Engineering Geology

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Lecture - 7
Chemical Characteristics of Minerals

Hello everyone, welcome to fresh lesson in an engineering geology. Today we are going to discuss about the chemical characteristics of minerals. If you recall, last time around we talked about, we talked about geometric and the physical and optical characteristics of minerals. Today we are going to have a look at the chemical features that gives raise to those physical properties. Before we begin with the, with the subject matter of the particular lesson, we are going to consider the question set of the previous lesson; I am going to give the answers.

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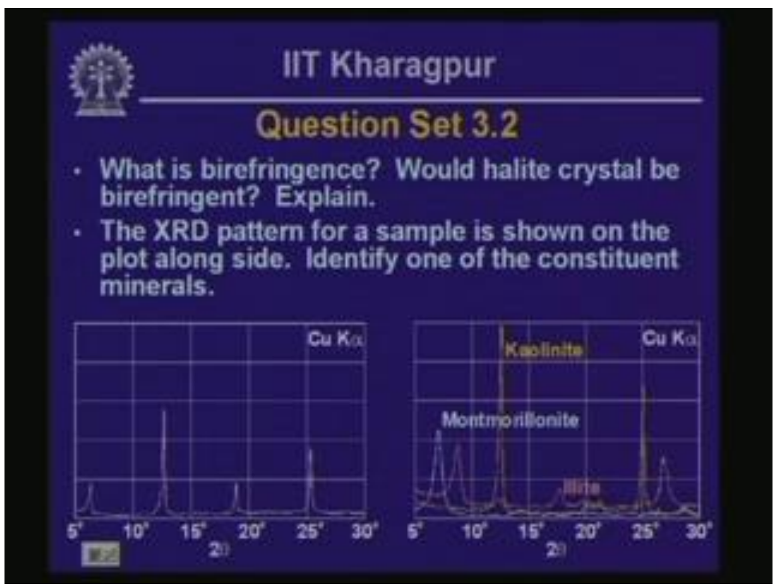

The first question that I asked was on by birefringence. What is meant by birefringence? Now, birefringence is an optical characteristic by which there is a double refraction of a waveform of electromagnetic waves that tries to cross a chemical, a mineral crystal.

Now, the second part of the first question was; whether you expect a halite crystal to be birefringent? Now, I said in the last lesson that if you have got a crystal that is isotropic, then it is not going to, it is not going to exhibit birefringence and as a result halite is also not going to be birefringence crystal because halite is an isotropic mineral.

Now, the second question that was asked was; you have given an XRD pattern for a sample and you were asked to identify one of the constitute minerals of the sample for which the XRD pattern was provided. Now, what I have done is I have put the XRD pattern that was given to you in the last question set on the left here and that is shown, I am going to actually I am go to just draw a line on the top of the XRD pattern provided to you because the line thickness was not adequate so that the resolution may not actually pick the input XRD pattern.

Now, this is the XRD pattern that was given to you. So as usual, intensity is on the vertical scale and on the horizontal scale, we have got the angle to theta that was explained in the last lesson. Now, what I have done here; I have put side by side the XRD signatures of three clay forming minerals on the plot shown on the right side on the right bottom of the slide here. So, let me actually highlight here the pattern that you would expect for a Montmorillonite crystal and not for the Montmorillonite, actually kaolinite crystal. So, this is the signature of a typical kaolinite crystal.

Now, what you can what you can see is that for the constituent minerals, for the mineral for the unknown mineral that is provided to you, can see there is a peek at about 12 degree value of two theta and in kaolinite also we have got a peek at a similar angle and also you can see that another intense XRD signal was obtained at about 25 degree value of two theta. Now, for kaolinite also, we have got a distinct signal at 25 degree value of 2 theta. So from this, we can approximately say that one of the constituent minerals of this particular sample is kaolinite. So, that takes care of last questions set.

Now, we get back to the subject matter of this particular, this particular lesson.

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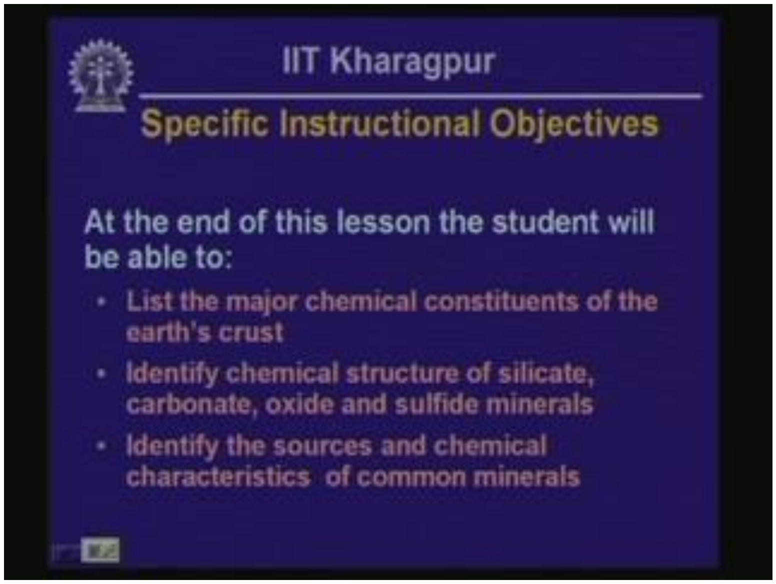

Now, what are the objectives of this lesson? We are going to actually list a set, we are going to list major chemical constituents of the earth's surface, we are going to identify the chemical structure of silicate minerals, carbonate minerals, oxide and sulfide minerals and these are the major building blocks of the crust of the earth as we will see in the course of this lesson and finally, we are going to identify the sources and chemical characteristics of common minerals. In other words, how these types of individual minerals form; we are going to briefly discuss those items.

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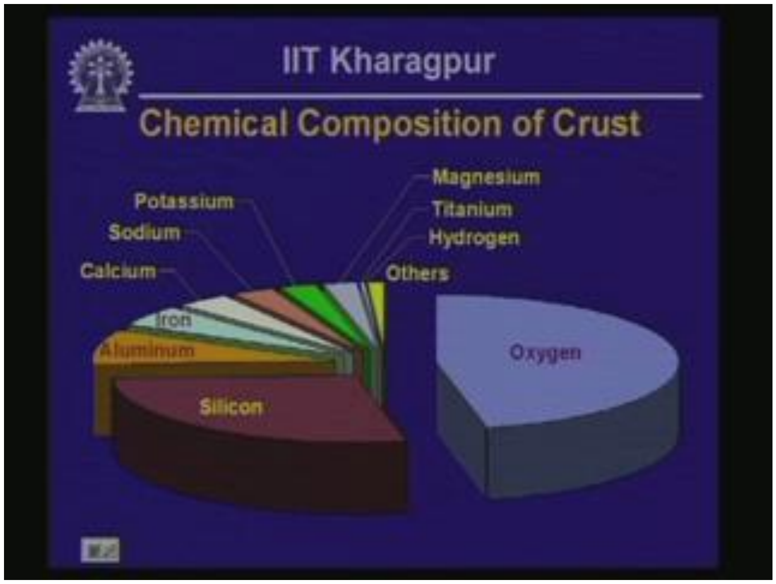

Now, what is the composition, what is the chemical composition of the surface of the earth? As we have seen, the surface of the earth is called crust of the geosphere and what is the constituent that? A large part of the earth's crust is composed of oxygen and the second most abundant building block of the earth surface is silicon as is shown on the pie chart of this particular slide; there are several other constituents.

The next most abundant one is aluminum and then you have got iron, calcium, sodium, potassium magnesium, titanium, hydrogen and finally you have got the remaining chemical constituent that are clubbed together as others. So, the most abandoned minerals are composed of them silicon and aluminum.

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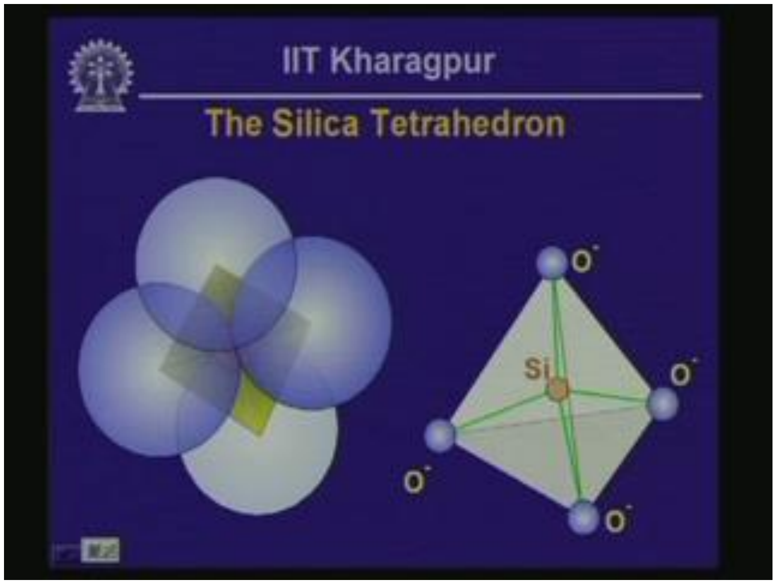

So, it is logical then to consider how the structure, how we are going to, what kind of chemical structure we are going to get for silicate minerals. Now, in order to do that, what we are going to do? We are going to look at the building block of the silicate minerals. The basic building block of silicate minerals is silica tetrahedral. Schematically, it is shown on the right; you can see that you have got a silicon atom, you have got a silicon atom near the center of the tetrahedral and at the four corners of the tetrahedral, there are oxygen, oxygen negative ions in the corners of the tetrahedral, in the corners of the tetrahedral. So, silica atom is at the center and there are four oxygen ions at the corners of the tetrahedral.

Now, this is a schematic; you should realize that the cartoon that is shown on the right of the slide is actually schematic; in order to prepare this, we did not consider the realistic size of the atoms of silicon and oxygen. If you do that, then the picture that we are going to get is kind of shown on the left side of the slide here.

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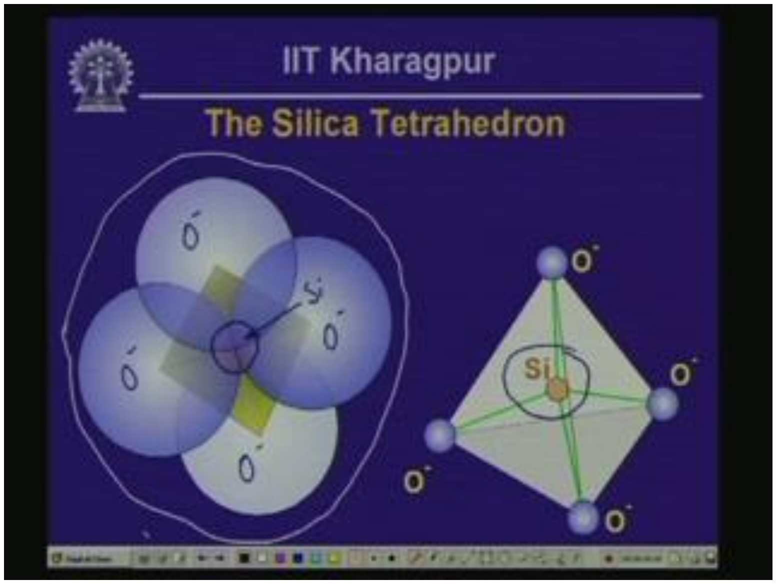

This one is a depiction considering the geometric, I mean considering the size of the individual atoms that is with which the silica tetrahedral is composed. Now, what we got here? You can see that the silicon ion is at the center or actually silicon atom is at the center, this is the silicon and then much larger oxygen ions are shown like this; this is the same thing, I mean the structure of this one is same as the tetrahedral but I just changed the relative size of the ions here on the right because it is difficult to comprehend what is the exact look of the tetrahedra from the figure that is shown on the left. But the figure on the left gives you an idea about the relative size of the silicon ion of the silicon atoms and oxygen atoms.

So, then you can, to reiterate what we wanted to say is that silicate minerals will be composed of different combinations of unit structures and these unit structures are essentially tetrahedral in shape and they are composed of a silica ion at the center and four oxygen ions at the corner of the tetrahedral. Now, let us look at how these individual building blocks combine to form different types of silicate minerals.

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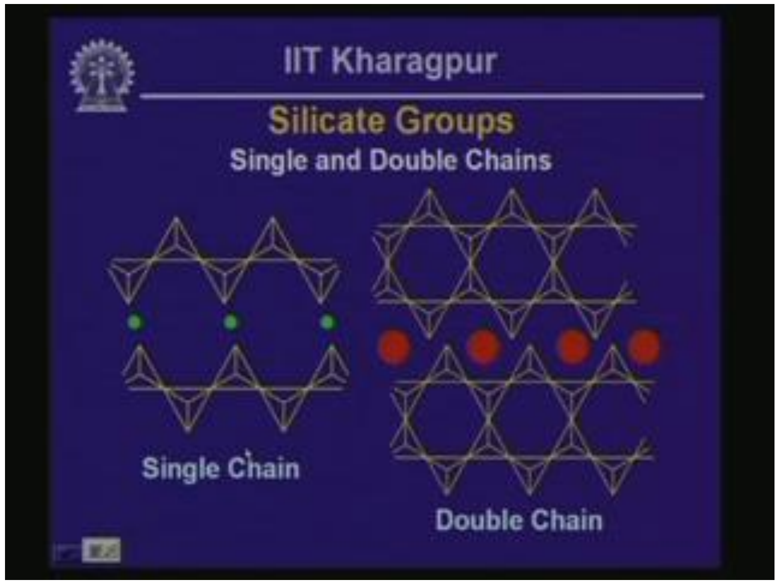

Now, the first sub group of the silicate groups of minerals that we are going to consider here will be single chain and double chain. Single structure is shown on the left of the slide here and here what we got is you have got silica tetrahedra oriented in an opposite manor, in an opposite manor like this.

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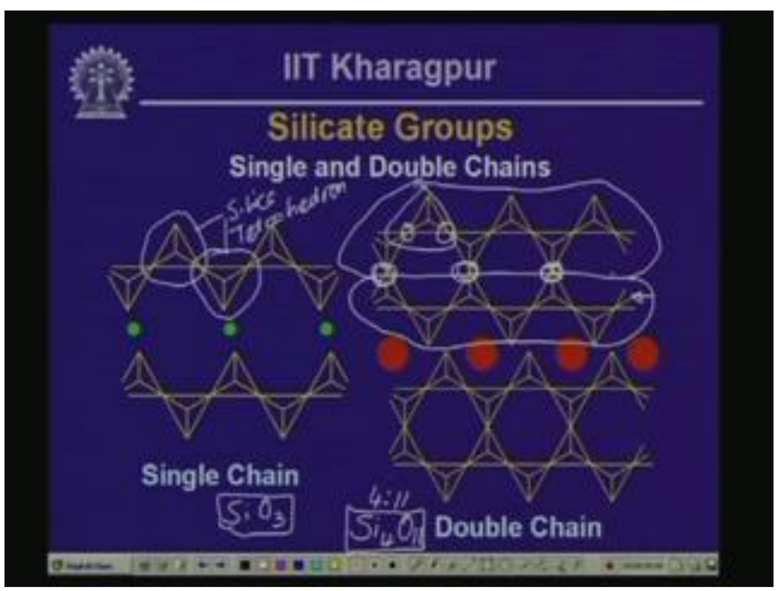

So, what happens here is that for each silica tetrahedral, you have got two oxygen minus ions is shared with other tetrahedral. So, what you got here is essentially a 1:3 combination of silicon and oxygen and then you have got each of these chains, they are going to actually combine with each other with different types of cations.

Now, what happens here then; you have got silica and three oxygens and the chemical structure, I mean the chemical formulation of a single chain silicate mineral will be having a radical which has got this type of, which has got a composition of SiO_3.

Now, let us consider what is meant by a double chain. Double chain minerals as shown schematically on the right of this particular slide and what you can see here is the three of the oxygen's here, actually rather two oxygen of each tetrahedral is shared again with other tetrahedra in the same chain. But what we got here which is unlike the previous one is that another oxygen for the, another oxygen here, they are also shared with a opposite, with a sort of like a mirror image of a change which falls on the other side. So this chain, this chain here is combined with another chain by sharing of oxygen at atoms like these.

So, it is obvious in this, it is obvious that in this case you have got more number of oxygen atoms oxygen ions are shared amongst different silica tetrahedra and as a result, the silicon to oxygen ratio is different in case of a double chain and here the ratio between silicon and oxygen is instead of 1:3 in case of single chain; here, what we got here is a 4:11 distribution of silicon and oxygen. So, what you got here is that you are going to get radicals that are going to be Si_4O_{11}; this type of radicals you keep on appearing in the chemical composition of double chain silicate minerals.

So, we are going to look at the examples, individual examples of these types minerals in due course of this particular lesson.

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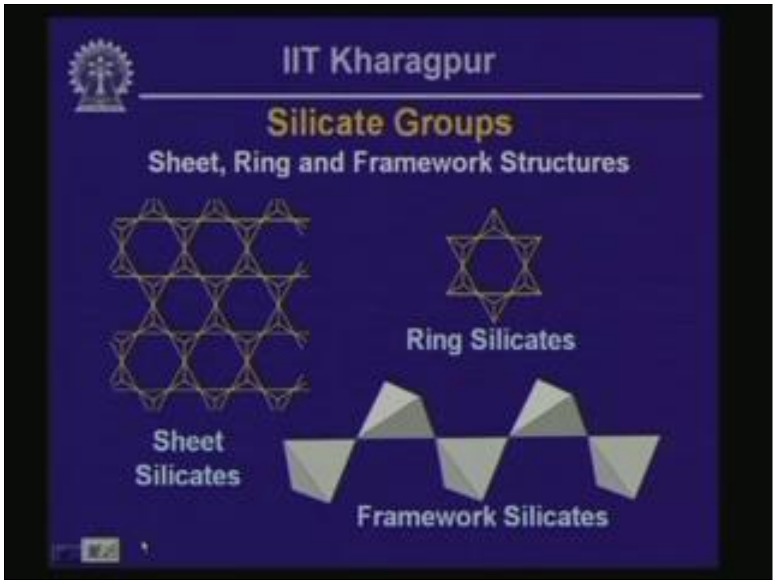

Now, let us move on to the next types, other types of silicate minerals. You imagine that what we did, we began with an individual silicate tetrahedral, then we could combine this tetrahedra in a combination of the single chain as we began, then we got a double chain structures and if we extend this particular concept a little bit further, then we are going to get a structure which is known as sheet silicate. So, what do you got in sheet silicate is that you have got a two dimensional network essentially of, two dimensional network of silicon tetrahedral.

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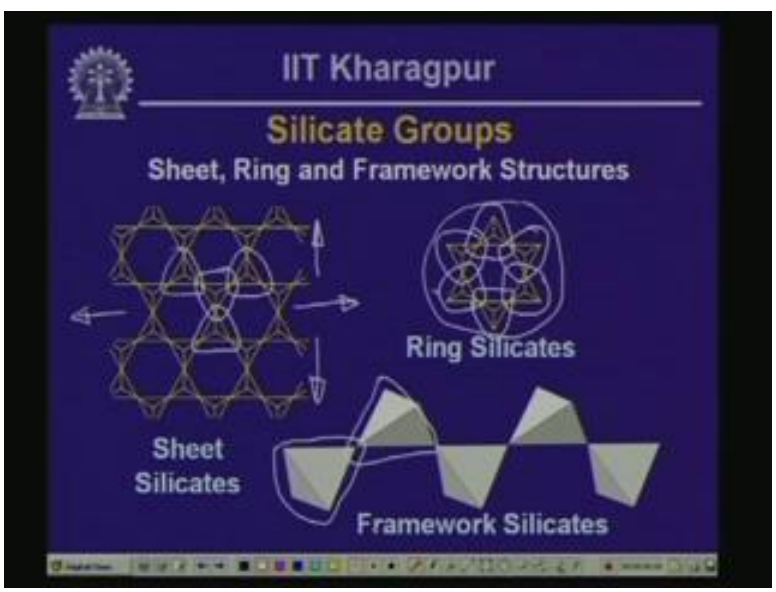

So, here for instance, all this individual triangles indicate silicate tetrahedra and this particular framework, these particular structure extents horizontally both ways in the plain of the tablet here as well as vertically in those directions almost indefinitely. So, this particular type of structure is called sheet silicate. As the individual tetrahedra, they combine with each other and they form individual sheets. So, here you can see more number of oxygen ions are shared between different shade between different tetrahedra and as a result, the oxygen percentage, oxygen as a percentage of silica will be even smaller in comparison with a double chain silicate mineral.

Now, a particular type of silicate mineral, you will get a structure which is not in a definite extension of a two dimensional, two dimensional mesh in a plain but it is a ring like structure as shown on the right here and for obvious reason, this type of minerals is called ring silicates. Here, you have got basically a series of silica tetrahedra that combine with each other to form a ring like structure. These minerals are relatively less abounded in comparison with other types of silicate minerals that we have so far discussed.

Now, if we extend the concept of sheet like structure, a step further and we consider in three dimensional of structure instead of a two dimensional one, then we are going to end up with the type of silicate which is known as frame work silicate. So, in this case, what you get is get tetrahedra combined with each other in a three dimensional sense and you have got a solid form out of combination of silicate tetrahedra in three dimensional, in all the three directions instead of the two directions that we consider in case of sheet silicates.

In addition to all this things, we can also have we can also have a self-contained silica tetrahedra. So, in addition to all the types we consider here; we can have single tetrahedra, many type many types of minerals as we will see later on will be comprised of single tetrahedra instead of a combination of several tetrahedra as we have considered here or there are minerals which are composed of double tetrahedra and double tetrahedral minerals or more rare than the other types of minerals, silicate minerals that we have discussed in this cash. So, that actually gives you chemical structures essentially of different types of silicate minerals.

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Now, let us consider individual rock forming minerals which classify as different types of silicate structures that we just now discussed. So, the first one that we are going to consider, the simplest one is the isolated tetrahedra. So, in this case, what you got is you would not have any oxygen sharing and the structure and the chemical formula that you are going to get for this types of minerals is going to be either X_2SiO_4 as in case of Olivine mineral or $X_3Y_2(SiO_4)_3$ as in case of garnet group of minerals.

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By the way I want to actually mention here that isolated tetrahedra are perhaps the most stable and they are the, perhaps they are the hardest and the most stable minerals of the silicate; the form the most stable and hardest group of minerals of the silicate family of minerals. Now, you can see that the olivine has got a hardness of 6.5 to 7 and garnet also has got a hardness of 6.5 to 7.

Now, let us move on to the single chain. In single chain we noticed earlier that you have got one oxygen share and the chemical formula of this class of minerals typically will look like this; $XYSi_2O_6$ and by the way you may have already understood that by X and Y, I am indicating cations of different types like a calcium or magnesium or potassium or iron or aluminum or there are could other types of cations as fell, these are just few examples of abundant cations.

So here, what you will get is a chemical formulation comprised of a chemical formula like $XYSi_2O_6$ and this one, this types of formulation is typical of the pyroxene group of minerals and these minerals have got a hardness of 5 to 6 and notice that these minerals cleave at 93 degree angle, they cleave more or less in orthogonal plains. So, if you want actually shatter a pyroxene group of mineral or rather if you want to actually break a mineral composed of single silica, single chain silica silicates; then you are going to cleave the minerals at in plains that are almost orthogonal to each other. This is important as we will see when we consider a double chain mineral.

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We have already seen that double chain mineral, in case of double chain mineral you have got a, you have got 2 to 3 oxygen atoms shared between different tetrahedra and an example of this class of minerals is Amphibole. One of the minerals of the Amphibole group is Hornblende. A hornblende has got a hardness of 6 and notice the cleavage angle in this case, this particular types of minerals actually cleaves at 56 degree angle.

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So, this is the angle of cleavage. Now, you should actually notice that double chain minerals, cleavage of double chain minerals is very similar to 120 degree or 60 degree and this is in contrast, this is in contrast with a single chain, single chain which we discussed just in the previous slide which cleaves, cleavage of single chain is approximately equal to 90 degree.

So, single chain minerals if you break them apart, then you are going to get orthogonal cleavage plains, almost an orthogonal cleavage plain. But in case of double chain, you will have cleavage plains that are oriented with respect each other at 120 degree or 60 degree angles. Chemical formula in this case; it will contain radical which is going to have this type of structure; Si_8O_{22} and this is 10 negative electrical charge.

Then we move on to ring silicates and in case of ring silicates, what we have already seen that again many of the oxygen actually, there is a mistake here; two of the oxygen atoms are shared in case of ring silicates and one of the example of ring silicate is Tourmaline and Tourmaline has got a hardness of 7 if you recall.

Now, I would also like to bring to your notice that these types of crystals also have got a trigonal symmetry. We noticed in our previous lesson that if you have got or if you consider a Tourmaline crystal, then the tourmaline crystal can actually, it has got threefold symmetry when you consider a tourmaline crystal. Let me just bring to your memory, the shape of the tourmaline crystal. Actually, this is going to be like this and here in the other side, it is going to be like this. So, this type of crystal has got one symmetry access here, another access here and another access of symmetry - the drawing is becoming awful - another access of symmetry is going to be on that angle.

So, these accesses of symmetry are again oriented at angles of 120 degree with respect to each other and if you remember; this one, the crystal here is going to be a prismatic form and in three dimensions, it is going to have a look approximately as shown on the sketch that I have just drawn. So, that kind of takes care of ring silicates as well.

Reverting back to the slides, now the next group of silicate minerals is the sheet silicate and in case of sheet silicate, what you got is all oxygen atoms in this case are going to be, all oxygen ions in this case are going to be shared.

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Now, you remember, I indicated in the last slide, there was a mistake in the last slide in which I was saying that in case of ring silicate, you have got all oxygen ion shared but that was not correct and in case of ring silicates, you have got just like sheets, just like, just like a two dimensional, I mean double chain, you have got two, you have got two oxygen ions shared but here what we have got, you have got all oxygen ions shared in case sheet silicates.

And, a very obvious example of sheet silicate is the mica and mica has got a hardness of 2.5 to 3 and then finally, we move to the framework silicate and aluminosilicates and in this case again, you have got all oxygen ions shared that means covalent bonds formed out of all oxygen ions and an example of that is quartz - it is got a hardness of 7, plagioclase feldspar - it has got hardness of 6 to 6.5 and the formulas of plagioclase feldspar are also mentioned on the slide there; these are basically calcium aluminosilicates or sodium aluminosilicates or potassium aluminosilicates. So, that kind of brings us to the end of different subclasses of silicate minerals.

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Now, we need to look at how different silicate minerals form? What is the origin? How the silicate minerals form in the nature? So, one of the sources of silicate minerals are formed by cooling of magma or metamorphism. So, this is the primary source, so most of the silicate minerals are formed by cooling magma or from metamorphism. Now, weathering, deposition and digenesis; that also is source or could be sources of silicate minerals.

And as we will see later on; sand stones, siltstone, clay stone and shale, they form in this manner and by weathering deposition and digenesis actually chemical composition of minerals could also change in the process and the third source of silicate minerals is chemical precipitation. Now, precipitation of amorphous silica from sea water is the mechanism that is responsible for this, for formation of flint and chart type of minerals.

So basically then, you could for, you could get silicate rocks formed out of cooling of magma metamorphism or from weathering and consequent alteration of the chemical characteristics of the original silicate mineral and also you could get silicate rocks formed out of chemical precipitation in case of flint and chart. That ends the discussion on silicate minerals.

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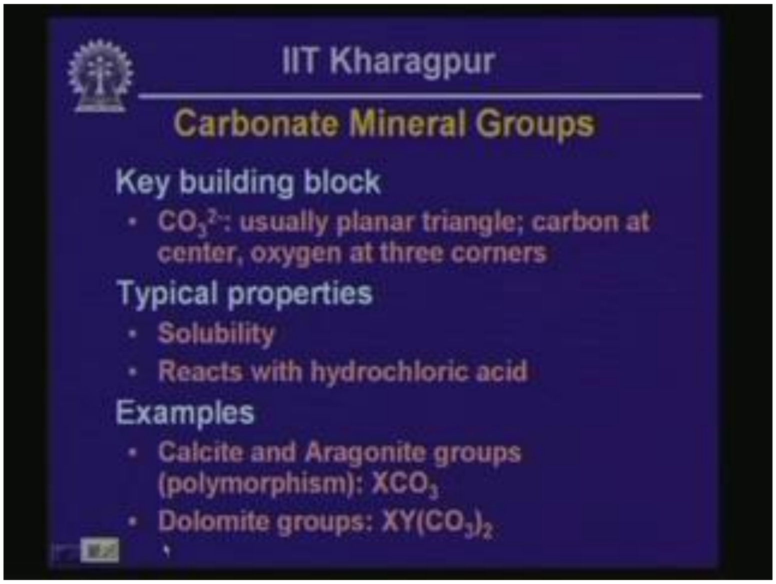

The second most important mineral group perhaps is the carbonate mineral groups. The key building block in this case is the $CO_3{}^{2-}$ radical and this is basically a plainer triangle and in this case, what you got is the carbon atom is at the center; in this case, you have got the carbon atom at the center.

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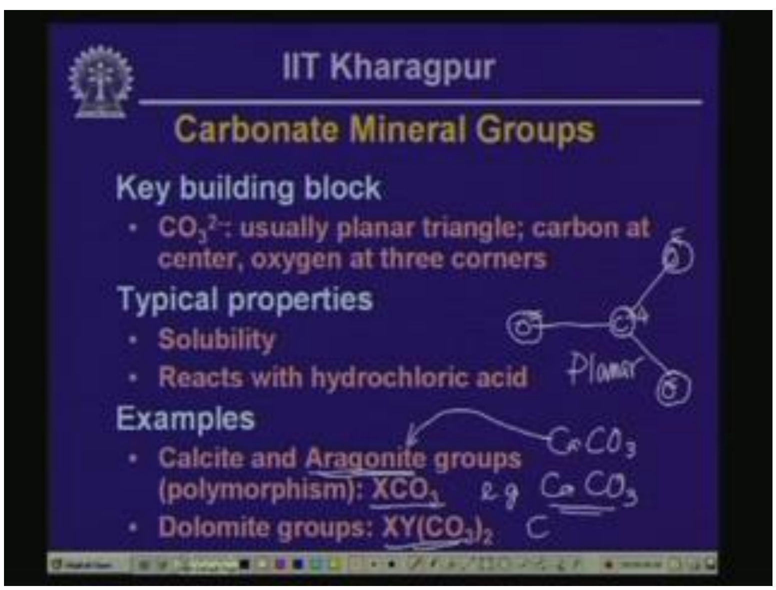

So, what you got in this case is carbon atom at the center and then you have got oxygen ions, carbon ion at the center and oxygen ion in the three corners of the triangle. So basically, this is the, this is the carbonate type of structure. So, if you recall, then each one of these things have got two negative, two negative charge and carbon will have four positive charges. So, the balance of this is negative of – 2. So, a carbonate ion has got a charge of negative -2. So, this a plainer structure as is indicated on the slide.

Now, what are the typical properties of the carbonate group of minerals? One of the very important properties is varying degree of solubility. It actually solubilizes in water to a varying degree. Now, it also reacts with mild hydrochloric acid. So, these are the two key properties of carbonate group of minerals. What are the examples of carbonate group of minerals?

The most abandoned mineral perhaps of the carbonate group is calcite and the other example of the carbonate group is dolomite and also you can think about several others like limestone. Now, I would like to also mention here that calcite has got a chemical structure which has got a formula of XCO_3. For example, you have got, you could get calcium carbonate. This is perhaps the most abandoned one of that group or you could even get calcium, magnesium carbonate which is actually of the, which is called the dolomite.

Now, aragonite is another mineral that also has got a chemical formula of calcium carbonate, I mean it is the same think as $CaCO_3$ same as calcite. This also has got the same chemical formula as calcite but the structure, the structure or the geometry of crystals of calcite and aragonite are totally different as we will see later on.

So, this type of, this type of different minerals which is got the same chemical formulation but different physical appearance or different crystallographic characteristics, this is called, this type of mineral is called polymorph. So, aragonite is essentially a polymorph of calcite. Aragonite is mineral that is more rare actually then calcite and that forms, aragonite forms on the high pressure but low temperature environments.

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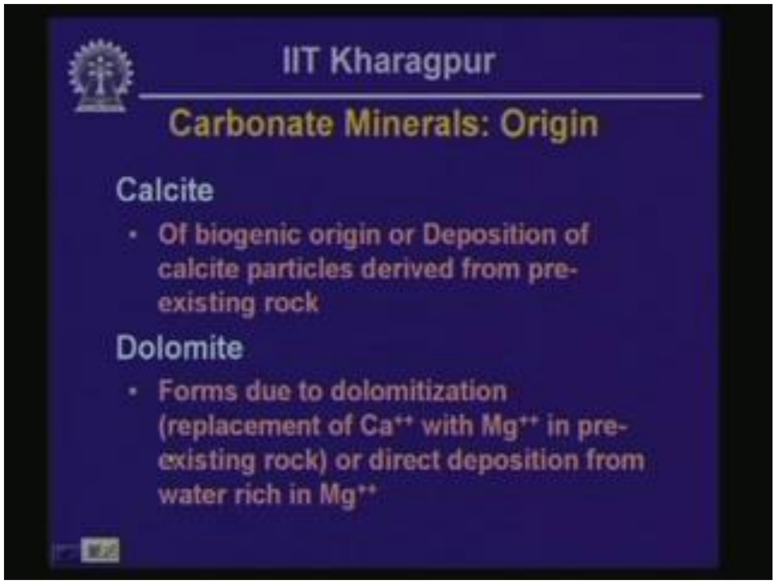

What are the origins of carbonate minerals? Carbonate minerals have got a biogenic origin or it could be deposited from the calcite particles from pre-existing rocks by the action of water. So, water can solubilize calcium carbonate from pre-existing rocks and you can deposit that through inorganic process and that also could give rise to calcite rocks. Dolomites actually forms from a process that is known as dolomitization and this is basically by replacement of calcium ion with magnesium ion of the pre-existing rock or from direct deposition of water that is rich in magnesium ion.

So basically, carbonate minerals, they originate from precipitation process; it could be either organic, it could be either an organic precipitation process or it could be an inorganic process from sea water or from the action of water basically.

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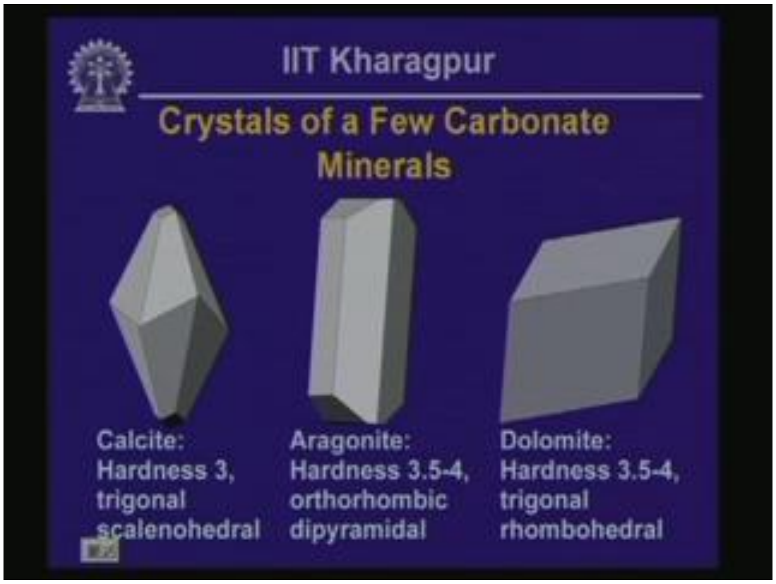

Now, as I indicated earlier, I gave you the example of two polymorph crystals, 2 polymorph minerals; calcite and aragonite and these two types of minerals is shown schematically here on this slide. You can see that the one on the left, the one on the left is of mineral calcite and this has got a trigonal symmetry, this is got a trigonal symmetry or 3 fold symmetry really; whereas when you consider mineral aragonite, then you have got a 2 fold symmetry only and this is essentially a rhombohedral structure which was discussed briefly in our previous lesson.

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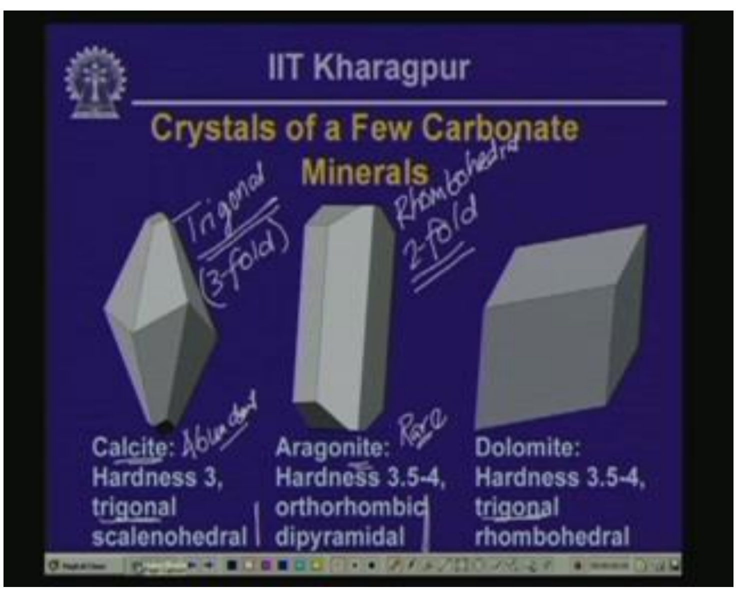

Now, basically in this case, what you have got is the hardness of calcite is 3, whereas hardness of aragonite is 3.5 to 4 and I indicated the crystallographic symmetry and it is also mentioned here. I also indicated that aragonite mineral is more rare than calcite, calcite is more abundant and now the question comes that and actually I also would like to mention that this type of mineral, actually aragonite in a sense is an unstable mineral under the normal condition of temperature and pressure.

Then the question comes; how you get this aragonite mineral at all? Now, aragonite minerals actually forms from calcite - could form actually, could form - that is one of ways aragonite minerals could form is from the metamorphism of calcite rich rock. So, if you expose calcite reach rock, in a high pressure environment, you could end up with a rock that is rich in aragonite mineral.

Now, that actually gives you an example also of how different types of minerals change in chemical characteristics when you expose them to different types of pressure temperature environment and we will examine in this one in more detail when we consider metamorphism later on in this course.

Now, the third example is given here is of dolomite and dolomite is got a hardness of 3.5 to 4 and this is got trigonal rhombohedral symmetry and just actually quite compare, actually trigonal rhombohedral symmetry and the symmetry in this case is quite comparable to the symmetry of calcite as indicated on the left, on the left most cartoon on this slide.

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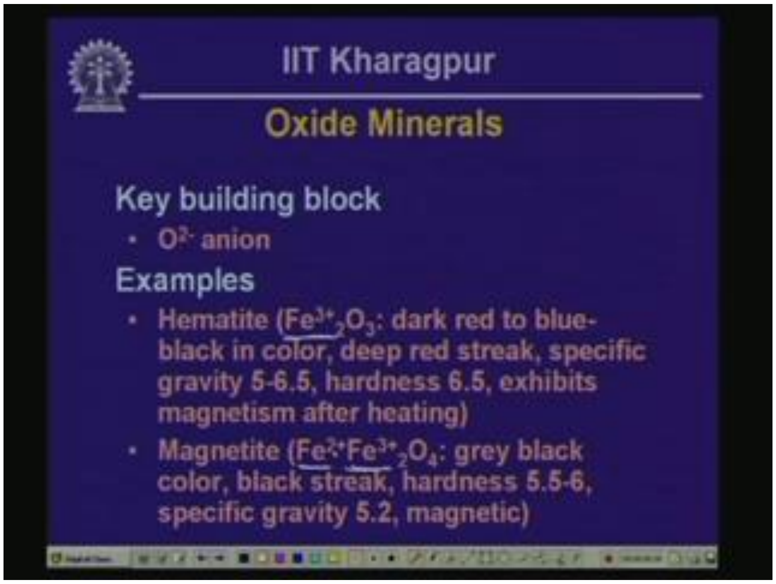

Now, another mineral group that is also quite abundant is formed of different types of oxides. Now, as the names suggests; in this case, you will get oxygen ions O -2 anion present in the chemical structure. Examples of this class of minerals are oxides of iron, hematite and magnetite. Now, hematite has got a chemical composition, hematite has got a chemical composition that is composed of trivalent iron, whereas magnetite has got a chemical composition that has got a bivalent as well as trivalent iron in the chemical structure.

So, they are essentially, they are very similar; they are very similar to each other in a sense. Let us look at this thing because that could be of interest. Now, hematite has got a dark red to blue black in color, very dark color in fact, it has got a deep red streak, the specific gravity of hematite is 5 to 6.5, hardness is 6.5 and if you compare these properties with magnetite; what you get is again a grey black color which is again a dark color, it is got a black streak, a deep colored streak again quite in comparison with hematite and then it has got a hardness of 6.5 to 6, then again the hardness is again not very different from the hardness of hematite, slightly reward perhaps and it has got a specific gravity of 5.2 that also well within the range these specific gravity of hematite mineral.

Now, the basic difference that you get in these two cases is that hematite exhibits magnetism after being heated. Hematite in fact is weakly magnetic, whereas magnetite is strongly magnetic and hence the name of that particular mineral. So, the very, the most obvious way of classifying hematite mineral from magnetite mineral is by looking at the magnetic properties of these two types of minerals.

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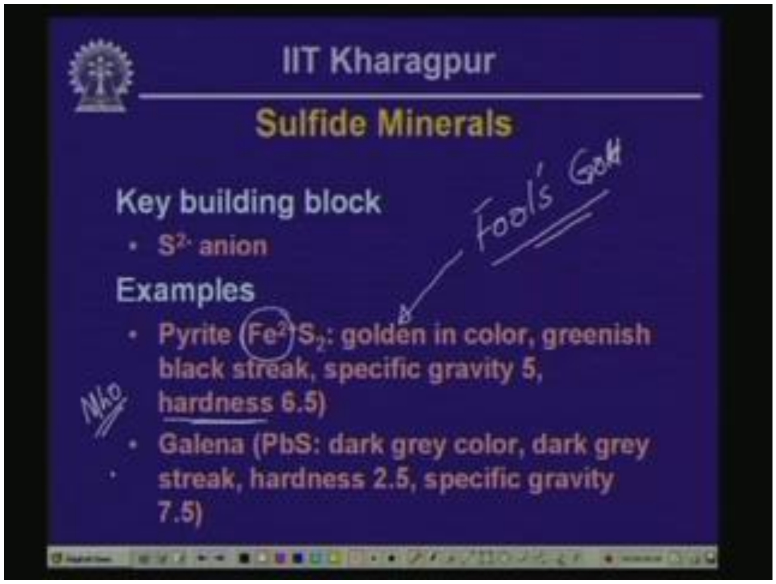

Another relatively abundant group of minerals are called sulfide minerals and here you have got bivalent sulfide, bivalent sulfide anion or sulfide anion and these things, examples of these things are pyrites and galena. So, if you recall, we looked at the crystal structure of pyrite and galena in the previous, in the previous lesson.

Pyrite in a sense is ferrous sulphate and here what we got is a bivalent iron, bivalent iron, ferrous sulfide and galena is essentially lead sulfide. Pyrite if you recall, it is got a golden color, this thing also call fool's gold because of this. It is not a precious metal but it has got an appearance which is similar to gold, it has got greenish black streak, specific gravity of 5 and hardness of 6.5.

By the way, the hardness that I am talking about in this lesson is in the mho scale which we discussed in this previous lesson. Galena on the other hand, it has got a dark red color, dark grey streak, it is got a hardness of 2.5 and specific gravity of 7.5.

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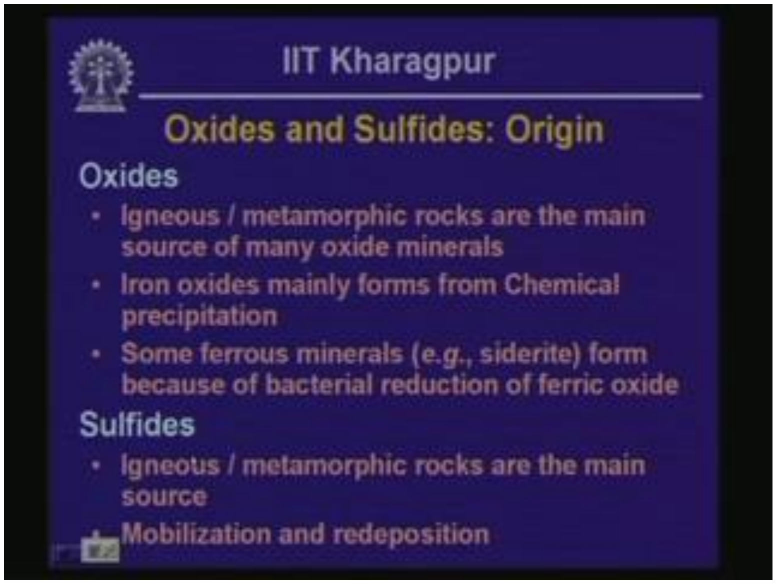

Now, we look at the origins of oxides and sulfides mineral, oxides and sulfides. The oxides are formed out of igneous or metamorphic rocks from volcanism which is the source of many oxide minerals and iron oxide by the way, iron oxide forms out of chemical precipitation. Some of the ferrous minerals also form because of biogenic action quite in similar manner as of a biogenic carbonate mineral. Then sulfides, sulfides actually form out of igneous, out of volcanism or metamorphism or it could be formed out of mobilization of sulfide minerals and redeposition through chemical action, chemical weathering.

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Now this one, this cartoon here, this slide here shows a few examples of unit sulfide, unit crystals of sulfide minerals, oxide and sulfide minerals. Now, hematite we discussed; it is an oxide mineral and it is got an unit crystals that is shown on the left. Magnetite, it is again an oxide mineral composed of bivalent and trivalent iron and the crystal is shown in the middle here and a sulfide mineral galena is shown on the right and we looked at this particular mineral in detail when we were considering the geometric characteristics of mineral last time in the last lesson.

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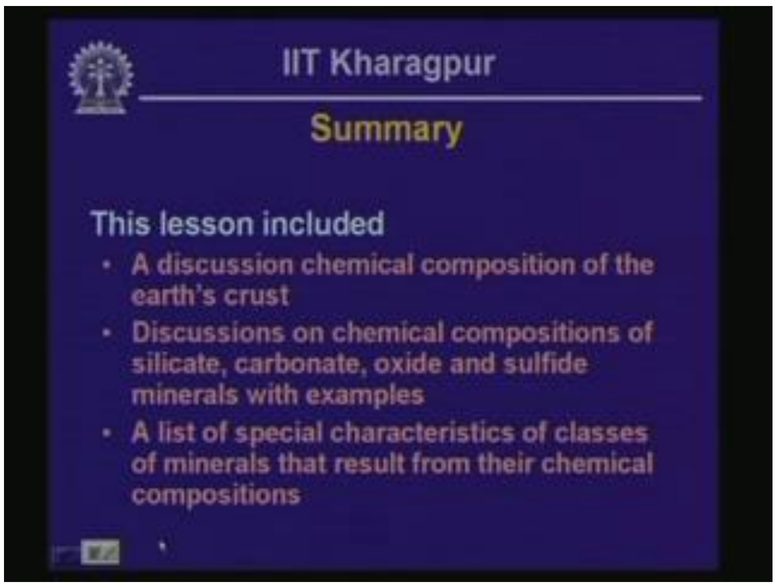

So finally, summarizing what we learned in this lesson; we discussed the chemical composition of the earth's crust, we discussed the chemical composition of silicate, carbonate, oxide and sulfide mineral, we considered examples of these minerals and these minerals composed a very large proportion of earth's crust, we looked at a list of special characteristics of classes of minerals that arise because of the chemical composition. For example, we looked at the cleavage angles of a double chain and single chain a silicate minerals.

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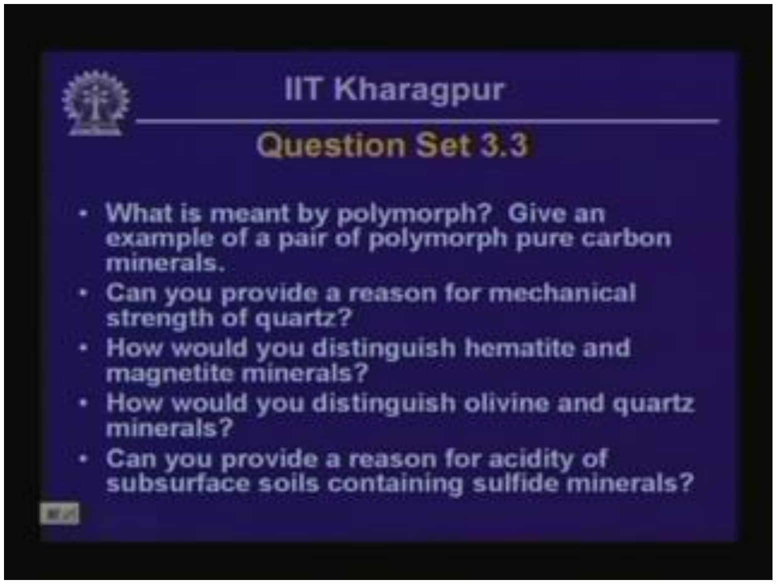

And, we end finally this particular lesson with a question set and try to formulate the answers of these questions. The first question is that what is meant by polymorph? Give an example of a polymorph mineral of pure carbon, pure carbon.

Now second thing, second question that asked is can you provide a reason for mechanical strength of quartz? You give a quality reason why quartz is so strong and in art. How would you distinguish hematite and magnetite minerals is the third question. Fourth question is how would you distinguish olivine and quartz minerals and finally can you provide a reason for acidity of subsurface soils containing sulfide minerals.

In fact, the ore bodies that contain sulfide minerals that is actually a very common source of mineral of different economic minerals, sulfides are very common source of several different economic minerals and these areas often affected by acidity and consequent loss of fertility within the area where the waste, mine waste is dumped.

Now, what I ask here is that can you give the reason why subsurface soils containing sulfide minerals would exhibit acidity? Try these questions in your spare times and I will also give you my versions of the answers when we meet next time for the next lesson.

Thank you very much.

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Hello, everyone and welcome to a fresh lesson on the engineering geology. Today we are basically going to talk about origin and types of rocks and also we are going to look at the different types of rocks that as commonly available, normally found across the country of India. But before we actually proceed with the subject matter of today's lesson, we are going to consider the questions that were asked the last time when we met. This is the question set that you already have.

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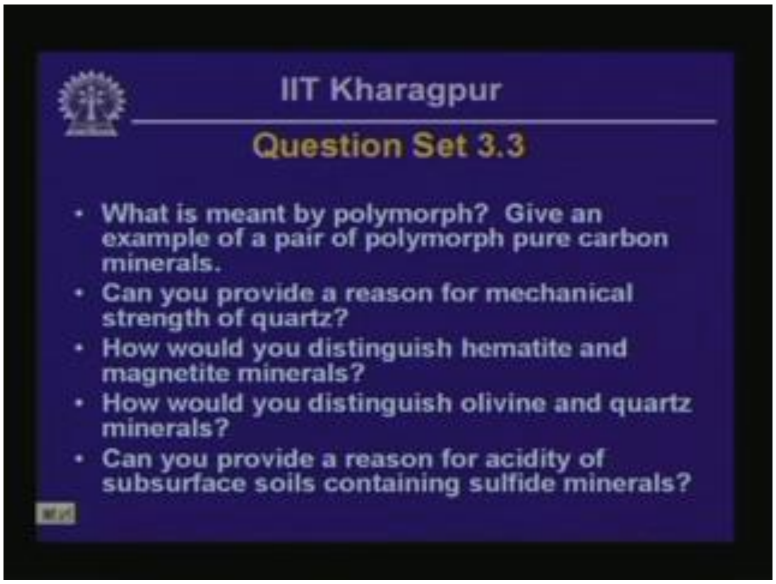

The first question was; what is meant by polymorph and I also asked you to give an example of a pair of polymorph of pure carbon mineral. Now, polymorph is actually are a bunch of minerals which have the same kind of chemical composition or chemical formula but they have got different crystallographic geometry or different structure really.

Now, two common two polymorphs of pure carbon mineral are graphite which is essentially a sheet, which has got a sheet structure like what we had for sheet silicates and then you have got diamond which is basically which has got a pair of tetrahedra…((Refer Slide Time: 55:52))

((… Refer Slide Time: 55:55)) essentially volcanic rocks and metamorphic rocks that generate out of volcanic rocks.

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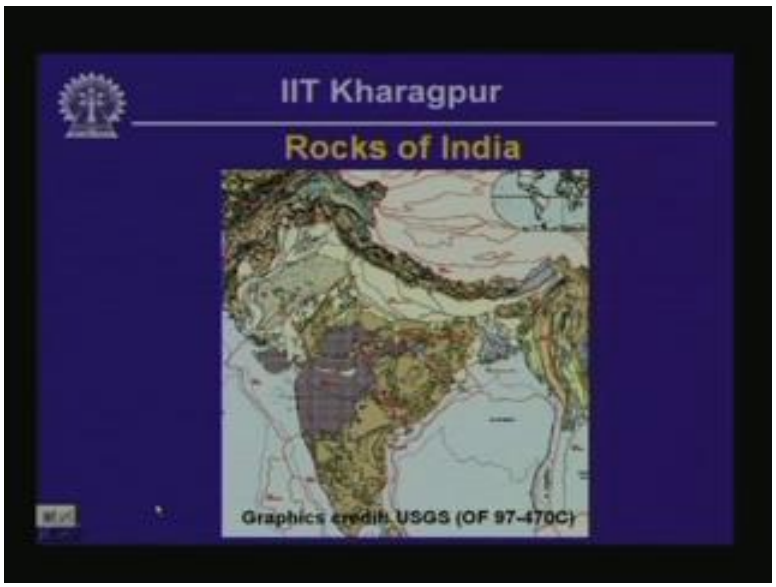

So, that in a nutshell gives you the inventory of different types of rocks found across our country.

((…Refer Slide Time: 56:18)) is still used in getting inside about the rock forming processes. What Bowen proposed was the fact that minerals actually change their characters as the temperature comes down and there are two classes of minerals; one along the discontinuous series shown on the left here, these are the ones, this is the class of minerals on the discontinuous series and then you have got another class of mineral that form a continuous series as ((Audio not clear Refer Slide Time: 57:19))

((… Refer Slide Time: 57:28)) essentially volcanic rocks and metamorphic rocks that generate out of volcanic rocks.

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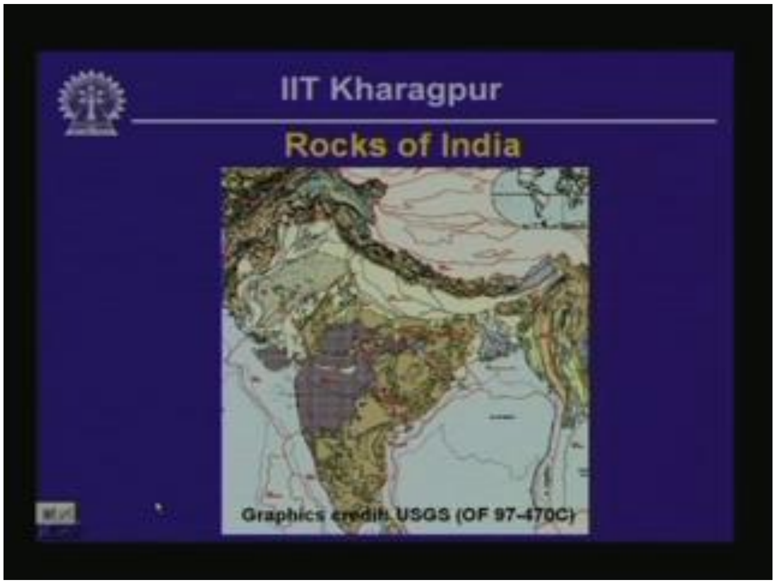

So, that in a nutshell gives you the inventory of different types of rocks found across our country.

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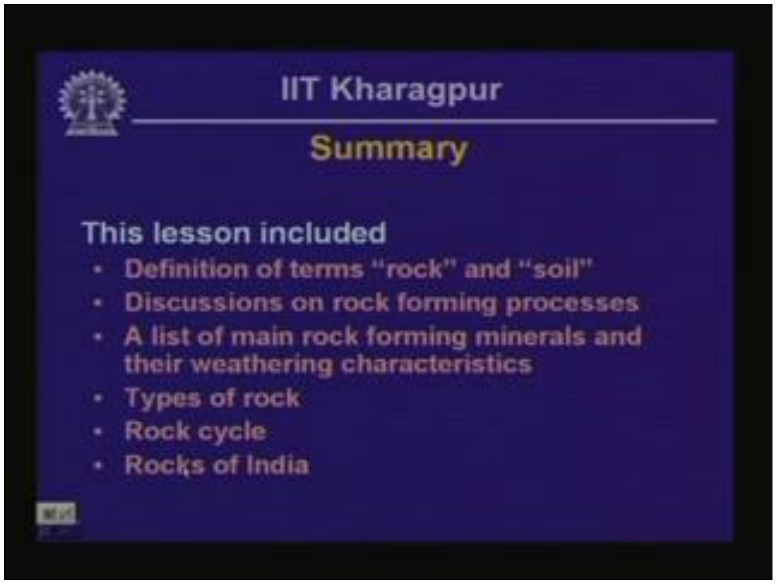

To summarize the lesson then, what we learnt in this lesson include the definitions of general terms all rock and soil, we have discussions on rock forming processes, we also looked at a list of main rock forming minerals and examined their susceptibility weathering characteristics or susceptibility to weathering. We looked at different types of rocks; volcanic, metamorphic and sedimentary, looked at rock cycle and looked at rocks that are found in different parts of our country.

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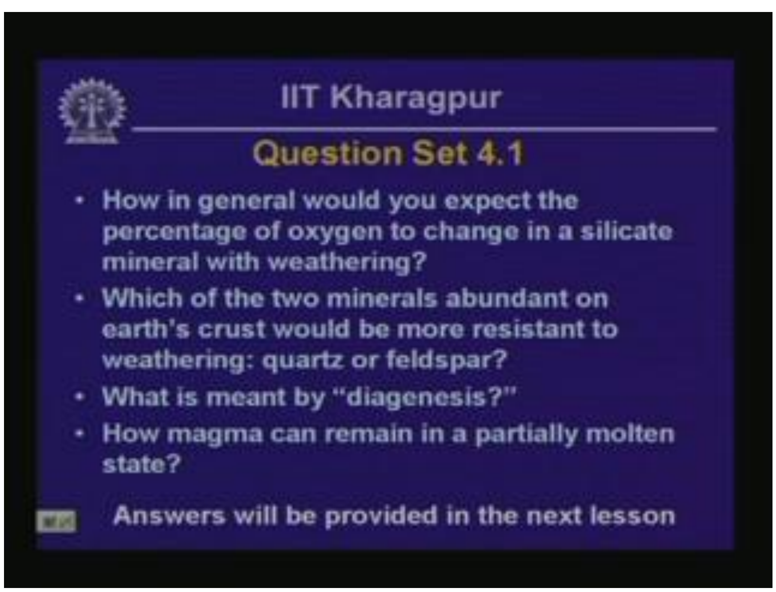

That brings us to the end of this presentation, so we close with the question set which you should try answering in your spare time. The first question is that how in general would you expect the percentage of oxygen to change in a silicate mineral with weathering? Second question is which of the two minerals abundant on earth's crust would be more resistant to weathering; quartz or feldspar? Third question is what is meant by digenesis and fourth one is how magma can remain in a partially molten state.

Try answering these questions; I will help you out with the answers when we meet in the next time. So, that ends this lesson and thank you very much for listening to me. So, until I meet you next time around, bye for now.