Photogeology in Terrain Evaluation (Part-2)
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Lecture - 04
Identification of Features Related to Ongoing Crustal Deformation and Mountain Building Process

Welcome back. So we discussed in previous couple of lectures about the faults and now in this particular lecture may be one or two lectures we will discuss mostly about the faults actually that how we identify the faults on the surface.

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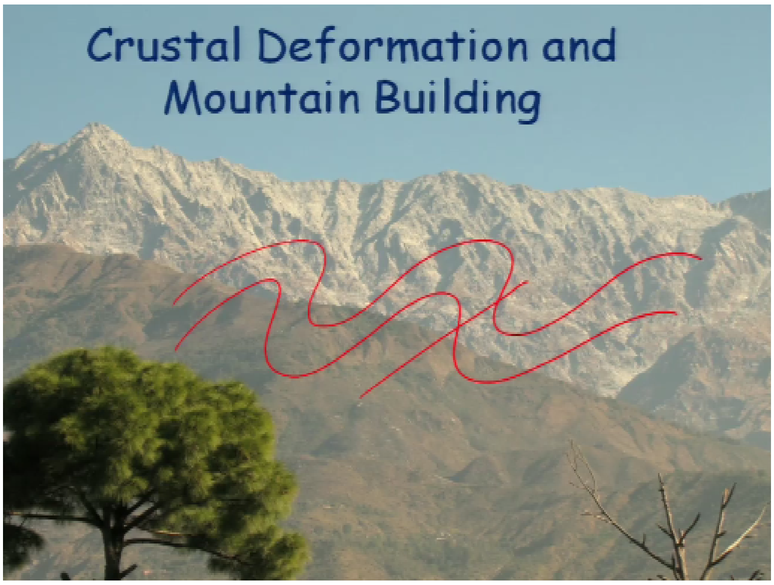

Now as I mentioned in my first lecture that overall deformation if you take I have shown one sketch where you must have availed the combination of the anticline and the syncline. Now this anticline and syncline will occur in combination and some locations you will have the fractures or the displacement among the strata and that what we call faults. So basically what we see that there is overall deformation will be seen in the area where we are having the ongoing crustal deformation and then mountain building activity.

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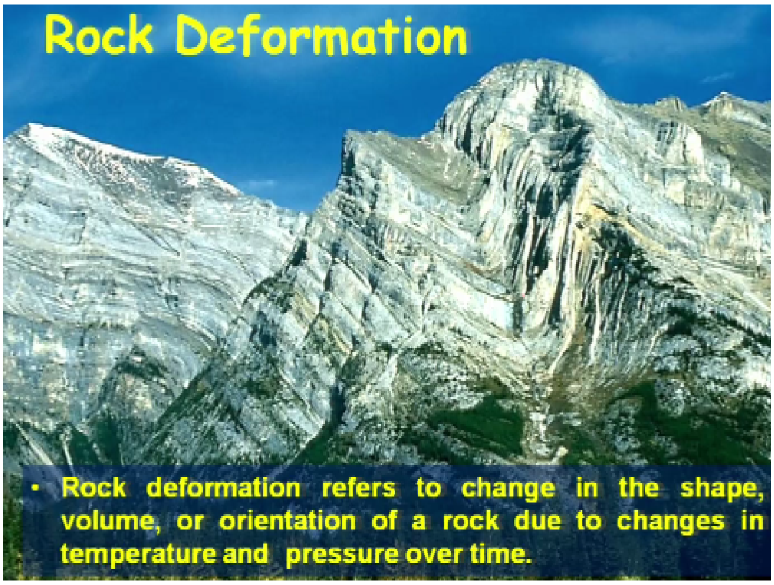

So if you take in a total sense what we will find is this is because of the ongoing crustal deformation where rock deformation takes place and which results into different attitudes of the rocks and where we will see the folds, faults, fractures and joints. So rock deformation refers to change in the shape, volume or orientation of a rock due to changes in temperature and pressure over the time.

This is there because of what we discuss in one of the course for (()) (02:05), but the brittle or ductile deformation if you take you will mostly see the folding of course the pressure and temperature will play an important role and the type of deformation that is whether it will take in the form of brittle deformation or it will be ductile deformation.

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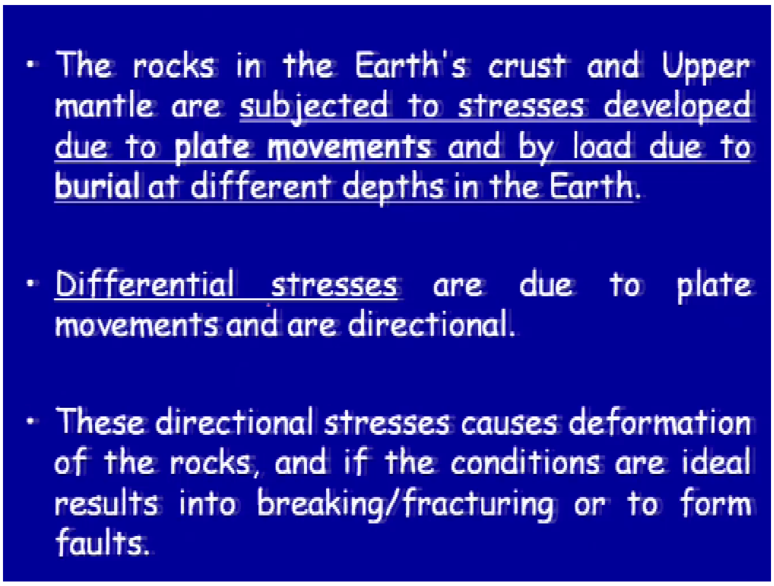

So the rocks in the Earth's crust and upper mantle are subjected to stresses developed due to plate movements and by load due to burial at different depth in the earth. So when we say at different depth in the earth interior there comes the importance of the pressure and temperature. So differential stresses are due to plate movements and are directional. So this differential stresses you will experience in the uppermost part of the crust.

But if you will go into the deeper part then it is almost uniform deformation. So this directional stresses causes deformation of rocks and if the conditions are ideal results into breaking, fracturing or which will result into the development of faults.

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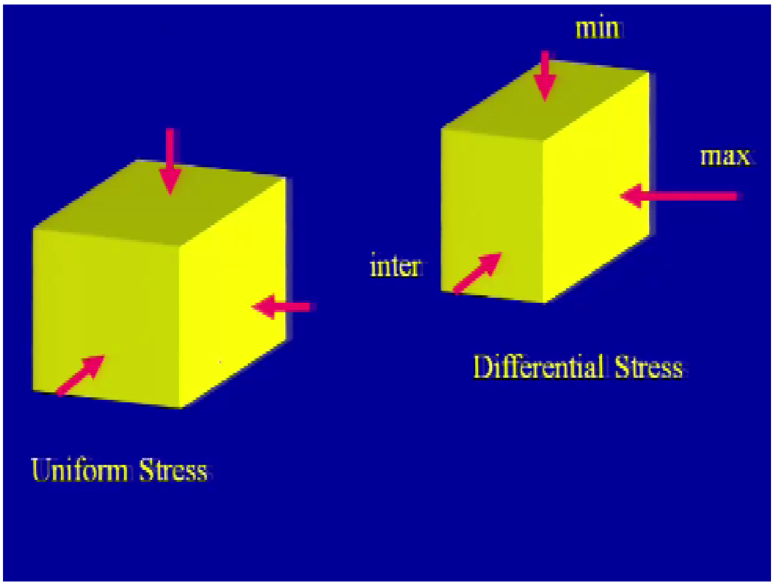

So if you look at the 3 stresses sigma 1, sigma 2, sigma 3 so at the deeper part of the earth interior you will see almost uniform stresses. So whereas in the upper part you will see that the stresses are one of the stress will be maximum and that is what we call differential stresses or the stresses are directional and that will lead to the deformation either we are talking about the compression power extension or slip past each other.

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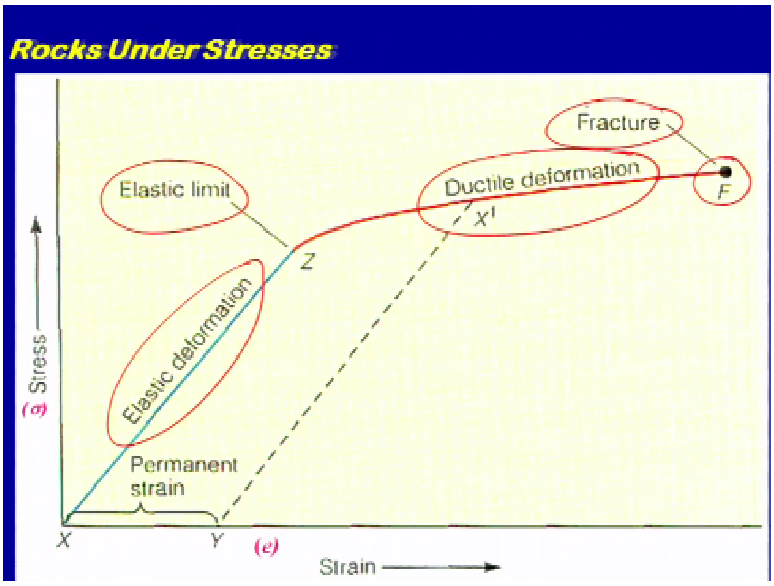

So these are the differential stresses Very commonly observed that if you keep on increasing the stress the strain will develop and initially you will have the elastic deformation. So any material or the earth material will go into first of all the plastic deformation and this will take place until a point of their elastic limit. Beyond that if you keep on applying stress the material will get into the ductile deformation.

And what we call at one point in time it will have permanent strain. So the format will not come back because (()) (05:19) then it may rebound back, but at some point of time it will not rebound back, but it will deform and will have permanent strain developed there. Further if you keep on going and increasing the stress after the threshold limit of any given material it will fracture.

And this fracture is seen on the surface because when you say a fracture then there will be displacement of stratus and that will lead to the formation of faults.

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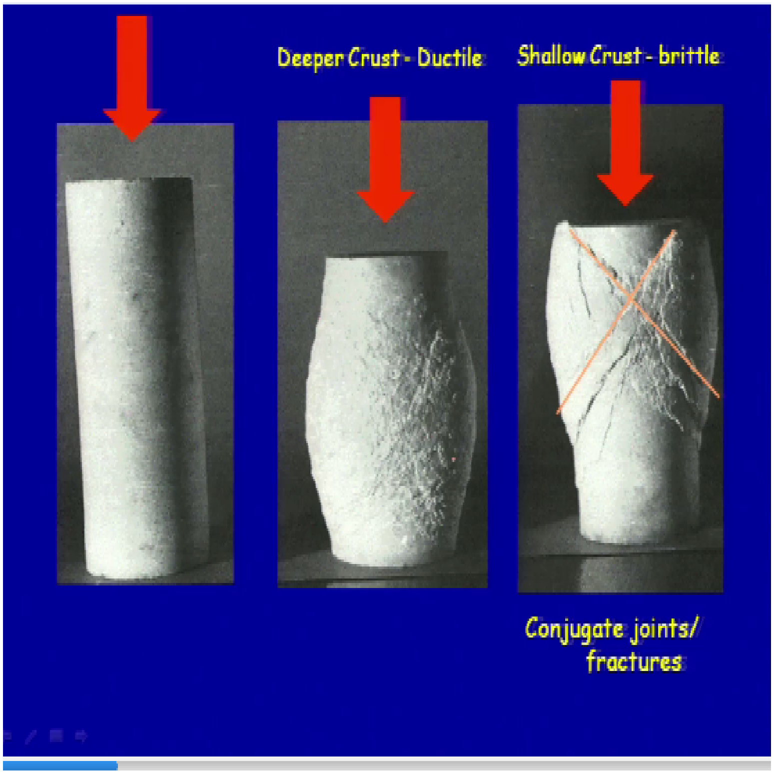

So this is just an example of a cylindrical rock which has been taken and when they keep applying the stress then at one point of time at the deeper portion what you will see that it will go into ductile deformation whereas in the shallow or crust you will have brittle deformation that means you will see the fractures and faults which are developed within the material.

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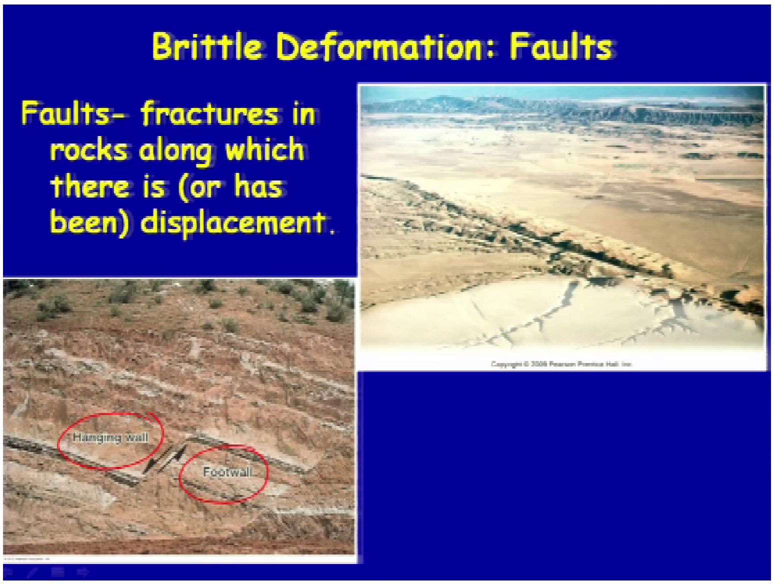

These are few examples of the fractures in rock along which there is displacement and there is a straight linear feature where some of us may say that this is a lineament, but this lineament is a fault actually. So fault the manifestation of ongoing deformation is seen on the surface. I will come to this fault this is an example from a San Andreas fault system and this fault is a right lateral fault.

Whereas here what you see is the displacement is again in the section and this displacement is typical of the normal faults where we classify the normal fault and reverse fault based on the relationship of the walls on either side of the fault-plane that is footwall and the hanging wall. So in this case the hanging wall has moved down and footwall has remained stationary.

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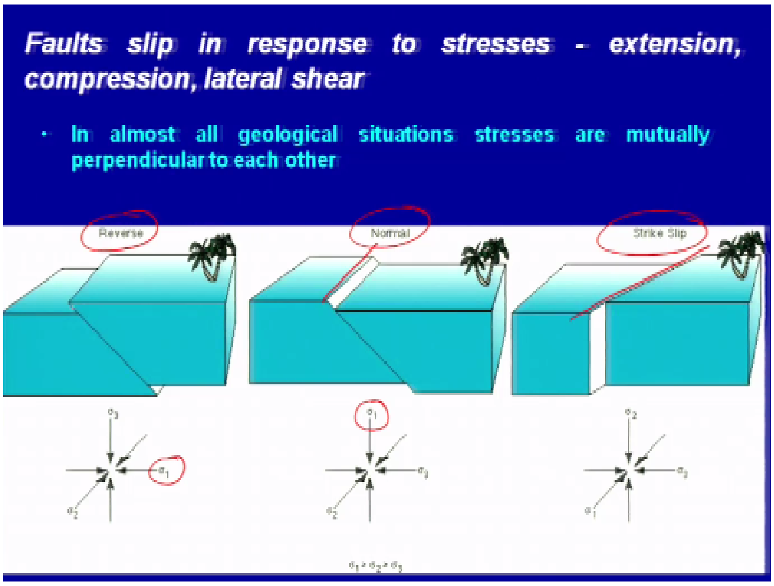

Now fault slip is response to the stresses either you will see extensional, compressional or lateral shear. So in almost all geological situation stresses are mutually perpendicular to one another. So this what we know that we have the sigma 1, sigma 2 and have sigma 3. So if you take the different type of deformation or the faulting areas you have reverse faults, you have normal faults and you have strike slip faults that is you are having the lateral shear.

So in lateral shearing mostly what you see is that the sigma 1 that is the least stress is along the fault-plane or the line of fracture whereas in case of the normal fault you have the least again along the fault-plane and the maximum is vertical. In case of the reverse fault the maximum is horizontal. So here we can say this is compression, this is extensional tectonic environment and this is you are having the lateral shear with the movement will take place along this plane.

But this is the fault line here and here we can see this one is the fault line.

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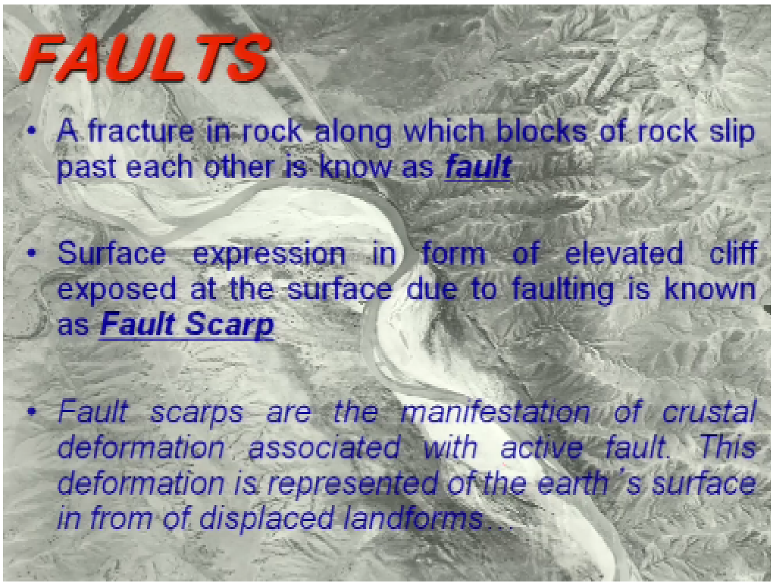

So faults in total if we take we have a fracture in rock along which block of rock slip past each other is known as fault. Surface expression in form of elevated cliff exposed at the surface due to faulting is termed as Fault Scarp. Faults Scarps are the manifestation of crustal deformation associated with active faults because what we see today is the ongoing or the manifestation of the ongoing deformation.

And since we term (()) (10:41) surface that there is a fault and it is active because otherwise we will say this is dormant. So dormant fault features or the morphology will not be sustained for a longer period because it will undergo erosion, but if you see a very sharp feature on the surface it could be related to the ongoing tectonic deformation. So this deformation is the representation of earth's surface in form of displaced landforms.

So this we will see in couple of slides now onwards that what are the different type of faults that we have discussed, but how they are been seen on the surface because what type of features we should try to look at to indentify of the irrespective faults.

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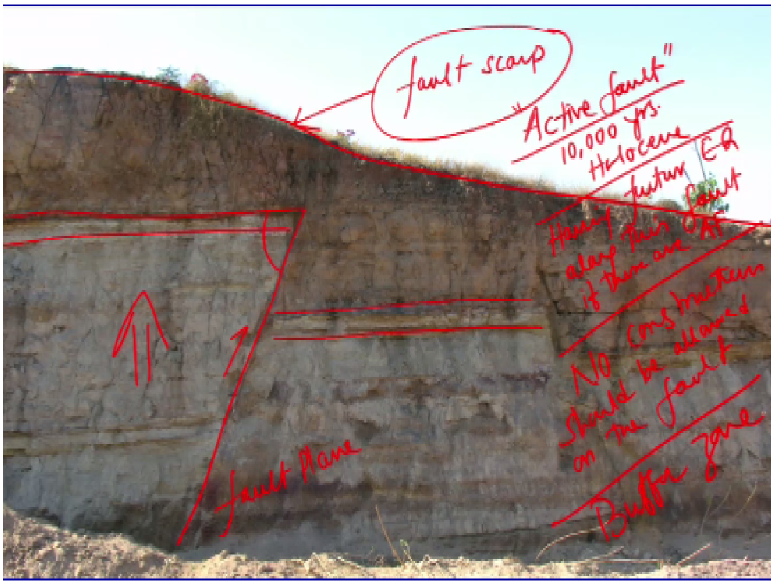

Now this is a very good examples which shows this section where is a sectional view as well as the topography of which is reflected. Now the reverse faults we have couple of slides later where we will classify and talk about the reverse faults, but here I would like to just emphasize about the displacement which is seen along the fault-plane and its manifestation on this surface.

So based on the color variation or the tonal variation of the rocks along the exposed section you can easily make out that what type of fault it is. So if you take this layer this is white layer here which sits somewhere here. So on the top you have this reddish sandstone here also you have reddish sandstone and this has been demarcated the displacement along this plane and this is what we call the fault-plane.

So the displacement what we see is about this block has moved up. So again we have the attitude of this fault. So with respect to horizontal you can measure this fault angle and of course the strike you will be able to see on the surface of the fault scarp. So what we have seen that this block has moved up and it is created the topography which you can see here. So this topography which will you will able to see on surface in a plan view is termed as fault scarp.

So we would not be able to see the section using satellite photograph or satellite data, but we will be able to see fault scarps and this is extremely important because if we say or define the active faults then as per the definition of the active fault what we say that there was a movement along this fault in last 10,000 years. This means that within the hollow scene and there is a likelihood of having future earthquake along this fault.

If we say that these have been the active faults. So this is one very important part Now we understand that this an active fault and you have identified the fault scarp on the surface so no construction should be allowed on the fault. So you need to avoid those areas and for this you need to mark the buffer zone and this is extremely important for the country like us where maximum or we can say infrastructure development is on boom.

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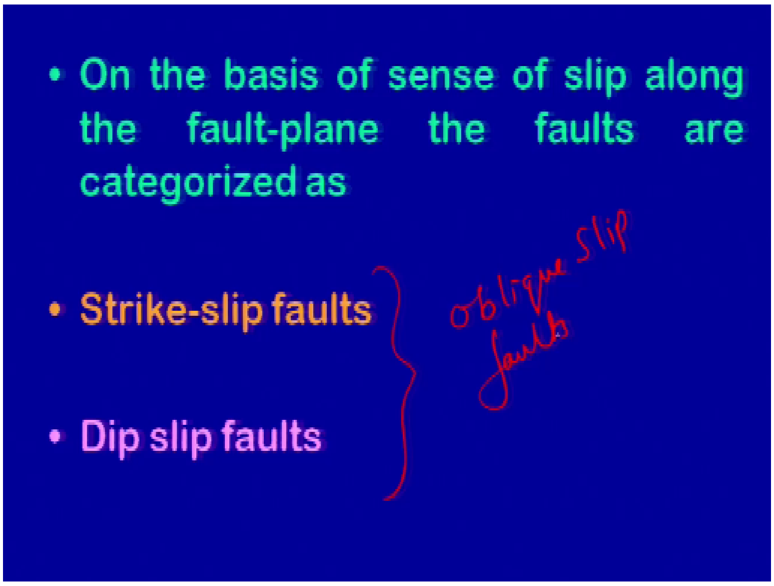

So looking at further this thing that what are the different types of faults on the basis of sense of slip along the fault-plane. The faults are categorized either as a Strike-slip faults or dip-slip faults. So if you see here and what we have is that either you are going to look at displacement along this strike and I am showing with my hand okay. So if you can see that so if you are taking place along the strike.

So this is the displacement you will see and that is what we will call the strike slip and if you are having displacement along the dip of the fault-plane then that will be termed as the dip slip faults. So either the block has moved up or the block has move down and you may have a combination of both. Both in the sense that you will have the movement along the strike as well as along the dip and that type of faults where we have the combination of this 2 are termed as oblique slip faults.

So let us see further in detail that different type of faults and how you will be able to demarcate those faults on the surface. So mostly we see such type of deformation or the manifestation of such deformation in the areas where we see mountain building activities.

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This is a beautiful photograph of Himalaya from Kangra valley where we have identified couple of good signatures of active deformation.

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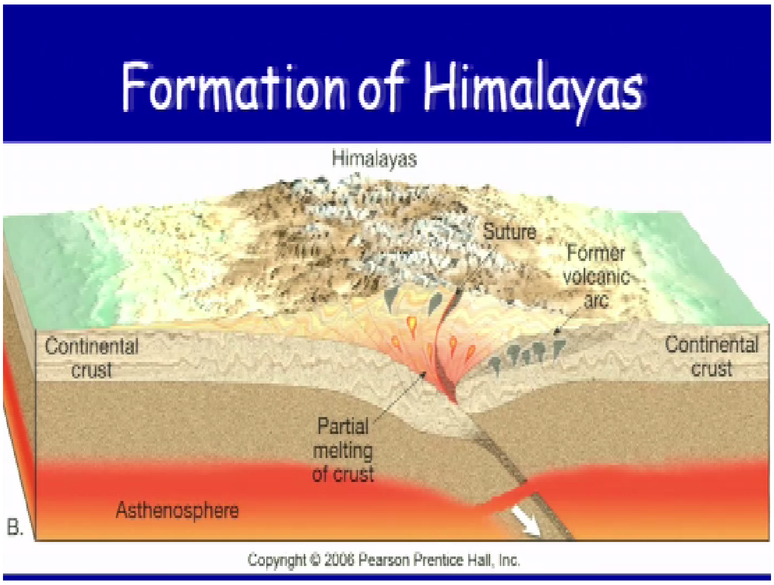

So this part we discussed in one of our course where we talked about that formation of Himalayas is the result of ongoing deformation or the collision between the 2 plates that is the Indian plate and the Eurasian plate where the Eurasian plate is riding on the top of the Indian plate and which has resulted into the formation of the mighty Himalayas.

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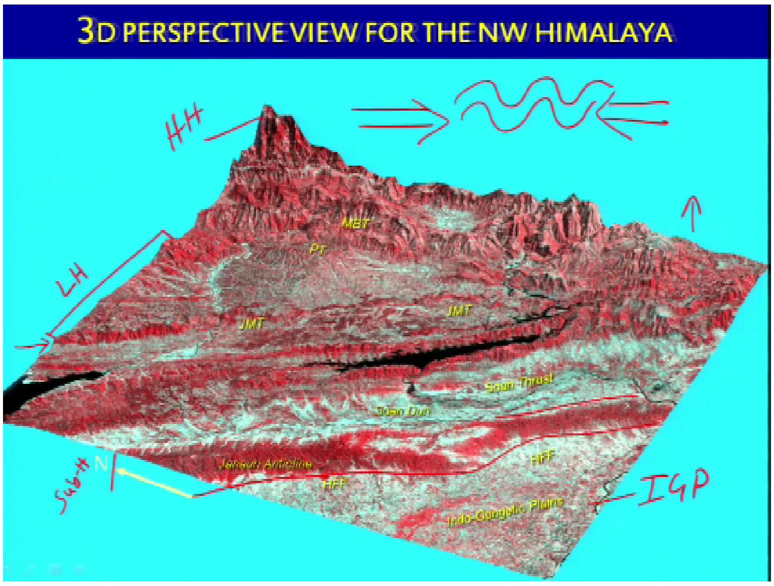

So this just to show that how it looks like. So this is on satellite data, Landsat data draped over the Shuttle Topographic Radar Mission data SRTM data to have a view of the terrain in 3-dimension, 3D perspective view. So what we see here is so when you deform we complete Himalaya what we are looking in one of the slides that you will find that deformation is something like if you deform the layers or you are colliding 2 plates you will be able to see the faults.

And if you try to read some textbooks where the explanation of the Himalaya has been given we say folded chain of Himalaya. So we have number of folded chain. So this is one which has been seen here I will just mark this one. This is the frontal most folded chain which is known as Janauri anticline and this is your Indo-Gangetic Plain. So I will just put it on the other side so that you can see it clearly.

So this portion is your Indo-Gangetic Plain and this is boundary between the Indo-Gangetic Plain and the youngest mountain chain that is your Swalik hills. Further if you move here you see a valley here and then another mountain chain is coming up and so on and then you are seeing a towering height, this is your higher Himalaya and this portion which you see here is your lesser Himalaya.

And this is what we call is sub Himalayas that is the youngest mountain chain and this blackish body which you see here is your Bhakra-Nangal Dam. So this is an interesting thing which has been seen here. I hope you are able to see that there is some (()) (21:25) effect which we observe when we prepare this 3D perspective view and one can easily make out this (()) (21:40) effects or the dome based on the drainage.

You can see the drainage which is flowing away from the center. So this was one of the features which we identified and this deformation could be related to this fault line. One another important thing is that all this mountain chains are bordered or bonded to their south as well as in some cases to the north also. So this is your north. So to the south and north by fault lines or the active faults you can say.

So this is Himalayan frontal thrust or Himalayan frontal fault. This is a Janauri anticline and the intermountain valley between the 2 folded chain of mountains we see that is known as Soan Dun and this is your Soan thrust over here then you are having a Jawalamukhi thrust over here which is responsible for this deformation in the Kangra valley and this is Palampur thrust sorry and then we are having main boundary thrust and so on.

So these are the few things which you will learn in coming slides also about Himalaya, but this is in broad classification what you can see in this area because of the ongoing deformation and collision between the 2 plates that is the Indian plate from South and then Eurasian plate or the Tibetan plate which is overriding the Indian plate from the north. So similar exercise can be done to evaluate the terrain as well as to identify the various landforms.

So this type of exercise you can do to generate the digital elevation model and draping the Landsat data or the satellite data to have a 3D perspective views.

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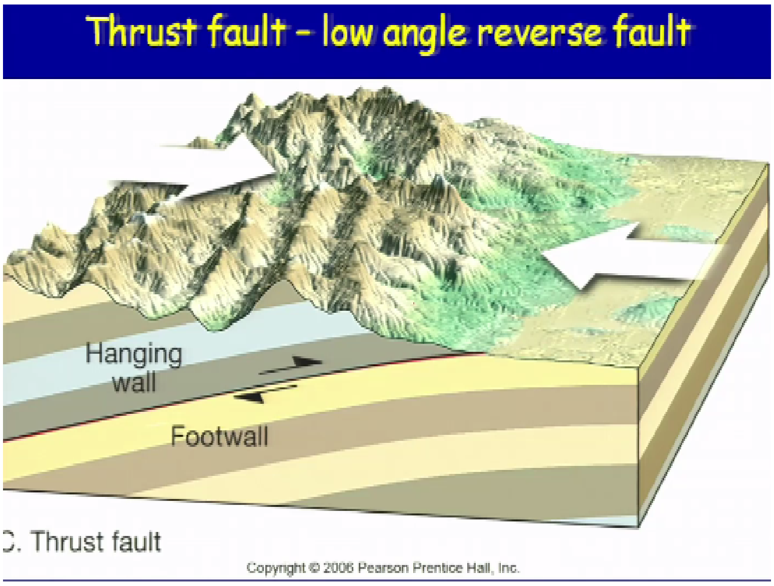

So this is what we are looking at. We have the ongoing deformation from both the sides and we are having an overriding plate or the deformed material riding over to the Indian plate.

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There is another example of again the normal fault, but of course you can think of that whether this should be called as a normal or as a reverse fault.

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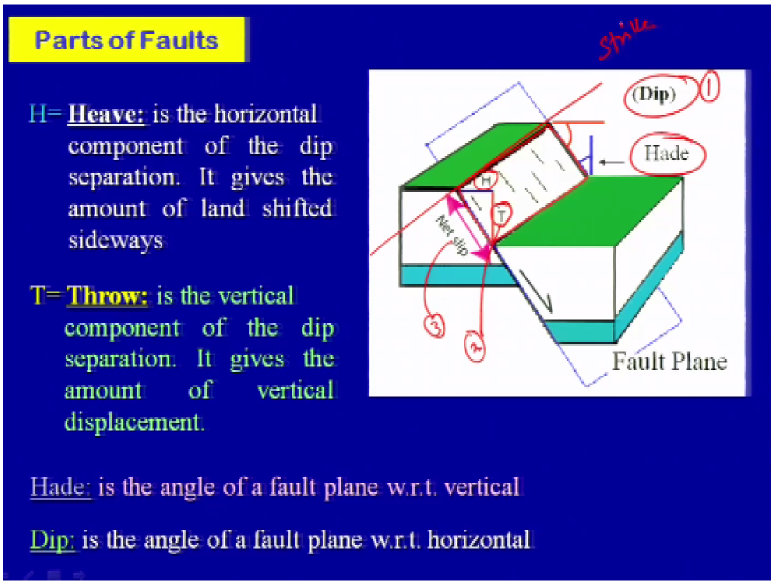

Now this is again an important, but whatever the parts of the faults which have been listed here can be obtained if you are able to see the section otherwise it will be difficult in using the satellite data interpretation. At least you will be able to see the fault scarp here. So this portion is your fault scarp. Now this is the case of normal fault. So we are based on the 2 units or maybe the surface offset you can talk about the net slip.

You can talk about the heave that (()) (25:32) which is termed as the horizontal component of the dip separation. It gives the amount of land shifted sideways then we are having throw. How much the land has vertically moved. So is the vertical component that is throw of the dip separation. It gives the amount of vertical displacement then we are having the hade that hade is the angle of fault-plane with respect to vertical.

And as we were talking about the dip. So dip has always been taken the amount of dip or the angle with respect to horizontal. So these are few points which you can keep in mind and when you go in field and try to look at the section you can measure all this information which is again an important one. The dip is extremely important, the displacement that is the sense of movement is extremely important.

Because these are the information which you will have to put in your report. So one is dip second is your throw third is the net slip if it is required, but I would say that these 2 are extremely important along with what we call the strike. So how the fault is oriented, what is the sense of movement and third is the dip in which direction the fault is dipping so this is very important.

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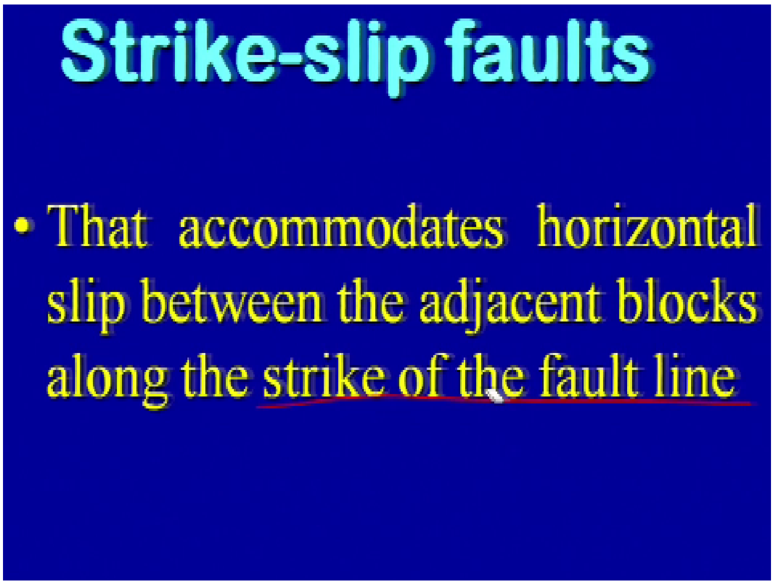

So strikes slip faults as we are talking about are those faults and that accommodates horizontal slip between the adjacent block along the strike of the fault line. So this is the important part of the strike-slip fault. The movement will take place or has been seen along the strike of the fault.

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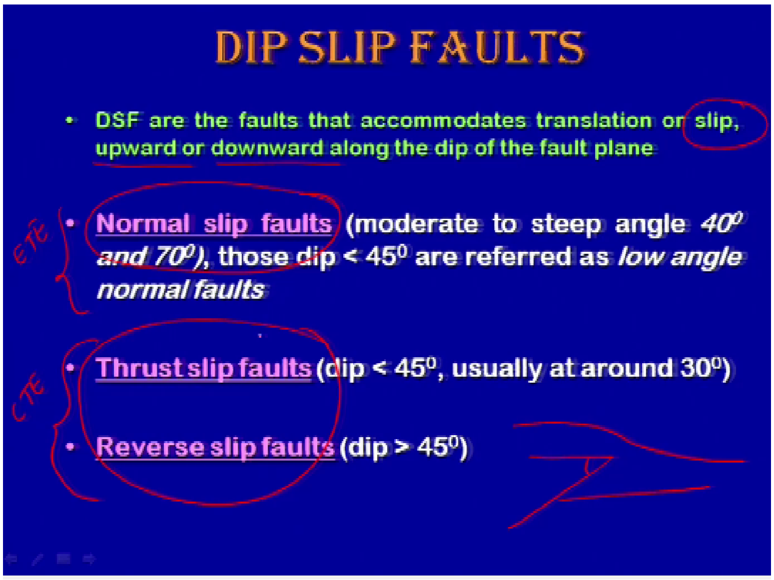

And dip slip faults are again different in sense because as I was showing you that the movement takes place along the dip. So the slip has been observed either upward or downward along the dip of the fault-plane. So if you classify the normal faults they are moderate to steep angle 40 to 70 degree and those dip < 45 degree are referred as low angle normal fault.

Thrust fault dip < 45 degree usually around 30 and the reverse fault dip is > 45 degrees. So this photograph which I was showing with a scarp like this under displacement of the fault like this. So this is a high angle hence we can classify this as a reverse fault. So in terms of the thrust fault you will have a lower angle that will be < 45 degrees. Now in this case of the both the cases like this one here.

There is a thrust and reverse fault are the result of compression tectonic environment whereas this one normal fault is extensional tectonic environment. This you will have to remember. And let me tell you as I was emphasizing that you need to be extremely careful while preparing your reports or the interpretation because you need to know that whether it is a normal fault or you are looking at the thrust of the reverse fault.

And which block has moved up and which block had moved down that would impact those parts or that information will be extremely useful and you have to do it critically.

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So if you look at this cartoon here what it shows. It shows that one block has moved this side another block is moving this side and that is taking place along this line here. This is typical of strike slip fault because this is the strike, this is the fault-plane here this one is the fault-plane. The fault-plane is almost vertical and the displacement which has been seen or observed is along the strike of the fault. So this is typical of strike slip faulting.

Now can we see this deformation or the manifestation on the surface that question we should ask ourselves the answer is yes. If the fault is active, then you will be able to pick up this on the surface.

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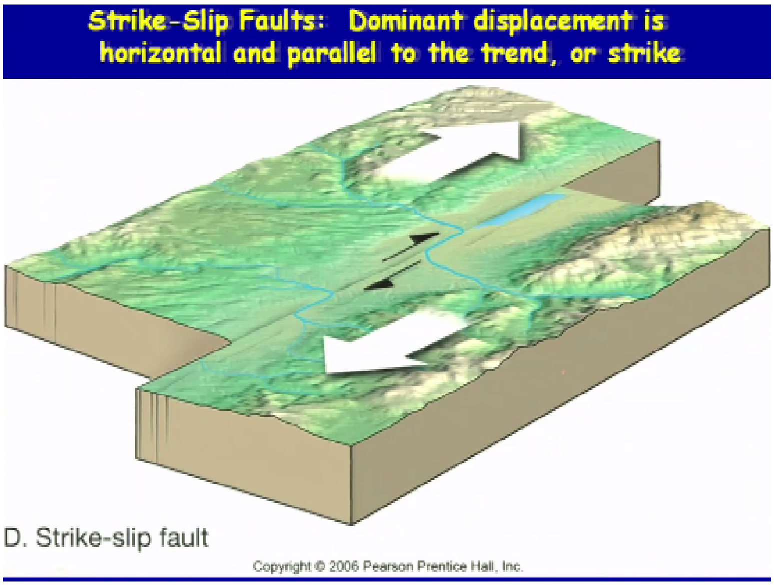

Now what are the features you should pick up or try to look at to identify or classify I would say the faults okay. Let us continue this in the next lecture. Thank you so much.