Earthquake Geology:A Tool For Seismic Hazard Assessment
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Lecture-34
Compressional Tectonic Environments And Related Landforms (Part IV)

Welcome back. So, today we will talk about the paleoseismological studies and normal faulting environment.

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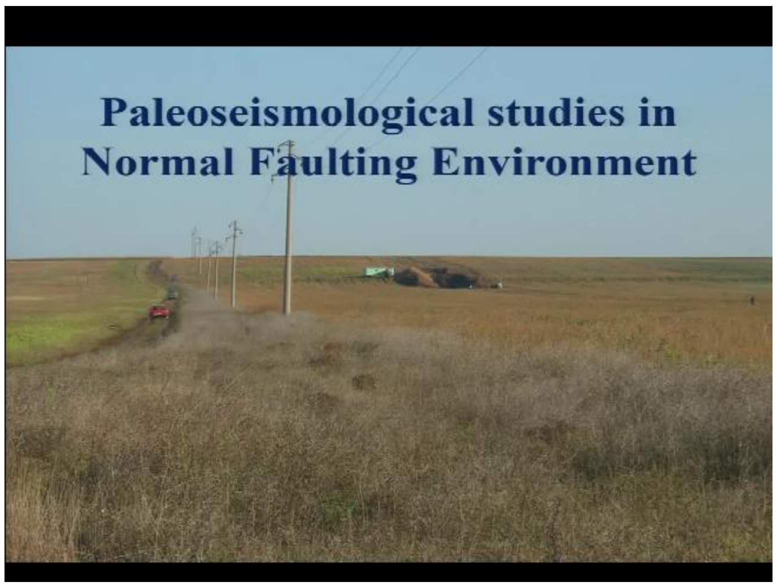

Now, as I told in the beginning and in number of lectures that the faults scrap, which we will come across in normal faulting environment will be very much similar. There is a morphologic very much similar to the faults scrap which you will be able to see in compressional tectonic environment. So, what you see here is the small warp here and this photograph is from Bulgaria which shows a very beautiful scarp.

This side is comparatively up and this is down but in case of the normal faulting this the hanging wall, this is the foot wall here. So let us see few examples from the nominal faulting environment and one which here I am going to put from Bulgaria and other is from the along the opinion fault in Italy. So, this presentation basically comprises the slides and the data which was supplied to be by the respective authors from this region who are working the basically the paleoseismologist.

So let us move ahead and see what and best we can learn from how to conduct the paleoseismological studies and what we should look in normal faulting environment.

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So there is the scarp in Bulgaria which is from the higher portion here and then you have the lower part at this stage, this is your foot wall and this is your hanging wall.

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It is close up of that, you have a very beautiful scarp. So, if you take in profile across this one, then you will be able to see something like this.

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Again another edge of the fault scarp.

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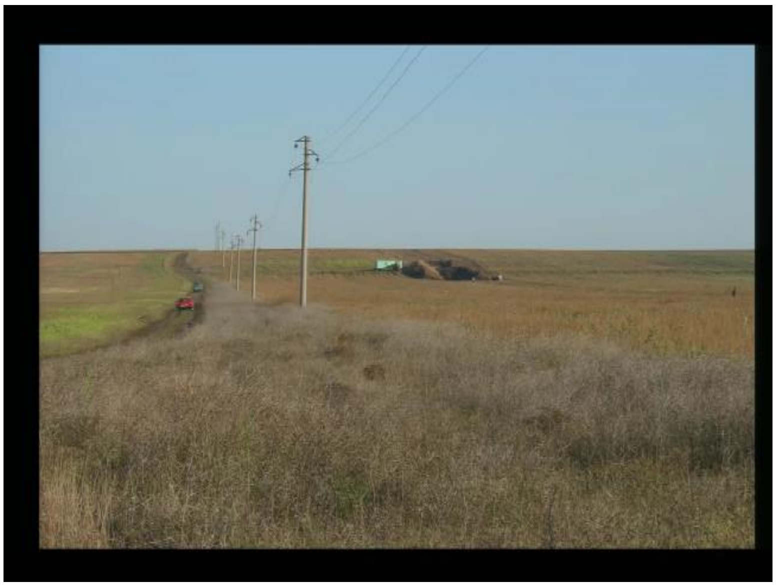

So, what we see in the section. So, basically we try to as we have discussed in the technique that we try to open the section and try to see the old earthquake signatures preserved in the sediment or in the stratigraphy.

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So, this is a trench and in techniques also I have discussed this field techniques that how we open the trench, you take this some part of this scarp and then you get down into the different bass part or the toe of this scarp and further in the crown which is undefined players and you will try to identify the different events. So, this is the same way it has been done. So, the trench wall has been cleaned properly the material which has been excavated has been kept out.

So, that you can move along the wall here on the top and then you do cleaning and mapping and all that. So, fault as if you look at in the previous slide. So, fault runs exactly at the base here. So, this is a very common way of identifying that way exactly when the displacement you will come across. So, mostly because of the erosion of the free phase and the deposition the fault will be seen at this location.

So, what you see is the displacement here and based on the different colors of the layers you can easily identify those things and then you have a very thick soil layer here event rich, organic rich layer is there. So, on the on the upper portion of the scarp you will have very thin deposit because this is down faulted hence you will have in very thicker material or the deposition and the power of this sediments which will take place here.

So, mostly we will see in the upper portion you will have thinner thickness of the events will be less whereas in the down faulted block you will have thicker sediment situation.

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This is the close up of that. So, you have any fault zone which goes here. So, one fault which reaches right up to this and other one goes and stops somewhere here. So, the cross cutting relationship has to be taken and this is the topography of the last event on which the deposition has occurred and the end resulted into deformation of soil. So, next event this will be this will break and this is what we call, this will be the event horizon for the next event in future.

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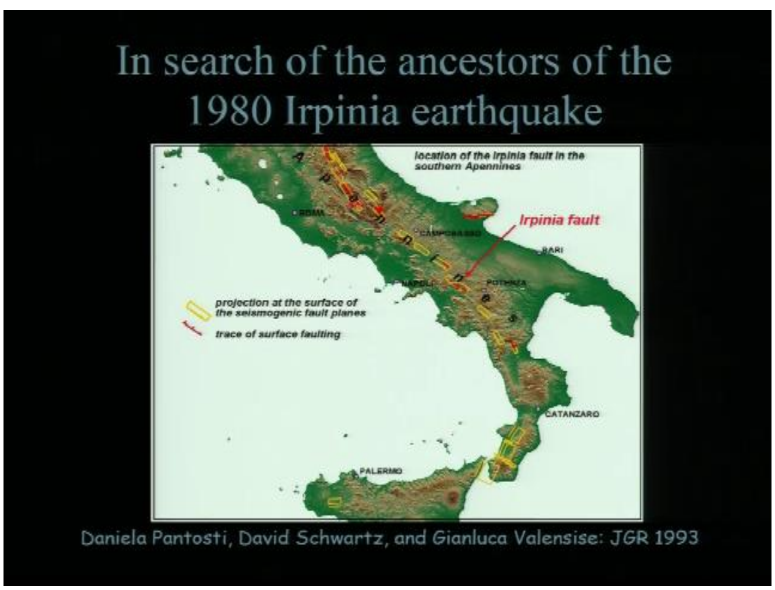

Now, coming to the one of the beautiful example of a normal faulting in Italy, and this work was being carried out by one of my close friend and her group, Daniela Pantosti from INGV Rome, and she supplied this presentation. So, usually I use this for teaching purpose and I hope that this is going to be a useful presentation to understand the defaulting environment basically an extension of tectonic.

So, if you want you can have the details from the Journal of geophysical research, the paper was published in 1993 by Daniela Pantosti and her group. So, this was the rupture, which occurred along the irpining fault in 1980 and that earthquake was named as it irpinia earthquake. Now, one thing which similar thing which we want to do in India also that we want to map each and every active fault phase on the surface.

And then we should have the detail. So, this is the is one way of putting the data in digital form that you when you click this, you will get the all information about the respective faults when it moved last and what is the history in terms of the earthquakes on particular fault and what are all geomorphic features. So, this is all data has been put on GIS platform. So and available for the users and public domain.

So, who is ever required this information for any development or any other project, then they can have this information using that site.

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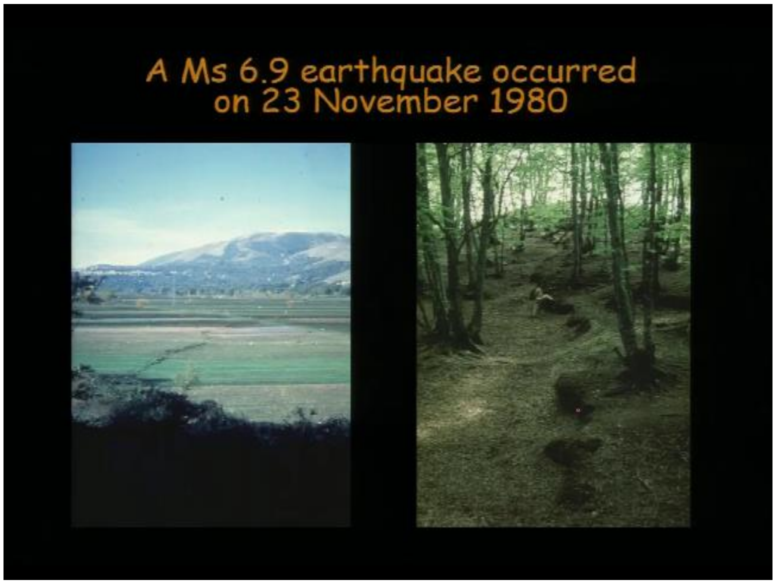

So, this was the rupture and the magnitude was not very high, it was around 7 6.9 that occurred on 23 November 1980, irpinia earthquake and the rupture has been seen here on the surface, and this was the scarp which were formed in that region.

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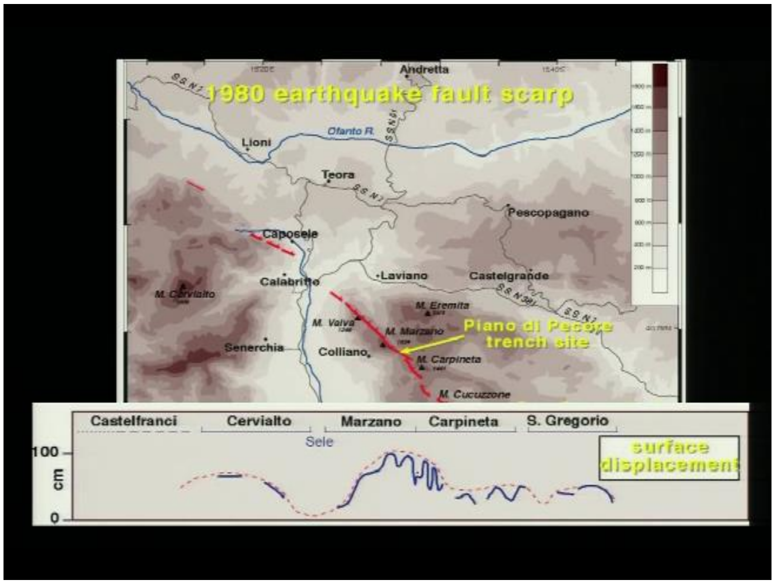

So, 1980 rupture was when identified along this fault and different locations. I will show couple of photographs of this, which they have taken and then finally, they decided to undertake a paleoseismic studies in one of the best location, which provided them the history of the faulting on irpinia fault. So, this was again the amount of displacement, which was like observed after the earthquake, which was measured.

And as I was talking in one of the lecture, that the maximum displacement was in the central area and it dies out on either end. So, this was the location where these are the 2 locations which had been shown here which shows maximum displacement and during the 1980s irpinia earthquake.

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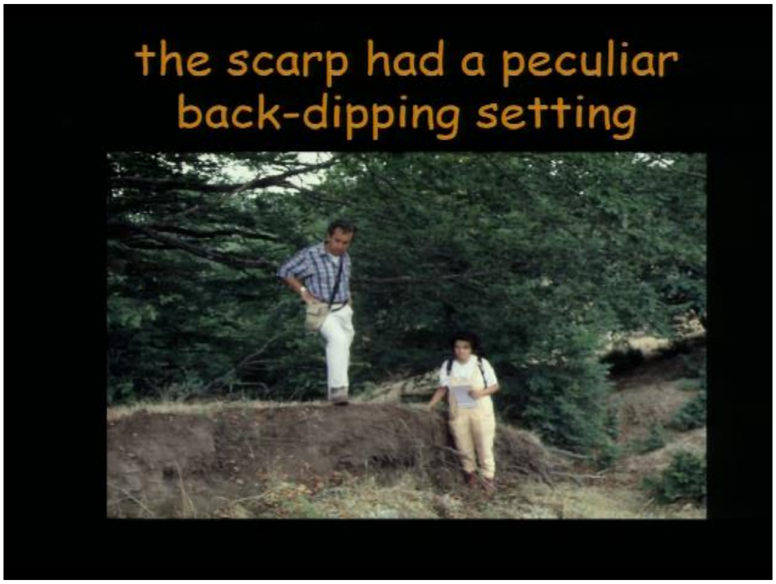

So, this was a scarp, very beautiful clear scarp and then deposit where the surface, this surface and this surface were same before the event which got displaced.

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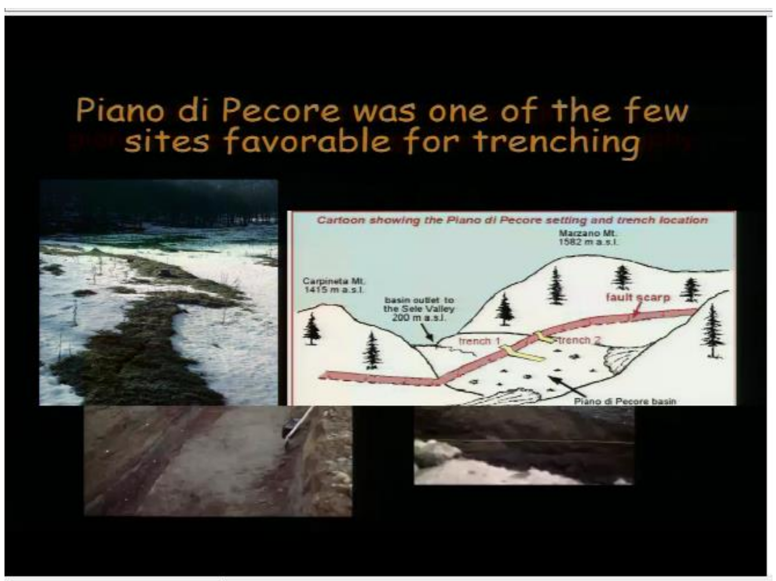

So, what they did was this other scarp was identified and this was the best area they felt based on the geomorphic studies that can provide them the signatures of the paleo earthquake if this fault has moved in the past. So this way the 2 trenches which have been dug, and I will just talk about that what they found actually in this region. So, they had like the river, which flow through this region got blocked along default.

So, they observed a sort of an ponding condition here. And ponding conditions will result into deformation of the events rich soil and that was one of the point they take took into consideration that if similar event has occurred in the past similar activity would have occurred some blocking of the channel during an earthquake and then for the erosion and dissection of this scarp. So, piano di pecore was one of the few sites favorable for trenching. So, that what they identified for paleoseismic studies.

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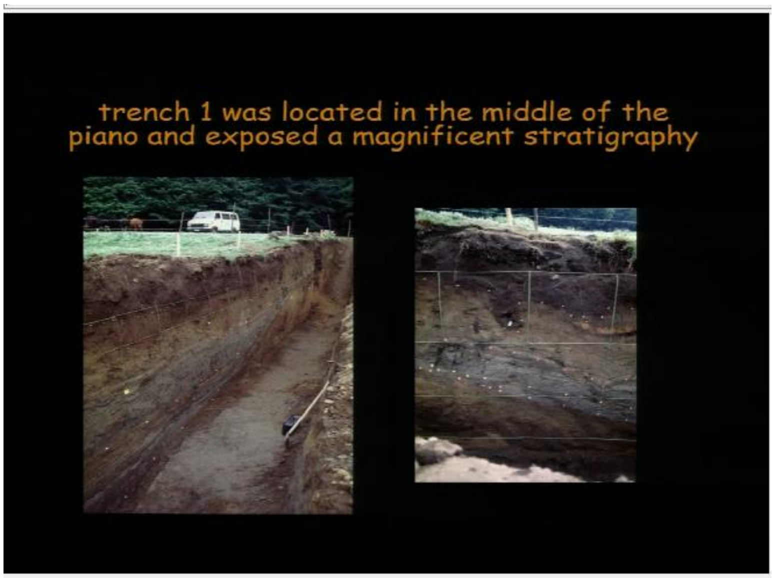

And this were the trenches which were open which clearly shows this previous scarp here and then you have the present one which has been seen here and the fault runs somewhere over here with the close up of that is been shown here. So, trench 1 was located in the middle of the area and expose the magnificent stratigraphy. So such stratigraphy exposed which you can compare with the foot wall this scarp with a very low scrap. But of course very beautiful stratigraphy was exposed along this.

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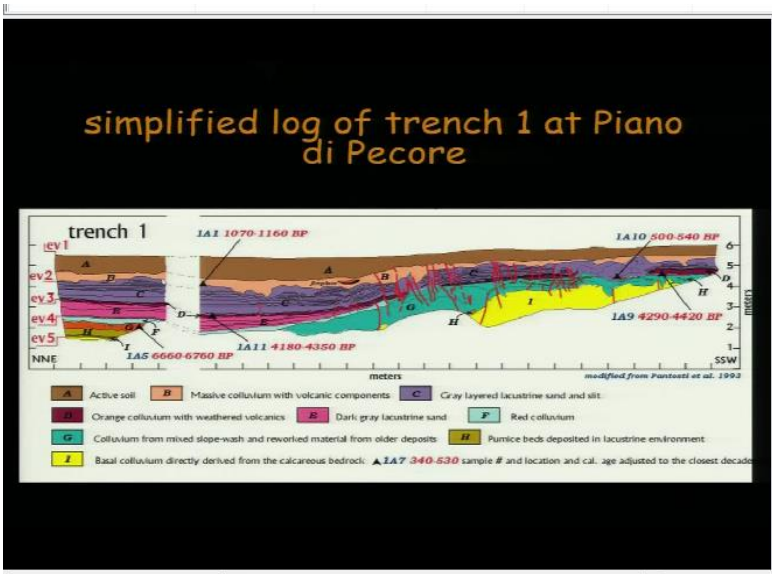

So, final trench which they sketched, they found that this is there are the faults are been identified here of course and that will tell you the cross cutting relationship okay. So, as we discussed in one of the lecture that the nominal faulting will not occur along single fault plane but you will have multiple faults. Now, there are few faults which are not exactly going deeper, but they are the part of the deformation.

So, this deformation should also be taken into consideration to identify the ancient earthquakes based on the cross cutting relationship with the best which you can see here that this faulting displaced or reached up to this point, but not across this one. So, this indicates the earlier event and this was which cut the right up to this point was the recent event.

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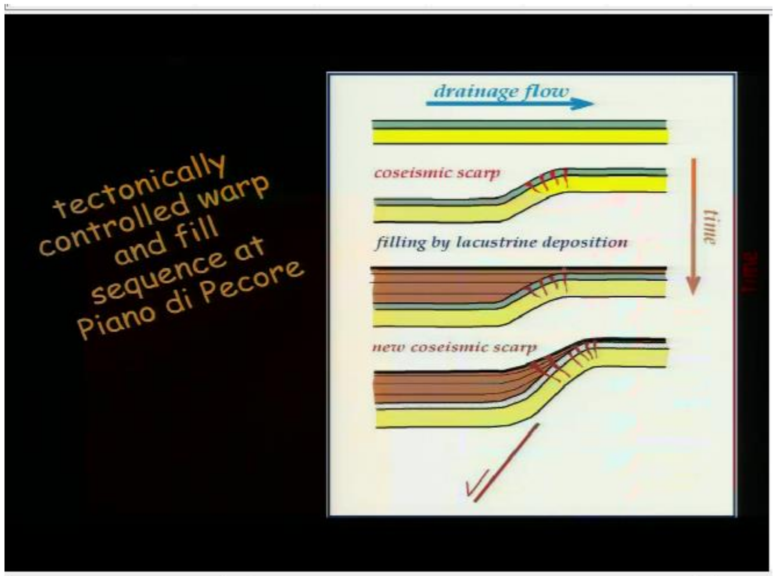

Now, based on this what they identified that there was a drainage flow in this direction. So, they reconstructed the tectonically control warp, fill sequence at this location. So, they had like whenever they will be in coseismic rupture then you will have the extensional cracks which are forming here or the displacement you will be able to see what has been shown here and that will help you in identifying subsequent events.

So, for example, the drainage which was flowing across this area during the fall just after defaulting means deformation of due to the earthquake formation of this scarp was resulted and you will have the blocking of this river and this will result into the filling up. So, this area will act as a pond and that what is been shown here that filling by the lacustrine deposit. So, over the time the next event will displace this one okay and then so on.

So, the fault runs somewhere here, the fault plane is here and the deformation which we see is the of course, the secondary one, but should be considered as the coseismic, the displacement or coseismic it is the coseismic given the deformation which is taking place. So, when they will be next event, then another scarp will form the same scarp of course, this will show an cumulative displacement but you will have the displacement which is going and cutting this deposits also.

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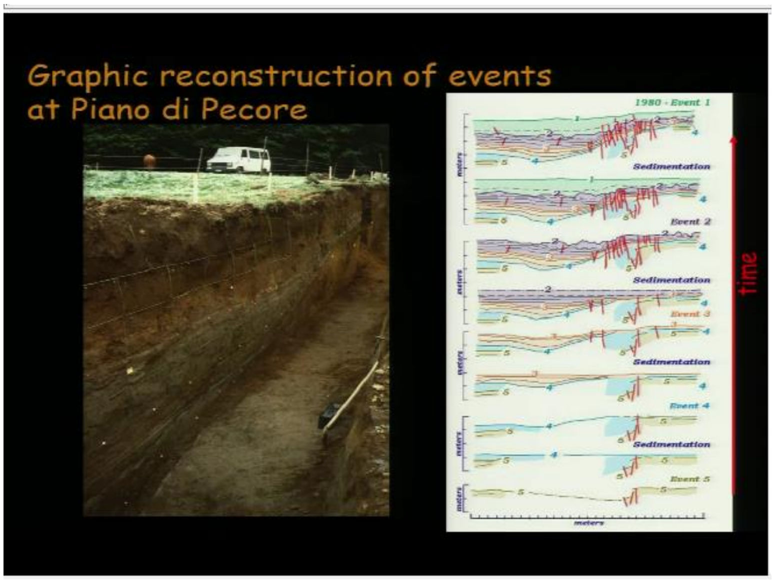

So, similarly based on that they were able to pick up at least 5 events, they were able to pick up 5 events and they have reconstructed the chronology of the events based on the cross cutting relationship of the faults which they identified in the trench.

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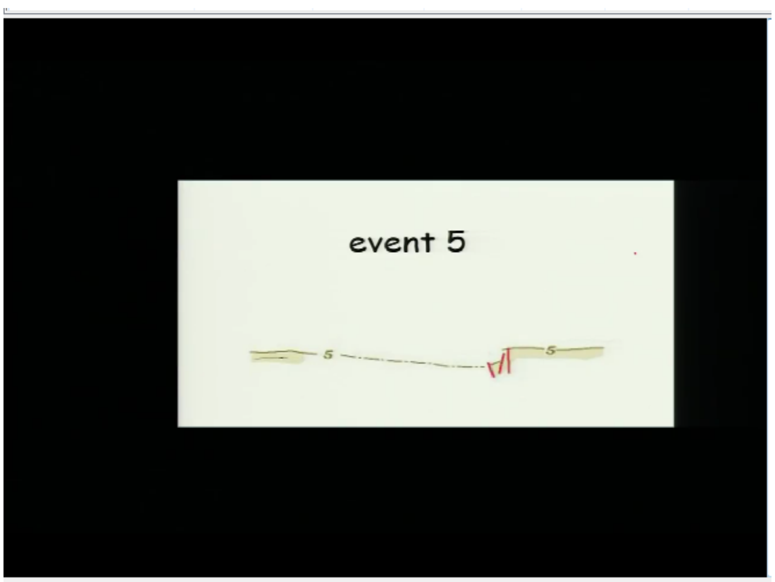

So, this shows this event 5, okay, where you have the event 5 has been shown here and then event 4 and so on. So, what it shows here is that you have the event 5 which was displaced and then further because of the again the blocking of the channel, deposition of event 4, which kept the event 5 deformed event 5, and then there was an event here which displays event 5 as well as event 4. That is your event 4, you have and similarly what has been shown on the previous one.

Then there was not phase of sedimentation that resulted into the deposition of event 3 which kept the displaced event 4 as well as 5 to the top contact is your event 4 and then you are coming to event 3. So, this was the phase of sedimentation again next event that is even 3 the layer 3 was the event horizon which got displaced and against the limitation it deposited or cap the event 3 over here. So, you see no displacement here but the next event 2 again displace the all the events okay like event 5 4 3 and 2.

So, this was the event horizon. Now, another phase of deposition that was in event 1 which kept the event which occurred that is even 2 and then finally, it displaced that was event 1 in 1980. So, this has been shown in the next coming slides okay.

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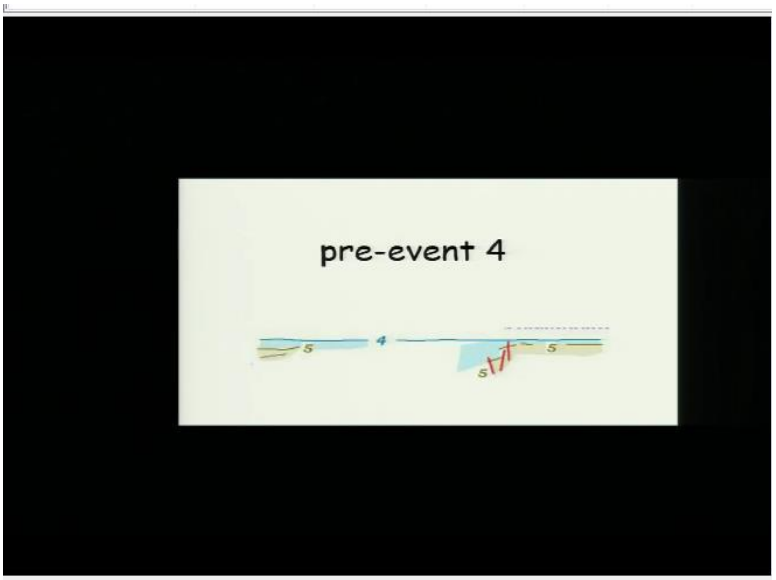

You have even 5 then the phase of the potion that is pre event 4 and then you have the displacement event 4.

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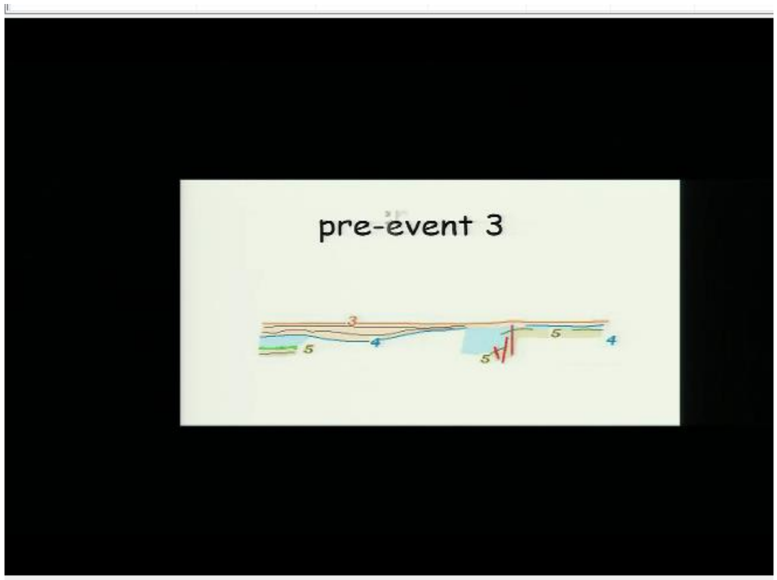

Then capping of even 3.

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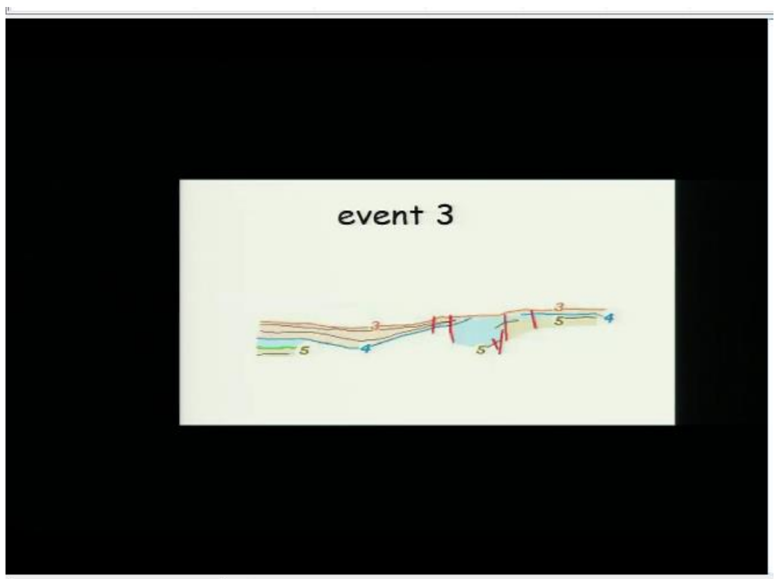

Then even 3.

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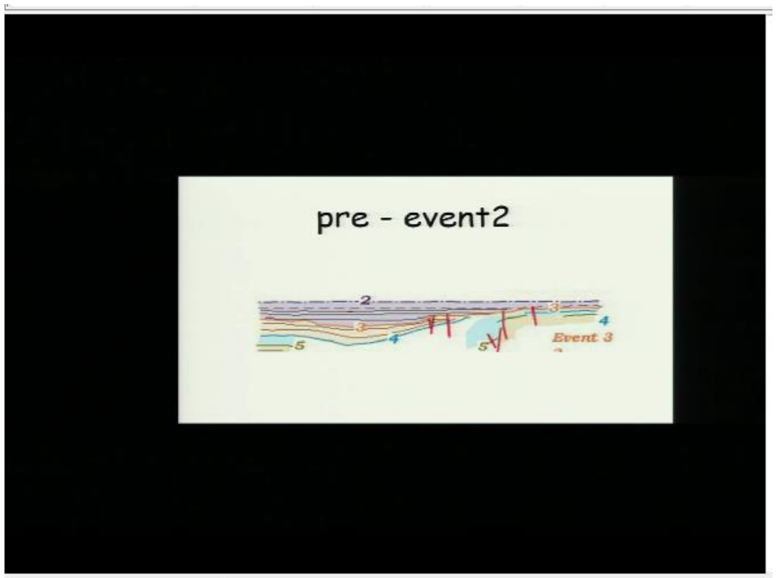

Displacing even layer 3 capping by event 2.

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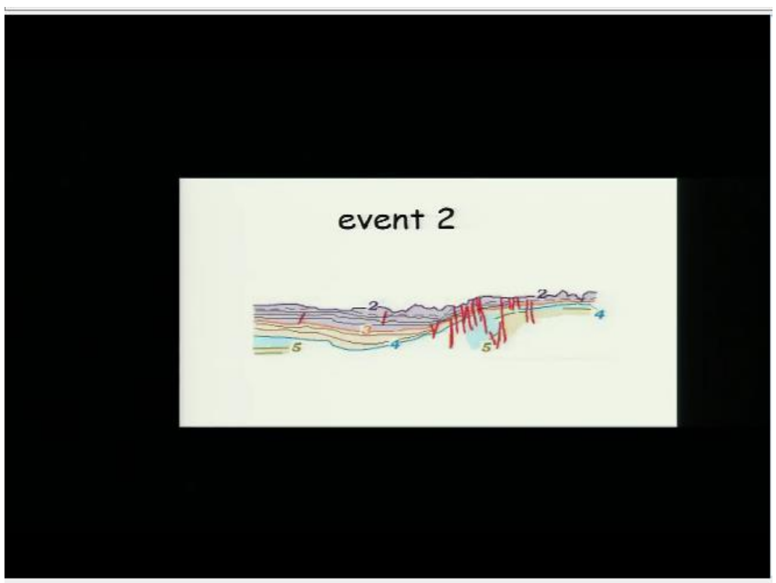

And then even 2 displacing event.

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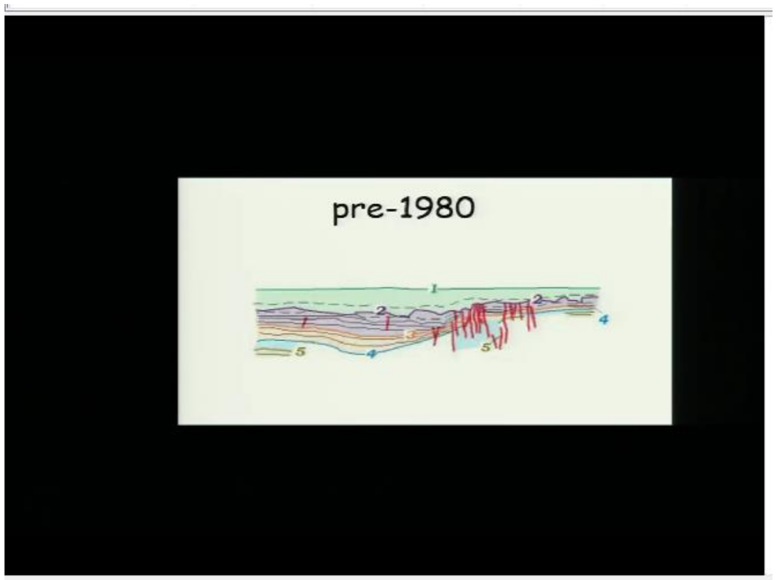

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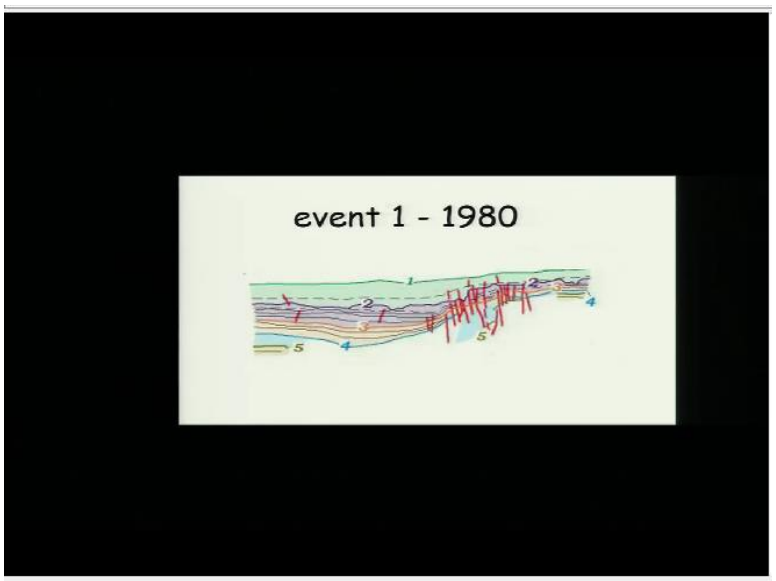

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And then finally, event 1 which displays the most recent event or most recently layer that is here, layer 1. So, this all this events are marking the event horizons of which are reflecting the different events event 1, 2, even 5. So, this is how you can deconstruct the history of the paleo which in this region. So, at least from this trench investigation, what you can discover that on this particular for this was not the only earthquake, which occurred in 1980.

But there were more events, now the pirate part comes is of the dating okay. So, the 2 trenches, was located less than 100 meters away from trench 1, but exhibits a very different style of deformation. So, again, this is an important part, which usually we come across because the fault will have different attitudes that is the depth and strike also it will change and it may result in 2 different style of deformation.

And also some places suppose we have default race here like this, okay. And then you have open up, so this is your scarp here. So, you have like just put here this is your scarp here and then you have the surface which is coming down here. And suppose you have opened the trench across this one and then you are opening the trend somewhere along this one here. Now, the possibilities are there, there is your scarp, the strike of this and this portion is different.

So, style of deformation may vary at different location. Another point is one as you have to take into consideration one, the strike of the fault change. And then second is your deposition also so, you may have difference in sediment succession also. So, you may be able to pinpoint the difference in the paleo earthquakes also in such regions okay. So, it is always better to have more than 1 trenches in the close by region.

So, that we understand that what exactly has happened to have the complete history at least up to the stratigraphic section which we have exposed. So, this shows the fault zone very much similar to what we were looking at in the trench in Bulgaria. So, red pins are marking the faulting. So, this is this portion has been displaced here very clearly. So, this is your down faulted block and this is your stationary block.

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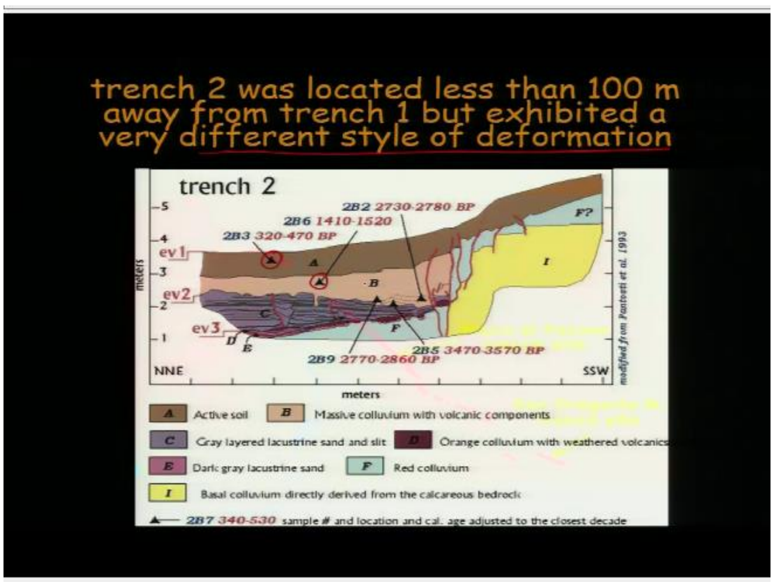

So, based on this the another important part which comes is the after identifying the event horizon then based on the cross cutting relationship between different layers or the symmetry events, then the task is to identify the location of the samples okay for dating. So, this what it has been shown here is the by triangles over here, these are the location of different samples which have been collected.

And the dating is basically done using the C 14 carbon 14 and dating has been done here. So, charcoal samples and this since this area was under the like a state of like (()) (20:56) was prevailing after the faulting of each event, then this portion showed good amount of the charcoal or the carbon content in the different layers. So, you have this ages are all showing the carbon ages and the samples have been collected of course, you may not come across the samples or the charcoal in each layer.

So, whatever, wherever you are getting, but you have to target few layers or few events which are important to talk in the history of the faulting on particular fault. So, these are all ages based on this the reconstruction was been done that when such as for example, if you take this sample okay and this sample, then at least to some extent if you say that this was displaced, so you can say that event was between this and this okay. So, after the deposition of the event and before the deposition of a event, if you are targeting the segment here.

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So, that we will discuss more when we are talking or discussing **0**of the faulting and compressional tectonic environment and all that.

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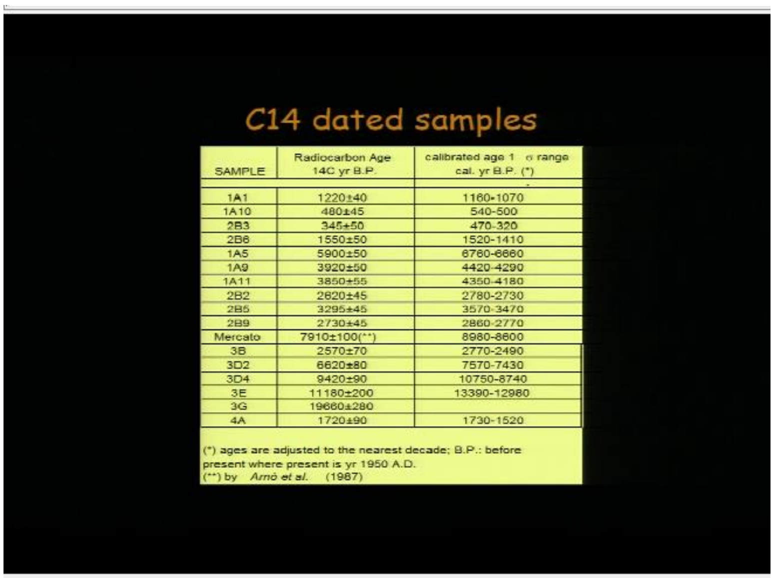

SAMPLE	Radiocarbon Age 14C yr B.P.	calibrated age 1 σ range cal. yr B.P. (*)
1A1	1220±40	1160-1070
1A10	480±45	540-500
2B3	345±50	470-320
2B6	1550±50	1520-1410
1A5	5900±50	6760-6660
1A9	3920±50	4420-4290
1A11	3850±55	4350-4180
2B2	2620±45	2780-2730
2B5	3295±45	3570-3470
2B9	2730±45	2860-2770
Mercato	7910±100(**)	8980-8600
3B	2570±70	2770-2490
3D2	6620±80	7570-7430
3D4	9420±90	10750-8740
3E	11180±200	13390-12980
3G	19660±280	
4A	1720±90	1730-1520

(*) ages are adjusted to the nearest decade; B.P.: before present where present is yr 1950 A.D.
(**) by *Arnò et al.* (1987)

Now, further, so trends 3 and then, so several trenches will have been done and based on that and the ages which will been compiled. So, this shows a very beautiful fault here again and displacing the blackest event. So, several ages have been obtained and based on the radiocarbon ages, they were calibrated, and then you have the ages in before present.

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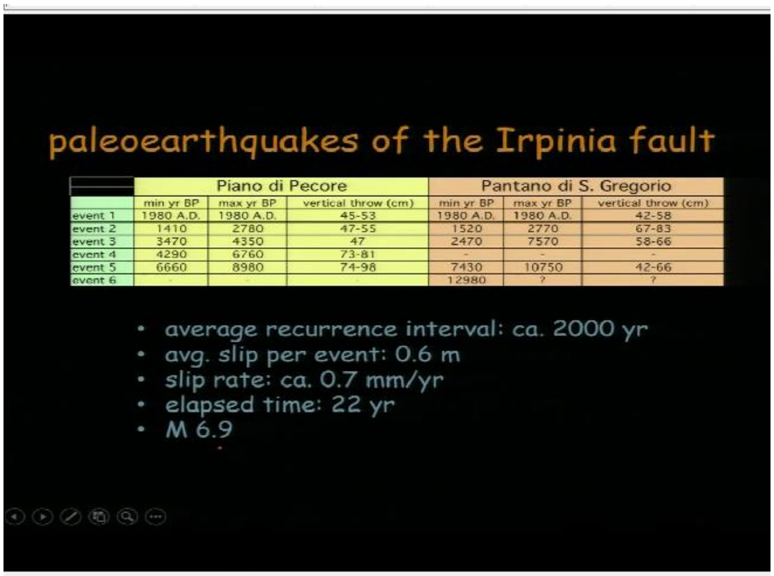

So, paleoearthquake of the irpinia fault, this what they identified based on this different events, even 1 which has the minimum age definitely was 1980 okay. And then even 2 which was during this period or between this 2 and even 3 in between these 2 ages and so on. So, based on this the average recurrence which was been identified was around 2000 years between the respective events.

And the average slip per event was almost around half a meter, slip rate which was been calculated per year and taking into consideration the age and the slip per event you can calculate the slip rate. So, ellipse time is around 22 years and the magnitude which was been picked up for each event and also which was the magnitude of 1980 earthquake. This was magnitude 6.9.

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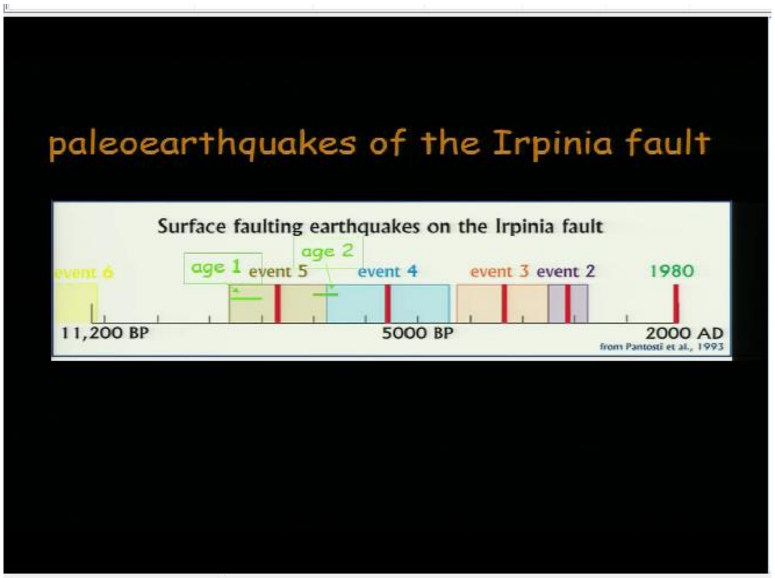

So, surface faulting earthquakes on irpinia fault, this is what has been given. So, you have the paleoearthquake events the time scale. So, this the elapsed time between the 2 events and that is a recurrence between the 2 events. And if you see clearly it is not exactly the same, okay. But you have in between, you have the pockets of smaller earthquakes here like even 2 and all that. So, this is how you can undertake the paleoseismic studies in different environment okay.

So this was from irpinia fault looking at the normal faulting environment. So, I will stop here. And will continue in the next lecture, we will see more on what we have to learn from the compressional tectonic environment. Thank you so much.