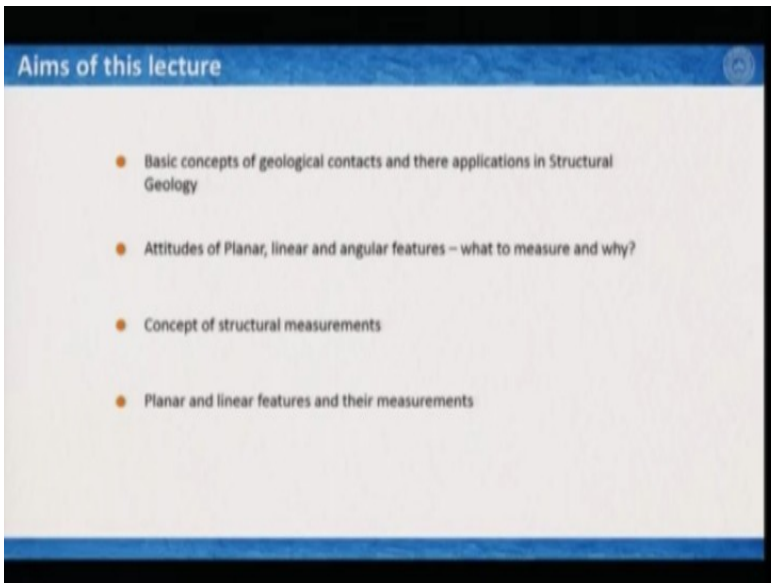
Structural Geology
Professor Santanu Misra
Department of Earth Sciences
Indian Institute of Technology Kanpur
Lecture 3
Structural Elements and Measurements

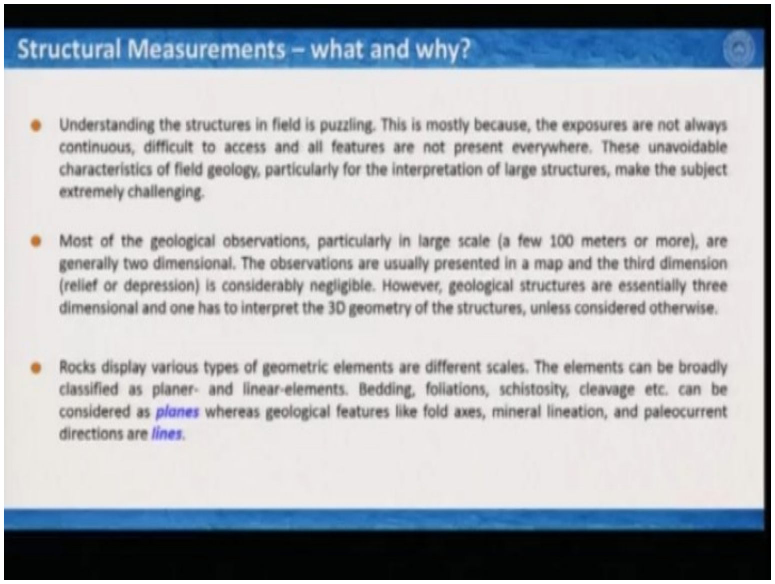
Hello everyone. Welcome back again to this online structural geology course. We are in our third lecture and today we'll learn about structural elements and measurements.

(Refer Slide Time: 00:33)



So the topics that we will cover in this lecture are listed here. We will first very briefly, okay, very basic ideas on geological contacts and their applications in structural geology and from that we will switch to attitudes of planar, linear and some angular features that we see in deformed rocks and then we will ask the questions. What to measure and most importantly why? Then we will go to the theory of structural measurements what the principles behind all sorts of structural measurements and then we learn how to measure all these linear and planar features together with how to plot them in the map.

(Refer Slide Time: 2:43)



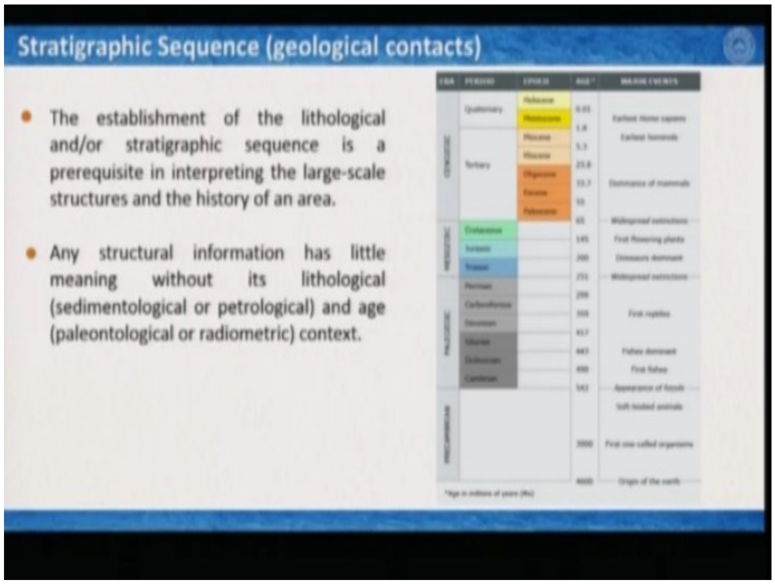
It is very important that in the field what we see. Exposed rocks and you must have understood so far that these rocks, the way they appear to us are extremely puzzling and this is mostly because the exposures that we see these are not always continuous. You see some parts here, some parts there and so on. At the same time it is also difficult to access all these features because they are not preserved everywhere and these are some sort of characteristics of the field geology which we cannot avoid.

For large structures to interpret how it is, what is the disposition and how to interpret the large structures, it is extremely challenging. There is also one point that I would like to mention here that most of the geological observations that we make in the field, particularly in the large scales are generally two dimensional. Though we see in the field a few meters elevations or few kilometers elevation when we work on active orogenesis but otherwise when we think of the long or large horizontal scale then the third dimension does not matter.

However, it is important that we also interpret the third dimension unless we are working in our 2D models. But third dimension geometry is important because most of the geological deformations do happen in the 3 dimensions and to understand all these deformation features, we have to identify and mark the various geometric elements that we see in rocks and these elements we can broadly classify in 2 different categories. One is planar and another is linear.

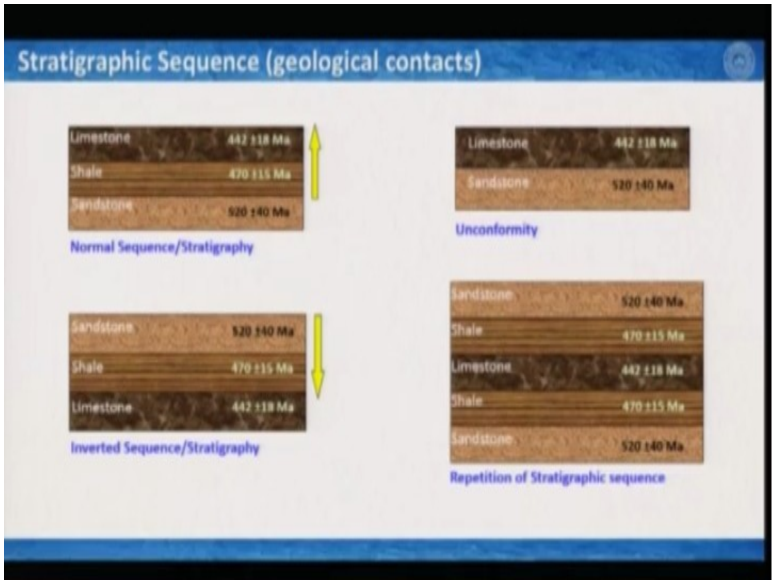
To give examples of planar features or planar elements in deformed rocks you can consider bedding elements, you can consider foliations, schistosity, cleavage, etc and then on the other side the linear features are mostly intersection of 2 planes or we call intersection lineations, fold axes, mineral lineation, paleocurrent directions, etc.

(Refer Slide Time: 03:34)



Now before we go to all these structural elements, planar and linear structural elements it is important we understand their disposition in the space and time and there it is very important that you always remember the geological timescale and the stratigraphy of the region you are working with. So this is important because the establishment of the lithological and stratigraphic sequence is a pre-requisite in any large scale structural interpretation and also to unravel the history of the area. It is also important to remember that any structural information if you do not provide that what is the age, what is the lithological consequences of this does not make any sense to anyone.

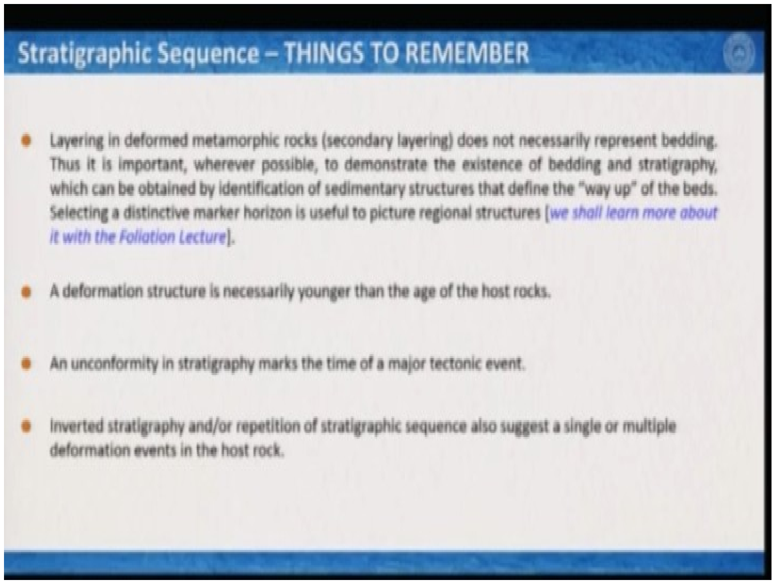
(Refer Slide Time: 04:34)



So their age, their lithology, their stratigraphy with respect to overall geological timescale is essentially important and these become somehow more complex when we see different kind of stratigraphic contacts. We will see it later what are the different kinds of stratigraphic contacts are but it is important that there are some sort of normal stratigraphic contacts. That means that we have older layers at the bottom and slowly you will stack up with the new layers. So if we see this then there is no problem. However in the field commonly also observe an inverted sequence or inverted stratigraphy that means we have younger layer at the bottom and older layer at the top.

Sometimes some layers are missing that means either they are eroded later or after the deposition or there was no sedimentation at that particular time. So if something is missing then we assign it unconformity. There are different types of unconformities we are not going into that part. You must have learnt it in your sedimentrology or stratigraphy lectures but if there is unconformity this is something that we need to consider. There is also a possibility that you see repetition of the stratigraphic sequence. That means same lithology you encounter when you walk along your field and all these have very important structural implications and tectonic implications in interpretation of geological structures.

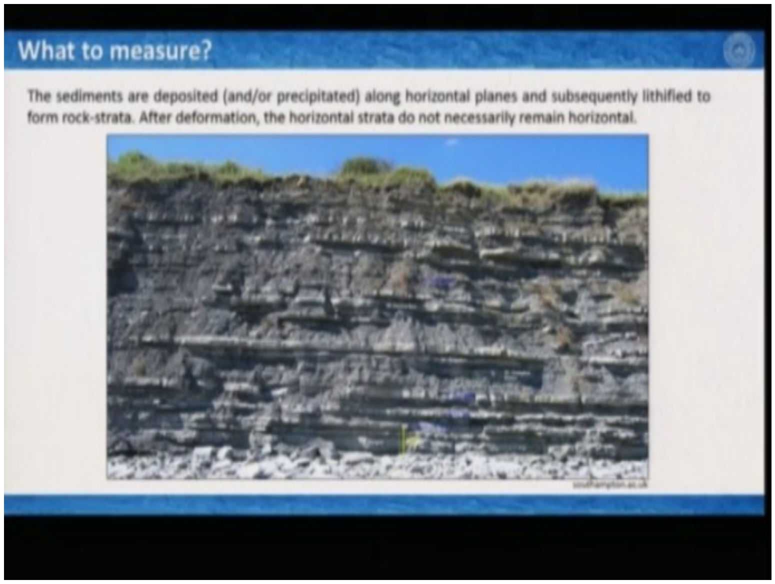
(Refer Slide Time: 05:57)



So in nutshell if I try to summarize what we discussed so far that why stratigraphic sequences are important. The first thing to remember is that if it is possible, if it is there try to first figure out what is your primary bedding plane or sedimentary bedding plane. Most of the structurally deform rocks are metamorphic rocks as well and it produces many different other layers. We will learn about it later but it is important that you learn or you are skilled to distinguish between primary layers and secondary layers and once you identify the primary layers, then it is important that you try to understand what is the direction.

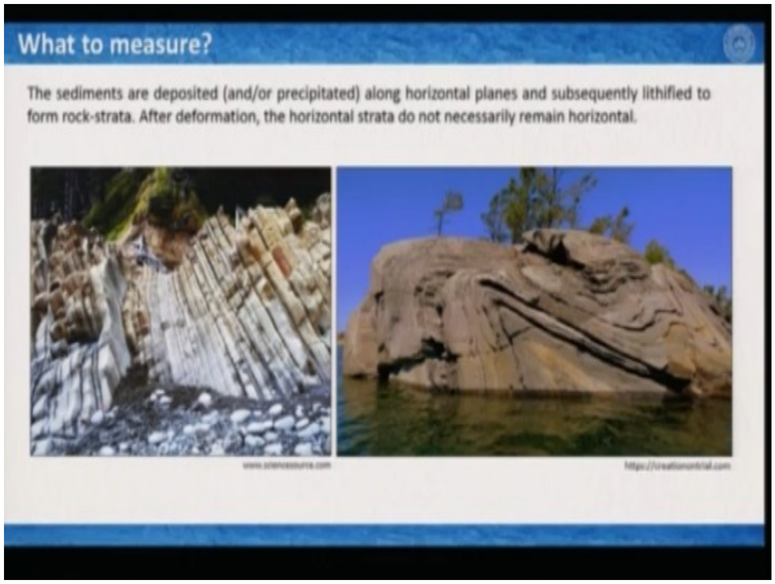
Any deformation structure that we see in the field are essentially younger than the host rocks. That something that you need to remember and it is obvious and if you see that we discuss in the previous slide any sorts of unconformity in the stratigraphy, inverted stratigraphy, repetition of stratigraphic sequence, etc all these things if you encounter in the field they suggests immediately that there must be either a single or multiple events of structural deformation or tectonic phenomena.

(Refer Slide Time: 07:26)



So with this we move to the next part of this lecture that what to measure in the field. Now we know that when we deposit rocks, when the sedimentary layers get deposited then they generally deposit in horizontal manner. So all layers initially are horizontal, they get lithified, they also stay horizontal but if you have visited any deformed terrain you must have seen that these things do not remain horizontal. So if they do not remain horizontal that means there must be some sort of deformation in large or small scale. So in this image we see that these layers are essentially horizontal and if these are horizontal there is no problem. These rocks are probably not deformed or even if they are deformed they remained as they are.

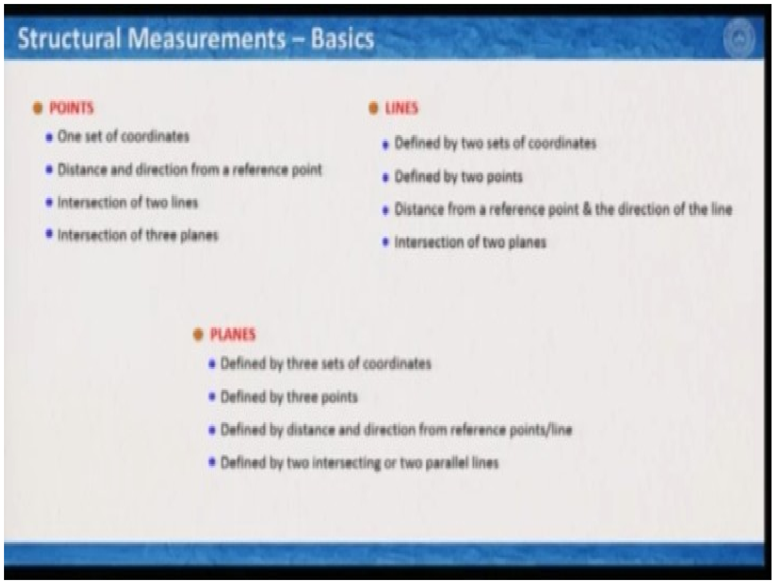
(Refer Slide Time: 08:17)



However, you must have seen in the field or if you go to a deformed terrain for example Himalaya, you must have seen that most beds are tilted towards the north side in the Himalaya. For example, this photograph here. Here at the beds are not horizontal compared to the previous image so these beds are tilted. How to represent fact, how to interpret it that is the challenge that is the question? We have to measure the orientation of these tilted bedding plants. In the second image we see that a layer is folded. In one side of this fold the orientation at least in this section is like this and in another side is different than the other side of this fold.

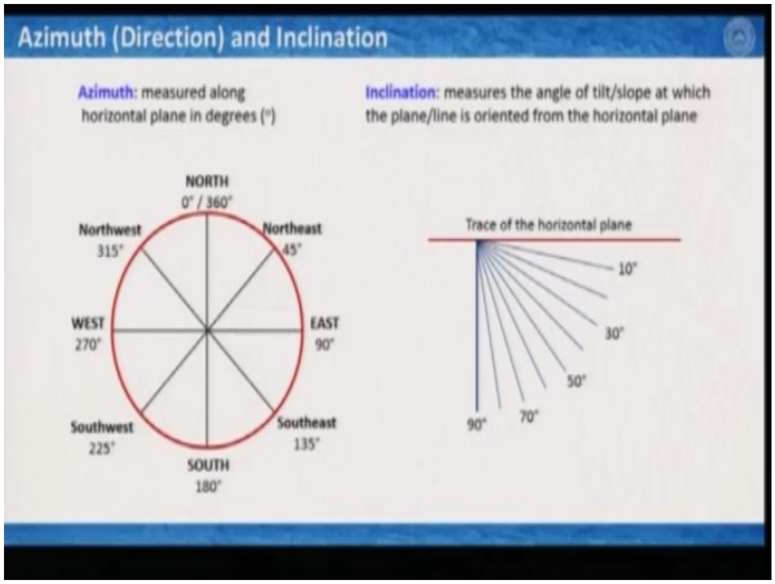
Now the question is can we measure it and can you represent. It is also important to understand that when these two planes with orientations like this and with orientation like this when they meet, they produce a line. Two planes they intersect to produce a line and this line also should have some sort of orientations and these orientations will learn later is known as fold axis and these we can plot as well. All these kinds of geometric dispositions of deformed rocks allow us to measure and plot them differently in the map and this is what we are going to learn now.

(Refer Slide Time: 09:49)



So the basics are that as I said that there could be points, there could be lines and there could be plains and there are many ways you can construct a point line and planes but in a nutshell if I have 3 planes they intersect, you can generate a point if I have 2 planes they intersect, you generate a line and then 2 intersecting or 2 parallel lines can produce a plane. So, given this background with us and given the idea that most of the geological maps that we produce are in 2 dimensions. We produce them in the piece of paper. It is important to understand or to plot them such a way that these 3 dimensional features or 3 dimensional measurements are represented in the map in 2 dimensions and this is exactly what we are going to learn now.

(Refer Slide Time: 10:50)



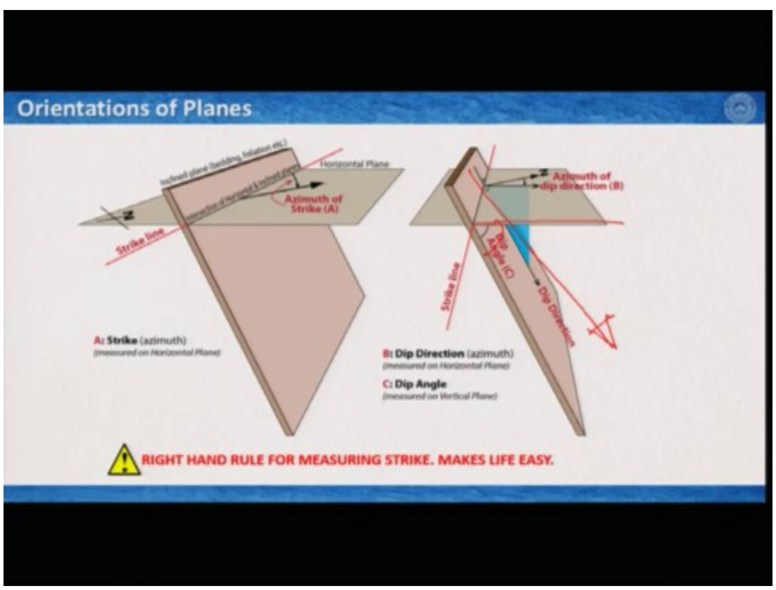
What we measured in the field or the basics of the measurements are considered in general on two planes. One is your horizontal plane, which is represented on the left side and we call it azimuth. Anything that you measure with respect to the North in degrees on horizontal plane, we call it azimuth. So clearly you have in terms of degrees 360 divisions from 0 to 360. At 90 degrees you have East, at 180 degrees we have South, at 270 degrees we have West and there are many in between. Apart from the measurement on the horizontal plane because we will be talking of the third dimension as well.

So there must be something that you are measuring away from this horizontal plane and this is known as measurement of inclinations. Inclinations measures the angle of tilt or slope at which the plane or line is oriented from the horizontal plane. So clearly in horizontal plane, you measure 360 degrees, but when you measure in vertical it is generally 0 degree to 90 degree and then 90 degree to 0 degree again, but because this is mostly symmetric so we cover from 0 degree to 90 degree.

(Refer Slide Time: 12:17)

So based on this background the structural geologists have their own vocabulary and these vocabularies considered all these terms. For example, trend, strike, plunge, pitch, back bearing, front bearing, dip angle and so on. Now what are these and how to present them in the map, how to measure them in the field is something that we need to learn.

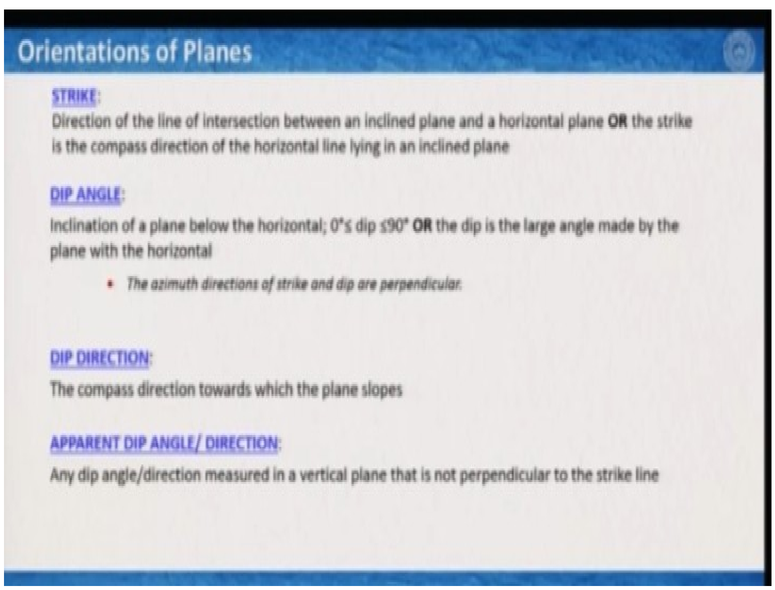
(Refer Slide Time: 12:46)



So first how to measure the orientation of planes or how to represent the orientation of a plane. What we see in this image that this is an inclined plane, this light brown plate that you see and if you imagine a horizontal plane is intersecting this inclined plane then intersection of this inclined plane and the horizontal plane would produce a line. Now this line is lying on the horizontal plane and the orientation of this line with respect to the north gives you the azimuth of the strike or the strike of this inclined plane. We will have the definition in the next slide

So if I have an inclined plane, I know what is the strike of this plane now and the inclination or the slope of this plane is known as dip angle. Pictorially you can understand that this is the same plane. I just rotated it and this angle that it makes with the horizontal plane is the dip angle and the direction this plane slopes is the dip direction. Now, there are some techniques of measuring it. Generally structural geologists do follow right hand rules. We learn about it later but there are many other ways people do measure dip strike and dip directions. I hope the concepts are clear.

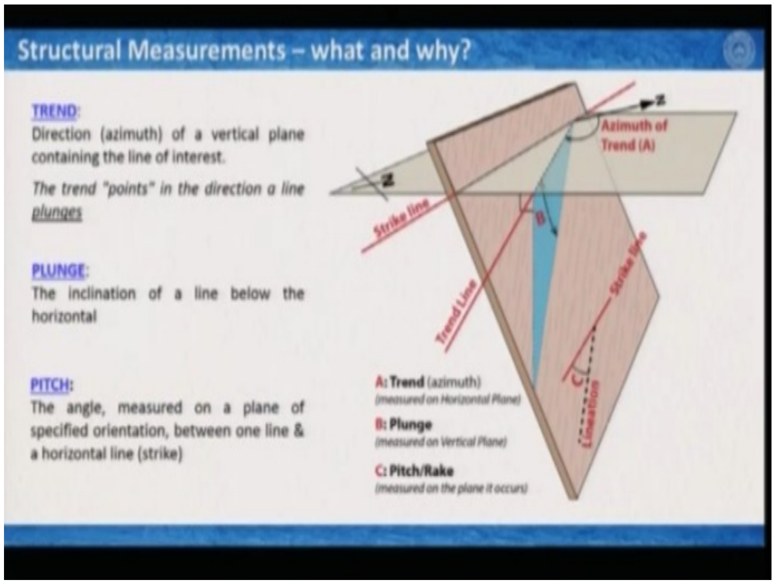
(Refer Slide Time: 14:25)



Let us have the definitions. I read what is strike. Strike is direction of the line of intersection between an inclined plane and a horizontal plane. You can also define it. The strike is the compass direction of the horizontal line lying in an inclined plane. If you have the concepts clear from the previous slide, you can understand what these two statements mean. Dip angle is inclination of a plane below the horizontal. It essentially ranges from 0 to 90 degrees. You can also define it that the dip is the large angle made by the plane with the horizontal.

Dip direction is the compass direction towards which the plane slopes and if you do not measure your dip angle perpendicular to the strike line, so there is many more there are many possibilities. These are all apparent dip angles and the angles along which you are measuring the direction is your apparent dip direction.

(Refer Slide Time: 15:28)



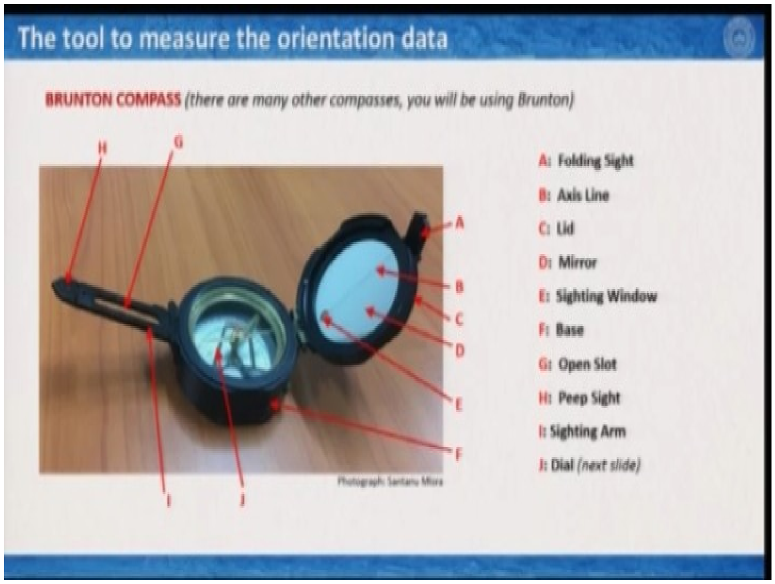
Let us have a look how to measure the linear features. So I have the same plane here and in this plane, I have a series of linear features as you can see. Now our aim is to measure the orientation or attitude of these linear features. Now, there are 3 terms associated with these linear features measurements. One is trend, one is plunge and another is pitch. Let us have the principles behind the measurements.

(Refer time slide: 16:11)

For example, if I take this plane as an inclined plane and I have a series of lines here then what is trend? So if I project this line on the horizontal plane, then this back of this pointer is indicating a direction on the horizontal plane. Now if this is my North, then the angle it makes with the, along the horizontal plane, this is my trend. The plunge is the angle I have to rotate this line to project it on the horizontal plane. And the pitch is if this is the line then if I measure it on the plane the angle directs the pitch or wreck.

So if I try to define it in words, it goes like this. Trend is the direction or azimuth of a vertical plane containing the line of interest. The trend points the direction of the line it plunges. The plunge is the inclination of a line below the horizontal and pitch is the angle measured on a plane of a specified orientation between one line and the horizontal line. This horizontal line is essentially the strike. Now from this image we can also realize that trend is azimuth that is you measure on the horizontal plane, plunge is inclination that you measure on the vertical plane and pitch or rake you measure on the plane itself, inclined plane itself you measure the pitch or rake. We learn more about it later.

(Refer Slide Time: 18:08)

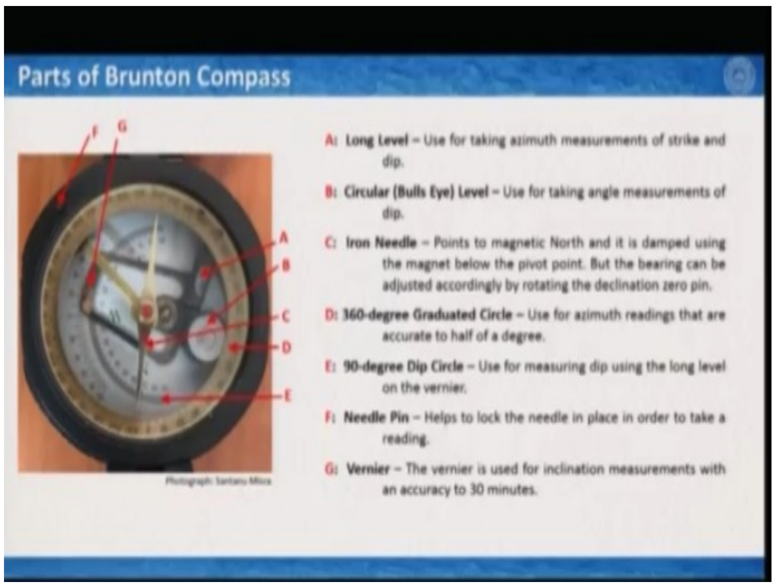


Now what is the instrument that you can measure all these attitudes in the field? So the common weapon or common tool that structural geologists do use are compasses. There are different types of compasses available but in this course, we will mostly look at very commonly used compass that is Brunton compass. So you have the image here and a Brunton Compass when it is a packed or kept in its original shape.

(Refer time slide: 18:23)

It looks like this. It weighs about 50 to 100 grams or something like that and you can open this compass. So once you open then you open this lead. So this part is the lead of the compass then you have the fundamental part the important component the dial and then you have one thing that is called sighter. Now as you can see you can rotate it all along from 0 to 180 degrees same here and then you can make everything straight as it looks like here. So we use differently, different orientations of this compass to measure different things and here in this slide you have the different components written here. Now what is important that this is the lead, this is the main dial and this is the sighting arm.

(Refer Slide Time: 19:30)

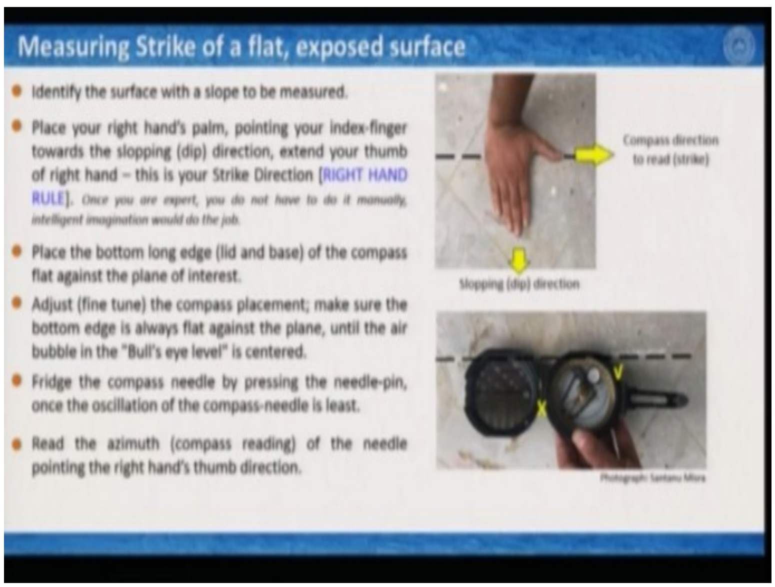


Now, let us have a look what we have inside this dial because this is most important part that you need to know. So in this dial we have one needle and this is a magnetic needle. One end always points towards the North and another end towards the South does not matter how you orient or how you keep it. Of course you have to keep it in the horizontal plane. Now how to make sure that you are keeping your compass along a horizontal plane. To do that we have one circular, if you look at the slide, we call it bull's eye level. So keeping this little bubble inside the circle makes sure that your compass is horizontal.

So measurement of azimuth that is all measurements on the horizontal surface is assured by keeping this bubble in the center, bull's eye bubble. Now how to make sure that your compass is vertical. To do that you have another level inside we call it long level, which is you can see it is this one or in the slide it is this one. You can actually rotate this bubble using an arm or lever at the back. So if I rotate this arm as you can see here that this lever rotates and this lever is known as clinometer and you can see that this clinometer is graded and also the dial at the back.

So you have to rotate such a way that these long levers, bubble stay at the middle and that makes sure that your compass is held in particle manner. So holding it horizontal or vertical gives you the idea or gives you the measurements in horizontal along horizontal planes and along vertical planes respectively. There are some other features like you have when you keep it horizontal this needle generally swings. So to make quick measurements, you have a little pin here, with this pin you can freeze this needle when it oscillates extremely less.

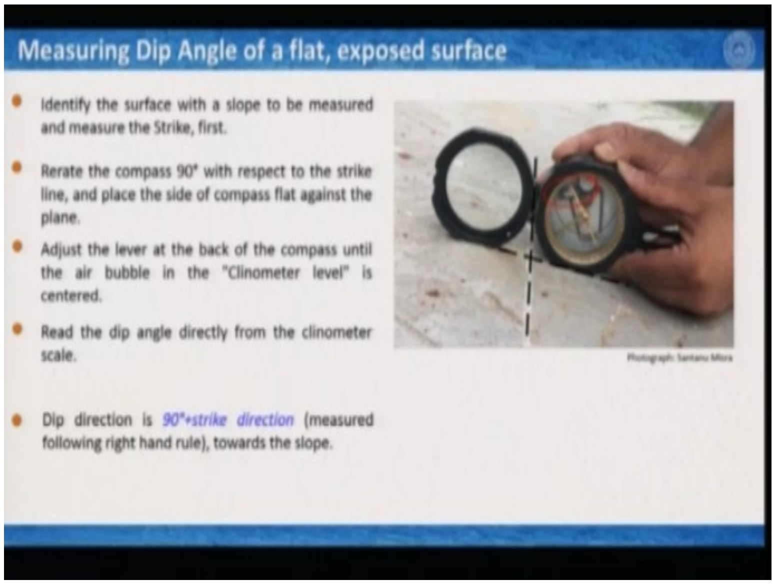
(Refer Slide Time: 21:48)



So there are some different ways of measuring dip, strike, trend and plunge in the field but the principles are always same. Different schools have different ways of measuring it. Make sure that while you measure your dip and strike or trend or plunge or pitch you do it so that you do not damage or you do not break the rocks and rock surfaces. That is the very important message I would like to give you. Do not mark also unnecessarily on the rock surface like your permanent marker pens and so on.

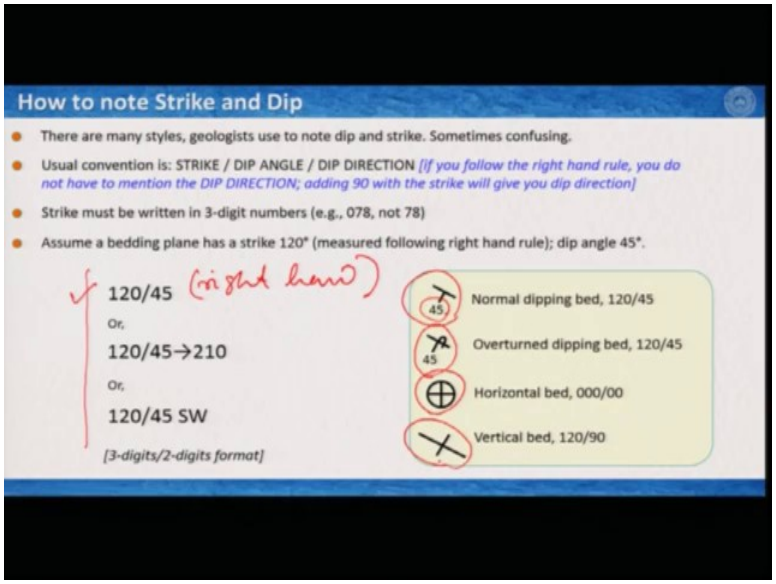
I will upload a separate video on how to measure a dip and strike. There are also many YouTube videos You just search in YouTube and you can find how to measure dip and strike and while you are doing this it you also make sure that the instructor there is showing you the right hand rule of dip and strike measurement. Here are the instructions. I am not going into the details of it because I will upload a separate video that you will click and see it later but few things you have to make sure that your compass is essentially horizontal when you are making strike.

(Refer Slide Time: 23:19)



When you are measuring dip, it is also important to make sure that here in this lead your, in this long lead your bubble is right at the middle of this lead. Otherwise, you would not get the actual a true dip okay?

(Refer Slide Time: 23:38)



Now how to note dip and strike in your field book, that means you measured in the field fine, but you have to note it so that you can reproduce it in the map or later use it for analyzing data because in the field you measure 100, 200 and so on dip and strike data. Interestingly there are many styles structural geologists used to note dip and strike and sometimes they are confusing.

So I am giving you what are the general ways people try to write. The usual convention that people follow, first you write strike, then you write dip angle and then you write dip direction but if you follow this right hand rule of measuring strike, then you do not have to mention dip direction. You just have to add 90 degrees with your strike and then you get your dip direction.

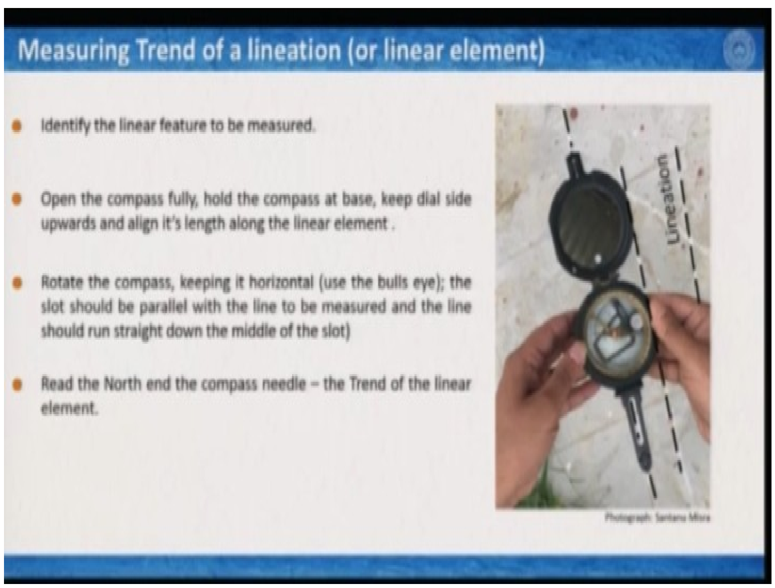
There is also very important convention that you have to remember when you write strike or anything you are measuring on the horizontal plane. That means any azimuth you have to write using three digits. If your strike is 78 degrees just do not write 78 write 078. It must be in three digits. Now how to note it? So, what example I have given here that if you have a plane with a strike 120 degrees that you measured following the right-hand rule and dip angle is 45 degrees that means the strike line is 120 degree and the plane is dipping 45 degrees. So there are 3 ways you can measure. You can note it.

First one is just 120 slash 45. This is if you use your right-hand rule. You can also write 120 degree 45 and then an arrow 210 that is the direction it is sloping. That means it is sloping towards southwest so you can also write it 120-degree slash 45 southwest. So, a 3-digit slash 2-

digit format. Now this is how you note in the field notebook your dip and strike and dip direction data, but how to plot them in the map or how to read them in the map. If you are looking at a structural geology map or a structural map you will see many symbols.

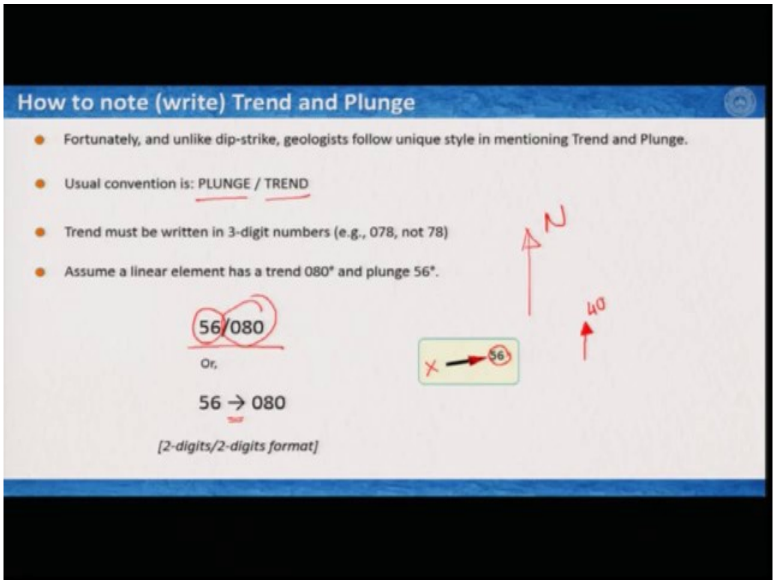
Now, you have to understand what is what. If you have a normal dipping bed with the same orientation 120-degree 45 degree, then the symbol is something like that. You have a longer line that it dictates or that indicates the strike line. So, it is generally drawn or it is generally mentioned with respect to the north of the map and then perpendicular to this giving the direction it gives you the value of the dip and dip angle and also the dip direction. If the bed is overturned then the symbol is like this. If the bed is horizontal then the symbol is like this and if the bed is vertical then it is given like this where the strike is given with a longer line.

(Refer Slide Time: 27:16)



So there the plunge you also measure in a similar way. I'm sorry. It is not the similar way in a different way, but it is done with the same compass and it is done differently but the technique or measurement principles is always same. How you do it? It is written here but as I said I will upload a separate video on the measurement of trend plunge and pitch of a linear feature in the rock surface.

(Refer Slide Time: 27:42)



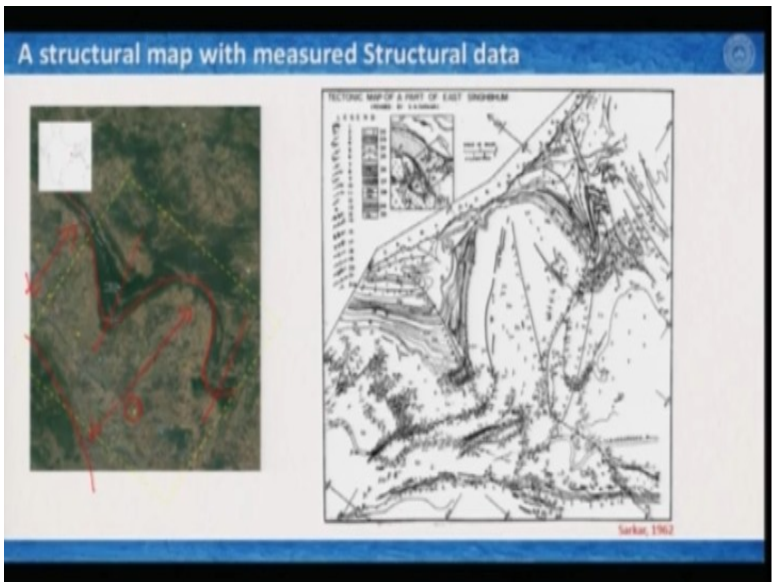
Okay so we will now look at how to note or write in your notebook trend and plunge and also we will see how we should plot this trend and plunge in the map. Now interestingly, unlike dip and strike where geologists do right dip and strike in different ways but for trend and plunge there is more or less a very unique style and the unique style is first we write plunge and then we write trend and the same rule applies here. That means if you have to write strike, then you have to always write in 3 digits. That means if your trend direction is 78 degrees you do not write it as just 78 you write it as 078.

This is simply because trend is measured on the horizontal plane, this is azimuth so it is better you add you write this in three digits and if we assume a linear element that has a trend of 080 degrees and it's plunging 56 degrees. That means it plunges 56 degrees towards 080 degrees. Then you can write it 2 different ways in your notebook after measurement in the field 56 slash 080 or 56 indicating an arrow towards 080. Now both of them have more or less similar meaning.

The first digit first 2 digits, this indicates your plunge value and then next 3 digits indicate your trend value. Now in the map again it is the trend because it is measured on a horizontal plane. So given the north of this map is in this direction. Then you draw a line and then this line would indicate your trend and if the trend is, if the plunging is happening on 56 degrees then you actually mark this 80 degree towards this side and then you mark the 56 degrees.

I repeat that you draw a line and then the plunge if it is directing towards 80 degrees, then you mark an arrow towards that side not in this side but in this side because this is the direction your plane is sloping or plunging or your not plane sorry, your line is sloping or plunging and it is 56 degrees. So this is how you write. If it was say, for example 0 degrees is your trend and 40 degrees your plunge. Then with respect to this is your north then you would probably would make it like this. So that indicates 0 degree and 40 degrees plunge. So you write it like this.

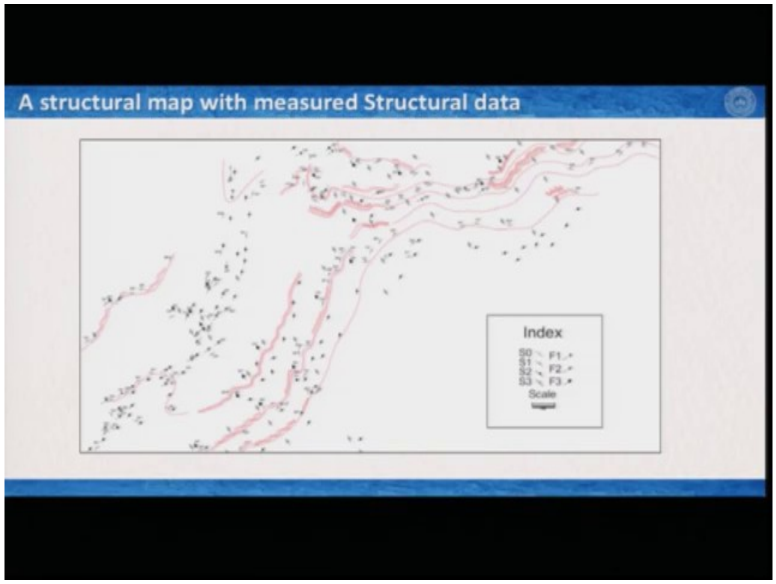
(Refer Slide Time: 30:43)



Once you have all these data measured here, I show you a very classic example of how to plot this data and represent them in the field. So on the left side, you have a Google Earth image showing the two classics syncforms that we see and of course when antiform in between in Singhbhum area. So these 2 syncforms this one and this one around dolma volcanic you have classic Singhbhum shares in here the river Subarnarekha is flowing in between and the entire range is known as Chaibasa formation.

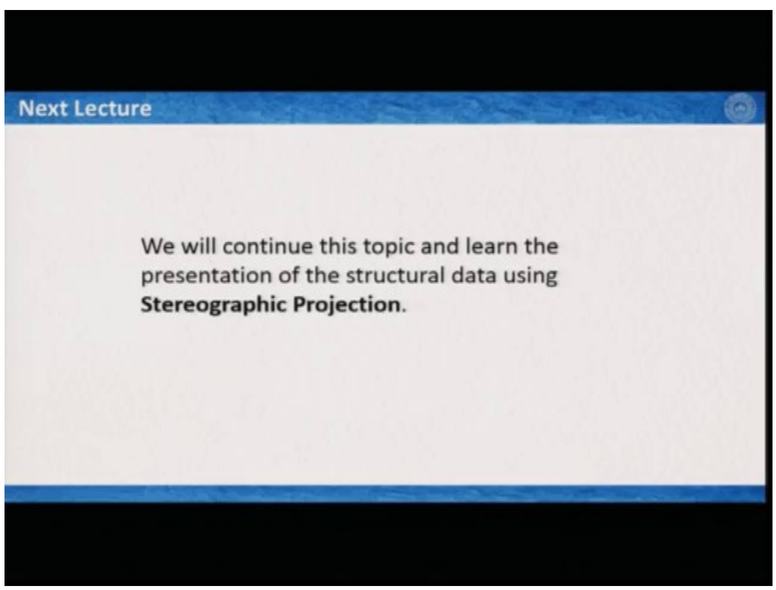
You have this classic place Ghatshila located somewhere here. Now once we see this and you would like to represent it structurally, the one of the classical maps I like of this region is made in 1962 by Sarkar and this is how it is. You can download this paper and look at this map but in general our students also do plain paper mapping where you don't have any help of the topography.

(Refer time slide: 31:45)



So this is one of the maps our students produced in the field and all symbols here are different measurements of planar and linear data and this is how a map can be produced. So with this note I conclude this lecture.

(Refer slide time: 32:07)



In the next lecture we will learn how to analyze all these structural data. You cannot plot all your data in the map and even if you can plot it is important that you summarize them, you interpret your structural data and to do that we use a technique called stereographic projection. That will be the topic of the next lecture. Thank you for now and see you in the next lecture. Bye.