Structural Geology
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Lecture No 04
Stereographic Projection in Structural Geology

Hello and welcome, everyone. We are in the fourth lecture of this online structural geology course and today's topic is stereographic projection and its application in structural geology.

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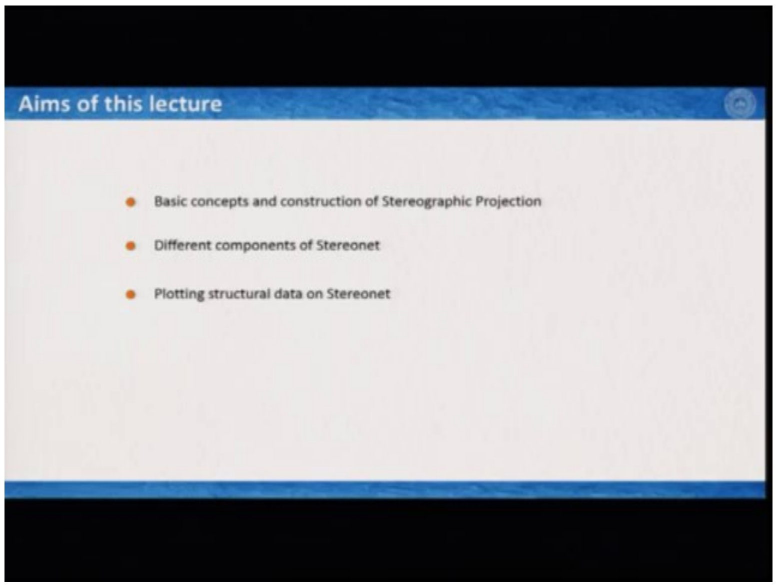

So what we will cover today is mostly the basic concepts and construction of stereographic projection. The different components of stereonet and finally will see how to plot structural data on stereonet.

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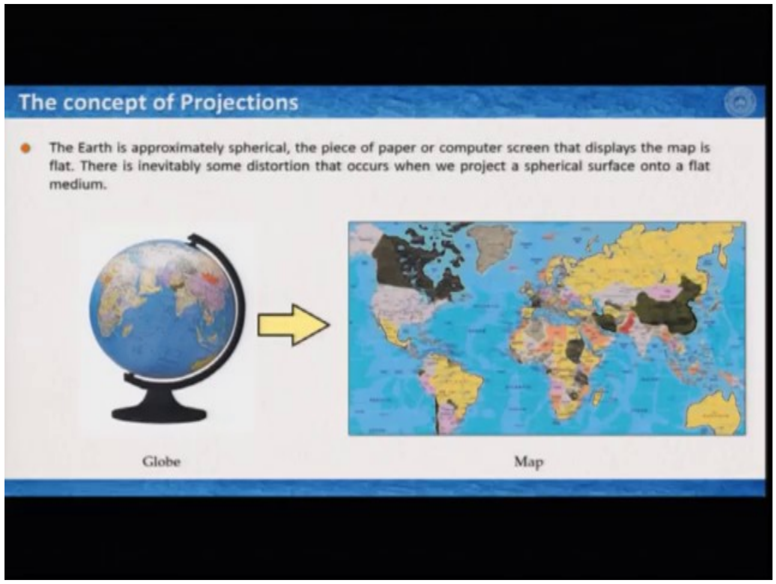

Now, before we go to the actual topic of stereographic projection let us have some ideas that what is a projection? Now imagine a globe that we have all seen and you also have seen the map, the world map, which we see in our computer screen or a piece of paper, which is flat and what we see in a sphere is not flat.

Now how this spherical map is converted to this map is a question. And if you try to do that, that means, say, if you break this globe and then try to make a rectangular area interestingly, you cannot do it. If you have to fit it, you have to stretch some areas you have to deform some areas of this globe and then only you can make this flat map.

Now the stretching or deformation of this globe or pieces of this globe is the concept of projection and the stretching or deformation of the pieces why you just don't do it randomly, you do it using some mathematical relations, mathematical formulations and therefore you achieve the projection of the map on a flat surface from a globe.

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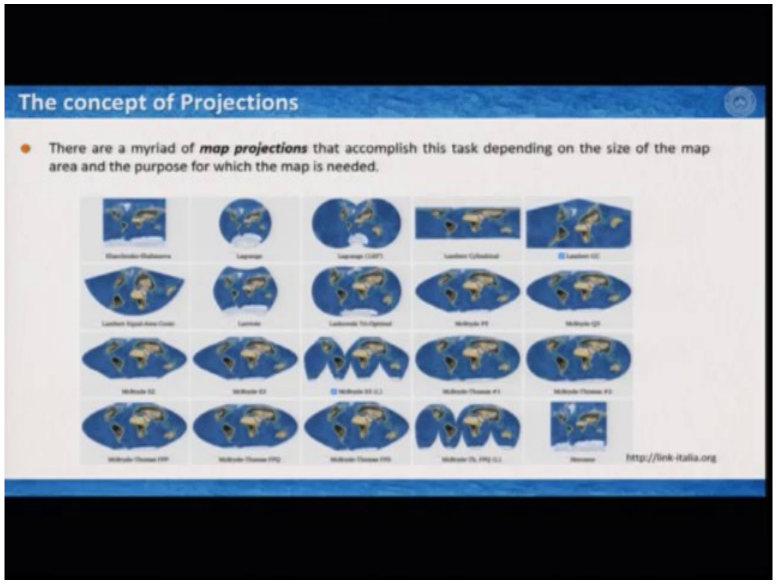

Now there are many ways one can project the map. So the different ways are essentially a function of that what is your need of projecting the map so based on that, people do project the map in different ways.

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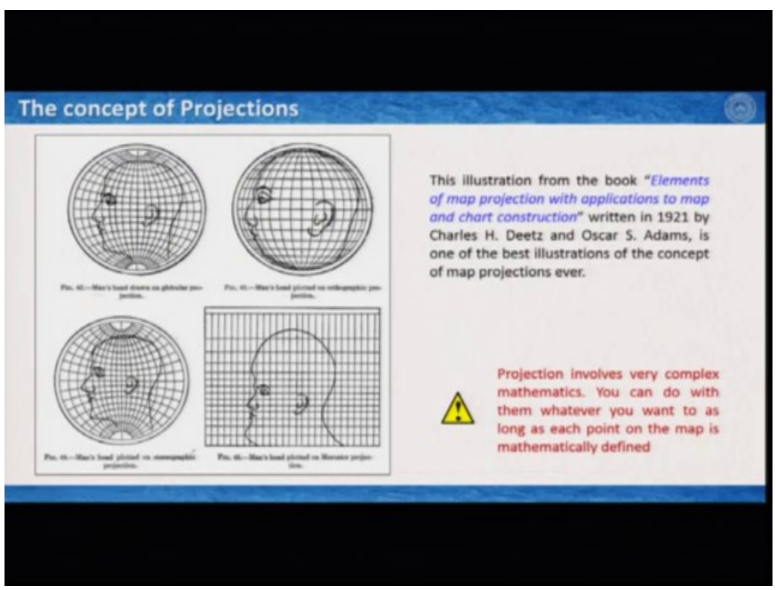

Now, this is not only valid for map, you actually can project anything in any different ways. So this illustration that we see these are human faces is one human face and you can see that based on the different grids that we see the face has been projected differently in this area.

So this is one of the classic projections that I took from a book and it dates back of 1921. What is important that I said already that, any projection or any projection operation involves extremely complex mathematics. So you can do with them whatever you want to, as long as each point on the map or on the object you are projecting to are mathematically defined.

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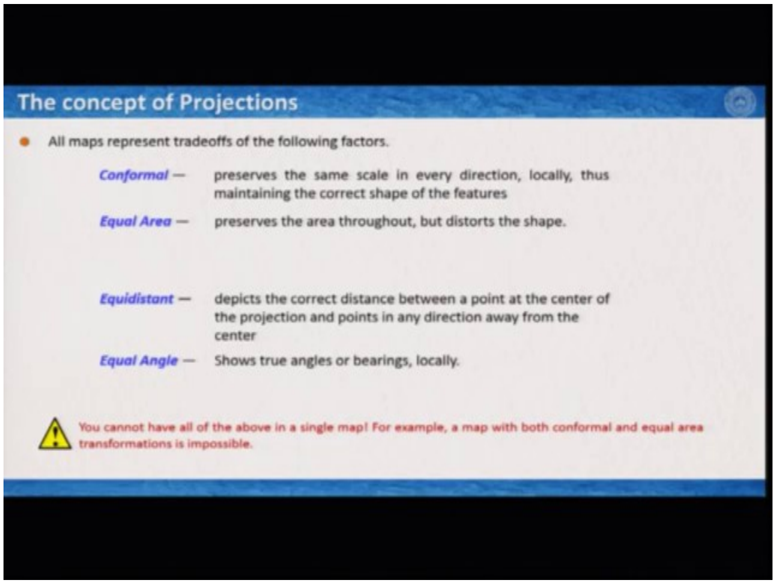

So there are many ways of projections. But in structural geology, there are mostly four different ways we project maps. One is conformal, one is equal area one is equidistant and another is equal angle. Now all these four are somehow related to each other. For example, in conformal projection, it preserves the same skill in every direction locally, thus it maintains the correct shape and the features. On the other hand, the equidistant projection depicts the correct distance between a point at the center of the projection and points in any direction away from the center.

So conformal mapping keeps the shape and equidistant projection keeps the distance between two objects. Equal area and equal angle, equal area map you preserve the area, but it distorts the shape and in equal angle you keep all the angular relationships equal to the projected map. Now it is important to understand here that you cannot have all of the above or all of this conformal mapping, equal area mapping, equidistant mapping and equal angle mapping in a single map because, though they are somehow related, but you cannot project them together.

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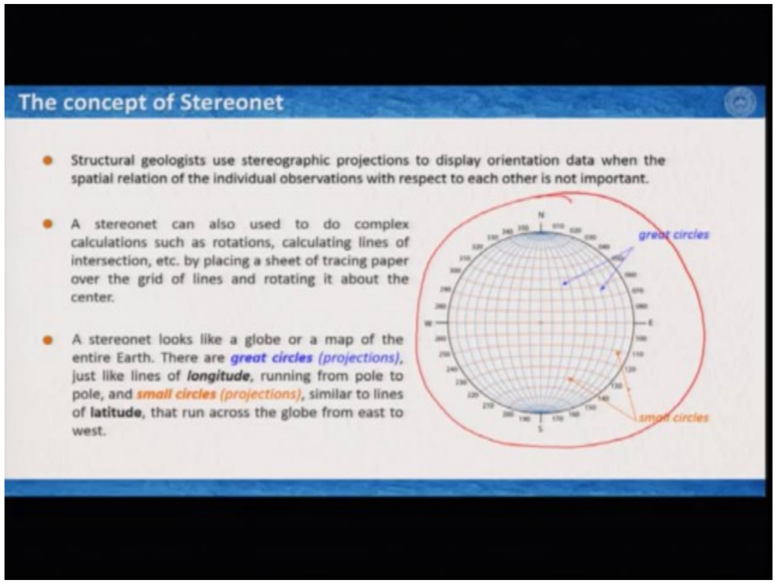

So in structural geology we use stereographic projections mostly to plot or display orientation data. We have learnt about different orientation data about planar features, about linear features and so on. What is most important that you can collect data from the field and then you can gather in a single place and plot them in the stereonet. So, in addition to that, a stereonet can also used to do complex calculations such as rotations, calculating lines of intersections etc, we learn all of these.

So in general, what do you see in stereonet, what we generally see it is essentially looks like the globe in plane and it has some grids. There are some vertical grids, and there some horizontal grids, the vertical grids are known as great circles and it is very analogous to what we call longitude, running from one pole to another pole. And then there are some small circles that runs that run from east to west of this circle. So in this image, the great circles are marked by blue color and small circles are marked by orange color.

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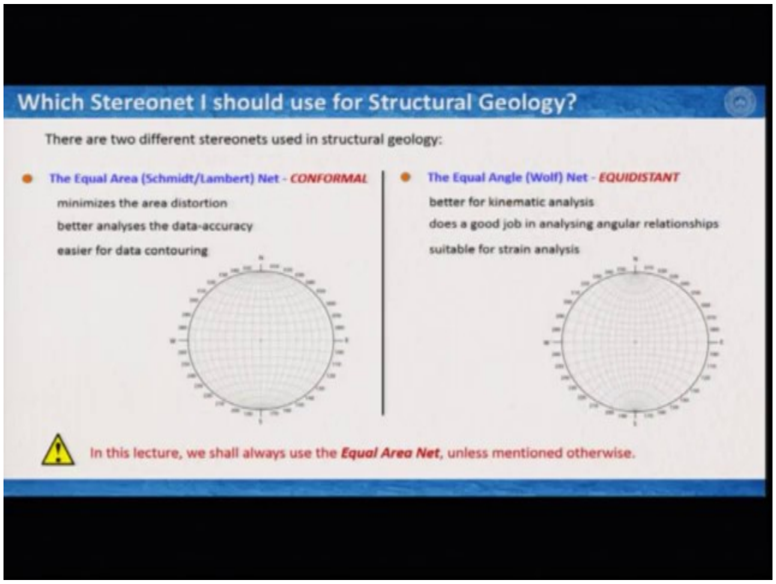

Now, as I said that there are many different projection styles, there are many different possibilities. So in structural geology there are two different types of stereonets that we use. One is equal area, and another is equal angle. The equal area map is also known as Schmidt Lambert, Net and equal angle Projection is also known as Wolf Projection or the stereonet is also known as Wolf Net. The advantage of equal area projection is that it minimizes the area distortion as it defines, so it better analyzes the data accuracy and it is also easier for data contouring.

On the other hand, the equal angular, Wolf Net it does an excellent Kinematic analysis, it does a good job in analyzing the angular relationships, and therefore it is suitable for strain analysis. In this lecture and in most of the structural geology operations, at least in basic levels, people use mostly equal area net. So in this lecture will also use the equal area net unless we state otherwise in some places.

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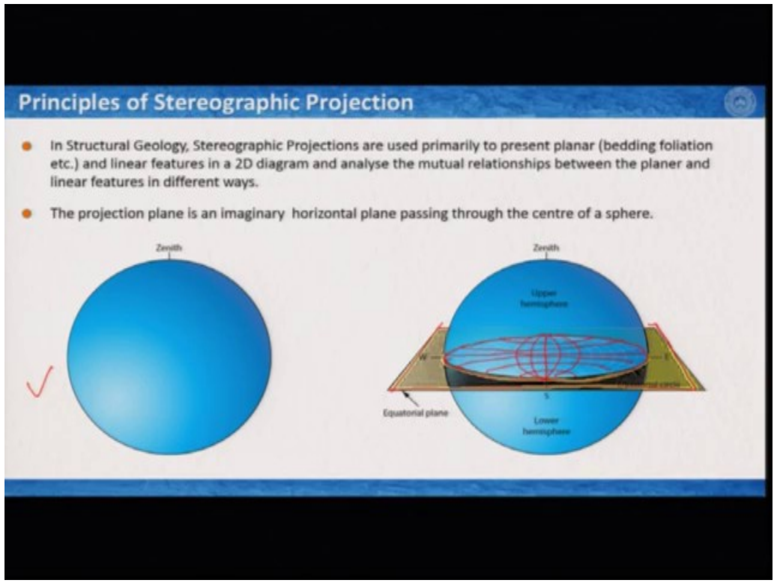

Okay, let us go to the concept of the stereographic projection. A stereographic projection generally, as we have seen it is a circular area, but what is this circle? Now this circle is achieved by inserting a horizontal plane inside the sphere. As you can see here on the left side you have a sphere. And if I insert this green horizontal plane through the equator of this sphere, then it creates a circle in the middle and this is your stereonet or projection plane.

The circle is also known as primitive circle. As you can see here, here are, these are your great circles on different sides and these are your small circles running from west to east. So we will see now that how using this concept of stereographic projection; what we have learnt in our last lecture that we will plot a line, we will plot a plane and we will also learn how to plot the normal of a plane in the stereonet.

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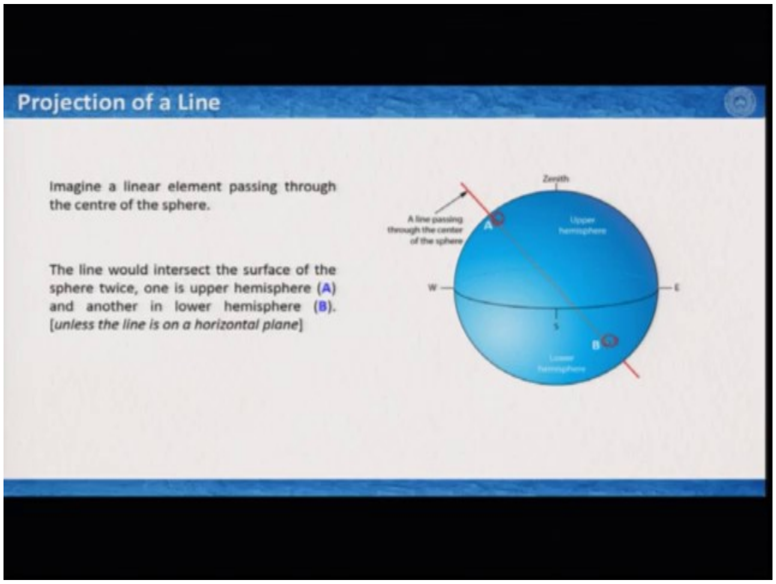

Let us look how to plot a line. Now, the fundamentals of plotting a line in the stereonet is you have a line which is inclined and you have to pass this line through the center of this sphere and also through the center of this primitive circle or projection plane. If you do that, then the line would intersect the surface of the sphere two times, one at the upper hemisphere, which is the point A here and one at the lower hemisphere, which is point B here. Now this is only possible if the line is inclined. If the line is horizontal, then it would probably lie on the equatorial plane. But that is on, that is not the case we are discussing here.

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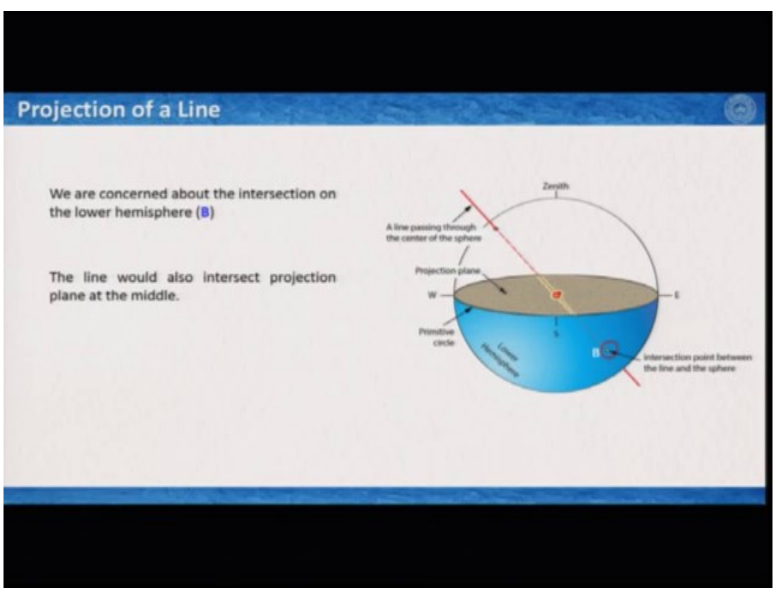

So, because we will be projecting on the lower hemisphere, we call it lower hemisphere projection. So, we will be concerned or we will be concerning with only the point B. So, this point B, if we consider which is actually the line, this would also intersect at a middle point of this projection plane or the primitive circle.

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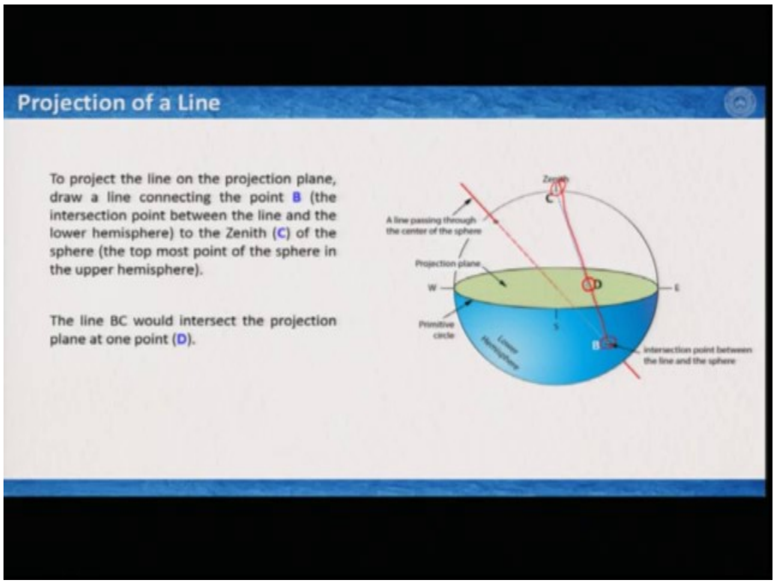

Now to project this line on this primitive circle, the task is to draw a line connecting the zenith of the sphere, which is the point C here and the point P, that is the intersection point between the line we are concerned with and the sphere. Now, while we do that when we connect this line from B to C it also passes through the projection plane and we get a point here, which is D.

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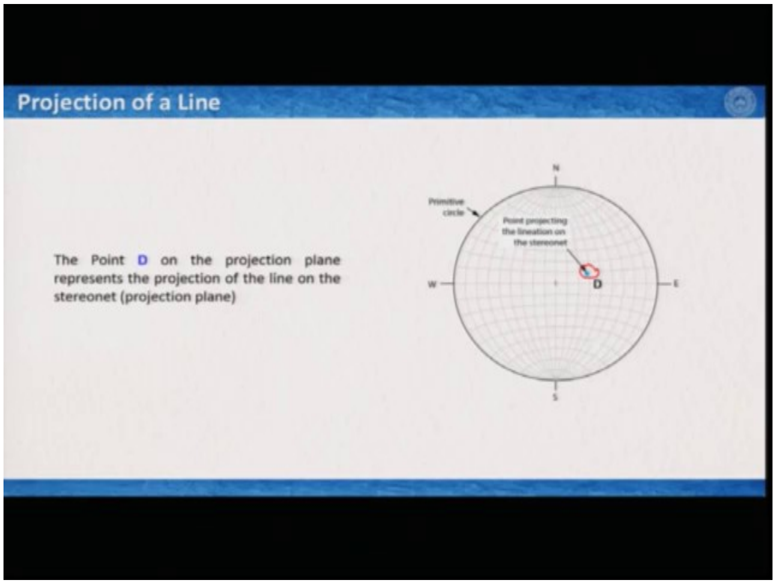

Now this point D is actually your projection of the line that we have seen before. So if I now project this circle in plane, then the point D would appear somewhere here and this is the projection of this inclined line on the stereonet.

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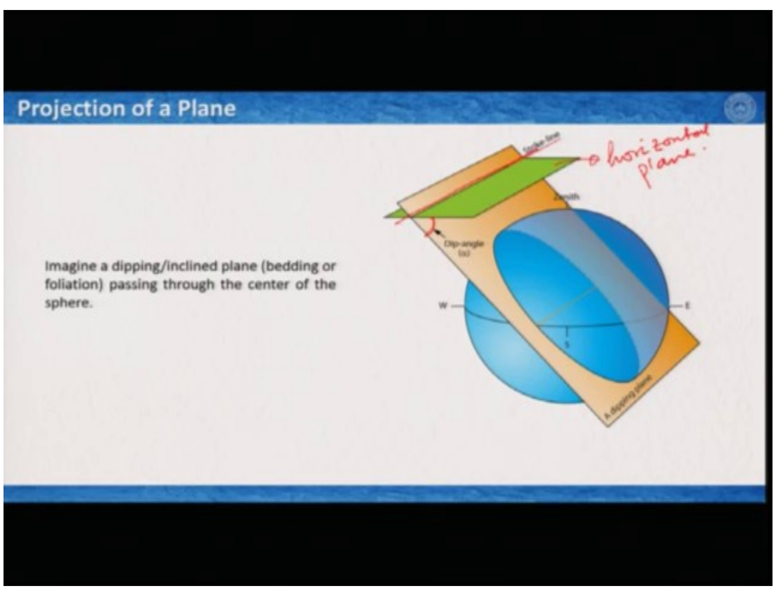

Let us have a look how to project a plane on the stereonet, or what is the basic of projecting a plane on the stereonet. It is very similar the way we projected the line, but because it is a plane, so it involves a little complexity. But first, let us define the plane. In this diagram what we see, we have this blue sphere. The zenith is there. Then this is your equatorial plane and we have a plane which is orange in color here and inclined. And also we have a green horizontal plane.

Now this green horizontal plane and this yellow and the orange sloping plain would intersect along the line, and from the definition we learnt on the last lecture, this line is your strike line and the orientation of this line with respect to magnetic north is your strike of this sloping orange plane. The angle it makes with the horizontal on particle plane is the dip angle, in this case, this is Alpha. Now this plane is inserted such a way through this circle that it passes through the center of the sphere.

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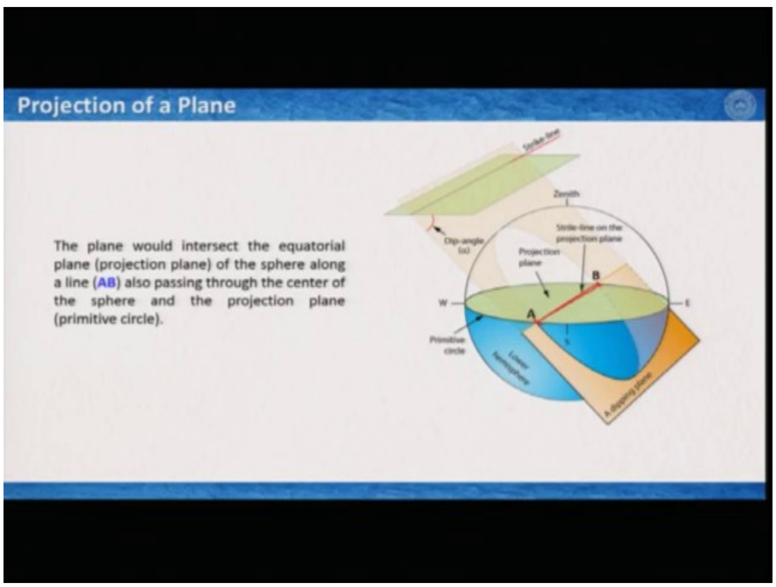

Again, we are concerned with the lower hemisphere, so I sort of made the top part little transparent to get better focus on the lower hemisphere and what we see here that when this plane is passed through the center of this sphere intersects the projection plane or the primitive circle along the line A and B. Okay, now, this line is very important because this is your strike line.

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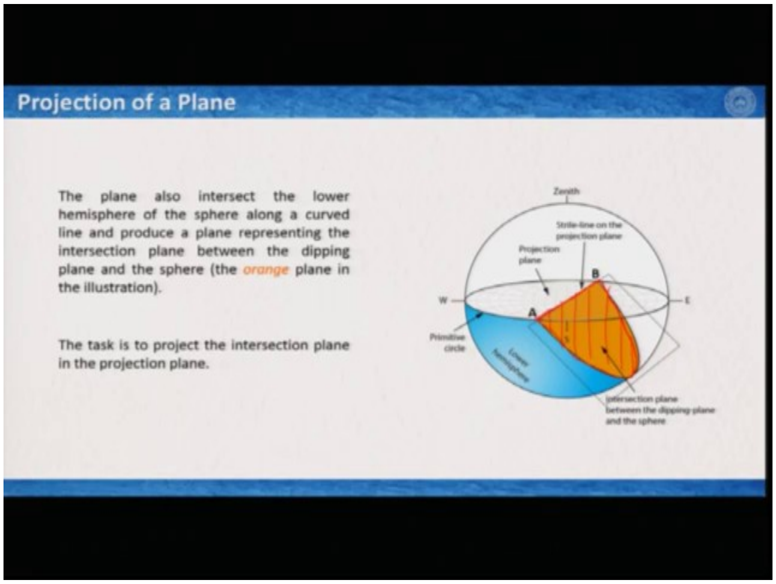

We can also figure out that the intersection of this sphere and this plane also makes an intersection plane, which is highlighted by orange color here and this is the intersection plane between the dipping plane and the sphere. So the challenge or the task is to project this intersection plane in the projection plane. And you can clearly visualize that this sort of semi circle is the actual plane we were concerned with. So we have to project it on the projection plane.

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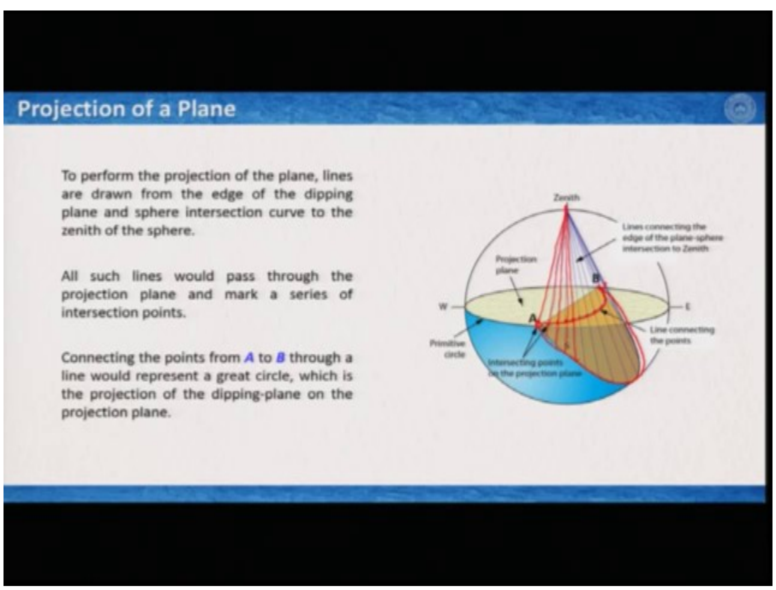

Now to do that, as we have done with the line, we will draw a series of lines from the edge of this intersection plane and the sphere to the zenith. So all these violet lines, if we can connect continuously, it would produce some sort of a cone and this cone, individual lines of this cone would also intersect on this projection plane. Now it is possible that you can connect all the points starting from A to B by a curved line. Now, this curved line is actually the projection of the dipping plane on the projection plane.

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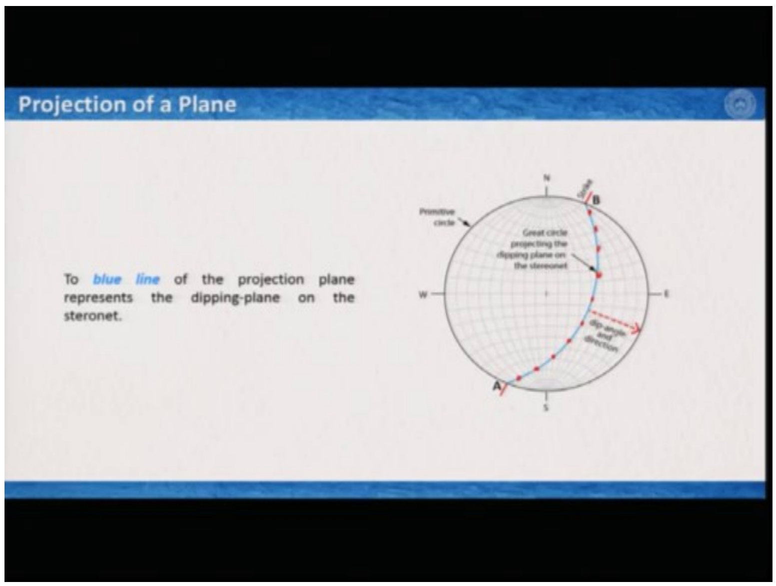

So if we now see the projection plane, only then it appears something like this. So this A and B, these are the two points and this blue line actually, these are different points that you have drawn which at the intersection lines between this plane at the lower hemisphere and connecting it to the zenith of the sphere and we have connected this points through a curve and this curve is actually the projection plane that represents the dipping plane on the stereonet and the dip angle is this one. Now how to read it or how to interpret all these types of features differently we will learn it later.

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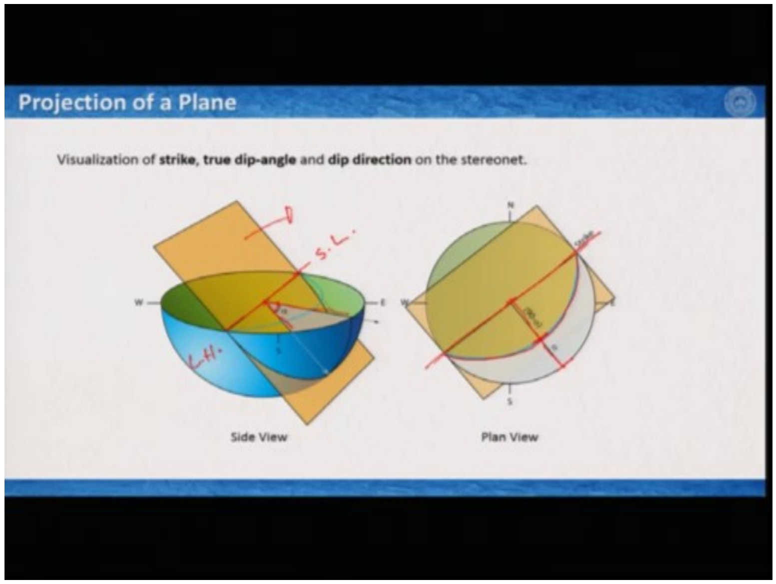

So to visualize this in a different way that whether we are actually projected our plane to the stereonet, here is a different illustration. Now what do we see here? This is the sloping plane that we are concerned with. This sloping plane passed through the center of the sphere. Now, this is the half sphere. This is the lower hemisphere. So, this line, this intersection line between the equatorial plane and this projectable plane is your strike line and this angle here is your dip angle.

Now, if I make this and see this in plane view, then this is the strike line, this is the projection of the plane and this angle defines the dip angle of this plane and rest is 90 degree minus your dip angle or which is in this case, Alpha. Let us have a look how to plot the pole of a plane or what are the basics or what are the theoretical ideas when we plot the pole of a plane on the stereonet. So pole of a plane is nothing but the normal line on the plane.

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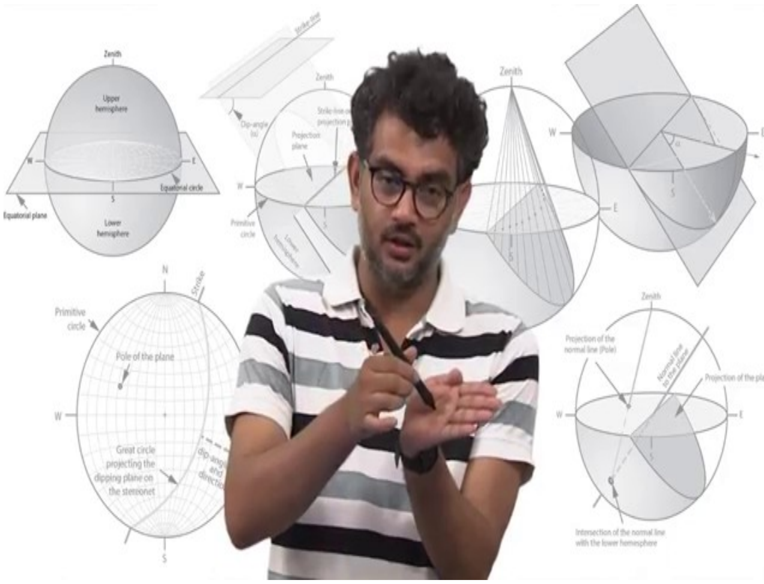

So, if I have a sloping plane like this, then the normal to the plane is the pole of this plane. Okay? The challenge is to plot this line on the stereonet given I have the plane on the stereonet.

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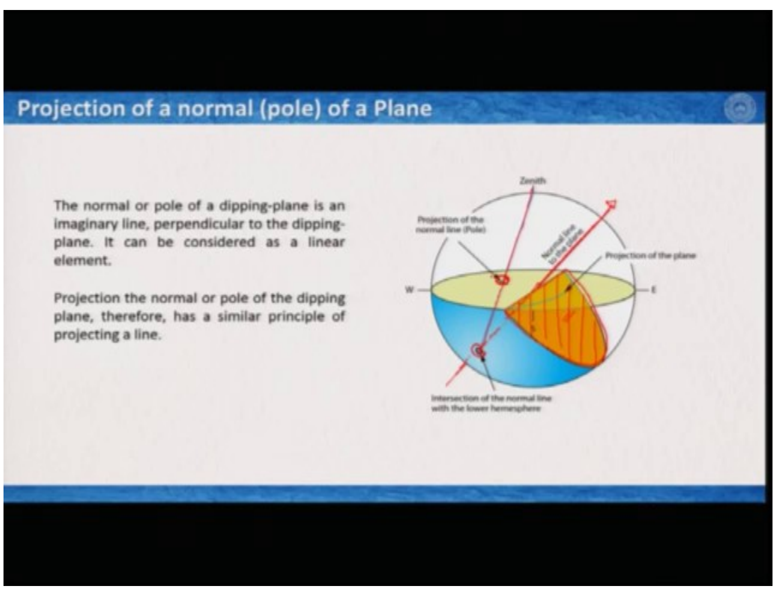

Tt is very similar the way we have plotted the line. But we use somehow different technique because we do not have the data of the line or the line is not there, we have the plane only. The normal of a pole of a dipping plane is an imaginary line perpendicular to the dipping plane and as I said, it can be considered as a linear element.

So, projection or projecting the normal or the pole of the dipping plane therefore has a similar principle of projecting a line. What we see here in this diagram? This is again you can, you may remember this is the plane we were concerned with and then we have to draw a normal on this plane. This red line here is the normal to the plane.

Now, because we will be doing lower hemisphere projection, so we will extend this line so that it passes through the lower hemisphere and intersects the lower hemisphere and here is the point where it intersects with the lower hemisphere. Now the task is simple, we have the intersection point at the lower hemisphere then we connect this point to the zenith, it would intersect somewhere on the projection plane or on the equatorial plane or on the primitive circle. And this point is the pole of this plane projected on the surface.

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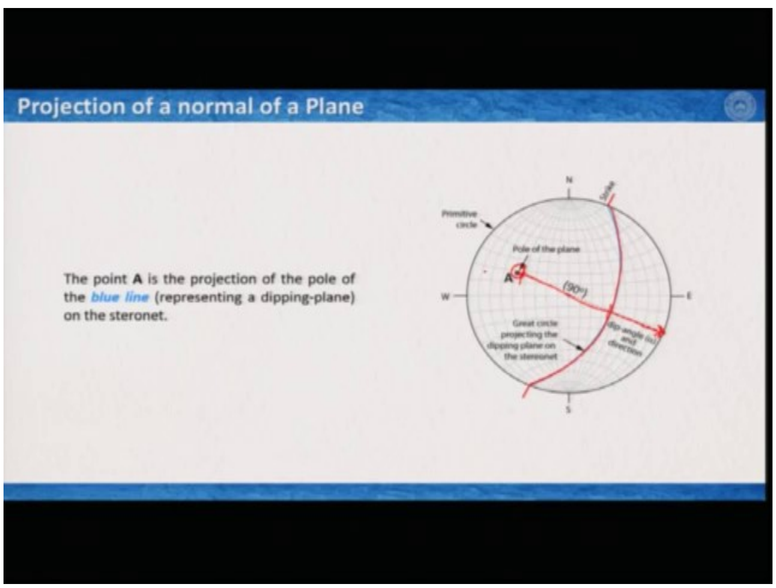

So this is how it looks like once we are ready with the projection. So the plane is similar plane that we have projected before, this blue line and now this point A here is the projection of the plane of the blue line, which is a dipping plane on the stereonet. Now, this is your dip angle, as we have seen before and this angle from here to here is 90 degree and therefore it is the pole of this plane, which is a blue line in this diagram.

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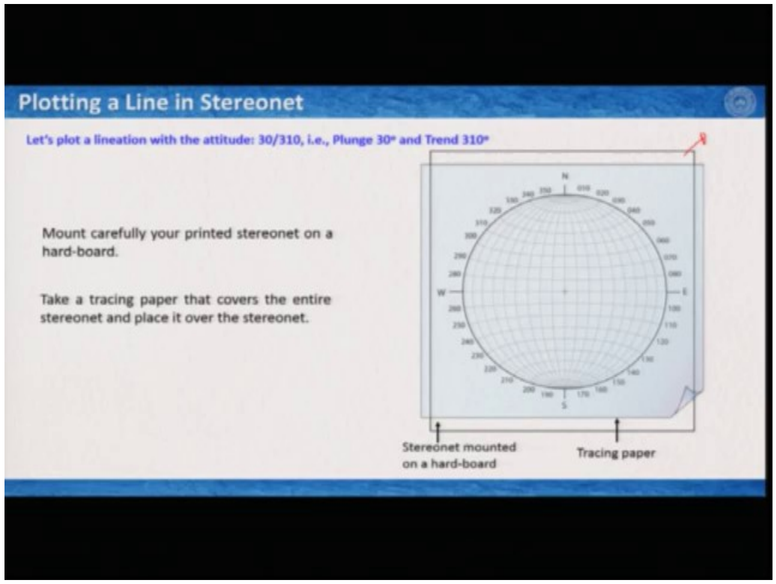

Now, I believe the concept is clear. We will try to see how if a data of plane, line or any other structural measurements are given, then how to plot them in the stereonet. Now, generally in classes, we show students directly but here because this is an online lecture, it was not possible to show you one to one or sitting on a desk. So what I try to do, I try to give a series of illustrations that would at least help you to understand how it is done.

All the illustrations are given very clearly with arrows and other features and what is being done with all these illustrations, I have given instructions or the steps written on the right side. So again, the way we understood how the projections are done, or what are the basic concepts of the projections from line then to plane and then pole of a plane will follow the same sequence and refers to it. First start with plotting a line in stereonet.

So let us start with a lineation with an attitude 30 310, that means it has a plunge 30 degrees and trend 310 degrees. To plot this data on the stereonet, you need a stereonet. You can download it from Internet but be sure that you are downloading on equal area stereonet and if you cannot find you can write to me or you can ask any of the teaching assistants, they can help you and then once you downloaded this stereonet you print it, keeping the aspect ratio constant and mount carefully on a hardboard.

Once you are done, then you have to have a tracing paper to cover entirely the stereonet. So in this illustration or in the following illustrations this background the white color is your stereonet and it will be referred as stereonet throughout. And this translucent bluish paper with a little folding on this southeast corner is your tracing paper.

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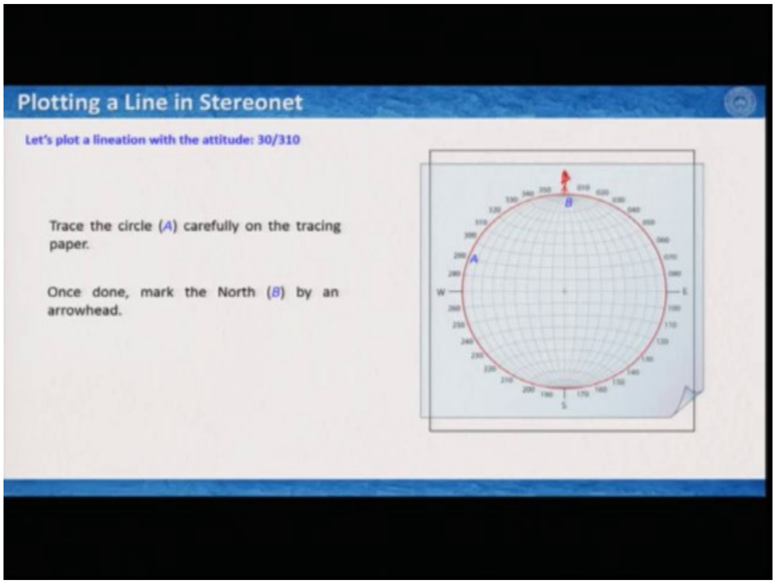

So to plot this line, what you have to do first, you have to trace the circle on the stereonet, the primitive circle on the stereonet and mark the north with an arrow head as it is done here at point B.

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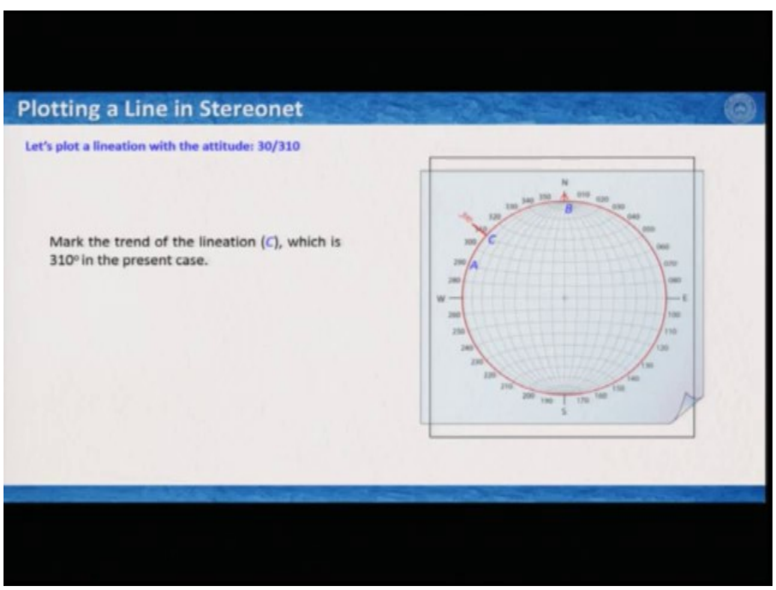

Now, our linneation trends 310 degree. So you have to find the 310 degree on the primitive circle. In this case, the 310 degree is point C in this illustration.

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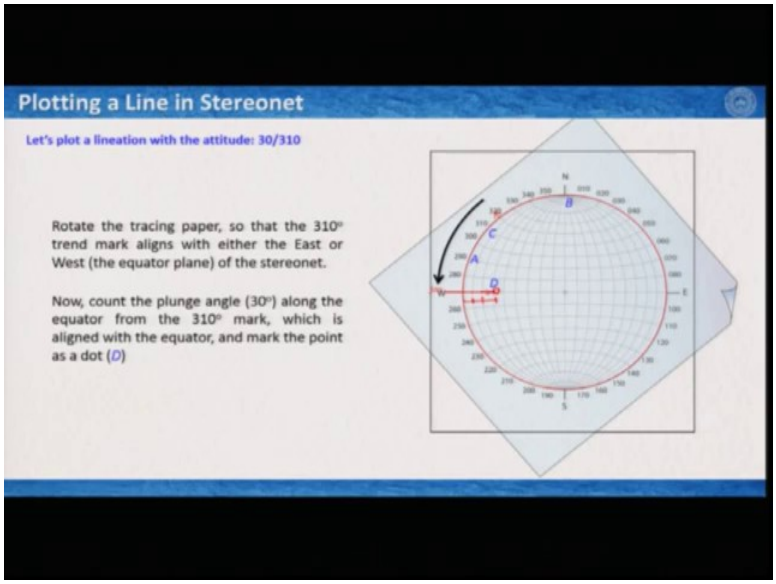

Now, you have to rotate this tracing paper such a way that this 310 degree trend mark aligns with either the east or west side of the stereonet along the equatorial plane. Now, once it is done then you count the plunge angle, which is 30 degree along the equator from the 310 degree mark which is aligned with the equator and mark the point as D. So in this stereonet, which is at the bottom, each grid is 10 degrees. So here we count 10 20 30 and we arrive at this point D.

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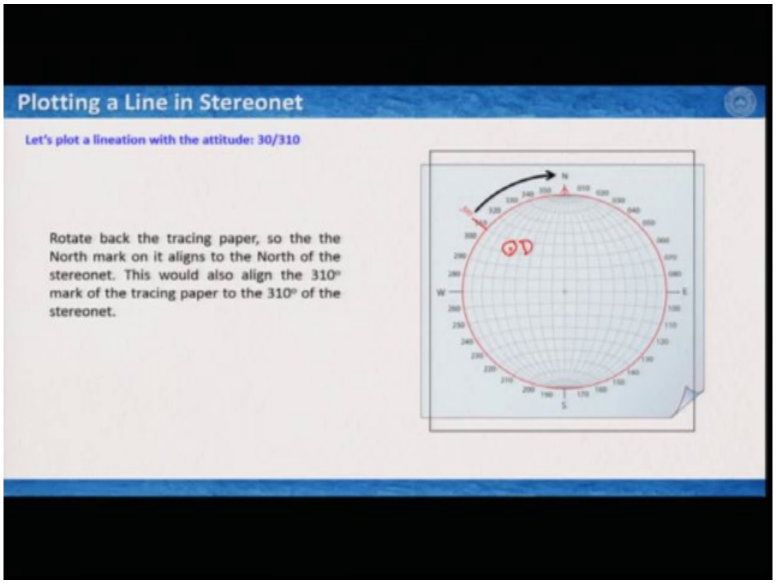

And then once you are done then you rotate back the tracing paper so that the north mark on it that you made on the tracing paper at the very beginning aligns to the north of the stereonet and this would also align simultaneously the 310 degree mark on the tracing paper to the 310 degree mark of the stereonet. Now, this would also rotate this point D that you have marked in the previous step.

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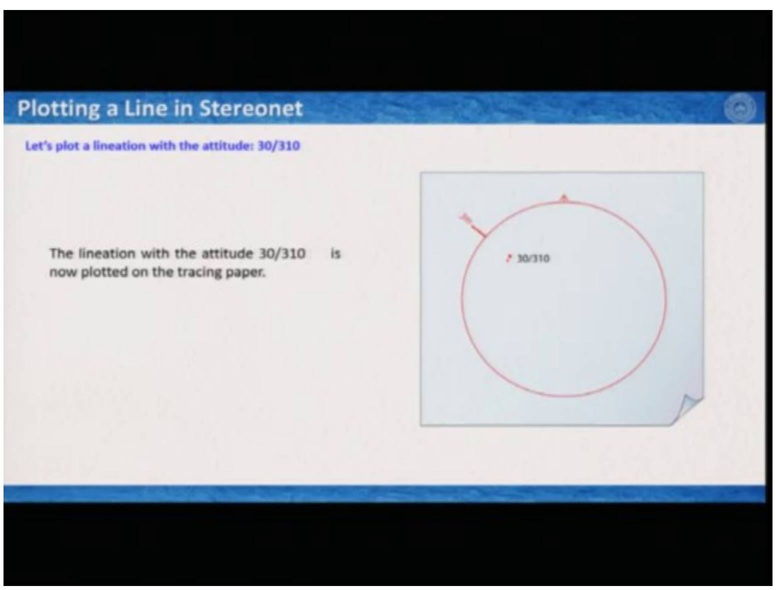

So this is the point D and this point is the plot of the lineation with the altitude 30 degree 310 on the stereonet.

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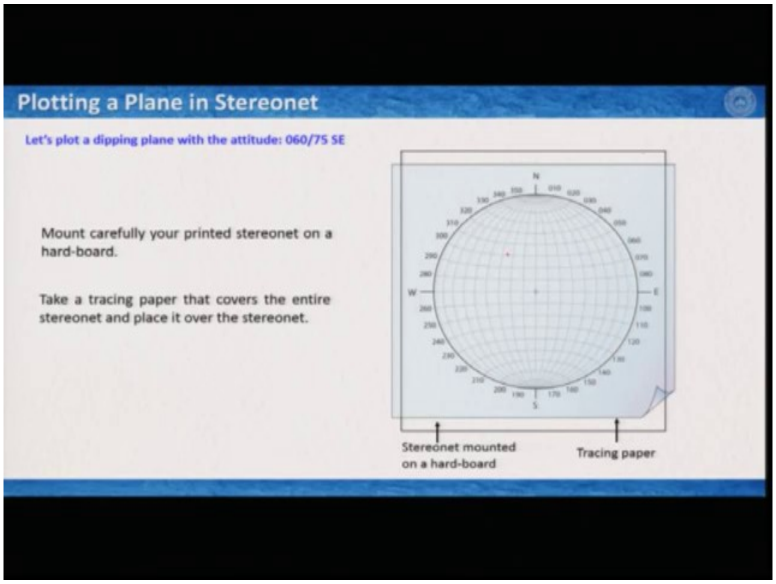

Now, let us see, how we can plot a plane on the stereonet. In this case, we have the example of a dipping plane with the data 060 slash 75 degree southeast. That means its strike is 60 degree. It dips 75 degree towards southeast direction. Now the initial steps are very similar, that means you have to mount carefully your stereonet on a hardboard and then you have to find a tracing paper that covers the entire stereonet and then you place it over the stereonet.

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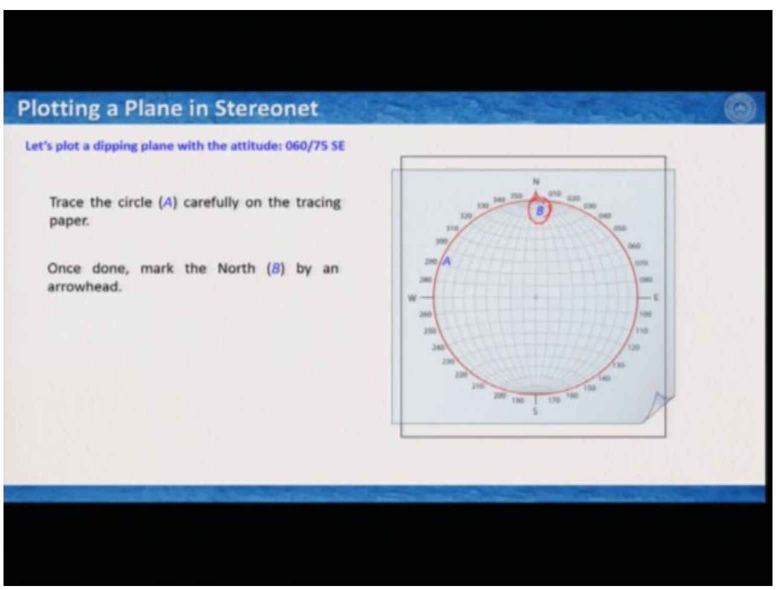

Again, you mark or you trace the primitive circle on the tracing paper and you mark the north, which is here the point B on the tracing paper.

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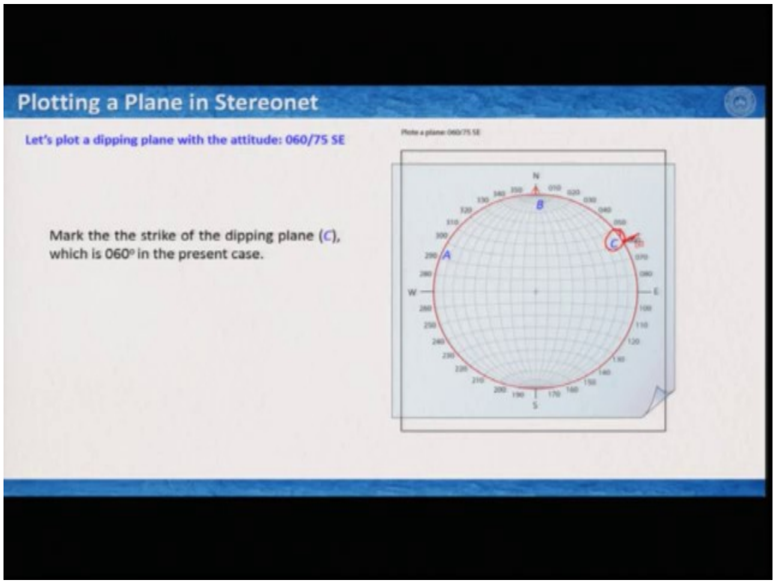

Now, as the strike is 60 degrees, so in a very similar way you mark the strike 60 degree on the tracing paper, the way it is done in the previous step and then you this time you do not align this 60 degree towards the east or west, you align this to the north.

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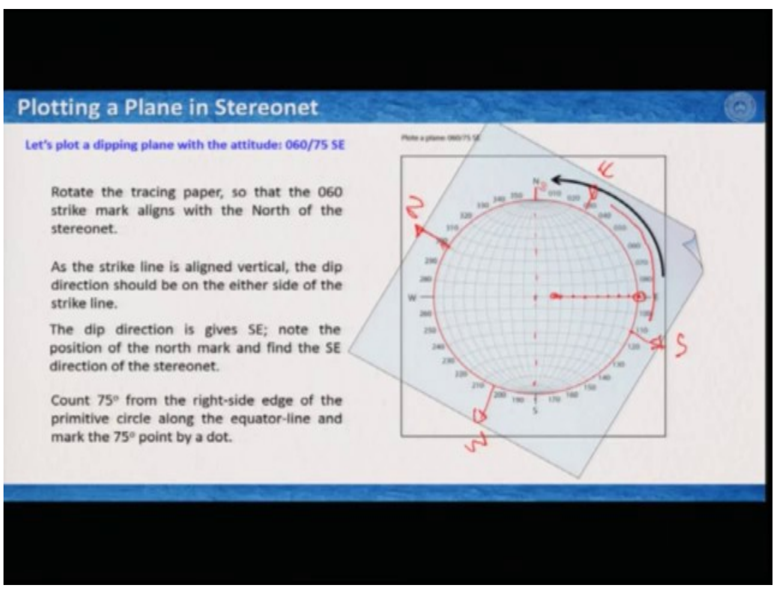

So you rotate the stereonet such a way that it aligns to the 60 degree, the 60 degree mark to the north of the stereonet okay. As the strike line is aligned vertical because this is your strike line and you can see this is aligned vertical, so the dip direction should be on either side of the strike line.

So if I have this my strike line, it can dip either this side or it can dip either this side unless the bed is not vertical. But in this case, it is not vertical. We know it is dipping 75 degree towards southeast. So now I have rotated my stereonet and with this arrowhead here, I know that this is my north. If this is north then this is my south, this would be west and then this would be east.

If this is so and the bed is dipping on the southeast side so it must dip in this direction. So we have to count therefore from the east or the equatorial intersection here, 75 degree towards the center of the stereonet. So again, the grids are 10 degrees. So you count 10, 20, 30, 40, 50, 60, 70 and here you have 75 degrees and you mark this 75 degrees point with a dot.

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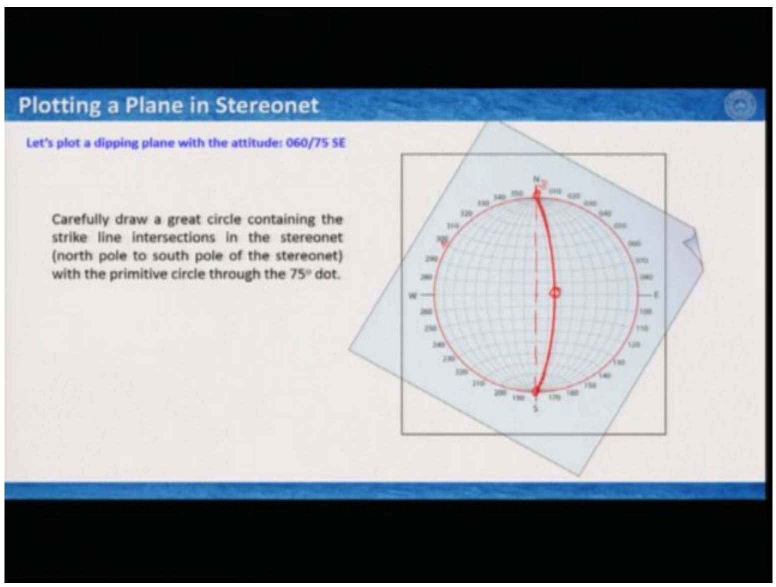

Now this task require requires a little skill but with practice you can do it very easily. What do you have to do? You have to carefully draw a great circle containing the strike line intersections. That means your North Pole and South Pole and the 75 degree dot that you have made on the previous step. These other great circles, which are printed below, would guide you to draw the great circle.

Please note you cannot draw a straight line. If you draw a straight line, then you will indicate that your plane is actually vertical but this is not because it is dipping 75 degree towards the southeast direction. So this is how you carefully draw a great circle containing North Pole, South Pole and the dip angle 75 degree that you have plotted on the stereonet.

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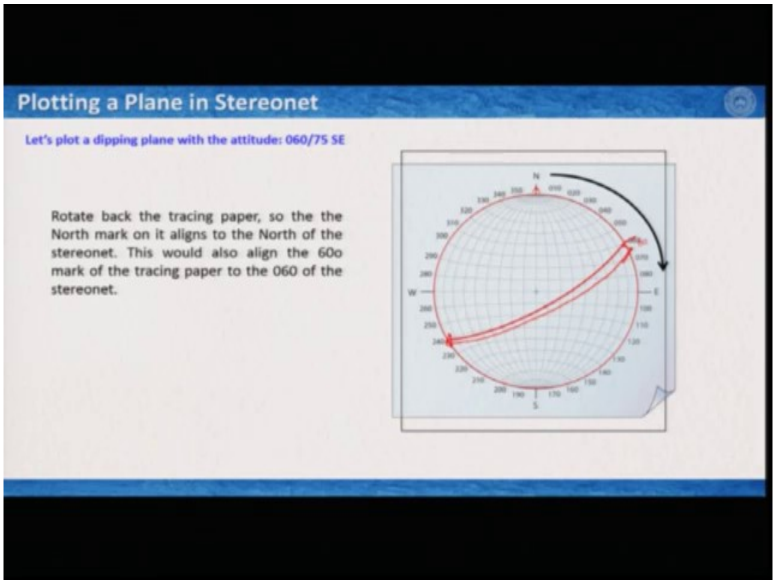

Now your task is to rotate the stereonet back again and align your north mark on the tracing paper to the north mark of the stereonet, doing so your 60 degree mark on the tracing paper would also align to the 60 degree mark of the stereonet and the great circle that you have drawn in the previous step it would appear like this and this is the projection of the dipping plane 60 degree, 75 degree southeast.

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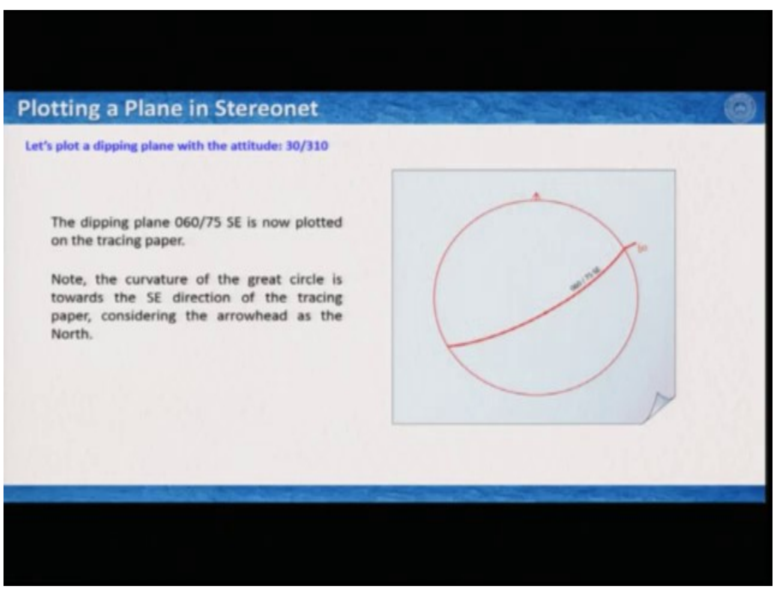

So if you take off it from the stereonet it would look like this. You just write the value here. What is the data of this plot? And you are done by plotting a plane on a stereonet.

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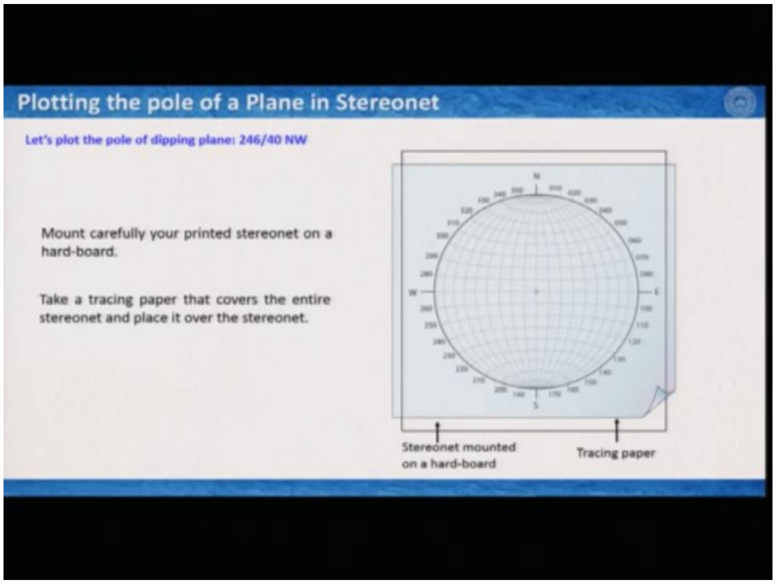

Let us have a look how to plot the pole of a stereonet. I remind you, pole of a plane is nothing but an imaginary line which is normal to the plane. So we will follow the similar process and in this case, we have the dipping plane with the data 246 degree, 40 degree northwest. That means the strike is 246 degrees. 40 degrees is the dip angle and it is dipping towards Northwest. We will follow the similar procedure, that means we will, mount the stereonet on the hardboard. We find the tracing paper and cover the interested unit with the tracing paper.

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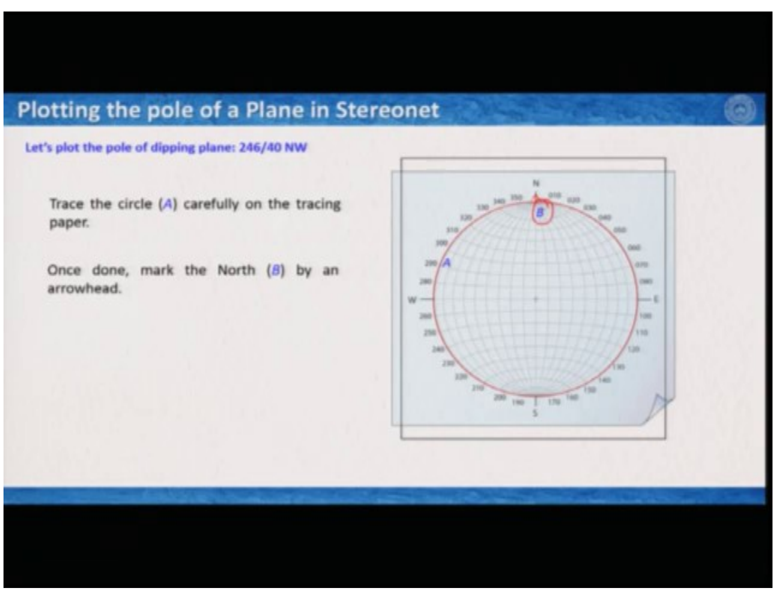

Next stage is to trace the primitive circle on the tracing paper and mark the north on the tracing paper which is point B in this illustration.

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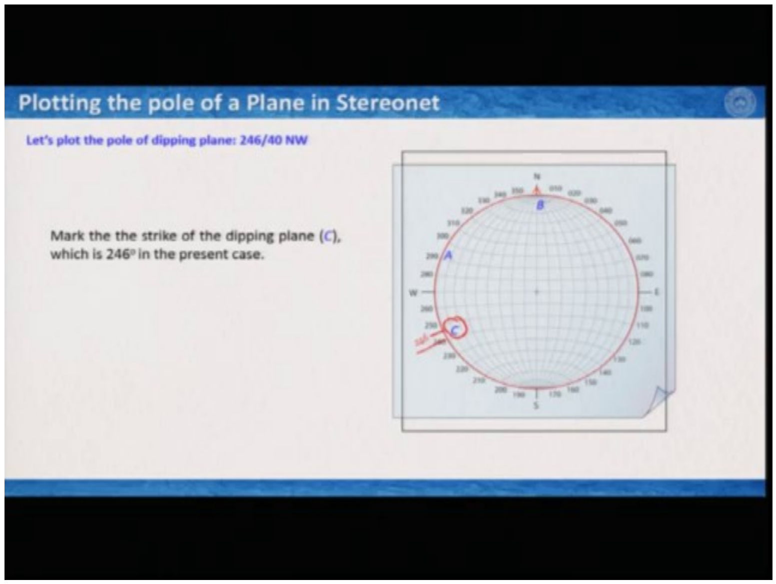

Now our Strike line is 246 degrees. So we have to mark 246 degree on this primitive circle based on the data which we have at the stereonet. So in this case, this is your 246 degree marks that is point C here and this is how you mark it. Now we will follow very similar process.

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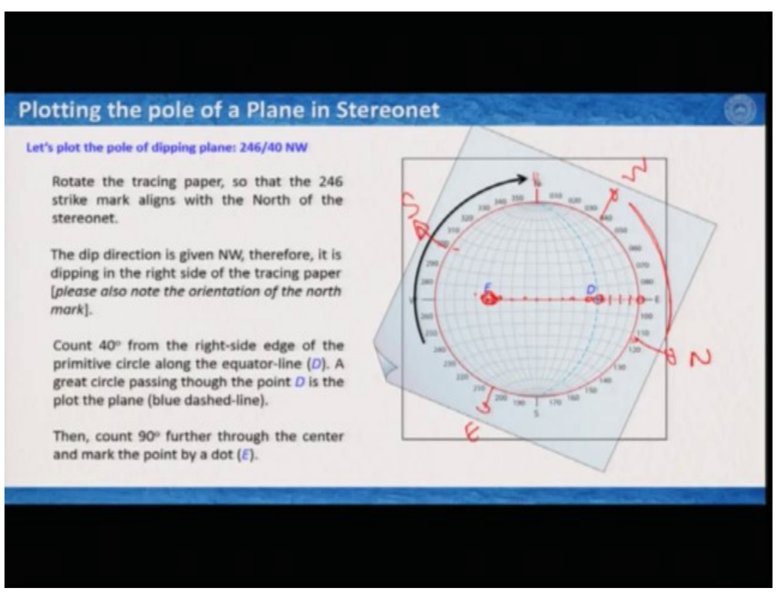

Now, this 246 degree mark we will rotate it such a way that it aligns with the North of the stereonet. Now, once it is done, we will follow the same practice. This is the north, so this must be the south, this must be west and this must be east. This is based on the orientation of the tracing paper because north is always marked. And what do you see that the dipping plane is dipping 40 degrees towards northwest. So in this case, it must be on this side. So again we can count 40 degrees, which is the dip angle.

So 10, 20, 30, 40 and we get our dip angle here in the stereonet. But that is not the end, because we have to plot the pole. Pole is 90 degrees added from the dip point towards the center of the primitive circle. So we further proceed counting 90 degrees from this point. So 10, 20, 30, 40, 60, 70, 80 and we come to 90. Did I make a mistake? 10, 20, 30, 40, 50, 60, 70, 80, 90. No, it is right. So this must pass to the center of this primitive circle and this point, E you can mark by a dot.

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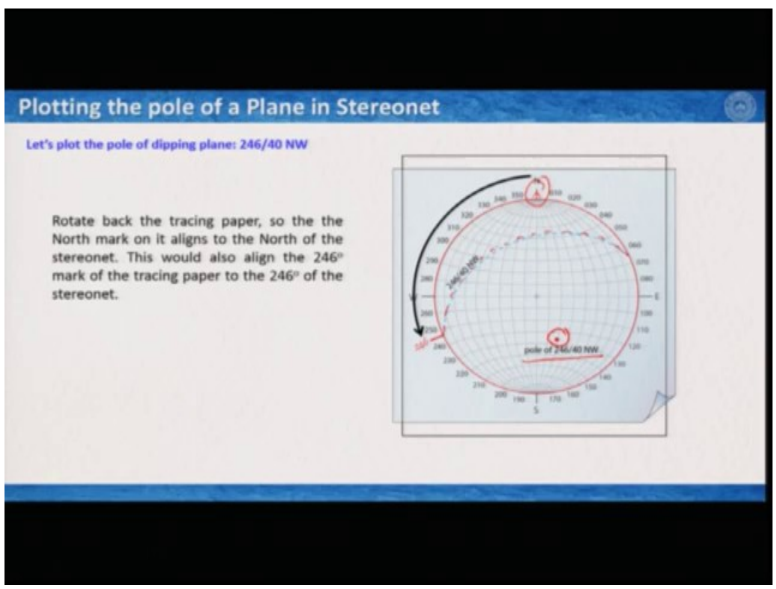

So again you have to rotate it back so that this 246 degree marks comes back to 246 60 degrees and also the north that you marked on the tracing paper aligns to the north of the stereonet. In this case, what we see this point E that we have marked in the previous slide is actually the pole of this dipping plane 246 degrees 40 degrees northwest and if you would see that this blue dotted great circle is actually the projection of the plane 246 degrees 40 degrees northwest.

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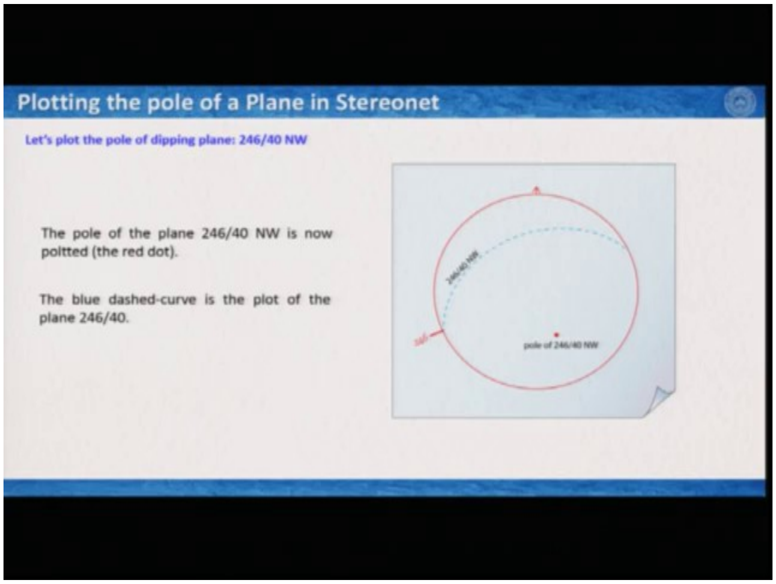

And if you take it off from the stereonet it would look like this.

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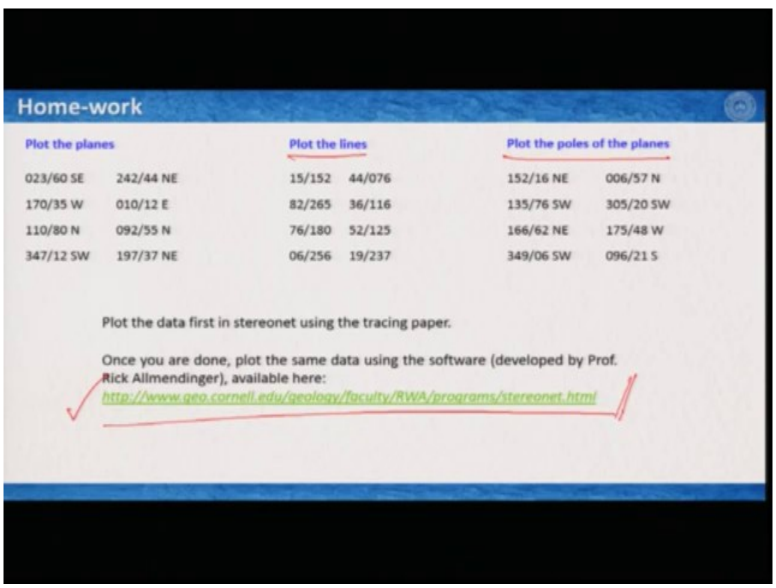

Okay, so because we are doing it here online and I just have given you some illustrations and some advices how to plot it but you can do it sitting at your home or at your classroom. So I have given a series of data, 8 data for plotting the planes, 8 data for plotting the lines and 8 data for plotting the poles of the planes. You do it manually the way I have advice to you; once you are done and to see that if you are done it correctly, you can actually download a stereonet software from this website. The link is given here and you can check whether your manual plottings are correct by plotting them also with the softwares. And if you have any questions, you can always write me back or you can contact the teaching assistants.

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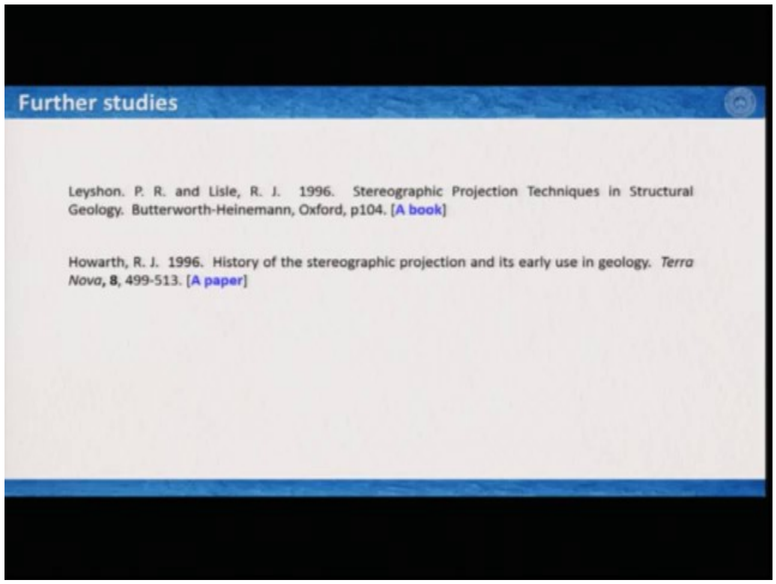

If you are interested with this operations and would like to know more then I have given two references you can download them and read them. These very interesting to read and you would have a very good idea and you will be a skilled expert of stereonet if you follow these texts and do the exercises which are given in these two PDF's.

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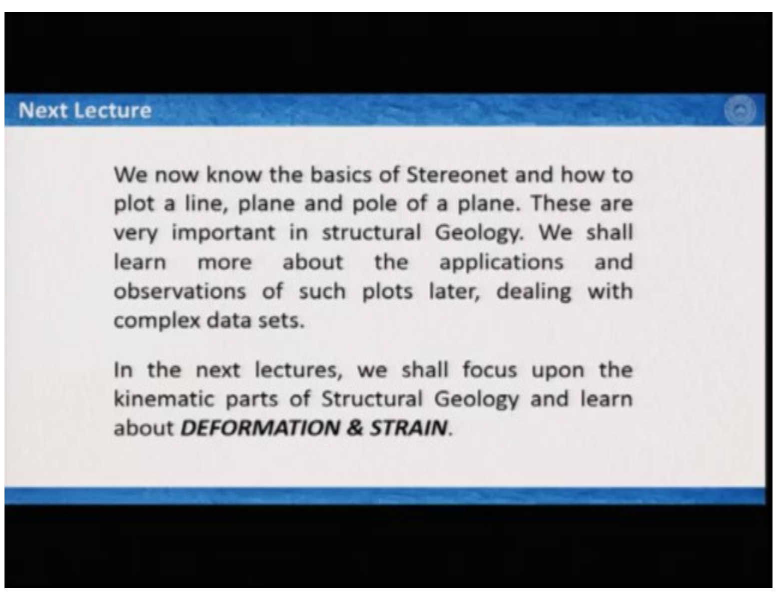

What we have learnt today in this lecture that the basics of stereonet, different components of the stereonet and we learnt three very basic plotting- how to plot a line, how to plot a plane and how to plot the pole or normal of a plane. These are the very basics but on the fundamentals of these basics we structural geologists do very complex analysis and sometimes simple analysis as well. So we learn all this analysis in time when we learn about more complex structures, we will deal with complex data sets but for the time being we are done with the stereonet.

With time with associated lectures, we will include the exercises with stereonets. For example, if I have two differently dipping planes of a fold, then I can figure out what is the fold axis using a stereonet. If I have the data of fault planes I can and the lineations and other features, then I can figure out what is the direction of the fault movement using the stereonet. So this is how this stereonets are useful for structural geology but we learn it in course of time. So in the next lecture will focus on the Kineamatic parts of structural geology and we will learn more about deformation and strain. Thank you very much and bye for now.