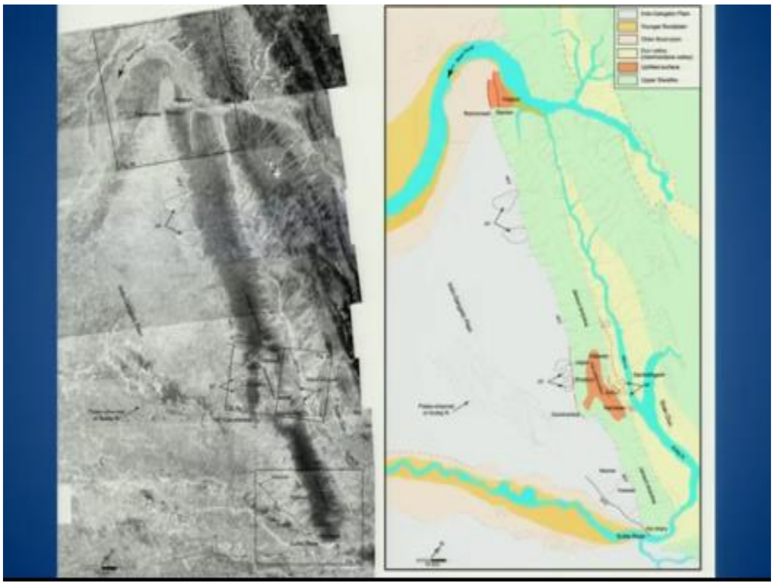
Earthquake Geology: A tool for Seismic Hazard Assessment
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology, Kanpur

Lecture – 40
Compressional Tectonic Environments and Related Landforms (Part-VI)

(Refer Slide Time: 00:21)

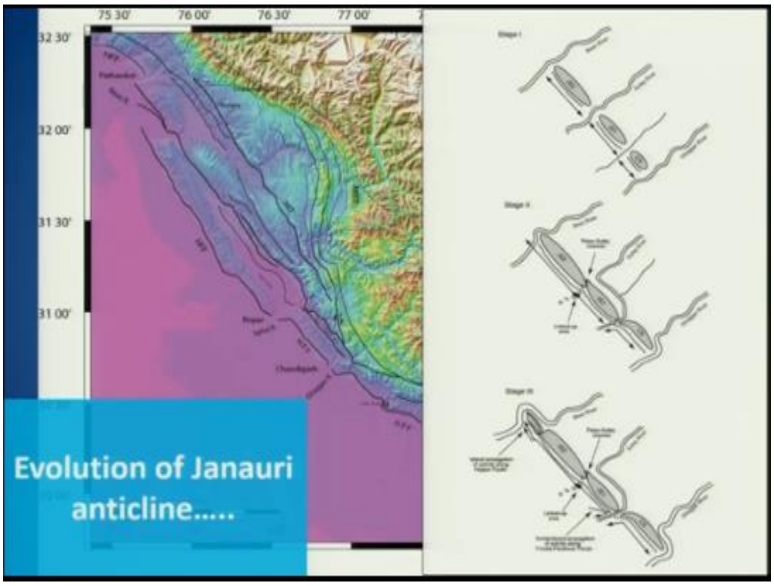


So welcome back, so in the previous lecture, we discussed fault growth and segmentation. So before, we get into the detail of this part here that is the north-western portion of the Janauri anticline. I will just try to explain in 2 slide and how this interaction of the two segments took place.

(Refer Slide Time: 00:38)

So if we look at the overall topography here and as, I explained that this portion is here, the segment of linkage between the two segments of the Janauri anticline. And when it linked up it resulted into the formation of a 100 kilometer long whole range.

(Refer Slide Time: 00:58)

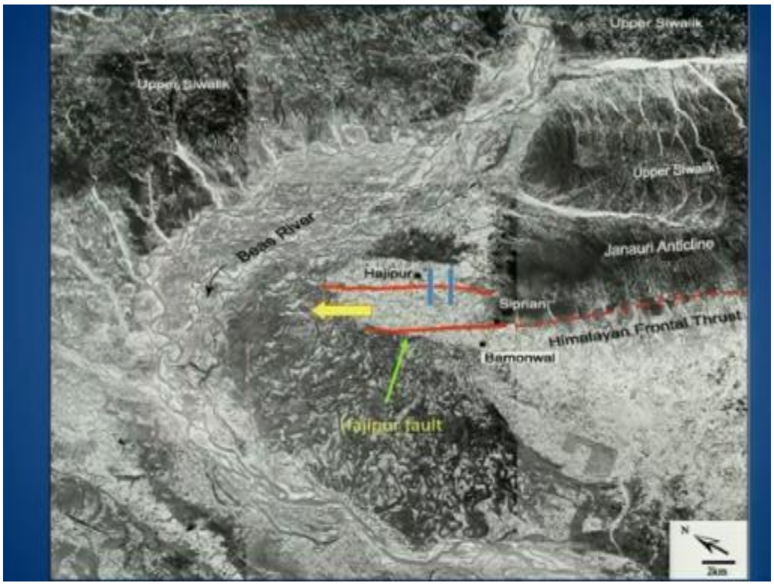


So, this is just a model which has been given here, which explains not initially of this segment. Janauri anticline segment two and one started propagating away from the center, here and either direction and then they got linked up. So before the linkage the shuttle is used to flow through this gap and after the blocking of these two that is the merging of the link area linked up area and this was blocked.

And it faulted the channel to flow on its own, along the parallel almost parallel to the Janauri anticline, take nine along the bank back link of this major feature and further now after the linked up this portion start growing up and this is what we will be discussing in the next coming slide and at how this was responsible, so initially this Beas also flowed without having any interference from this dip.

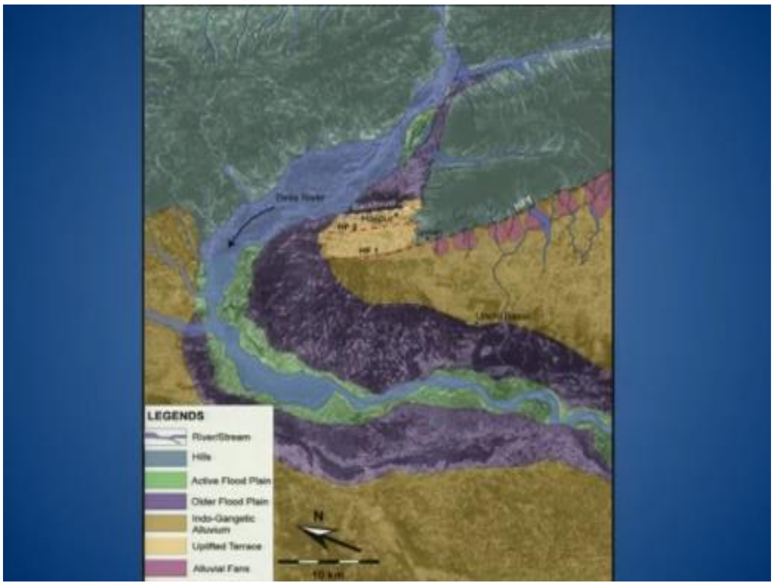
But now, what we see is that Beas have been pushed further north-west because of the growth on the dip of the Janauri anticline.

(Refer Slide Time: 02:22)



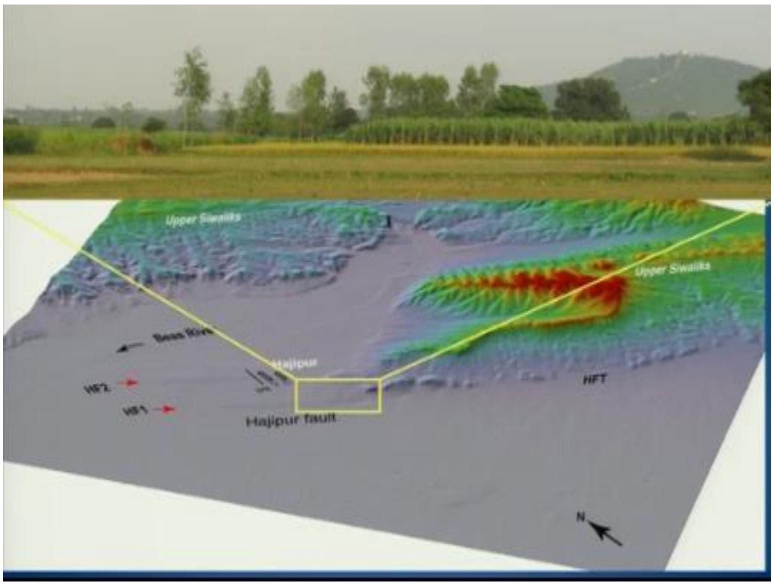
So, coming to this part, again as I have already discussed. So these are the two faults which are propagating in north-west direction and pushing further Northwest and we did our Paleoseismic studies over here. So this I will explain in the coming slides.

(Refer Slide Time: 02:38)



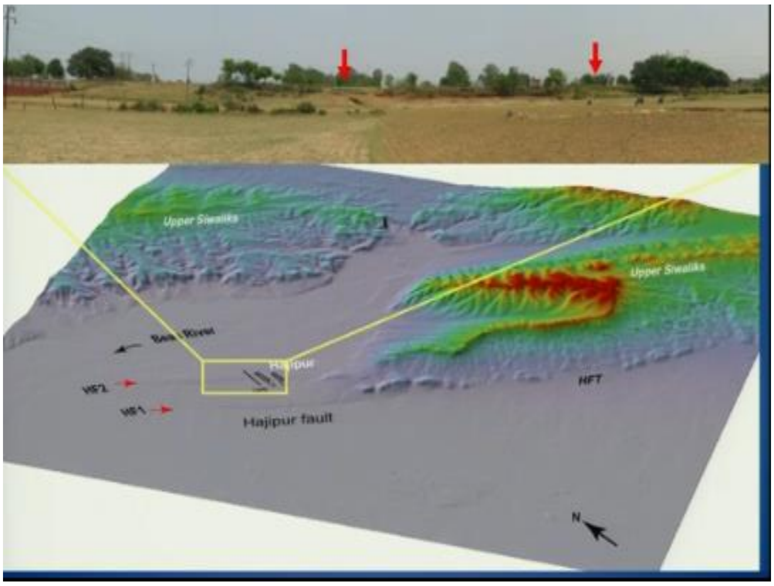
So this is the sketch of the geomorphic map, which we have prepared which shows that Beas is present. It is the present day channel, here and this is the Paleo floodplain and Beas used to flow through this earlier and then slowly it moved further north-west

(Refer Slide Time: 03:02)



So after doing the tectonic geomorphology part, we started looking at a detailed topography of the active fault and what we see here? This is a shaded relief map which shows the young topography of the active fault, displacing very young deposits of Beas River. So if you look at this portion here and then on the ground, you will be able to see this exactly the same there is also I have shown this photograph earlier also.

(Refer Slide Time: 03:40)

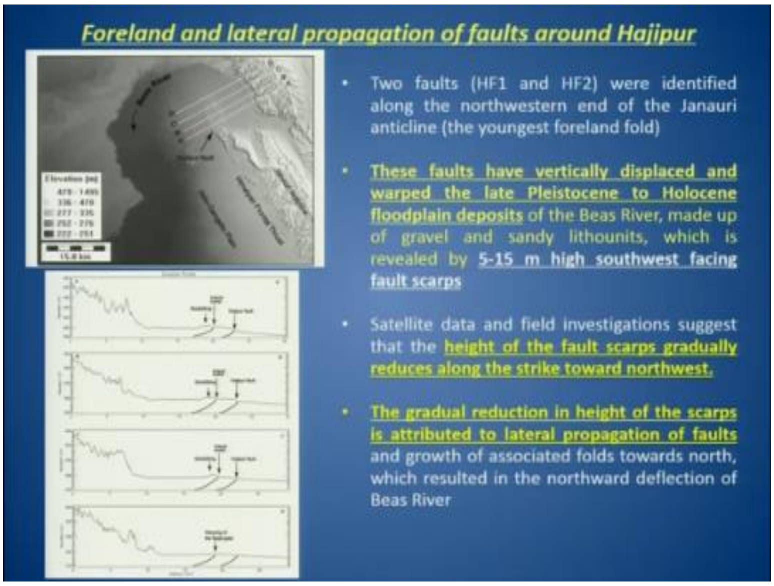


And then this is the topography of that one coming to this part here where we did detailed Paleoseismic studies. We open up the trenches over here one trench here another one here so I will explain one of the trenches from this portion.

(Refer Slide Time: 03:55)

Now we also did, because if you look at the topography here, what we see is not, you have like the higher scrap here and further if you move along the strike towards the direction of propagation, then this where the height reduces and this is because this portion of the scope is showing the cumulative displacement whereas this one is taking the younger, one so the height is clearly.

(Refer Slide Time: 04:33)



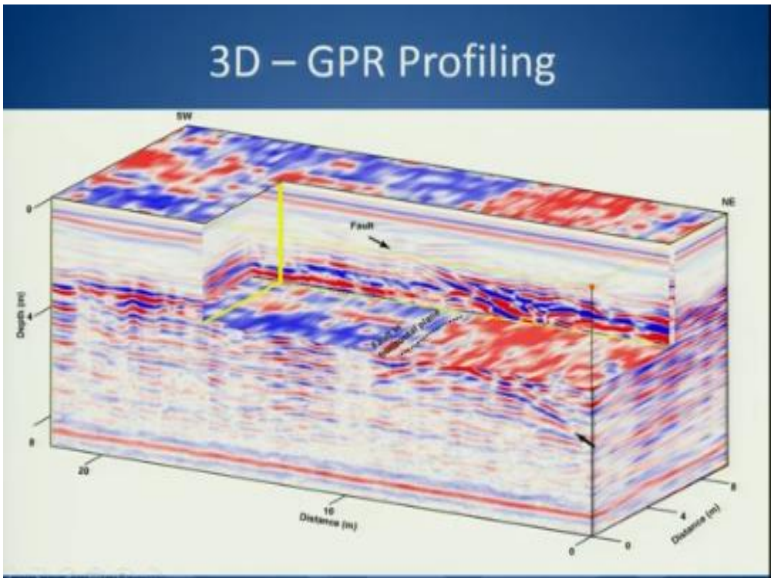
Picked up from the topographic profiles which we extracted from a digital elevation model, so if you look at the A, A dash, B, B dash, C, C dash, and D, D dash. What we see is the topography here of which is closer to the front here or the hills, we has some higher topography and as you move further along the strike here, then the topography reduces, so this clearly indicates that the fault and fold is propagating in this direction.

So the height close to this portion was around 15 meters in some areas and reduces up to up to 5 meters or to up to 2 meters further in the north-west direction.

(Refer Slide Time: 05:21)

So coming to this part here where we did detailed Paleoseismic studies, so initially we took the topographic profile of this fault scarp and the fault scarp was not at all disturbed by any anthropogenic activity. So we selected the side, keeping in mind that of course, when we say anthropogenic activity. That means this has not been modified by human activity.

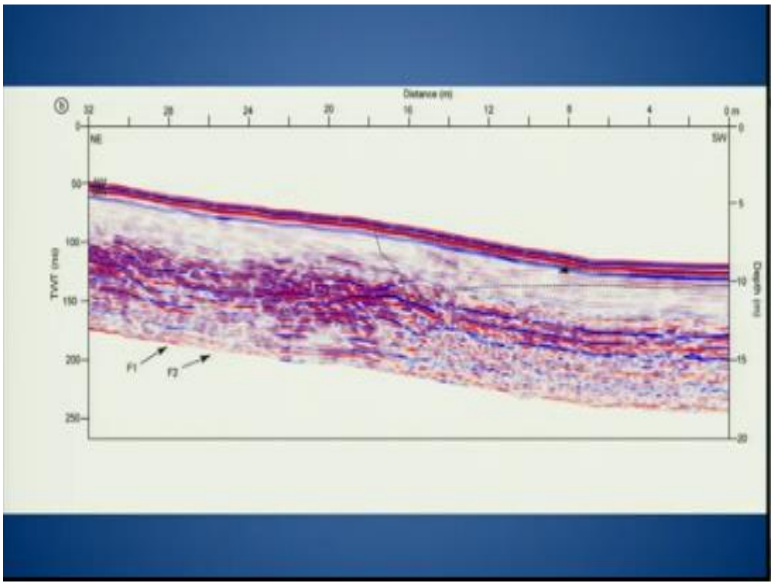
(Refer Slide Time: 05:52)



So before we got into the trenching business, we did GPR profile and this shows the 3d GPR profile section and we were able to pick up clear-cut deformation at this level. So you just need the depth here it is almost like more than 8 meters and we can see the fault which is very prominently seen along with the deformation of the sediments up to 6 meter or so on.

Even if we did 3D slicing now, they have the high contrast between this, it shows clearly that you have the softer deposits here or finer deposits and these are all gravels now. How we are able to say that these are gravel, when we opened up the trench we were able to see the contrast between these sediments.

(Refer Slide Time: 06:43)



So this is another topography, the topographic profile which we use to do the topographic corrections and the GPR profile and the section again, you see what we went up to more than like. If you take this as 5 meters then you have more than more than 7 to 8 meters, over here and fault we were able to easily pick up to 6 to 8 meters depth and also the deformation. So this is your north-east side, so this is your up thrown block and this is your down thrown side.

This is your footwall, so this is this part is here towards the Indo-Gangetic plain and this is towards these are Himalayas, so this portion, we opened up because we were not able to go deeper. So we opened up the trench here, which was almost like if you take this one length here it was almost like 16 and if you put more here, almost like close to 18 meters and the depth was not much or hardly or 2 to 3 meters deep, we were able to go.

But with the help of the trench section and the GPR we will be able to extend the fault deeper up to 8 meters, like this also what we identified from this portion of the fault strand, that is your F1 is showing the older deformation and the younger deformation has been taken up by this one now this again was based on what the experiment, we did in the sandbox, that the younger deformation will be taken up by the other fault in the frontal side.

But nevertheless, as we have seen in one of the lectures that deformation can also be taken up by the older faults in some cases, but in this it was very clear because it deformed the younger deposits. Hence, we concluded at least before getting into the trenching, that this F2 has taken of the young deformation along the Himalayan frontal thrust.

(Refer Slide Time: 09:04)

So trenching part, we opened up the trench here, so GPR profile was taken across this one and then we started digging.

(Refer Slide Time: 09:13)

So, this is our final photo mosaic of the north wall, which shows clear deformation and that is the folding of the gravel and the sand layer climbing up on the finer deposits, so the contrast in the GPR which you were showing in the red. Okay, more contrast and the lesser contrast here was the difference between the sediment size and the type of the deposits.

(Refer Slide Time: 09:46)

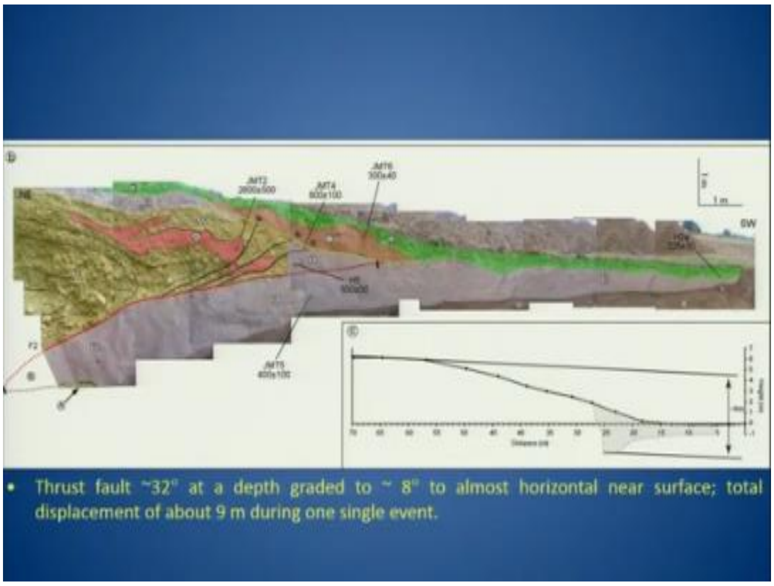
Close of that, so you can easily make out a deformation here which can be drawn like this. Okay, so we have in contrast here this is in sharp contrast of the fault, so this I am drawing very rough.

(Refer Slide Time: 10:10)

But the sketch which you will see here is something like that again, so you have still along with this main fault, we see some imprecated faults which are coming out of this again and this is on the small miniature scale. But on the large scale or the mega scale, also you see similar types of deformation, what we were trying to explain from this sandbox model and also if you look at the cross-section schematic cross-section of Himalaya.

So we have the older faults and the younger fault which are taking up the deformation in the foreland side.

(Refer Slide Time: 10:47)



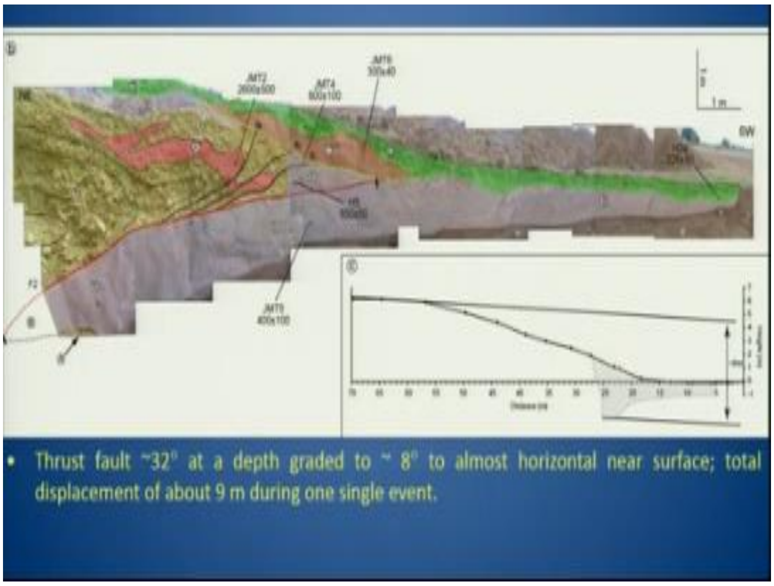
Now the idea was to defined after preparing the detailed sketch based on the different units.

(Refer Slide Time: 10:55)

Which were been identified from the exposed trench wall and that we have the sand units and the sharp contact here and different units were been identified, like what we have shown here is A, B and then you have the C. Here, okay C is your fluvial, fluvial which is scrapping the this, all falls these small bodies branching out fall like FA, FB and FC and the main fault is your F2 and as I explained in the GPR profile.

That we considered this has resulted into the young displacement have been focused on this one and you see the final scrapping by unit D here, so based on this cross-cutting relationship we picked up this we picked up the samples.

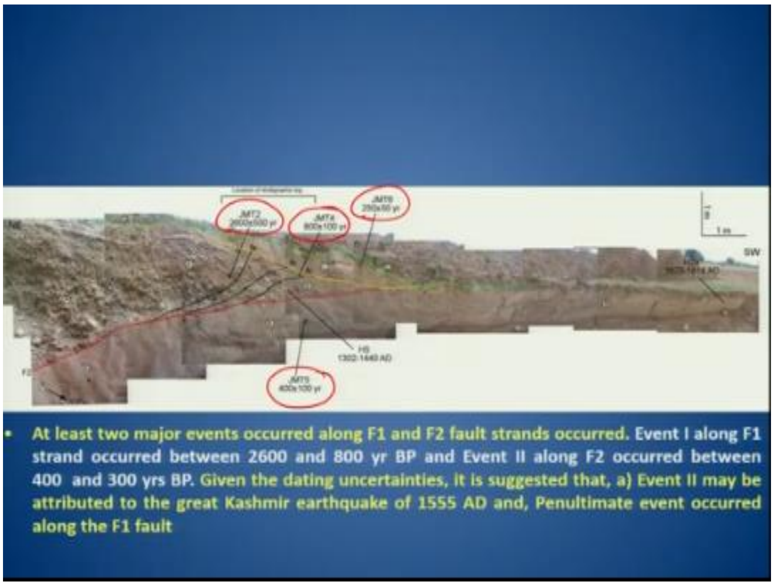
(Refer Slide Time: 11:48)



From different units, so we were lucky to have some samples of charcoal like from here we got charcoal and from another location, like here we got some charcoal rest of the samples we did with OSL so this is another exercise which usually has been done that we have a very long topographic profile not only just confining to the trench area but we try to take the tropical topographic profile, further up in the scarp area as well as the un-deformed region.

And then we place our trench and this helps us in understanding that what is the total displacement? Because this top is your what we found is the gravel here and the same unit is sitting down, here on the footwall side, so this is the hanging wall and this is the footwall side right? So the total displacement, what we found between the gravel displacements of the gravel unit was almost like 8 meter, but the same had not been seen during this scrap. That is the young scrap here, the displacement what we found was much less.

(Refer Slide Time: 13:04)

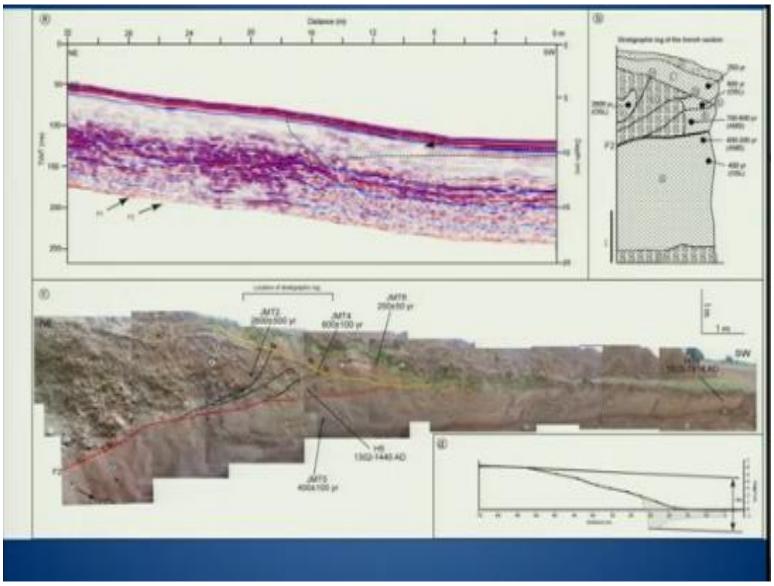


So finally, what we have concluded from this is that at least two major events occurred along the F1 and F2 fault strands and F2, F1 has not been seen in the trench. But F1 was been picked in GPR profile, so even one along F1 strand occurred between 2600 years and 800 this was been based on the ages, which we got from this unit. So gravel we were unable to date but the (()) (13:38)) which was within the gravel we were able to date that and that gave us an age of 2600 years.

So we have bracketed this between this age and the scrapping age of this unit, that is your unit B here, so we have the age of this, so we have scrapped this two events between this one so we say that okay find the event one which was along F1 was between 2600 years and 800 years whereas event two was along this F2 and that occurred between 400 years and 300 years, so 400 years the ages here we got and then 300 years we say is based on the less age.

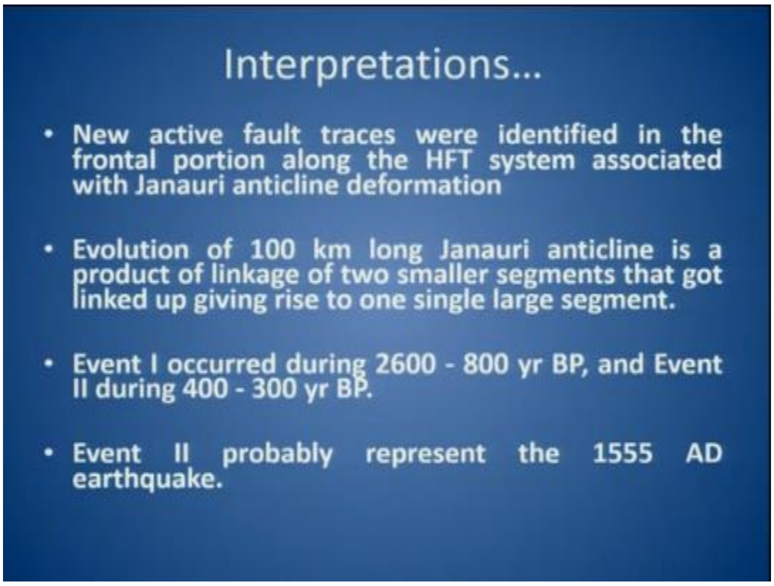
Because this has been kept by and the fluvial material, so we have this age, so given the dating uncertainty, it has suggested that the event two that is this one was probably the event which was recorded in the historical data. That occurred around 1555 AD and, the penultimate event along F1 fault which has not been seen in this trench.

(Refer Slide Time: 14:58)



So finally, what you see here is that you have the F1 here and the F2 which has taken up the at least the younger event here. So, this you can compare easily what we saw in GPR and what we were able to see in the section here of the trench.

(Refer Slide Time: 15:21)



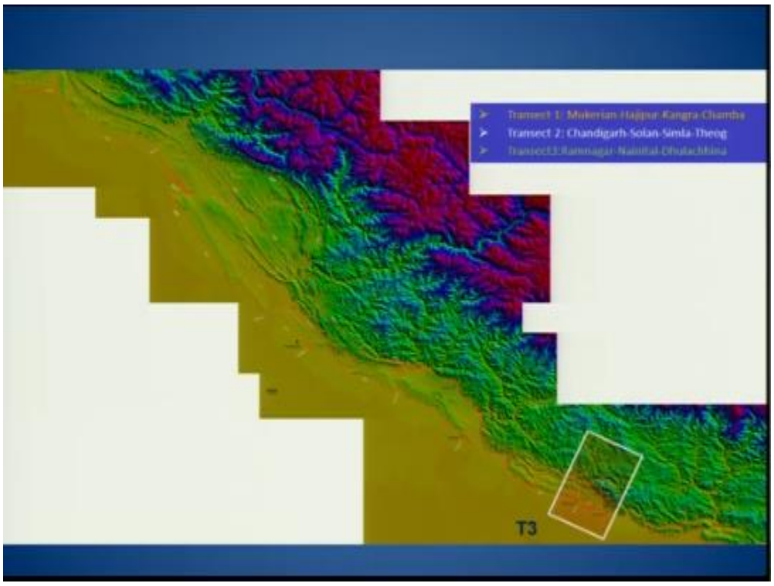
So interpretations, we have that the new active fault trace were identified in the frontal portion along the HFT system and associated with Janauri anticline, evolution of the 100 kilometer long, Janauri anticline is a product of linkage of two smaller segments, so this time I am trying to give you the complete overall evolution of not only the events and but we are talking about the evolution of the landscape.

So this was the result of the linkage of two smaller segments and event one occurred between 2600 and 800 years and event two during 400 and 300 years and event two probability presently 1555 AD earthquake in this region. Now this is how, we are going to interpret the different trenches I will give one more lecture on from central Himalaya where we opened up the trench and which gave us an evidence of 1505 earthquake in that region.

(Refer Slide Time: 16:27)

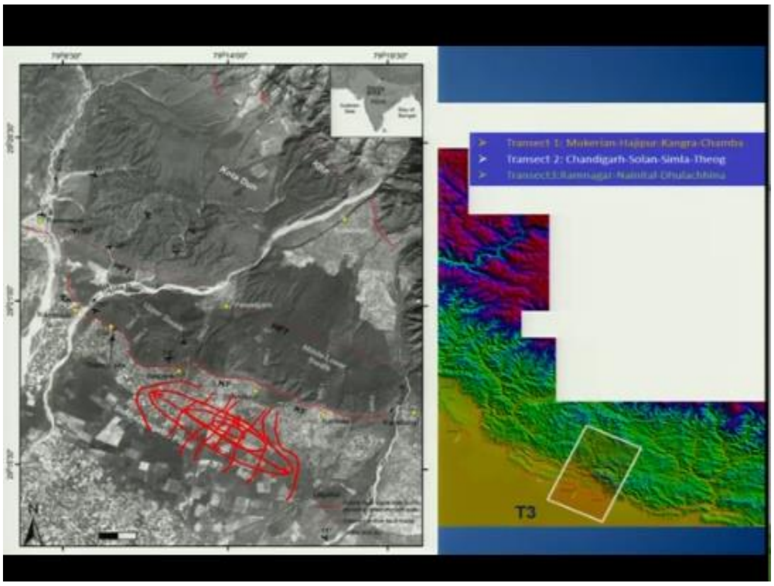
Now coming to the central Himalayan part, we have another good example of similar fault propagation folding.

(Refer Slide Time: 16:36)



From this region, an excellent example of the imprecated fault system also, so what we have is the, we have the Himalayan frontal thrust here, I will come to that and when detail in the next slide and the frontal part is sitting here which is an imprecated fault from HFT.

(Refer Slide Time: 16:54)



So this gives you a complete idea, that on surface. So if you take the 2D of view of this region. There is an high-resolution satellite photograph, this is the portion of HFT and the frontal part, is this one right now, which is just taking up the deformation, so this is not part of the integrated fault of HFT and this we have named as Kaladhungi fault, so again a very beautiful topography here which explains not how fold has grown over the time.

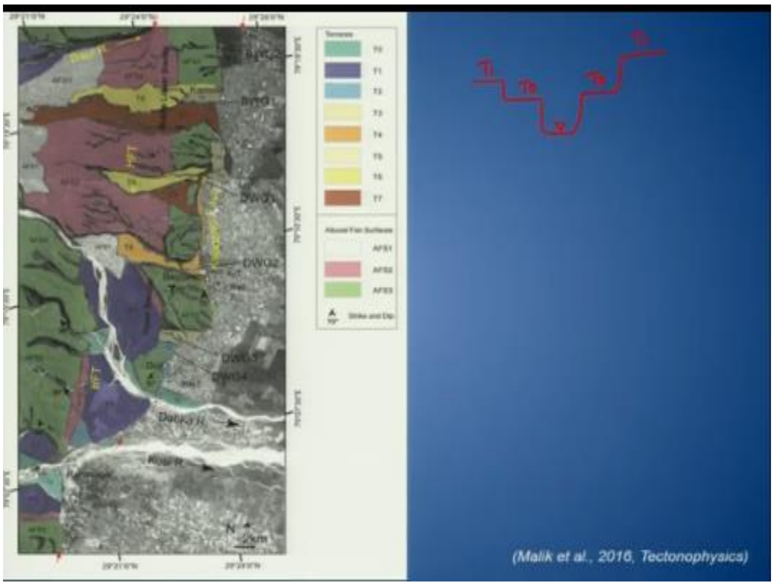
And how the landscape got evolved and what we see in terms of the deflection of this stream one here and that is your Dabka stream and another is Baur stream. Now Baur River flowed through this so initially it flowed through this one, here whereas the Dabka River flowed through this one before this fault propagated on either side. So as we, I have explained that the fault will keep growing. Okay?

So first it will it will grow like that okay and then second it will further grow like, this and then further it will keep going like that. Okay, so it will acquire the displacement here as well as it will acquire the length along the along the strike. Okay, so it will keep growing radially as well as it will keep growing vertically also as the displacement has been taken up. So these streams, which are flowing on this, will keep on deviating.

For example, which has been shown here, so it will keep dividing here like that and then like this. Okay and further and the further, what we see is that these streams are flowing on the either edges, okay so this Paleo wind gaps appear are indicative of the previous channels which floats. So this is DWG1 is your the river flowed through this initially and similarly you have the BWG1 and even that is the Baur wind gap and this is your Dabka wind Gap.

And similarly then the next stage as the fault grew then this was the second location, where it flowed and then finally what we see is the present day.

(Refer Slide Time: 19:21)



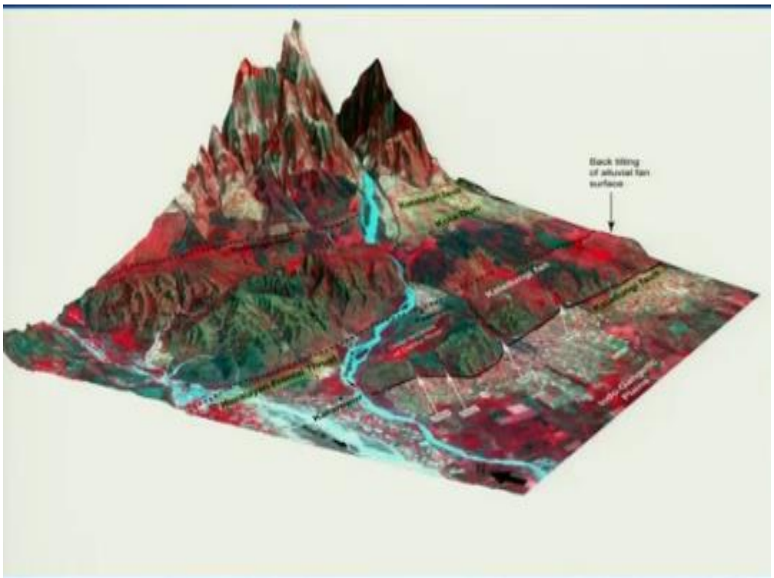
So, detailed topographic mapping of the landforms were been carried out and that what we call the geomorphic mapping or the detailed geomorphological map was been prepared and different terraces, this we will talk what do you mean by terraces and all that in coming lectures. But this is important right now, what we see is the surfaces, so if you have to call terraces, then it is something like that you have the channel and you have the terraces.

So this is your river channel and these are the terraces T0, T1 and all that. So what we did was we also mark the alluvial fan surfaces as well as we mark the different terraces. So in total we were able to pick up 7 terraces in this area and the alluvial fan surfaces also, so this are the all alluvial fan surfaces we have an alluvial fan surface 1, alluvial fan surface 2, an alluvial fan surface 3 marked with different colors here.

So this is your AFS1, alluvial fan surface 1 then you have the pink, one is alluvial fan surface 2 and the green one is your alluvial fan surface 3 and then different terraces which have been marked here along the front as with us along the different small streams and within the gap also, so we have the these are the gaps, wind gaps, we have DWG1 and for the Baur BWG1, BWG2 and similarly you have 3 and 4 here.

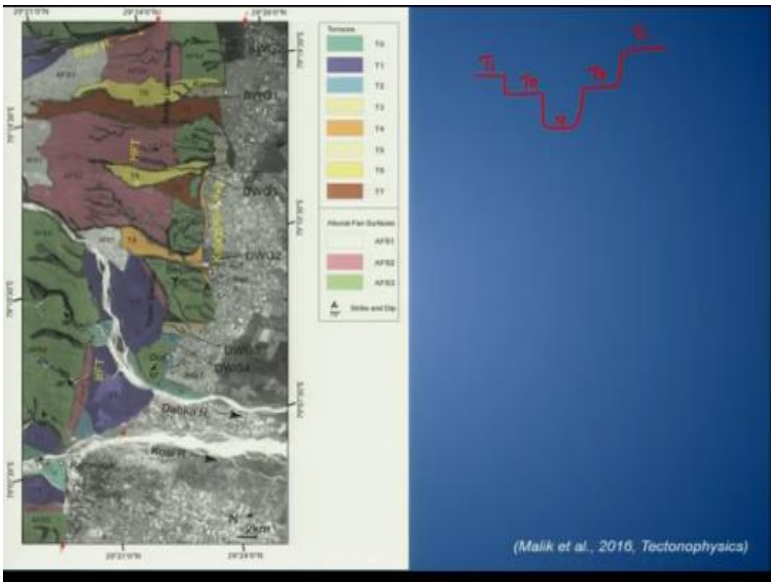
And the present day channel is flowing at the edge of this fault that is the fault which has developed because of the displacement along the Kaladhungi fault.

(Refer Slide Time: 21:11)



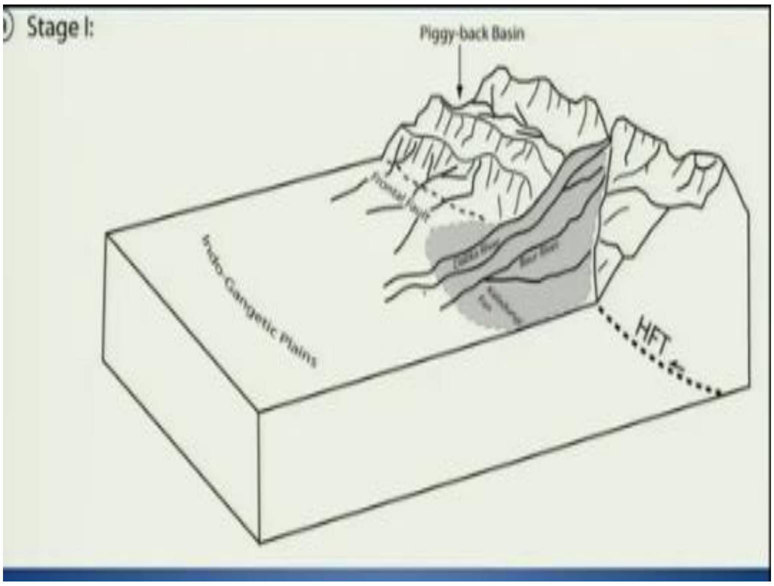
So, if you view this and 3D prospective view then it keeps and complete bird eye view of the region, so this was the gap here, earlier gap was here of Dabka and similarly the final one is flowing across this, so this portion is having lesser height as compared to this one here. So this portion is having higher height and this portion is also the middle part, so this is having higher height as compared to the edge of the fault. So, what we did was after detailed investigations.

(Refer Slide Time: 21:47)



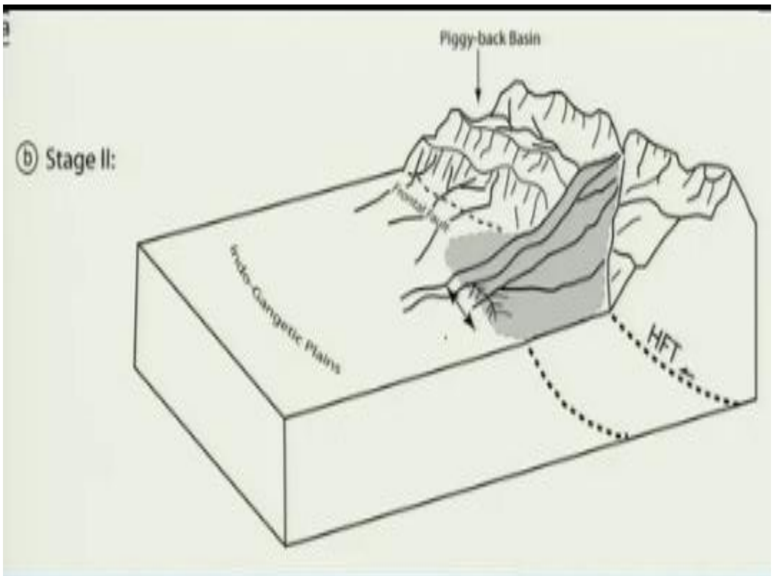
We identified that this portion of course is the younger landform, which was deformed there is your T2 which has been marked here, this will give us and most recent events if it has been displaced and that was here, that this got displaced and the fault runs over here.

(Refer Slide Time: 22:10)



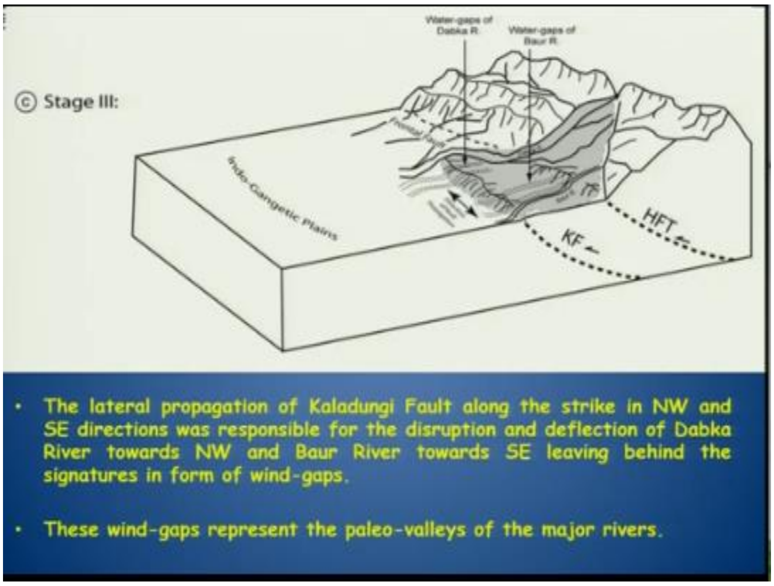
So again a similar schematic diagram, which we have prepared for this or we have tried to infer based on the deformation, that we had and HFT here but that no deformation has been seen here. But this change in the topography allowed the streams which were debauching into the Indo-Gangetic plain or on the Indo-Gangetic plain, resulted into the formation of the Kaladhungi fan and the Stevel River both the river still continued flowing across this one.

(Refer Slide Time: 22:46)



But later, the new fault took up to the formation that is an indicated fault of HFT and that is what we named us Kaladhungi fault and it propagated in either direction okay.

(Refer Slide Time: 22:59)



So this resulted in two final not allowing the streams to flow across this one and fault the streams to flow on the edges and that, what we see an excellent example of the fault propagation and for growth because of the ongoing deformation taken up by Kaladhungi fault. So, this is what we see the final exit of these two rivers. Okay?

(Refer Slide Time: 23:30)

So as I was talking about the wind gaps, this typically marks the topography in the field, so what we see is the small like separation type. But this separation is nothing, but the Paleo wind gap okay? So this was the river bed, which is uplifted along the Kaladhungi fault, which is running here, so this is your Kaladhungi fault and this portion is your Paleo channel and this belongs to Baur River. So you will find such topography, all along the strike of the Kaladhungi fan.

(Refer Slide Time: 24:18)

Another photograph of this, you have this wind gap of which was very wide. We were not able to pick up in one shot, but on the edge we found that this is your fourth wind gap of the Dabka river, ever there is another one again you had the uplifted riverbed of Baur River another uplifted riverbed of the Baur River. So this marks you are the most youngest fault that is your Kaladhungi fault and imprecated fault off from of HFT.

So I will stop here and we will talk more about the Paleoseismic studies, which were carried out in this region and we will discuss the events and all that, how we collected the samples identified the different event horizons, thank you so much.