Geomorphic Processes: Landforms and Landscapes

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

Lecture - 27
Tectonic Geomorphology (Part IV)

So welcome back. In last lecture, I promised that we will show you some examples from Indian subcontinent and then in particularly from India where we observed a very distinct and prominent signatures of the drainage which got affected because of the ongoing deformation and this is very true that the landscape evolution is not only just because of the climate which is changing but in total if you understand whatever the morphology we are studying or the geomorphology or geomorphological features we study on the earth's surface keeps changing.

And one of the major component which governs in terms of the sculpturing the landscape is the tectonics or we can say the plate tectonism. So, if you consider the formation of Himalaya is because of the plate motions where 2 plates have collided or one plate subtracted initially below the Eurasian plate that is the Indian plate.

So, I feel that there is a direct relevance of ongoing deformation which not only affect the change of river patterns or drainage on the surface, the landscape but also force the human settlements to transfer from one place to another place and such an example we will try to show you from Great Rann of Kutch. The Great Rann of Kutch is again one of the prominent geomorphic features on Indian subcontinent but we do not see such feature anywhere in the region, so it is one of its kind.

But if you look at that whether if you go back into the history or geological past, then you will try to understand that it was not having the same environment in geological past and even during the recent past if we can say and correlate it with the settlements, they may one of the major settlements which flourished or the civilization which flourished in this region. So, either we call as in Saraswati civilization or Indus civilization.

So, Harappans they state or they had the settlements along the Indus valley but now you see that most of the settlements are in ruins. So, one of the major settlement, which was identified from the Indian part was Dholavira. So, that part also we will try to show you the signatures

of the deformation and the reasons which were given by different groups including our group that one of the reasons for the decline of the Harappan culture or the civilization was because of tectonic activities in Kutch region.

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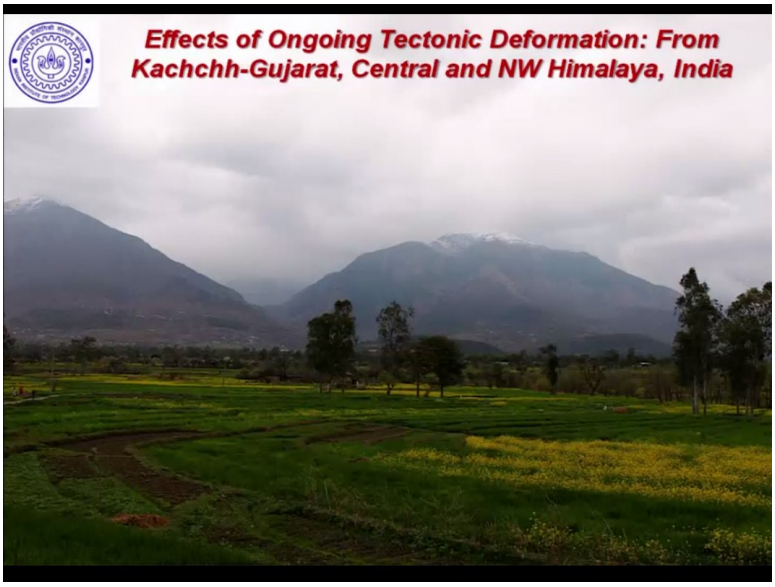

So, let us move ahead and see what we have with us. So, we say that the effect of ongoing tectonic deformation and then effect of ongoing deformation on the landscape evolution and the examples what we have is from Kachchh-Gujarat, Central Himalaya and the Northwest Himalaya. So, first we will try to look at few examples from Northwest and Central Himalaya and then we will have lecture on Great Rann of Kutch.

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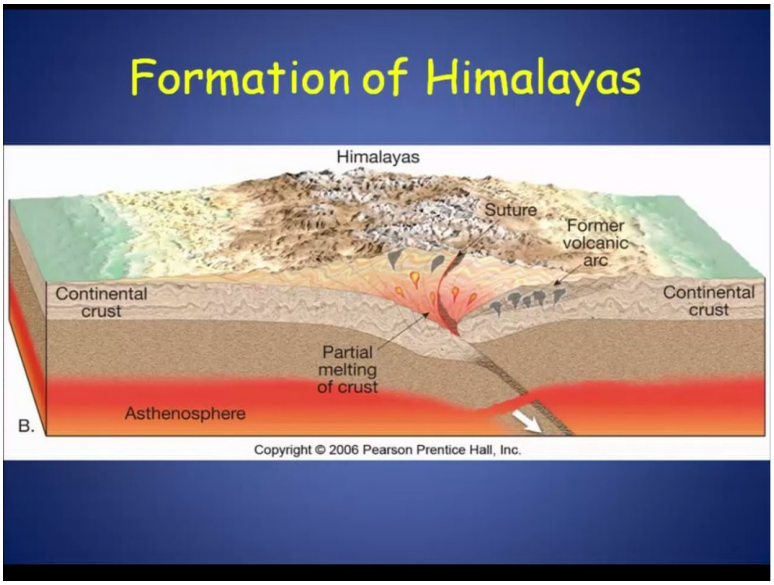

So, as we all now understand that the formation of Himalaya was because of the subduction and subsequently collision of 2 plates that is an Indian plate and the Eurasian plate and what

we see now is the towering height of Himalayas is because of the collision which is going on between the 2 plates and this is not only resulted into the formation of the fertile land in the frontal part or the foreland part of the Himalayas that is your Indo-Gangetic plain.

But also the topography and the monsoon which was the result of the towering height of Himalaya resulted into formation of major drainage systems. Now, the drainages which started flowing over the slope crossing the deformational structures where time-to-time modified or disrupted, diverted because of the landforms which were being formed related to the formation and that what we are going to discuss here.

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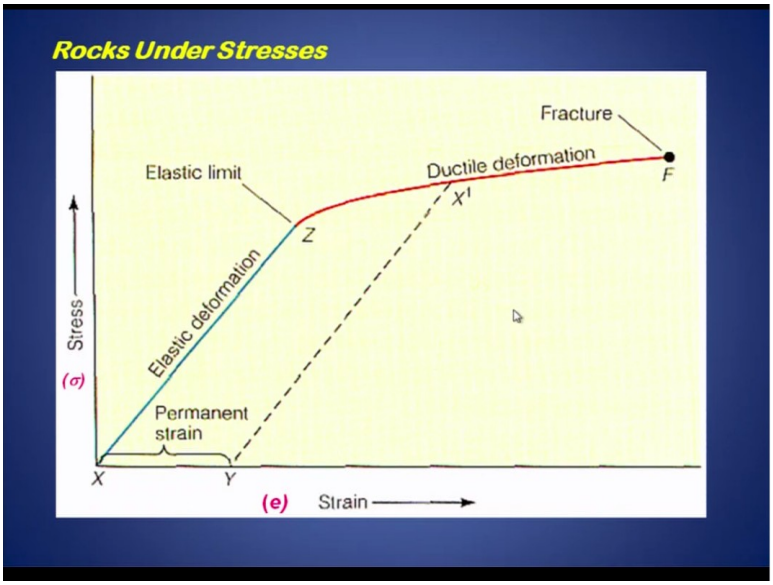

So, rock under stress usually what we see is that because we talked about that the 2 plates are colliding with each other. So, lot of strain has been developed between the or within the rocks of these 2 plates and the overriding plate which is coming from the Eurasian side if you remember the previous slide in which I was showing you the 2 collision plates colliding with each other.

Then, if you look at this one here, then what you see is these rocks which are been shown here are under tremendous pressure. So, lot of strain has been developed even this (()) (07:45) has been shown here both the side both the plates are under tremendous strain. Now, rocks usually so what you are doing is you are applying stress and that stress is coming from the 2 plates which are moving towards each other.

So, you apply, keep applying, the stress is constantly applied because of the movement of the 2 plates. So, the rocks have the elastic property, they can deform under the ductile deform like they can undergo ductile deformation and finally that they will break and this fracturing usually what we call is the earthquake. So, the strain which has been accumulated over the time because of this stress finally will result into the sudden release and this sudden release is your earthquake.

So, what we usually see that initially the deformation will get into the elastic deformation of the rocks and then get into ductile and finally it will fracture.

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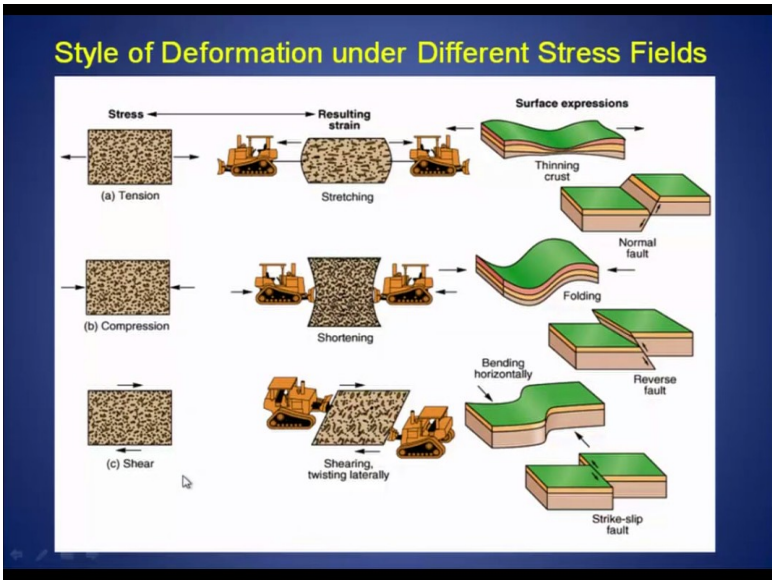

So, this process is ongoing and we see that whenever there is a fracture on the surface, it will result into the displacement and that displacement can affect or usually affect the geomorphic features or the landforms and most of the time the landforms evolve because of the displacements and the landform will get evolved or will be affected, the drainages which are flowing in that area will also get affected and that what we are going to understand.

So, for example what you see here is and this is some one of like the deformational pattern which is shown here or the style of deformation and the different stress fields. So, if you are having stretching of the plate that is even in the plate tectonics we were talking about that if the 2 plates are moving away from one another, so if you are stretching, then you will have thinning of the crust and the faulting which you will experience is termed as normal fault where one block will move down with respect to the stationary block on this side.

Whereas if you in the compressional deformation what we see in Himalayas basically, so we are losing out the area and we are having the shortening. So, Himalaya is growing and this is because of the folding of the material which I was showing in the previous slide where 2 plates are colliding and the rocks, rock layers are crumpled.

Now, finally when it breaks at the point at the critical point where it will and that will be where that will be the threshold limit of the particular rocks, then sort of reverse faulting will take place where one block will move up with respect to this stationary block on this side and if you are having the stress which is applied slightly oblique to the deformation direction like this.

Then, mostly the twisting will take place and twisting of the plate or the material will result into the faulting horizontally as well as the component of vertical movement will also be seen here and those type of faulting has been termed as or displacement are termed as strike-slip faulting. So, we have strike-slip faulting, reverse faulting and the normal faulting. So, in the coming slides we will be mostly looking at the reverse faulting and strike-slip faulting from Himalaya.

So, these 2 style of deformation persist nevertheless even tensional cracks are very common or tensional fractures or the faults are very commonly seen in Himalayas but this too under the compression and shear are the most common one.

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So, surface manifestation, this is the photograph of an active fault or the surface expression or surface manifestation of the ongoing deformation on surface. So, the displacements on the surface you will see something like this and this is what we call the faults scarp from California. So, this is also a part of tectonic geomorphology, which is important before the seismic hazard or earthquake hazard assessment.

In most of the areas, such features in most of the areas and not only in areas but in countries such features are on priority basis they are identified because to avoid the construction by mistake across this type of features because such features are having the capability of triggering earthquake and will move surely in future earthquake because the strain is developing and when sudden strain which is accumulated is released when we release along such weak zones.

And this weak zone will result into displacement and if such features are displaced then whatever the structures we have constructed across it will be destroyed. So, the important of identifying such geomorphic feature is also very important.

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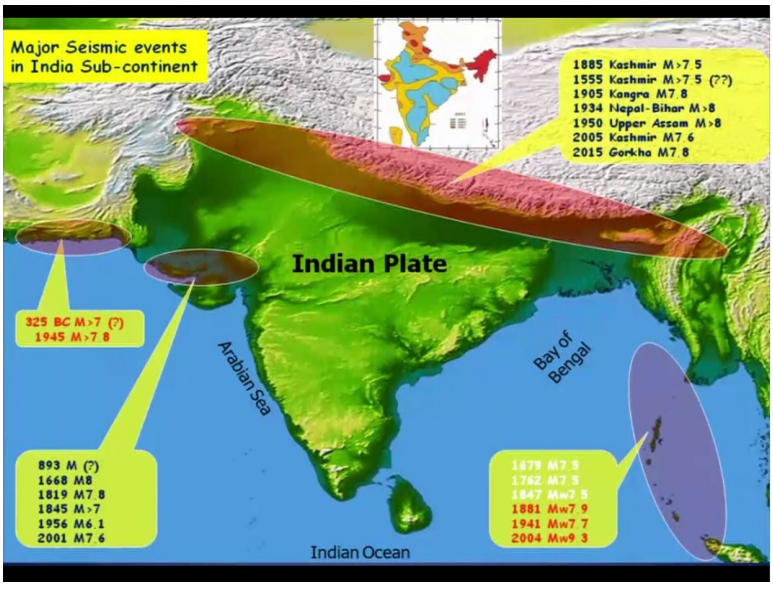

Now, coming to the India, we have like 3 zones which are the most active amongst all and in one of the lecture I was talking about the GPS measurements which have been done between the Indian plate and the Eurasian plate. So, it shows that whole plate is under strain and the Himalaya is contracting earth in higher velocity or the convergence rate as compared to the rest of the plates.

So, total convergence between this point and the point fixed point in Eurasian plate is around 55 millimeter per year or 50 to 55 millimeter and out of that hardly 5 millimeter has been consumed between this point and this point. So, what we can say that the entire plate is deforming at a very low rate whereas Himalaya is taking up half of the like around 20, 22 millimeter per year.

So, out of 50 half of the convergence has been consumed by the Indian plate and maximum has been consumed across the Himalayas. So, the deformation is also experienced by the Indian plate and one of the pocket in the western India that is called Gujarat has shown the from the history that this region is again capable though it is sitting away from the Himalayan front which is one of the active deformation front or the plate boundary that is sitting away.

But not very away from this one because the plate boundary runs like this here and then we are having the subduction zone in this region, this is known as Makran subduction zone and similarly another subduction zone what we have is along this Sumatra-Andaman subduction zone. So, we have 2 subduction zones, we have the earlier subduction but now the collision zone we have over here that is the product what we see the Himalayas.

So, to some extent probably there is some connectivity of this but this is not very sure. This is a guess but it could be responsible, an extension of the plate boundary could be responsible for generating so many large magnitude earthquake in this region and also it shows the very distinct change in the landscape in this region. So, why it is so happening in this region when this area is sitting away from the Himalayan front or the tectonically active region.

But what probably could be one of the reason that there is a plate boundary which exists here or extension of the plate boundary and the prominent deformation which we see in this particular region and earthquakes are the manifestation or the indication of that ongoing activity is just because of the probable plate boundary which exist here but that is still not proved but anyway we have the records.

So, we will see 1 example from here and 2 examples from this region and the examples which I am trying to show you are the most common examples which one can see in any deformational zone on the earth's surface. So, this is not that just we found in India but this is

most common examples which persist on the earth's surface and mostly in the regions where the active deformation is going on.

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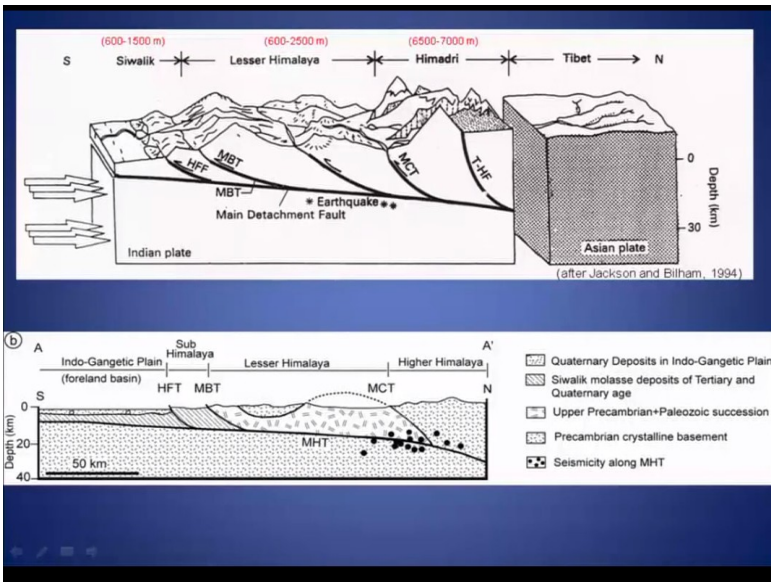

So, just I am giving an idea of the entire Himalaya what we have, so we have like different ranges actually we have the higher Himalayas which are termed us Himadri, the height ranges from 6500 to 7000 and the highest peak what we have is the Everest above 8000 and then we have the lesser Himalayas and then we have Siwaliks. Now, all these ranges if we see in terms of the order, we have the highest, the higher here, then we have the lesser height lesser Himalayas then Siwaliks.

So, in age this is youngest and with the understanding what we have that due to the ongoing deformation that this was the first range which was formed after the collision between the Indian plate and the Eurasian plate where the rocks were buckled up or pushed up and no range existed in front of this one. So, this portion was occupied by what we have the configuration here like younger Siwaliks and the Indo-Gangetic plain.

So, similar condition existed in the past over here, then another range came in and then the same condition existed here. Now, we are having the Siwaliks and we have the present condition we have the basin here that is Indo-Gangetic plain and slowly of course for sure the new range will come up in the frontal part over here and then Siwalik will become the older one and then further the Indo-Gangetic plains or the plane areas or the basin area will propagate in the foreland side.

Now, one interesting thing which has been marked here is that all these ranges either you call Siwalik you say lesser Himalayas all to their south are bounded by a major fault system. So, there is a displacement which has been experienced along this plane is a cross-section which we are saying and this is a topography which has been shown here.

So, the movement has also been consumed or experienced or the displacement because of the deformation between this, so this is the plane where the Indian plate is subducting below the Eurasian plate. So, this will keep going and because of the ongoing deformation between the 2 plates and this is what we were talking about that most of the ranges lesser Himalaya is bounded like if I say like talk here then higher Himalayas to which South is bounded by MCT or main central thrust.

And then similarly lesser Himalaya by MBT main boundary thrust. Thrust is a fault which has been categorized as a reverse fault and then further we have the Himalayan frontal thrust and then we have the Indo-Gangetic plain that is the foreland basin. So, this is the most commonly seen configuration in thrust and fold belts because whatever the deformation is going on what we see is the formation of folded mountain chains.

And these are the older one and this is the younger one. So, over the time, the landscape got changed because of the ongoing deformation and this is one of the reasons that what we are having the higher Himalayas and the lower Himalayas that is existing here.

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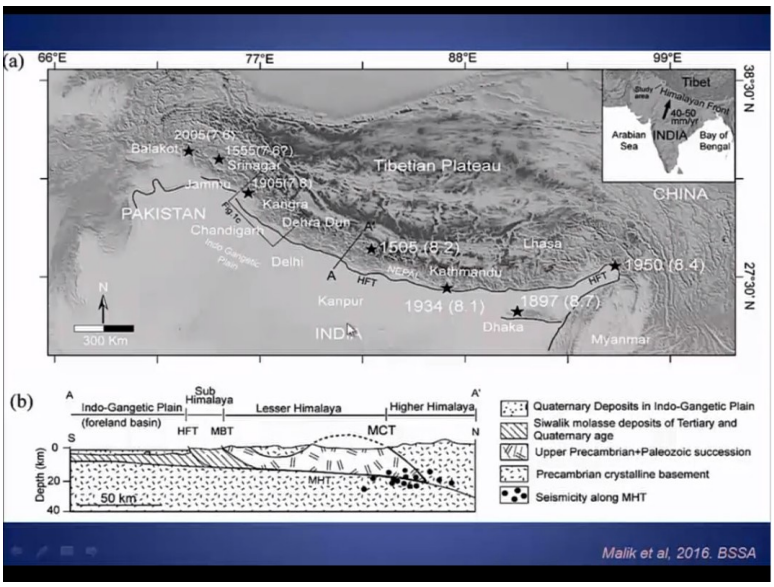

Now, we have some example from this region we will talk and this is just to show you the location or the epicenter of major earthquakes, which have been recorded or experienced during the historical time and recent in last 2 or 3 decades. So, this is the testimony of the ongoing deformation between the 2 plates that is Tibetan plate or Eurasian plate and the Indian plate here.

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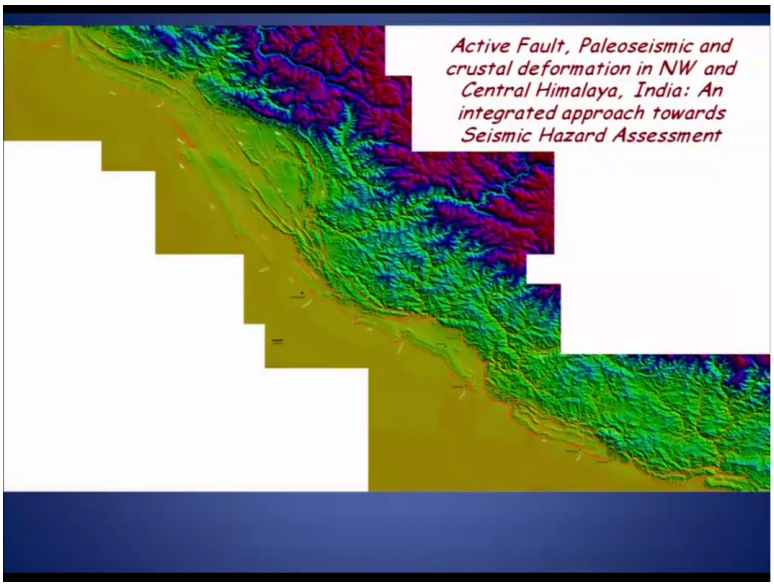

So, considering this I would say that the Ministry of Forest Science gave us major project. This project was been given to IIT Kanpur to identify the fault lines. So, if you see the shaded relief map of the Himalaya basically about what we are showing is the central Himalaya, so Nepal is somewhere here, it is sitting here and then we have the Kumaun Himalaya here and then we get into the Northwest Himalaya and then further here Jamboo and further into the Kashmir Himalaya on this side.

But we have right now we are showing you the digital elevation model or the shaded relief map of the central Himalaya and the Northwest Himalaya. So, this project is aimed to identify the tectonic features and to identify the old seismic events but I would say that the approach what we have taken is that we study the drainage and based on the drainage either they are deflected or disrupted or there is a landform which has tried to damp the channel or something like that.

The drainage has helped us in identifying or the displaced landforms have helped us in identifying the active faults.

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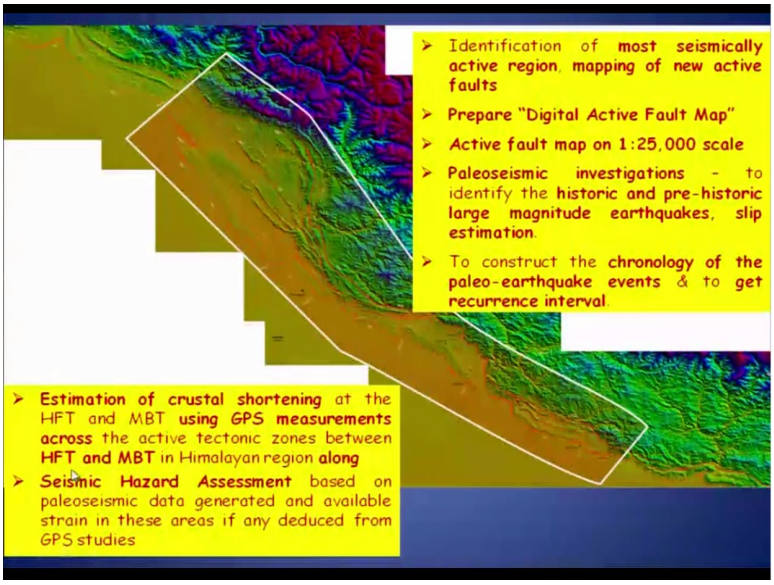

So, this is the area which we are covering and the aim is I will just quickly because this is not the part of this but we have to prepare a digital active fault map and then we will also reconstruct now. This is important we are doing is that these events we have also tried to correlate with the evolution of the landscape here and that what you will see in the coming slides.

Along with that, we are also measuring the GPS measurements, we are carrying out the GPS measurements across the Himalayas or across the active faults and that will eventually help us in seismic hazard assessment.

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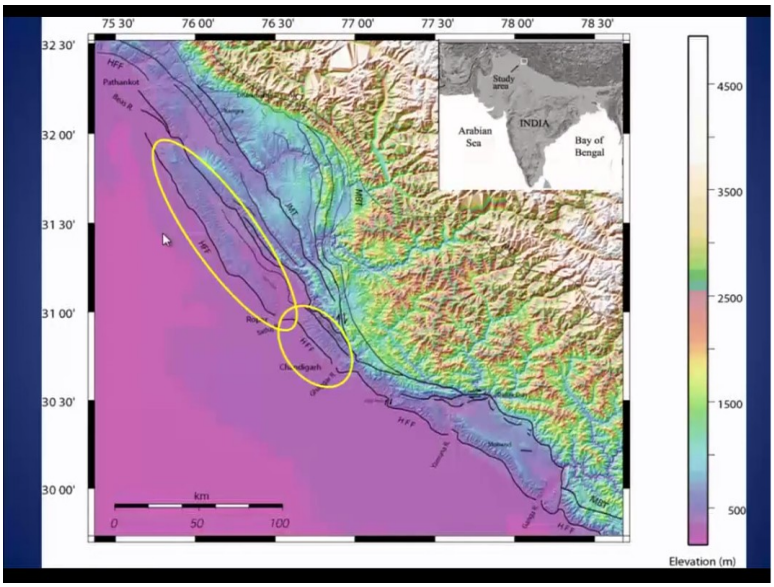

So, coming to this region, in the previous one of the lecture, this area we talked about keeping in mind the drainage pattern where I was talking about the drainage pattern from this region

and then we also discussed where we see some bulging here and the dendritic pattern and then we also discussed about the signature of tight meandering somewhere over here when the Sutlej is crossing the Jwalamukhi thrust.

So, we talked about that the change in the channel pattern, we also talked from here this region again the warping in the Siwaliks where we were able to see very prominent radial drainage and then we were also talking about this area but we will now see that how this. So, the point here is that how this fold range which has been almost like 100 kilometers long evolved.

And what are the signatures which helps us that is geomorphic features, which helps us in understanding that earlier this was not the case but now what we see is the collision of 2 or the joining of 2 or the linkage of 2 small folds or the folded range and resulting into the formation of the longer one. So, let us see that and then this one here.

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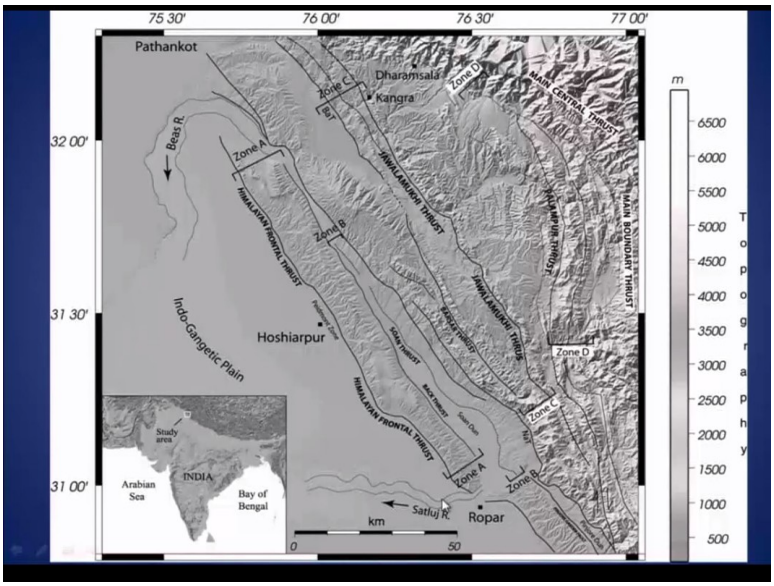

So, what you see here is of course the black lines are the fault boundaries between the folded mountain chain and the Indo-Gangetic plain and similarly over here and then what it shows that this terrain over here where I am moving my cursor, we have some dissected surfaces over here. So, these are the drainages which are flowing in either direction from the center here, so this is the drainage divide.

But over here we have a very flat surface which marks the elevated portion. I will come to this point and then later and then again we have a very prominent drainage divide. Over here

we have the bifurcation, one drainage divide is here, another trainer divide is here and what we see is that on the either side of this 100 kilometer long fold of the hill, 2 channels which are flowing and show some turn actually here.

So, there is a turn, U-turn where the Sutlej is taking and very prominent U-turn and as well as over here this is flowing from here. So, what exactly happened in the past, we will discuss in the next lecture and we will try to understand that how the tectonic, ongoing tectonic deformation influences the drainage. Thank you so much. Let us see in the next lecture.