**Earthquake Geology: A tool for Seismic Hazard Assessment**
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**Lecture – 49**
**Tectonic Geomorphology (Part – I)**

Welcome back. So in previous lectures, we discussed about the different type of channel pattern and drainage pattern. So let us look at that what the channel pattern has to tells us about the tectonic signatures on the surface. In branch, this is again a sub branch of earth sciences where we study the morphology of the surface and if the surface morphology has been carved or sculptured by tectonic activities or they are influenced by the tectonic activity, then this branch we term as in tectonic geomorphology.

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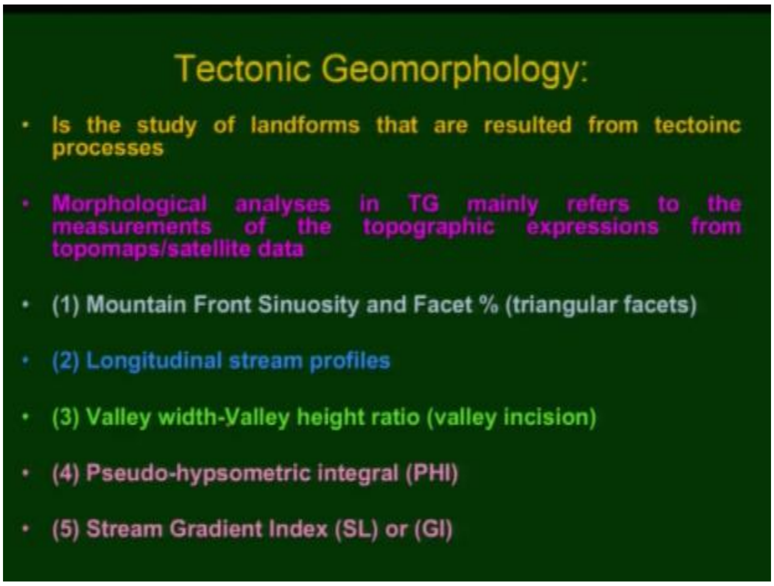


So, tectonic geomorphology is the study of landforms that are resulted from tectonic processes. Morphologically, this tectonic geomorphology mainly refers to the measurement of the topographic expression from topomaps and satellite data. So, mostly we try to extract the information from high-resolution satellite images as you have seen in one of the slide where I was showing that how we were able to identify the warped area as well as how we were able to pick up the change in channel pattern and that was related to the tectonic deformation.

Then, we have some parameters which one can study and try to identify if the area is tectonically active or we can also differentiate in terms of whether the area is more active or less active based on the parameters here. First is your mountain front sinuosity and the facets, so mainly we call as triangular facets and what are those we will discuss in the next coming slides. Then we also look at the longitudinal profiles of the different streams which helps us in looking at if there is any warping or subsidence and the area will be reflected in the stream profile.

Then we also take into consideration the valley width-valley height ratio where we mostly look at the valley incision and the shape of the valleys, the amount of tectonic activity in particular region. Pseudo-hypsometric integral is again related to the stream profiles and then amount of incision in the area. Then we also talk about the stream gradient index, what we call as a SL index. So let us see one by one. So we are not going to get into the details of all, but I will try to talk about few of this in this lecture.

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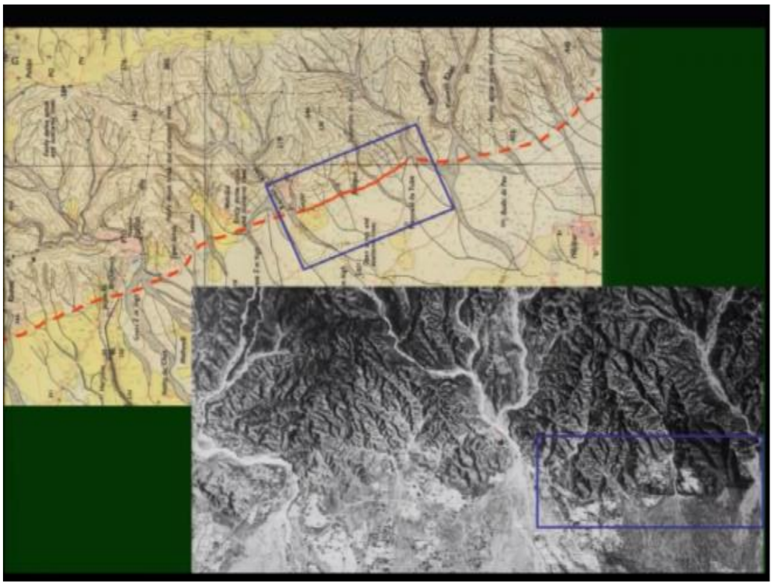

So as I told that one can extract the information from the topomaps and the high-resolution satellite data, so topographic maps usually have been prepared from the high-resolution aerial photographs or satellite photos and what we see in terms of the information on the topographic maps are the drainages and we have the contours which talks about the elevation in the area with respect to mean sea level. So if you look at these contours here, this is like 400 meters and then reduces further down.

Some locations the contours are very closely spaced, whereas if you move towards the, side then you are having very widely spaced contours. So, this is 400 and this contour which goes as 340. So this is 340 meters. So the next contour here is your 360, this is 380, and then 400.

So interval between these contours is 20 meters. This also tells us about that since these are the widely spaced contours and these are closely spaced contours, this clearly indicates that in this area the elevation change is very rapid, rapid in the sense in a very short distance okay.

Whereas here, the elevation changes covering a very wide area, so that is like 340 here and 380 here, it is the elevation is changing very gradual whereas here it is changing very sudden okay, so sudden in the sense, because of the closely spaced contours. So this marks the mountain front whereas this marks the flat plain area. So as we move away from the front, then the spacing between the contours increases and the scores like 340, 320 and 300 and so on. So, one can also make out that there is a change in the elevation here.

So if you take the cross section here, so you will be able to see something like this okay. So there is a sudden change here and then it becomes slightly flat okay, so I will put it like this okay because it is sloping like this okay. So you have the slope, very gentle slope, but here you have very sharp change in the elevation. So this marks the front and this area is from again Northwest Himalaya and this portion we picked up as an active fault scarp. If you compare this with the satellite data, so this portion is over here this one and this portion.

So if you compare the stream here, this is the stream which goes this one. Based on this, one can easily pick up the topography of any particular area and this portion as I told is this one here. So you have the small stream which is coming here and then you have a flat area over here in this portion. So the stream basically is, yeah okay, this stream is reflecting this one here okay, this joint.

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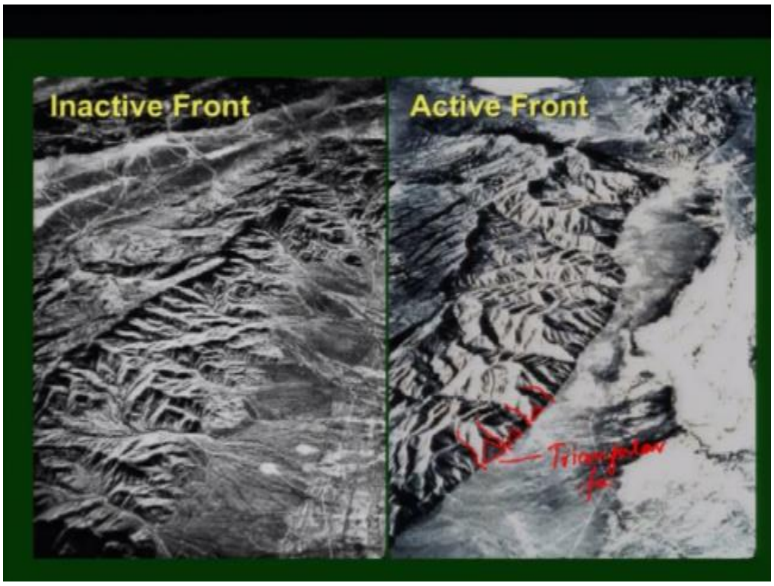


Difference between the active front and inactive front one can easily make out based on these 2 aerial photographs where you are having a very sharp front here and you have a diffused front in this area. So this shows an inactive front and this is active front. So sharp demarcation and geomorphic features also help us in identifying preliminary identification or interpretation that the area is active, and in the next coming slides, we will talk about the triangular facets, but here I would like to show that if you have the what we call the triangular facets on which are indicative or active front, this is what will be coming across.

So, typical triangles will be seen along the active front, okay. Now, these are the features which are formed because of the erosion of the drainage on its either side, okay. So the streams are flowing across this one here and these are this triangular facet. So in some locations, you may come across multiple triangular facets, so these are typical of what we were talking about the triangular facets.

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So again coming back to the area from Northwest Himalaya, so this portion what you see this the well-planned city Chandigarh and the mountain front is sitting here, very sharp contact between the hilly terrain and the flat hilly region. So this is your upper Siwalik or sub Himalayas and this portion is your Indo-Gangetic plain.

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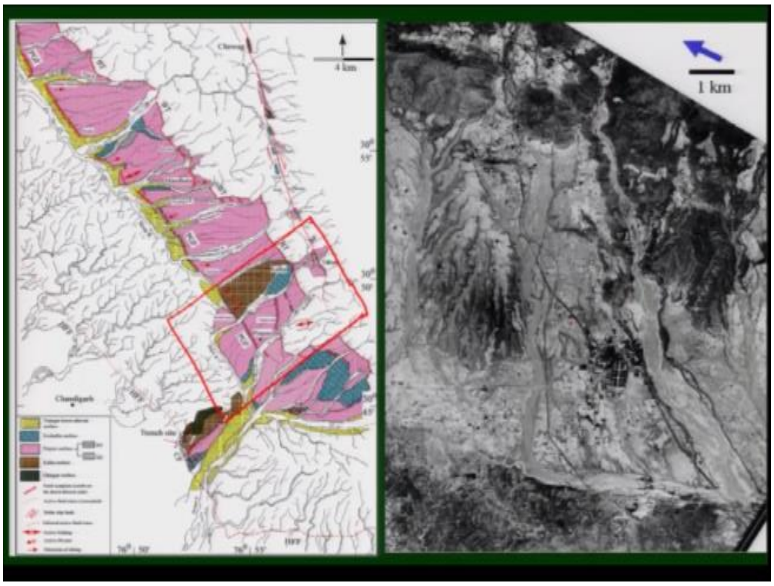


So, this also I have discussed in one of the lecture that how we can demarcate the active falls and how important it is to identify the different landforms and those different landforms have been displaced by the single fault okay. So here, we also discussed about that this area shows the displacement of multiple terraces along the same active fault, hence it indicates that this fault has remained active since the evolution or the formation of this terraces, whereas this fault has displaced only one surface but also along with that an older surface.

One can easily use one of the way to identify the older and younger surface, if you can see this for photograph is like this channel if you compare, is here this one, this is the channel okay. So this photograph is showing the portion somewhere over here okay, like this. I am roughly marking it, but yes of course. So this channel is here this one and this meets somewhere over here, so the fault passes through this area. Now, what we have marked in this map is you are having a younger surface and you have an older surface.

So, if you see in the lagend here this is the Kalka surface here which we have marked with hatch lines and then the brown color and then pink color with dotted symbol is showing Pinjore surface. So, we have the fault here. Now how and on what basis we say that this is an older surface because the older surface definitely was exposed to erosion more as compared to the younger surface. Hence, it will show much more dissection as compared to the younger surface which you can see here okay.

So this is an older surface and this is younger surface and also if you view this in 3D, then you will find that this surface which is more dissected as compared to this one which is older one is at greater elevation as compared to the younger surface which is less dissected.

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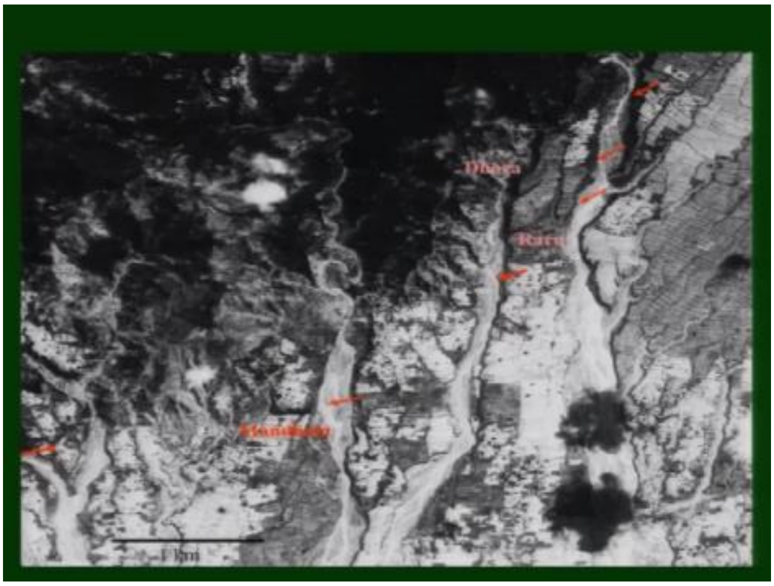

Then this also we discussed in one of the slides the back tilted surfaces and all that. So these are all features which we can take into consideration as the features which are helpful in identifying the tectonic activity.

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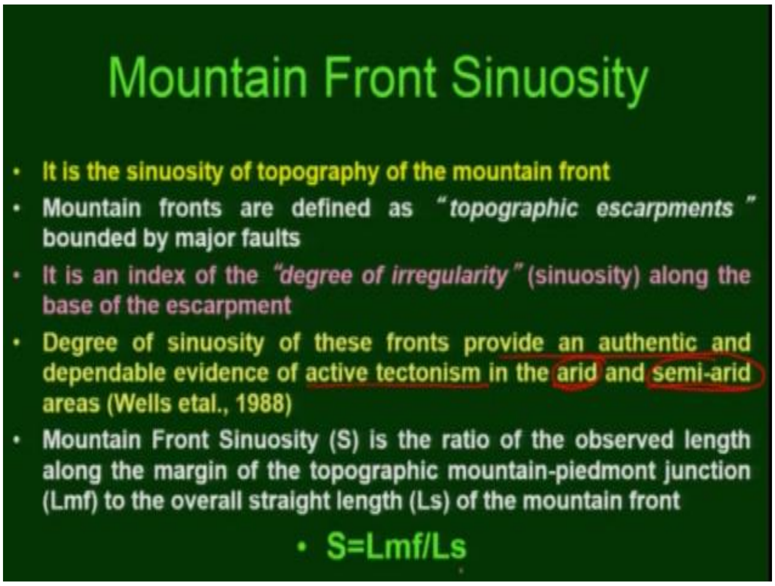


Now coming to the mountain front sinuosity, it is the sinuosity of topography of mountain front, okay. Mountain fronts are defined as topographic escarpment bounded by major faults. So, you have an escarpment like this, so if I put in 3D, then you have an escarpment here. So this is an escarpment here. So, this escarpment will be bounded by fault here and it is an index of degree of irregularity that is your sinuosity. So as we were talking about the sinuosity of the channel similarly here, we talk about the degree of irregularity of the escarpment, so how irregular the front is okay.

So, suppose we have a very straight front and this is the portion of the drainage which is going on, I am drawing the plan view and some places we are having a very irregular front. This front is less active as compared to this one because it is less irregular whereas this is more irregular. Now this is again indicating the amount of erosion, so more erosion, less erosion. So this means that this area has remained active but this area has remained inactive and was subjected to more erosion. So that also one can interpret based on the irregularity or the degree of a regulatory or sinuosity of the escarpment.

The degree of sinuosity of this front provides an authentic and dependable evidence of active tectonism in an arid and semi-arid areas because in the areas where we are having high rainfall and the river systems are more dynamic, then the erosion will be very fast and we will not be able to see very sharp fronts. So, we will have more irregular fronts in the humid regions. So the technique what we are using mountain trends to identify the tectonic activity usually provides a very authentic results for the areas with arid and semi-arid climate.

The mountain front sinuosity is the ratio of the observed lengths along the margin of topographic fronts that is the junction what we term as in piedmont junction and it has been given as Lmf to overall straight length Ls of the mountain front. So if we take the mountain front here, then we give this as an S is the mountain front sinuosity which shows the ratio between Lmf that is the topography of the mountain front and the overall length. Let us how we are going to identify Lmf and Ls okay.

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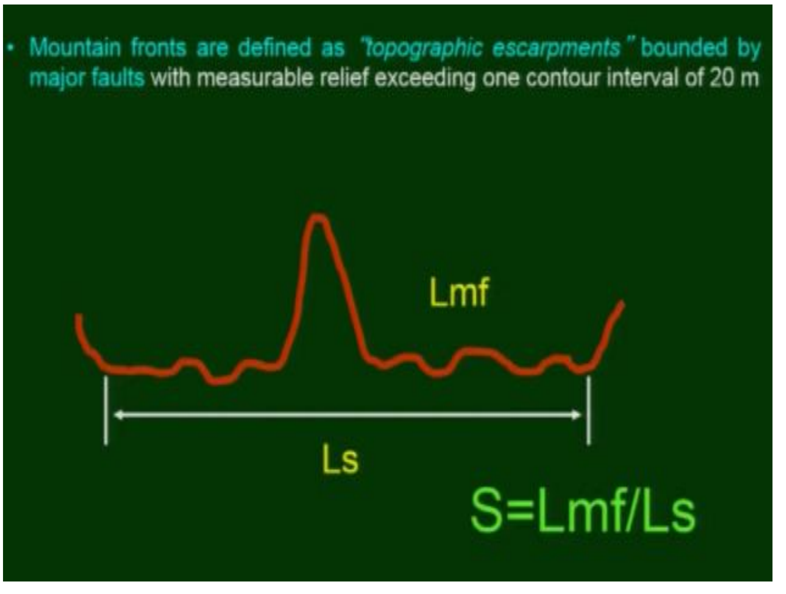


So you have this front which you can extract from the topographic maps or the contours or we can generate digital elevation model using stereophotos, mainly the satellite photos, and you generate DEM and then you extract contours. So this will also help you in extracting the mountain fronts okay. So one is your what you take is the straight length your Ls and then this one is your Lmf okay. So the ratio is your S is the mountain front sinuosity, so you have the length measured here of the front and the straight length.

Now, this ratio will tell you whether the area is active or not okay, and as I told that you need to keep in mind that whether this is more erodible or less erodible. So in terms of the more erosion, then you will have higher length, whereas if you are having less erosion then you will have lesser length of Lmf. Mountain fronts are defined as topographic escarpment bounded by major faults with measurable relief exceeding one contour interval of 20 meters.

So this you can identify on your topomaps or if you have extracted contours from the digital elevation model prepared from your high-resolution satellite photo with stereovision capabilities.

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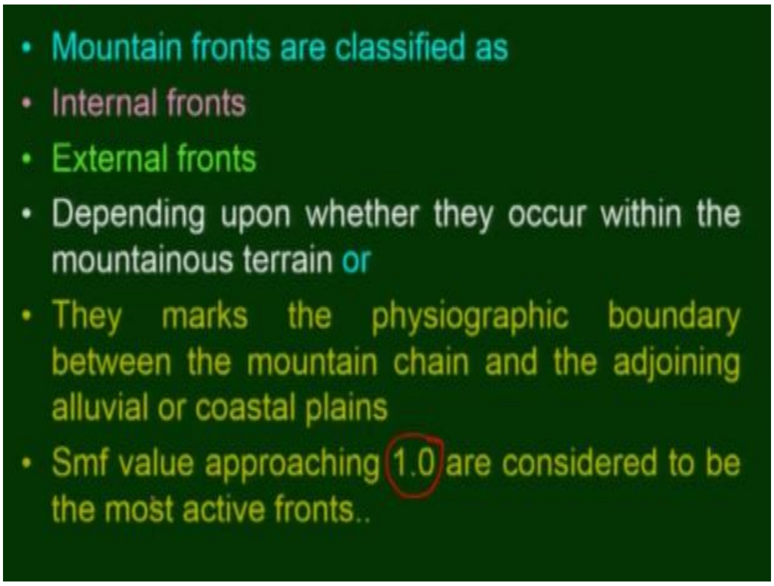


So mountain fronts sinuosity are classified as internal as well as external fronts because not only we will be able to see the mountain fronts in the frontal part but we will be able to identify the hinterland side also. So depending upon whether they occur within the mountain terrain or they mark the physiographic boundaries between the mountain chain and the adjoining alluvial or coastal plains. So these are the locations where you will find the external mountain fronts, okay.

Now Smf value approaching 1, this is important okay are considered to be the most active front. If we take the Smf values approaching 1, we consider that as the most active front.

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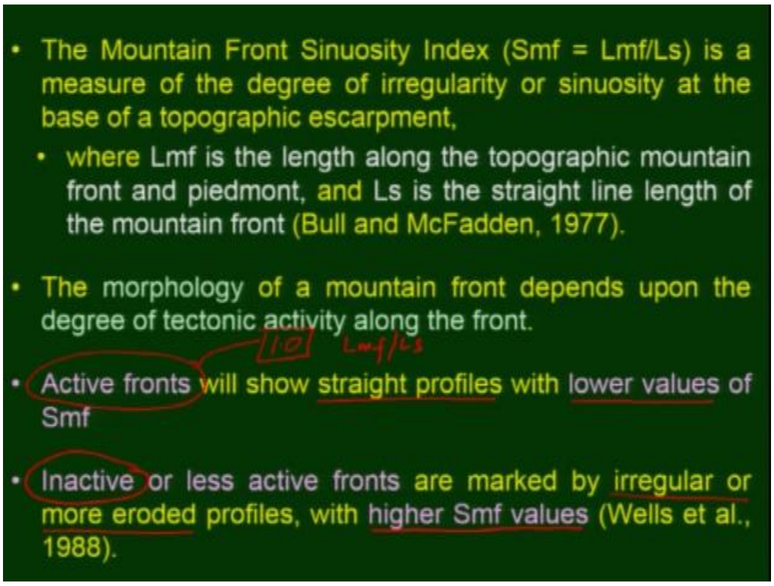


The mountain front sinuosity index is the measure of degree of irregularity, this is what I was talking about that if you have more erosive fronts, then they are indicative of less activity, okay. So where Lmf is the length along the topographic mountain fronts and piedmont and the Ls is the straight length of the mountain front. The morphology of the mountain front depends upon the degree of tectonic activity along the front. Active fronts will show straight profiles with lower values of Smf, whereas it will be exactly opposite for the inactive fronts okay.

Inactive fronts or less active fronts are marked by irregular and more eroded profiles okay. So, this you will keep in mind that active fronts usually will show the values approaching to 1 that is in ratio, that is the ratio between Lmf and your Ls okay, so it will be in straight profile with lower values, where as the inactive fronts will have irregular more eroded profiles with higher Smf values, okay. This is the important point which one has to keep in mind when we are calculating the mountain front sinuosity.

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Now, facets as we discussed that it will show on very sharp fronts and the triangular facets which I was showing in the previous slide, the same slide here. So these are the triangular facets. So they are defined as the triangular facets are the polyhedral shaped hill slopes, so you have the hill slopes here, that lies between two adjacent drainages along the mountain front escarpment. So this is your triangle here and there between two adjacent ranges, okay. Tectonically active fronts display prominent large facets that are generated by recurring faulting events okay.

Otherwise, you will not be able to see such sharp fronts within prominent triangular facets.

That means that the front is less dissected, again this you can correlate with the values which you have obtained from mountain front sinuosity, but there also we were talking about the amount of erosion or dissection okay. Less tectonically active fronts contain fewer and smaller facets, means more dissected fronts, because of development of more drainage across the front.

So, in that such areas you will have mostly the more dissected fronts, so you will not have very distinct and sharp fronts available in an inactive area. So, these are the two comparisons which you can do with the mountain front sinuosity and the facets.

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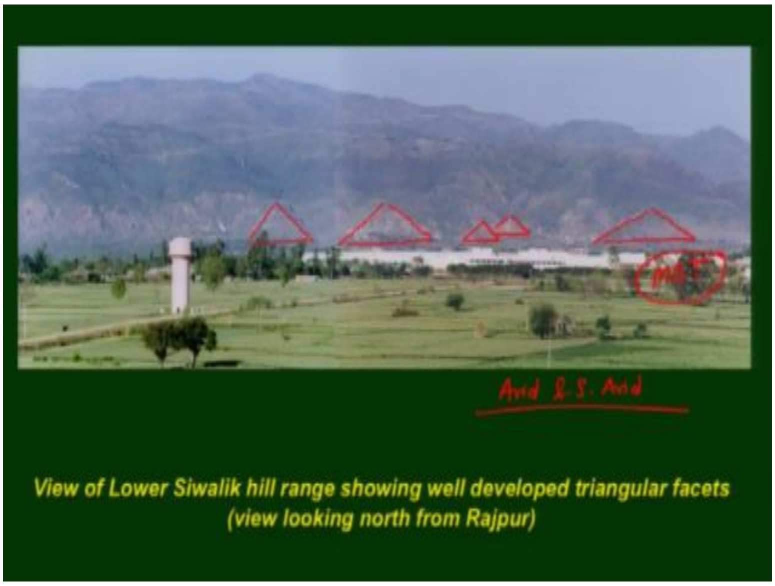


Now another part which we were talking about that mostly the triangular facets will be seen in arid and semi-arid regions, but what we found in Himalayas which again fluvial dynamic is very different than the arid and semi-arid areas where the fluvial activities very intense here but then also what we were able to pick up is a very distinct triangle facets. You can see this, these are all very distinct triangular facets along the front and this fault is your main boundary thrust in Northwest Himalaya. So, we were able to see in some location multiple facets.

So with this, we were able to indicate that it is not always that we will be able to see the triangular facets in arid and semi-arid regions, but also in the areas where we are having high rainfall okay. So view of the lower Siwalik hill showing well-developed triangle facets and this is along the main boundary thrust, NBT.

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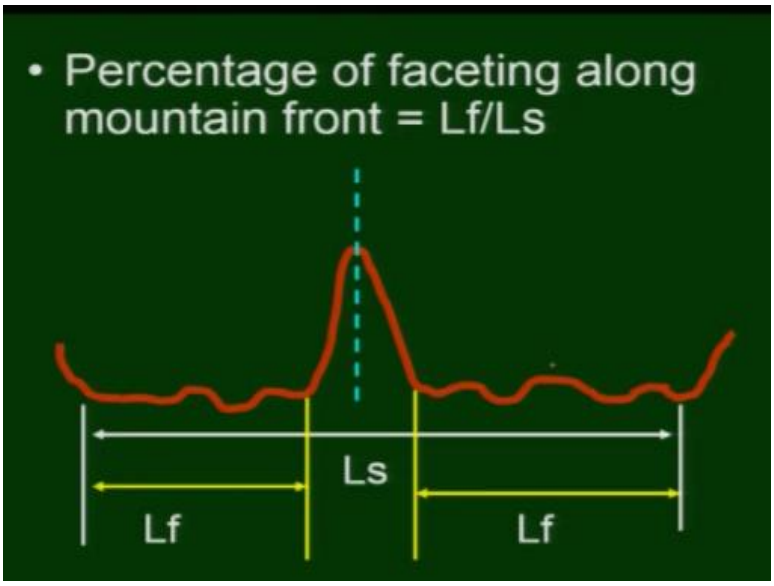


So about the triangular facets what you can do is you have one of the parameters which we were taking about the Ls that this traced length of the mountain front and you can have the divide here between the drainage and then you can have the left front and the right front and that can give you the percentage faceting, okay. So with the help of again Lf by Ls, you will be able to calculate the percentage of eroded fronts.

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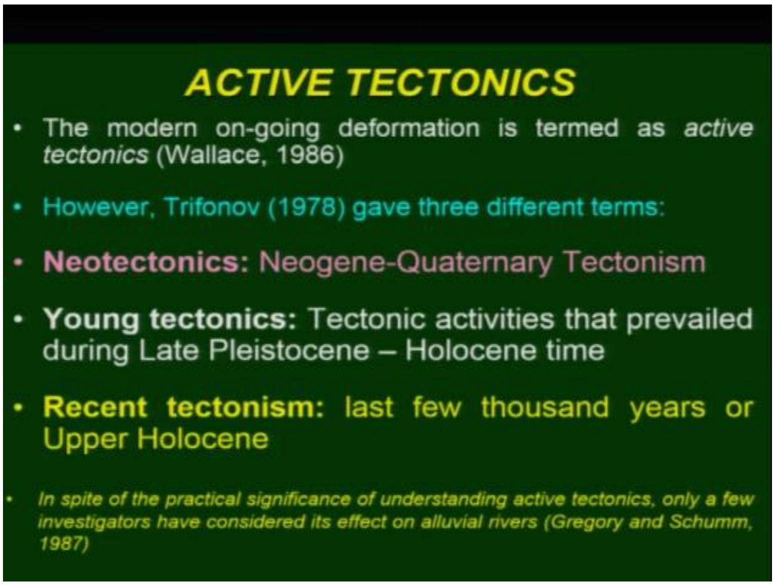


Now, active tectonics and rivers morphology. This is again the part which we were talking about that how best the drainages can tells us about the surface features as well as the influence of tectonic activity. Now active tectonics, the modern ongoing deformation is termed as active tectonics. However, Trifonov, he gave 3 different terms. One is the neotectonics where we call the Neogene-Quaternary tectonism that has transition phase between the tertiary and quaternary.

Then we have the young tectonics, tectonic activities that prevailed during late Pleistocene and Holocene time, and then we have recent tectonism which is continuing of course in the Holocene but in the upper Holocene part okay. So you have last few thousand years or upper Holocene, the activity has been termed as the recent tectonism. In spite of the practical significance of understanding the active tectonism, only few investigators have considered its effect on alluvial rivers okay.

So mostly we try to look at the signature of tectonism in hard rock okay and we try to talk about that if there is a shear zone or faulted stratas or faulted rock stratas or sediment layers, but even the surface morphology if you carefully study it, it can tell you a lot about the ongoing tectonic deformation. Alluvial rivers are very sensitive and they can talk about the past history of the tectonic activities as well as climate change, okay.

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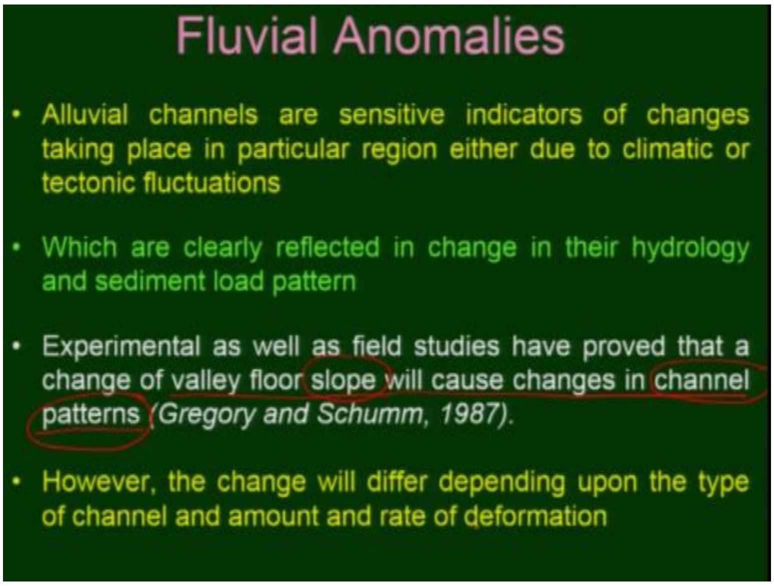


So, let us see a few examples of this. If you look at the fluvial anomalies, what we see is the alluvial channels are sensitive indicators of changes taking place in a particular region either due to climate or due to tectonic fluctuation. So as I was talking that these signatures should be taken into consideration when we are talking about the deformation in the regional scale as well as on the local scale. So, this clearly reflects the changes in their hydrology and sediment load pattern.

Because if you are having the different climatic phase, then that will definitely going to effect the hydrology of a particular channel and even if you are having tectonic fluctuation it is going to affect the hydrology of the channel as well as the bed load of that particular basin okay. So, experimental as well as field studies have proved that the change of the valley floor slope will cause changes in channel patterns. So as soon as you change the channel slope, you are going to change the channel pattern.

So, this part will try to look in detail in the next lecture, but further however the change will differ depending upon the type of channel and amount of and rate of deformation, okay. So type of channel whether it is straight, meandering, or braided that will affect the next change downslope or in the upstream side, but this part we will talk in the next lecture. So, I will stop here. We will continue in the next lecture. Thank you so much.