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Course

Introduction to Refining and Petrochemicals

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Content

CHAPTER I : Formation and Exploitation of Oil and Natural Gas.

1.1. Definitions

The term oil comes from the Latin **Petra-Oléum**, which literally means "**stone oil**". It is a flammable oil varying from yellow to black in color. It is made up of a wide variety of hydrocarbons found in the sedimentary strata of the earth.

• Petroleum designates a liquid composed mainly of :

- hydrocarbon molecules (formed only of carbon and hydrogen).
- This oil also contains, in fairly variable proportions (15% on average), more complex heavy molecules (including oxygen, nitrogen and sulfur) called resins or asphaltenes.

This oil was formed within sedimentary basins by transformation of organic matter.

One of the essential conditions for the formation of oil lies in the accumulation of a large quantity of organic matter which must be buried quickly, in order to limit bacterial degradation in the presence of oxygen.

Some of its components may be:

- ✓ Gaseous,
- ✓ Liquids,
- ✓ sometimes solid

And this depends on temperature and pressure.

This explains the variable consistency of oil, more or less viscous or liquid.

I.2: Origin of oil

Many scientists have studied the origin of oil.

Two theories were born: that of mineral origin and that of organic origin, it is the latter theory which is considered today as the most likely. Oil and gas would be formed from animal or plant organic matter. The transformation of organic matter into oil takes place over tens of millions of years, passing through an intermediate substance called kerogen. Organic matter would thus have accumulated at the bottom of seas, oceans, lakes and deltas, mixed with mineral materials (clay particles or fine sand), thus creating sedimentation muds and forming "sapropel".

The pressure gradually developed by the accumulation of sediments over geological time, the temperature, the action of bacteria in a reducing environment, that is to say in the absence of oxygen, would have gradually transformed this "sapropel" into oil.

I.3: Formation of oil deposits.

The part of the subsoil in which the oil was formed is called source rock.

Once formed, it is subject to several forces: the weight of the sediments, geological forces, differences in densities with the salt water that accompanies it, etc.

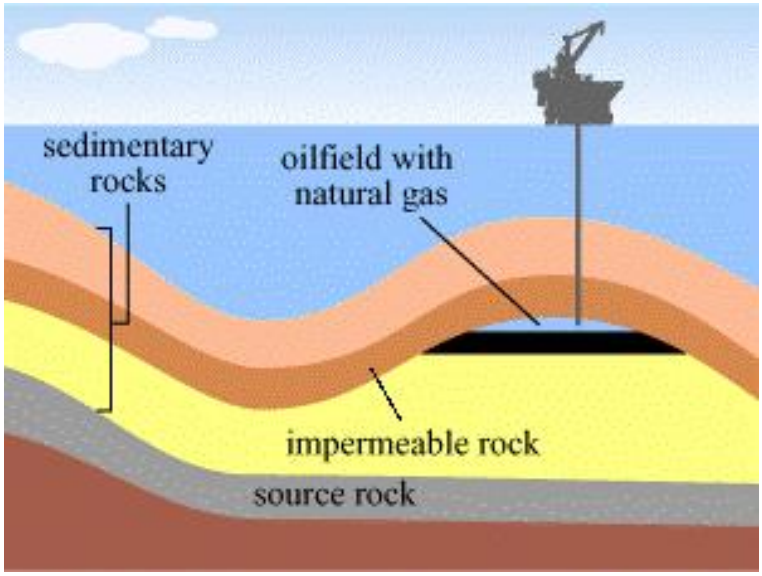
In an attempt to reduce the effect of these forces, oil tends to move to other locations by taking a path through the more permeable rocks or cracks existing within these rocks. This migration takes place from the parent rock towards the surface of the earth, crossing the sediments; This is because the density of oil is lower than that of water. The place where oil migration stops is called a "**trap**".

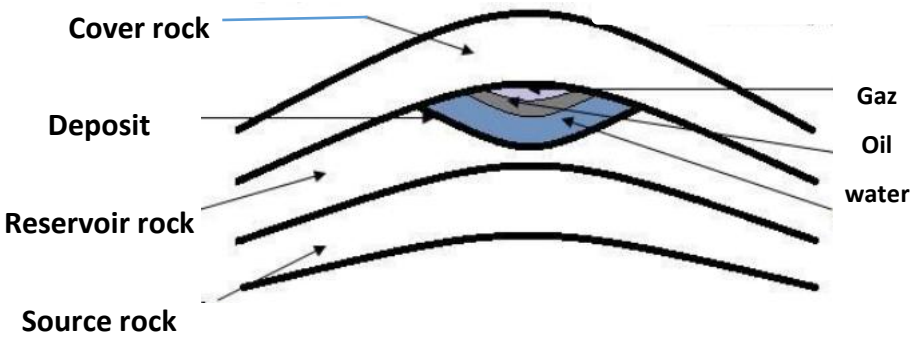
A trap includes:

- a **porous rock** in which oil accumulates, this is what we call "store rock" or "reservoir rock".
- above this "**store rock"**, a sufficiently impermeable layer to prevent the oil from migrating to the surface; This is what we call "cover rock" or also "impermeable rock", like a layer of salt for example.

All the source rocks and reservoir rocks constitute what we call an oil deposit.

In this porous reservoir, the gas accumulates above the crude oil, which is found above the water due to the respective densities of these products (natural gas is lighter than oil, itself lighter light than water)





Simplified diagram of an oil field

I.4: Classification of petroleum.

Every formation process is unique: an oil deposit contains a mixture of hydrocarbons which characterizes it according to the geological history of the area where it developed.

Geographic origin is therefore one of the criteria for classifying oil (Persian Gulf, North Sea, Venezuela, Nigeria, etc.).

However, to establish comparisons between different sites, other criteria exist.

The most important are measurements of viscosity and sulfur content of crude oil.

A) **Depending on viscosity,** four types of deposits are defined (light, medium, heavy or extra-heavy and bitumen), the more viscous the crude oil, the "heavier" it is:

- light oil deposits: the appearance of crude oil is similar to that of diesel. The Saharan deposits present this characteristic;
- medium oil deposits: the viscosity of crude oil is intermediate between light oil and heavy oil. These include, for example, deposits in the Middle East;
- heavy or extra-heavy oil deposits: crude oil practically does not flow at room temperature. The deposits of South America are an example;
- bitumen deposits: crude oil is very viscous or even solid at room temperature. The main reserves of this type are in Canada. This property is important in determining the profitability of the operation. In fact, low viscosity or light oil is easier to extract and process than heavy oil.

B) The sulfur content distinguishes crude oil into either sweet (low sulfur content) or sulfide otherwise. Deposits of sweet oil are found in particular in Africa, those of sulphide oil in North America.

I.5: Oil deposits and exploitation

A) Search for deposits

• To find new deposits, geologists and geophysicists seek to identify geological structures likely to contain oil. The first study samples of soil and rocks. The latter examine the earth's crust in depth at the presumed locations of the deposits, and reconstruct the image of the deposits and deformations of the geological layers, in order to help the former locate the locations where the
oil may have been "trapped".

B) The characteristics of the deposits

For a deposit to be exploitable, it must have the following characteristics:

• **a porous and fissured rock**, limestone or sandstone for example, allowing the oil to be collected;

• **an impermeable rock**, which stops the rise of oil and gas, less dense than water, and constitutes a trap where oil accumulates.

C) Oil prospecting

Oil prospecting is the study of petroleum geology. This prospecting begins with the establishment of maps using aerial photos. Oil prospecting is the set of techniques for predicting the location of oil deposits; it is divided into two branches:

- The geological study, or geological prospecting itself, focusing on the formation of deposits and other characteristics of rocks as reservoirs (or covers).
- The study of internal structures is geophysical prospecting carried out by teams traveling through the land to be prospected (explored) and drawing structural maps.

D) Prospecting (oil exploitation) methods

a) Geological prospecting

It is accepted that all rocks which can constitute an oil deposit are sedimentary, but there are no direct methods of searching for hydrocarbon deposits in sedimentary terrain. On the other hand, there are indirect methods which make it possible to detect the possible presence of "traps" without being able to determine in advance whether these traps contain or do not contain oil.

b) Geophysical prospecting.

This method uses the variation of certain geophysical parameters of the land caused by the presence of hydrocarbons; this prospecting only provides qualitative results. Among the methods used to carry out this prospecting, we can cite:

- **The gravimetric method:** based on the measurement of variations in the gravity field caused by the presence of oil deposits, because, in a soil, the presence of rocks containing hydrocarbons increases the gravity field.
- **The magnetic method:** measures the variations in the variation of the vertical component of the earth's magnetic field caused by the presence of oil deposits.
- **The electrical method:** based on the variation in the resistivity of sedimentary terrains when they are traversed by electrics (in the absence and presence of an oil deposit
- **The seismic method:** this is the most used method. A charge of a few kilograms of explosives is ignited in a shallowly dug well. The sound waves resulting from

the explosion propagate through the sedimentary terrain surrounding the location of the explosion, an appropriate study of the different sound waves collected at different locations can conclude on the presence or absence of a deposit of hydrocarbons.

C) Land drilling methods

For the rational exploitation of deposits, all geological and physical methods are used to obtain information on the physical and mechanical properties of rocks in order to reconstruct the characteristics of a deposit and estimate the corresponding reserves. It often happens that the necessary information is only available several years after the drilling of wells intended to exploit the deposit. Economic investments are therefore always at risk, and we are now multiplying simulations using mathematical models which make it possible to predict the profitability of a deposit. Well drilling represents 80% of investments.

Drilling

Once structures that may contain oil have been recognized, either by geological prospecting or by geophysical prospecting, we can move on to the next step in oil exploitation which is drilling.

Definition of drilling

Drilling is the action of digging a hole (also called a "well") in the Earth; it consists of sinking a string of drills into the subsoil by injecting a special mud. This will make it possible to bring rock fragments and gas samples to the surface. It will be necessary to drill in several locations to better delineate the potential deposit.

Nowadays, the most used process is the rotary process, which, to dig the well, uses a cutting instrument called a bit, which is driven by a rotating movement at the bottom of the well.

Well drilling is carried out using a bit (or tricone).

A drill bit is a drilling tool mainly used in the petroleum industry. It has the shape of a single cone made of very hard special steel or of three cones nested together. The

lower surface of these cones, at the beginning of its invention, was encrusted with diamond dust which made it possible to break the hardest rocks when drilling. While drilling, these cones rotate, break the rocks they pass through and gradually sink into the subsoil.

Drill bit

Rotary drilling rigs are classified into three categories:

- Light devices for depths less than 1500m;
- Medium devices for depths ranging from 1500 to 3000m;
- Heavy devices for depths greater than 3000m.

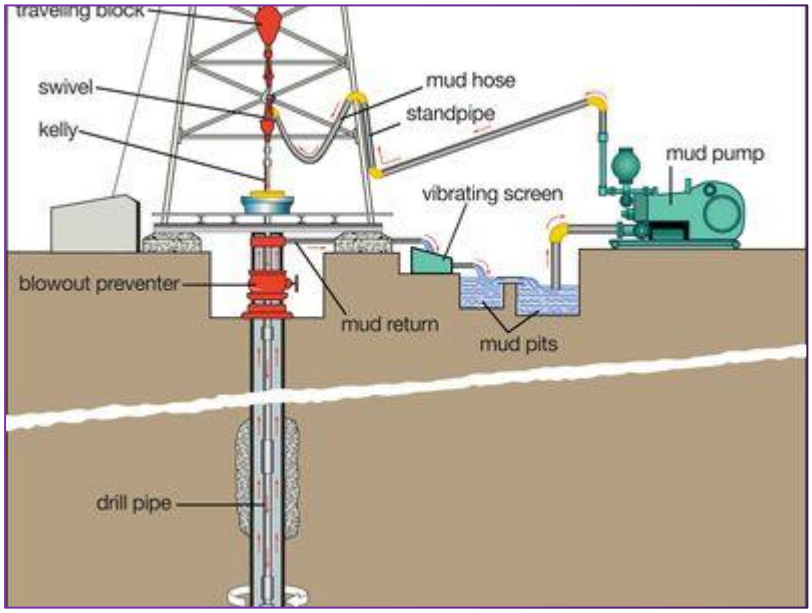
Drilling mud

As the well is dug, the resulting spoil is evacuated to the surface by a continuous flow of mud which is introduced at the same time as the drill bit. It is prepared using water, special clays (bentonites) and different chemicals.

In addition to its main role, which is to evacuate the ground spoil, drilling mud has other secondary roles:

- It holds the walls of the well in place by depositing a thin layer of clay on them.

- It holds in place, by the hydrostatic pressure it exerts, pressurized fluids encountered in the different layers
- It cools the bit and lubricates the various elements to reduce the speed of its wear.
-When the ground to be drilled does not contain water, it is possible to replace the mud with compressed air at 40 bars. Advance speeds are better and the bits wear less quickly



D) Starting production of an oil well

Once drilling has been carried out in a deposit and we are able to reach the reservoir rock where large quantities of oil accumulate, a set of conduits is set up to transport the oil to the surface.

Two cases should be considered:

- **The pressure** at the reservoir level is sufficient for the oil to rise to the surface and flow at a sufficient rate. This is called controlled blowout.
- **The pressure is too low** for the oil to reach the surface with a suitable flow rate, we then use the mechanical pumping process which consists of sending a gas under pressure which makes it possible to increase the pressure at the level of the deposit and thus allow the rise oil to the surface.