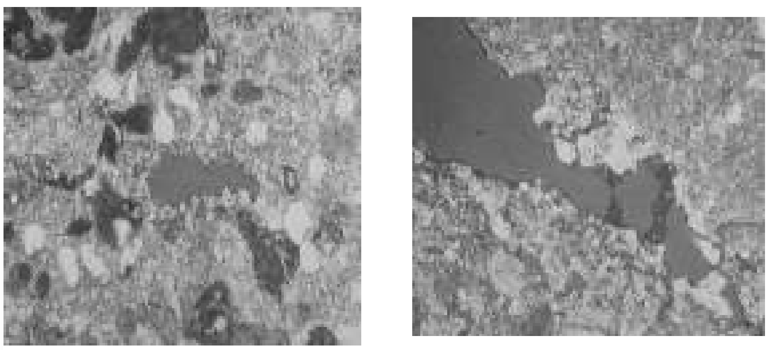


Fig. 9: Iintergranular & intragranular porosity



Vug porosity   Fracture porosity

Fig. 10: vug & fracture porosity

B: Engineering Classification of Porosity

In terms of engineering classification, porosity can be subdivided into two categories: total and effective (Fig : 11). Total porosity (ϕt) is the total pore volume of the rock divided by the bulk volume. On the other hand, effective porosity (ϕe) is the interconnected pore volume divided by the bulk volume. Ineffective porosity is the isolated pore volume divided by the bulk volume. Figure shows the difference between effective and ineffective porosity. Usually in sandstones, $\phi t = \phi e$ as they are relatively homogeneous rocks. Carbonate and dolomite rocks, on the other hand, usually have $\phi t > \phi e$ since carbonates are typically heterogeneous.

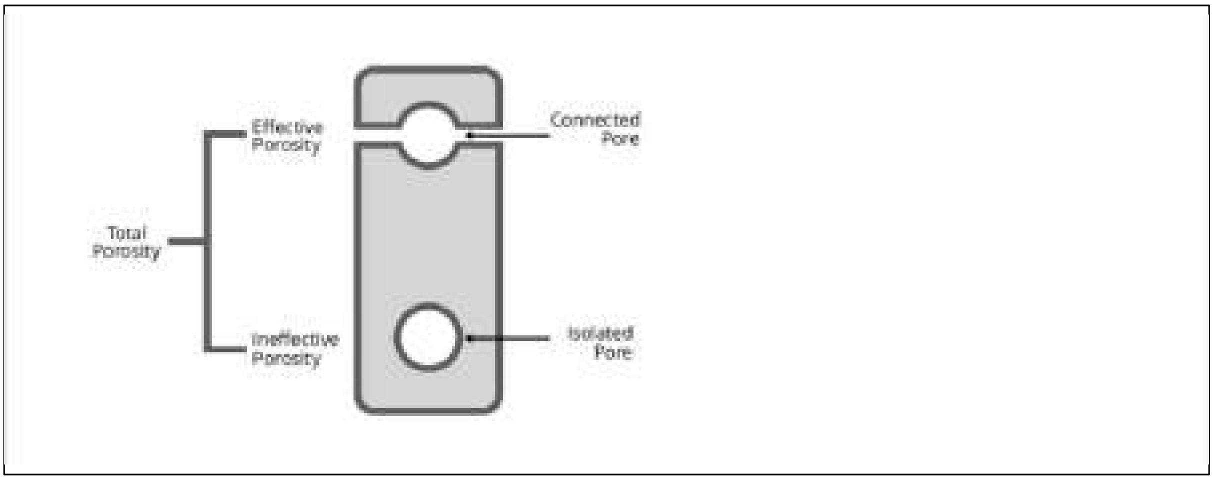


Fig : 11: Effective and ineffective porosity

$$\varphi e = \frac{interconnected\ pore\ volume}{\text{bulk volume}}$$

Porosity is measured in two ways:

1- Core sample (vp,vb0
2- Open hole wire line logs.

2- Permeability :

The ability, or measurement of a rock's ability, to transmit fluids, typically measured in darcies or millidarcies. The term was basically defined by Henry Darcy, who showed that the common mathematics of heat transfer could be modified to adequately describe