Earthquake Geology:A Tool For Seismic Hazard Assessment
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Lecture-33
Compressional Tectonic Environments And Related Landforms (Part III)

Welcome back. So, in previous lectures, we discussed mostly about the difference between the primary structure and the secondary structure and what sort of like shear fabric we should look in the trenches and all that. So let us move ahead in one of the slide I told that the colluvial deposit which is been seen due to the erosion of the fault scrap at the base of the fault scrap that can be used to identify the events. Let us see the importance of the colluvial wedge in this picture.

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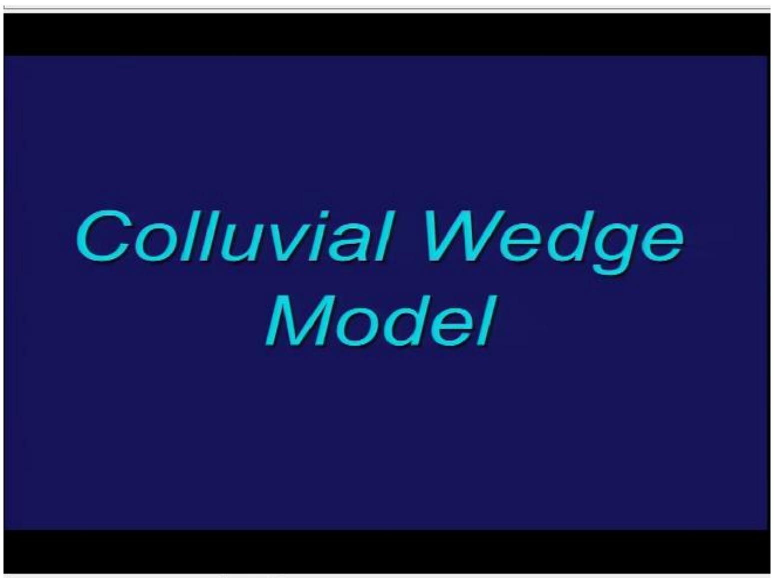

So colluvial wedge model helps in identifying the events in many of the trenches, which we excavate, and this also again remains common for all other environments, whether we are opening the trench in the or the normal faulting environment or your are having the reverse or thrust faulting.

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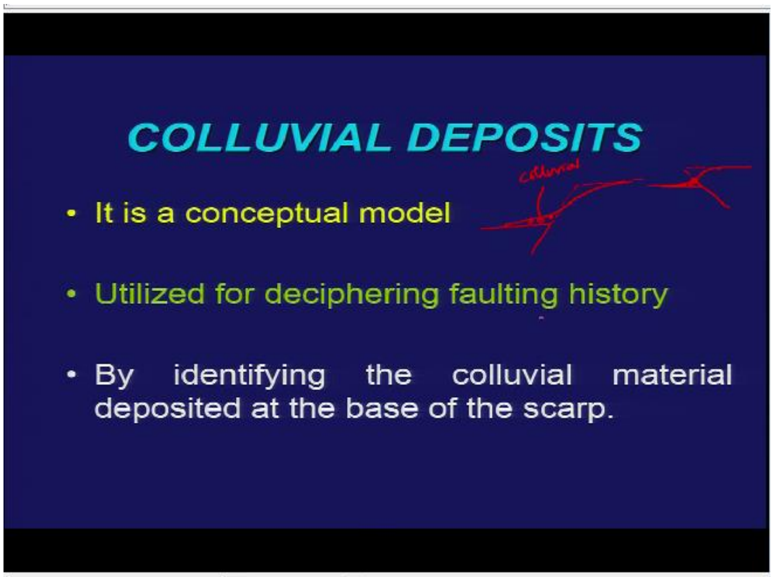

So, colluvial wedge deposit it is an conceptual model again and utilized for deciphering faulting history. So, this is important for us, now we can use the number of colluvial wedge which are seen and how we will differentiate between the colluvial wedge and the other deposits I will come to the slides in few minutes. So mainly we utilize this to decipher the faulting history.

And that means how many earthquakes have occurred along that particular fault. And this can be done by identifying colluvial material deposited at the base of the scarp. So, just I will put a sketch here and that can help you in understanding. So, suppose we have like faulting, which has occurred and in case of the either take the normal fault, where this block has move down sorry, and in case of the reverse fault you will have this block is moving up.

So, now over the time, there will be an erosion which was been shown to you in the previous lecture, that you will have the erosion here and then deposition part here. So, what you will see is modify, just modify this part here. Then you have this scarp profile which is going like that and the previous one was sitting somewhere along this line here. Now, you have the final this profile and that also depends on the angle of depose as we have discussed in the previous lectures that when the slope is at around 30 degrees or so.

Then this will become stabilized okay and no more erosion will be there of course, slight will take place, but not as much as what has been eroded initially from the scarp and this portion will have your material which will term as in colluvial material. So, whenever there is next earthquake, this colluvial deposit will also get displaced. So, if you are able to pick up the colluvial material.

And that there as I told that will be coming in the next slide that how you will differentiate between the colluvial material and the rest of the material in that area which has been faulted, you will be able to talk about the faulting history. Similarly, here you will have like the erosion of this scarp and then you will have another surface which is coming up. So, even have the deposition taking place at this base.

So, finally what you see is not you have the default is sitting somewhere here or maybe not exactly cutting the colluvial material, but the default will be covered by the colluvial material and we will have the profiles something like that in previous one was like this. So, considering the colluvial wedges, one can talk about or get back into the history of faulting on that particular fault.

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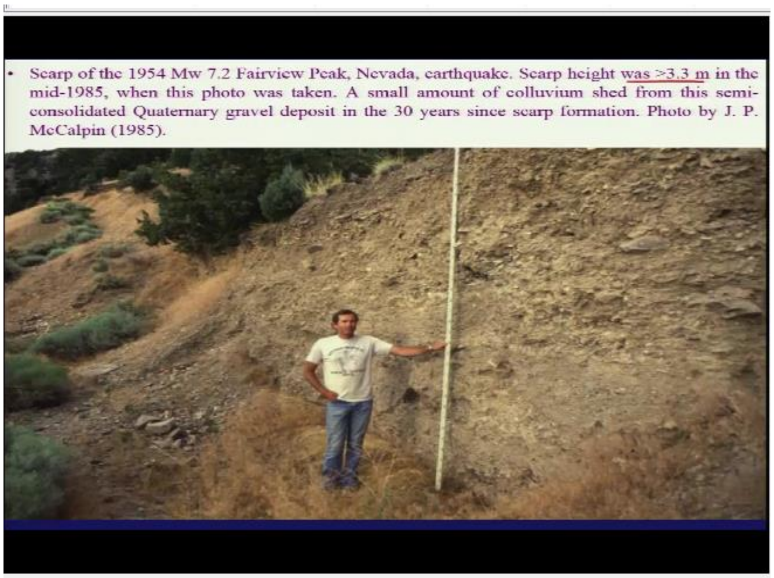

So, this was the slide which I have shown previously also that you have an scarp which was formed in 1954 earthquake in Nevada with a magnitude of 7.2 and this scarp height was around 3.3 meters and what we see is a small amount of colluvial shed from the material which was eroded and deposited in this region okay. So, over the time this will also get covered up and we will have the preserved material that is colluvial material along with this scarp profile.

So, this will be your colluvial deposits. Now, when you open up the section because this is the exposed fault scarp, but when you open up the section how you will differentiate this with this one okay. So, one thing which I can, I would like to mention here is that the material which has fallen on the top of this scarp is very loose, it is not as orient it will not show this the structures which you will be able to find out from the scrap material or the space material or intact material it will show some sort of difference.

In terms of the material in terms of the compactness as well as the orientation if you are having larger blocks which have been eroded and deposited over here.

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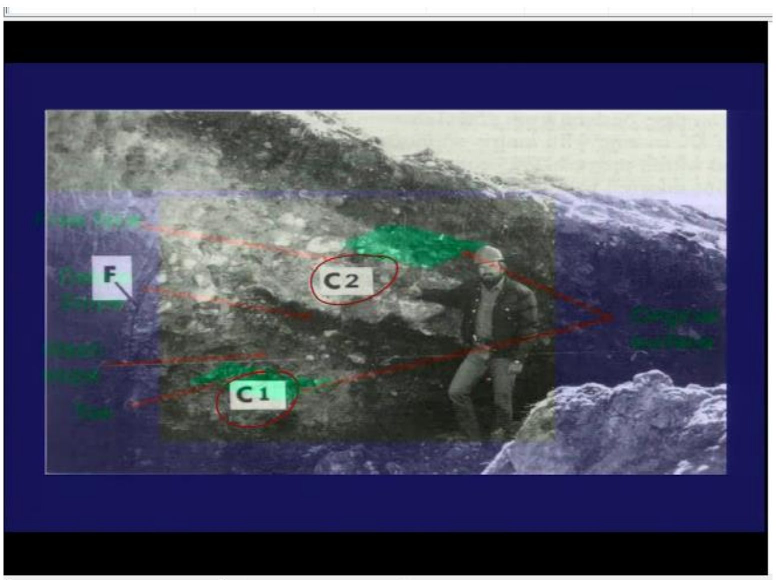

So, let us see quickly that what we will be able to make out with the help of the colluvial wedges. Now, here in this trench, you have the colluvial wedge one and colluvial wedge 2. So, this is in case of the nominal faulting. So, having 2 colluvial wedges, you can easily differentiate between the normal deposits which have been seen here. So this colluvial wedge has been kept by the next deposition event.

But you can easily differentiate between the colluvial wedge will not going to extend for distance from the scrap as we will we can see here okay. So, they will not be deposited thing. So, we will have the coarser deposits here and final one somewhere sitting a little far away and that what we call wash slope deposits. So, based on this we have C 1 and C 2 colluvial deposits are there at least you can infer that this fault has experienced minimum 2 earthquakes based on the exposed section you have in this trench.

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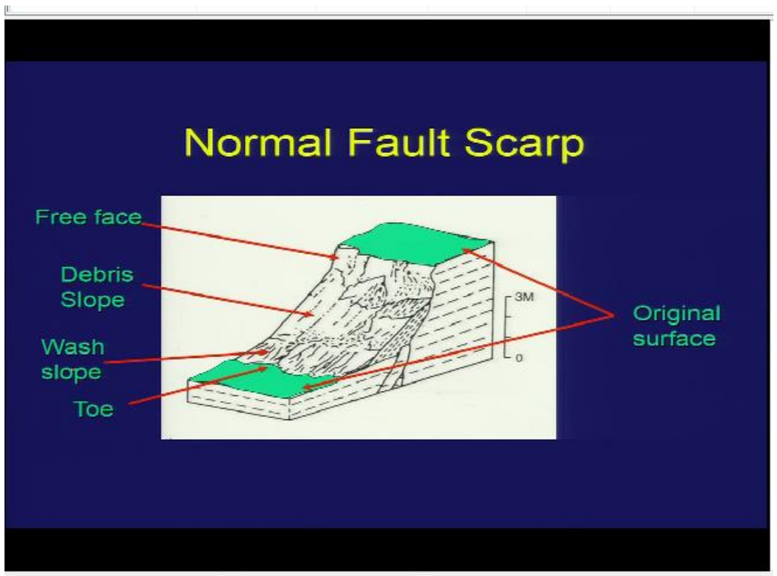

So, if you recall this process we are having initials surface here faulted and the other processes which are operating along the free phase will be your debris, flow debris slope deposit and wash deposit. So, in this portion we will see more of course deposits and then if you move slightly away from the scrap you will see the finer wash slope deposits.

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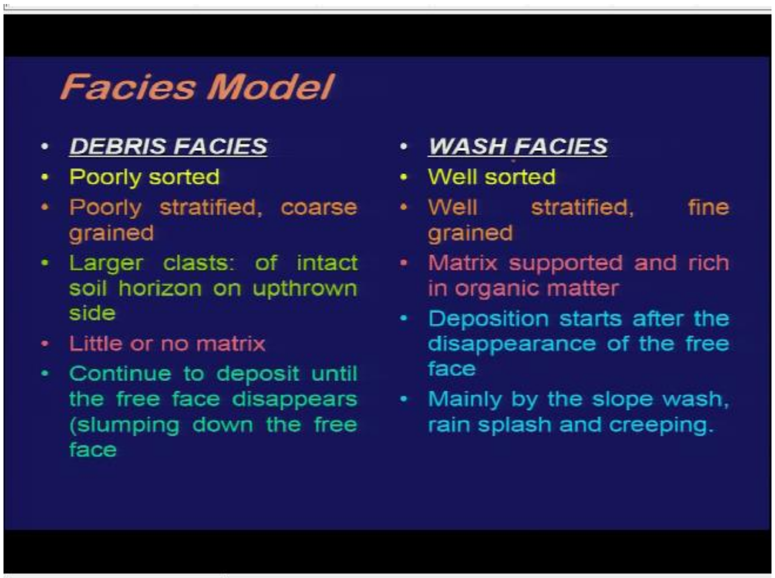

So, facies model if we take in comparing the debris facies they will be poorly sorted, poorly stratified coarse grain material, larger clasts of intact soil horizon from up thrown side. So, what are the from the scrap you will have the intact soil horizon. So, you can have the larger clast or larger blocks which are coming and getting deposited in form of the debris deposit. So, as you refer that in the previous slide, we have the debris facies or the debris slopes sitting very close to the scarp.

Then it will have little matrix, continue to deposit until the free face disappears. So, this is the point which we should refer to the slope stabilization. So, this process of deposition of the debris with the coarser material will continue until is getting stabilized and the wash facies will be comparatively finer, well sorted, well stratified fine grain, matrix supported and rich in organic matter.

Deposition starts after disappearance of the free face. So, if you refer the previous slide, so, what we had was that you had like the surface here and then you are having the surface over here which has been shown and then in this slope what we see is that you have so here you will have all debris okay and this will stop the debris will stop deposition of the debris stop until the slope disappears that is in free face disappears and slope is stabilized.

But the finer one will wash face which will be somewhere here, you will see that and they are comparatively finer and well sorted. So, mainly the slope deposits will be the part of the slope wash process and they will be getting the rain splash or creeping because of the creeping. So, these are the main difference between you can identify as a part of the debris or sorry as a part of your colluvial material where you can differentiate between the debris facies and wash facies.

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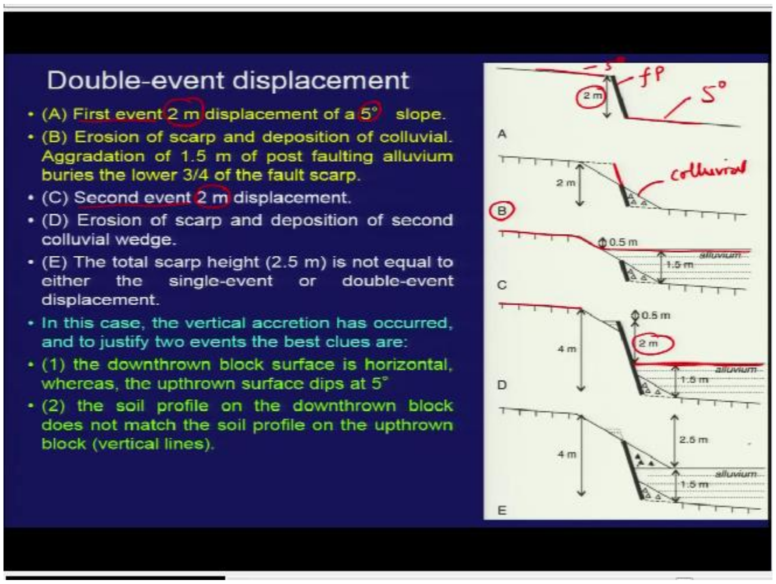

Now taking into consideration the colluvial wedge material, how we will be able to identify the different events and what other parameters should be taken into consideration has been shown in the sketch. So, for example, if you are having the defaulted surface, you are marking this as an surface which was displaced along this fault okay. So, the displacement was around 2 meters here.

So, over the time, what you will see is the erosion of this surface here. So, if you extend a compare this one with this one here then you had like this fault is extending here. Now, this part eroded and there will be deposition here. So, this scarp in total what you see at the end like what you are having at the E, then you are having at least 2 earthquakes have been added, but now how let us see quickly.

So, the first event 2 meter displacement. So, you had the 2 meter displacement, where this surface and this surface was the same t faulting surface was been displaced along this fault. So, this is your fault plane. So, erosion of scarp, this is now we are talking about the B here. So, erosion of scarp and deposition of the colluvial material. So, you see this as colluvial material. So, thing an aggradation of 1.5 meter of post faulting the alluvium buries the lower worth three 4th of the faults scarp.

So, what we see is that we have the after this we see this one here, we have the deposit of alluvial material, which covers almost three 4th of the on this scarp. So, you have deposition by of 1.2 meters and one thing which you can keep in mind that you will have deposition structures sitting in this okay. So, we have been very clear deposition structure. So, if you take B then we have the A of course, there is a displacement here.

And then getting into the B and this part 2 parts will be covered here and then further the second event. So, after this deposition now, what we are in section deposit is we have we are also looking in this section, but in real case on the surface you will not be able to see this part. So, what you will be able to see on ground will be this profile. So, what you see here is that you have this scarp which is showing the height.

Because you will take this as an height here with respect to this one. So, that is only half a meter which is left out and this was been covered by an the deposition event which is of height of like 1.5 meters. So, on surface only this profile is available. So, what it says the third one that is your C, second event again was of 2 meters.

Now, this again depends on very hypothetical case, but you may not come across the same amount of displacement during first event and the second event, you may have different displacement but let us take the same displacement which are occurring in an event 1 and event 2. So, second event there is a displacement of 2 meters again. So, what we have 1.5 was already left out on the surface and then we have 2 meters here.

So, erosion of scarp and deposition of the second colluvial material. So, this was the surface at the time of the second event or second earthquake, this was the surface now with respect to the surface what we see with the older one here. So, we have the scarp height, which goes up to 2.5

meter, but 5 meter was available, that is your because of the deposition here, which has gone to 1.5 meter, but the actual was 2 meter here.

So, what has been left out for 0.5 meter has also been added as an cumulative scarp height here. So, we have erosion of scarp and the position of the second colluvial which here that displays okay. So, E what we see is the total scarp height is getting what I was explaining here is now 2.5 meter. So, this 2.5 meter scarp height is a total scrap height is not equal to either the single event or the double displacement.

Now, this you will not be able to figure out unless and until you are not having the complete section exposed okay. So, after this event that is earthquake event 2 you what you have after the erosion and all that you have the profile which you will have something like this okay. So, this height you take then it will be 2.5 meter. Now, the actual displacement is not exactly the same, because what we have started with that 2 meter displacement in one event.

And then another event was also with the 2 meter displacement. So, what we are under sizing the amount of displacement here okay. Now, in this case the vertical accretion has occurred and to justify 2 events the best clues are what we have is one the downturn block surface is horizontal whereas, the upthrown surface is dipping at slightly sloping surface like with the 5 degree of that. And this if you remember, if you readout this the slope of the surface was around 5 degrees okay.

So, this was the original slope and that original slope you will be able to see from this one. So, this and this one okay. So, I will just put it in a slightly bolder lines. So, you can compare this to this 2 are having your slope of 5 degrees, whereas the slope of the surface which was formed later on that is this surface. So, we are talking about this one here, this surface or the surface and this exist here is horizontal.

So, when we looked at the change in the slope of this 2 surfaces and compared with the block here, then it can be easily we can make out that this is not the actual surface which resembles or is matching with this one, okay because this is almost horizontal. So, this is one clue which we can take into consideration and then second is the soil profile on the downthrown block that is what we are looking at here does not match the soil profile on the upthrown block with vertical lines okay.

So, if we consider that okay fine this was the slope this was the surface which was available at the time of the earthquake and when we match this soil of this one okay and the soil or the material with this surface then it does not matches okay. So, that what we are trying to explain. So, we have like this as a difference and this matches with the surface or the material which is sitting further down at around 4 meters.

So, having an understanding of the soil or the sediment type is also important when you are going to infer about the amount of displacement. So, this surface and the material as the slope matches with one another. So, this 2 were the same. So, total displacement what we are having here is a 4 meter. Now, if we measure between this 2 then we have 4 meter, but when we measured between this surface and this one is this 2.5 meter or so. So, this can take this type of exercise helps us in identifying that probably they were not a single event.

But this total scarp which we see here of 4 meter is because of the cumulative event and if you come across the colluvial wedges here. So, colluvial 1 and colluvial 2. So, this is older one and this is younger one that also helps in suggest define that this 4 meter is the result of 2 events and not a single event. And again with the help of this, you can take 1.5 meter here, which was been covered and that you can understand that how much was the total actual displacement during this event.

So, these are the techniques or the exercise one has to carefully do when you are opening up the trench. So, what are all expertise we have all the understanding we have applied here that we have taken into consideration this slope of the different contacts here and compared with the surface which is exposed on this scarp on the upper part of the upthrown block and the downthrown block here which is covered by the alluvium and also we have compared the colluvial wedges here.

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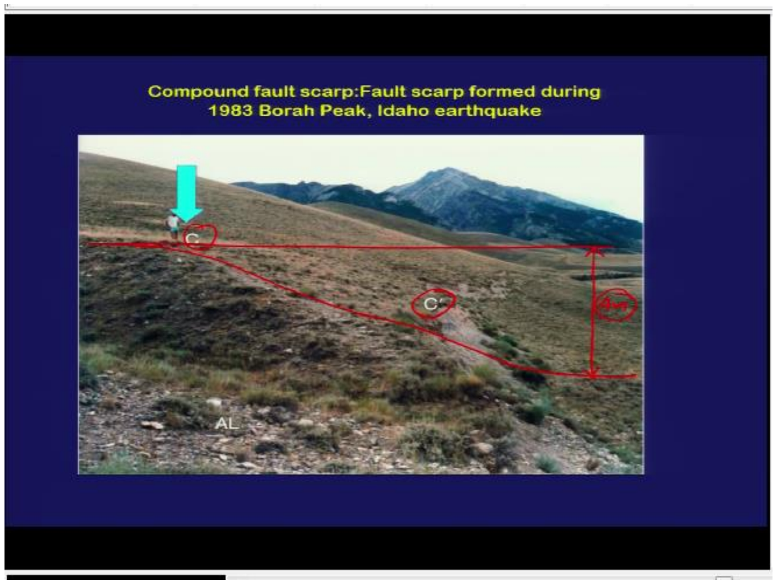

Now compound faults scarp formed during the Borah peak earthquake and that can be seen here what we were trying to explain in the previous slide. So, this is an actual ground photograph. So, this you can easily make out of this there is slope here is gentler okay and then as you come here is much sharper okay and then so the slope between this of course, the photograph is not so perfect here.

But of course this slope is wider here and then you have the very sharp young displacement which has been seen here. So, this is young displacement, this is older one. So, over the time this will be like something like you will find that this is having like this structure, okay. So, in that case what you will have is not he will say that okay find the total displacement between the ground and the upthrown block is say for 4 meters here.

But this 4 meters is not during the single living, this showing the cumulative effect. So, we usually also usually take into consideration the angle of the surface here as well as will take into consideration the slope of the surface the existing surface on the upthrown block and existing surface on the downthrown block as well as the slope which we find while taking the precise topographic mapping.

So, even with this profile, we can make out that there is a break here at 2 locations, which can also tell us that this scarp is cumulative of compound faulting scarp okay.

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So another example. So, the we have like what you will see at the time of the young displacement or the recent displacement, very sharp scarp and over the time it will get modified because of the erosion. So, this scarp is from 4th April 2010 earthquake in Sierra El Mayor. This is in Mexico US border.

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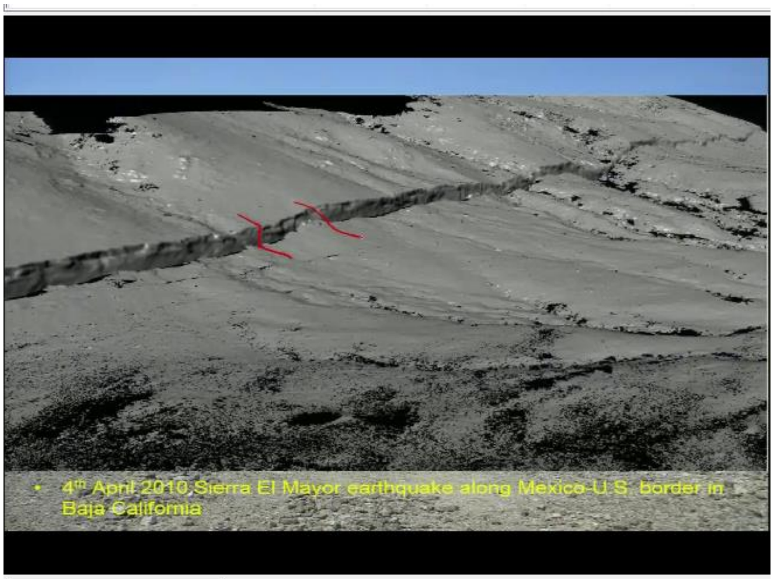

And another this is your dam which shows the ladar data which shows the this scarp in very sharp. So right now what we see is very straight sharp line but over the time this will be modified something like that.

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So relation between the geomorphic surfaces and faults scarp. So the previous part which we were talking about was related to your the stenographic record. So, we need to complement both the data actually, and what we see on surface and what we will be able to see in the stratigraphic section. So, the previous part which I have discussed will remain same for all environments.

Because the scarps will be formed in all environments and the erosion will not be having any boundaries that if it is taking place in different environment, it will be more or less similar. So, relation between the geomorphic surfaces and faults scarp this part is also important and this remains applicable for other environments also.

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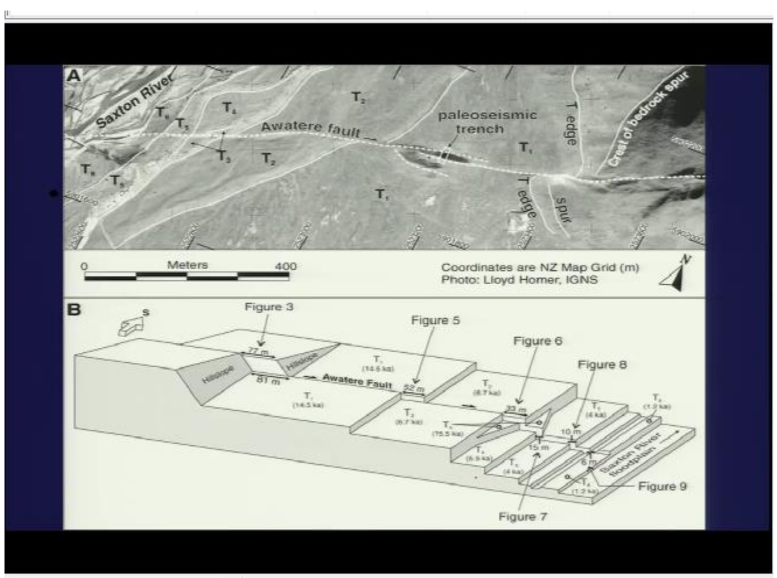

Now, what has been shown here is very important and useful when we are looking at the displaced surfaces or displace landforms along the faults scarp and how we will be able to justify that how many events have occurred along a particular fault. So, we have like this is an example of and strikes the fault here which shows the amount of displacement between the different surfaces.

So, you have the colluvial surfaces over here and for this cutting through this one here. So and the displacement between the surfaces varies from Milan defaults okay it is not the same. So, that can also help in identifying that what was the recent displacement during single event and what we see is the maximum displacement in the older surface, because if you have to list down the stresses which have been marked here like T 1 T 2 and T 3 T 4 5 to T 6.

So, these are all surfaces which are showing the different amount of displacement. So, they basically they show that the older as well as younger surfaces were displaced along this fault and the older one will show as a sort of cumulative displacement what we see in the younger one okay. So, you will have this also has been taken up by the older. So, you have like if you look at the hill slope, so, you have the mountains here, which shows the displacement of 81 meters. And then T 1 is been displaced by 52 33 10 and 6 here.

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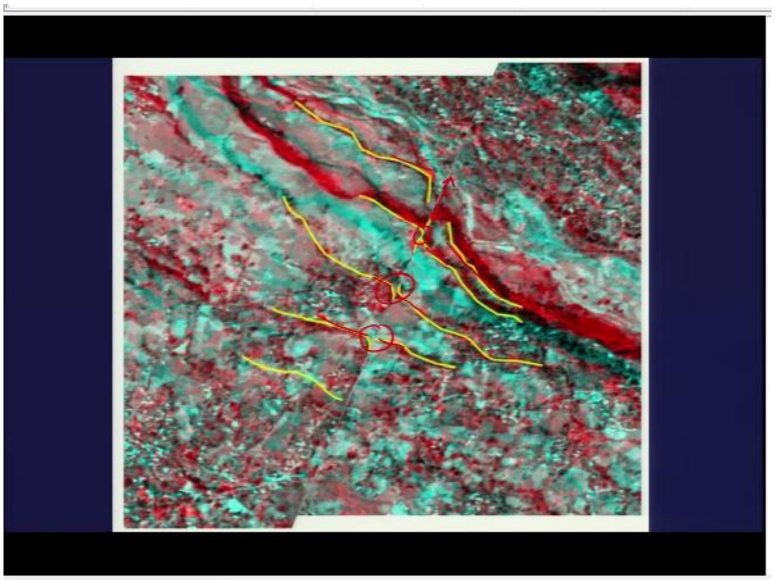

So, this exercise again we did the in case of the Congra Valley fault and I am going to discuss this in detail when we are talking about the strike slip environment but this is what you see and blue and red tone on the image is the enable if and I will request TAs to put an email to you people where you will be requested to at least purchase a glasses and they are very cheaper and those glasses you can use to view the slides or the supplementary data which we will supply and to see the terrain in 3 dimensions.

So, this is an (()) (28:53) of the portion from Congra region which shows the ages here and that what we call the terrace rises. So, when we get displaced and matches the edges of the terraces then one can easily make out that if we just match this one there is a lift out displacement between these 2. So, if you match the age the edge of the scarp here this one is matches well, but this one is not matched.

So, it shows further the displacement remains okay. So, this clearly suggests that and even this one is not completely matched you have the displacement left out, this matches to some extent. So, at least we can say that the latest displacement was this match okay and still it has been remaining in the older sections okay. So, this is again the terrace boundaries which we have marked.

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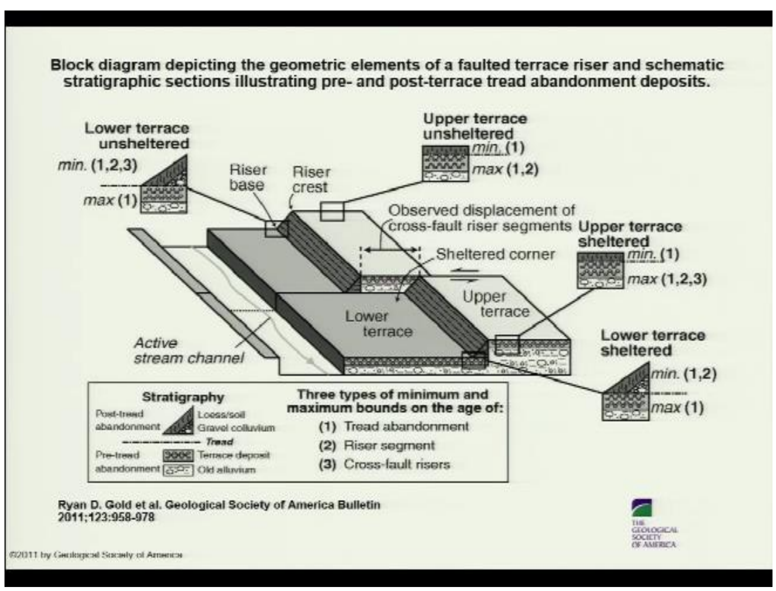

So, that what we will look at if I am termed as a terrace risers okay. So, you have these are all been termed as what you have the terrace risers. So, we have fault here. So, you have the lower terrace and then you have the upper terrace. So, you will get displaced okay. So, a block diagram depicting the geometry elements of faulted terrace risers, okay. So, these are been termed as terrace risers here.

And this is the base of the riser and this is the top of the crust of the riser and then if we if you getting a chance to see this exposed of stenography and that will mark here 4th plane.

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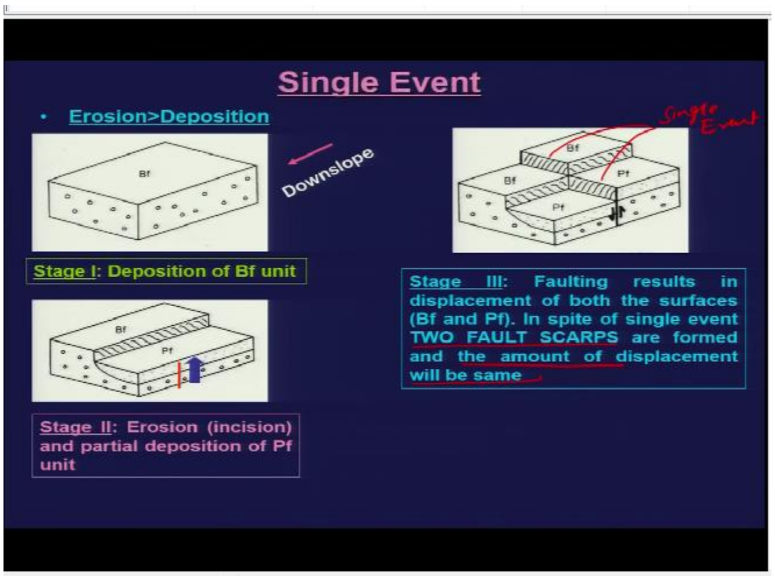

Now, if you consider different scenarios of the erosion and deposition of facies because this process will keep operating after the faulting during the faulting and before also it must have been existing. So, suppose for example, what we see is that we have the material which has been deposited along the down slope and this is the surface what we see Bf okay. So, stage I the position of the Bf unit.

And stage 2 erosion and incision erosion or you can say incision and partial deposition of Pf units and what you see is that we have the, this is erosion on scarp and that is not related to the tectonic but this is the erosion on scarp which is left out after the deposition of this Pf unit. So, you have the channel erosion, the river has eroded this portion hole and then also deposited Pf okay.

So, you what you see is the left out this scarp. Now suppose there is an event here, because usually what we have been taking into consideration that we have the displacement if you see or the 2 surfaces are separated by with some elevation we mean say that there is a fault here in this region or the fault if it is crosses here okay. Now, one has to be very careful to differentiate between the depositional and erosional or erosional mainly the erosional scarps are escarpments which are non tectonic in nature.

Then if suppose you have an fault here, so what will happen if you allow this to get displaced during an earthquake, then you will see that this block has for example, has gone up okay. Then what you see is the stage 3 faulting which results in displacement of both the surfaces that is the Bf and Pf and both the surfaces are been displaced here. Now in this case in spite of single event 2 faults curves are formed.

Now this 2 faults graph because you have the fault trace here and this is in section you have the fault and the fault trace is running like that okay. So, you have 1 scarp here, another scarp here. So, you may confuse that you have the 2 following events or 2 earthquakes here because you have 2 faults scrap, but the amount of displacement is same. So, based on that you can at least be able to justify that both this scarps were formed during single event.

And not because of the 2 events okay. Now, so, this is the case when you are having erosion is greater than deposition. So, erosion is greater than deposition, the erosion the deposition was not able to cope up the erosion which took place again. So it left out the portion here and that is one of the reason why we see this carp here and so there is an erosional scarp here which is left out which you can compare with this one. And this is your this 2 scraps along the fault is the tectonics scarps. So, this is because of this single event.

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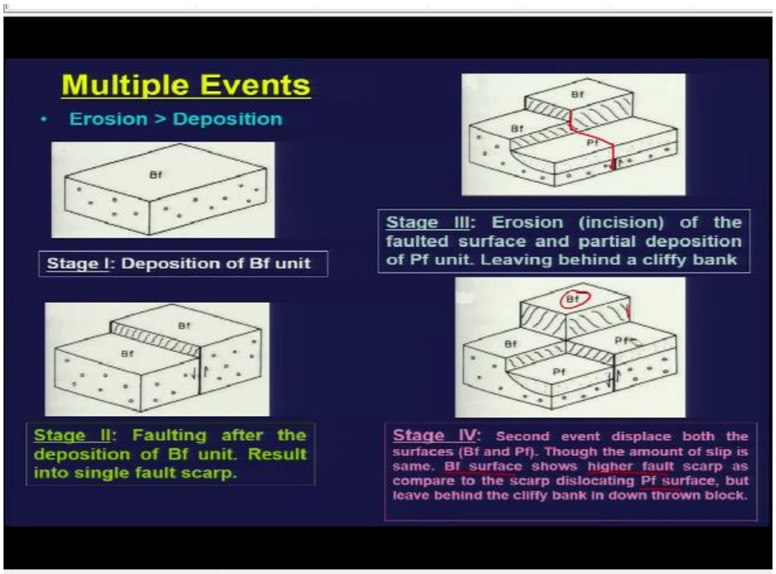

Now, we see multiple event the conditions remains the same where erosion is greater than deposition. So again we will have the deposition of Bf okay and then we have the erosion is greater than deposition, then you have the displacement and this is lift out this part okay. And it is stage 3 the erosion of the faulted surface. So you have the because we are talking about the multiple events. So event 1 has displace the Bf has resulted in the formation of scrap.

Now the erosion of the defaulted surface and partially deposition of Pf unit okay leaving behind a cliffy bank. So, what we see here is that you have this part which existed because of the displacement here okay and this portion whole portion was been eroded okay which we can see here and then partially covered because of the deposition here, leaving behind this cliffy bank here.

So, stage 3 and further if you go to 4 what we have we have the second event, so, again we are displacing, so, what will happen, this will also get displaced okay, along this line. So, this will also get displaced as well as this one okay. Now the height of this or the scarp height of this displacement will not match this one okay. So then in the second one what we see is that displaces both the surfaces Pf and Bf though the amount of slip was same.

That is during 2 events the amount of slip say in first event it was 2 meter in second events was again 2 meters, okay. But, the Bf surface shows the highest scarp and a higher as compared to this scarp which was dislocated the Pf surface. So, Bf surface is showing higher scarp and the Pf surface is competitive with lesser one. So because this was during the recent event.

But leaving behind the cliffy bank in the downthrown block. So you have the cliffy bank here and you have the displacement which has been taken in place here okay. So, we have much more higher height. So, you have to you can easily make out and this is not related to the single event, but there were 2 events okay here.

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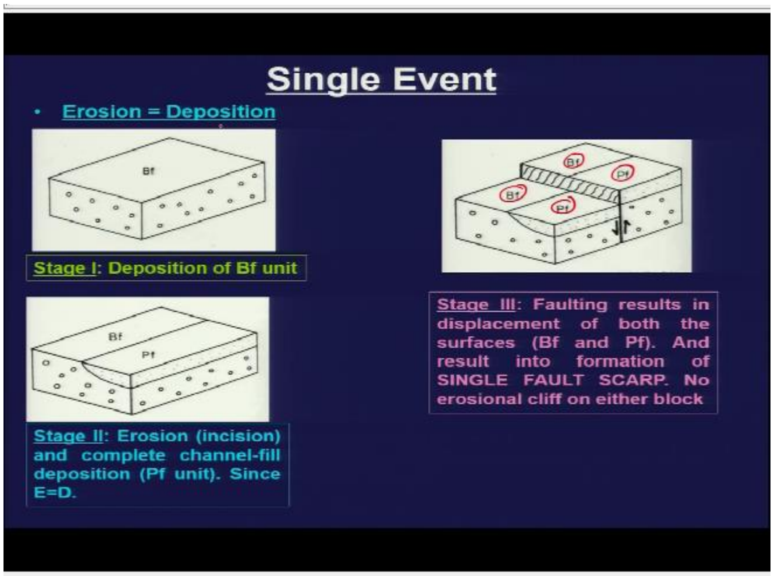

Now, let us take the example of where the erosion is equal to the deposition. Now, in this case again we will deposit Bf surface or the Bf material unit and then we will have the erosion. So, erosion is level by the deposition because we are taking the scenario where erosion is equal to the deposition. So, the erosion and will be in the second stage complete channel filled deposits since E = D that is erosion is equal to deposition.

Then stage 3 what we see as the faulting results in displacement of both the surfaces Bf and Pf and result into formation of single faults scarp. Now, where the erosion was greater than deposition then we had 2 faults scarp of same height, but here since those are 2 level one okay. So, then we see that we have this one full surface, but of course, at the age of this 2 surfaces are different whereas, this 2 surfaces are also what we see here okay.

And it has resulted into a single scarp. So, we need to be very careful, when we are we need to date the surfaces which can help us in comparing what are the ages of this fault scarp. So, this is the single event. So, this is the case in the single event and when we are having erosion is equal to the deposition same both are equal.

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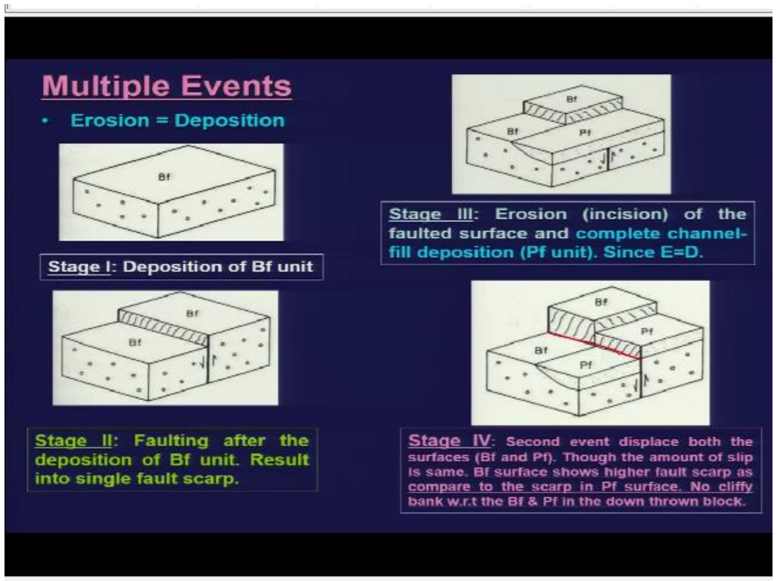

So, again if we look at the multiple events and we keep the process similar like erosion is equal to deposition. Then again we deposit the unit Bf, and then the erosion is equal to deposition and before that we had 1 faulting here. And that will be so whatever the erosion has occurred, it is been covered but this part is because of the faulting, okay. This has nothing to do with that, because this was the part portion which was eroded.

And filled up by the next phase of degradation or deposition, which the deposited Pf. So, this faulting event has been kept by Pf unit. So we have erosion of the faulted surface and complete channel fill deposition since E = D here, now the 4th stage in case of the second event it gives you different scarp height default trends here, but what we see is that you have the different for scarf height.

So, the second event displaces both the surfaces B and f though the amount of slip is same Bf surface shows higher faults scarp as compared to the scarp in Pf, no cliffy bank has been seen in the downthrown site. So this can help you in justifying because no cliffy bank has been seen on this one, but you are able to see the 2 scarps in this one, if you quickly look at what we saw in the previous one.

So we had like only 1 scarp okay. So but here we see 2 scarps and these are the indicative of your multiple one and in the process what we had the erosion is equal to deposition. So this can help to some extent that justify that this was the event which resulted into the cumulative displacement, which you can see here. And this was the latest event. So with this I will end this lecture here and we will see more in terms of the other environments in the next lecture. Thank you so much.