Geomorphology
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Lecture-59
Seismic Geomorphology- I

So, Friends good morning and welcome to this lecture series of geomorphology. Today we will discuss about seismic geomorphology. So, if you remember or summarize up to the last class, that too we have already covered these geo-morphological processes that are acting on the surface at the present time. And mostly it is the aeolian process, fluvial process, glacial process and coastal processes and weathering, erosion, mass wasting and tectonic geomorphology that means all aspects of geomorphology that we have covered and the maximum geomorphic processes that we have discussed.

They were working on the surface only their modified 24 X 7 to the surface and making this earth surface peneplain. So, today we are going to discuss something about geomorphology which was the past that means the geomorphic processes, which are acting in the past to make this landscape peneplain and now we are recording through our instruments and these techniques like seismic and through this seismic profile we are studying geomorphic processes that were acting in the past.

So what is its utility first the use of this seismic geomorphology is to understand the Paleo geographic conditions and to understand the paleo or the ancient depositional environment, the ancient geomorphic processes that were acting in millions of years back or in the 1000's or lakhs of years back and those signature of this geomorphic processes, they are recorded within the rock and being detected with our instrument like the seismic technique. So, moving forward, if we say what does it mean? What is seismic geomorphology? if you see here, there are three figures and the photographs.

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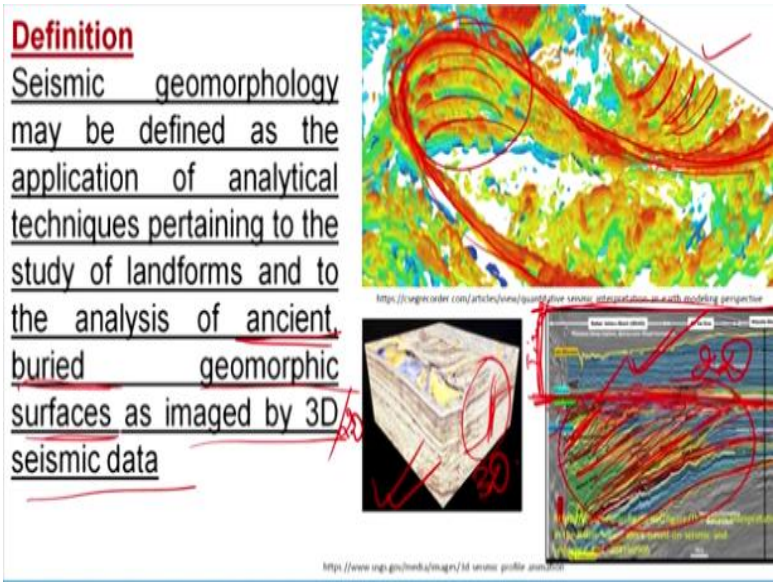

That are taken from this a Google and these three it is indicates that the seismic signatures of particular geomorphic and tectonic processes that are acting in the past and they are preserved in rock record, it is looking like a river that means a river, which is they are moving in this way and these are the point bars if you remember, they are fluvial geomorphology is at this point bars and at this point bar migrates that is a separate part of story, but if you see here, it is looking like they river and they are the point bar migration similarly, if you see these are the migration of the point bars.

So, that means, now a geologist who has experience by looking this image, he or she can guess yes, it is a river or it is a fluvial process and meandering river and this meandering river that is here, this point bars are abandoned. And now we can correlate it the fluvial geomorphic processes. Now, if your question arises, if this fluvial process is there, when it was working and how it is preserved now, see this is a slice simply it is a slice from a 3d surface or the 3d cube and within a particular timescale, when a particular time slice we have make it available 2D form.

And now, we see that means, within a 3D sequence or within a subsurface sequence, this part, this particular geomorphic process or particular river processes meanders, it was there. Now, we have removed the upper part now, we are able to look what was happening in the geological past because once we have removed upper part, that means we have reduced the time, we have

deducted some geological time and we have moved back in geological time to a certain timescale and a certain point of the geological time, we found there this river process was working and it is a meandering river.

Now, here you see this is a 2d seismic profile and the seismic profile if you see here these are this the depositional systems that this onlap off-lap, down lap that you know, it is probably you know it from your sequence stratigraphy. So, now you see, how it happens. It happens it is an interaction between the fluvial and marine process, the sedimentation process. So, that means if we are able to interpret these things, so that means we are able to interpret the past geomorphological processes acting at that particular place.

So that means here, suppose this is this for example, suppose this is the surface level and at this level, we are getting this onlap, down lap, whatever these sequences that are the sequence stratigraphic signatures are there. That means we have to see it, we have to move up to this much depth. So, this much depth means it is corresponding some geological time. So that means, if we are removing this much geological time from that place, we are able to see it on the surface.

So, that means, those geomorphic processes which are working in a particular geological time that processes are the product has been they are fossilized there. And through the seismic process, we do not know the subsurface. So, for turning the subsurface we are going for indirect method of study like the seismic because we do not know the surface of what we cannot see it directly what is what was happening in the subsurface process.

And here, once we are removing this much geological time and this much rock, we are reaching here in a sequence where the sequence boundary are they are something, whatever the sequence stratigraphic nomenclature is there, that we are getting it. So, that means sequence that means here if you see the marine process and fluvial process they are interacting here and with time. If you see this made and earlier for example, it was here if you project it back it will be somewhere here.

So for again if we are changing this sea level it again this depositional process progradation will be there and it is coming here. So, that means with time, how the paleogeography changes with time how the sea level fluctuation was there with time how the depositional sequence or the fluvial processes they were migrating to seaward or landward so, these are the geomorphology that that means, part of geomorphology as we have discussed.

So, that means in this seismic stratigraphy or the seismic geomorphology, we are interpreting the geomorphic processes and their product from seismic profile. So, seismic profile, maybe of 2d or maybe of 3d for example, here this is a 3d seismic profile it is given 3d seismic cube or tectonic block is there, if you see here particularly as a geologist experience, you have experienced some geological structure you can see here it is coming and here. Here expecting there is a there should be a fault here.

So, here we are getting and this fault is not exposed may or may not expose. So, now that we have information about the subsurface structure, we have information about the subsurface processes, we have information about this time processes. So, that means, in a particular geological time, what was happening in this subsurface that means, then surface nowadays it is subsurface, then it is surface because geomorphic processes.

They are near surface processes or surface processes, except weathering and erosion that is, that can affect to certain depth, but all other geomorphic processes they are the surfacial processes. So that means these are the geomorphology of ancient past. So, that means these are once upon a geological past these were the surface processes within the surface and with time they are buried and due to burial, now they are in the subsurface through the seismic profile.

We are able to interpret what was the geomorphic processes and their products they were in the geological past. So, this is the main aim of seismic geomorphology. So, by definition, if we move seismic geomorphology may be defined as the application of analytical techniques pertaining to the study of land forms and to the analysis of ancient buried geomorphic surfaces as imaged by 3D seismic data.

So, it is may be 3D or maybe it is 2D. So, here it is a 3D profile and here it is a 2D profile. So, so that means it is the study of ancient buried geomorphic surfaces. So geomorphic surface now it is for example, whatever is happening nowadays for example, take example of the East Coast, we have interaction of marine and we have interaction of the rivers. So, these are the surface process that are happening in front of us in the surface. Now, suppose for example, there is rise of sea level or there is a coastal encroachment of marine transgression.

So, that means, nowadays the surface which are happening in front of us the surfacial process that will be buried by sedimentation and in geological future if you want to study what was happening in their time that means the present time so, we have to go for either we have to go for trenching, pitting or drilling or indirect methods of seismic or any other geophysical methods. So, that means, these past geomorphic processes past geomorphic surfaces, how we can unravel through seismic profile how we can interpret that is the main aim of this seismic geomorphology.

So, aim of this study is reconstruction of a paleo geography, then analysis of paleo environment of a deposition and surficial processes that we know first is this reconstruction of paleo geography because land and sea distribution, this profile that we discussed in the last profile, how these sea level was moving, how this coast was moving to and fro. Similarly, how this fault was acting in the geological past, how they are affected in the sediment over overlying sediment cover.

So, that means it is reconstruction of paleo-geography where the river either this river processes which are acting in geological past, the same river process acting present or in recent geological past so, that it is buried or it is occupied by another process the marine process or aeolian process. So, that means different geological processes, they can be clubbed or they can be they can be seen through a seismic profile in a particular geographic location analysis of paleo environment of depostition and surficial process.

Paleo environmental depostition that means, it is the geomorphology and sedimentology and you see these depositional processes, they are the product and the geomorphic process, see river process, it is geomorphic process but depostition is either a flood plain deposit or it is natural

levee deposit or it is a point bar deposit. So, there is a product sedimentology is the product geomorphology is the process. So, the geomorphic processes that lead to the depositional process, the deposition of materials, deposition of sediments so, geomorphology is the process and sedimentology the product.

So, that means paleo geomorphological processes that can be studied through seismic geomorphology know how to do it, if you see here, this is done by reflection seismic map and sections. So, reflection seismic map and sections. So, that means there is principal in seismic we go for seismic data acquisition and then seismic data processing. So, acquisition if you see this figure it is just a fundamental diagram it is given.

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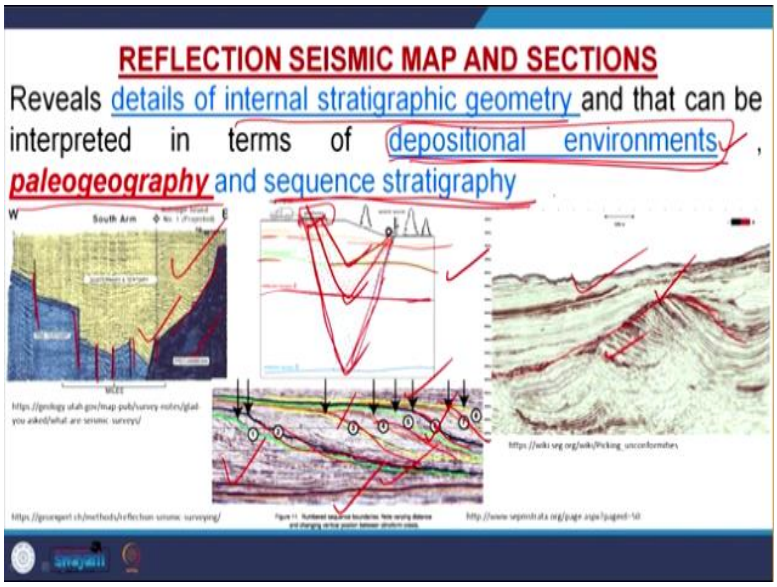

So, here we have a seismic source from the source, we are sending these waves and the waves they are moving back at different geological interface. Suppose for example, here one interface is another interface it is third interface. So, from the different geological interface so, the interface that means, it may be the lithological boundary, it may be any that means, it may be water table it may be any interface which is different in characters than the first so, that means that will reflect these into from this interface this wave will reflect back and this is reflected back wave that will be recorded through geophones.

Now, we have to interpret it we have two processes and after processing we have to interpret it. So, these are the process data these are the process data these are the process data. So, this process data has to be interpreted through geological knowledge. Now see, once it is now you see here from this interface it is reflecting back from these interface it is reflecting back from this interface reflecting back that means, we are getting here one interface second interface third interface.

So, either it is a lithological boundary or it is a density contrast of anything. So, these are this main surfaces from which the reflection will come back and will be record here. Now these from these data if you see it is geologist experience geologist what you can interpret here. So, this is representing an unconformity surface is it? Similarly here, these are the sequence boundaries, this seismic stratigraphic sequence stratigraphy to know it.

So, these are the sequence boundary. Similarly here, these are these faults they from here, this is seismic data is interpreted these are the faults within the basin. So, that means, I want to say, unconformity surface depositional boundaries, structures, all those things all those geomorphologic elements that can be detected and interpreted from this seismic profile. And then can be correlated with the geomorphic processes were acting in the geological past.

So this seismic reflection, it reveals details of internal stratigraphic geometry, we have internal stratigraphic geometry, either it is unconformable strata, conformable strata either onlap off-lap down lap condition whatever may be. So, we can interpret here so why I am talking about this this onlap off-lap down lap unconformity, these are this process these are the product, but the process is the geomorphic process.

For example, onlap off-lap down lap there the geomorphic processing involved is the interaction of marine and fluvial system sediment progression sediment distribution system. Similarly, here this unconformity unconformity is a product of erosion or non-deposition. So, that means, here also geomorphology involved here geomorphical process involved here geomorphical process involved.

So, everywhere we want to pick out the geomorphic processes that are involved in this geomorphology in the in this seismic profile, is not it? So, it reveals the detailed internal stratigraphic geometry and that can be interpreted in terms of depositional environment and paleogeography and sequence stratigraphy. So, these are the informations we can retrieve from a seismic profile.

So, we have the information about the depositional system and we know the depositional systems or depositional environment, they are governed by the geomorphic processes deposition, where depositional will takes place? There will be aeolian processes, aeolian geomorphology leads to the deposition there will fluvial geomorphology that leads to deposition or glacial geomorphology leads to deposition coastal and marine process leads to deposition.

So, that means, the depositional environment transfer say that means we are bracketing some geomorphic we are involving some geomorphic processes in that. Similarly paleogeography, paleogeography means it is the interaction with the geomorphology process sequence stratigraphy interaction of geomorphic process internal stratigraphic geometry that means it is a product of geomorphic process, is not it? So, everywhere geomorphology attached with it.

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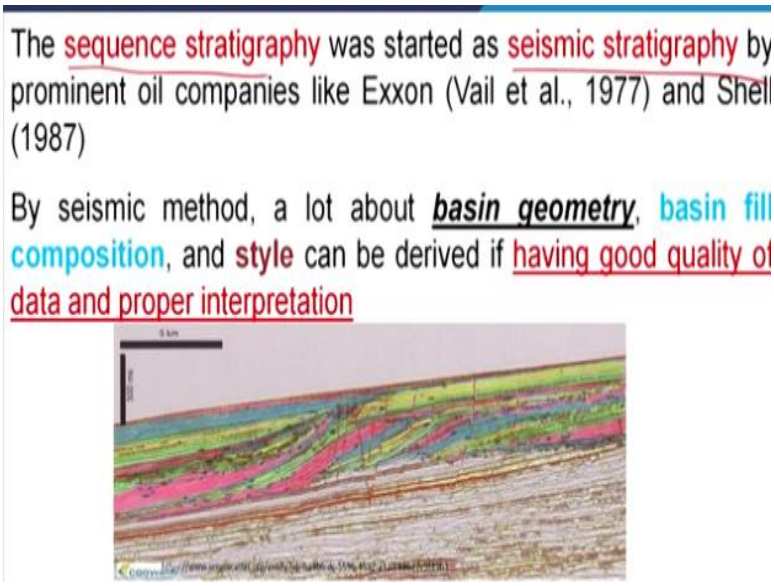

This sequence stratigraphy was started as seismic stratigraphy by the prominent oil companies like Exxon and shell. By seismic method, a lot of a lot about basin geometry, basin fill

composition and style can be derived and if having good quality of data and proper interpretation, this is also important. This seismic geomorphology where it comes, it comes from this seismic profile and first it was started with sequence stratigraphy and then seismic stratigraphy from the stratigraphic record.

We are unraveling we are retrieving the geomorphic processes involvement and this seismic method it says a lot about the basin geometry, how the basin will look like.

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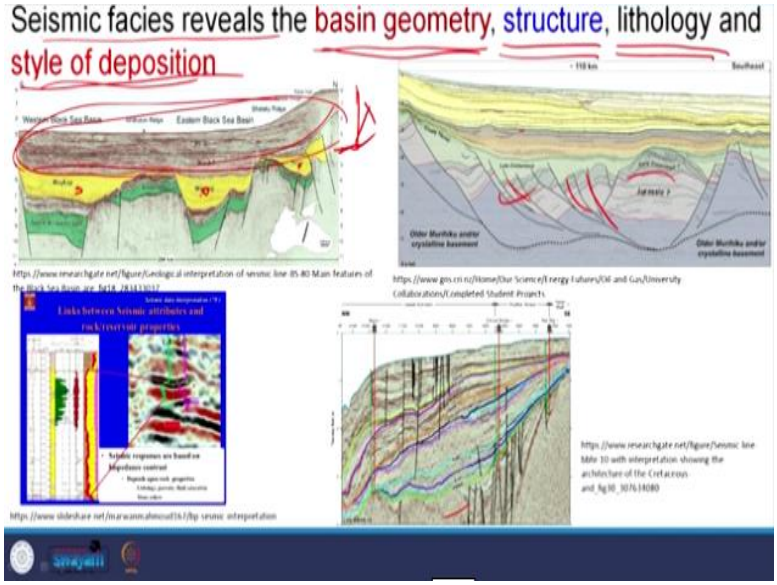

If you see here, this basin geometry that means now you see here how this basin either earlier there are two basins. Now, there now it is representing one basin here. But if you remove this much geological timescale; you remove the much sediment and finally, we are coming isolated basin one here, one basin here, one basin here. So, that basin is geometry in geological past, either that is in evolved through one basin to multi basins or multi basins is correlations, it is forming now representing it is one basin.

So, it is this reveals the basin geometry, then structure structure means, if you see here, we have faults, we have folds we have unconformities. So, like these are the structures that can be that can be retrieved or information about the structure can be retrieved. Then lithology, lithology here differently lithology either we are dealing with the sandstone limestone shale or whatever may be, lithology is there that can be retrieved the style of deposition style of deposition.

Similarly, we have onlap, off-lap, truncations so down lap whatever may be or there is a unconformity bound sequence.

So, that means, how this style of deposition was there that means everywhere we are involving geomorphic processes. So, that means seismic facies or this seismic stratigraphy or the seismic sequence, this is seismic profile that will reveal the information about the basin geometry, about the structure about the lithology and about the style of deposition and which in turn are related to geomorphic processes inbound in their formation in geological past.

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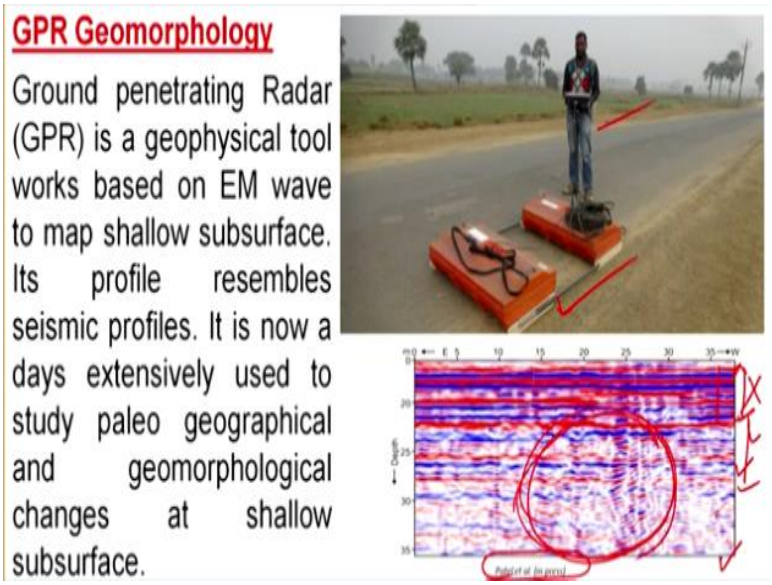

So, like seismic geomorphology, we have another geomorphology that is called GPR geomorphology GPR stands for ground penetrating radar. It is equivalent to seismic, however if you see this profile, this profile is looking like seismic profile, but actually it is a geomorphic whether it is a GPR profile. So, here some geomorphological information, some geomorphic information in the recent geological past that means it is a depth wise its restriction is there up to 45 meter or 40 meter or 50 meters or so.

So, that means, at this shallow subsurface level, what was the geomorphic processes was involved in their formation in the recent geological past that we can unravel for example, if you see this on this photograph from GPR profile, it is a learning or experienced geologist you can say here you can restrict yourself that is looking like somewhat a channel. So, that means now let

us see at the surface level, this much we do not have any information only parallel reflections are there but once you are moving to this much depth.

We are getting a patch which is looking like a channel which is buried. So, that means it is a paleo channel and this is a GPR and this was taken from patel et al which is in press and it is a Patel is standing. So, that means this information which you are retrieving from a GPR profile, it is equivalent to seismic profile and the difference is that the depth and the process here we are using EM wave and in the seismic profile were using shockwave that is the seismic waves.

So, this principle is different, but this aim is same and the seismics we can go up to kilometer up to kilometer of 4, 5, 10 kilometers, but here we are restricting ourselves within few meters, we even if less than hundred meters. So, in this shallow level, shallow level means, very recent geomorphic processes. So it is a low level what was happening now very recent geomorphic processes that can be retrieved through GPR profile and the deeper level in kilometers depth, what was happening, what are the geomorphic processes was there that we can retrieve from the seismic profile.

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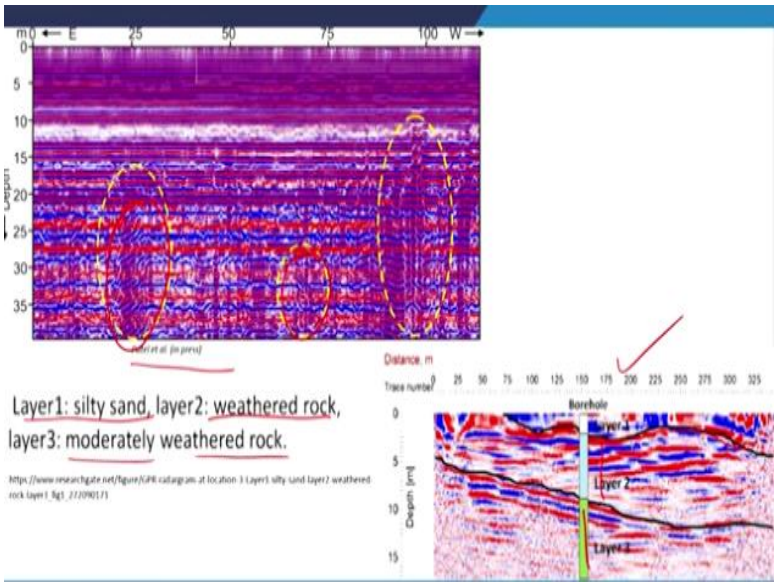

Here is another photograph and it is also from the same here you see there are faults, shallow subsurface faults and here shallow subsurface faults and in this photograph you can see seismic. This is the also a GPR profile you can see here, layer one it is silty sand is layer 1 here it is

interpreted or silty sand layer 2 weathered rock and the layer three moderately weathered rock that means even if the intensity of weathering, the degree of weathering that can be detected through so, weathering which is geomorphic process.

So, that means, either it is the seismic profile or it may be a GPR profile through which we are unraveling the geomorphic processes acting in recent or in an ancient geological past that is clubbed or that is fossilized there and we are able to extract it interpreted it from the seismic profiles and the GPR profiles.

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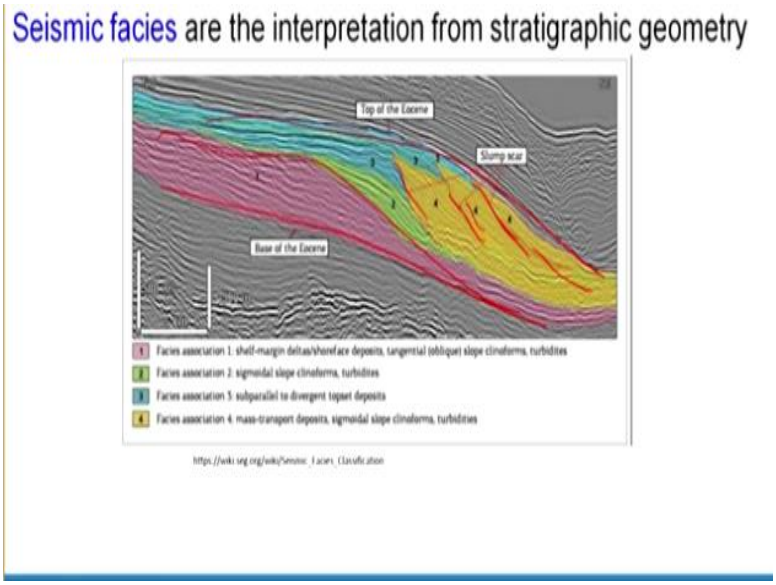

Seismic facies are the interpretation from stratigraphic geometry these are called the seismic facies and there is stratigraphic arrangement if you see how the sequences sequence boundaries there and from sequence boundaries there will be onlap down laps. So, it was there will be a landslide and there will be a name, tsunamis sequences tsunamis deposits so, there is a depositional sequence. So, all these informations can be retrieved from this type of profiles.

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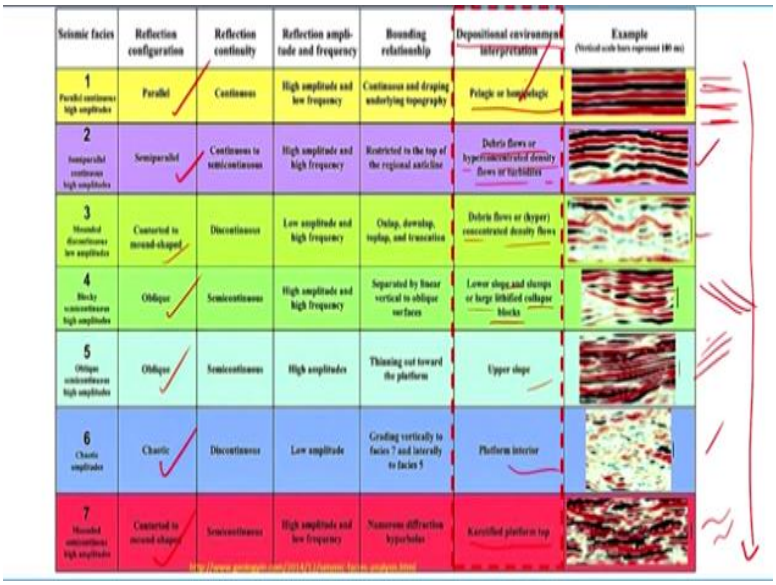

So, here there are certain pattern which is defined by this pattern of reflection of seismic profile you see there is parallel pattern then semi parallel then contour or mound shaped, oblique then again it is oblique, chaotic then contour mount shaped. So, that means these are this if you see here this is parallel pattern. So, there are the reflections which are parallel. Similarly, here reflection that is not exactly parallel it is called semi parallel.

Here it is contour and mount shaped here your mount shaped are there contour and you can draw contours at different levels, then oblique if you see here it is oblique, it is moving like this, it is a oblique type, then again. Similarly, it is a oblique like this, then it is chaotic there is no any arrangement there is no any particular site of reflections there is chaotic, then again it is contour to Mount shaped different shapes.

These are this ideal reflects on patterns through which the depositional environment can be retrieved and those depositional environment can be correlated well with the geomorphic processes involved. For example, here we have parallel reflections that can be interpreted pelagic and hemipelagic. That means, it is deep sea geomorphic process is not it? Then it is debris flow, hyper concentrated density flow and turbidity.

It is also at the continental slopes then debris flow hyper concentrated density flow here is landslide mud flow landslides that we have discussed in mass mass wasting processes, then

lower slope slumps and large lithified collapse blocks it is land slides sub marine landslides, then it is the inverted upper slope then platform interior then it is Karstified platform top. So, that means here this depositional environment or publicly we can say it is the geomorphic processes involved.

So, that can be interpreted through this type of reflection and these are the ideal reflections not necessarily in a particular area in a particular seismic profile, all types of information all type of reflection patterns we can get.

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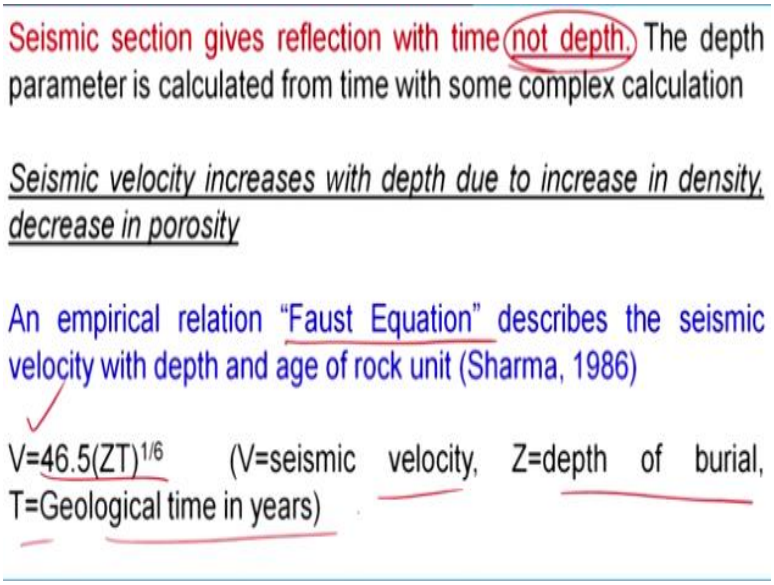

Seismic section gives reflection with time not depth mind it here whatever this 2D seismic profile we are getting or whatever here it is giving this axis it giving time not depth, but from the time to depth we have to calculate and this is basically done by the geophysicist of the seismologist. So, seismic velocity increases with depth due to increase in density and decreases in porosity because once we are going down so, due to more and more overburden pressure, the porosity decreases.

Similarly, the density increases because once porosity decreases that means, the pore space is occupied by grains and the density increases. So, that means, with increasing density, the velocity increases and an empirical relation that is called Faust Equation. It is equation described seismic velocity with depth and the age of the rock. So, here, velocity equal to $V= 46.5ZT^{1/6}$.

So, V is the seismic velocity Z is the depth of burial and T is the geological time in years. So, this is a first equation, but not necessarily this equation is the qualified to be applied in every geological sequence depending upon the terrain depending upon the rate of sedimentation, depending upon this proximity to plate boundary or at the basin interior or at the basins of periphery. So, that means though this equation it is empirical equation is there empirical relation intervals between the time and velocity in geological time, but it is not applicable everywhere.

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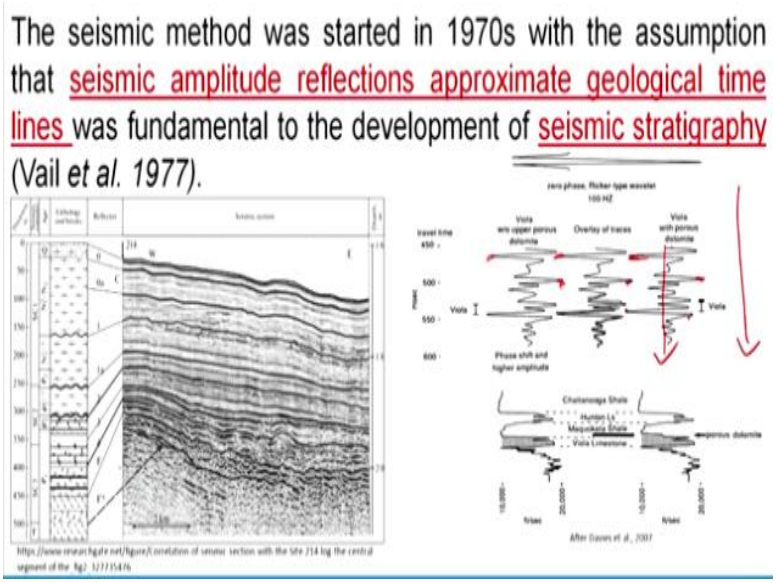

So, the seismic method was started in 1970 with the assumption that seismic amplitude reflections approximate geological time lines was fundamental to develop seismic stratigraphy or the seismic geomorphology. So, here if you see, suppose, we are sending these seismic waves down. Now, you see here this reflection, this is a reflection this reflection, similarly, another reflection here there is changing in amplitude. So, if you are getting this the wave propagation the depth, so, there are certain points where the amplitude is very high or very low.

So, this low and high amplitudes these are these the product or these are the function of the change in formation properties, the formation properties maybe due to density change, maybe due to a lithological change, maybe due to presence of fluid within that. So, these changes can be retrieved from here by this by this amplitude changes and this can be interpreted to two different lethal units and lethal units they are related to geomorphic processes.

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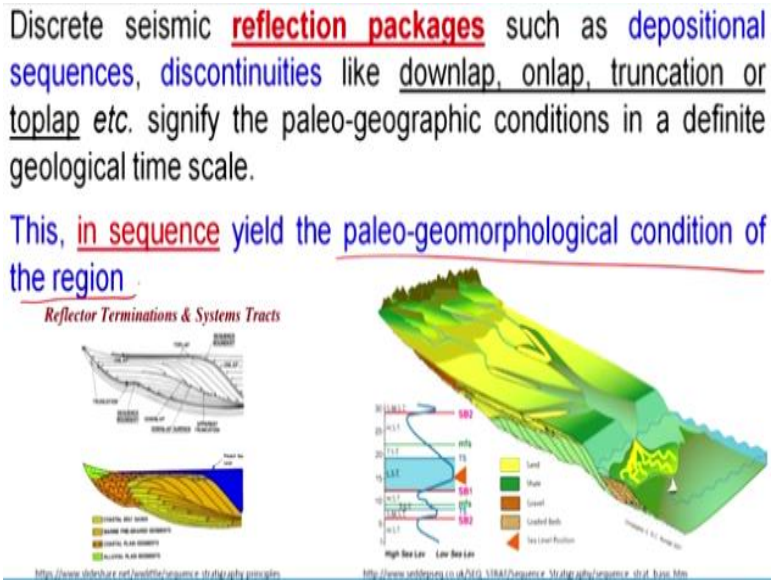

So, discrete seismic reflection packages such as depositional sequences, discontinuities like downlap, onlap, truncations or toplap, it is a signify the paleo-geographic conditions in a definite geological time scale. This in sequence yield the paleo-geomorphological condition of the region. So that means those depositional sequence, they are indirectly or directly they are reveling, or they are pointing towards the involvement of the geomorphic processes in a particular geological geographical area and the geological timescale.

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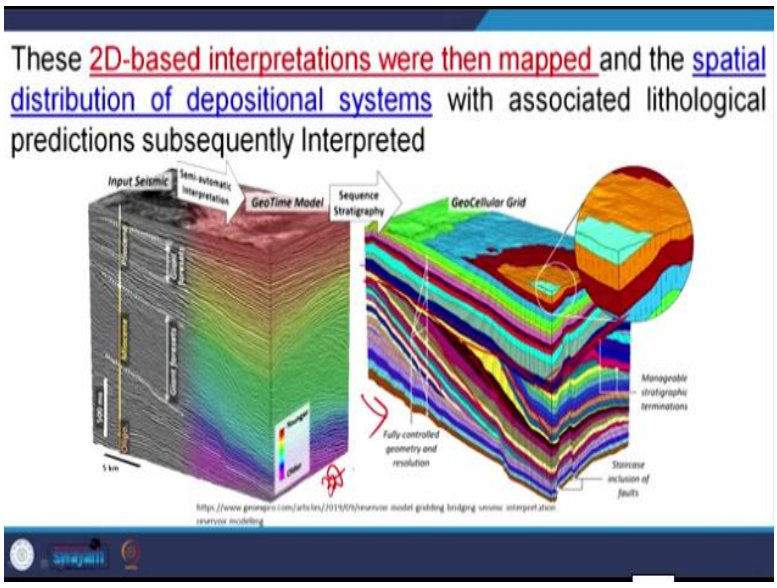

So, these 2D-based interpretations were then mapped and the spatial distribution of the depositional systems with associated lithological predictions subsequently interpreted and if you

see here these are the interpreted map and these are the seismic block the 3d seismic sequence from the 3d seismic sequence they are the interpreted now if you see their interpretations here, we have some inclined strata. And now we are getting a parallel strata here. So, that means we can say it is a unconformity surface, is not it?

So, this type of interpretation is comes out and that now suppose, we are involving here, that is a unconformity surface here, that means they are exposed to the surface the erosional processes. So this erosional processes in involved in this interpretation of from this seismic profile.

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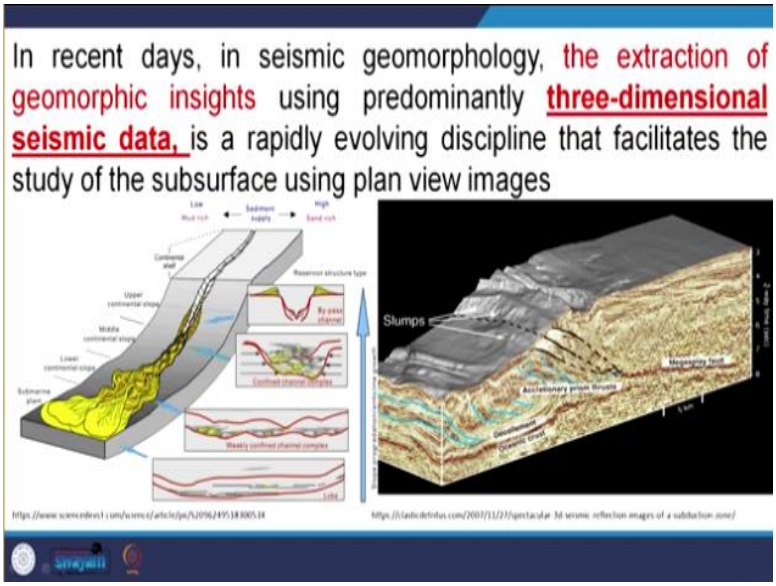

In recent days, in seismic geomorphology, the extraction of the geomorphic insights using predominantly three dimensional seismic data is rapidly evolving discipline that facilitates the study of the subsurface using plan view and images. So here are the there are 3D seismic sequences. From the 3D seismic we can interpret how depending upon this reflection pattern, which type of geomorphological processes, what type of the depositional processes involved, we can interpret through it.

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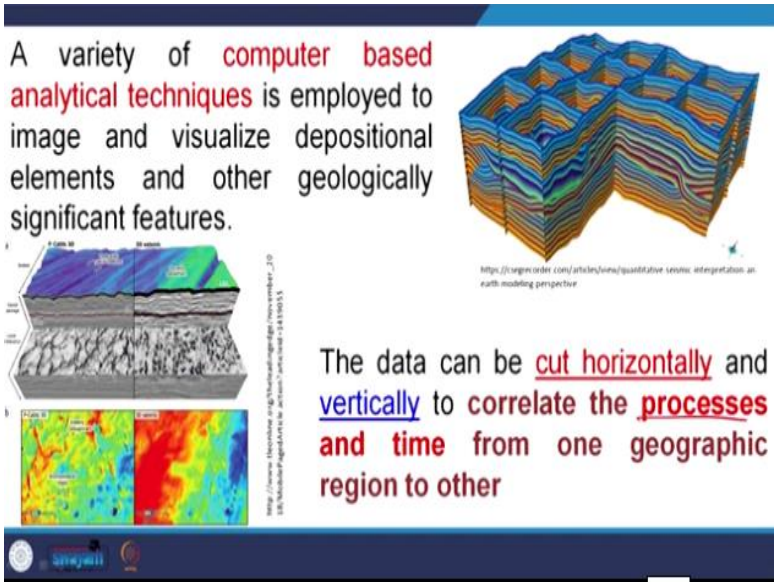

A variety of computer based analytical techniques is employed to image and visualize depositional elements and other geologically significant features, the data can be cut horizontally which is and vertically, which is representing the process and time because horizontally that means the geological processes the geomorphological processes side by side and vertically that means geological processes with time.

So, the vertical line is indicating the time sequence, the horizontal line indicating the lateral or the longitudinal change in the geomorphic processes as well as the depositional systems. So, that means, with time whatever the changes are there, similarly, laterally or with space, what are the changes in there so, both time and space, with time and space how geomorphological processes evolved and changed that can be retrieved that can be correlated that can be interpreted from the seismic data.

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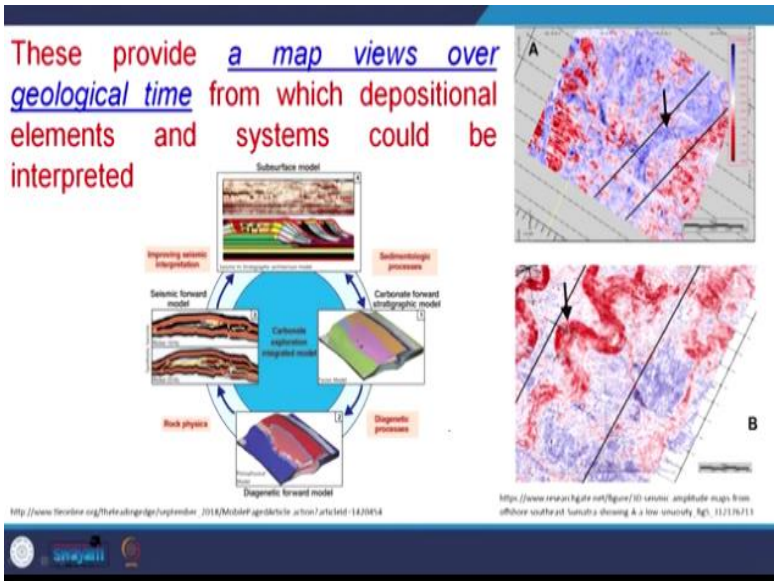

So, this provides a map view over geological time from which depositional elements and system could be interpreted.

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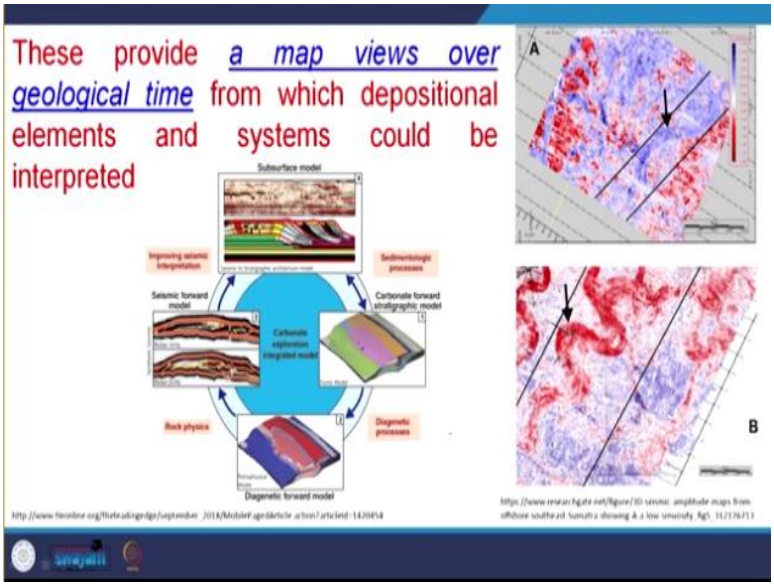

So, these are this sequence of how this things works, we have seismic data input, then seismic data enhancement, then replace refinement of interpretation, then seismic attributes, then it is seismic facies analysis then it is actually index Map. So, starting from the input data and how we are coming to interpretation that is the process. So, I think we should stop here and we met in the next class. Thank you.