Earth Sciences for Civil Engineering
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Module 4
Lecture No 20
Geological structures (Part-4)

Welcome back. Last lectures we discussed about folds.

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Now another one which is left out in structural geology part is the fault. It is extremely important and 1st of all we will learn about the different types of salts and as similar to what we have discussed in folds, we talked about different parts of folds, here we will talk about different parts of faults and how we classify the different faults okay. Maybe, it is quite possible that we will try to finish in this module.

But we will try that if not in this module, we will try to finish in the next module. So faults are extremely important and we will learn how different faults are classified here okay.

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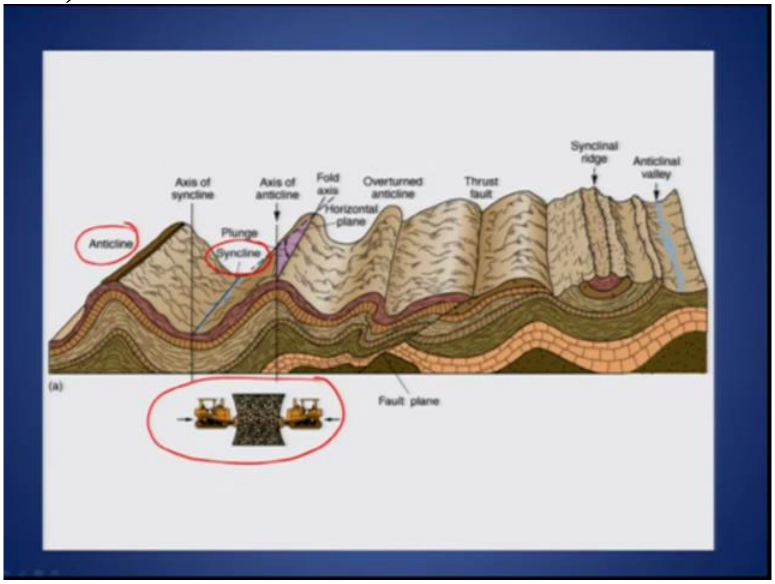

So as we have been talking about that we have the folded landforms when the area is subjected to tectonic deformation under compression. So what basically you will see is that you will see in combination of anticline and along with that you will see the synclines okay. So this folded layers of rocks or the sediment successions are will be seen in the form of anticlines and synclines.

Now all rocks or the material of the Earth have some elastic limit okay. And after that if the threshold limit crosses, it will break or what we call it will fracture. And that fracture will result with the displacement. So that displacement will what we call along the fracture plane where the displacement is taking place is termed as fault plane okay. So this fault different type of fault planes or the faults we will talk about, so let us let us move ahead in this course now.

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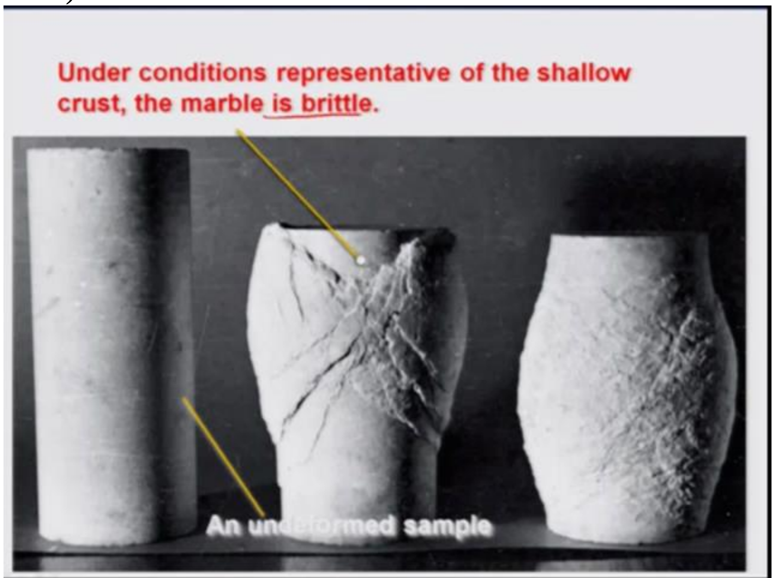

This is how rock deforms, this we have, we discussed in one of the lecture that if you are having an un like this is an undeformed cylinder which has been shown here, then you are having, you keep on pressing it. You have the fracturing and in so this is this is the kind of a brittle fracturing.

But at some locations like if you are having this, you are putting the same material in the deeper part of the Earth, then you will have different type of deformation. You will not really fracture in the sense. So the Earth’s crust is a very brittle part and that that usually fractures along the weak zones and these weak zones with that as an faults okay. So this is under the condition representative of a shallow crust okay.

Like for example this is the marble which has been shown. So it will be it will break okay. Because it is brittle in nature. But under the conditions representative of deeper crust okay, the marble will be in ductile form okay. So it will deform in a ductile form. It will not fracture as what we see near to the surface okay.

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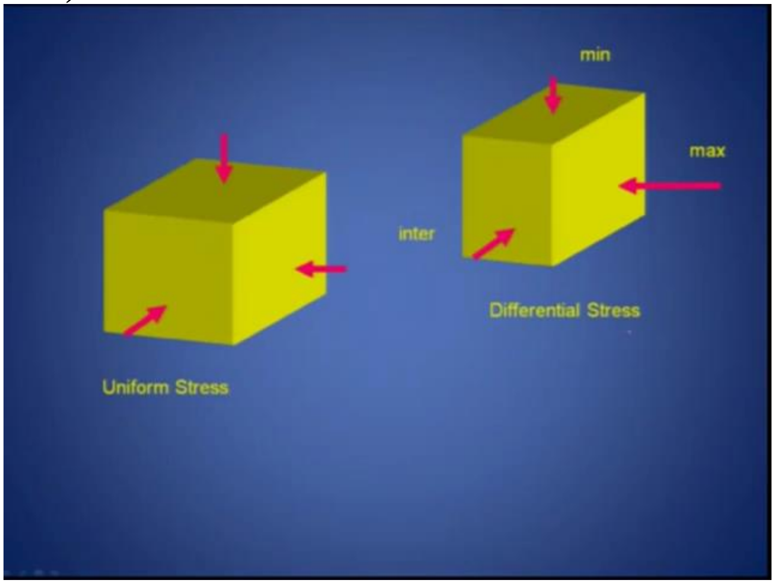

Now I already discussed about this part that if you move into the deeper part of the Earth, the deformation which you see will be uniform okay. And then where there we expect uniform stresses okay. But on the surface, we have directional stresses. So we have Sigma 1, Sigma 2, Sigma 3 where if we define this then we are having the Sigma 1 is the maximum. Then we are having intermediate Sigma 2 and we are having Sigma 3 is the minimum one okay.

So the deformation will maximum along the along the Sigma 1 okay. So that is what we call the differential stresses okay. So due to the differential stresses, we have different type of faulting or fracturing which is is been seen in the rocks okay.

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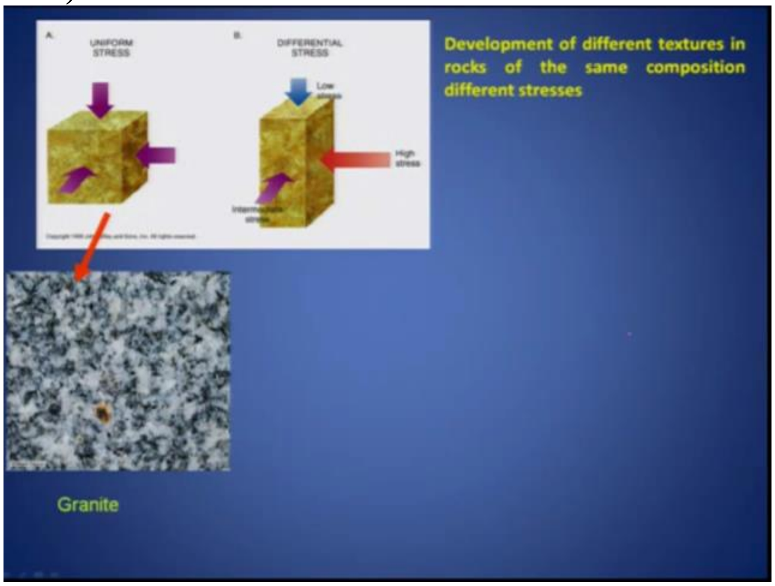

Now development of different textures in rocks. This we have already discussed. So I will just move ahead. So please refer to your previous slides when we were talking about the igneous rocks getting converted into the metamorphic rocks okay.

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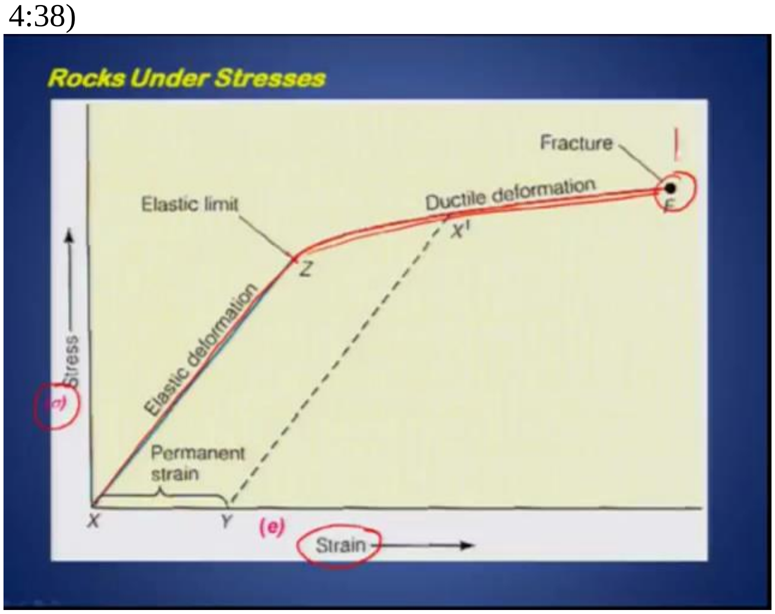

This also we have discussed to some extent that that we if you deform the material, so under you keep on increasing the stress, you keep building up strain okay. So you have the energy which is getting stored. So initially, the energy will be stored elastically and finally it will break okay. Before that we have some deformation will be in ductile form okay.

So there will be an deformation in a ductile form but finally or eventually it will break. And this is your earthquake okay. This we have discussed at the time of when we were talking about the interior of Earth also okay.

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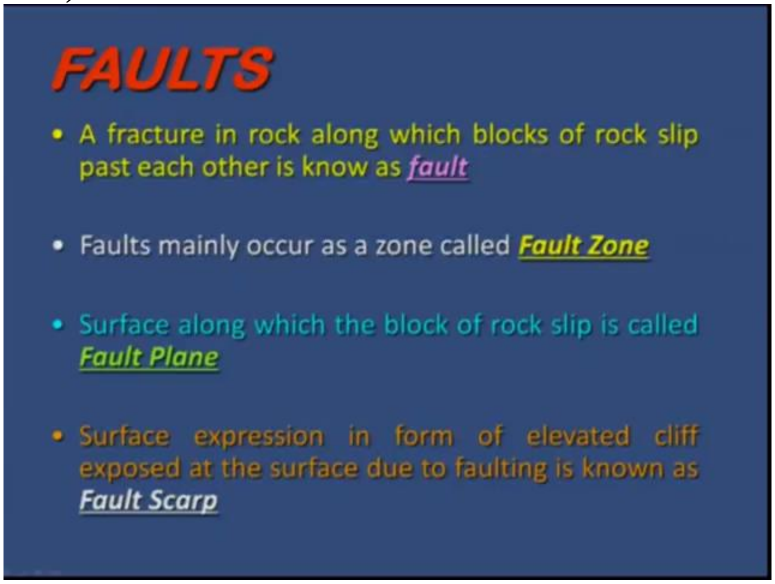

Now faults if you define is a the fault is a fracture in our rock along which block blocks of rocks slip past each other is known as fault okay. So along a fracture, if you see any displacement okay, then you will term that as an fault okay. But that displacement may be related to the earthquake or maybe related to the deformation or it may be just gravitational also okay. So that we have to be extremely careful how to differentiate that okay.

But anyways, if we in a proper sense if we take any displacement in rock layers or maybe stratas or the sediment succession, we will term that as an fault okay. And faults mainly occur as a zone okay what we call the fault zone. Also it will not be in single line or single plane or fracture. But it will be having multiple and it will it may have a wider zone okay.

And surface along which the block of rocks slips is called fault plane okay. So this we will see the part when we are talking about the parts of the faults will talk about that. Surface expression in form of elevated cliff exposed at the surface due to faulting is termed as fault scarp. So these are all terms extremely important for us okay. The fault zone, fault plane and the fault scarps. So surface manifestation is termed as fault scarp okay.

So during deformation, there will be that the or or or during an earthquake there will be displacement and that displacement is reflected on the surface and that surface expression is termed as fault scarp.

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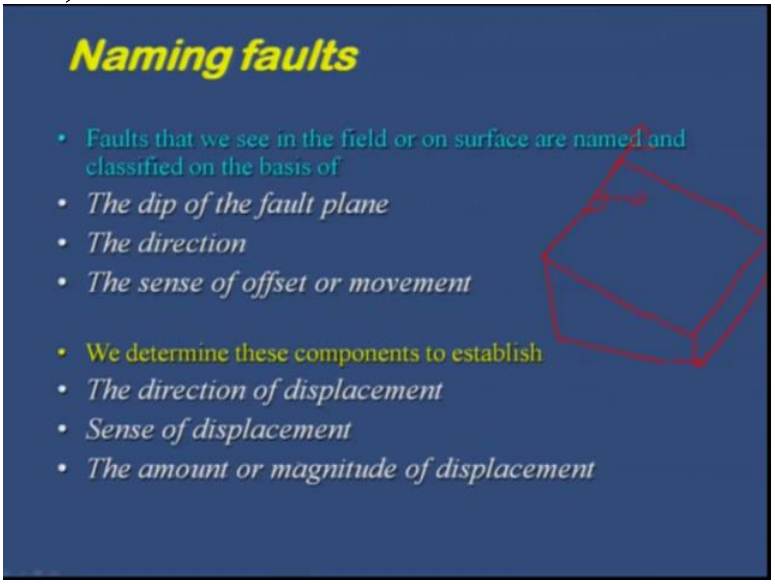

Now naming faults. Basically what we see in field or on the surface are named as named and classified on the basis of one, the dip of the fault plane okay. In which direction the fault is dipping, one. 2nd is that that is one is the amount of dip sorry. And then another is the direction of dip, in which direction that fault plane is dipping. Then we talk about the sense of offset okay.

So whether the block has moved up or block has moved down or whether the block has or it is it is passed by each other laterally okay. So we determine with the help of this, the components to establish mainly the direction of displacement, in which direction the fault moved. Then the sense of displacement as I was talking about that up and down, we can also measure that. The amount of magnitude and displacement, how much it moved okay.

It moved for metres or it moves in feet or it moves in centimetres, that you can make out okay. So again as we discussed in the strike and dip, what we did in the strike that we had like if this is strike then this what we are having the like sorry this we are having like for example if we have the inclined plane like this, so you have the strike here and this will be the dip direction and this will be with respect to the horizontal you will have the amount of dip and all that okay.

So this is the amount. Similarly, we also try to look at offset okay and then we measure the amount of displacement, direction of displacement and the sense of displacement. So now we will see what are the different type of faults and how we classify those okay. So just keep in mind that what we have taken about the strike and dip because we are going to use some of the parameters which we used for measuring the strike and dip.

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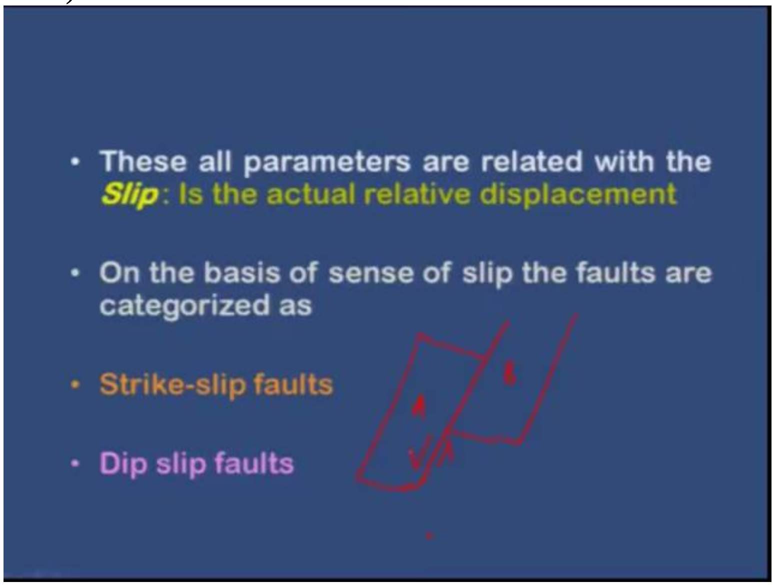

So these all parameters are related to slip which is the actual relative displacement. And on the basis of the sense of slip the faults are categorised as as strike slip fault and Dip slip faults. So either the displacement is along the strike, if this is the strike, so displacement is the movement is along the so if you if you look on the plan view, you may be able to make out that in which direction the block has moved okay.

So these are the 2 blocks, A and B. So the moment here what we see is that moved by this amount okay. So you can make out that in sense the block has moved. Now this is along the strike. So this will be the strike of the fault. This we are looking at the plan view. Now along with this that we will also come across that there will be an sleep along the dip of the of the fault plane.

So we are having for like what we were talking about the bedding planes, we also have the fault planes along which the displacement will take place okay. So based on this we can classify the faults. Either they can be categorised as strike slip or dip slip faults.

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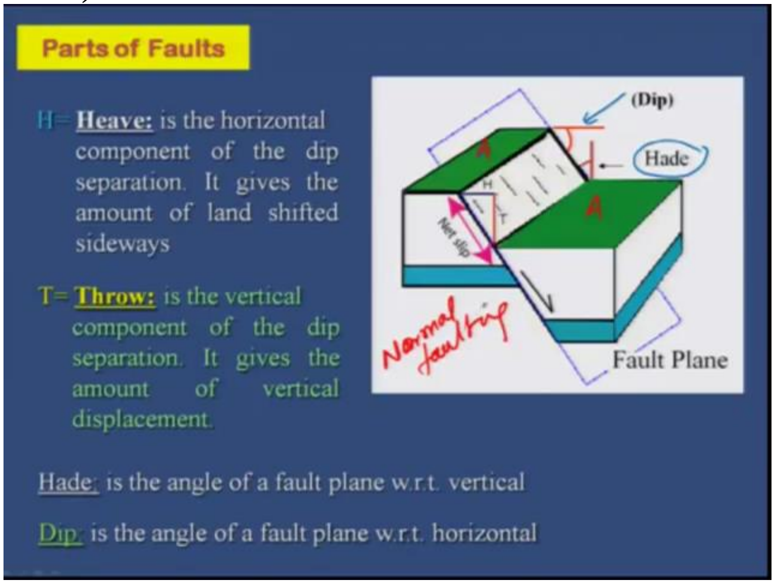

So parts of faults again very much similar to what we did in the dip and strike **or** and then further we could talk about the departure of faults. Here there are parts of faults, different faults okay. So we have different terms and those are either with respect to the horizontal or with respect to the vertical. We try to collect the maximum information of the displacement, the sense of displacement, amount of displacement and all that is okay.

So 1st coming to the heave. Here the H is denoted as heave. And this is the horizontal component of the dip separation okay. So if any movement which is taking place, suppose you are having this is a fault plane here. So if anything moves, then there will be an horizontal component of the displace plane. And that will tell you that how much the land has moved okay or shifted sideways.

So that is the heave. So heave is over here this is the heave which we will measure okay. So this is with respect to, this is an horizontal. Now coming to the throw that is T denoted by T which measures the vertical component of the dip separation. This is the throw which we are getting here okay. So so heave is this one here. We have heave. And the next is what we are having T is the throw. That is an vertical component.

Then comes the hade. Hade is this one over here. So hade it is the angle of faults plane with respect to vertical. As we were talking about the dip which is respect to the dip is here. This is the dip here which is respect to horizontal but this angle is with respect to vertical okay. So these are the components which you measure when there is an displacement along the fault plane okay.

So what has been shown in this figure is that this block case which is marked by Green okay that is that was once together okay. It was together. So the green one here, this is A and A and this one we marked. So these were together and then during an earthquake, it moved down. So it moved along the particular dip. And this portion here, we will call this as an fault scarp.

So we will see some signatures of this type of features what we call fault scarp in ground or on the ground field Photographs. I will show that okay. So for us, it is extremely important to know the angle, at what angle the fault is dipping? How much is the horizontal separation? How much is the vertical separation?

And what is the net slip okay which has occurred along this one. Now coming to the strike, that was an example but I will I will talk later also. This is an example of normal faulting okay. What we call normal faulting where one block moves down with respect to another one.

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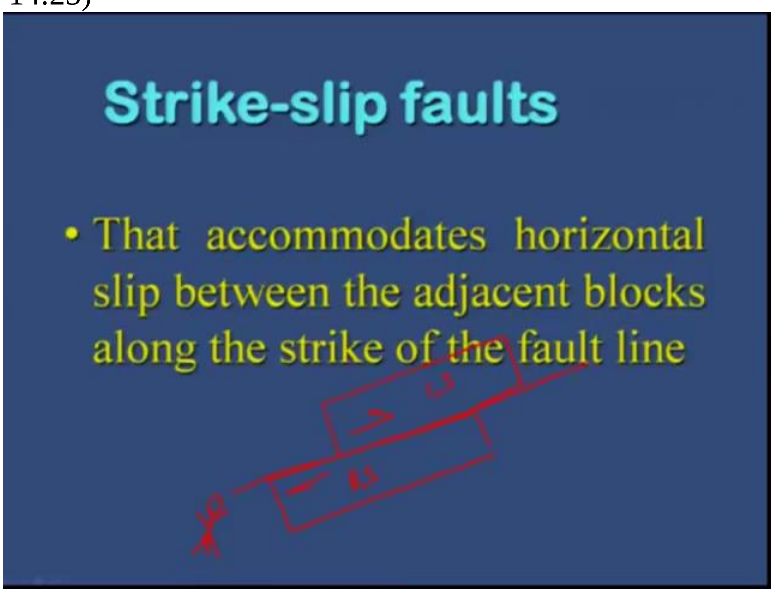

Then coming to the faults which are taking place. The strike slip faults. So let us talk what what are the different types of strike slip faults. Now strike slip faults that accommodates horizontal slip between the adjacent blocks along the strike. So if you are having a particular strike along that you will have so if this is the strike, so the movement is been seen taking place along the strike. Suppose the movement has occurred like this here, so this block has moved in this direction as compared to this one okay.

So this block has moved in the other direction. So with the sense that where you are standing okay, with this you will say that which block is moving. So this is your right. So this is the right-hand side and this is the left-hand side. So this is being termed as right lateral strike slip. We will talk about this very quickly in the coming slide. So in short, the strike slip faults that accommodates horizontal slip between the adjacent block along the strike of the fault. So the strikes of the fault will be around somewhere here. This will be your strike of the fault.

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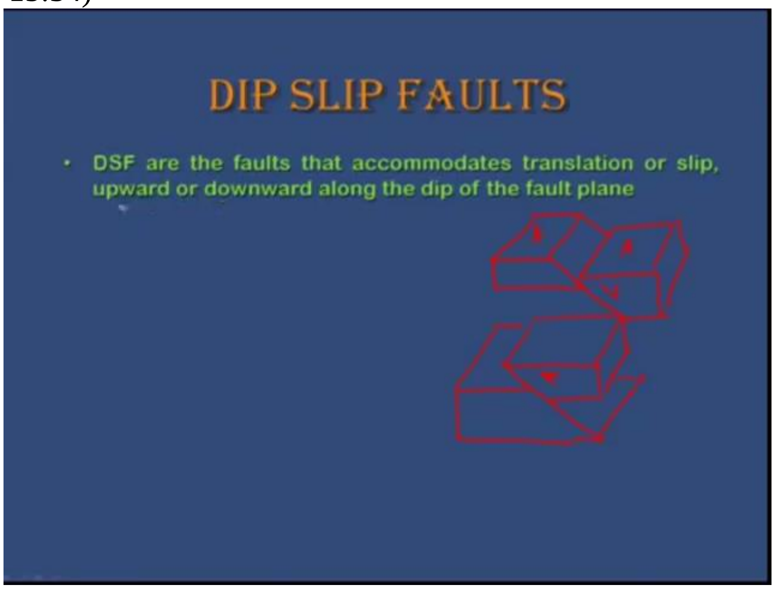

So dip slip faults again are the faults that accommodates translational or slip upward or downward along the dip of the fault plane. So either the block has moved about either the block has down okay. So in short if I sketch here very quickly then we are having this is the fault plane and one block has moved down with respect to the another one. So you have this block which has down okay.

So this is A. One is this one. Another one if you look at for example, then we are having a block here which is here what you see is that this block has moved up with respect to **this one**. This we cannot say that there is a movement okay. We will talk about that, what is happening here. So here this block has moved down, here this block has moved up here okay. So these are the different movements which are taking place.

Either the block has moved upward or either the block has moved downward okay. So that you have to keep in mind and then which is been used for the classification of the faults okay. So one classification is of the dip slip fault is your normal faults which we term as a normal fault.

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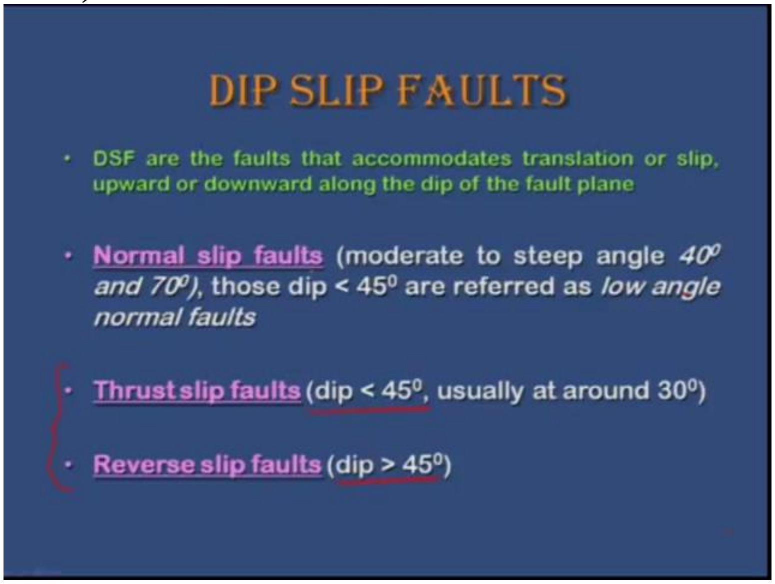

And the normal faults can be of different angles okay which can vary from say 40 degrees to 70 degrees. And those which are having dip less than 45 degrees are referred as low angle normal faults okay. So similarly we have thrust faults also. Now normal faults are usually seen in an extensional tectonic environment. So this is an extensional tectonic environment whereas the thrust and another one which is reverse fault, these 2 are seen in compressional tectonic environment.

So this is one major difference between these 2 and in normal fault what you will see is the block, one of the block will move down with respect to another okay. So this is very much important which you have to remember. But we will go in detail as in the coming slide. So one we are having the normal fault. Another we are having the thrust faults. Now thrust fault and reverse fault, both are in compressional tectonic environment.

But the difference here is the only the in terms of the angle okay. So you have if the fault is dipping less than 45 degrees then they are usually termed as the thrust faults okay. And if you are having the fault angle greater than 45 degrees then they are termed as reverse faults.

So in these 2 fault types which are of compressional tectonic environment, the block (())(18:46) will move up with respect to one another okay. Whereas here, in the normal slip fault, the block will move down.

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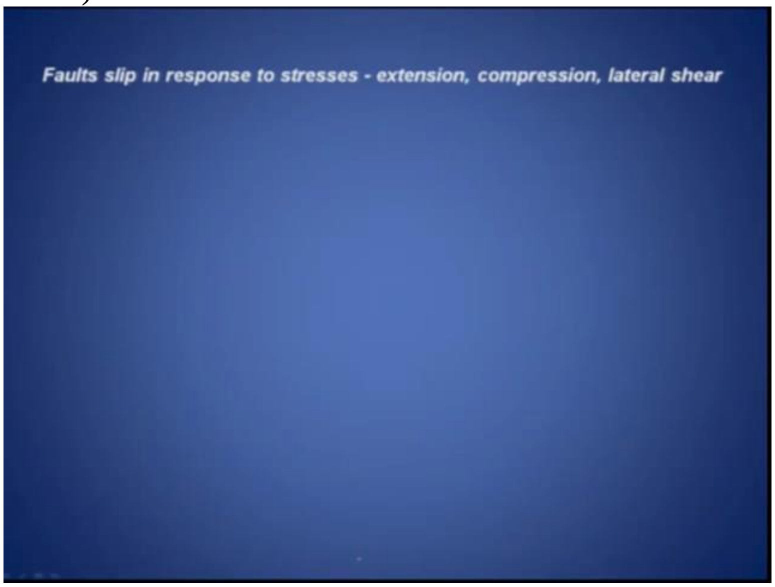

Active faults are very important because these are the faults along which we believe that the next large earthquake will occur okay. But in terms of the definition if we take, the active faults are faults along which the movement have occurred. That is the displacement have occurred during the last 10,000 years okay. So you remember this with the timescale, geological timescale.

This is what we were talking about the within the Holocene epoch okay. And likely to occur in near future. So you are expecting an earthquake along that particular fault line okay. And the active fault is the manifestation of crustal deformation by displaced landforms on the earth's surface. So this is what we are looking at on the earth's surface okay. So we try to identify the manifestation of deformed landforms on the surface okay.

So these are the remnants or the signature of ancient earthquakes. And that is what we call the study of earthquakes paleo seismic. So paleo is ancient, seismic is earthquake related phenomena. So this is this is the definition of active faults along which the movement occurred during last 10,000 years. Likely to occur in near future, that is the movement is likely to occur in near future.

And what we see is the manifestation of crustal deformation on the surface in form of displaced landforms okay. Now this is important is because they are considered to be the source for the large magnitude earthquakes in the near future and it is required because this is one of the vital information or the which is taken for the seismic hazard assessment. So any area which is seismically active, so for seismic hazard assessment, active fault information is extremely required okay. So this is one of the reasons for the why we want to identify the active faults **on** the surface okay.

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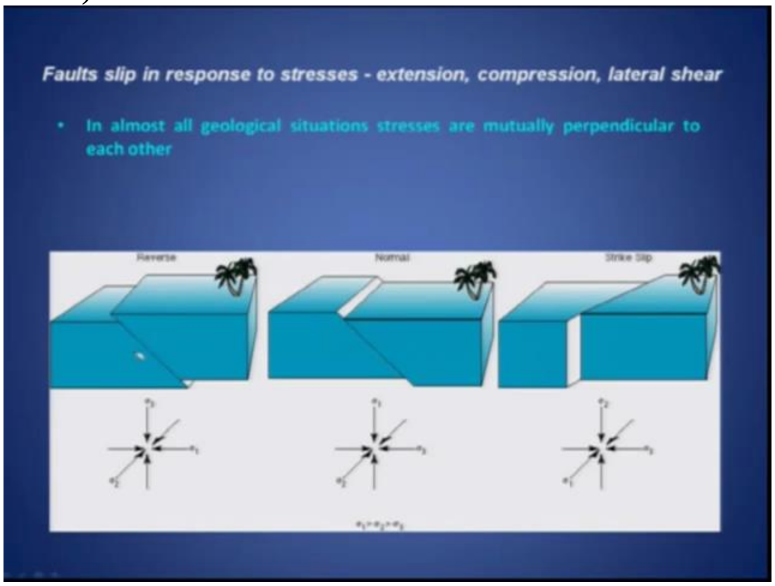

So fault slip is a response of the stresses. Either we talk about the extensional stresses, compressional or lateral shear okay. So in almost all geological situations, what we consider, the stresses are stresses are mutually perpendicular to each other okay. So if you are having like talking about the here the Sigma 1, Sigma 2 and Sigma 3, this is the maximum 1 and the intermediate and minimum. Depending on that is where the maximum stress is acting upon and where the minimum is, you will find the different type of displacements okay.

So in reverse, the maximum stress is along this direction okay and the minimum is at the top here. So this is Sigma 3 here and you are having Sigma 1 along the fault plane and minimum is along that is Sigma 2 here okay. Similarly here you are having the maximum is at the top okay. That is Sigma 1 in the normal conditions okay. So this what we **if** we find is when the block has moved down with respect to another one and then we call this as an normal fault.

Whereas here, we are having the reverse fault. And the 3rd one, the maximum stress is again oblique fashion but along the fault plane here okay. So this is again what we see the moment along the strike. So they are termed as strike slip faults okay. So this you can refer and try to understand this and remember that how different stresses are important in classifying the rocks also post sorry in classifying the different type of faults here.

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So style of deformation under different stresses. So if you have like the tensional one then what you are doing, you are stretching the crust okay. And you are thinning the crust in one or the other form okay. So you are thinning the crust here and then what you see is the type of faulting the normal faulting. In another one, you are compressing okay.

So you are shortening the earth's crust okay. And what final results you are getting is you will see either the reverse faults or you will see the thrust fault formation. So either you are having the reverse fault or thrust fault. And of course, before faulting or the displacement you will see the area is under compression resulting into folding again.

And then 3rd one is the shearing part okay. So shearing, you are again putting very oblique things and shearing or twisting the area. So you will have the bending in the layers resulting into strike slip motion okay. Now either the block will move in this direction or maybe in the opposite direction depending on the stress conditions okay.

So these are the different patterns which you remember we should remember. So you are having tension, you do stretching and you are having thinning of the crust. When you have compression, you are doing shortening and you are thickening the crust here and folding okay. And then you are shearing you are twisting the crust okay.

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Figure 4.2-1: Fault scarp near Crowley Lake, California.

Now here is the one of the beautiful examples of the fault scarp from California and this what you see here is the fault scarp which is which has displaced the landform. So let us see what are the faults, different type of faults in the signature.

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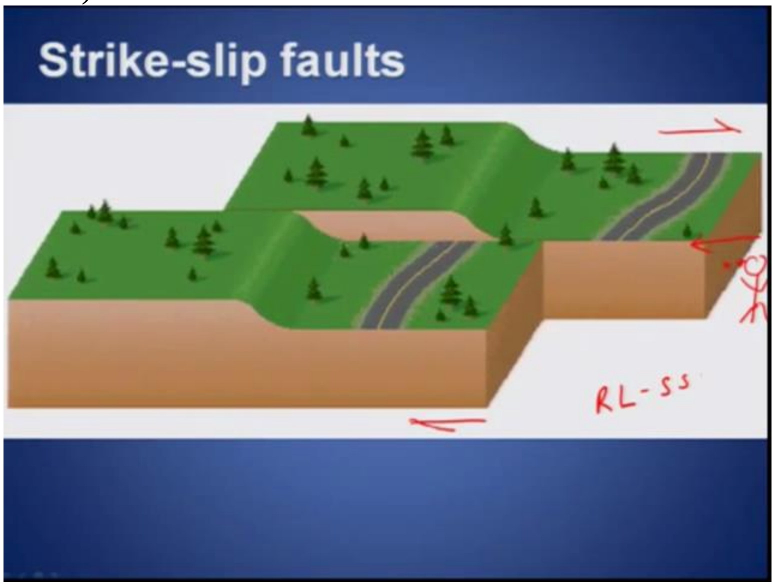

So here if you carefully watch, one block is moving or passing each other with respect to another. And this is what we term as a strike slip fault okay. So this block has moved in this direction bad as this block has moved in this direction here. And then slip is taking place somewhere along this plane okay. So this is the plane here.

So what you see is the displacement, lateral displacement along the strike and this is termed as right lateral strike slip fault okay. No matter where you are standing, if suppose you are standing here and then try to see the fault, then then also you will find that the right block is moving towards your site. Hence you can classify this as an right lateral strike slip fault okay. So you can talk about this okay. So the strike slip fault as we have discussed, they accommodate horizontal slip between the adjacent block okay.

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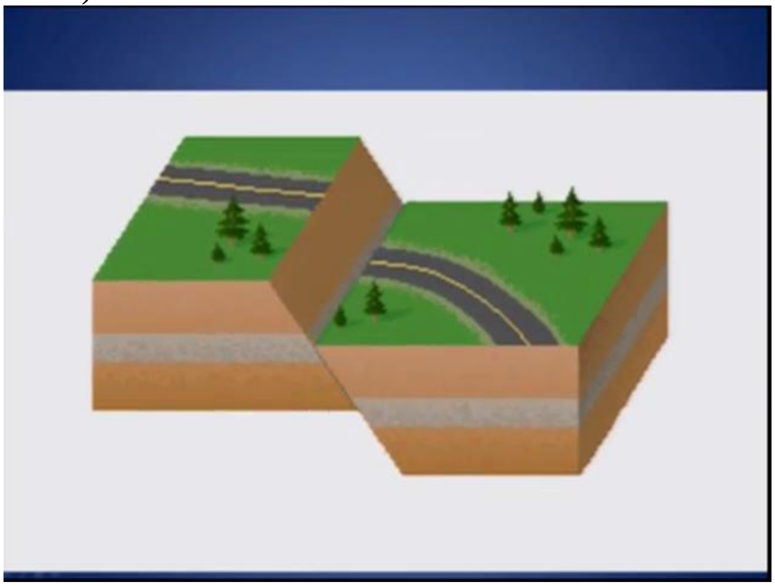

Now this one is again this is an fault plane here along which movement has occurred. The block has moved down and the strike of the fault is over here like this okay. This means the strike okay. And this what you are looking at which is coming up is the fault scarp okay. So now this is the type of dip slip fault because the movement is taking place along the dip component and one block is moving down the another. We are doing stretching. Hence we term this as a normal fault okay.

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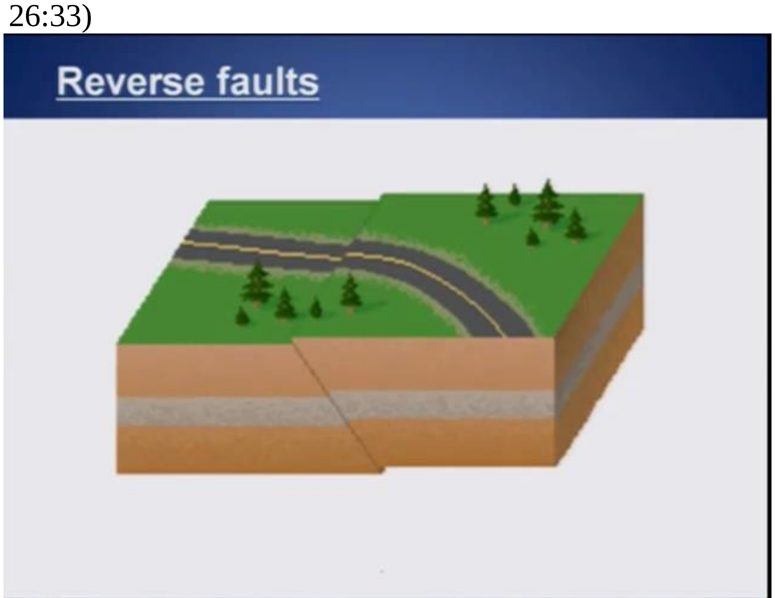

This one is reverse fault where one moving above the another one okay. So we see this is an reverse fault and this type of faulting is seen in the compressional tectonic environment. Now this one is very critical wherein the previous one if you see you are able to see the displacement between if you take the greyish layer or brownish layer, they are broken and they have been displaced okay.

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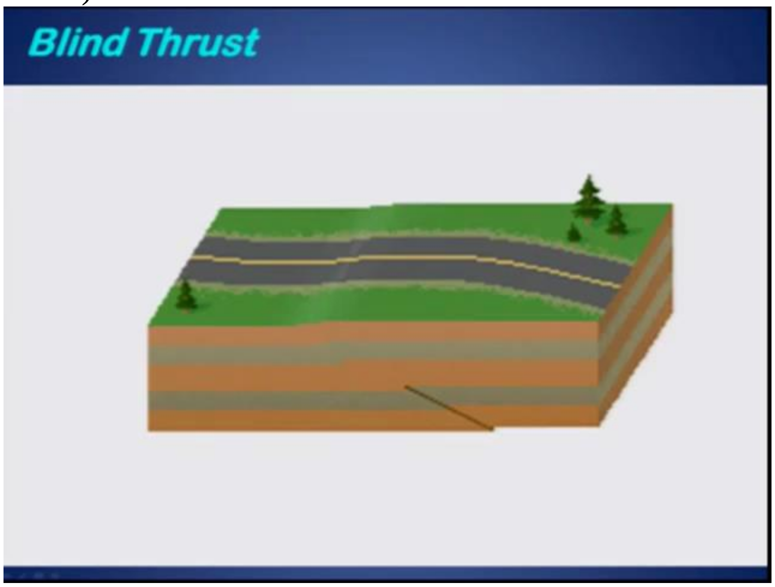

Whereas in this one, the displacement is seen below the surface but near the surface, just the folding is being seen. So no displacement or the breaking up of the layers are being seen. So such type of faults are termed as blind thrust. So where the displacement has not been able to see the surface, remain blind, hence we term this as an blind thrust okay.

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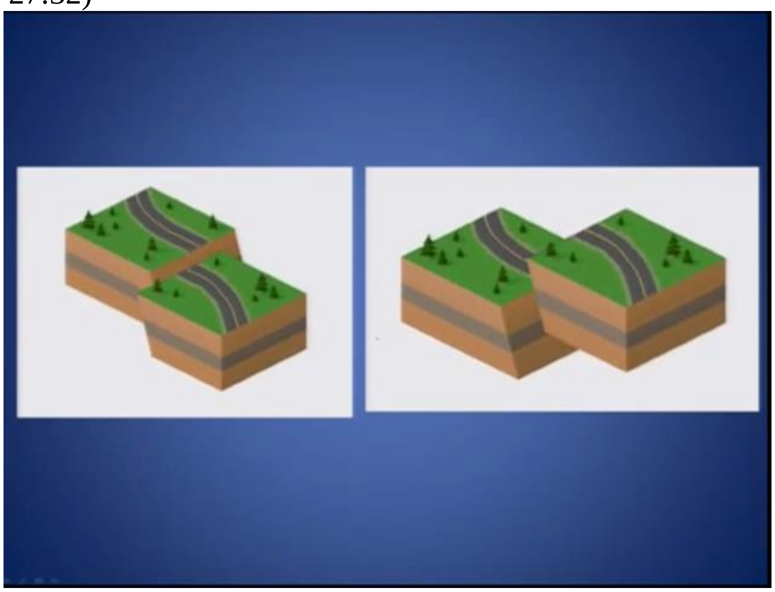

Now this one is having 2 different components okay. But the combination of those 2 components as we can see here and these are termed as oblique slip faults okay. So we have the left-hand side what we are able to see that there is an oblique, there is a slip along the strike also and there is a slip along the dip component also. Whereas here again it is slipping along the strike here and you are having a reverse component, the block is coming up.

Now as we have we I told in the beginning that we may have the additional module of this because the application part of the fault is extremely important and application of other geological structures and what we have learned regarding the rock types and all that we will we will try to talk in the application part of Earth sciences in civil engineering in the next module okay.

So I stop here and we will see you soon in the next module which will be coming up in couple of months. It will be announced and the hopefully to we see you all again okay. Thank you so much.