Structural Geology
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Lecture 28
Fractures and Joints -2

Hello everyone welcome back again to this online NPTEL structure geology course and today we are in our lecture number 28 and we are learning fractures and joints and we are in the part two of this lecture.

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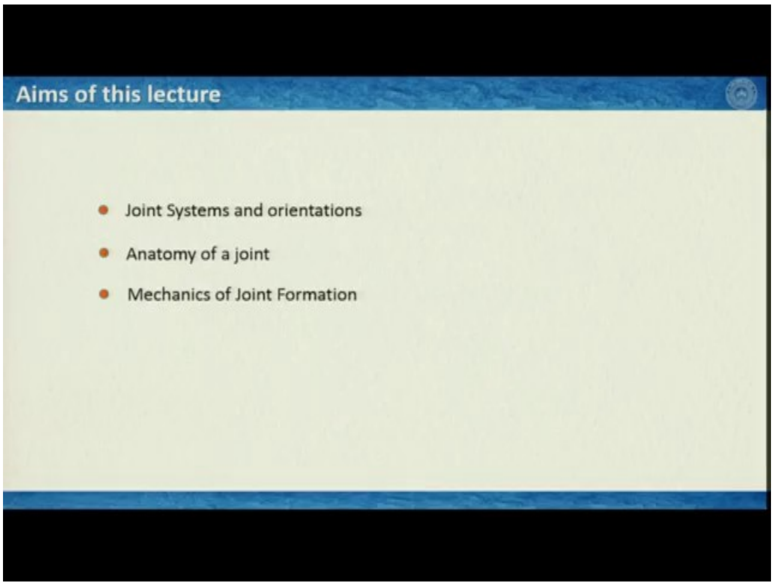

And today we will mostly learn joints systems and their orientation, anatomy of a joint and mechanics of joint formation. So, most of the contents of this lecture I adopted from lecture notes of Prof John Pear Burg. So, you can also go there and see further about this topic that we are going to cover today at the link of this professor Burg’s lecture notes were given at the very beginning of this lecture.

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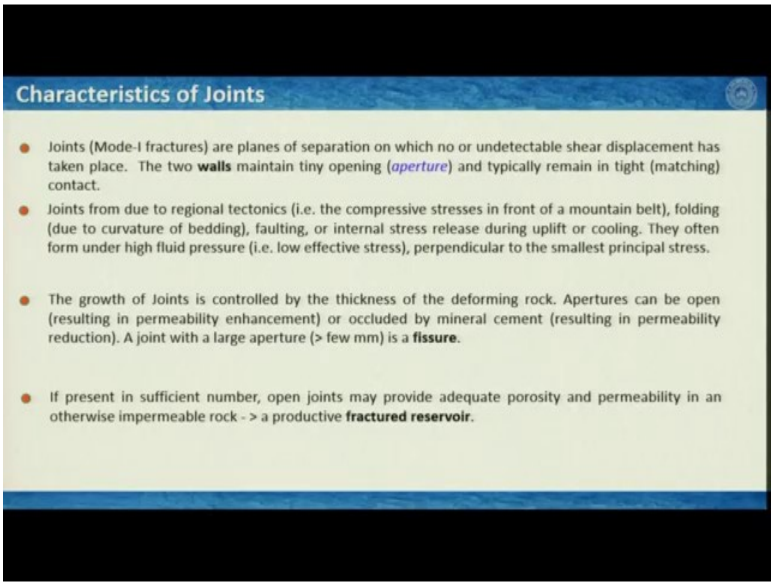

So yeah, we will define the joints again in a different ways. So, joints are mostly mode one fractures and these are plain soft separations on which no or sort of very negligible undetectable shear displacements has taken place and the two walls of the joints generally they maintain very tiny opening and the opening is known as aperture and they typically remain in tight or in matching contact.

Now, joints form due to of course, we learnt it that you need some sort of stresses. So, it can happen due to regional tectonics. So, you can consider the compressive stresses in front of a mountain belt and so on, folding due to curvature of the bedding or any foliations plains or layers, faulting also causes joints or internal stress release during uplift or cooling. So, all these are possible reasons for formations of joints.

They often form under high fluid pressure sometimes so that is the low effective stress when you have in your system. The porosity is there and the pores are filled by some fluids and this generally perpendicular to the smallest principle stress. So, this is how the joints do occur in the system and this is how we can actually identify or we can have an idea. Once we know the orientation of the joints what was the orientation of the stress axes.

The growth of the joints so once the joint forms then it grows. The growth of the joints is controlled mostly by the thickness of the deforming rock. The apertures can be open resulting in permeability enhancement. So, if you open the apertures that means you are adding more porosity to the system and sometimes you can close these apertures with some deposits the vain filling deposits.

So, that results in the permeability reduction. Now, when you have a joint with pretty large apertures so greater than a few millimetres, then we call it a fissure. Joints have a very-very important role in some sort of exploration geology. Now you can imagine that you have a significant number of joints in a system in a rock and then they have a little bit of opening.

So, apertures are quite high, they are like fissures and then they provide you adequate porosity and permeability and therefore, the jointed rocks in apparently the rock type maybe is very intact. Say for example, the granite and so on can act as a very productive fracture reservoir. So therefore, joints are important and we need to understand a few of its basic characteristics and that is the aim of this lecture.

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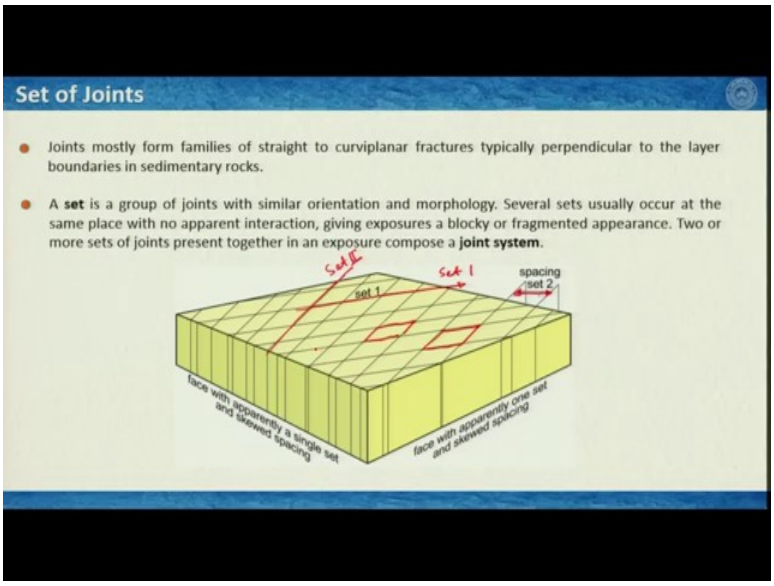

So, joints mostly form in terms of families. So, they have their sets and these sets could be straight or curviplanar fractures typically perpendicular to the layer boundaries in the sedimentary rocks. Now, what we see here in this illustration, that we have two different sets. So, one set is like this and another set is like this. So, this one is set one and this one is set two, they mostly form one after another.

So, a set is a group of joints with similar orientation and morphology. Now several sets usually occur at the same place with no apparent interaction, giving exposures a blocky or fragmented appearance as you can see here. We will see some photographs soon. So, you see this rhombic can be squarish as well. So, this fragmented appearance if you see in the fields that means this rock is jointed.

Now, two or more sets of joints present together in an exposure the compose generally a joint system and in the joint system you can figure out the spacing between the joints. So, for example this is the spacing between set two you can also figure out the angles between the joints and these are also sometimes important for structural analysis provided they form in a same time.

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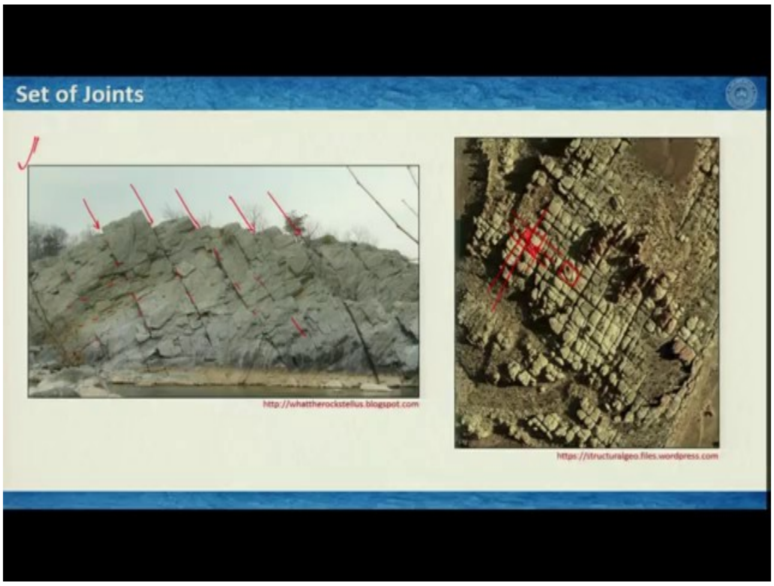

So, here is one example, the first one you see that it is predominantly one sets of joints which are this one. So, all these are joints in this rock. It has another set of joints which is running something like that but that is not dominant as this set is. However, the second image you can see as I was talking about this blocky nature. So, you have one set of joints going like this and another set of joints almost perpendicular to this giving rise to these little blocks. So, this is how you interpret or you see the set of joints in the field.

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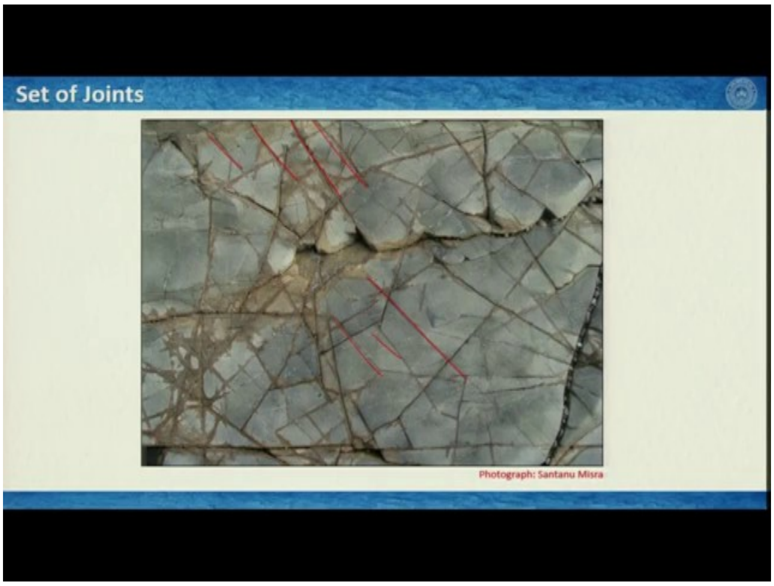

Now, not necessarily you always have parallel sets of joints. So, they can be in a different way, we will see this image again but you see there is no apparent parallelism of the joint sets. So, maybe these sets are little bit of parallel to each other but then they terminate with another joint and so on. So, this we call something which we learn later in the next slide.

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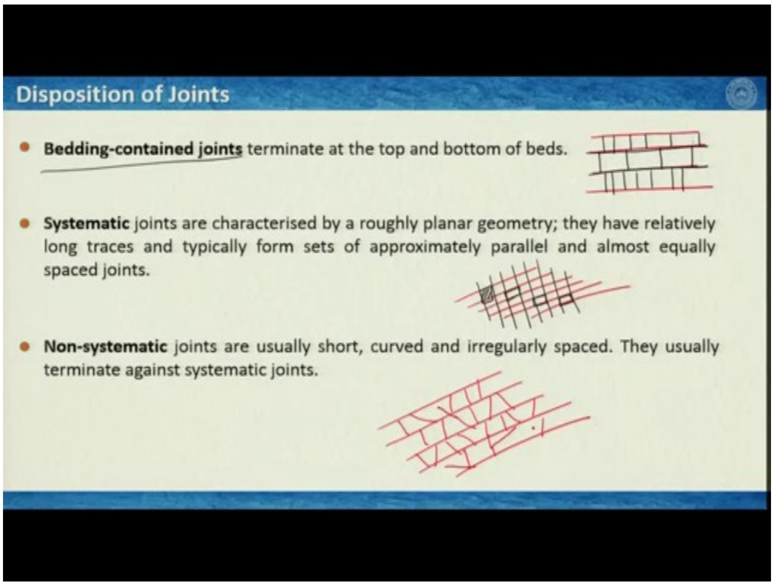

Now, one set of joints you can think that, this could be bedding contained joints. So, that terminates at the top and bottom of the beds. What I mean by that these are your traces of the bedding plain on the surface and if the joints do form, then you may have joints only confined in one set and then you may have joints confined in the other bed like this.

We will learn soon about what would be the characteristics of the spacing and so on, whether they would be similar spacing or a different spacing and so on but the point here with the bedding contained joints is that this joint did not propagate through this interface between the two beds and so on. If that happens then we call it bedding contained joints

Systematic joints are characterised by a roughly planar geometry, they have relatively long traces and typically form sets of approximately parallel and almost equally spaced joints. Exactly what we have seen in one of the first illustrations, that you have one set like this and then you develop a second set of joints like this. So, individual sets are mostly parallel to each other and then they develop this mostly equidimensional blocky shapes.

And when it is not systematic not systematic joints are usually short, curved and irregularly spaced. They usually terminate against systematic joints. So, in a similar way you can consider that if you have joints like this and then a second set of joints maybe they may originate in a different way not necessarily they are parallel to each other. So, they terminate at each place, they may continue but stop somewhere and so on. So, these are the processes of non-systematic joints.

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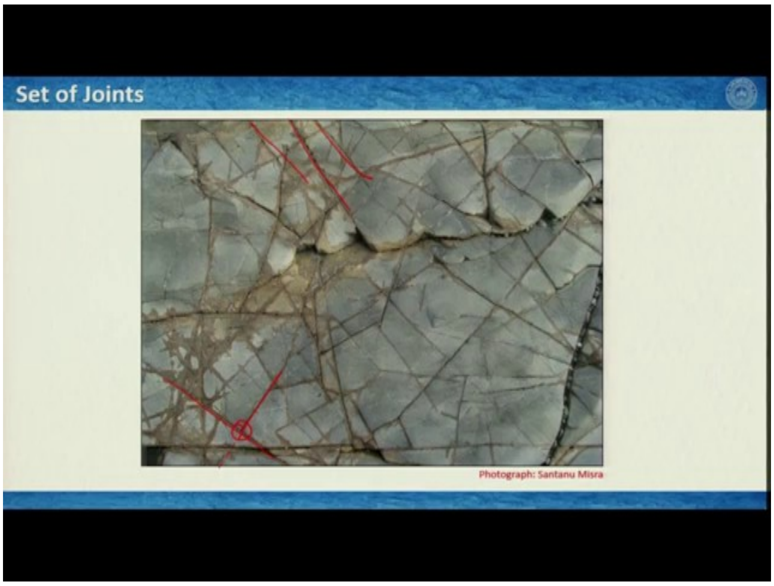

And here is again the photograph I added here again just to give you an idea. So, for example, here you can see that you have this set which is more or less parallel to the set we have seen here, but we generated another set that terminated here at this junction, it did not propagate in this side. So, these are non-systematic joints.

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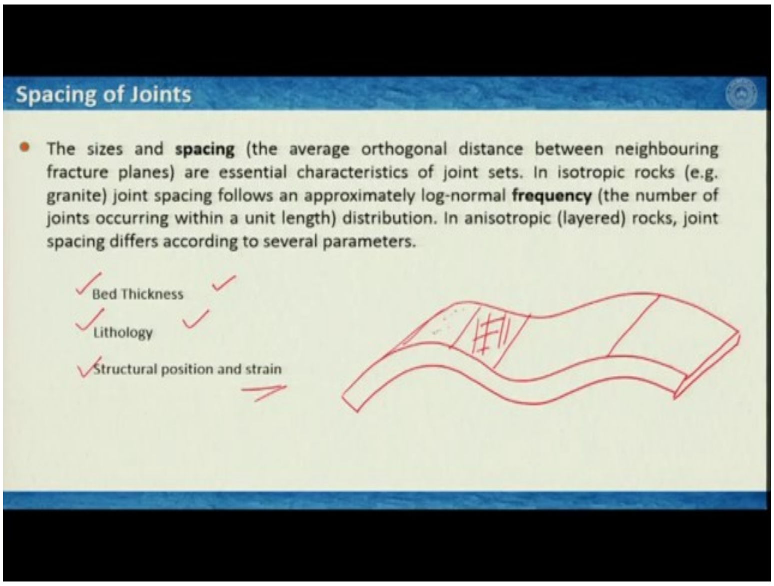

Now, spacing of the joints as you talking about that what control the spacing, the size and spacing. That means the average orthogonal distance between neighbouring fracture plains are essential characteristics of joint sets. In isotopic rocks, for example, you consider granite joint spacing follows an approximately log normal frequency, the number of joints occurring within a unit length.

So, in anisotropic layered rocks, joint spacing differs according to several parameters and these parameters mostly control by bed thickness, lithology and structural position along with the strain. Bed thickness we will see soon, lithology as well, structural position means that where the joint is forming in other words. If I have a folded layer like this then the orientation of joints or spacing of the joints at the hinge zone would be essentially different from those of the ling zone so on.

And if this fold is also, in this case this is a cylindrical fold if the fold is non-cylindrical then also you may expect different types of joints and also valuable spacings. The strain is of course how the magnitude of the strain influence the joint pattern and I tell you they do it. It is also important to understand at this point that the rate of strain or rate of deformation also influences the pattern, the size and the spacing of the joints we will see in one illustration soon on this.

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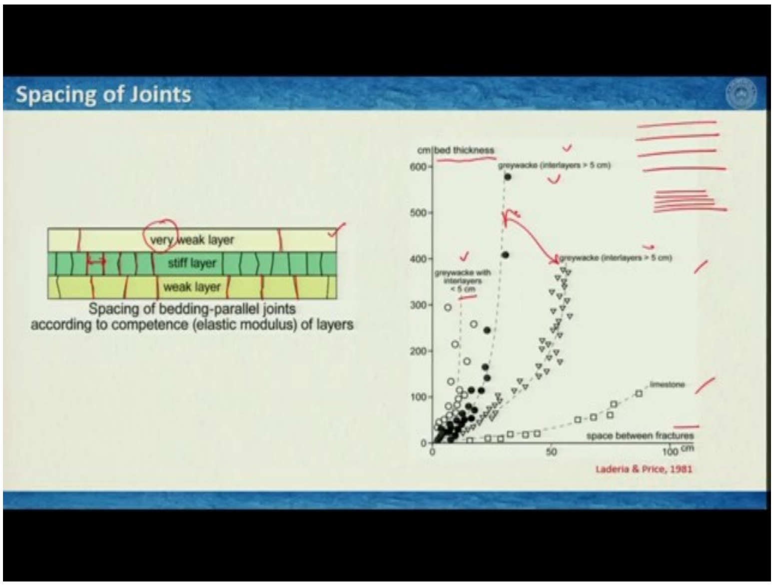

So, here is an example that if you have weak layers then the spacing of the joints is pretty wide. If you have stiff layers then the joints are very much concentrated that means the spacing is much less and if you have weak layers. So, this is a very weak layer and if you have a weaker layer then you see spacing in between the stiff layer and very weak layer. This is another example that is showing that the plot bed thickness versus space between the fractures. So, that means how lithology is controlling the spacing of the joints.

So this one is for greywacke this one is for greywacke which have inter layers greater than five centimetres and this is greywacke inter layers less than five centimetres and you can clearly see the space between the fractures in the same compositions but if the layers are thinner than spaces between the fractures are also less, in this case if the layers are thicker than the spaces also do increase.

And similarly, the greywacke if you have this way and in limestone it carries in different ways. So, these greywacke and these greywacke they are different in terms of their grind size and so on. So, you also see the grind size also do play a role in determining the spacing between the joints or fractures in rocks.

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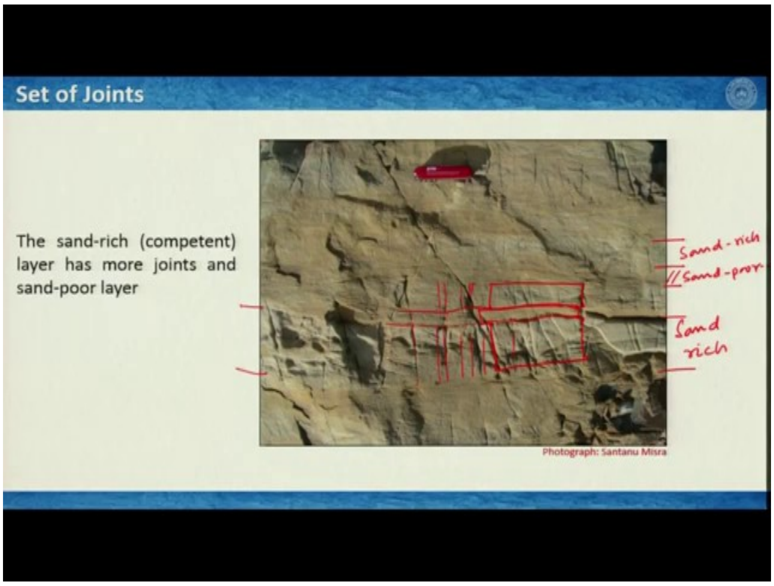

So, here is an example, a photograph you see that clearly understand that this little whitish layers here this are competent because they are whitish and they are most likely sand rich layers and these are sand poor layers. So, these are sand rich and these are sand poor. We clearly see that within the sand rich layers we have more joints here but this particular layer if I consider.

You see some of the joints pass through this but this one no, this one passes through this but all this two joints they did not pass through this. So, this is almost free of joints from here to here if I consider this space but the space just below and just above because these are sand rich layers you see the number of joints are very-very high within the same area that we are looking at. So, this tells you that the spacing of the joint is essentially controlled by the lithology of the rock.

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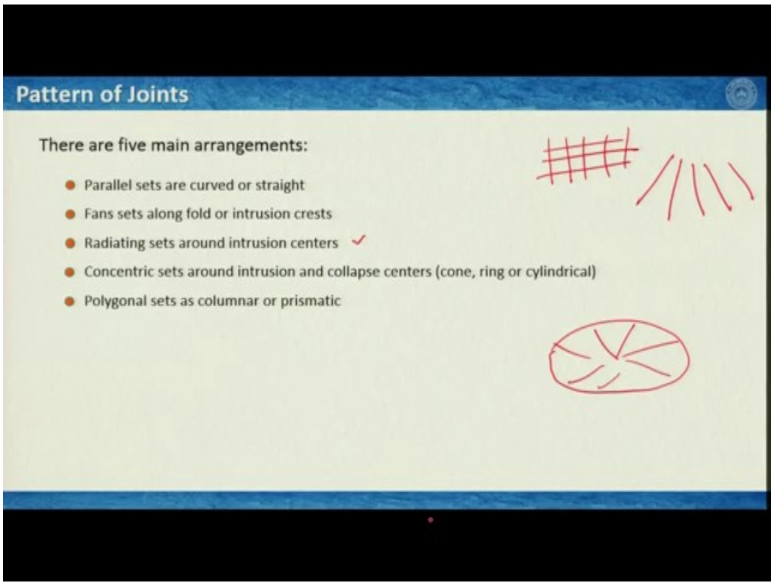

Now, the pattern of the joints they you can actually see many different types of joints. So, joint sets that mean their relationships with the other joint or neighbouring joint plains with another. So far we have seen most of the joints are parallel like this or sometimes they have angular relationships.

So, these are parallel sets and this could be curved or strained. Then fans sets so joints can be ready to radiate like this. Then radiating sets around an intrusion centre and this happens when you have, you particularly see this kind of joints, this radiating joints in pillow lavas. So, when the pillow lava cools then it generates radiating joints like this. Then concentric sets around intrusion and collapse centres.

So, this concentric set generally we need to see the x foliations and something like that then these are concentric set of joints. And then polygonal sets as columnar or prismatic joints mostly seen in the basaltic rocks and known as columnar joints we learn about it also in one of the slides.

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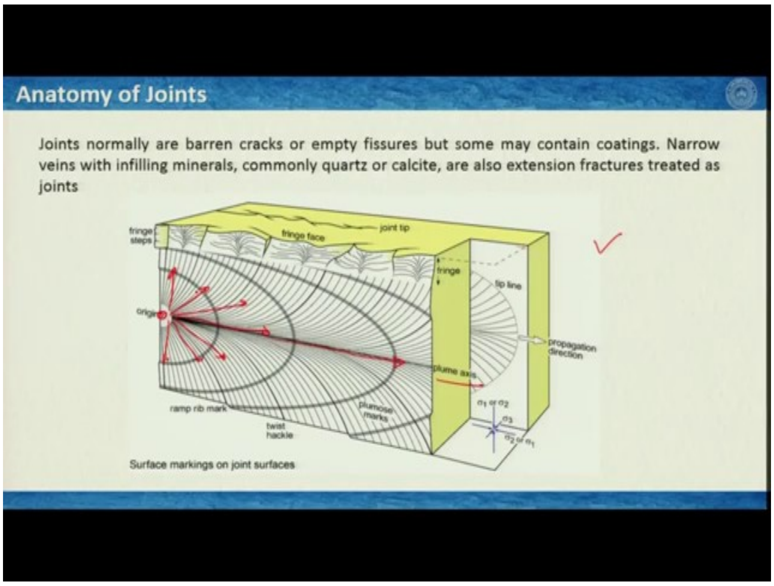

So, here is an illustration that shows what the different features that you expect are in a joint surface. So, joints normally are barren cracks so you will see just a crack surface but with a lot of interesting features. So, or it can be empty fissure but some may contain coatings. Narrow veins with infilling minerals, commonly quartz or calcite, are also extension fractures and you can treat them as joints but let us concentrate on this image.

So, what we see here, this plain where you have all these illustrations, this plain is your joint surface. So, it happens this way and this is another trace of the joint surface this is the joint tip and this is another surface you can see the joint is exposed. We will learn about it, so the joint originated from here and then it propagated in this direction. So, the fracture plain originated here and then it propagated radially this way. In all this direction with the major growth direction in this and this is known as plum axes.

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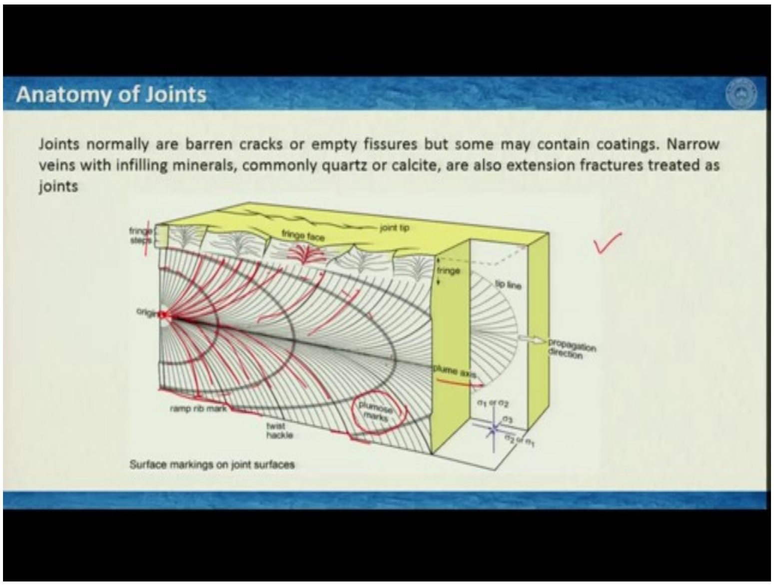

Now the joint surface is characterised by a feather like marks which you see here and this feather like features generally do originate from the origin from where the joint started and these are known as plumose marks. You can also see around this origin some radiating half circles or half ellipses like this, these are known as rib marks and rib marks are generally characterised by some sort of steps and these steps are known as ramp rib mark.

On the outer side of the joint where it intersects with the opening faces of the rock, you see the fringe face. So, these look like this and in this case these are also some sort of small scale plumose mark and these do happen by your step and these are known as fringe steps. So, these are also known as plumose marks and so on, these are also known as hackle marks and we will, in the next slide,we will talk about mostly on the plumose marks.

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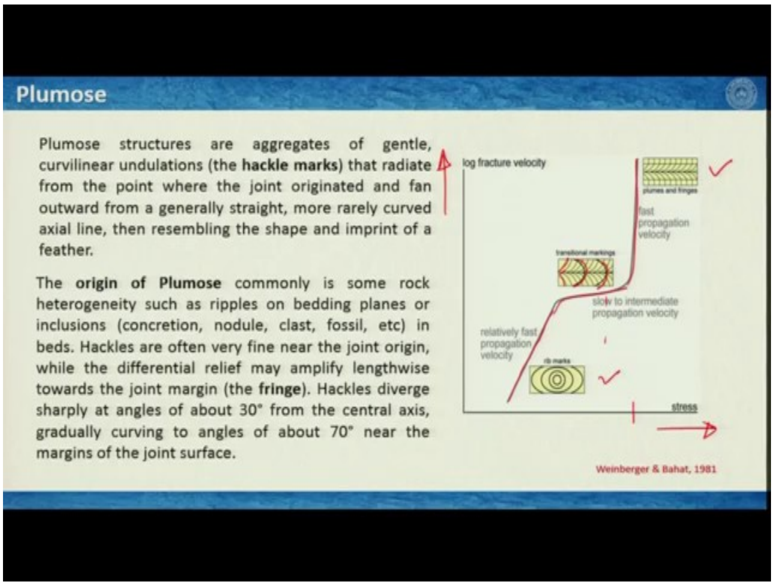

So, plumose structures are aggregates of gentle, curvilinear undulations and known as hackle marks as I just told you in the previous slide, that radiate from the point where the joint originated and fan outward from a generally straight, more rarely curved axial line.

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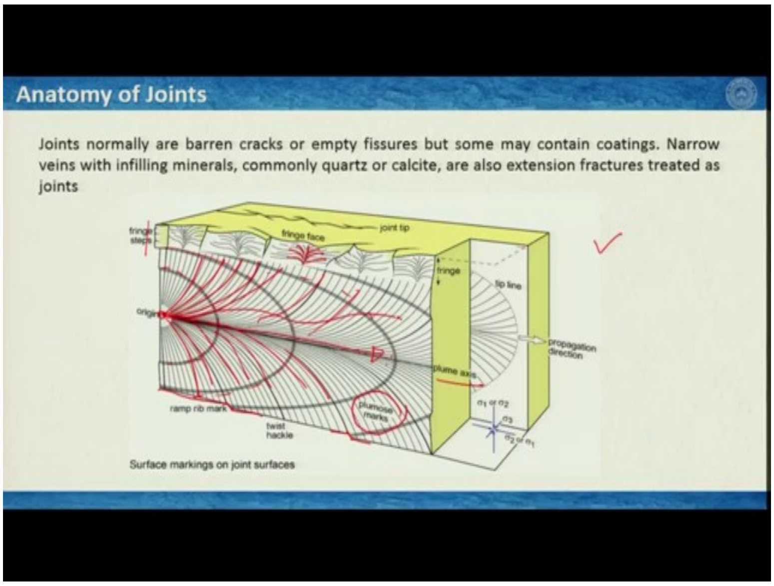

So this line you see here it is very much straight. However, in few cases we may see that this can be curved, but this is very rare and then it resembles a shape an imprint of a feather. So, sometimes you may mistake it by considering that this is a fossil of a feather or something like that but it is not.

The origin of the plumose commonly is that some rock heterogeneity you can consider them a ripples on bedding plains or inclusions. So, this could be a concretion, nodule, clast, fossil etc in the beds. The hackles are often very fine near the joint origin, while the differential relief may amplify lengthwise towards the joint margin toward the fringe. We will see the example very soon.

Now hackles diverge sharply at angles of about thirty degrees from the central axis and gradually this angle increases. So, curving to angles of about seventy degree near the margins of the joint surface. Now this plumose marks and the ribs mark these are also important in terms of or in correlating the stress versus the fracture velocity. So, I have stress access in this side and fracture velocity in log scale in this side.

At low stress if the propagation velocity is relatively fast then we see this radiating rib marks but we hardly see a plumose mark as it is represented here with this illustration. If the velocity is more or less constant or very slow but stress is intermediate then we see some sort of radiating rib marks and also plumose marks and these are known as transitional markings, but if the fracture velocity is very-very high and also the stress then we see features like this. So, you see plumes and fringes. The rib marks are absolutely absent in this kind of tectonic settings.

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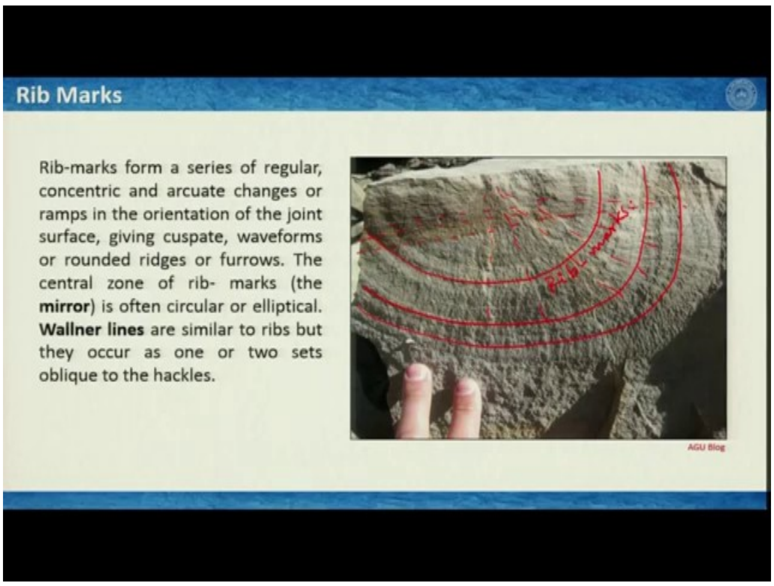

Now, rib marks, they do form series of regular, concentric and arcuate changes or ramps in the orientation of the joint surface, giving some sort of cuspate, waveforms or rounded ridges or furrows. The central zone of rib marks or you call the mirror is often circular or elliptical. And there is another terminology that is Wallner lines and these are similar to ribs but they occur as one or two sets oblique to the hackles. Now, what do we see here?

We will see fantastic images of plumose marks in the next slide, but you see probably the plumose marks like this here and these are your rib marks. So, this is a jointed surface and these things are your rib marks. Now, do not focus on these plains, these are most likely the marks of the water. So, this has nothing to do with the structural geology or tectonics. But these are rib marks in this joint surface. Now, not necessarily you see both rib marks and plumose marks at the same time.

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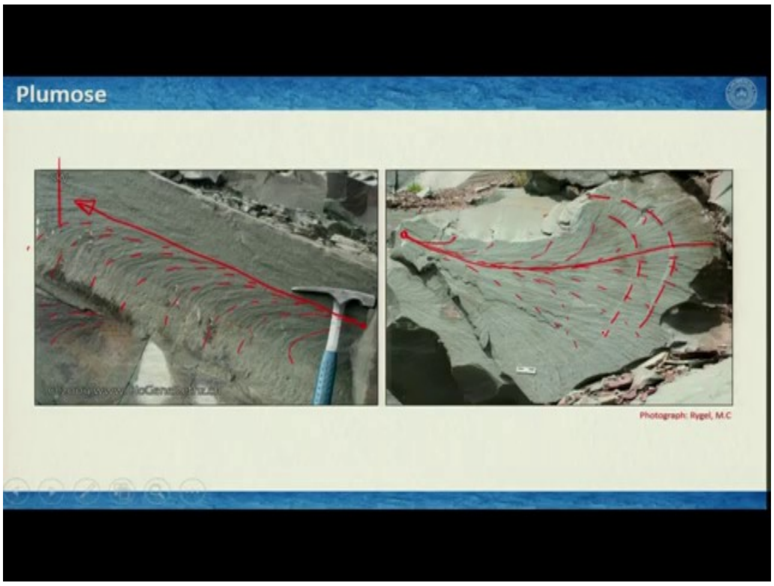

So, here for an example that you can figure that joint originated from here and then your plumose marks are going like this and just drawing this or looking at it, even you can look in the next surface. You can clearly figure out that the joint propagated from this side to this direction. Now, this does not have any rib mark but in this again you can figure out that it probably originated somewhere here and then it is going like this, it is a feather like feature.

And in this case this plume line is a little bit curved and these are your rib marks and these are the steps as you can see here they appear something like this. So, this is how if you see this kind of a features in the field, first you identify that this essentially a jointed surface, and when you are convince that this a jointed surface, then you try to figure out that what was the propagation direction of the joint, and then you also try to see whether it has rib marks and other features or not.

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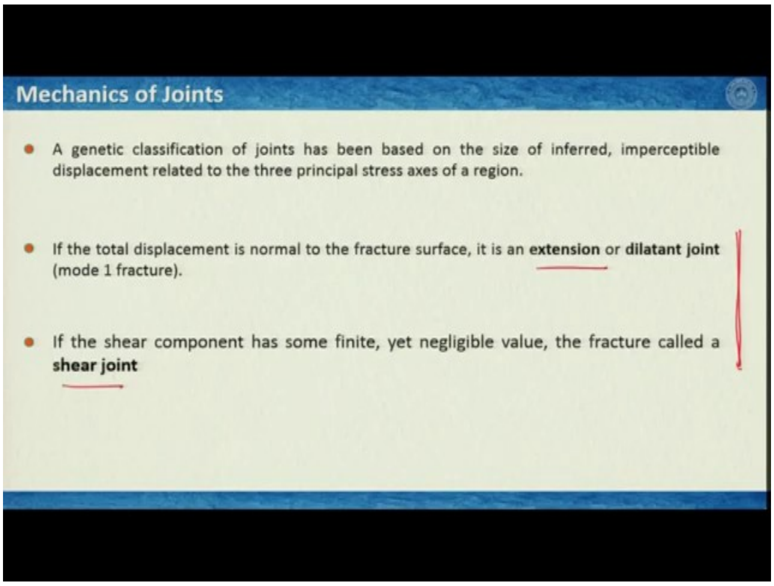

Now, the mechanics of the joint are also very important. So, we mostly talked about it and we know that most of the joints are generally mode one fractures. So, extensional or dilatational but there are deviations. So, genetic classification of joints has been based on the size of inferred, imperceptible displacement related to the three principal stress axes of a region. Now, if the total displacement is normal to the fracture surface, it is an extension or dilatant joint or mode one fracture as we are talking about.

If the shear component has some finite, but very negligible value, then the fracture is called a shear point. So, we can have extensional joints and we can have shear joints. Now, these definitions are or classifications are essentially restricted to the point when joints just have formed. Now, an extensional or dilatational joint or a shear joint at latest stage of the deformation can eventually produce a fault and so on. But this is exactly what we are not going to look at right now.

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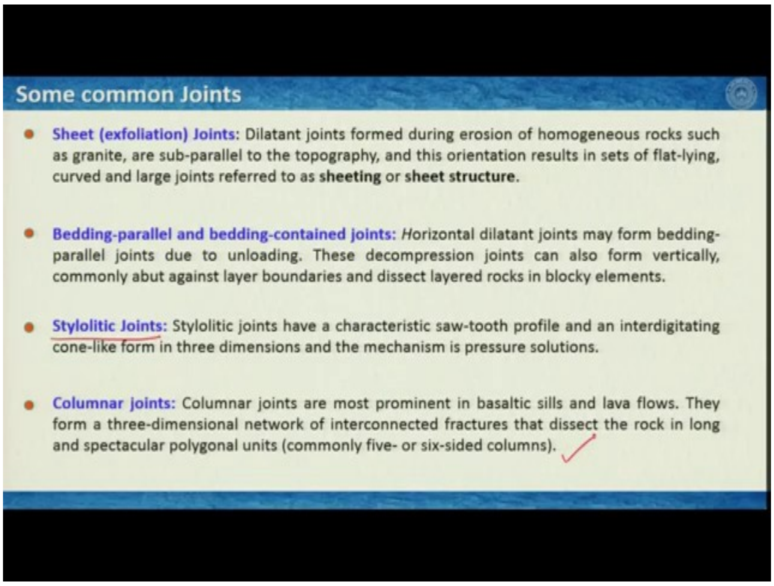

So, there are some common joints. I am just reading their names and their characteristics that we generally find in the text books or sometime in the class lectures or in the field. The field in the structure says that this kind of joints and you can also figure it out by yourself after this lecture I believe. Now, I just giving here only four names but there are many other names but these four are the mostly common used terminologies related to identifying joints in the fields.

One is sheet or exfoliation joints mostly seen in the granitic rocks. So, these are dilatants joints formed during erosion of homogeneous rocks such as granite, are sub parallel to the topography, and this orientation results in sets of flat lying, curved and large joints referred to as sheeting or sheet structure. Now, if you go to the field and see a granitic exposure you must have seen that it is like exfoliating, it is like onion. So, some curved joints appeared there going out or falling apart. So, this is the process of weathering and these are essentially termed as sheet joints.

Now, you can have bedding parallel and bedding contained joints. So far we have seen bedding contained joints, which are perpendicular to the bedding plains but you can also generate bedding parallel joints and both of them can happen during the decompression. So, horizontal dilatants joints may form bedding parallel joints due to unloading or decompression and these decompression joints can also form as I was talking about vertically and commonly about against layer boundaries and dissect layered rocks in blocky elements.

We have learnt about stylolite in one of the previous lectures when you are talking about the diffusion crips. So, stylolitic are actually kind of joints and stylolitic joints have a characteristic saw tooth profile. So, in other joints it is more or less straight flat the surface are characterised except the plumose related undulations or rebilated undulations but stylolitic joints are essentially different because these are amalgamated there is no opening or shearing but compaction is working there.

So, stylolitic joints therefore have a characteristic saw tooth profile and an interdigitating cone like form in this dimension and the mechanism is pressure solutions. We have learnt about it in one of the previous lectures. And finally the most spectacular joints are columnar joints. You are seeing this in the background and columnar joints are most prominent in basaltic sills and lava flows.

So, they form a three dimensional network of interconnected fractures that dissect the rock in long and spectacular polygonal units commonly five or six sided columns. So, columnar joints are very spectacular, if you see them you are lucky, but you see in India or if you travel to Lakshadweep and so on there you can see these columnar joints spectacularly. So, with this note I finish this lecture. This is a relatively shorter lecture.

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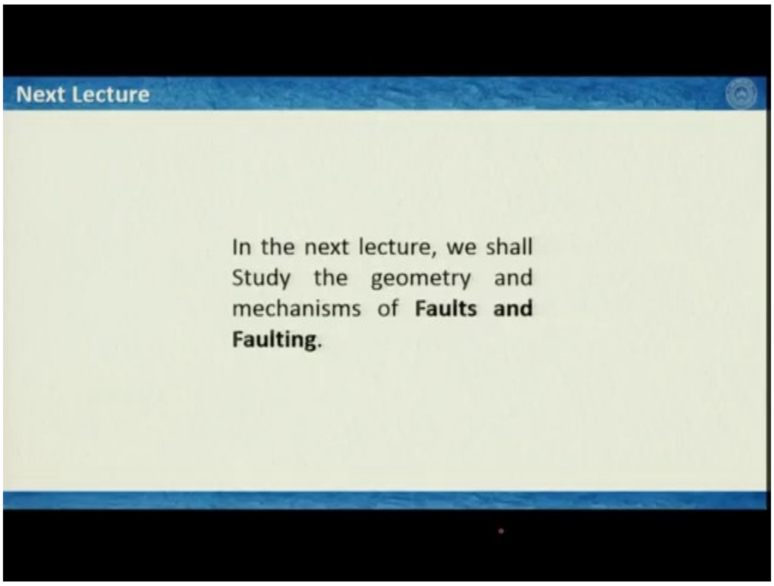

But you will be having a long lecture on faults and faulting there will mostly look at the geometry and mechanisms of these terminologies or these two very-very important structures of structural geology and also in geology. Faults and faulting is the topic for the next lecture. Thank you very much, have a nice time I will see in the next lecture.