Geomorphology
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Lecture-58
Exploration Geomorphology in Oil Field Sandbody Geometry-II

So, friends, welcome to this lecture series of geomorphology at next class we are going to continue this exploration geomorphology in special reference to oil and gas explorations. So, in the last class if you remember we are talking about the sandstone body geometry and which found that different geometry may be characteristics of different geological environment and geomorphic processes.

And similarly, in particular this sheet type of deposits sandstone body may be a product of many geomorphic processes individually or together and today will continue about this porosity and permeability changes and the depositional environment with special reference to the geomorphic processes.

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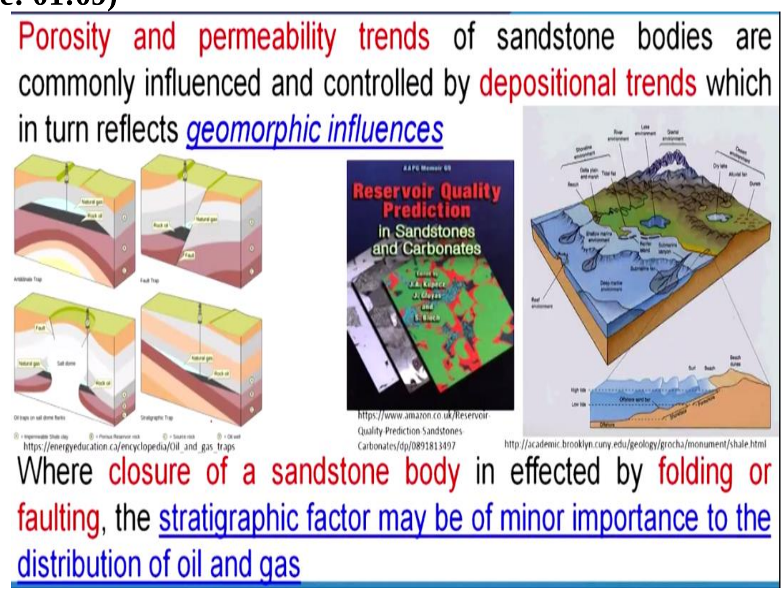

Involved in the formation of this sandstone bodies. So, if you see the porosity and permeability trends of the sandstone bodies are commonly influenced and controlled by the depositional trends, which in turn reflects geomorphic influences. So, because we know this porosity, we are talking about the delta in the deltas these depending upon these geomorphology the distribution of the geomorphic processes like distributories the levees this delta front this pro-delta and the upper deltaic plain lower delta plain.

So, depending upon that this porosity and the sorting of this grain size or the grain size distribution of a sandstone body is changes, where closer if sandstone body is affected by folding or faulting in there this stratigraphic factor may be of minor importance, rather than this will be structural for because it is structurally controlled, it is faulted it is folded. So, that the structure plays a major role rather than stratigraphy there.

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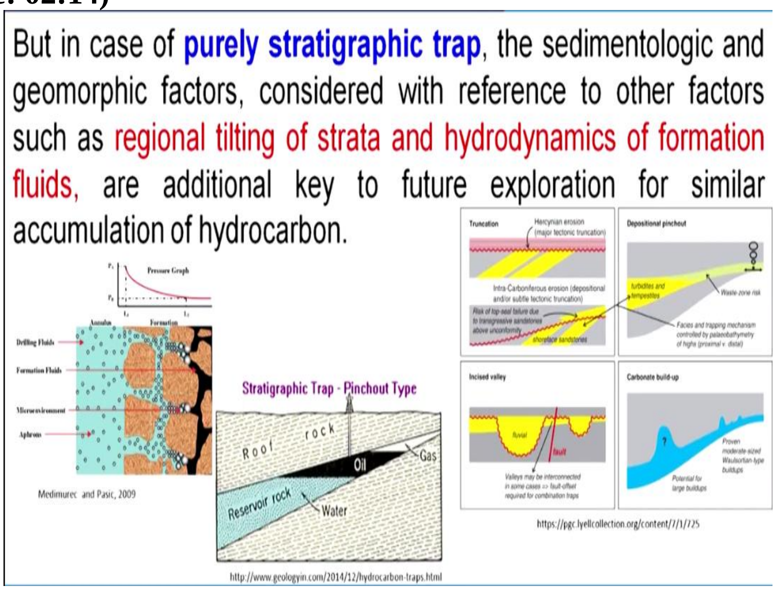

But in purely stratigraphic trap, the sedimentologic and the geomorphic processes of geomorphic factors that considered with reference to other factors such as regional tilting of the strata and hydrodynamics of formation fluids are additional keys to future further exploration and this similar for the similar accumulation of hydrocarbons, you see here, we are talking about the stratigraphic trap, stratigraphic trap it is not affected by structure trap.

So, that means, here the depositional environment and depositional environment it is related to geomorphic process. So, geomorphic process is controlling the depositional environment and depositional environment it is controlled distribution of porosity permeability within that sandstone body. So, that means if we can say these type of geomorphic processes, they are influencing where this porosity will be more or less and something like that.

So, that means this porosity permeability distribution, the sandstone body geometry that is purely of geomorphic characteristics depending upon the geomorphic environment on which it was deposited.

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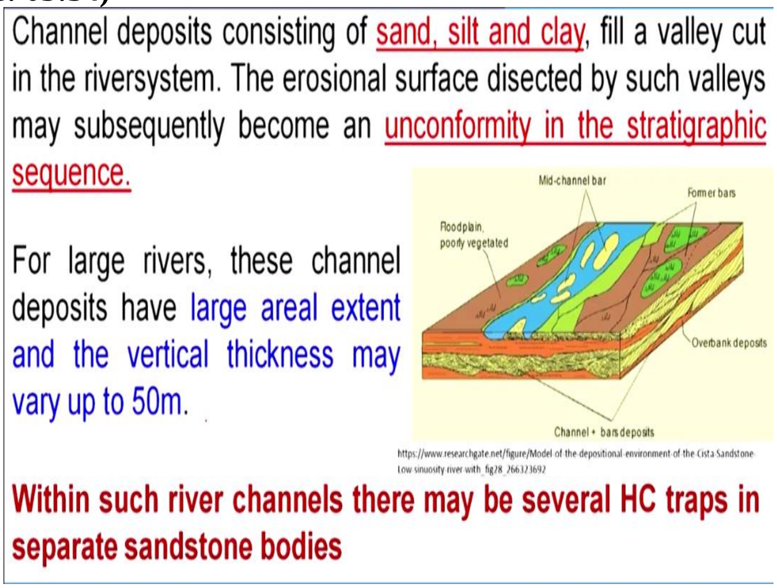

Channel deposits consisting of sand silt and clay fill a valley cut in the river system. The erosional surface dissected by such valleys may be subsequently become an unconformity near stratigraphic sequence. So, this unconformity we know this unconformity means, it is a face within the rock body or the near surface within the rock body, which are very much important in terms of petroleum.

Hydrocarbon exploration as well as heavy mineral exploration in the heavy mineral exploration to for large rivers these channel deposits have large areal extent and the vertical thickness may vary up to 50 meter, but within such a river channel, there may be several hydrocarbon trap in separate sandstone bodies.

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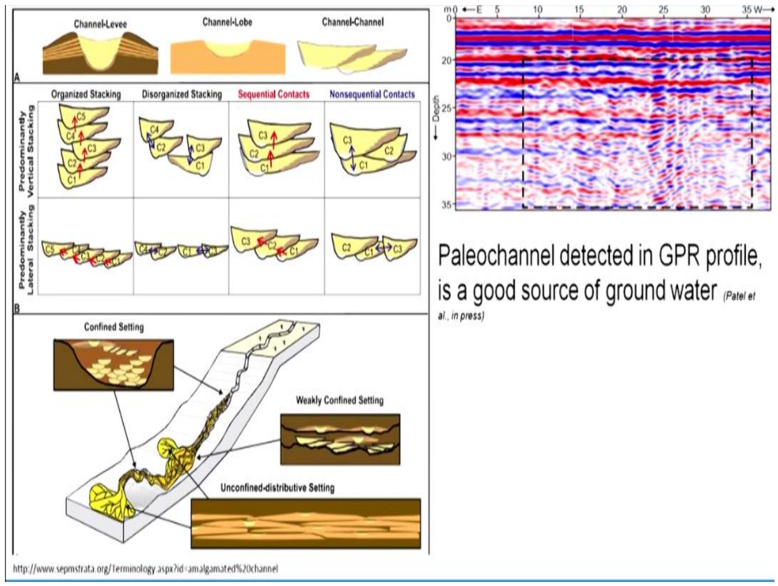

So, if you see here, both vertical and lateral change in the depositional environment change in the lateral changing geomorphic process, they create distinct sand bodies for example, if you see these figures, we have distinct sand bodies, they are vertically as well as laterally. So, that means individual sand bodies is changing laterally similarly vertical individual sand bodies are changing so that in the each individual sand body that may behave as individual reservoir and they are occurring.

They occur as isohydrodynamic conditions. So that means, if they are isolated, they are called pools in the isohydrodynamic condition means here if we are retrieving oil and gas that will not affect the pressure of this, this pool. So, that means, in a geomorphic environment in in a fluvial environment, individual sand bodies or coalescence of sand bodies may form and they may behave as good reservoir for petroleum hydrocarbon and not only this petroleum hydrocarbon.

These individuals sand bodies maybe also important in groundwater exploration also. So, for example, if you say you are talking about this, paleochannel shallow depth that means is you see it is a depth of about 35 meters, this is under in press by Patel et al. Now, you can see here this is paleochannel and you are looking at cross section. Now, imagine this channel it is filled with water. So, that means for hydrocarbon exploration for oil and gas exploration for mineral exploration for heavy mineral exploration for sand mining, so, we are getting where we sand bodies are very much important.

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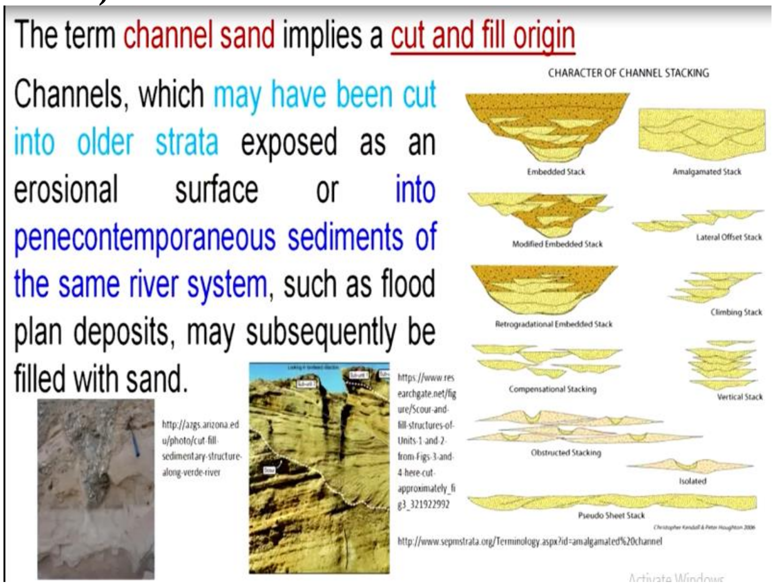

When we term use the term channel sand that means it is always of cut and fill origin. So, this cut and fill maybe by the same river of different time, may be of different river, which is encroaching these river surface or this river bed of this former one. So, irrespective of it is their origin if this valley was there and later it is filled with sediment while particular this sand, then it is called this a cut and fill origin that is called channel sand.

so channels which may have been cut into older strata exposed as an erosional surface or into pene-contemporaneous sediment of the same river system, such as flood plain deposit may subsequently be filled with sand suppose for example here, this is cut and fill origin. Earlier this deposit was there, and as cut and it is fill was sediment as cut and fill origin subsequently if you see another surface, it is in this cut and fill origin structure. Similarly, here you see, this is another this is cut and fill structure. So, that means, if we having a channel and this later filled with sand, this is called channel sand.

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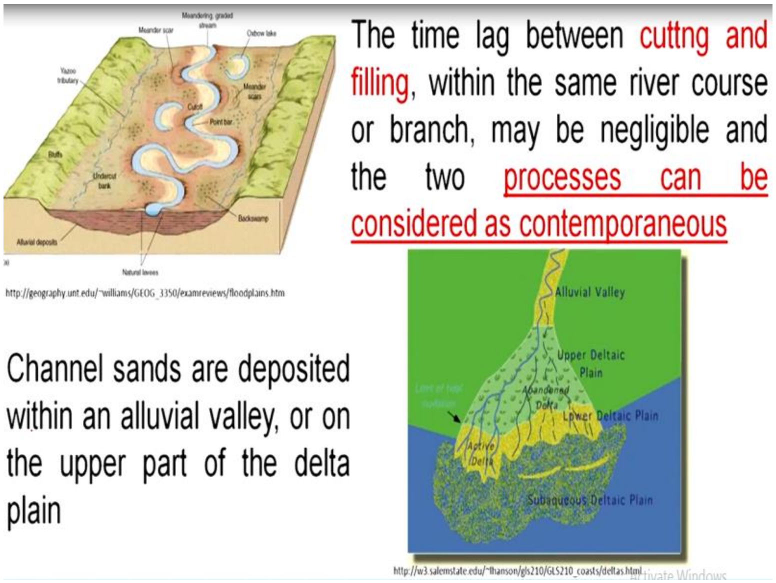

Channel sand are deposited within an alluvial valley or on this upper part of this delta plain for this delta plain, this is a upper delta plain that is lower delta plain. So, here we are getting these channel sand the time lag between cutting and filling within the same river course or branch may be negligible and thus it can be considered at contemporaneous. However, the other river which is encroaching this former one, so, that is called the unconformity is there and it is not considered contemporaneous.

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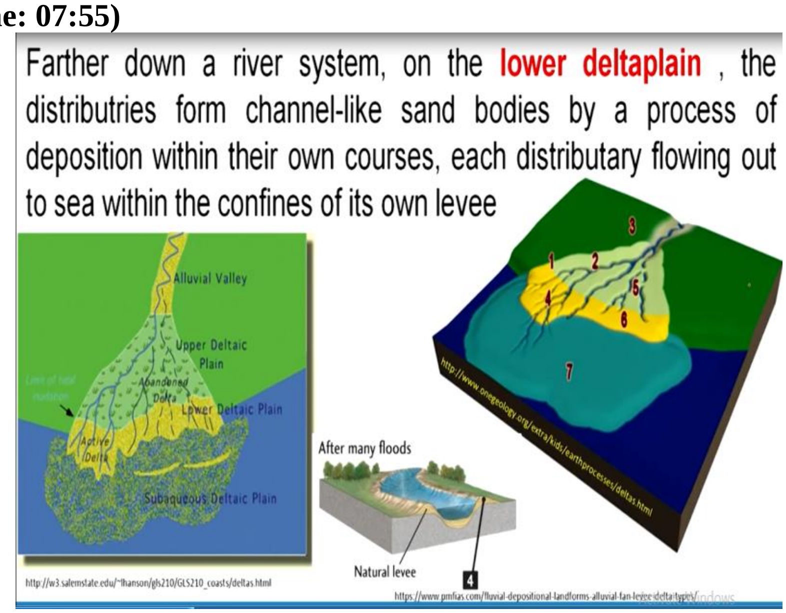

So, farther down, coming from this upper delta plain to lower delta plain this lower delta plain for reaching here, this is distributors from channel like sand bodies by a process of deposition within their own course. So each distributary flowing out to see within this confines within the river levees, they are lower delta plain and this yellow part we are talking about this is upper delta plain and this is lower delta plain.

If you see here, you are getting the lower delta plain we are getting this natural levees natural levee we know that was in the old stage of the river if you remember our fluvial geomorphology classes, this is naturally levees formed here and this natural levees there positive geomorphic feature as compared to the river sand.

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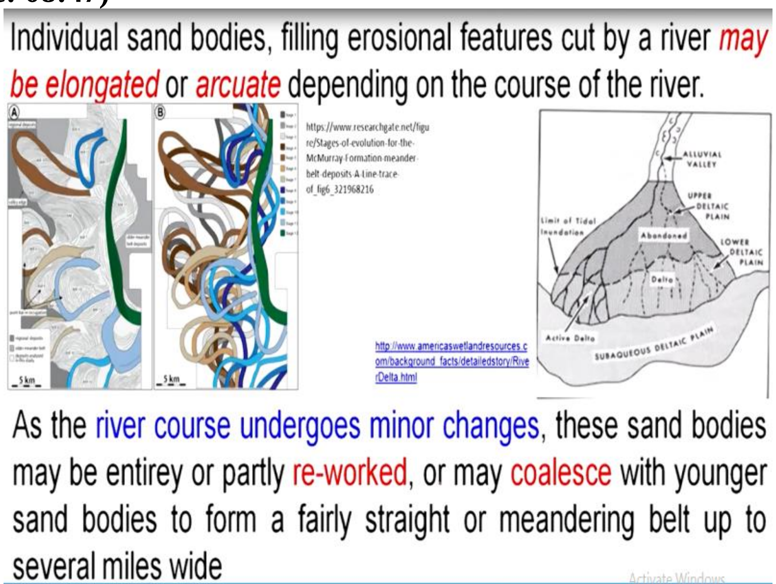

Individual sand bodies, filled erosional surface cut by river may be elongated or may be arcuate depending upon the course of the river. It is the upper reaches, it is simply a straight line or simply it is sinuous type of depending on individual channels sand there. But if you see here in this particular figure, there are a number of meanders, they are cross cutting each other and finally, it is forming a channel belt. So, if you remember when we are talking pod and dendrite then these channels that is dendrite, then belts.

So, this is channel belt, the river course undergoes minor changes these sand bodies may be entirely or partly reworked, and may coalescence with the younger sand bodies to form fairly straight and meandering belt up to several miles wide. So, that means, depending upon this process involved and depending upon the frequency of process involved, the frequency changes lateral as well as vertical changes, the sand body geometry will totally depending upon it

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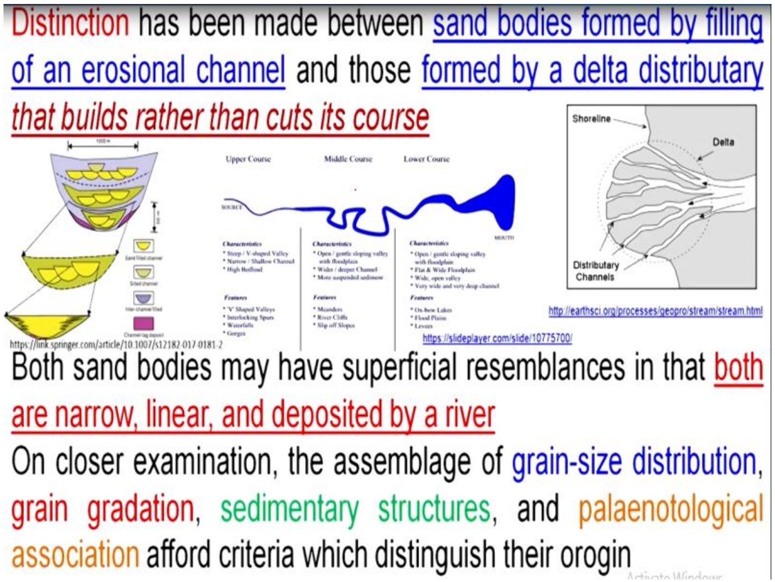

distinction has been made between the sand bodies formed by fill of an erosional channel that is the cut and fill structure and those formed by this delta distributed that builds rather than cut its course. So, the delta distributors it built the course and this channel sand it cut the course. So both sand bodies have superficially resembles in that both are narrow, linear and deposited by river.

But on closer examination, these assemblages of grain size distribution, grain gradation, sedimentary structure paleontological evidences such as fossils so, they may distinguish either you are talking about this channel fills or the delta distributary system.

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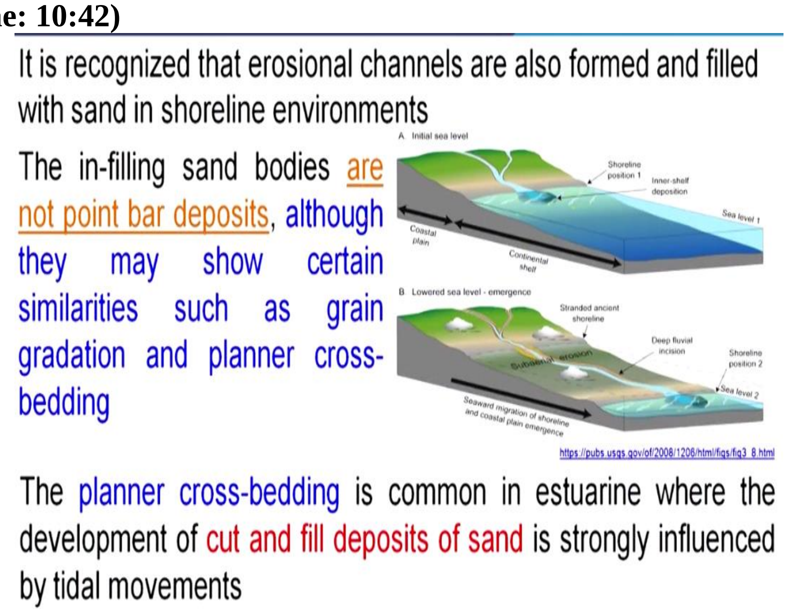

It is recognized that erosional channels are also formed and filled with sand in shoreline environment. Not only in this fluvial environment we are talking so far, the shoreline environment also, this environment this type of deposition, cut and fill structure occurs the infilling sand bodies are not point bar deposits, although they may show certain similarities such as grain gradation and planner cross bedding stratification, the planner cross bedding is common in estuarine where this development of cut and fill deposits of sand is strongly influenced by tidal movement. So, once the tidal movement is there, generation of cross bedding will be there.

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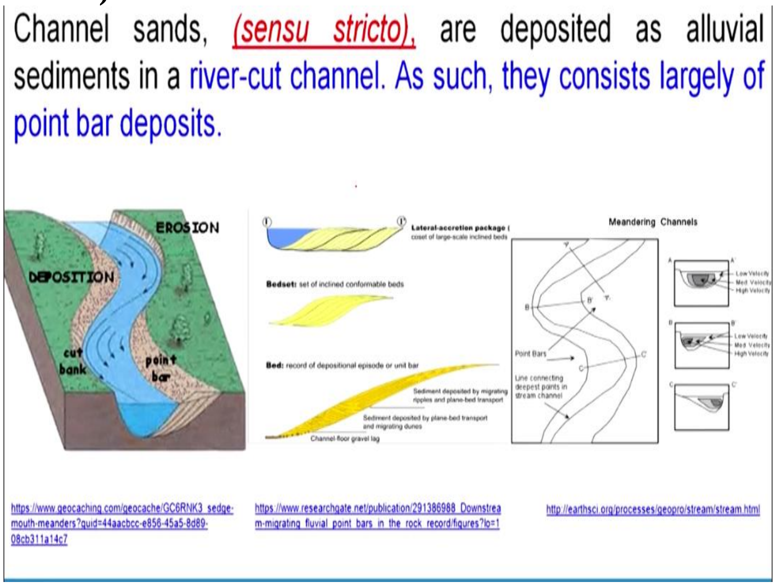

So, channel sand if we are using this terminology sensu stricto that means, it is cut and fill structure deposited by alluvial sediment in a river cut channel. So, that is not that means we will not use that cut and fill that means, channel sand deposit in this delta environment or in this the river mouth or it is influenced by the tides. So, channel sand once we use that is sensu stricto. It is used in fluvial environment only as such they consist largely of point bar deposited.

So point bar deposited to you know, in fluvial environment we are talking something about this point bar deposit, it is started with coarse grain, then it is cross beddings. Then finally, it will be the planer beddings which are climbing ripples are developed here. So, this is a particular type of environment, it is found in the point bar deposited the river meanders

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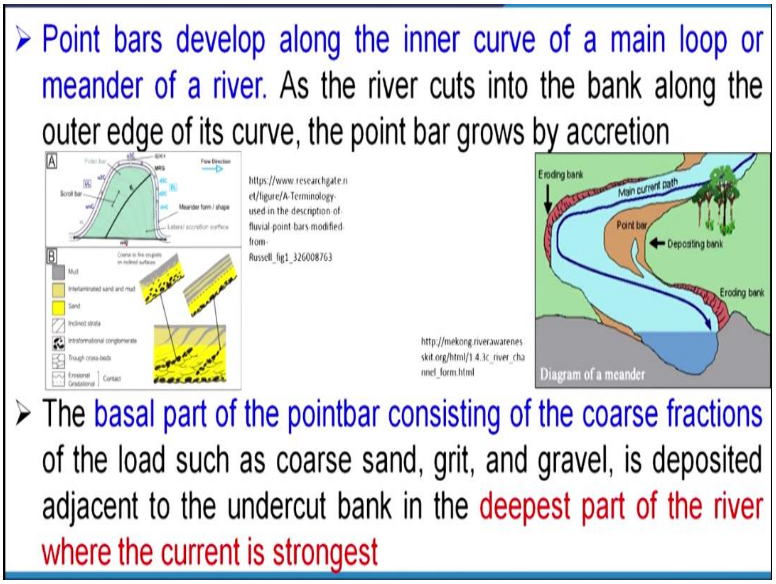

Point bar develop along the inner curve of the main loop of this meander of the river. As the river cut into the bank along this outer edge of its curve, the point bar grows by accretion. So, it is lateral accretion is there, the basal part of this point bar consisting of coarse grained fractions of this load such as the coarse sand, grit and gravel is deposited adjacent to this undercut bank in the deepest part of the river, where the current is strongest.

So, we have this velocity of the river velocity contours of different as we have discussed in the fluvial geomorphology if you see here from C to C' that means in the meander here the maximum velocity will be here and this minimum will be this side similarly, in this the maximum velocity is here and minimum is here, but in this straight course of the river, you say the velocity is uniformly distributed. So, depending upon the distribution of the velocity, which part will be deposited which will be eroded, that will be distinguished.

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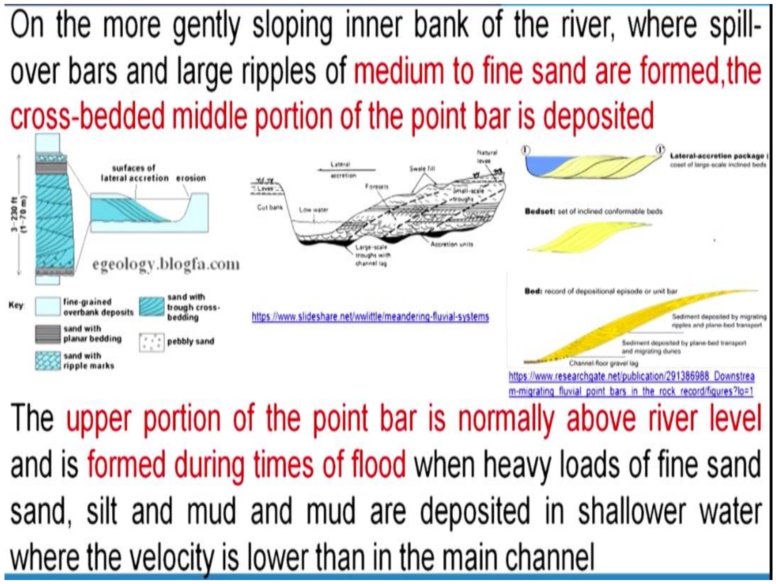

On the more gently sloping inner bank of this river where spillover bars and large ripples of medium to fine sand are formed the cross bedded middle portion. Cross bedded middle portion of the point bar deposited. The upper portion of this point bar is normally above the river level, and is in the sedimentation occur during floodplains during flooding. So, that is alternative silt and clay. Mostly they are found and they are climbing ripples small ripples are developed there. They are called of climbing ripples.

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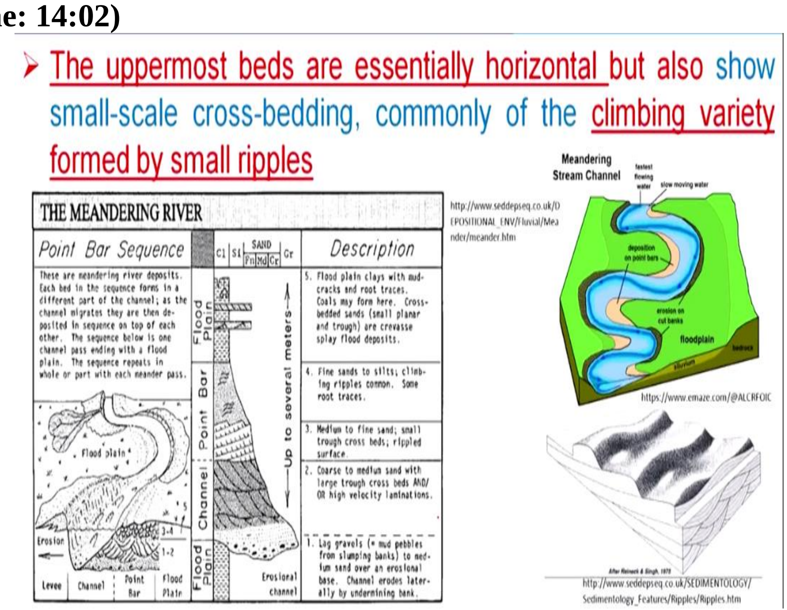

The uppermost bed are essentially horizontal, but also shows small scale cross beddings commonly climbing variety on the small ripples like if you see the climbing ripples. So here if we are talking about here we are getting floodplain deposit mostly it is fine grain, and some climbing ripples are there and most if it is flat bedded, it is horizontal. And here is the point bar if you see here, middle to form sand small trough-crest ripple structures, you have cross stratification and ripples are there.

And at the bottom gravel, this is called channel lag deposits the gravel grits coarse sand that we deposited here and here just above it, coarse to medium sand with a large trough crossbeds and it high velocity laminations are there.

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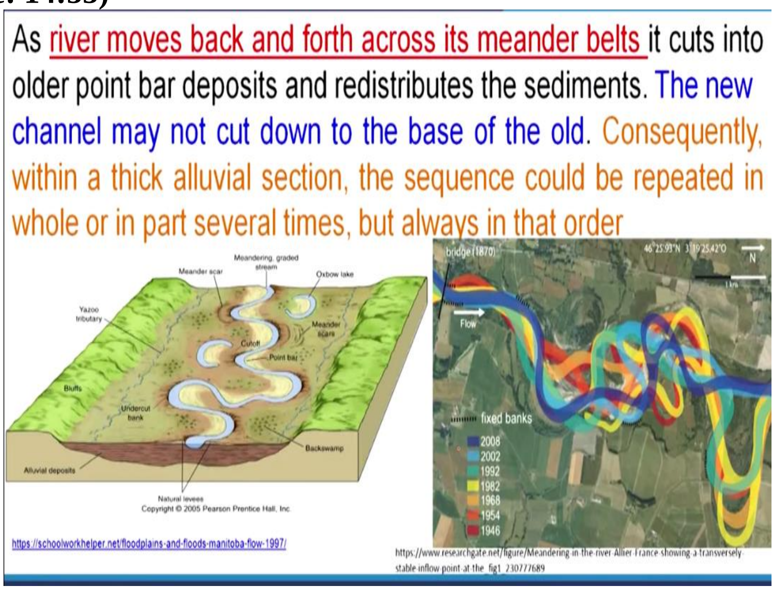

So as river moves back and forth across meander belts it cuts into older point bar deposit and redistributed the sediments, this new channel, may not cut down the base of the old consequently within a thick alluvial sequence or thick alluvial section a sequence could be repeated in the whole or part several times, but always that order. So that means with a migration of this river lateral migration of this river, this point bar deposit they repeats vertically and this repetition may be of a continuous sequence may be of some part of the sequences is there depending upon this flow velocity depending upon this migration depending upon the flooding frequency like that.

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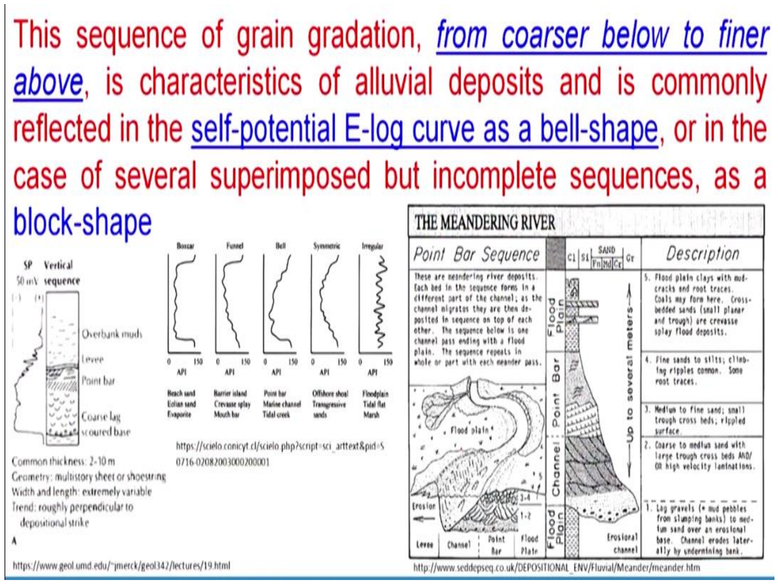

This sequence of grain gradation from coarser below to finer above. It is characteristic alluvial deposits and is commonly reflected in self potential E log which is of a bell shape, bell shape thing you see, there are different types of shape here is box shape, this is funnel shape this is bell shape that means, if you see the grain size reduction it is on the top the grain size is decreasing and bottom the grain sizes is increasing.

So, this is of bell shape. So, if you see here, this is a vertical sequence of a point bar deposit and we are getting these channel lag or scour deposits, then coarse sand then this point bar then is levees then overbank mud. So, if you see this log SP log, so, it is it resembles to this one that is bell shape deposit. So, this is a characteristics SP potential log, which is the point bar deposit is looking like a bell shape

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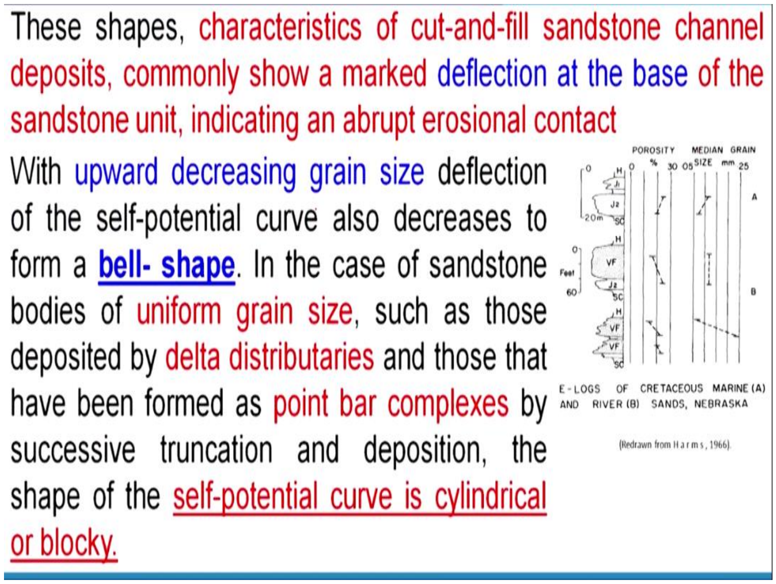

These shape characteristics of cut and fill sandstone channel deposits commonly show a marked deflection at the base of the sandstone unit indicating an abrupt erosional contact because as we say to the channels and deposit that means earlier, it was a river bed there and it was filled with sand. So, to this bottom part of this of this channel sand it is abrupt relationship with the low lying units with upward decreasing grain sizes, deflection of the self potential curve also decreases to form a bell shape.

In this case of sandstone bodies of uniform grain size such as those deposited by delta distributed and those that have been formed by the point bar complexes are successive truncations and deposition the shape of the self potential curve is cylindrical or blocky. So, here if you see here, it is a blocky, blocky one similarly, it is a blocky one and this is if you see this is a bell shaped one, this is a bell shaped one. So, depending upon this positions depending upon the geomorphic environment is involved. Either it will be bell shape or blocky shape. So, in that means, it is a distribution of a grain size distribution of porosity and permeability.

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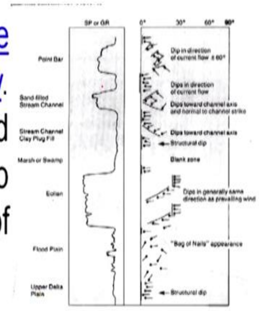
The self-potential curve gives an indication of permeability which apart from the effects of cementation caused by the introduction of calcite, etc. and diagenesis, is commonly related to the clay content of the matrix of the original sand

In general the coarser the sand the lower the clay content and higher the permeability. Secondary cementation of the matrix and sever compaction of the sandstone will also affect the permeability and the degree of deflection of the self-potential curve



The self potential curve given indication of permeability, because as we are discussing this is self potential, it is a measure of the permeability of the formation, which apart from this effect of the cementation caused by introduction of the calcite or any other secondary minerals and the diagenetic minerals is commonly related to the clay content of the matrix of this original sand. So, that means, it is the measure of the permeability only.

So, permeability whatever the factors that influence the permeability there is also consider here in general, the coarser the sand the lower the clay content and higher the permeability secondary cementation in the matrix and sever compaction of the sandstone also effect the permeability of this formation and the degree of deflection of the self potential curve. So, the shape of this curve it is totally depends upon these permeability, which may be affected by clay content may be secondary mineral diagenetic minerals such and such things like that.

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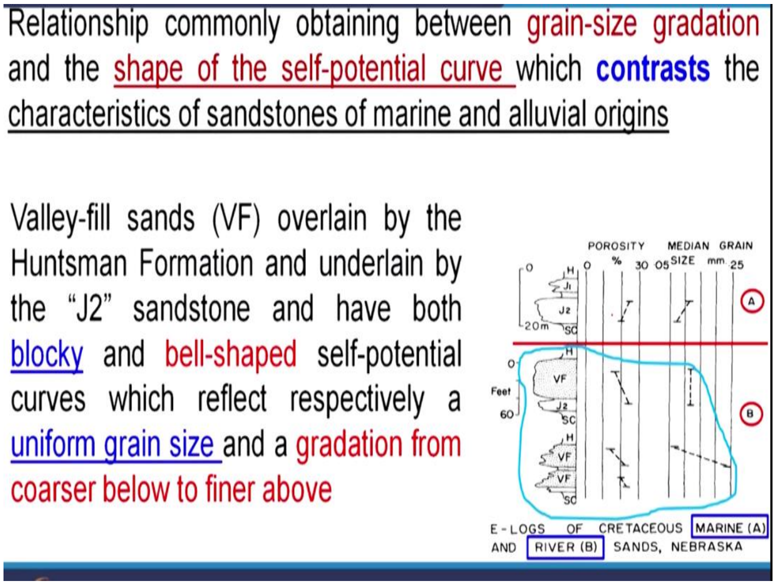

The relationship commonly often between the grain sizes gradation and these shape of the self potential curve, which contrast the characteristics of sandstone of marine and alluvial origins. So, self potential self curve, it is different for marine origin, different for alluvial origin for lacustrine origin like that, because the porosity permeability is different. This geomorphic processes are different the depositional environments are different, so that this geophysical log that can also merit to distinguish between different type of geological environment geomorphic environment.

So, valley fill sand VF for example, here, valley fill sand overlain by this huntsman formation of underlain by this J2 sandstone and have both blocky and bell shaped. If you see here, this J2 which is here. Here if you see it is valley fill it is. Bell shape one, but here the valley fill blocky 1. So that means though is the sandstone body sheet type of body, but depositional environmental deposit both cases it is valley fill, but this process of deposition is different, so that we are getting somewhere blocky 1 somewhere it is getting bell shaped.

So, if you see here, both have blocky and bell shaped self potential curves, which reflect respectively a uniform grain size and gradation from coarser below to finer above. So here we are getting uniform grain size, but here it is coarser below and finer above similarly coarser below or finer above. So that means here, these 2 that we can distinguish this deposit by this point bar deposit.

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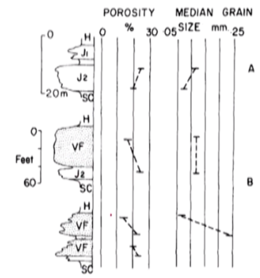
In the figure, a uniform grain-size appears to be little variation in permeability, although porosity increases toward the base of the sandstone body.

In the figure, showing an increase of grain-size toward the base of the unit both permeability and porosity increase, as indicated by the self-potential curve.

In contrast with the “J2” sandstone, which originated as a regressive marine shoreline sand, shows a decrease of porosity, permeability and grain size toward the base of the sandstone body.



E-LOGS OF CRETACEOUS MARINE (A) AND RIVER (B) SANDS, NEBRASKA

In this figure here given a uniform grain size appears to be a little variation in the permeability, although porosity increases toward the base of the sandstone body, in the figure showing an increase of grain size toward the base of this unit, both permeability and porosity increases as indicated by the self potential curve. In contrast with the J2 sandstone, which originated as a regressive marine, shoreline sand, shows a decrease in porosity, permeability and grain size towards the base of this sandstone body.

So that means different depositional mechanism, different geomorphic process involvement that also controls the porosity and permeability. So that means in turn, that will reduce or increase the amount of petroleum hydrocarbon accumulation as well as yield. So, that means it is totally a function of the geomorphic process and the depositional environment with which is controlled by the geomorphic process.

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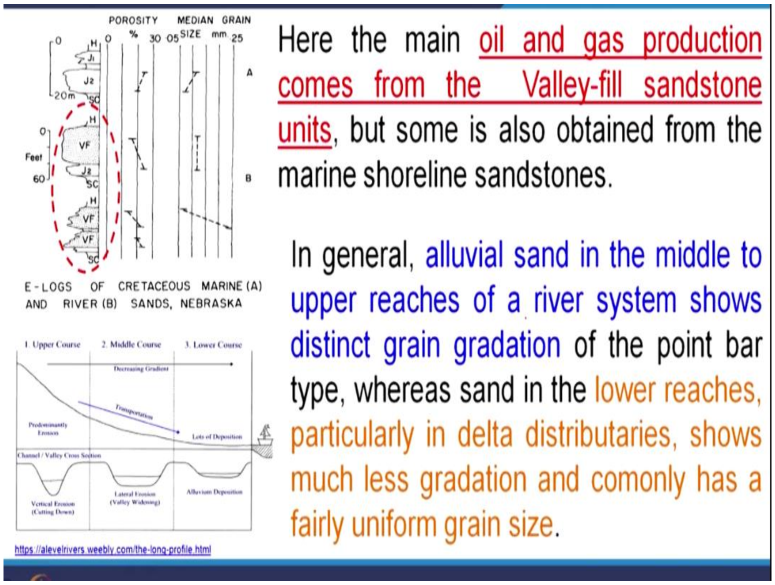

Here the main oil and gas production comes from this valley fill sandstone units, but some also obtained from the marine shoreline sandstone bodies in general alluvial sand in the middle to the upper reaches of the river system. Shows distinct grain gradations of this point bar type whereas sand is in the lower reaches, particularly in the delta distributors shows much less gradation and commonly has a fairly uniform grain size.

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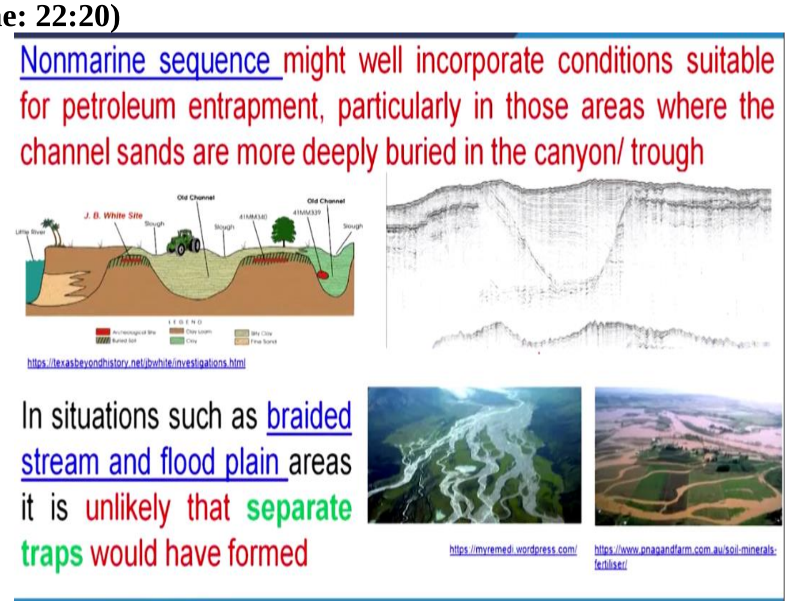

Nonmarine sequence might well incorporate conditions suitable for petroleum entrapment particularly in those areas where these channel sand are more deeply buried in the canyon or troughs in situations such as braided streams and floodplains areas is unlikely that separate traps would have formed. So that means, separate trap will be formed if the sandstone body will be isolated. But if these sandstones they are coalescence, which either like braided systems like floodplains that will separate it is difficult to form a separate trap here are the otherwise this will upon a tender type or a field type deposit rather than isolated deposited

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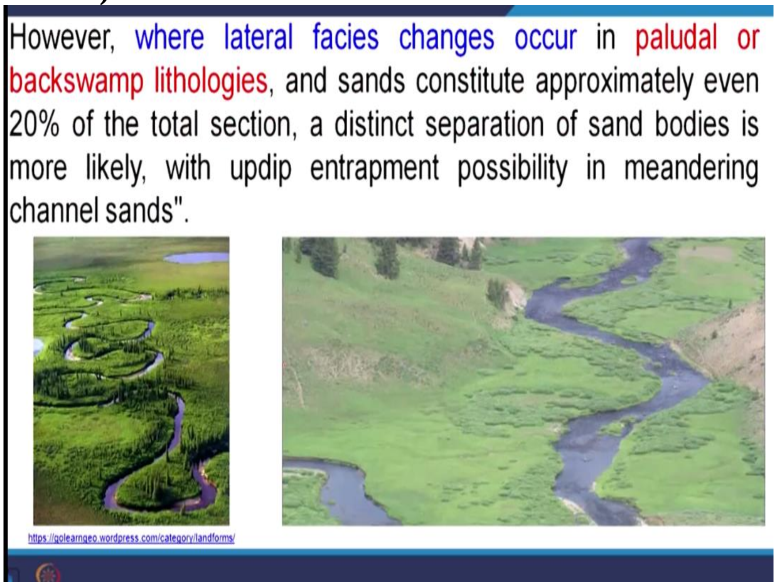

However, where the lateral facies changes occurs in paludal or these bankswamp lithologies, the sand constitute approximately even 20% of this total section a distinct separation of the sand bodies is more likely with updip entrapment possibility in the meandering channel sands. So, that means, here the depositional environment that is more or less it is controlling the sand hydrocarbon entrapment.

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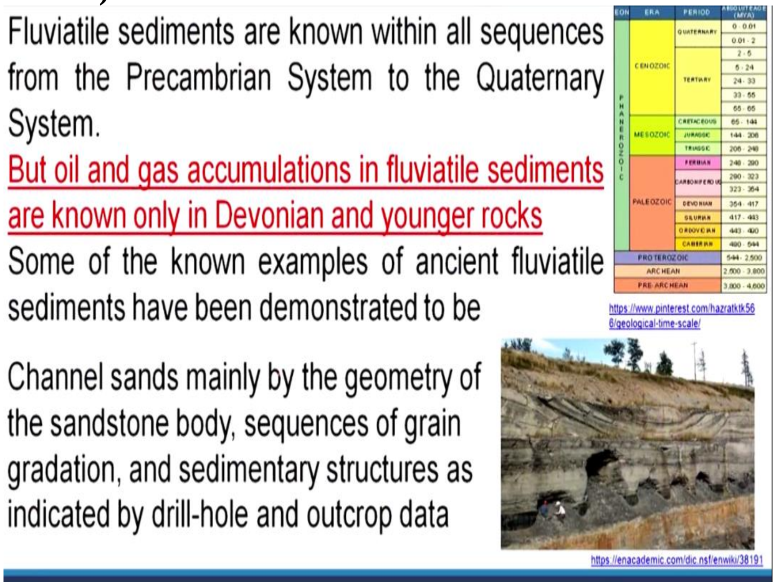

Fluvial sediments are known within all sequences from the precambrain system to the quaternary systems, but oil and gas accumulation in fluvial sediment are known only in devonian and younger rocks. It is very important, though we have fluvial environment from starting from the precambrain to recent but those fluvial system which are found in the devonian and the younger they are containing petroleum, petroleum hydrocarbon.

Some of these known example of some of the ancient fluvial sediments have been demonstrated to be the channel sand mainly by this geometry of this sandstone body sequence of grain gradation sedimentary structures as indicated by drill hole and outcrop data. So, this fluvial environment can be distinguished from other based on this type grain size this settings that means sedimentary structures so, like based on that fluvial environment distinguished.

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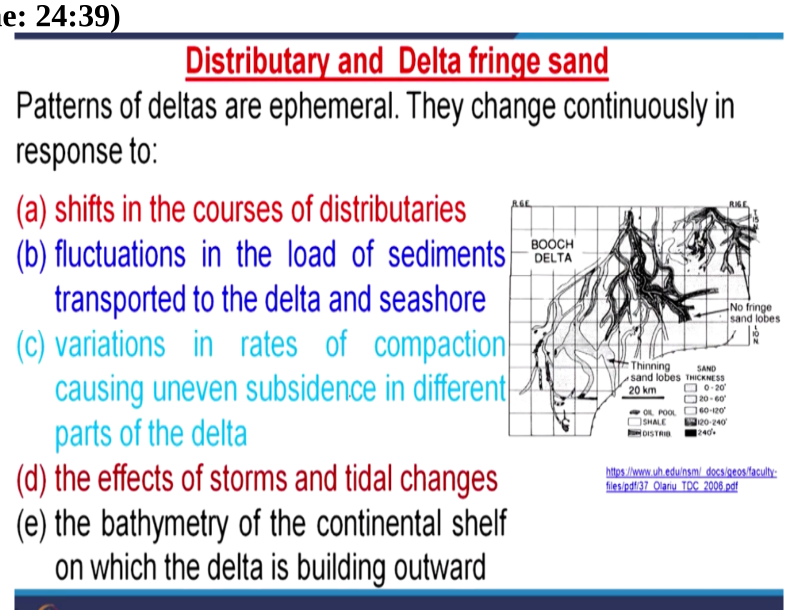

This we are talking something about the marine at the river mouth, the river systems the fluvial systems lacustrine system let us talk about the delta distributaries in the delta fringe sand so, patterns of deltas are ephemeral. They change continuously in response to shift in the courses of the distributaries, fluctuation in the load of sediment transport it to the delta seashore. So, variations rate of compaction causing uneven subsidence in different parts of the delta.

These effects of storms and tidal changes the bathymetry of this continental shelf on which the delta is building outward. So, all these factors that controls the delta distributary geometry and the sediment distribution.

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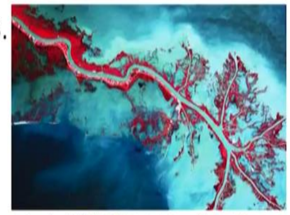
The dendritic pattern of the classic birdsfoot delta of the present-day Mississippi River has been formed as a result of the shallowness of the continental shelf and the comparative slight variations in tidal levels

The Niger River cuspate-arcuate Delta currently building outward on a very narrow continental shelf subject to large tidal variations with strong current and wave action, has smooth, curved shoreline of delta-fringe sands.



https://artisscienceisart.com/post/103988904128/mississippi-river-delta-fractal-from-space

The dendritic pattern of this classic birdsfoot delta of this present day Mississippi river has been formed as a result of this shallowness of this continental shelf and comparatively slight variation in the tidal level. So, here, this marine geomorphology or the coastal geomorphology is influencing the fluvial systems, but in the Niger delta, it is cuspate or arcuate type of delta currently building outward on a very narrow continental self subject to large tidal variations within the strong current and wave actions and has smooth curved shoreline of delta plain sand.

so, that means, you see here we have a coastal environment or coastal geomorphic system, we have a fluvial geomorphic system and this is the transitional system. So, whatever the geomorphic processes, we are getting here; there is the combination of marine process as well as the fluvial process. So, the dominance of one process to another dominance of one process and another that will govern what type of sandstone body geometry will be and what is the porosity and permeability distribution.

Will be similarly, under the direction or variation of the porosity permeability with sandstone that depends upon this geomorphic processes. So, it is this fluctuation of shoreline this is the increasing or decreasing of sea level this is sediment supply, this frequent change of the river course, the climate, the tectonism, all those factors that control the geomorphic processes and in turn, which are controlling this sand body geometry, the distribution of porosity, permeability and in turn which is very much essential to understand the distribution of petroleum hydrocarbon within the sandstone body.

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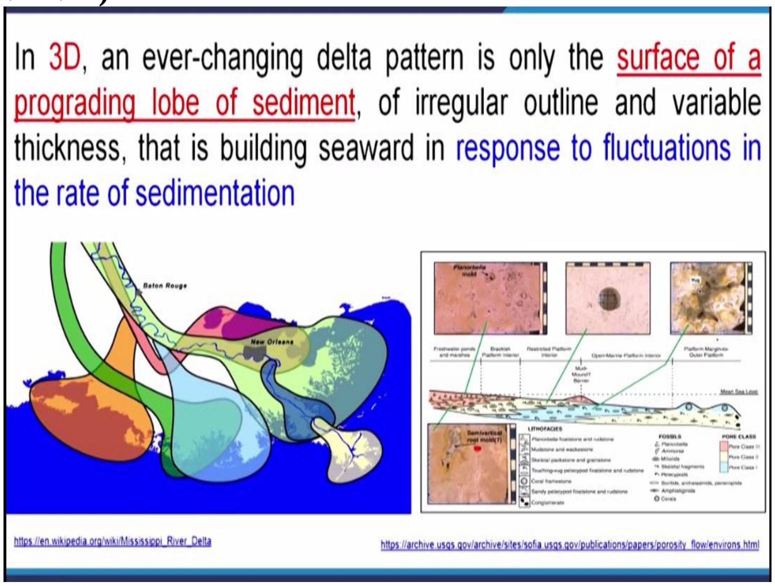

So, in 3D and ever changing delta pattern is only the surface of a prograding lobe of sediment in an irregular outline and variable thickness that is building seaward in response to fluctuations in the rate of sedimentation, so, the rate of sedimentation that is depending on the how frequently or how effectively a delta is growing and similarly, that also depends upon the fluctuation of the sea level. So, if the sea level is rising, the sediment which is transported by the river will be at the river mouth it will not transported on the self edge. So, that the delta building will stop or will retard.

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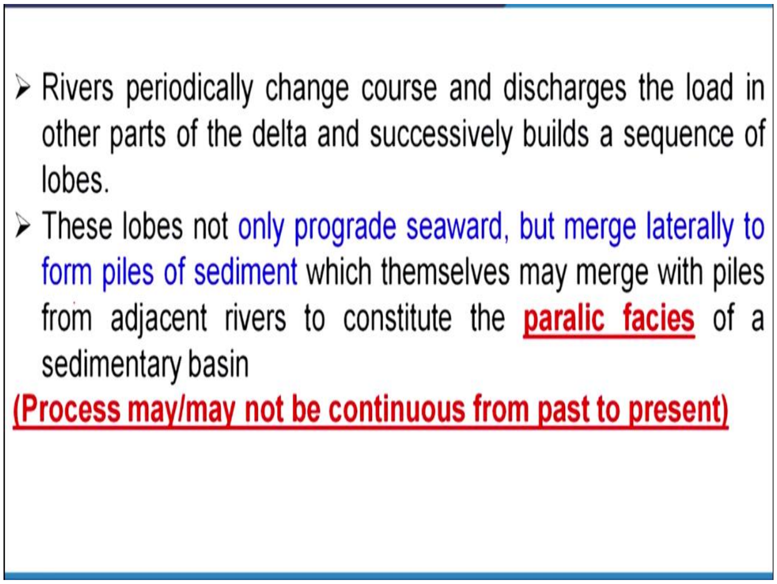

Rivers periodically change course and discharge the load in other parts of this delta and successively builds a sequence of lobes, these lobes not only prograde seaward, but merge laterally to form piles of sediment, which themselves may merge with piles of adjacent river to constitute the paralic facies of a sedimentary basin process may or may not be continuous from past to present. So, that was the geomorphic process, they are ever changing process.

Some process that we have already discussed earlier classes also some deep it means geomorphic processes maybe it is encroached by other geomorphic process for example, in this glacial time, this river was 100s of metres or this sea level was 100s of metres below and it was mostly dominated by river process but with increasing sea level, this river mouth they are, they are submerged with the seawater and now, this fluvial system is occupied or it is that means hijacked by this marine process.

So, that means, these are the ever changing processes that changes with the time in space. So, that this change of the geomorphic process that will control the depositional environment and the depositional environment that will restrict the grain size distribution, the geometry of this sandstone bodies and in turn, which will affect the oil and gas accumulation within that.

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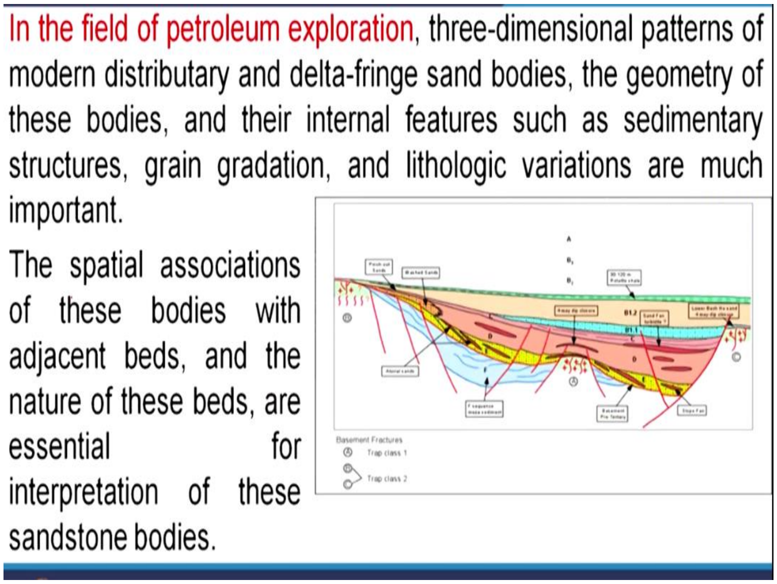

In the field of petroleum exploration, three dimensional pattern of modern, distributary and delta fringe sand bodies the geometry of these bodies and their internal features such as sedimentary structures, grain gradation and lithologic variation are much important. The spatial association of these bodies with the adjacent beds and the nature of these beds are essential for interpretation of these sandstone bodies.

So, this lithologic variation, sedimentary structures, grain gradation, internal features, these are very much important to distinguish which type of geomorphic environment we are dealing with, because our geomorphic environment will lead to the depositional environment. The depositional environment led to this sandstone body geometry sandstone porosity and permeability size geometry, extension of this sandstone body and which in turn will affect our accumulation of petroleum hydrocarbon.

That is why the basic idea of the fundamental of this oil and petroleum gas exploration is the understanding of the geomorphic processes involved for the formation of the sandstone body. And we are talking once we are talking about this we are talking about the stratigraphic trap structural because structural trap later disturbed and the oil and gas accumulation is not due to stratigraphic in arrangement it is due to the structural arrangement.

So, whatever this is, in this class we are discussing we are discussing about the arrangement of the stratigraphic system. In the lower reaches of a delta bordering the shore, where the surface of this subsiding landmass has been has an elevation at the less than 1 meter above the sea level. The main distributaries flow through the area of marsh and the channels bounded by levees are commonly higher than the surrounding marshlands.

Which receives mud and silt during time of flood. When the distributaries overflow their bank said we have discussed about this levees deposit. And I think this is the end of this topic. So we will meet in the next class. Thank you very much.