Geomorphic Processes: Landforms and Landscapes

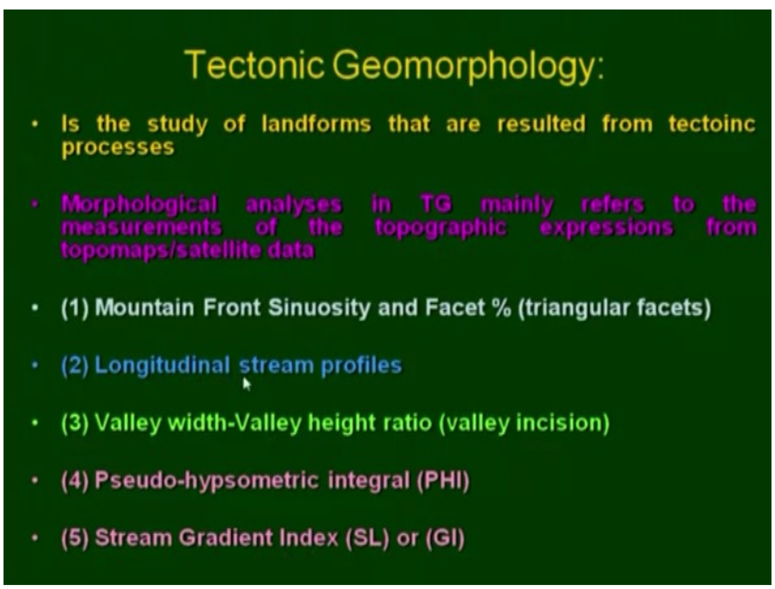
Prof. Javed N. Malik
Department of Earth Sciences
Indian Institute of Technology – Kanpur

Lecture 24
Tectonic Geomorphology (Part 1)

Welcome back. So as I told that in this new lecture, we will start with a new topic. This topic is of course related with the fluvial geomorphology, but this portion in which we are going to talk, we will mainly talk about the tectonic geomorphology. So tectonic processes are mostly related to the ongoing deformation because of the plate motion and this, basically the landforms which we are going to talk about, are influenced by the tectonic movements.

And how we can decipher or infer the influence of the movements along the fault lines over the weak zones. So any deformation, which is taking place between the 2 plates, the deformation is manifested on the surface and the most affected part of the surface will result into the formation of different drainage pattern. So the fluvial drainage or the fluvial system are one of the common features, which will be influenced by tectonic deformation. So let us see the tectonic geomorphology and discuss more in detail.

(Refer Slide Time: 02:12)



So tectonic geomorphology is the study of landforms that are resulted from tectonic processes. Morphological analysis in tectonic geomorphology mainly refers to the measurement of topographic expression from topomaps or satellite data. So the surface manifestation because of the influence of the tectonic movement, one can easily extract the signature from high resolution satellite data and this can help you in identifying the relatively active areas in terms of the deformation and that can be taken into consideration for better seismic or hazard assessment.

Why I am saying seismic, because any deformation, that is ongoing deformation within the plate or along the plate boundaries will result into the earthquakes. So the plate boundaries and within plate boundary, if it under deformation, of course along the plate boundary, the deformation is ongoing, that causes or triggers the earthquakes. So earthquake is not the process, which will keep happening everyday.

Of course, the earthquakes along the plate boundaries keep happening everyday around the world, but along with particular plate boundary, major earthquake, which are the damaging earthquakes will occur in the recurrence interval of almost like 400-500 years, or more. So morphological analysis in tectonic geomorphology mainly can be done by the measurements using topographic signatures from topographic maps and again topographic maps means, we are talking about very high resolution topographic map.

So for example, we can use maybe 1:10,000 or 1:5000 or 1:25,000 and so what you can measure from the satellite data or topomaps is mainly the mountain front sinuosity or facet. We can also term this as triangular facet. So these all are what we are going to discuss are the tectonic geomorphic features. Then, you can also talk about, as I told that the fluvial system are very sensitive to tectonic processes.

So longitudinal profile as we looked at this portion, when we were talking about the drainage basin, so if you have, if you say the longitudinal profile, then longitudinal profile is the elevation and the length of the channel or the drainage. So mainly if you take this, the longitudinal profile, that can also help you in understanding the ongoing deformation. So this will result into the local base level change and local base level change can affect the drainage basins or the drainage system.

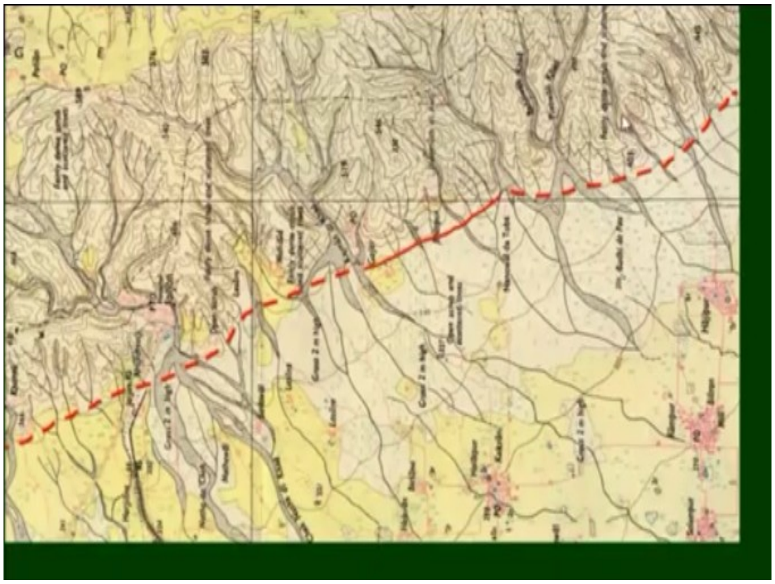
Then third is valley width-valley height ratio, so this parameter can also help you in understanding that whether the area is active or inactive. If the area is active, then the terrain or the valley will remain in a very youthful state. So youth state what we will see as mostly the incision of the valley will take place and will always deliver a very young features like gorges or deeply in size valleys. So you will have narrow valleys and if you are having less activity area, then you will have.

That is activity means we are talking about the tectonic activity. Then, the influence will be less and you will have wider valleys. Then fourth is pseudo-hypsometric integral. So what are all these parameters, we will see one by one and then the SL index or stream gradient index can also help you in deciphering or identifying the ongoing deformation. So these all parameters or the data which you can generate is related to, all the parameters listed here 1 to 5 are related to the fluvial system.

So mainly, you put basically the landforms, which are associated again the drainage are influenced and this type of landforms have been carved. If you say the mountain from the sinuosity again, the sinuosity will depend again on the drainage, which are evolving from the mountain and flowing across the uplifted mountain fronts and the facets are also developed there. So we will see one by one and then longitudinal profile, valley width-valley height ratio, pseudo-hypsometric integral.

This is again related to the longitudinal profile and stream gradient, is again also related to the so and so this. All parameters are related to your fluvial system.

(Refer Slide Time: 08:52)

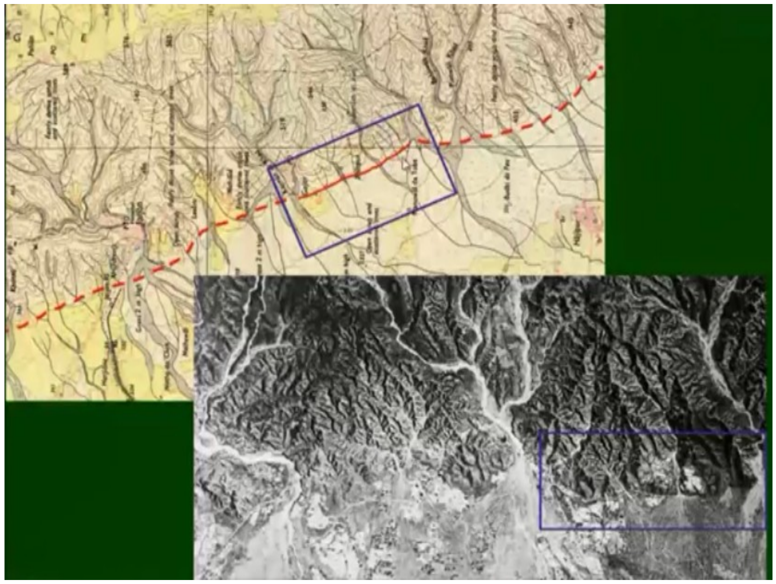


Now if you take the topographic map, this topographic map is from Himalaya and 1:50,000 map. So what it shows is that these are the, one can easily make out or identify what is the terrain in this region based on the contour spacing. So if you see here this is the boundary where the contours on the upper side, the contours are closely spaced, whereas you move or leave this point and move towards down, then you have widely spaced contour.

So one contour is here and another is here and third one is here and the contour interval what you see here is you are having around 240, then you are having this one as less than that and then you have over here. So here the contour are wide spaced. If you move towards this side, this marks the closely spaced contour. So this indicates that these are the hilly terrain and this is more or less flat surface.

So if you look at the boundary, this is the boundary marked here and this portion the bold line indicate the active fault, whereas this one is indicative of the inferred fault lines and this marks the contact between the sub-Himalayas and the Indo-Gangetic plane.

(Refer Slide Time: 10:39)



So this is the photograph of the same area where this channel, if you see, where I am moving my cursor, this one is over here. So this channel is this one here and this one is this channel, and this one is this channel here. So this contact or the meeting point is this one. So the boundary which you see here is between the Indo-Gangetic flat and the rugged terrain or the hilly terrain. So one can easily make out if you have or you study the topographic maps.

So this portion you see, an active deformation signature. Of course the fault continues here also, so this area is also under deformation, but some signatures, which helps us in studying better the mountain fronts and all that and even one can classify that this region or this portion is comparatively deforming at the higher rate as compared to this one.

(Refer Slide Time: 11:52)

So relative deformation can also be identified. Then comes the active front and inactive front. So these are inactive front where you can see the boundary or the contact between, it is almost eroded. The front is eroded or if you have a very sharp contact and you have, this is what if you talk about, then this is the triangular facets. So triangular facets are also indicative of active fronts and sharp boundaries.

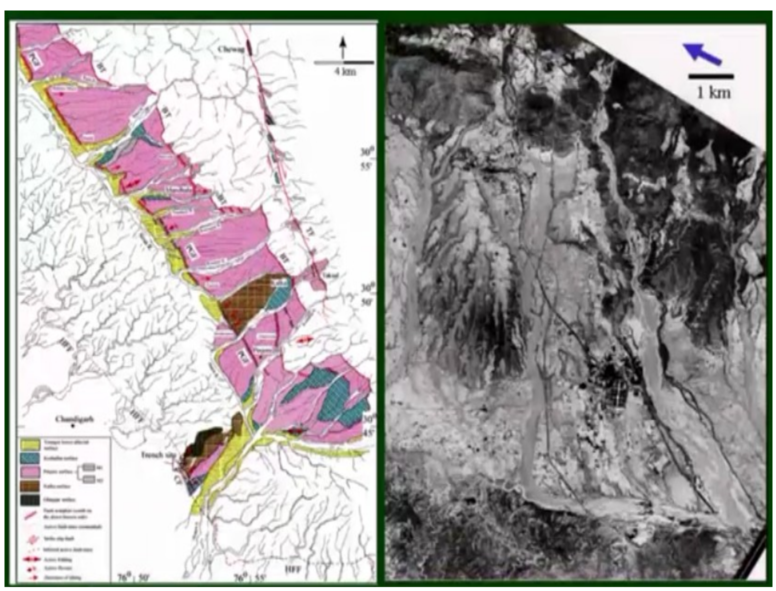
So sharp geomorphic boundary between or contact between the hills and the plane areas or indicative of active fronts. So this is active region in terms of tectonic deformation, whereas this one is an inactive where you see a sort of subdued activity. Of course, there is change in the elevation at this point and you see the formation of alluvial fan, so similarly over here also, but relative deformation if you look at, this is inactive and this is active.

Because this is much more sharp and the terrain remains or we can say that the tectonic movement result into rejuvenation of the terrain again and again and keep the terrain active or the incision will keep taking place and erosion is very fast as compared to this region.

(Refer Slide Time: 13:21)

So again if you see this satellite photograph a very sharp front or the contact between the sub-Himalayas and the Indo-Gangetic plane and this is the area close to Chandigarh, which shows the sharp front and this portion is one of the most active region in Himalaya and that is your Himalayan front and the fault line, which marks the boundary between the Siwalik Hills and the Indo-Gangetic plane is turned as Himalayan frontal thrust.

(Refer Slide Time: 14:01)

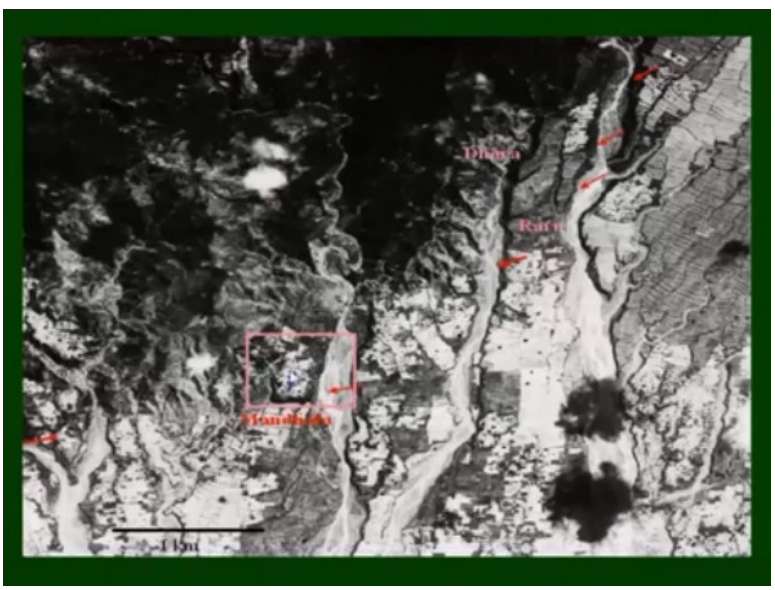


So another signature, so what we usually do is, that try to identify the active features or tectonic geomorphology. Based on the tectonic geomorphological studies, we tried to identify the active feature, which are tectonically formed and marked and prepare a detailed map. So what this includes is all the fluvial geomorphology. So the colour which have been marked here of different are the terraces. So different terraces, this is the oldest one, so much higher terrace.

And then you have the younger one, as you move closer to the river channel and all these parallel drainages here, this is what you see is the dendritic drainage and the contact between the hills and the plane area. So this portion is the Indo-Gangetic plane and these are the hills and in between two hills, that is over here and here you have the dun valley. So this is termed as inter-mountain valley, which lies between two mountain ranges and the line over here, which has been marked with combs is indicative of active fault.

So this side is along this, the terraces are displaced. So one side has gone up, that is this side has moved up as compared to this one. This is a hanging wall and this is the foot wall. So such fault lines have been marked are weak zones on the surface are marked based on the displacement of the alluvial surfaces. So terraces or the older flat planes are displaced along the fault.

(Refer Slide Time: 15:58)



So again another signature, so in the previous slide, if you look at, then you have in this region in particularly what you see over here, so the drainage which is flowing this is the same drainage, which takes on here. This is the same drainage, which takes on here and then you are having the major stream, which is flowing. This is the same stream, which flows. This point where the two channel meet is this one here on the satellite photo.

So the fault which has been marked here, this one the PGF that is Pinjore Garden Fault, it runs through here displacing the older landform and this one is the older landform, which is marked by hatched surface. So this one is the older landform and if you see this, the morphology of the older landform as compared to the younger one, which has been marked in pink. Pink is the Pinjore surface.

Now pink is younger one and this portion, which has been termed as Kalka surface is the older and even on the satellite photograph you can easily make out that this portion of the surface, which is older Kalka surface is much more dissected as compared to the Pinjore surface, which you can see here and here, is less dissected. So this also tells about the morphology of the surface that the older surfaces will be more dissected as compared to the younger surfaces.

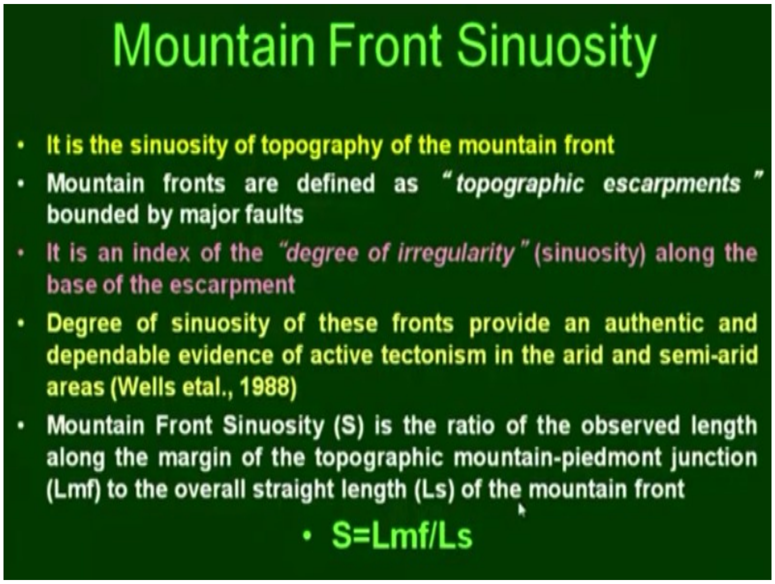
Why, because the older surfaces are subject to erosion since long as compared to the younger surfaces and the fault, which is marked here, this line passes through this one here and go ahead and another fault, which is marked here is this one. So this sharp feature, which you see is the fault which is marked here, another one is over here. So the next photograph, you will see in the next slide is the area from this region, which shows this portion as in back tilt.

So if you see this one, this is the portion which I had marked and then you have multiple faults over here. These are all faults or tectonically formed landforms and this portion is having the back tilt towards this side. So it is uplifted along the fault, which passes through here and this region and this is back tilted. So the arrow shows the location of faults of faults corpse, we can say. So this side down, this side is up and the arrow shows the direction of tilting.

So this is back tilted and in general, what we have been seeing is that most of the alluvial fans, which are formed at the base of the mountain front have the slope towards downstream, but this is having the slope towards upstream, which is usually not possible, but tectonic deformation can result into the development of such type of slope, which is we say back tilting, so tilting in the opposite direction.

So example of this in the field, photograph was taken from this bank to see the back tilting looking to this portion here, if you see.

(Refer Slide Time: 19:46)



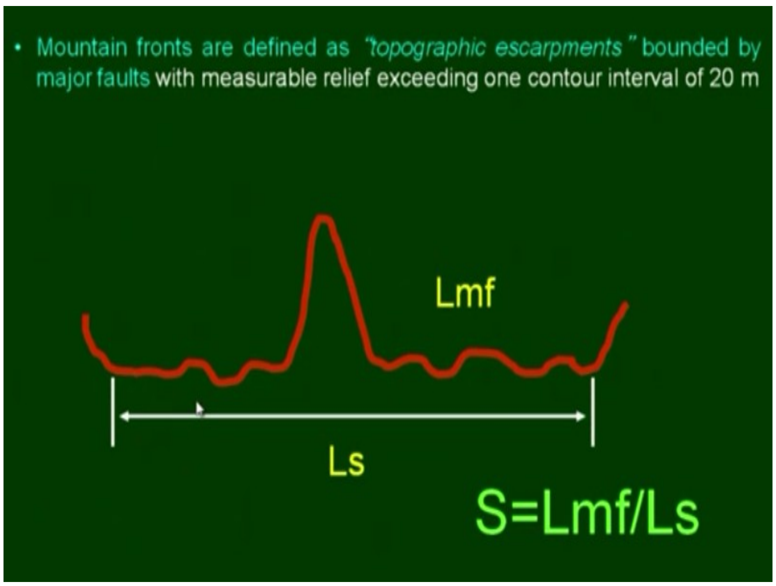
It has been shown in the next, maybe I do not have the photograph right now, but we can show it later on, but now coming to the mountain front sinuosity, it is the sinuosity of topography of the mountain front and the mountain front are defined as topographic escarpments bounded by major faults. So I was talking that mostly the mountain fronts if they are the active fronts, then the sinuosity will be different and what type of sinuosity one, we can see and the sharp fronts, we will discuss very quickly in the coming slide or the next slide.

So it is the index of degree of irregularity. So if you are having sharper fans, then you will have less irregularity or sinuosity or if you are having the highly irregular fans, then the erosion is more and that area has remained quiet for long period. So it is the index of the degree of irregularity sinuosity along the base of the escarpment. Degree of sinuosity of this fronts provide an authentic and dependable evidence of active tectonism in the arid and semi-arid areas.

But this was also true when we looked at the mountain fronts in the areas like Himalaya, which is very dynamic area in terms of the erosion and all that. So mountain front sinuosity S is the ratio of the observed length along the margin of the topographic mountain or the piedmont junction and so this is the ratio observed, length of the topographic mountain front junction LMF to the overall straight length LS of the mountain front.

So based on this, the ratio if it is close to 1, then you can easily say that the front is active. If it is higher values, then we can easily make out that the front is inactive. So this has been given as S is equal to LMF, LMF is the length along the margin of the topographic mountain-piedmont junction and the overall length LS.

(Refer Slide Time: 22:28)

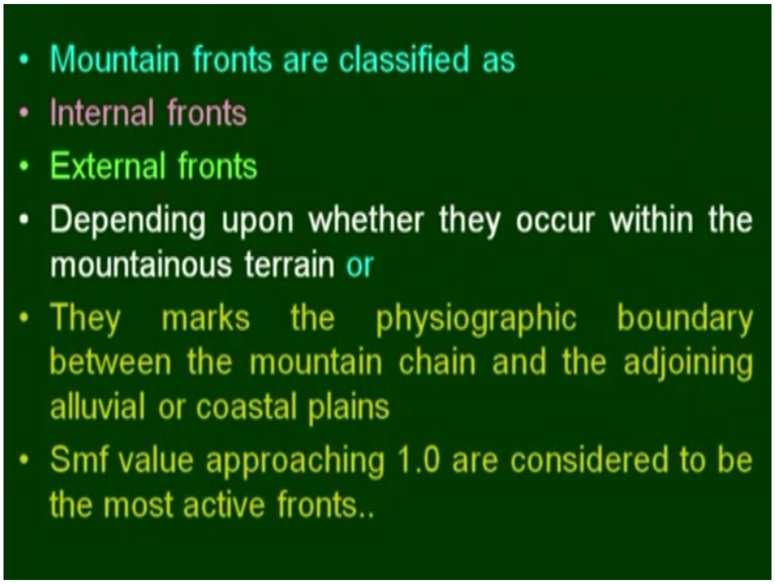


So if you want to measure this, this is the front here, so this is the mountain front and the mountain front sinuosity has been taken as this one. So this is your LS and this one is your LMF. So ratio between LMF and LS will give you the mountain front sinuosity. So mountain front sinuosity are defined as topographic escarpment bounded by major fault with measurable relief exceeding one contour interval of 20 meters.

So you have the 20-meter contour close to the front, if it exceed one contour interval of 20 meter, then you can consider those as mountain front. So these values can be extracted from topographic maps, but with a high resolution satellite data, one can easily extract such mountain fronts after digitizing the features on the satellite data itself and one can calculate using GIS and all that. So now the things have become much more easier to identify the active front.

But the straight identification or you can say the preliminary identification, one can also do based on the morphology. So if you are having a very straight sharp front, contact or geomorphic boundary between the hills and the planes, you can easily mark at least at the initial stage that this area is active area and tectonically active region.

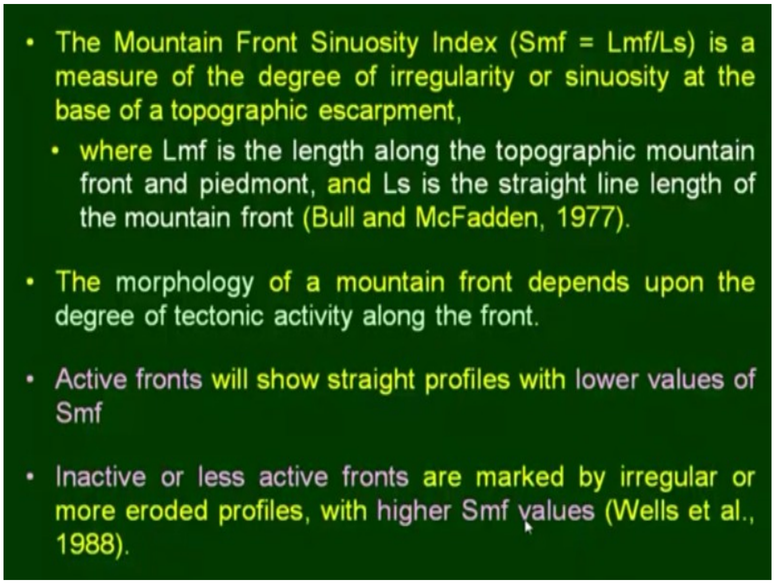
(Refer Slide Time: 24:16)



Now coming to the mountain fronts are classification, what you can see is if you can classify as an internal front, you can classify as an external front. Depending upon whether they occur within the mountainous terrain or they mark the physiographic boundary between the mountain chain and the adjoining alluvial or coastal plains. So one can mark the internal and the external fronts also. SMF value approaching 1 are considered to be most active fronts.

So this is important, which you can make out. So this exercise one can do it using topographic maps and satellite data. So if the mountain front sinuosity if you take LMF by LS, if the ratio is approaching towards 1, then they are the most active fronts as compared to the relative or relatively adjoining fronts.

(Refer Slide Time: 25:16)



So the mountain front sinuosity index SMF is equal to LMF by LS is a measure of the degree of irregularity or sinuosity at the base of topographic escarpment, where LMF is the length along the topographic mountain front and piedmont and 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 profile with lower values of SMF.

So that means that the values are approaching towards 1, so then those are active fronts and they will be very straight. So this you should remember. So straight profile, lower values indicative of active fronts. Inactive fronts are less active fronts are marked by more irregular or eroded profiles with higher SMF values. So this is extremely important point, which you should remember and based on the ratio, which you are getting either if it is approaching 1, then those are active and even if you see highly irregular fronts, so that indicates more erosion.

So time which has been taken by the erosion activity by the drainage is quite more. So no tectonic movement has occurred. If the tectonic movement is taking place, continuous ongoing deformation is there, those fronts will be more sharp and the values of the mountain front is close to 1.

(Refer Slide Time: 27:03)

Now coming to the facet again, these are close to the front. So the facets are the triangular to polyhedral shaped hill slopes that lies between 2 edges and drainages along the mountain front escarpment. So again if you are having a sharp front and you have a triangular feature, so these are the, what it says that facet, triangular shaped hill slope. So triangular shaped hill slopes, this is the triangle over here, hill slope, which exist between the 2 edges and drainages.

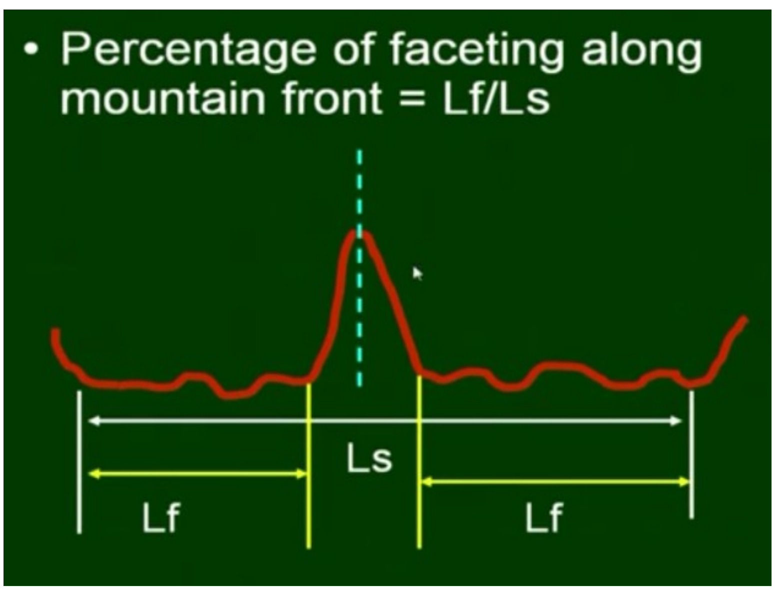
So one drainage is flowing here, another drainage is flowing here. So between the 2 adjacent drainages along the mountain front escarpment are termed as triangular facets. So tectonically active fronts display prominent as being shown here in this picture or the satellite image, large facets that are generated by recurrent faulting are then seen. That means, the front are less dissected. So they are less dissected.

If the dissection is more, that means more erosion is taking place and they are less active. So less tectonically active fronts contain fewer and smaller facets means more dissection of the front because of the development of more drainage across the front. So this is another parameter based on which one can identify the tectonic movement or this is one of the important parameters of tectonic geomorphology based on which one can talk about the tectonic movement in the region.

(Refer Slide Time: 28:58)

Now if you see the triangular facets, this is from Himalayas. So these are all the triangular facets which have been marked along the front of main boundary thrust and these hills, which you see is of less Himalayas and the foreground here is the Dun valley or the intermountain valley and the contact has been marked here by very sharp fronts in the region. So view of lower Siwalik ranges showing well developed triangular facets.

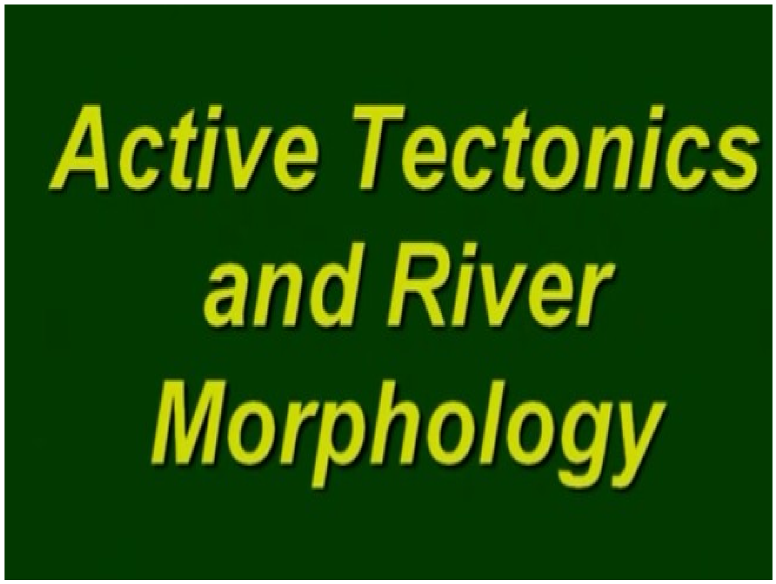
(Refer Slide Time: 29:34)



So triangular facets, one can also talk about the left hand side and right hand side, so percentage of faceting along the mountain front can be either left, this is the faceting index, so more erodability. So one can talk about the facet, that is LF/LS. So if you measure the distance between the left front and the right front and then the area, which is eroded in between, so that will give you the percentage of faceting along the mountain front.

So this data again can be generated where you have marked the mountain fronts. So mountain fronts same data you can use and calculate the percentage of faceting along the front.

(Refer Slide Time: 30:39)



Active tectonic and river morphology, so we can stop here and continue in the next lecture.