ENGINEERING GEOLOGY

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LECTURE - 5

Physical Properties of Minerals

Hello everyone and welcome back to the class room session 5 for the video course on engineering geology. Today we are going to learn different aspects of physical properties of minerals and we will try to identify different minerals based on their different types of physical properties; we will try to list them and we will try to see, how they differ mineral to mineral.

But as is the practice; we are going to answer, we are going to prepare the answers for the problems given in the previous presentation.

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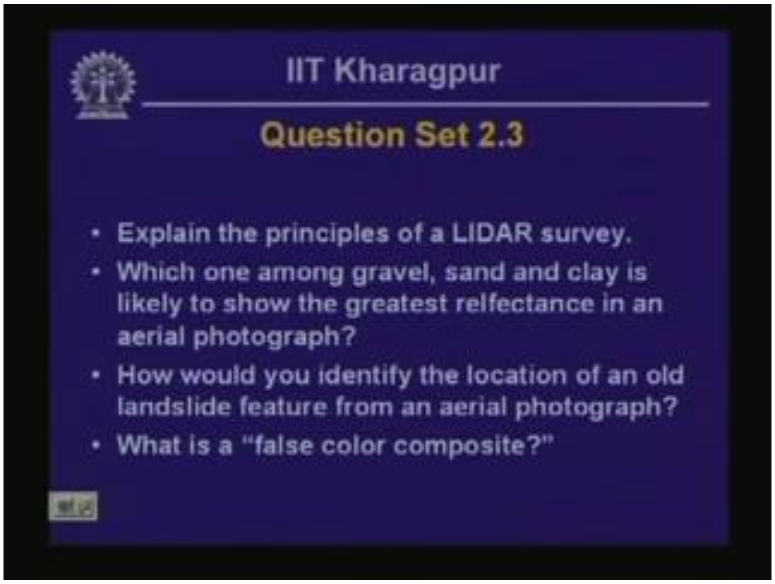

So, the question set that we had in the last presentation went like this; explain the physical, explain the principles of LIDAR survey. Let me explain with a sketch.

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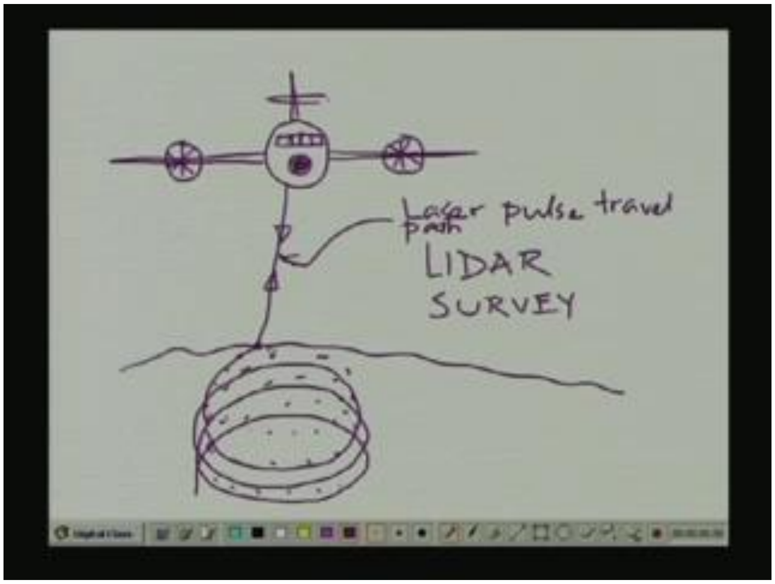

So, what is done essentially is from an aircraft, we emit RADAR, actually LIDAR LASER pulses and those pulses are made to bounce off on the topographic features. So, this is our aircraft and there is a LASER source onboard the aircraft and that emits pulses of LASER signals and there is an onboard instrumentation system that actually picks up, calculates the two way travel time of the laser pulse and it also keeps track of the positional attributes of the aircraft and from those information, it actually computes the X Y and Z coordinate or the two horizontal and the vertical coordinate of the point of which the LASER pulse was reflected.

Now, as the aircraft progresses forward, what is done is to emit a series of LASER pulses in this pattern of an elliptic spiral and using information from each one of those pulses together with all the other information, all the other two way travel times for other pulses from the same area, the survey actually computes the topography of that particular area. So, that in a nutshell is the principle of a LIDAR survey.

So, this one is the LASER pulse travel path. You have to realize that because of the atmospheric conditions, some corrections are necessary on computing the two way travel before the topographic attributes of a particular point on the surface of the earth can be computed.

The second question that we had earlier was that which one among gravel, sand and clay is likely to show the greatest reflectance in an aerial photograph. What we said in the previous lesson is that poorly grained and fine grained soils, they actually tend to appear darker on an aerial photograph.

So, from that perspective, the areas underlying by gravel etcetera, gravels or sands etcetera are going to appear much brighter compared to the areas underlain by poorly drained clay soils or those kind of similar poorly drained areas. This is actually a general guidance though because the colour of the deposit itself is going to affect the brightness of the image depending on the wavelength that is used in capturing the aerial photograph.

The third problem that or third question that I asked was that how can an old landslide feature be identified from an aerial photograph? Now, if the landslide is large, then it is relatively easy to identify what is the landslide scarp in an aerial photograph. Secondly, if the landslide is young, then the growth of vegetation on the failure mass is relatively poor compared to the surrounding area in an otherwise vegetated landscape. So, these features are used commonly by engineering geologists in identifying landslide features on a series of aerial photographs.

Sometimes, they also use time lapse images captured several years apart that cover the same area to identify whether there is any landslide movement or not or the landslide which was earlier there has already stabilized or not.

The fourth question that was asked was that what is a false colour composite? Now, false colour composite is a procedure that allows us to obtain a visual graphic or a visual presentation of a series of satellite images. Now, I said in the last presentation that satellite images cover a large range of electromagnetic, large range of wavelengths within the electromagnetic spectrum. Now, some of those bandwidths are in the area which is not in the visible part of the electromagnetic spectrum.

So, in order to get visual image, those wavelengths need to be mapped onto the visual wavelength using some mapping scheme and the composite that are obtained by super position of individual, of images in individual channels after the mapping is called false colour composite. The name actually indicates that the colour that appears on those images are not true colour but they are a pigment of the mapping scheme of getting from the non-visible portion of the electromagnetic spectrum to the visible portion of the electromagnetic spectrum. So, that takes care more or less the problems or the questions that I asked in the previous presentation.

Now, we move on to the subject matter of this presentation.

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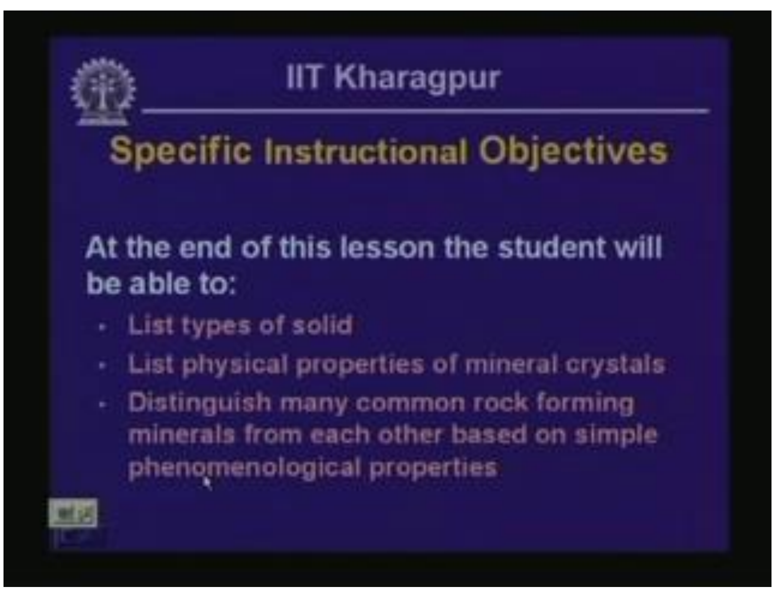

So, we begin with the objectives of this lesson, what we try to learn from this lesson. We try to learn what are the different types of properties, what are the different types of properties of minerals in essence. Now, in order to do that, we first list the types of solids that are encountered in day to day activities. Then secondly, we try to list the physical properties of mineral crystals that are of importance from the standpoint of engineering geology and thirdly we try to distinguish different types of common rock forming minerals based on how those physical properties that we are going to learn from each other depending on whether you are talking about mineral A or you are talking about mineral B.

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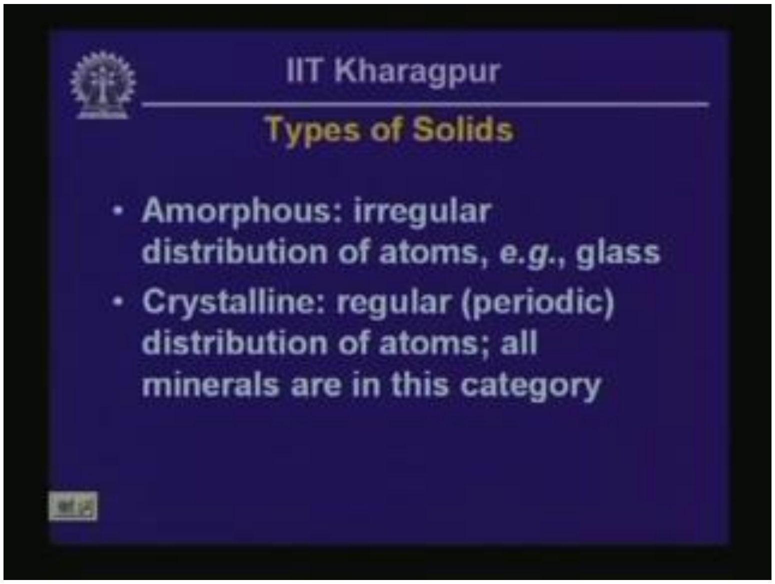

Now, first we will try to learn, what are the different types of solids that you might encounter on a day to day basis? The solids are primarily of two types; the first one is called amorphous solids and the second one is called crystalline solid. Now, what is an amorphous solid? Amorphous solids have got a haphazard atomic structure. So the atoms, individual atoms within the solid are all haphazardly arranged. There is no pattern whatsoever within the matrix.

Now, the examples of that type of solid, a very common example is essentially we can think about is glass. So, glass is very similar in all the other respects to a liquid but it has got some shear strength unlike liquids. So, we call it, we classify it as a solid. But just like liquid within matrix of a glass piece, the atoms are all haphazardly laid out.

The second part, the second type of material, the second type of solid is called a crystalline solid. In crystalline solid, what you have got is your individual atoms; they are all laid out in a regular pattern. So within the matrix, you will have a regular repetitive pattern; there are dislocations, there are irregularities but they appear that is those dislocations or irregularities, they are not the actual I mean they are not a common feature on the, I mean they do not cover most of the volume that comprises the solid mass. So all the minerals, all the minerals are within the category of crystalline solids.

Example of a crystalline solid; we show an example of chlorite mineral, the atomic structure of a chlorite mineral on this slide here and what you can see is a regular structure comprised of aluminum hydroxide octahedral.

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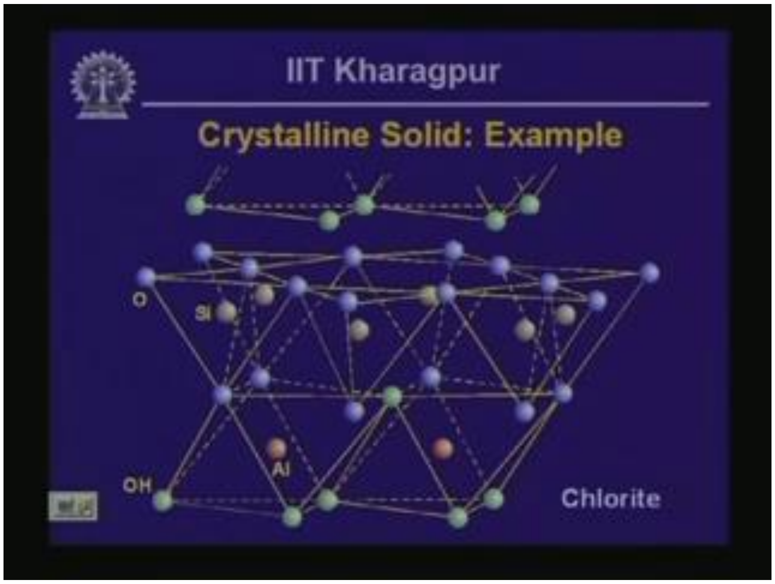

So, these are aluminum hydroxide and they are of octahedral form and then this layer, the layer on top of it is comprised of silica tetrahedral.

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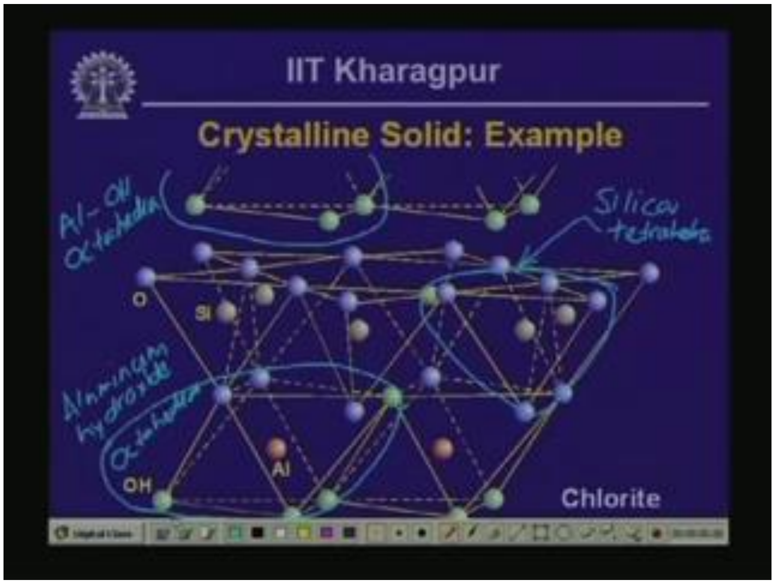

Then again, this particular layered structure is going to repeat. So, you can start, you can you can see that the aluminum octahedra are again starting to reappear. So, this one is aluminum, aluminum hydroxide octahedral once again. So, this kind of repetitive structure actually is typical of minerals and we are not going to be concerned with the amorphous solid in this series of presentations as such. So, this one is an example, this one, the slide that was just shown gives you an example of chlorite mineral which is a very common clay forming mineral.

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All the other rock forming minerals, we are going to consider in this study is of comparable nature in the sense that the layout of individual atoms is quite repetitive. Now, how do we define minerals? Minerals are essentially naturally occurring crystalline solids. There are approximately three thousand different types of minerals in terms of chemical compositions and these minerals include widely occurring mineral; there are only a few minerals out of these 3000 that occurs very widely on the surface of the earth and there are approximately 9 such minerals and we are going to consider them in detail somewhat in this lecture or in one of the lectures later on in this in this series of presentation.

Now, the widely occurring rock forming minerals can range a wide variety of different types of minerals. Some of these minerals could be quite expensive actually. So gem stones, for that matter are examples of those expensive minerals, diamond is also a type of mineral actually and that is one of the most expensive gem stone that one can find.

Then, on the other end of the spectrum in terms of price are minerals which do not have any engineering value. Somewhere in between are engineering minerals which are used in construction activities. Now, we now get on to different types of physical properties of minerals.

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The first one, the first property that we are going to consider here is the colour of minerals and colour is actually one of the properties that can be used to distinguish from one mineral to the other. For example, you can think about gypsum. Gypsum has got a white colour; on the other hand, if you talk about hematite, hematite has got a dark colour. So, based on what colour it is, we roughly can identify minerals. But colour is not a very good identifier of minerals because colours may change as the mineral is exposed to the nature or the colour may vary depending on what kind of impurity is present within the mineral crystal lattices.

So, depending on all these, depending on all these things, although you understand that although colour can be taken as one of the attributes or one of the identifying attributes for different types of minerals; but it does not confirm, I mean it is very difficult to distinguish minerals purely based on the colour itself. You can think about several minerals actually which show a wide range of colours. Those minerals are called allochromatic. In contrast, isochromatic minerals, they are of a single uniform colour.

Now, an allochromatic mineral, example of allochromatic mineral is feldspar; on the other hand, isochromatic, an example of isochromatic mineral is a mineral called kyanite.

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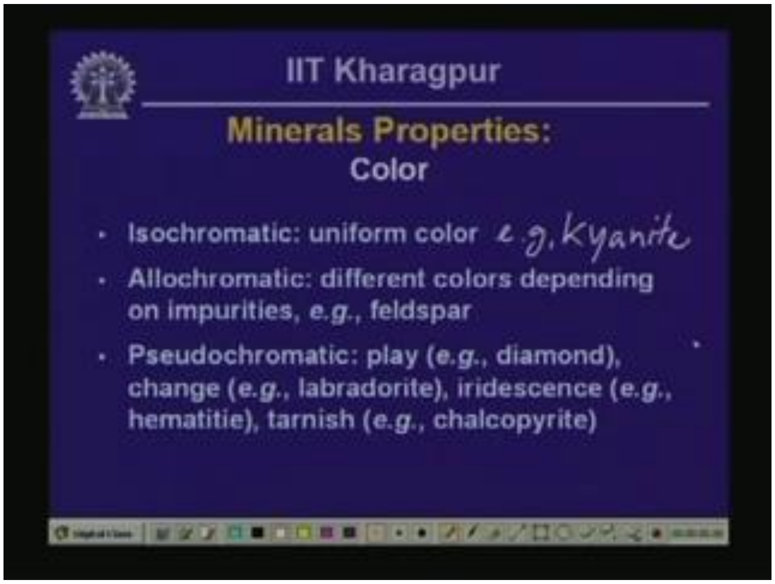

The name kyanite itself comes from Greed work which mean, Greek name for the colour blue. That actually means that you are looking, you are talking about a mineral which has got a blue colour. There could be pseudochromatic minerals also. Pseudochromatic minerals have got a play of colour. So, if you take a piece of that mineral on your hand and if you turn it around depending on from which direction light is coming, you are going to see a play of colour, the colour is going to change; example for that one is diamond.

Then there is another possibility which can, which is also an attribute of pseudochromatic minerals and that is iridescence. Iridescence means a rainbow like colouring appear on the surface. And, tarnish is another type of attribute for pseudochromatic mineral and tarnish is I mean if you if you keep this kind of mineral exposed to the nature, then the colour becomes dull. An example of a mineral that shows this kind of colouring which tarnishes is chalcopyrite that is copper pyrite, copper iron and sulfate.

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Now, the second mineral property that we are going to consider is luster. What is luster?

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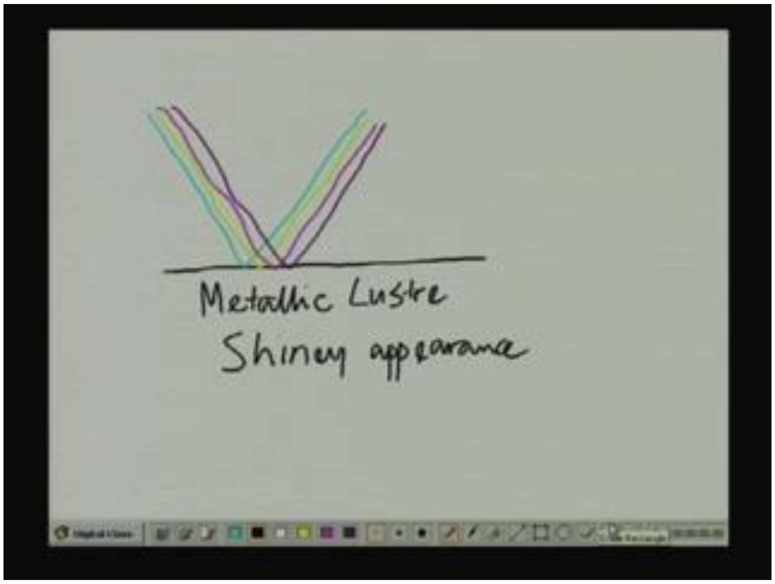

Luster essentially gives the property that shows the reflectance characteristics of the mineral surface. For example, we take a mineral surface and if you have got this kind of a reflectance property from that mineral surface, then the surface is going to look quite I mean it is going to reflect it is going to reflect light that may come from another source rather brilliantly and this kind of reflectance property gives rise to a thing called, often it gives rise to a thing, a type of luster called metallic luster which has got a very shiny appearance.

On the other hand, you could also think about a surface like this, about a surface of mineral which is like this and the way it reflects different wavelengths of light is like this.

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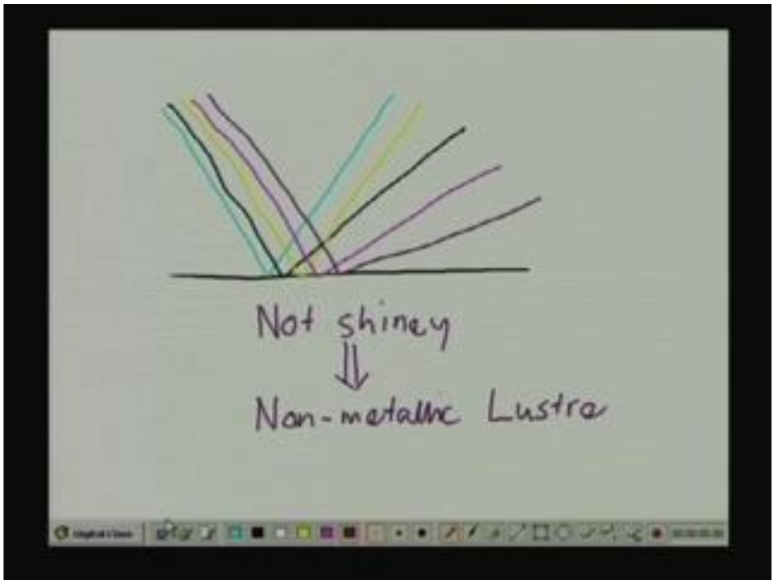

So, in a sense, this type of surface upon reflecting, it is going to scatter different wavelengths in different directions and this type of, this this type of behavior actually gives rise I mean, it actually gives rise to a luster which is not shiny not shiny and this thing often classifies, is classified as non-metallic luster.

Getting back, here it is indicated; on this slide, it is indicated that you could have metallic luster as shown in the first bullet there or you could have several other types of lusters and these things, these lusters are non-metallic, non-metallic; whereas this one here, was a metallic luster, was the metallic luster.

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So, what are the different types of non-metallic luster then? Non-metallic luster could be ritreous luster which looks like, which which makes the mineral appear like a piece of glass; an example of that being quartz. Then there could be partly luster which makes the mineral appear, it gives a texture, the surface texture of the mineral appears, makes it appear like the surface of a pearl. Then there could be silky luster where the mineral appears like silk fabric; not quite as shiny as a metallic mineral or mineral with a metallic luster but quite shiny otherwise.

Then there could be resinous luster in which it it actually has got a very peculiar feel when one actually runs his or her finger on top of the mineral surface, it has got a slippery, slightly slippery feel; that kind of luster is called resinous luster and finally we can have dull luster like the surface of a piece of chalk and this kind of luster is typical of mineral bauxite.

So, these things are listed over there in the slide that was shown with the examples.

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There is an example on the right side of the slide for a non-metallic luster which is shown here; that is a piece of gypsum actually and a metallic luster, given by an example of showing a piece of metallic pyrite. You can see the shiny pieces over there in that portion in the metallic pyrite. So, that is actually typical of metallic luster.

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Now, we go to another mineral property; this is the third one actually. First of all we considered colour, then we considered luster and this is the third one and this is called streak. Now, colour was, when we talked about colour, we talked about the piece of entire mineral. Now, if we talk about the colour of powdered mineral, then that attribute is given the name lust, given the name streak.

So, if you actually take a piece of, a hard a hard piece of quartz and rub another mineral on top of that piece, what you are going to get? You are going to get a marking depending on what is the colour, what is the colour of powdered mineral and that particular colour is going to identify, going to give the streak of that particular mineral.

Now, streak is a very important property and that actually allows us to distinguish several pierce of mineral for which we have very similar properties, very similar properties otherwise but the streak is different. Example for that are two minerals - chromite and magnetite. These two minerals are very very similar in properties. Even the magnetic properties of these minerals could be or does not sometimes allow them to be distinguished from each other. But the streak of chromite is black; streak of chromite is essentially brown in colour, whereas the streak of magnetite mineral is black in colour.

Now, let me give the chemical composition also of these two minerals so that actually, in order to complete the discussion here. Chromite essentially is, it has got this kind of chemical composition whereas magnetite, the chemical composition of magnetite is this, so that is the chemical composition of magnetite.

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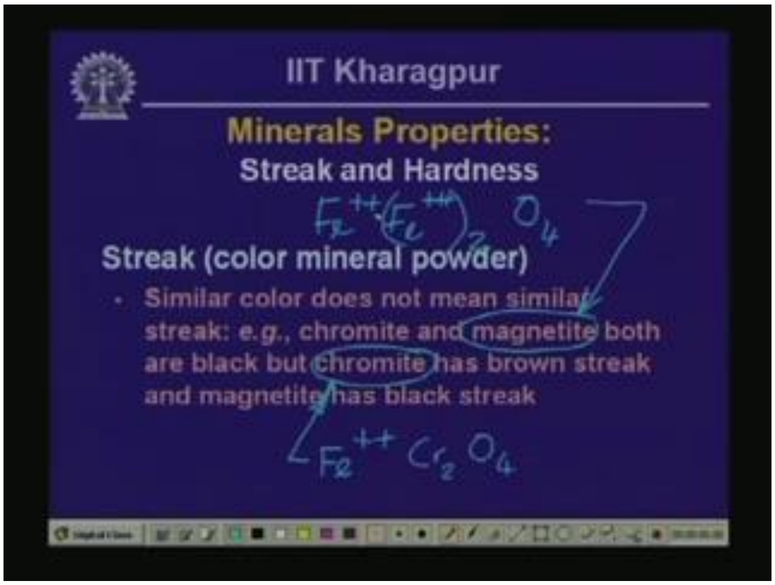

So, the plus signs used as superscript in the symbols, you all know that indicates the valence of the atoms and here, for the magnetite actually, the iron, the triple valent iron actually can be substituted by chromium. In that case, the chemical structure, the chemical composition actually of magnetite could be very similar to the chemical composition of chromite.

So, this is actually, this actually tells you, this actually illustrates how difficult it could be at times to distinguish one particular type of mineral from a second type of mineral.

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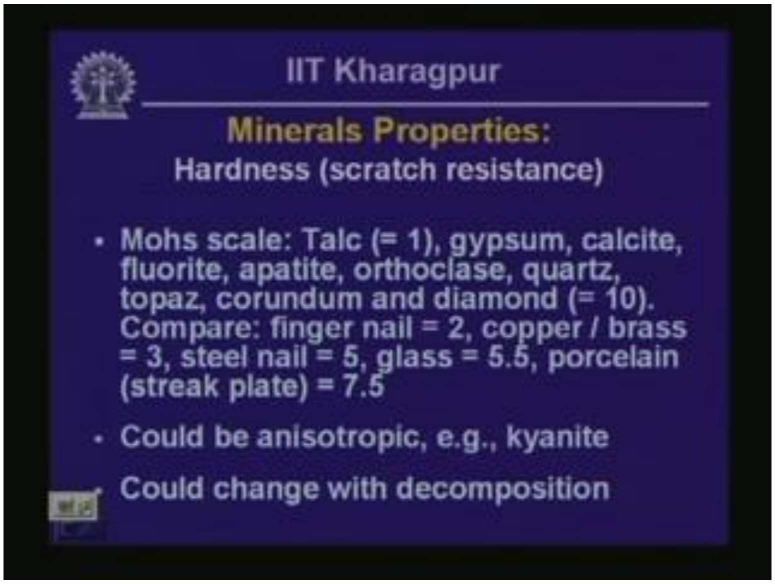

Now, the other property, the other attribute, other physical attribute of minerals that allows us to distinguish different types of minerals is hardness. So, how do you actually, what is hardness? Hardness essentially means resistance of a particular mineral from being scratched. So, the more resistance there is against scratching, then the hardness is greater. The scale is not a numerical scale but it is rather of a phenomological type and this scale is given the name Mohs.

So, the scale goes like this; the mineral talc has got a moh of 1, then gypsum has got a moh of 2, then comes the calcite - 3 in the moh scale, fluorite – 4 in the scale, apatite, orthoclase, quartz, topaz corundum and diamond. Diamond is the hardest mineral that many of you already know; it has got a value, it has got a hardness of 10 on the moh scale of hardness.

Now, sometimes it is difficult to, see how actually, how actually hardness of a particular type of mineral is determined is to have different pieces of minerals available and if there is an unknown mineral given for identification, then that mineral is scratched using all these different minerals. So for example, if we can just scratch the mineral using mineral talc, then the hardness of that particular mineral is only 1.

On the other hand, if we have to take a piece of diamond to scratch that mineral, then that mineral has got a mho scale of, it has got a hardness of nine on the mho scale of hardness. This is the way of rigorously finding out what is the hardness of a given mineral. Now, more often than not during field reconsiance missions, you would not have with you available, all these different minerals that you can use or that you can try to scratch the unknown mineral with in order to identify the hardness of that particular mineral.

So in that situation, actually, as a rule of thumb, you use for example finger nail; a finger nail typically has got a hardness of 2, then you could use a piece of copper or brass that has got a hardness of 3, a steel nail could be used, it has got a hardness of 5, a piece of glass can be used to scratch the other mineral it has got a hardness of 5.5.

So, if for instance, if you could scratch a mineral using a piece of glass and you could not scratch the mineral using steel nail, then the hardness of that particular unknown mineral is somewhere between 5 and 5 and a half. Then you could take porcelain, a plate of porcelain, a kind of plate that is used for finding out streak of different minerals and porcelain plate has got a hardness of 7 and a half. Now, hardness is also, I mean the property hardness could also be tricky at times.

Now, for some minerals, hardness is an isotropic. So for example, you take the mineral kyanite that we discussed earlier; kyanite has got a blade like structure which we will come to see later on in this presentation. If you actually try, test the hardness in the direction, in the short ward direction then the hardness is going to be different from the hardness that is measured in the direction perpendicular to the short ward direction.

Then hardness could ((Audio Problem 36:33)) if weathering actually decomposes the minerals near the surface of a particular aggregate of minerals. So, these are a few catches actually you should be aware of when you are trying to identify the hardness of a particular mineral.

Now, the other mineral property of interest is the cleavage of crystals.

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Now, cleavage when you try to break a crystal, then crystals break on definite plains of cleavage. So, if there is definite cleavage, then the form, the way those cleavage plains are oriented with respect to each other that will give you enough clues in order to distinguish many types of minerals. Cleavage could be cubic or it could be rhombohedral or it could be prismatic or it could be basal.

So, these are actually the characteristics; as you can see from the names that are used for classifying these things, they actually talk about crystal shapes. Now, the other way of classifying cleavage is eminent where you have got very distinct cleavage surface; example for that is mica and then in order in the decreasing order of prominence of the cleavage surface is perfect, good, distinct and indistinct.

So, if you have got, if you have got for instance, a piece of chalk, then that we will not have any distinct cleavage. So, for that type of mineral, you are going to classify the cleavage as indistinct. Now if you find, if you find cleavage plains, then there could be one cleavage plain or there could be more than one cleavage plain. For instance, for mica - biotite and muscovite, you have got one distinct cleavage plain. Then there could be 2 cleavage plains that are oriented at 90 degree between each other; those types of minerals include feldspar and pyroxene.

Then there could be 2 directions but they are not the included angle between those 2 directions is not 90 degree, an example being amphibole. Then there could be 3 directions at approximately about 90 degree, example being halite and galena; halite is essentially rock salt. There could be 3 directions but not at 90 degrees, example is calcite and dolomite and there are 4 directions, this is an octahedral structure and the example for that is fluorite.

Some examples of the different types of cleavages; For instance, we talked about one direction cleavage in one distinct direction, example is a biotite mica, a dark coloured mica in which the plains of the slide itself essentially is the cleavage plain.

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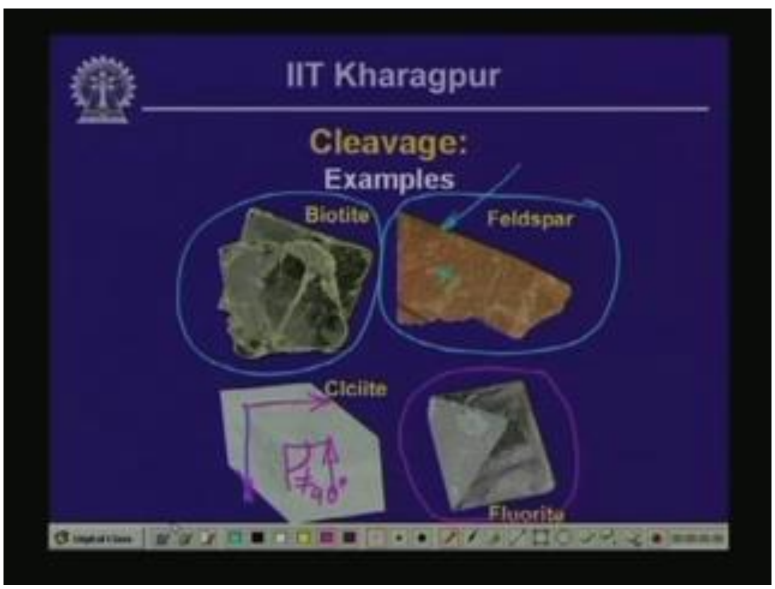

Then the example of two cleavage plains is feldspar and this one is approximately at 90 degree; you can see one of these cleavage plains here and the other one which is not very distinctly shown on this photograph and that is in a direction perpendicular to this direction that is appearing straight on the plain of the slide here.

Calcite, it has got 3 cleavage plains; one is this one, one is that one there and other is that one there and the other one is this one. So, you can see that the angle between these cleavage plains is not 90 degree, not 90 degree as we indicated earlier.

Then this is the example of I mean, this is the example where you have got a rhombohedral structure and here you have got several cleavage plains actually 1, 2, 3, 4 and there are so many on the other side that is not appearing straight on as well. So, that kind of illustrates about how you could use cleavage plains in order to distinguish different types of minerals.

Then the other physical property of interest is fracture.

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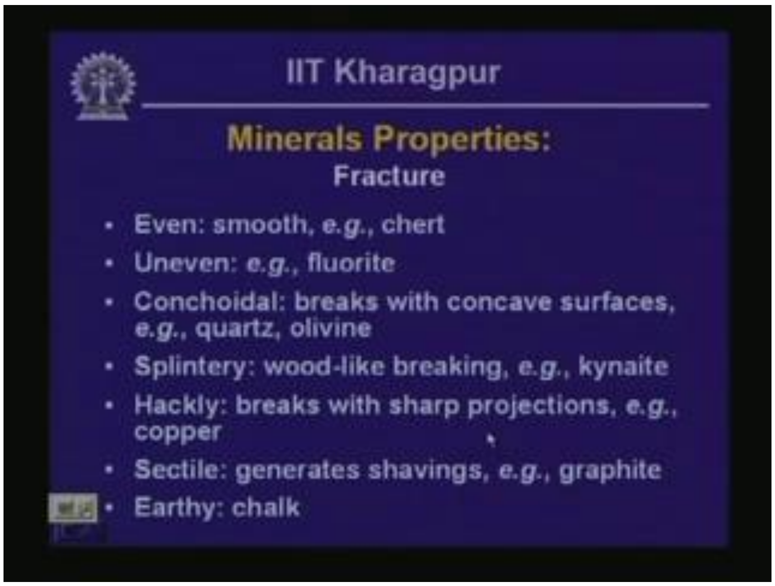

Now fracture, when you try to break a mineral, then the fracture could be smooth as we saw when we talked about cleavage, it is quite analogous to that type of property, here you have got a smooth fracture. And, when we talked about cleavage plains, we talked about eminent cleavage for instance, then fracture could be uneven. When you have got uneven fracture, then the surface in which the mineral aggregate breaks is going to be uneven as the name suggests.

And then, there could be other types of fractures like conchoidal fracture, example being quartz and olivine and what is a conchoidal structure? It is essentially, when you try to break a piece of quartz, it is going to break in a surface that is slightly concave. You might have seen this kind of fracture when a piece of glass shatters as well; you see a series of concentric, a series of actually a concave surface developing when you try to break certain pieces of glass as well.

Now, fracture could be splintery when the breaking is like, is very similar to the type of fracture that you will get when you try to break a piece of wood for example. The piece of wood sometimes shatters in the form of splinters, example for that is kyanite. Then the mineral can actually fracture as with hackly fractures; hackly fractures essentially indicates that there are I mean, the mineral breaks with sharp projections like mineral copper actually breaks in this manner.

Then the mineral could also break in a sectile manner. Sectile manner is a fracture that is typical of graphite, for example. You all have used graphite pencils; when you try to sharpen the pencil using using a blade or something, then you will see shavings of graphite actually comes out. So, that is an indication of sectile fracture.

And finally, you have earthy fracture in which the mineral actually breaks in the form of powder. Example of that one is; not actually, it is not powder but the surface at which it breaks, it does not have any reflectance at all, it has got a dull appearance and that kind of that kind of mineral I mean, that kind of example for that type of fracture is chalk.

Then we get on to the other type of physical property that also allows different types of minerals to be distinguished from each other and that is called form, crystal form. This is essentially physical shape, physical shape that you get for different types of mineral crystals.

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Now, there are several different types of forms, some of which we have already seen. The first one being tabular, example for that is calcite and orthoclase and the property of it is that it has got essentially a tabular form. I am going to draw a few sketches once I list all different types of forms on this particular slide.

Then next one is elongated, example for an elongated mineral is quartz. Then crystals could be bladed, the structure is just like, you know just like blades. It has got two flat surfaces and the distance between those two flat surfaces is relatively small.

Then the fourth one is lameller, lameller is essentially very similar to a bladed structure but here what you have got? Here, the thickness of a lameller is rather small, it is even smaller than a bladed form, a mineral that is classified that classify as a bladed mineral.

Then there could be foliated structure; foliated structure, an example for that is muscovite,

muscovite is a type of mica actually. Then there could be fibrous minerals which has got one long dimension, all the other dimensions of a piece of mineral is relatively short.

Then there could be radiating type of minerals, example is pyrite. Granular minerals in which the entire mineral matrix is, it appears as an assemblage of mineral grains, little bit course mineral grains; example being chromite.

Then there could be globular structure, it is just like you know an assembly of minerals, roundish roundish mineral pieces, each of which looks like you know rounded tables cemented together. Then there are reniform structures; example for globular mineral is hematite. Reniform structure is very similar to a globular mineral in which each of those pieces, each of those roundish pieces take the shape of a human kidney.

And finally, you have got mammillary; that is also very similar to the globular and reniform structure but a mamillary mineral kind of looks like it may takes an appearance of a head of broccoli or I mean it is very similarly in appearance to a head of broccoli or cauliflower.

Now, let us actually sketch out these different types of minerals, these different types of mineral forms. So, we first talked about tabular form and the tabular form is going to be, going to look like this; so, this is a tabular form.

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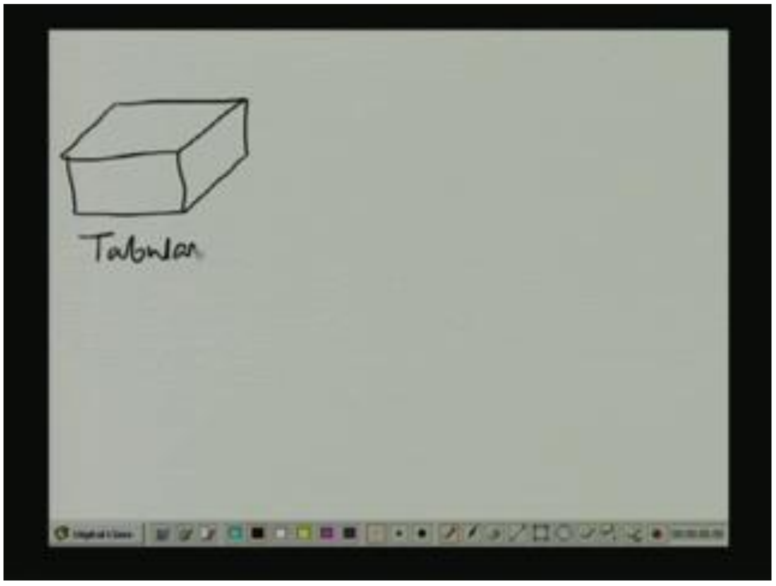

You could also have another type of tabular mineral which sort of looks like that. So here, so here what you have got actually; so this is also another example of tabular mineral.

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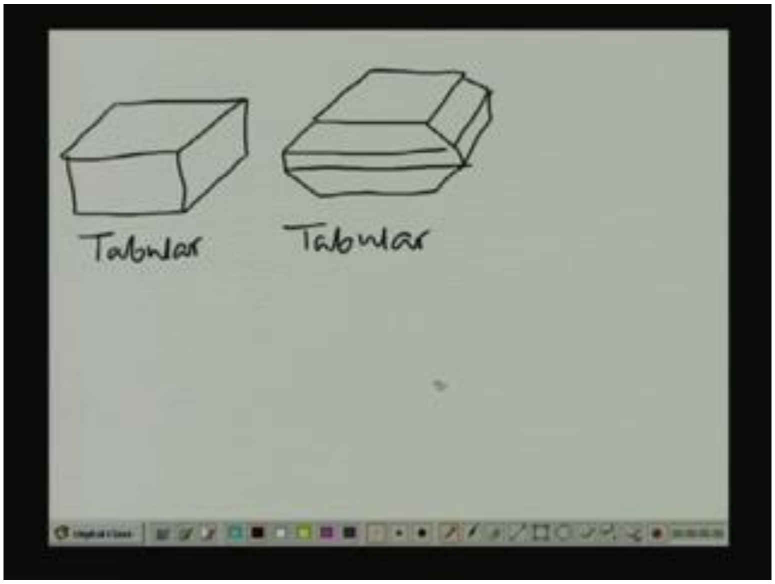

Then you have got elongated structure; let us take an example, this could be an elongated, structure elongated structure.

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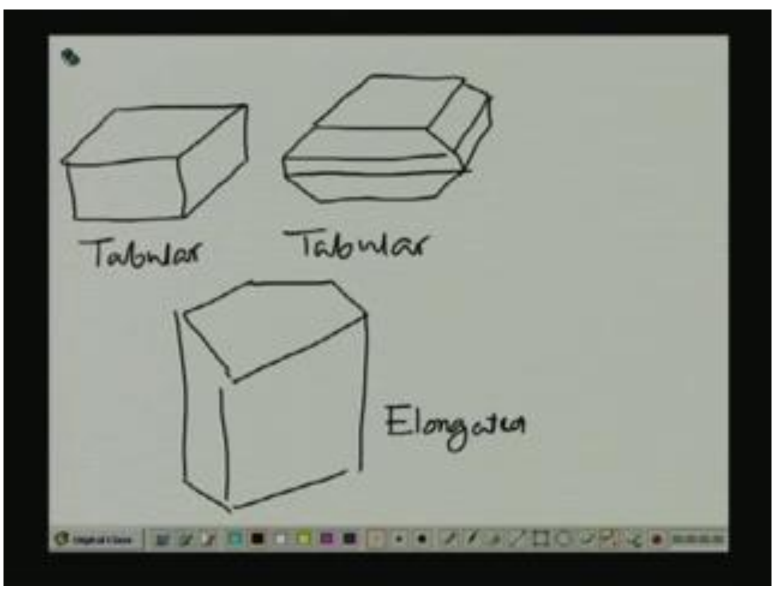

Then you have got bladed structure that kind of looks like this; this is bladed structure.

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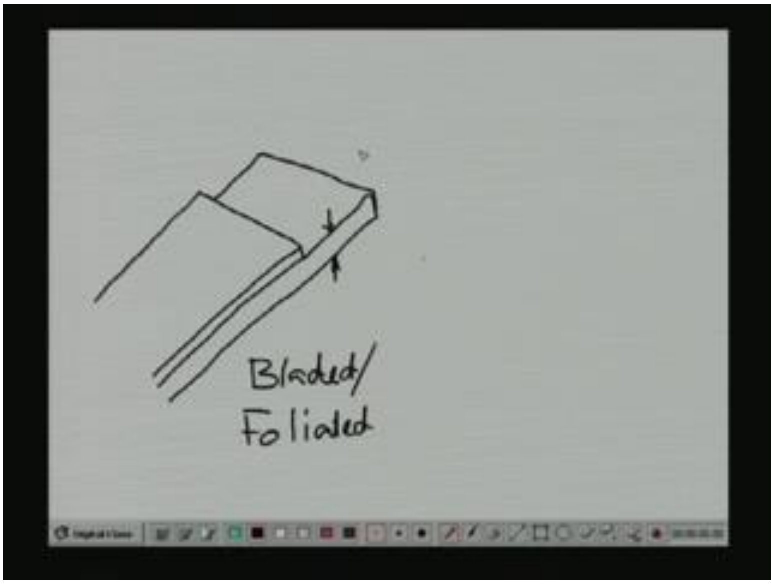

You could have foliated structure in which this thickness is much smaller than this one becomes foliated. You could get, let us take an example of globular or reniform structure that kind of looks like this.

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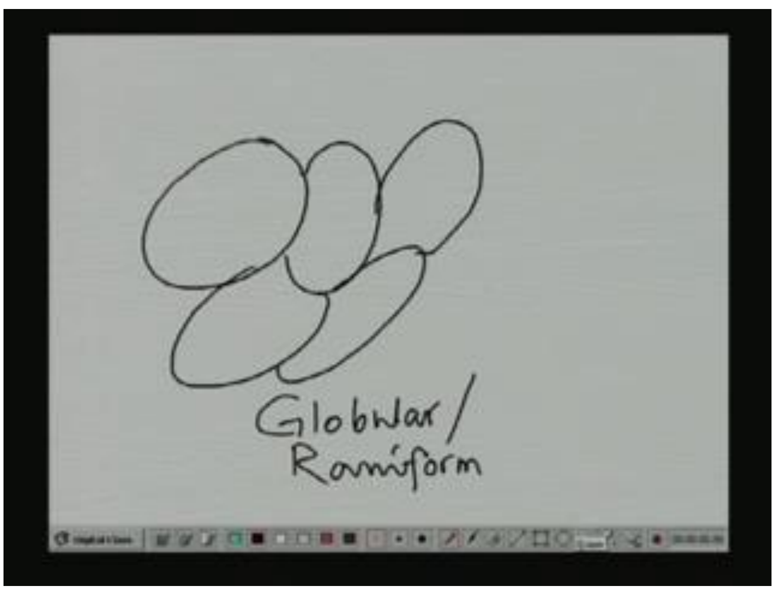

So, this is globular reniform. Then you could have actually radiating structure which we did not illustrate it so far.

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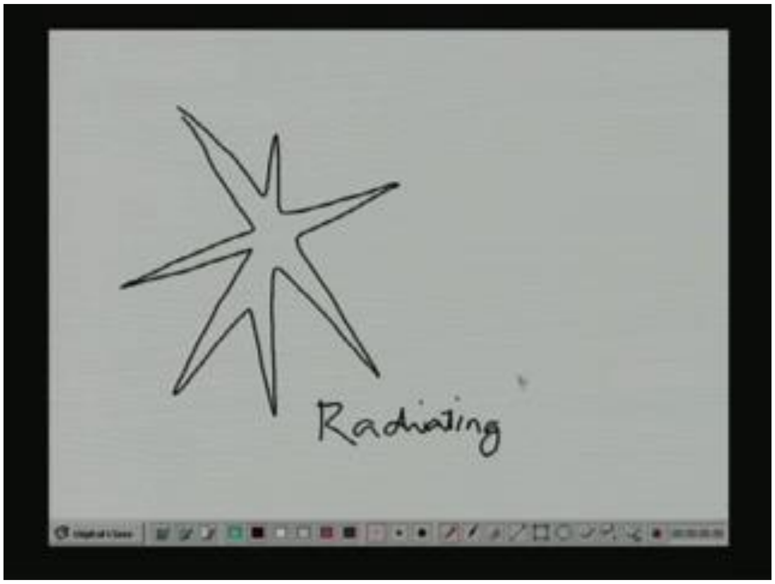

Radiating structure, sort of looks like this. Actually, ice crystal also, it has got radiating structure. So, this is radiating. And then, granular structure is sort of like this.

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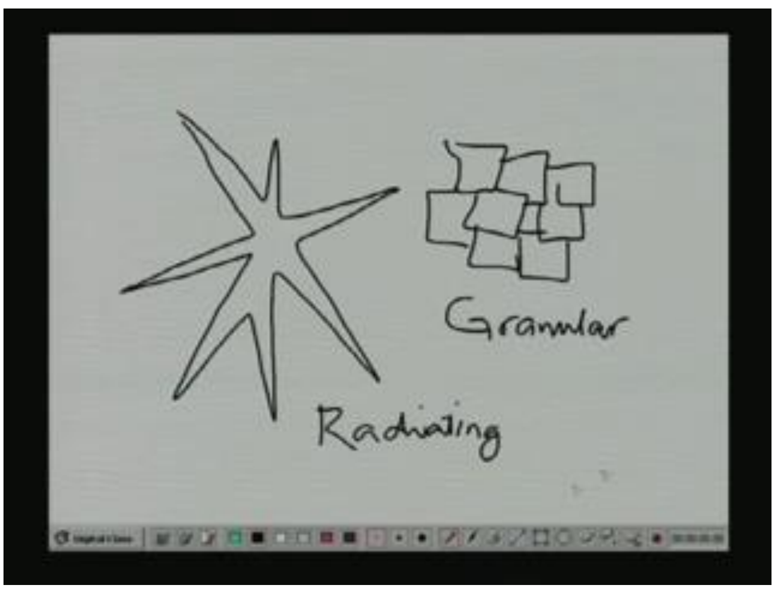

The matrix starts appearing like an assemblage of different grains. So, this one is a granular structure. So, that kind of takes care of different types of crystal forms. There are several other types of mineral properties that also allow minerals to be distinguished from each other one of which is specific gravity.

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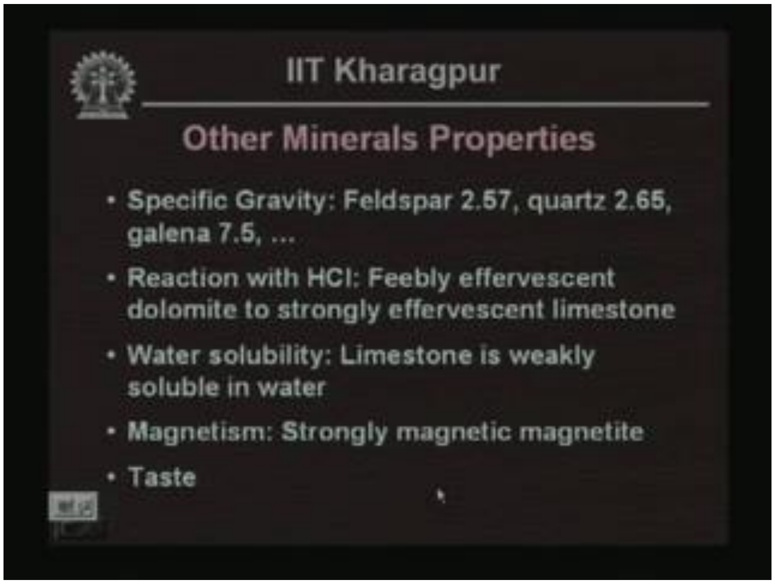

For example specific gravity of feldspar is 2.57; on the other hand, galena could have a specific gravity as high as 7.5 because of the presence of lead within the chemical, in the chemical composition.

Then you could also distinguish minerals depending on the reactivity to different types of chemical reagents. For example, reaction with HCl allows distinguishing dolomites from limestone. Dolomites, actually feebly reacts with HCl - hydrochloric acid whereas limestone, actually vigorously reacts with HCl.

Water solubility is another one, another property that allows distinguishing one type of mineral from others. Limestone is weakly soluble in water; particularly if the limestone becomes open structured, its water solubility actually increases.

Then magnetism is another property that allows some minerals from being distinguished from other minerals; example being magnetite, magnetite is strongly magnetic.

And then there is, you can also taste; you can also distinguish minerals depending on what taste it is, example being halite.

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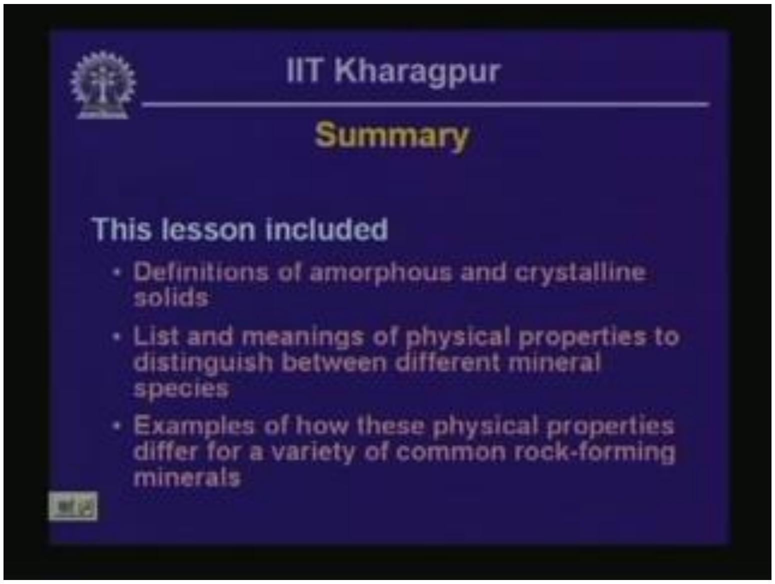

Now, we want to summarize the, summarize what we learnt in this particular presentation. We found, we actually understand now, what is the distinction between amorphous and crystalline solids. We can list the meanings, list and find the meanings of different types of physical properties that can be used to distinguish different types of mineral species and we got a few examples of how these physical properties can be used in distinguishing different common minerals.

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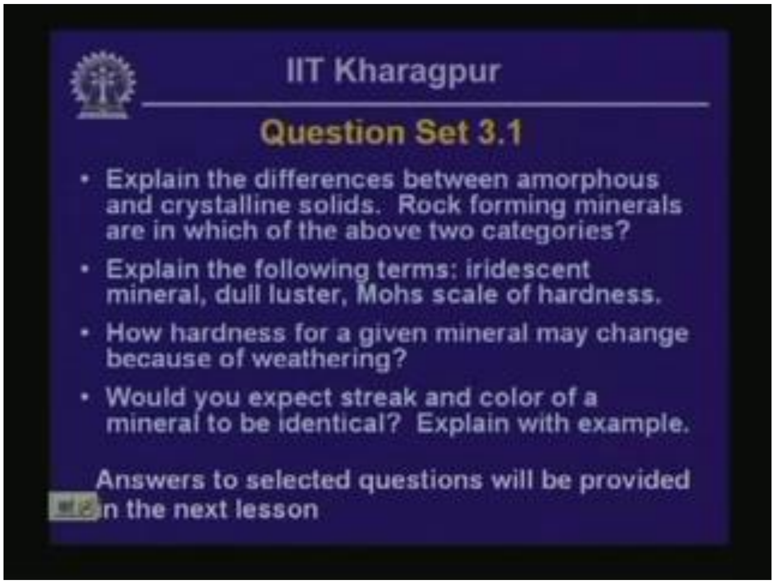

And finally, we end with a question set for you to ponder on. The first one is; explain the difference between amorphous and crystalline solids. Rock forming minerals are in which of the above two categories? Then explain the following terms; iridescent mineral, dull luster and Mohs scale of hardness. How hardness of a given mineral may change because of weathering? That was the third question and fourth one is that what would you expect streak and colour of a mineral to be identical? Explain with an example.

You try to answer those questions at your free time and when we meet again for the next presentation, I am going to give you the answers for those examples. We are also going to meet later on for a laboratory course, laboratory presentation in which we will take physical examples of different minerals and try to distinguish them from each other depending on these properties that were listed in this presentation.

So, with that I am going to end this presentation and until I meet you again, bye for now; thank you very much.

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Hello every one and welcome to lesson 3.2 of engineering geology. Today’s topic is crystallography of optical properties of minerals.

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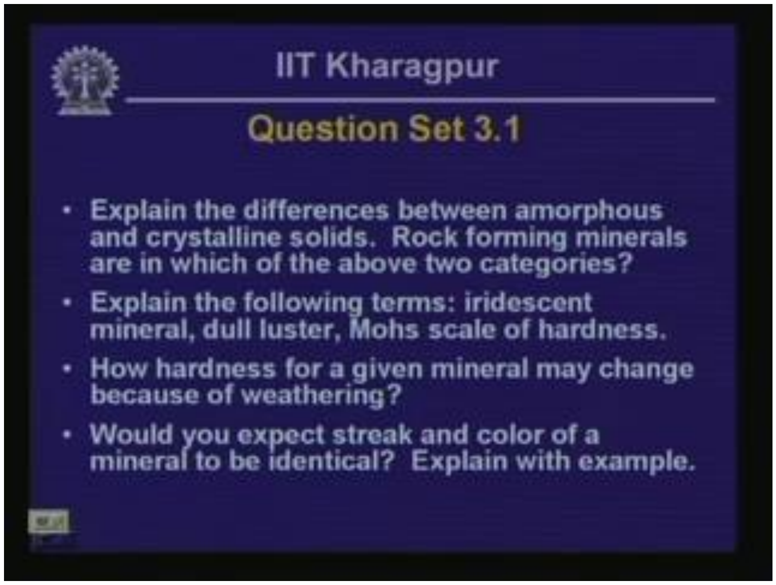

As usual, we are going to begin with a discussion of the previous lesson's question set. The first question that I asked last time around when we met was to, I asked for an explanation of the differences between amorphous and crystalline solids. Now, amorphous solids do not what show any regular pattern of individual atoms that constitute the solid; on the other hand, crystalline solids have got a regular pattern of atomic structure, regular and repetitive pattern of atomic structure.