Conservation Geography
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Module - 3
Lithosphere and landforms
Lecture - 9
Evolution of Landforms

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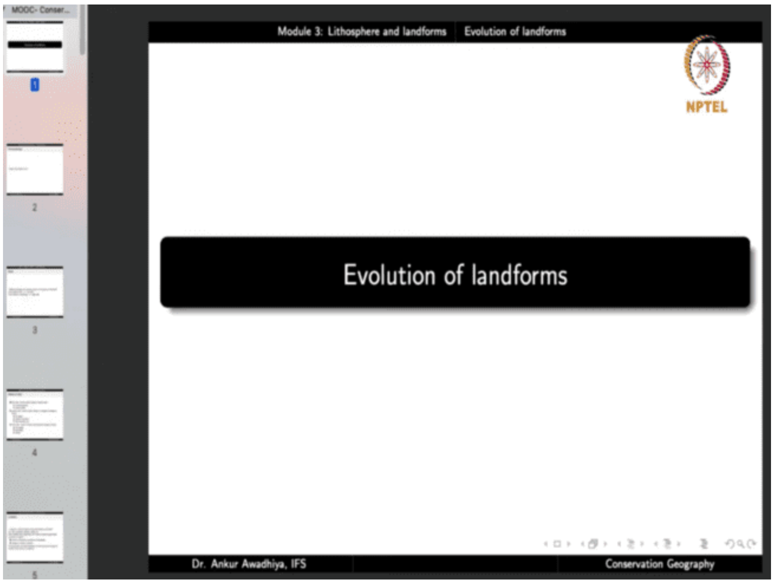

Namaste! We move forward with our discussion on lithosphere and landforms and in this lecture we shall explore the evolution of landforms.

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Now as we have observed these topics fall within the purview of geomorphology which is the study of the form of Earth or the study of Earth's form or the study of landforms.

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Now one of the most important topics in the, or concepts in the case of geomorphology is relief. Relief is the difference between two elevation points on the surface of the Earth. If the surface is flat we say that there is a low relief. If the surface is undulating we say that it is having a high relief. So, it is the difference between two elevation points on the surface of Earth.

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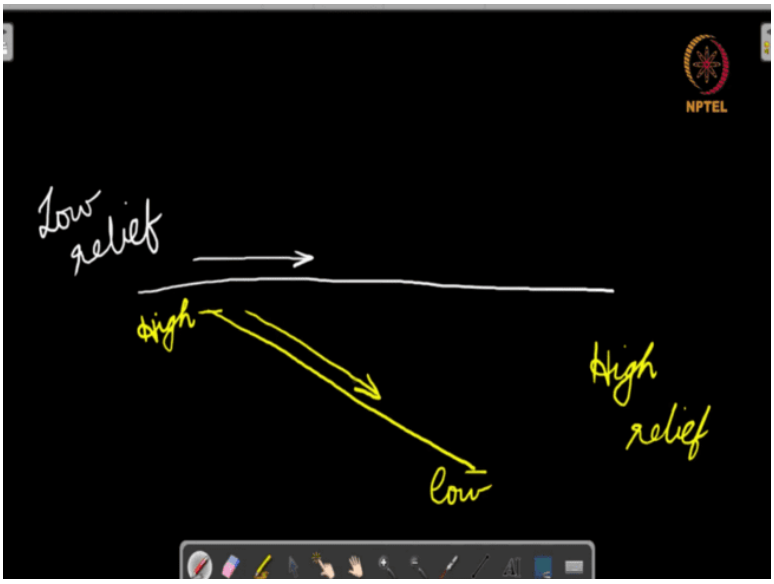

Now why is it important? It is important because if you have flat area with a low relief. In that case the speed of geomorphological agents such as water will be less. Whereas if you have an area that has a high relief, so you have certain areas that are high and certain areas that are low. And so because there is a difference in elevations between these two points, we will say that this area is a high relief area.

Now in the case of a high relief area, water will move down very quickly and we have observed before that the erosional capacity of water is determined by the speed of water. If the water is moving at a greater speed in that case it is able to erode more it is able to transport more. Whereas, when water is travelling at a low speed in that case it is not able to erode as much it is not able to transport as much.

And so relief becomes very important and thus the geomorphological agents such as water are able to play a much greater role in high relief areas as compared to in low relief areas.

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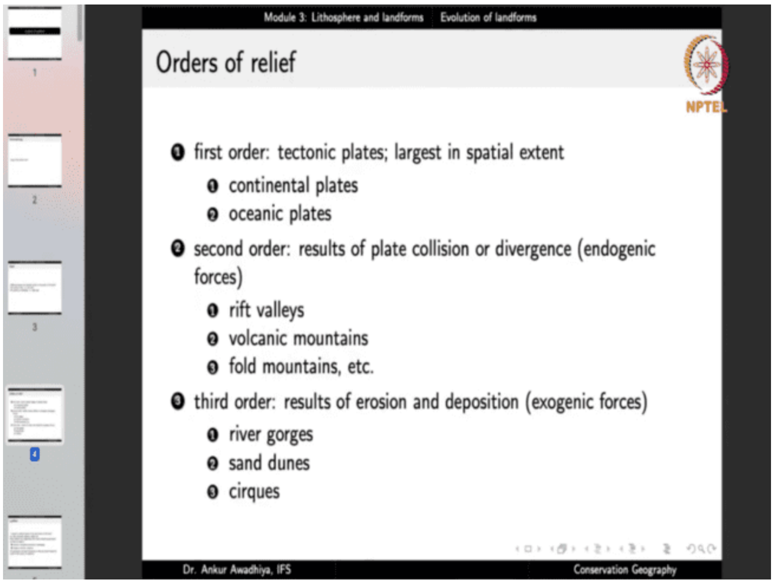

Now relief can be looked at different scales. So, we can, when we say that relief is the difference between two elevation points. What is the distance between these two elevation points? Are we looking at close by points or are we looking at points that are very far apart? So, in this context we talk about the orders of relief. The first order comprises of tectonic plates that are the largest in spatial extent. So, we have continental plates and we have oceanic plates.

And when we talk about the relief of first order we will ask the question what is the difference between the highest and the lowest elevation points on a tectonic plate. So, we are looking at very far off areas and the differences in elevations will tell us the first order relief of the tectonic plate.

The second order relief is at a much more local scale. These are the results of plate collision or divergence that is the result of androgenic forces and here we talk about the reliefs of rift valleys, relief of volcanic mountains, reliefs off old mountains. Now in this case because the endogenic forces have resulted in a change in elevation or a differential elevation between two points, the relief is known as the second order relief and on a much more local scale, we have the third order relief which is the result of erosion and deposition because of exogenic forces.

And in the third order relief we talk about things like river gorges or sand dunes or cirques. Now we noted before that endogenic endo is inside, inside genesis which means that these are the forces that originate from within the Earth. Exogenic, exo is outside so exogenic forces are those forces that originate outside the Earth typically through the force or the energy of the sun.

And in this case when we talk about the endogenic forces we talk about the second order relief. When we talk about exogenic forces we typically talk about the third order relief and first order relief is on the scale of tectonic plates.

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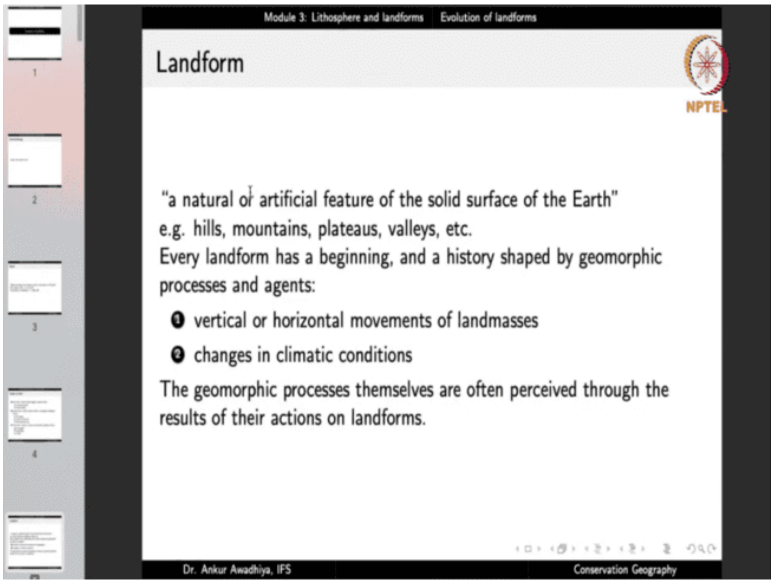

And how do we define a landform? A landform is a natural or artificial feature of the solid surface of the Earth. So, it is any feature whether it is natural or artificial on the surface of the Earth and which portion the solid surface. So, it is there on the lithosphere. So, landform comprises things such as hills, mountains, plateaus, valleys and so on.

Now every landform has a beginning and a history that is shaped by the geomorphic processes and agents. So, if we talk about a mountain say the Himalayas, then the Himalayas also have a history. The Himalayas originated when the Indian plate collided with the Eurasian plate. So, there was a beginning time when the Himalayas started to form.

There was a time to which they will grow and in that time period there will also be a time when the exogenic forces become dominant forces to bring down the Himalayas, to cause degradation of the Himalayas. And so for each and every landform, we can talk about what is the history of that landform. If there is a plateau, when did this plateau originate, how did it originate?

And when did it start to rise, when did it begin to degrade? So, these are the things that you can talk about for any landform. So, every landform has a beginning and a history and this history is shaped by geomorphic processes and agents. And what are these processes in agents? They are the vertical or horizontal movement of the land masses and changes in the climatic conditions. So, when we talk about vertical and horizontal movement of land masses, we are typically talking about the endogenic forces and when we talk about changes in the climatic conditions, we are typically talking about the exogenic forces.

Now the geomorphic processes themselves are often perceived through the results of their actions on landforms. So, how do we know that there is a particular geomorphic process that is happening? By looking at the landform.

So, if you find a hill that has been heavily eroded, in that case you can ask the question okay what led to this erosion and the answers will tell you that probably it was water, probably it was wind and so wind and water acted as geomorphic agents. Now you did not know about wind and water beforehand but by looking at the structure, by looking at the features on the landform you can make a deduction that okay it was degraded by such and such agent. So, the geomorphic processes are often perceived through the results of their actions on different landforms.

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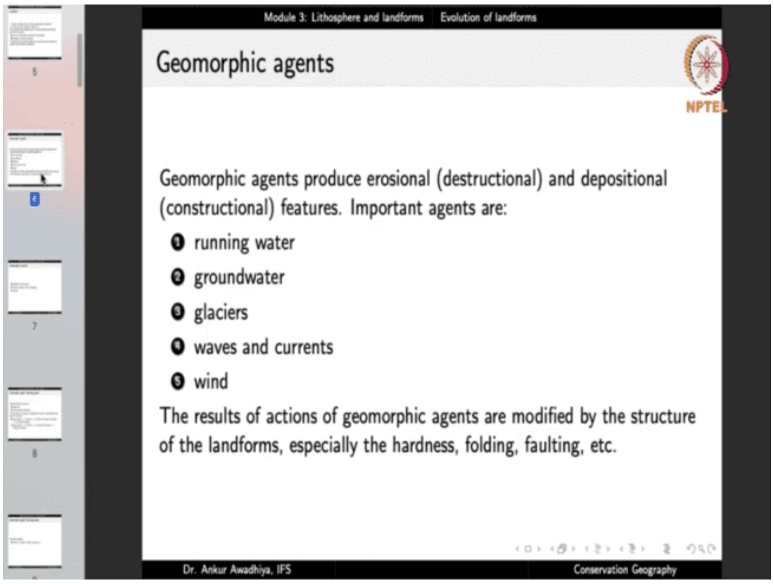

Now what are these geomorphic agents? These are the agents that produce erosional and depositional features. So, they can lead to erosion. Erosion is the destruction of the landform or the degradation of the landform and they can also produce depositional features, which is a constructional activity.

And we will look at a number of geomorphic agents. Important agents are running water, groundwater, glaciers, waves and currents and wind and the results of actions of geomorphic agents are modified by the structure of the landforms, especially, the hardness, folding, faulting and so on. So, basically the geomorphic agents such as running water or wind they produce changes. These changes can be destructional changes in which case the landform is being degraded down, the relief is being reduced or they can lead to constructional changes where something is being deposited somewhere.

Now the results of actions of geomorphic agents are modified by the structure of the landforms such as hardness, folding, faulting and so on. So, if there is a landform that is made up of materials that are extremely hard, in that case erosion will be difficult. If the landform is made out of components that are soft then probably erosion will be easier.

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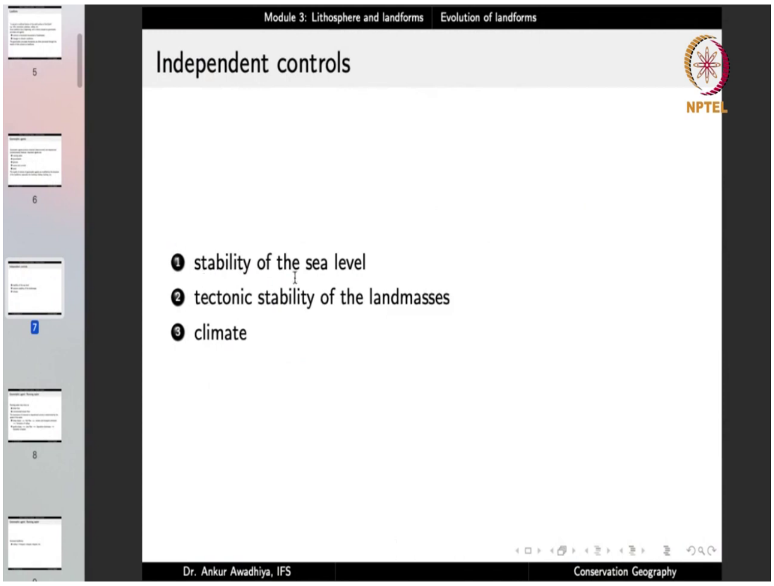

Now not only do we have the impacts of the landforms, we also have several independent controls on these geomorphic agents. Independent controls such as stability of the sea level. Now why is it an independent control?

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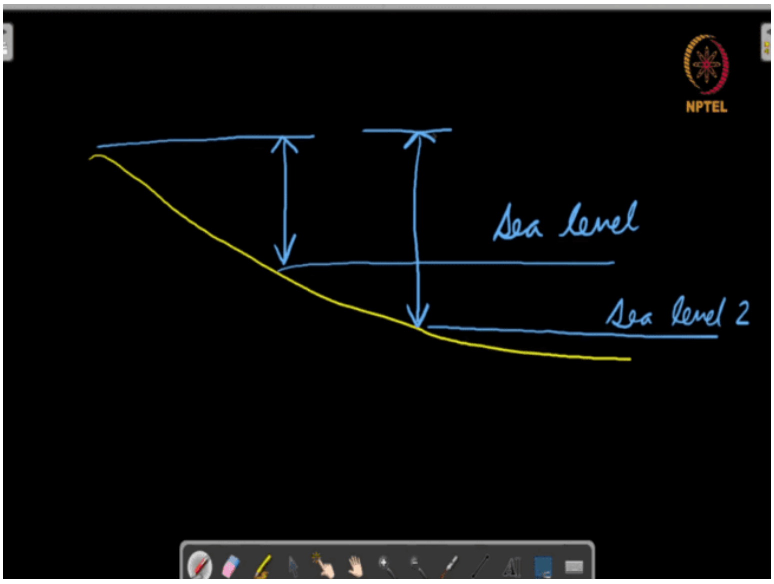

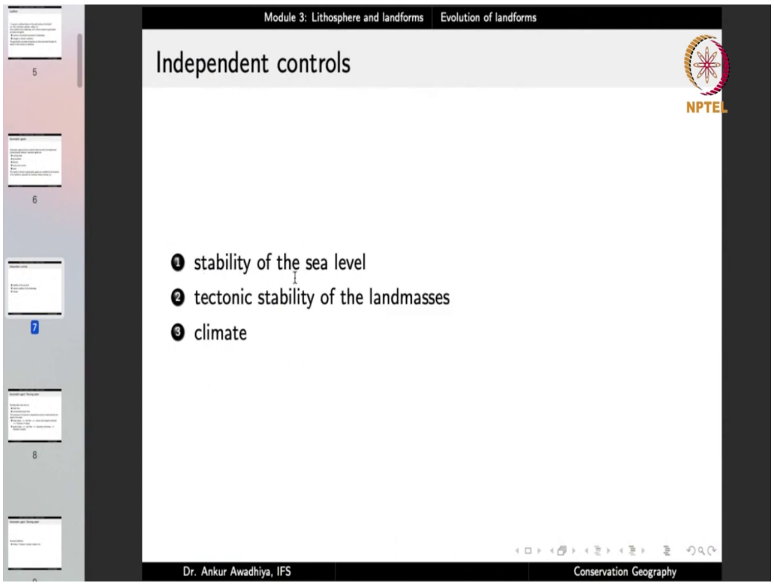

Let us consider this landform and here you have the sea. Now this is the sea level. Now in this case, the difference in the relief is from this point to this point. So, this is the amount of relief that we have. Now if the sea level goes down and so this becomes the new sea level let us call it sea level 2, now in this case, the relief has increased.

So, we are not talking about a much higher amount of relief and if the relief is more, then the water will be able to move at a much faster pace and so the amount of erosion will be more when the sea level is going down. On the other hand, when the sea level is high in that case typically the amount of erosion will be lesser.

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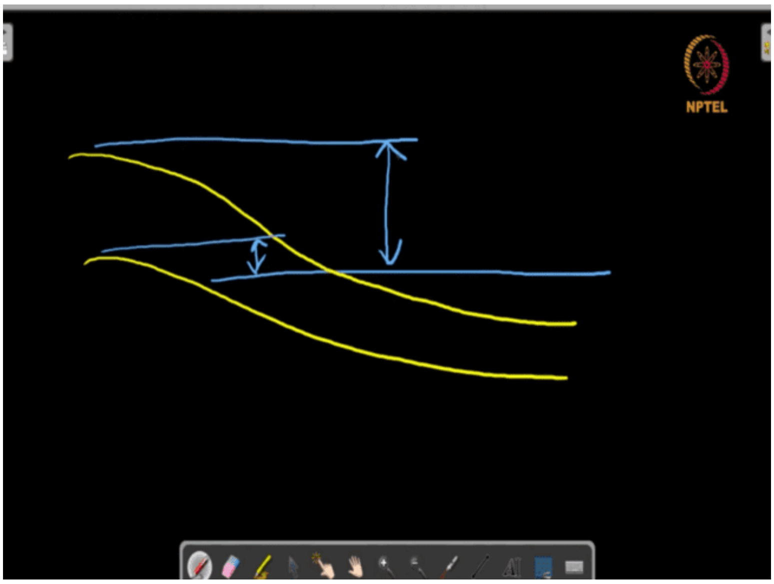

Another independent control is the tectonic stability of the land masses because in this case what happens is that you have this landform, the sea level remains the same, but let us say that this is the sea level. Now, the sea level remains the same, but probably the whole landform is pushed upwards because of tectonic forces. So, earlier the relief was this much, but now the relief is this much.

So, here again even though the sea level remains at the same level but because the whole landmass has been uplifted, so the relief increases with more relief we have water that moves with a much greater amount of energy and so the amount of erosion also increases. So, this is another independent control. Yet another independent control is the climate of the area.

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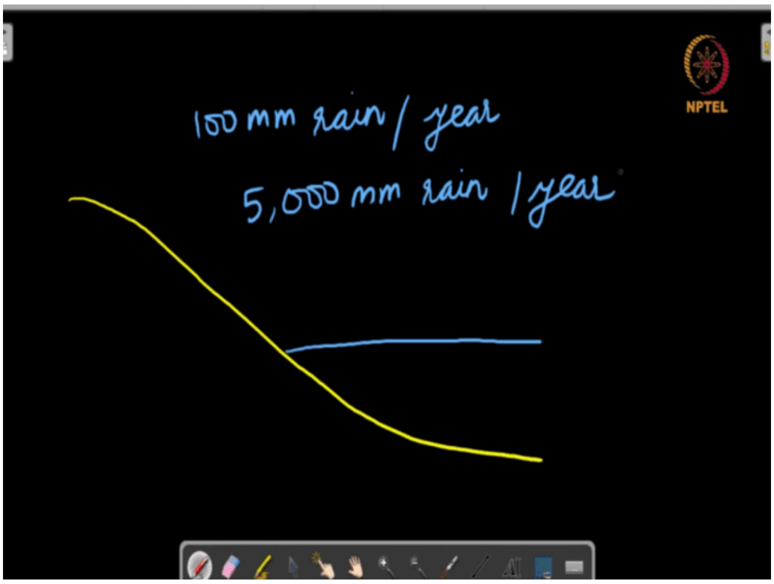

So, suppose you have this area. So, this is your landform. This is the sea level, but earlier you were only getting say 100 millimetres of rainfall in a year, but now because of changing climate, you are getting say 5000 millimetres. Now in this case, if you have more amount of rainfall you have more amount of water that is able to do the erosion. And so climate also acts as an independent control.

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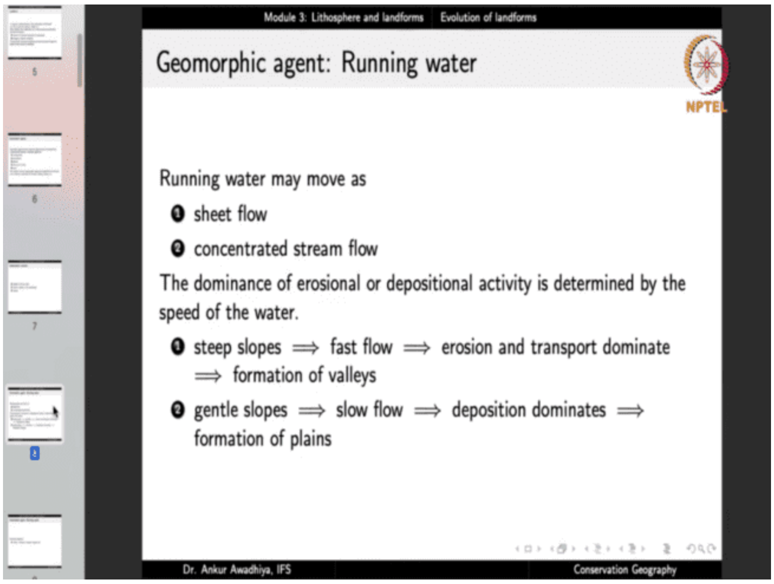

Now let us look at the impacts of these various geomorphic agents beginning with running water. Now water is the biggest erosional agent it is the biggest geomorphic agent, most of the landforms that you look around yourself will probably be because of the action of water. Now water can move either as a sheet flow or as a concentrated stream flow.

In a sheet flow, the water flows all over the land, all over the surface of the land in the form of a sheet of water. In the case of a stream flow, the water gets concentrated, it gets concentrated in the form of streams or channels. Now when water gets concentrated more amount of water flows per unit time period in a much smaller area of land. Now because of this concentration the erosional activity of water increases many fold.

Now the dominance of erosional or depositional activity is determined by the speed of water. Now most of the geomorphic agents are not just agents of erosion, but they are also the agents of transportation and agents of deposition. In the case of water whether water does erosion or transportation or deposition or two of these together or all three of these together and in what proportions is determined by the speed of water.

So, the speed of water is very large in that case the erosional activities will dominate. So, there will be a large amount of erosion, a large amount of transportation, but a very small amount of deposition. When the speed of water is less then depositional activities take predominance.

So, in the case of steep slopes, we have fast flow erosion and transport dominate, which result in the formation of valleys. In gentler slopes, the speeds reduces when speed reduces the ability of water to transport things reduces. The ability of water to erode things reduces. And so in these cases deposition dominates and this leads to the formation of plains, such as flood plains.

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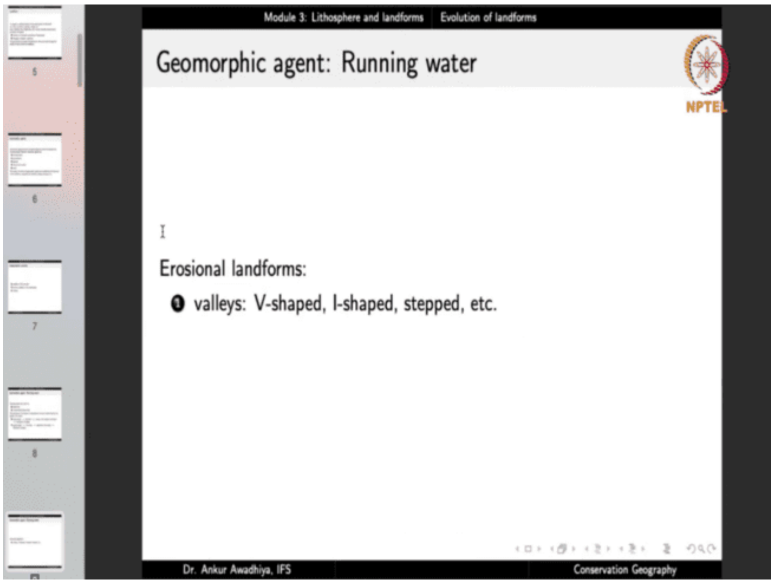

Now let us look at the erosion and depositional landforms that are created by running water. The erosional landforms include things like valleys. Now valley is the V-shaped or eye shaped or stepped structure through which a river flows or a channel flows.

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And here we can observe the river Colorado that flows through the Grand Canyon.

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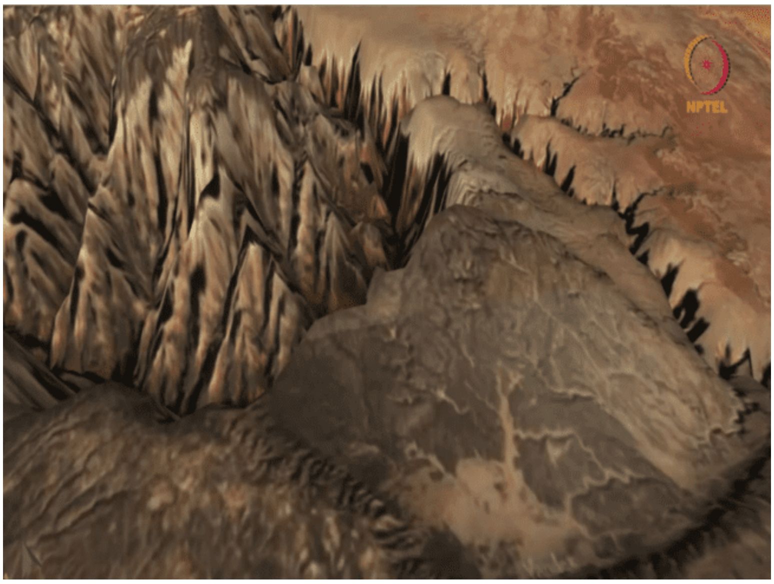

So, how does a valley or a canyon look like? So, this is a 3D model of the Grand Canyon. Here we have the Colorado River and here again we have superimposed the satellite imagery over the digital elevation model of this area. So, let us now look at one of this area in detail.

So, this is your river Colorado and as you can observe, this was the earlier land and now the river is flowing so deep inside. So, this is the river and you can observe that the river has led to a great amount of relief in this area because this is a high point this is a low point. This is one of the tributaries of the river here again you can observe that you have a very great amount of difference between the normal land area and the point where the river is flowing now.

And if you look inside one of these valleys, you can observe let us zoom at this point. So, now you can observe that this has created a very large sized valley, which is the canyon. So, the rivers can create different kinds of valleys.

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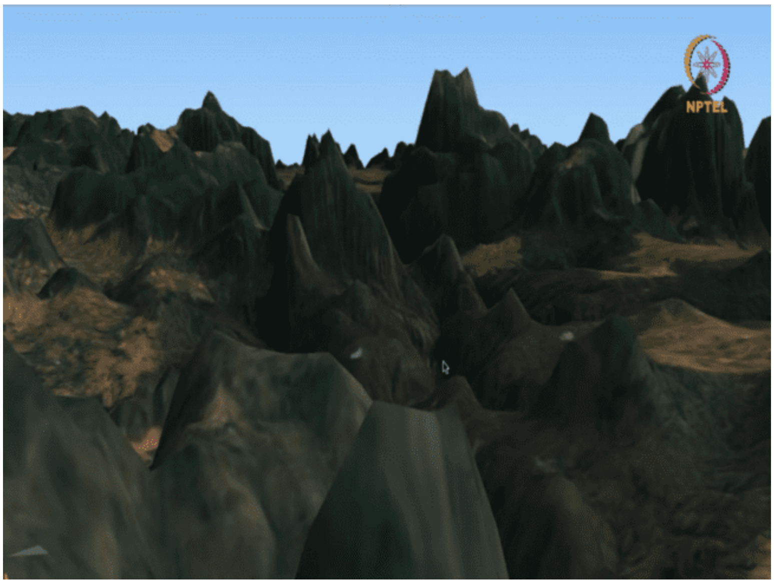

In our country in Hogenakkal, we can look at the valley of the Kaveri River. So, this is the Kaveri River, this stream and here if we look at the valleys, we can observe that here again we have these V-shaped valleys.

If you look at another area, so in this location you can observe that the slopes are very great and this is roughly vertical. So, we have V-shaped valleys and we also have I-shaped valleys here. So, like in this location if you look here so this is V, but in this region it becomes more like I.

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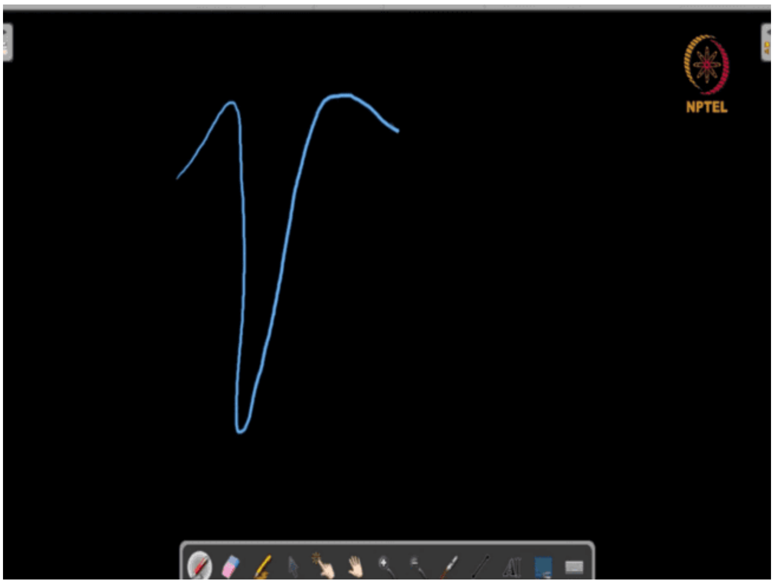

So, essentially a V-shaped valley looks like this but when the erosional activity is very large in that case we will find a valley like this. So, this is an I-shaped valley. Now in the case of an I-shaped valley, the amount of erosion is so large that the river just goes on chiselling down the slopes resulting in an I-shaped structure. In the case of a V-shaped valley, the amount of erosion is large but not as large. Also, we typically find I-shaped valleys in those areas that have been uplifting with time.

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So, you have a river. So, this is a river and the land that is surrounding it undergoes an uplift. In that case if the erosional activity of the river is large it will just go on chiselling down and result in the formation of an I-shaped valley.

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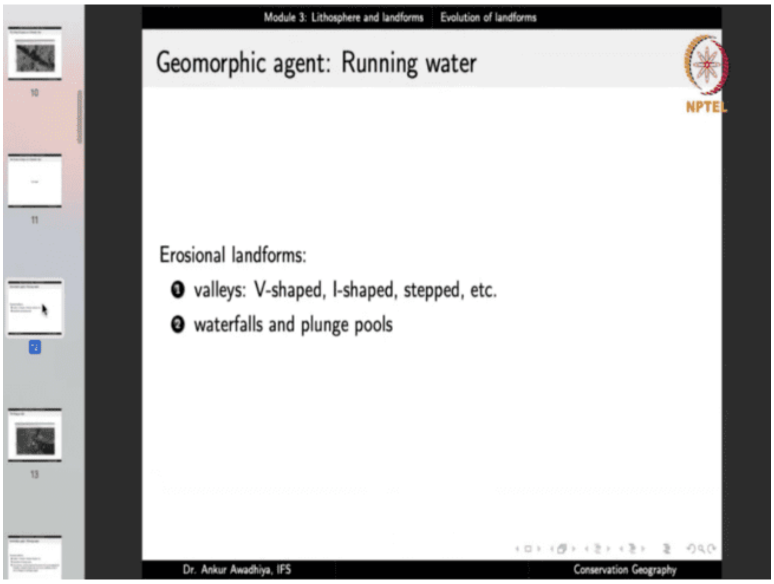

Other structures are waterfalls and plunge pools.

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So, here we can observe the Niagara waterfall. Now here again you have an elevation here and you have an elevation here. So, this area has a higher elevation this area has a lower elevation because of which the river just falls from the top and forms a waterfall. Now when you have a waterfall in this area you will also have a plunge pool.

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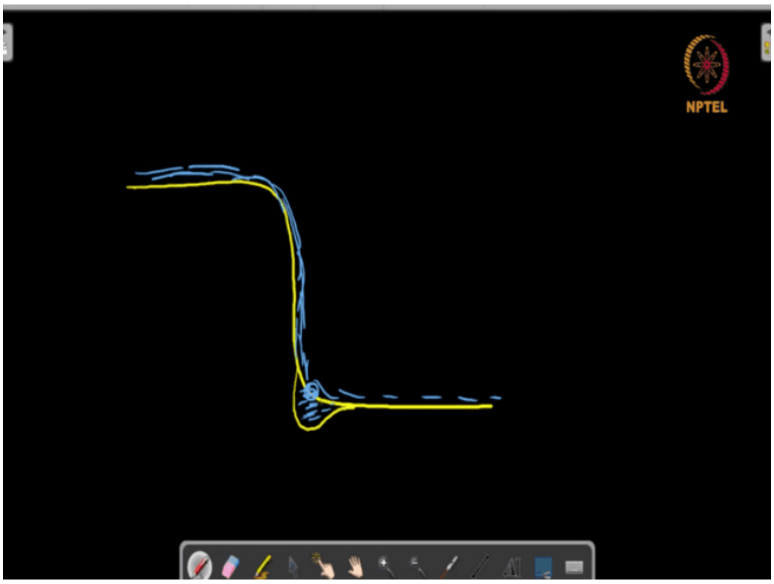

What is a plunge pool? If you have a land like this and you are having the river flowing like this, so this is a waterfall, but in this location, the amount of erosion will be very large, because the water is just hitting at this area. And so with time this area will be eroded and it will become something like this. So, this area is now all full of water and this is a plunge pool. So, this is another landform that the river creates.

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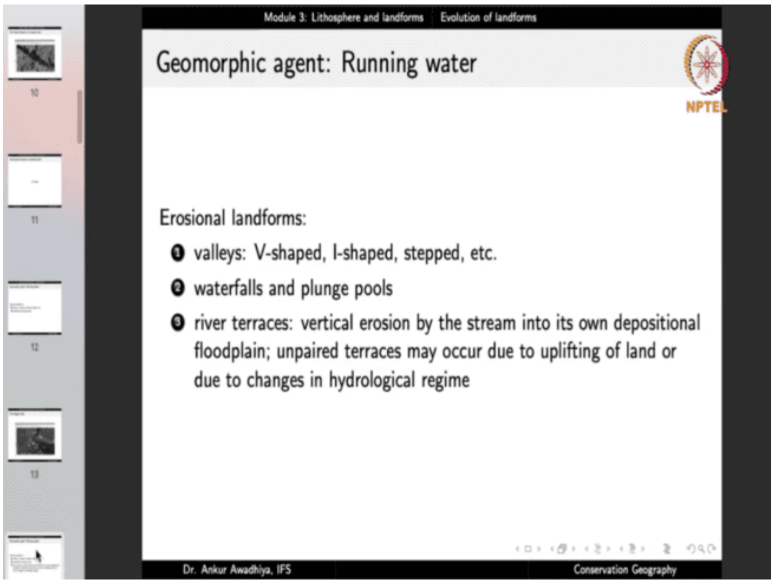

Yet another landform is river terraces. Vertical erosion by the stream into its own depositional flood plain creates terrace.

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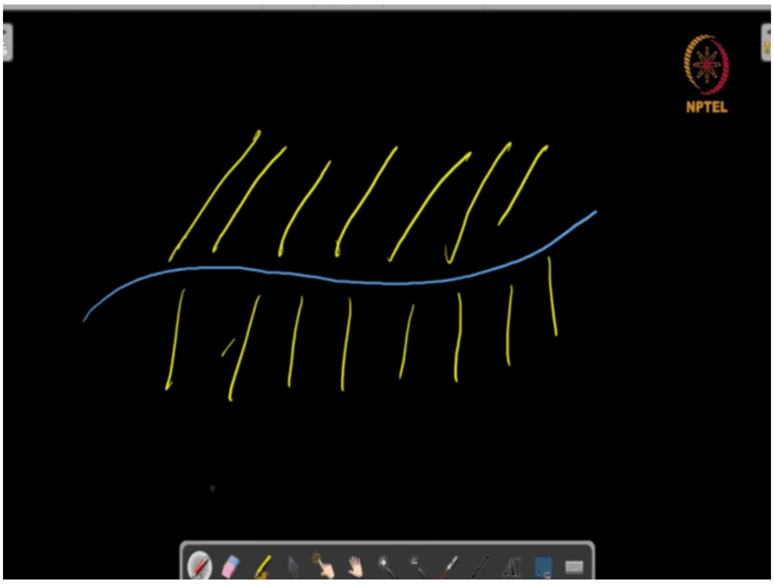

So, what happens is if you have a river and if this river is flowing in the plain areas in that case the speed is going less and so the river is depositing material on both the sides. So, this becomes the flood plain of the river. Now if the river changes coarse or in certain seasons when it has a greater erosional activity because more amount of water is flowing so it can lead to an erosion in its own flood plain. When it does that it results in the formation of river terraces and these terraces can be paired terraces or unpaired terraces.

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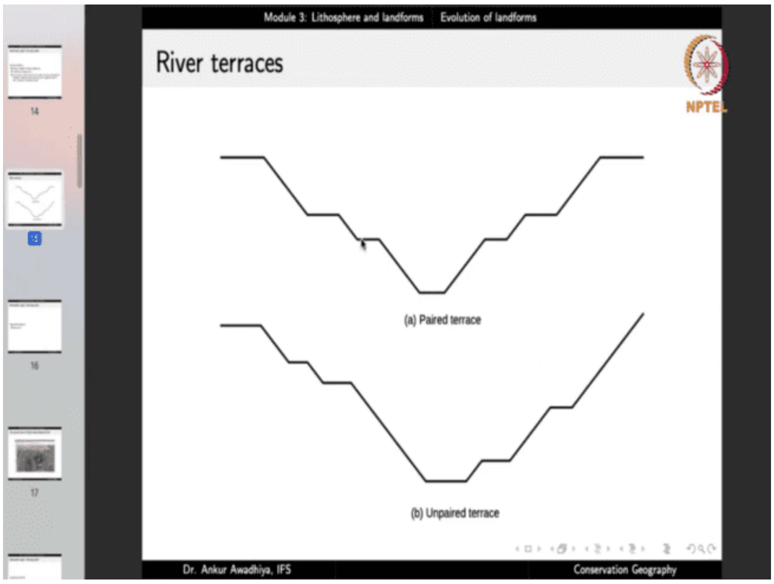

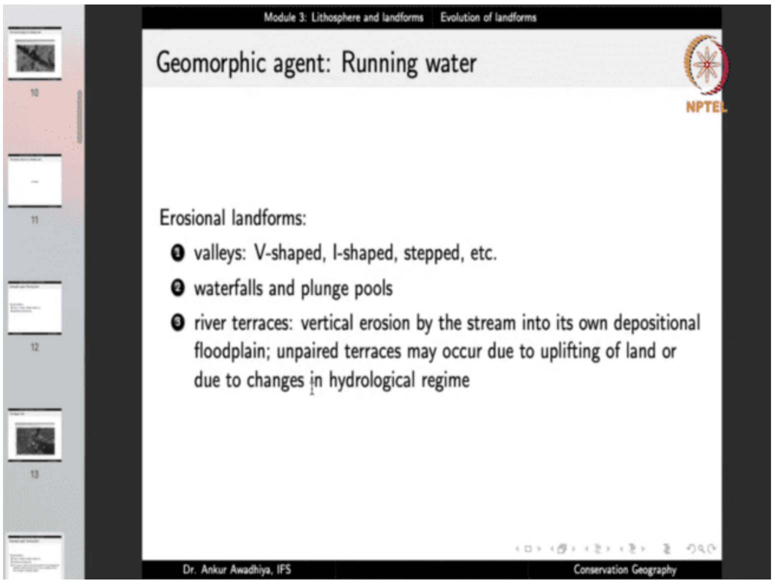

So, this is an example of a paired terrace. So, in a paired terrace both the sides will look symmetrical. This is an example of an unpaired terrace. Now in both the cases the river is flowing here in the centre. Now in the case of unpaired terrace, both the sites are not symmetrical. Now unpaired terraces occur due to uplifting of land or due to changes in the hydrological regime.

So, it is possible that when the river was creating this terrace the whole area was getting uplifted and it was getting tilted. So, it is tilting like this. So, when it is tilting in that case you will have more amount of erosion on one side and less amount of erosion on another side resulting in an unpaired terrace. Or suppose one portion is going up and the second portion is not going up or one portion is actually going down. So, in that case because of changes in relief, the amount of erosion activity on both the sides will be different resulting in an unpaired terrace.

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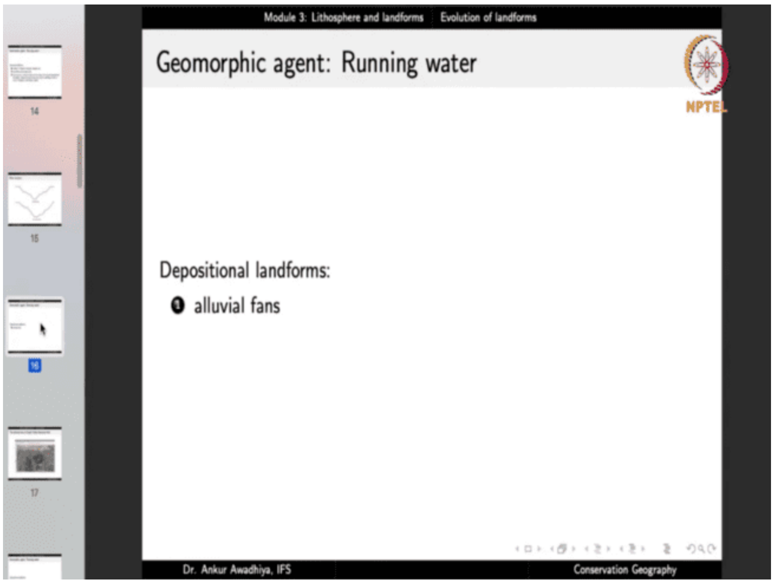

Now along with the erosional landforms, we also have depositional land forms where the river is depositing sediments such as alluvial fans.

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Now this is an example of alluvial fans as we can observe in the Death Valley National Park. So, what is an alluvial fan?

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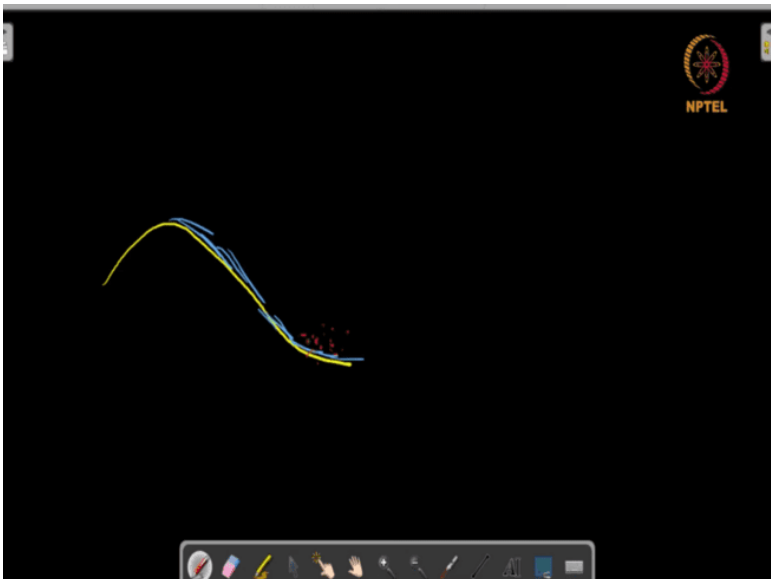

In this case you have a small hill like structure and the water is eroding the top portion and as soon as it reaches here the speed reduces and so it starts to deposit the sediments here. Now when it deposits these sediments, they will result in these fan-like structures.

So, this is the view from above this is a satellite image and in the Death Valley the amount of rainfall is very little, but as soon as you have a rainfall there will be some amount of erosional activity here and a large amount of depositional activity here resulting in this fan like structure. So, you can observe a fan here there is another fan here there is another fan here and so on. So, alluvial fans are depositional structures that are created by moving water.

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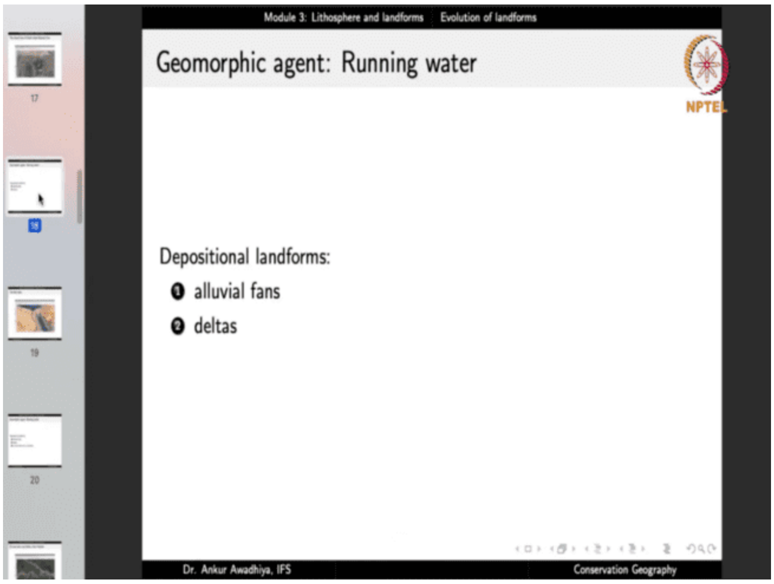

Another depositional landform is the deltas.

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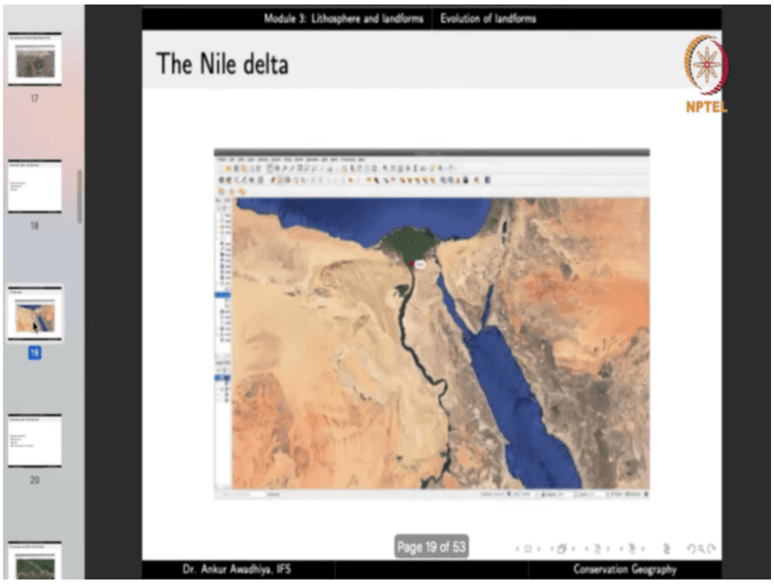

The most prominent one being the Nile delta. So, this is the Nile River, it flows from south to north direction and when the river reaches to the sea so this area is known as the mouth of the river and here it creates a triangular shaped structure, which looks very similar to the Greek alphabet delta. So, a delta is a triangle adhere you have a triangular structure that gets created.

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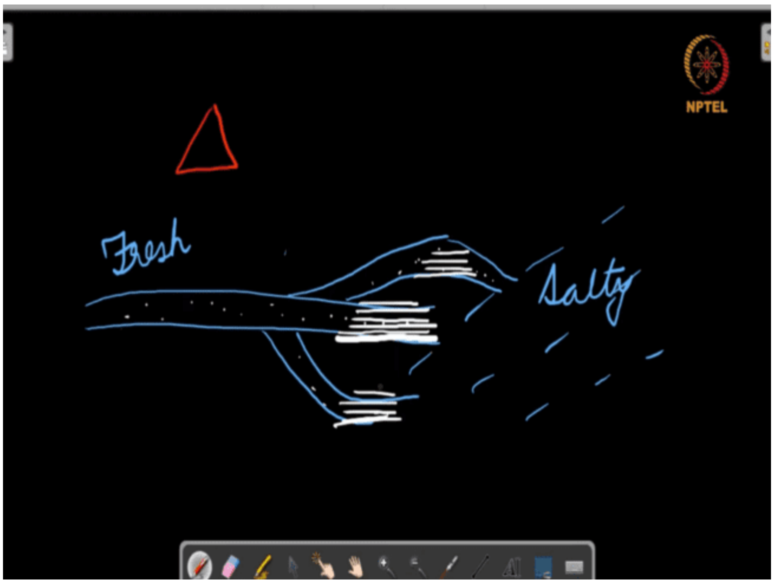

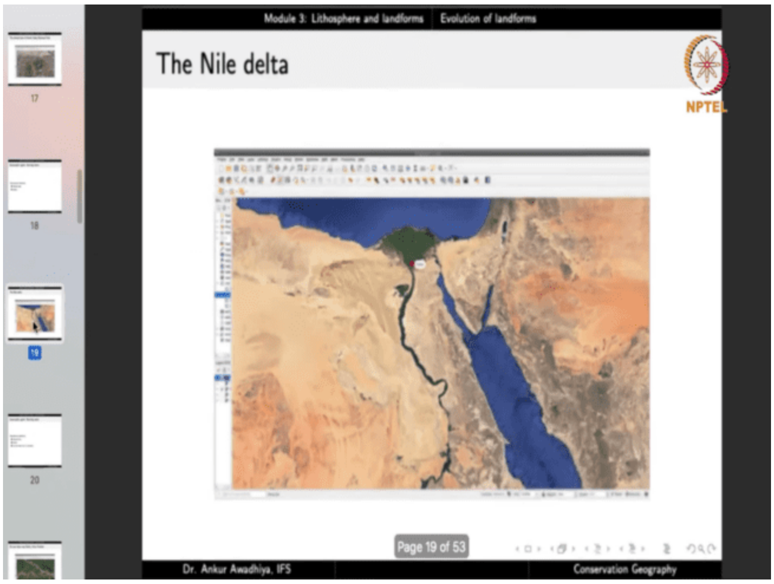

Now why do rivers form delta rivers form delta because when you have a river that meets the sea. Now the sea has salty water, whereas the river is having fresh water. Now in the fresh water, when the river is carrying these sediments a lot of these sediments stay suspended because of their charges.

So, suppose you have sediments that are say positively charged or negatively charged they will remain suspended. But as soon as the water mixes with the salty water then the salt in the salty water it attaches itself to the sediments neutralizing the charge. Once the charge is neutralized then the sediments can no longer remain suspended and they begin to precipitate out and when they precipitate out we get this structure.

Typically, also when you have these precipitations you have this deposition of sediments in that case the relief changes because earlier the river was moving on this flat area, but now because of this deposition this area is now increasing in elevation. Now if this area increases in elevation what will the river do?

The river cannot go from below to above and so the river will change its course the river will start to move like this and then the river will perform our deposition here and then slowly and steadily this area will also increase in elevation.

The river will again change its course, it will move from some other area and this process of changing the elevation and changing the course goes on and on resulting in a number of distributaries in this area. So the river breaks down into a number of smaller streams and this whole area becomes a delta.

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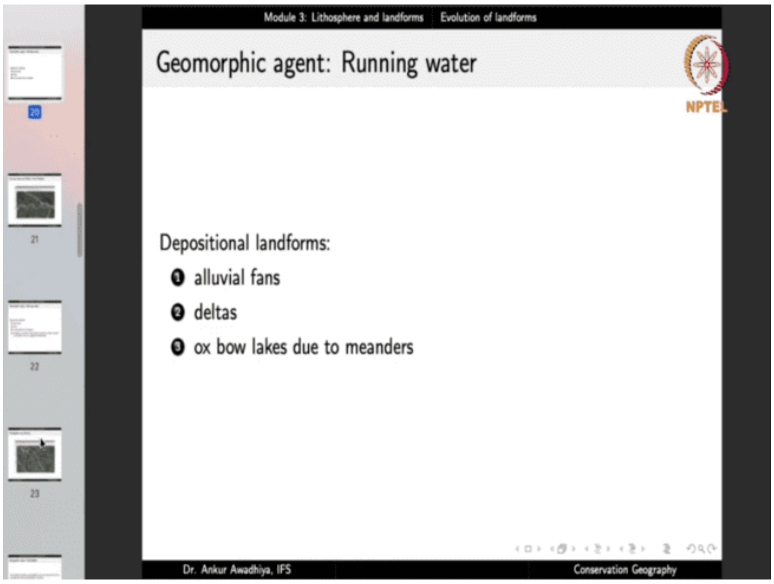

Another deposition landform is ox bow lakes that occurs because of meandering.

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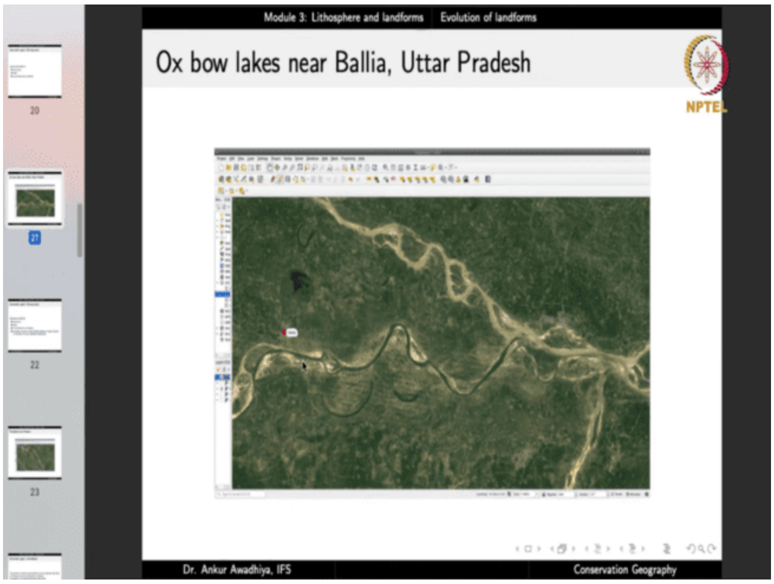

So, what is meandering? If you look at the river, the river is going in a curvy fashion here, here.

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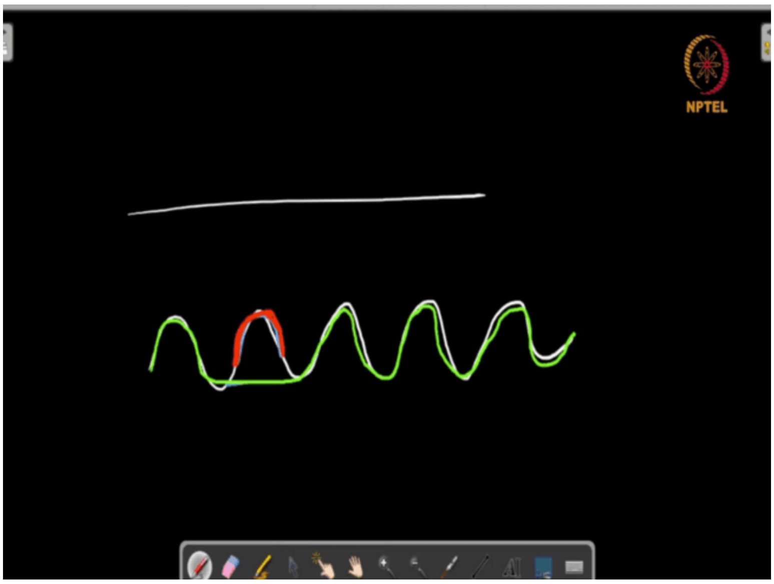

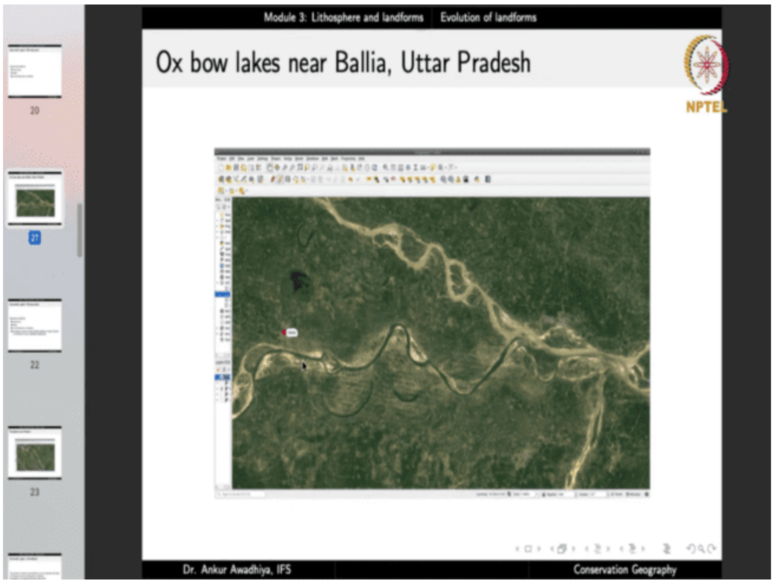

So, what happens is the river does not flow as a straight line it generally flows incurves and this is known as a meander. Now it sometimes happens that the river once it has meandered like this after awhile something happens there is a change in the course and the river begins to flow like this. So what happens now is that now you have the river that is flowing like this and then you again have these meanders.

But what happens to this portion? Here earlier you were having the river you still have water here and this becomes an ox bow lake. So, here we have the examples of ox bow lakes. So, these are all different oxbow lakes that have been created. So, earlier the river used to flow like this, but then there was some event because of which say some amount of sedimentation here, because of which now the river changed course now it is moving straight like this it is not flowing in this direction, and so this area where water is remaining it becomes a lake which is known as an ox bow lake.

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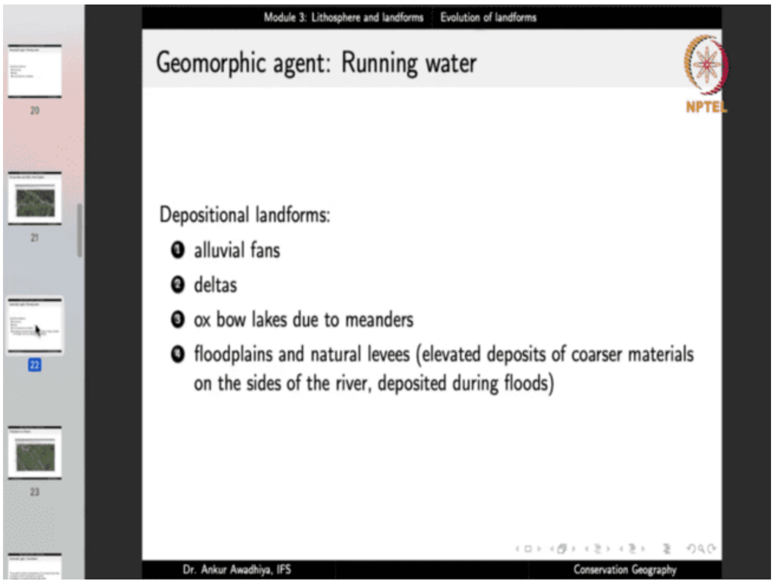

Another depositional feature is floodplains and natural levees. Levees are elevated deposits of coarser materials on the sides of the river deposited during floods.

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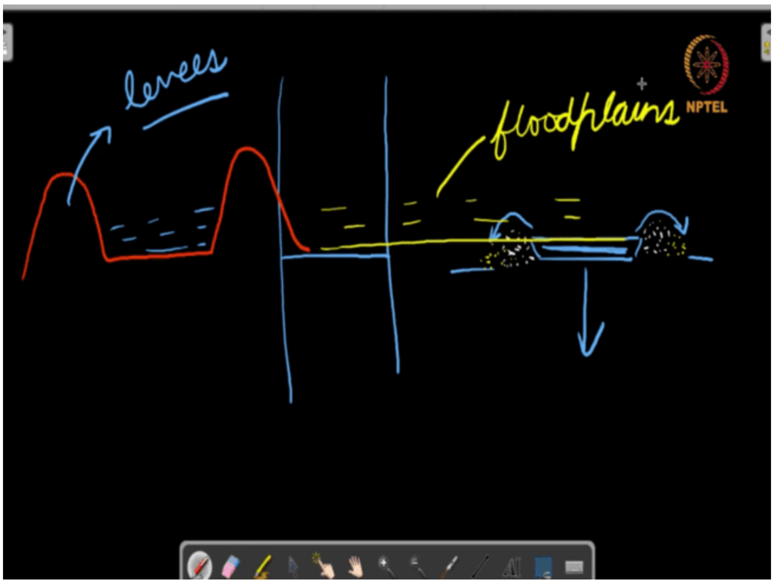

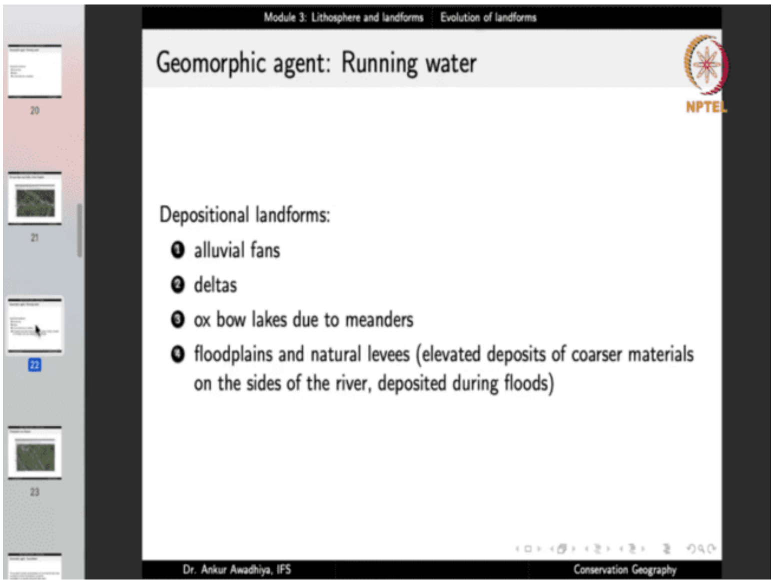

So, what happens in the case of levees is that suppose there is a river that is flowing like this and we are looking at the cross section of the river, so the cross section looks like this. So, this area is water and the river is flowing in this direction. Now when the river goes into a flood during the monsoon season, you have a large amount sediments and typically the river deposits the sediments on its banks.

Now, when there is the flooding season the river overcomes these barriers and it flows like this, but as soon as it reaches this portion, their speed reduces again and it makes more and more amount of deposits here and ultimately what you will observe is that if you look at a river you will be having two humps on both the sides and in the centre you have the river that is flowing.

So, these humps are known as levees and typically when the river breaches the levees it goes on depositing sediments for a very large distance and these become the flood plains. So, levies and floodplains are also depositional landforms.

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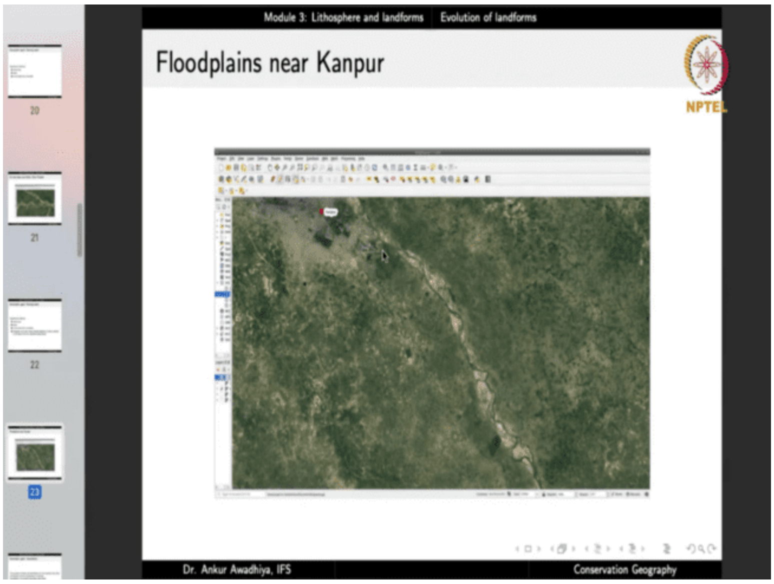

So, if you look at the Ganges River near Kanpur, we will find that you have a very large sized flood plain that was created by the river when it breached the sites during a flood.

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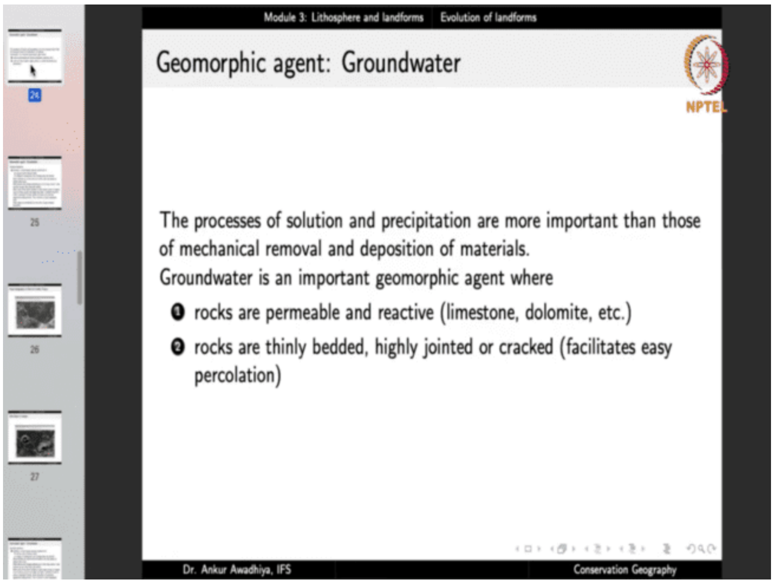

Another geomorphic agent is groundwater. Now in the case of groundwater, the process of solution and precipitation are more important than that of mechanical removal and deposition of the materials. Why is that so? This is so because the groundwater typically moves at a very slow pace. And so dissolution and precipitation are more important as compared to their to the mechanical action of the groundwater.

So, the process of solution and precipitation are more important than those of mechanical removal and deposition of materials. In the case of rivers, the most important processes are the mechanical removal and deposition, but not in the case of groundwater. Now groundwater is an important geomorphic agent where the rocks are permeable and reactive again because you need to have solution activity.

Now solution will happen when the rocks are reactive and if the rocks are permeable then more and more amount of groundwater will be able to play a role. And so groundwater is an important geomorphic agent where you have rocks like limestone and dolomite. Now these are typically calcium carbonate and in the case of calcium carbonate, if the water has a slight bit of acidity then solution becomes a very easy activity. As soon as you have slight amount of basicity in the water, precipitation will happen and so solution and precipitation both are easy to do.

So, calcium carbonate bearing rocks such as limestone and dolomite are very important when we talk about the geomorphological agent of groundwater. Then it also helps if the rocks are thinly bedded, highly jointed or cracked because it facilitates easy percolation of water. So, easy reach of groundwater to all different areas.

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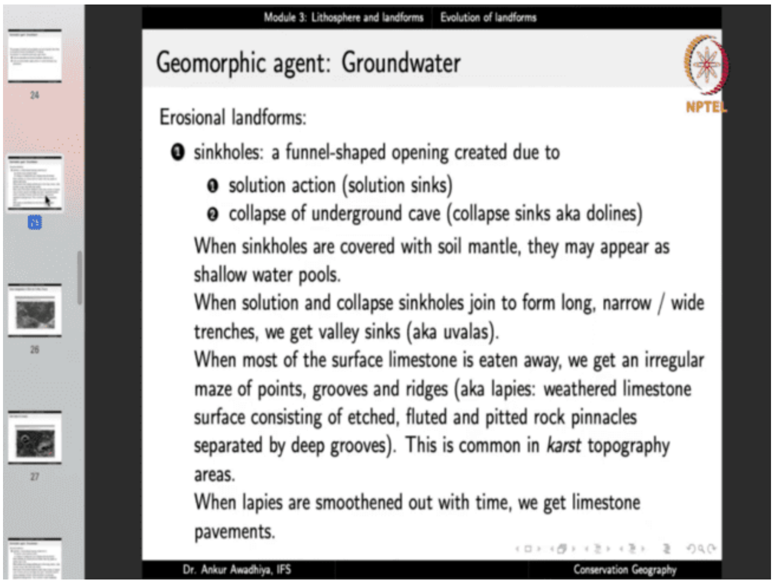

So, what are the kinds of landforms that groundwater creates? Groundwater creates sinkholes which are funnel shaped openings that are created either because of solution action or because of collapse of underground caves. Now if there is solution action we call it a solution sink, if there Isa collapse we call it a collapsed sink also known as a doline. So how will it look like?

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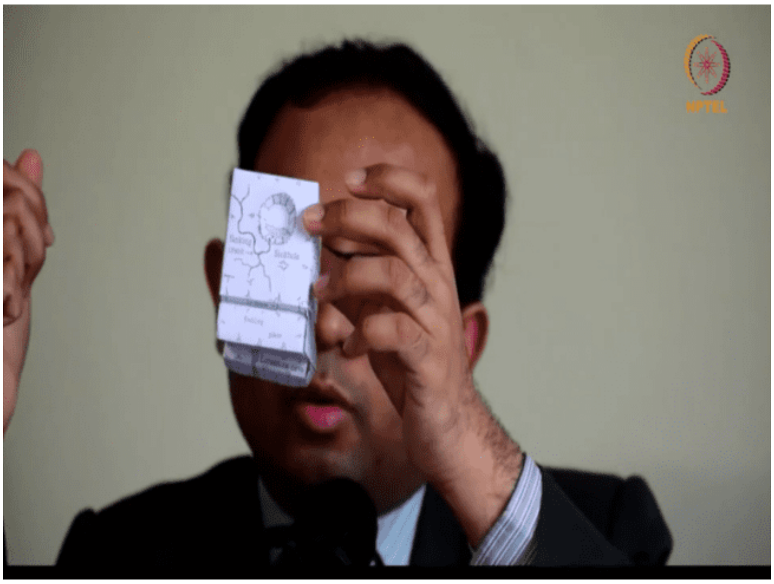

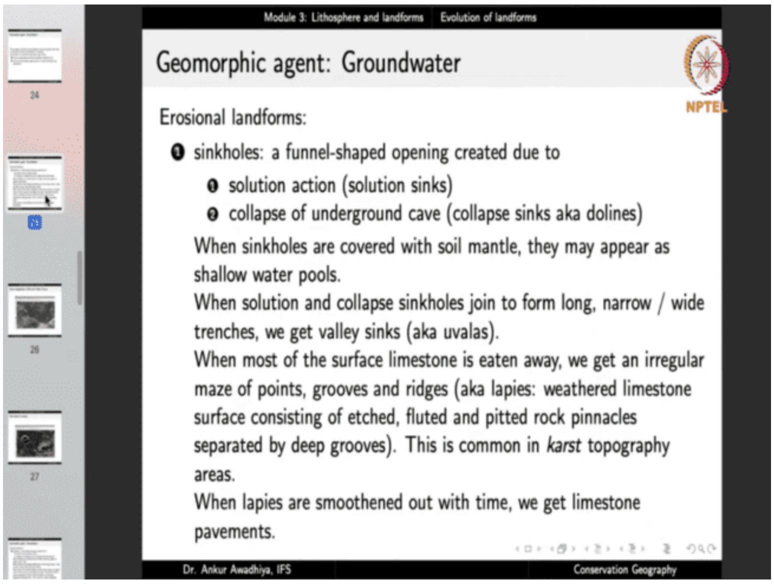

So this is a model and here you can observe that we have a river that is flowing. So, here you have the river and in this area you have a sinkhole. So, basically this is a depression that has been created probably one of the streams of the rivers it goes there and it gets lost. So, this dark coloured portion is an opening that has been created and this is a hole that has been created in the form of a sinkhole.

Now when sinkholes are covered with soil mantle they may appear as shallow water pools. When solution and collapse sink holes join to form long narrow white trenches we get valley sinks. So, essentially these sinkholes if they are there in a large number then if they get connected then it will result in a valley-like structure and this valley-like structure will be known as a uvala. When most of the surface limestone gets eaten away we will get an irregular maze of points, grooves and ridges. Ridges are also known as sleepies which are weathered limestone surface consisting of edged, fluted and pitted rock pinnacles separated by deep grooves. And this is common in a karst topography area.

So, what is happening in the case of ground water is that if you have an area that is rich in limestones, then you will get a depression here you will get a depression here you will get a depression somewhere else and all of these depressions or the sinks that are getting created they ultimately go on merging with each other.

When they merge with each other then there is more and more amount o loss of material. With continuous loss of material you will have a situation where this whole landform is slowly getting degraded and it is getting taken away and this is known as a karst topography.

Now a karst topography looks like an area that is extremely degraded. So, you will not find a plane area you will find this area all full of holes, all full of streams which are sinking anywhere out of nowhere and it will look like an area that is a very rotten area. When lapies are smoothened out with time we get limestone pavements.

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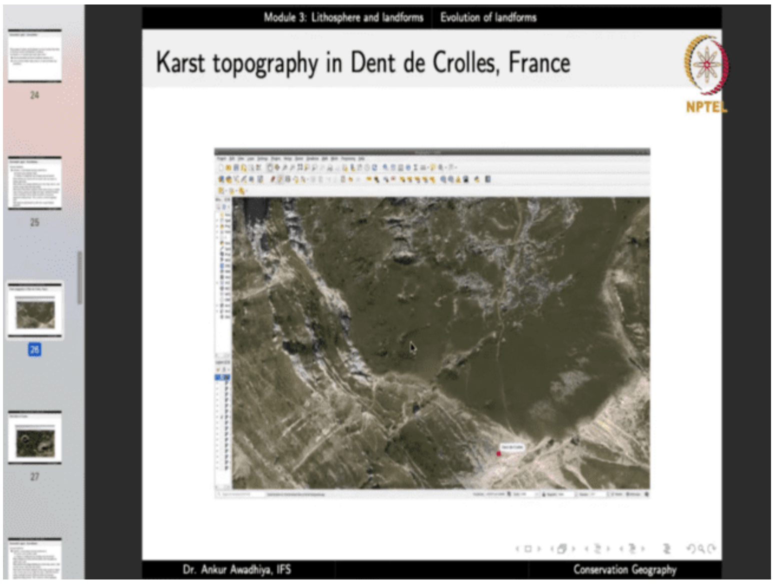

So, how does the karst topography look like? Now this is a karst topography in France. One easy way to identify a karst topography area is through the lack of vegetation, especially trees because this area is typically rich in calcium carbonate it is very alkaline area and so it does not support a very large amount of vegetation.

Now in this area, you will find that so much of it is denuded it is looking white in colour and there are a number of holes in this area. So, the landform it is full of holes and pits.

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This is how a sink hole looks like. So these are sink holes in Croatia and here we can observe that these are all filled with water and this is what a sink hole looks like. So, these are the erosional landforms sink holes.

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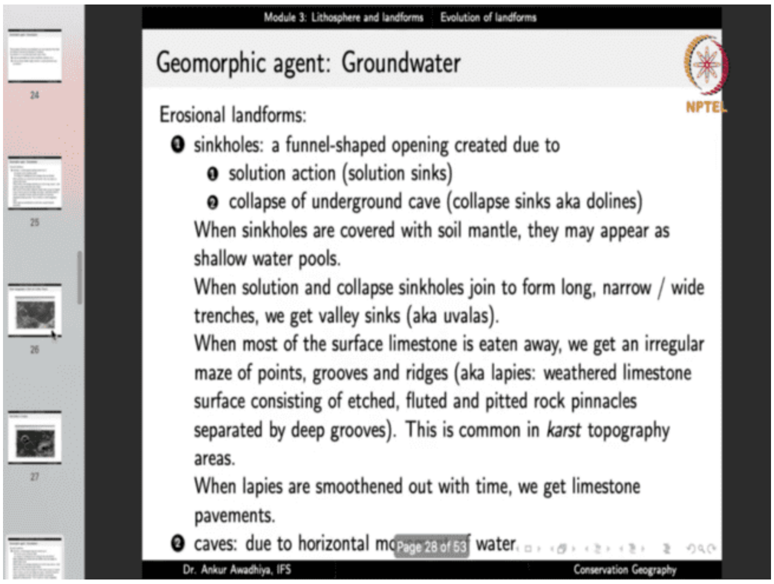

Another erosion landform is caves. Caves are formed due to the horizontal movement of water.

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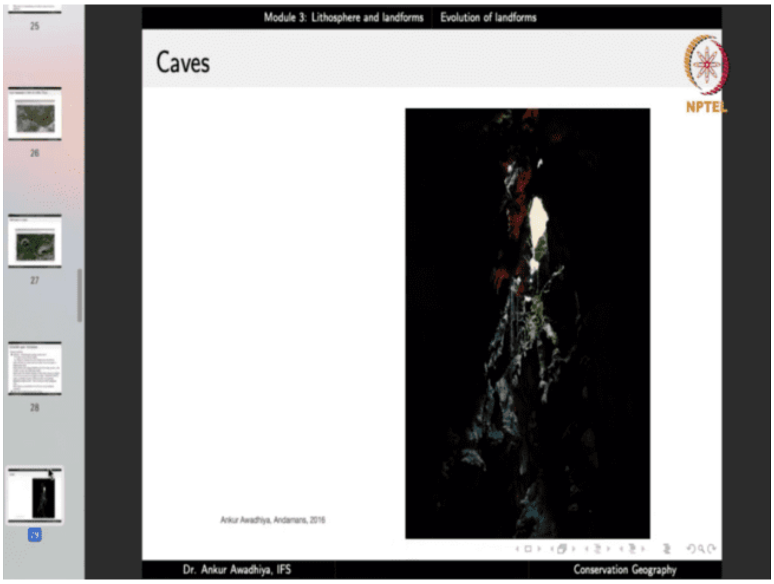

So, this is an example of a cave from Andaman and the inside no doubt it is dark.

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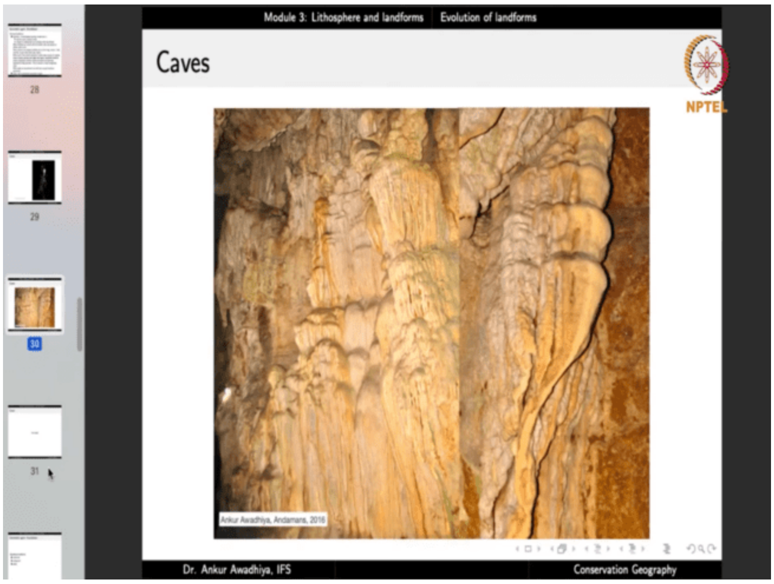

And if you look at the walls, this is how they look like. Now the walls of the cave are showing that there has been a great amount of solution and precipitation both that has been occurring here because of which we are getting all these strange shapes in the walls.

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So, how does a cave look like? If you look at our model this is how the cave will appear in a karst topography area. So, here you have all these jointed limestones and here you have a depression, a hole that has been created because the water that was entering here it moved from inside and then it came out from here and so all the inside it has been eaten away and resulting in the formation of a cave.

If you look at the cross sections, this is how it will look like. So, these cross sections will show different structures. So, from the inside the cave has been eaten up in a very large area, you get some features such as stalactites and stalagmites in this area. This is where the water is flowing and when the water entered through this sink hole it has been moving inside these rocks and it has resulted in the formation of a cave.

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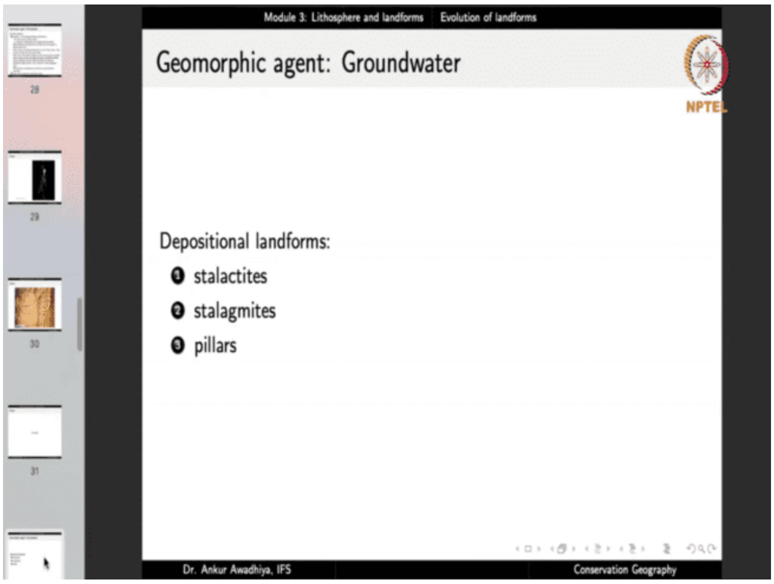

Now the groundwater also makes certain depositional landforms mostly because of precipitation and these include stalactites, stalagmites and pillars.

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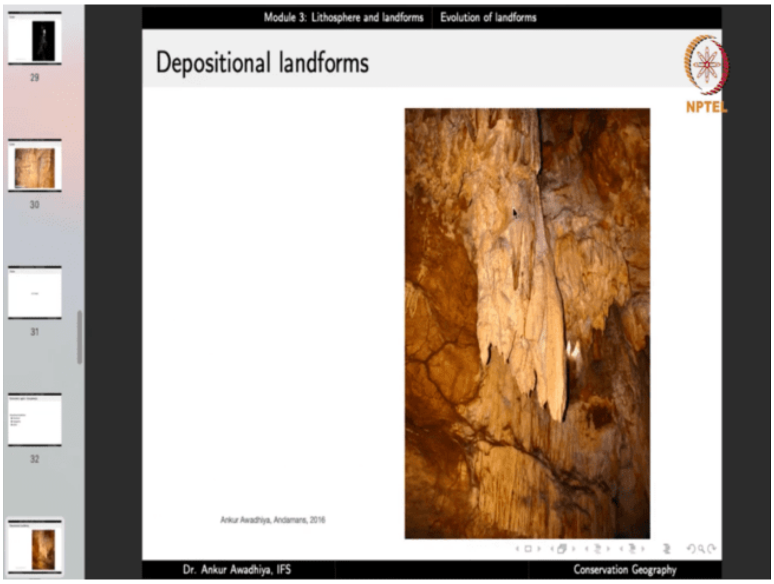

So, what is a stalactite? Now when the water is moving inside a cave, then when the water is dripping in some areas then it is possible that the water gets evaporated and there is some amount of precipitation that happens here. And so you will find that there is a pillar that has been growing from the top. So, it grows from the roof of the cave and it slowly goes down. That is a stalactite and when the water is dripping, it will probably create another structure that goes from, it grows from the bottom and it is known as a stalagmite.

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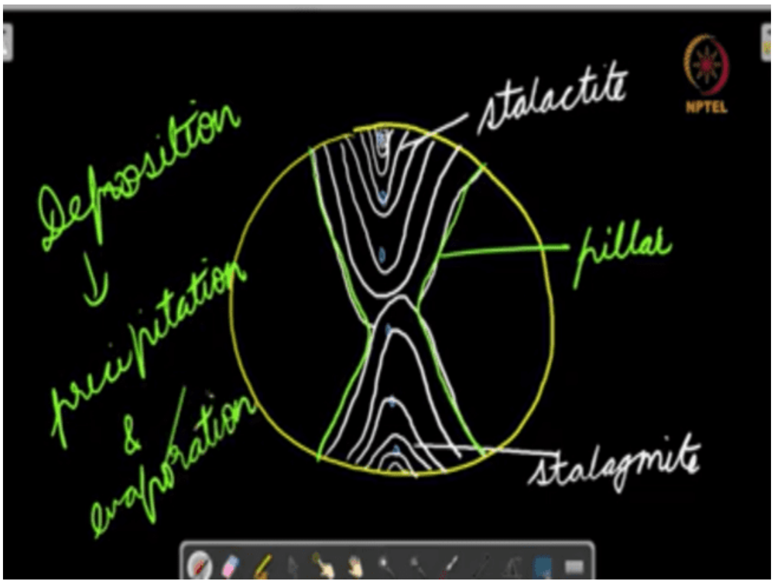

So, this is how it is created. If this is your cave and suppose because this is a karst topography area so what is entering at all different locations it is exiting from all different locations. Now from the top, probably the water has been dripping down. Now because this water has been dissolving calcium carbonate, so here you will get some amount of precipitation of calcium carbonate that happens here.

Once that happens, now the drops start from this point, later on with more and more amount of precipitation you have a structure that has been formed here, and this structure will go on growing like this. So, from this it will become like this then it will become like this then it will become like this and so on.

So, this structure is a stalactite and at this point where this dripping water is falling will find another structure that starts to grow because of deposition of calcium carbonate here and it grows like this and this is stalagmite. And when they go on growing like this, they will reach a point where both of these will ultimately meet with each other.

So, it will become something like this. Now this is converted into a pillar, so it starts from here and it goes like this. So, this has now converted into a pillar. Now stalactites, stalagmites and pillars are getting created because of deposition especially due to precipitation and also sometimes evaporation. So, these are the depositional landforms that get created.

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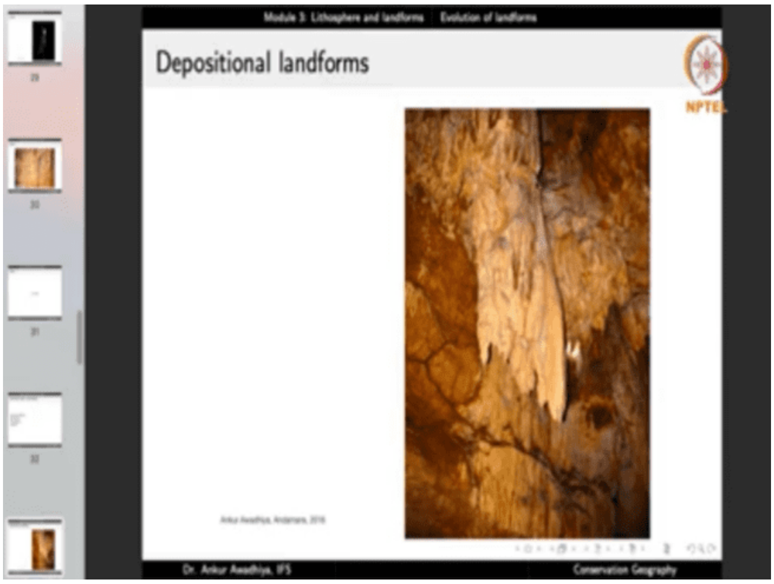

So, this is a stalactite.

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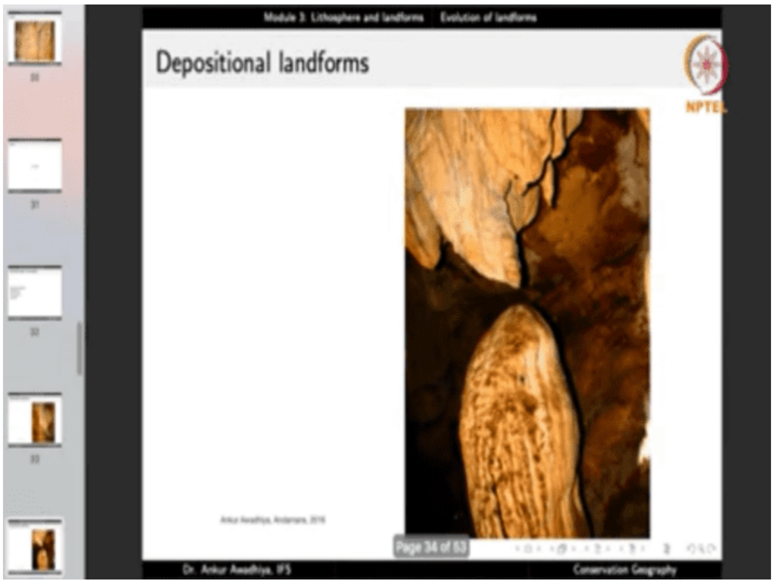

Here we can observe a stalagmite. So, you have a stalactite here and a stalagmite that has been growing from the bottom.

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In certain areas, so in this case both of these are just now touching each other. So, this is now getting converted into a pillar once both of these join together it will become a pillar.

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Another geomorphic agent is glaciers. Now glaciers are masses of ice moving as sheets or as linear flows. So, essentially they are rivers of ice. The movement is very slow generally a few centimetres in a day however due to the large mass the amount of erosion becomes substantial. And so they become important geomorphic agents, especially in those areas that have them. So, glaciers are very important in carving out the topography of mountainous areas that have the glaciers.

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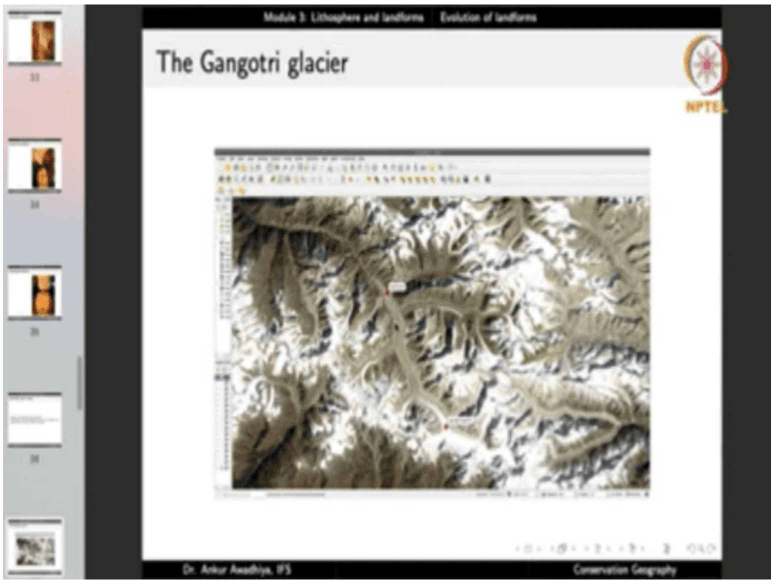

So, this is an example of a glacier. This is the Gangotri Glacier and this all white portion is the snow and this point is known as Gaumukh.

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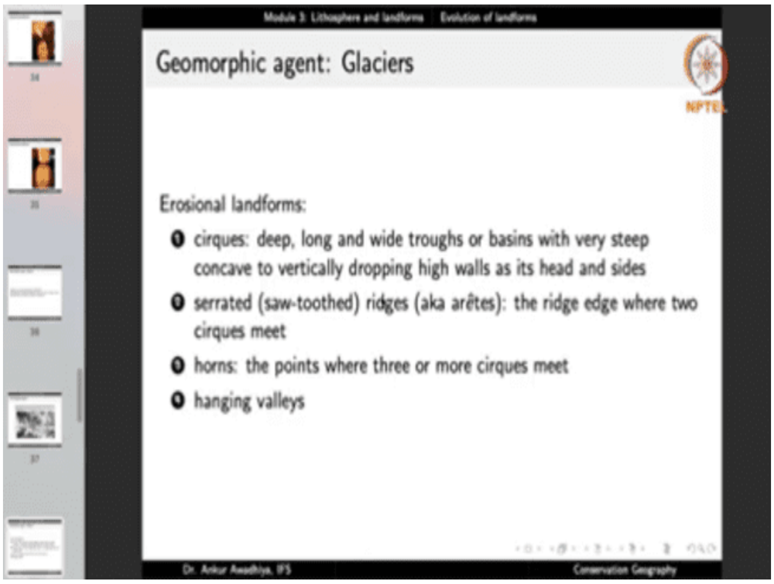

Now what are the landforms that are created by the glaciers? The glaciers are very massive bodies of ice that are moving. Now because of their large mass, they create a great amount of force on their bottoms and on the sides. At the same time when the ice moves, it typically also carries with it some amount of rocks and stones that it has picked up from the bottom.

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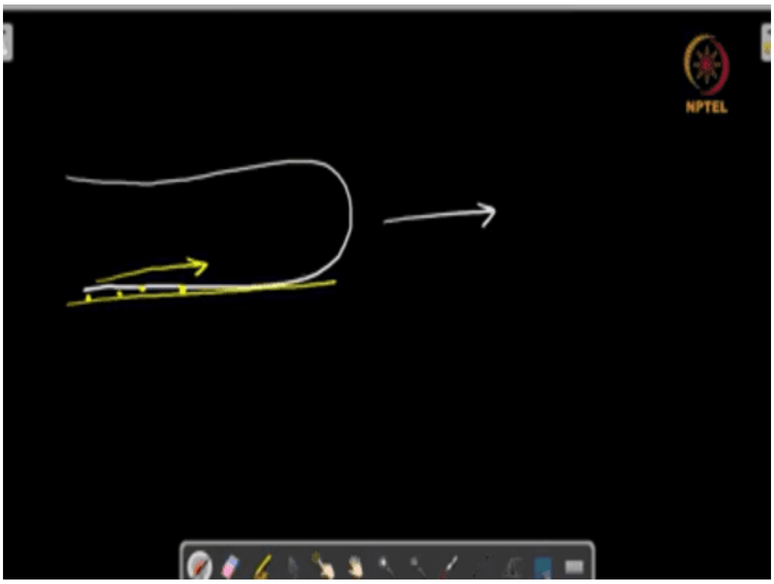

So, what happens is if you have a mass of ice and it is flowing in this direction. So typically it will pluck the rocks and boulders from here and it will carry them forward with its own movement. Now these rocks and boulders act as sandpapers and they go on eating up the rocks that are there on the bottom and on the sides of the glacier.

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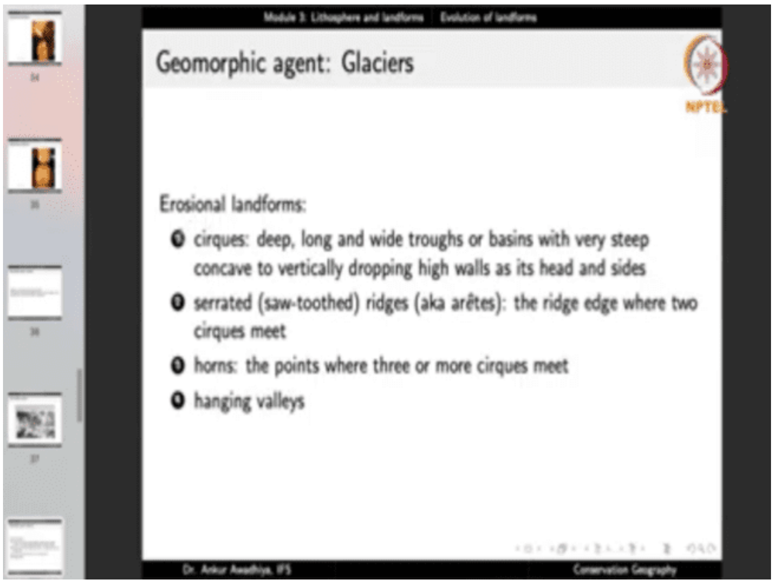

So, they form several big sized erosional landforms such as cirques. Now cirques are deep, long and wide troughs or basins with very steep concave to vertically dropping high walls at as its sides and head. So, they are deep long and wide troughs or basins with very steep either concave walls or vertically dropping walls as its heads and sides.

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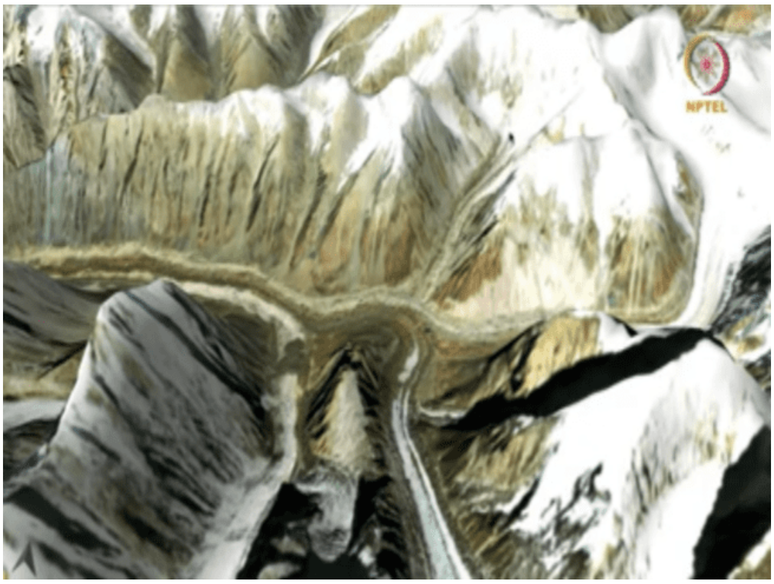

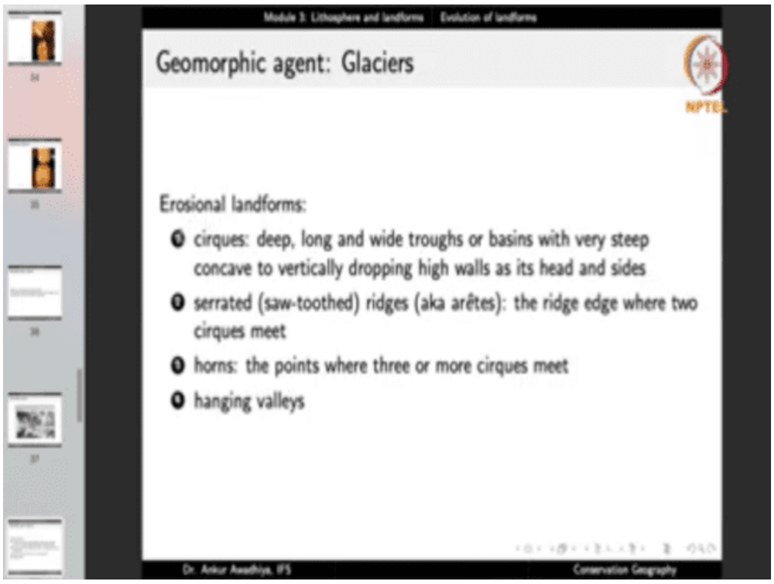

Now to understand the cirques, let us have a look at the Gangotri Glacier in three dimensions. So, let us zoom at this point. Now in this point what do you observe? You have this glacier that is moving along this line, so in the winter season all of this area is full of snow and the ice is more and the snow is moving from hereto the downward locations. Now what do you make out of this valley?

Now this valley has a concave or steeply dropping sides as well as a head that is also steeply dropping. So, this is a cirque. Deep, long and wide troughs or basins with very steep concave to vertically dropping high walls as its head and sides, cirques. Then we also have arêtes which are serrated or saw-toothed ridges. The ridge edge where two cirques meet.

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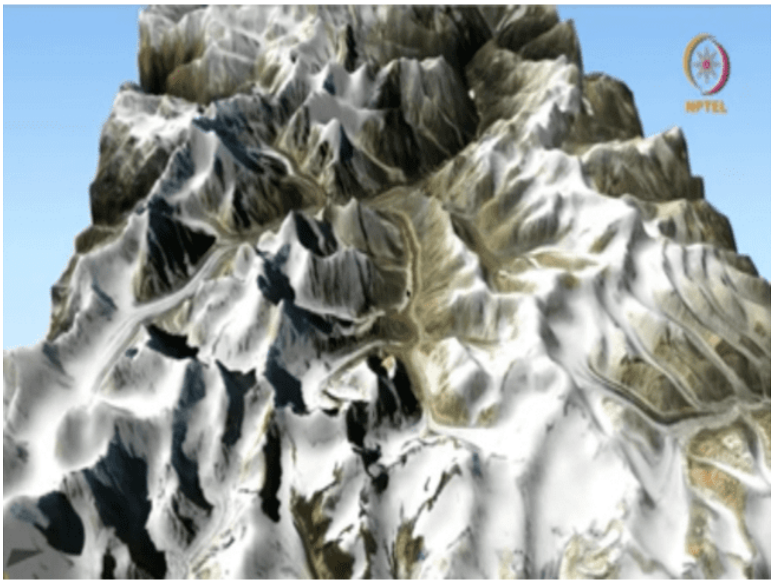

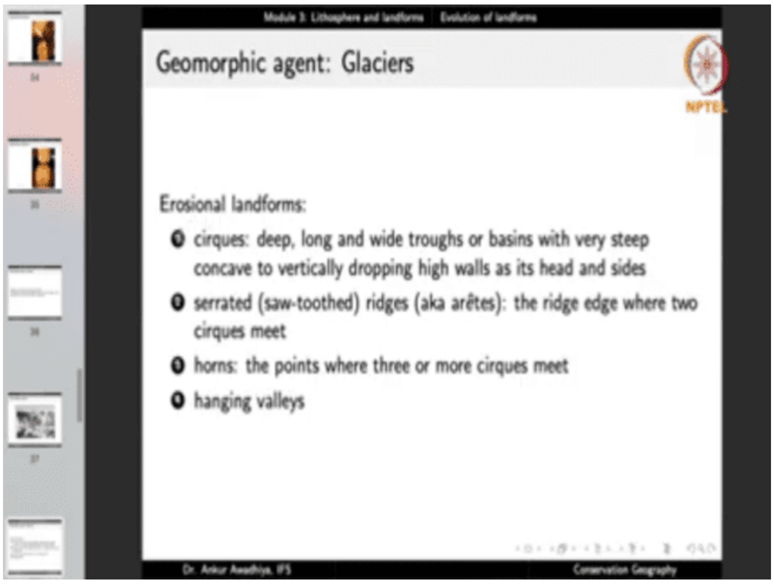

Now, if you look at this edge. So, here we have a cirque here, we have a cirque here. So, the glacier when it moves like this it is eating up from this side when the glacier it moves here it is eating up from this sideband ultimately you get this edge which is a very sharp edge and this is typically a sharp, a saw-toothed edge.

So, you can see it is up and down up and down up and down and you can find it in all different places. Here you have a cirque here you have a cirque in between you will have this edge. So, these are all different aretes. This again is another arete. So, in the case of a glacier this is another of the erosional landforms, the aretes or the serrated saw-toothed ridges, the ridge edge where two cirques meet. We also find horns in the glaciers, which are points where three or more cirques meet.

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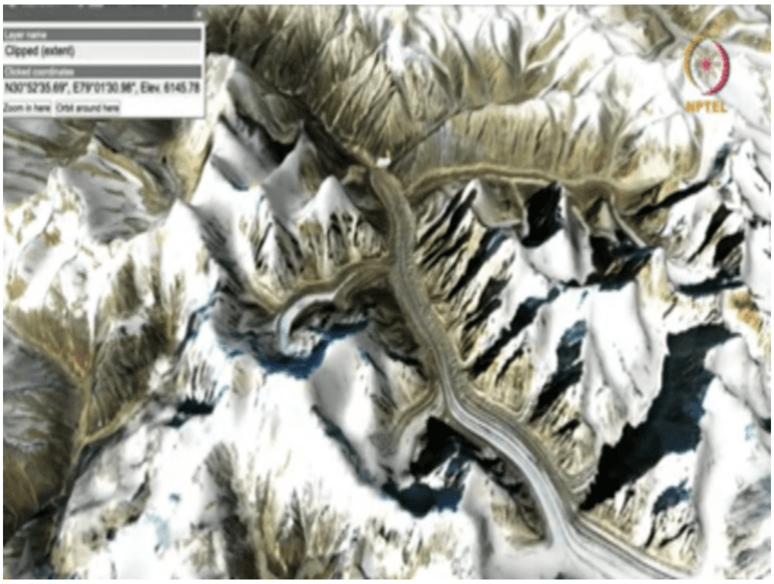

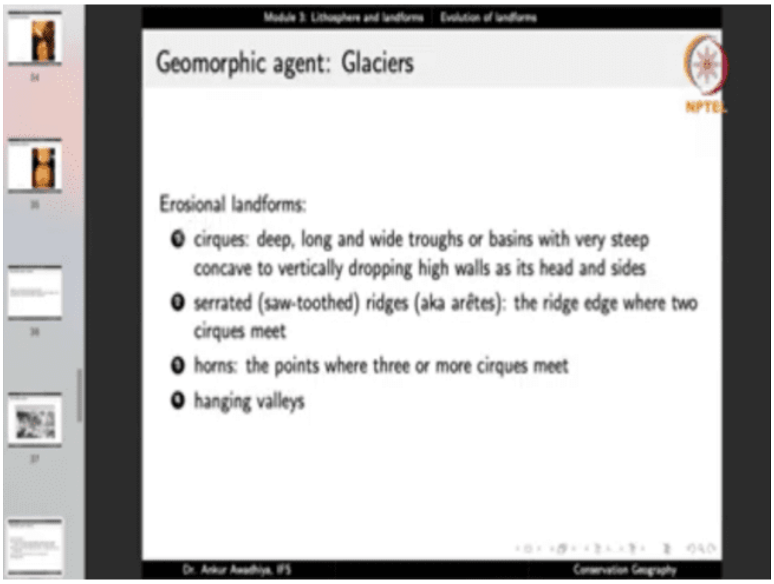

So, here again if you look at this point, so here you have a cirque here, a cirque here, a cirque here, and a cirque here and this point will become a horn. So, this is a horn. Again if you look at this point, here you have glaciers here, here and here all three of them are meeting at a point which is this point, and so this is again another horn. Here again you can observe this saw-toothed ridge, which is going up and down.

Similarly, you can find a horn here. So, here you have the glacier cutting from here from here from here and you get a horn. So, the horns are also very important erosion landforms that are created by glaciers. Another is hanging valleys. So, in this case you find certain valleys.

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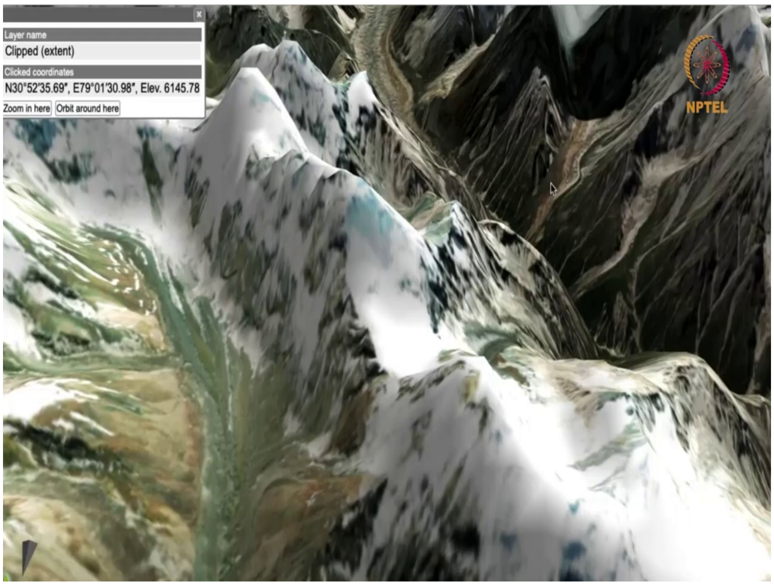

So let us look at a hanging valley. This one. So, in this case, you are getting a valley that sharply falls down. Here you are having a valley and then at this point it suddenly ends and it sharply falls down. So, this is a hanging valley. So, these are all different your erosional landforms that are created by glaciers.

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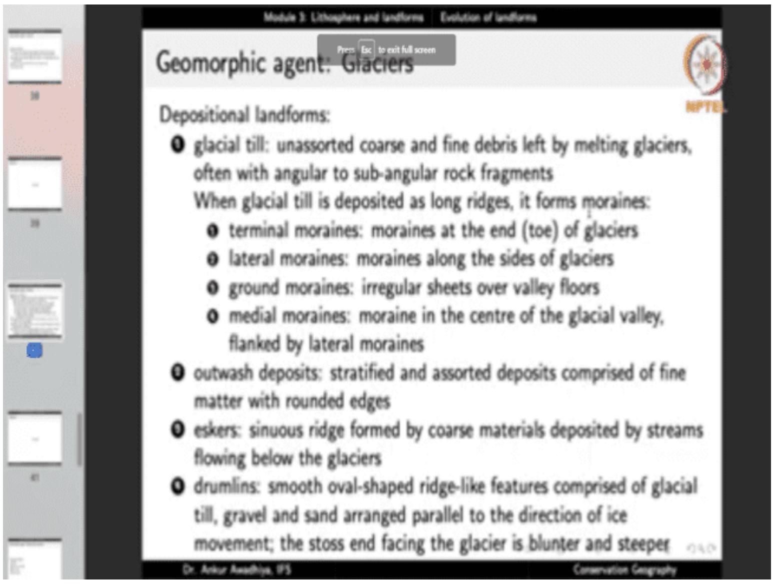

They also create a large number of depositional landforms in the form of glacial tills, outwash deposits, eskers and drumlins. Glacial till refers to unassorted coarse and fine debris left by melting glaciers often with angular and sub-angular rock fragments. So, these are unasserted coarse and fine debris that are left by melting glaciers.

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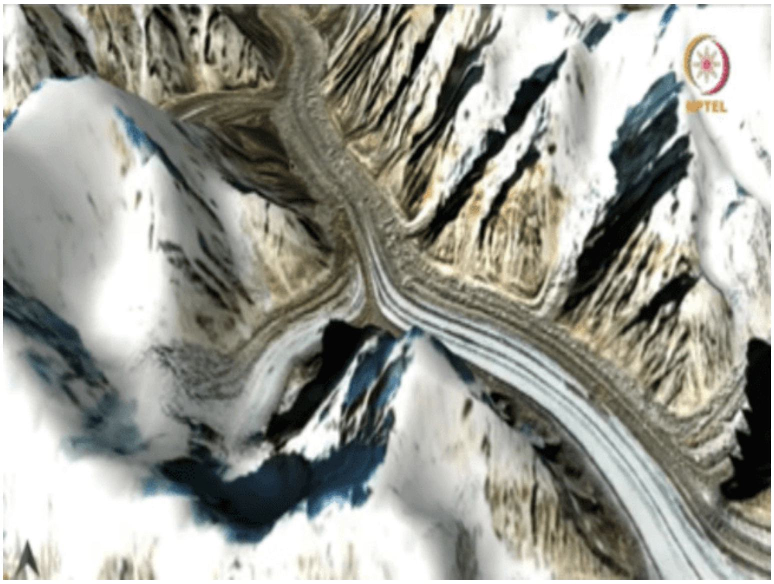

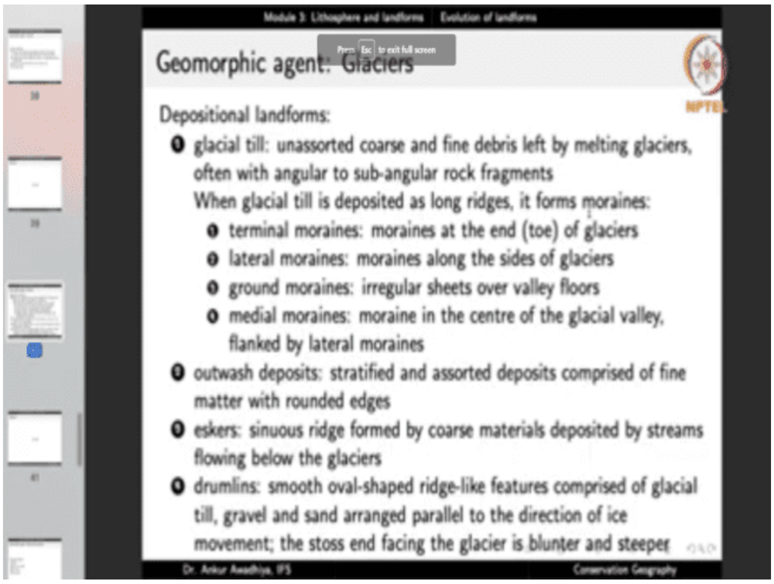

So, let us refresh this page and if you look at the areas where the glacier is ending, so in this case so you have the glacier here. So, if you look at these points, these locations now these locations are having all different kinds of sediments that have been deposited by the glacier. So, the glacier actually was moving from there, so this is the flow of the glacier it moves from thereto here and when the glacier is ending, you can see that there is some amount of deposits that are being left in this place.

So, these are the deposits. Now these deposits can lie just as it is or they can be arranged in the form of these small ridges. Now in this case glacial till refers to unasserted coarse and fine debris that are left by the melting glaciers. They often have angular to sub-angular rock fragments.

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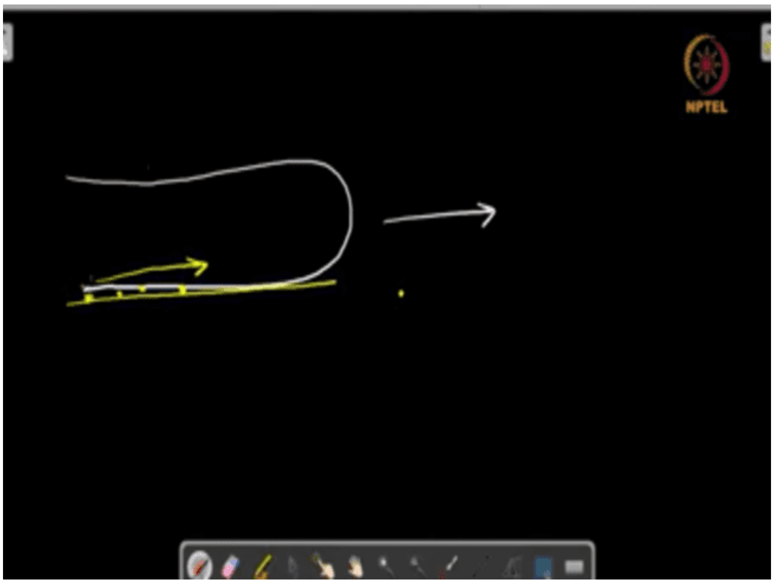

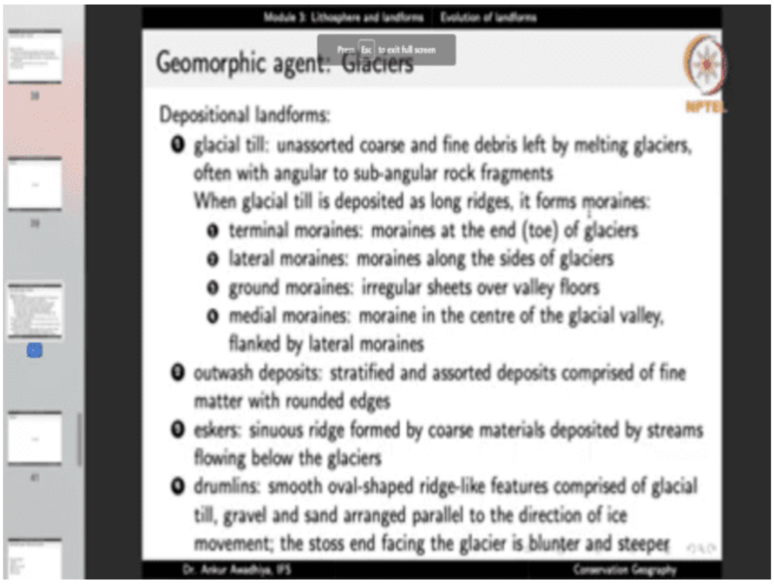

Now why do they have these because when the glacier is moving when it plucks one of these rocks then in a number of cases these rocks break and when they break they create very sharp angles and very sharp edges. Now when the glacial tail is deposited as long ridges it forms moraines.

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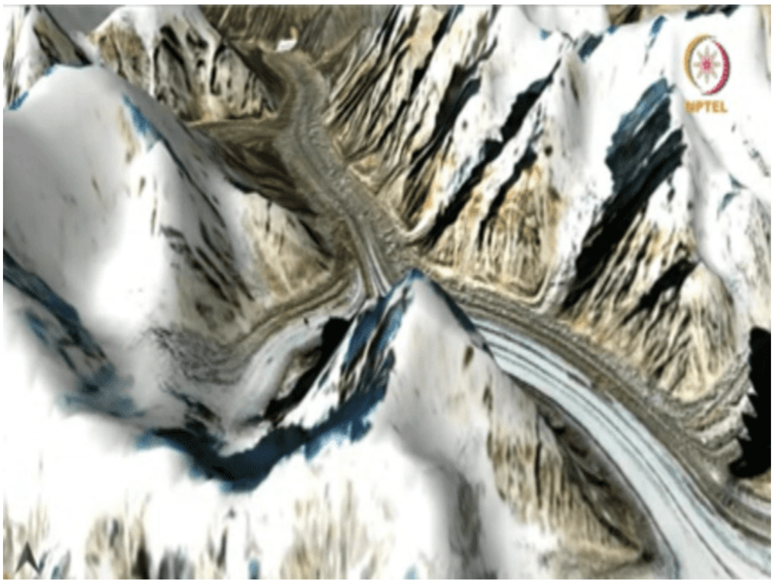

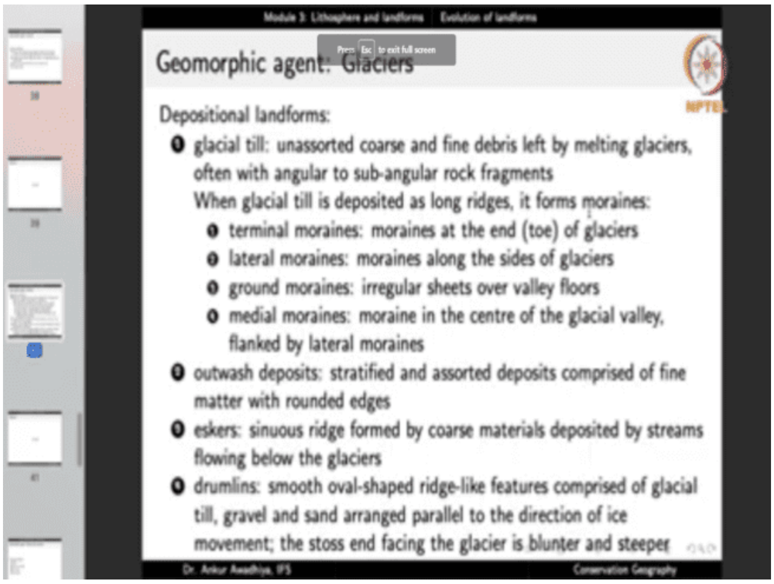

So, moraines are what we saw here. So, these are moraines they are being deposited in the form of ridges and these ridges can be terminal moraines if they are at the end of the glacier, they can be lateral borings if they are on the side of the glacier, they can be ground moraines when they occur over the valley floors or they can be medial moraines in the centre of the glacier valley flanked by lateral moraines. So, this is not important you just need to understand that you can have moraines in different locations.

We also have out wash deposits which are stratified and assorted deposits comprised of fine matter with rounded edges.

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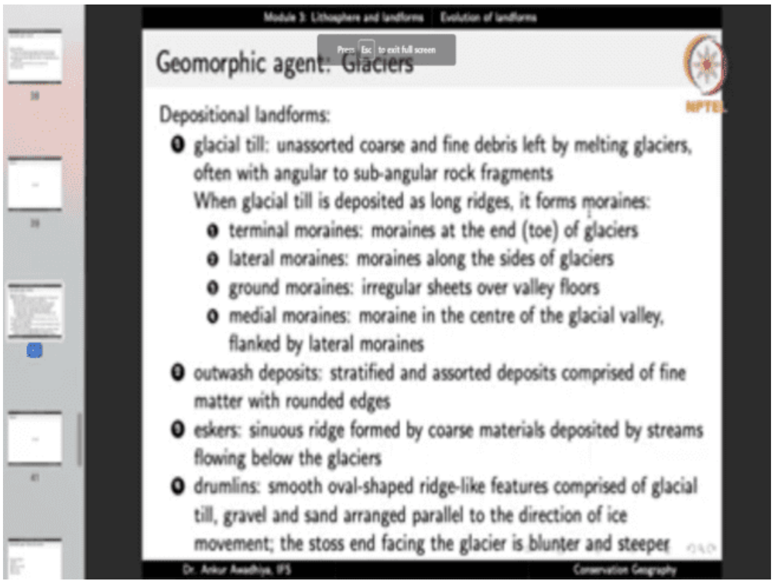

Now in the case of outwash deposits what happens is that you have the glacier that has ended here and when it ends you will have a stream of water that starts to flow. Now this stream will carry the fragments that were therein the glacier and the coarse sediments will get deposited here and the finer one at certain distance. So, this leads to the formation of an outwash deposit it is stratified and it is assorted in a way that you have coarser fragments that are near the glacier and final segments that are far off.

Then we have eskers which are sinuous ridges that are formed by coarse materials deposited by the streams flowing below the glaciers. Now it is not that you have this block of ice and snow that is moving and it is moving and is the complete block.

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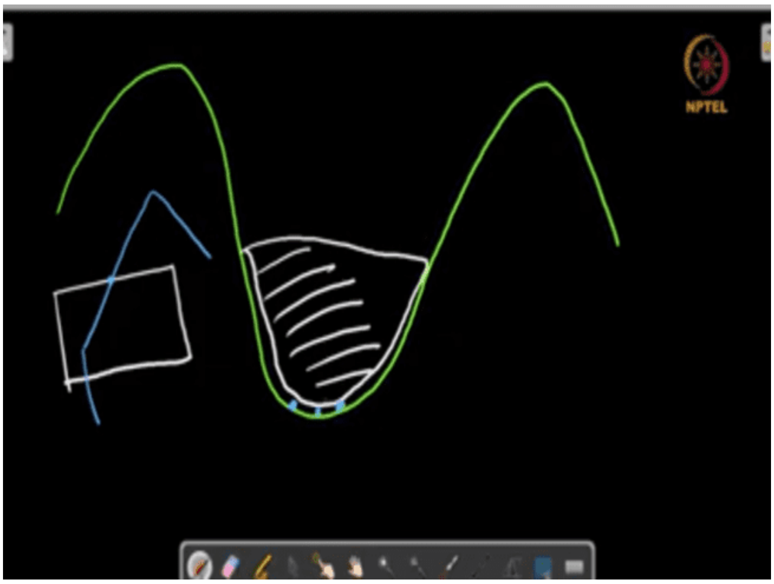

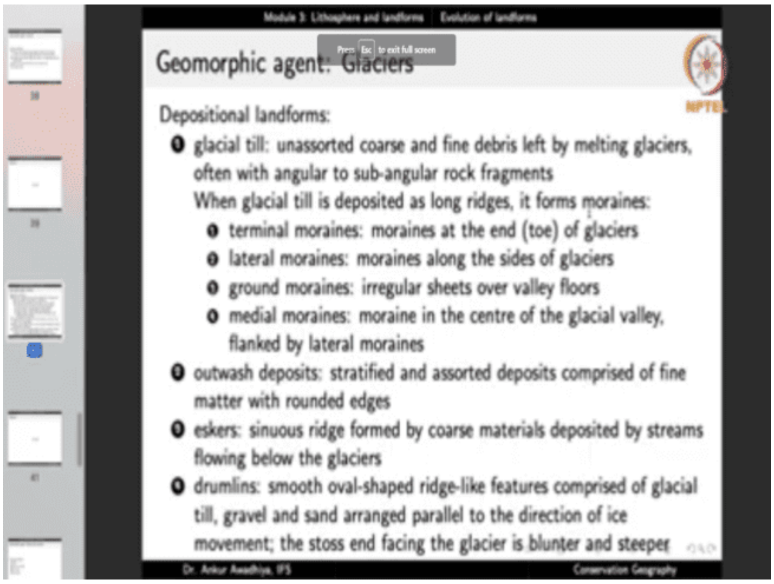

What happens is that if we consider this mountain and we are looking at the cross section of a glacier, so from this point the glacier looks like this. It has filled up all the area so all this is ice, but what happens is because of the great amount of pressure due to the weight of the of the glacier, at the bottom edge you will be having a few streams. Streams of liquid water.

Why? Because when you press ice, when you compress ice then the melting point of ice it reduces and so in that case the ice turns into water. A very common example is that if you take a block of ice and if you take a string and if you attach weights on both the sides then the string will be able to cut the ice, it will be able to go inside the ice because at these points where it is touching the block the amount of pressure will be very large.

Now similarly here you will be having liquid streams, streams of liquid water that are flowing beneath the glacier and when they deposit the sediments, they form eskers, which are sinuous ridge formed by coarse materials deposited by streams flowing below the glaciers.

In this case these streams are working very similar to the action of river sand then we also have drumlins, which are smooth oval shaped ridge like features comprised of glacial till, gravel and sand arranged parallel to the direction of movement the stoss and facing the glacier is generally blunter and steeper. So, these are again another form of deposits.

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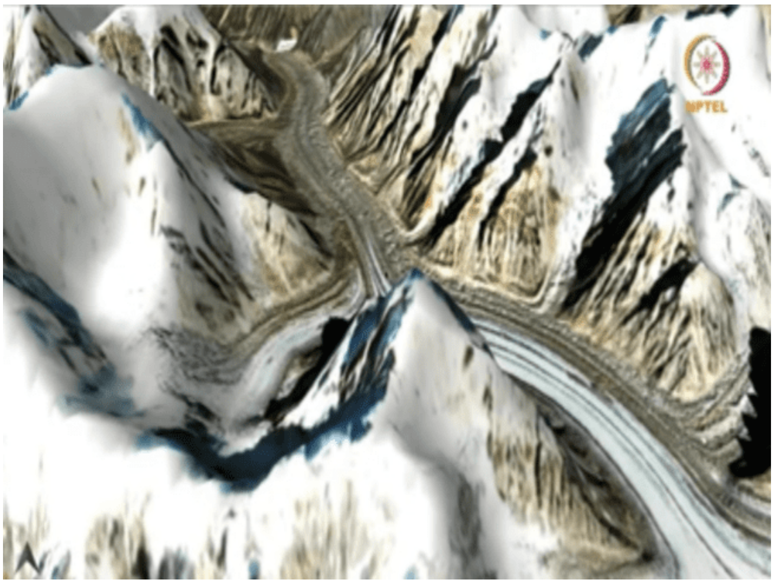

So, we find different kinds of deposits at the end of the glacier and even beneath the glacier.

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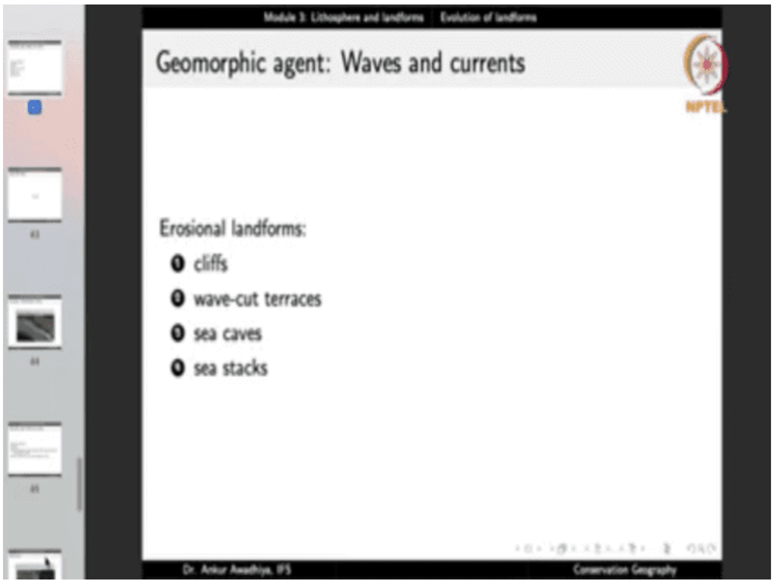

Yet another geomorphic agents are waves and currents. Now waves and currents primarily act because of the mechanical action. So, when the waves are bumping against the rocks, they are going to break the rocks and typically the waves and currents also carry with them sediments such as sand or small rock fragments, which can also act as sandpapers. And they create several erosional landforms such as cliffs, wave-cut terraces, sea caves and sea stacks.

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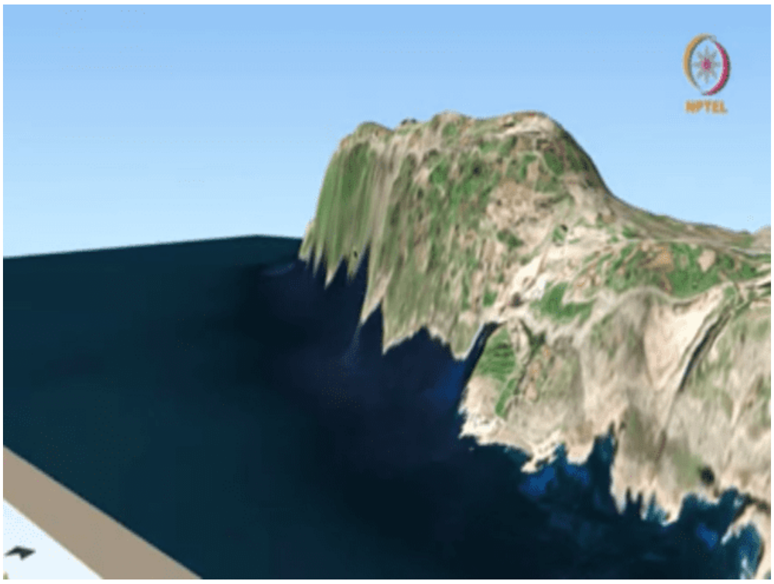

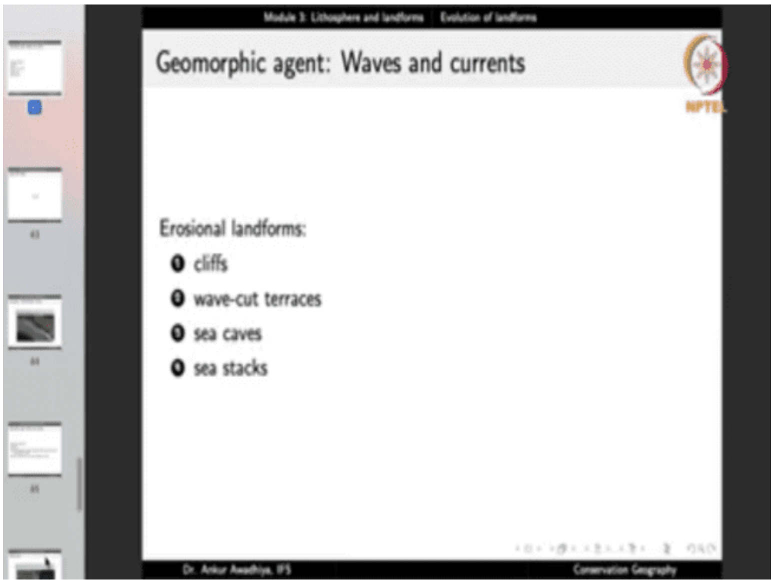

Now what is a cliff? Let us look at the example of a cliff which is the dingley cliffs of Malta. Now in this particular case, here again we have added the satellite imagery on top of a digital elevation model. Now here you can observe that you have the sea and you have the land and the land moves in a very steep fashion.

So, you have a very high amount of drop that you see in this area. So, this is a cliff. Now a cliff occurs because the sea waves have been hitting at these rocks and they have been eroding away these rocks. So, these are cliffs. We also get wave cut terraces typically when either the sea level has been changing or there has been an uplift of the land.

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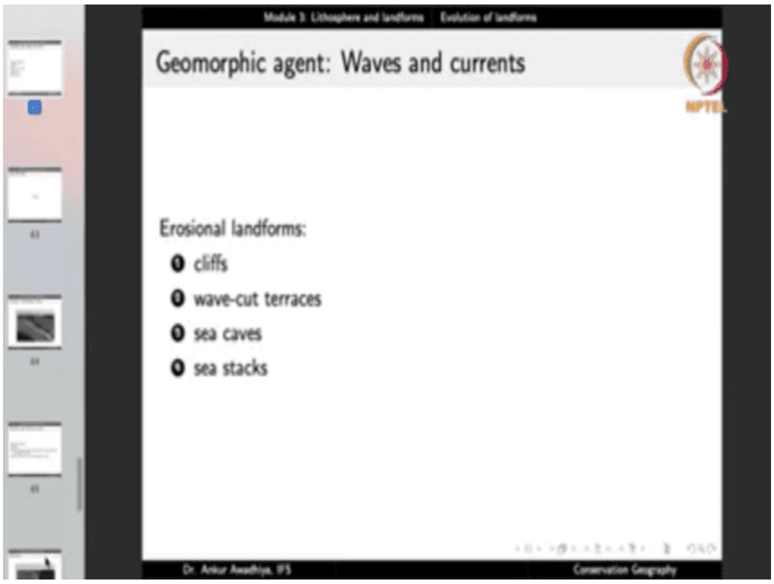

So, in that case what happens is we get a terrace something like this and here you have the sea. So, these are different cliffs that have been created and because you have different cliffs you have a wave-cut terrace. We also get sea caves. Now in this case the waves and the currents are able to cut through the rocks to create a cave. When the caves collapse, the portions that remain they will stand like a wall or they will stand like a pillar and in that case we will call them as sea stacks.

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So, these are the examples of sea stacks. Earlier this area used to have caves, but now the caves are gone and just some fragments remain. So, this is a fragment, this is a fragment, this is a fragment and so on. So, these are the sea stacks.

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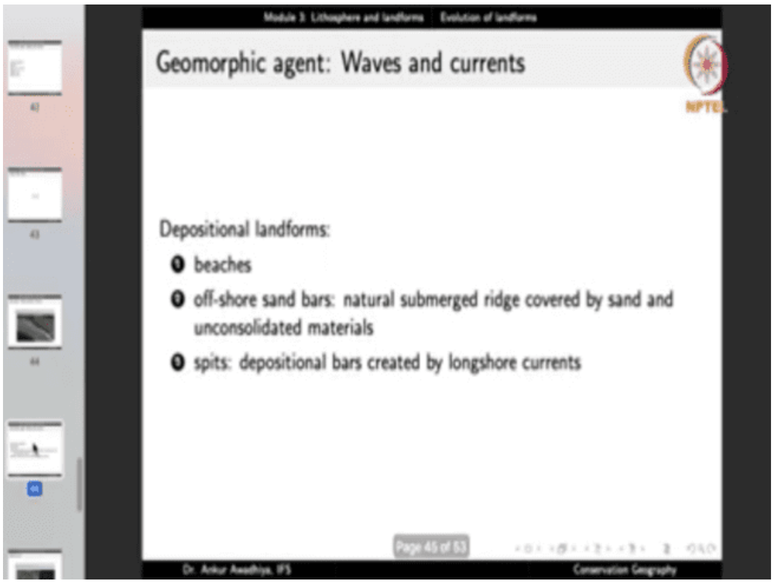

The waves and currents also create depositional landforms such as beaches.

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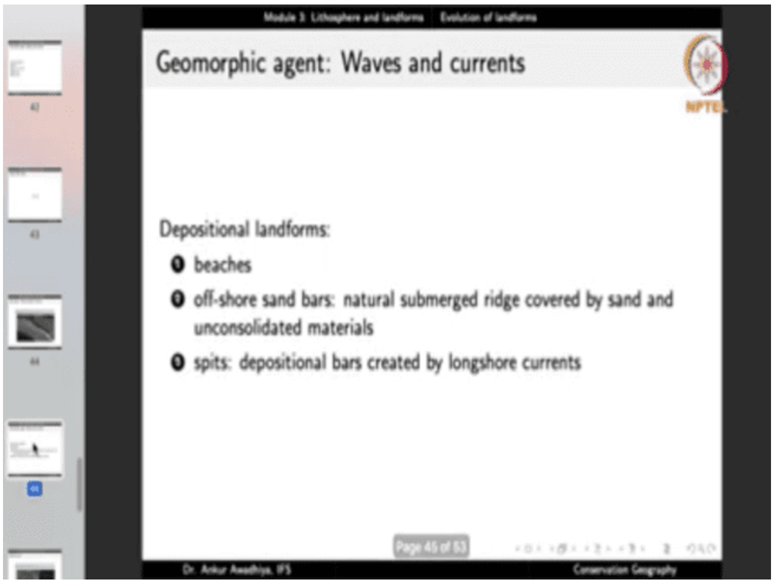

This is the Marina Beach in Chennai and this is a depositional landform. So, the waves have brought sand and they have deposited sand here. Or they can create off-shore sand bars, which are natural submerged ridges that are covered by sand and unconsolidated materials.

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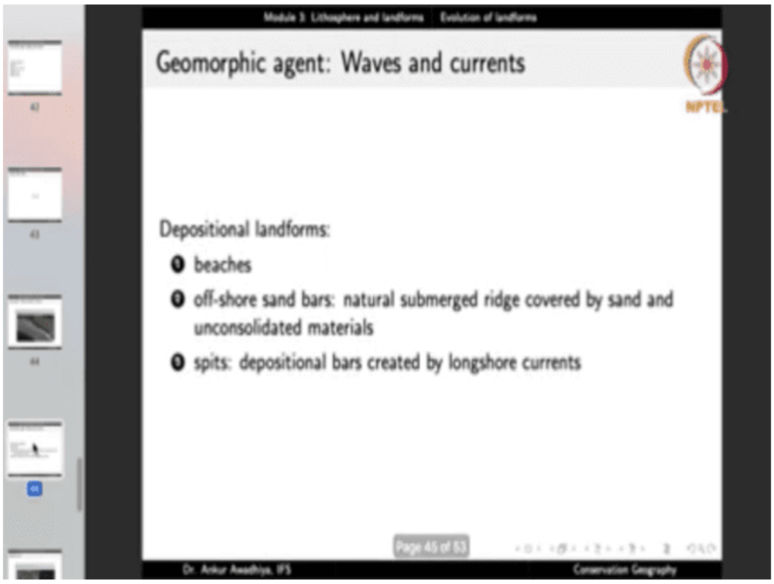

Now this is an example of a sand bar. So, you have an island here you have an island here and in between this is a sand bar. Now this again has been created because the waves have been depositing and unconsolidated material in this location. Or you can also have spits, which are depositional bars that are created by long shore currents.

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This is the example of a spit.

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Another geomorphic agent is wind. Now winds also lead to the creation of erosional as well as depositional landforms. Now the action of wind is multi-ferrous. Winds can cause deflation which is lifting and removal of dust and small particles from the surface of rocks.

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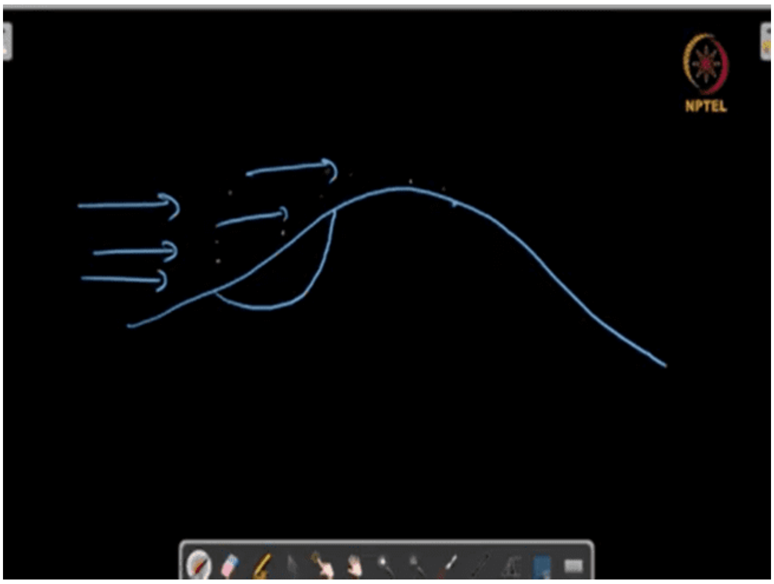

So, in this case if you have a landform like this and you have winds so the winds can carry away material from here and lead to the creation of a hollow which is known as a deflation hollow. Winds can lead to transportation, so the materials that are removed will be transported with the winds. Winds can lead to abrasion in which case these particles can act as sandpaper and abrade other rocks.

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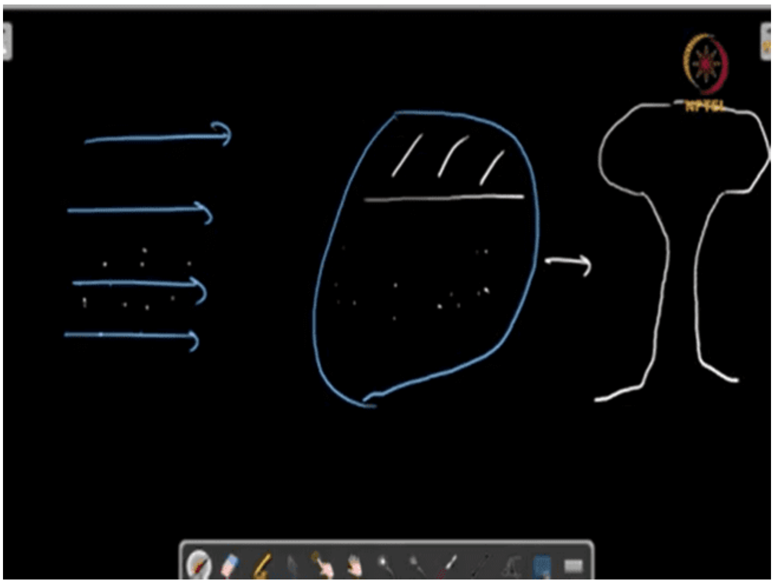

So, for instance if you have a rock like this in an area where you have wind, now typically the sand particles that are carried with the wind they can only be elevated to a certain height. They cannot be elevated to a very great height because of their weight. Now in this case, the lower portion will be abraded more and so there will be more amount of weathering in this region as compared to this region and so ultimately this will result in the formation of a rock that looks something like this.

So, the upper portion remains the lower portion is more abraded and so it looks like this now this is a mushroom rock. So, winds can also lead to abrasion. Winds also lead to impacts. So, when these particles are impacting you can also be getting certain holes that created because of the impact and winds also lead to deposition.

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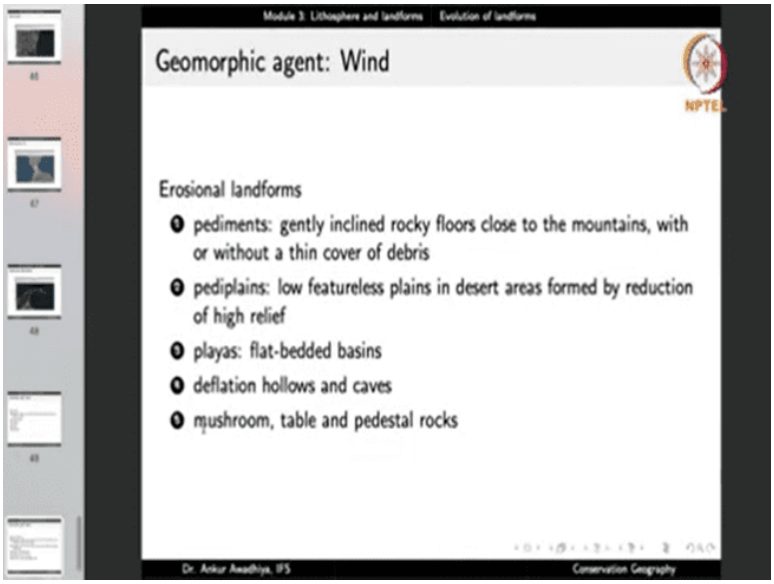

Now, the erosional landforms consist of pediments. Pediments are gently inclined rocky floors close to the mountains with or without a thin cover of debris. So, what is happening in the case of pediments?

The winds are taking away material through erosion and they are leading to the generation of a surface which is gently inclined and typically it is rocky area. Rocky area close to the foot of the mountains and it may or may not have a cover of debris or soil. When the pediments grow ultimately they areas formed by reduction of high relief.

So, what is happening is that the winds are eroding away all the high relief areas and ultimately what remains is just a flat plain and that plain is known as a pediplain. They also lead to the formation of deflation holes and caves. These deflation hollows can become playas which are flat bedded basins and they also lead to the generation of mushroom or table or pedestal rocks.

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And when this material is carried, it will be deposited somewhere and it is deposited in the form of sand dunes.

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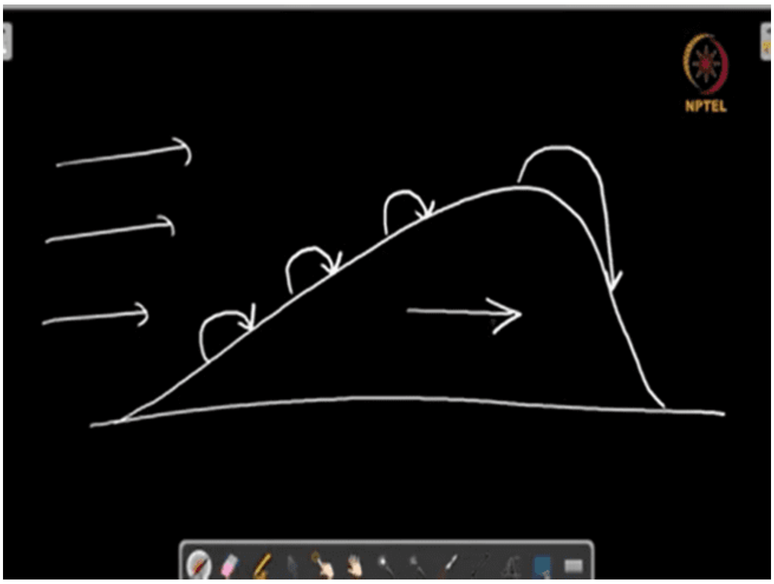

So, what happens is that if we consider a sandy area like this, this is the example of how a dune gets created. So, you have winds that are blowing like this. Now the wind will be carrying the particles here dropping them here, carrying a particle here dropping it here, carrying a particle here dropping it here.

So, we are getting an erosion of the sand and transportation and deposition at the same time. What happens when the particle here is taken out? It will be deposited down here. And so slowly and steadily, we will find that the sand dune begins to move. So, you have areas of erosion, transportation and deposition together in a sand dune and because of this, you can have sand dunes in different shapes.

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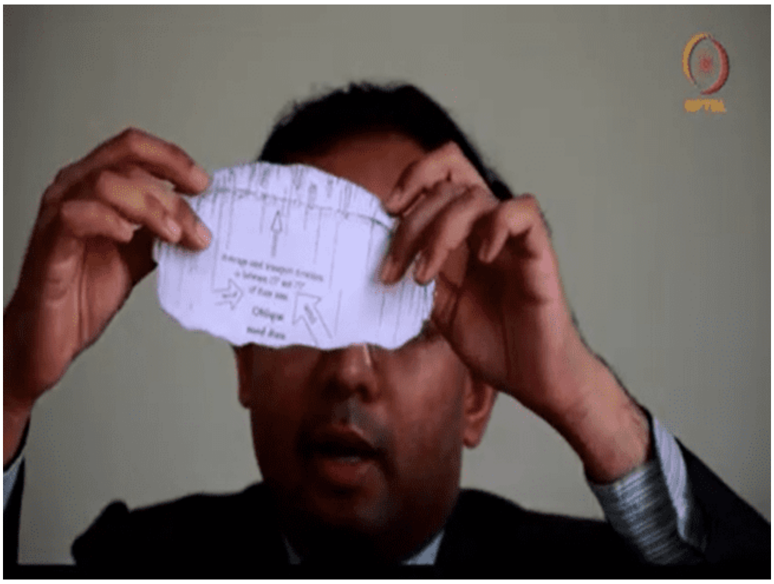

So, you can have oblique sand dunes that look like this. So, you have the winds that are moving from these two directions and you get an oblique structure something like this.

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Or you can have a longitudinal sand dune that looks like this. So, this is a longitudinal sand dune in this case the wind is typically moving in this direction and so you get a longitudinal structure. This is how it will look like.

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Or you can have even a star-shaped structure so we even get star dunes. Now a star dune will occur when in those areas where the wind directions are not constant and in this case you will have a sand dune that is having different arms.

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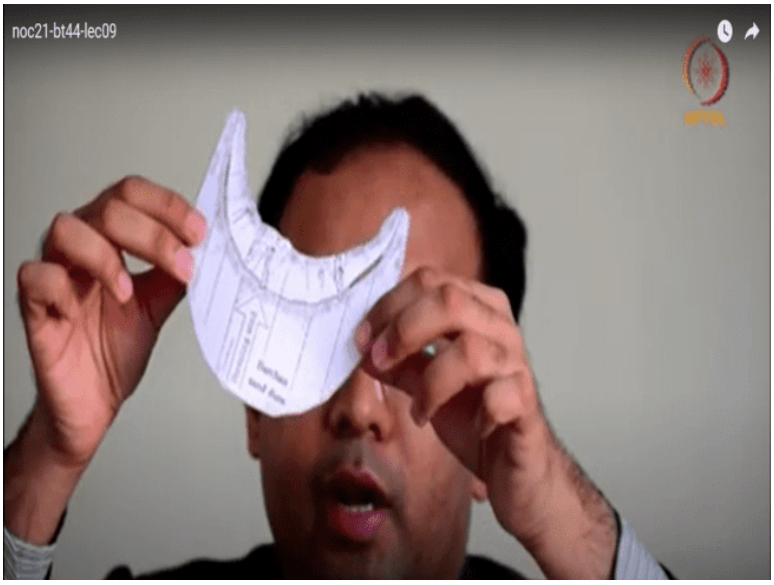

You can also have barchans. Now this is how a barchan would look like. So, this is the prevailing wind direction and this has two arms. So, this is a barchan. So, the wind also acts as a very important geomorphological agent because it is creating all these different land such as sand dunes, such as playas, such as deflation hollows, such as mushroom rocks and so this also becomes a very important geomorphic agent especially in those areas that have sand or unconsolidated materials and especially in those areas that do not have a very great amount of rainfall.

So, you will have certain areas where glaciers play a predominant role, certain other areas where water plays a predominant role certain other areas where wind plays a predominant role and below the ground we always have ground water and near the seas we have the sea waves and the currents that play a dominant role as geomorphological agents and all of these agents are doing erosion they are doing transportation and they are doing deposition leading to the creation of different landforms.

So that is all for today. Thank you for your attention. Jai Hind!