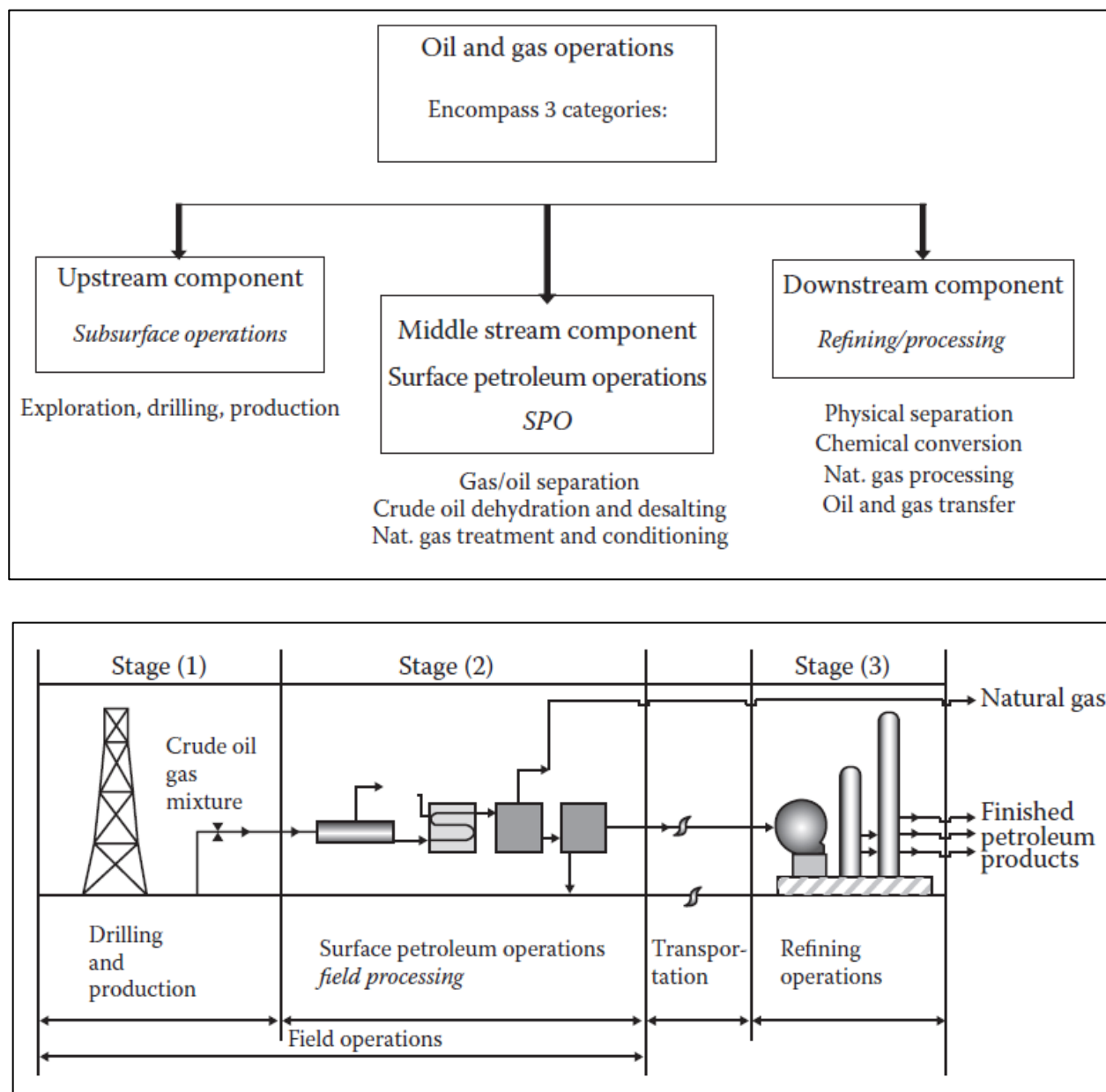


1.1. Petroleum engineering

- ❖ **Petroleum engineering** is concerned with the production of petroleum from subsurface reservoirs.
- ❖ Oil field operations in general encompass three main phases, as shown in the following block diagram.



1.2. General Overview of Petroleum

- ❖ The word petroleum originated from the Greek word, "Petra" (meaning rock) and "oleum" (meaning oil).
- ❖ Literally, it means 'Rock Oil,' and can also be defined as a non-renewable fossil fuel or oil that is found underground.
- ❖ Petroleum is any naturally-occurring flammable mixture of hydrocarbons found in geological formations.
- ❖ Technically, the term petroleum refers to describe any **solid, liquid, or gaseous** hydrocarbons. It's also known as 'crude oil' or 'mineral oil.'
- ❖ Petroleum is a complex mixture of hydrocarbon compounds which may be either gas, liquid, or solid depending upon its own unique composition and the pressure and temperature at which it is confined.
- ❖ Petroleum products are all substances made from petroleum.

1.3. Origin of Petroleum

There are two theories that explain the origin of petroleum, **organic** and **inorganic theory**, which state as:

- ❖ The **organic theory** of petroleum formation is one of the most widely accepted theories on the origin of petroleum. The organic theory states that petroleum originates from marine life. These organisms, which contain carbon, die and accumulate in water-rich environments and ocean floors. Following the accumulation of sediment over millions of

years, deposited marine organisms became buried under kilometers of sediment. Under increased pressure and temperature due to overburden formation pressure from layers of sediments and organic matter, a mixture of organic chemical compounds called **kerogen** is formed. At high temperatures in the earth's crust, kerogen releases hydrocarbons, which then migrate towards the surface where they are either trapped in reservoir rocks before reaching the surface or escape to the surface.

❖ **Inorganic theory** (not derived from living matter) states that petroleum was formed through a chemical reaction between water, carbon dioxide, and several inorganic substances such as carbonates and carbides in the earth.

1.4. Steps of petroleum formation

Over many years, pressure, temperature, bacteria, and other reactions caused these dead organisms to change into oil and gas. The gas was formed under **the higher temperature** conditions, whereas the oil was formed under **the lower temperature** conditions.

Step 1: Accumulation of the remains of plants and animals and their burial mud and sedimentary material of ancient seas.

Step 2: Decomposition of these remains by pressure and temperature to form petroleum.

Step 3: Migration of petroleum from the source rock to the reservoir rock.

1.5. Petroleum System

petroleum system consists of six elements:

- 1- Source rock.
- 2- Generation.
- 3- Migration.
- 4- Reservoir rock.
- 5- Seal rock.
- 6- Trap.

1. Source rocks

The rocks where oil and gas were formed are known as **the source rock**. Source rocks are rich in organic matter that can generate hydrocarbon when subjected to high temperature and pressure. A very important characteristic of the source rock is the total organic content, which is the organic richness of a rock represented as the weight percent of organic carbon (from kerogen and bitumen) and gives a qualitative indication of petroleum potential.

2. Petroleum Generation from Source Rock

The requirement for release of petroleum from source rock is temperature. The earth's interior is characterized by a temperature increasing with depth. The change in temperature of the earth's interior per unit depth change is called geothermal gradient. Large quantities of hydrocarbons are formed around a depth of 1–2 km, with oil generation reaching a peak at 3 km. Gas dominates depths between 4 and 6 km due to the high temperature, which leads to

the cracking of oil to form gas. At deeper formation depth, greater than 6 km, kerogen becomes carbonized and is no longer able to produce hydrocarbons.

3. Petroleum Migration

Oil and gas move out of the source beds and accumulate in the reservoir rocks.

The transfer from source rocks to reservoir rocks is called **Primary migration**, where the oil and gas transformation cause micro-fracturing of the impermeable and low porosity source rock, allowing hydrocarbons to move into more permeable strata.

The movement of petroleum within the porous and permeable reservoir beds is known as **secondary migration**, where the generated fluids move more freely along bedding planes and faults into a suitable reservoir structure.

After its formation, petroleum may migrate from the source rock into a porous and permeable bed where it accumulates and continues its migration until finally trapped.

4. Reservoir rocks:

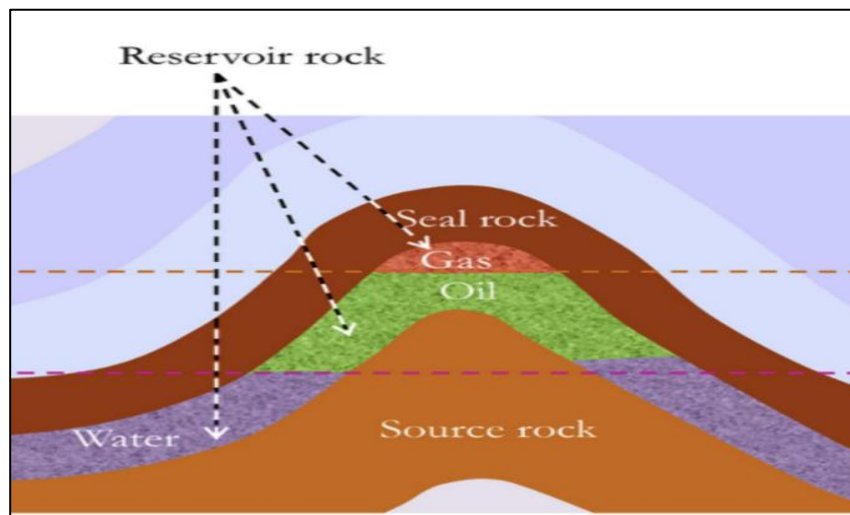
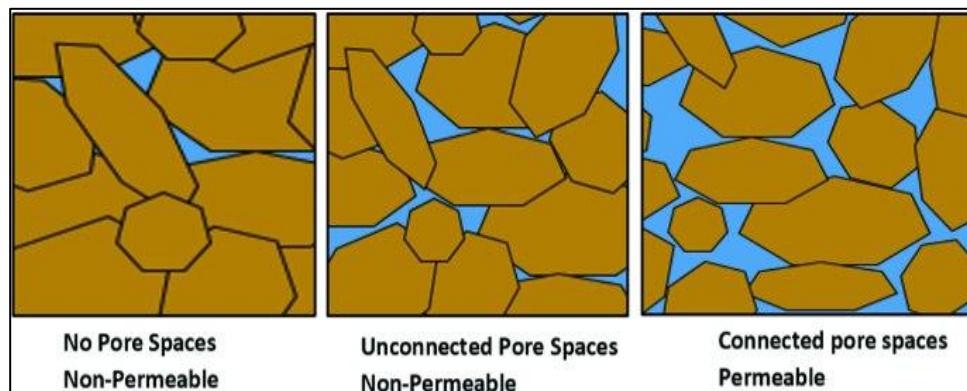
They are rocks in which hydrocarbons accumulate after migrating from the source rocks. Reservoir rocks are characterized by being permeable rocks and rocks with effective porosity, allowing fluids to pass through them.

And rocks, if they are not permeable, then fluids cannot collect in them, and therefore they cannot form an oil reservoir.

5. Seal Rock (Cap rock):

A reservoir must have an impervious seal or cap rock that ensures that hydrocarbons are preserved over geological time. Though cap rock can have pore spaces, the absence of interconnected pores (permeability) ensures the hydrocarbon does not escape from reservoirs. Common reservoir seals include shales, clay, chalk, and evaporates (salt, Gypsum). Seal rock consists of: grains aggregated and packed together by means of cementing.

There are no pores inside these grains, and there may be pores inside it, but these pores are not interconnected, so they do not allow liquids to pass through them, which makes them impermeable rocks. The reservoir rocks are the first and second figures from the left.

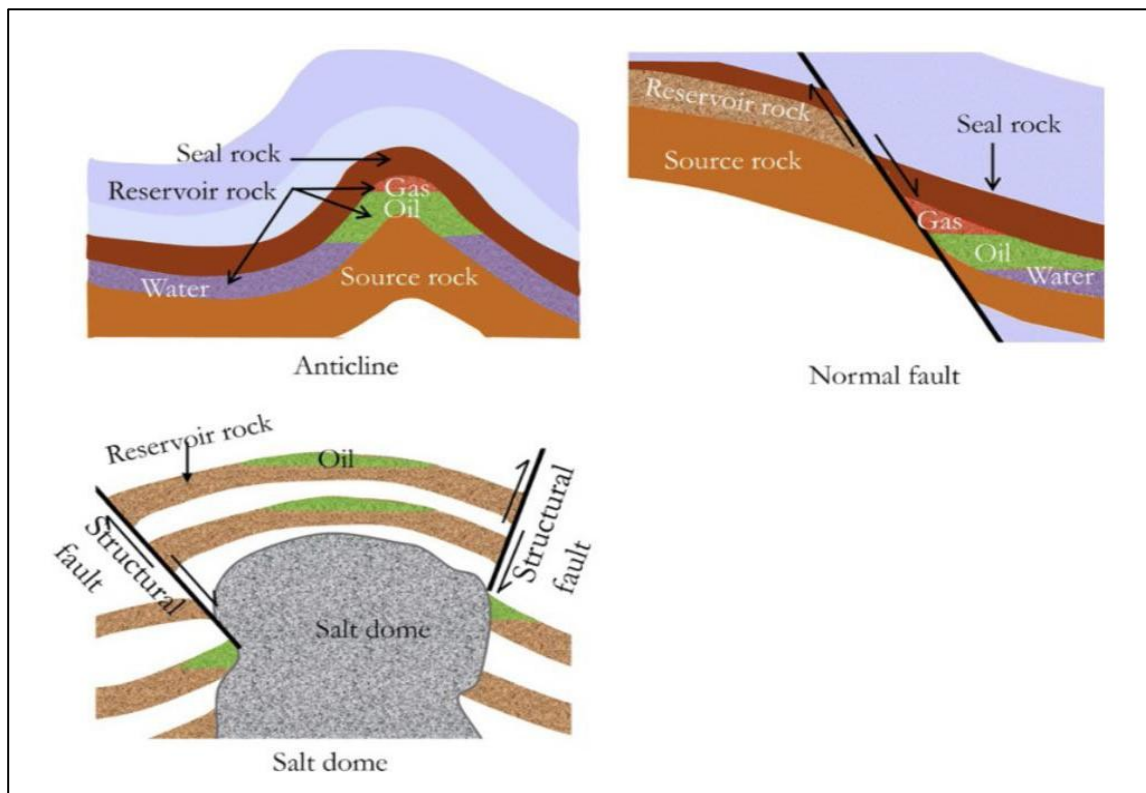


6. Traps

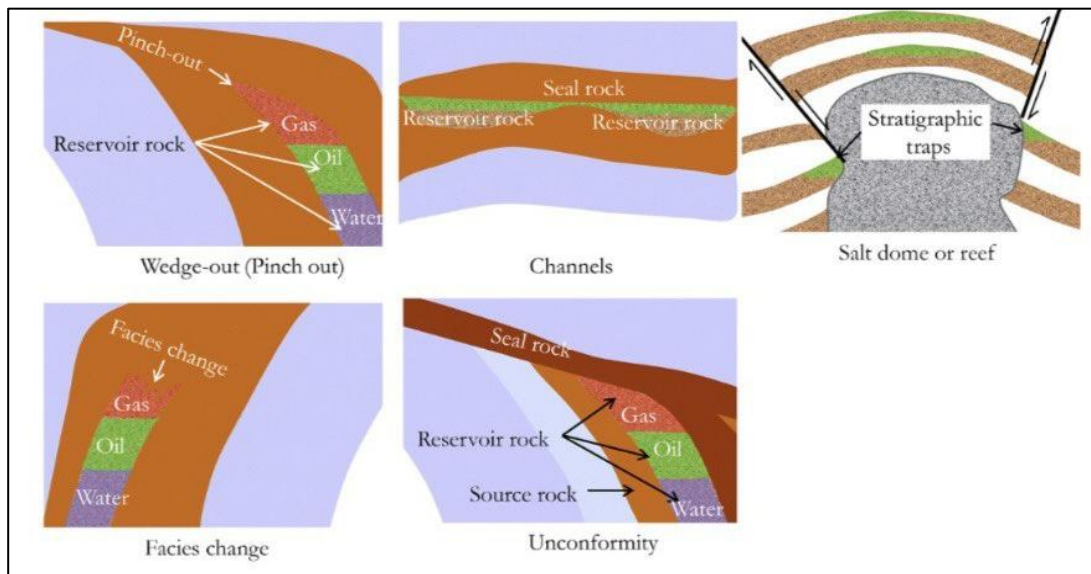
Traps are an arrangement of rock layers that contain an accumulation which is covered by cap rock to prevent hydrocarbon from rising to the surface. It consists of an impermeable layer of rock above, porous, permeable layer containing the hydrocarbon. There are three types of reservoir traps:

- ❖ **Structural traps**
- ❖ **Stratigraphic traps**
- ❖ **Combination traps**

1. Structural traps: traps formed by ground movements that occur in the earth's crust such as **fold traps (anticlines), fault traps, and salt dome traps.**



- ❖ **Salt dome traps** are formed as a result of the movement of blocks of salt upwards. It is formed as a result of the different densities of the salt and the sedimentary layer above it. The salt is less dense so it moves up, causing the formation of domes.
 - ❖ **Anticline Traps:** Where the petroleum collects at the top of the convex fold.
 - ❖ **Fault Trap:** Faults place impermeable strata in the path of petroleum-bearing strata.
2. **Stratigraphic traps** formed during the sedimentation process. They are primary stratigraphic traps which resulted from discontinuous deposition of sediment (changes in lithology) and secondary stratigraphic traps which arise from changes in porosity of the rock after sedimentation has occurred. About 13% of the world reservoir is characterized by this kind of trap (Fig. 1.3).



3. **Combination Traps:** There is also the possible combination of structural and Stratigraphic traps. About 9% of the world reservoir is characterized by this kind of traps.