Rock Engineering
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Lecture – 05
Geologic Structures and Discontinuities

Hello everyone. In the previous class we had the discussion on how to identify the rocks. I discussed with you this rock identification procedure by means of flow charts and then we discussed some typical characteristic of few rocks which were belonging to various classes like igneous, metamorphic, and sedimentary. At that time, I told you that it is equally important for us to know about the geological structures and the discontinuity, because in the field it will not be only the rock.

But along with the rock there would exists some or other kind of discontinuities or the geological structures. So, today we are going to learn about these geological structures and discontinuities. How these discontinuities are represented in the graphical form. All those things we will discuss today. So, to start with first of all let us discuss about the geological structures.

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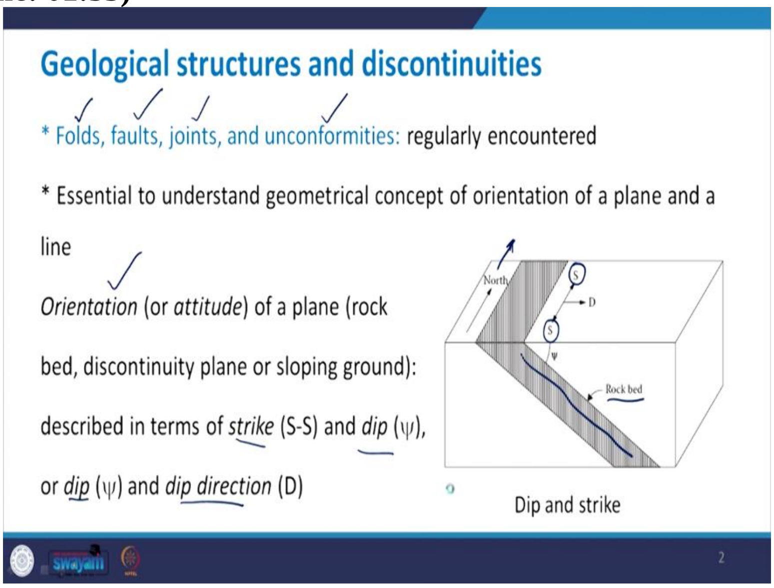

Usually encountered geological structures or the discontinuities, they include folds, faults, joints and unconformities. It is very much essential for us to understand the geometrical concept of the orientation of a plane and a line before we learn about these geological structures. Because the moment we encounter any kind of geological structure and the discontinuities we need to represent them. Now, these structures are 3 dimensional.

In case if we have to represent it on a 2D plane, we need to have some quantities such that we are in a position to represent these 3-dimensional structures on a 2D plane. So, for that the graphical representation comes into picture. Therefore, the orientation of a plane and this orientation is also called as attitude. Now, this plane can be anything this plane can be rock bed, this plane can be a discontinuity plane, or it can be a sloping ground.

So, the orientation of any such plane in 3 dimensional situations, it is described in terms of strike and dip or dip and dip direction. Have a look at this figure and you can see that we have the north in this direction. Then this is the rock bed whose inclination we want to represent graphically. So, you see wherever it intersects the horizontal plane or the horizontal trace that is strike, which is represented as S-S. Let us see in detail how we can determine this strike or what exactly is the definition of this.

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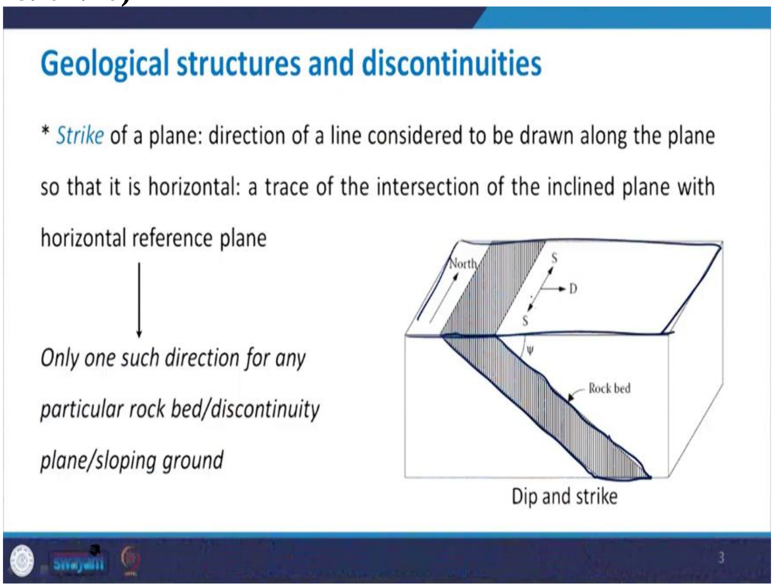

So, as I mentioned that a strike of the plane is the direction of a line which is considered to be drawn along the plane so that it is horizontal. Or in other words, it is the trace of the intersection of the inclined plane with the horizontal reference plane. Just imagine that, this is what is the plane traverse this line; this is the plane. Now, this plane is there and then you have this as a horizontal plane. This as a horizontal plane.

So, wherever these 2 planes they are intersecting or this rock bed is intersecting that horizontal plane that is called as the strike. That means, it is the trace of the intersection of the inclined plane, that is, this plane with the horizontal reference plane, that is this. And you need to keep in mind that there can exist only 1 direction for any particular rock bed or discontinuity or sloping ground. Therefore, this strike it will be unique for any particular plane.

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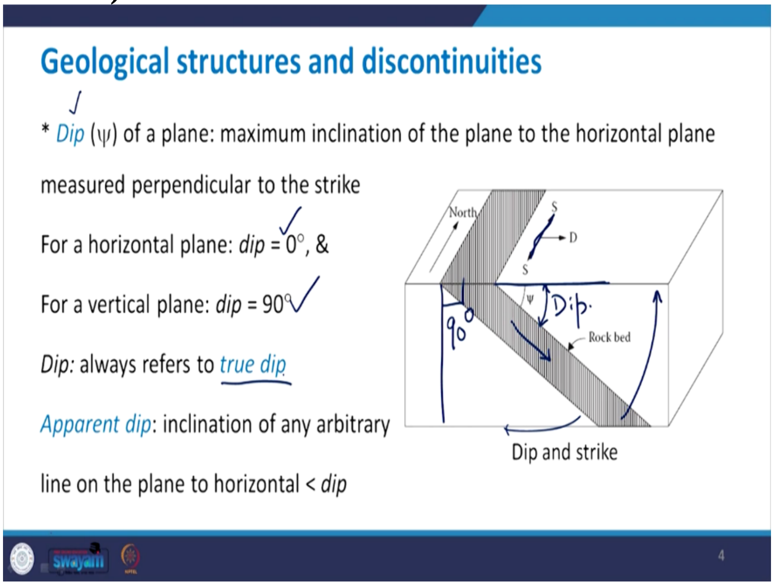

Coming to the next aspect, which is dip of the plane and you can see that, it is the maximum inclination of the plane to the horizontal plane which is measured perpendicular to the strike. So, you see, this is the strike. The horizontal line is this. This is what is a rock bed. So, this angle is going to be dip of the plane. Now, just imagine if I just rotate this rock bed and make it horizontal. So, what will happen its angle with the horizontal will become equal to 0 and therefore, the dip of our horizontal plane will be equal to 0.

Then you just rotate it in other direction so, that it becomes vertical. Now, what will happen this angle will become equal to 90 degree and therefore, for a vertical plane the dip is going to be 90 degree. Keep that in mind that when I say dip that means it is true dip that means the term dip refers to true dip. Now, if this is true dip, what is apparent dip? So, apparent dip is inclination of any arbitrary line on the plane to the horizontal, that is apparent dip. This apparent dip will always be less than dip or true dip.

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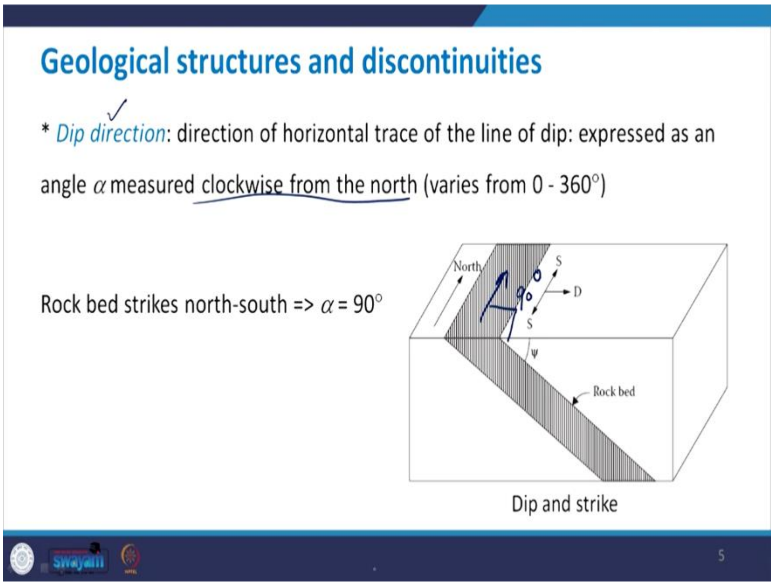

Coming to the next part, which is the dip direction. So, it is the direction of the horizontal trace of the line of the dip and it is expressed as an angle alpha which is measured clockwise from the north and it can vary from 0 to 360 degree. Now, see in this case the rock bed strikes north south. This is the north and then this the south direction and therefore, the angle alpha works out to be that means it is the angle from the north. So, notice this direction, so, this angle is 90 degree and therefore, dip direction in this case is 90 degree.

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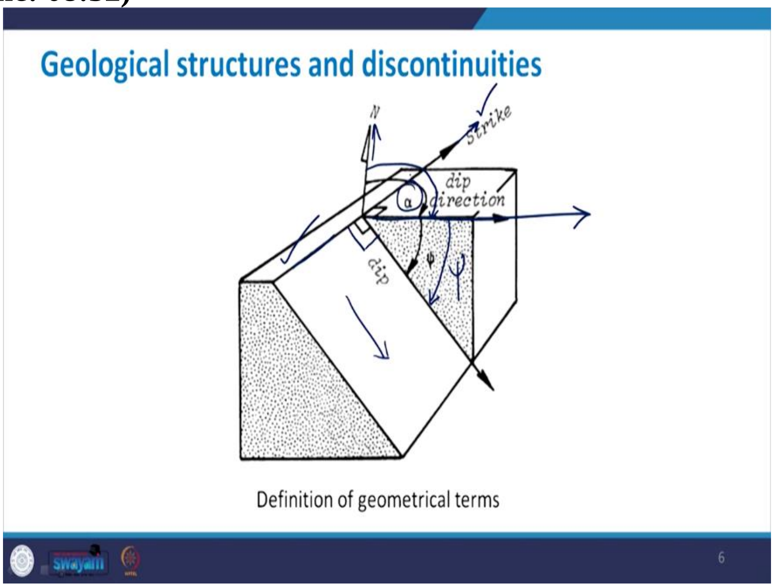

Once again try to understand all these 3 terms. This is the plane which is dipping in this direction. This plane and this is the horizontal reference plane wherever they intersect, this is the strike direction, strike. Then, perpendicular to the strike, that is this. Horizontal trace of the line, that is this. Whatever is the angle in the clockwise direction, that means this. This is going to be angle ψ which is dip. Then this dip direction is defined as the angle of the horizontal trace which is this with the north.

So, here this is what is the north direction? So, the angle which you which it makes from the north, this angle is your dip direction. So, please remember this thing, what is strike what is dip and what is dip direction. So, either we would need strike and dip or dip or dip direction in order to represent any plane graphically.

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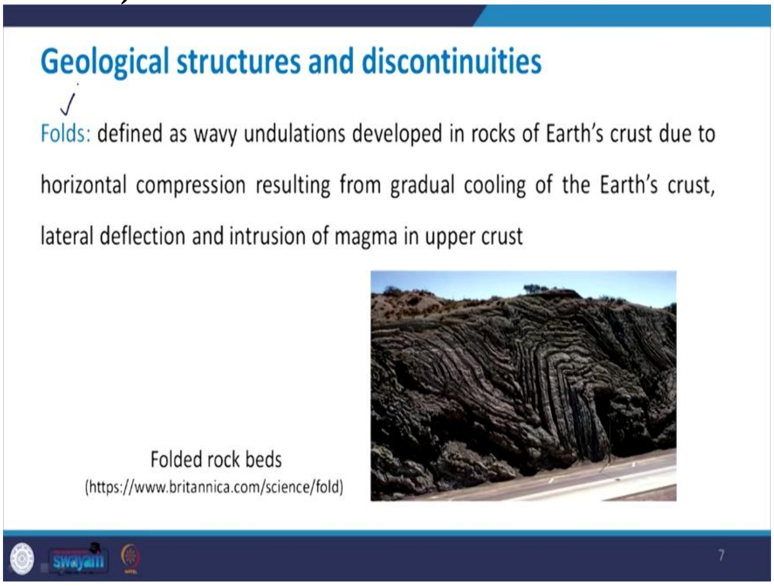

Coming to the next geological structure; that is fold. So, this fold it is defined as the wavy undulations, which are developed in rocks of Earth's crust due to the horizontal compression, which may be the result from the gradual cooling of the Earth's crust, maybe lateral deflection and intrusion of magma in the upper crust. See in this picture, these folds have been shown. See, one is like this and another one is like this.

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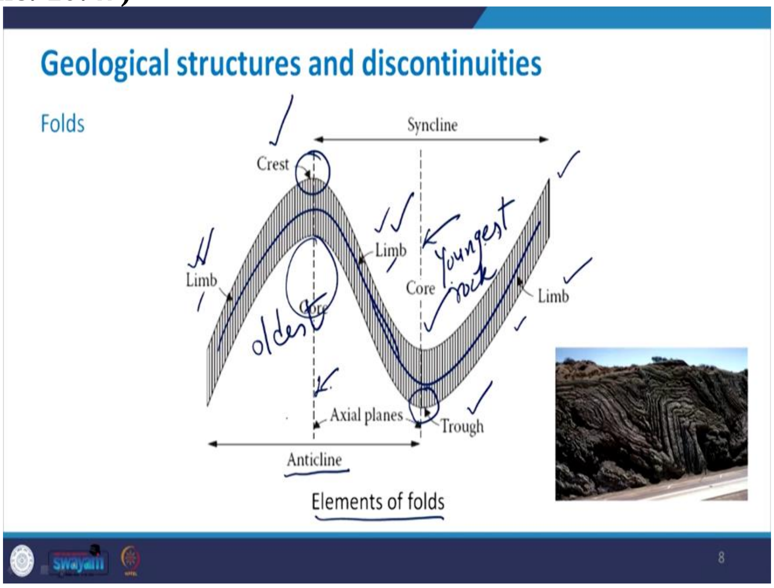

Now, what are various features of this. Let us try to understand with the help of this figure. So, you see that this figure shows us the elements or folds and you can compare this figure with this picture and then you will be able to visualize what we mean by anticline and syncline here. So, here this anticline, please note that this anticline is an upfold that is in this direction it is upfold, where these limbs they dip away from the axis of the fold in either side.

So, this side also and this side also they are dipping away from the axis of the fold. However, take a look on the syncline in this case, this is what is your syncline. In this case, the limb on both the sides, they dip towards the axis of the fold. Now, the highest point of any anticline is called as crest and the bottom most point of any syncline is called as trough. The obviously, we have already seen that the sloping sides they are called as limbs.

Now, a reference plane that divides any anticline or syncline into 2 equal halves is called as axial plane. So, in this figure, there are 2 axial planes; one is this one another one is this one. So, these are 2 axial planes. Now, the line of intersection of the axial plane and the surface of any constituent rock bed is called as the axis of fold. The inclination of which with the horizontal is called as the plunge of the fold. Now, you see, in case of the anticlines, older rock beds generally occupy a position in the interior, that is on this side, that is core.

Whereas, in syncline the rock beds in the interior they are generally young. So, here it is the oldest rock and here it is the youngest rock which will be formed. So, these are the various elements of the folds and then in this picture you can appreciate very nicely an anticline as well as syncline.

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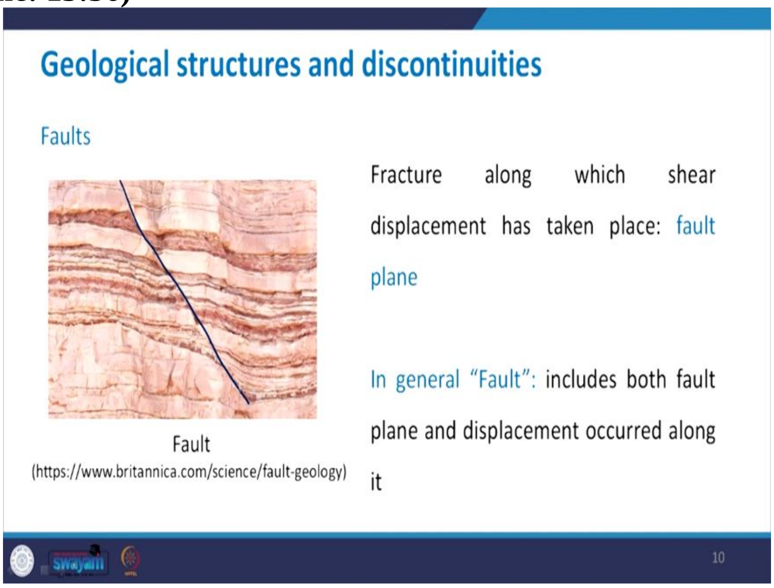

Coming to the next geological structure, which is the fault. So, basically these faults are the fractures in crustal strata along which appreciable shear displacement of the adjacent rock blocks have occurred, which are relative to each other. And this may be probably due to the tectonic activities. Here is a picture which shows very clearly the fault. Can you see that? This is the fault plane. And you can see that along this the shear displacement of the adjacent rock blocks, that is this block and this block has taken place. Like you see, from it was this location and this has come to this. So, this much has been the displaced.

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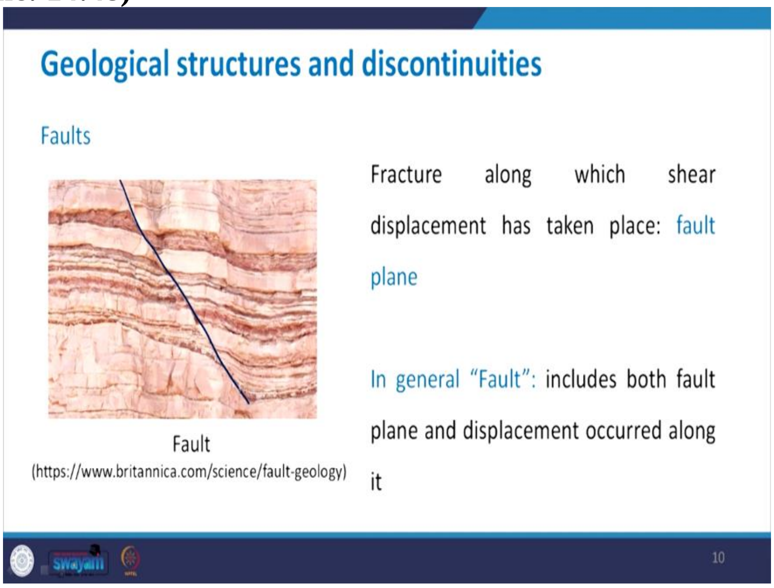

Now, coming to the next aspect that is the fracture along which the shear displacement has taken place that we call as default plane. So, in this figure, this is what is the fault plane. So, when we say in general the term fault, it includes both fault plane as well as the displacement which has occurred along it. Now, there can be different types of faults, which have been shown in this particular figure.

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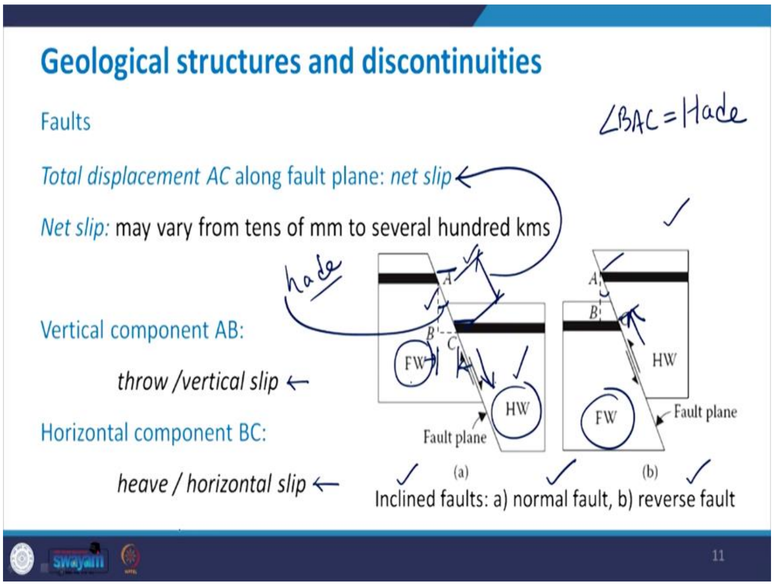

Where this inclined faults, have been shown, 2 types: Normal fault and Reverse fault. So, this figure deals with the normal fault and this figure deals with the reverse fault. You can see that the total displacement which has taken place along the fault plane. That means see this band location was here and now after displacement its location is here. So, this distance AC, this is what is called as net slip.

So, the total displacement is AC along the fault plane is called as net slip. Similarly, in the reverse fault also this is what is your net slip. Now, the amount of this net slip may vary from 10s of millimetres to several 100 kilometres, depending upon what are the activities that the rocks have been subjected to. Now, you see there are the vertical component of this slip that is the vertical component of this AC is AB which is called as throw or vertical slip and the horizontal component which is this component BC, which is called as heave or the horizontal slip.

Please remember vertical component is throw horizontal component is heave. Then the angle which is subtended between the fault plane and any vertical plane which is striking in the same direction is called as hade of the fault. Now, you have a look at this figure, this angle BAC. So, you see this angle is hade in this case. That means, it is the fault and a vertical plane which is striking in the same direction, then, that is the angle between these is called as hade.

Similarly, in this case angle BAC, so, angle BAC in this figure that is hade. It is observed that the 2 blocks which are lying on either side of the inclined fault planes they are dissimilar in their configuration and orientation in space. Of these 2 blocks one appears to rest on the other. So, the former one is known as the hanging wall, that is HW and the later one which supports the former one or the hanging wall is called as foot wall.

So, first focus on the normal fault. In this case, the HW, that is hanging wall appears to have moved downwards, relatively downwards as compared to foot wall. Whereas in the reverse fault, it is the other way round. That is this hanging wall appears to move upward as compared to this foot wall. From the mechanics point of view, the presence of tensile stresses causes the development of normal faults while compressive stresses they lead to a formation of reverse faults.

Fault plane, net slip, throw, heave and hade they are called as elements of the fault. Once again what are the elements of the fault? Fault plane, net slip which is AC, throw, which is the vertical component of the net slip. Heave, which is horizontal component of the net slip and this angle BAC, which is hade. These form the element of the faults.

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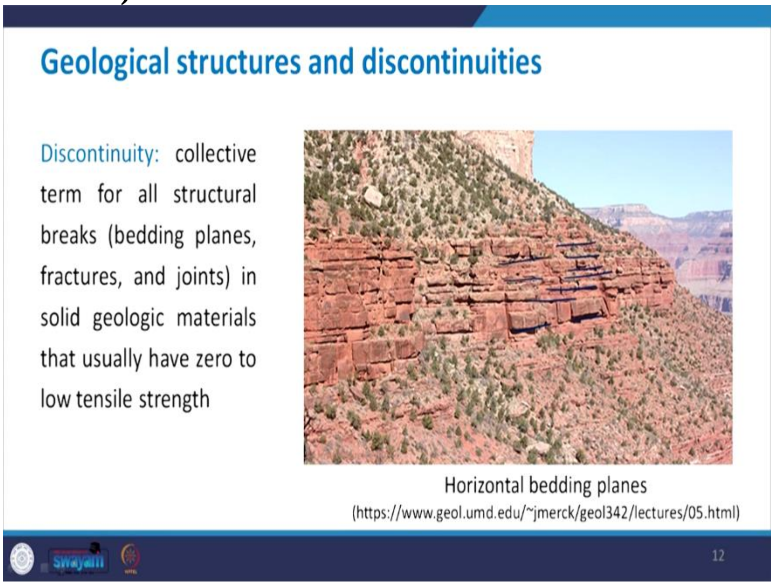

Coming to the next geological structures, which is the discontinuity. This term discontinuity is a collective term for all structural breaks. Now, these structural breaks include bedding planes, fractures and joints in solid geological materials that usually have 0 to very low tensile strength. Now, this picture shows the horizontal bedding planes. So, you can see there are many horizontal bedding planes. But it is not necessary that you always have the horizontal bedding plane.

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The next picture shows very clearly that how the planes can be inclined. So, in this case, you can see that these are the inclined planes. So, these bedding planes depending upon what is the geological activities that the rock has undergone, these planes can be horizontal, or these can be inclined bedding planes.

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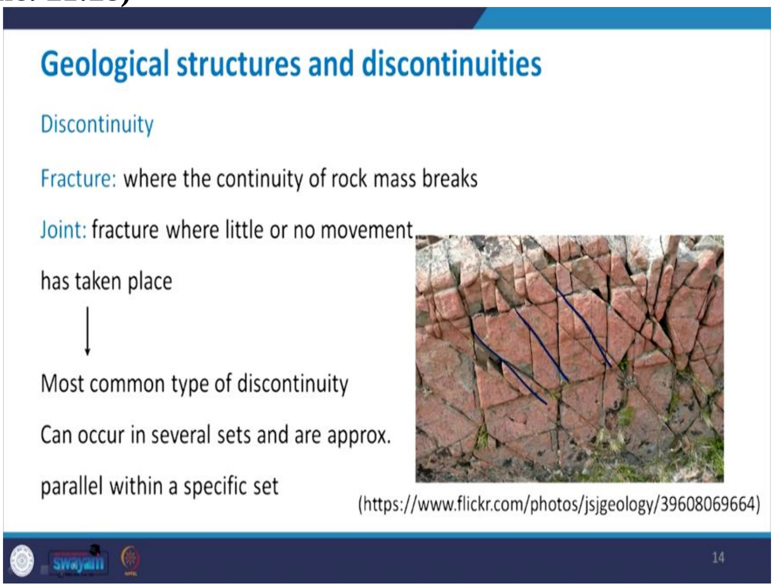

Now, look at the next one, that is the fracture. Fracture is defined wherever there is the break in the continuity of the rock mass. Joints they are the fractures where little or no movement has taken place. So, you can see here that these are the joint planes in this case. So, the most common type of the discontinuity is the joint and this can occur in several sets and are approximately parallel within a specific set.

Now, the discontinuity set, when we say discontinuity set, they represent the series of discontinuities that have the same geological origin, same orientation, spacing and same material characteristic. And these joints they introduce an isotropy and we will discuss all these issues later towards this course, when we discuss about the concepts related to rock mass.

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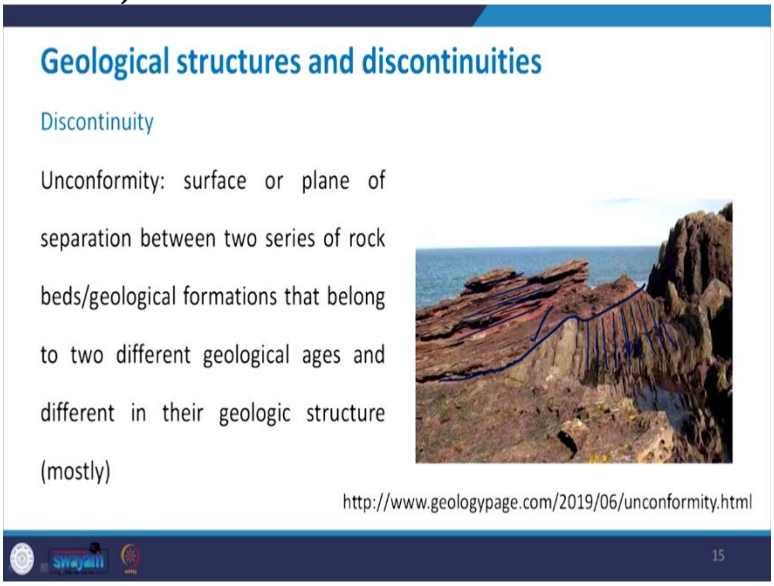

Coming to the next type of discontinuity, which is called as unconformity. See this is very interesting and bit different than what we discussed till now. So, you see here, this picture, take a look at it. You see here you have 1 set of rock 1 set of rock surface that is dipping like this. Now, you see that you have another set, which has this kind of orientation. So, basically, unconformity is defined as surface or plane of separation between 2 series of rock beds or geological formation which belong to different geological ages and they are different in their geological structures most of the time.

So, in this case, if you just take a look, this is what is the unconformity below that you have another rock type and then above that you have another rock type and this is the plane which is separating these 2 different types of rock which have different geological structure. So, this kind of discontinuity is called as unconformity. There are different types of unconformity, which can be looked from any textbook that I have already given you the references.

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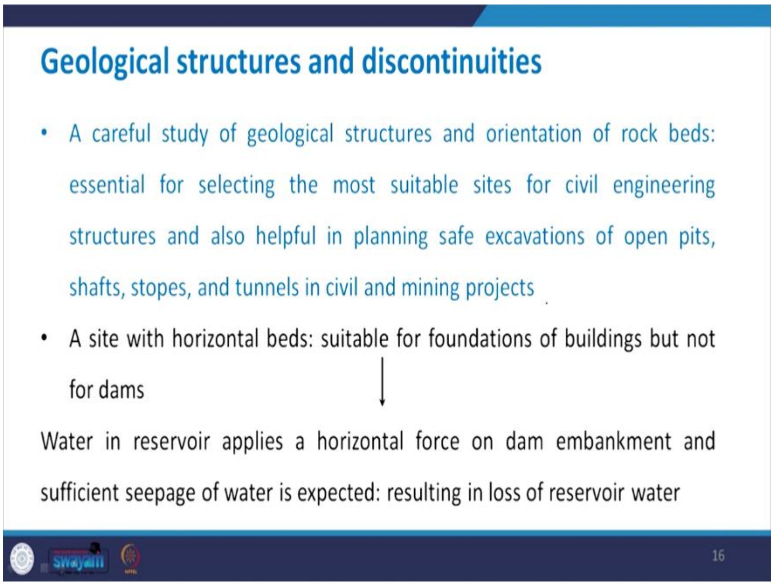

Now, the question is why are we doing all this why it is important for us to know the geological structure? So, by this time, it must have been clear to you that until or unless we know about these geological structures and their orientation in rock beds. We really cannot select the most suitable site for civil engineering structures. Further a proper knowledge of these is extremely helpful in planning the safe excavation of open pits, shafts, slopes and tunnels in civil and mining related projects.

For example, let us say at a site you have horizontal beds, that site may be suitable for foundation of buildings, but not for dams. What happens if you have a dam foundation on horizontal beds, what will happen is that water which is there in the reservoir, it will apply a horizontal force on the dam embankment and therefore, the sufficient seepage of water is expected and once that sufficient seepage takes place, there is going to be immense loss of reservoir water which is not desirable as far as functioning of the dam is concerned.

So, what happens we say that as far as horizontal bedding planes are concerned at a particular site, it is not suitable for foundation of dams.

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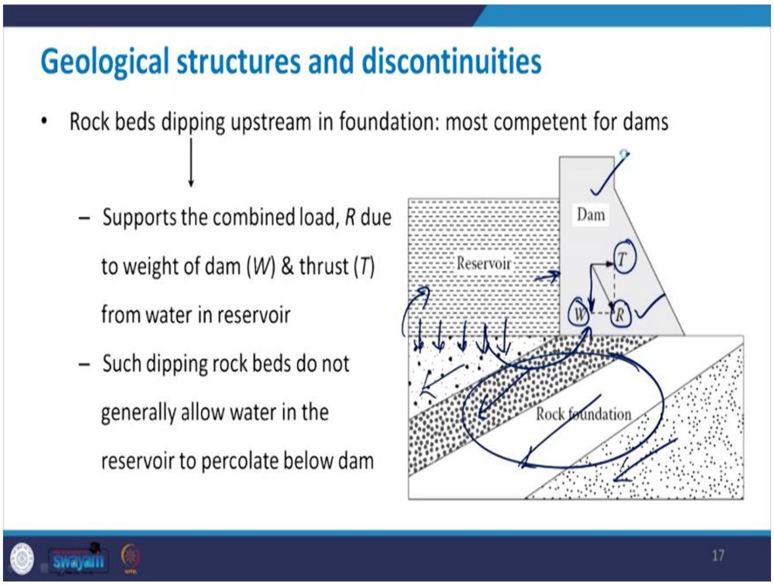

See here, in case if you have the rock beds, which are dipping in the upstream side. You can see this is what is the rock foundation which is dipping in the upstream side this is the most competent for dams, because this supports this combined load which is R and that is due to weight of the dam W which will be acting in the vertical direction and the thrust from this reservoir that is the from the water which is there in the reservoir which is T.

So, the resultant of T and W is given by R. So, this rock bed has to support this combined load R. Now, such dipping rocks do not generally allow water in the reservoir to percolate below the dam that means here this this will not go like this. The water will not go like this. In fact, what will happen is, whatever is the water, that is, let us say in case if it is percolating it will flow upstream and it will go back to the reservoir area.

Thus, the reservoir will not lose much of the water due to seepage through the dam foundation and at the same time, the foundation that is this part, it will remain watertight and the dam is not subjected to any appreciable amount of uplift pressure. So, you see how important it is for us to know these geological structures, their orientation in order to decide whether a particular site is useful for any particular type of construction activity or not.

So, as I explained for the case of a dam, the rock beds dipping upstream in foundation is the most competent. So, this is what that I wanted to discuss with you related to geological structures and the discontinuities. So, what we discussed today, it is a different type of geological structures, including fault, folds and unconformities. Then, we had the discussion on the joints, various elements of each of these structures. And then why it is important for us to know the exact features of all these geological structures in order to plan the construction activity on rocky strata.

So, in the next class, we will learn about how to have the graphical representation of these features in 2D plane. Because all these features they are 3 dimensional in field in order to represent them in 2D, we need to use some kind of a special projection and that all we will learn in the next class. Thank you very much.