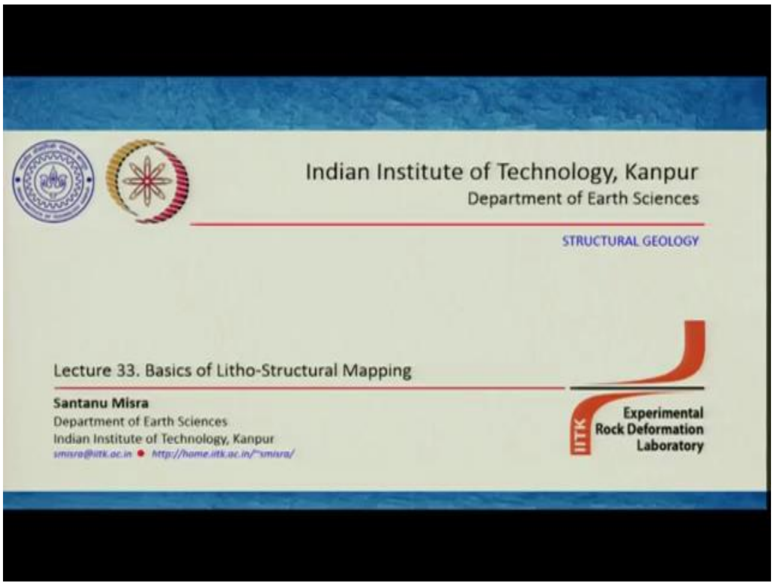
Structural Geology
Professor Santanu Misra
Department of Earth Sciences
Indian Institute of Technology Kanpur
Lecture -33
Basic of Litho-Structural Mapping

(Refer Slide Time: 00:28)



Hello everyone, I hope you are doing well. Welcome back again to this online structural geology NPTEL course. This is our last week. That is week number 12 and we are in our lecture Number 33. As we have concluded in the last lecture of the previous week that we more or less have learnt the basics of structural geology.

So it is a very beginning we understood the different processes. Then we understood stress, strain. We learnt how to measure dip and strike different structural elements out of that we moved to the rheology the deformation mechanism and after that we learnt a series of important structures their characteristics, geometries, how to interpret them and these included folds, fault, joints, buddinajs and so on.

In this lecture will particularly focus on the basics of Litho-structural mapping. As a geologist it is very very important that he or she knows the basics or the methods of geological mapping. Nowadays there are many techniques which are digitized or there are many equipments which are essentially helpful or reduces time and also you do not have to go to the field always.

Some you can use some satellite images and you can use several techniques or modeling techniques to interpret some very interesting geological feature that sometimes we cannot interpret going to the field. But as an undergraduate student it is important that you understand the basics of structural geology and its mapping techniques.

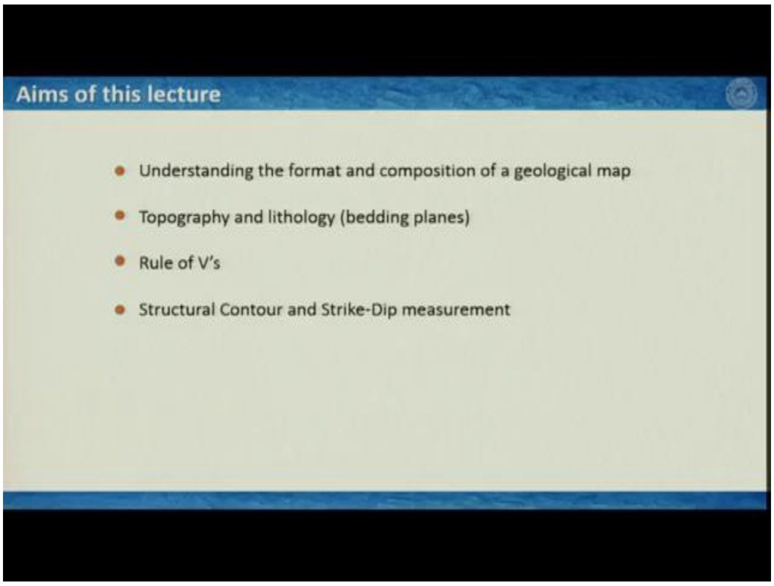
This lecture will particularly focus on that having said this I must say that structural mapping or geological mapping is something that one has to learn in the field and because this is an online course it is not possible to demonstrate all these techniques. What I have included in this lecture is mostly some very basics in the sense that so far we have learnt about the structures their geometries and so on. These we mostly considered about their geometries there dispositions and so on and we restricted them inside a block diagram either in three dimensions or two dimensions.

Now we have not considered that how they would look like in the field. Well we have seen some outcrop patterns of superposed folds and so on also it we learnt about them in the fault lectures. But again and the surfaces that we constructed that this would be the map view was essentially a flat surfaces is not it.

But you know that earth surface is not flat even within 10 or 15 meters it can be extremely unrelated and therefore the interaction of the structures with the earth surface is something very important to consider and understand to particularly figure out the local and regional structures.

In this lecture will mostly focus on that and we will figure out the processes that one can have some ideas about litho-structural mapping. We will learn some very basics will not go into the complex structures we even do not go even deformed structures for example will not going to include fold, fault and so on but we mostly restrict our self on a flat bed which is dipping differently and we will see how and why we can interpret different structural features out of it.

(Refer Slide Time: 04:28)

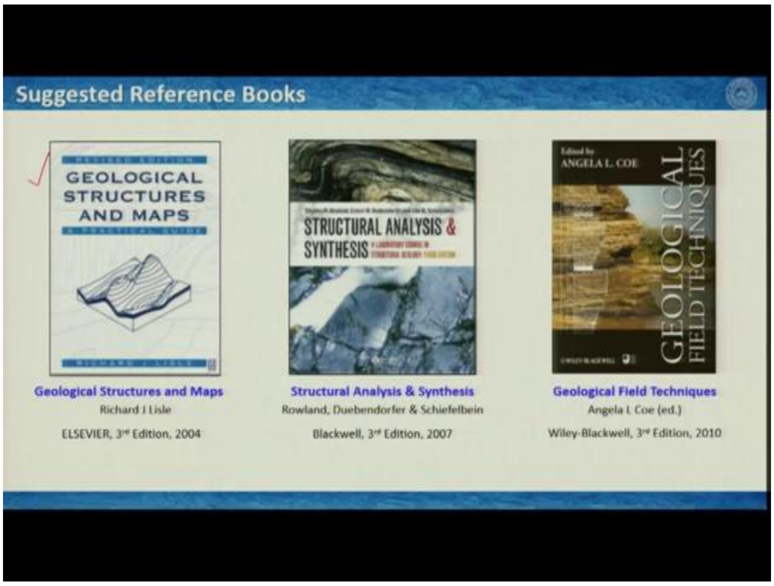


Continuing this we will learn in this lecture some very basic formats and composition of a geological map. Then will try to understand what is topography and its interaction with the lithology and mostly bedding planes or any planer fabrics that how they interact with each other.

After that we will see when you are discussing this topography and lithology will discover that there is something very interesting which is rule of V and finally will figure out that even if a bed or a feature is not exposed on the surface that where you cannot measure dip and strike but you can have the line which is connecting the two different lithologys on the surface of the Earth which is contoured which is which has a topography then how to calculate the strike and dip with the help of structural contour.

So, let us start with the very first Idea and the books I have suggested you at the very beginning of this lectures may not be very very helpful in understanding this lecture or feature analysis related to structural maps and so on.

(Refer Slide Time: 05:40)



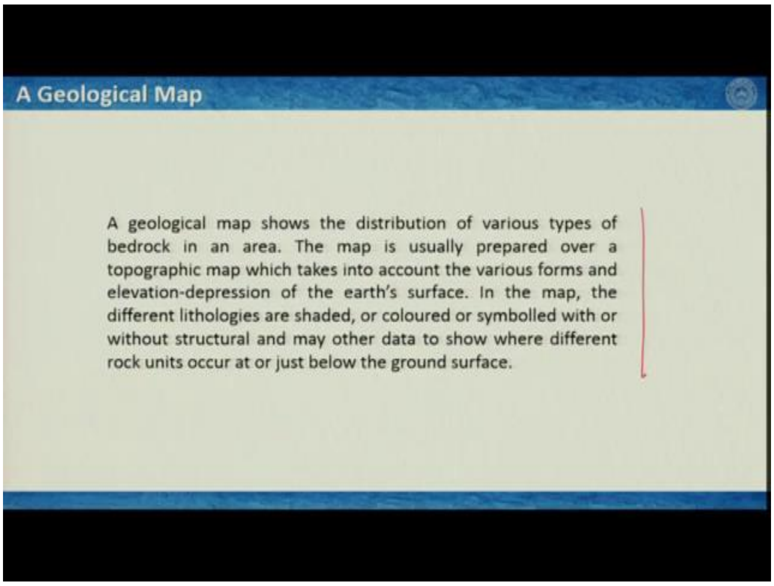
So here are 3 books that I personally like and I also would like to recommend this books for this particular class and also a for your future reference. The first one is geological structures and maps written by Professor Richard lisle this is a published from Elsevier 3rd edition 2004.

The second book is structural analysis and synthesis it is written by Rowland Etel published in 2007 from Blackwell and the third one is one of the latest once it talks about geological field techniques Angela Coe edited this book along with 4 or 3 coauthors I exactly do not remember but this is published in 2010 and it is from Wiley and Blackwell.

Now, I personally would recommend the first book a must to have if you would like to continue with geological mapping and to be very specific with the structural geology. The second and third book interestingly deal with many many techniques that you should learn in the field it gives you the very basic ideas what is dip? What is strike? How to measure it? How to hold the compass? How to take the reading? How to take the reading On the Notebook? How to interpret them? How to construct things in the field directly and so on.

These are very handful but again these are not the scope of this lecture I hope in future I can come up with another course I have to design it differently on geological mapping and so on particular with Emphasis of structural elements. But these 3 books are very very important and in this lecture whatever I am going to show you is mostly derived from the book of Professor Lisle the illustrations and diagrams I have redrawn it but it is essentially from his book.

(Refer Slide Time: 07:29)



So what is the geological map? You know all this what is but this is how more or less you can define it a geological map a describe it in way it you do not have to define everything. A geological map shows the distribution of various types of Bedrock in an area. The map is usually prepared over a topographic map which takes into account the various forms and elevation depression of the Earth surface.

In the map the different lithologies are generally shaded or coloured or symbolled with or without structural data and may other data to show where different Rock units occur at or just below the ground surface.

So many things are written here let us take the highlights of these statements. So for this first of all a geological map essentially gives you the surficial data maybe few meters or few tens of meters and so on. So what you see on the surface is essentially included in the geological map looking at a geological map you may not conclude what is happening at 10 or 15 kilometers down or even 1 kilometer down it may be completely different.

And then therefore a geological map essentially represents the various features various Rock types that you see in the field and you compose them together with the different Rock type that we have seen their contacts and so on. And generally, the map if it is very large scale map it is done over a topographic map which you can consider that this is a reference of your area and the topographic map is very very useful we have a couple of slides and topography and it is a topographic map and its usefulness and so on.

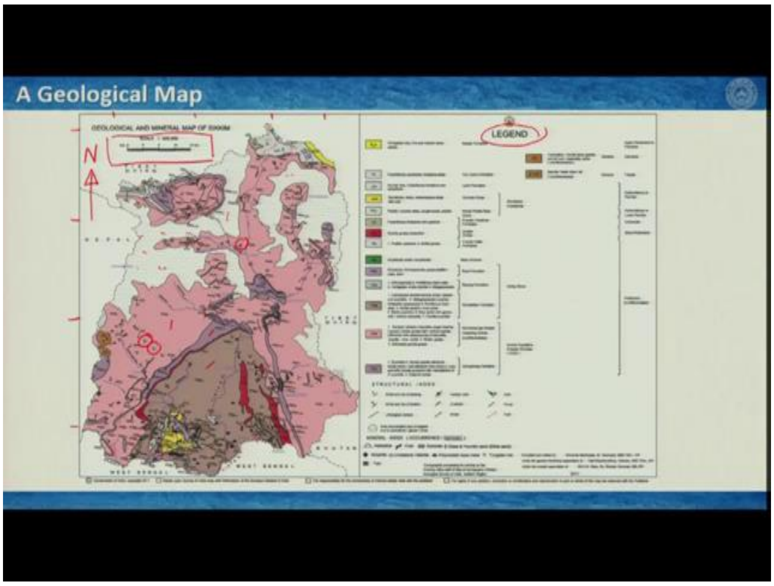
So generally large-scale maps are drawn over topography topographic maps but you can also considered a plane paper mapping and so on. If we have to do a very detailed mapping in say a 10 meters by 10 meters area then topographic map is not that much useful because topographic maps are generally very large scale. Again, these are different techniques but there are large scale mapping and plain paper mapping in large-scale mapping you need the help of topographic map but in plain paper mapping no.

The primary thing in a geological map is mostly the lithological contacts and their disposition on the surface but if say a lithological contact is faulted then you can use some symbols and therefore you start introducing the structural elements on your map or maybe you have series of lithologies planar lithologies and their deep into a certain direction so you can include the strike and dip in the map and therefore you again introduced the different structural features.

For example, you see that in the field this is synform so I can use the symbol of synform you can use a symbol of anti form and so on and by this slowly add many many many information as much as you can based on you need to the geological map. People also add many other features say geophysical measurements say you can add density you can add many other features conductivity in the corresponding to particular lithology of particular feature of your map.

So geological map is essentially very very important not only for geologists not only for interpreting the structure original tectonics or know what is there but it is essentially important also for engineers for constructing dams or buildings or roads and so on. So yes this is very very important we have to learn how to read and how to interpret and how to prepare it is a geologist that is a primary job of us.

(Refer Slide Time: 11:34)



So here is an example of a geological map I took it from geological survey of India and this is what you see the map of Sikkim is a state in the North Eastern part of India. So the state is like this this part is the Whitish part that you see this snow-covered and people could not figure out the lithology and so on but you see that this map shows very nicely the different lithologies with different colours.

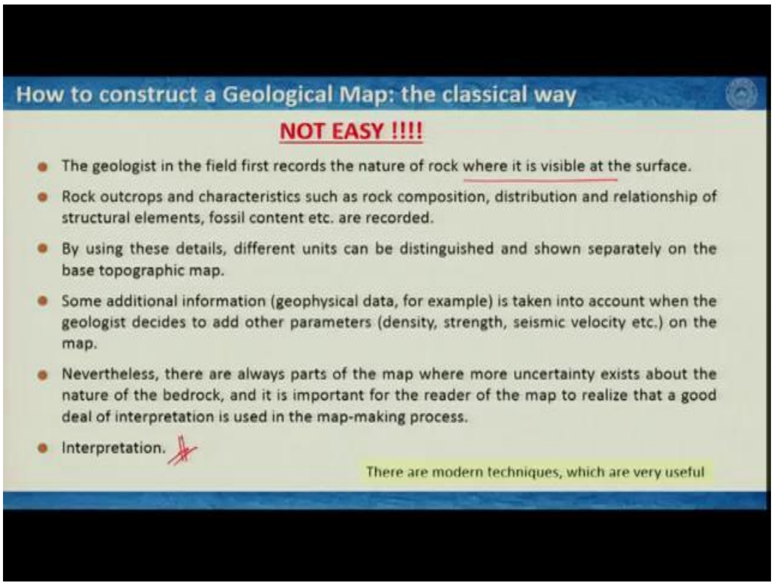
So this pink has a different lithology, this purple has a different lithology, this red has a different lithology, this grey has a different lithology and they are disposed in a different way in a map and you can see many other maps just type geological map and you will see many different features in this map.

Also you can see that here these the structural data are included there the dip and strike are included here and so on, so this also tells you a very very important information about this area and a geological map essentially comes with something called Legend. So you have to explain what are the different colours or what the different symbols are you have to explain what are the different features that you are using the line drawings and so on.

These are also very important and finally what is most important in any geological map is that you provide the scale this is very important will learn about it that what scale I am looking at that if I measure 2 centimeters in this map that means how much I am measuring in the real scale is it hundred meters is it 1 kilometer or is it 4 kilometer or even more and this is also very important that you indicate what is the direction of North sometimes people indicate the direction of North at the same time the indicate also the latitudes and longitudes in the map that also tells you where exactly in the earth you have mapped or the map is located.

So these are the very important aspects of this map apart from the different colours indicating different lithologies the different symbols of structural data and so on. You have to have a legend, you have to have a scale in your map. You have to assign what is a north direction and if possible, in the map you also if it is large scale map is suggest what is the latitude and longitude your mapping area is.

(Refer Slide Time: 13:54)



Now how this map is constructed again I am not going into the detail, but I tell you it is not a very easy task. So there are series of processes geologist in the field first has to go and then he has to record the nature of rock where it is visible at the surface and it is not visible everywhere that is quite common.

Then Rock outcrops and characteristics such as Rock composition, distribution, and relationship of structural elements fossil contents etc, the geologists to do record in his notebook and so on and nowadays maybe in the mobile phone, a laptop or with some digital mapping softwares.

Now using all these details, the geologist then distinguishes different units in the field at he has she has seen and then he tries to plot them separately in the map or on the base of the topographic map. Now the geologist can include some additional information for example of geophysical data is taken into account when the geologist decides to add other parameters like density, strength, seismic velocity and so on the map. Nevertheless there are always parts of the map where more uncertainty exist about the nature of the Bedrock and it is important for the reader of the map to realize that a good deal of interpretation is used in the map making processes.

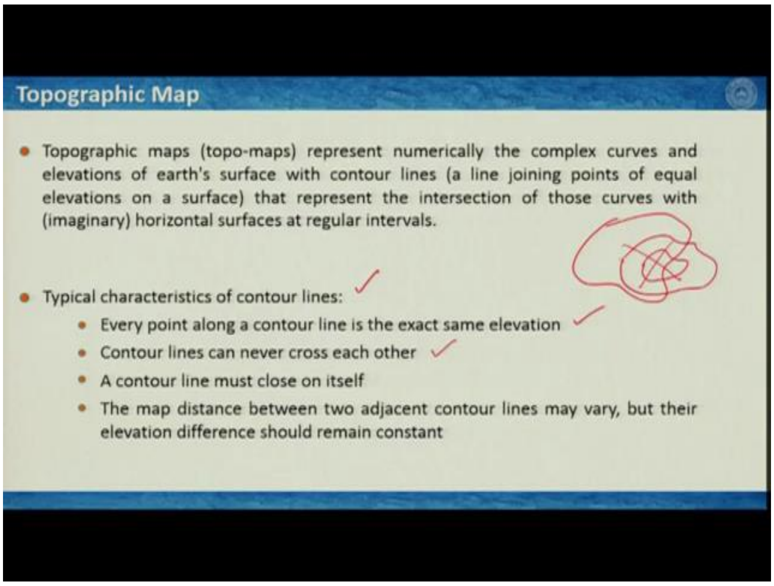
What I mean by this that it comes actually from this place that where it is visible at the surface. I do not see rocks everywhere but you map it and then you use your intelligence to interpret that if I see this rock here and if I see the same rock here how they are connected maybe your interpretation is wrong but based on your experience based on your intelligence based on your theoretical background you conclude this is how it should be someone can challenge it but this is how we always work.

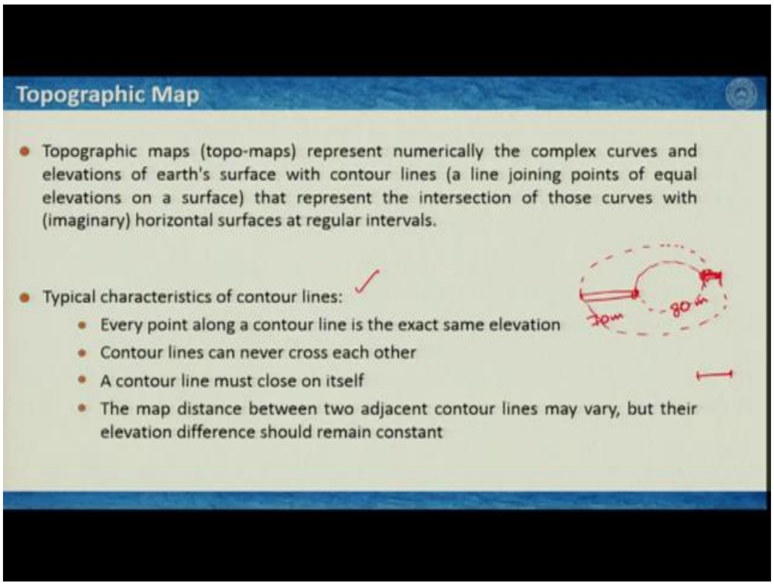
But once you look at a geological map you be sure that a lot of uncertainties are involved in this map so do not take any map as granted unless I mean particularly if it is really required for some very special jobs so better you go to the field match it that is this is what is happening otherwise you take it if it is from a good source.

And final part is of course the interpretation that once you have a geological map this is a job done but after the map is ready then it is very important that you interpret the structure you interpret the feature you interpret the lithology and so on but this is something else that you would learn in a different class a different lectures.

So, as I was talking about their many modern techniques which are very very useful, but it is also important as a student you go to the field with your field instructor structure with your teacher and learn how to hold a compass learn how to take back bearing learn how to take front bearing. You take your steps with a measuring tape and then do Different techniques because not always everywhere you will you can use all this modern techniques.

(Refer Slide Time: 17:11)





So let us talk about the topographic map for a while you know that what is a topo map we generally called it topo map or topo sheet, so a topographic maps represent numerically the complex curves and elevations of earth surface with the contour lines. Now a control line is a line joining the points of equal elevation on a surface and the contour lines I represent the intersection of those curves with imaginary horizontal surface at regular intervals.

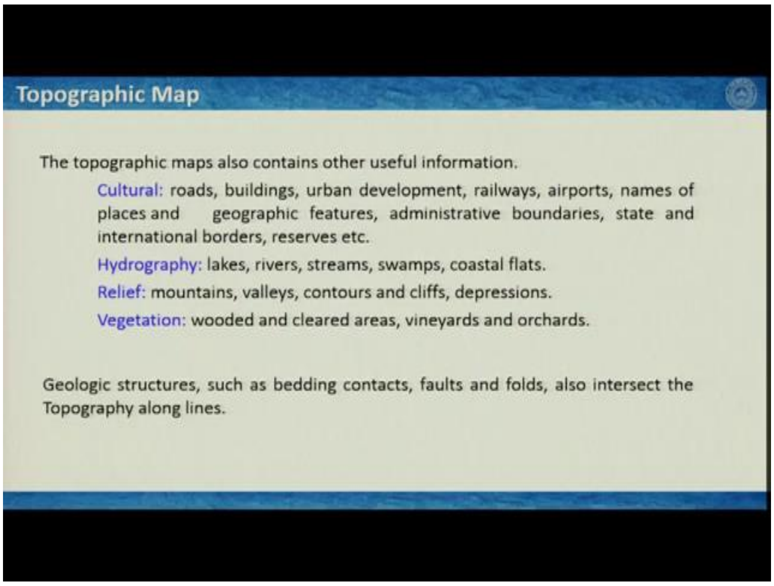
We will see topographic map and other things with some good illustrations later but a contour line or a series of contour lines should have some very special characters because the contour lines indicate equal elevation on a surface. Every point along a control line is the exact same elevation.

Contour lines therefore can never cross each other if you see a Contour map going like this going like that and then another country map like this then this is something very very strange and you discard the map immediately. So this is not something you should look at.

A contour line must close on itself. So that is also something that you need to see maybe it is not closing in your map area but it has to close somewhere and the lowest closing point is of course sea level will see that. The map distance between two adjacent contour lines may vary but there elevation difference should remain constant. What I mean by that that say you have a contour line going like this and you write this is say 80 meters then you have the next control line something like that this is 70 meters and this is your saying on a map say this is you have a scale for that.

See the map scale this distance and this distance is essentially different but the change of elevation from here to here is 10 meters and here to here is as well 10 meters so does not matter how far the contour lines are. But two adjacent contour lines always should represent a very similar elevation and that gives you an another idea when the 2 adjacent contour lines are closely spaced that means this is steeper compared to when they are spaced far from each other that means they have a gentle slope will see the soon.

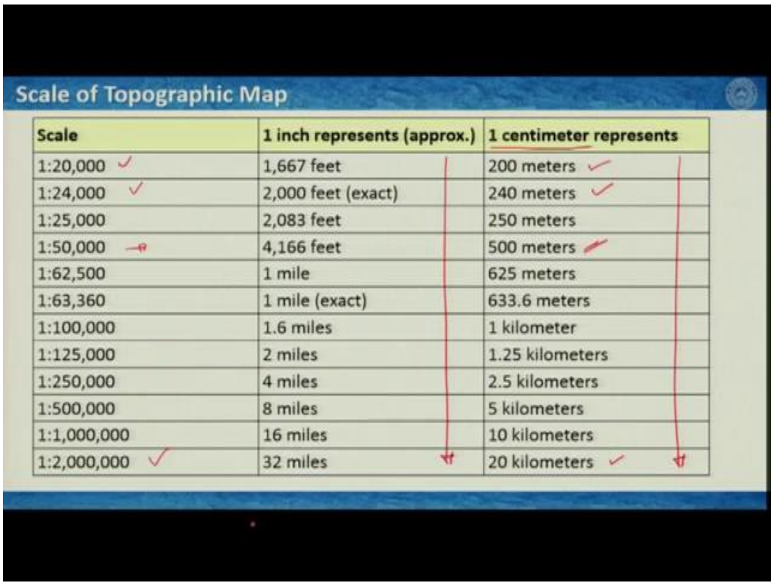
(Refer Slide Time: 19:30)



So the use of topographic map is very significant and topographic map also do contains significant information. It tells you about the roads, buildings, urban development, railways, airports, names of the places and geological features, geographical features, then administrative boundaries, state and international boundaries, reserves and so on. It also tells you about the water bodies of this area like lakes, rivers, streams, swamps, a coastal flats excreta. It also tells you because it is a topographic map about the relief of this region say mountains, valleys, contour and cliffs, depressions, basins and so on.

It also tells you about the vegetation of this area so whether this area is a jungle, wooded area, reserved forest, vineyards lands or orchards and so on. All these things all this information you get from topographic maps. So a topographic map it is not necessarily we geologists use it is used in every community particularly those who deal with the nature. In addition to that geological structures such as bidding contacts faults and folds also do interact and intersect the topography along some lines and this is exactly what you are going to learn in this lecture after a while.

(Refer Slide Time: 20:48)

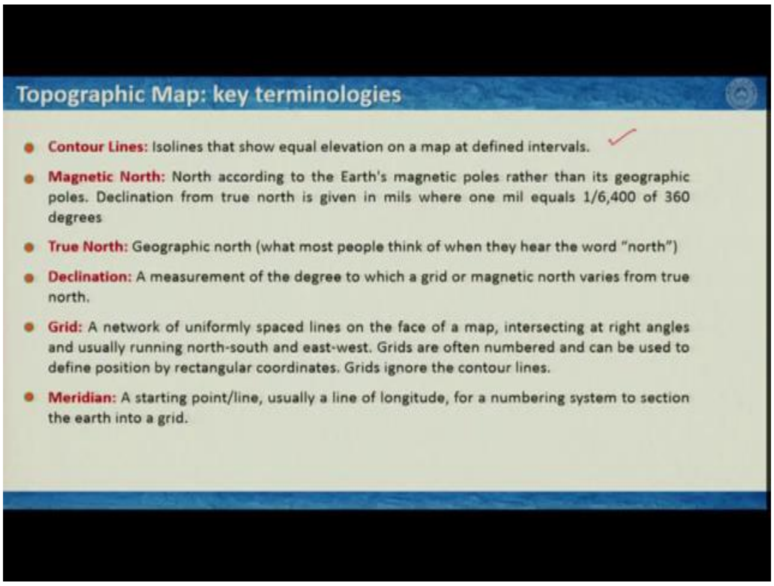


Scale	1 inch represents (approx.)	1 centimeter represents
1:20,000	1,667 feet	200 meters
1:24,000	2,000 feet (exact)	240 meters
1:25,000	2,083 feet	250 meters
1:50,000	4,166 feet	500 meters
1:62,500	1 mile	625 meters
1:63,360	1 mile (exact)	633.6 meters
1:100,000	1.6 miles	1 kilometer
1:125,000	2 miles	1.25 kilometers
1:250,000	4 miles	2.5 kilometers
1:500,000	8 miles	5 kilometers
1:1,000,000	16 miles	10 kilometers
1:2,000,000	32 miles	20 kilometers

So topographic map generally come with different scales and the scales are given generally in this for that what topographic map you have and I said 1 to 50,000 what does it mean it means that 500 meters is equal to 1 cm so this is how is it is given. So if I tell that I have a map of 1 to 50,000 that means in the map if I measure 1 centimeter by my scale or ruler that distance represents 500 meters in the actual area. So similarly you can have 1 to 20,000 that means 200 meters, 1 to 24,000 that means 240 meters and so on. And then finally 1 to 20 Lakh ratio that means 1 centimeter in the map is equivalent to 20 kilometers in the region.

So this column represents this things in centimeters or meter scale and their it is inch and miles scale. So very similarly 20 kilometers in 1 to 20 Lakh map scaled map it should be 1 inch in the map if you can measure that represents about 32 miles in the actual area.

(Refer Slide Time: 22:07)

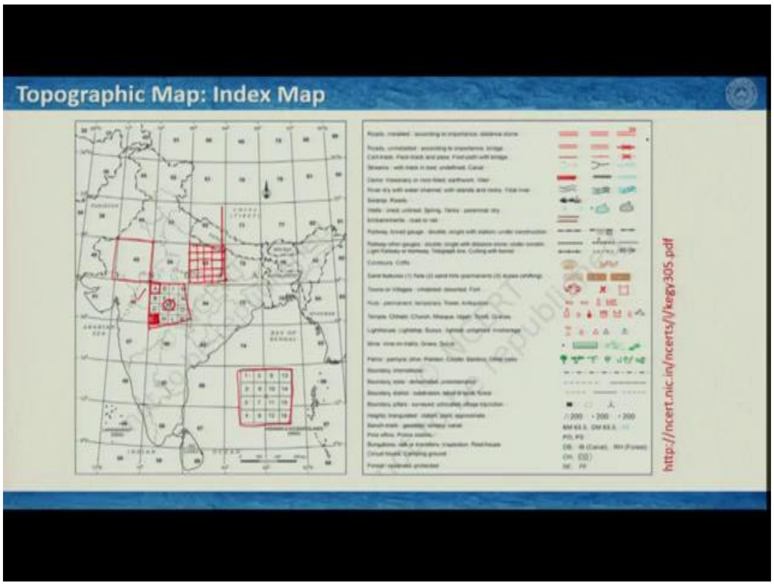


There are some terminologies that involved in the topographic map so we learnt few of them but let us have a look in in this list. So contour lines contour lines are isolines that show equal elevation on a map at defined intervals this you have learnt. Then magnetic North not according to the Earths magnetic poles rather than its Geographic poles therefore if you have magnetic pole then you must have declination, so declination from the true North is given in mils 1 mils is equal to 1 divided by 6400 of 360 degrees.

The true North is the Geographic north and this is what we all understand when you talk about North declination have learnt so a measurement of the degree to which a grid or magnetic North varies from the true North. Then grid is a network of uniformly spaced lines on the face of a map intersecting at right angles and usually running north south and east west.

Grids are often numbered and can be used to define position by rectangular coordinates and grids generally does not care about the contour lines so does not matter how steep the slope is or how gentle the slope is or whether it is flat or not grids ignore everything and generally run either north-south or east-west or if you have define them in a different way. And then you have Meridian. Meridian is a starting point or line usually line of longitude for a numbering system if the numbers continued to the section of the earth into grid.

(Refer Slide Time: 23:48)

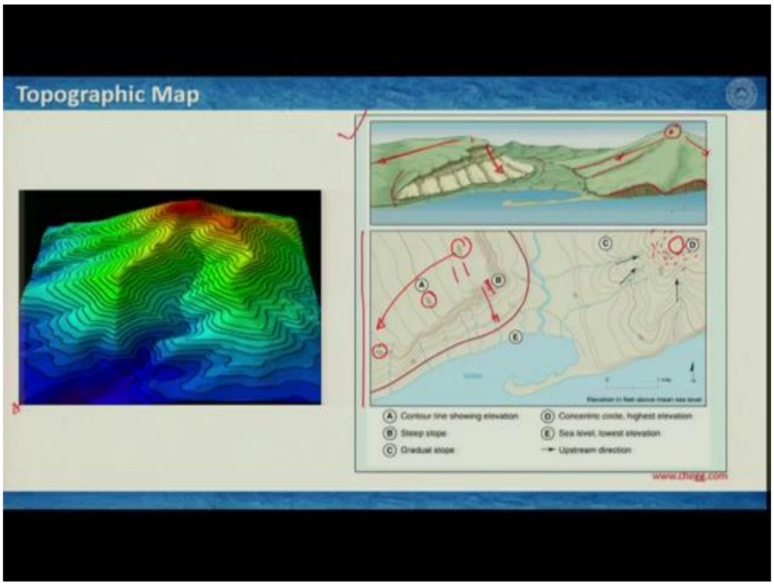


Now this is how the topographic maps are indexed. So this is our India. So India is generally gridded with this numbers for example we can have this 45 here or 63 and so on. Then this is a single grid now within this grid you actually divide this grid in 16 sub grids and then you define them as it is written here A, B, C, D, E, F, G, H up to P and then each of these grids A for example here it is given here then again you sub divided by 16 grids and then you again numbered them 1, 2, 3, 4, 5, 6, 7, 8 and so and so this process continuous.

So for example if I want map of D here then I have to say that I need 55 D and if you need a map of 55D3 that means you have this grid 55 then you have this D and then D is divided again in 16 segments and then you are looking for something here. So more numbers and alphabets you add to your topo map more high resolution you go with the mapping process and the topo map as well has legends so these are the different things that you see in the topographic maps.

So, it is important when you look at it for the first time you actually read this and see what is what that is that is also important so that once you read it will remember so you do not have to look back every time unless you forget. But it is important ones you read a map you see what it is and not necessarily in each and every map you see this Legend is attached maybe you scan something for you crop something and then the scanner thought that ok legends are not important so he cut it out or cropped it out and you do not have it so it is better you remember what is what.

(Refer Slide Time: 25:54)



Now this is how a topographic map looks like. So this is something digitally constructed so you see the colours are varying. So the highest elevation is marked by red and slowly it is going to the cooler colours to the blue and you see that these black lines these are actually making your equal elevations in this region. But this image here is representing in a much better way.

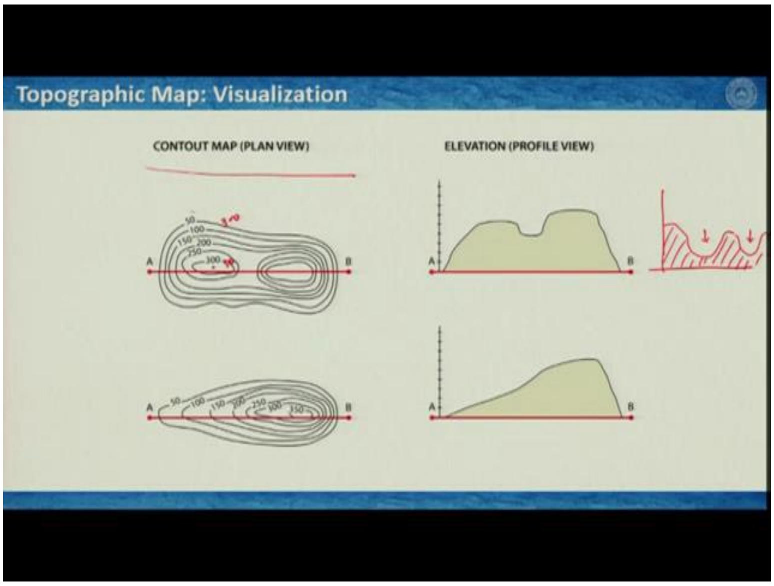
So what you see here we have a valley, a river is flowing through this valley and we have 2 little elevations here. We also see that in this elevation the slope is going down here the slope is going down here it is going down this side. This is one of the maximum elevations we see. We also see that slope is here very gentle here the slope is extremely high. We also see some little rivers or whatever channels are flowing along these valleys and so on.

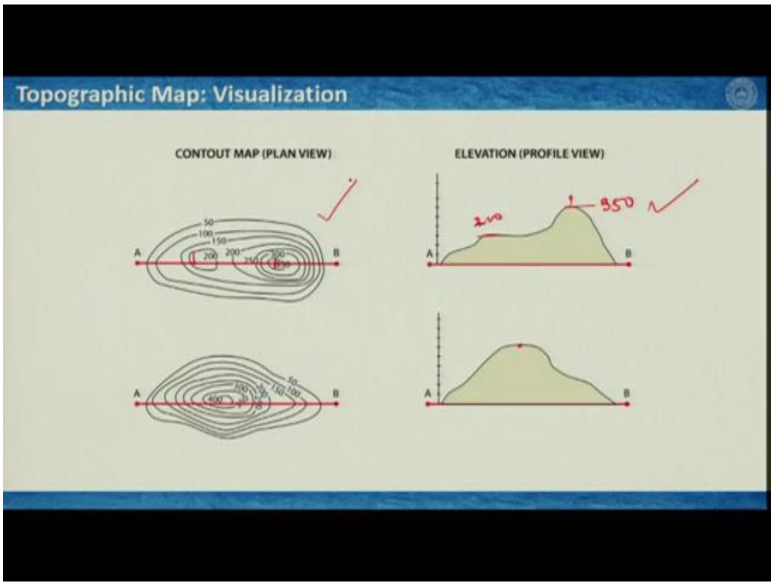
And this is where you have the sea and on the sea you have also some cliffs where the slope is almost perpendicular. Now if I have to represent in the topographic map then it looks like this. So here you see that it is contoured and by this you can actually figure out though it is map view but you can figure out towards which direction the slope is changing.

For example this is 260 this is 200 this is 100 so you can clearly figure out that this is how the slope is decreasing and once you know that then you can also figure out that this is how it is decreasing here but here you see the spacing is much much higher compared to the spacing here. So this is a steep slope and this is exactly what we have seen here.

Now this is the river is flowing and we also see that here we have the highest elevation and at highest elevation if you see a concentric circle that is the highest elevation of this region and that must be closed by a circle and then the other contours must should follow it in different ways, but this is how it is.

(Refer Slide Time: 27:57)



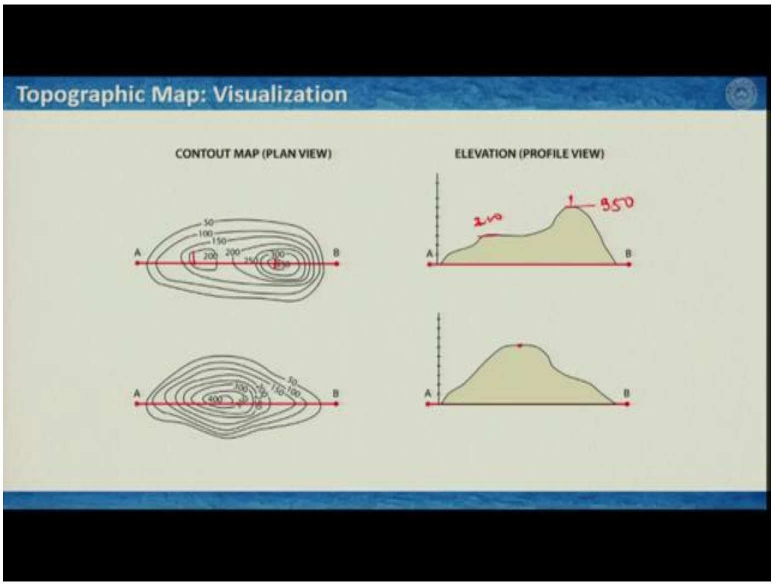


Now it is also important that you train your eyes so when you look a topographic map you try to visualize that what is the elevation of that region, so I have given 4 example here 2 are in this slide so the first column is outcrop map or plan view and you see here from 50 that is the lowest elevation in meters to 300 it is going. So 300 is the highest peak here and here is the highest point and it is marked by a concentric circle.

If we have to make a cross section from A to B of this region then I should get something like this. So if I see something like that and values are given then it should be like this. Now if the values are opposite way for example this one is 300 and this one is 50 then A to B in this case should be something like that. So these are actually depressions but here the values are increasing towards core of this contour so this is you have 2 hillocks here 1 hillock this one another hillock this one this one and this one.

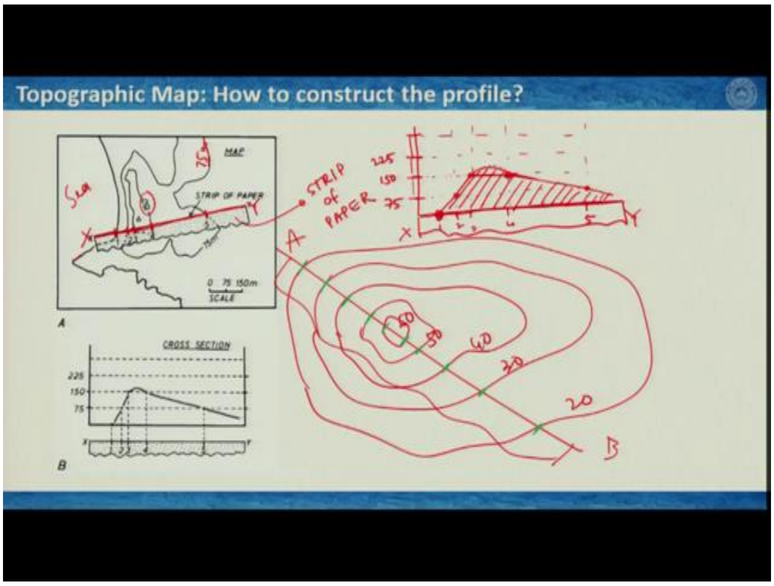
Very similarly you see here as I talked about so here we start again at 50 and end up 350 meters. In this side the contours are closely spaced in this side contours are not that closely spaced. So here the slope is very gentle here slope is extremely steep. So just you look at this contour pattern and you can figure out what is the section or how it should look like when you actually see them in the field.

(Refer Slide Time: 29:27)



This is another one so you see we have 2 concentric circles but this concentric circle closes at 200 meters and this closes at 350 meters. So therefore this must be of higher elevation compared to this and if you make a section you actually can see that this is your 350 and this is somewhere is your 200. So this is how you actually visualize and this is another one we have a single peak and we get a single peak here will see in one of the next slide that how to construct this elevation map profile map from this contour maps and this is exactly where it is.

(Refer Slide Time: 30:06)



So we will have a lab demonstration on this but I explain you briefly. So whenever you see a topographic map and if you have to draw the profile the first thing you have to decide that from which section you would like to draw the profile. For example here the profile should be drawn along this line, so this is X and this is Y.

Now we have series of contour lines so for example this contour line is 75 meters and then this contour line is closing here and then we have 150 meters here which is this one and if this is 150 this is 75 then this one should be even lower. But if we do this then we can figure out that it is cutting across this XY line the number of contours.

So what you do you take a strip of paper which is this one and align the age of this paper along XY line and once you aline it then you mark this places or points where it is intersecting the contour lines. So here for example number the 1, 2, 3, 4, 5 and so on. Once you are done then it is important that you draw a Cartesian co-ordinate system where your horizontal axis should be the distance XY and this should be your elevations.

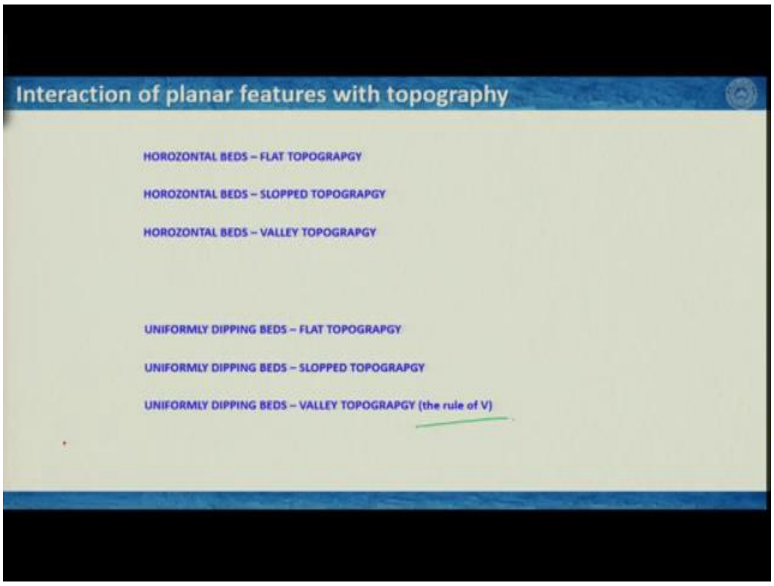
And this distance you can fix by yourself depending on the scale you would like to see but make sure that these are all equal. Say for example you can figure out that this is 75 meter this is 150 meters and so on.

Now you arrange your strip here this paper strip that you have where you have marked this 1 then 2 then 3 then 4 and then 5 intersections of the strip of the papers so this comes here. And you see that 1 your value is almost at the sea level so because this is sea so this close to 0 so at 1 you have somewhere here. Then at point 2 here the value is 75 meter, so you have to plot a point here at 75 meter.

At 3 your value is 150 meters the value of the point 3 so you come here and the value is 150 meters. At 4 again this contour is coming back and we are at 150 meters so we come here and plot it like this and then at 5 again we are touching this 75 contour so it is like this, of course you can grid your map first so that you do not have to do it but once you are expert you can do it just by putting your scale accordingly the way you need. But these are the points that we got and simply you can connect these points like this. Now here you can make it flat or you can make it little curved there is no harm. So this is the elevation or profile along XY line of this.

So does not matter how is your topography and so on you can cross section say A to B say this is 20 this is 30 this is 40 this is 50 and this is 60. So if you draw a profile along this again we have to put a strip paper, paper strip here. So you mark this point, this point, this point, this point, this point, this point, this point, this point and so on we go on and then you again may make your grid and then you know the values you plot it you will get series of points and then you are done. But we will have little lab demonstration on this that how to construct the profile from a topographic map.

(Refer Slide Time: 34:45)

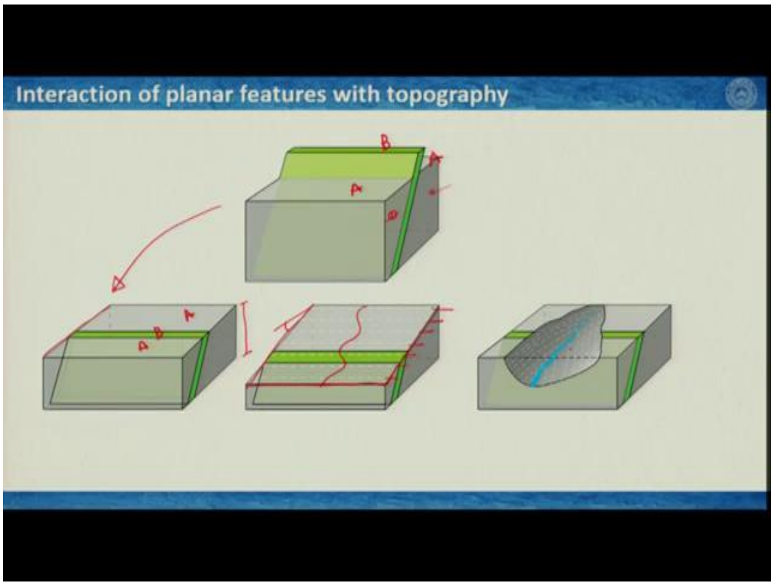


Now let us come to a very important part that so far we have figured out what is topographic map? How to get the profile and so on. But you may have different lithologies which are intersecting or interacting with the topography. For example if you have a flat horizontal bed and if you have a flat topography then you do not see the other beds which is below the flat bed because it is only single bed you will see because bed is flat topography is flat.

Now if your bed is again flat but your topography is in a particular slope in a very gentle slope then topography would go down and at one point of time it would cut the contact between one bed to another bed. So other bed will be exposed on the topography. And this can be a valley topography, a mountain in topography and so on.

So there are 3 possibility that you have horizontal beds with one is flat topography, slope topography and Valley topography. Then you can have uniformly dipping beds and again you can have flat topography, slope topography and valley topography. And this is exactly what rule of V is we learn about it soon. But let us try to understand this process in a better way.

(Refer Slide Time: 36:21)

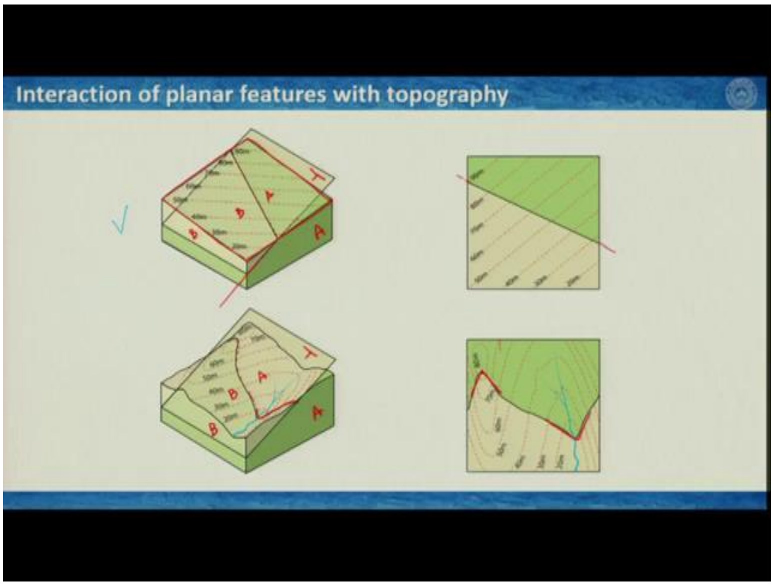


Say for example you have a bed here like this which is a green one which is sloping and this is some other rocks. So we have a bed which is sloping in this way and then you have some other rocks around this. Now with time what can happen it can erode uniformly. So you see that this got eroded and because this bed is sloping then you can clearly see that this is a horizontal surface. So you see that you have say lithology A then lithology B and again lithology A. So you have A then B then A and they are absolutely fine no problem.

Now if the erosion happens and you get a sloppy topography so the topography is uniformly sloping here as you can see here so this is the slope. Then you of course generate some contour lines, these is white dotted lines are your contour lines and again there is no variation here except bed thickness changed on the exposed surface area. But now if there is a river flowing here as we see here so it would cut a gorge or make a Canyon or whatever.

Then the question is how on this river valley this bed would look like? Because it would have also contours like this. So would it look like this or would it be a straight line straight bed or it would be like this and so on. You may guess how it should look like but there is a rule and this rule is known as rule of Vs. We will see this soon but before that let us see some other interesting features.

(Refer Slide Time: 38:18)



What do you see here in the first image or first illustration that is the surface of the Earth for example which has a flat sloping surface and then you have to 2 different lithologies say this is A the green one and this light cream one is B and their contact is somewhere here. So when it intersects like this and this is a topography, so this is the lowest elevation that you can see here 20 meters and it goes up to 90 meters towards this direction and this is the line it is cutting or intersecting the topography the boundary between A and B. So in this side you have A and in the side you have B.

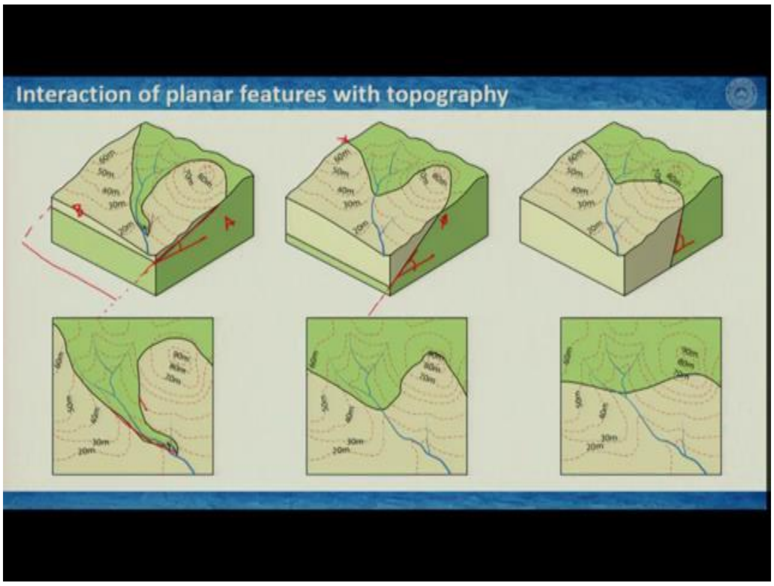
You can also see that if this topography is not as flat as we have seen or maybe river is flowing along this then you have very similar thing A and B the beds are dipping exactly similar way. So to strike and dip of these two contact lithological contacts are very very similar but if I change the topography in this case if I have an undulatory topography, Then the interaction of this topography with this uniformly dipping bed would be along this lines, so here you have A and here you have B. So if I try to see them this is a block diagram if I see them in a topographic map their appearance would be something like this if I have to plot it.

So here because the topography is flat we clearly see that the flatbed interacting uniformly dipping bed which has no deformation it is not folded or something like that this is very much straight line. But same flatbed if the topography is undulating then which is given by this little red dashed lines then it is not anymore a straight line.

So there must be happening something and I would like to also a emphasize the fact that we have already talked about that you see here this appears like V or in this case this is like V with a mirror image. So we will learn about it later.

So we see here that same bed but in one case we have flat topography another place we have undulatory topography and we may have 2 different intersections on the topographic map. But if we have same topography but the bed is dipping differently then what should be the condition?

(Refer Slide Time: 41:22)

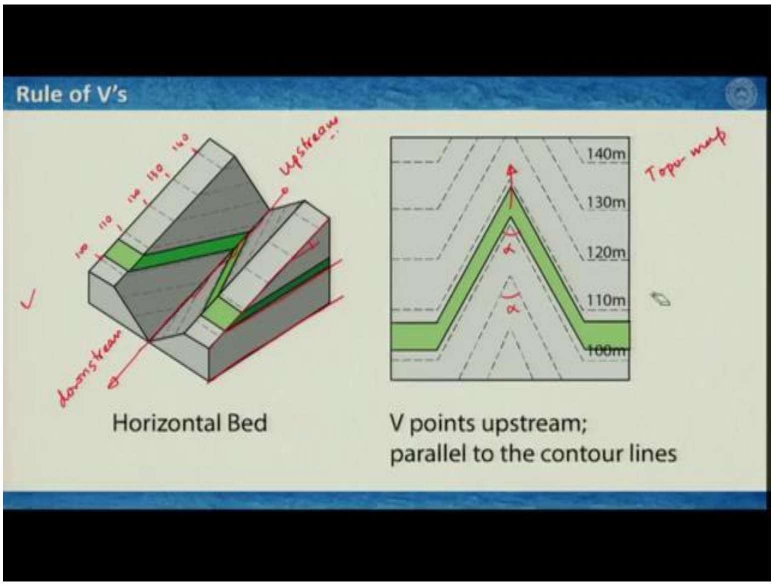


Here at the examples the first one again we have A and B the bed is dipping very gently. Okay you can see that this is the deep of the bed this is the lithological boundary and this is the topography where you have some river network and the interaction would be something like this if the bed is moderately dipping in this case the interaction is something like this with the topography on the surface. And if the bed is highly dipping then the interaction is something like this.

So in the topographic map we see them differently. So same topography but bed is dipping in different ways the appearance or exposers of these topographic maps would be completely different. So this is the take home message from this slide and the previous slide and based on that a geologist have constructed the rule of V. Again you see that this is a V this is again going to be a V and this is a V of different shape and so on. Let us see how does it look like.

Now will look up the V rules and will look after one and then the next one and then we have 6 illustrations to demonstrate what is the V rule. But before we go to the actual V rule let us talk about what does it say to us.

(Refer Slide Time: 43:00)



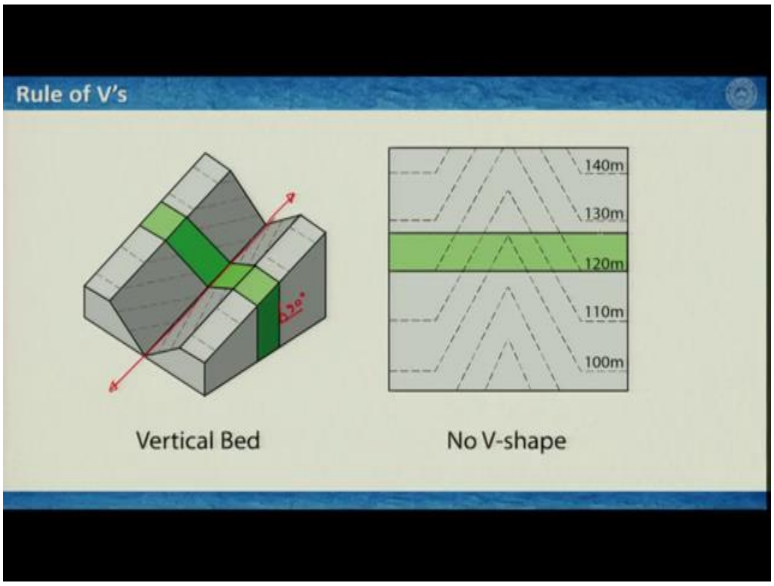
So the first illustration in all figures will see that on the left hand side that means this one is like a V block that used in lathe machine something like that. But this has a slope say for example this contour me have 100 meters this is say 10 meters spacing so 110 then 120 then 130 and then 140.

So from here to here we have changed of elevation of about 40 meters and then the countries are running like this inside the valley and you can imagine that a river is flowing in this direction. So this is the downstream and essentially then this would be upstream. So river itself as a slope and this is also maintain a slope the walls of the valley and this is horizontal.

So this concept will first look what happens if we have a horizontal bed in this condition. So horizontal bed means that this dip is 0 here and we see if the bed is horizontal then the V rule suggest and this is the a top view on the topographical map, so this is a topo map.

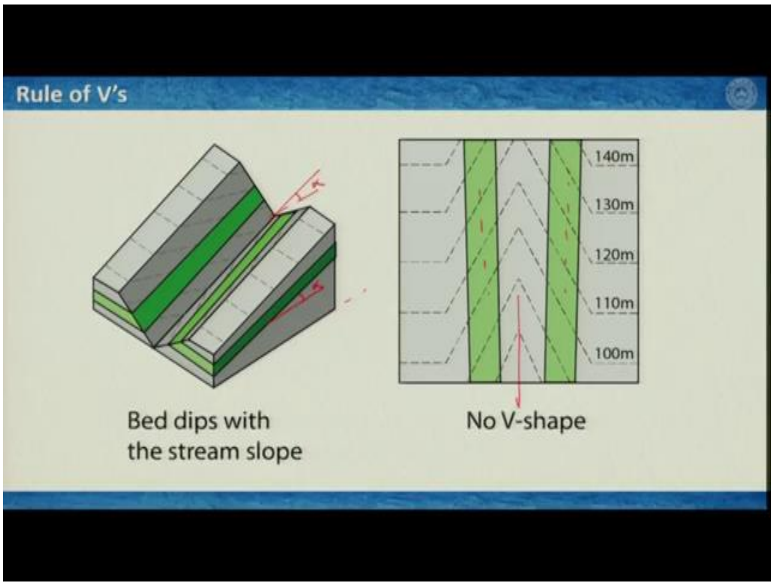
So the way horizontal Bed would intersect the valley or it is something like this. So it would the V that would be created it would point upstream. So this is exactly what to see here and the angle of V is very similar to the angle of the contours or contour lines you can think of. If this is alpha then this has to be also alpha. What happen if the bed is a vertical? Is given in the next slide.

(Refer Slide Time: 44:55)



If we have a vertical bed that means this is 90 degree and again this is the downstream that is the upstream and the vertical bed interestingly would not produce any V in this section in the top view on the topo map view. So it would not be influenced by any of the contour lines and it would run straight as it was.

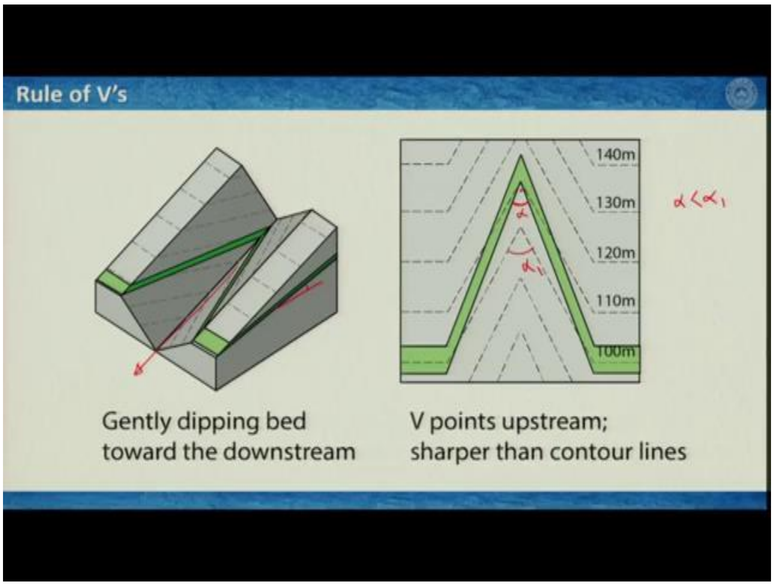
(Refer Slide Time: 45:21)



Now if we have the beds which are dipping along the slope of the stream. That means the stream has a slope along which it is flowing and the bed also has a very similar slope of the stream. So this is the deep of the bed and this is also the stream the way it is flowing.

So, if this is a horizontal line if I can reproduce it here so this angle and this angle are very similar. In that case the V rule suggests that you would not produce any V shape. However the 2 projections of the beds on this V they would slowly try to intersect towards the downstream.

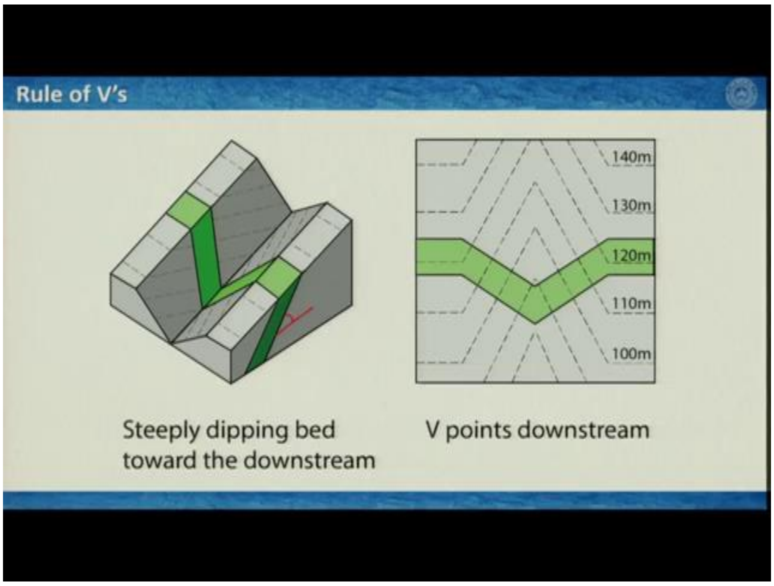
(Refer Slide Time: 46:10)



If the bed is gently dipping towards the downstream, so this dip is very very low, low angle dipping bed. This is again the downstream then the V would be something like that and in the plan view it would be very interesting that when it was horizontal we saw that this angle of the V and this angle of the V were equal.

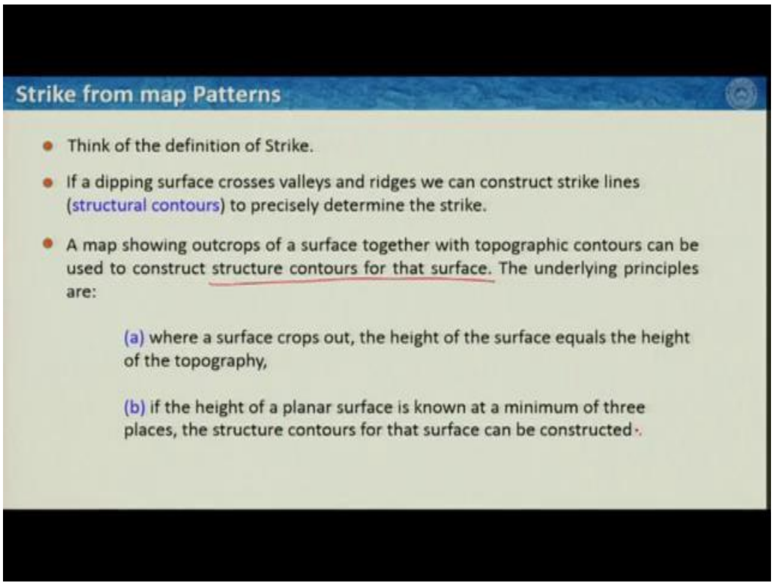
But in this case if the bed is gently dipping towards the downstream then the angle made by the bed inside the valley the V angle if this is alpha and if this is alpha 1 then Alpha is less than Alpha 1. So V points also upstream in this case and it is also sharper than the contour lines.

(Refer Slide Time: 47:00)



Now if we have steeply dipping bed towards the downstream. So bed the dip of the bed is very high in that case we will see that V is pointing downstream in this manner.

(Refer Slide Time: 47:18)



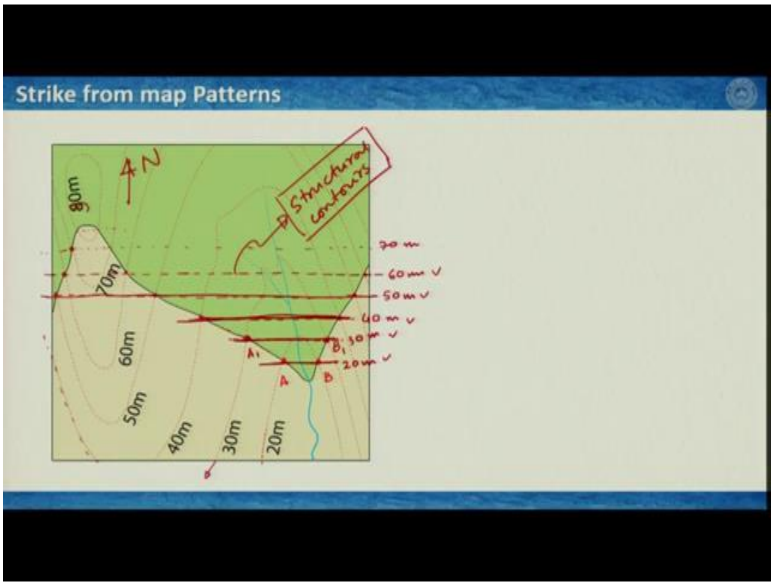
Now we look at something very interesting that how we can figure out the strike and then the dip of the bedding plane which is uniformly dipping inside the surface and it is intersecting with different topographies. And if we remember the definition of the strike then you can figure out the fact that strike was nothing but the intersection of an inclined plane with the horizontal plane and horizontal plane is imaginary so they would producer a line.

The azimuth of the line is the strike, so from that idea of the definition of strike we actually can construct on the topographic map even if we do not go to the field. If we have this intersection line on the topographic map of a bedding plane then we can construct something what is known as structural contour. So if a dipping surface crosses valleys and ridges we can construct strike lines which are known as structural contour to precisely determine the strike.

Now a map showing outcrops of a surface together with topographic contours can be used to construct structure of contours for that surface. And when we construct these structural contours it has 2 underlying principles. The first principle is where a surface crops out the height of the surface equals the height of the topography.

So that means if I have an intersection point between the contour line of a particular value and also the intersection line of the two surfaces on the earth surface then if I find a similar point somewhere and if I connect these 2 points so these 2 points would have also very similar elevation value and is the height of a planer surface is known at a minimum of 3 places the structure contours for that surface can be constructed.

(Refer Slide Time: 49:43)



Let us see how does it work I think instead of reading the text let us do this directly. We have seen this illustration before this was an uniformly dipping bed. So what is important to draw the contour lines structural contour lines that you have to figure out the intersection between a fixed value contour line for example this 20 meters which the intersection of the 2 lithologies which is coming up on the surface.

So in this case this is one point and this is one point. So these two points are relevant for 20 meter contour lines. Now interestingly if this point is A and this point is B as both point A and B are falling on the contour line so the elevation of A and B should be same. At the same time this point A and B also showing you the fact that the elevation of underlying bed or the intersection between these two layers is green and creamy layer also has same elevation values at these two points. So I can actually construct a line like this and this line indicates that this bed has or this litho boundary has an elevation of 20 meters.

Let us go to the next contour which is 30 meters. Now again in a similar principle we can figure out that where this contour is intersecting the boundaries between the 2 lithologies in this case it is here and this is coming around and in this case this is also here. So, similarly if I considered this A1 and B1 then point A1 and point B1 has similar elevation and because these 2 points are sitting at the intersection between the 2 lithologies.

So the lithology itself has also similar elevation. So I can draw another line here suggesting that this is 20 meters this is 30 meters. These 2 lines indicate that the boundary between the 2 litho units have similar elevation along these lines.

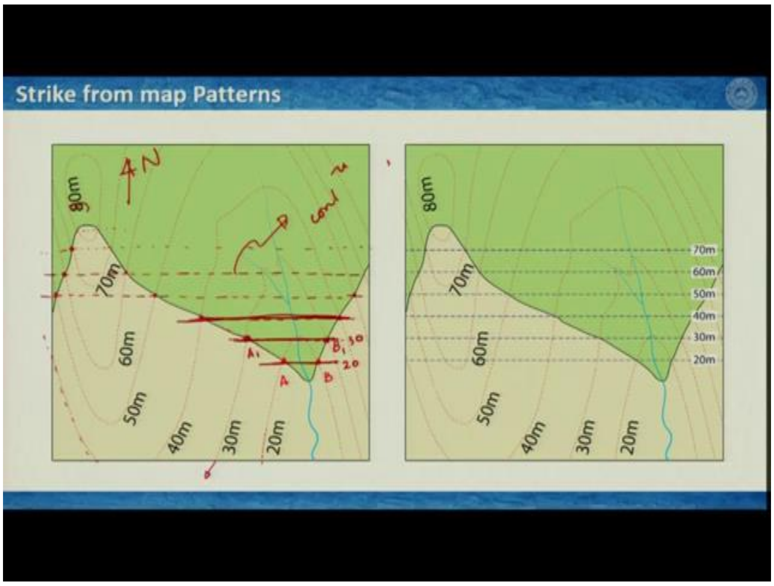
Similarly, we can construct for the 40, so 40 meters contour so it goes like this comes back here again to draw a line like this. We can figure out the 50 meters here and then it goes and it comes here again interesting these 50 meters also crosses another point here and that is actually the perfect one because now we have 3 points. So we can construct a line of same elevation of this plane and this is of 50 meter this was of 40 meter.

We can similarly do for 60 meters here and it is coming here and again it is possible that we can. What is interesting you see that these lines are parallel to each other. Dotted lines that we have drawn these 20 meters, 30 meters, 40 meters, 50 meters and 60 meter suggesting the elevation of the bed or of the lithogical contact. These are parallel so first hand they are telling you that the bed is uniformly dipping and the next one is 80 meters and it is also running parallel.

Now these lines what this lines actually do signify this signify as I talked about that the same elevation of the bedding plane. The contour lines that you have seen here these, these do indicate same elevation on undulatory surface and these lines indicate the same elevation of contact or lithological boundaries or a bedding plane or an uniformly dipping plane and these are known as structural contour.

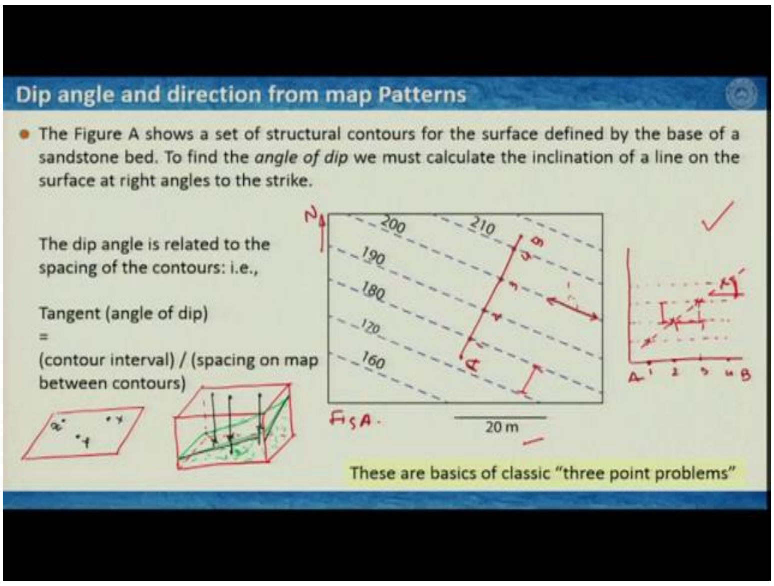
And we see that these lines actually are horizontal lines at different elevations. So the bed is inclined and I have their intersection line on the horizontal plane, which are all these lines. So these lines the orientation of this line if this is the strike line as well. So in this case the strike line is oriented east west.

(Refer Slide Time: 55:01)



So this is how you construct the strike lines and if we have to see it in a different form it is something like that. So you can construct series of structural contours and structural contours are essentially different to that of the topographic contour unless I let you decide what it is. There should be a specific conditions, say for example I tell you if the bed is horizontal then the structural contour should be exactly similar to that of your topographic contour.

(Refer Slide Time: 55:32)



Now this is how we have constructed the strike and now will learn how to figure out the dip angle of the bedding plane or the litho contact from the structural contour. So the first thing you have to do you have to draw the structural contours. So in this case this figure this is figure A, show the set of structural contours for the surface defined by the base of a sandstone bed. This example I took from the book of lisle.

This is the north direction, so if this is a structural contour then the strike is 120 degrees. So this is the strike line. So from North if you count it would be 120 degrees. Now to find the angle of dip we must calculate the inclination of a line on the surface at right angles to the strike. So the dip we have to calculate at a right angle of the strike line that is the definition the true dip.

Now one can be confused here that which way the dip direction is it is on this side or it is on this side. Now that is not very tough job because you see that structural contour is increasing the side here it is 160 here it is 210 so that means the bed must be dipping in this side not in this side. So Dip direction is towards this side.

Now, to figure out the dip angle what you have to do, so this is the section that will be working on you simply have to draw a line like this say AB and also scale is given you can have this distance and in a very similar way the way we walked on the paper strip and so on. You can actually figure out this thing so it first cuts 180 then 190 then 200 and then 210. At this point it cuts here say it cuts hear say this 1, 2, 3, 4. So this is 1 this is 2 this is 3 and this is 4.

So it is possible that you can get a line like this and the slope of this line is actually the dip. Now how to calculate the slope of course you know the distance and you know this distance as well from the scale. So dip angle as it is written here is related to the spacing of the countries that is tangent or angle of dip is contour interval.

So in this case this is 10 meters divided by spacing on map between the contours and this is exactly what you can figure out. So once you know the dip and strike from the topographical map this kind of basics actually help you to understand the problems like 3 point problems and so on.

Particularly when people do bore hole in an area that do not see the actual Rock. So what I mean by this lets to a very simple block diagram. See you have a dipping plane at the subsurface and this is of your interest and what are you doing you doing some boreholes say you have done one borehole here you get something here you get something here and maybe one here you get something here.

So every time you touch your desired bed at different points. So here on the plan you actually have 3 points where are you touch the desired bed at 3 different values of X Y and Z and if you sure that this is an uniformly dipping bed then using this basic of finding dip and strike you can figure out that what is the dip and strike of this bed which you actually do not see.

So this is something very interesting of this kind of problems there should be some problems associated with this and the demonstrations of this lab works would be given along with this this weeks lecture series.

So with this I conclude this weeks lecture because we will have a hand full of demonstrations which are very useful and would be uploaded in this week by the teaching assistants. So I request you to check them and practice. I not only conclude the lecture of this week as your instructor but I also sign off from this course because this is last lecture.

I thank you very much for joining this course and I particularly enjoyed a lot in teaching this course. I learnt a lot as well, I hope this course was useful for you and I still remain at your (())(60:54) distance if you have any ideas that you would like to discuss with me your more than welcome to write me through my email. So, thank you very much stay well. I hope I will see you again with another series of lectures. Thank you.

(Refer Slide Time: 61:10)