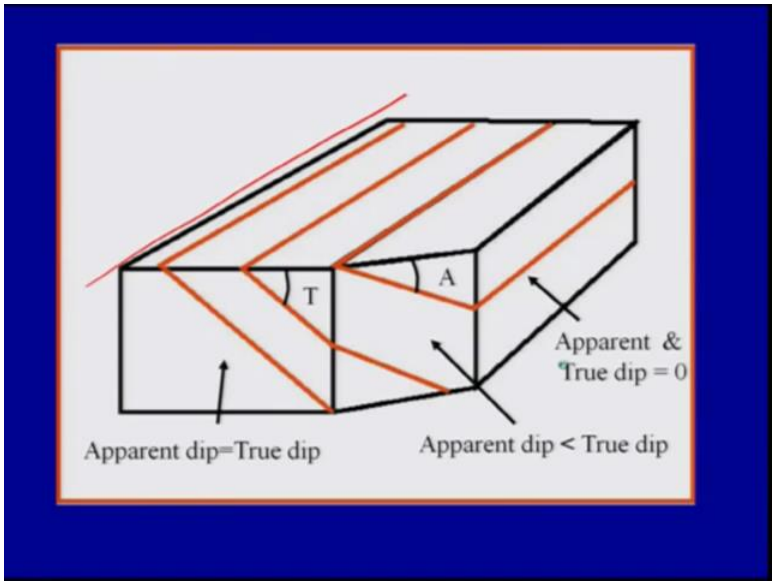
Earth Sciences for Civil Engineering
Professor Javed N Malik
Department of Earth Sciences
Indian Institute of Technology Kanpur
Module 4
Lecture No 18
Geological structures (Part-2)

Hello everybody, welcome back. So yesterday we started a new topic and talked about the attitudes of rocks.

(Refer Slide Time: 0:37)

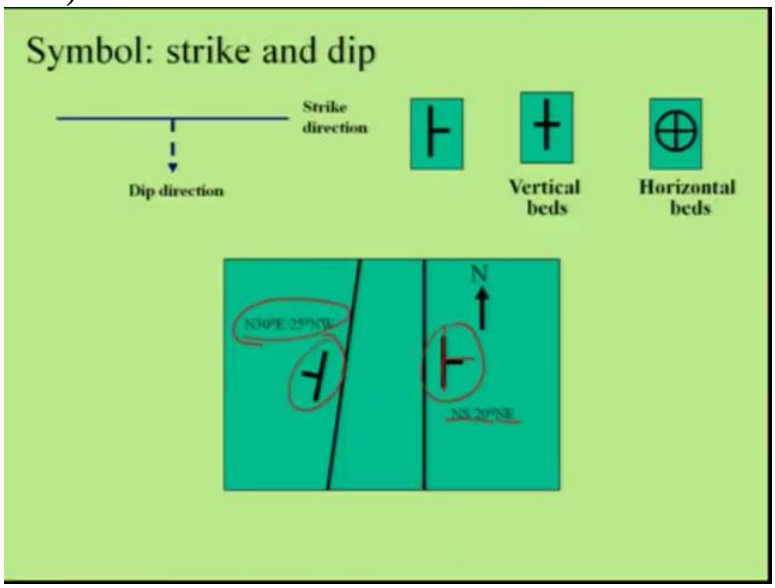


So I will start with this slide where we were talking about the importance of the face which we look at, that is the outcrop in the field. So if you come across any incline or dipping status or the beds, it is extremely important to know and understand that which face you are looking at because that will depend on that whether you are looking at or measuring the true dip or you are measuring the apparent dip., that is extremely important.

So here is an example which shows this is if you are measuring exactly perpendicular to the direction of the strike, because this will be your strike here that will give you the true dip. So here, apparent dip and true dips are almost same. But if you are having slightly oblique face which were looking at with respect to the inclined beds or the strike, then you are having your having the apparent dip which is less than the true dip.

And then if you are looking almost parallel to the dipping surfaces, then you will have horizontal players. You will not see any that you will not be able to see any inclined layers. So here the apparent dip is almost 0 and even the true dip is 0 because you will not be able to measure anything.

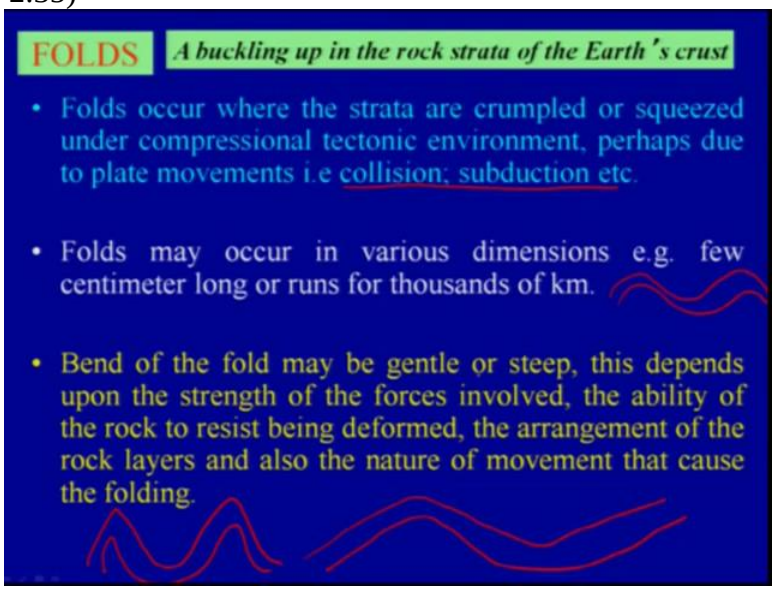
(Refer Slide Time: 1:49)



Next what we took was that we talked about the decide can dip symbols and then we talked about the there is an representation of the plan view of any beds. So on geological maps, you will see such type of symbols which indicates the strike, this indicates the strike and this is your dip direction.

So and it will be given in form like the 1st is the strike and the 2nd is the angle of amount of dip and the direction of dip you will be given. And similarly which has been given here also for this bed. And then we what is the symbol for the vertical beds and what is the horizontal beds has been given here.

(Refer Slide Time: 2:35)



So we will move to the next part of this topic and what we call the folds. So we look at the different type of folds and the different parts of folds mainly and how we classify the folds because in nature if you look at, we will see most of the crust is folded if it is under defamation. So the buckling up of in our rock strata of the earth's crust will result into the formation of folds.

And best example if you see what we call the folded Himalayan chain. So Himalaya is all folded sa layers we see in the Himalayas. They are all mega folds. But we will see how we classify the folds. So folds occur where the stratas are crumpled or squeezed under compressional tectonic environment perhaps due to the plate motion. That is either we call, we see most of the time, the fold formations in the collision zone and the subduction zone. Folds may occur in various dimensions.

Example-either they are very tiny, centimetres long or they run for almost 1000 km. So this we are talking about the wavelengths. So how large will be the folded beds. So this is one part. Then, the bends or fold may be gentle or steep. So either you will see they are very gently folded or you see they are very steeply. So like something like this.

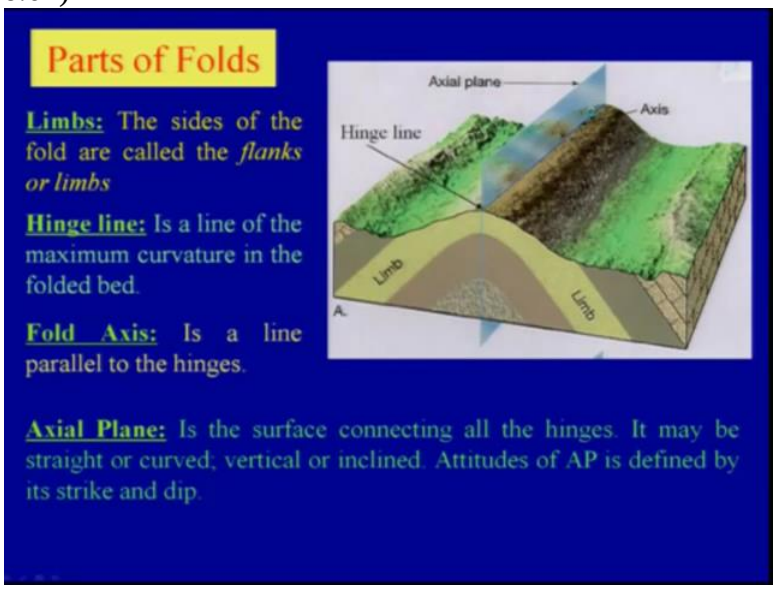
We are having very steep folds. So the beds of the folds maybe gentle or steep. This depends on the again the strength forces involved. So how much compression has taken place? Whether the rock layers or the maybe we can say the stratas were subjected to these type of forces or

deformation for longer periods. So they will they have undergone that sort of an long deformation larger period as compared to the other.

So if you are having less deformation then you may come across a very gently slipping beds but your having more deformation than you will have the crumpled. And even sometimes this is overdone. So this is what we call the overdone force also. So one is the strength of the forces which is involved that will result into the steepening or gentle force. And then the ability of the rocks to resist the deformation.

Sometimes the rocks are not rock layers are not enough to like they are not having more strength to to resist this deformation. And they will deform very fast. And that 3rd one is the arrangement of the rock layers. And also the nature of the movement that causes the folding. So whether the lock rock layers are all competent or you are having the competent in competent beds. That will also depend on the all will result into the gentling or the steepening of the folds.

(Refer Slide Time: 6:04)



e

So now moving ahead with the parts of the folds. So we have several what they classify as Limb of the fold. Then we will say that what is the axial plane of the fold. What is the hinge line and what is the axis of the fold and all that? So limbs what we see here this is the 2 limb of the fold. So one is here and the other is here. So either the left limb or right limb.

So limb of the fold are called flanks or the limbs or the sides of the folds are called flanks or the limbs. Hinge line is the is a line of maximum curvature in the folded beds. So you are having the

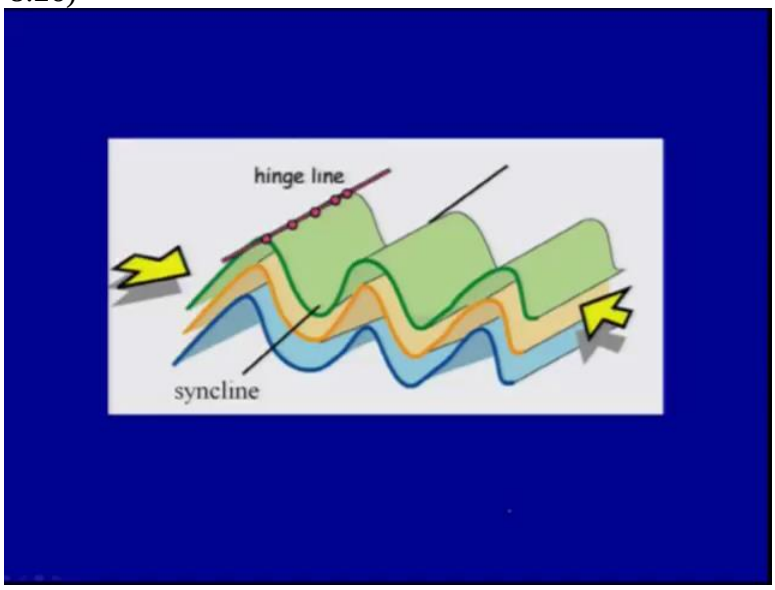
maximum curvature over here. So that will be your hinge point and if you join multiple hinge points and you connect the line that is your hinge line actually. And then you have more is the fold axis.

So along which the folding will occur. that is the axis. The axis maybe vertical, maybe inclined also. So that depends upon what type of folding it is taking place and what are the forces which are acting on it. Then we have the axial plane and here this surface usually connect are the plane which is connecting all the hinges. So for this outer fold curvature you are having this hinge point.

And then you are having more hinge also. If those are connected uneven which are occurring over here along the axis then that plane which is been is again an imaginary plane and that plane is termed as the axial plane. And axial plane again could be straight, curved, vertical or inclined. And the attitude of the axial plane is defined as defined by its strike and dip again.

So whenever you are having the inclined beds as well as the inclined your axial plane, that will also help in classifying the different type of folds. So let us move ahead and see what are the different type of folds we have.

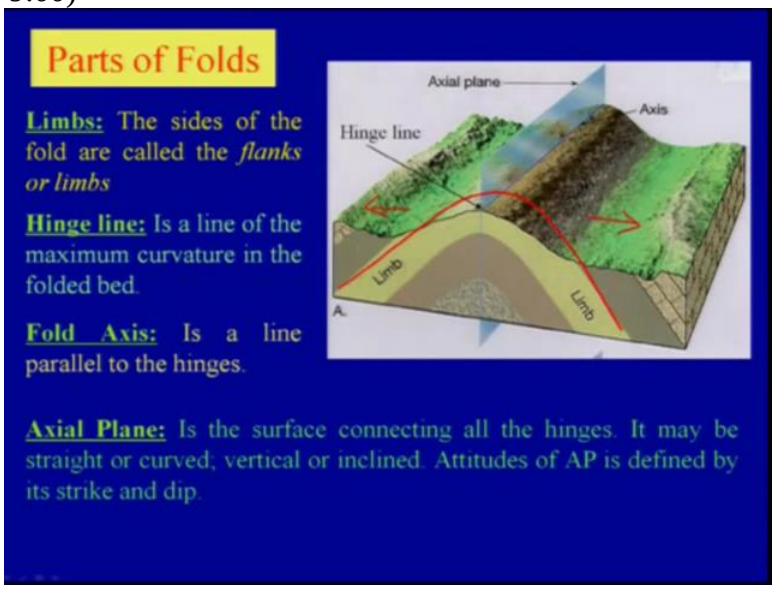
(Refer Slide Time: 8:26)



So this is an what I was talking about, that maximum point of maximum curvature you are having all along this and if you join this then you will have that is the hinge point. Now if

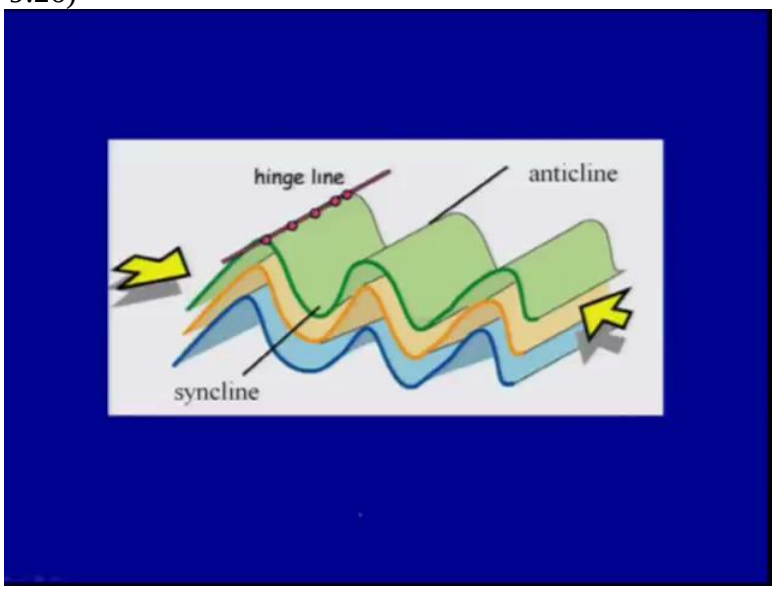
suppose you are having the fold the upper surface is curved a little bit. Then you may have this is the average you can take and then that will be your hinge line here.

(Refer Slide Time: 9:00)



So the previous one which we were looking at, this slide. So where we are having the limbs, if you take this limb here, one is dipping in this direction, another is dipping in this direction. So if we have a fold limbs are dipping away from each other, then we will term that as an anticlimb.

(Refer Slide Time: 9:26)



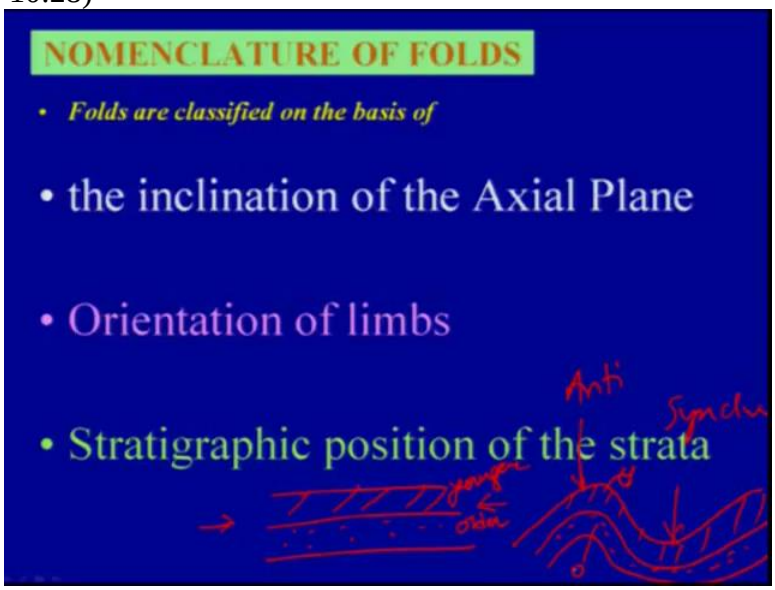
And then which are dipping towards each other, so if you take this one here, so they are something like this. So you are having this is dipping in this direction and this one is dipping in

this direction whereas in the anti-climb, you are having the dip direction is this one here and they are dipping opposite to…

Ok. So this will be your sync line. So this is your sync line and this will be your anti-climb. So these are anti-climbs and these are sync lines. And mostly in nature you will find that both will be together. So you will find you will look at the anti-climbs and the sync lines are both associated together. So in Himalayas, if you have to look at, you will find the anti-climbs and sync lines.

That what we call anticlinal and synclinal valleys. Synclinal valleys basically. So anticline, these are the anticlines and these are the sync lines you are having.

(Refer Slide Time: 10:28)



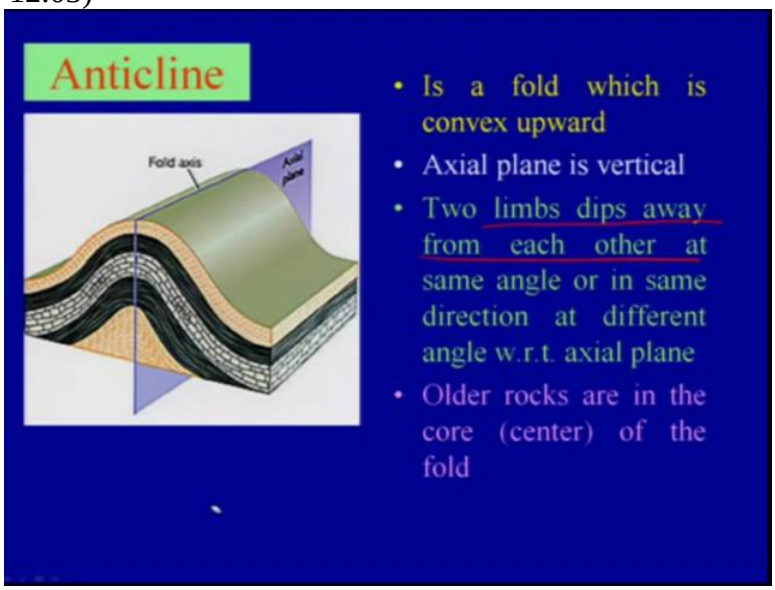
So nomenclature for the folds if you take, folds are classified on the basis of one, the inclination of the axial plane which is also important and the orientation of the limbs. So based on this, we will be doing the classification mainly. And of course, the stratigraphic position of the strata which is very important. Because initially if you look at, all the layers will be deposited horizontally.

So we are having all the layers which are deposited horizontally and when they are subjected to forces, then we are having the folds which are coming up. So these are the folds which we see which will be developed. So we are having this layer here and then we are having this one here. So this is your what we see anticline and then we are having this one is the syncline.

So this is what we will see. So one, the classification you have to remember this that it depends on the inclination of the axial plane. Then the orientation of limb. And of course, the stratigraphic position. Now here, the stratigraphic position if you take or the this is that thumb rule that the layer which is which was been deposited 1st in the in the stratigraphic order, so this will be older and the capping one will be younger.

So this here what we see is this one is younger and this one is older we are having. So this you have to keep in mind.

(Refer Slide Time: 12:03)



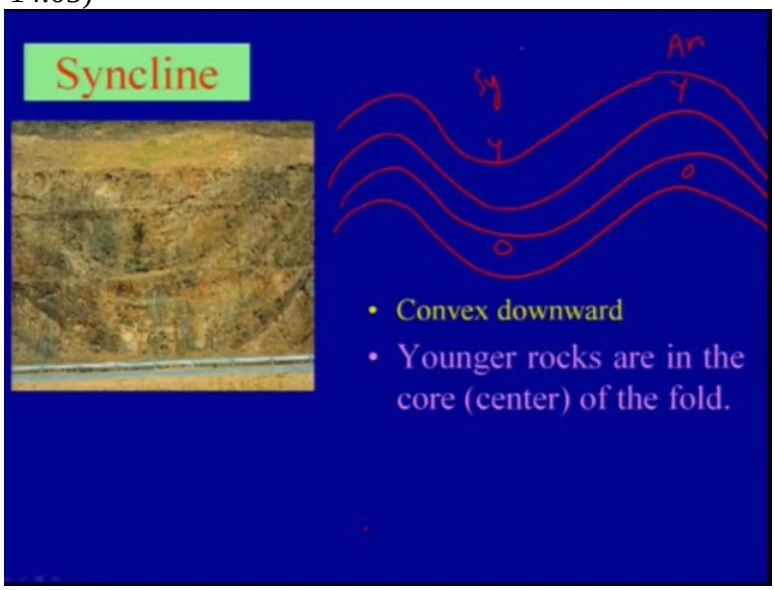
So coming to the next one that is the anticline. So what we have is that the which has the fold is convex upward. It is convex upward. We are having the boundary here, the convex upward. And then, axial plane is vertical. So will come to later on that about the we will talk about the axial plane inclined and all that. But right now, the simple and symmetric fold if you want to talk about then we see that the fold axis or the axial plane is almost vertical.

So 2 limbs dip away in this one, away from each other. That is an what we call as an anticline. And then if you are talking about the symmetry, symmetrical fold, then the angle between this. That is the angle which we are taking about and this is there and then this is the angle here. If we take this has to be almost same. Then we can say that they are all symmetrical anticlines.

So with respect to the axial plane. Older rocks are in the core or the centre of the fold. So we if you look at here then what we are able to see as I was talking in the previous slide that we are having the all beds are deposited in horizontal fashion. So here if you look at, this one is older and then in top this this one is younger. So in the core, we are having so this is termed as core. So core, we are having the older rock that is in the centre.

Whereas in the at the top we are having the younger rock. So this is one typical characteristic of the anticline that in the core you will have an older rock and in the top you will have the younger rocks.

(Refer Slide Time: 14:05)

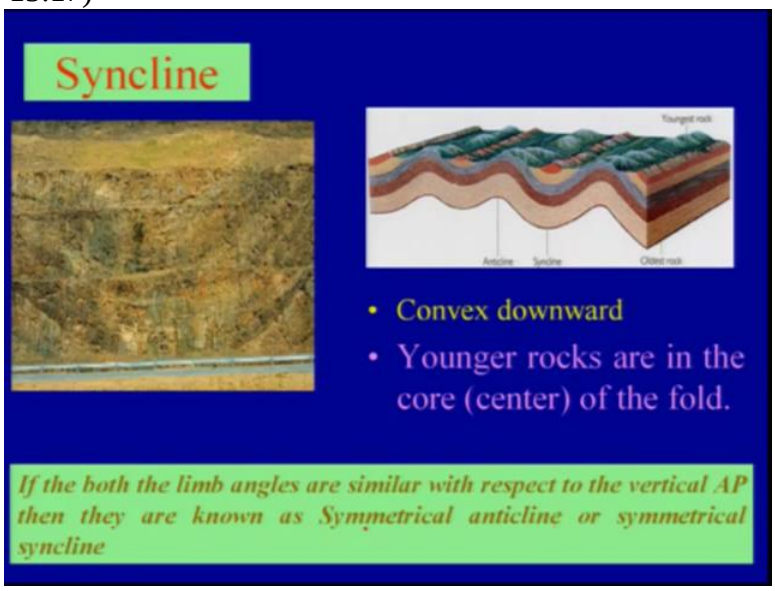


Then moving to next one that is syncline again. This is an field photograph of syncline. So you can see that they are convex downward. That was convex upward. This is convex downward. And the younger rocks will be at the core, at the Centre. So if you draw a a section here like we are having anticline and syncline then you have so you have this different layers which are been folded.

So you have an older layer here. Then you are having the younger one. Whereas here you are having the younger one and then here you are having the older one (inaudible 14:41). So you have that sequence. So this is convex downward, this is convex upward. So this is your anticline and this is your syncline.

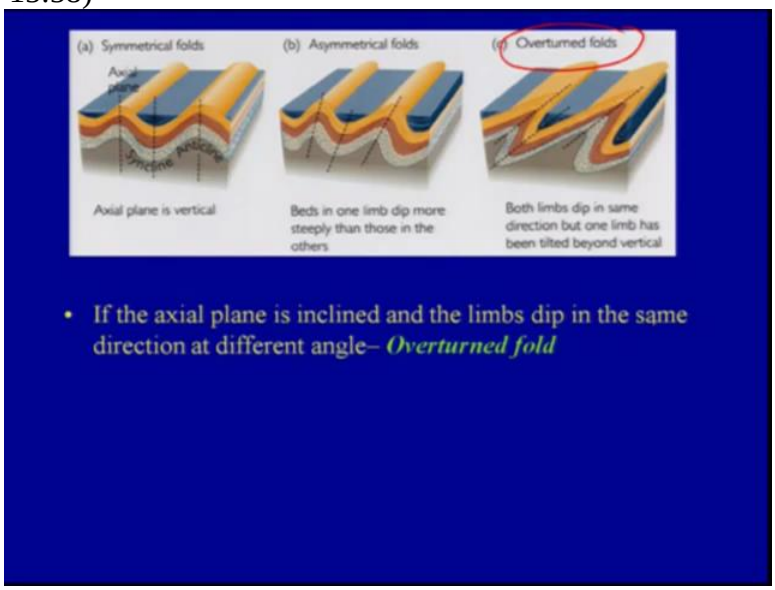
You have these 2 important points you should note down. Again, this is important that what we were talking about that here, the dips are towards each other. They are dipping towards each other.

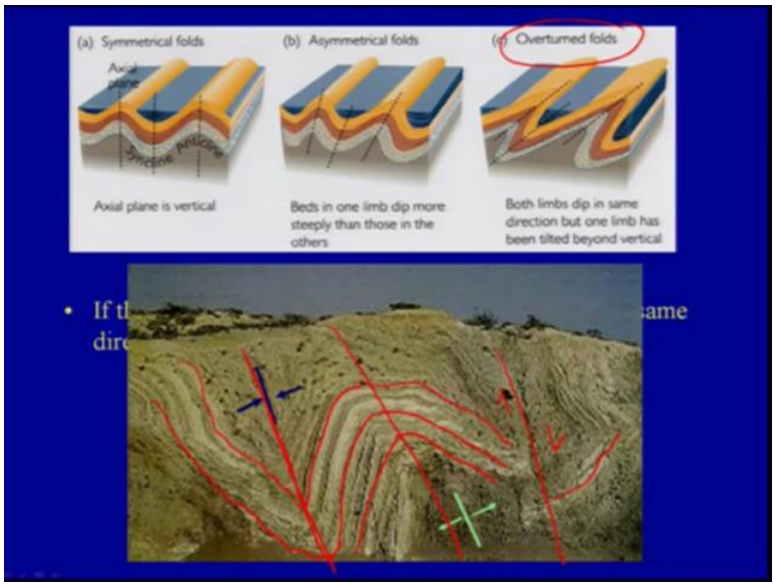
(Refer Slide Time: 15:17)



So now if you look at the overall features, then what we have the anticlines and the synclines together. So older and younger rocks as we were talking about. So we will have the older rocks in the core here and the younger at the top whereas in the syncline, younger will be in the core and so (())(15:43) the Centre. So if both the lame angles are similar with respect to the vertical plane then they are known as symmetrical anticlines or syncline or symmetrical syncline.

(Refer Slide Time: 15:58)





But if you are having the axial planes are inclined then they are termed as a symmetrical folds and further inclination is been seen or both the limbs dip in the same direction. Now here in terms of the asymmetrical folds beds in one limb dip more as compared to the another one. Then steeply. So they are dipping, one limb is dipping most deeply than those of the others. Then we say they are asymmetrical folds because the angle of the limb is not same.

Whereas here in the symmetrical fold, we have the angle is almost same and they are dipping away from each other. And here on overturn, as mode formations goes on then you have both the limbs dip in the same direction but one limb has been tilted beyond vertical. So then we term that

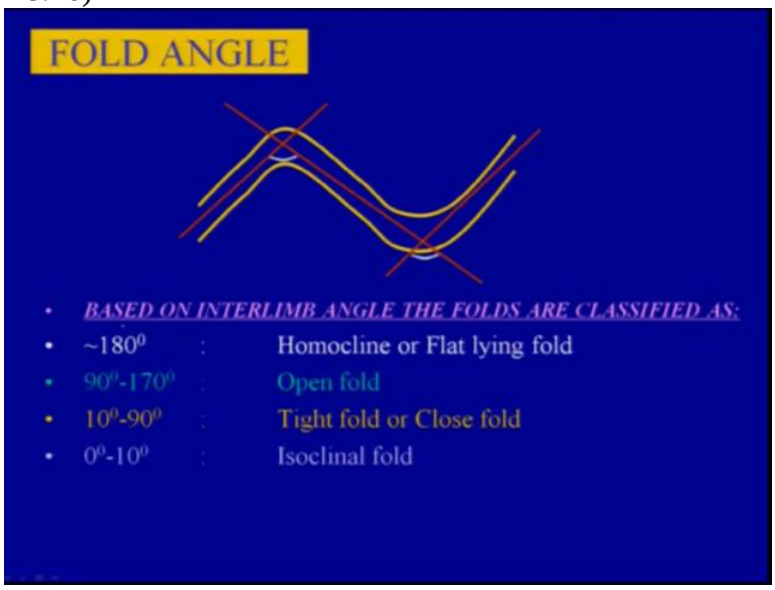
as an overturned folds. So this you can you can remember. So if the axial plane is inclined and the limbs dip in same direction at different angle, that we term that is an overturned the fold.

So here if you look at this field photograph, you will find that there is an the limbs which are here, so this is your axial plane and then this goes like this. So this is your anticline and then if I am carefully putting this lines here and tracing the bed, then you are having something which is not continuing on this side.

It goes something like this but here it does not continue. But here you can easily trace out all this beds. So this side your anticline they are dipping away here. And so this will be your axial plane. And here this one is your axial plane here. Further though I can trace this part here which connects like this and then this one goes like this.

So this is your syncline, this is your anticline, they are dipping towards one another, away from one another and somewhere here probably there is some some anomalies where is the what we call there is a displacement and the layers have been broken and moved down.

(Refer Slide Time: 18:16)



Now fold angles if you take so if you are having around 80 degrees, so interlimb angle what we call so then we term that as a flat almost flat folds or Homoclines. Then we are having 90 to 170. Then we term that as an open fold. 10 to 90 degree, tight folds or close folds. Then 0 to 10

degree, isoclinal folds. So this is the interlimb angle what we can measure. So based on this you can classify whether it is an open fold or it is tight fold.

(Refer Slide Time: 18:46)

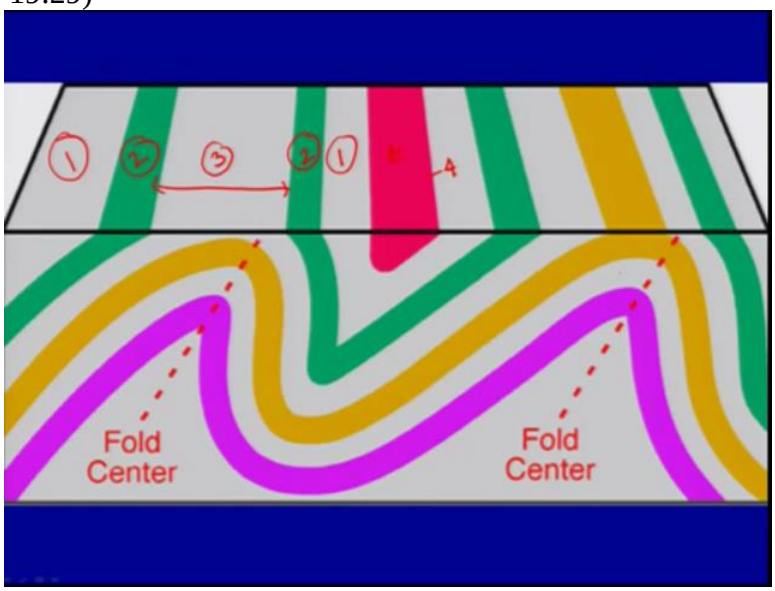
Here is an another example where we see this syncline which shows the axial plane here or the fold axis. And then you are having the 2 beds which are dipping towards one another. This is a syncline. And you are having the younger one here. So if you can classify, this is the West and East limb.

So you can talk about that what type of fold it is. So this is axial plane here, fold axis. So along this it will keep on folding.

(Refer Slide Time: 19:17)

This is another example which shows the syncline over here. So we have an beautiful one. So this will be your fold axis your.

(Refer Slide Time: 19:29)



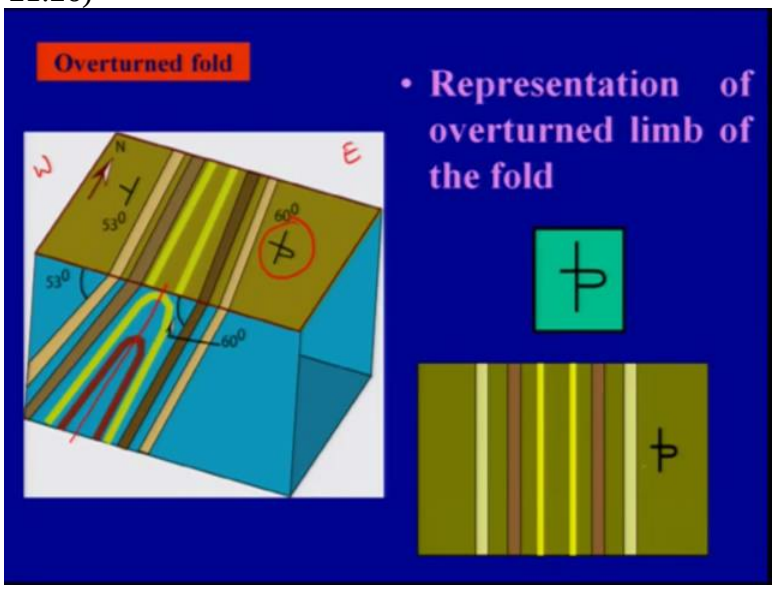
Now in nature as I wear talking about that everything will not be so clear but sometimes what you come across is that only on the surface, you will be able to see the beds. But whether they how to identify whether the these are the part of the folded beds or they are just the vertical beds here. So what you are able to make out in this figure is that you are having a a section which is given.

But suppose this section is not exposed and you want to understand that what is the type of whether this area is folded or it is just the different layers you are able to see. So what you are able to note here is that oppose this we mark as an 1, this as an 2. Then this is an 3 and this again is 2.

This is again 1 and then this you are having the we can say 4 here which is not coming up so this 4 here. So what you are able to see, there is an repetition of the layers or the beds. That is again an important part which you can make out and also that the this white layer that is the 3 is comparatively whiter than the other. This is because it is the top of the crust or the crust of the anticline.

That is the one of the reason why it is showing the wider space here. Because this is an eroded surface, this part what we see in the top is an completely eroded one. So just we see the layers which are coming up. So if you suppose erode from here then you will be able to see this yellow layer also which is being seen here. So you are having the repetition of the beds. Hence we can say that this area is folded.

(Refer Slide Time: 21:26)



Then another one is overturned folds and overturned folds basically if you look at, the top surface, above surface here, the plan view and this is a sec section view. If you have like you are having the inclined beds here, again both the beds are dipping in the in the same direction. They

are, so we can say that this is an overturned fold. Now suppose you are having the dip of this bed here or this beds on the left-hand side of the, this is your axial plane plane I am sorry.

So this is your axial plane. So if you have marked the north here, so this will be your East and this is your West. So West Western West beds or the western side of the limb you are having the dip is around 53 degrees. And this is also dipping in the same direction but this what we call they have overturned. As we were talking about that if the layers are been overturned above more than the vertical then we term that as an overturned fold.

So what we looks here is the top view, all beds which we see are like just the horizontal lines here. But we do not see that, we do not know whether they are dipping or not. So for that, we need to see the sections at some point of or some places. That is very much important. But at least the repetition of these beds are also, will tell you that fine they are overturned or not.

Representation of the overturned limb of the folds. Then we are having. So this is the symbol which you will find on the on the map. This is typical of the overturned folds. You are having the straight line, that is your strike. And then you are having the overturned folds. So you are having the dip direction is this one but they are overturned. So they are indicated by that.

So on the top you may just look at the all horizontal lines but if you come across such symbols, then you can say that fine this this layers are overturned.

(Refer Slide Time: 23:51)

So if you look at this one, this this is the normal limb but this one is getting overturned. So it has it has moved beyond the vertical. So if you look at this one, this is getting overturned. And in fold axis or the axial plane will be somewhere here. So this is an overturned fold.

(Refer Slide Time: 24:15)

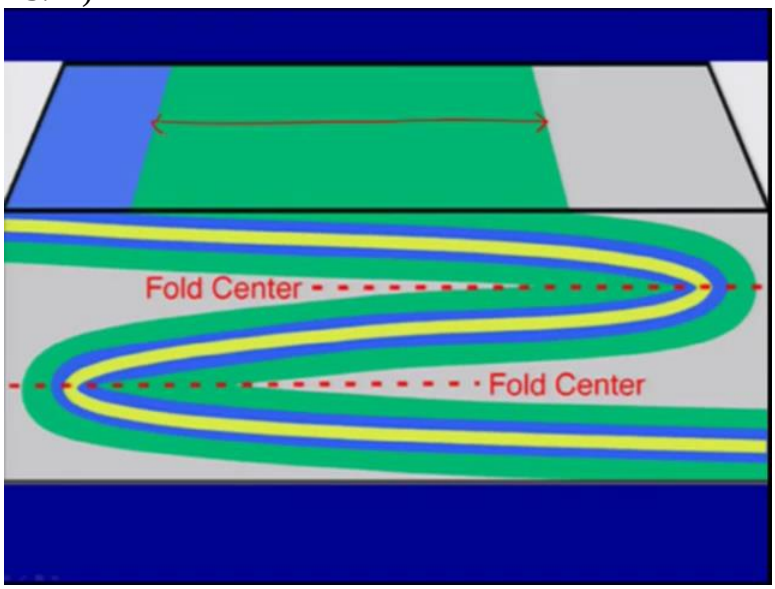
Now suppose it is getting folded further. So if you look at this photograph, what you are able to make out, this is the limb of the fold which is coming here and then getting here. So this is one, you can trace out very clearly. Here also, you can trace out this one very clearly. So what we are able to see? This one is another one here, this one is another one here.

So what we are able to see is this is the axial plane here and this is the axial plane here. So axial plane is almost horizontal here. So we have the axial plane there. So we are having the, so I will just remove this part here and then you can make out the axial planes, where are the axial planes.

(Refer Slide Time: 25:11)

So these are the axial planes which we see. So if the axial plane is almost horizontal then that those type of folds are termed as recumbent fold. So this you need to remember. These are the recumbent folds.

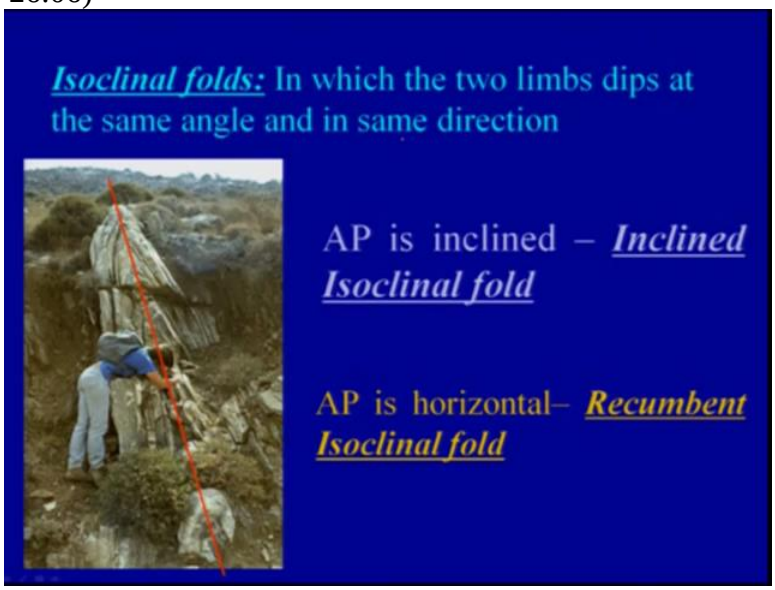
(Refer Slide Time: 25:27)



So in recumbent fold what will happen is that you will find that there is no repetition of the beds. But the beds will be very widely like the thickness will be very different and one of the layer will have more thickness as compared to the another one. So that can also indicate because when when this layer is getting folded, overturned then this is covering large area.

And that is one of the reasons that you will see that the beds which are having they are having different thickness but one of the beds will have very large area which will be covered during the recumbent folding.

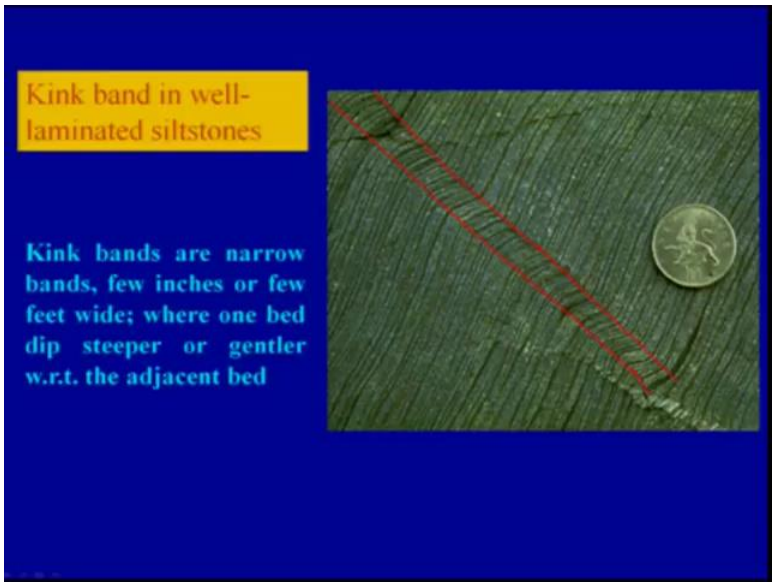
(Refer Slide Time: 26:06)



This is another example of different if we classify different folds. Here, there is an isoclinal fold in which 2 limbs dip in the same with an same angle or at an same angle in the same direction. That is termed as isoclinal fold. And the axial plane is inclined. Then we say inclined isoclinal fold. And if the axial plane is horizontal then we say that is an isoclinal fold, recumbent isoclinal fold. So this will act here.

So isoclinal fold, 2 limbs this at the same angle and in same direction.

(Refer Slide Time: 26:46)



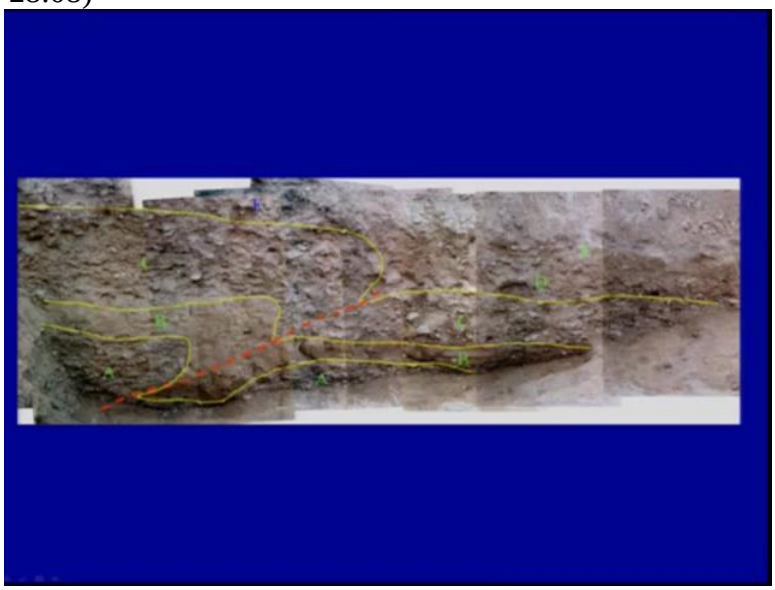
Then this is again depends on the type of material you are having and we will we will also we will be able to see the kink bends and that. So this is again if you are having the brittle deformation and all that, you will be able to see the kink bends or so. The bends will be quite sharp here and steeper. Those are termed as the kink bends.

(Refer Slide Time: 27:15)

Then you are having the monoclinal fold. Only one limb will be folded. Another will be almost like horizontal or you can say one limb will be inclined. So this is the example of the monoclinal fold where one limb may dip up to 90 degree. So it may be something like this here. So it may dip up to 90 degree and another limb will remain almost horizontal.

So plateau type plateau and elevator, this is an the example which we can see mostly in some areas where we see the plateau. So an elevated land which is abruptly on one side abrupt and drops abruptly. The elevation drops abruptly on one side. So this is an example of that. So this area we can say, these is an plateau area. So here we are having the one limb which is dipping steeply. So that is an monocline.

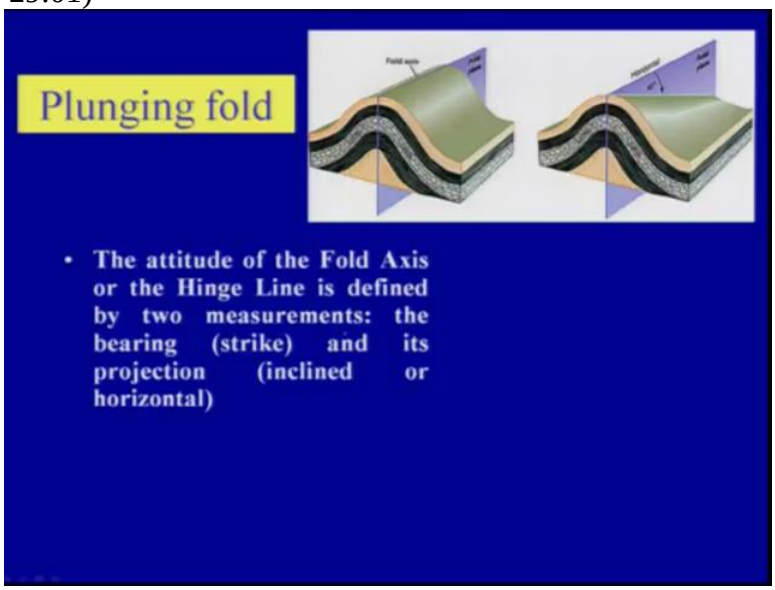
(Refer Slide Time: 28:08)



Now this is an example from Himalayas where we dug a very young fold along which we found a deformation. So this is again an example of the monocline. What we can see, only one bed is dipping, another one is almost horizontal. So you can see the line deposits here which are being marked. These are all gravels we are having and another one is we are having the soil here which has also one limb is dipping.

Another is almost horizontal. This one is horizontal whereas this is dipping here. And the axial plane if you have to draw, will go along this one. So this is an axial plane along which or the or we can say the Faulting which has been taking place along this one. So this is an example of monocline which we were talking about.

(Refer Slide Time: 29:01)



Then we talk about the plunging fold. Now here, the importance of the axial plane will come in. So a plunging fold mainly if you look at the fold axis, so here the fold axis is having some attitude. Whereas in this one, we see the fold axis is almost horizontal and like very much along the axial plane but here we are having some attitude. So this buildup. So the attitude of the fold axis or the hinge line is defined by two measurements. That is the bearing, that is the strike and then and the projections at its projection. So inclined horizontal. So we will continue in the next lecture. Thank you so much.