Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture – 38
Compressional Tectonic Environments and Related Landforms (Part-IV)

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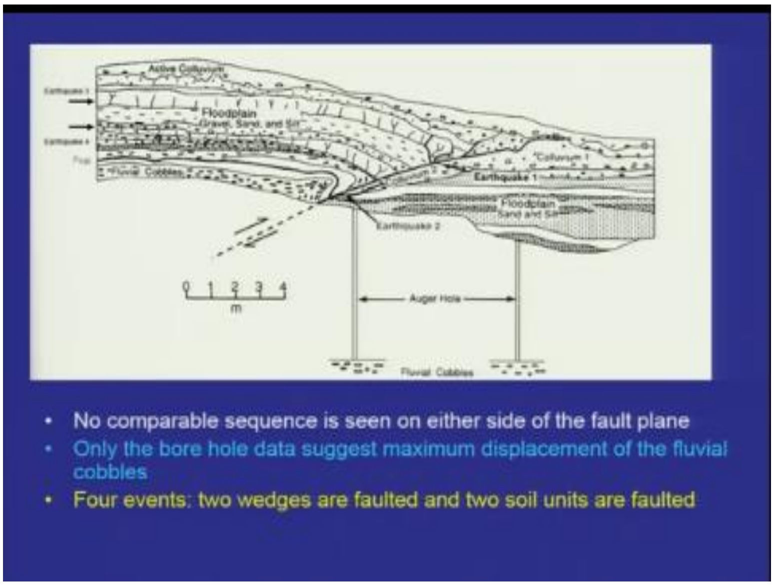

Welcome back, so previous lecture we were discussing about the colluvial wedges. Now if this was again our experience that sometime in the trenches you will not come across a correlating sequence on either side of the fault and also the well-defined what we were talking about the colluvial wedges. Now this is an example which shows the very low angle thrust fault which has resulted into atleast four earthquakes along this that was been identified based on the trench which is exposed here.

The trench lock shows atleast four earthquakes along this know and the point here is that you will do not see the comparative sequence on the how the footwall side and the hanging wall but based on the soil formation because the soil formation will help you in identifying that this was the previous surface which got deformed and then subsequently capped by the next depositional event.

So based on the soil also and that is what we discussed in the initial lectures that understanding of soil formation and all that is important when we are interpreting the events. So this shows that this is the event one along this one and so the oldest event and then event two was, because we have the two soil you do not see here, so atleast those two soils were been displaced.

However we do not see the sequence probably in this two layers are sitting far way in the deeper part of the footwall. So this is an event three that is the next event. So what we see here is that no comparable sequence is seen on either side of the fault plane. So there is no need to worry for that, but a close interpretation or the understanding of the sequence of the position can help in identifying the events.

So only the bore hole data suggests maximum displacement of the fluvial cobbles. So if you take the course here which has been shown here, that you have this portion that is the fluvial material comprising of courses deposits were sitting far deeper which will not been encountered in this section. So sometimes you can do this, but this is again going to mean very expensive exercise.

But you can based on this atleast you can understand the thrust faulting you have the older sequence overriding the younger one here. So four events were been identified and those were based on these two soil units and then two colluvial materials which was been encountered in this trench so based on this, so this was the colluvial material which is also faulted along the fault.

Who was represents the second earthquake that is the penultimate earthquake and the final latest one was along this and which suggest the formation of this Colluvial material.

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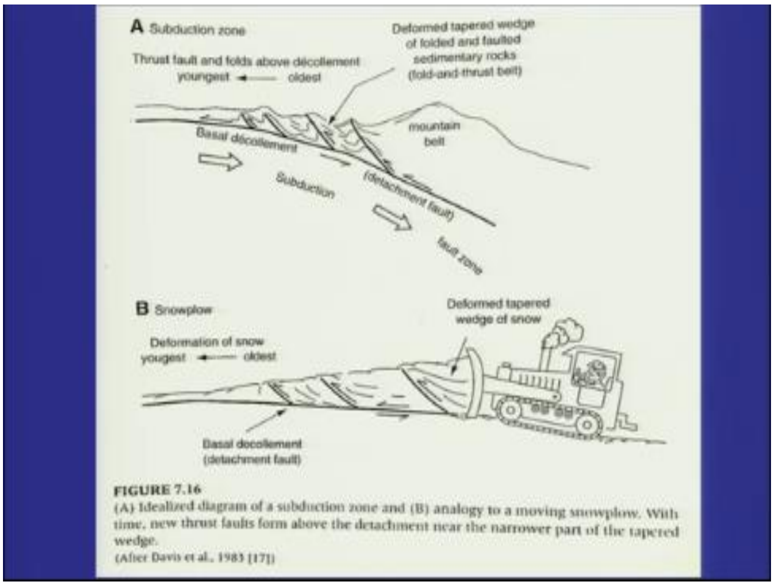

Now usually in particularly in Himalaya this what I was explaining earlier that you will have a very typical low angle or detachment and you will see the imbricated fall system and this can be explained with the help of the, if you bulldoze the material on a very low angle surface then you are bound to see the imbricated falls which are coming on the surface and you will see the young in-sequence.

That is you will have this one is older this one is younger and this youngest. So the deformation is getting younger towards the foreland side. So this is not typical or we can say idealized seek pattern of deformation which is seen in Himalayas.

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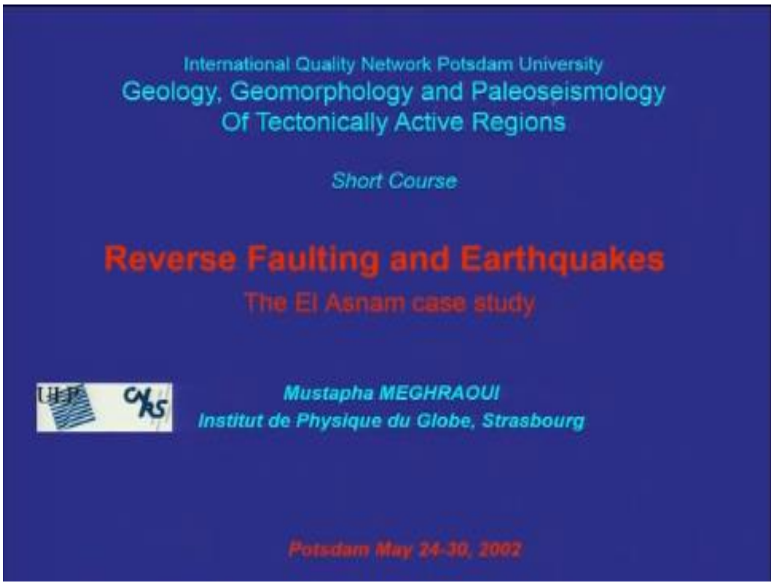

Now there is another presentation which I borrowed from Mustapha MEGHRAOUI from Strasbourg IPGP and average for the studies we have been carried out on the El Asnam earthquake. So let us see that, how we see like the geomorphology and what we encountered in the paleoseismictries and how the deformation pattern varies along the fault.

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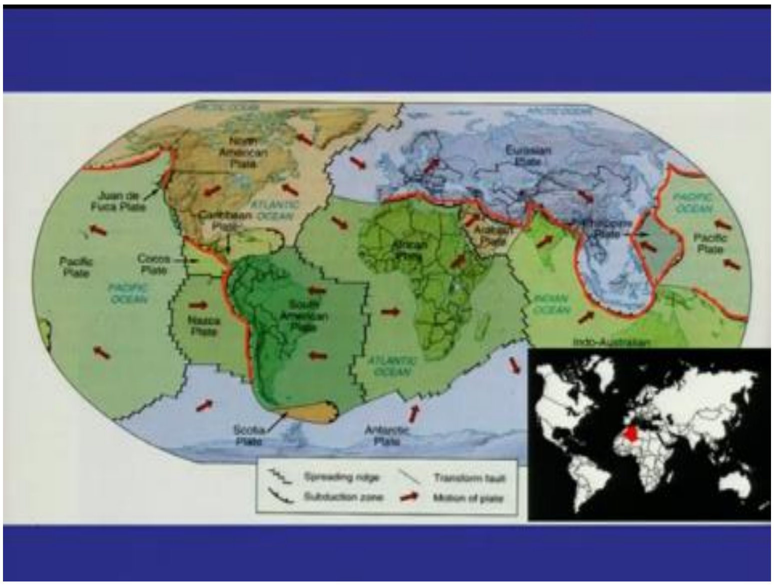

So this portion is from this region particularly where we have the deformation along the El Asnam earthquake. So you have the Algeria is sitting here, so we have the similar tectonic framework which we see in the Himalayas so there is a part of the Alpine Himalayan range.

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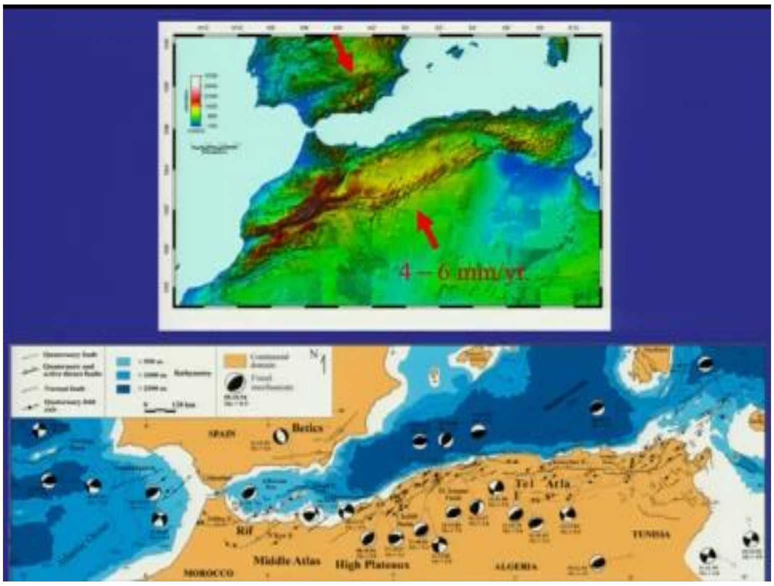

So the very clear-cut fault is been seen on the surface along this plate, the plate boundary between these two plates. We have and the slip is that the convergence rate is around 4 to 6 millimetre per year. So you have like the fault system which has been developed here as well as along this line.

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So for the strike of the fault changes in different segments. So you have the fault race which runs here and this is the close-up image of the Landsat image or video old from 1977. So it shows the trace of the fault over here and goes like that and the different segment shows different patterns of deformation. So segment B and A, the strike is not the same of course they belong to one same fault system.

But the strike is differing in segment 1 and segment B and then you have the segment C also, the strike is slightly different. So you had this, like this they have marked.

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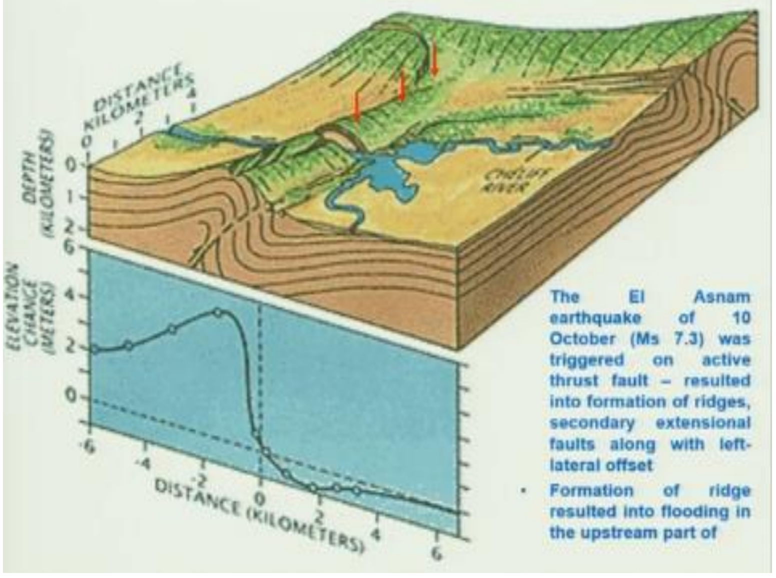

At different sequences, so the major deformation was along the thrust fault, which is been shown here and this was the typical folding which was experienced in the form of the false cap on the surface. So the El Asnam earthquake was on 10th October and that magnitude was 7.3.

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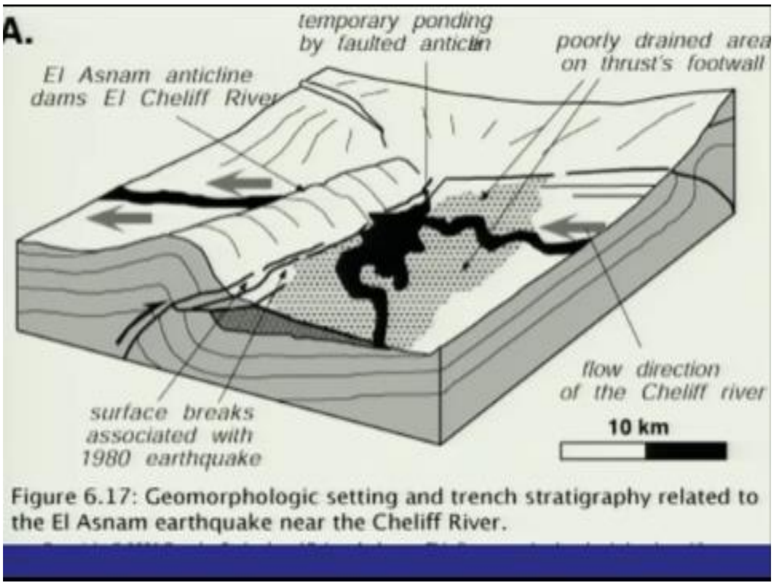

Figure 6.17: Geomorphologic setting and trench stratigraphy related to the El Asnam earthquake near the Cheliff River.

So this is the same sketch which has been shown that you have the low angle so at the base you have a high angle and then it becomes the low angle towards the surface. So typical of fall bent folding which has been seen and experienced in El Asnam earthquake.

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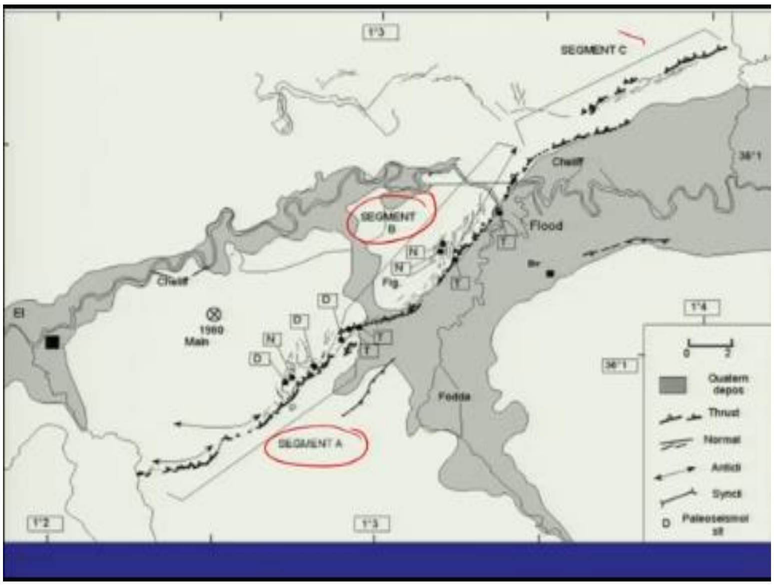

Now coming to the different segments and what they did was they carried out a detailed mapping along this different segments. Where the strike is not the same strike varies and what type of deformation they were able to encounter in different segments. Segment A segment B and segment C. Now coming to the part of.

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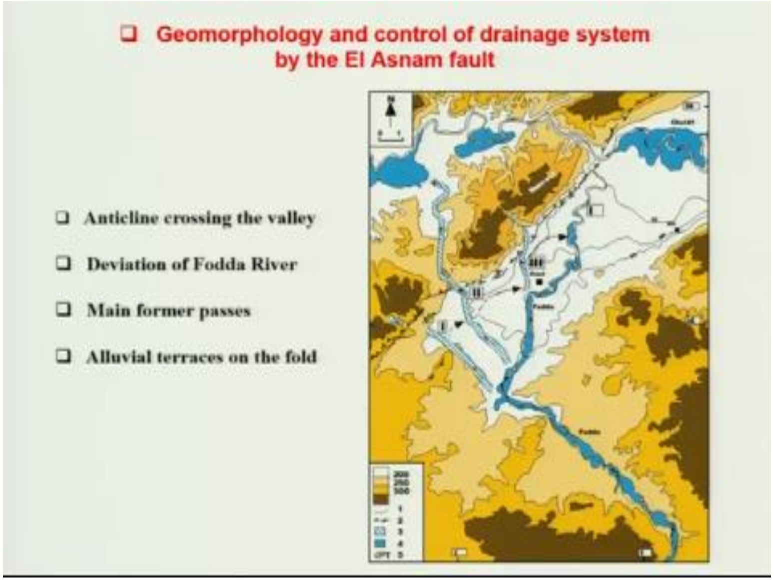

The geomorphic and the drainage control because of the El Asnam fault what was been identified that because of the folding and there was an damping of the or the blocking of one of the channel as you can see in the previous slide.

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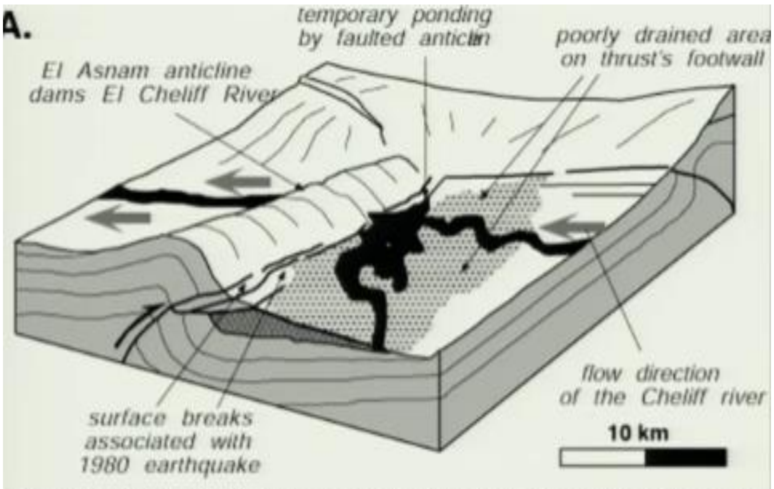

Figure 6.17: Geomorphologic setting and trench stratigraphy related to the El Asnam earthquake near the Cheliff River.

Here that you have the added stream which was blocked because of the, so this blackish portion is shown as the stream here so this cliff or the formation of the anticline because of the deformation along the low angle fault here resulted into the deformation of a pond here so this shows that this channel was disrupted and blocked because of the natural dam and temporary pond fault, faulting by the anticline.

So this portion remains as a poorly-drained area on the thrust footwall. So this was the hanging wall and this is the foot wall here. So this was because this process was experienced because of the 1980 El Asnam earthquake and they also like identified in the trench that similar problem phenomenon has occurred in the past also.

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Now along with that they also tried to look at the different deformation pattern in segments one segment that is A segment, B and segment C because of the change in this strike. So the deformation from blocks they channel here which was flowing, so you can see this was the main channel which used to cross this and this is your hanging wall side and this is your foot wall side and this resulted into the flooding in this particular area.

Now a similar earthquake as I told that they were able to pick up the similar type of sequence that is your Lake deposits or because of the ponding condition in their trenches.

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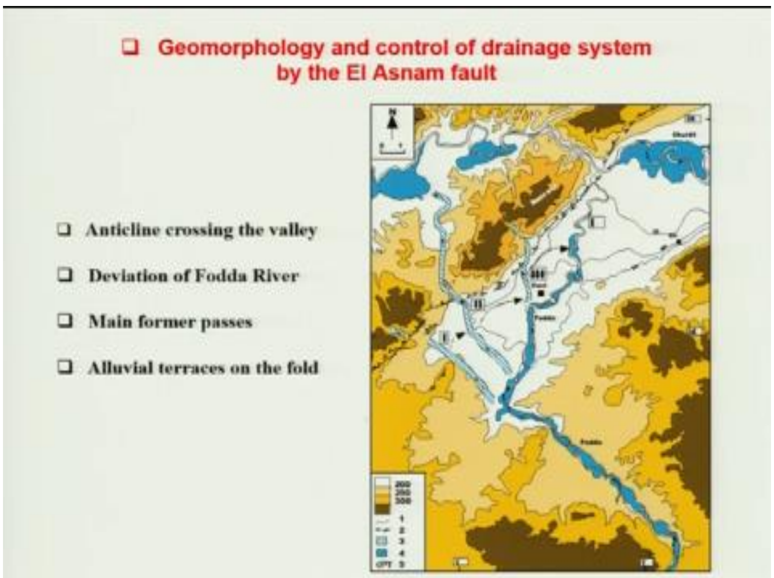

And also they have been able to pick up some paleo channels here,

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So this was the pattern of deformation so you can see the scrap here the one scrap is running over here and another is seen very blood image but you can easily make out the scarp which was developed in this area and then we have a very clear scarp which was developed on;

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One side and another one also very similar to what we were talking about from the Kutch. So you have the collapsed material and dragged along this scrap. Then along with that what they were able to pick up was on that some oblique moment which shows the strike-slip. So lateral movement was also picked up along the fault, so this shows the boundary here which is shifted here along this fault line.

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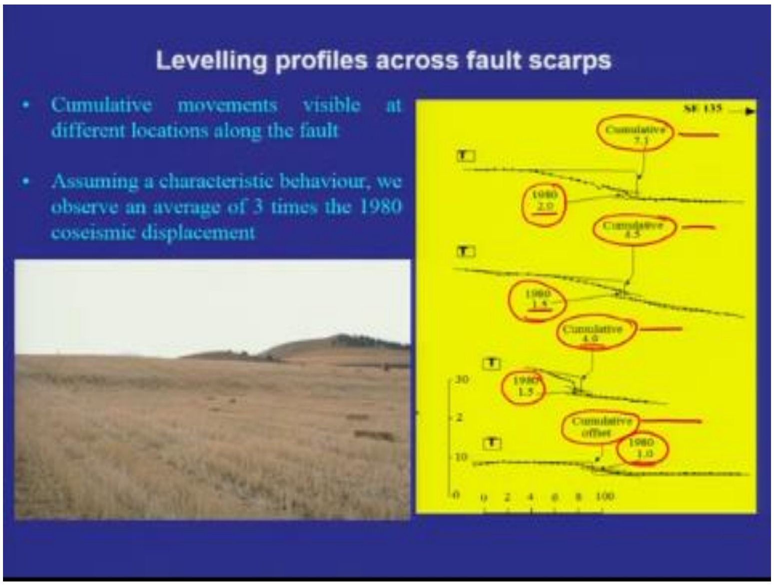

And then scarp here so levelling profiling across the scarp what they did, so they measured the displacement of the surface at various locations. And the two meter of displacement was experiencing in 1980 El Asnam earthquake. Where the cumulative displacement of the surface was around 7.1 meter and in some places like here they identified 2 meters there in some locations they were able to see 1.5 meters and so on. So what this suggests not the extra height which they have, they encountered at various locations, was because of the previous earthquake.

So this shows the cumulative displacement because this they were able to pick up from the recent rupture, so it was very clear they were able to pick up with that but the actual height of the scarp when they did the topographic profiling then they were able to pick up that it was comparatively larger than what it was experienced in 1980 earthquake at various locations. So this suggested that they had the cumulative displacement averages which is manifested at the surface.

So cumulative moment visible at different locations along the fault assuming a characteristic behaviour, where they observed an average three times the 1980 coseismic displacement. So that they inferred initially that if you compare the cumulative displacement and the displacement which took place at the time of the earthquake 1980 earthquake then it shows at least 3 times more the displacement observed in terms of the offsetted surface.

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So the objective of the paleoseismic investigation usually remains the same. So what they did was to identify the paleo earthquakes or the ancient earthquakes, they investigated the marsh area which got flooded. So if you are having for example that is what they were showing that this was the stream which was flowing, for example, like that and then there was an uplift here along this fault so it blocked this channel.

So then use what they were able to identify was that this channel did not cross here and because of this whopping they saw that there was flooding here, so ponding condition definitely if the cumulative scarp which they saw was more than 2 meters because the 2 meters was approximately the average displacement which was been picked up into a 1980 earthquake. So it was more than the smaller phenomena would have occurred in the past.

So the investigation was on the marsh marshy area trench, the main fault scarp and document success of displacement major vertical offset with the levelling. So what they did initially was that they identified the offsetted area or the displaced area they did the profiling of that area based on that where they were able to identify that they had the cumulative scarp. So the trench was across the main fault scarp to document D and the previous displacements.

So this was the area where they put the trenches multiple trenches were being opened up in the region and that gave them clear indication that this scarp cumulative scarp, which they were identified was not because of the single event. So the multiple trenches were being dug across the scrap here.

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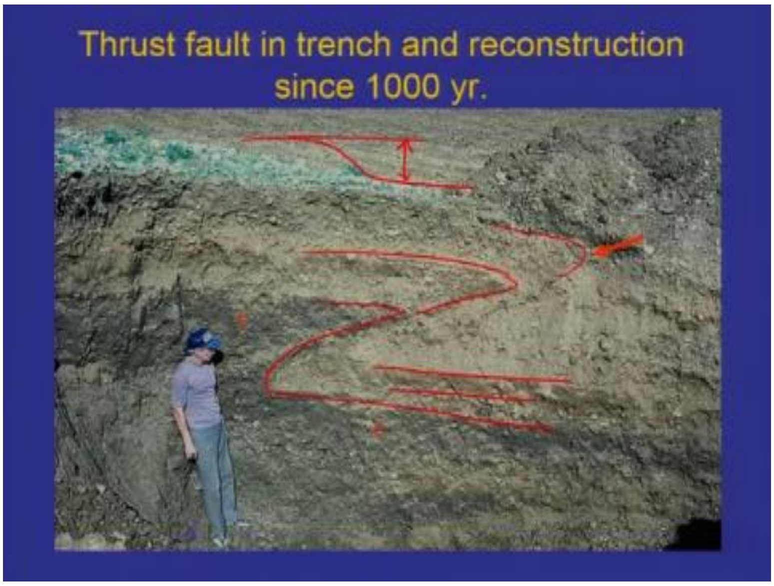

So this is the scarp which they identified. So thrust fault in trench and reconstruction since the last 1000 years. So that what they saw, they have like this is one unit which can be clearly picked up and another matching is this one here. So of course that what we have been discussing is that the older one will show the maximum displacement. So and finally what they have is the displacement of this material here on the surface so this was 1980 rupture.

So as you will come across that you have the maximum offset and that shows cumulative offset of the surface similarly in the trench you will have the lead in the older units will get displaced. We will show more displacement as compared to the younger ones. So these are the different units which they have been picked up but this was the most prominent one which goes something like this here, and this unit you can pick up over here and then finally what you see is this one.

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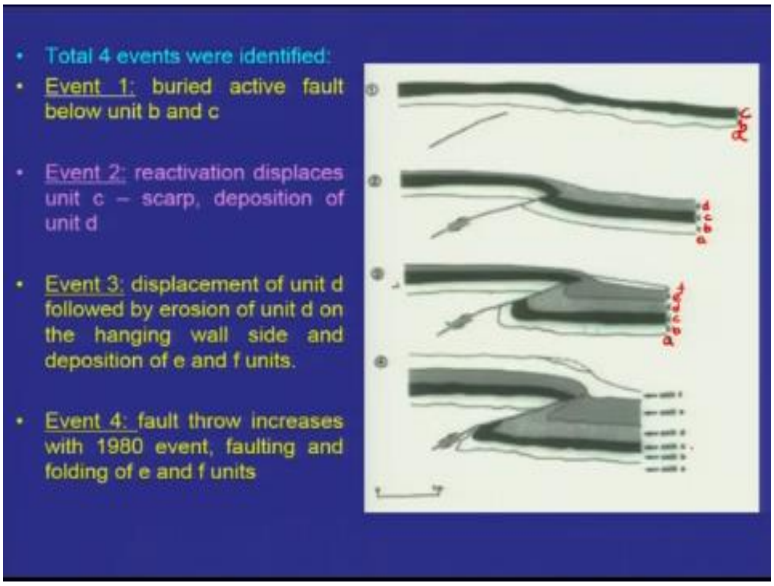

Now if you reconstruct this then what you will be able to talk about is that the fault existed before this event, so you had some scarp which was present there along the displacement along the fault. So total 4 events they have been able to pick up, so if you see the event1, buried fault below unit b. So you have unit B here, so you have the buried fault for being below unit b and a.

So these are the two units I am sorry for the image is not clear but this is b and this one is c here and then you have a here. So event 2, reactivated displaced unit c scarped the position of the and then so this has been displaced either you take this as an abc. So if you take this a b and c that what it says not this scarp which was, which existed at the c scarp and then finally the deposition of unit d.

So you have now the a b c and d here. So the next phase after the faulting covered the event 2, then we have like we see here and we have a and b and c, d, e and f here. So even 3 displacement of unit d so this was displaced so you have the displacement of unit d, the event is occurring after d so then you have the displacement of d and then you have the deposition and the displacement of e, also in this sketch which has been shown.

But the second event was after the unit d. So event 3, displacement of unit d followed by erosion of d on the hanging wall side and the deposition of unit e and b. So in this phase of the deposition you will experience a bit in a deposition of unit e and f. Then last one, which displays the complete sequence, so fault throw increases with 1980 event, faulting and folding the unit e and f. So you can regenerate or retro deform the sequence in this way of any trench. So I will show a better example from the trenches which we dug in the Himalayas that how you can reconstruct the events and identify the paleo earthquakes.

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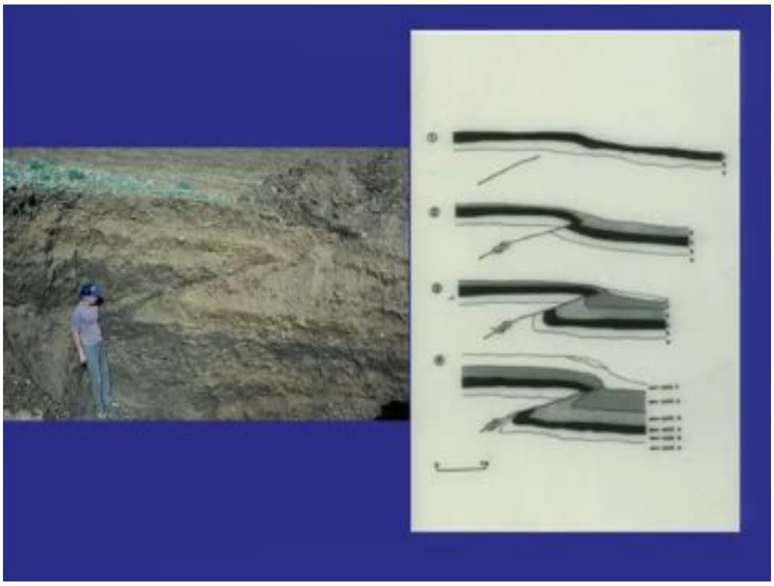

So this is the same sequence which we were discussing the previous one, so you have different events which were been picked out at least 4 events we have been picked up in this small trench. So along with this we will also come across;

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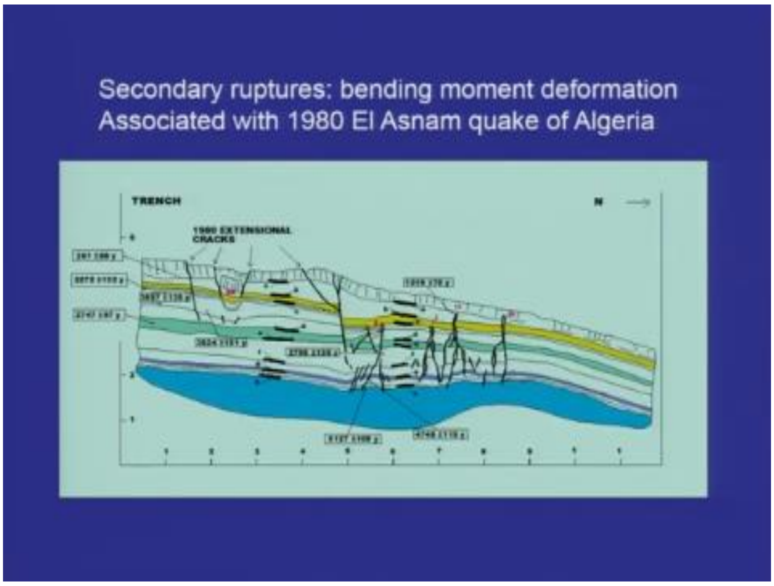

And the secondary faulting and this was another trench which exhibit just the whopping. But the formation of or the development of the secondary faults and this displacement along the secondary fault helped in identifying different events.

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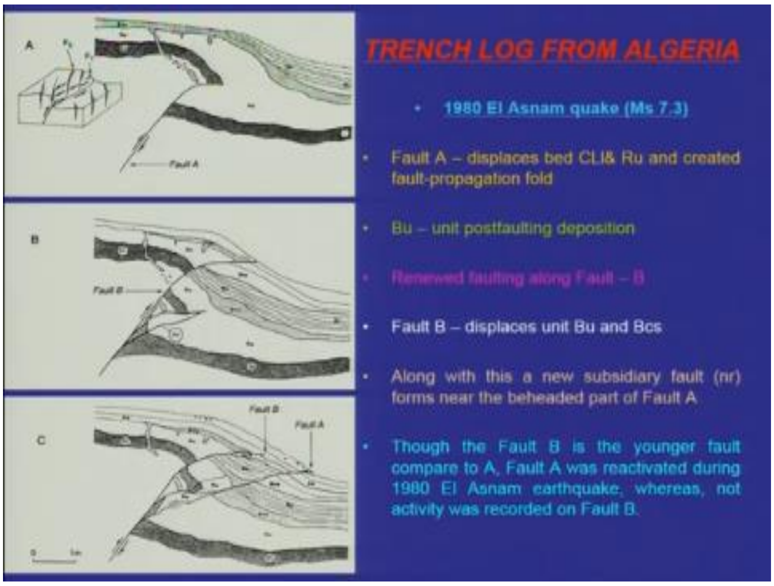

So another trench it explains muggingthe earthquake of El Asnam. So having high angle and then getting into low angle displaces unit fault a, and this Fault a, displaces the bed CLI and Ru and you have the Ru and CLI here and created a fault propagation fold. So it did not reach right up to the surface but it created a fault propagation fold and Bu unit post faulting depositions. So we have post faulting deposition here and then the displacement of the event.

So the deformation was the next event again displaced or took place along the same fault but along with that two subsidiary faults or the branching out faults were also developed and they also displaced the events that endure the faults they displays the units at the lower portion. So renewed faulting was along B, so you have another fault which came right up to the surface was the branching out Fault from Fault a.

So you can either identify that different faulting events along the different fall strengths. So fault b displaces Bu and Bcs and along with this new subsidiary faults that is your nr forms near the beheaded part of the unit that is fault strand a and that also displaces the older units. So finally, what we see is the most recent earthquake did not slip the material along the fault strand b, but it again got reactivated along Fault A.

So this old fault which was the first and then the branching out fall came in and displacing the younger sequence and then finally what you see is that Fault B, did not take up the slip but the most recent earthquake was along fault a. So though the Fault B is the younger fault compared to A, Fault A was reactivated during 1980 El Asnam earthquake. So we have to be extremely careful talking about which faults trend has taken up the slip during the recent event and that can be done based on the cross-cutting relationship you will examine in the trenches.

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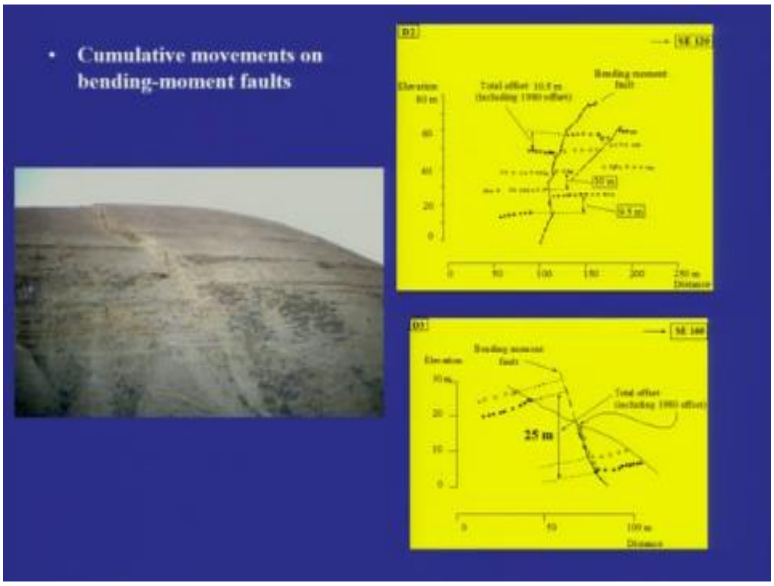

So this is another example of the cumulative movement that is an offset which they were able to pick up along one of the default trace in different segments, which shows the right-lateral strike-slip moment.

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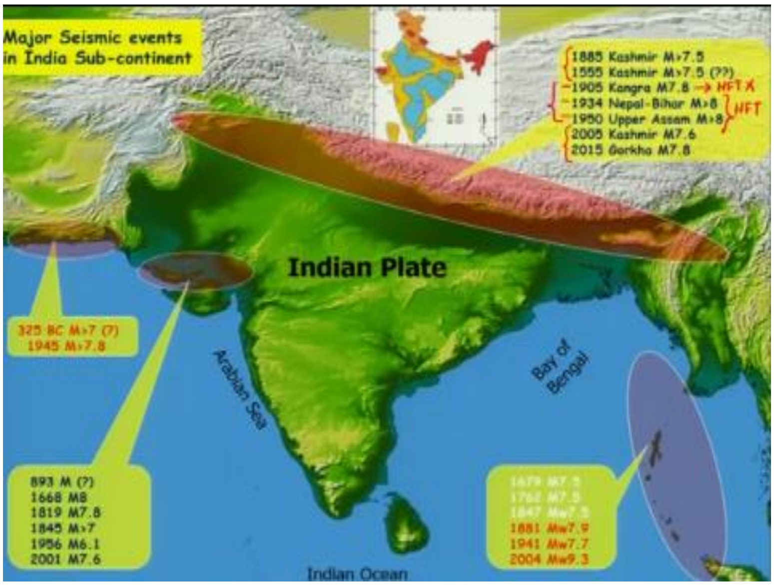

Now coming to the Indian part what if you see, then we have the most active region which is sitting in this zone there is northern portion and that marks the plate boundary between the Indian plate and the Eurasian Plate. So we have like incomplete record I would say rather now which open but to some extent we have the historical data which shows that there were earthquakes are based on the damage and all that.

But recent studies have helped us in identifying the ruptures of at least these 3 events. This were two were very recent, so we know that what happened even the Kashmir earthquake of 2005 was ofcourse along the earlier identified thunder fall in Pakistan and 2015 remained blind but this was along the Himalayan frontal thrust but we never have the idea that where exactly and this two earthquake on which fault this will been triggered.

So we have some understanding taking into consideration the ancient earthquake, all this 3 where in 20th century, but again no surface ruptures will been identified till last recent years but in last 4 or 5 years many paleomic studies have been able to identify this rupture. So this 1934 and 1950 where along Himalayan frontal thrust and this was been believed that this was a long Himalayan frontal thrust, but this is not along the Himalayan frontal thrust.

I will talk about this at least this earthquake and what we have been able to pick up about the ancient earthquakes which have occurred in this region. So now with having this understanding and what we see the earthquake, earthquakes which have occurred in different regions along this what we have is the micro macro seismic zonation. So this is an seismic zonation map, which shows the different zones that is zone 5 is red and then zone 4 zone 3 and zone 2.

So the blue one is your zone 2 and we do not have zone 1 now this was been modified after the 2001 Gujarat earthquake. So I will stop here and we will continue in the next lecture.