Earthquake Geology: A tool for Seismic Hazard Assessment

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Lecture – 48
Geomorphic Markers (Part – III)

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Welcome back. So in previous lectures, we discussed about fluvial landforms like terraces and alluvial fan and then we also discussed about the fault scarps, back tilted terraces or we can say alluvial fan surfaces. Now these are the most common features which we will come across when we are looking for the active tectonic deformation or the manifestation of the tectonic deformation on the surface.

Now apart from this, we also looked at some details of different type of channel patterns mainly straight, braided and meander and I will try to give one lecture if possible on the tectonic geomorphology pathways. We can utilize the importance of the different channel patterns straight, braided, and meander and how they change over from one to another depending on the change in the base level or change in the slope gradient or we can say the river profile.

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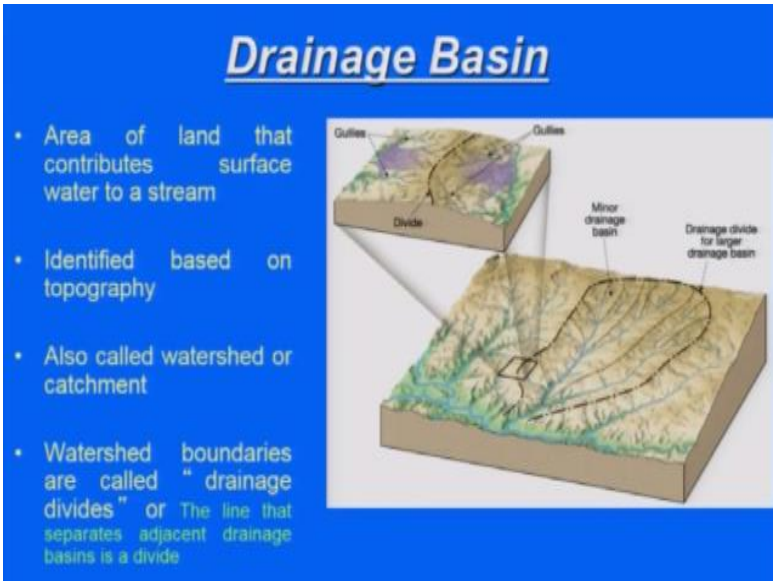

Other than that, we have another one is the basin that is drainage basin, usually we take into consideration and a different type of drainage pattern. So drainage basin will be consists of the mainstream and the tributaries and within the main basin you even have the sub basins also and the drainage divide usually has been marked where we have a slightly elevated portion which separates the flow direction of two drainages on either side and those drainages are contributing to the different drainage basins.

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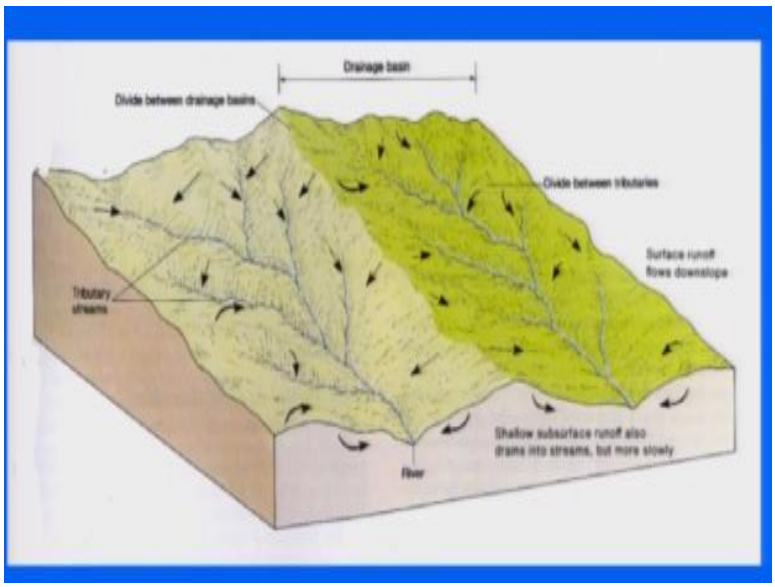

So this is what has been shown here. So this portion is your drainage divide and you have the twin streams flowing in different directions to respective drainage basins.

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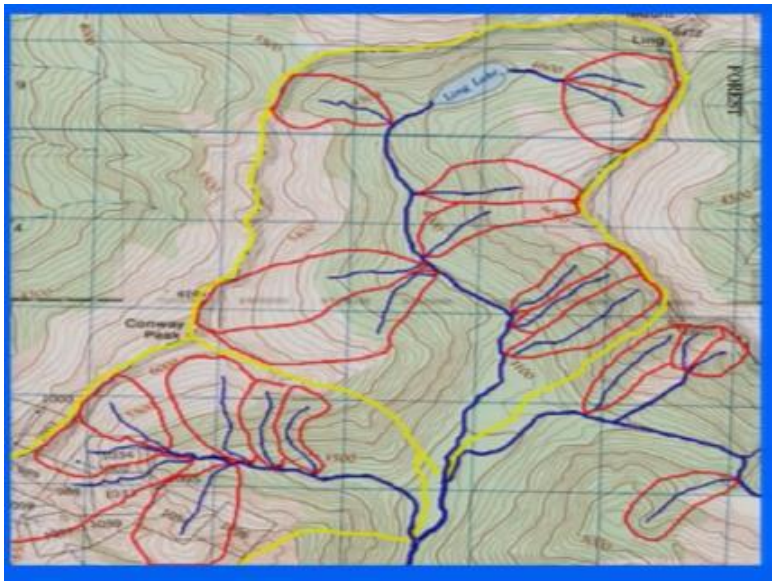

This also shows the major drainage basin is marked by this yellow line and then red shows the sub basins which are related to the tributaries.

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Now as we have discussed about the terraces and all that see, this is what we came across on a beach in Andaman. So what was coming in and there is this beach area where the tidal water comes and goes back and it has a slope break here

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So how the landforms have been formed, this you can you can visualize on a miniature scale. So you have a meander here. So this is an erosional side and then you have the depositional side here and at the same time there is an incision which is going on which is resulted into the formation of terraces. So, this is terrace 1 here, terrace 2 here, and then finally the top one here. So at least we have T0, T1, and T2 here on the depositional side.

At the same time what we see is that where there is a slope break or the break in the slope, you have the incision is more here and the new channels are getting distributed and we have in-between marked by the braid bars. So, these are all channel braid bars.

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Close up of that. So you can see the terraces here and the incised channel at this location here.

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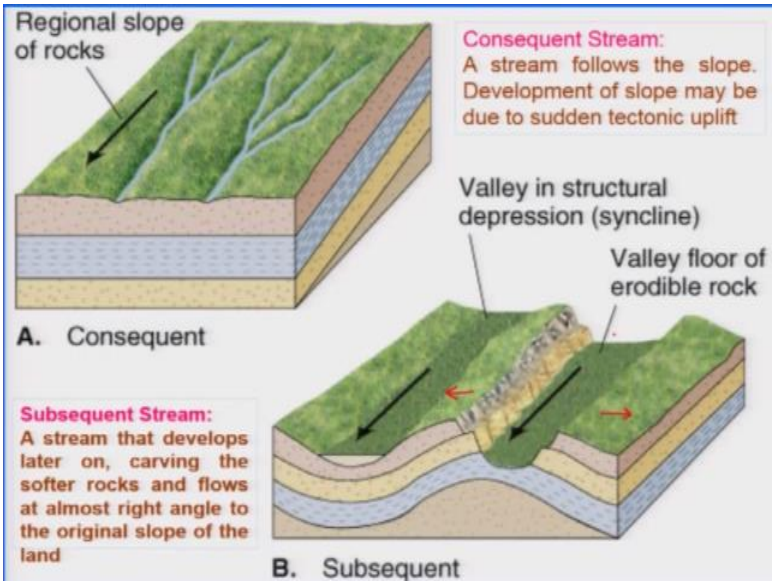

Now further look into the drainage. One can classify the different type of drainage. So, one is your consequent drainage and subsequent drainage. We see in the consequent drainages, we see in the consequent drainages mostly the consequent drainage will follow the slope developed initially because of the sudden tectonic uplift. So the streams which will develop on the surface will follow the slope and in terms of the subsequent drainage, it will not exactly follow this slope because this slope here is if you take the fold here.

Then the slope is in this direction as well as the slope is in this direction here, but the stream is incising across the slope. So the stream that develops later carves the softer rocks and flow almost right angle to this original slope. So, the main difference between the consequent stream and subsequent stream is that they follow the slope and development of the slope may be because of the sudden uplift whereas here there is a subsequent stream which follows almost at right angle to the original slope.

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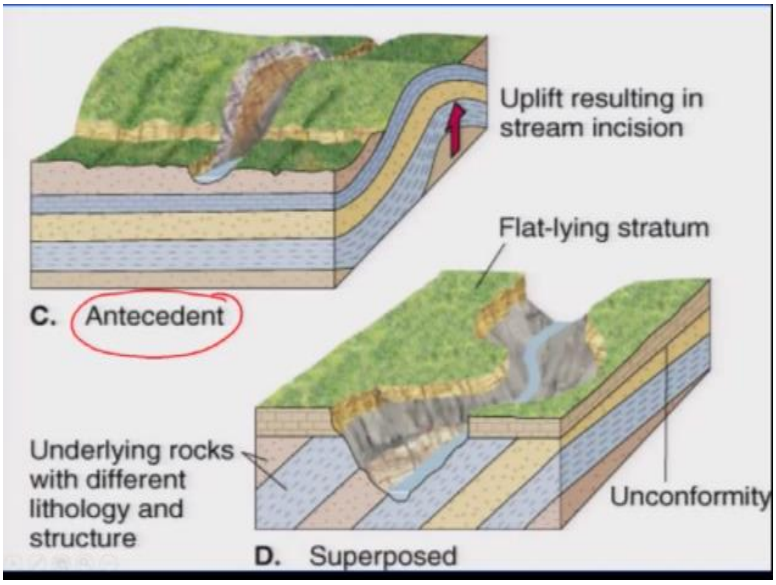

Then, we have also the term called as antecedent streams. Your antecedent streams are those which will cross across or flow across the uplifted part okay. So they are capable enough to erode the uplifted area. So for example if we are having the folds which are in a developing stage due to ongoing deformation, then this stream which is flowing in that area will be able to cross in size and flow through the uplifted portion.

Those streams are termed as antecedent streams and then another one is your superposed streams which are the streams where the underlying rocks with different lithologies have been seen and they will flow in direction eroding the flat-lying surfaces or flat-lying strata as well as inclined strata. So, this has been termed as the superposed streams.

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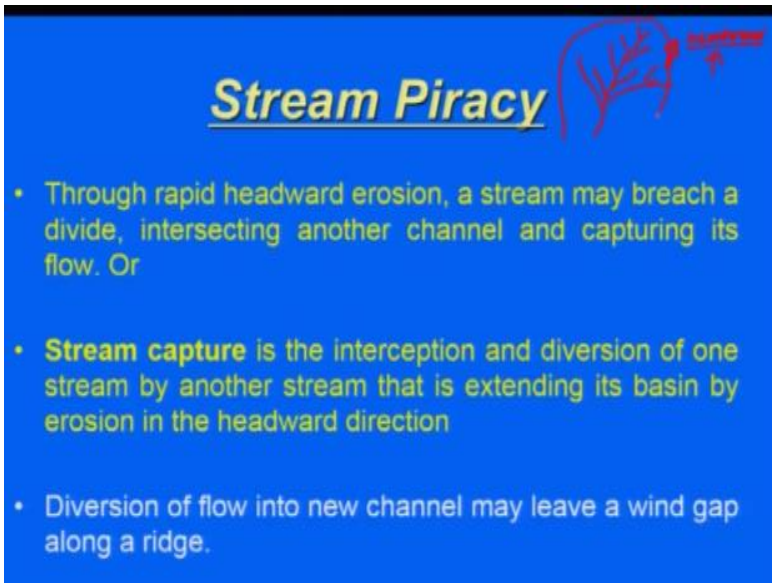

Another important part which usually we come across because the drainages usually have

been seen developed like you have a slope, then the streams will or the drainage will keep developing in the headward direction. So this is the pattern where we see the development of the basin will be because stream will keep adding from the headward side. So the basin will extend towards the headward side. So, we usually say that the basin develop towards headward side okay.

So if you are having for example the basin which is adjacent to this, then sometime this erosion because it is eroding it in the headward direction, then it may breach the other streams or the basin and will capture the other basin and the water flows in that basin. So basically what we see is that through rapid headward erosion, a stream may breach the divide, so if you have a divided here for example and then you are having another divide. So another important aspect what usually we come across on the fluvial landscape is what we called stream piracy.

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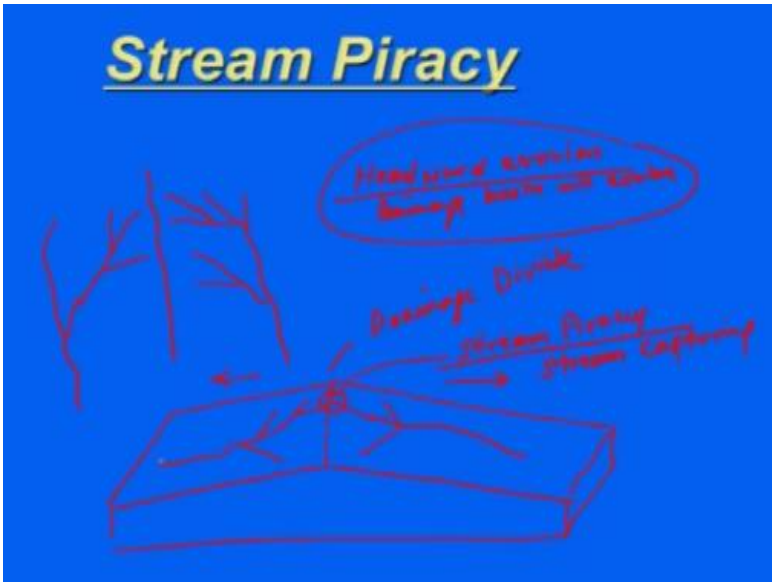

Now the drainage and if you recall the first 2 slides which we were talking about the divide here and the streams are flowing into one basin and here the streams are flowing another basin and meeting the main stream. So, this becomes your drainage divide. Now, the drainage usually evolves towards headward side. So due to headward erosion, the basin is that is your drainage basin will evolve. So, you have one stream here then it will second if you see then it will keep on adding here like this and then further it keeps going up okay.

So you have the addition of the drainage are smaller by smaller stream and you keep developing that. Now suppose you are having a slope that you will understand in the next

slide okay. Suppose you are having a slope, this I am putting profile here, so if you see this one here like this okay. So, you have these streams flowing along this slope so you have these streams which are going like that okay and then here the streams are flowing in this direction because the slope is in this direction here, the slope is in this direction here, and this will mark your drainage.

Take into consideration the headward erosion and the drainage basin evolution, then what will happen is that this will keep eroding the side and the time will come this will connect okay and that what we call is the stream piracy or even we call this as stream capturing. So, the whole drainage basin will be captured by either of one basin and then we will have the flow getting into the one single basin. So, this usually happen where you have the erosion is going on and erosion is high in the region.

So, such features are also important in understanding that how the drainage basin evolve and whether there was any sudden change in the overall flow patterns of the respective drainage basin.

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Through rapid headward erosion, a stream may breach a divide, intersecting another channel and capturing its flow or stream capture is the interception and diversion of one stream by another stream that is extending its basin by erosion in the headward direction. So, it keeps rolling towards the headward direction and finally it will reach to that extent that it will capture the stream okay. So, diversion of the flow in new channel may leave a wind gap along the ridge. So, this one can look at in terms of the wind gaps if they are available.

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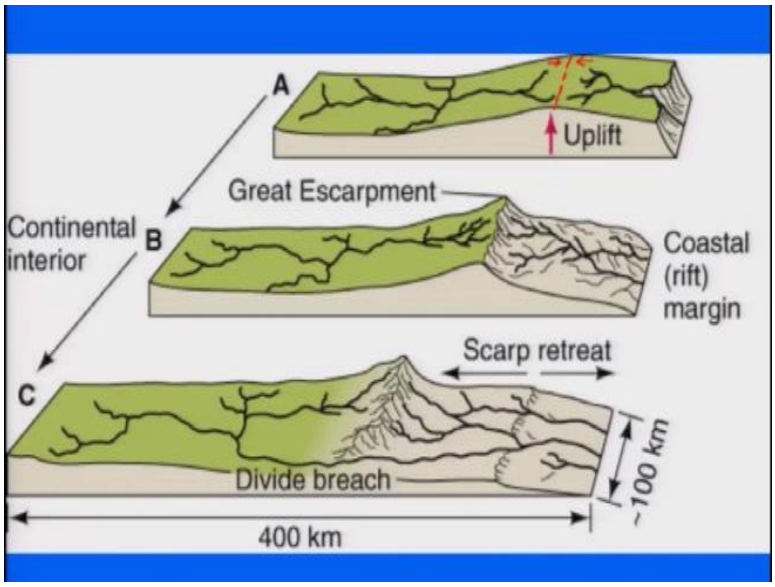

So, suppose you are having an uplift going on here, so basically the drainage divide for this part and as we were talking about that the drainage will fall in the headward direction. So, the time will come it will breach and it will try to capture the whole drainage from the side.

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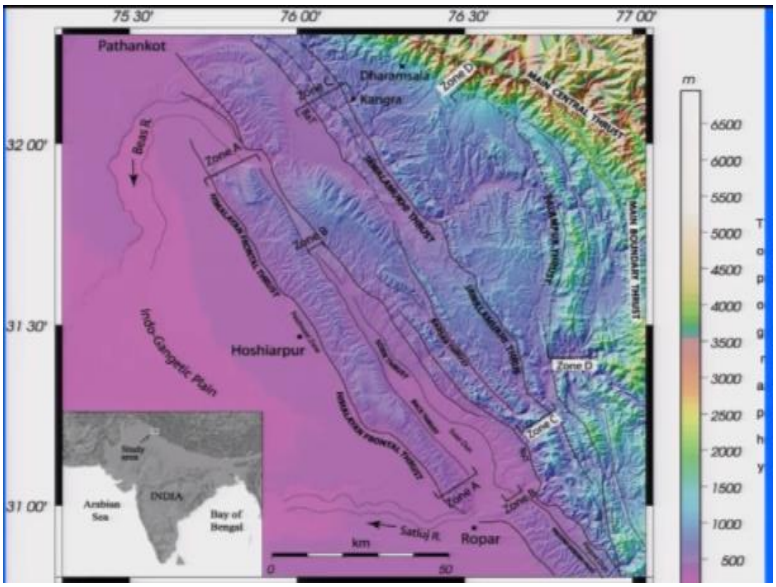

Now other than that what we also look at is the drainage pattern and the channel morphology. So, I will talk about a few examples from this portion that is I mean in the Northwest Himalaya, in Punjab region and this is Hoshiarpur and the feature which is here is the Janauri anticline and you can easily mark the drainage divide which goes like that okay. So this is the top ridge line and the slope in opposite direction.

So these drainage are flowing like that and the streams are flowing from here in this direction

into the Indo-Gangetic plain and this is the major streams. So, we will what drainage has to tell us about the subsurface topography.

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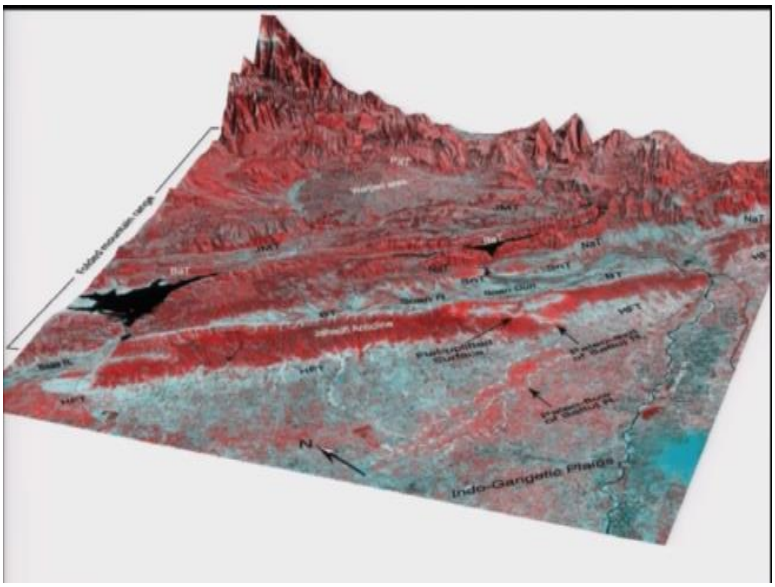

So, what we found was not, of course there is a very sharp distinct geomorphic boundary here which marks the anticline and the indo-Gangetic plain and as we were looking in the previous slide that we have the trenches flowing in this direction and this direction here and this is the ridge line, but in this portion what we found is in dune area which was devoid of drainage and which is when we moved in field it was as good as flat area which you see like similar to the indo-Gangetic plain.

So, our interpretation was that this whole area was uplifted and very quickly in a very short time which did not allow the stream to flow through or leave a major river because Sutlej flowed through this area here and this was the remnant of the paleo Sutlej which was connected through this and flowing through this area here. So, this is our interpretation, but because of the rapid uplift of this area, it did not allow or Sutlej was not able to cope up the uplift, hence it took the return or deflection.

It started flowing through a gap which was available and this area is now left out as an flat uplifted surface. So because of the devoid of drainage here, we were able to pick up that this is a flat area and that whatever interpretation supported when we looked at or identified the paleo channel here. Now similarly if we look at in this portion, this portion we were able to see that there is a very distinct drainage which is flowing in all direction here, hence we interpreted this as a warped area.

So if you are having suppose a slope like this, what do you find is that you have the streams flowing in either directions okay. So, this becomes a sort of the warped area or deformed area. So, this also it helped in identifying that what are the features we see on the surface and what the drainage has to tell us about the subsurface features.

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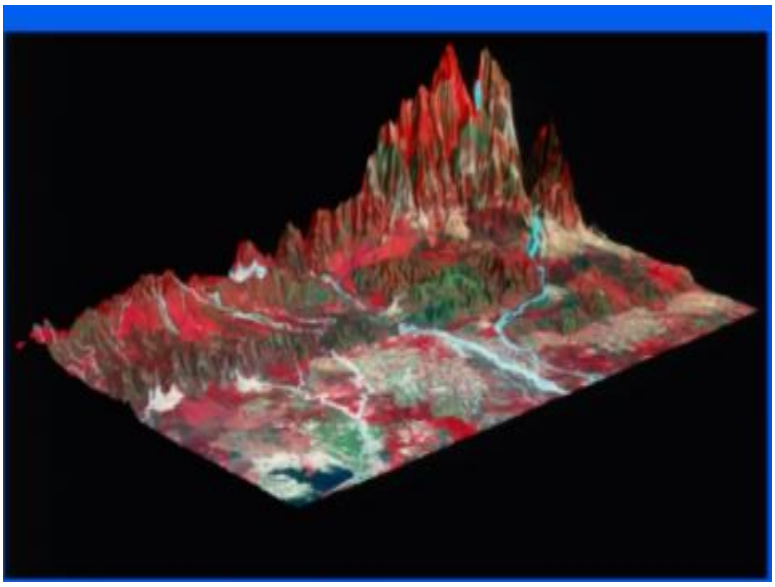

Another important part which we were able to pick up from the drainage itself that we found some wind gaps okay and this is from central Himalaya. This portion is, this city is Ramnagar and Nainital sits somewhere over here. So, what we found was that this drainage which is right now flowing from this portion earlier flowed through this one because this marks the wind gap here and then later on it shifted its course here, then further here, and that finally it is flowing here okay, but later in future if the there is an tectonic movement along this fault line, then it may go and merge the main Kosi river.

This stream is Dabka river and this is Kosi river. So, this also one can interpret and identify that what has happened in the past and reconstruct the tectonic geomorphic history of any region okay.

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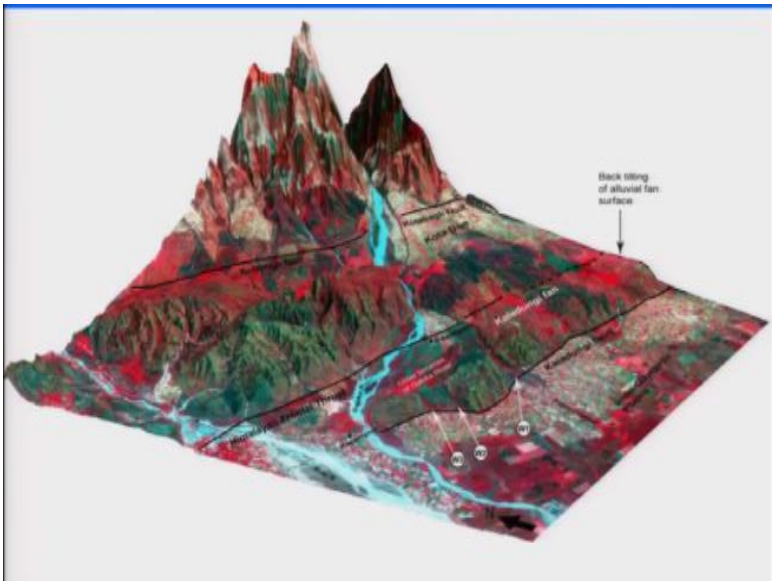

So, this is the close-up of that which you can see the stream has left out their eminence or the paleo tunnel of what we have marked as a wind gap. So we marked as wind gap 1, wind gap 2, wind gap 3 and then finally it is flowing here and similarly in one of our research article, we have also tried to highlight that there was another stream which used to flow and has left out the wind gaps in this area also and that was Bohr river.

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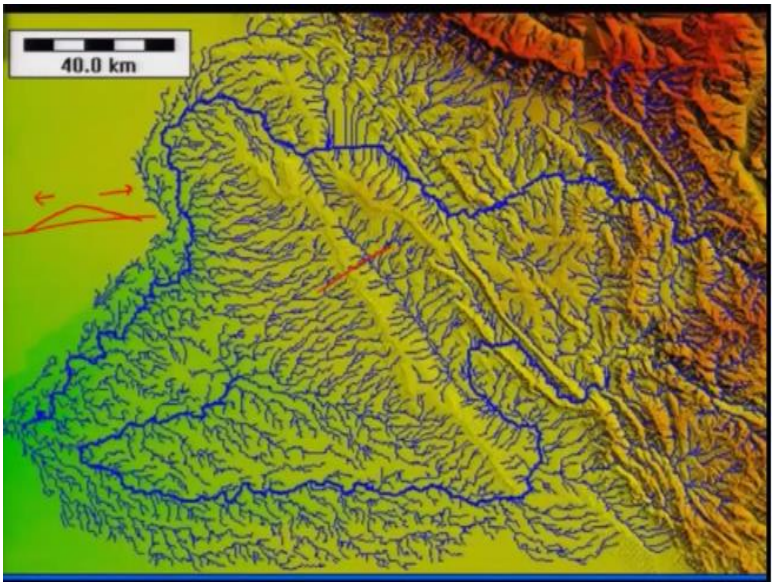

So again coming to the northwest Himalayan part, what we did was we quickly extracted this drainage using SRTM data and the dark blue lines are showing the higher-order streams or the drainage of the main trunk stream and the smaller are all tributaries. So as we were talking about that we can easily mark the drainage divide if we are carefully take into account in which direction the streams are flowing. So this stream for example is flowing and joining this main stream here and these are the all streams which are flowing in this direction okay.

So, this portion becomes here and then this portion is here, they have divide whereas this portion is not occupied much by the drainage and this is your flat area. So, one can also take into account the drainage pattern and try to identify what type of structure is sitting subsurface. So, this clearly marks that this portion is folded area. So if you take the cross section here, then you will find that this is something like this okay. So you have the slope in this direction, you have one slope in this direction.

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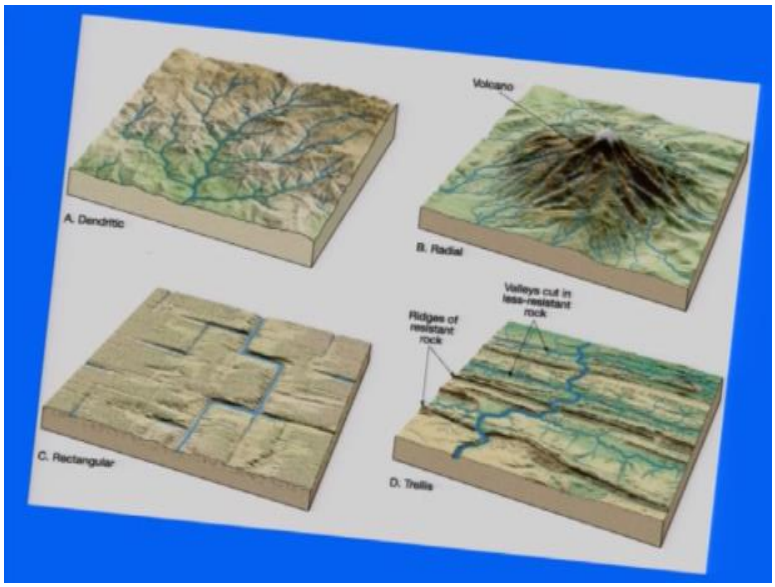

So you have different type of drainages and drainage pattern if you take into consideration like dendritic pattern, radial pattern, trellis and rectangular. So how and what is the importance of this and can we interpret the subsurface lithology or the structure based on this? Now, a rectangular drainage again will be seen in the areas which are having very typical fractures because of ongoing deformation and they will flow almost at a right angle and this will be seen in the area where you are having homogeneous material.

Whereas the radial drainages will be seen in the area where you are having either volcanic cone or any dome structure whereas trellis pattern you will be seeing where this main stream and the tributaries will be joining it almost right angle and this type of drainages are seen in the areas where we are having softer rocks and the resistive rocks mostly in the folded terrain you will be able to come across and find the trellis pattern.

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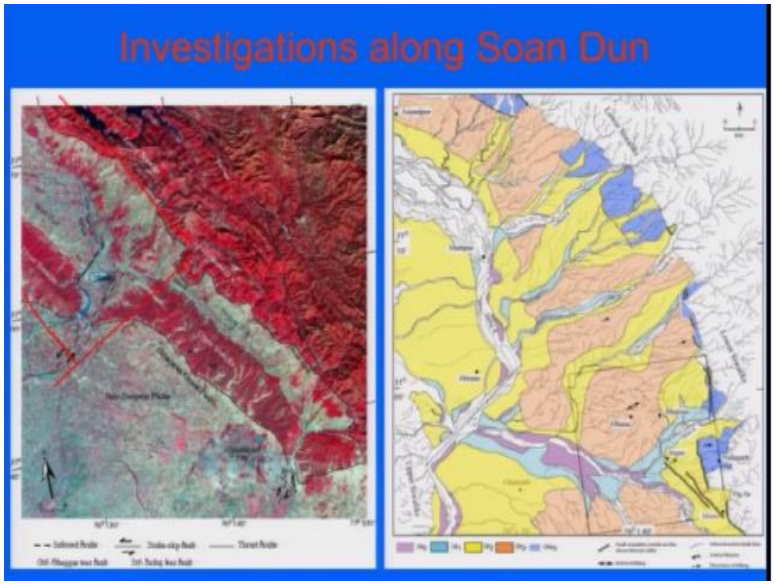

Now as I was talking about that we did some studies in this area and tried to look at that what exactly the drainage is telling us about the landform okay. So this is the map of this portion here from this area. This is the area which has been covered in this map, you can see here this one okay and this is the exit of Sutlej which is coming here, this is the portion and up to this one here. What we found was this region was showing us these streams which are flowing in all directions.

We were not having idea that why it is showing so because this usually should have been a flat area because this is an area which is similar to the Pinjore Dun. So Pinjore Dun is a flat region, almost flat valley between the two mountain ranges that is what we call intermountain valley and dun is the term which is locally used for intermountain valleys like Dehradun, Pinjore Dun and Soan Dun.

So we expected that this area will show flat surfaces, but this portion which has been shown here showed us that this is not exactly flat but we see sort of a radial drainage here and then we also picked up some anomalies of the channel pattern over here which I will show in the next slide.

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So we looked at the lithology, of course it is old deposits of tertiary age.

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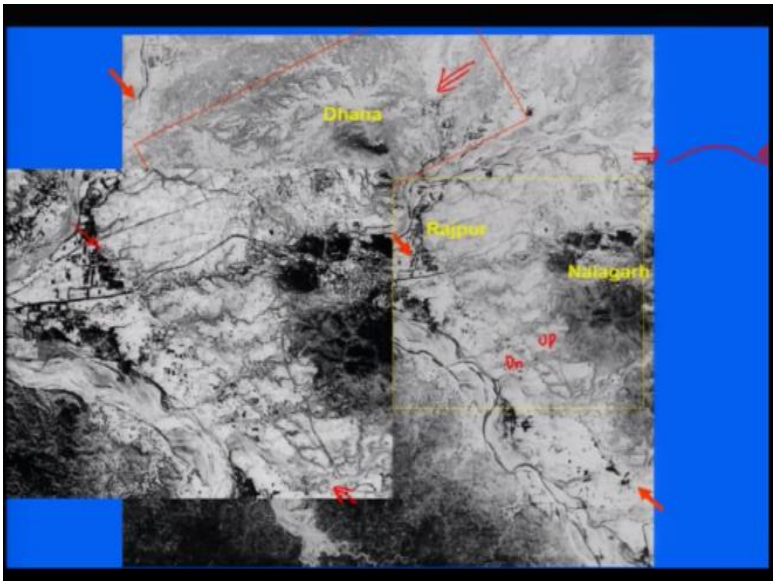

Then when we looked at the high-resolution photographs of particularly this area and this portion and then what we see here is that the drainage here is showing a typical radial pattern. So there definitely this area should be showing a warped surface in the field okay, and then second one we will come to that. So first this was the warped areas, so we marked a fault here that was responsible for deforming the surface. So the deformation is like your sigma one will be like that and this area is getting deformed like this okay.

So this is the deformation and this line which also marks the present day road, so when we looked at this in 3D, we were able to identify every distinct change in elevation, so this side is up and this side is down and this portion we marked as fault trace okay. Now further when

we looked at this one, what we found was that in the portion which is uplifted okay, the drainages are showing very tight meander whereas it comes in the downtown side or the footwall side, then the drainage becomes almost straight.

So, this is the portion here and this portion the next slide I will show the close-up of this if you look at this portion, then you will be able to make out this clear demarcation here okay. So, this is the form of the line fault line which goes here and the drainages which are in the uptown side is tightly meandering, whereas this portion is almost straight okay. So, this again is showing very tight meanders whereas this portion is almost straight.

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Then we looked at the warped area in field, so we were able to pick up very clear and distinct topography which was showing the warping here at Dhana.

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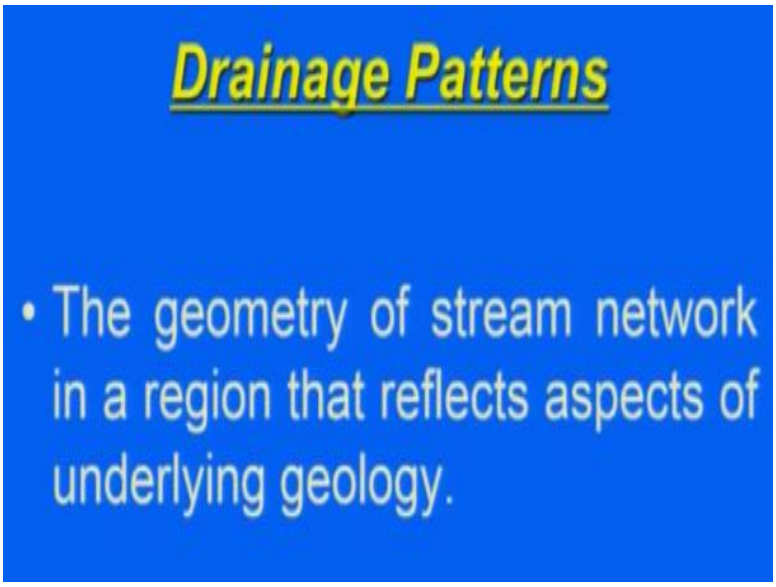

Now drainage pattern usually tells us about the underlying geology.

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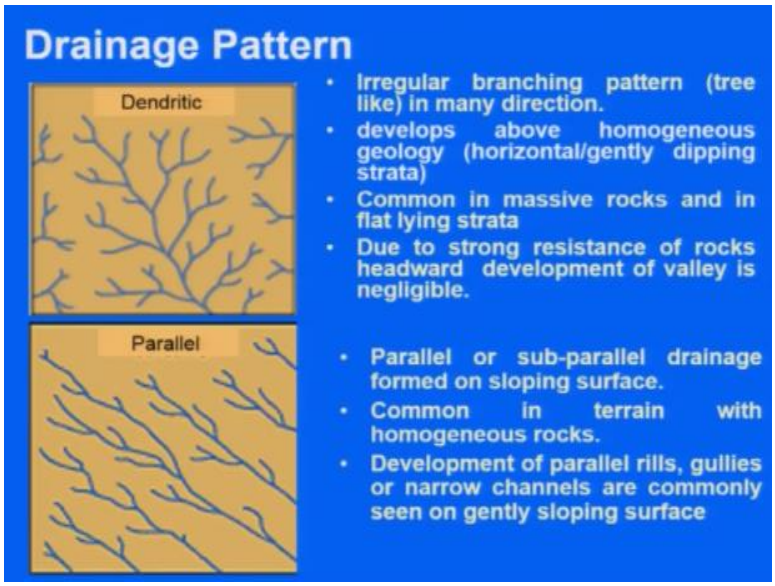

So quickly we can look at this one. So at the dendritic pattern which is very irregular branching tree like features and common in massive rocks or we can say that where we are having mostly the homogenous geology. Parallel drainage again are very much similar to what we are talking about the consequent drainage. They will develop parallel to the slope.

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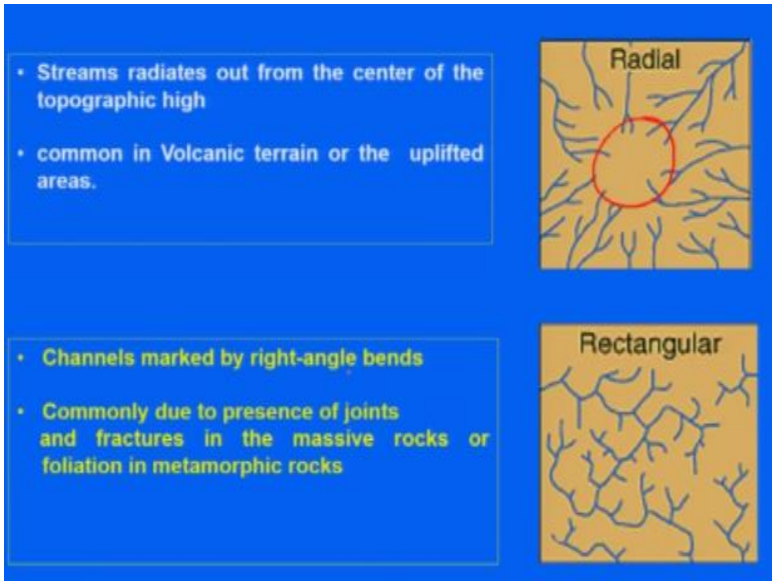

Then we have the radial patterns which indicate that there is an elevated portion in the center and that has allowed the drainages to flow in either directions okay, and then we have rectangular drainages commonly seen in an area where you have fracture or jointed rocks and they are almost at a right angle along its bend.

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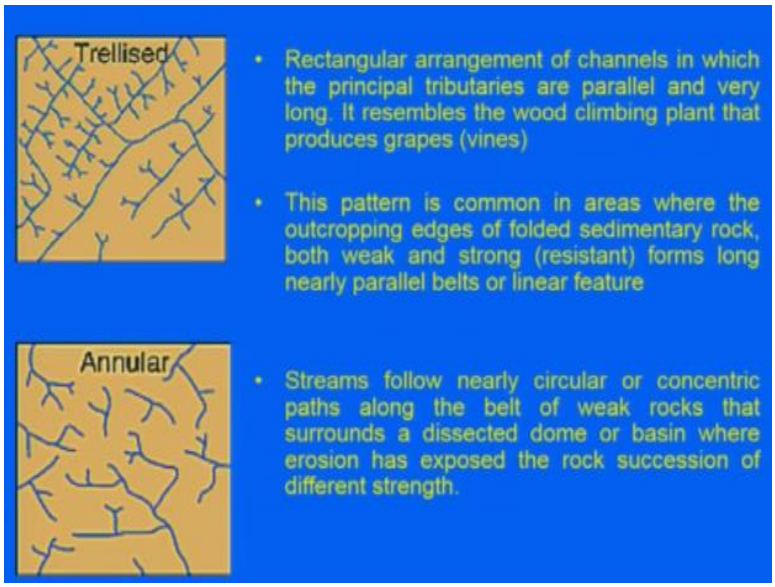

Then we have trellis pattern. So these are common in area where outcropping edges of the folded sedimentary rocks both weak and strong are seen and mostly the tributaries will be at almost like a right angle to the main stream and then annular patterns are merely circular, slightly similar to your radial pattern and all that. Now this all like understanding of drainage network or drainage pattern or channel pattern you can use to interpret the subsurface area.

If there is sudden change in the drainage pattern or there is sudden change in the channel

pattern, one can interpret in terms of the tectonic deformation or it could be related to the climatic change also. So, one has to be careful while talking about this okay. So, I will stop here and in the next lecture we will continue on coastal landforms, but before that I will try to quickly talk about the tectonic gemology part if time permits. Thank you so much.