Structural Geology
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Lecture – 17
Planar Fabrics (Foliation/ Cleavage/ Schistosity) - I

Hello everyone! Welcome back again to this online Structural Geology NPTEL course.

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We are going to start a new week and in this week we learn Foliation and Lineation or in other words planar fabrics and linear fabrics in deformed rocks. So, we will have three lectures in this week. The first two lectures would cover foliations or planar fabrics, and the last lecture would be dedicated for linear fabrics.

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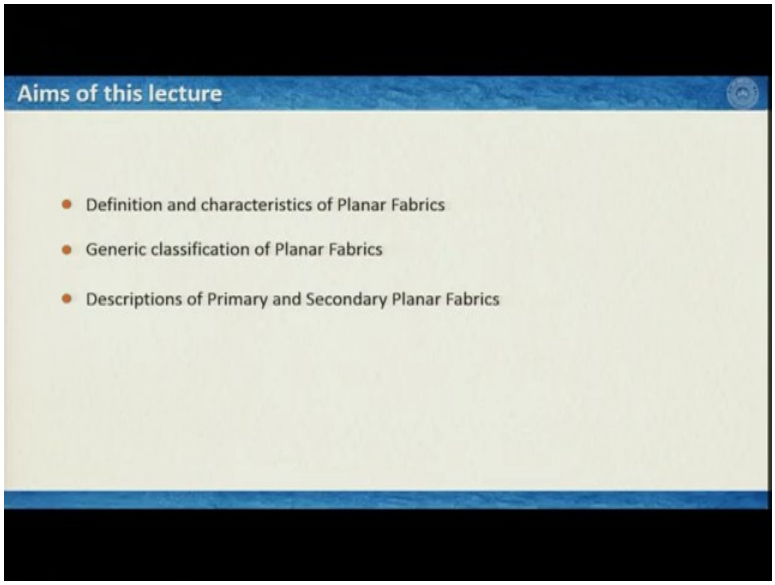

Today's 17 no. at the levcture, we will learn mostly the definitions and characteristics of planar fabrics or foliations, and then we will classify foliations based on their origin or genesis. So, generic classifications of planar fabrics and then will very briefly sort of describe the different kinds of planar fabrics mostly focusing on primary and secondary planar fabrics.

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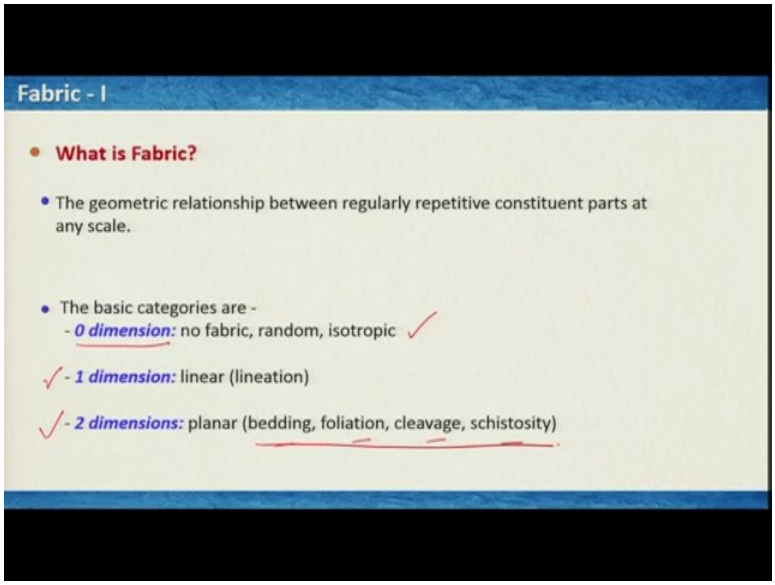

Now, before going to the details of this topic planar fabric let us first discuss what is a fabric? Now, technically fabric is defined as it is written here, the geometric relationship between regularly repetitive constituent parts at any scale. So, in any volume it is constituted by some elements. Now, these elements are distributed within the volume, and the fabric is their

arrangements, their geometries and their relationship with the neighbouring grains and so on which constitute the entire volume is known as fabric.

Here, I repeat the geometric relationship that is very important and it is geometrical parameters. So, geometric relationship between regularly repetitive constituents parts at any scale that means it has to be all over the volume of the body we are concerned with, and if we think about this fabric, which is geometrically distributed all over the volume then we can consider it in three ways.

The first one is if there is no fabric at all so the elements are distributed very homogeneously, they are not defining any fabric, then we call it 0th dimension of the fabric so there is no fabric or it is very random, and we can assign it as isotropic fabric. And these two are important if they are in 1 dimension then we call it linear fabric or lineations.

So, (fabrics is) fabrics are only visible in one direction and, of course, there are 2 dimensional fabrics which we will be discussing in this lecture and in the next lecture known as planar fabrics and that includes, that include bedding, foliation, cleavage and schistosity. So, we will learn about all these terms very soon but let us focus a little bit more on what is planar fabric.

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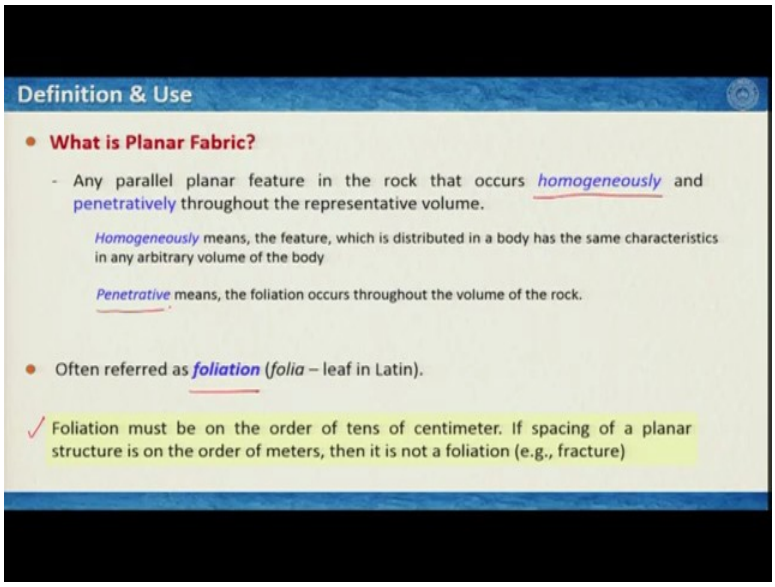

Now, as it is as the name suggests that it is planar fabric so that means any parallel planar feature in the rock that occurs homogeneously and penetratively throughout the representative volume. So, it is a two dimensional feature that is why it is planar feature. The features have to be parallel to each other or to some extent sub parallel to each other throughout the volume of the rock and they have to be distributed homogeneously.

Accordingly, to specify these two terms in particular, homogeneously means the feature which is distributed in a body has the same characteristics in any arbitrary volume of the body and penetrative means the foliation occurs throughout the volume of the rock. So, that means if I have a planar fabric in the rock except the plane it is occurring, if I cut at any direction of this volume of the rock I should see the presence of the fabric.

So, the trace of the fabrics should be present at any orientation except the plane it is occurring.This planar fabrics as we have already understood is known as foliation. Now, foliation word comes from this Latin word is folia which means leaf. Now, how frequent should be the planar fabrics that might be a question, that if I see a feature 1 kilometre apart of a planes are occurring within the rock 1 kilometre frequency is this a foliation or they are occurring in micron scales? So 2 microns intervals I see a planar fabric within the rock is this a foliation?

If you ask this question then here it is written within this yellow highlighted box – foliation must be on the order of tens of centimetres. So, the repetition or the spacing between the two planar fabrics must be within 10 centimetres or less. Now, if the spacing is much higher, then we do not consider is them as a foliation because it is not worth of studying their features and they may not be represented it.

For example, you can consider fractures or joints they occur in very large spacing's and you may not consider them as a foliation, however, if they are very concentrated sometimes we consider them as a foliation from case by case basis.

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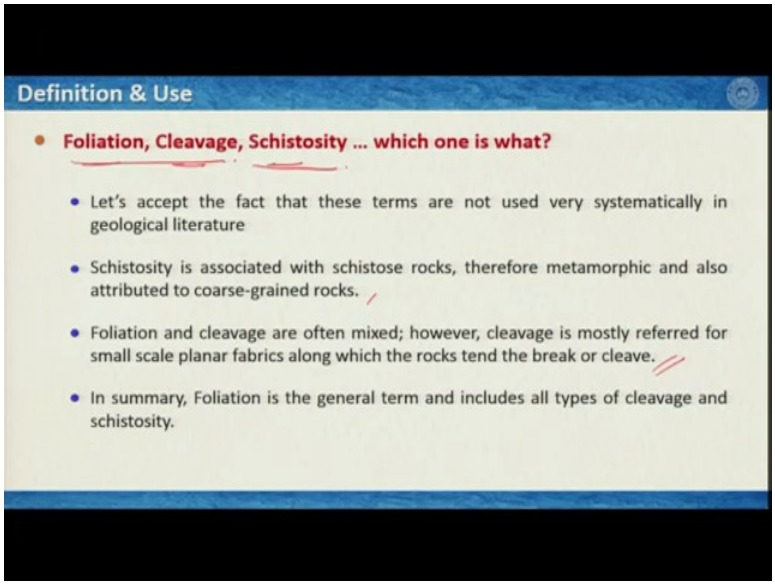

You also have heard a series of terminologies related to foliation or planar fabrics in general, so three commonly used terms are foliation, cleavage and schistosity. Now, it is always confusing if you read the literature or text that which one is what? We commonly referred these three terms almost on every aspects. Let us accept the fact at the very beginning that these three terms foliation, cleavage and schistosity are not used very systematically in geological literature and texts, they are often mixed and sometimes they are use is very much confusing.

However, in this slide we will try to more or less describe that which one is what to have a better understanding, having said that it is still not very wisely and systematically used these three terms because it is just a legacy and that we are following as a structural geologist. Now, schistosity, let us first focus on this term is associated with schistose rocks, so therefore, it is something which is related to metamorphic rocks and it is also attributed to coarse-grained rocks.

So, if I call schistosity of some or assign the term schistosity to some planar fabrics that means that this must be a very coarse-grained rock and it must be a metamorphic rock or it is in a metamorphic rock and then the confusion comes between the foliation and cleavage and as I said they are often mixed but cleavage is mostly referred for small scale planar fabrics, whether foliation is generally for large scale features.

However, that is not always maintained and cleavage is also referred to the fact as the name suggests that along the planes, along which the rock tends to cleave or sort of break apart. So, this is how you can think of the difference between foliation or cleavage or you can consider or if I summarize it that foliation is sort of a general term, that is umbrella under which it contains itself, foliation term cleavage and schistosity so it includes everything.

If you say planar fabric is equal to foliation then it is fine but we use sometimes these terms cleavage and schistosity for specific purposes, but I repeat not very systematically. So, let us go with that and we will see that in different places somewhere we are using foliation, somewhere cleavage and somewhere schistosity.

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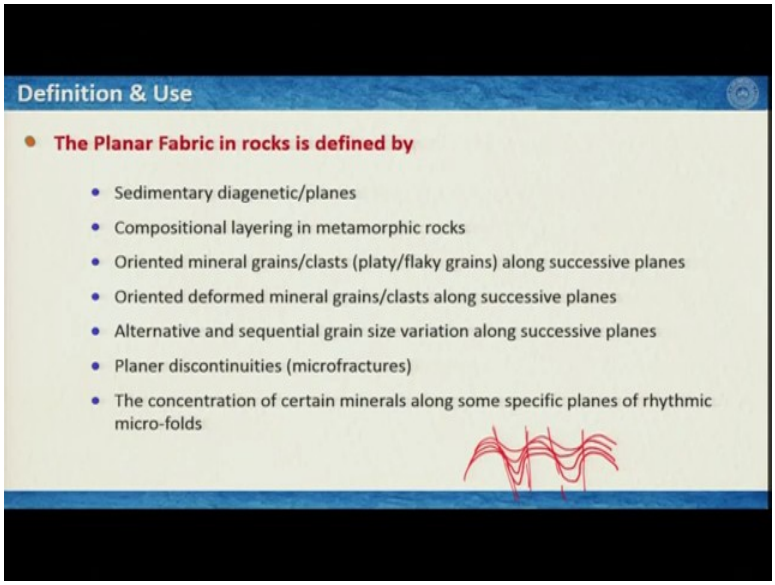

So, what defines the planar fabric? Here is a list for you. The first one is sedimentary or diagenetic planes. So, sedimentary beds or sedimentary layers or bedding planes or diagenetic planes generally define planar fabrics in sedimentary rocks. Then compositional layering in metamorphic rocks that means during metamorphism if compositions are segregated along different layers then we can refer it as foliation and that defines foliation as well.

If we have oriented mineral grains or clasts maybe platy or flaky grains along successive planes in the rock that defines the planar fabric. Similarly, oriented deformed mineral grains or clasts along successive planes in the rock that also defines the planar fabric. Now, if we have alternative and sequential grain size variation along successive planes that means I have coarse grain deposition then fine grain deposition, coarse grain position, fine grain deposition composition is same you can consider sandstone.

So, a coarse grain vary than fine grain, so you can consider this also their boundaries between coarse spread and fine grain as foliation claims. As I talked about that if the fractures are closely spaced that means micro fractures and if it is occurring penetratively within the rock we can call it planar discontinuities and we can assign it as also one type of planar fabrics.

And, of course, the concentration of certain minerals along some specific planes of rhythmic micro folds, so what I mean by this that if you have series of folded layers like this, then along these planes we sometimes have some sort of, along these planes we have deposition or concentration of some specific minerals mostly phyllosilicates and they also define a plane

penetratively in three dimensions and these also are included in the domain or they also define in the planar fabrics in the rocks.

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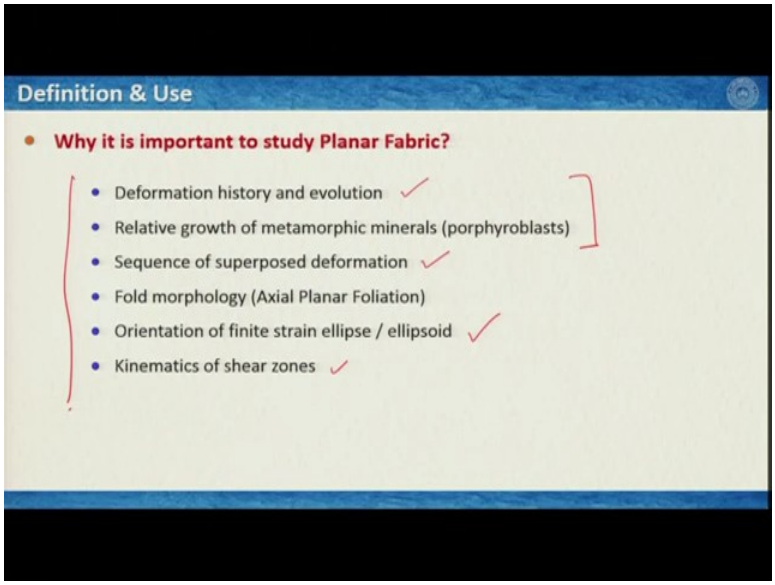

So, and the final question that we should ask that why should we study planar fabric, what is the importance of planar fabric or studying planar fabric in the context of Structural Geology. Well, it is one of the primary and key features in deformed rocks that one should understand for particularly many reasons and here I have listed a few. The first one is deformation history and evolution, we will learn more about it particularly when you go with more structural details of different kinds of structures, but foliations reveal deformation history, particularly their relationships with the host rocks and other pre-existing foliation and so on.

In a similar way, you know when metamorphism do happen then new metamorphic minerals do grow and at the same time foliation also do develop, we will learn about it later. But these new minerals, new metamorphic minerals they also be very helpful to understand the deformation history and evolution along with their relationship with the host rocks foliation or the new foliations that may generate after the metamorphism or after the growth of this new minerals.

So, if we have to get these things to very clear that leads to figure out that what would be or what was the sequence of superposed deformation most of the geological terrains deform geological terrains are deformed in series of deformational phases. So, if we have understand the fact of foliations and their mutual relationships along with the porphyroblasts then we can reveal the sequence of superposed deformation.

Now, foliations are mostly associated with buccal folds we will learn about it soon. The relationship between the buccal fold and the associated foliation tells you that what is the fold morphology, you may not see the entire fold in the field you may see a part of it maybe the limb, may be the hinge and so on. So, the angular relationships between foliation and the fold defining surfaces would give you the geometry of the fold and morphology of the fold.

Foliations are also very important in figuring out the orientation of the strain ellipse and strain ellipsoid, we will learn about it later. And finally to reveal the kinematics of the shear zone that whether the shear zone is moving dextrally or sinistrally, foliation are one of the key parameters that we use to unravel this kinematics of shear zones. So, all these are very important and based on the problems you encounter in the field you may use foliation in different ways but these are the general use of foliation as a Structural Geologist you can think of.

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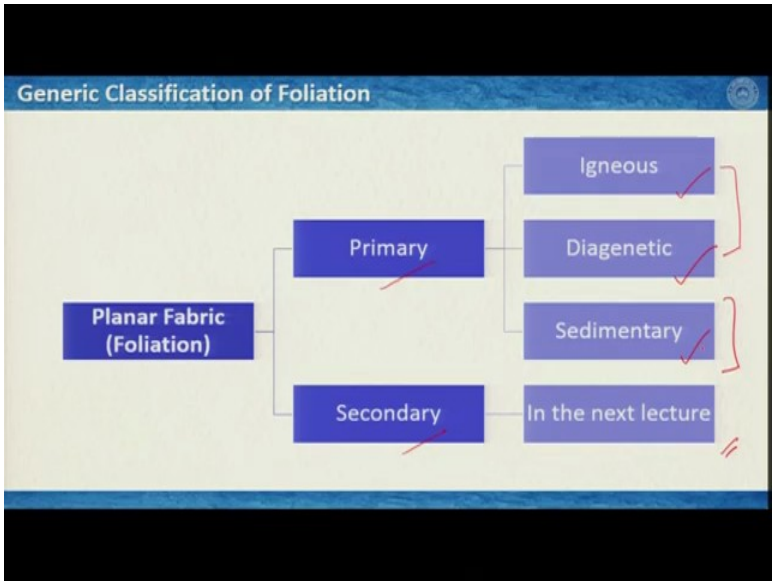

So, let us do the classification of foliation and we will as I said we will do generic classification. So, on this side we have a planar fabric and or foliation and we can classify it in two major classes one is primary foliation and another is secondary foliation, we will define them very soon. Within the primary foliation we have igneous related foliation or igneous activity related foliation, diagenetic foliation and sedimentary foliation.

Secondary foliations are classified in many different ways and this will learn in the next lecture. So, let us have a look what is primary foliation. As the name suggests primary foliation is essentially associated or they essentially develop during the genesis of the rock or

when the rock is taking it is birth. If it is associated with igneous rock during the formation of igneous rock then we call it primary foliation in igneous rocks.

If it is associated with diagenesis of the sedimentary rocks, then we call it diagenetic foliation and if it is associated with sedimentary rocks we call it primary sedimentary foliation. Now, in the context of structural geology or studying structural geology, this igneous and diagenetic foliations are not that important.

However, I have couple of slides to give you an a sense that how do they look like, what is their appearance but sedimentary foliations or sedimentary primary foliations are essentially important in studying Structural Geology particularly in low grade rocks and we will, of course, learn the secondary features or secondary foliations in the next lecture and their classifications. So, let us have a look to this igneous, diagenetic and sedimentary foliations, ok.

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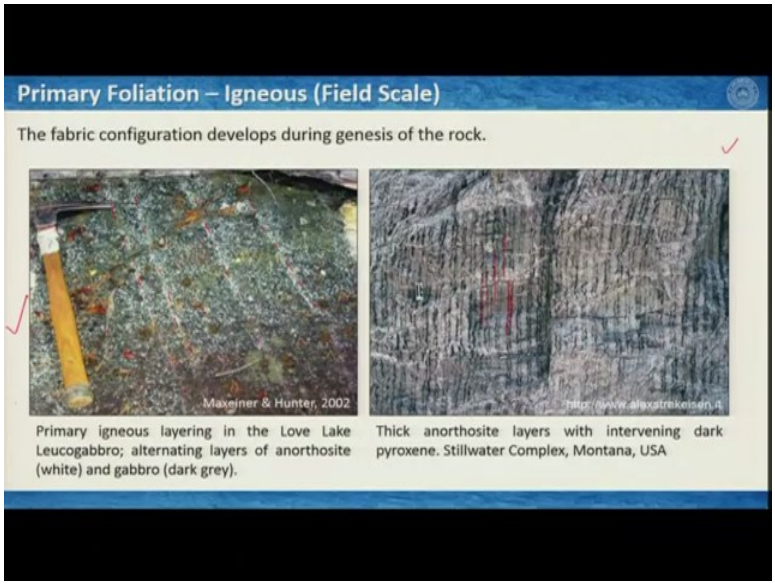

Here you see two images, so this is primary foliation igneous and they are field scale. The first image that you see here this is an image of a leucogabbro, what you see here that this field photograph reveals alternating layers of anorthosite and gabbro. So, these white lines that you see here which are repetitive they occur in the field penetratively, these white things are anorthosite and all these dark things that you see as the host rock these are gabbro.

The second image is also very interesting that this is a thick anorthosite layer with intervening dark pyroxenes. So, the host rock the whitish rock is anorthosite and within this anorthosite you have thin alternating layers of pyroxenes. Now, how do they form? Let us

have a look at their microstructures. So, this we have seen as the field photograph and let us have a look at their microstructures.

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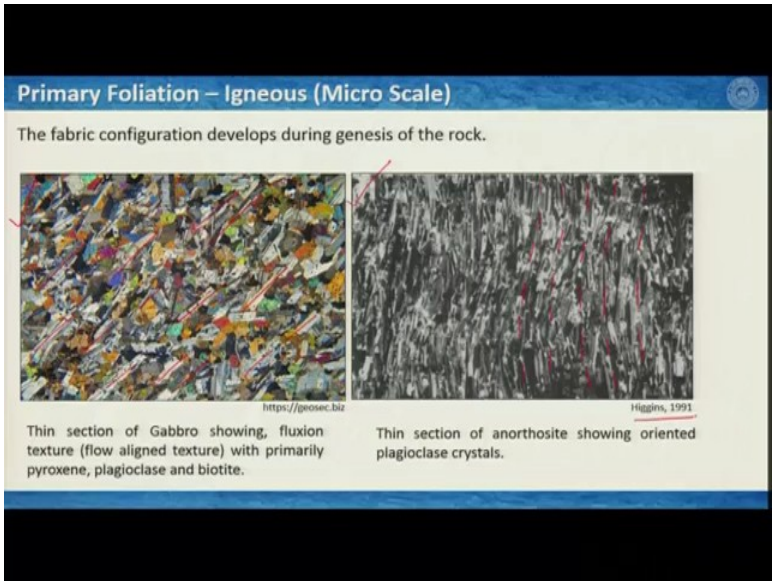

So, the first one is a thin section of gabbro and the texture we see here is fluxion texture or that means flow aligned texture with the compositions here we have mostly as a primary minerals pyroxene, plagioclase and biotite let us not investigate that which mineral is what in this image but what we can figure out at least looking at this photograph of this thin section we see that this plagioclase feldspar are giving some sort of fabric in this rock, right.

It is not a very strong fabric but it is define a fabric and this has formed during the genesis of this gabbro so therefore this is a primary foliation. The second image, this one is even more spectacular, this is a thin section of anorthosite and it shows the oriented plagioclase crystal as you can see it is defining an excellent fabric or trace of the planar fabric on the sections the image was taken.

Now, how did the forum, the authors of this paper in particularly the Higgins 1991 he suggested that during the formation of this rock anorthosite the batch Magma's got in placed in the system and while they were being in placed the boundary layers got highly sheared and while they (got there) they are getting sheared these things or these minerals or the these crystals they either grew (along these) along the shearing direction or the old crystals old long plagioclase laths they oriented themselves along the shearing direction.

Now, at this point you can certainly ask this question which is a very valid question that so this is associated with the deformation, so why these are not secondary foliation? Why we are

assigning this as primary foliation? And as i said this is a valid question and you are right, yes these foliations did form due to deformation to some extent however they formed when the rock was forming.

So, there are still magma from the magma, the crystals are being nucleated they formed, they grew. So, everything was associated during the genesis of the rock and as a student of Geology you may consider the fact that entire art is a very dynamic system. So, it is very rare that you do not have differential cells stress in some places of this art. Therefore, though these arts some sort of signatures of deformation but these are primary fabrics.

We will learn secondary fabrics soon must have formed in a pre-existing rock system. So, we have a rock, now if this rock, for example, this anorthosite got deformed further then this plagioclase crystals may further recrystallize, and then they can orient in a different way defining the planar fabrics and these planar fabrics would then be your secondary planar fabric but in this case because these are associated to the genesis of the rock so these are primary fabric.

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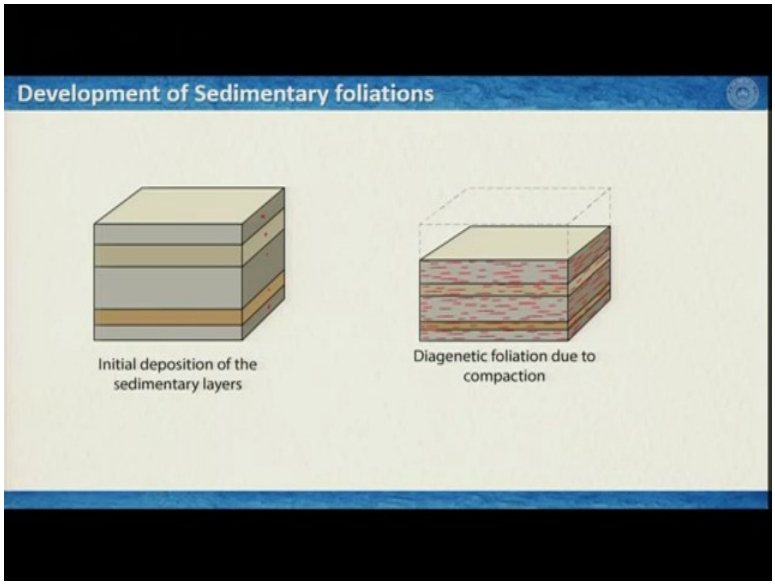

Now, for sedimentary foliations we define it in two different ways, one is bedding foliation and another is diagenetic foliation. The bedding foliations are essentially compositional layers. So, as you see in this cartoon diagram that initial depositions do happen and the depositions within the basin can happen with different compositions due to the flux of the sediments or from where the rivers or whatever is flowing and bringing the sediments to the basin and they are being deposited.

The compositions may vary from one layer to another layer and because they are deposited along a plane so they define planar fabrics and we call it bedding foliations. When this rocks got lithified due to dewatering then some minerals do form at the time of dewatering, at the same time the flaky minerals also reorient themselves along the compaction direction and the foliations that develop at that time we call it diagenetic foliation. So, these red lines, here red dotted lines you can think these are diagenetic materials, let us have a look of the photograph.

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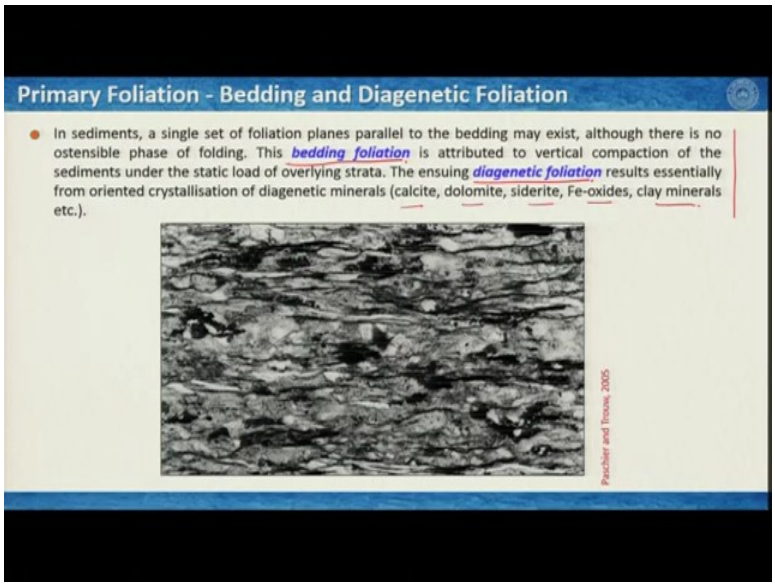

This photograph I took from the book of Passchier and Trouw 2005 micro tectonics and what is written here it is defining the bedding foliation and the diagenetic foliation. So, the diagenetic minerals that commonly form during the diagenesis include calcite, dolomite, siderite some iron oxides and essentially some clay minerals. So, this is where we have learnt that what is bedding foliation and what is diagenetic foliation.

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Let us have a look on series of photographs where we will see that how do they look like, we all have seen this kind of features when you have gone to the field or maybe in the photographs. So, the primary sedimentary foliation as I said is the fabric configuration has to develop during the genesis of the rock. So, what do you see here? This is a carbonate terrain, the alternate these are carbonates and these are some Shelley rocks, the dark grey ones and you see that these layers are these are sedimentary layers and they have deposited at one point of time and now they are lithified so this is a primary foliation.

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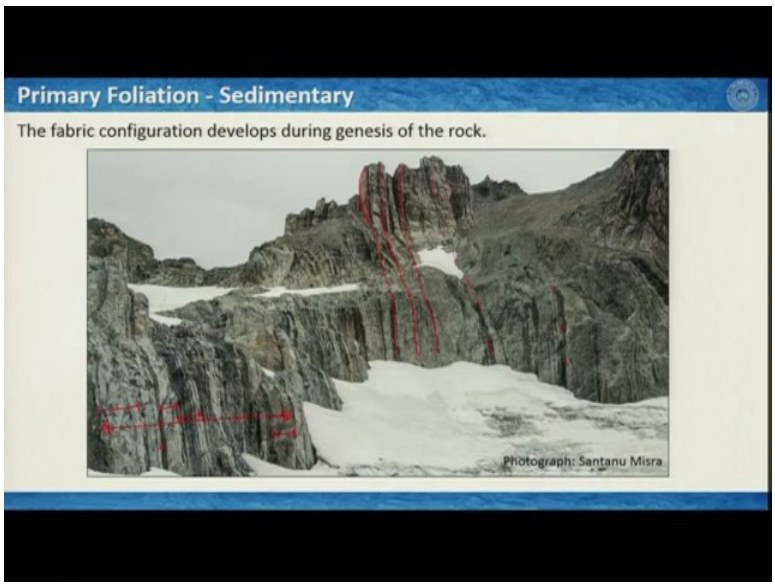

And not necessarily they have to be horizontal they can be rotated due to some deformation but their initial primary characteristics would certainly remain there. For example, what you

see here, these sedimentary foliations are almost vertical so a plane is exposed here and the traces on this eroded surface of this bedding plane is going something like that. So, this is your sedimentary primary foliation.

Now, at this stage I would like to very briefly a guide you that how to identify this primary foliation in the field. First of all, you see that across the foliation you have different colours, the foliations are defined by different colours and, therefore, different compositions. Across the foliation as well the layer thickness are also vary even within the same composition. So, here you see some laminations and then a thick layer and so on. So, this is very much characteristics of sedimentary foliation or primary foliation.

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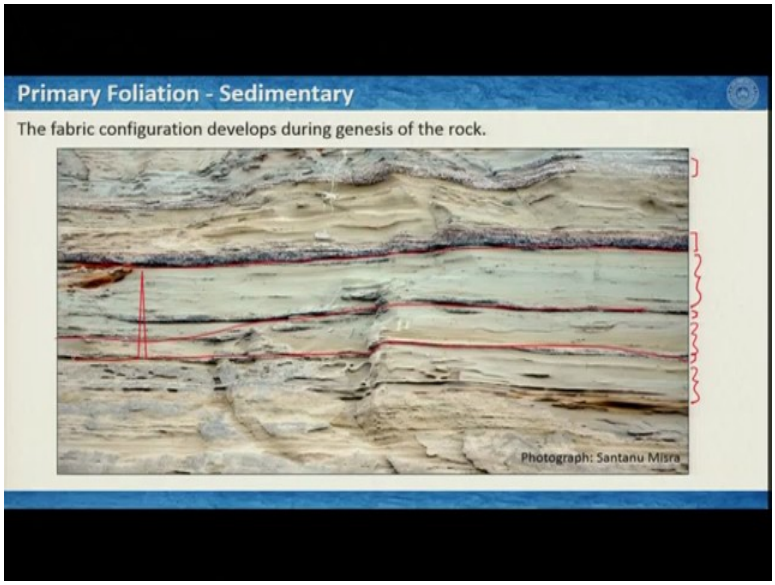

Here in this image what you see here? These are some these layers I am marking these things are defined or these layers are defined by coarse grains whether these areas are defined by fine grains, their compositions are also different that is why the colours are different but this alternative coarse and fine grained features are also very much characteristics of sedimentary rocks and therefore, these things do define primary foliation in your sedimentary rock.

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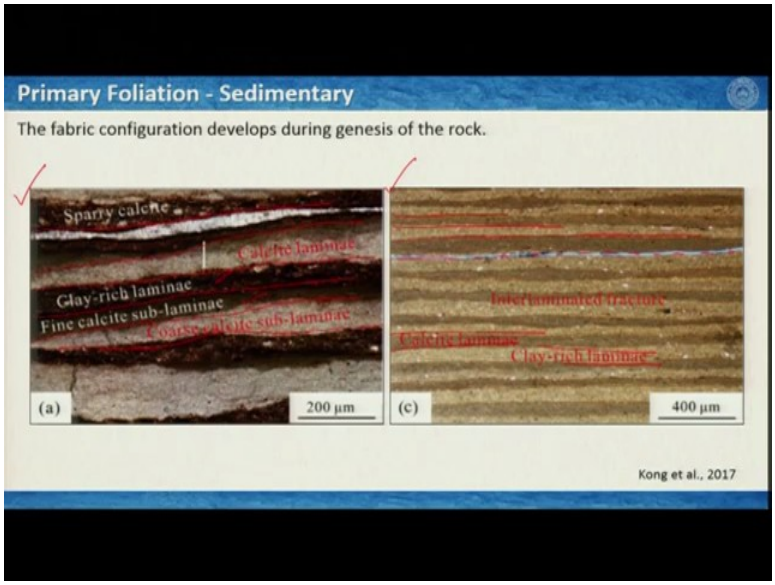

You can also see sedimentary foliation under thin sections as I have shown here in this slide; I took these two images from a very good paper of Kong et al published in 2017. What we see here in this first image that you can see there is alternate dark and white layers, the top part as the authors have defined this is sparry calcite, and then here this is some sort of calcite laminae here and then again this dark layer is the authors have divided in two different layers the top layer is clay-rich laminae and second layer is fine calcitic sub laminae and this layer is coarse calcite sub lamina.

So, the grain size is also varying and at the same time the compositions also do vary in defining the primary foliation in this sedimentary rock. The second image, we can also see that very nicely rhythmic almost constant thickness deposition of this sedimentary rock which are defining the foliations here. So, the alternate layers are defined as calcite lamina this one the darker one and the whiter one is a clay-rich laminae and also this blue line here is a fracture plane. So, you see that does not matter which scale we look at, even in thin scale we can see the sedimentary layers or sedimentary foliation and we can also see in micro scale, ok.

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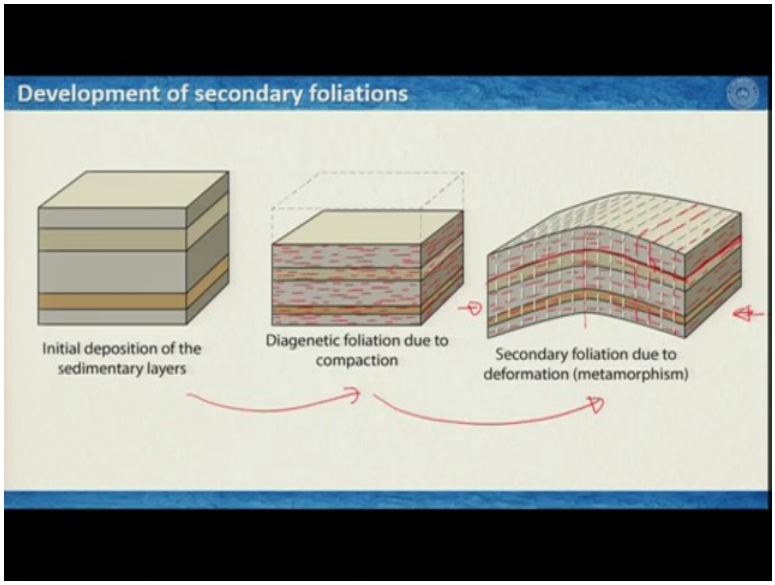

Let us have a look on this cartoon diagram that how do we form secondary foliations out of a rock that may or may not have primary foliation. So, these two we have understood that we have a sedimentary rock or sedimentary depositions, then diagenetic foliation formed, and after that if there is a directed force or directed stress that can deform the country rock, then these white lines, white dashed lines that we see here, these features do appear in the rock and defining secondary foliations.

And as you can see that these primary foliation layers which is carved here on this surface and straight here on this surface, on this section. This secondary foliation cuts across these layers and they also maintain some sort of angular relationship with this primary layering and these angular relationships are very-very important in revealing several structural features and deformation histories, not necessarily they have to be always at an angle, they can be parallel to as well, but we will see this later that what happens if the secondary foliation and primary foliations are parallel to each other.

But the concept I tried to give you here that how the secondary foliations do form, we will also learn later that this is a special type of foliation so you call it axial planar foliation or axial planar cleavage but we learn about it later.

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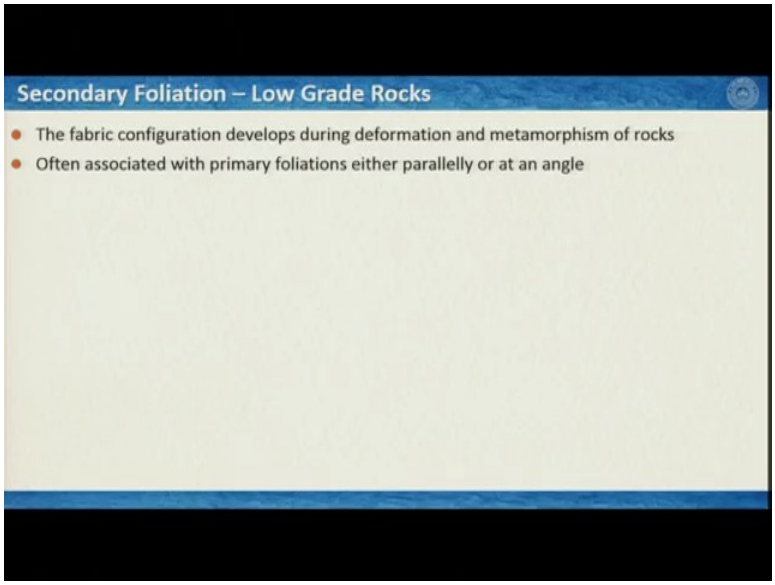

Now, let us have a look how these secondary foliations do look like in the field. The secondary foliations are the fabrics as we have defined that must develop during the deformation and metamorphism of the rocks. So, we have the primary rock with or without primary foliations and when you deform it you develop some foliation, alignment of some minerals or fractures or whatever that defines the planes in the system, and new planes in the system and these are your secondary foliations and as we said these are often associated with primary foliations either parallel or at an angle.

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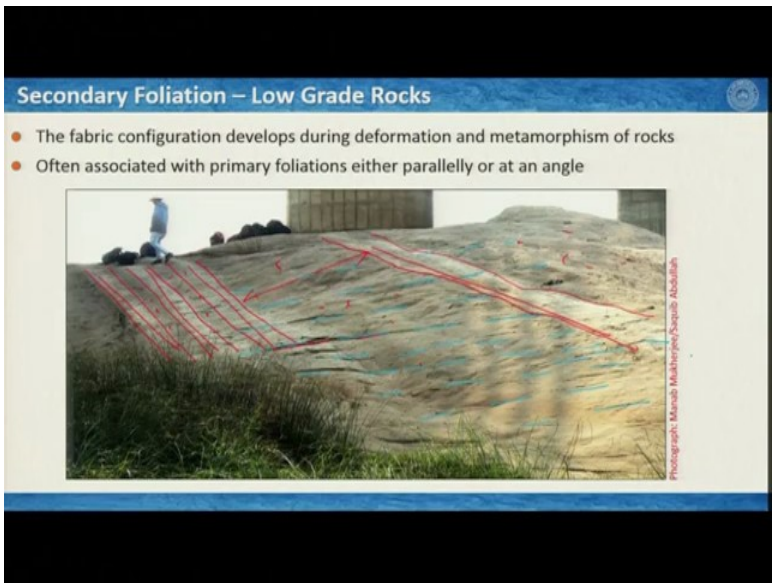

So, what we see here in this image, this is from Chaibasa formation in India. First of all, as we have understood how to identify the bedding planes or primary foliations and as I said that

compositional layering or colour banding is very important, particularly if you are dealing with a low grade rock and in this case this Chaibasa formation is yes, because this is deformed under green cyst fascist I am sorry metamorphosed under green cyst fascist.

What we see here this alternating lighter and darker bands, this is quite thick dark, band and then we have again one lighter band and so on so this is darker band and this is alternating lighter and darker bands. Now, this define your sedimentary or primary foliation however in this volume of rock or in this outcrop we can see that there is another claim which is being defined in a different way or a series of planes that appeared here in a different way relative to the primary layering which is oriented in this manner.

And this other orientation as you can imagine is like this, let me have a different colour. As you can see that there these planes are appearing like some sort of fractures or so on, on the surface but they are very much aligned and I tell you these are very much penetrative or in a way they are appearing like some sort of mechanical damage in the rock and these are your secondary foliations. So, you have primary foliations the red ones and the blue ones are your secondary foliations, we will have a few more photographs.

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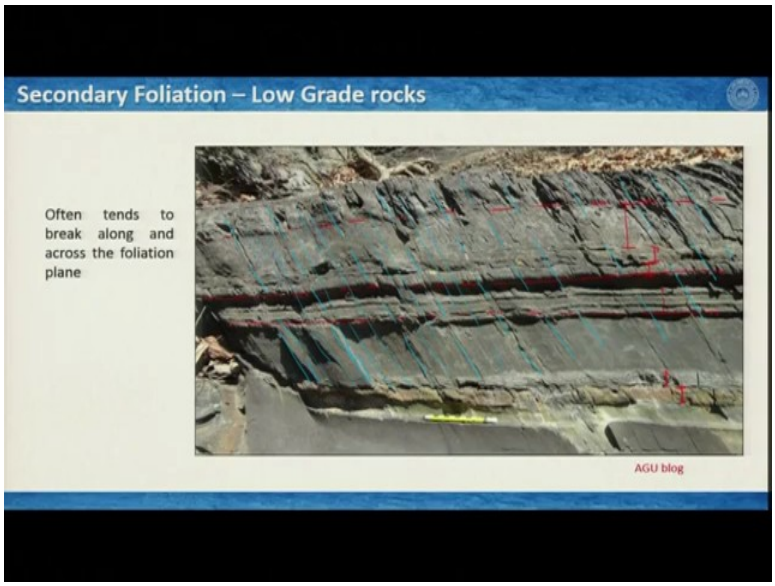

This is a classic one from, I took this photograph from AGU blog and without understanding first that which one is what, let us first identify the planes here that is also another way of looking at it. So, clearly we see the trace of plane one goes like this and another trace of plane we can figure out from this image it is going like this, ok. Now, what is the difference

between this red and blue traces, that we have just identified on this broken surface or eroded surface?

The first one is the red ones as we see that these are consistent and present throughout the rock volume so this is a primary foliation however these are being defined by some sort of thickness variations in the rock and also composition variations these are horizontal red traces. The other one the blue one is cutting across all these red layers and as you can see that like we have seen in the previous image they appear like some sort of mechanical disintegration of this rock.

At the same time the rock is also tend to cleave or break or fracture along this so I just wipe this one out. So, you can see here you see that it got some sort of fracture here, here, here so most of the fractures are along these blue lines. Now, these are your secondary fabric or secondary foliation, whether the red ones are your primary fabric or primary foliations. Now, why so? Again I see that alternative layers this red ones and they are varying their thickness.

So, this is quite thick, this is quite thin, thin and again alternative bedding planes and laminae and so on going on there. But on the other hand the blue ones we do not see some sort of we do not see any thickness defining features. So, because these are big so maybe we see this but if you look closely you also have a series of fine planes which are present all over the rock volume and these are your secondary foliations.

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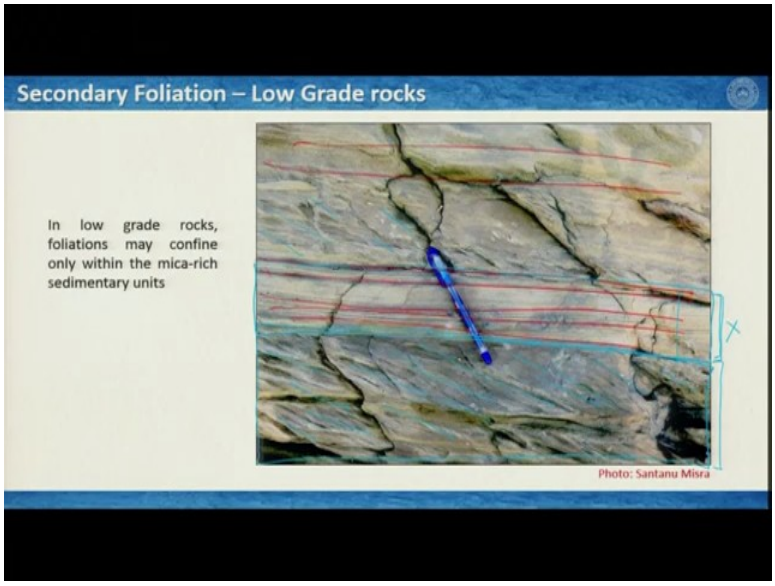

Now, not necessarily throughout the volume of the rock you will form the foliation and this is a classic example to form foliations you need some characteristic minerals at least at the low

grade deformed rocks. What we see here in this image this is again from the Chaibasa formation of India. So, as you can see here again I am not going to define it repeatedly so these are your primary foliations, right this alternative laminae and so on.

Now, do we have a secondary foliation here? The answer is yes. The secondary foliation are present or confined in this band or in this layer which are in this case something like that as you can see here from the previous experience that these are defining your secondary foliation cutting across the entire layer here, interestingly the foliations are not present in this layer but it is faintly present in this layer and so on.

So, why these foliations or secondary fabrics are not present in these particular layers, it is because as you can see from this composition that this is mostly sand rich grains and this one is appearing like consisting of mica and so on I have seen this rocks so I tell you that in this area we have concentration of phyllosilicates or mica-rich minerals more compared to this region.

So, though this rock is deformed it could not form foliation because it does not have or it did not have the foliation defining minerals within it. So, a foliation not necessarily has to be present in all the sedimentary layers are all along all the primary layers you may have it restricted only within a layer where you have concentration of foliation defining minerals. Now, in high grade rocks the foliations nature of foliations become little different.

High grade rock means the rocks underwent the primary rocks underwent very high pressure and temperature therefore you do not expect or it is better not to expect any primary foliation in high grade rocks. So, the foliations we mostly see in high grade rocks are primarily secondary foliations they may be of different generations we learn about it later but mostly these are secondary foliations and the traces of primary foliation are almost absent.

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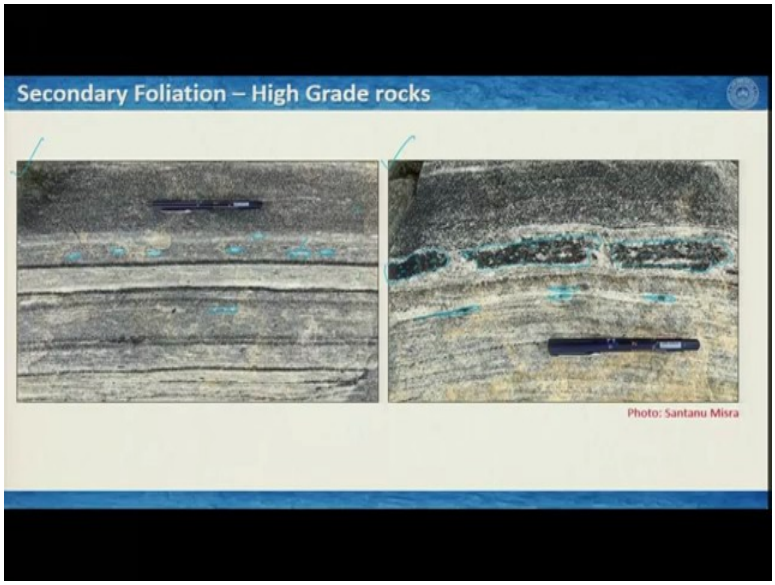

Then how do you understand that what is primary and what is secondary? The primary idea of identifying that these are not primary foliations in the high grade rocks is essentially the minerals that some high grade minerals you see in a high grade deformed rocks, high grade metamorphic minerals you see in high pressure temperature deformed rocks. At the same time, for example, you can say hey these are alternative colour bands, the compositions the compositional bands and so on if I consider this first image so why this is not at the primary foliation?

Now, to answer your question you have to be very careful in secondary foliations you must see particularly in high grade rocks features like this flattened clasts something like that. Here these are generally parallel to the fabric you look at here and these colours are generally dark and white or black and white, they define alternative black and white layers or dark and lighter layers unlike sedimentary rocks where you see variation of colours.

So, here the thickness may or may not vary in this case it varied, but these are secondary layers and use secondary foliations and you can get it from the experience and if you can look for some sort of features like elongated clasts and so on. You can also figure out from the second image that these features are also associated with secondary foliations and so on that these are essentially not your primary bedding planes.

So, these are some dark minerals and here again you also see the features we saw here you also see this kind of features and this clearly defines that these are your secondary foliations and so on.

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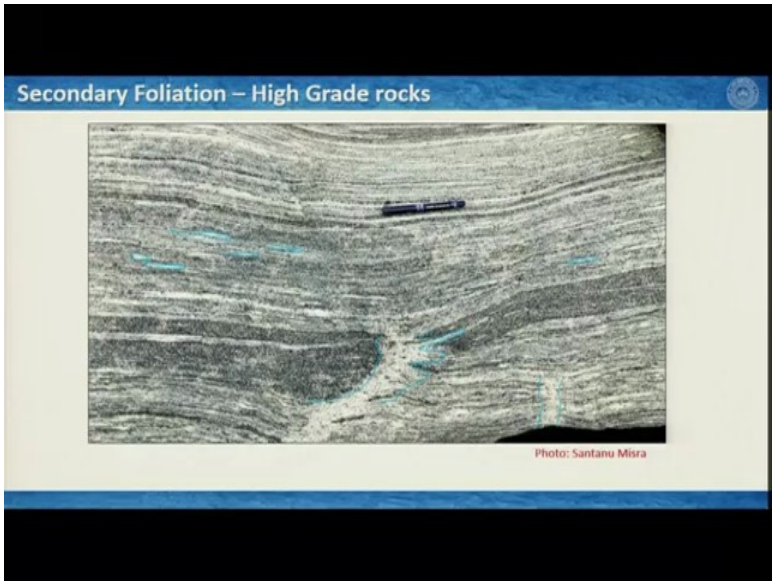

You can also see in the next slide where you can figure out that this actually is a fantastic secondary fabric and here as well you see this kind of elongated clasts here, here we learn later that these are parts of the pinch and soil structures or flattened clasts. So, these happen due to extreme stretching of this secondary foliations and here you can also see what we learn later that this is known as foliation boudinage or composite boudinage.

We also see here these individual layers got broken, this also can happen with sedimentary layers no problem but the appearance, the look of the rock is essentially different when you deal with high grade rocks.

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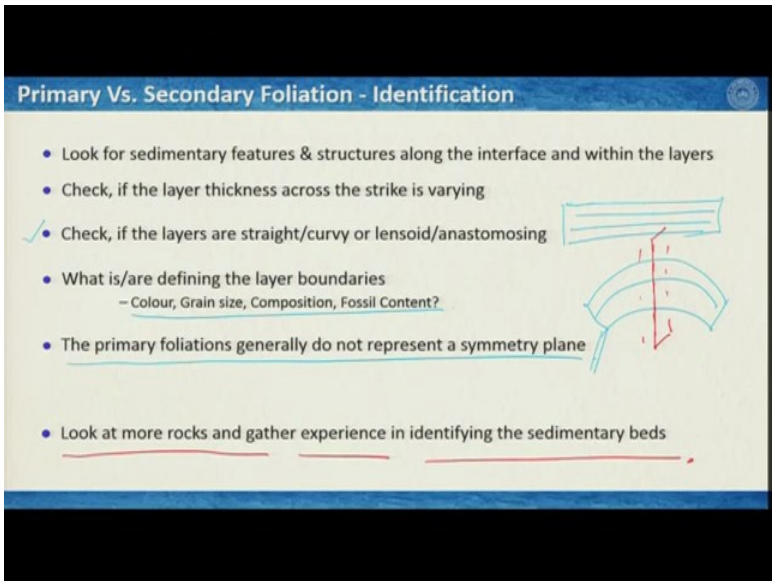

Here is a summary that how to differentiate or how to identify secondary and primary foliation in the field. First of all it is something that one should always think when they go to the field that what is the primary foliation and what is the secondary foliation, how they are oriented and so on this is an important aspect or important part of studying structural geology in the field.

So, you have to go to the field more and more, you can recognize more rocks and become more experienced in identifying or differentiating primary versus secondary foliations but here I try to give you some clues or some hints on how to figure this out in the field. If we have to find sedimentary foliations or primary foliations then look for sedimentary features that are generally present at the interface of the layers.

Say for example, you can figure out load clasts, you can figure out some sort of convoluted laminations, you can figure out the cross laminations or cross beddings and so on. So, all these things define that you have the primary foliation present there. Now, if the layer thickness vary across the foliation plane that you have identified but you could not identify whether it is primary or secondary, sometimes in sedimentary layers the layer thickness do vary consistently, but in secondary foliations if it is in a low grade rock the layer thicknesses do not vary or the foliation spacing's do not vary largely.

Now, also check if the layers are straight or curvy, so if that happens if the straight or very gently curving then it is primary foliation, but if the foliations you see these are some sort of repetitive anastomosing and length side, these are your secondary fabric or secondary foliation. It is also important to figure out or look very carefully what is defining the boundaries or what is defining the foliation planes, is this colour, is this grain size, is this composition or a particular layer you are looking at has a particular fossil but other layers do not have.

So, all these things give you an idea based on your theoretical background that whether you are looking at primary foliation sedimentary foliation or a secondary foliation. Now, primary foliation also they do not represent a symmetry plane. Now we will talk about this later but very briefly if I have primary foliation they just developed like this but if this layer got folded then the foliations the secondary foliation I just interchange the colour it develops like this so this is your secondary foliation we have learnt it.

So, if I consider this plane it represents a symmetry plane of these deform structure. So, secondary foliations are always symmetric or they represent a symmetry plane and primary foliation they do not do that. And as I have said in the beginning of this slide that look at more rocks and gather experience in identifying the sedimentary beds and secondary foliations so this is very important.

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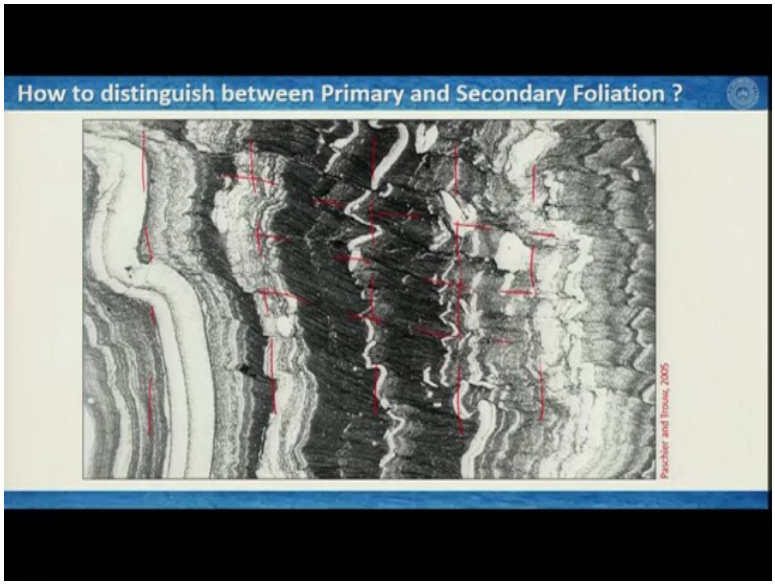

So, to give you some clues I have added three photographs. The first one is from Passchier and Trouw I just tell you that there are two layers I come back to my original conventions. So, as you can see that this image is defining two different planes at or on this image we have traces of two different planes one is of course going north to south this alternate white and dark boundaries and another is something like that running east to west. Now, you think of yourself and look at the photograph and figure out that which one is primary foliation and which one is secondary foliation.

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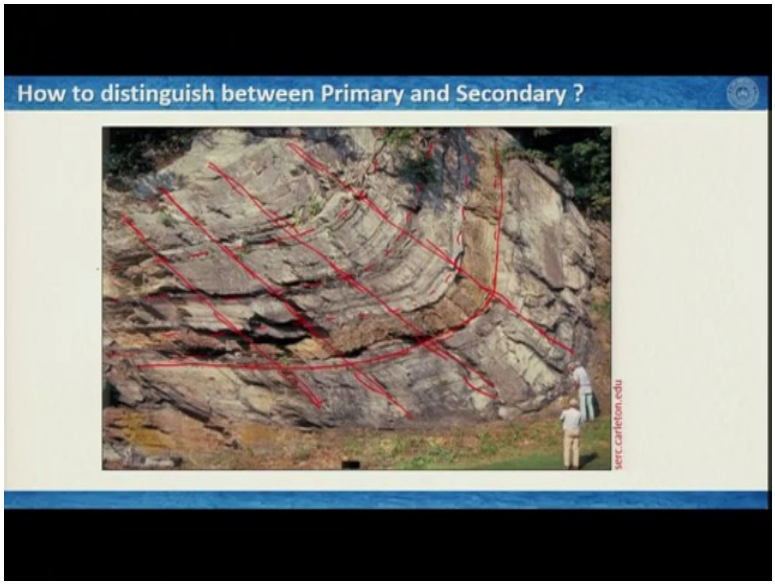

I have two more for you, this is another one again I define the two planes for you. So, one as you can see here this is a curve plane this foliation plane is curvy and then you have another fabric another foliation which goes like this in the system. So, you try to identify that which is what? Whether this curved line is primary or secondary or whether these straight lines are primary or secondary.

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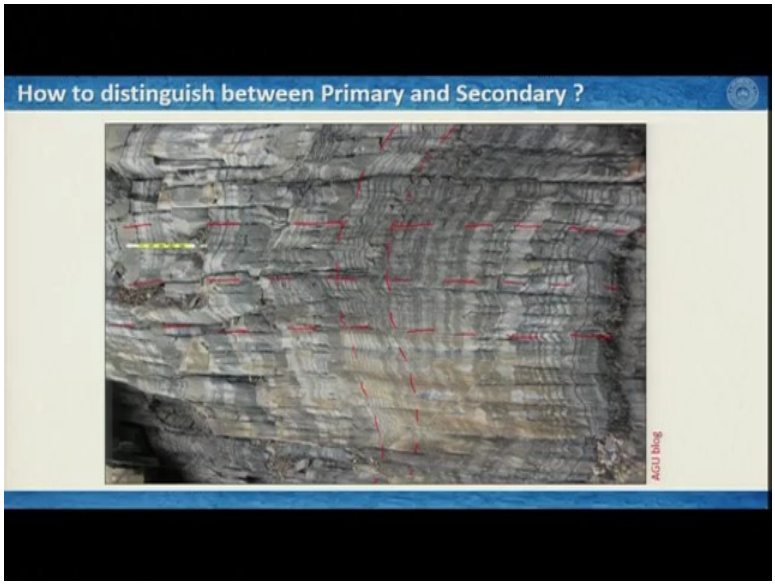

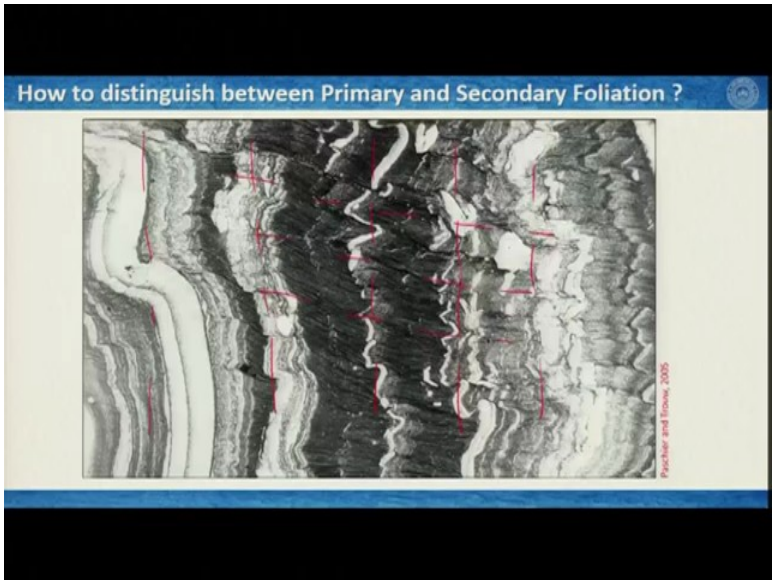

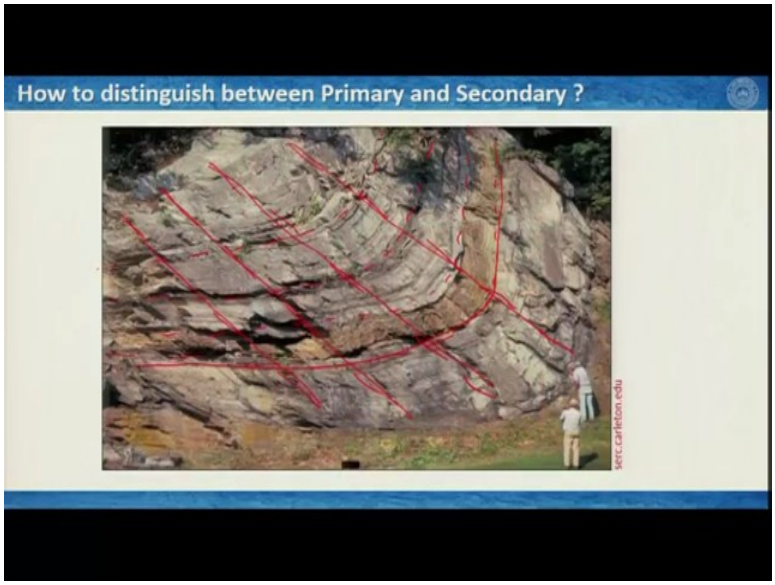

And the final one here I also define it and again this is running one set of planes running east west and another set of plane running north south, which in this case is again little curvy. So, these three images this is the first one, this is the second one and this is the third one you try to identify which one is primary foliation and which one is secondary foliation.

And you do not restrict yourself only to these images you search Google or any search engine you prefer, try to download images and figure out based on your experience or whatever we learned so far that which one in this image could be primary foliation and which one in this image could be your secondary foliation. So, with this I conclude this lecture.

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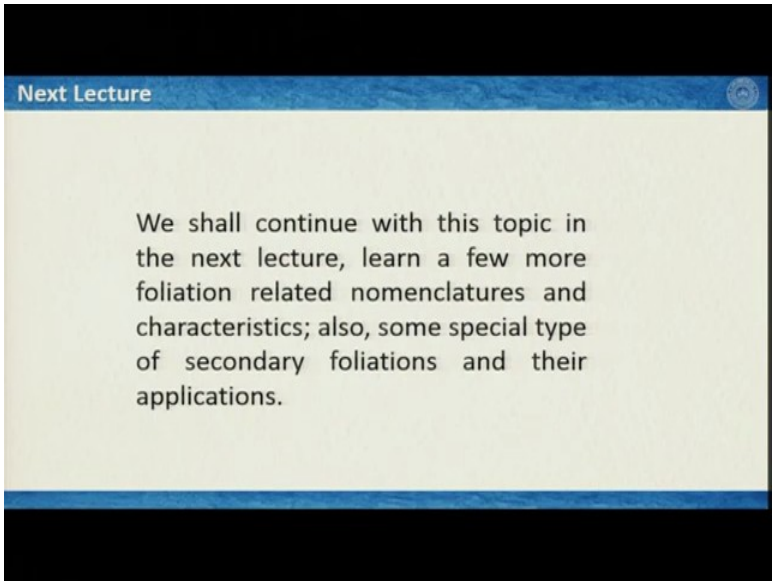

In the next lecture, we shall continue with this topic foliation and will mostly discuss in the next lecture the secondary foliations, we will learn some sort of nomenclatures and also we learn some special type of secondary foliations and their applications, thank you very much I will see you in the next lecture.