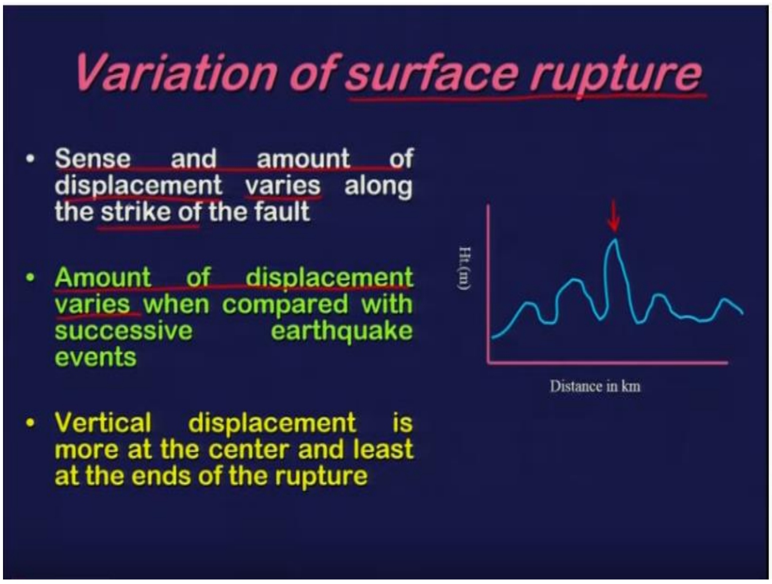
Earthquake Geology: A tool of Seismic Hazard Assessment
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology– Kanpur

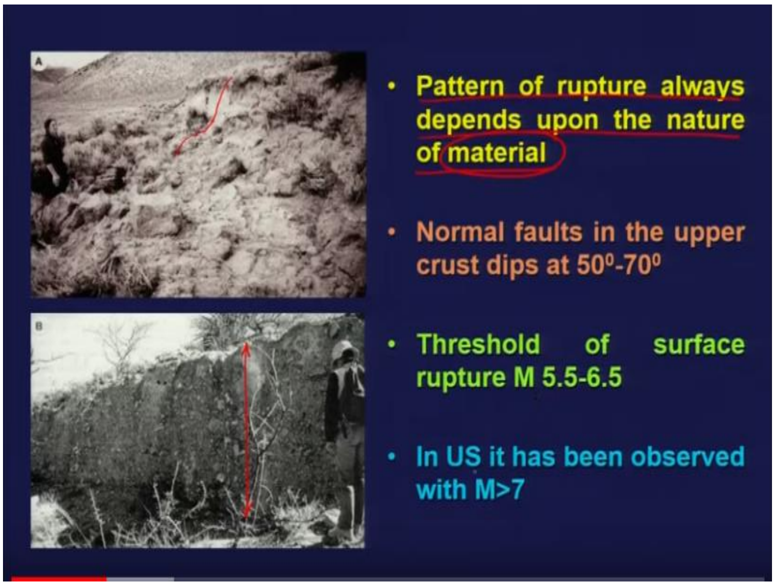
Lecture – 32
Extensional Tectonic Environments and Related landforms (Part –II)

(Refer Slide Time: 00:25)



Welcome back. In previous lecture, this was the last slide we were discussing about the variation of surface rupture in terms of the sense of movement or in terms of the displacement, and the amount of displacement on fault or along the fault and this is what usually has been observed. The maximum displacement will be in the area where you are having the maximum energy has been released at the time of the earthquake. There you will have the amount of displacement will be comparatively larger in the center and it reduces or become least on either side.

(Refer Slide Time: 01:21)

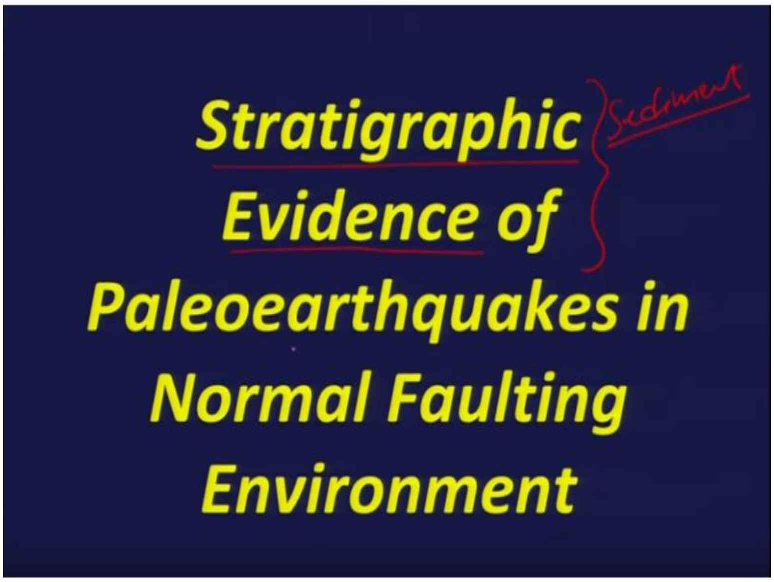


So, further if you look at the pattern of rupture that comes straight up to the surface that again depends upon the material. Now, what you see in this photograph is that you have the very sharp rupture or the displacement and here you have like roll-on blocks, which are been seeing here in the ground, and this is not as sharp as what you see here. This depends on the material. So the pattern of rupture always depends upon the nature of material and this parameter or the part will remain the same for all faulting environment.

So, most important is here the material. So, if you are having hard rock, then you will have very sharp displacement coming right to the surface, but if you are having the loose material then you will see that this scarp of the rupture is not prominent as compared to what we see here as a very sharp plane and usually the normal fault in the upper part of the crust will dip up to 50 to 70 degrees.

Further it has been taken into consideration based on the ruptured pattern that if you are having an earthquake, which is less than 6.5 or 5.5, then you will not have the surface coming right up to the surface. So this is the threshold limit or the threshold for this surface rupture to be reached, or faulting coming right up to the surface, the earthquake required is around 5.5 to 6.5, but in US, for the normal faults and other faults, it has been identified that the rupture is observed with the magnitude if it is greater than 7.

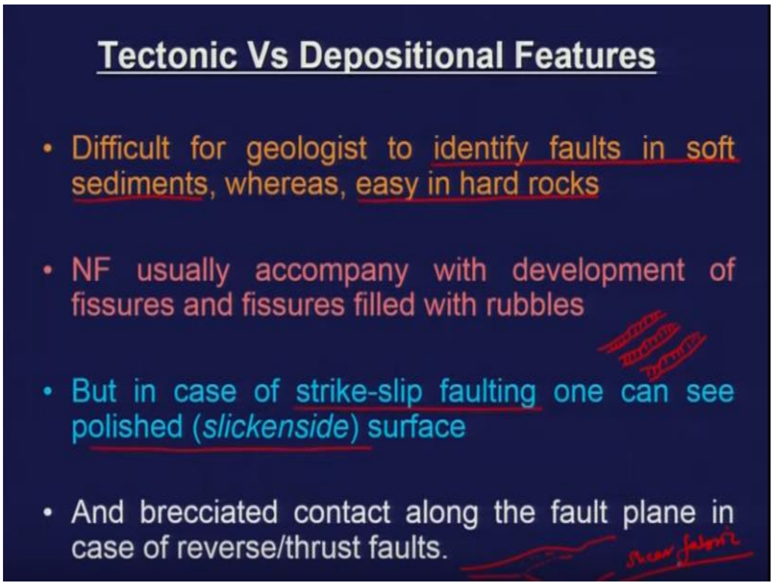
(Refer Slide Time: 03:15)



Now, further it is important for us to understand what are the different signatures that preserved in the stratigraphy, which helps us in identifying the Paleoearthquakes in Normal Faulting Environment. Now in this, of course, we will try to look at these signatures, when we are talking about the stratigraphy evidence, then we are going to look at the sediment succession.

So, how best we will be able to differentiate the signatures of Paleoearthquakes and how best we will be able to assign that whatever we see the signatures are related to the Paleoearthquakes and not to the depositional or non-depositional environment. So, that we initially we talked in the initial lectures where we are talking about the primary and the secondary features and all that. So, here also we will quickly look at how we will be able to differentiate between, for example, the tectonic versus depositional features.

(Refer Slide Time: 04:23)



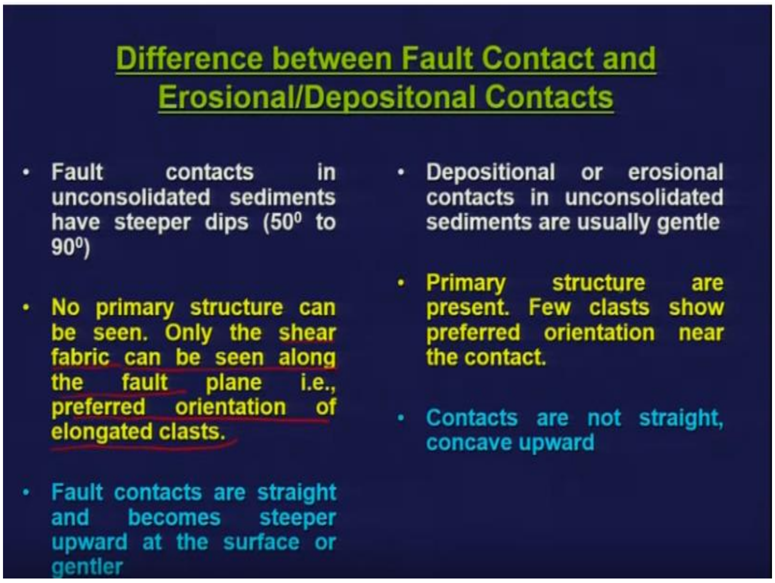
So, usually it is difficult for the geologist to identify faults in soft sediments. So, mostly the structural geologist, it will be difficult for the paleoseismologist to make the structural geologist comfortable and it will be difficult for them to make them agree that what we see here is deformation related and not the depositional or erosional feature because in hard rock, it is easy to identify as I was showing that in one case where you were looking at the previous slide that you are having the scarp like this somewhere and in the normal fault scarp, but in another one, you will be having very sharp displacement.

So, normal fault usually accompany with development of fissures and fissures filled with rubbles. We will not see a single line, which has been observed at the time of an earthquake, but in case of the strike-slip faulting, one can see polished slickenside surface. Normal faulting is one of the slide in the previous lecture, we were looking at that we will have the rupture along the multiple planes. Of course, you will have the displaced surfaces over here like this, but this can be due to the secondary effect also. If you have an lateral spreading over extensional cracks, which are developed can also can mimic the normal faulting.

So, this is what we have been trying to explain you that, but in case of the strike-slip faulting to some extent, if we are able to see the fault plane, then we will be able to see the polished slickenside. Nevertheless, we use geomorphology and if we are able to explore the section, we will be able to justify that this faulting is related to tectonic or non-tectonic. In case of the reverse fault or the thrust fault, then what you will see either if you are having in the hard rocks, then you will see the brecciated contact along the fault plane, but in case of the soft material.

So, one of the slide if you recall, I was trying to explain that what we call the orientation of the pebbles. For example, what we saw in one of the trench, there was gravel's where been displaced, and you had an elongated gravels which were aligned along the fault plane and that what we call the shear fabric or we can talk about that this is related to their faulting. So mainly you will be able to see in case of the thrust faulting environment and you will be able to see such brecciated contact in terms of you are having hard rock, but in case of the soft deposits, you will be able to see the typical shear fabric.

(Refer Slide Time: 07:55)



So, now let us look at the difference between the Fault contact and the Erosional contact, and this is very much similar to what we were talking about the primary and the secondary structure, and in the previous slide we discussed about mainly the surface rupture pattern of this surface rupture in unconsolidated or consolidated sediments or hard rock. So, now in case of the unconsolidated loose material, what you will see the fault contact usually is steeper and very sharp and in most of the cases, we will not be able to see the primary structures.

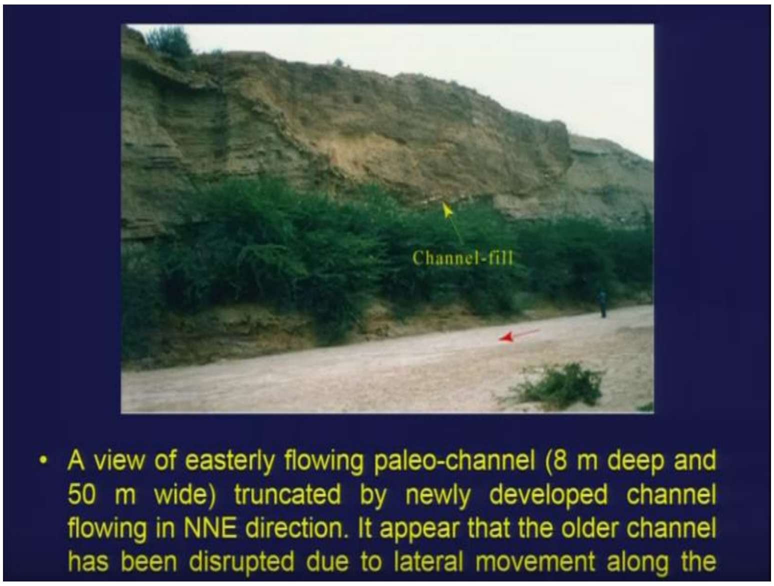
So, no primary structures can be seen, only the shear fabric. That is what I was explaining in the previous slide, that if you are having and one of the slide in the previous lectures, I talked about that we can see a shear fabric that is along their fault plane and that can be looked at based on the preferred orientation of elongated clasts. So, this is important which you should remember and that will help you in differentiating between the fault contact, or erosional or depositional contacts.

Then, fault contacts are straight and becomes steeper upward at the surface or they may be gentler also, but then other parameters, which you will take into consideration will help you in differentiating between the fault contact and the erosional contact. Whereas in the depositional contact or erosional contacts in unconsolidated sediments, they are usually gentler.

So, we see the steeper dips, because the contact will be like very much similar to the fault contact, but then we have take into consideration what other parameters you are going to use. Primary structures are present, whereas here the primary structures will be absent. Few clasts will show the orientation near the contact. Contacts are not straight, they are concave upward. So these are the few points, let us see the few examples, which we can help us in differentiating between the fault contacts.

So what we see here is that just remember that this will be a bit gentler, whereas this you will have the steeper contacts. Here you will see a very much preferred orientation of elongated clasts, whereas in this case, you will get a few, but you will not be able to see the shear fabric, and in case of the fault contact, you will not be able to see the primary structures, but here you will be able to see the primary structures.

(Refer Slide Time:10:38)

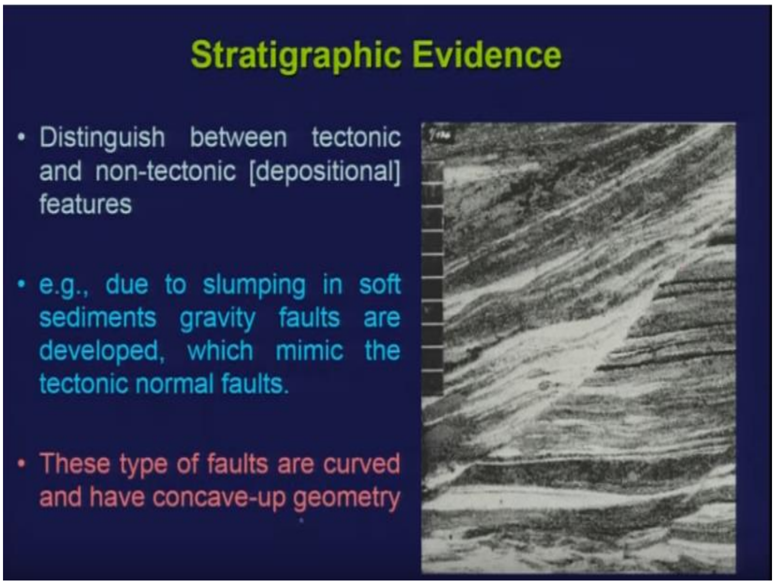


So, this was the example, which I was showing in one of the slide in the introduction part where you can differentiate between the primary structure and the secondary structure and this is what you are having the erosional contact. You are having the erosional contact which is due to the erosion by a channel, a river channel, and you have a very general contact with respect to the adjacent layers or the succession and also you see the sedimentary structures here.

So, this primary sedimentary structures can help in distinguishing between what this contact exactly tells and since we are able to see this in whole like in total, we will be able to judge easily that this portion with a trough like feature is nothing but the Channel-fill. But in cases where I was showing in the initial lecture, I was showing this that if you just come across this part, then you may confuse, but in that case you will have to take into consideration the preferred orientation of the material here.

Then of the shear fabric and then the deformation in the sediments over here or in this region that will help you that you are not having confusion between the primary structure and the sedimentary structure. That is what primary structures, we are talking about the sedimentary structures here. So this is a clear example of a paleo-channel and the contact that you see between the underlying deposits is your erosional contact.

(Refer Slide Time: 12:25)



Now coming to this part here, as I was saying that if you see the part of this, probably part of this, you may mimic that as a fault now, and what do you see here is that you have a contact here though the orientation or the sedimentary structures are horizontally stratified and then you are having a contact like this, and then you have another primary structures here. Now, this is a fault or this is related to your primary structure and that is your erosional contact.

So, distinguish between tectonic and non-tectonic, that is your depositional contact. Example, due to slumping in soft sediments, that is your gravity faults are also developed, which may mimic to your tectonic normal faults. So, sometime you will come across this, because there is slumping along the weak plane, you may have a very sharp contact between the material, which slump down and the adjoining sedimentary succession and that can mimic to the tectonic normal faults.

These type of faults are curved and concave-up in geometry. So, this will be very much similar to what we were talking about in the Channel-fill deposit again. So, there will be concave-up geometry, you will not see a very sharp and steep contact. So, this is another example, which you will remember that we will be talking about. Contacts are not straight. They are concave upward and that is the scene what we are talking about here. So the contacts are not seen. So, this is again a nontectonic contact.

(Refer Slide Time: 14:36)

Now this part I have briefly discussed earlier, but if you carefully look at that this are not primary faults, but this is secondary faults, which you can easily make-out that they are related to the tectonic deformations. We have the lines, which goes here, one marking the sharp contact and another one is over here. Now, one thing which I would like to emphasize here that we are talking about the soft sediments and the consolidated or unconsolidated sediments, but this is what see the deformation are all in unconsolidated sediments.

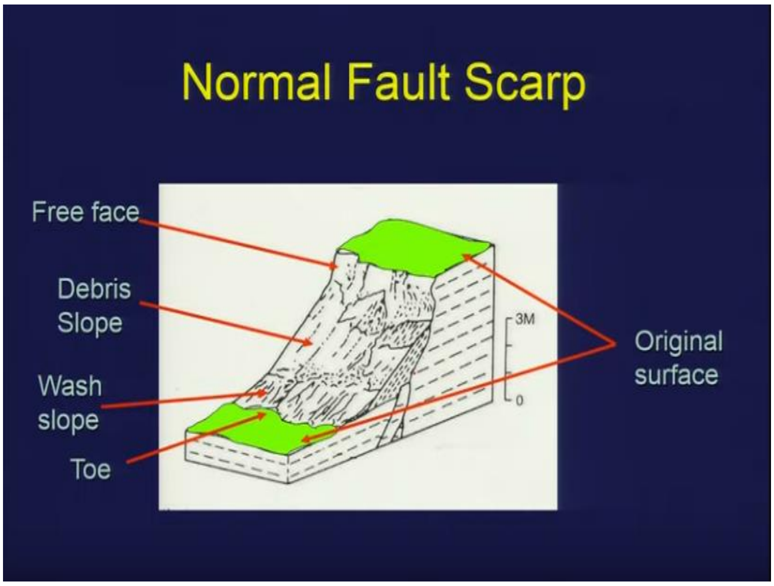
So you can see many lines, you will be able to pick up and draw, which shows the displacement and deformation. Now, based on the deformation feature, which are on either side of fault plane, that helped easily that this is not related to any erosional or depositional feature, but this is exactly what we are talking about the tectonic features. Now, if you see this part here, and this layers are getting like this and we have that goes like that.

Even you can see the sidewalk over here along this and even you will be able to fix up at some location the very thin shears on, which you can see over here. If you draw a line, it goes like this, and this is what you see in the plane. Plane is very sharp, but of course very steep here, even though it is a very loose sediment and you have some faults. These are all micro faulting related to the large deformation in the area. You can see the folding here very clearly and so on.

(Refer Slide Time: 16:44)

Similarly, also we had discussed this. I will just go ahead.

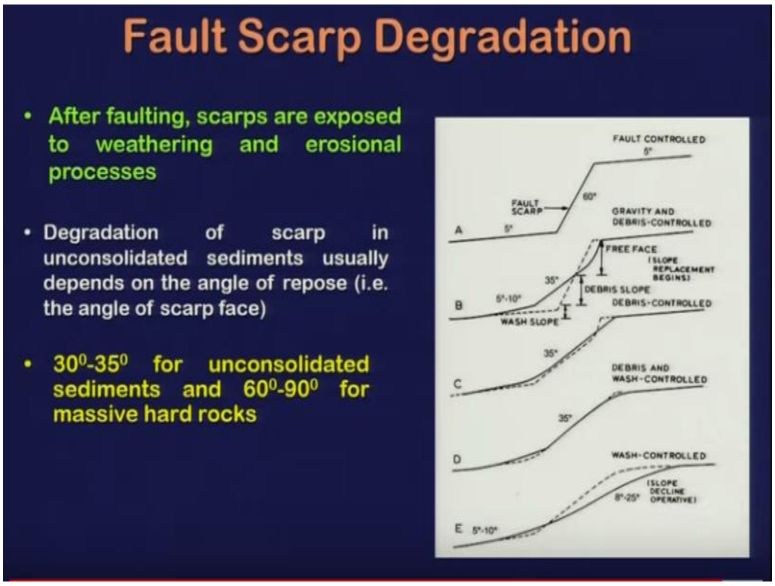
(Refer Slide Time: 16:49)



So, normal fault scarp, if we look at, what we have, you have very clearly understood that we have one block is moving down with respect another one. So, this was the pre-faulting surface, and this slip has occurred along this plane and resulted into the formation of the scarp. So, you will have unconsolidated deposits, you will bound to see that you will have the scree material, which is sitting on the fault scarp. So, you will have the original surface and you have the Free face.

The Free face will be occupied by the colluvial material or debris. So, you will have like the larger chunk of the blocks of the soil or the material, whatever the area is comprised of, you will have the debris here and the final wash deposits or the slope deposits you will see at the two of the scarp. So, let’s see in detail what we have if we have the faulting taking place and what happens later on due to erosion.

(Refer Slide Time: 18:15)



We have like the Scarp Degradation. Again, has been training that few of the slides or the part that we are discussing here will remain same for any environment irrespective of whether it is normal fault, faulting environment, extensional and compressional out-strikes. So, coming to the fault scarp part, Fault Scarp Degradation, so what we have is, we may come across the cumulative fault scarps.

So this is one and this is another one we are having, which was the recent one, but this is the older one. So, you may across the cumulative one, but for example if you are having this one, which can be compared here, so you can have the surface, which is coming here and displacement here, and then it goes further down here and then here you are having some scree material what we call the colluvial.

Now, let us see how the scarp over the time will get degraded and what profile we will be able to see. So, if you compare this one, that is the scarp C, then what profile you will see, the topographic profile is very gently coming here, and getting flood, and then from here, you are having very sharp. If you compare this and this one, you will be able to judge that initially because this is a recent displacement, so initially you will have very sharp Free face or the free fault scarp.

But over the time due to erosion, you will have a very smooth surface, which will develop because of erosion and deposition. So let us see in detail what we will be able to understand with this. So after faulting, scarps are exposed to weathering and erosional processes. So degradation of scarp in unconsolidated sediments usually depends on the angle of repose, that is the angle of the scarp face. So what is the angle of repose you have here.

So, let us see further, so you will see the gravity and debris controlled, so this is your on the Free face here. This is the previous one at the time of the faulting, so you had this one, but later on you had like the erosion of this portion and then getting deposition over here. So the Scarp profile will vary and you will have like this portion, is eroded. This will keep on eroding and the material, which is coming down from here, in form of the larger chunks what we call debris material will be deposited here and then you will have the wash face material here.

That is mainly the final one. So, initially the angle of repose what you have usually, we take the 30 to 35 degrees for unconsolidated sediments, and 60 to 90 degrees for massive hard rocks. So, if you are having more than this angle than what 30 to 35, then you will see that this will keep on eroding, and it will become stable, until you reach this angle and that is the other side, nothing will happen if the steep face, up to 60 to 90 degrees, but if you are talking about the hard rock and this we are talking about the fault scarp.

Recall one of the slide where we are looking at that the pattern of rupture will depend on the type of material. So, what we have is that we have this slope, which has been changed, which was steeper here. It becomes gentler and it starts stabilizing if you are reaching the angle of repose, which is for the soft sediments or unconsolidated sediments, and finally what you see is the slope stabilization and that is how you see the profile.

(Refer Slide Time: 23:10)

So, if you compare the profile, which I was showing in the previous slide. Probably in the next one, I can continue in the next lecture and we will discuss more about that what is the importance of the material, which is slided down or eroded and deposited here, and what we can see in the trench if you are coming across with the colluvial wedges. So, I will stop here and we will continue in the next lecture.