Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture – 44
Strike Slip Tectonic Environments and Related Landforms (Part- III)

Welcome back so let us talk about in the same domain of strike slip in the case study, as I told in the last lecture.

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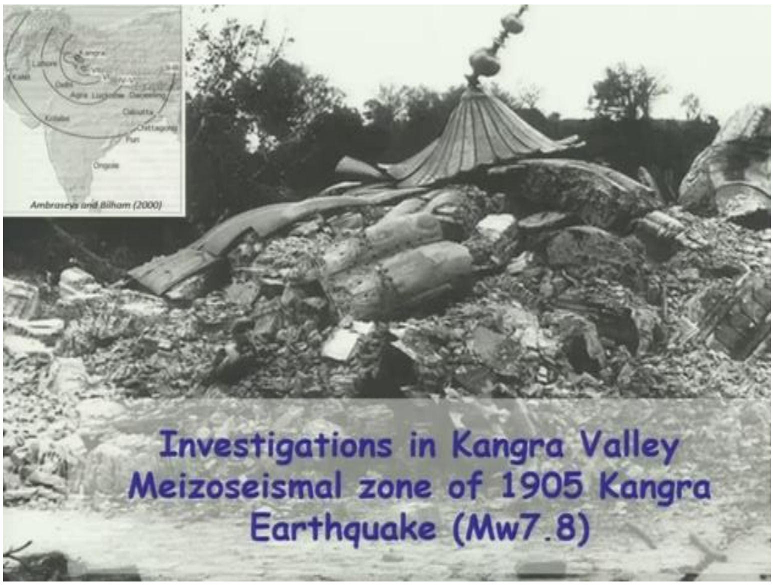

On Kangra valley fault, now the photograph which you see here is the damage pattern of which was resulted because of 1905 Kangra earthquake and this was in Kangra valley in Dharamsala. So basically this is in the hinterland side of the Himalayan front. So this fault was been identified, I will talk about that in Kangra Valley new fault which based on the Paleoseismic studies.

We believe that this was the fault which was responsible for triggering 1905 earthquake and if you look at the magnitude then the magnitude was 7.8 and the intensity of this earthquake was felt right far away in the north-east up to Calcutta and further up to Gujarat in the west and further west you can see north-west in Pakistan also. This was the epicentral area now keeping this in mind and the damage pattern in Kangra valley.

We started looking for the signatures of any deformation if at all it was preserved on the surface because with an understanding that in epicentral area maximum amount of energy must have released during an earthquake looking to the damage because the intensity was very high and huge damage was experienced in this region that is Kangra Valley. So with that background we started hunting for the active fault in this region.

But we were never aware because the previous studies indicated that the Kangra earthquake of 1905 was along Jawalamukhi thrust which is like towards the south of this Kangra valley.

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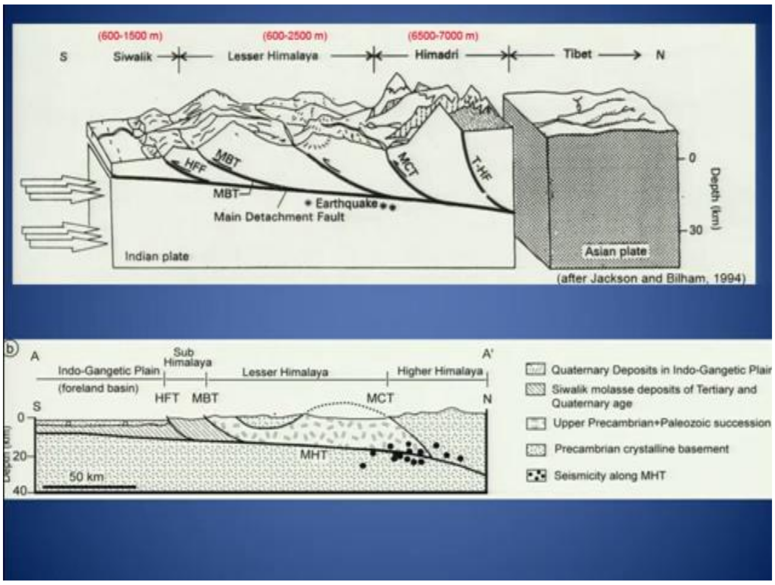

So when we started looking for the active faults before that we thought of let us understand that what could be the reason for this region which is sitting like between HFT and MBT would have triggered the earthquake of 1905. Now if we look at this already we have discussed earlier also so we have the detachment and the faults which are been implicated are playing out major fault system.

We see from the despoilment MCT and MBT and HFT and the Kangra Valley sits somewhere between MBT and HFT. So we have sub Himalayas and then we have this one will come to that details where exactly the Kangra is located, Kangra valley and will discuss about the topography also and again with the background that most of the earthquakes now what we see are concentrated between MCT and MBT and this portion the frontal portion is locked this is based on GPS measurements.

So that also was in our mind that whether the frontal most fault which as per the tectonic activity which has progressed towards south in the foot foreland side repeats the most active then why this is locked and weather the faults which are sitting in the hinterland may also get reactivated. So that was another idea or the question in our mind before we started this study.

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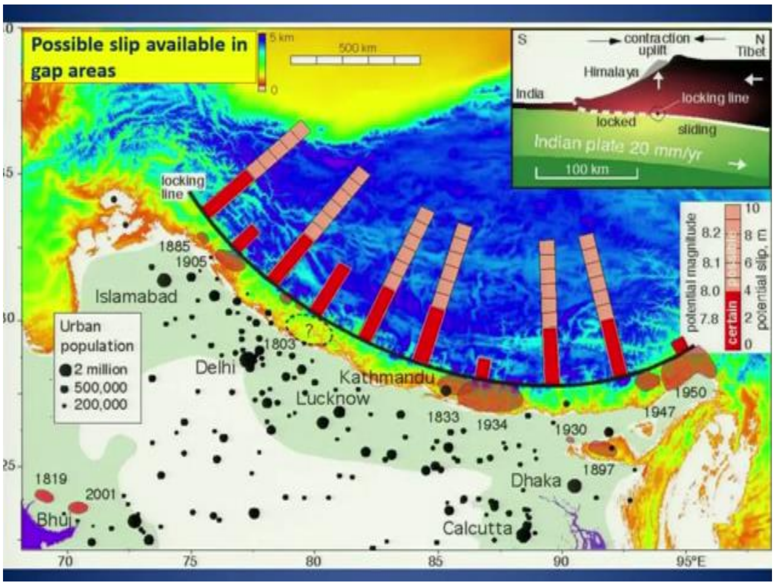

And this also we took into consideration that of course based on the earthquake data it was been proposed that this region; that is the Kangra region, in Himalaya has already released the available slip or the energy. So this area will not be in potential area for having or hosting another large magnitude earthquake in near future as compared to what we see here, so this marked the central seismic gap.

Which is marked between or suggested as in central seismic gap between 1934 and 1905 earthquake and further this is also we have discussed that another gap is between 1950 and 1934 Nepal, Bihar this is Assam earthquake. Now as I have emphasized in my previous lectures also that we have multiple fault lines in Himalaya and which fault was responsible in triggering these earthquakes where it was not very clear.

Like 1905 earthquake whether it was along Jwalamukhi thrust or is it was hosted or triggered along Himalayan frontal thrust or it was triggered along MBT it was not clear but yes of course one study suggested not based on the Paleoseismic investigation but based on the GPS data that Jwalamukhi thrust was responsible for hosting this 1905 earthquake and recent Paleoseismic studies.

Which have been carried out in central Himalaya in Nepal and in northeast portion of Himalaya and the Brahmaputra Valley it suggests that 1905 and 1934, 1950 and 1934 with along the Himalayan frontal thrust. So this was again a question that what where exactly because the epicentral area our the damage or the ruptured area which was been marked in published maps and all that was sitting way back away from way back north away from the frontal part here.

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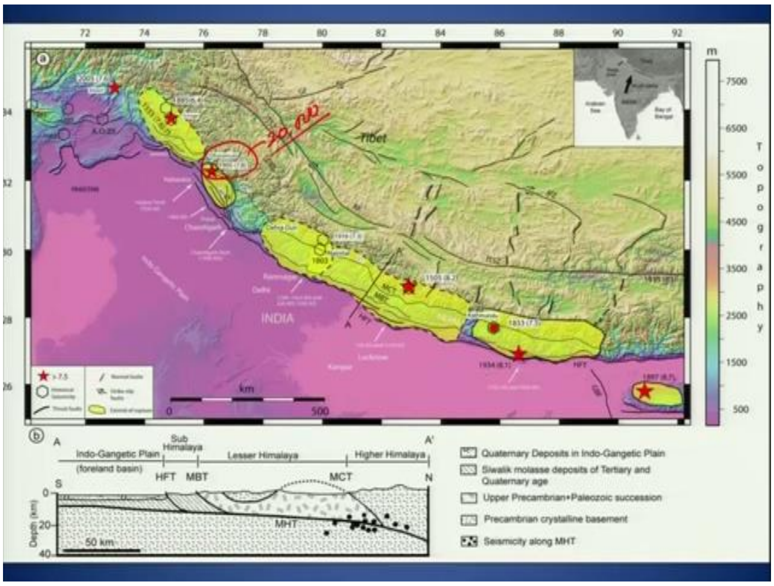

So many questions we started working on this and this map of course is the old one, but yes at least we can understand that the rupture of the large magnitude earthquakes have been given here, starting from 1555 in Kashmir 1905 here and the epicentres which have been marked are setting far away from the Himalayan front and then we have this is again it is not really clear that where was this the epicentre some literature shows that it is again in the hinterland site.

Then we had another one which is 1505 again literature suggests that the epicentre was much away to north from HFT but 1934 was close to the Himalayan front and 1950 which is located somewhere here was also along the Himalayan front. There are few Paleoseismic studies which are been listed here but none of the Paleoseismic investigations. So the point here is that most of the work which was been carried out was along the Himalayan front.

But no attempt was made to look at the Paleoseismic history in the hinterland side and considering that 1905 was one of the largest earthquakes which took away almost like 20,000 lives at that point of time was definitely would have been damaging one and is one of the largest events. If we compare in terms of the damage and all that of course in terms of magnitude we have this one is larger so with this questions in mind.

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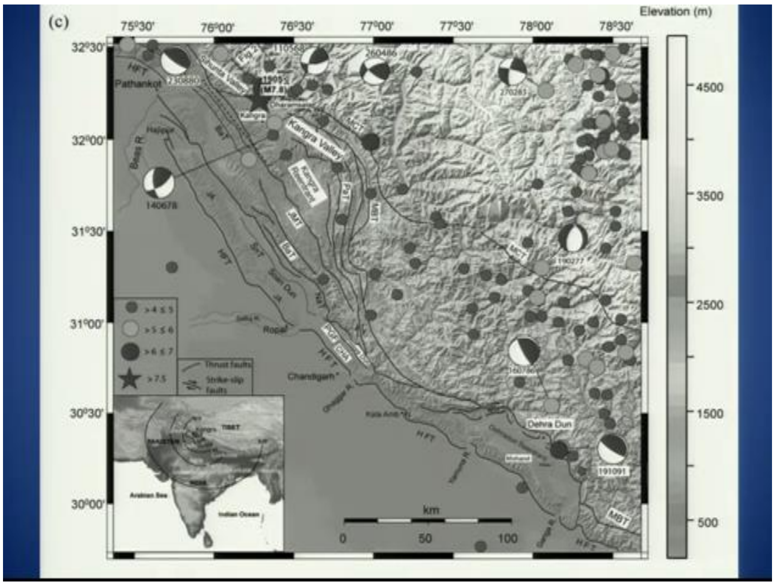

We moved and started looking for the first initially we looked at some historical data but it was not available from this region then we looked at some seismic data which was published and we found some literature which again indicated and many unusual thing that in this region the earthquakes with magnitude greater than 5 where we found the focal plane mechanisms mostly those earthquake shows the strikes with motion.

So again how we were having this fault which was identified which was strike-slip and then our more work which was been carried out along this one also indicated strike-slip. So we were not surprised to see this moment that is in strike-slip motion here but no fault was been reported till we started our work here in this region, so this one is your Kangra valley portion and as I was talking about that.

The previous research suggested that the Kangra earthquake 1905, Kangra earthquake was hosted by Jwalamukhi thrust, still there is a debate whether it was actually everything was along the slip was taken up by Kangra this or partial slip was along the Kangra Valley fault. But we have our justifications why we say that this was the fault which was responsible and hosting the 1905 earthquake and also triggered several more earthquakes during historic past.

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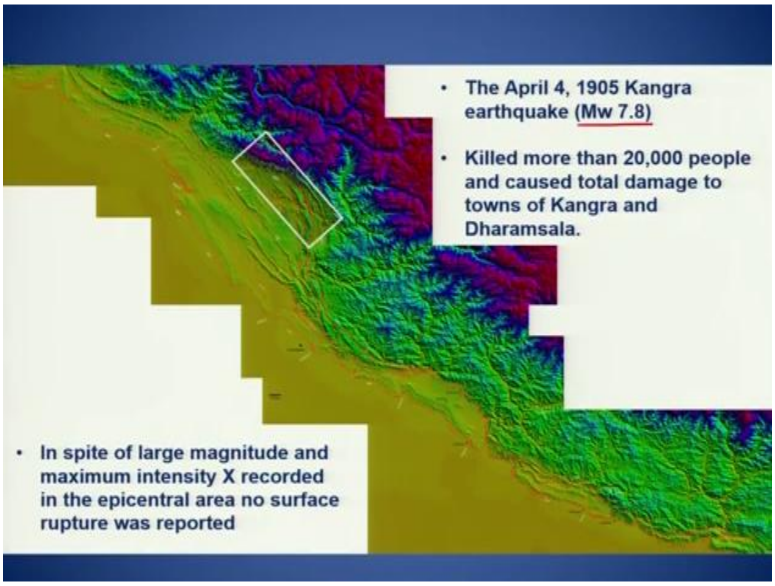

So overall pattern if you take then we have the Himalayan trend here, we have multiple faults, which are sitting further north or northeast from the front this is HFT and Jwalamukhi thrust and goes like that here and this one is Jwalamukhi thrust and then we have the new fault which we identified here this marks the MBT. So this is a valley very large valley as compared to the valleys which we have seen like Dehradun.

And then small one is here in Pinjore dun and even Kathmandu which is sitting here in Nepal and the eastern side. So this is quite large as compared to and the structure also which we see is from here it swings and then take a curve here which has also played an important role in sculpturing this Kangra valley. So this portion we took and we started using high resolution satellite photograph with an understanding that this April 4 1905 earthquake was with magnitude 7.8 killed more than 20,000 people.

And caused total damage or to the towns of Kangra and Dharamsala. So we considered this as an epicentral area and so and we thought that since the magnitude was 7.8 it must have resulted in to surface faulting. So in spite of large magnitude and maximum intensity are going up to 10 recorded in the epicentral area and no surface rupture was reported. So even the team who worked here mostly at that time, we were been ruled by Britishers. So they did study and take this survey here but no surface rupture was reported.

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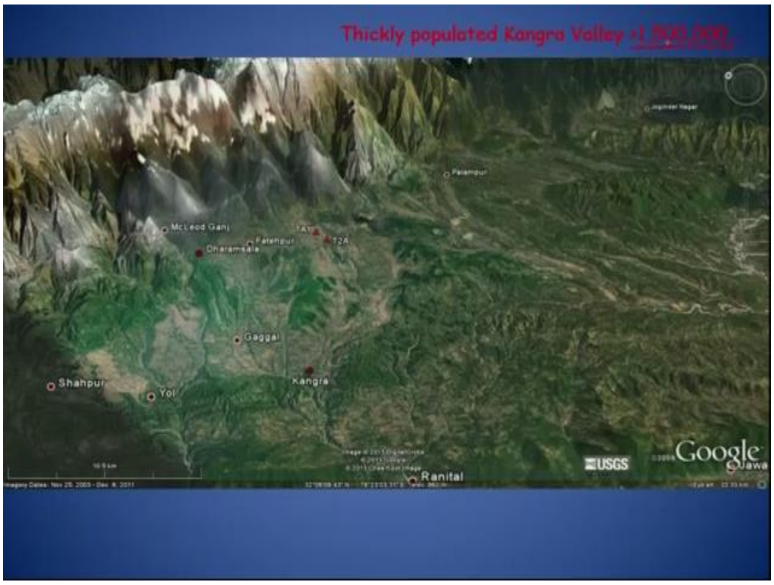

Now this, 3D Google Earth image I took from the recent Google image. So what we see here is this is what we are having the high Himalayas and very flat surface over here and the extent of the Kangra those value goes like that and this were the 2 towns where, which were damaged extensively not only this but other towns were also affected. So now if you see now then the population is almost like more than 1.5 lakh.

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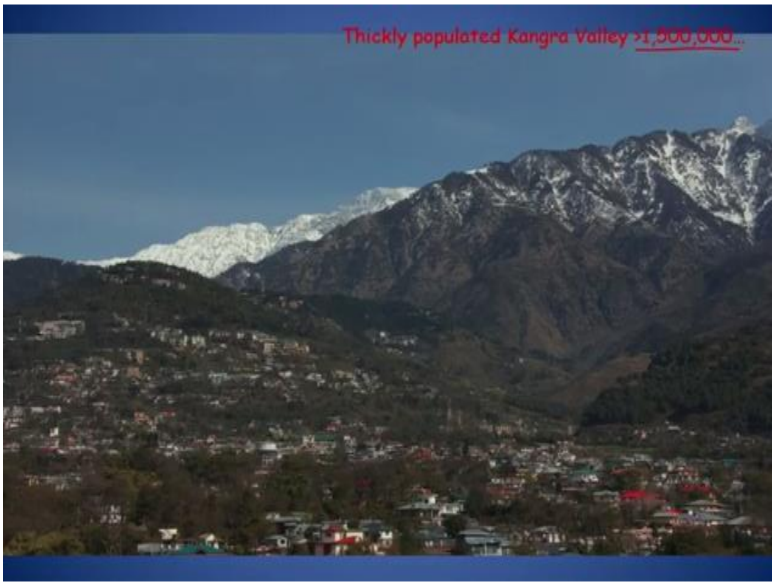

And the housing or the settlement if you look at the construction then the full valley has been filled up and no, so if next earthquake you can imagine that what will be the amount of damage and the people who will be affected because of this.

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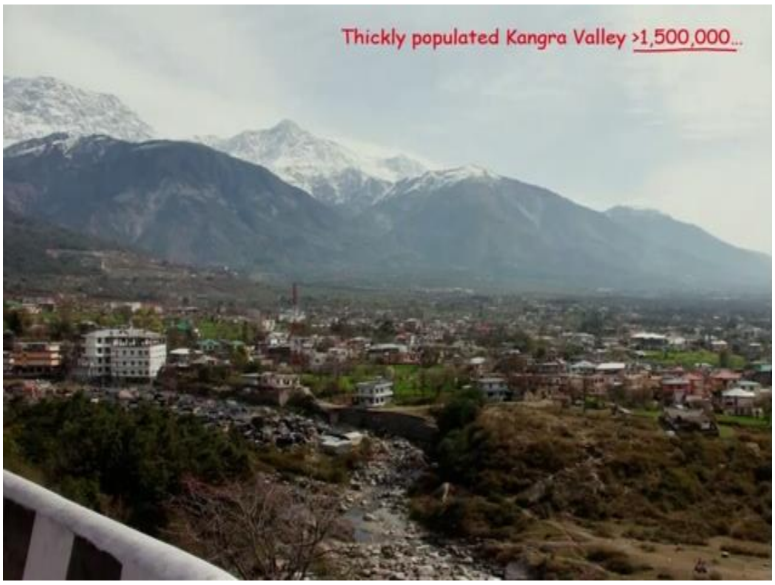

So this is the way of construction and what we found is that the fault runs exactly across the valley, which was unidentified this portion marks the displaced alluvial fan surfaces one alluvial fan surface you can see over here and there are many small alluvial fans. Of course the valley itself is resulted due to the degradation of alluvial fan surfaces over here. So you have the very typical fan topography of the surfaces and which those fan surfaces are been again dissected by the streams here.

And we have more other features, fluvial features we can see like terraces and all that. So those things had been kept in mind but we were not very sure that whether we will be able to see the strike-slip here or not. Because but of course we were able to pick up thrust falls along this one, this is the MBT which runs here which marks the boundary between the high Himalayas and the Kangra valley.

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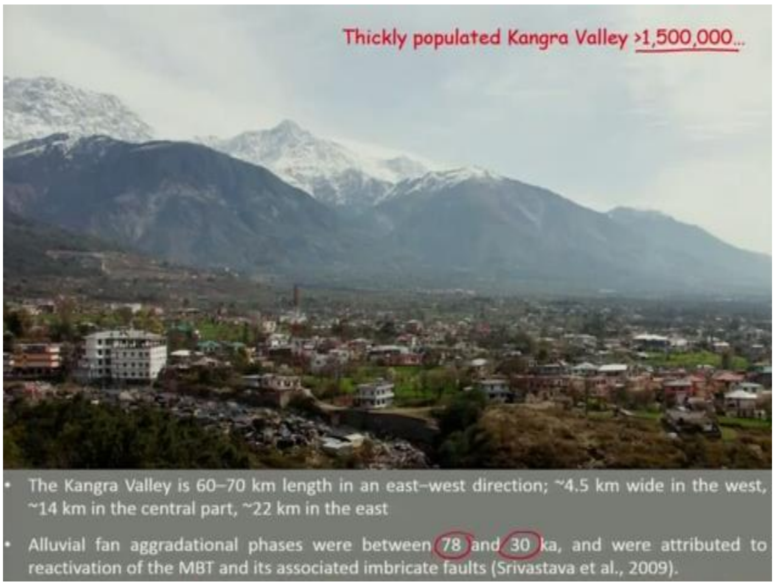

So Kangra valley if we look at as I told that it is quite long and quite wide, so it is around 60 to 70 kilometre in length. If we look at east-west direction around 4.5 kilometres wide in the western portion 14 kilometres in these central portion, so it is quite wide and 22 kilometres in the eastern side and alluvial fan aggradational phase where between 78 and 30ka, and this work which was been given done by Pradeep Srivastava and his team.

And they attributed this the aggradational phase at this to time zones were related to your reactivation of MBT and its associated imbricated faults.

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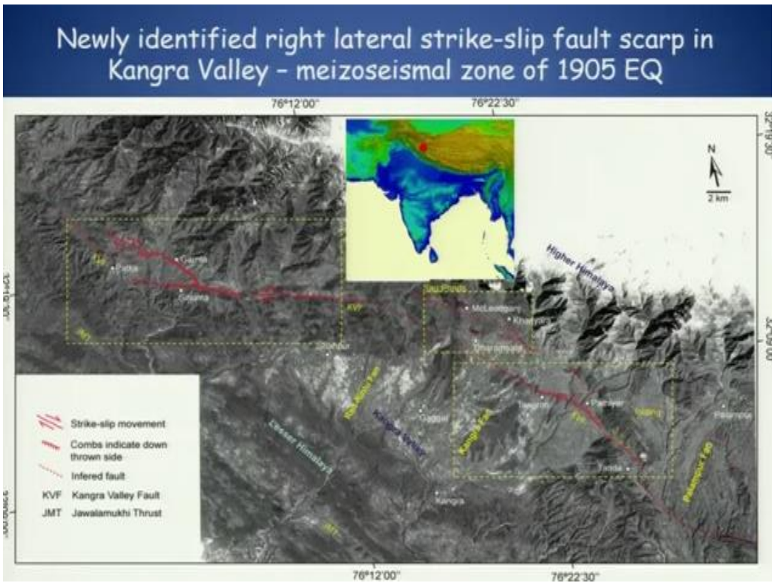

So this is the active fault trace map which was been prepared using high-resolution corona satellite photographs and we will discuss the most prominent signatures one by one where we have marked these yellow boxes. So for topography has been shown here, so those are all legend has been given here so this dashed line and went red it marks the inferred fault. We are not very confident about this but; of course there is something which could be an indicator of active faulting on the surface.

Then wherever we were sure we have marked with the continuous red line and then the combs here which has been marked it shows the down thrown side. So this side is down this is up here and that whatever shows we have like even marked here which we found on the surface folding and then the fault runs here and of course takes turn displacing landforms. As well as you see the displacement or the offset of the streams formation of the sag ponds and all that.

So this fault topography which was been picked up using high-resolution satellite photos and then subsequently we visited field. We did very detailed fieldwork, walked through all this interpreted observed falls and tried to locate that in field.

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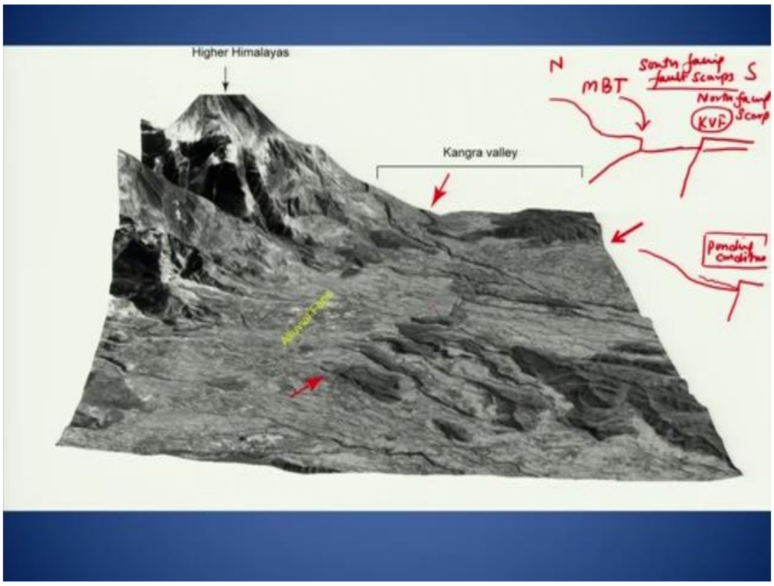

So this is an 3D view of Kangra valley and this data which is again the Cardozo data and the fault is running over here, this arrow has been marked with the fault runs and very surprising thing which we were able to pick up was that we expected that in this region because we have main boundary thrust and main boundary thrust if I take the topography then what we were able to see is that this is the topography coming here.

And main boundary thrust will show something like this and then we are having the flat surface that is here and we will be able to see defaulting something like that. So this we will be able to see the, for example the Kangra valley fault or any other fault which is cutting through this one and this is your MBT. So if we take this as north and this south then, what topography we were able to pick up here.

Was all your south-facing faults comes but we were not able to see this everywhere that is south-facing faults scarps. What we saw was, we are not very sure what is the, we fall probably it is almost vertical here and then we were able to see something like that. So we in Kangra valley fault which we identified it showed us north-facing scarp. So, but other features we were able to pick up I will talk in the coming slide.

But before we entered into the digging trenches and all that we wanted to understand that in what way the environment got affected, which prevailed on this alluvial fan surfaces so you have alluvial fan surfaces here and if this was the faulting pattern and then if you take the general slope of the area and then you are uplifting something here then whatever the drainage is coming here will get blocked here.

So what we will be able to see, so we use in very fundamental thing that here we should see some sort of information of ponds or ponding conditions. So this was first thought process which we came with before we enter into the field so let us see this whether we are able to see this or not and whether we were able to justify our thought process along this one, so this is again this side is up and this is down and the streams are flowing here and then getting offset it along the fault.

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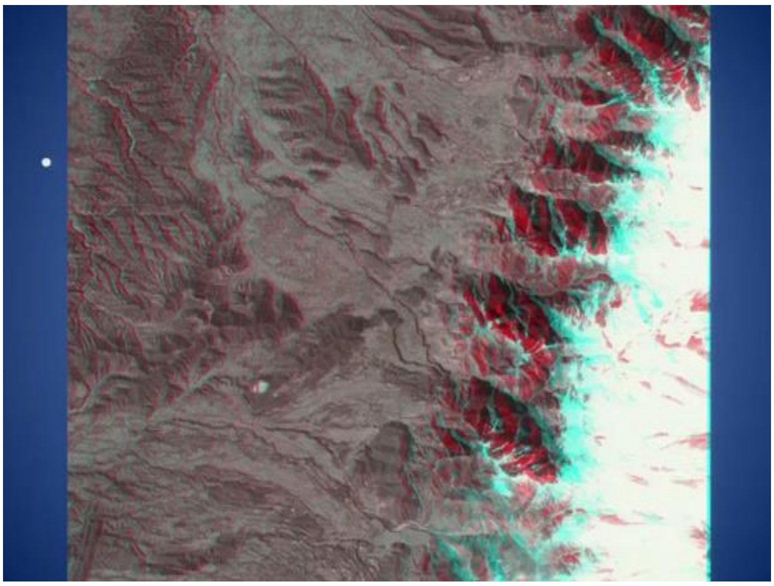

So as I was been talking about, so this is an anaglyph; so we will request you to buy if you can purchase the 3D glasses and they come very cheap you can buy that and if you are having this image you will be able to see this in 3 dimensions. So you will see the terrain in 3 dimensions. So and we will also give a lecture on this that how you will be able to prepare 3D or anaglyph basically and using the 3D glasses how you can see the terrain in three dimension.

Now this type of technique is going to help you in locating or demarcating the surface deformation or the manifestation of faulting on surface.

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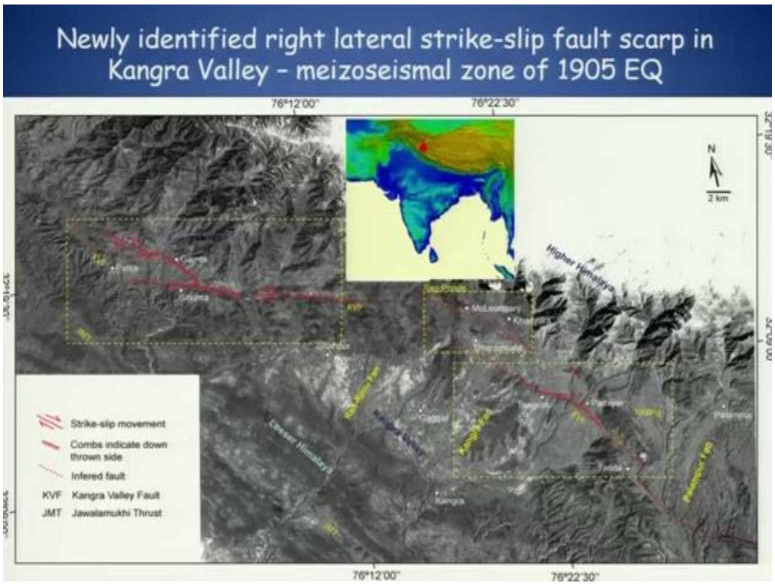

So let us go one by one into the detail so if we look at this part we will start from the western side most prominent one and as I told you that the combs are indicative of the down faulting side and but here what you see is very interesting. So you have the this portion is down this is up but at this location this portion is up this is down let us see that in field and again it changes over here.

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So this is what we solve on the satellite data that font fault runs here and very sharp linear features we were able to pick up offset of streams here.

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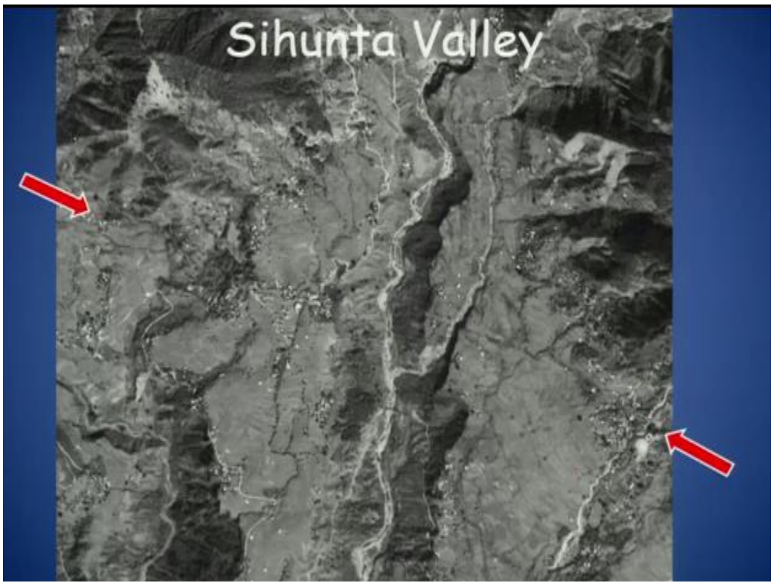

And close up of that let us see that, so this portion is from here this area now we are able to see and the 2d image. 2D image was also quite good which showed very straight and sharp features on the surface. Now this was not marked before even after 1905 earthquake until 2005 this was not marked. So what you are able to see is a very beautiful sharp offset here, this is the fault which runs close up of that portion, you can pick up.

So you have the offset of streams here you no longer offset here which did not say if I mark this line here it goes like that. So there is an offset here, so we immediately like that our detailed survey which was been carried out along this before getting into trenching part.

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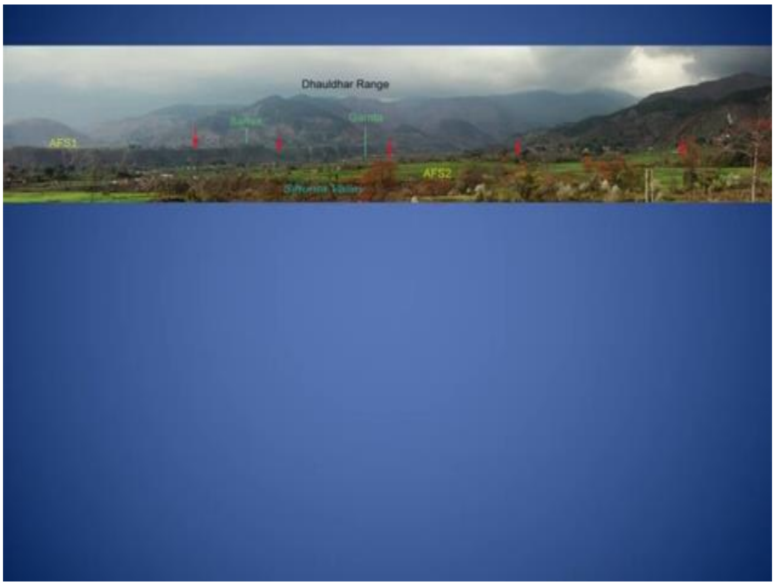

And what we see here is now we have an flat surface here, you have an another flat surface which is sitting here. So we have these are the two alluvial fan surfaces one is sitting at greater height and another is at lower height. Now the fault has run the arrows which have been marked here vertical arrows are indicating the fault trace and this is exactly the same area which we were looking here.

So this is the area and the photograph has been taken from here we are seeing the lower surface here higher surface over here and then fall goes like that and then we see this part here also.

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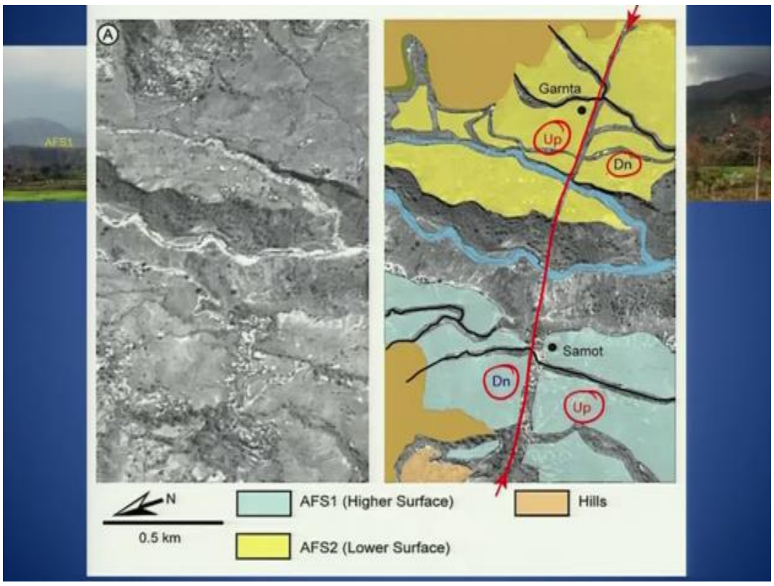

So we were able to pick up this very sharp faulting creature and detailed map was been prepared, again using stereo pairs here, so these are the same two forward an after photograph of the same area which helped us in the marketing the fault trace of the fault-trans here and we have the offset of streams here, getting displaced here and we have an interest stall feature and also we picked up that which side is up which side is down here.

So what it shows here, if you put and this is down and the opposite side. So you have the fault which runs here and this is up, this is up and this is down. So I will explain how this happens and this is really typical in and strike-slip environment. You will be able to see the opposite fault curves within a short distance. So this is the north here; so this you have the north side downside and south side up and here you are having the south side down at the north side up.

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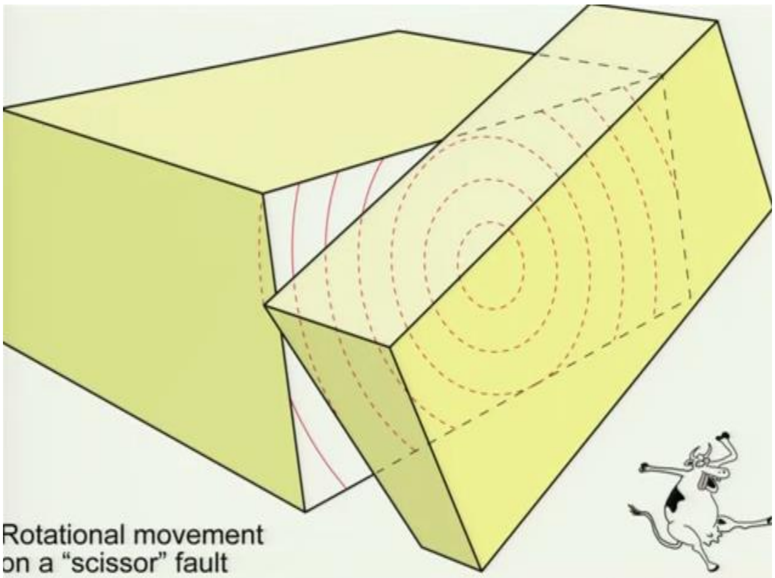

So this usually happens because of what we call the rotation, rotational movement and we also term this as a scissor fault. So if I can show here if you can so what we are looking at that we have the moment one that we have right lateral movement is of course is absolutely okay. So, we the one block moves towards your side but if you are having the block rotation likes this with along with the slip if you are having that.

Then what you see is this is down, this is up and this side is down and this is up, so this you will be able to see in terms of the rotation for what we call this scissor fault.

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So if you look at the topography here this from the different angle which we have taken, so this side you see is up this is down this side is up this is down. So this, what we were able to pick up in the field also. So this is up this is down this side is up this is down and the fault has displaced both holder as well as younger surface. So this also helps us in justifying or at least a preliminary interpretation that fault has remained active.

Since long because it has been able to displace both the younger as well as the older surfaces or it could be that the fault was formed or the displacement took place after the formation of this two surfaces. So there are interpretations which you can have options with you, before coming to the main conclusions. But of course once we wanted to develop the control on the typography part.

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So the fault typography we wanted to map first and then we wanted to move ahead.

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Now this photograph is from this portion here, so the scarp which we have photograph is from here viewing this side, so this your what you can see and the hut is this house, this house is this one here sitting here. So we have what we see is that this side is up that is your north side is up and south side is down and that what we see here the north side is up and south is down.

And the fault scarp which we mapped with the total station was almost like 14 meter high. So this definitely is not the result of one single event, could be in multiple events, this again was an and first interpretation which we did.

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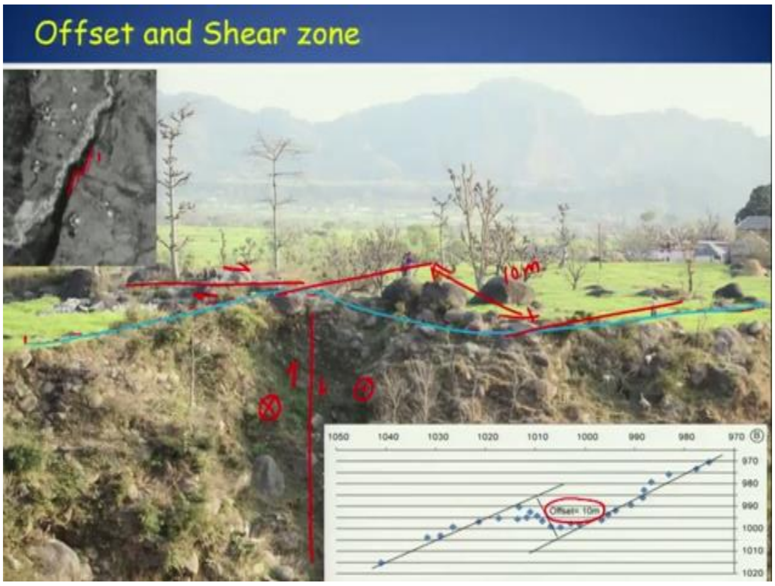

Then offset of stream here, so this four part I will just go by quickly, they do the most beautiful one which I was showing probably, it is here so you have this offset here, this goes like that and we are exactly on this boundary, so we walked on this here then we can do that. So this first start if I mark is somewhere here and then we walked along this one here so you can have the offset here.

So this was been mapped in field, so the fault is exactly which is running here and on the section and on the plan view it goes like that, and the displacement is that what we see. So right lateral slip. So if I put the line in blue then you will be able to understand well. This goes like that and four here, so this is an offset, this the fault trace and now if I have to mark the based on the topography.

Then we have this side is up and this is down and again with that which we have. We were talking about the symbol that will mark this as moving towards our side and this is moving away from us. So this is on the surface we see in strike-slip displacement and vertical were here. So this was the offset which we marked almost by 10 meters. So the offset was this offset between this line and this line it was 10 meters. I will stop and we will continue in the next lecture. Thank you so much.