Geomorphic Processes: Landforms and Landscapes
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Lecture - 26
Tectonic Geomorphology (Part III)

So welcome back. So, in previous lecture, we discussed mostly about the change in the channel pattern because of tectonic deformation and after completing this topic on tectonic geomorphology, I would like to discuss 2 more examples from Kutch, Great Rann of Kutch and Himalayas where we have identified evidence of change in channel pattern as well as the direction or I would say the diversion of the channel.

The main channel of major river system took place during geological past because of active tectonic deformation and this is basically important because and I hope it will interest you people because this change of the channel or diversion of the channel affected the habitation, one of the major settlements in Gujarat and that was Dholavira which was like 4500 years back it so happened.

So and even in Himalaya it affected and in future it will keep on happening. So, this is important topic for all of us to understand that what generally happens when there is an influence of active deformation. So, under the preview of the tectonic geomorphology we were going to discuss this topic and the evidence of tectonic geomorphology from Himalayas and from Kutch.

So, before we go ahead with that topic, let us finish few things which are also important and related to the basically the change in the channel pattern. So, we had few slides on which we discussed about the river from new Madrid which was influenced because of the county uplift. So, before the uplift of, where the river crosses the uplift and so before in the upstream and downstream and while crossing the uplifted area, how the drainage pattern change that what we discussed in the previous lecture.

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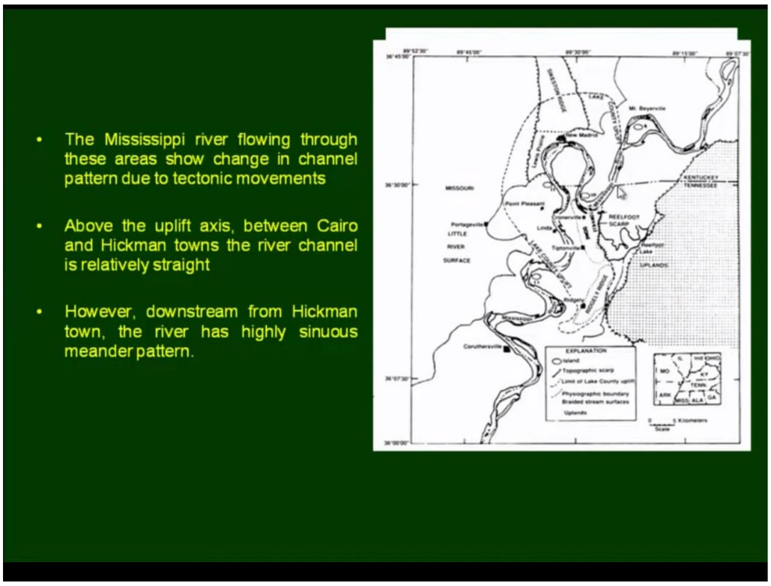

So, let us start with this. So, if you look at the slide, this shows that this is of the Mississippi river in the new Madrid reach and the uplift. So, above the uplift axis what it shows that is the city name is Cairo and Hickman. The river channel is relatively straight that what you can see here. It is quite straight channel and this is before the axis of the uplift. So, this is the axis it comes here before that.

And then however the downstream of Hickman town, the river has high sinuosity pattern. So that it becomes highly sinuous as it moves downstream from the Hickman side. So, this is one of the important points which you should note it down that the change in the elevation or you can say the relative gradient of within the channel pattern, within the channel or the river bed, the channel pattern will change or it will be affected, so this is very important.

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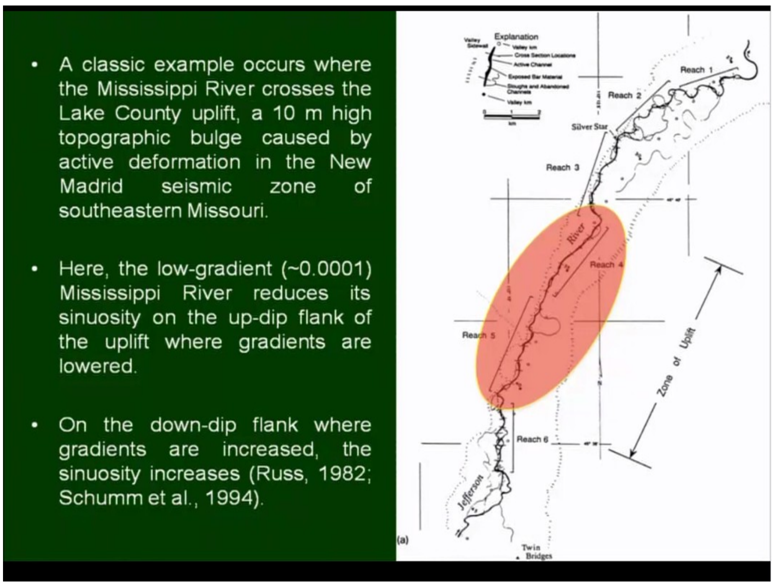

Now, this is again the same area which shows the sinuosity pattern in different oceans and this is what they have done that reach 1 reach, 2 and reach 3 they have tried to look at in detail. When smaller segments, the change in the channel pattern or the sinuosity, whether it is highly sinuous or less sinuous or the channel has become straight. So, this is the zone of uplift which shows the less sinuosity.

So, what it shows is that the classical example occurs where the Mississippi river crosses the Lake County at 10 meter high topographic bulge caused by active deformation in New Madrid region. So, New Madrid region as I was talking about is the part of the stable continent, has been considered as stable continent but this area is seismically active region and this will be like justified by the occurrence of small and large magnitude earthquakes in this region and continuous monitoring of the seismic activity in this part.

So, here what it says that the low, the Mississippi river the gradient is almost like very low 0.0001. Mississippi river reduces its sinuosity on the up-dip flank of the uplift where the gradients are lowered. So, gradients basically is on the uplift part where you are having the bulge or the wall. So, on the upstream side, the gradient is lower because of the uplift. On the down-dip flank where the gradients are increased, the sinuosity increases.

So, this you have to keep in mind and in one of the previous slide we also gave the cartoon that if you lower the gradient, then the sinuosity reduces and if you increase the gradient, the sinuosity increases. So, this point is extremely important and as I was mentioning in one of the lecture that whole Indian plate is under deformation.

So, if you are having a local change in the channel pattern which also we learn during this topic of tectonic geomorphology that local ponding, local braided channels or the local evidence of local meandering and all that are could be considered as the signatures of active deformation. Nevertheless, this could also happen because of excess amount of bed load which has been supplied to the main channel by the tributary.

So, one has to be careful but in total what we can justify this part is that the change in the gradient in any region or any portion of the channel or river valley will result in o change in the channel pattern. So, this is direct evidence, which are the signature which will indicate you the ongoing deformation. So, in the Indo-Gangetic plain, one can also look for such signatures and identify the pockets where the ongoing deformation, the tectonic deformation between the Indian plate and the Eurasian plate is influencing.

And the overall plate and the local deformation is taking place and that can also result into the diversion of the channels and all that. So, that we will look in the coming lecture, so let us move further and see. So, this is the area of zone of uplift which has been marked by the red portion.

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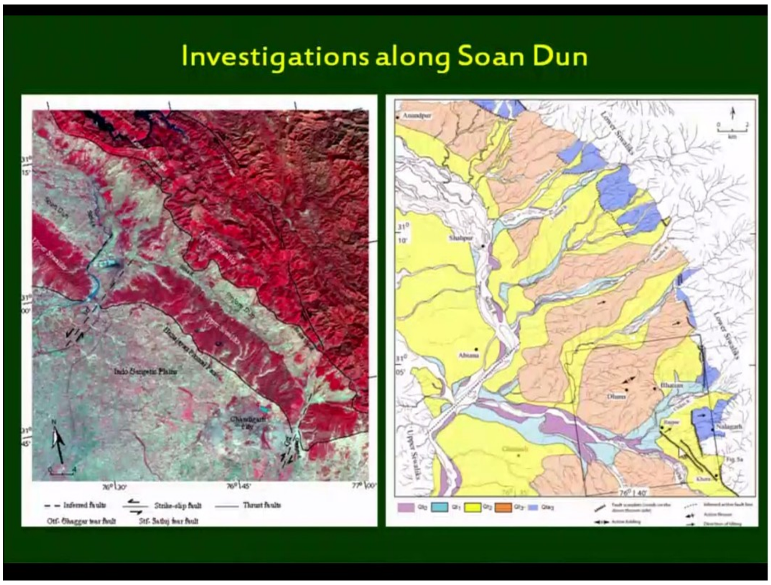

So, investigation along Soan Dun, this is what I was showing but now I would like to discuss this in little but greater detail. So, in the previous lecture, I was showing about the portion from here this area that is a warping which we identified and where we talked about the drainage pattern. So, we were able to identify pick up the radial drainage pattern which has been shown here.

But in this topic, I am going to talk about this one, this portion here where the drainage channel pattern has changed because of the change in the gradient here.

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So, as I told earlier also that this area has been occupied by the lower Siwalik Hills as well as the younger deposits, quaternary deposits which has been shown here. So, these are all the tertiary hills but some portion on the top of this has been covered by the younger deposits which have been shown here as Q0. So, this is on geomorphic map of the area and these symbols they mark the fault lines over here.

And this portion yes I have shown here by double arrow is the active folding. So, active folding is taking place along with there is a fault here which has not been marked but there is a fault here and then. In some locations, what we see is this active fracture has been shown here and this symbol is active fault and these are all thrust fault but the symbol which is being shown with the (()) (10:35) on this direction this side means that this portion of the surface is down and this portion is up.

So, this is a thrust fault within 4 fault dipping and almost Northeast direction. So, this is another one and then this one is the direction of tilting. So, this portion has been tilted in the same direction that is in the north east direction. So, this is on warp or we can say the folding fracture which has developed here and so on. So, we have the fault line which runs through this one is which we later on we identified.

And the deformation of the landform is well reflected by drainage pattern here as well as change in the channel pattern over here. So, drainage pattern which shows radial drainage and we have already seen the warp here, so this is the situation in the exposed road side as well as in the river valley which shows the tertiary deposits.

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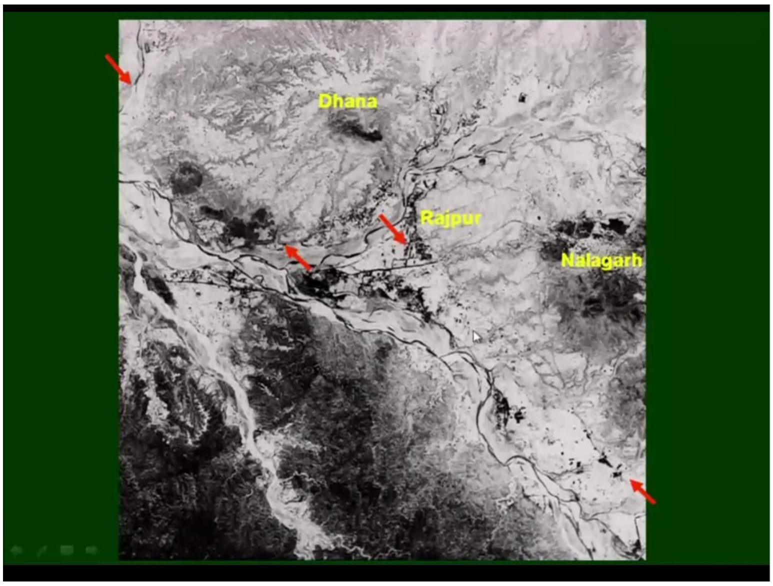

And high resolution satellite photograph which shows the drainage pattern almost radial drainage pattern in circular which you see here. So, this portion is higher ground this we have already discussed, so I will just move ahead and then most important one which I would like to discuss here is this area here this one. So, if the arrows which I have marked here shows the trace of the fault and this side is up of the fault, this side is down.

And it also in the previous slide which I was showing, it also shows the tilting in this direction. So, it is back tilted because of the deformation along the thrust fault here. So, let us see the close up of this one. So, carefully if you look at then you find that the channel is quite tight here in the sense of the sinuosity. So, tight meandering or tight sinuous channel, all channels which are crossing this line, this is fault line here shows the tight meandering.

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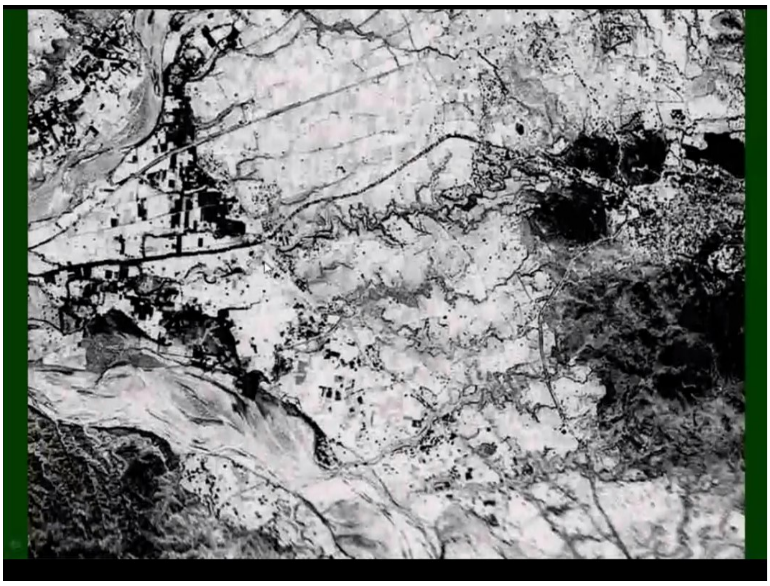

So, next slide if you look at this one here, this is a small close up of that. So, you can easily make out that as soon as it crosses the thrust folded area; here this is a fold here. As soon as it crosses this line, of course the straightness of this feature is also because of the local people or the administration has constructed the road here because they found the topography, the best topography to have the flat area adjacent to the slightly elevated portions.

So, they have also used this advantage as in to construct the road. So, the road runs parallel to the fault line and this is the deformation feature. So, as soon as he crosses this line here, the sinuosity reduces, the channel become almost straight. So, you can see here also, the channel become almost straight. So, local deformation in any region active tectonically active region will result into the change in the channel pattern.

So, you have a tight meander just and similar example we saw from the Jwalamukhi thrust from the higher Himalayas, not from the higher Himalayas but it is all the portion of the lesser Himalayas and this we talked in the previous lecture. So, similar example, very similar that the Beas River which was crossing the Jwalamukhi thrust show straight meandering before it crosses the fault line and then it becomes trade.

And similarly, here also there is the thrust fault and fold, related fold which has affected the channel pad. So, please remember that you have the higher sinuosity and as soon as it crosses this portion, then it becomes the sinuosity reduces.

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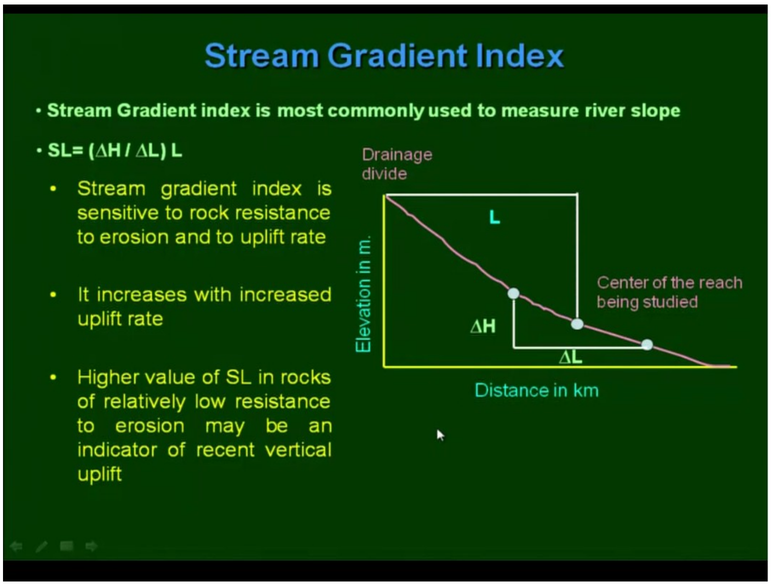

Now, the gradient index, this is another parameter which is important indicator of ongoing active deformation. So, stream gradient index is most commonly used to measure river slope. So, it has been given as an expression SL = delta H by delta L into L. So, if you take the longitudinal profile of any major or trance stream which can help you in identifying the locations of active deformation, then you can have the length what is its elevation.

So, the distance from the origin or any point from where you want to draw the longitudinal profile, so distance in kilometer and elevation in meter. So, if you have a profile like this, of course most of the profiles will look like this only because you have the source area headward area or head water area or water shade and then towards the mouth of the channel and you want to measure the SL index at any given point.

So, what you will do is you will take the centre of that point and you will have so. So, if you want to measure the SL index of this point and so you will take the distance upstream and the downstream and that will be the difference between the center of this location. So, you have taken this stretch or the segment of the channel and the center of this point will give you the SL index of this area.

So, from this the difference between the height or the elevation, you will get the delta H and the difference between the distance will give you the delta L. So, center of the reach being studied which will give you this thing. So, this portion will be your drainage divide and this will give you the L. So, from the drainage divide that is the point from where you have started the profile from the center of this, the study which is being, the reach which is being studied center of that and the distance up to the drainage divide will give you the L.

So, stream gradient index is sensitive to rock resistance to erosion and uplift rate. So, it increases with increase in uplift rate. So, if you are having the area is continuously uplifting, then you will have higher SL index of the region. So, higher value of SL in rocks of relatively low resistance to erosion may be an indicator of recent vertical uplift. So, you can do this exercise again either using to topographic maps or you can use the satellite data.

So, with the help of GIS and doing remote sensing, you can work out the SL index also which is again a very important parameter to identify the ongoing local deformation or regional deformation also because if you are having a regional deformation then all rivers or the channels which are crossing the deformational area will show the signatures of change in the SL index.

I was showing that in the previous slide, the change in the channel pattern, all the channels which were crossing the uplifted or the deformed area along the thrust fault in Himalayas were showing different type of channel pattern.

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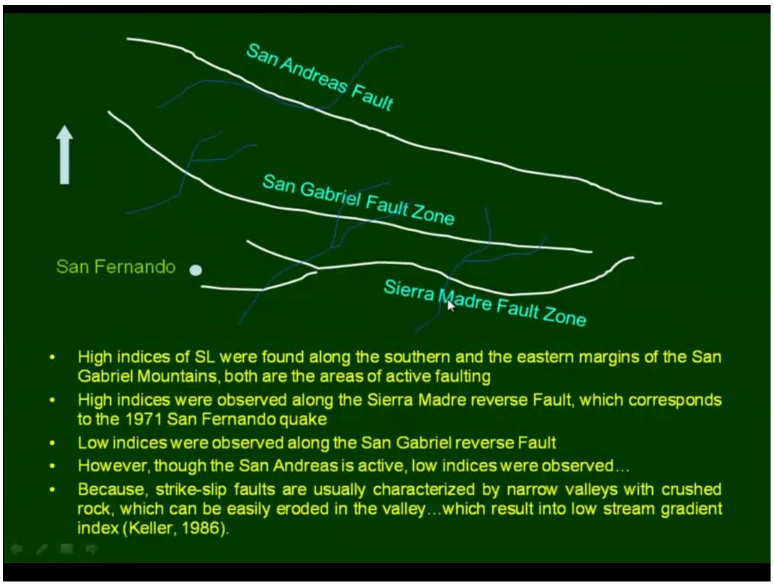

Now, this an example from US, which shows 3 fault lines but this all 3 fault lines belongs to the San Andreas Fault System. So, San Andreas Fault System, then you have a smaller fault splay in San Gabriel Fault Zone and then Sierra Madre Fault Zone and this area is close to San Fernando City. So, what it shows that high indices of SL. So, the blue lines, the white lines are all your faults and the blue lines which have been shown here are the channels which are crossing the faults.

So, of course this is just a sketch which shows but not with the detail of the sinuosity and all that but what they picked up to show that wherever they are crossing, the SL index was different and the reason was we will see in coming bullets actually. So, high indices of SL were found along the southern. So, this is the north which has been shown here. This side is north and the southern side is this one.

So, southern and the eastern, so east is this part, eastern margin of San Gabriel mountain, so the higher indices were been seen in this portion. Both are the active faults, so this, this, these 2 faults are being categorized as active faulting area. So, high indices were observed along Sierra Madre reverse fault, so this one. So, high indices were observed here which corresponds to 1971 San Fernando earthquake.

So, even the deformation resulted because of the earthquake because whatever we are talking about until now about tectonic geomorphology and all that whenever there is, we talk about the ongoing deformation definitely the strain is developing within the rocks and the strain will be suddenly released which will result into the ground shaking and that is your earthquake.

So, this also shows that 1971 San Fernando earthquake was responsible for deformation here and that resulted into having the higher indices in the area, the southeastern area of the San Fernando region and whereas what so higher indices in this area was because of 1971 earthquake, low indices were observed along the San Gabriel reverse fault, so along this one the low indices were been observed whereas here higher indices were found because of the 1971 earthquake.

However, though the San Andreas is active, low indices were observed. So, even the San Andreas Fault is one of the most active faults in the world actually. So, even then the comparatively or we can say relatively low indices were been observed on this two faults because this was the higher indices were related or were correlated with the 1971 earthquake.

So, further what it says that this all system (()) (23:55) the fault system is strike-slip fault system usually characterized by narrow valleys with crushed rocks which can be easily eroded in the valley which results into low stream gradient index. So, one has to be careful again because you have to be, you need to understand that what type of faulting is also we are looking at actually.

So, this is a strike-slip fault system, San Andreas Fault System is a right lateral strike-slip fault system usually characterized by narrow valley. So, this portion is moving in this direction and this portion is moving in this direction along the fault and so and so on. So, that will result into the crushing of rocks and which are narrow valleys which can be eroded very fast and this can result into low stream gradient index. So, this was the part of the gradient index here and the higher one was been found over here.

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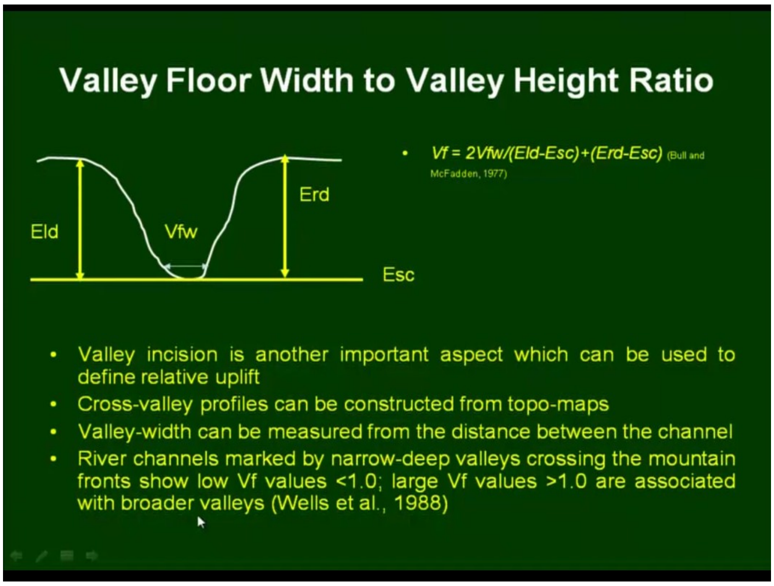

So, valley floor and valley width ratio, again another important parameter, which one can use high resolution topographic maps or high resolution satellite data and one can easily identify the areas under active deformation and this is again important because in most of the areas heavy, if we are we are going ahead with the construction and all that, we need to understand that which area is under the influence of the active deformation.

So, this is a simple cross-section. So, previous slide we were talking about the longitudinal profile where we considered the elevation and the distance between the source and the mouth whereas here we are just putting the cross-section of the channel. So, this is the valley floor here and these are the 2 banks, so you have the right bank and you have the left bank. So, you take the parameter here that is the width of the channel.

Then, the elevation of the right bank and elevation of the left bank with respect to the depth. So, you will get an elevation here of the channel floor and you will get the elevation of with respect to that of your east riverbank and right and left riverbank. So, either the expression or the equation which you can use to calculate this is Vf, Vf is valley floor ratio is equal to the 2 Vfw valley width by Eld, Eld is this one, the left bank minus Esc is the elevation of the channel bed plus Erd is the right bank minus Esc.

So, valley incision is another important aspect, which can be used to define the relative uplift. So, relative uplift will result into the change in the channel profile or you can say basically the change in the gradient or channel floor elevation. So, change in the gradient will definitely affect the incision and it will result into the formation of different landforms also. So, cross-valley profile can be constructed from topo-maps or high resolution satellite data.

Valley width can be measured from the distance between the channel. River channel marked by narrow-deep valleys crossing the mountain fronts and mountain fronts are associated to some extent, most of the time they are associated with fault at ranges. So, shows low Vf value less than 1, large Vf value greater than 1 are associated with broad valleys.

Now, if we consider this values, so what we should see is that most of the places where the river is crossing the active mountain front or seismically or tectonically active mountain fronts, then they will have narrow valleys and the values will be close to or less than 1 but if the Vf value is greater than 1, then it will be marked by broader valleys.

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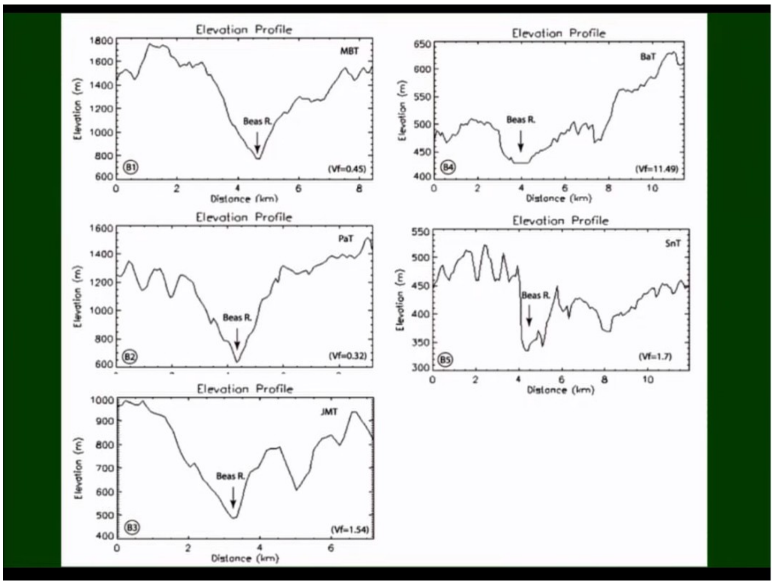

Now, this exercise with that where along the Beas River and the data which we extracted was from the satellite topographic radar mission data SRTM data where we got the DM and based on the digital elevation model we extracted this information. So, again what we have here is the cross-section of different channel and what we did was that we took the cross-section of channel where the river was crossing main fault system.

So, this MBT in Himalaya is main boundary thrust and this is the local or we can say the branching out fault of MBT Bursar thrust. Then, we have Palampur thrust, then we have Soan thrust and then we have Jwalamukhi thrust. So, what you find here is that most of the channels, which are crossing this fault system, are showing V-shaped valleys. So, if you see this one here, V-shape you see along Palampur thrust.

So, river flowing across MBT shows V-shaped valley, river flowing across Palampur thrust show V-shaped valley, river flowing across Jwalamukhi thrust shows V-shaped valley. However, river flowing through across the Bursar thrust shows broader valley and this is also comparatively broader Soan thrust. So, what we see now because we have this right bank, left bank, we have the elevation of the channel floor and we have the width of the channel floor.

So, all these information you can just track and what you find here is you carefully look at that Vf value is 0.45, Vf value here Palampur thrust is 0.32 whereas the Vf valley here is 1.54. Now, relatively wider than these two, relatively wider whereas if you move here quite wide and what Vf value you are getting 11.49 and this here so Vf value here is 1.7 keen wide.

So, this exercise clearly indicates that these two fault system and even this one but these two compare to the rest is quite active whereas this is also relatively active than these two but these two are not so active and this is quite showing very less activity because of higher Vf values. So, one can do this exercise along with the mountain front, sinuosity and faceting triangular facets, percentage of triangular facets and also do the exercise with SL.

So, what we will do is we will try if time permits. I am not promising right now but if time permits, then we will try to design 1 exercise and you will perform the lab experiment on this actually. So, will try our best and let us move ahead and see what we found here is.

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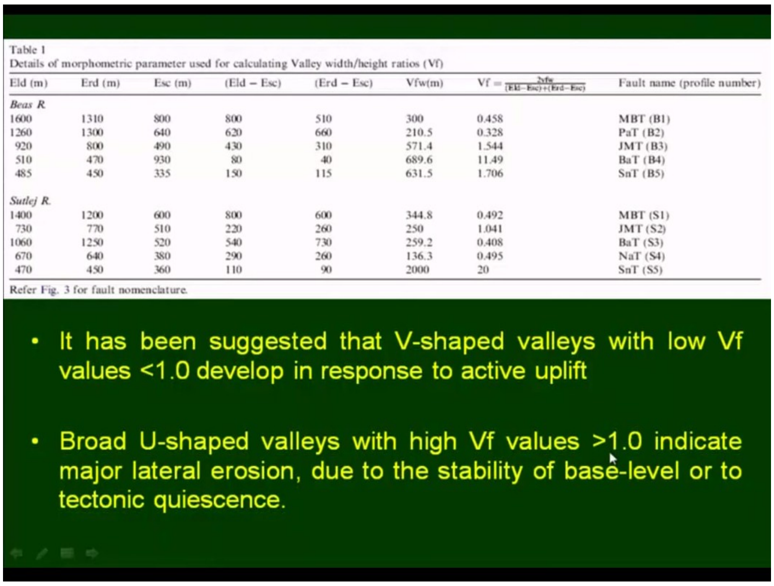
Table 1
Details of morphometric parameter used for calculating Valley width/height ratios (Vf)

Eld (m)	Erd (m)	Esc (m)	(Eld − Esc)	(Erd − Esc)	Vfw(m)	$Vf = \frac{2Vfw}{(Eld-Esc)+(Erd-Esc)}$	Fault name (profile number)
Beas R.							
1600	1310	800	800	510	300	0.458	MBT (B1)
1260	1300	640	620	660	210.5	0.328	PaT (B2)
920	800	490	430	310	571.4	1.544	JMT (B3)
510	470	930	80	40	689.6	11.49	BaT (B4)
485	450	335	150	115	631.5	1.706	SnT (B5)
Sutlej R.							
1400	1200	600	800	600	344.8	0.492	MBT (S1)
730	770	510	220	260	250	1.041	JMT (S2)
1060	1250	520	540	730	259.2	0.408	BaT (S3)
670	640	380	290	260	136.3	0.495	NaT (S4)
470	450	360	110	90	2000	20	SnT (S5)

Refer Fig. 3 for fault nomenclature.

So, this is the table which shows the details of morphometric parameter used for calculating valley width, valley height ratios Vf. So, as I was talking about that we have Eld, Erd, so right and left bank and then we have the Beas river, this is in meters, so elevation, then the base of the channel and then we have the based on the equation what you have used you can have the parameter and then we have the Vf that is the width of the channel here.

And these are all the fault names which are been given here and the values which we got was this one here. So, even some places the value was almost 20. So, this area is inactive. So, it has been suggested that V-shaped valleys with low Vf values less than 1 develops in response to active uplift. Broader U-shaped valleys with high Vf values greater than 1 indicates major lateral erosion.

Because you have given enough time to the channel to migrate within the active valley, so that will erode sideways and result into the formation of wider valleys or you can say U-shaped valleys due to this stability of the base-level or to tectonic quiescence. So, no tectonic activity is taking place, the area has remained quiet for long period and there is unstability in the base-level.

Whereas here the uplift, the active uplift will not allow the base-level to remain stable. So, the base-level in this region is changing continuously and the river floor is getting rejuvenated again and again resulting into erosion and formation or development of V-shaped valley which gives the Vf value which range is less than 1 whereas here is stable base-level results into major lateral erosion resulting to formation of wider and U-shaped valleys and the values of Vf will be greater than 1.

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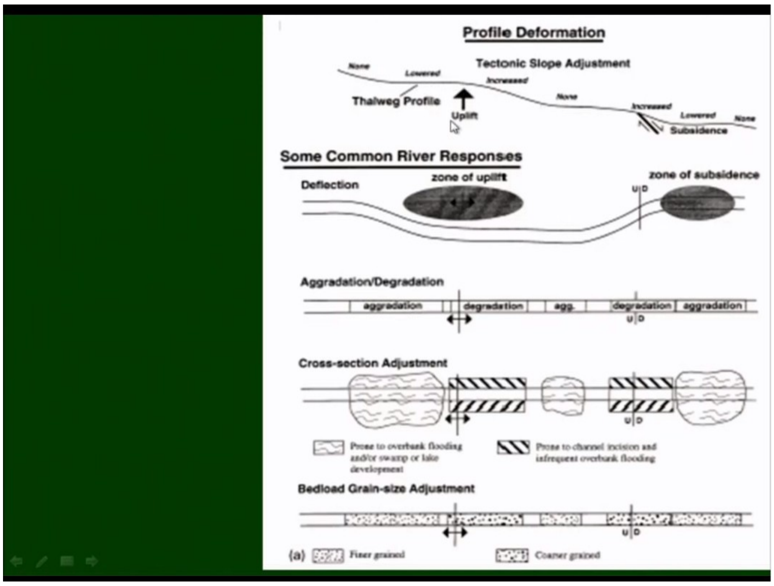

Now, these are few examples again which we have already discussed. So, I would like that you go through it and which can help you in identifying the local, the responses of the uplift and the subsidence. So, what will happen if you change, if you are having an uplift and you are having a subsidence along the journey of the channel which will result in profile of deformation.

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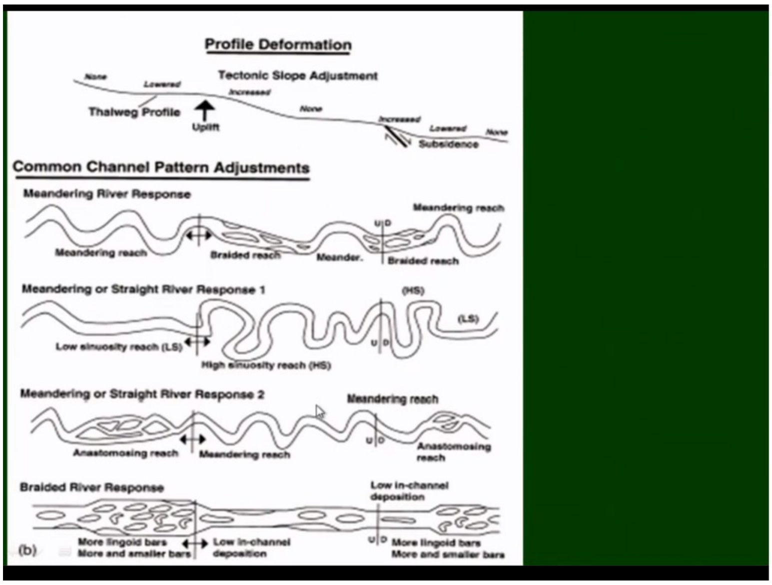

For example, you are having an uplift here, so you are using the base of the channel or the stream gradient here, you are increasing the stream gradient here whereas with the faulting what you are doing is you are increasing the fault gradient here. So, subsidence in this block has moved down. So, this will increase the channel gradient whereas here the upstream is lowered and this is increased.

So, common channel pattern adjustment if you have then what you see here is that it will change from meandering to braided and then meandering, so braided to braided and meandering. So, change and this is an uplift and down faulting here and this is the area of work which has been shown here. So, this will result into the change in the channel pattern and similarly if you are having straight channel, then the sinuosity increases.

And then the sinuosity decreases as we move in the downstream side. So, this is the up area and this is down area. So, if you remember this what we were looking in Himalayas where we are having the thrust fault. So, this portion is the wall is up and this is down here. So, that also will result into the change in the channel pattern and similarly over here. So, these are few examples which show with respect to the change in the elevation along the journey of the drainage.

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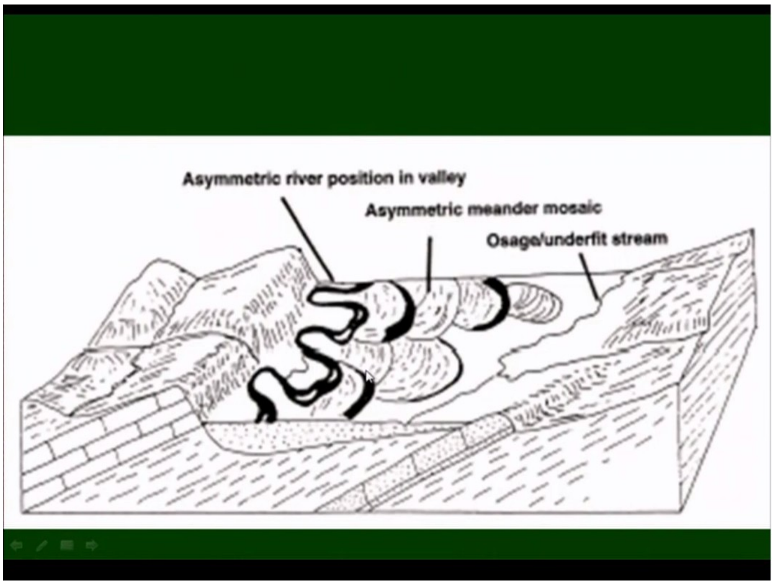

And just a last example that if you are having a regional tilting, then you will have the shifting of the channel which is also commonly observed in most of the region because of the regional tilting because of deformation. So, this is the last slide. I will stop here and we will continue in the next lecture, talk about the 2 examples from Himalaya and Kutch. Thank you so much.