Lecture 01: What is Petroleum How it is stored under the earth Exploration of petroleum underground

Hello and welcome to the first lecture of my course, petroleum technology. In this lecture, I will cover different topics: what petroleum is and how it is stored under the earth, the exploration of petroleum under the ground. All these topics will be covered. Now, what is petroleum? Petroleum is a mixture of various hydrocarbons and hydrocarbon derivatives in the form of gas, liquid, and solid. Not only hydrocarbons, we find several other heteroatom compounds such as sulfur, oxygen, nitrogen compounds, and even some metals also present in this mixture. And this mixture is found in several geographical traps under the earth's crust.

How the petroleum is formed? In fact, millions and millions of years ago, some marine animals after their death, came under the sea bed, and the mud layers are deposited on them, layers above another layer. This way for these millions of years, the layers are formed. Due to the heavy pressure of the mud layer on these dead organisms, their dead remains are transformed into oil-like material. Now, at this high temperature and high pressure underground, these oil-like materials undergo different types of decomposition.

Not only the high temperature and high-pressure decomposition under the ground, but some anaerobic bacterial decompositions are also found in them. Bacteria under the ground decompose those compounds into several other compounds such as the oxygenated compounds that can be reduced to form paraffin, naphthenes, and aromatics. Usually, it is seen that the olefin components such as the double-bonded hydrocarbons are very rarely found in the petroleum mixture. Due to this high pressure on this petroleum oil, the rock in which the petroleum is formed is called the source rock. It is a more compacted rock.

From this source rock, petroleum migrates to a less compacted rock which is called reservoir rock and during this migration of petroleum, petroleum undergoes different types of changes due to the filtration, adsorption, etcetera. Now, what is a reservoir rock? Reservoir rock is a coarser-grained rock which is having many pores in them in it, and it is having a complex network structure of pores. If we see the picture, you see in this picture, that the black parts are the holes or pores and the white parts are the rocks and the black parts are the pores. The pores are big in size, but they are not interconnected to each other. So, although this rock has high porosity, it has less permeability.

Rather, if we look at this type of rock here, the white parts are the rock particles, and the black parts are the pores that are interconnected to each other and they form a complex

network structure of pores. So, that in this rock structure, the porosity and permeability are compatible with each other. So, the criterion of a reservoir rock is that it should have a fluid holding capacity that accounts for its porosity. Also, it should have the fluid transmitting capacity, which is permeability, and permeability is determined by the network structure of pores, interconnectivity of the pores. So, the rock must be porous in order to be permeable. Although there is no direct relationship between porosity and permeability if the rock is not porous, as well as if the rock is not interconnected to each other, we will not get good permeability of the rock.

So, a reservoir rock should have porosity and permeability as well together. There are several kinds of reservoir rock we find, those are limestones, dolomite, sandstone, etcetera. Now coming to another type of rock which is cap rock. What is cap rock? Cap rock we find on the top of the reservoir rock which prevents the oil and gas reserve within the reservoir rock to migrate through the cap rock and come to the surface of another pore structure. So, cap rock prevents this migration, cap rock prevents this escape of gas and oil from the reservoir rock, and retains the gas and oil within the reservoir rock.

The cap rocks are having very fine rock particles. So, it is having very thin pores in it and so, its porosity is very low and its permeability is also low as well and as it is having very thin pores it poses high capillary pressure to the gas and oil. So, as a result, the gas and oil cannot escape through those pores to the upper surface. Examples of cap rocks are clays and shells, and sometimes it may be some salts, anhydrides, gypsum etcetera, these are the cap rocks. Hence coming to the next discussion how different fluids are distributed within the reservoir rock.

Say this is a section of the reservoir rock where you see the rock particles are stacked and they form the pore network between them and within these pores oil gas and water you know we have the brine water underground all the time. So, we cannot escape from that. So, oil and gas as well as brine water are stored within this pore. How are they stored within a pore? We are taking a section of the pore and say this is a very simplified diagram of a pore and we see the gas, oil, and water are arranged according to their density. The gas occupies the uppermost zone of the pore then coming to the oil, oil occupies the middle zone and brine water is obviously, the densest one occupying the lowest part of the pore.

As I have shown over here the boundary between water and oil and gas is not this well-defined. Actually, in the oil-gas interface, we will always see some gas dissolved in oil, and some oil droplets are found within the gas. Similar to the case of the oil and water interface, we will find some oil is coming as the droplet into the water phase and some

water vapor is always going to the oil phase. So, this boundary is much diffused. Usually, when we see in under the ground, the reservoir rocks, the pores form almost horizontal contact boundaries between the oil-gas and oil-water, but in many cases, we find this interface is not horizontal also.

Now, coming to different types of petroleum traps within which the petroleum oil and gas are reserved. This is a very simple example of the storage of petroleum within the trap. You see this is the porous rock this is the reservoir rock and within the pores, we find the gas and oil storage. On the top of the reservoir rock, we find impervious and nonporous cap rock as well as at the bottom, we find a nonporous gas rock. These two rocks do not allow the oil and gas to migrate from the reservoir rock to the other rock structures.

Now coming to different types of structural traps. Once the sedimentary rock is formed it undergoes different types of deformations due to the pressure formed under the earth's crust. These sedimentary rocks form different shapes. So, if a sedimentary rock experiences the push from the sideways, a lateral push, then it forms wrinkle, up-wrinkle and down-wrinkle. As an example, if you take a piece of paper and push from sideways you will find it forms an up fold and down fold.

Similarly for sedimentary rock when it forms an up-fold it is called anticline structure. When it forms a down-fold then it is called a syncline structure and petroleum is reserved in this type of trap. Look at this rock structure, where you find one anticline and by its side a syncline and another anticline and these structure/ structural traps are extended miles after miles under the earth's crust where we get the petroleum reserve. Now whenever we see that there is a circular type of anticlinic structure which extends some tens of miles long and it reserves petroleum, that type of structure is called dome-shaped traps, that is anticlinic and almost circular in nature. If we get a large depression that is also circular in nature under the ground which is a synclinic structure then that type of trap is called a basin.

Here you find a basin, a long reservoir rock which is having a synclinic structure. This one is a simplified version of the anticline oil and gas reserve. You feel you see that gas is stored on the top of the trap, called the gas cap and next is coming the oil zone, oil is reserved at the bottom of the gas and the lowest part, we get the water, which is the water zone. Now coming to the fault traps. What are the fault traps? Those are actually the breaks or fractures of a reservoir rock. There are several types of faults. Let me come to the first one which is a normal fault.

What is the normal fault? When one side or one section of the reservoir rock slides down

by gravity against the next section of the rock, then we get a fault which is called normal fault and we can expect the reserve of petroleum at this fault. The next type of rocks are reverse faults and thrust faults. How are they originated? When one part of the rock goes up and above the side part of the reservoir rock, then if this sliding or if this faulting occurs at a large angle that is called the reverse fault and if this sliding or faulting occurs at a small angle then this type of fault is called the thrust fault. Now we will discuss how we can detect the subsurface petroleum-bearing rock. Whatever discussion we have made till now we can compile them and we can make the gist of those where we find there are four basic requirements for petroleum accumulation.

The first one obviously, should be organic-rich source rock where petroleum is formed at the very beginning, millions of years ago. Next, there should be a porous and permeable reservoir rock that will store petroleum within it, without porosity and permeability it cannot behave as a reservoir rock. The next one is an impermeable cap rock or seal, which will not allow the gas and oil to escape from the reservoir rock. And the fourth one is that we need a structural trap in the reservoir rock which will store the petroleum, which will trap the petroleum within it. So, a rock configuration, such as an anticline is an example, we are taking to trap the petroleum within the reservoir.

So, now, how can we come to know that where there is a possibility of petroleum reserve? There are several techniques for the exploration of petroleum. One must gather as many clues as possible and then compile those clues or data together. After analyzing those data individually with some imagination people can start exploring petroleum at a definite location on the earth's surface. There are several ways, the very inexpensive/ least expensive one and most easy one is to map a location and look at the type of rocks present on the surface of the ground. Accordingly people may visually assume that there is a possibility of a petroleum reserve underground. If it is not there the scientific methods are there scientific techniques are there which get the scientific data depending on that we proceed with the exploration of petroleum rocks. So, in that let us discuss several of them the first one I will talk about is the magnetic method.

What is the magnetic method? The earth, under the earth and also on the surface of the earth, we see there is a variation in the strength of magnetism at different locations. A magnetometer is an instrument, that is nothing but a precision magnetic compass that measures the magnetism at different locations of the earth. We find that the different locations give different types of magnetic data. So, this variation of the magnetism under the earth's crust makes the series of data, and accordingly, geophysicists convert this data into exploratory data. We are not going into very detail on this, let us just give this introduction to the magnetic method. Similarly, the gravity method is also employed we know that the Earth does not have the same gravitational pull at all the positions on the

Earth.

So, there is a difference in the pull of gravity. Gravimeter is the instrument that is used to measure the differences in the pull of gravity at different locations. The dense rocks are petroleum-bearing rocks that behave differently than the other types of rocks which do not have petroleum in them. So, the difference in the pull of gravity also gives us an idea about the subsurface rocks. Another kind of this is important tool to measure the exploratory data that is the seismic reflection method.

In this method what is done, sound waves or seismic waves are generated to get the subsurface data properties. Here, sound waves are generated on the surface by some explosion or some other thrust on the ground and sound waves diverse through the subsurface in all directions. Then at a definite rock layer they reflect back and those reflected waves are captured by some detectors and the data are generated. Those data are analyzed. We will talk in a little detail about this seismic reflection method in our next lecture. Thank you for your attention.