Plate Tectonics
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Week - 12
Lecture - 56
Neotectonics- II

Welcome to this class of plate tectonics. So, if you remember the last class, we were talking about the neotectonics and we discussed about this ambiguity of this definition, the time and space and the importance of studying neotectonics and particularly neotectonic studies are mainly for the societal use. And today, we will discuss about the evidences of neotectonic activities, how the tectonic activities which are going on can be determined and the tectonically adverse features associated with this can be identified and mapped and marked so that during this developmental project that area can be avoided. So, this indicators of neotectonics movement it says the fluvial system it is the dominating the pioneering agent in determining the neotectonic activities and followed by the ravines, the mountain front sinusity or the mountains and these tectonic scarps. So, here you see in this name of fluvial systems, there are number of points like river terraces, longitudinal river profile, stream length index, valley width to height ratio, basin tilts. So, just I have mentioned few of them.

However, if you search in the web or any literature, you will find number of parameters nowadays people using to determine the neotectonic features or neotectonic activities. For example, if you see this two figures here in the right hand side, the first one you see this is the mountain which is rising by thrusting and these are the Piedmont area and this is the plain and it you can say it is the replica of this, Ganga Foreland basin This is the Himalayas and this is the Piedmont area and this is the Ganga basin. What is happening is this is the exposed thrust you can say this is the MFT though this is not MFT just for understanding. So, I am saying it is the MFT and some of these thrusts parallel to the MFT they are concealed within this plain and in the Piedmont region.

So, now increase the time after some geological time, now you see this thrust which was earlier at this level so that means this much depth below now it is close to the surface. Similarly, this thrust earlier which was of this much depth now it is again it is near about close to the surface. Then addition to that two new thrust have been developed. So, now the question arises what is its utility? So now you see the fluvial systems how they are behaving. Earlier the Piedmont was up to this level and the rivers or the channels which are moving from here, now you see the channels they are modified.

So that means with the growth of this fault these channels are being modified and this modified channels they are just indicator of this growing faults. So, that means I can say when the fault is growing it is affecting the fluvial system and the fault growth it is related to this tectonic activities or neotectonic activities. So that means the fluvial system is responding to the neotectonic movement actively and mostly these channels these particularly the smaller channels they are responding very precisely as compared to larger channel. For example, suppose in the Ganga plane we have number of large rivers like Ganga, Yamuna, Ghagra, Kosi, Gandak like this and addition to that there are few tributaries which are very smaller in size. Now suppose we are putting a fault just across those rivers.

So, if this fault scrap is for example 1 meter say, so to this 1 meter this larger rivers they hardly respond to that. So their competency or the strength of these channels are so high that they can peneplain this 1 meter difference easily however in response to that this smaller rivers they try to readjust themselves. So that means I want to say these fluvial channels particularly the smaller channels in the plane they respond very precisely to this neotectonic movement and very accurately to this neotectonic movement as compared to the larger channel that does not mean the larger channels do not respond. So that means this fluvial characteristics like the river terraces, longitudinal river profile, stream length index, then valley-width through height ratio, basin tilt that we will discuss one by one and we will see how their implementation in detecting this neotectonic movement is there. For example, first let us start with the river terraces.

Terrace as we know it is a step-like appearance and even in hilly terrain this terraces identification is very easy and in this alluvial plains generally this identification of terrace is become difficult. But still as I belong to this place IIT Roorkee, so I am taking the example of this river terrace which is actively present here. So, IIT Roorkee the main building or the main administrative building it is on a paleo-river bed and if you are moving just below it, and so you are getting a depression here this is linear so that means one step is here and further going down you will reach to this place again there is a step appearance and further there is a step-like this. So that means, if I see it in diagrammatic manner, so here this main building or this place is here and with time if you are going down and down you are going in steps and these steps are nothing these are the river terraces. So, once upon a geological past a river which is called Solani which was flowing here and this is the abandoned Solani river bed and due to upliftment due to tectonic activity due to upliftment the Solani river is migrated around 2 kilometers or so.

So, now this Solani river is flowing here and this earlier course it is abandoned at steps and these are the terraces. And there are number of terraces you will find in the hilly terrain particularly if you go to the Himalayan terrain there are number of terraces associated with different rivers and some of these terraces may be a tectonic origin and some of these terraces may be of climatic origin. But if you talk about the tectonic terraces mostly they are unpaired terraces. So, this unpaired terraces most cases they are of tectonic origin and that can be dated. There are different dating techniques available in the quaternary dating techniques.

So, through this dating techniques these terraces can be dated and the age and this height difference that can be used to determine the rate of upliftment or the rate of subsidence or the river migration in turn during the terrace development. So, here we have T0 surface that is the present day river bed and except that we have T1, T2, T3 that means 3 terraces are there. Similarly in continuing with that at other places also there are terraces available and those terraces that have been dated around 2500 and 1600 years B.P. So, that means I say that around 2500 years back the river was flowing here and then around 1600 years back the river was flowing here and now the river is flowing here. So, these time gap and this distance or this height difference you can use or people have successfully used to determine the rate of upliftment.

So, this unpaired terraces that is the tectonic terraces that suggest temporal activity of the Solani fault in particular in this case and there are number of faults in the Himalayas and the number of rivers they are cross-cutting those faults and those terraces which are available in the Himalayan terrain that can be dated and the rate of upliftment among the different fault segments that can be determined. And to exemplify this, this is Haridwar another case study. So, this is Chandi Devi temple and similar work has been carried out at the MBT too that is main boundary thrust. Now in case of Haridwar when we are talking about the Chandi Devi temple, so the Chandi devi temple was or it is here and the present day Ganga river is here.

So now, we have found 1, 2, 3, 4 terraces that means 4 terraces earlier Ganga was flowing here then due to upliftment this is shifted to this place, further shifted this place, further shifted and this is at present position. And this height difference between these 2 terraces and the age difference that is the dates available. So, this age difference and height difference they can be used to determine the upliftment in the region or along the

MFT or particularly the area of study or along the MFT or particularly the area of studies. So, this is not new thing that people in world over they are using this technique to determine the tectonic activity particularly the rate of upliftment activities in the tectonically active regions.

So, that we are talking about the terraces which are in the hilly terrains it is easy to find terraces. However, in the alluvial plains particularly if you go to this coastal plains or in the Ganga plain it is totally flat and identification of terrace may be difficult. In this case we use the remote sensing image and particularly the geomorphological features available on that to determine the different terraces. For example, if you see this is the Ghagra river which is flowing here and here we identified 2 terraces and the 2 terraces how it can be determined if you see the paleochannels the number of channels here in the older terraces it is less as compared to the younger one. Why because from the younger one the river has recently retreated.

So, earlier the river was flowing here and there are number of paleochannels and oxbow lakes that are present here and gradually when this river was here the same oxbow lakes were formed. However, due to increase of time due to Peneplanation process, due to anthropogenic activities, cultivation process now the numbers are reduced. Similarly, the degree of prominence it is decreasing from younger to older one. So, in the older terraces the number of paleochannels and number of oxbow lakes will be less and their prominence will also be less. However, in the younger channel there is number of paleochannel will be more and this degree of a prominence will also be more.

So, in this way these paleo-terraces can be identified in addition to that soil it is a very good indicator. We can study the soil properties in the older terraces you will find that this degree of development will be relatively more as compared to the younger one and provided that the parent material are same and particularly the alluvial plain like the Ganga plain the parent materials are like the alluvium sand and silt clay. So, it is more or less same. So, that is why the degree of development of soil here and compared to here it says the high degree of development it is representing the more time of exposure to the atmospheric system. So, that is why based on this geomorphic characteristics based on the soil properties we can identify different type of terraces in the alluvial plain particularly.

So, another example with this same river that is Ghagra and another river is here Rapti. and this is one fault that is Ayodhya- Dinkarpur Fault and this is Colnelganj–Balrampur Fault. So, now you see this abandoned floodplain of this Ghagra river gradually its width is decreasing and finally, ending here and similarly the Rapti it is also it is decreasing and decreasing is ending here and it is coinciding with a fault which is Ayodhya- Dinkarpur Fault and very peculiarity of this photograph is. So, here this value floodplain it was the left bank of this river similarly this is also left bank of the river. So, now if I am putting a stress from here so that means this tectonic block which is bounded by this fault it will simply tilt to this direction this is the direction of tilting and due to this tilting the river migrated from this place to this place similarly this river is migrated from this region to this place.

So, as a result once the river is migrating from its place it is leaving its old channel so these are the terraces. So, river terraces in the alluvial plain that will be of different than compared to this hilly terrain counterpart. Another is the longitudinal river profile. So, longitudinal river profile if you see it is concave up undisturbed longitudinal river profile it is concave up, but there may be slight convexity in between that depends upon the local base level that depends upon the fault that depends upon the bedrock perturbations like this. So, particularly I am talking about the alluvial rivers.

So, the long profile shows the gradient of a river as its journey from the source to mouth it spans the source of a river where it starts and the mouth where it ends. So, that means the longitudinal profile ideally it should be concave upward. However, within that concavity if there is a fault line so here local convexity you may find for example, you see overall it is concave upward, but within that concave there is a local convexity it is a fault. Similarly here there is a local convexity that is the lithology contact here that is dam that is a dam landslide or dam constructed here or artificial or natural. So, that means I want to say if there is nothing either artificially or naturally it that means no dam is there and no bedrock perturbations is there and no fault is there then ideally this longitudinal river profile should be concave up.

And otherwise if we are putting these faults this lithology contact this dam and then another thing is the river confluence, river confluence if it is there within that river profile so it may give you this local convex upward because huge sediment or contribution the other river or the tributary is there sediment contribution is there so local convexity may occur. So that means I want to say this longitudinal profile when you are using as a marker to neotectonic activity we must be cautious about whether there is a confluence or whether there is a bedrock perturbations, whether there is a lithological contact, whether there is a natural or artificial dam is there. If it is not there that means local convexity definitely it is indicating a tectonic movement. And some example from this Ganga basin it is given here. So here you see this is the Yamuna river this longitudinal profile and here you are getting this local convexity and this is the Mahendragarh-Dehradun fault MDF.

Similarly another river this is called Kirsuni river we are getting this longitudinal river profile local convexity is here and there is another local convexity is here but this is related to the confluence because here one river is moving and this is the Kirsuni river and this is the confluence and due to this confluence local convexity is there. So that means I want to see when there is no local convexity at all so that means it is an ideal and undisturbed longitudinal profile of a river. And similarly here there are different rivers in the Ganga plain that will be studied for this neotectonic activities and the different river terraces that has been identified based on this population of this paleochannels oxbow lakes present there and it is found the more populous oxbow lakes they indicating very recent abandonment of this plain and gradually it fads out with time. As we have discussed the confluence, bedrock perturbation and fault systems they provide local convexity to this ideal concave of longitudinal profile of rivers. Then another parameter that is called the stream-length index.

So, stream-length gradient index SL index otherwise it is said it is the parameter that is frequently used to highlight the presence of anomalies in the area of intense fluvial erosion as it is strictly related to stream power. So, how it is related to how it is calculated? The SL index can be calculated using the formula like this

$$SL = (\Delta H/\Delta L) \times L$$

SL is delta H by delta L into L. What is delta H? It is the change of elevation of this reach. For example, if you see here this is first reach, first point of study, this is second point of study and the elevation difference between these two it is called delta H. Similarly, delta L is the length of the reach that is the horizontal length of the reach and this is the actual length of this reach.

So, that means L is the total length of this channel to this point where the SL index being calculated upstream and the highest point of this channel. So, that means this is the L, this is the highest point and this is the point where we are calculating. So, this is the L. So, finally, we are getting SL index and SL index it is indicating that means whether this area is tectonically active or not active that can be calculated from that. So, the SL index remains approximately constant along a graded stream and variation in the SL index appears to be attributable to tectonics or to the structural and lithological control.

And the SL index highest value coincides with the knick points of the longitudinal profile. So, here if you see we have a knick point or this longitudinal profile. So, the SL index highest value will be here. Then another point it is called valley width to valley height ratio. So, we have a valley here and its width to height ratio that can be used as parameter for neotectonic activities.

For example, here this valley floor width to height ratio that is called VF it is defined as the index that is formula is here and this formula says that this

$$Vf = 2Vf\,w/\,(E_{ld} - E_c) + (E_{rd} - E_c)$$

where this parameters are just explained what exactly it means. And this utility of this parameter is that in the area deep and narrow valley shows the Vf value less than 1 and this valley can be classified as V-shaped valley and we know the V-shaped valley particularly the river valley and U-shaped valley the glacier valley. So, Vf value between 1 to 1.5 are indicate moderate to active region and Vf values greater than 1 can be classified at U-shaped valleys. So, particularly the tectonically active regions, so the valley shape will be different.

And here if you see the uplift rate can be calculated or can be interpreted from this Vf ratio. So, if Vf is less than or equal to 0.5 that is called high upliftment rate. So here it will be V-shaped value and if it is 0.5 to 1 that is moderate uplift rate and it is greater than equal to 1 it is low upliftment rate.

So, that means more upliftment rate more is the V-shaped approach. So, these are the ratios or the value with the height ratio that how it can be used in determining the tectonically active to inactive regions. Then another parameter is called basin tilt that means we are tilting the basin due to tectonic activities. So, once we are tilting the system, the fluvial system that means gradually it is taking asymmetric shape. So, here the asymmetry factor that is called the AF, it is widely used to evaluate the existence of tectonic tilting at the scale of drainage basin.

So, this asymmetry factor is defined by this.

$$AF = (A_r/A_t) \times 100 - 50$$

So, what is Ar and what is At it is explained here. Now, you see this is the right hand side of this channel, this is the total basin. So, here this right hand side is the area right side of this basin and At is the total area of the drainage basin. So, that is the how the basin is asymmetric or symmetric whether it is a longitudinal basin, this is a circular basin, this is oval shaped basin that can be calculated from the this basin tilt.

And if it is circular that means no tectonic activity, it is longitudinal more tectonic activities. So, the degree of tectonic activities particularly the neotectonic activity that defines the basin shape. Then another is the ravine. So, ravine is the landform that is narrower than canyon and is often the product of stream bank erosion and more erosion more activities. Why a river can cut deep inside? Because once it is uplifting.

So, when it is region is uplifting that means these channels are cutting deep inside incision is taking place. So, the ravines may or may not have active streams flowing along this downslope channel which is originally formed there. And the directional analysis of ravine orientation shows that the ravine trends are related to neotectonic activities along the older structural trends during Quaternary. So, that means the ravine's direction orientation it is indicating the structural trend or the fault trends.

Then another is the mountain front sinuosity. Sinuosity we have heard about the river sinuosity. Mountain front sinuosity that means how this mountain and this valley or the mountain and the plain they are interacting. So, that is called mountain front sinuosity and this can be calculated by this

$$S_{mf} = L_{mf} / L_s$$

So, what is this mountain front sinicity is the index and it is Lmf is the length along the edge of this mountain Piedmont junction and the Ls is the overall length of this mountain front. So it is similar to this sinuosity of channel and this is the mountain front, this is the called mountain front sinuosity.

And when we are talking about the fluvial system and we see this that the fluvial system is very much responding to this tectonic activities. So this fluvial system there are different types of channels or channel behaviour can be identified and those are very deterministic about this fault location and the activity of this fault. For example, in these four figures here the drainage system and the faults interaction are there and you can see these arrows of different symbol are given. One is convergent drainage. So convergent drainage when there is a fault and there is a high land which is separating or the fault is separating from high to low land there will be convergence of streams along the high lands.

Not all converging streams there indicator of fault, not all very clearly you should understand here. Whenever there is stream convergence you should not put your fault here. There are some specific cases and specific points where this convergence of stream there indicator of fault. Similarly, increase in sinuosity of channel. This channel sinuosity is increasing and across the fault there will be drastic change in the sinuosity and that can be used as a indicator of fault.

Then offset channels, the fault it is offsetting the channels and you can see from these figures there are whatever I am discussing here all these are examples are here. And then generation of new stream that means once we have a fault system and erosion will take place from here and new that is rills and gullies they start forming and finally, a new stream will generate from here and will deposit sediment from eroding from here and deposit will be here. So that means new stream generation, offsetting channels, increase in sinuosity, convergent drainage these are indicator of the faults particularly in the alluvial plains. I am not talking about the hilly terrain it is easy to identify faults in the hilly terrain. However, in the plain area particularly the alluvial plain it is a difficult task.

That is why these indirect evidences and with the help of this fluvial geomorphology we are capable of identifying this fault system. And when we are talking about a fault system in the alluvial plain, so this is a fault suppose for example 100 kilometre length it is just going, but that does not mean this 100-kilometre length fault it was formed at a single time at a single go. For example, if you see here this is the strata's gently dipping strata in the alluvial plain and the channels are flowing. Now this fault is gradually developing and now you see this is one segment, this is another segment and this is the third segment. So that means with time the segments are growing and finally one full fledged fault it is representing.

And during this fault growth now you see the channel which was moving undisturbed, so once the fault is coming across its path gradually its sinuosity is increasing. It is responding to this fault growth. And similarly this channel which was an independent channel earlier it is sinuosity increased here and with more and more growth of this fault it is not able to cross-cut this difference or this height difference finally it has to bend and it is meeting here. So that means here you see the river is offsetting and at the same time the channel earlier it was flowing here it is leaving a value channel here. So with time now you see all these channels they are merging together and this is the convergence point, it is confluence point.

So that means it is river convergence channel convergence for example here convergent drainage. So now you see we are getting a convergent drainage here and indicator of fault and when this fault growth at the initial stage there are just fractures that are distributed and with time the growth that is increases and with time they join together and a full-fledged fault is coming. So any fault you take so not necessarily the whole length of this fault it was formed in a single time at a single growth it is not possible. So that is why different segments or segment wise it was developed with time the adjacent segments they add with each other and finally a full-fledged fault system was developed. And another very promising indicator of fault particularly in alluvial plain it is called terminal fan.

You have heard about the alluvial fan, the submarine fan but terminal fan it is very less known to the geologist and it is a very promising indicator of fault. For example suppose we have a unconsolidated material alluvial I am talking about the alluvial or alluvial planes we have unconsolidated material and we are creating a fault here. So that means we are creating micro-relief difference and the sediments are unconsolidated. So erosion takes place from here and deposition takes place from here. So that means eroded material from this region are depositing here and forming a fan that is called terminal fan.

And this terminal fan why it is called because most of these channels they terminate around this fan that is why it is called terminal fan. Anyway so that means now see if I am putting a fault here so across this fault for example here across this fault there will be erosion in this upthrown block and there will be local that is deposited at the downthrown block. Irrespective of its nature of the fault either it may be a normal fault or it may be a thrust fault but erosion is taking place at the upthrown block and deposition at the downthrown block as fan that is called terminal fan. So this alignment of this terminal fan along a topographic break in the alluvial plain particularly there indicator of fault. And we know this fans can be dated with different dating techniques.

So that means these indirectly these dates that indicates the date of faulting or the time of faulting. So that is why in Ganga plain particularly this alluvial plain like this Ganga plain these faults have been identified and dated and the tectonic episodes or particularly neotectonic episodes have been established. Then tectonic scraps and linear mental analysis tectonic scrap if you see this field photograph this is the scrap and this is the fault scrap is here and this is the upthrown block and this is the downthrown block. So this much is the fault scrap. And the neotectonic activities along this fault might have got linear high scraps and the intensity and clustering of other similar and less extensive linear trend are suggestive of increased tectonic activities.

For example, if you see this geological map have different lineations they are clustered and their orientation it says this mostly this is the direction of this neotectonic deformation. Then this tectonic scrap it is easy to identify in the hilly terrain. However, in the plane particularly the alluvial plane it is difficult that is why we exaggerate it whatever this surface elevations we exaggerate it and due to exaggeration we are getting this type of micro relief difference and these are the indicator of fault. And very promising indicator is the soil as a geomorphic marker. The soil development as we have discussed gradually decreases with time.

So that means older soil that is showing high degree of development and the younger soil that is less degree of development. So a tectonic system or a fault system for example, it was active around 10,000 years back and across this whatever this sediment were deposited now they are representing thick soil development and is fault which was created around 2000 years back whatever the sediments are deposited with respect to this fault. So as the time is less so very less degree of soil development will be there. So that means the degree of development of soil it is indicating the fault or the time of its or relative time of its activities. And now you see we are talking about this fault system in the alluvial plain like that means we are talking about the surface faults.

So what about this fault which are lying below for example in Ganga plain we have number of basement faults, number of basement faults lying around 4 kilometre or 5 kilometre below the surface and they are also active with respect to Himalayan tectonics in response to Himalayan tectonics. So now the growth of the fault for example here a normal fault is growing at the basement so it is just affecting the overlying sediment and with time with these sediments are more affected and finally the surface we are getting a fault zone. So that means one fault at the basement it is creating a fault zone on the sediment overlying. Similarly in reverse fault movement same model with reverse fault so what we are getting at this stage these two images look alike.

So that means we are getting a topographic break only at the surface. So here it was a normal fault but here it was a reverse fault but their growth to the surface it is simply giving us a topographic break irrespective of the nature of this fault which is lying below. So that means looking at topographic break at the surface you cannot say it is related to a normal fault or related to a reverse fault and this reverse processes, the fluvial processes they behave to this topographic break. So this more the topographic break their behaviour will be accordingly. So that means I want to say just this reverse either it is a normal fault or it is a reverse fault at the subsurface they do not understand.

They understand only the topographic break at the surface. So thank you very much. We will meet in the next class.