Structural Geology
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Lecture 18: Planar Fabrics (Foliation/Cleavage/Schistosity) - II

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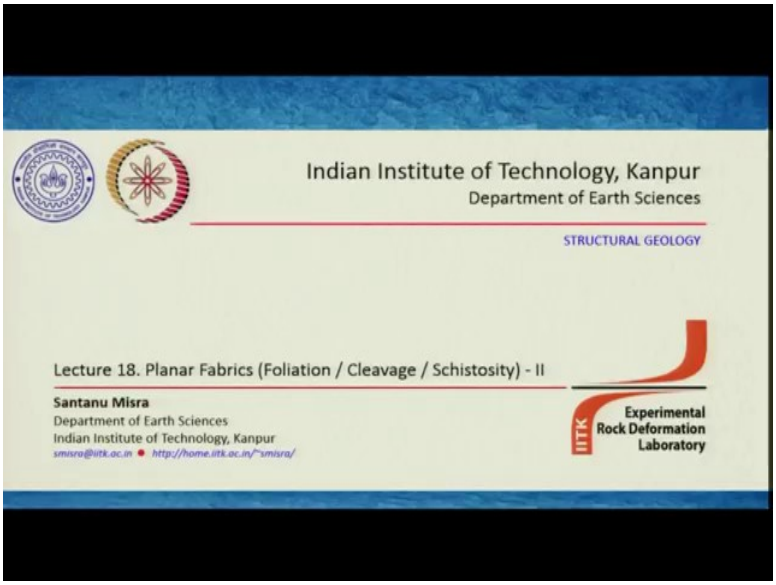

Hello everyone, welcome back again to this online structural geology NPTEL course, we are at our lecture number 18 and this week we are learning planner fabrics and linear fabrics, so we are at lecture number two in this week, in the previous lecture which is a lecture number 17 we learnt the very basic and generic classifications of planner fabrics, we also learnt how to differentiate primary and secondary fabrics, in primary fabrics we mostly consider the sedimentary layers and secondary fabrics we considered the deformation induced fabrics. So in this lecture we will mostly covered this following topics.

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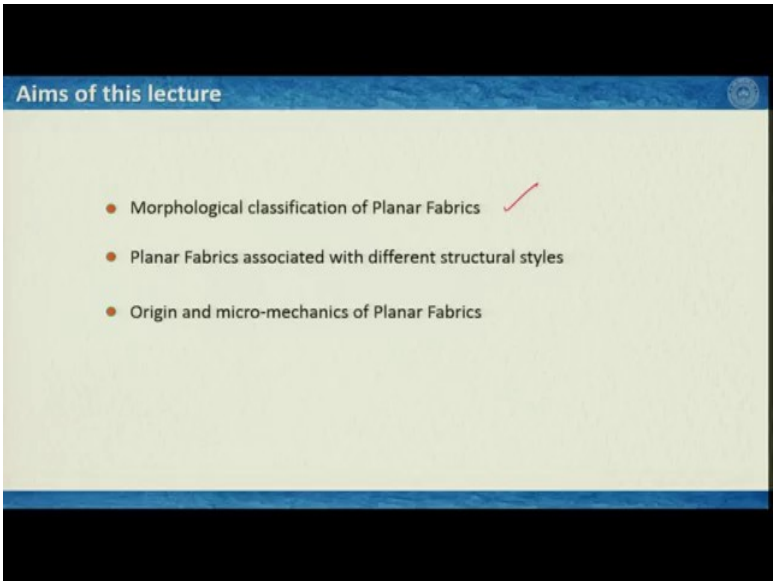

So first we will do morphological classification of planner fabrics that means the way they appeared it is not their generic nature and then we will actually look for some very special attributes of planner fabrics which are associated with the different structural styles, particularly folds and they have some special names as well so we learned what after another we will also try to figure out what is their mechanism of formation and at the very end of this lecture we will particularly focus on the origin and micro mechanics of the planner fabrics.

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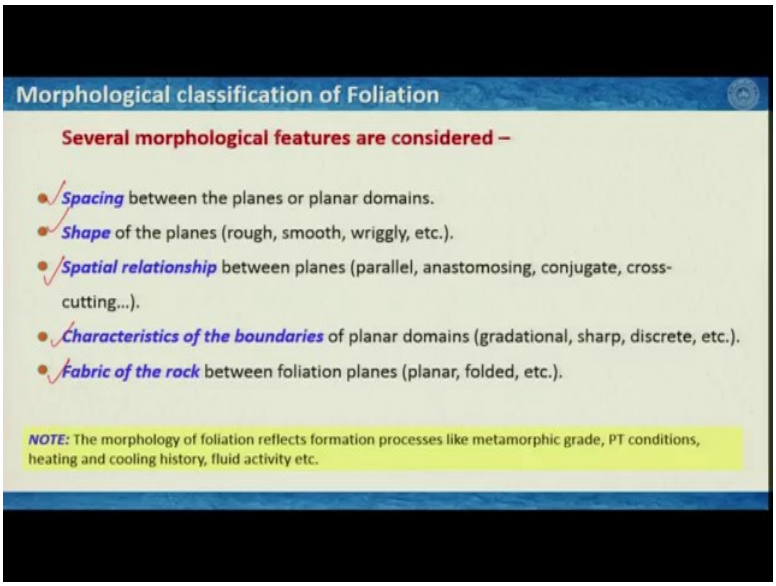

So when we talk about the morphological classification of foliations or secondary foliations in particular a series of morphological feature are considered and what are these specially listed here mostly five characters we consider, so first one is the spacing between the planes

or the planner domains that how closely they are spaced and what ease within the space we will look at it soon then shape of the planes where there it is rough, smooth, wriggly, etc etc. then we will also consider special relationship between the planes that means whether this planes are parallel to each other, anastomosing to each other, whether this are conjugate, cross cutting and so on.

We will also look what is the characteristics of the boundaries of the planner domain, whether these boundaries of this foliations are gradational, sharp, discrete, etc and essentially finally look at the fabric of the rock between the foliation planes that means whether this is planner or folded and so on. Now one thing is very important to understand at this point all these morphologies that we talked about whether be its spacing, shape the special relationship, characteristic, characteristic of the boundaries, fabric of the rock, etc. all these are functions of the metamorphic grade of the deformation or metamorphic grade of the rock what was the PT conditions, what was the heating and the cooling history, what was the fluid activity etc. we will look at it latter but the spacing, shape, special relationship, characteristics of the boundaries, fabric of the rock, etc all these do very greatly with the metamorphic grade of the rock.

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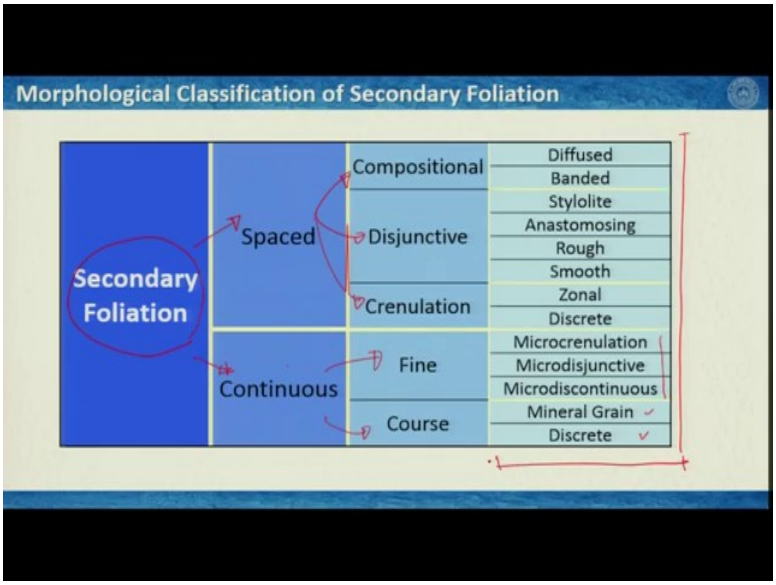

So here is the table which classifies the secondary foliations. So if we consider secondary foliations at one end then we can classify it in two broad domains, one is spaced foliations and another is continuous foliation, the spaced foliation is further subdivided in three different categories, the first one is compositional foliation or compositional spaced foliations then disjunctive foliation and crenulation foliation or crenulation cleavage. Within in the

continuous domain we have fine grained continuous foliation and course grained continuous foliation or the fine foliation or course foliation based on their spacings and so on.

Now within the compositional cleavage or compositional foliation we have two subclasses, defused or banded so that means whether the boundaries are defused or sharply banded then within the disjunctive we have the stylolite, anastomosing, rough and smooth, within the crenulation we have zonal and discrete and then in the domain of the continuous cleavage we have two classes we discussed fine and course, within the fine we have micro crenulation, micro disjunctive and micro discontinuous these three and within the course foliation we have mineral grains and discrete. So we will not really look at the last column here but we certainly talk about spaced foliation, continuous foliation and within the space we talked about compositional, disjunctive, crenulation and then within the continuous we very very briefly discuss the fine and course grained foliations.

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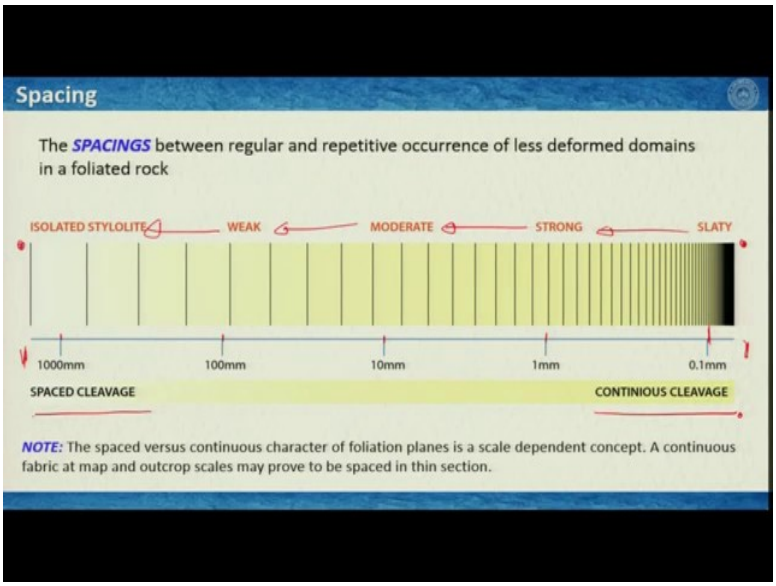

So let us have a look what do we mean by the spacing in the foliations and how do we characterized them, as you can see in the illustrations that from this end from your left side to the right side of the screen you see a series of lines are drawn and on the right side the spacing between the lines from the left side has continuously decreased. Now if you try to put them in a scaled form, so if I consider here the spacing is about 0.1 millimeter, here is 1 millimeter here is 10 millimeters, here is 100 millimeters that means closed to 10 centimeters and here is 1000 millimeters that means 1 meter so this is in log scale. So if the spacings between the 2 cleavages or 2 deformed domains in the foliated rock is extremely closed or is

closed to 0.1 millimeter or less, then we define it as slaty cleavage, that means you cannot distinguish between the space between the two foliations or two layers of foliations.

However, if the spaces increase or how however if the spaces increase then we arrive to strong foliation where the spacing is about the 1 millimeter then we arrive to moderate where the spacing is 10 millimeters then weak then here we arrive to isolated stylolite which we actually do not consider as foliation because if you remember in the first lecture we decided that whatever is more than 10 centimeters the spacings between the two foliations if it is more than 10 centimeters particularly for secondary foliations we do not consider it as a foliation.

Now there is also one important aspect in considering this slaty, strong, moderate and weakly range because in the field not necessarily you are carrying the scale or you would be measure so you generally you look at by your eyes but when you take this rock in the laboratory the foliation you consider in the field as slaty cleavage or strong cleavage when you look at under microscope you might find that this is actually a space cleavage, so this is also very scaled dependent, though I have tried to give you some sort of scaling ideas of what is the foliation, so in summary if you do not have much space between the two foliations then we assign the name as continuous cleavage and if we have spaces between them that we can recognized be infield or be under microscope we called it space cleavage.

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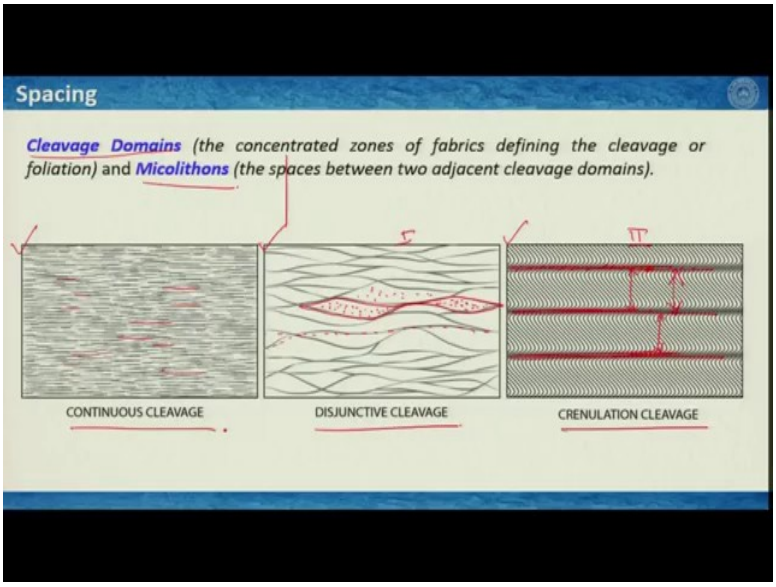

Now based on whether this is continuous or spaced we classify it in a different way, so the two nomenclature come in the picture one is the cleavage domain and another is Microlithons, what are these two? these two are very important in the contest of the spaced and continuous foliations or cleavage. Now cleavage domains are generally assigned to the

fact that it describes the concentrated zones of fabrics which actually defines the cleavage or the foliation, so if I see that a rock is foliated so what is defining the foliation or the zone which is defining the foliation is the cleavage domain and what is in between the two adjacent cleavage domains is microlithoms.

So in other way we can define now the continuous cleavage which is this one I have made an illustration for you so if you do not find a space between the cleavage domains so in this case all this striation like think this line is here you see this is the traces of the foliation on this screen there is no spacing in between or at least this spaces are not very well defined or visible so therefore we assigned it for continuous cleavage that means a cleavage which has only cleavage domains but not microlithons at the scale we are looking at we call it continuous cleavage.

Disjunctive cleavage on the other hand is where you have microlithons in between the two adjacent cleavage domains, for example in this image the second one what we see here again this is the trace of the foliations on the screen we are looking at, what we see here this this grayish lines are your cleavage domains and in between the cleavage domains so if I consider this area so what I am drawing with the red line is the cleavage domain and in this case this are anastomosing and what is in between within the two cleavage domains here and here this two are the microlithons, so in this entire illustration you have alternating microlithons and cleavage domains in anatomizing manner.

In the third image what we see here that cleavage or foliations are defined by this lines which are the traces of this very closely placed micro folds or micro curvatures, now we will see later that this particular domains which are actually defining this domain this domain and this domain which are actually defining the foliated nature of the rock, we will see latter that this are mostly defined by the concentration of phyllosilicate mica and so on. And what we having between this and this is the exposition or the disposition of this micro folds. Now what is the difference between then this image and this image, the second one and the third one, in the second one we see that this microlithons are actually isotropic, they do not have any fabric within them.

However, here this is the microlithon domain between the 2 cleavage domain and we have very consistence fabric within them so the disjunctive cleavage is if we do not have fabric within the microlithons then we call it disjunctive cleavage, I repeat if the microlithons are divide of any fabrics then this is disjunctive cleavage, on the other hand if the microlithons

have some fabrics then this are crenulation cleavage, we will see some actual images soon. So I believe now it is clear what is continuous cleavage, what is disjunctive cleavage and what is crenulation cleavage.

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Now we will see a series of photographs, so first we start with continuous cleavage in the fields scale, the first image you see on the left side this is shell and as the title suggest that this is slaty cleavage so you can actually figure out immediately that this is your secondary foliation based on the appearance of this and they are continuous because you do not see any space between this foliation they are very very much continuous foliation, in the second image as well you may figure out that this may be there are some spaces between these two but if you look closely then you will figure out that even within this mica schist which is the photograph from again the chaibasa formation, actually this are like books the sheet of the books or the pages of the books, it is very closely very densely spaced you don't find the thickness of the pages or you do not figure out the thickness of the pages by your naked eyes.

So these are the examples of continuous cleavage as you can see here I also give you a tip continuous cleavages are generally the first cleavage that you form after the deformation, so if i have sedimentary rock and I deform it or even an igneous rock the first foliation that forms out of the formation is generally continuous in nature, the next generation foliations are mostly space cleavage where the form surface is the continuously foliations itself.

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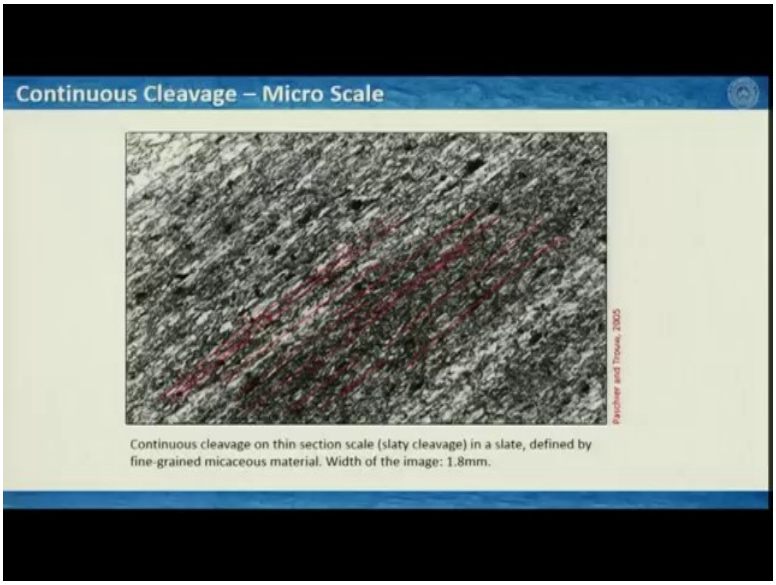

Now this is an optical photo micro graph, what you can see here that entire width of this image is 1.8 millimeter, what you see here again this is also slaty cleavage and this is also in a slate that is why the name came from slaty cleavage and you also can see you hardly can figure out the space between the two foliation planes or the traces of this lines where you do not find any space between them, it is very much continuous in this side and they are very very closely spaced, so the sense of the foliation is certainly there but you can not figure out the spaces between them so this is a continuous cleavage in microscale so we have seen continuous cleavage in field scale in the previous slide and they more or less appear in a very similar way in the micro scale only the scales are different but characteristics are very much similar.

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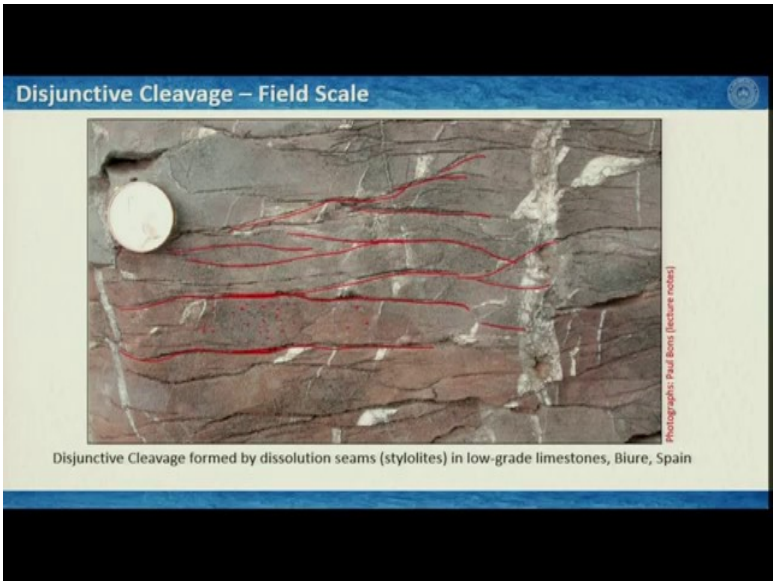

Let us have a look to the disjunctive cleavage in the field scale, what we see here this are some sort of solutions seams, so clearly these are your cleavage domains, they are anastomosing in nature as you have seen in illustration in few slides back, few are strong few are weak but what is important as you have defined disjunctive cleavages that within these two cleavage domains if I consider this one and this one the material here is very much isotropic in terms of their fabric the fabric is of zeroth dimension, so there is no fabric in between just this anastomosing cleavage domains we see.

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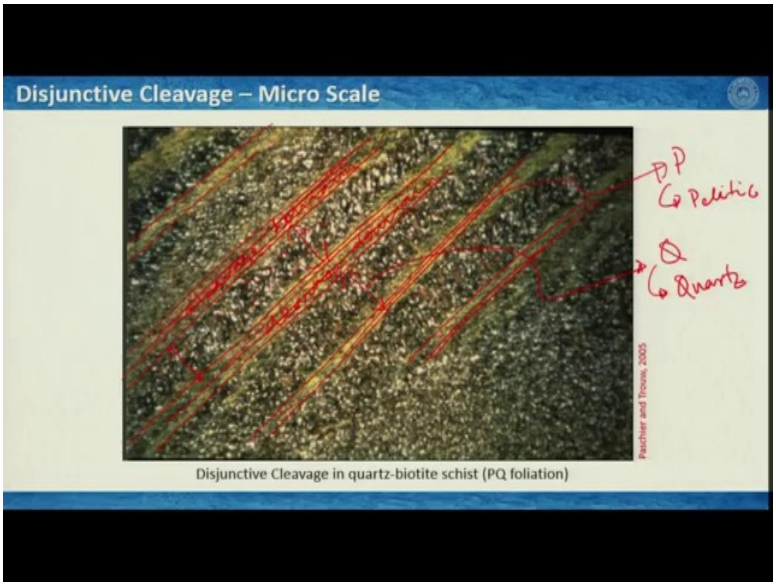

So this is disjunctive cleavage in the field scale, do we see it in the micro scale, the answer is yes. So here is one of this microscopic image under cross polarized light and you see here

that the cleavage domain here is quite broad where we see the concentration of biotite this greenish mineral and in between and this is cleavage domain and this is as well and in between what we have is the microlithon, now the microlithon we see there is virtually no fabric and this microlithon at least in this optical image we see it is mostly composed of quartz whether this is with biotite rich mineral phyllosilicates sometimes this kind of structure where you have bands in micro scale or in field scales alternating bands of phyllosilicate layers and quartz of (()) (18:45) layer again phyllosilicate layers and quartz of (()) (18:49) layers and so on, this is also sometimes known as PQ foliation or PQ structure.

So this is known as P whether P stands or pelitic and these are known as Q whether Q stands for quartz and together we call them sometimes PQ foliation or PQ structure, so this is something new for you but again I repeat what we are learning here that we have cleavage domains series of cleavage domains and in between we have microlithons and microlithons here in this image have no fabric, so we saw this in the field scale and now we have seen in the micro scale, again the mechanism are very similar only the scales are different.

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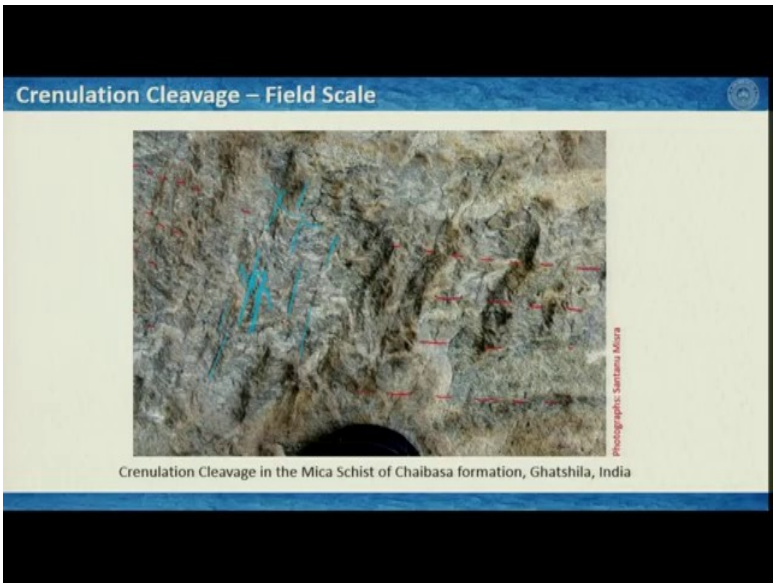

Now we will see the crenulations cleavage in the field scale, this image is again from the chaibasa formation and you may figure out little bit difficult to comprehend that where is the crenulations cleavage, I hope I can convince you that. Now first let us figure out where is the foliation here, as I said that continuous cleavage is generally the first order foliation, the first foliation it generates and then comes the space cleavages and so on. So crenulations cleavage in most of the cases are the second generation cleavage so this is they developed in response to the second stage of the deformation.

So if you see here we clearly can figure out that we have a foliation going on like this and this is your right this is your continuous foliation. Now the question is where is the crenulation cleavage then, now if you look carefully you may see that a fabric is being developed like this and this is how you identify the fabric in the field you come closer you go little farther you look at it and then you use the shadow and then you try to sense what sort of fabric I can figure out from this rock. I believe now you are convinced that this red one is your continuous foliation no issues that there is some sort of spaced fabric which is there defined by this blue lines now if I write this one and I try to figure out what is there in between the spaced fabric again this image is little blurred but I try to convince you but you will be convinced when you look at in next image.

So what we see here if I try to look at that if I consider for example this layer and this layer and this layer and this layer and so on we clearly see here that this continuous foliations they are getting some sort of folded and then coming here like this we also can see it here and these particular orientation is defining the cleavage so therefore this we can consider as crenulations cleavage because I have cleavage domain and at the same time what I see here that within the microlithons I have some sort of fabrics, the image you see at the background of this lecture is actually a thin section of this rock and I believe you are now convinced that this is the crenulations cleavage.

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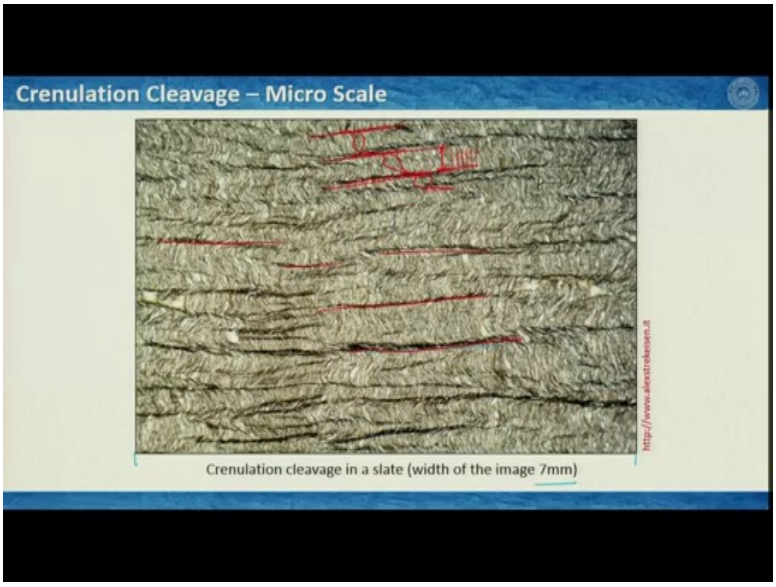

So here is an example of crenulations cleavage again from the micro scale this is 7 millimeter is the width of this image and you clearly see that these are your cleavage domains and within the cleavages if I consider here and here we certainly have some sort of fabrics going on

which are defining your cleavage and because we have in between the two cleavage domains microlithons and microlithons have some fabrics so therefore this is crenulations cleavage.

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Let us have a look to another example, so what we see here these are your again muscovite-biotite rich zone and these are your cleavage domains, so these are your cleavage domain this is also cleavage domain and this is also cleavage domain and in between you have microlithon and so on. Now how are these microlithons yes we have a fabric here within this microlithons and therefore this is the crenulations cleavage.

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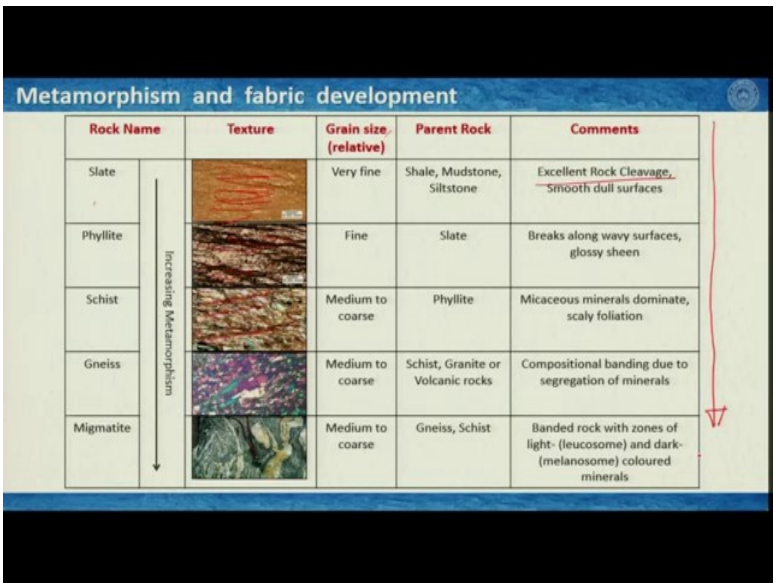

So if we try to figure out now that what is the relationship between the metamorphism and the fabric development, I have summarize the table here which is very much comprehensive

for you so on the left side I have we have the rock names and we started with slate which is a very low grade metamorphic rock then we slowly approach to phyllite, schist, gneiss and migmatite so from top to bottom the grade of metamorphism has increased then how do they look like under thin section is defined in the second column, you can see here slate is define by very very fine grains so the grain size is here, relative grain size and it is generally produce and this generally produces excellent cleavage so the comments are here, excellent rock cleavage and we have learnt this must be the continuous cleavage.

Then in phyllite the grain size is fine and we have foliations that develop like this in schist, this is medium to coarse grained rock, mostly micaceous minerals are present and we see some sort of scaly foliations as we see here this way. The gneiss is again medium to coarse grained rock or sometimes pretty coarse grained rock and here we mostly see compositional bandings due to segregation of the minerals and if the segregation of the minerals happen in a very very extensive way then what we form is migmatite due to the portial melting of the gneiss or granitic rocks.

So here we see alternate dark and lighter colour band so this is essentially a banded rock but here you do not see the primary foliation at all so it is mostly secondary foliations and this banded rocks are characterized by zones of light and dark colour minerals, so they are concentrated and segregated, the light coloured area are known as leucosomes, you know it from your metamorphism classes and the dark colour zones are called layers are known as melanosomes. So this is a very comprehensive table to guide you that what sort of foliations or what sort of secondary cleavages you would expect with the degree of the metamorphism, what would be the grain size, what is your parent rock and so on.

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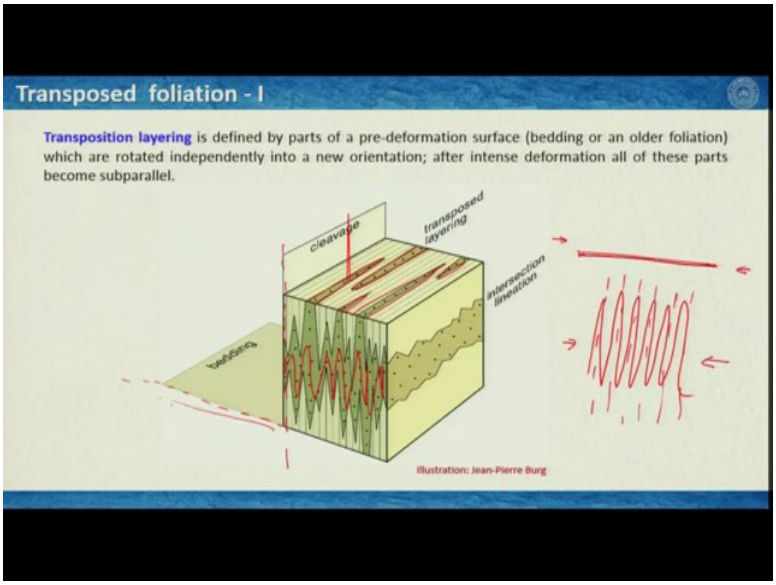

Now there are some other type of foliations where we will look at it after the basic classification, these are very typical but they are very important to identify and go with. The first one we take over is transposed foliation, the transposed layering is something which is defined by the parts of the pre deformation surface so it could be bedding or older foliation which are rotated independently into a new orientation after intense deformation of all this part becomes some sort of sub parallel. What we see here in this illustration I took it from the lecture of John Pierre Burg, so this was the initial orientation of the bedding plane and this is the orientation of the foliation plane or cleavage plane they are perpendicular to each other.

Now if the beddings were parallel to this then this beddings actually, so I had initial bedding like this and because of compression so this was my primary foliation layer, because of compression it can fold very very tightly and then you develop your secondary foliation in this manner, we will learn soon that this are actual (()) (29:24) cleavages. So this is exactly what we see here, these are tightly folded and on this side if we cut it along the bedding planes we see that the traces of this are something like this.

So they become so tight sometimes they are isolated and they actually also are parallel to the foliation, so they transpose themselves to the foliation plane to the secondary foliation planes and these are known as transposed foliations.

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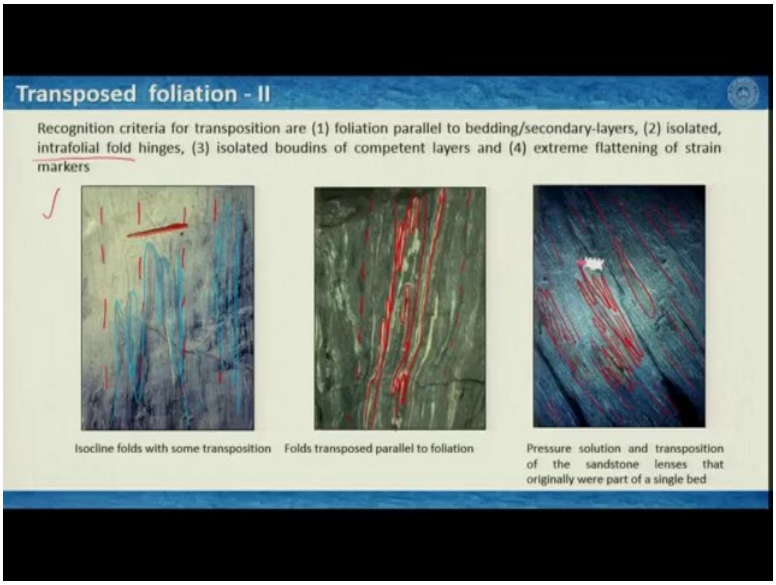

So here are some examples as you can see here, so it mostly happens when the fold is very tight and there are many ways you can recognize this transposition or transpose foliation, so one is this foliation parallel to the bedding or secondary layers, second one is isolated intra folial fold hinges we learnt about this term during our fold lectures then isolated boudins of competent layers and of course extreme flattening of strain markers, so if you have a circular strain marker and that got extremely flatten then it becomes like a line like a plane and therefore like a line in a section and plane on the surface.

So what we see in this image, the first one you clearly can identify that this is your foliation plane and if you carefully look at you will see that some tight folding is going on this way and I do not know where did it go but yes here there might be some extremely tight folding. So these are almost sub parallel to the foliation plane. In the second image if you try to look at again we have the foliation plane as you can figure out is vertical in this case and you can clearly figure out this white layer which gave you the fold like this and so on here as well this is very interesting and so on this probably went up and then probably it has a rotation and came back somewhere like this.

So this is extremely complex but you can see that this is almost align sub parallel to the foliation and here as well we can see this is little difficult to figure out but we see here the foliation is like this and this is the continuous cleavage or a continuous foliation and we see some rootless sedimentary layers here then something here and here you actually can see these are very very fine, so these are again also align with the secondary continuous foliations. So sometimes these things did happen due to pressure solutions and the

transposition and these what you see here or what I have drawn here these are some folded lenses or sand stone lenses which got folden and now they are aligned with the foliation planes.

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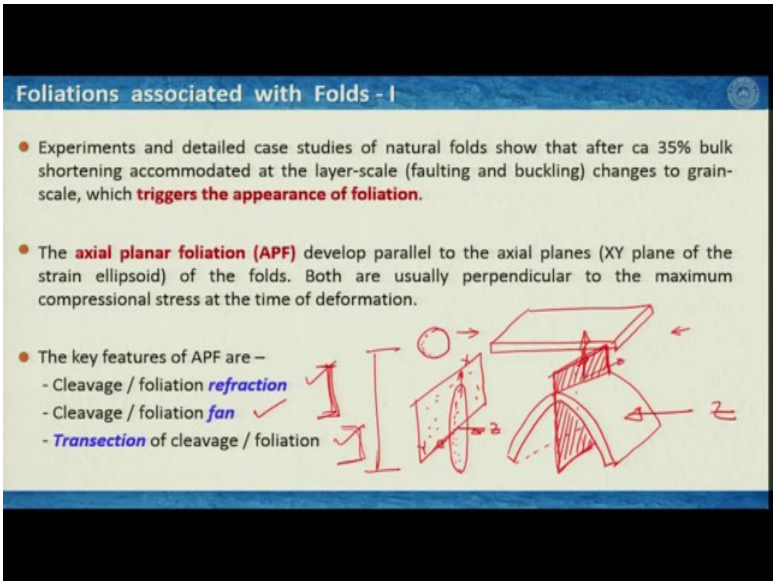

Now we will look at after the transpose foliations the most important part of starting foliation is the foliation associated with folds. Now I have drawn a few sketches and you have also seen that folds are associated with mostly foliations or vice versa. Now experiments and detail case studies is of natural folds so that after about 30 percent of the bulk shortening accommodated at the layer scale that mean you are shortening the layer by 30 percent then it changes the grain orientation and then it triggers the appearance of foliations, you need at least close to 35 percent or more bulk shortening to develop the fold induced foliation.

Now this foliations which are associated with the fold are known as axial planar foliation or axial planar cleavage that develops parallel to the axial plane or in other words this is first time you are stating it xy plane of the strain ellipsoid of the folds and both are usually perpendicular to maximum compressional stress at the time of deformation. So what we mean by this that if I have a layer like this and we deform it this way then if the layer get folded like this then clearly if I had a sphere here then sphere would turn to an ellipsoid at least in this case I can consider that this is my x direction, this is my y direction and because this is the shortening direction so this is the z direction.

So actual planar cleavage would form in this manner or there will be series of lines, so you clearly see this plane this actual planar cleavage plane which i am now sort of making some hatches, this plane is actually parallel to the xy plane of the strain ellipsoid. Now whether this

is x direction or this one is x direction we will figure it out latter but in this case yes as I have drawn this is the x direction but essentially this is your z direction and this is your xy plane, so actual planar foliation most of the cases are parallel to the xy plane of the local strain ellipsoid and both actual planar cleavage and the xy plane are generally perpendicular to maximum compressive stress at the time of deformation.

Now when you talk about this actual planar foliations it has many many applications but today we will look at on many any structural features but today we will look at mostly three aspects of this, one is cleavage or foliation refraction, another Is cleavage or foliation fan and another is transaction of cleavage and foliation. Now refraction and fans are more or less a very similar process but we see them in a different scale and transaction is a different process. Now we will look at all these three in detail in this lecture but before that let us talk more about actual planar foliation for a while.

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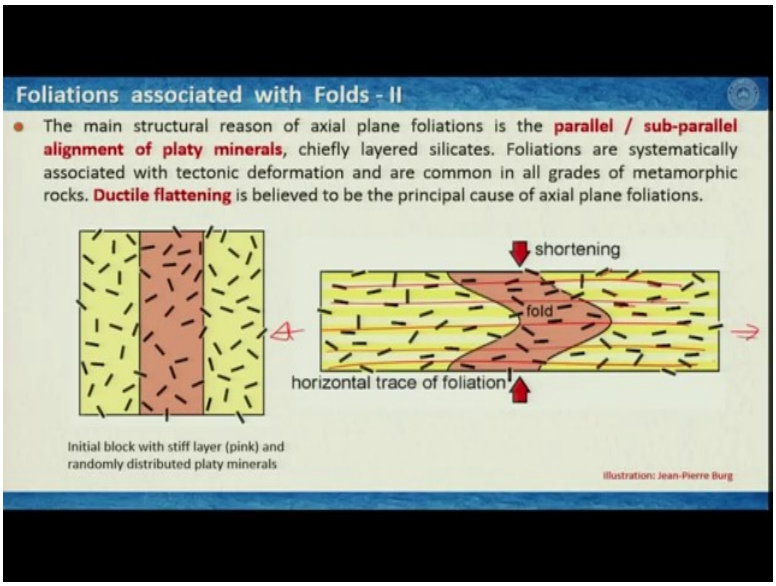

The main structural reason of actual plane foliation is the parallel or sub parallel alignment of platy minerals, so this we probably have understood right now, now foliations are systematically associated with tectonic deformation and are mostly common in all grades of Metamorphic rocks and the mechanism which is believed to be behind the development of the foliation is the ductile flattening. Now what we see here in this illustration that this pink layer is the stiff layer and this yellow layer is the soft layer and if we deform it this way this has a series of micaceous minerals like we have seen like here this black lines here and if we shorten it then we see the horizontal trace foliations where all this little black minerals they try to align along the extension direction of this deformation, so if shortening in this way then

try to they try to align in this way and then we developed a foliation which is known as actual planar foliation.

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We will have a look on some photographs, before stone as we can see these are your primary foliation and the primary foliations are curved so they get folded and we certainly see the series of continuous cleavage developed here. So these are your actual planar foliations.

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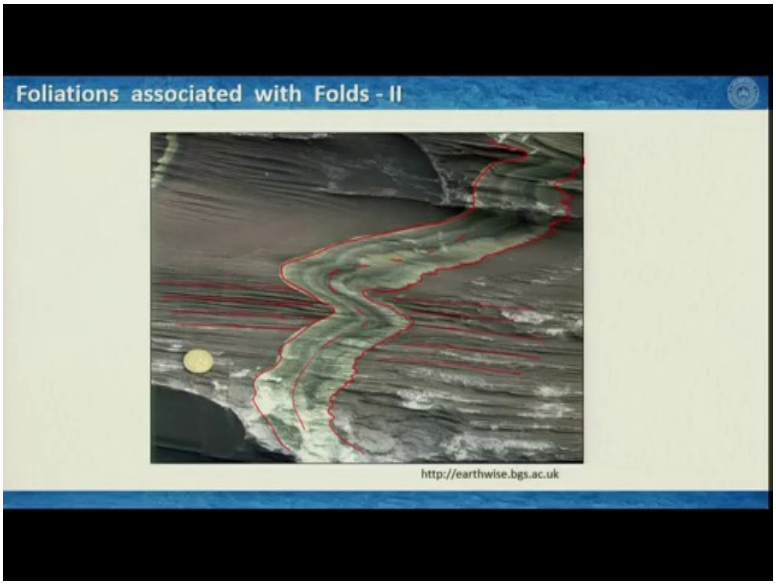

The next one is one of my favorite photographs, I took it from British geological survey web page, so you see these are your traces of the bedding planes or primary foliations you can think of, it has some (()) (39:50) and so on. But so nicely you see the actual planar foliations have formed in this image and it is a very similar mechanism the rocks are different but

whenever we buckle a rock or buckle some layers competent in competent layers we generally form a foliation and these are known as actual planar foliations.

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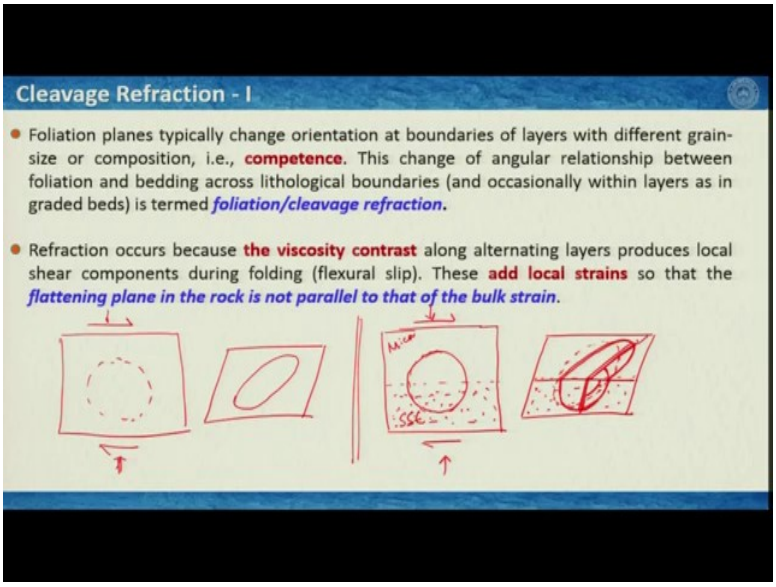

Now let us talk about these three terms that we have just talked about cleavage refraction, cleavage fanning and transaction of the cleavage. We will first take over cleavage refraction. Now cleavage refraction is something very interesting that do happen particularly when you have folding in multilayers where the two layers or the 2 - 3 different layers have different grain sizes or different compositions, so that means there rheology is different, now if that happens then this changes the angular relationship between the foliation and bedding across the lithological boundaries and therefore we have we do not see the foliations are very straight, so they go in a zigzag manner and this is known as foliation or cleavage refraction and this refraction mostly occurs because of the viscosity contrast along alternating layers which produces the differential strain at different places in different ways.

So if I try to summarize it, say for example I have homogeneous body, I have a circle we have learnt all about it and I deform it by both compression and shear then I know that this would take a shape like this, I am sorry this should got little shorten as well and this ellipse would this circle would take a shape of this ellipse but if I have two different layers, say this one is competent and the top one is incompetent, say this is sand stone and say this is mica rich rock.

Now initially I have the same circle I have drawn here and I am applying the same deformation here and if we deform it both of them would get will get sheared however because mica rich rocks are rheologically weaker this ellipse after deformed area would not

be this ellipse here would not be as systematic as we have drawn here because this would differ more, this ellipse would be like this and here it would deform less. So we will get a local variation of the strain ellipse due to rheological contrast. So clearly here the long axis is like this and here the long axis is like this and this is the reason of your cleavage refraction, so in incompetent layers or layers like mica rich layers the angle is less and in strong or incompetent layers this angle is high.

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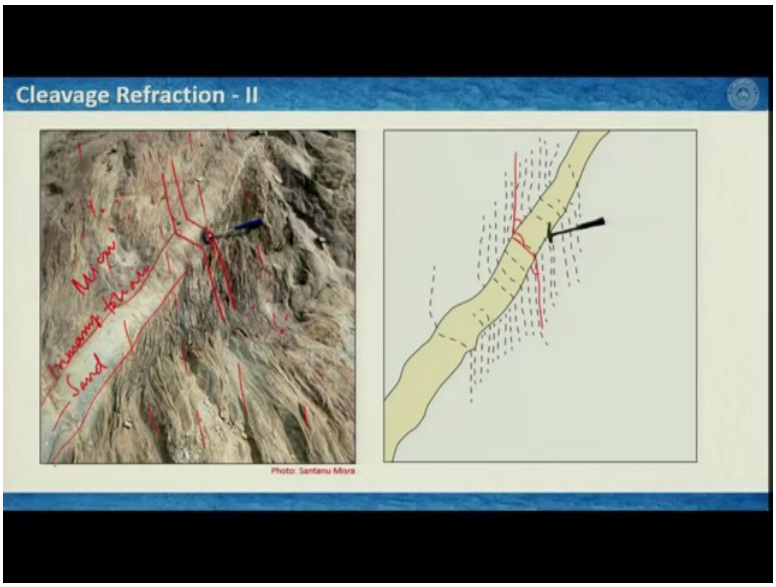

Let us have a look on some examples, what we see here I made a sketch on the other side but you can clearly figure out that this is your primary foliation layer and what is overall coming from this side to this side is your secondary foliation that is the general trend this dash line I have drawn. But if you look closely here as I have drawn here that at this area this cleavages are little bit deflected again these are coming at low angle here, here this are at high angle and again here they are going at low angle, so it appears like it is refracted and therefore this is known as cleavage refraction and from this image we can figure out that this has more mica than this area and I was in the field so I know this was mostly sand rich layer and this was mica rich layer. So this is the classic example of the cleavage refraction.

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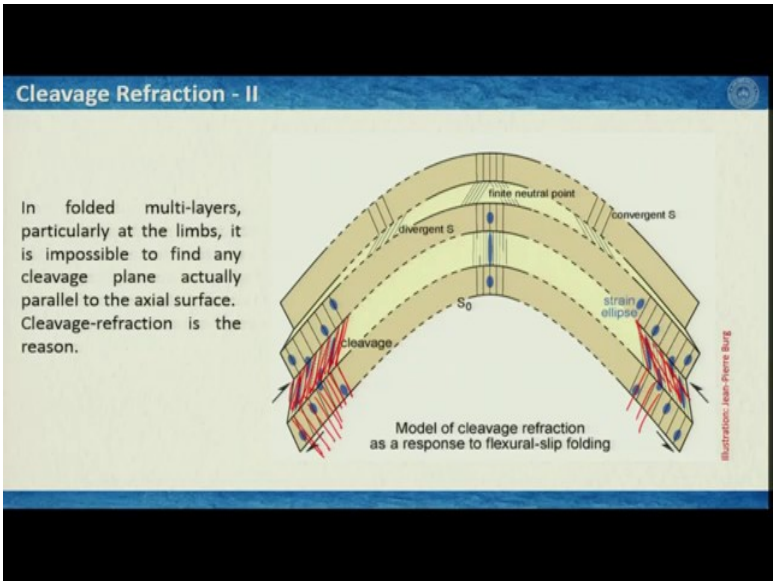

Now if this cleavage refraction do happens systematically in a folded layer then it gives a fantastic pattern which is known as cleavage fanning. Now what happens you see that this is he fold so here I would have a pattern like this, the low angle here on the other side I would have pattern like this, so over all the foliations would try to diverge away from the core on the other hand in the competent layers they would try to converge towards the core and this makes a fantastic wavy pattern all over the fold, of course you have to see the entire fold and this is known as cleavage fanning and this happens due to cleavage refraction.

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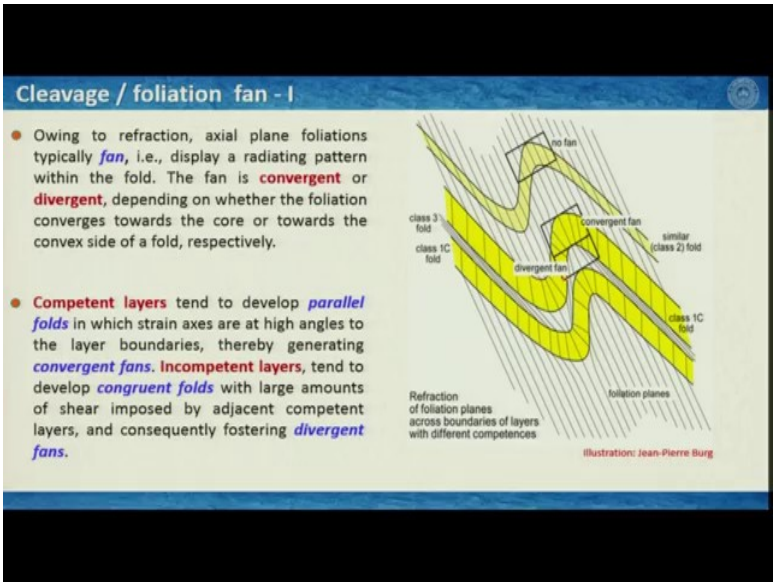

So in cleavage refraction actual plane foliations typically fan that is the display a radiating pattern within the fold. The fan could be convergent or divergent, depending on whether the

foliation converges towards the core or towards the convex side of the fold respectively. Now competent layers tend to develop parallel folds in which strain axes are high angles to the layer of the boundaries, thereby generating convergent fans. The incompetent layers on the other hand tend to develop congruent folds with large amount of shear imposed adjacent competent layers and consequently fostering diverging fans.

Now a series of terminologies are here like parallel folds then congruent folds and so on we will learn about it later but I believe you understood the mechanism if the layers are strong layers that means competent layers, the foliations would converge towards the core and if the layer is incompetent layer or weaker layer the foliations would diverge away from the core.

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So here is the cartoon diagram but we will see the real field photographs in this slide. The first one is the field photograph as you can see that this is your competent layer or all this alternating layers are your competent layer, here you can clearly see the foliation is not that much developed but you can figure out they are converging towards the core, even here if I try to figure out the trace of the foliations at least I this section is something like that and I can figure out these are converging toward the core.

However if I try to look at this incompetent layer which is this one this area it got little bit eroded but I clearly can identify that these are diverging away from the fold core and therefore these are your perfect example of your cleavage fanning where in the convergent layers incompetent layers they are converging towards the core, in the incompetent layers they are diverging away from the core, this is also a very classic example of thin section a photograph of a thin section, the photograph from John Ramsay, we can see this is this

pinkish layer is a quartz layer and this is of course a strong layer compared to this micaceous layer outside the greenish one, you can clearly see that if this I consider this is a fold core the layers are diverging away and this is absolutely what is known as cleavage or foliation fanning.

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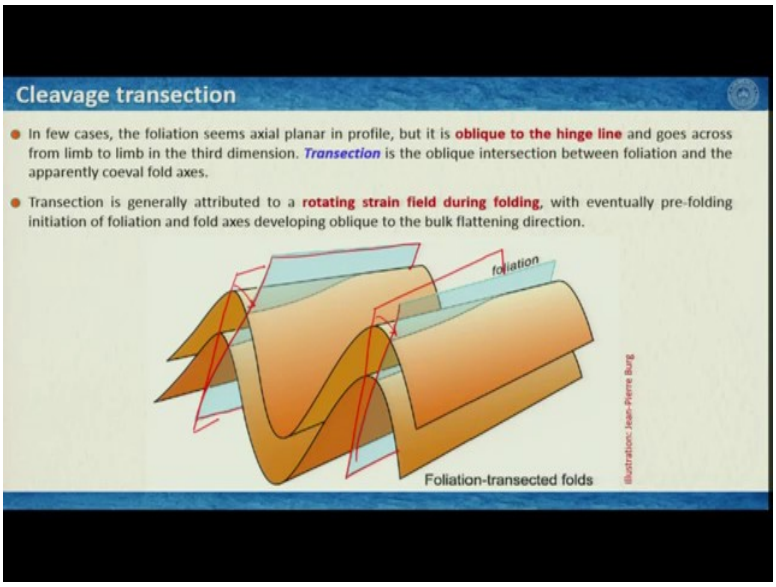

The cleavage transaction is something different. So what happens you have form the fold you form the axial planar cleavage but the fold is continuously rotating due to shearing or some sort of oblique deformation. So therefore the axial planes or the axial planar cleavage would also tend to rotate and they not necessarily track the axial plane of this fold. So in this illustration if you see that this is actually your axial plane or this is the actual axial plane, however this foliation is drawn by this blue shade plane is not tracking the axial plane it is slightly deviated and this is known as cleavage transaction. So transaction is generally attributed to a rotating strain field during folding which eventually pre folding initiation of foliation and fold axes developing oblique to the bulk flattening direction.

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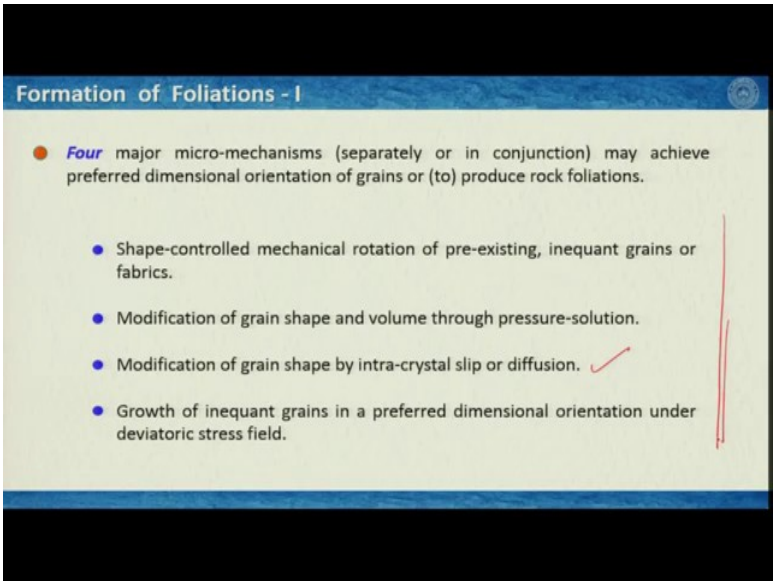

Now we more or less have covered the basic terminologies related to foliation. What is left is the mechanism of formation foliations, how do they form. We will not go into the detail of this part but I just give you some example so I just give you some examples. So there are four measure micro mechanisms responsible for the development of the foliation in the different rocks, and these four measure mechanism they can work separately or in conjugation.

The first one is shape controlled mechanical rotation of preexisting, in equant grains or fabrics. The second one is modification of grain shape and volume through pressure solution, the third one is modification of grain shape by intra crystal slip or diffusion if you remember that the slip system or diffusion creep they produce some sort of shape preferred or crystal preferred orientation this is exactly what we are talking about and the fourth and the final one is growth of in equant grains in a preferred dimensional orientation under deviatoric stress field.

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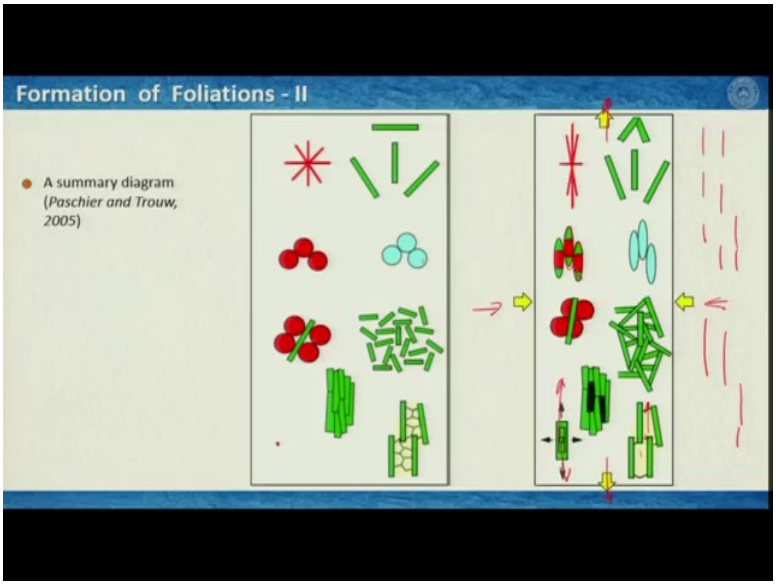

So all these four mechanisms are actually summarize by fantastic summary diagram by Paschier and Trouw in the year 2005 book of micro tectonic, so here the mini texture or mini features geological features which got deform this way, compress this way and got extend this way and you can see they all them are showing some sort of fabric development along this direction. You can look at this image in detail so for example here you have the elongated grains which were initial spherical, you have some sort of pressure shadows, and we have grain uniaxial unidirectional grain growth here so multiple crystals, single crystals came you have unidirectional grain growth so you have a nucleus here and because of this compression the grain is growing mostly in this direction and so on so this is a fantastic summary diagram defining or describing the formation mechanism of foliations in different rocks.

So I conclude this lecture here on foliation and in the next lecture we will discuss the linear feature of the different rocks in other ways we will talk about lineation. Thank you very much, see you in the next lecture.