Petroleum Reservoir Engineering

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Lecture 10: Primary Drive Mechanisms

Hello everyone. Welcome again to this class of petroleum reservoir engineering. In previous lectures, we had discussed about properties of the fluid, gas, oil and water and in detail we discussed about the rock properties where these reservoir fluids are stored. In today's lecture, we are going to understand how these reservoir fluids underneath the surface in the reservoir rock are getting produced to the surface. through primary drive recovery mechanism. So this diagram showing here is actually a representative of reservoir rock formation where the hydrocarbon fluids are stored underneath the surface.

Three prerequisites are there. Source rock from where the hydrocarbons are getting produced and migrating from source rock to the reservoir rock where these fluids are stored. They are stored in microscopic and macroscopic manner means they may be forming some pool of the reservoir fluid formation as well as the fluids of the reservoir are in small micro porous region that is present in the reservoir. So they are trapped in those porous region.

To hold this reservoir fluid at appropriate place in the reservoir rock another rock is required that we call the seal or the cap rock that is holding this reservoir fluid at appropriate position in the reservoir formation. To reach this fluid, we need to drill the well and when we reach this fluid production wells are installed, completion is done and the production well start producing this fluid to the surface. What exactly happens in the reservoir domain is the discussion of today's lecture in terms of the energy that is present in this reservoir to push this fluid from macroscopic and microscopic region towards the production well. So the aquifer could be there. Aquifer means a water bearing rock that is having a large quantity of the water nearby the reservoir formation.

There is a gas cap that depends on the amount of the gas present in the reservoir and the movement of these fluid towards the production well. The solution gas in the depleted reservoir that goes down towards this production well or this production well passing

through the contact layer between oil and gas. Similar thing happens for this water encroachment from the aquifer that is moving towards the production well. So, lot of the things happen in this reservoir. This is just a representative feature where the setting of the reservoir rocks and the fluid within the reservoir.

So if we discussed about the crude oil production by the primary recovery mechanism that is actually the first stage of the hydrocarbon production. So both oil and gas get produced because of the natural energy that is present in the reservoir. So one is the overburden pressure under that pressure reservoir fluids are there underneath the surface and the production happens the pressure declines. So there are certain other mechanism those occur within the reservoir formation to maintain the pressure up to certain extent so the fluids are getting produced through this bellbore. The mechanism could be many we will discuss one by one in today's lecture.

The purpose of this primary recovery mechanism is to understand the reservoir formation that will help us to understand under what condition the reservoir fluids are getting produced from reservoir to bellbore and then from bellbore to the surface. And this understanding is useful to decide the secondary and tertiary recovery mechanism means improving the oil and gas production from the reservoir formation. Each reservoir is composed of unique combination of geological formation, their geometric formation, the fluid characteristic what type of the fluids are present and accordingly the different terry mechanisms are present in the reservoir those are responsible to let the fluid flow towards the production well. This is a very simple systematically shown diagram where oil, gas and water are in the reservoir at a very high-pressure PE that is the reservoir pressure and when production start here at the surface the pressure decline and because of the pressure difference fluid moves towards this production well. The second diagram is showing the arrangement of the fluid in the reservoir formation because of the density difference the gas cap will be formed there if gas is present there and followed by the oil and the water is denser than both of them oil and gas it will be at the bottom.

Now the placement of the oil, gas and water could be very different this is one way of the presentation of their arrangement but because of the density difference gas will be on top then oil and then the water. The arrangement could be different in the sense in this diagram it is showing the water is in the form of is water. So the water that is present in the reservoir connected through some aquifer that is actually not in the direct or horizontal contact with the oil layer but only the ages part of this water are in the contact with the oil. As I mentioned there could be several arrangements possible underneath the

surface some of them are shown here. So for example here the gas cap on the top then the oil giant and then the water, water from the age side but if we see this kind of the arrangement where the entire oil section is in the contact of the water and oil water are in the contact and this arrangement is called the bottom water contact.

So the entire water is in the contact with the oil layer. The water that is present underneath the surface will also get produced over the time so the depletion of water may also happen but there could be a possibility where this aquifer the water wearing rock is getting recharged through the surface water by some channels. So the amount of the water may remain constant. Some more kind of the features could also be there where the wells are drilled to a location to the gas formation only or to the region where the oil joint is there. In this diagram we are seeing the wells are drilled to the oil joint so the oil will have the direct access towards this production well while the gas cap needs to pass through that layer between the oil and gas to get produced through this well.

So, some more combination could also be there. So to understand how the production is happening what kind of the pressure energy that is contributing to produce this reservoir flow to the surface there are certain indicator of performance characteristic those can be measured to understand which derived mechanism is responsible to produce the flow to the surface that could be the pressure of the reservoir that is declining as the production is happening. We can estimate the declination rate of the pressure and that is one of the indicators in terms of what kind of the dry mechanism is present in the reservoir. Second is how much gas and oil is getting produced at the surface so the GOR ratio water cut in case of when the water is also getting produced how much water is getting produced at the surface that is also one of the indicator and ultimate recovery of the hydrocarbon fluid to the surface that is actually give the indication of what kind of the dry mechanisms are present in the reservoir. So there could be only one type of the dry mechanism or the combination of the dry mechanism in general it is the combination of the dry mechanism those are responsible to maintain the pressure or the energy or primary energy to let the fluid produce but depends on which particular type of the dry mechanism is having significant contribution the dry mechanism are classified for both oil and gas production.

So let us look about the dry mechanism those are present in the reservoir they are the source of the natural energy to let the fluid flow from their reservoir location to wellbore location. Actually the same pressure energy is required to let the fluid from wellbore to the surface but the dry mechanism are understood in terms of how the fluid is migrating or flowing from reservoir location to wellbore. The recovery of oil by any of the natural

dry mechanism is called the primary recovery. So we are talking about the primary recovery in current scenario secondary and tertiary recovery will be discussed later. So the natural dry mechanism those operative in the oil reservoir are six type.

So there are six types of the dry mechanism those are responsible to produce the oil to the surface in the oil reservoir. Oil reservoir means it is primarily producing the oil it does not mean it is not producing gas and water they are also get produced. So the dry mechanism are liquid and rock compressibility, solution gas dry or the depletion dry, gas dry, aquifer that is getting influx of water to the reservoir rock, gravity segregation of different fluids and the combination of some of these dry. So the six types of the dry mechanism may be responsible one of them or all of them may be responsible to let the oil produced to the surface. In terms of the natural dry mechanism for the gas reservoir this is gas expansion or the depletion dry similar to this one and the water aquifer that is letting the gas flow from aquifer to the production well while maintaining the pressure of the reservoir and the combination of these two.

The reservoir pressure and the oil gas and water production are actually the indicator that we can see with respect to the dry mechanism but they are dictated by geological and geophysical characteristic of the rock under what condition what type of the rock is this under what condition the geological formation is deposited underneath the surface how the primary migration of the fluid happened what are the possibility of the secondary migration from that. The properties of the rock and fluid that is present in that formation and the heterogeneity of the reservoirs it is not a homogeneous reservoir. Homogeneous reservoir will behave differently than the heterogeneous reservoir and most of the reservoir those where the hydrocarbon fluids are the sedimentary reservoir and the heterogeneity is present in those reservoirs and then the natural production mechanism those we discuss here for the oil and for the gas and fluid flow mechanism how the fluid flow is happening through the permeable region within the reservoir rock. So let us discuss one by one all this dry mechanism those are responsible for oil production first one is liquid and rock compressibility dry mechanism this kind of the dry mechanism may be responsible to produce the oil to the surface through this well bore in case of this kind of the dry mechanism the crude oil, cornet water and the rock are only present in the formation. So this dry mechanism may be contributing to maintain the pressure or providing the energy when there is no gas cap there is no gas formation and there is no means aquifer also attached with the reservoir.

So this reservoir mechanism is effective when the reservoir is under saturated condition it means the pressure of the reservoir is above its bubble point pressure in that case what is happening if there is no gas initially present keeping the pressure above the bubble point pressure the gas is also not getting liberated out from the oil and most of the time the reservoir is not producing any gas when this recovery mechanism is supporting the primary energy. The pressure declines happens the fluid and rock expansion happens so what exactly happens when the production started the pressure will decline because of this pressure energy the fluid is producing now when pressure declines the rock that was under very high pressure that is also start expanding and the similar phenomena happens with the liquid that was having not very high compressibility but still it is having the scope to get expand because of this expansion of both individual rock and the liquid they reduce the pore volume that is generated by the production reducing the pore volume means reduce the porosity it means the fluid or the oil that is stored in the micro porous region that comes out because of this expansion and that contribute towards the oil production and maintaining the pressure compressibility of the liquid and rock are quite smaller and usually in the order of 10 to the power minus 6 so the contribution of these rock expansion and the liquid expansion is not significant the liquid and rocks are only slightly compressible reservoir will experience a rapid pressure decline until the bubble point pressure is achieved in this case as there is no gas present in the system the gas and water are not getting produced because the reservoir is under conate water situation that water will remain in the reservoir there is no associate aquifer so the water is not getting produced in terms of the GOR the value will remain low or constant because there is no source of the gas production but overall the liquid and rock compressibility drive mechanism is considered the least efficient driving force to let the fluid flow from their original place to the well bore and the recovery is also very small only 1 to 5 percent or in terms of the average 3 percent of the original oil in place can be produced when this kind of the dry mechanism is present in the reservoir formation so the indicator that I was discussing is pressure GOR and the water production or the water cut so we will see these features GOR reservoir pressure oil rate and the water cuts actually there are four parameters those characterize the reservoir performance in terms of the drive mechanism those are there and how much maximum recovery can be achieved so the second drive mechanism is this solution gas drive also called the dissolved gas drive or depletion what happens in this kind of the dry mechanism it occurs in a reservoir which contains no initial gas cap or underlying active aquifer to support the pressure so there is no active aquifer there is no gas cap it is similar to the previous one but the difference in this drive and the previous one is that the pressure is declining and the pressure declines below the bubble point and in that case what happens as the pressure is declining below the bubble point the gas evolved out from the oil because of the solubility the gas was there now pressure declines the evolved gas is liberated out from this oil and that actually supporting the formation in terms of the pressure so since the liberated gas has a higher

compressibility the rate of decline of pressure per unit production slows down because it is supporting the pressure the principal source of energy is a result of gas liberation from the crude oil and the subsequent expansion of the solution gas as the reservoir pressure is reduced so if we see in terms of these parameter on time scale this time scale is not just few hours or few days in several month or in year where we see the pressure of the reservoir initially was pi the reservoir pressure and as the pressure decline the pressure declines below the bubble point the gas start evolve out from the oil and because of that the GOR ratio increases and it increases to a maximum value where most of the gas get produced and then further it declines the oil rate is declining over the time it also reaches to certain maximum value when the reservoir pressure is above the bubble point and beyond that the oil rate also start declining because the gas is also getting produced along with the oil in the reservoir formation the pressure continuously decline and become the constant as there is no active aquifer so there is only a small amount of the water gets produced through this kind of the dry mechanism so the researcher Cole in 1964 summarizes all these parameters those are the indicator for the dry mechanism like pressure of the reservoir it declines rapidly and then continuously it remains like this GOR initially low then gas evolved out and it reaches to the maximum and when the gas production happens gor value further reduced water production no active aquifer no water production is there and the ultimate recovery by this mechanism ranges from 5 to 30 percent with an average value of 16 percent this kind of the dry mechanism if it is present in the reservoir supporting the primary production is a very good candidate for the water flooding mechanism and water flooding should be implemented in this kind of the reservoir formation when the reservoir formation is having gas cap drive it means little or no water is there only the gas that is initially present in the reservoir so the reservoir formation is like this water oil and gas if gas cap is there and that gas will push the oil towards the production well in that case the dry mechanism is called the gas cap dry mechanism when the initial reservoir pressure and temperature are within the two-phase region so the pre-re characteristic is in this case the temperature and pressure is such that early two-phase region is present in the reservoir formation gas is already evolved out because of the density it stored on the top of the oil and that is actually helping to maintain the pressure in the reservoir gas being the lighter than oil it rises above the oil zone due to gravity segregation as the pressure declines with the production the gas cap expands resulting in gas cap drives so production declines gas expansion happen because gas is very highly compressible pressure declines it volumes increases large then actually it is pushing the oil towards the production well in terms of the indicating parameter the reservoir pressure it falls slowly and continuously water production either absent there is no water source there or very small amount is getting produced from this kind of the dry mechanism GOR initially gas is produced due to the free gas saturation because already gas is present in this case and as the pressure declines the GOR also rises to maximum and then finally it drops out ultimate recovery of this

kind of the dry mechanism ranges from 20 to 40 percent with an average value of 25 percent what is the conditions for this kind of the dry mechanism the ultimate recovery from gas dry mechanism depending largely on these six parameters like the size of the original gas cap that is actually the definition of m a parameter that determines the ratio of initial volume of gas cap to the initial volume of the oil that is naturally present in the reservoir formation so how much the original gas is present that's actually contributing towards this dry mechanism so the size of the original gas cap is one of the pre-requested for this kind of the dry mechanism larger the value of m the more force or the more contribution of the gas cap drive for the recovery purpose vertical permeability so the gas will move upward and the reservoir rocks would have the permeability to let this movement of the gas happens initially to get stored on the top and later on when it is pushing the oil the downward vertical permeability should also be present so it is letting the gas flow through that vertical permeability similarly for the oil also towards the production well the oil viscosity so that is not letting the gas bypass if the oil is less viscous it means the flow characteristic is improved but in case of the high viscous fluid the bypassing of the gas can also be reduced so the optimum viscosity of the oil is required while production rate at what rate the oil is getting produced and the degree of conservation of gas so the gas that is on the cap it is getting conserved it is not just we started the production and gas just pushed the oil and get produced along with the oil the gas would remain in the reservoir means it should get conserved in the reservoir for a longer time to support gas cap drive mechanism and then the dip angle means the geological formation of this reservoir rock with respect to the horizontal surface so at what angle the formation is there that is actually also helps in this case cap drive mechanism to let the pressure maintain for a longer time the next drive mechanism is the water drive mechanism in this case what happens the nearby water rectifier or these rock that is having the significant amount of the water that is actually letting the pressure maintained so when the production is happening oil and gas are getting produced to the surface along with some amount of the water the pressure is declining but that pressure is maintained by some nearby equifier and that may happens in case of the bottom or age formation of the water both the arrangement of the equifier either it is in the bottom case or it is in the age case they support the reservoir in terms of the pressure so when an oil and gas reservoir is in communication with surrounding a key fire production from the reservoir result in a pressure drop between the reservoir and the equifier this allows the influx of water into the reservoir means the pressure difference is happening between the reservoir and the equifier because the produce the fluids are getting produced and because of that pressure difference the water influx is happening towards this reservoir rock a producing reservoir is referred to as the bottom water is or the is water drive that I mentioned like the arrangement of the rock formation may have either the bottom or the is water drive that depending on the location of the adjacent equifier that is providing the energy for the production natural water drive is usually the most efficient drive to

produce the fluid naturally because it is significant quantity of the equifier that is actually maintaining the pressure for a longer time and in fact it produce one third of the world reserves by the primary mechanism so the water drive mechanism is so significant that one third of the crude oil by the primary mechanism is getting produced by a water drive mechanism in terms of the indicator the reservoir pressure remains high because as the fluid is getting produced the server will decline but the same time the water influx is coming in and maintaining the pressure GOR remains low if pressure remains high so if pressure remains high because of this water influx then the oil is still having the pressure above the bubble point pressure it means it is still under the under saturated condition it means the gas is not liberated out from this oil and the GOR value that is gas oil ratio will remain low if the pressure remains high if pressure declines the gas will liberated out and GOR will also get change what about the water production as the water is getting influx into the system initially the water will be produced then remain constant for a longer time but after certain time the significant amount of the water will get produced from this kind of the reservoir and actually the water cut will be very high ultimate oil recovery by water drive is usually the most efficient reservoir drive mechanism and it contribute 30 to 80 percent in terms of the recovery factor on the size and strength of the aquifers what size of the aquifer at what rate it is getting influx into the reservoir domain will determine the recovery factor but it is still high compared to the other one and it ranges from 30 to 80 percent the next drive mechanism is the gravity drive mechanism that's occurring petroleum reservoir as a result of difference in the density of the reservoir fluid so the gas on top while underlying the gas and water underlying the oil is arrangement of the fluid within the reservoir formation so here we can see in this diagram if all oil gas and water are present in the reservoir domain then the gas will be on top followed by the oil and then the water many things are shown in this diagram but few things quickly we will discuss about this is that dip angle that's the formation is making where the reservoir fluids are at certain angle inclined to the surface and they are contributing towards the production because of the gravity now gravity will also applicable depending on at what angle they are if it is a vertical then it is simply G otherwise it would be G cos (theta) for example so the dip angle becomes very important in this case the tendency for the gas to migrate up and the oil to draw down clearly as influenced by the rate of flow of these fluid as the permeability is allowing them so the permeability of these fluid in the upward direction or in the downward direction in this dip angle will also be responsible to let the fluid flow towards the production well the indicator like the pressure reservoir that is variable of pressure declining depending principally upon the amount of gas conservation so the situation could be the arrangement of oil gas and water like this where we are having the original gas while contact original while water contact at the interface of two phases now the position of the production well where the production wells are located or where the production string is having the perforation and from where the fluid is getting produced will also determined

the efficiency of the different recovery mechanism to get the fluid produced for example here in this case the oil needs to move upward direction to get produced if we are having this kind of the well arrangement where the perforation reason or the production reason of the well is either in the gas cap or somewhere at the near the interface so this oil and water needs to move against the gravity or the permeability in that direction should be quite enough to let the fluid migrate from their original position towards the production well if the wells are in this region so the gas and oil both moves downward to reach in this region and get produced so the not only the dip angle the location of the well is also important and that's actually determined what we are going to produce from a particular well at what angle the formation is there and what is the exact location of this production string within the geological formation we will discuss a little bit more detail in the later slide let's discuss in detail about the indicator so for example the reservoir pressure it is variable rates for pressure declining depending amount of the gas conservation is happening so if the gas is here and the production well is here the gas will remain for a longer time in the reservoir formation compared to this production well system and it will be contributing to maintain the pressure for a longer duration. GOR low from low wells on the other hand is structurally high wells will experience an increase in gas so this is these are the high wells means they are at the above height in this formation arrangement so the gas is having the easy access to this production well while at the low side the gas needs to move in this manner gas is lighter tries to move upward but it has to move in this direction to get produced in that case the production of the gas will be low so the GOR will be low for the low wells and it will be high for the high wells water production little or no water produced because the water needs to be produced through this aquifer and when the aquifer is responsible to produce the hydrocarbon fluid to the surface then that is not the gravity drainage dry mechanism that falls as a water dry mechanism so when the fluids are getting produced under the gravity drainage the GOR is variable but the water production that is actually no water is getting produced a very small water is getting produced from this kind of the dry mechanism ultimate recovery by the gravity drainage is 30 to 80 percent and that is again depends on several factors those factors is permeability in the direction of dip like the fluids need to move upward direction or the downward direction the dip of the reservoir at what angle the formations is storing the fluid reservoir production rate the oil viscosity that becomes very important as I explained if the oil viscosity is less the movement of the oil will be faster or the permeability of the reservoir rock formation for the low viscous oil will be more or means the fluid will be moving easily in that manner the relative permeability characteristic so there will be a competition between the oil and gas to move either the upward direction or downward direction depending on the formation so the relative permeability is also an important characteristic to contribute towards gravity drive mechanism for the oil production to the surface next one or the last one is the combination drive mechanism in that case the gas cap and a key fire both are contributing

towards the production of the primary recovery in this case the driving mechanism most commonly encounter is one in which both water and free gas are available in some degree to displace oil towards the production well so not only the gas cap not only the water but both significantly contributing towards the production the combination could be in this manner where the depletion drive and a weak water drive is present in the reservoir second is depletion drive with a small gas expansion and a weak water drive so in both the cases you will see the weak water drive is considered if a strong water drive is present then it will qualify to water drive mechanism not to the combination drive mechanism because the contribution of the water drive towards the production will be much higher than the solution gas drive or the gas cap drive gravity segregation can play an important role so how the fluids are stored underneath the surface because of the gravity so it is not a very systematically that I shown you because of the heterogeneity of the reservoir there is not a very clear-cut lines this is oil this is water this is gas but in most of the reservoir because of the gravity it is horizontal line that is separating oil gas and water based on the gravity so the combination drive reservoir can be recognized by the occurrence of combination of some of these following factor what those factors are relatively rapid pressure declination happens in the combination drive mechanism so water encroachment happens but that water encroachment is a weak water encroachment and the pressure decline rapidly compared to water drive water encroachment slowly into the lower part of the reservoir so the structurally low producing well will exhibit slowly increasing water production rate so those are at the low height they will be showing the slowly increase in the water production rate if a small gas cap is present continuous increasing GOR will be encountered in this case that provided the gas cap is expanding so if the situation is there where the pressure is declining and the scope is there where the gas cap is expanding pushing the oil towards the production well ultimate recovery from this combination drive mechanism in the reservoir is usually greater than the recovery from depletion drive but less than recovery from water drive or the gas cap drive so the water drive and the gas cap drive are more efficient in terms of the ultimate recovery but the combination of water and the gas cap drive could be more than the depletion drive the history of the different drive mechanism over the time can be shown here so the reservoir pressure declines for the water gas and the depletion drive in case of the water drive you will see the pressure is not declining so rapidly the GOR is also almost constant because it is assumed like there is no gas but when the pressure is declining below the saturation pressure or the bubble point pressure the GOR will improve and the water cut will also be more compared to other two drive mechanism like the gas drive or the depletion drive mechanism so in depletion drive mechanism the pressure will decline bubble point pressure will be achieved gas will evolved out so more GOR will be produced when gas is produced significantly the GOR receive will further decline while in case of gas drive the GOR will remain almost constant because the pressure is declining sometime the gas is coming out and the gas and oil are getting

produced almost with the same rate similarly the recovery efficiency of different drive mechanism can be estimated with respect to the pressure and this presentation of recovery efficiency in terms of the percent on the x-axis with respect to the reservoir pressure in terms of percent of original pressure on y-axis are plotted means this is again like a representation for different drive mechanism so the source of this information is from Sator and Thakur where the pressure declination is happened very rapidly in case of the liquid and rock expansion while the recovery is also very less than 10% we can say while the solution drive recovery is better than the previous one that's further improve if the gas expansion recovery mechanism is existing in the reservoir followed by the water influx so the initial pressure decline will be there but later on as the water influx is coming it will maintain the pressure and the reservoir will be performing for a longer duration and overall ultimate recovery by the water influx will be higher segregate gravity drainage process also significantly contribute towards the higher recovery process the pressure declination is following almost the same process the water influx even the pressure maintain for a longer time because the gas cap is also contributing along with the water influx to maintain the pressure in the reservoir formation and the recovery is around 60% by the gravity drainage so relatively we can see how the pressure is declining with different recovery mechanism and what is the recovery efficiency to have the comparison of the recovery efficiency by this different drive mechanism there are certain pre-recoustic record like the region should be porous and permeable significantly porous and significantly permeable so there should be vertical permeability for the gas cap reservoir and the highest recovery potential is associated with the reservoir having the water influx we can see the recovery is more in case of the water influx from an adjacent aquifer and this recovery is followed by the gravity drainage so the more recovery by the water influx followed by the gravity drainage but again the emphasis is that the reservoir should qualify under certain criteria to understand this drive mechanism like the porous and permeable reason is required so when it comes to gas reservoir the recovery efficiency by the depletion drives ranges from 80 to 90 percent of the recovery of the gas the water drives falls in the range of 50 to 60 percent because of the bypassed gas and the high reservoir pressure the recoveries or by the water drives in the range of 50 to 60 percent so in summary of the primary recovery mechanism we discussed six types of the recovery mechanism like the rock and liquid expansion drive pressure decrease rock and fluid expense pressure decrease porosity decrease because of this expansion and this process is least efficient in terms of the recovery depletion drive solution gas and dissolved gas expansion happen because the reservoir is falling below the bubble point reason gas kept right initially the gas is there the gas from this solution gas from the oil can also be contributing for this gas kept right because of the secondary gasket formation happens so the gas that is liberating out from the oil will move upward direction and if there is a space this will get stored there that is called the secondary gas cap water drives that is from the water wearing rock the

water influx is happening in the reservoir domain gravity drainage that is difference in the density of the fluid they are stored and they contribute combination drive that is because of the gas cap and the water drive that is commonly affecting the recovery factor and maintaining the pressure within the reservoir domain so the reservoir pressure water production GOR ultimate recovery and the well behavior are some of the indicator those can be utilized for the purpose of identifying what kind of the drive mechanism is underneath the surface that is letting this fluid to produce by the natural energy this arrangement that I mentioned how these oil gas and water are segregated there are contact layer between gas and oil and oil and water if the well position is here we will get oil gas and cap and the solution gas will also get produced in this case oil and solution gas will produce because the gas that is originally present will be helping to maintain the pressure but the production will be at the later stage while in the third case you will get oil solution gas and water significantly production of all three phases in this case and the gas cap expansion and the other mechanism those are letting the gas liberated out from the oil are responsible to maintain the GOR or seeing the trend of the GOR production so along with this recovery mechanism it is very important the dip angle that the formation is making with the horizontal section and the permeability in the upward direction and downward direction depending on the arrangement and the location of the production wells where they are actually situated so the combination of all these things will affect the recovery process and accordingly the primary drive mechanism will be identified with respect to knowing this dip angle and the production well position. With this I would like to end today's lecture in the next lecture or week we will continue our discussion about this primary drive mechanism but in terms of the volumetric performance equations mathematically we will try to understand under what condition which drive mechanism is responsible or overall we will do the material balance on oil and gas reservoir in such kind of the system where the reservoir is there oil gas water and the rock are present and what exactly is happening when we start producing so the performance equation by the volumetric balance will be the topic of discussion for the next lecture with this I would like to end today's lecture thank you very much for watching the video see you in the next lecture thank you. Thank you.