Earth Sciences for Civil Engineering
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Module 3
Lecture No 12
Introduction to Geosciences in Civil Engineering
Rock types and their Properties (Part-6)

Hello everybody, welcome back. So this is the last portion in different type of rocks. So in the previous lecture, we discussed about the sedimentary rocks and this one is the metamorphic rocks.

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And as we discussed in the beginning that the metamorphic rocks are formed in the deeper part of the crust or the interior of Earth. And and it is because of the under high temperature and pressure. So we will see again the different type of metamorphic rocks and what are the importance of different rocks in CE, that is civil engineering okay.

Now before just I start what we did in the igneous rocks and the metamorphic rocks, we looked at different mineral (inaudible 1:07) and we looked at whether colour of the rock is darker or brighter, maybe it is and and that was basically based on the felsic and mafic minerals.

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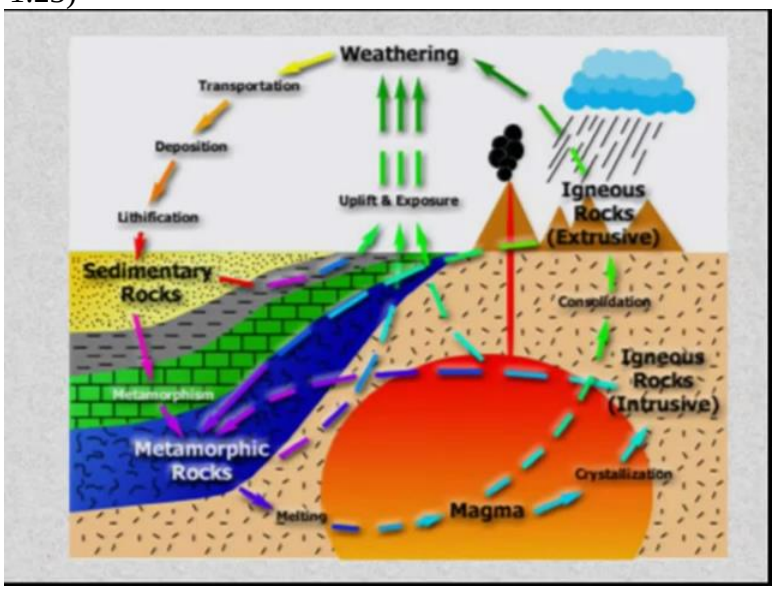

And then we looked at the grain size and the textual features of the rock. So in both the rocks that is sedimentary and igneous rocks, we looked at the different composition as well as the grain size and the texture of the rocks. Now here also we will move ahead and different minerals which are ordered from one mineral to another one due to high temperatures and pressures, what different types of rocks we get, that is basically the metamorphic rocks and how the different textures are been formed in terms of when they are the rocks are subjected to high temperature and pressure.

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So again starting with the so the previous slide if you look at, this is one of the, the most beautiful monument: this is from Taj Mahal. So you see the White Rock behind this one is all is the marble. So marble is a metamorphic rock.

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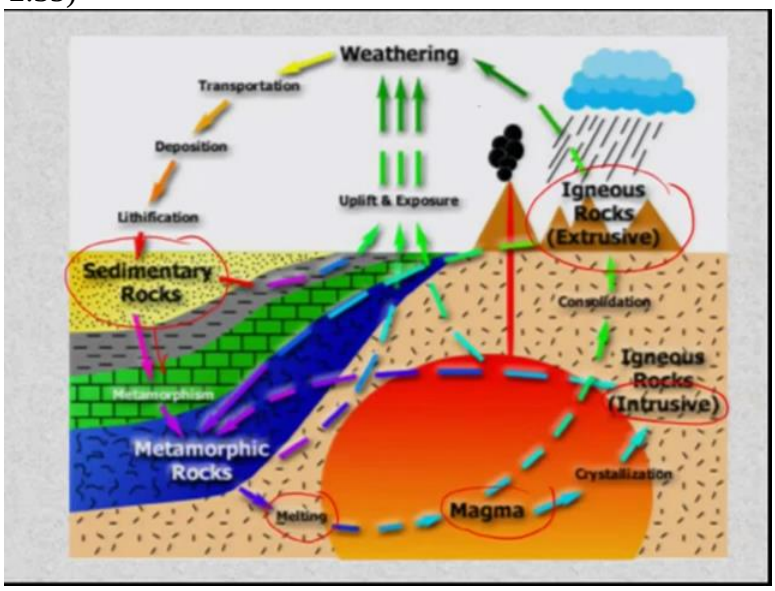

So with this I will start and then briefly we will talk about that what exactly we discussed regarding the the rock cycle. So we reached up to this in the previous lecture. We talked about the formation of the sedimentary rock and when sedimentary rocks are subjected to high temperature and pressure because if you move in the deeper part of the earth, then you will have high temperature and pressure.

So if they are subjected to high temperature and pressure, they will deform, they will got buried and and then result into the formation of different type of metamorphic rocks spending on what type of sedimentary rock is been metamorphosed. And further down, it will again melt, get into the magma chamber and it comes out on the surface in the form of again the exclusive igneous rock or it may remain an intrusive igneous rock.

So the cycle continues and we see the formation of the rocks, weathering of the rocks, solidification and again subjected to deep burial under high temperature and pressure.

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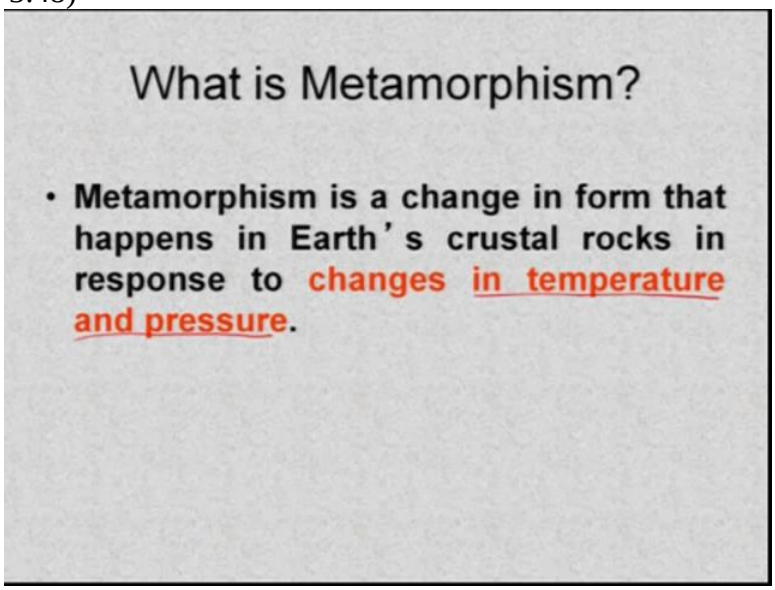

So what is a metamorphism okay? So metamorphism is a change in form that happens in earth's crust crustal rocks in response to changes in temperature and pressure. So this is the most important. So the temperature changes, changing the temperature and pressure will result into the metamorphism of different rocks. For example, I am giving one is this, if sandstone is subjected to high temperature and pressure, will result into the formation of quartzite okay.

So similarly, the limestone if subjected to high temperature and pressure, it will result into the formation of marble. So the minerals got changed from mica to chlorite and all that. So this is the process in which we see the different type of metamorphic rocks.

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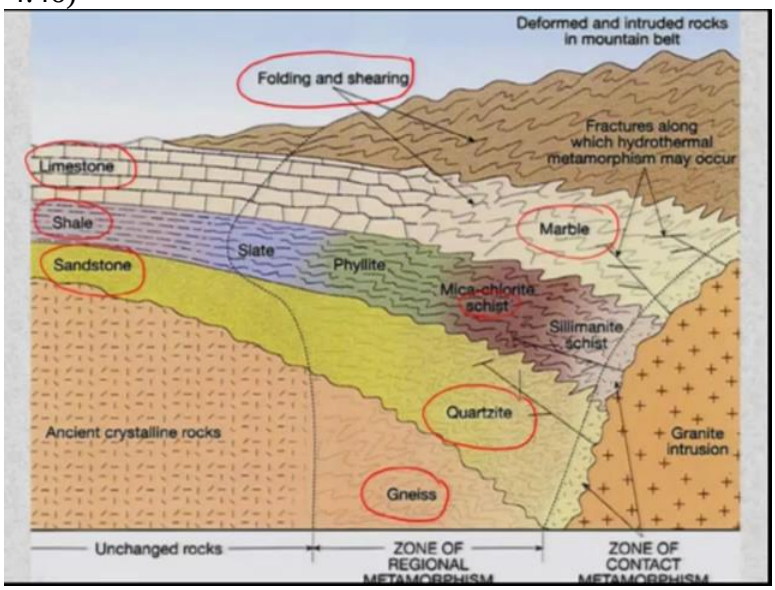

If you look at that how these rocks, sedimentary rocks are subjected to deeper burial or they are subjected to high temperature and pressure at the deeper part of the earth interior is mainly because of the ongoing tectonic movements okay. So when the plate subducts it take the surfacial material in into the interior of Earth and which will be subjected to folding, shearing. So this folding and shearing also will result into the metamorphism.

And at deeper part of course it has an advantage having the high temperature and pressure. So these are some of the examples which are been given which says that deformed and intruded rocks in the mountain and then they are subjected to fracturing and metamorphism. For example limestone if it is subjected to metamorphism at the deeper, it will result into the formation of marble. And then shale which we talked about, these are all argillaceous rocks okay.

And these are talked about the limestone are either from the dissolution or maybe the formed because of the organic rich shales and all that okay. So limestone is that which will result into the formation of marble. And then we are having shale which will be converted to slate. Further metamorphism which result into the formation of phylites.

And then schist, this one is there, schist and then sillimanite schist and all that. These are minerals here okay. And mica and chlorite is again minerals we are looking at. And then we are having sandstone. If it is subjected to metamorphism, it will result into the formation of quartzites okay. And then again if you are having the again crystalline rocks, for example, you

are having granites okay then if they are subjected to metamorphism they will result into the function of Gneiss.

We will see those rocks because again these rocks are having very typical characteristics and based on that what we say, the foliated and non-foliated metamorphic rocks, we will try to see that.

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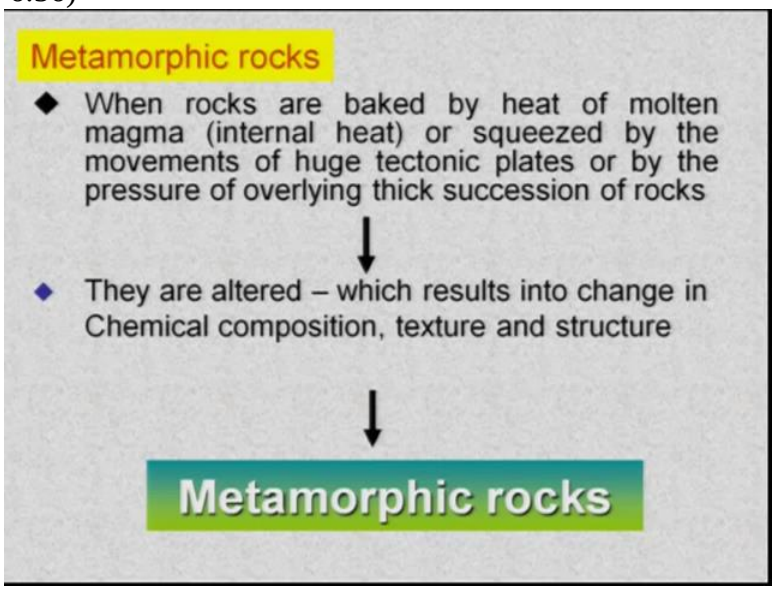

So metamorphic rocks, when rocks are baked by heat of molten magma, that is the internal heat coming in or squeezed by movement of huge tectonic plates or by the pressure of overlying thick succession of rocks okay, so you are having one, the defamation going on, subduction which is resulting and then you are having the burial pressure from the top.

All will result into the formation of metamorphic rocks because of the conversion of one mineral to another mineral, that is what we call the diagenesis okay.Then they are altered. So minerals are altered or the rocks are altered in complete which results into the change in chemical composition also okay, texture and structure. So this is the extremely important part.

So under the under the internal heat, either they are squeezed or by by the huge tectonic plate forces or by the pressure of the overlying successions, then the rocks are altered which may result into the change in the chemical composition, texture and structures okay. These are termed as metamorphic rocks.

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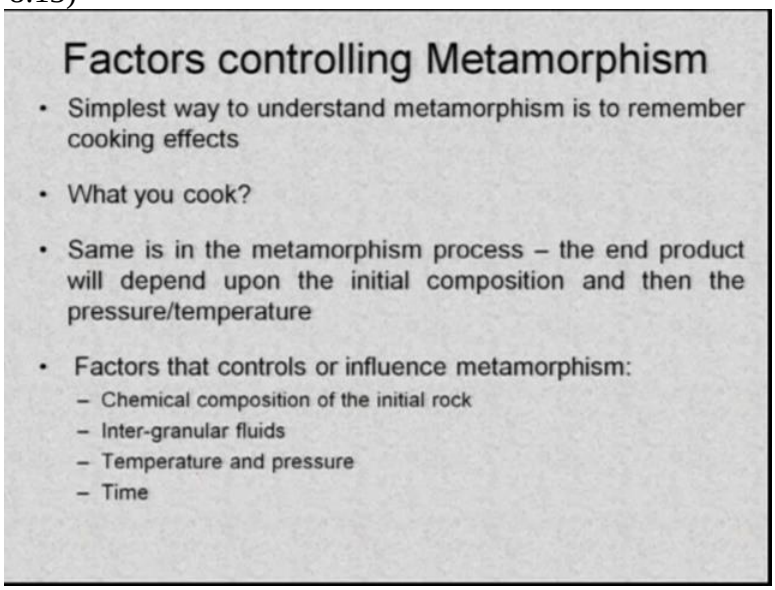

So factor controlling metamorphism, of course the simplest way to understand the metamorphism is to remind the cooking effect okay. So what you cook that is extremely important. So if say that I want to cook limestone and then have the quartzite, it is not possible. So you should know what you are cooking okay. So depending on that you will find the same is in the metamorphism process okay.

The end product will depend upon the initial composition and the pressure and temperature okay. So if you are at the shallow depths, you may not expect that you will have schist okay from directly or **or** you may not have phylite, you may have schist okay. So from schist, further you go down, then you will have the phylites and all that okay. That we will see okay.

And then factors that controls or they influence metamorphism are one, the chemical composition of the initial rocks which have been put in okay. And then inter granular fluid which you are having. So what what is the composition of the fluids and all that? And then we are

talking about the temperature and pressure at the greater depth and the time also ok fine.

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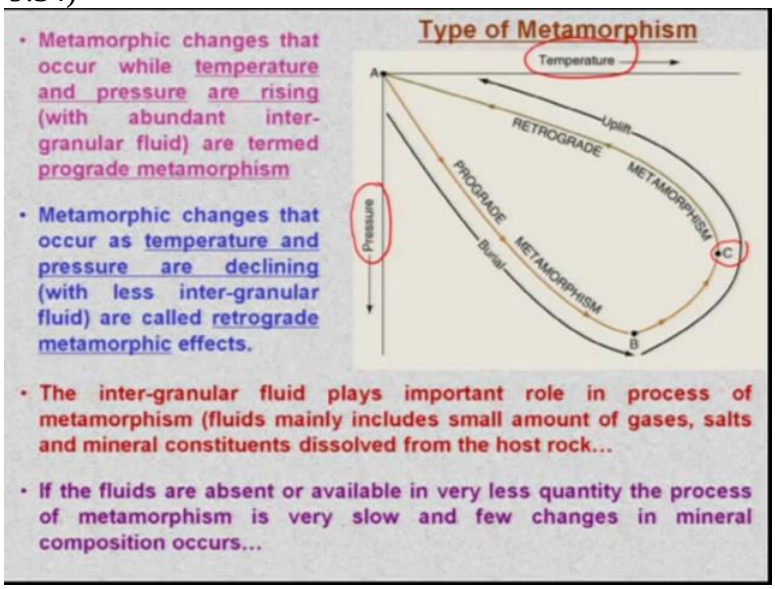

So type of metamorphism, this has been explained in a very simpler way okay. What we have? We say okay fine, if you say if you keep on increasing the depth, you are increasing the pressure, you are increasing the temperature okay. So if you are subjecting the different rocks at high temperature and high pressure, the process which leads to that is termed as prograde metamorphism okay and which goes up to C from A to point C.

Now process is like is because of the subduction subducting plate or the material which has been subducted below the surface within the crust and then time will come, the tectonic movements okay stop here somewhere. But when and after that okay, if suppose you are having an uplift going on, in that process again the pressure decreases no doubt but but there is some increase in the temperature over here but it slowly it decreases okay.

But it does not decreases very smoothly. So even the prograde metamorphism continues up to the C and then you are the having the uplift that is coming, the rocks are coming or exposed up to the to the towards the surface where we will have again the pressure decreases and the temperature also decreases, that is termed as the retrograde metamorphism.

So metamorphism, the metamorphic changes that occur while temperatures and pressures are rising with abundant inter granular fluids are termed as program metamorphism. And then

metamorphic changes that occurs as temperature and pressure declines okay so this is the retrograde metamorphism okay.

So inter granular fluid plays an important role in process of metamorphism okay. And these fluids may include some amount of gases, salts and mineral constitution dissolves from the host rock okay. Now if the fluids are absent or available in very less quantity the process of metamorphism is very slow okay. So this also affect on that that I was talking about that the cooking process okay.

So if you have less fluid available, then the process may be a little bit slow few changes in the mineral composition will take place okay. So alteration of one mineral to another mineral will be in a slow process okay. So this also is important.

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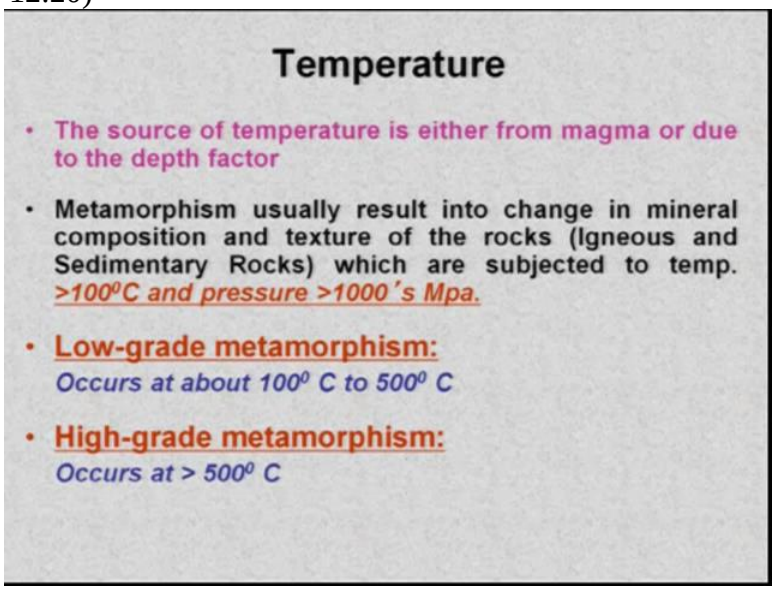

Now the temperature, the source of the temperature is either from the magma or due to the depth factors okay. And this we have discussed in the beginning when were talking about that how temperature and from where it comes okay. So internal heat is from the either the radioactive minerals or the radioactive material, elements within the Earth's interior or from the magma chamber we are having at the depth okay.

So metamorphism usually results **in** into change in mineral composition and the texture of the rock okay. So textural features will also change and of igneous and metamorphic rocks which are subjected to temperature. So the temperature is as high as almost like you can say greater than

100 degree centigrade and pressure will be more than 1000s of mega pascal. So low-grade metamorphism, we have to look at the temperature occurs at about 100 to 500 degree centigrade.

Whereas the high-grade metamorphism, you are having the temperatures greater than 500 degree centigrade okay. So these are the 2 types of metamorphism we term as low-grade and high-grade metamorphism. So depending on this, we will have different types of rocks which are been formed.

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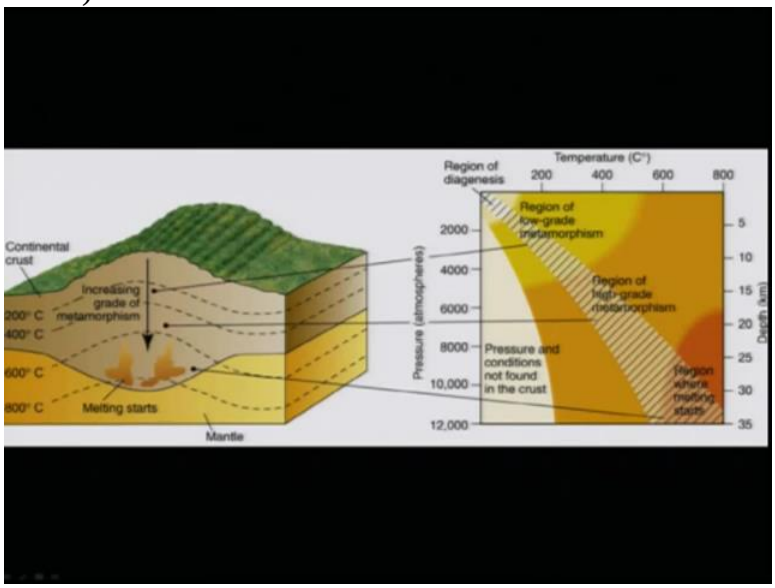

So for example, if you look at this section, it shows that this is an this is an increase in pressure you are having and here you are having increase in temperature okay. So this area that is the region of diagenesis okay where the process starts changing the mineral composition okay. So region of low-grade metamorphism and this is a region of high-grade metamorphism. Finally, you are getting into the region where the melting starts okay. So melting starts somewhere at around 800 degree centigrade.

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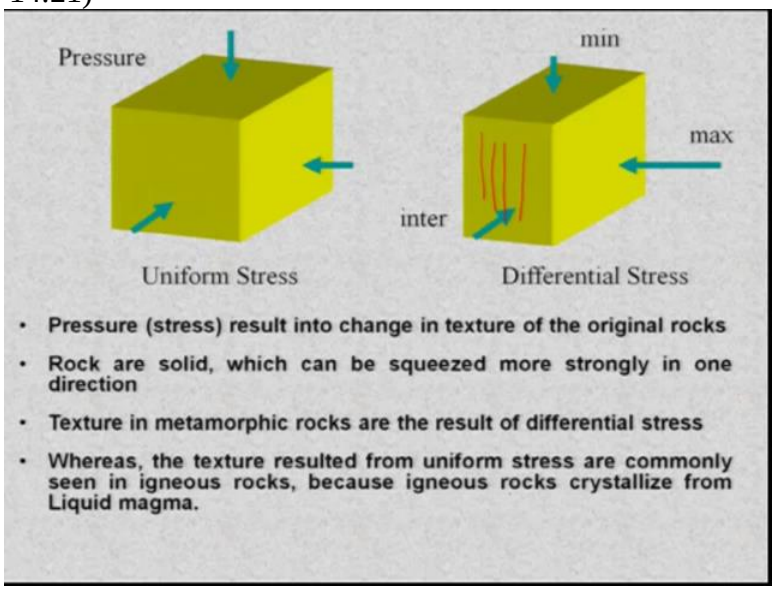

So pressure is extremely important and if you if you look at that if you are having Sigma 1, Sigma 2, Sigma 3, all are same, then what will have is the uniform deformation okay. But suppose you are having so this is under the uniform stresses and suppose you are having different in the Sigma 1, Sigma 2, so you are having high or maximum, minimum and intermediate, then you will have directional deformation or we can say differential stress okay.

So you will have differential orientations of the minerals which will be aligned almost perpendicular to the maximum stress okay. So pressure what we call we take as stress here resulting into change in the textural parameters okay. So textures will change of the original rocks. Rocks are solid we know that okay which can be squeezed more strongly in one direction if you are having differential stress okay.

But at the greater depth, you will always see that the stress is uniform okay. So at the greater depth of, within the Earth, you will find that they are they are very much uniform. But close to the surface of the crust, you will have differential stress. So you will find the rocks which are formed are having very preferred orientation of minerals and we will see the examples of that in the next slide.

So textures in metamorphic rocks are are the result of differential stress okay. Whereas the texture resulted from uniform stress are commonly seen in igneous rocks because igneous rocks

are crystalline, they get crystallised at greater depths as in what we see the intrusive rocks and all that okay.

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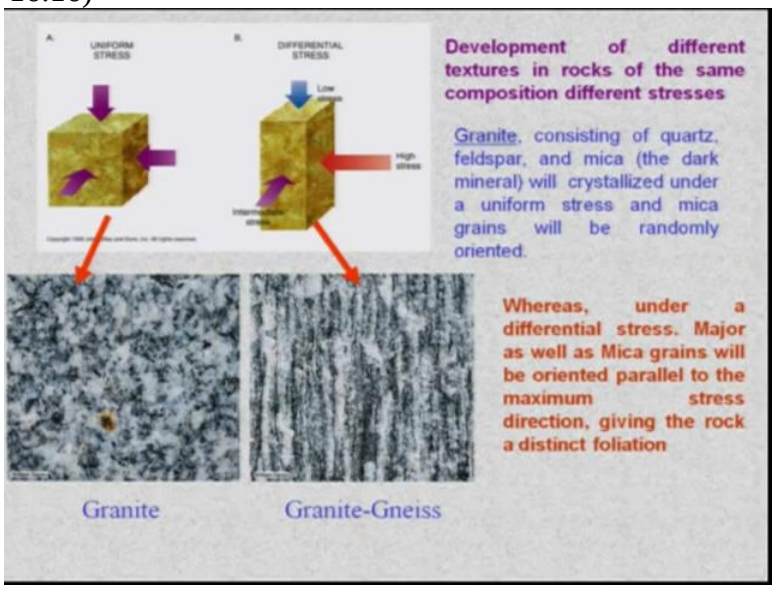

So now for example, development of different textures in the rocks of the same composition, and if you are if you subject those rocks to differential stress and example here is the at the uniform stress if you are having you will find deformation of granite. Again, the granite is not an extrusive rock. It is an intrusive rock. Hence you see the minerals are are uniformly formed okay. They are not showing any preferred orientation. I want to say that here.

But if they are subjected to differential stress, then the minerals will get oriented parallel to the or perpendicular to the high stress direction okay. So you have what we call as a granite gneiss. So this gets converted into metamorphic rocks and they are termed as granite gneiss. The composition more or less remains similar here.

So under differential stress, major as well as the mica grain, so the major is quartzite and all that will be oriented parallel to the maximum stress direction okay giving rise to distinctive this thing okay. So this you will find that a preferred orientation has been seen.

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This is an example of granite whereas this is an example of your gneiss okay when they are subjected to differential stress. This is again very much preferred orientation you can see here. The clast here are oriented. So the stress direction if you want to see, is something like this. They are compressed in this direction okay.

And we are having the all this foliations which are formed here okay. These are all what we call the foliated rocks okay. And this is we term this as a budines.

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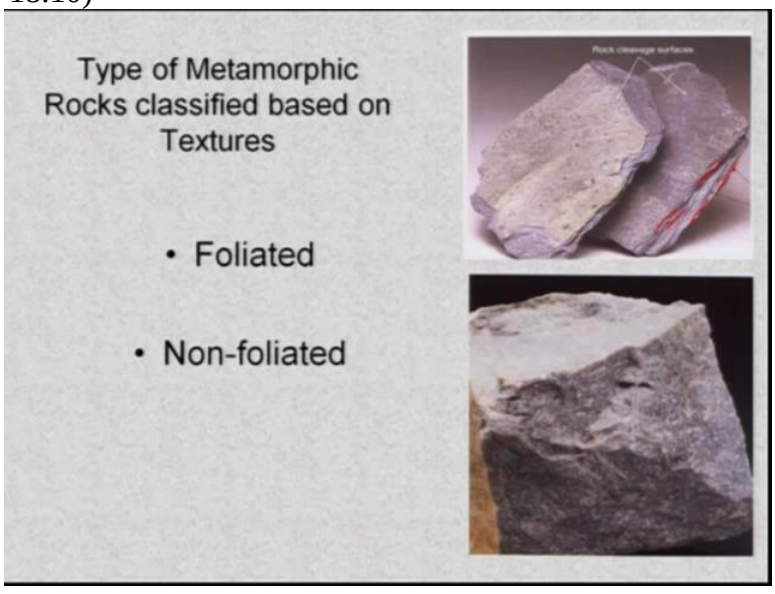

So type of metamorphic rock if we have to classify based on their textures, we say either they are foliated rocks. So foliated again, we will have very definite, cleavable planes okay. As we have learnt in the minerals, the different type of cleavages, here also we will have cleavages or the cleavage planes which are being seen here okay. So these are all foliations or the foliated rocks. But in terms of the non-foliated rocks, you will not be able to see such type of plains okay. So they are all massive rocks okay. So they are non-foliated. So we have foliated and non-foliated metamorphic rocks which are classified based on the textures.

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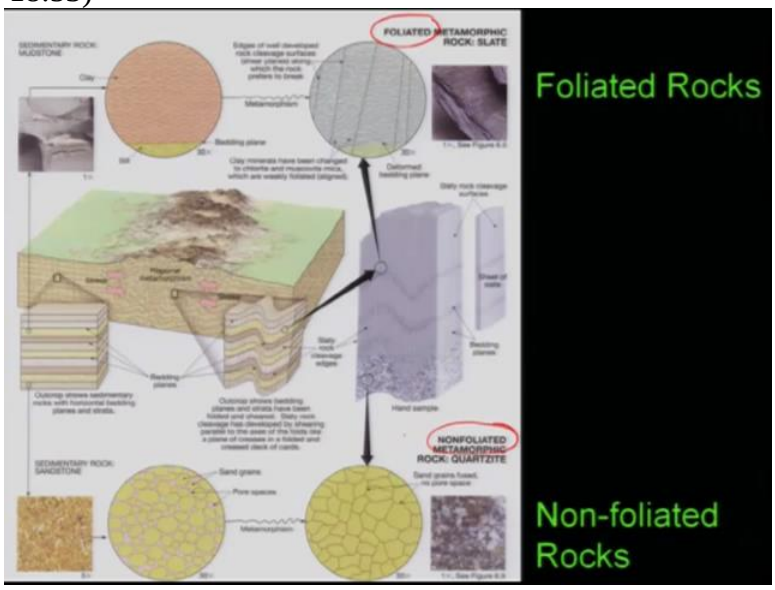

So this figure if you look at, on the left-hand side, you are having all the sedimentary rocks, on the right-hand side you are having the metamorphic rocks comparatively what we have here okay. So for example we are having clay here, which if they are subjected to metamorphism, we will have like foliations okay because the clay minerals will again have the the sheetlike features and then on the deformation, we will have the foliated rocks here.

So we can be can have deformation of slates. So mudstones if they are subjected to metamorphism so then we will we will see the development of cleavable surfaces and those cleavable surfaces will be easily break you can break easily along that plain okay. So the beddings will be created and the clay minerals will change to chlorite and Muscovite micas okay.

So this will provide the weak coalitions and align preferred orientation okay of the bedding plain. So we have the support this is the outcrop here **of the** of the sedimentary succession. When it is

subjected to the regional metamorphism on large-scale because of the ongoing deformation, the material will get folded and will get lined okay.

So you are having the, these are the bedding planes. These are the bedding planes here. But you have this preferred orientation okay what we call the cleavage edges okay. So this will be seen when you look at the sample and hand specimen. And then further if you are having the sedimentary rocks like for example sandstone okay, and you are having the grains, sand grains, or main ecords or other minerals and you are having inter grain space what we call the pore space, when they are metamorphosed, they will try to squeeze.

No pore spaces found any more in that rock and then we what we see is the very beautiful locking between one grain and another grain and result into the formation of massive rock without saying, we do not see any **structure, sorry** texture in this and these are all non-foliated rocks. Whereas this one which were looking at the, they are all foliated rocks.

These are non-foliated rocks okay. So in foliated rocks, you will have very definite, cleavable plains of weakness okay. So foliated and non-foliated rocks. So we will see different types of foliated and non-foliated rocks in the coming slides okay.

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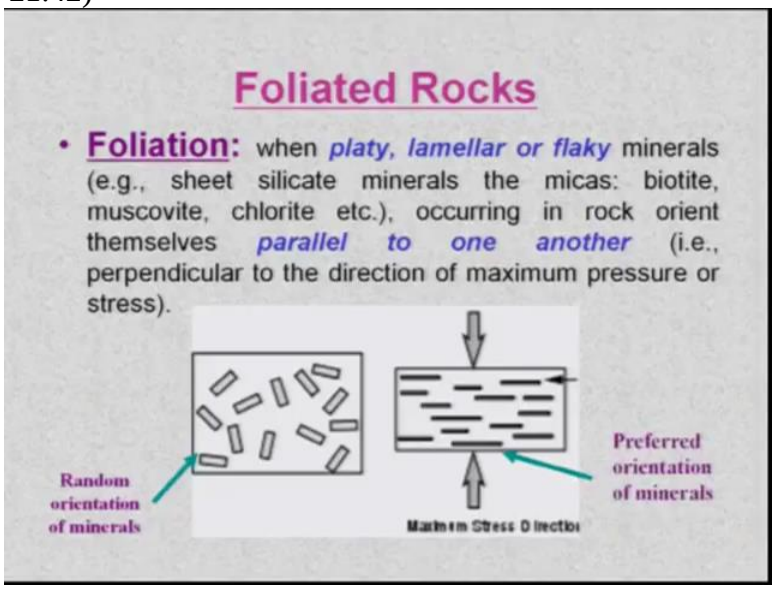

So coming to the foliated rocks, when platy, lamellar or flaky minerals, sheet silicate minerals, the micas like for example the biotite, Muscovite, chlorite, etc occurring in the rock oriented

themselves parallel to the parallel to one another okay. So they will orient themselves parallel to one another, perpendicular to the direction of maximum stress okay.

That will result into the form, the alignment of the minerals almost perpendicular to the or we can say we will have the preferred orientation of the minerals. So these are unpreferred minerals. Like for example we are having granite here but then got preferred along the definite plane or the perpendicular direction maximum stress okay. So we are having randomly oriented orientation of minerals and we see preferred orientation of minerals due to metamorphism.

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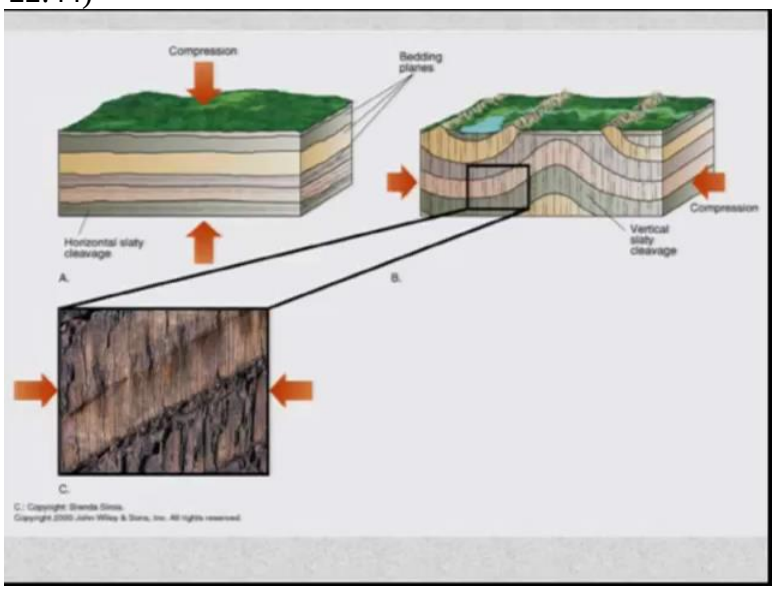

Same example but this is because of the burial we can say. The sedimentary rocks here what we are having, this is where having slate which which are formed because of the burial of the overburden okay. So we are having the compression here and then these beds are when having the greater depth will have preferred orientation okay.

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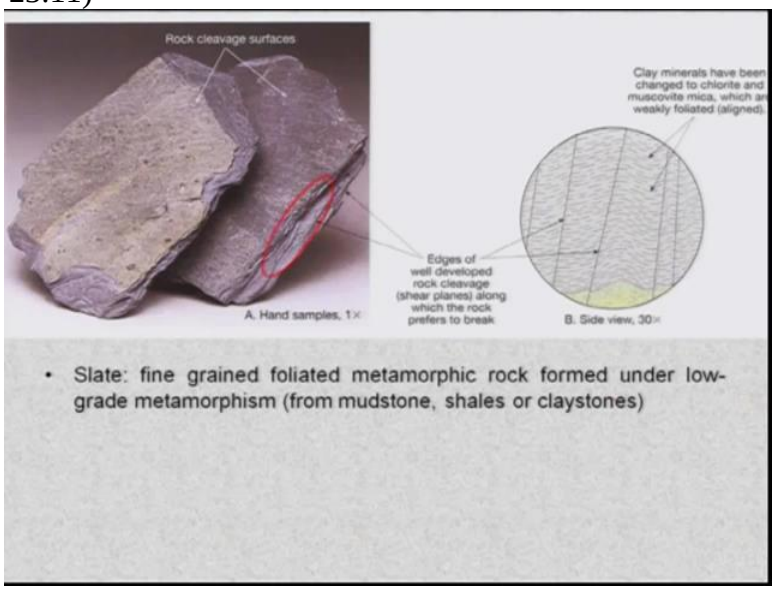

And another example of the slate if you look at in the close up you will find that the edges are having very typical, cleavable or the cleavage along which the rock prefers to break okay out of multiple cleavages okay. So this is a typical characteristic of slate okay. So slate is again fine grain, foliated metamorphic rocks formed under low-grade metamorphism.

So they are not high-grade metamorphism. You will see okay. And they are formed from mudstones, shales or Clay Stones. These are sedimentary rocks. Mudstones, shales, and Clay Stones and we term this as an argillaceous rocks. So these are the plane of weakness.

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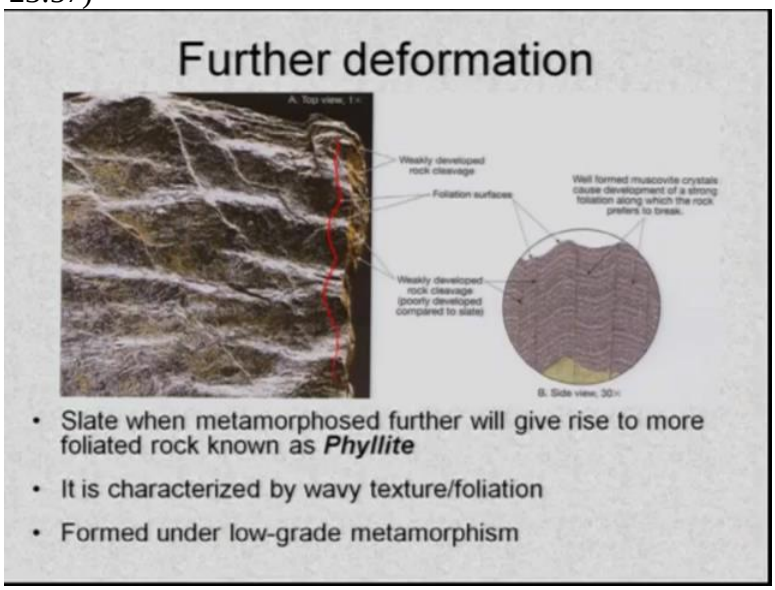

Then further deformation of slate if we take then what will happen okay? It will result into the further deformation and we see more weak zones and then you can the wavy structure here okay and this is typical of what we say phylites okay. So these are the phylites. So when the slates when metamorphosed further will give rise to more foliated rocks known as phylites. So 1st we are having shale that is sedimentary rock subjected to low-grade metamorphism will result into formation of slate.

And slate further are metamorphosed will result in the formation of phylites. So it is characterised by wavy texture of the foliation. So this is typical of the phylite, phylitic rocks okay. So you will see this wavy structures if you look at in the hand specimen okay. Formed under low-grade metamorphism again, still we have not reached to the high-grade metamorphism. So slates shales, slate and phylites okay.

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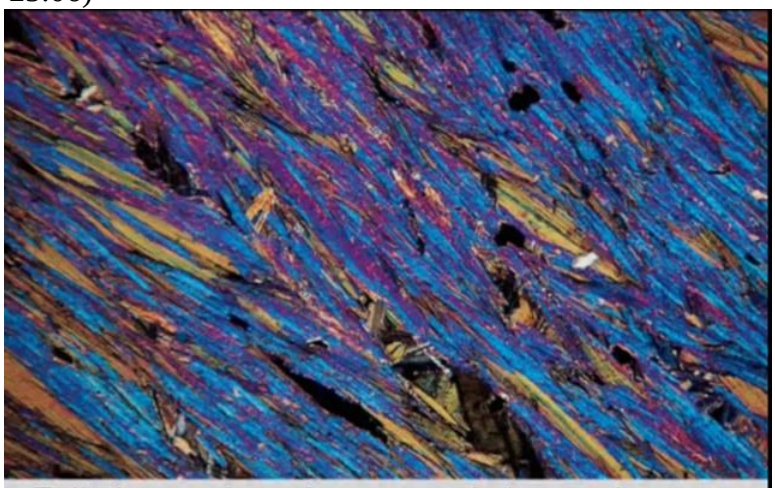

So in thin section if you have to see, then what you will be able to look at, a very colourful picture and we are having the colourful preferred, oriented minerals which are mica and the darker ones are your quartz okay.

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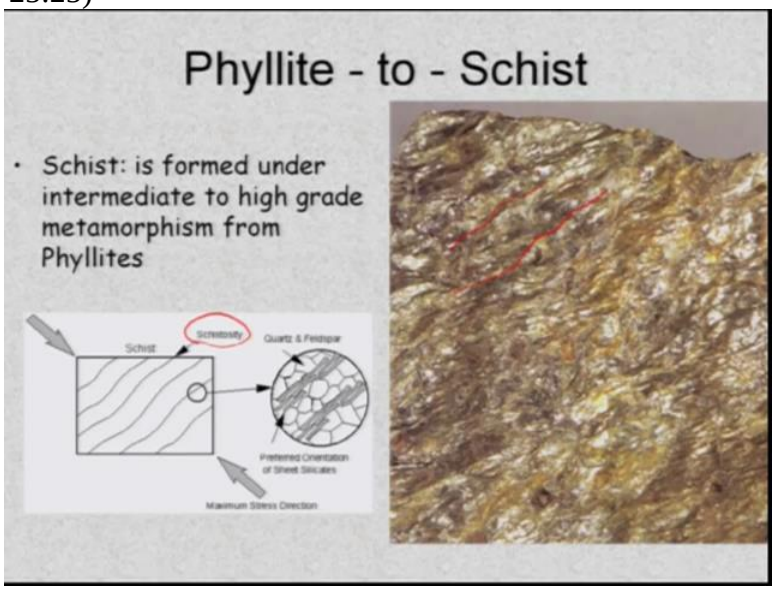

So schist again another metamorphic rock is formed under intermediate to high-grade metamorphism and phylites are subjected to the higher pressure and temperature. They will result in the formation of c schists okay. And schists again we have the what we call the texture is termed as schistocity.

We will see the preferred oriented sheet of silicates okay and the minerals surrounded by that okay. So you will have from phylite to schist we have, so we have slightly larger grains and again, will be able to see a very similar a typical wavy structure here also but not very much prominent as we have been looking at the in phylites okay.

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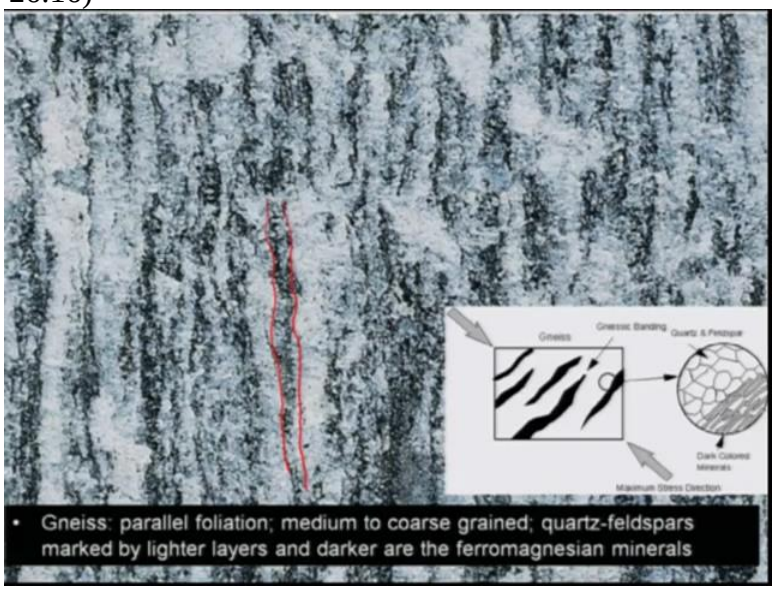

So these are the Gneiss as we have seen we are talking about the from granite to granite ‘s Gneiss okay. So parallel foliations, medium to coarse-grained, quartz, feldspar, mainly marked by lighter layers and the darkers are the ferro-magnesium minerals here. So these are Gneissic Gneissic rocks. So you will have some very typical dark layers which are been found in the Gneiss okay. So non-foliated rocks, these rocks lack foliation okay.

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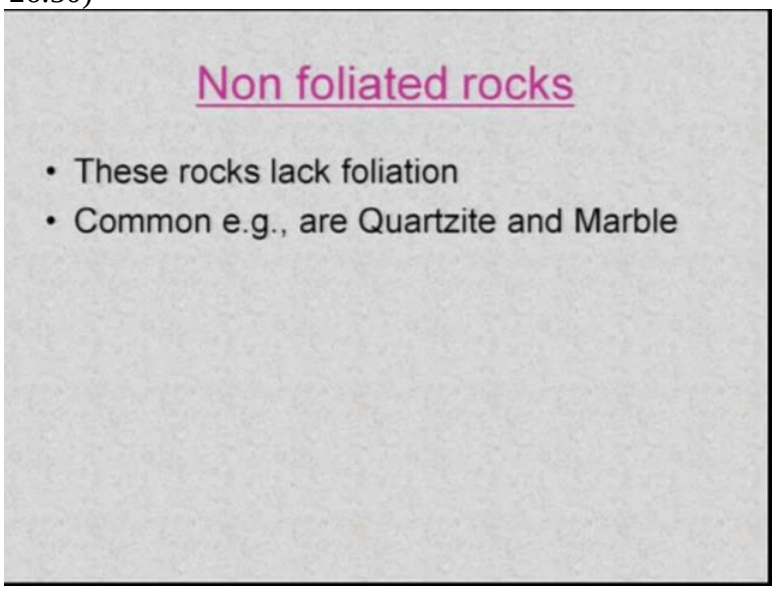

And the best examples are quartzite and marble.

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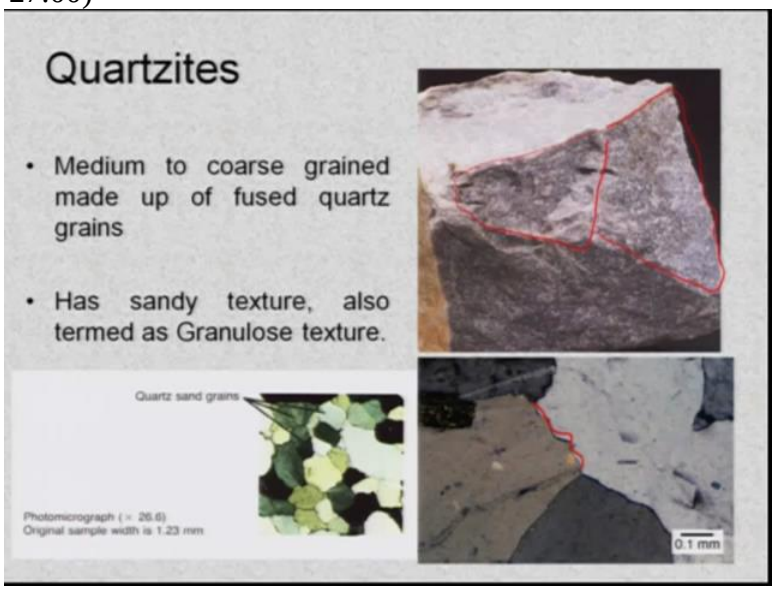

So quartzites, they are extremely massive, no cleavable plane you will find in this and whenever you break this, it will be a bit difficult, very hard. Of course it will break but it is tougher than the other rocks okay. So if you break it, it will break with very irregular surfaces okay. You can see this one here. And this one here okay. They are absolutely not along the preferred plane as we see in the foliated rocks.

Medium to coarse-grained, made up of fused quartz grains. So they are having fused quartz grains and the texture of this we termed as granulose texture okay. So and **they are** they are very well interlocked okay. So if you see this in thin sections you can see the contacts between the different grains okay very much preferred contact and a very prominent one.

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Similarly like marble again if you look at, this is a close up of marble metamorphosed from limestone. I was talking that limestone to marble and that was sandstone to quartzite we are having okay. So we have medium to coarse-grained grain size mostly. Crystalline texture. Shows tight interlocking of calcite grains okay. So that was having quartz mainly.

Here we are having most of what we see is the calcite grains okay. Formed under intermediate to high grade metamorphism. This is the best example of that. So 2 non-foliated rocks we have seen okay.

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And the best example in terms of the monuments if you look at is the Taj Mahal okay. So thank you so much. I will stop here and continue in the next lecture.