Geomorphology
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Lecture-57
Exploration Geomorphology in Oil field Sandbody Geometry- I

So, friends, welcome to this lecture series of geomorphology and today we will talk about these exploration geomorphology in particular the oil and gas exploration, you see exploration geomorphology is nothing, it is like exploration geomorphology it is the experience we received or we gained from these various geomorphic environment like fluvial, glacier, Aeolian, coastal. So, those geomorphic experiences we will use in exploration, because particular geomorphic environment, it is also it is particular depositional environment it is corresponding with.

So, that is why in particular for example, we are talking about a fluvial environment talking from this head of the river up to this mouth, we have the erosional zone, we have depositional zone, we have transportation zone. So, similarly in these fluvial environments in particularly the delta regions in the flood plane, we develop sandbodies and sandbodies are developed with the clay's alternative clay's. Similarly, in Delta's we have sand clays silt like that so, that they are very good source for petroleum hydrocarbon generation as well as reservations.

Similarly, if we talk about this mineral exploration. Similarly, mineral exploration there is nothing like a mineral exploration geomorphology but this geomorphic environment or this geomorphic that means the topography different topographic controls, how they behave in exploration that is the exploration geomorphology for example, suppose we are talking about this coastal environment. Coastal environment you have, we have already discussed there are good examples of heavy mineral deposits in the east coast of India.

Though that means our this geomorphic experience that means there is a break there is Eastern Ghat there is close to coast and continuously wave action is there so that the fine material the lighter material as removed and the heavier material they are concentrated. So, that is why we are getting some heavy mineral deposits in Gopalpur in Kerala, some heavy mineral deposits are

there. Similarly, at the mountain fronts, we have alluvial we have deluvial and landforms. So, we have creeps.

So, in that creeps we are getting some heavies they are deposits at their. Similarly in the river at this river meanders we have some heavy mineral deposits and like that say mineral exploration, oil and gas exploration. So, everywhere our geomorphic knowledge is very much useful to define what type of mineral or what type of wealth we are looking for. So that what type of a geomorphic environment we should target for that and today, we are going to discuss elaborately about this exploration geomorphology in spatial reference to oil field.

So, why that is important, what does it mean this oil field geomorphology? Generally if you see oil and gas they mostly 99% of petroleum hydrocarbon PHC it refers to petroleum hydrocarbon.

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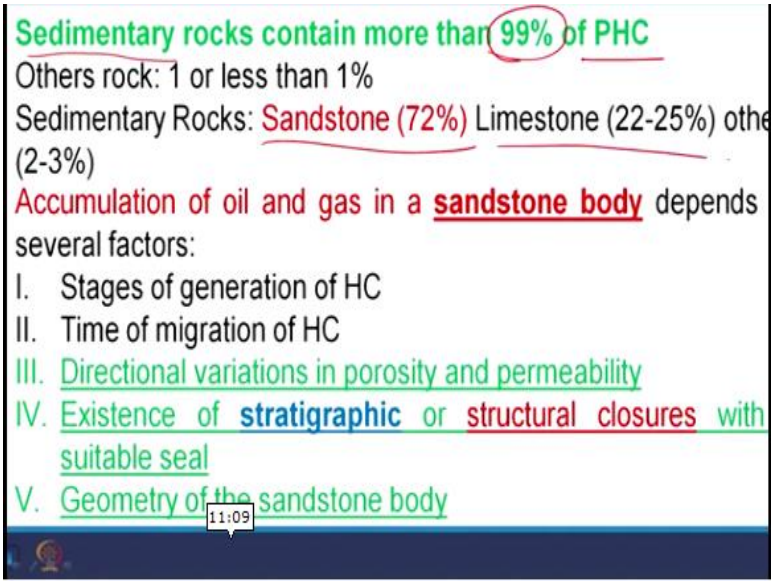

It is found in sedimentary rock so far we have whatever our exploration information, so we have so that means 99% of this petroleum hydrocarbon, the remains in the sedimentary rock. So, that means this sedimentary rock this formation environment the geomorphic environment, which is responsible for formation of those sedimentary rocks, they are important rather than every geomorphic environment.

So, that means, in this class we will concentrate very particularly in those type of sedimentary environments sedimentary that geomorphic environment which leads to the deposition of a particular type of sedimentary rock, which are suitable for generation as well as preservation of petroleum hydrocarbon in that in particularly here if you see within that sedimentary rock the sandstone it contains 72% of this petroleum hydrocarbon, limestone it is 22 to 25% and other 2 to 3%.

So, here we are talking about the reservoir we are not talking about the formation sandstone is a very good reservoir rock no not a source rock. Similarly, limestone may be a source rock may be deserver rock depends upon its organic contain so far and others they are 2 to 3% like somewhere it is fractured basalt is there somewhere it is fractured granite is their fracture shale we are now a days we are exploring shale gas.

So, it is shale it is a source as well as in a reservoir rock also. So, that means, particularly when we are talking something about the oil and gas so far we have whatever the information we have, it says the sandstone contains 72% of this petroleum hydrocarbon so that is why accumulation of oil and gas in a sandstone body depends upon several factors sandstone body we are emphasizing here in this class because the sandstone that forms in particular geomorphic environment starting from this aeolian environment, through coastal environment, through fluvial environment.

So, that means it is a broad geomorphic environments are their different geomorphic environments which lead to the deposition of sandstone. That is why sandstone is very much important in terms of petroleum hydrocarbon exploration is concerned. So, accumulation of oil and gas in your sandstone body depends upon several factors what are those factors one is stages of petroleum hydrocarbon generation.

The stages of petroleum hydrocarbons generation means in petroleum hydrocarbons generation we have different stages like diagenetic stage, catagenic stage, metagenic stage, metamorphic stage in the diagenetic stage we do not have much petroleum very less amount. The catagenic stage and mutagenic stage we generally we get maximum petroleum hydrocarbon in these two

stages. So, at which stage the petrol or the organic matter has matured that depends upon how much petroleum it will yield.

Similarly, time of migration of hydrocarbon, time of migration time of migration means how much time it is taken for migrating either it is less time that means, it is all the petroleum hydrocarbons already migrated. If it is more time that means, in the sandstone body different part will get petroleum hydrocarbon, then directional deviation porosity and permeability, this is a very important factor, porosity permeability it is where porosity is required to store the petroleum hydrocarbon and permeability is required to transmit.

So, until unless a sandstone is porous and permeable we do not get petroleum hydrocarbon. So, existence of stratigraphic and structural closures with a suitable seal stratigraphic and structural closure as we know there are 2 types of trap. One is stratigraphic trap that means I am talking about the prominent traps. One is stratigraphic trap, another is structural closures or structural trap within that we are getting some that means we are getting petroleum hydrocarbons.

Then geometry of the sandstone body geometry of the sandstone body that means either it is a very thin or thick body or a elongated body, it is a pool shaped body it is a sheet type of body, then what type of this sandstone body looks like or it appears to that also depends upon how much petroleum hydrocarbon contain because a small body it will only accumulate a small amount.

It will only store a small amount of petroleum hydrocarbon a large elongated body it will contain more petroleum hydrocarbons. Similarly, sheet types of body again contain more petroleum hydrocarbons. So, that means these factors that influence this petroleum hydrocarbon and sandstone body.

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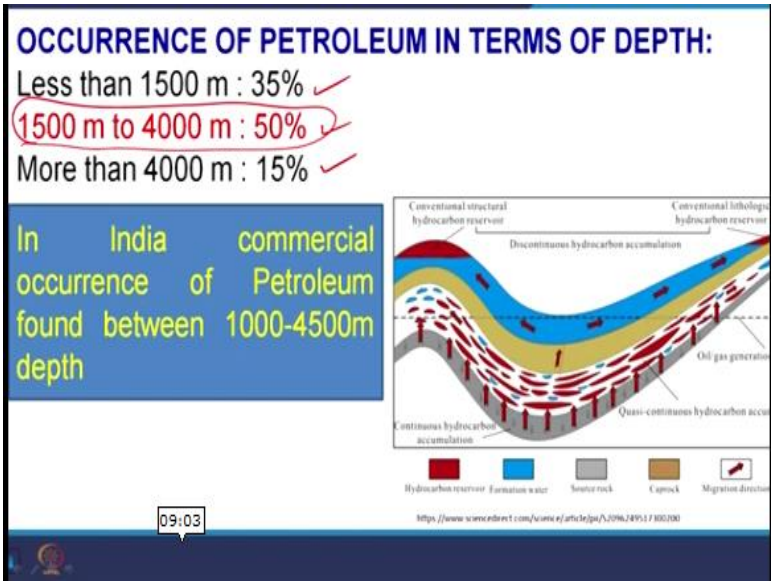

Now, if we go in depth wise the petroleum hydrocarbons occurrence, less than 1500 meter we are getting 35% 15 to 4000 meter we are getting 50% more than 4000 or we are getting 15%. So that means here maximum occurrence of petroleum hydrocarbon it is between 1500 to 4000 meter depth. Similarly in India commercial occurrence of petroleum hydrocarbon it is found between 1000 to 4500 meter depth.

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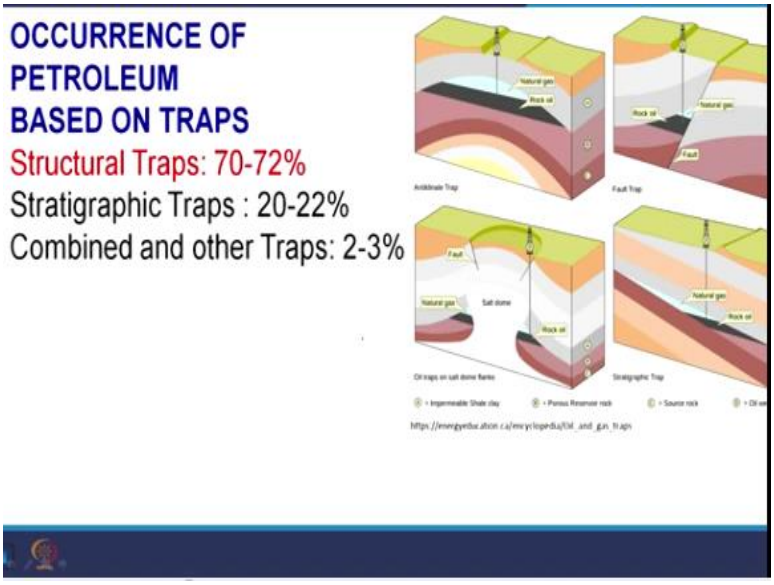

Similarly, as few minutes back we are talking something about the trap you know in its petroleum geology, there are structural trap, stratigraphic trap and combination of other traps unconformity trap and other traps also they have been structural and stratigraphy may be

combined together. So, here the structural trap it is more important because its contains maximum petroleum that 70 to 72% of petroleum hydrocarbons forms in the structural trap.

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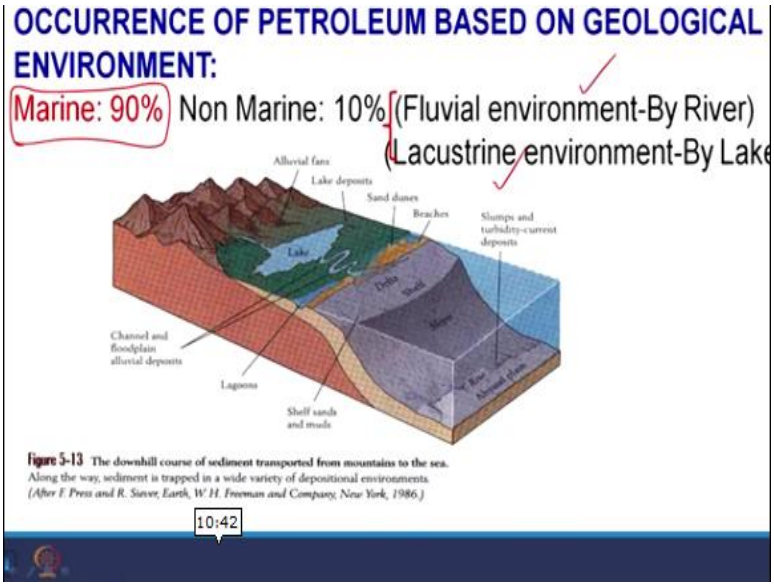

So, occurrence of petroleum based on geological environment. Geological environment means it is marine environment or non marine environment. Non marine environment means it is a fluvial environment, lacustrine environment it is aeolian environment it is a glacial environment. So, that means is you see 90% of this petroleum comes from the marine environment and 10% is fluvial environment and lacustrine environment. So that means so, here you can say, these geomorphic processes, which are acting in the marine, that means marine geomorphology are these coastal geomorphology.

And the near coastal geomorphology where, because we are talking about the sandstone. Sandstone is a near coast product or a shallow water product that in periphery basin periphery product. So, that means near coast product, marine environment, they are more prone to generate or more prone to store or more prone to generate those type of sandstone where they are more prone to deposit those type of sandstone body which are very much suitable for this accumulation of petroleum hydrocarbons.

That does not mean other sandstone body they do not contain petroleum hydrocarbon we have fluvial environment we have fluvial sandstone, we have lacustrine sandstone that do contain

petroleum hydrocarbons too. That is why it is a range of geomorphic process starting from the fluvial more emphasized on the marine or the coastal process. And other processes also, they are very much responsible for generation of such type of sandstone bodies, which are more prone to contain petroleum hydrocarbon in a commercial occurrence manner.

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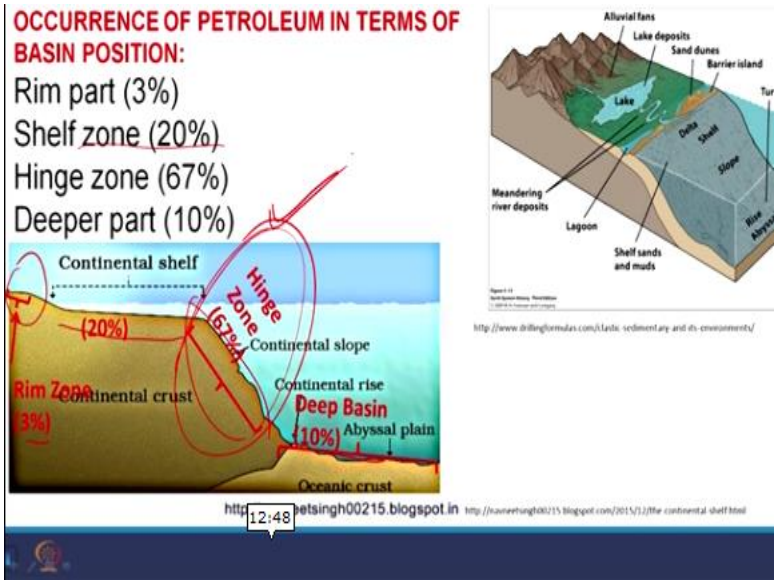

So, occurrence petroleum in terms of basin position, that the rim part it is if you see here, this is the rim part. Rim part it is contains 3% shelf part it is 20% then hinge part it is 67%. So, deeper part is 10%. So, that means within the marine environment if you see restrict these part it is contain maximum petroleum hydrocarbon. That means, we are very much concerned about those sandstone bodies, which are formed in these zones of the hinge zone of a marine environment, they are more prone to hold petroleum hydrocarbon within that.

So, that is why these geomorphic processes which are which are working particularly in these environment, they are more important as compared to other parts that does not mean other parts that are do not contain petroleum hydrocarbon. For example, we have fluvial environment, we have point bar deposits. In delta deposit near coast sand sheet type of deposit in the river anastomosing river braided river system we have shoe-string sand type deposits that do contain petroleum hydrocarbon too.

So, that is why a range of geomorphic environment we are going to discuss here and which are prone to generate sandstone body and in turn which will accumulate petroleum hydrocarbon of commercial quantity.

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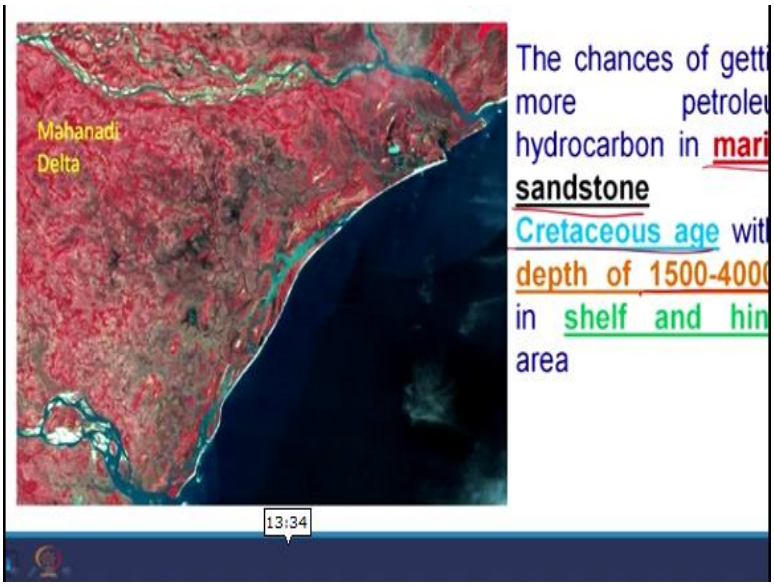

So, the changes of getting chances of getting more petroleum hydrocarbon if we summarize here, all this depth, this geological age, this marine depositional environment depth wise so, everything if we summarize here, though more chances of getting petroleum hydrocarbon in marine environment so, environment wise as we have concluded marine is the most suitable one. Then lithology wise it is sandstone. And it is cretaceous age age wise it is cretaceous time which was deposited, the depth of 1500 to 4000 meter depth constant is there and self and hinge area in environment wise.

So, in a one sentence if we summarize this occurrence of petroleum hydrocarbon worldwide in sandstone body, so the chances of getting more petroleum hydrocarbon in marine environment, sandstone lithology of a cretaceous age the depth of about 1500 to 4000 meter, self and hinge area. So, this the key of this petroleum hydrocarbon occurrence. So, these lines summarizes all types of lithology age, depth, environment, all that summarizes here in the one line.

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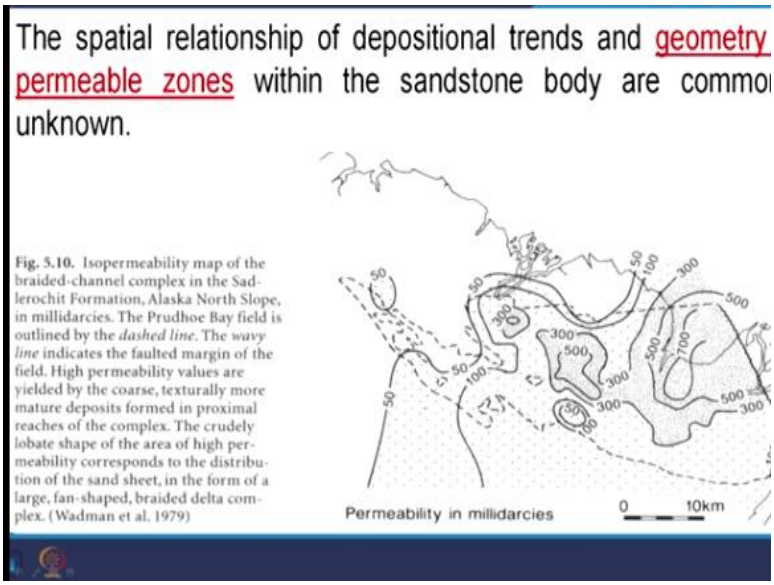

This spatial relationship of a depositional trends and geometry of permeable zones within the sandstone body are commonly unknown, because if you see when we are talking about the sandstone body, either in delta environment or it is in a near coast environment, or it is a fluvial environment we do not know in a sandstone body in which direction the porosity is increasing or permeability increasing or decreasing. So that is why there is more and more information will get with more experience and exploration.

So, if you are very thorough in this geomorphic processes we know there for delta so, for example, we are talking delta process in a delta sandstones deposit in delta environment, we know this delta is a transition between the fluvial environment and the marine environment. So, there will be influence of both fluvial system as well as the marine system. So we are getting a sandstone body and within sandstone body, but depending upon it is a depositional trends. Depending upon these depositional processes involved.

This porosity will be change in a particular direction, the permeability will change in a particular direction. That is why we need to know that means we need to clarify ourselves which direction or which particular direction or which regions in a particular sandstone body which are more porous and more permeable because we are very much interested in petroleum hydrocarbon exploration and petroleum hydrocarbon exploration that means we will be interested in those area which are more porous and permeable.

Because they can hold more amount of petroleum and that can actually yield around amount more amount of petroleum hydrocarbon easily because it is permeability is more. So, that means getting a sandstone body is not enough that we are getting petroleum hydro carbons suppose everything is satisfied that we are getting a cretaceous age sandstone body of 1500 to 4000 meters deposited in the hinge zone area. So, that is not enough.

So, the enough is within that sandstone body we have to restrict ourselves, we have to record ourselves in which direction on which part it is more porous and more permeable and more thickness, which part is more because more thickness is there because it depends on the geometry. So more thicker the sandstone more amount of accumulation petroleum hydrocarbons. So, that means getting a sandstone body is not enough within the sandstone body.

We have to find out where is the more thickness is there, where more porosity and permeability is there, it may possible within a sandstone body there are a number of patches which are more prone to generate petroleum hydrocarbon more easily as compared to other part it is shown in this figure if you see here this is a sandstone body of some area here it is Alaska, North Slope of America, It is a isopermeability map of this braided-channel complex in the sadlerochit formation, it is this area if you see here, these are this isopermeability.

So, that means here these contours they are looking about isopermeability it is 500 millidarcies there 300 millidarcies 315. That means if you see, though we are getting this area is a sandstone body it is a whole sandstone body within that, here we are getting maximum permeability here. That means up to here we are getting 300 permeability like that so, that means within the whole sandstone body, all this whole body or the entire body is not suitable for us.

So, we are mainly on concentrate our self in these areas or this part of this sandstone body, which is more porous and more permeable. So, that there is expectation that it might contain more petroleum hydrocarbon and it can yield petroleum hydrocarbon very easily if we drill a hole there. So, that means simply getting a sandstone body or sandstone geometry is not enough, it is the some additional or the additional and more important information we required about the

sandstone body, the thickness its porosity distribution, it is permeable distribution within that sandstone body.

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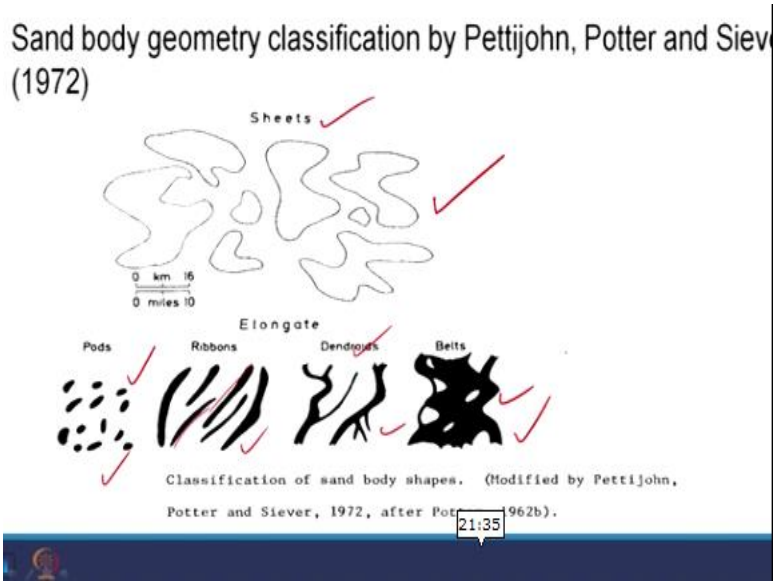

Sand body geometry has been classified by Pettijohn and Potter and siever in 1972. And it is still we are adopting or we are following these classifications. So, if you see here, there are the five types of sedimentary these sandstone bodies here, one is sheet type, another is pod, ribbons dendroids, belts. So, if you see here these sandstone bodies, their geometry is different, the thickness is different and there depositional environment is different and in turn is geomorphic processes involved for the formation of sandstone body is different.

So, that means different geomorphic environment may deposits same type of sandstone body and same type of geomorphic environment may create different types of sandstone body for example, if you see here, sheet type of deposits, sheet it can be found in the alluvial plains. Sheet it can form in the marine environment like near coast, in the deltas, in the flood plains in this due to migration, continuous migration of this point bar so, that means geometries one that is sheet type, but we are getting in different geomorphic environment, different geological depositional environments.

So, that means, both all these geomorphic environment we have there are important for us that is marine environment, deltaic environment, floodplains that is migration of this point bars alluvial

plains, all those geomorphology we should be clear about how the geomorphic process work, how the geomorphic processes change within that geomorphic environment. So, that this type of sandstone body it can generate.

Similarly, pod, pod is a small one as the figure says it is small and isolated one ribbon, ribbons means elongated, like a that is ribbon, that we use for this students or girls that use and dendroids, dendroids means like dendroid they are branching out, belt it is correlation of more dendroids. So, that means these type of sandstone bodies, they are particular or some combination of some geomorphic environment.

So, by if we have experienced about the different geomorphic environments, then we can predict that this type of geomorphic environment it is there and we are expecting these type of sandstone bodies so, that our exploration strategy will be defined depending upon our experience.

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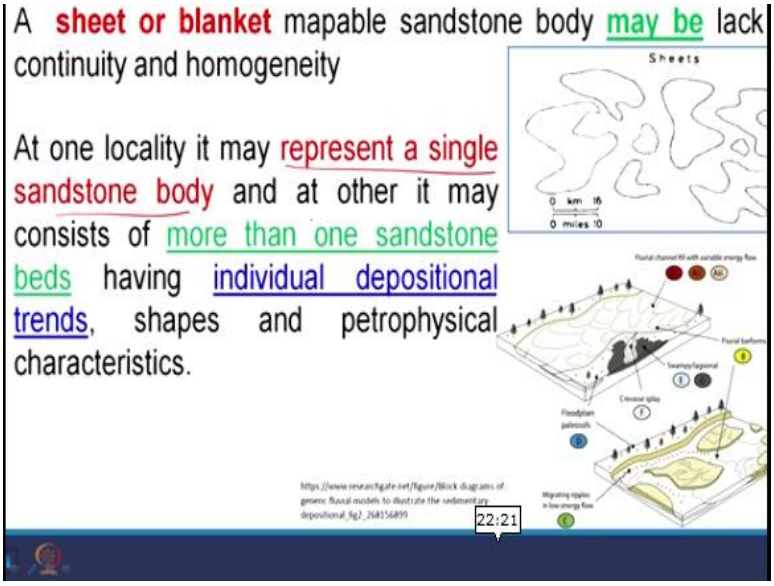

Talking about the sheet or blanket type if you see a sheet or a blanket mapable sandstone body may be lack of continuity and homogeneity. At one locality, it may present a single sandstone body and at other it may consist of more than one sandstone beds having individual depositional trends, shapes and petro physical characteristics. So, the example here that means, geometry is one depositional structure is one, but geomorphic processes are different. For example, and we are discussing a sheet may be formed in different geomorphical environments.

So, the one locality it may present is single sandstone body and the other it will consist of more sandstone bodies. For example, taking Suppose, we are talking about the sand sheet type of deposit in the near coast, in the near coast, we have and the coastal environment we are getting sandstone body parallel to the coast, the whole coast is ranging one it is connecting with a sandstone body, but in between when there is a rivers, which is cross cutting this coast. So, that means there is a discontinuous discontinuity among the sandstone bodies.

So, that though it is a single sandstone body but it is divided due to this rivers perturbations. So, that means one environment, but different sandstone body disconnected sandstone bodies. Similarly, suppose in a flood plain, flood plain we generally deposit sand and silt, sand silt clay also deposited during flood time. So, that means, we are getting a blanket type sandstone body, suppose river migrates river cross cuts its own deposits. So, that means, sandstone body will be dissected into different parts different segments.

So, that means, it is represented either it may represent a single sandstone body or it may be more than one sandstone body, but the individual depositional trend individual depositional trends. Suppose, we are talking about the sandstone body formed in the alluvial plains. In the alluvial plains generally, river migrate continuously. Because due to the sediment load more sediment load so river channel has to accommodate itself.

So, now suppose for the formation of the sandstone body in a alluvial fan this is the position the present condition, this is the position of the alluvial fan we are getting the sand body here. So, once the river migrates here that means, the sand body trend about here will be changed. So, that means, earlier the sand sheet was deposited here, strike wise and now, it will change like this. So, that means, the single sandstone body may found in a different depositional process and the trend of the sandstone body that depends upon the geomorphic processes and the geomorphic agents which are involved in their formation.

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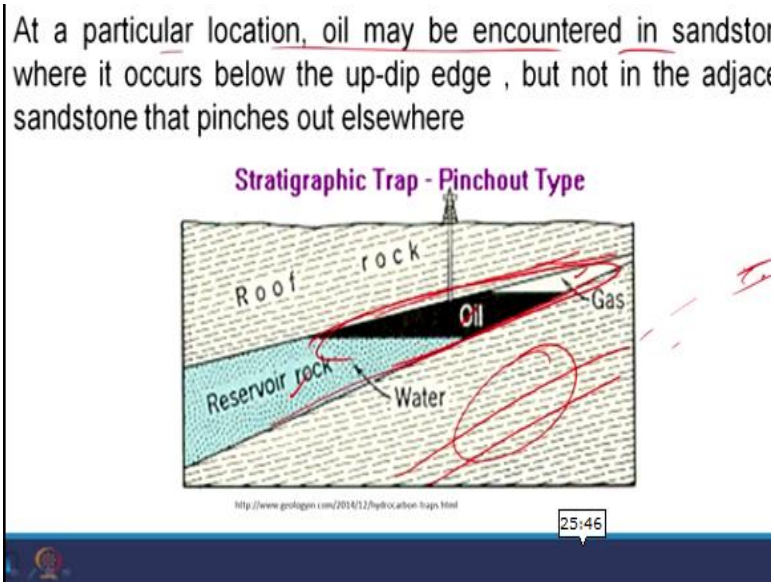

At particular location, oil may be encountered in sandstone where it occurs below the up-dip edge, as but not in adjacent sandstone body that pinches out elsewhere. So, it is possible that if you are getting oil and gas in one sandstone body it is not necessarily this sandstone adjacent to its also contains petroleum hydrocarbon that depends upon the geomorphic environment. So, for example, here suppose a particular location oil and gas may be encountered in the sandstone body, but it occurs below the up-dip region.

So, for example, here if you see, this is the up-dip and this is the sandstone body, the reservoir rock and we are getting gas here, oil here and water here. So, that means here we are containing petroleum hydrocarbon, but others sandstone suppose for example, it is here just close to it, but it pinches out somewhere there here. So, that means here we may not get petroleum hydrocarbon, petroleum hydrocarbon if it is there we may get somewhere here.

So, that means it says so, at a particular location oil may be encountered in sandstone where it occurs below the up-dip edge but not in the adjacent sandstone pinches out somewhere else if it is pinching out somewhere else. So, there may be good chance that getting petroleum in the other part rather than adjacent this system adjacent to the present sandstone body.

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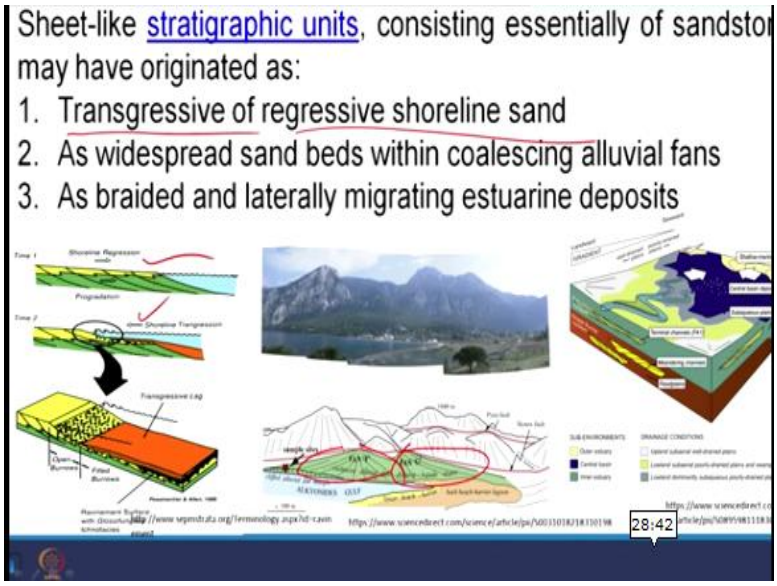

So, sheet-like stratigraphic units consists of essentially of sandstone may originated as transgressive or regressive shoreline sand, transgressive or regressive shoreline sand example are here, shoreline regression, shoreline transgression. What is transgression and regression it is the coastal encroachment of sea its transgression and this retreat of sea is called regression. So, it is sea level rise at a transgression regression and are different thing, sea level rise and fall a different thing in a particular case sea level may rise.

But there may be regression that depends upon this sediment supply depends upon coastal upliftment and subsidence. If, for example, sea level is rising but the coast is uplifting at a higher rate. So, that means those sea level rising but there will be sea level that there will be regression rather than transgression. Similarly, if it is sea level is falling, but coast is subsiding at a higher rate as compared to the sea level fall so, there will be transgression. So, that means, sea level rise and fall and marine transgression regressions are 2 different things.

So, one is transgressive or regressive shoreline sand. During transgression, the rivers has to restrict their deposit during regression the river migrated deep into the sea. So, in either of this case we are getting sandstone bodies then as widespread sand beds within coalescing alluvial fans coalescing alluvial fans we know in the geomorphic and when we are talking about fluvial geomorphology, that is called bajada when 2 or more alluvial fans, they are meeting or coalescence this geological structure is called by bajada.

So, that means here is a alluvial fan and here is the alluvial fan that means, here is the sand sheet and here is a sand sheet and once they are coalescence each other. So, that means we are getting a sheet type of deposit is braided and the laterally migrating estuarine deposits laterally migrating estuarine laterally migrating that means that depends upon the sea and this river interface, this interaction. So if it laterally migrates the braided channels, they are migrating laterally, this is a estuarine deposite this is migrating laterally. So in either of these cases, we may get a sheet type of deposit of sand body.

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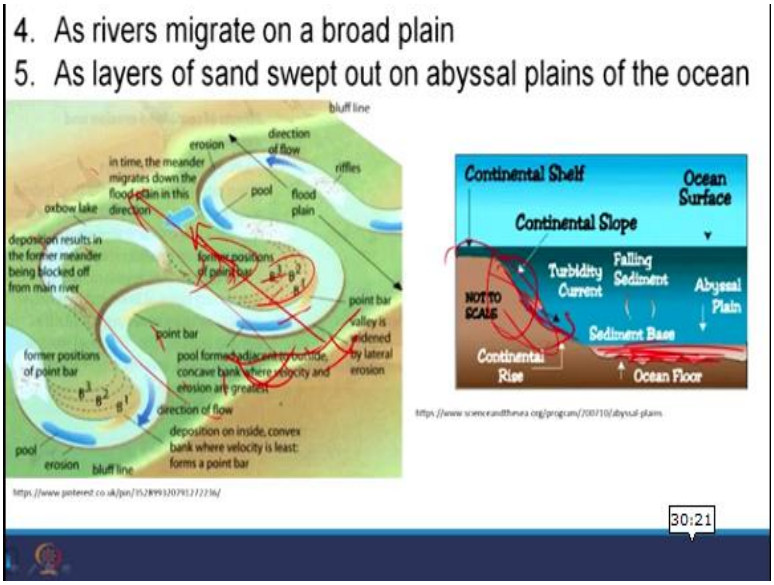

As rivers migrate on a broad plain. So if you see here, this is the flood plain of river and river is migrating. So it is river is migrating along this plain that means sandbody one sandbody was supposed the river was here, the sand was deposited somewhere here and somewhere here. Similarly, rivers migrating this way for example, or this way for example. So, here we will get another sand body here will get another sand body. So it is time this sand body of different generations, I am talking about these sand bodies of different generations.

They will coalescence with each other and finally, forming a sheet type of deposit, but age is different. So that means different type of environment, they can create sand bodies in of similar type of different age. It is layer of sand swept out on abyssal plains of the ocean or example here, this most part of the sand they are deposited up to here, but due to turbidity current due to sub

marine land slide suppose this sand body here it is disturbed and sand migrants downward so, it will be distributed in the abyssal plains.

So, that means a layer of sand swept out on abyssal plains of the ocean we are creating a sheet type deposit. So, that means starting from this landslide of this turbidity current, this river migration at this different stages, and this transgressive, regressive shorelines and changes and alluvial fans. So, all those different environments, they are creating a sand body of similar type that is the sheet type of deposit.

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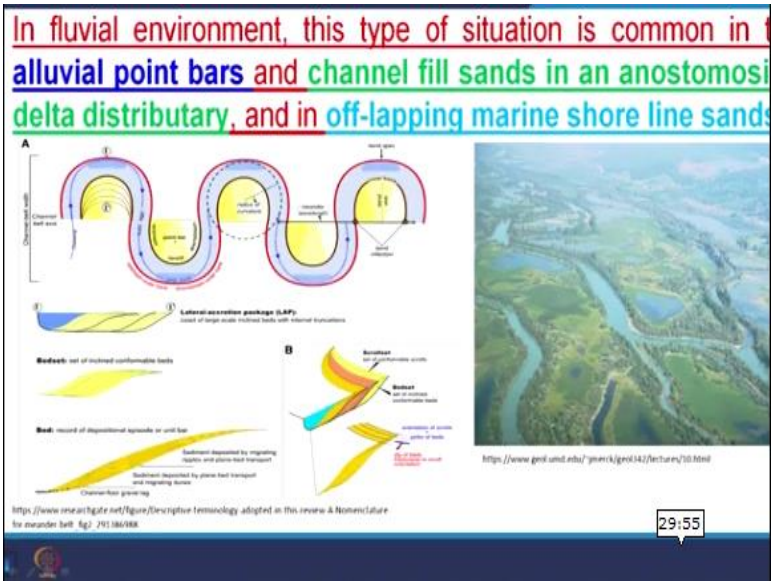

Some fluvial environment this is common, like right for example, if you talking about we are talking about the migration of this point bars, the point bars coarser grained deposits are here, then this side is cross bedded deposite in the upper part it is in parallel deposits. So, if it is migrating this way. So, that means here if you see it is migrating the river is migrating in this way earlier here or the sand stone body, then sandstone eroded to it, then there is sandstone eroded and finally, we are getting a sheet type of deposit.

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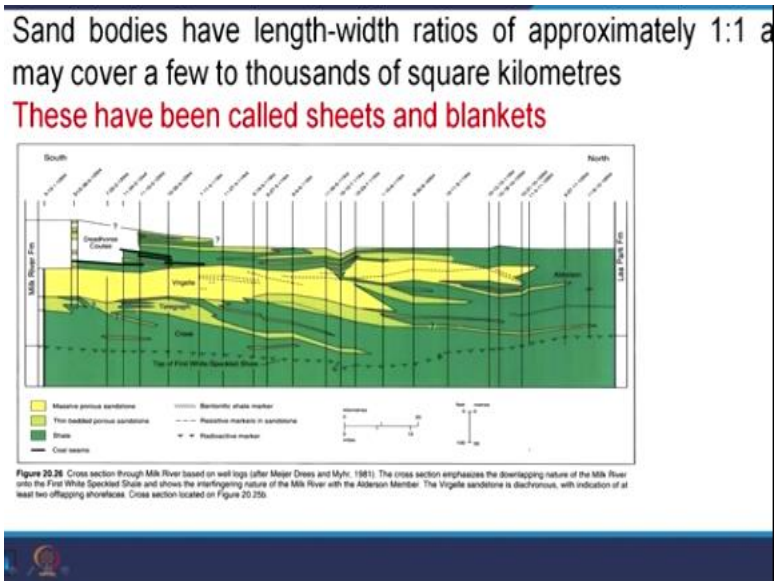

So, sand what is the length-width ratios of approximately 1:1 may cover the few to 1000 of square kilometers are these have been called sandsheets and blankets.

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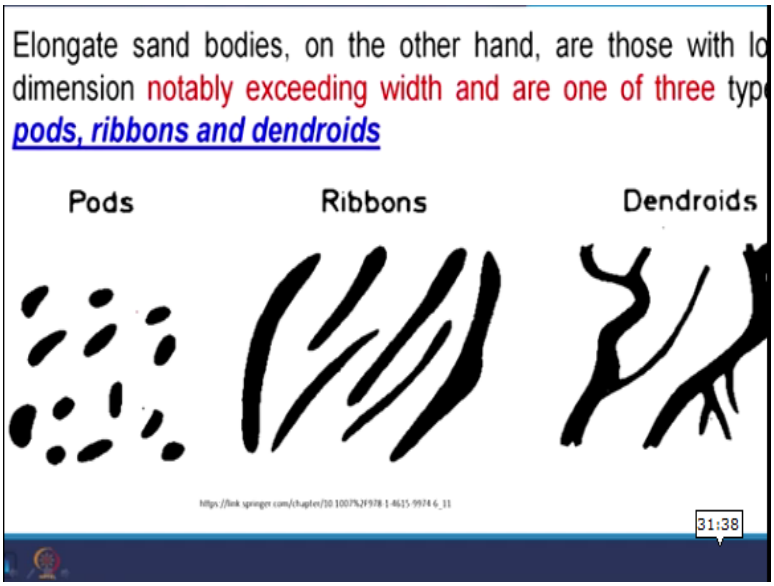

And elongated sand bodies, on the other hand are those in the long dimensions notably exceeding width and are one 3 of this dimension that is pods, ribbons and dendrites.

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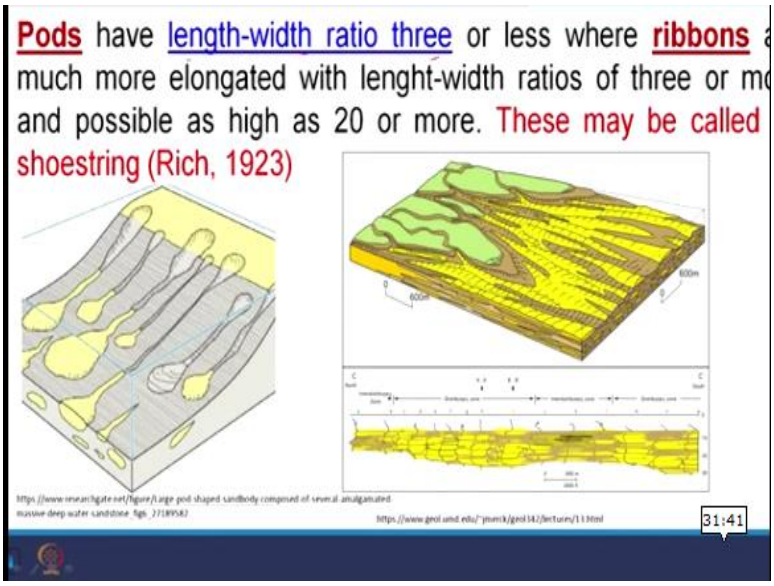

Pods if you see it is length-width ratio or 3 ribbons it is more than 10.

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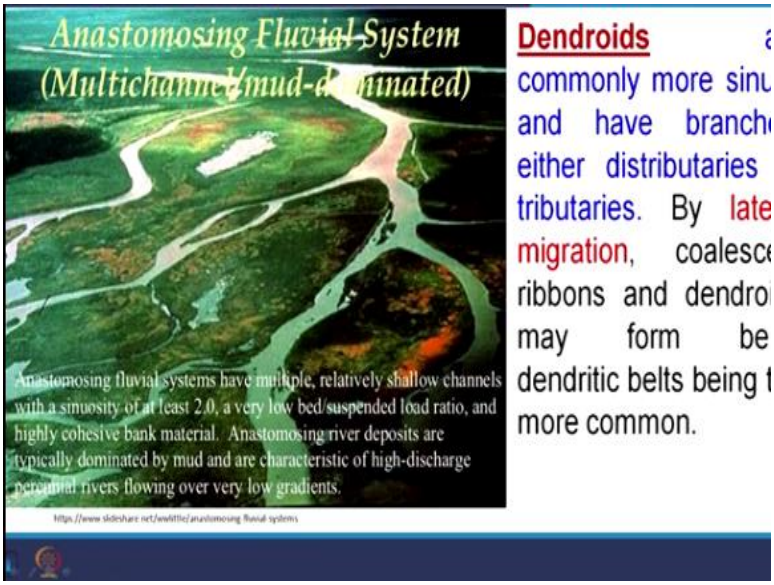

Then dendroids are commonly sinus and have branches either distributed or tributaries, by lateral migration, coalescence, ribbon and dendroids may form belts and a dendritic belt becomes more common.

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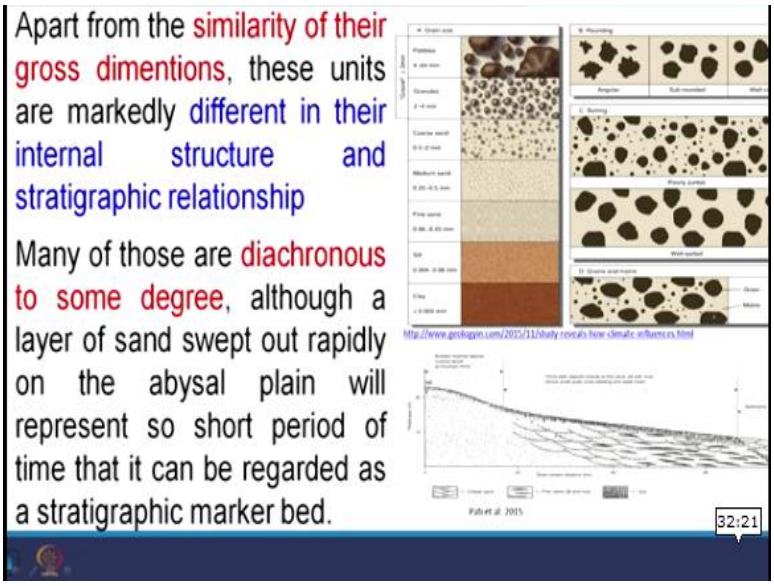

So, if you are moving within their sandstone body, they are looking similar, but they can be distinguished based on their internal structure, their stratigraphic relationship internal structure, fossil content, their grain size, based on that, then their degree of a compaction. So, by looking those that sand bodies can be distinguished though they are look similar sand sheet irrespective of where the origin they look like, but they can be distinguished which environment therefore, by that it is a coalescence of a alluvial fan or it is deltas or in this coastal plains or it is migration of this point bars, all these sandstone bodies that can be distinguished.

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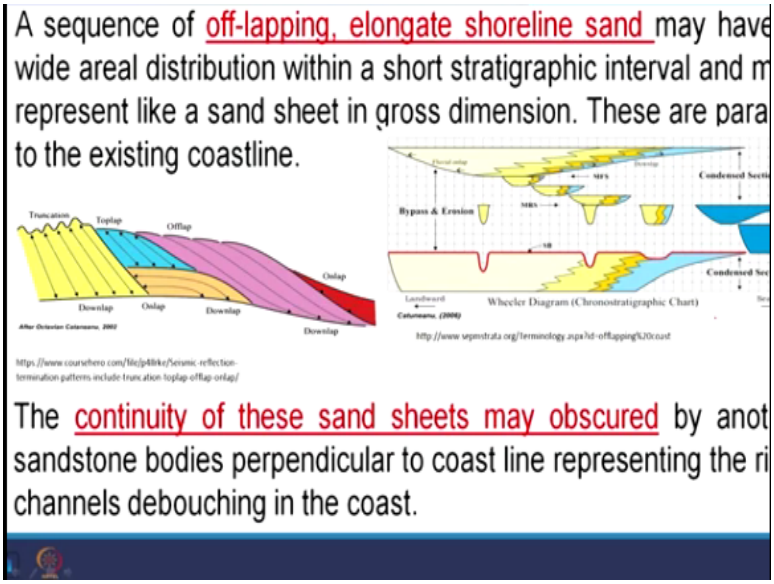

Similarly, off-lap, on-lap as we have already discussed which migration of coast, or this migration of shore line that creates a off-lap and so, on lap that also create this sand sheet type of deposit.

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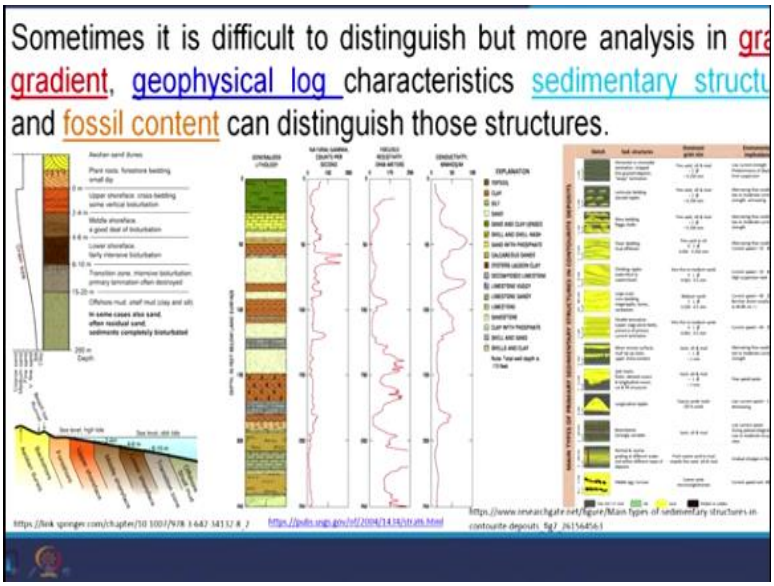

Similarly, sometimes it is difficult to distinguish, but as we have discussed based on grain gradient, based on the geophysical log, sedimentary structure and fossil content these sandstone bodies can be distinguished.

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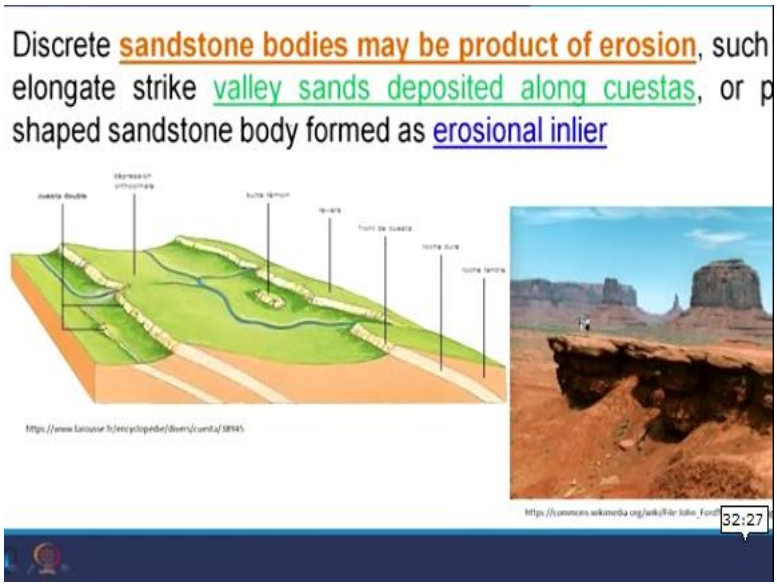

And it may be sandstone body may be a product of erosion, they give the erosion of layers if you are getting here. Similarly, the sand stone sands formed in the cuestas as they can form the sandstone bodies like that.

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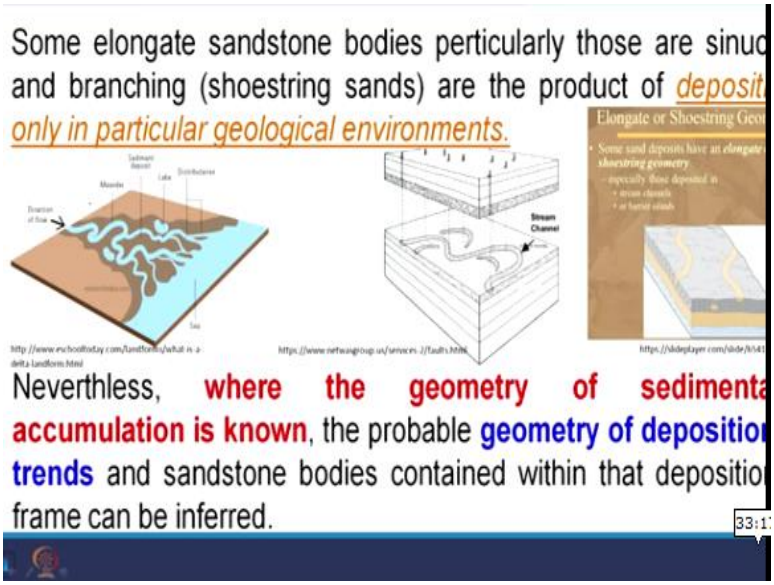

And similarly, some environment like here, this deltaic environment this river environment that can form some type of deposit which is a ribbon type or dendroid type deposit. So, nevertheless, there geometry of sedimentary accumulation is known, the geometry of the depositional trend, the sandstone bodies contained within that depositional environment can be inferred.

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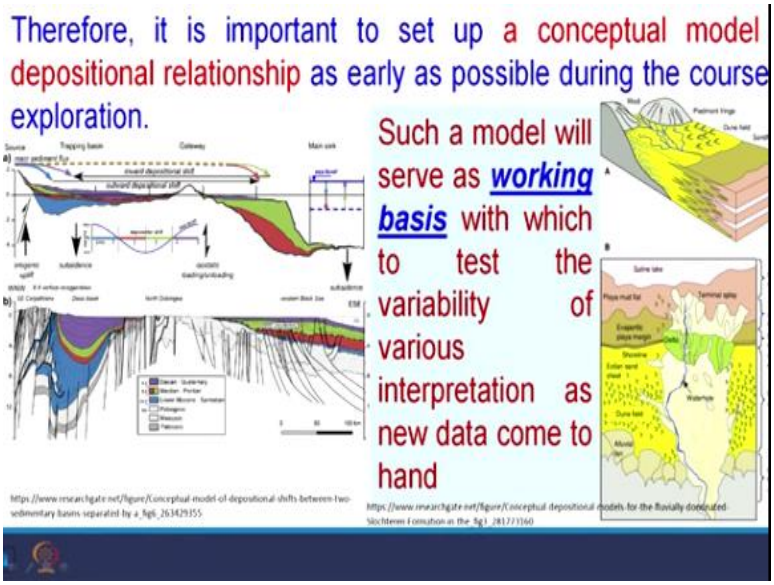

So, we should have thorough knowledge about how this is sandstone are deposited which geomorphic environment was responsible for it. So, if we have thorough knowledge about this, we can create an a working basis which we test the variability of various interpretations as a new data comes in hand, so that we can use we can plan our exploration strategy which directs our exploration goes, which direction we go for drilling, which place of this environment we can expecting petroleum hydrocarbon.

If we have sufficient knowledge about the depositional environment, if we have sufficient knowledge about the geomorphic processes involved in this particular depositional environment that know we can find out which direction we are, our exploration work is going on. Okay. So I think we should stop here, and we will meet in the next class. Thank you.