Earth Sciences for Civil Engineering
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Module 4
Lecture No 17
Seismology and the internal structure of the Earth (Part-5) & Geological structures (Part-1)

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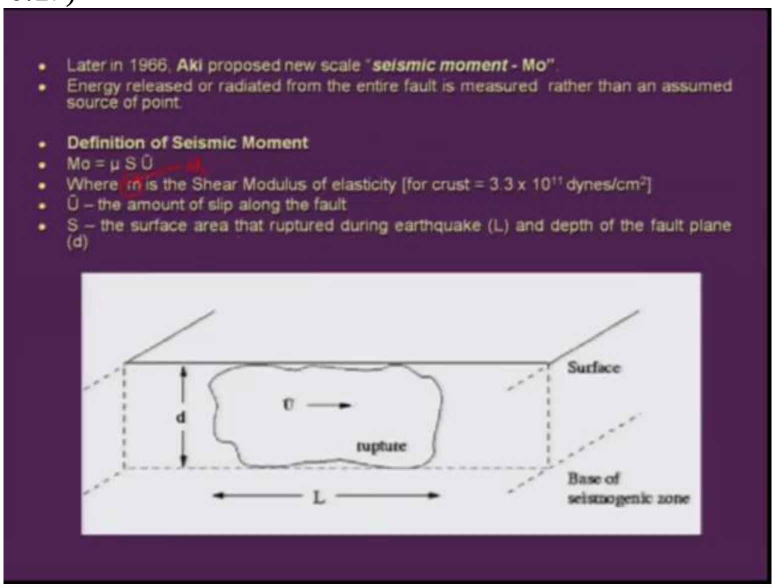

Welcome back. So in the last lecture we were talking about the different type of Scales whether it is an local magnitude scale, body wave magnitude or surface wave, now all had some limitations. So in 1966, as I was talking in the last lecture, Aki proposed a scale which was been termed as seismic moment . So it was necessary that the entire energy which is been radiated by the entire fault is measured rather than measuring the point source.

So here what they defined was that if you take the definition of the seismic moment, then it has been given as MO and myu S and this is the slip, amount of slip with this is myu this one. So this is you are having myu which is the shear modulus of elasticity. For the crushed around 3.3 into 10 raised to power 11 dynes per centimetre square and then we have the slip, there is a amount of slip which occurs during during an earthquake along the fault plane.

And then we have the surface area. Surface area during an earthquake, how much area was been affected or ruptured? So you have L here and the depth of the fault plane you are have. So this will give you the total about what was like total amount of rupture. Then the slip which has been taken. So based on that, MO is been calculated. And that helps in knowing the moment magnitude.

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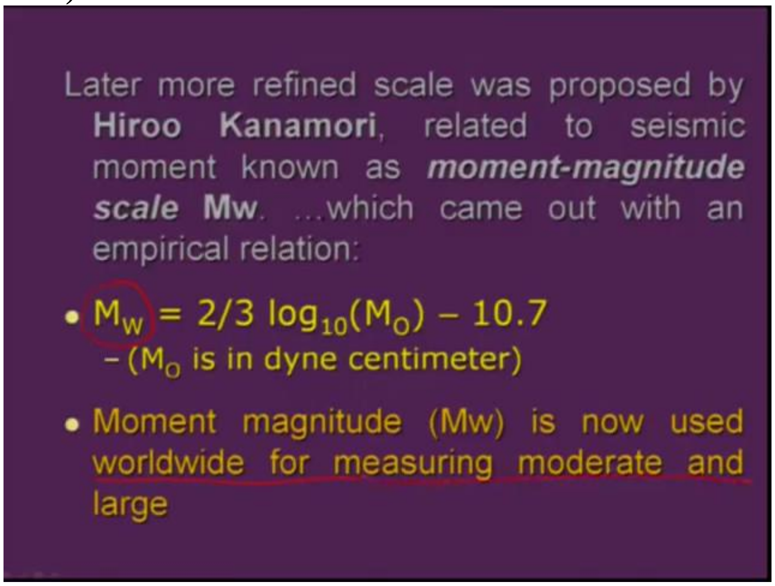

That was been proposed later with more refined skill which was been proposed by Kanamori and related to the seismic moment, known as moment magnitude. So MW is now the most used scale and again, there was an empirical relation which was been given. So when you when you have the MW, you you you put in this given equation which will give you the MO sorry. MO is been, you know the MO then you get the MW.

So the moment magnitude MW is now used worldwide for measuring the moderate to large magnitude earthquakes. So the previous stages which we were talking about had some limitations to measure the large magnitude earthquakes as well as the earthquakes which are occurring at greater distance. But this scale which take into consideration the energy which is radiated through the entire fault and it also includes the rupture area and the depth at which the earthquake has occurred.

So based on that, you can have the complete the magnitude which is termed as W. And this is you should remember that the this is the most appropriate skill which has been used worldwide for measuring moderate as well as large magnitude earthquakes.

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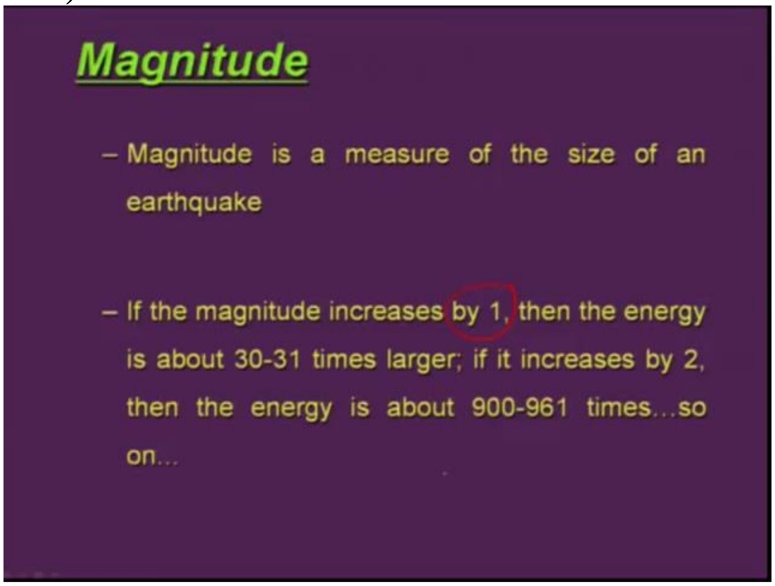

So in short what we look at is the magnitude is a measure of the size of an earthquake. And now this is important. Now if the magnitude increases by one, so you cannot just say that it may be the magnitude of 3 or 4 or you can say 7 or 8. There is a hell of a difference between 7 and 8 magnitude or even 7 and 7.5 magnitude or 8 to 8.5 magnitude.

So is the magnitude increases by one, then the energy is about 30 to so 30 to 31 times larger. So for example, if there is an increase by 2 then the energy 900 times which is more released more in the next scale like you are having.

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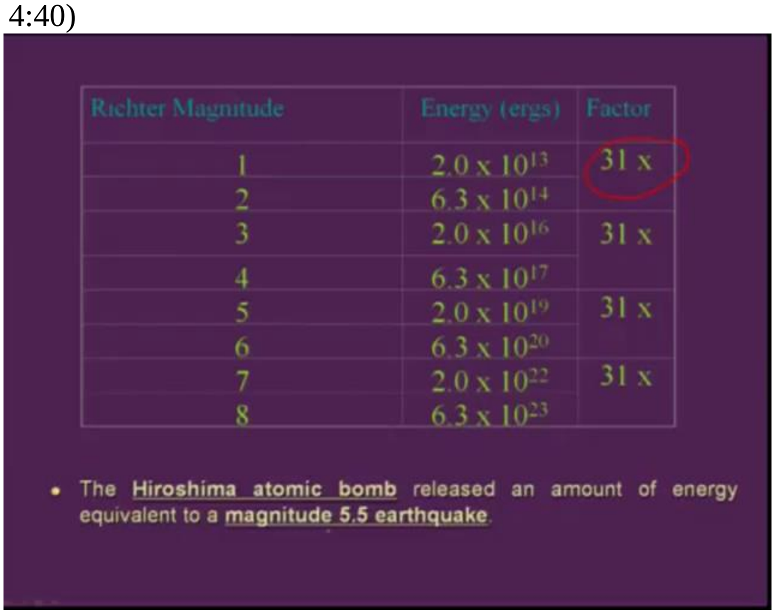

For example, here it has been given. So it is with the factor of almost 31. So next magnitude earthquake will be multiply by the factor of 31. So that will increase. So for example, so Hiroshima atomic bomb the energy amount of energy which was been released during that time was equivalent to magnitude 5.5.

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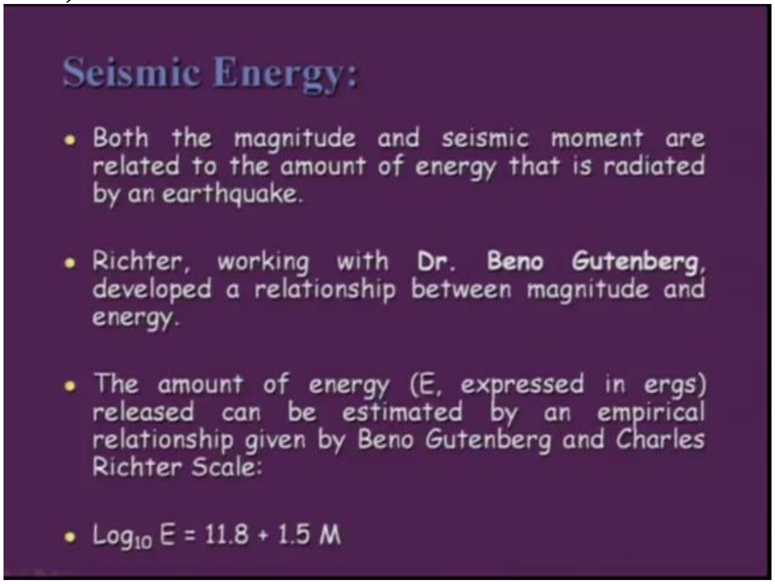

So the seismic energy, both the magnitude the seismic moment are related to the amount of energy that is been radiated by an earthquake. So the Richter working with Gutenberg so they gave gave a relationship which helped inmeasuring the energy also . So if you know the magnitude and you want to understand or know that how much energy was been released during an during a particular earthquake, then you can use this empirical relation relation which has been given.

So log E where these 2 are constant and set the magnitude here . So 11.8 plus 1.5 M. So if you have the magnitude say 3, then you will know that how much amount of energy is released. And similarly, you can do one exercise where you can have the magnitude 8. So you can look at that how much is the energy released and then you should say that fine, at magnitude 3, how much will be the energy released and how many 3 magnitude earthquakes will be required to compensate that 8 magnitude earthquake?

So likewise, few group of people, they say that ok fine that there are continuously small magnitude earthquakes or modern (medium) magnitude earthquakes which are occurring in

Himalaya or maybe in the seismically active regions. That means that the energy is continuously been released . But if you compare that amount of energy which is released during an 8 magnitude earthquake with 3, you will understand that how many 3 magnitude earthquakes will be required number of earthquakes you will require to compensate the energy of 8 magnitude earthquake.

So it will be you can you can do that and try to understand that what exactly is the difference between the 8 magnitude earthquake and the 3 magnitude events .

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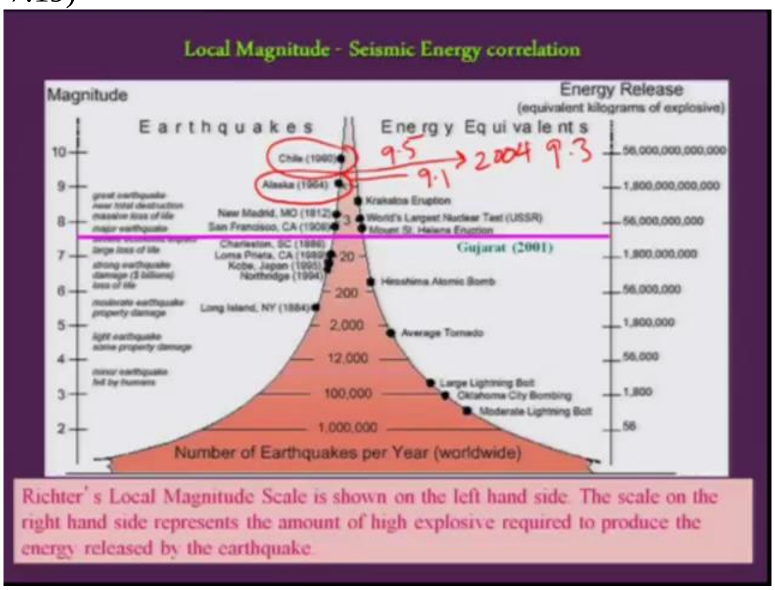

So this is an the chart which has been given which talks about that how much, what is the magnitude and the amount of energy released during an particular earthquake. So if you compare this one, this is the 2001 earthquake which occurred 7.6. So this was the energy which was been released. And we have much much larger energy which has been released here during the 1960 earthquake.

So this Alaskan was the 2nd largest. But now if you say this was 9.5 and the Alaskan was around 9.1 or so. But then if we believe that the 2004 was 9.3, then the this is Andaman Sumatra earthquake, then this becomes the 2nd largest here. So this was 2001 Bhuj earthquake. So this part, I end here and then we will start with the new one where we will be starting start talking about the geological structures.

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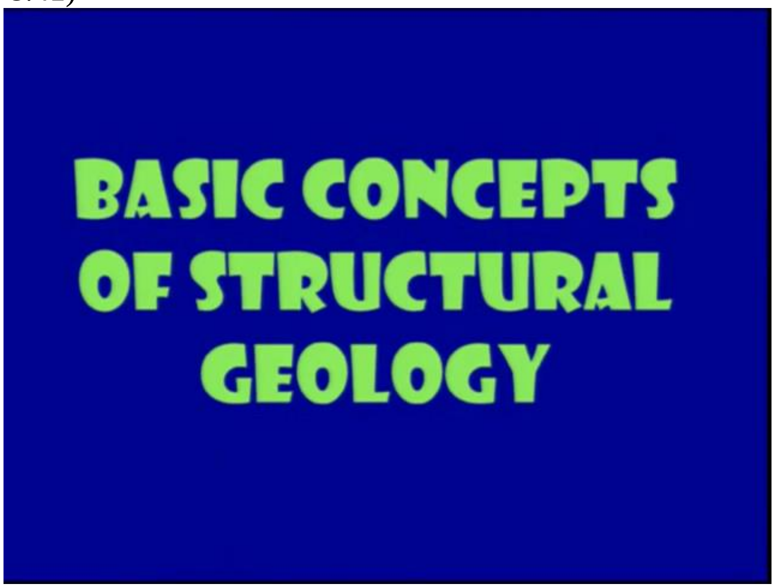

So I will start with that. So this is an another very important aspect of the geosciences which we all should know and if we are doing the mistakes and ignoring this part we are going to invite we are we will be inviting more of disaster. So this is what we call the structural geology.

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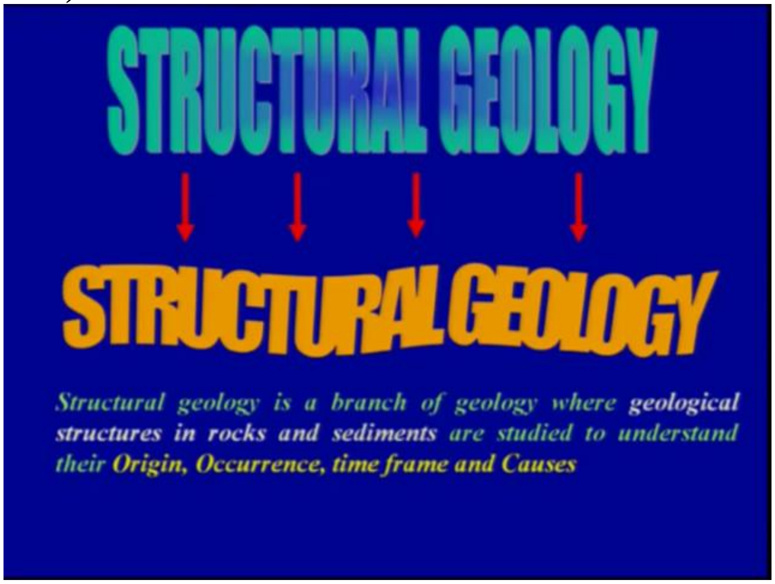

So basics of structural geology. What is structural geology? Is a branch of geology or Earth science where geological structures which are basically seen or found in rocks or within the sediment succession are studied to understand their origin, their occurrence and the timeframe and causes, how they were formed, where they were formed and where they ask. So this is what we call the branch of geology or Earth sciences known as structural geology.

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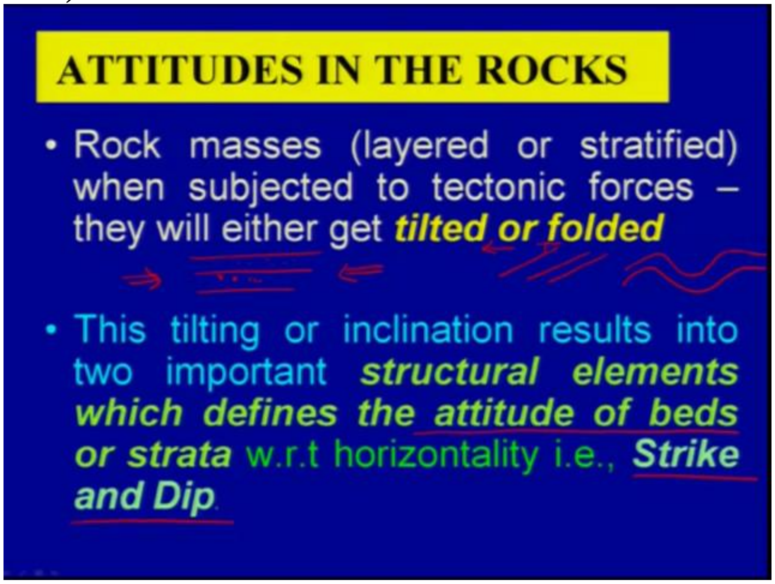

Now this is very much important where we need to talk about the attitudes of the rocks. So each rock or the sediment succession will have some attitude. What are these attitudes is mainly we deal with is that that when rocks are tilted or folded, when the rocks are tilted or folded, then we will be seeing this attitudes which are developed in the rocks.

So mainly it is related with the in which direction they are oriented, how much they are tilted, what is the amount of tilt, in which direction they are tilted, those are termed as the attitude. So rock masses or the layered or stratified when subjected to tectonic forces that is what we were talking about, the plate tectonics or the deformation, they will either tilt or will get folded.

So so either you will see that they are tilted. So you are having basically, all sediments will be developed deposited in horizontal fashion. So when these are been subjected to deformation by the tectonic forces, either they will be tilted or they will be folded. So when you say that they are tilted, so they have the direction in which they are folded or they are tilted. Again, they have the amount of that is the angle at which they are tilted. That is, all information we will we will talk in this lecture.

So this tilting all inclination results into two important structural elements and this is what we call the attitudes of the beds or attitudes of the stratas. So with, this will be with respect to horizontal we will be talking about. So we will be talking about with respect to horizontal plane. And they are termed as strike and dip. So what is strike? What is dip? We will see in the next slides.

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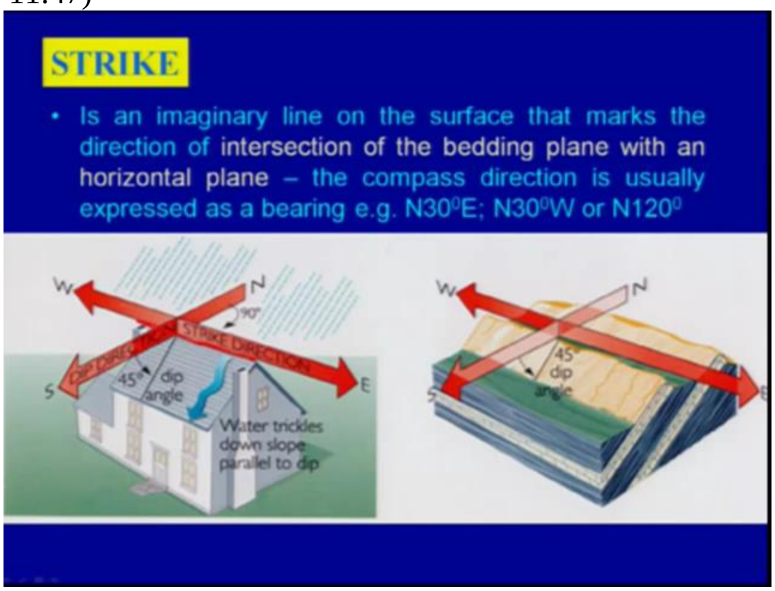

So strike. So let us imagine a hut, the top of the hut. And we are having here the 2, this is the line which is what we call the hinge line and then we are having the 2 sides of the roof which are tilted. And they are tilted in different directions. So one is tilted in this direction, another one is tilted in this direction. So they have some slope. And that is an angle which we will be will be talking about.

So the strike what we call is an imaginary line on the surface that marks the direction of intersection of the bedding plane with an horizontal plane. So you are having the horizontal plane. So suppose we are having an horizontal plane here and or or you can say that fine, we have some beds which are tilted. So inclined beds are there and then we are having so beds are tilted like this and then we have the horizontal plane.

So this is this line will be your strike actually. Or with my my hands I can show. Suppose the beds are tilted like this. These are the horizontal ones, these are tilted. And with respect to the horizontal line, the intersection of this plane, horizontal plane and the inclined one is your strike. So this direction is your strike direction. So here, it has been explained if you carefully look at, you can see.

So this is the intersection of the inclined plane and the horizontal plane. So this line which has been imaginary line, we have, we consider is your strike direction. And in perpendicular, exactly perpendicular to that is your dip direction. So this is your dip direction here. So if you look at this one, so this is your strike, this is your inclined plane, this is your strike and this my thumb here is your dip direction.

And this angle is your amount of dip, that this and amount is an amount of that is an that how much is the inclination of your beds. Either it is shallowly tilted or they are almost vertically tilted. So this is extremely important when we are putting any structure or the civil structure in the area which are affected by the tectonic movements. And innature you will find most of the places they are they are having inclined beds.

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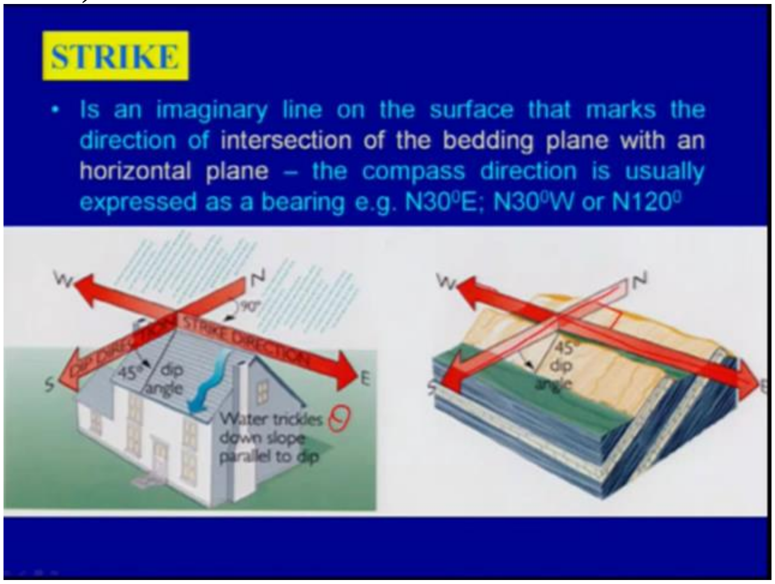

Now the 2nd figure if you look at, we have the beds which are inclined here. And and with respect to what we have discussed in this slide here, this figure here, this is your imaginary line which has been at the contact of the inclined plane and the horizontal plane. So that will be your strike direction and the exactly perpendicular to this, you are having this is your dip direction. So so this is an imaginary line, you have plane here.

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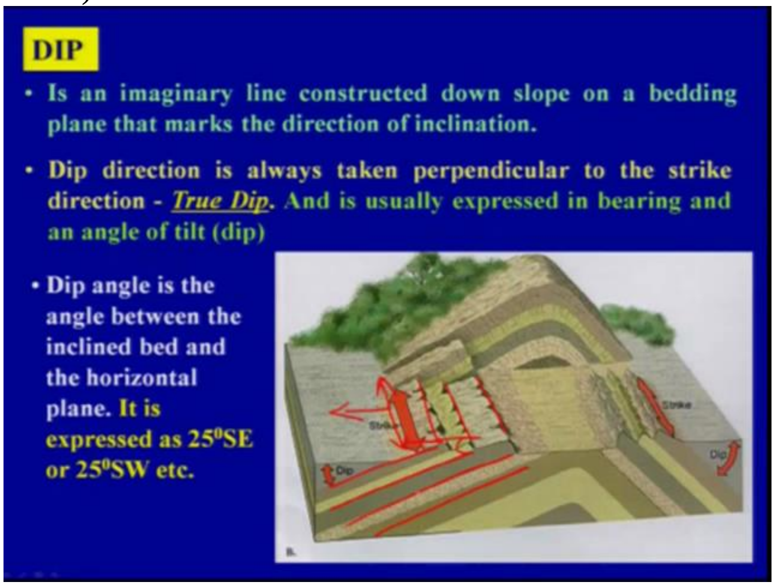

Then now we will look at the dip . Again is an imaginary line constructed downslope on a bedding plane that marks the direction of inclination. Now the dip direction is always taken perpendicular to the strike which is termed as true dip and is usually expressed in bearing and angle of tilt. That is the amount of dip. So it is expressed as like for example, 25 degrees South East.

So 25 degree is your so this 25 degree is your amount of dip. So if you are having this, so this is your amount of dip, 25 degrees. And this is what you think the next is your direction. Either it is South East or Southwest. So when you will put this information on the map, you will write 25 degrees South West for whatever it is.

If it is South East, you can write that. So it has been expressed in that way. Whereas the strike straightaway you can say the strike is either north 25 degrees East. So with respect to North, you will be talking in terms of the strike. So in the horizontal plane, you are talking that what is the direction of your beds and all that, in which direction they are striking.

So unless and until you are having horizontal beds, then no strike. It is difficult to measure the strike and all that. So this is what has been shown here. So if you are having the outcrop suppose which is exposed which shows the inclination so you are having the inclined beds here. So these are the inclined beds which are been seen. On the surface you are having this exposure here.

And so you know that this is the direction of your inclination. This will be your strike. So this will be your strike direction. And then this will be the and the angle which you will measure with respect to the horizontal, that will be your amount of dip.

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Now here, this is an example from Himalayas where the beds are dipping away from the this grain. Again here, so if you just come across such type of beds, so you can see that the beds are dipping like these are the bedding planes. So this will be your, this will be your strike.

Your strike will be too away from us and then inclination will be in this direction. So this is your dip direction. So you can say that this is your strike direction.

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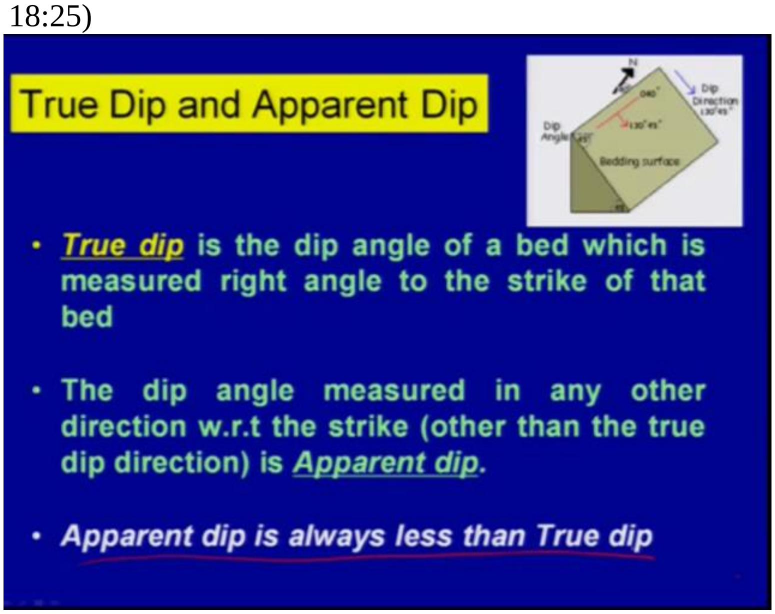

So true dip and apparent dip, these are again in nature it is difficult or if when you are moving in the field and trying to measure the dip, you may not always come across the that you are measuring the true dip. You end up measuring the apparent dip most of the time. So one exercise we will do where you will be given the true dips, sorry the apparent dips and based on the apparent dips, you will calculate the true dips.

So true dip is the dip of a bed which are measured right angle to the strik. This is what the true dip is ok. And the dip angle measured in any other direction with respect to the strike other than the true dip are all termed as apparent dips. So if you are having for example it has been given here or maybe we can say that fine, this is your strike.

So if you are and this is your plane here, the horizontal plane, so if you are measuring maybe I am not good right now but I can try. So suppose you have the inclined plane like this. So which are dipping in this direction if you are measuring, this is your strike here. This is your strike and if you are measuring exactly perpendicular, then that is no problem.

But if you are measuring in this direction or in this direction, then you are coming up with the apparent dip here. This is your true dip and this will be your apparent dip here. And this is what you are having is the strike. And one more thing which is important, you should remember is the apparent dip is always less than the true dip. So this you should remember that the apparent dip is always less than the true dip.

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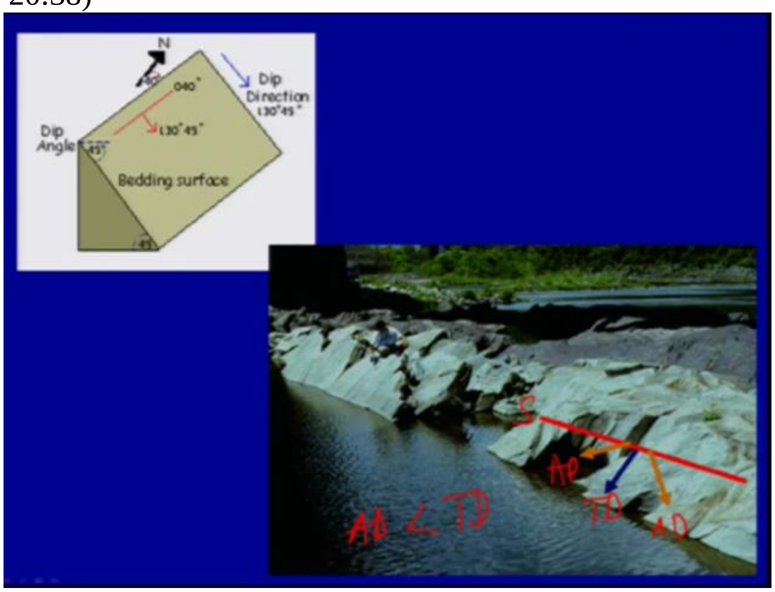

They are shown here. So if you are having the inclined bed like this, so this is your strike and then this if you measure is your true dip but if you measure in any other angle with respect to the strike, then you are measuring the apparent dip. So this will be your apparent dip, this is your true dip.

This is apparent dip and this is your strike. And we have what we discussed was the apparent dip is less than the true dip. So this you should remember this part, this one that the apparent dip is less than the true dip.

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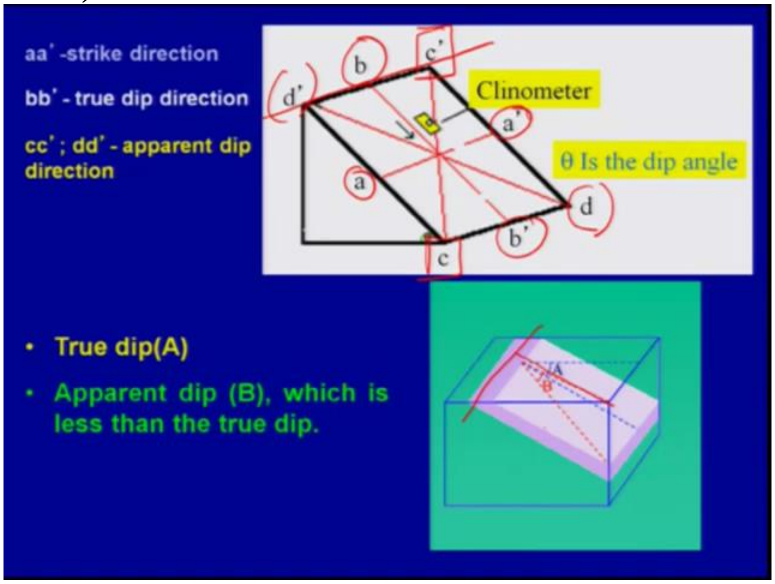

This is again the same, to explain the same part. So you are having this A A dash is your strike direction which is equivalent to here, the same. And then we are having B B dash in this one which is the true dip and C C dash. We are having C C dash. And then you are having the D D dash. So if you are having this, these are all apparent dips.

So further, another example which has been shown here, so you are having the inclined beds here. This is your strike and if you are measuring the amount of dip along this A, then you are measuring the true dip. But if you are mentioning here, along this angle, along this one, B then you are measuring the apparent dip.

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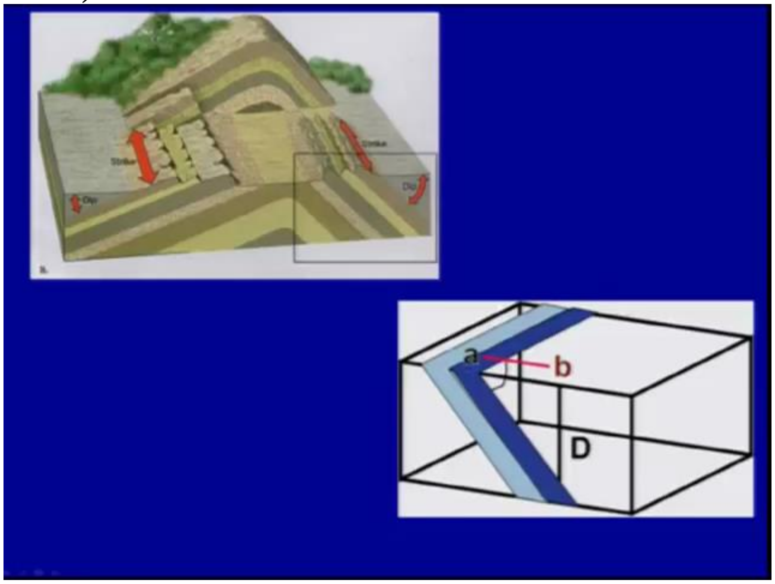

Now this is another important part which is you can use a very simple trigonometry and know the inclination of the bed that is the angle of the bed, then you can easily calculate the dip at which at particular point suppose you want to know the dip of this bed that is A at this point or the blue bed at this particular point and you know the angle. So you can easily make out that because you know the angle and all that.

So with an simple trigonometry relationship, you can calculate the D which is equal to AB Tan Theta or Tan alpha. And this will be the thickness of the bed that is calculated perpendicular to the bedding planes. These are the bedding planes here you are having. So you can do a lot know the altitudes of the rocks. One is the strike. Then another is the amount of dip and the dip direction.

So if you know all this then you can make out and you can like a lot of formation of the at the what depth the you will encounter the bed and what will be the thickness of the bed and all that. Now as I told that in nature, we will not come across exactly at what like what is the angle which we are measuring?

Either it is apparent dip we are looking at or we are looking at the true dip. Or we are we are looking at the phase which is slightly inclined with respect to the strike or it is exactly perpendicular to the strike.

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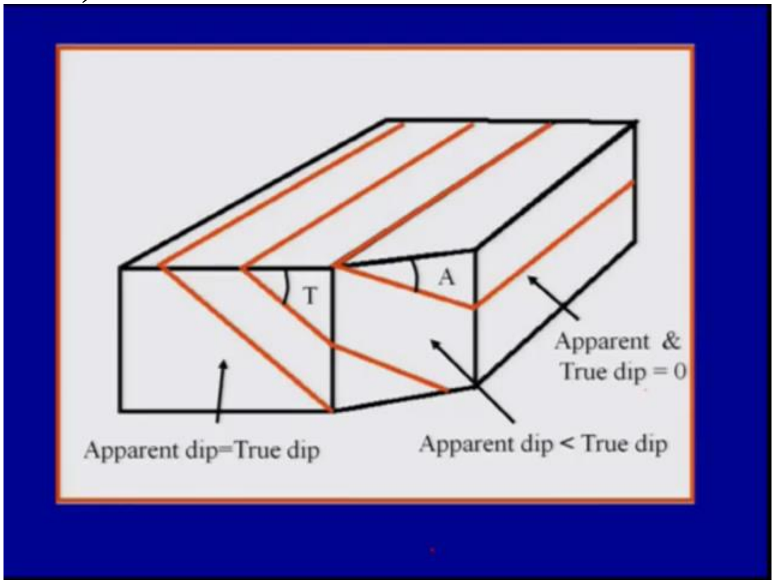

So this is one example which has been given here. So if you are having exactly like this phase, then the apparent dip here in this one will be almost equal to the true dip because you are measuring in perpendicular. Whereas if you are having slightly inclined phase of the inclined beds with respect to the slide then here apparent dip is greater than sorry less than the true dips here.

And at this location, what you will find is the apparent dip is almost 0 because it is horizontal. So you can do this experiment or maybe you can have the inclined beds and try to cut. So if you are having very much parallel to the strike, then you will not be able to see any amount of dip though the beds are inclined.

So what in short is the importance here that when you are doing the survey and trying to note down whether it is an the true dip you are measuring or you are measuring the apparent dip, you you should look at more exposed faces of the exposure and have as much readings you can to nullify whether looking at any horizontal beds or you are actually looking at the inclined beds. So it depends on what face you are looking in the field which is extremely important in talking about the attitudes of the beds.

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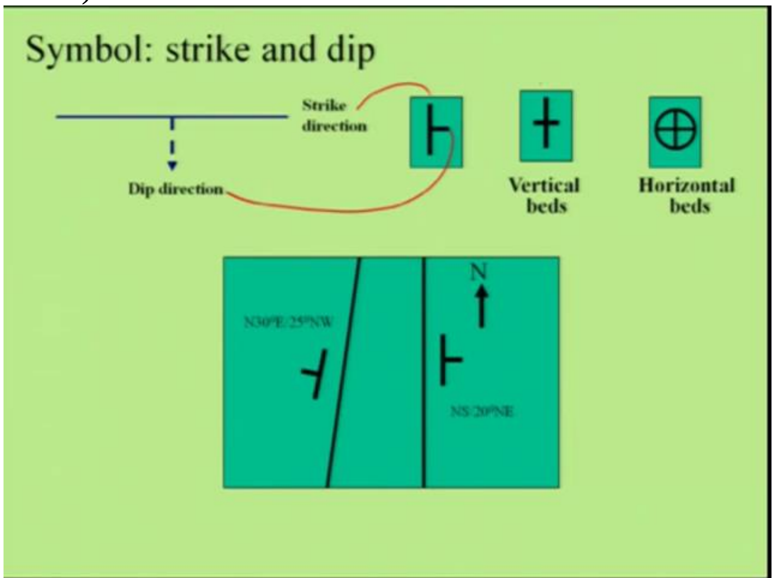

These is the symbols which is being used which you will find in most of the geological maps with only show the one bigger horizontal line and then you are having exactly perpendicular to smaller one. So this one is your strike direction and this one is your dip direction. So considering that the beds are dipping and we are looking at the true dip.

Now suppose there are 2 lines, this is the plan view which has been given here which are representing, these 2 lines is representing the bed subsurface. So you have not here and then you have, this is the dip, the strike of the bed here. And then you are showing the dip here. Where as this one is having slightly different direction. So if you look with respect to North, then this is almost North Northeast South Southwest we are having.

So we have so this bed is having the strike North-South and we are having 20 degrees north east. So the inclination is 20 degrees north east. Then another one is having north 30 degree east because there are slight angle between this one. So this is if you take north here, if this is North, there is slight angle which is being seen here.

So this is you are having the North 30 degree East. It is been the strike is different here and then the amount is again 25 degree Southwest. So this is indicating the strike direction and this is what your amount of dip and this one is your the direction of dip. So you can you can easily make out that this is what the 2 beds which are inclined in different directions.

So if you are having like vertical beds than this is the way it will be represented on the map. So it will have no dip direction. So they are they are almost vertical beds. Still they are having the strike. And this you are having horizontal beds. So there is no strike, no inclination is being seen.

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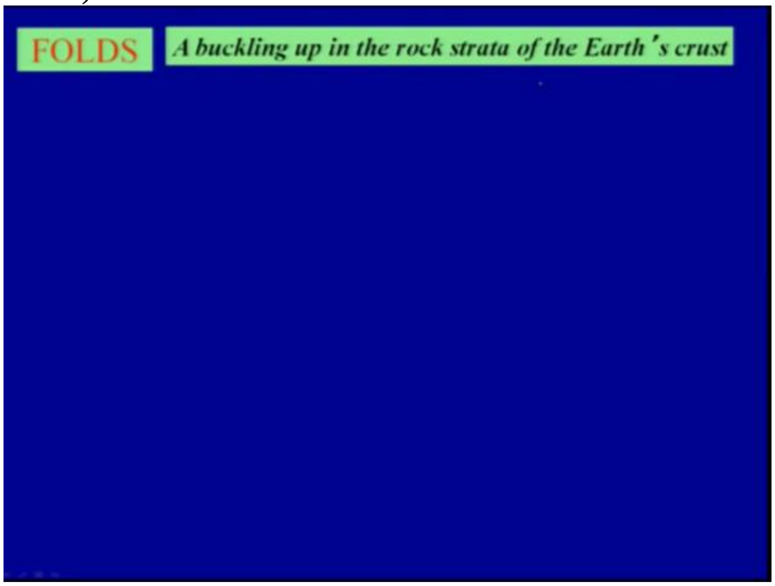

Now another aspect of the structural geology which is again very important and in most of the regions you will find this type of folded rocks. So one, we were talking about the attitudes that is the inclined beds and all that. Now this one is we are talking about the folds which are defined as a buckling up in the rock strata of the earth's crust

So hopefully we can be can do what that we will start this part in the next lecture and we will try to finish the structural geology part in that. Thank you very much.