Conservation Geography
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Module - 3
Lithosphere and landforms
Lecture - 7
Rocks and minerals

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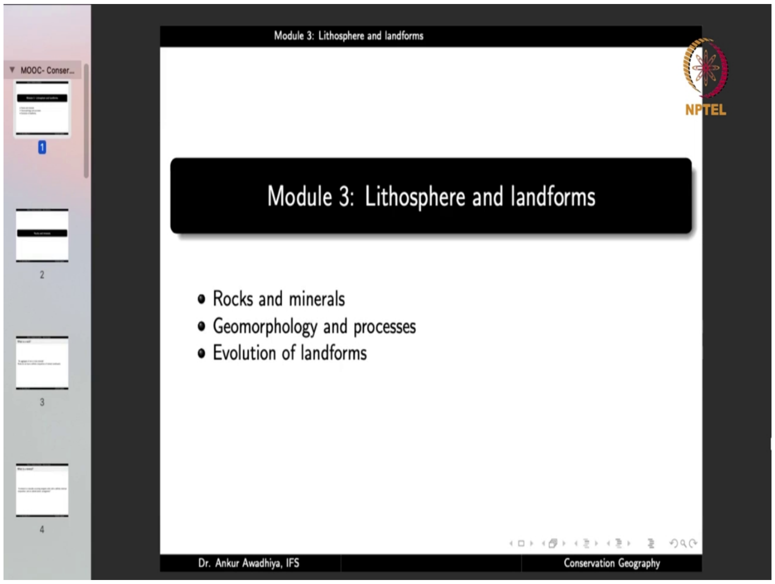

Namaste! Today we begin a new module which is Lithosphere and landforms.

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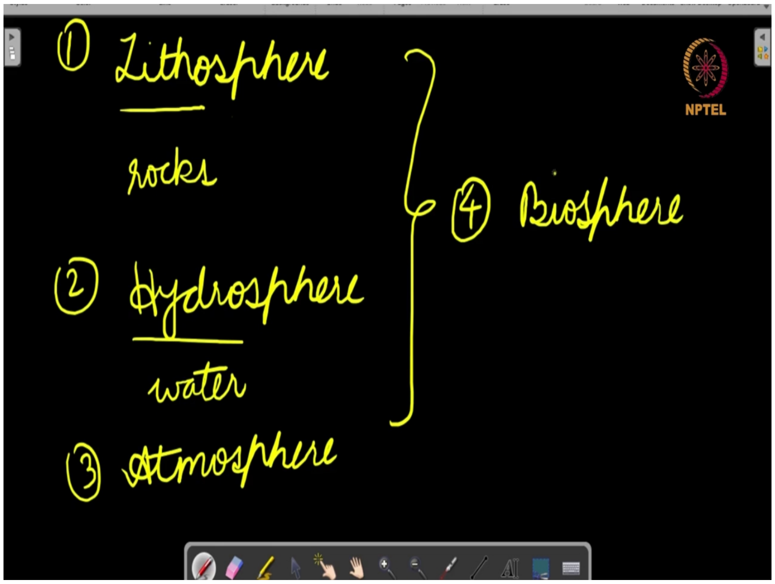

Now lithosphere is one of the four spheres of the Earth. Lithosphere. Litho means rocks. So this is a rocky sphere or a sphere that is made out of rocks and solid elements, solid elements such as the soil or sand and so on. Along with lithosphere we also have the hydrosphere, where hydros is water. So this is the watery sphere or the liquid sphere. And we also have the atmosphere which is the gaseous sphere or the airy sphere. And all these three together lead to the working of the biosphere or the living sphere. So essentially we have four different spheres on this planet, the solid sphere which is the lithosphere, the liquid sphere or the hydrosphere, the gaseous sphere or the atmosphere and the living sphere or the biosphere.

Now for living beings to survive and to exist they require air, they require water, they require nutrients. And so they require some, certain portions of all these three different spheres lithosphere, hydrosphere and atmosphere. Now when we look around us the solid sphere can be in the form of, say, pebbles or rocks. Or it can be in a form of, say, a hill. Or it can be even in the form of very tall mountains. So the lithosphere is found in different forms. And in this module we will also have a look at these different landforms. Similarly the rocks give rise to soil. And we also have different kinds of soils.

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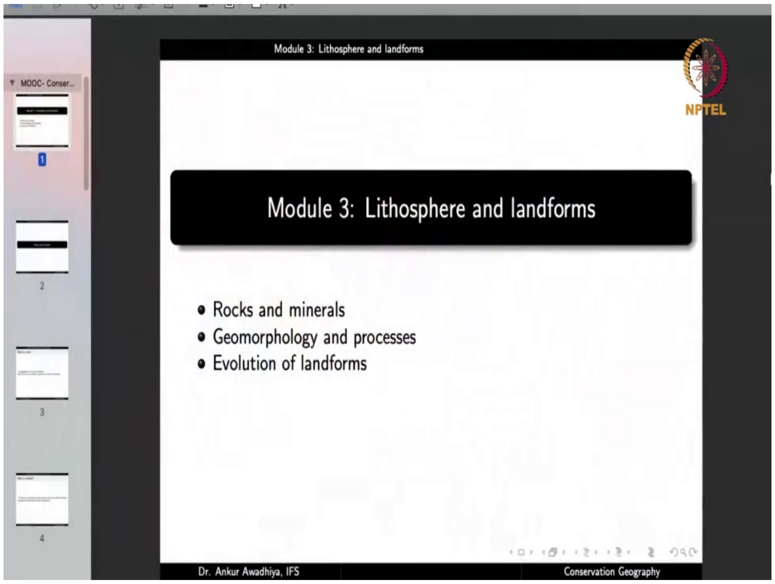

So this module is going to concentrate on the solid sphere that is the lithosphere. And it will have three lectures. The first is rocks and minerals. What are rocks? What are rocks made of? What are the different kinds of rocks? Now rocks are made up of minerals. So what are the different kinds of minerals, how do we characterize a mineral and so on.

This will be followed by geomorphology and processes. Now geo is Earth, morpho is form, logy is study. So this is the study of Earth forms. So what are the different Earth forms that we have on this planet? What are the processes that have led to the development and evolution of these landforms? And in the third lecture evolution of landforms, we will build up on these two lectures to understand the different land forms and their evolution.

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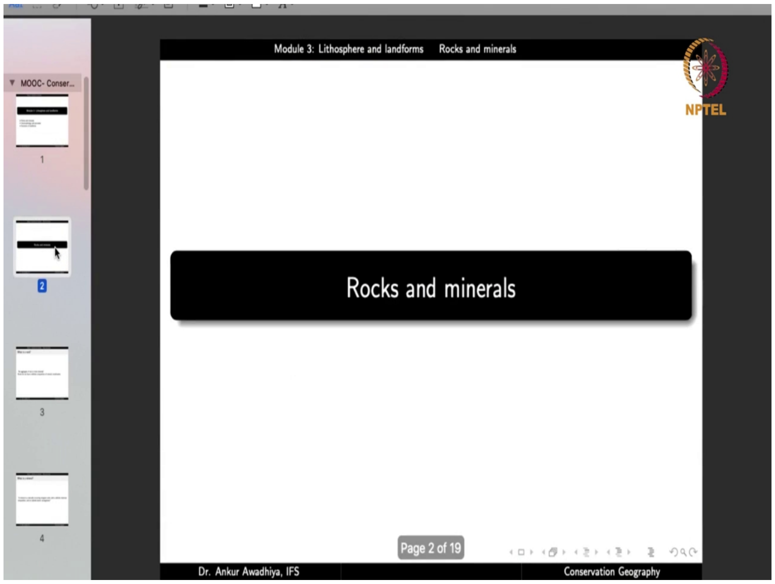

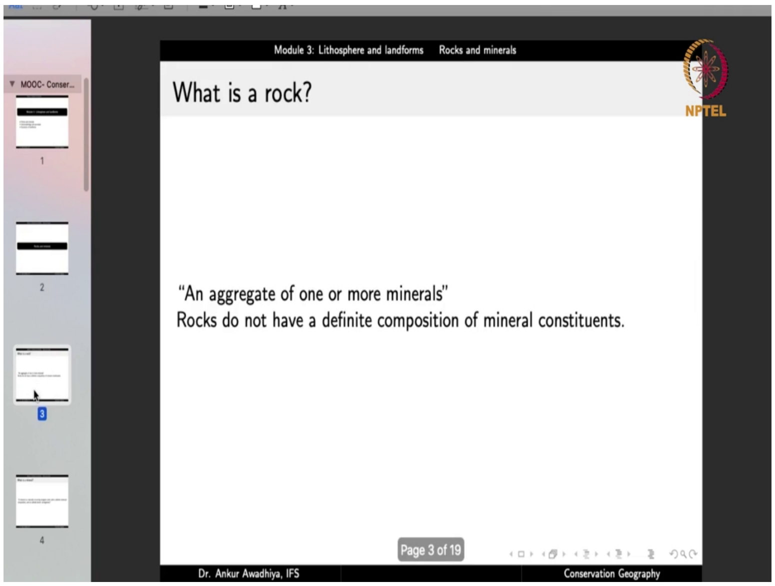

So let us now begin with rocks and minerals, and we begin with a definition of a rock. What is a rock? A rock is defined as an aggregate of one or more minerals. So it is an aggregate. It is a combination of what? One or more minerals. So you can have rocks that are made up of just a single mineral. Or you can have rocks that are made up of more than one minerals. Now one important characteristic of the rock is that it does not have a specific chemical composition. Rocks do not have a definite composition of the mineral constituents.

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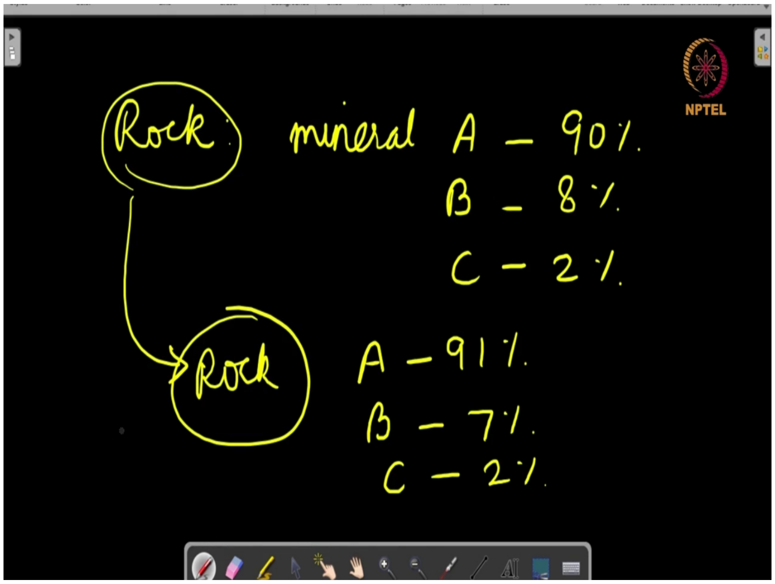

So, for instance you can have a rock that is made up of, say, three minerals. So let us consider a rock. And this rock has mineral A which is, say 90 percent; mineral B which is, say 8 percent and minerals C which is, say 2 percent. Now we can have another rock with composition of A which is 91 percent, B which is 7 percent and C which is 2 percent.

Now both of these rocks are having different mineral compositions. So in this case do we say that this is one rock and this is, that is say, this is another rock? So we give it one name, we give this another name? No. Because rocks do not have a defined or specific constitution of the minerals. So even if the mineral composition goes up or down we will say that, okay, this is the same rock.

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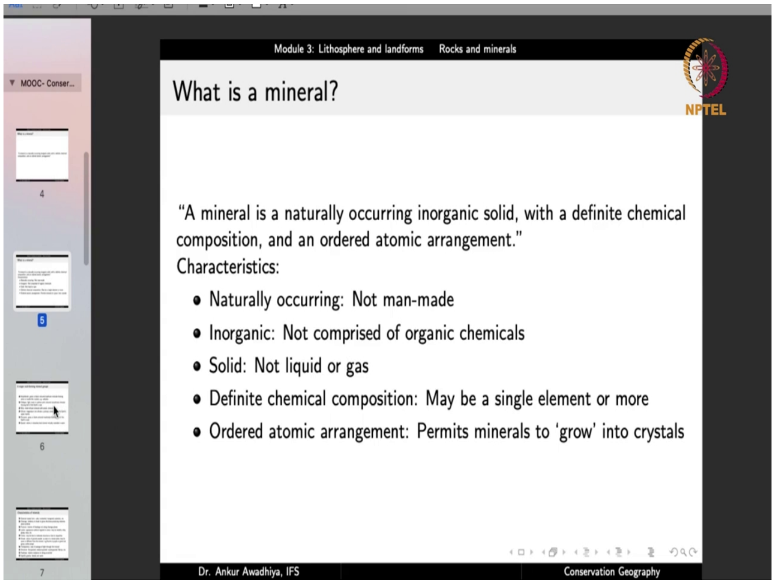

On the other hand a mineral is defined as a naturally occurring inorganic solid with a definite chemical composition and an ordered atomic arrangement. So, one major difference between rocks and their constituent minerals is that while rocks do not have a specific chemical composition, each of the constituent minerals inside the rock will have a specific chemical composition. And not just a specific chemical composition, but it will also have an ordered atomic arrangement.

So, if we explore this definition we will see that a mineral is a naturally occurring inorganic solid. It is naturally occurring. We do not have manmade minerals. So, even though we can construct a mineral from its constituents in an artificial manner but we will give it the same name as is there in the case of a naturally occurring substance, a naturally occurring mineral.

So, minerals do not have to be made by man. They are naturally occurring. They are inorganic. They are not comprised of organic chemicals. They are solids. We do not have liquid minerals. We do not have gaseous minerals. So, they are naturally occurring inorganic solids with definite chemical composition.

Now this chemical composition may be comprised of a single element or more than one element. But the chemical composition will be definite. So, for instance, if we say that gypsum has a particular formula $CaSO_4.2H_2O$ then anywhere if you get gypsum you will have the same chemical composition. If the chemical composition changes the mineral changes.

So, if you remove water from it, it will no longer remain gypsum. It will become anhydride which is another mineral. So, a mineral can be very specifically characterized on the basis of its chemical composition. And not just the chemical composition, it also has an order atomic arrangement, which permits the minerals to grow into crystals.

What does that mean? It means that the atoms in a mineral will be arranged in a definite fixed manner. So, for instance we can have a structure in which, say, sodium is surrounded by chloride and each chlorine or chloride is surrounded by sodium and this pattern will go on repeating in this plane, and will also go on repeating in a three-dimensional manner.

So, for instance, if this is the first plane; in another plane we will have chlorine here, in the bottom plane we will also have chlorine here. Here you have chlorine, so in the bottom plane you will have sodium; in the upper plane you will have sodium, and so on. Now this is a very fixed arranged ordered arrangement. Now because minerals have an ordered arrangement so it permits them to grow into crystals.

Now how will they grow into crystals? Because if you consider, say, a mineral, say, sodium chloride itself and suppose you have a small crystal here. And you keep it in a solution, and in this solution you also have sodium chloride that is dissolved inside. Now, if on the surface at this point, suppose we have chloride. In that case the sodium ion that is there in the solution it can come, stick right next to it and it will begin a new plane that is parallel to the existing plane.

And so in this case the crystal will slowly grow a plane here. Similarly it will grow a plane here. Similarly it will grow a plane here. And lo and behold, your small crystal has now grown into a larger crystal. And this process can go on and on, again and again till you have a very large size crystal. So, the ordered arrangement of atoms in a mineral permits them to grow into crystals.

Now these crystals can be formed in a solution or they can be formed when, say, the constituents of the mineral are there in a molten state. So, for instance if we consider lava. So, lava has the foundations, or the constituents of number of minerals. And when the lava cools down then the minerals, if they are there in the form of very small crystals, they will accumulate their constituents and they will slowly grow into size, larger sizes.

So, these are the characteristics of a mineral. They are naturally occurring, inorganic solid with definite chemical composition and ordered atomic arrangement. And we have different minerals. We have n number of minerals of which 6 are considered to be major rock forming mineral groups.

So, if we consider this definition you can have very large number of minerals; because you can have, you can take any compound; and probably that compound if it gets into an atomic arrangement that is ordered and if it is found naturally and if it forms a solid which is an inorganic solid then probably there will be a mineral that corresponds to that compound. So, there are a very large number of minerals. And in this course we are not going to look at each and every mineral in detail because that is beyond the scope of this course.

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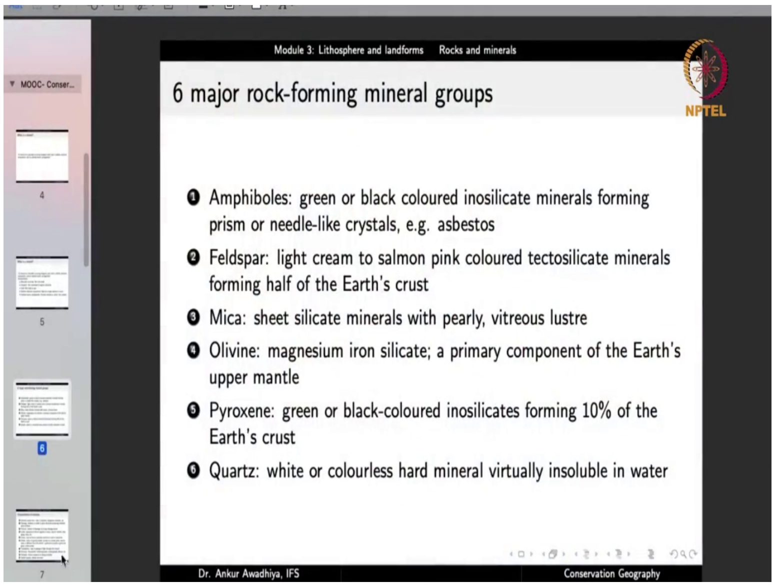

But we are going to look at six major rock forming mineral groups. The first is amphiboles. Amphiboles are green or black colored inosilicate minerals. Now inosilicate means that in these minerals you have a silicon atom that is surrounded by oxygen atoms. So, this is Silicate: SiO_4. In the case of inosilicates, these silicates are arranged in the form of chains. So, in the case of amphiboles, these are green or black colored inosilicate minerals, that is minerals in which the silicates are arranged in the form of chains forming prism or needle-like crystals. And a good example is asbestos.

Another major mineral rock forming mineral group is feldspar. Feldspar is light cream to salmon pink colored tectosilicate mineral. Now in the case of tectosilicates, the silicates are arranged in the form of a three-dimensional lattice. So, inosilicate is chain like; tectosilicate is three-dimensional. In the case of feldspar there is three-dimensional arrangement of silicates and they roughly form half of the Earth's crust. So, they are very commonly occurring minerals.

The third is mica which are sheet silicate minerals. So, in this case the silicates are arranged in the form of sheets. So, we have chains, we have sheets and we have three dimensional structures. In the case of mica we have sheets. So, these are sheet silicate minerals with early vitreous lustre. Now we will look at lustre in the short while. So, these look like pearls. They have the appearance of a pearl or they have the appearance of glass. So, they look like glass, they look like pearls that is slightly whitish and transparent like, so it is glass-like and it is in the form of sheets.

Another mineral group is olivines. They are magnesium iron silicates and a primary component of Earth’s upper mantle. Then we have pyroxenes. Pyroxenes are green or black colored inosilicates that form around 10 percent of the Earth’s crust. And we also have quartz, which is white or colorless hard material which is virtually insoluble in water.

Now if you look at any rock these are the major minerals that you are going to find in them. But because we have very large number of minerals so you will also find other minerals, or you may also find other minerals. But these are the predominant minerals. And by looking at which mineral is present in a rock, in what amount, in what composition, you can make an idea about how this rock was formed, which is why it is important to understand these mineral groups.

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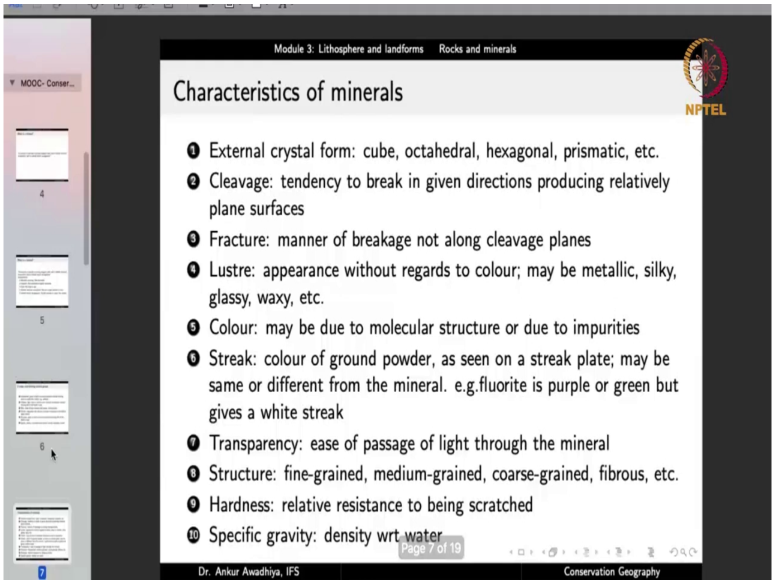

Now when we talk about minerals we can characterize minerals on the basis of several of their characteristics. One such characteristic is the external crystal form. Now because minerals have ordered atom arrangements, so they form crystals. Now if you have a crystal of a mineral you can have a look at that crystal and you can look at what is the shape of that crystal. Does that crystal look like a cube? Does that crystal look like an octahedron? What does it look like? So, the first characteristic is the external crystal form. You can have cubes. You can have octahedrons. You can have hexagons. You can have prismatic crystals and so on.

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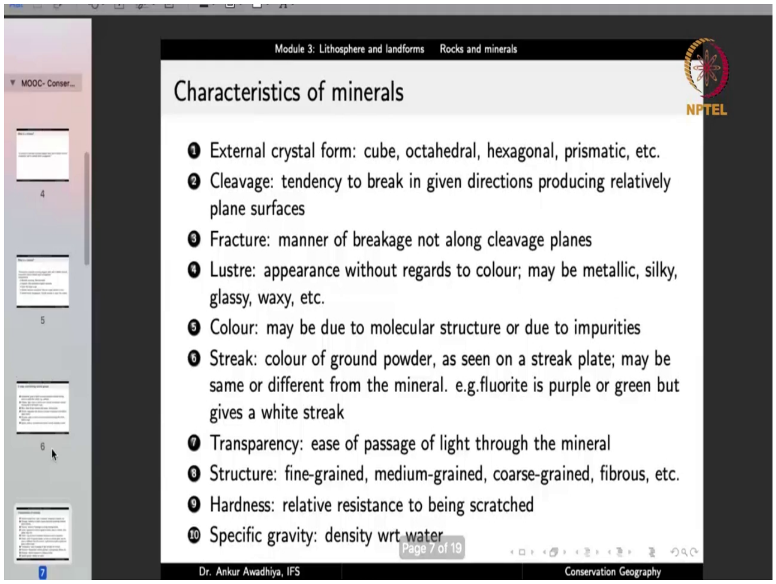

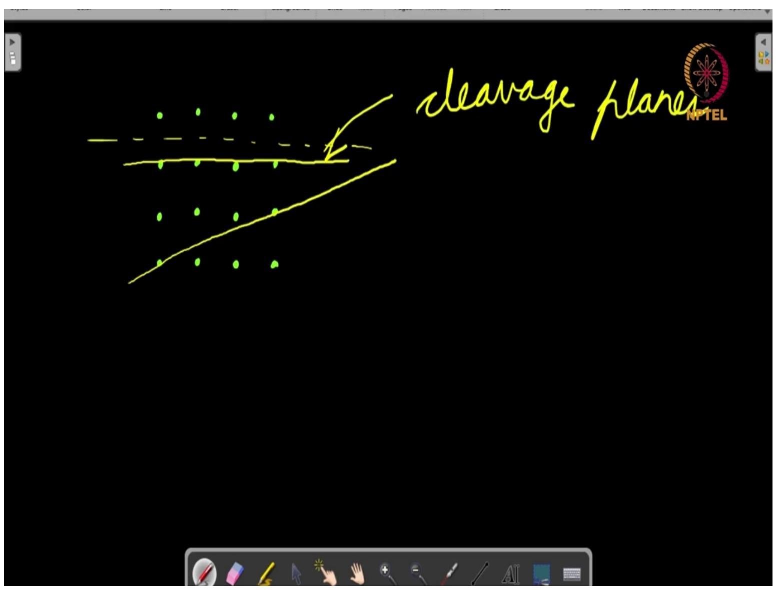

Second is cleavage. Cleavage is the tendency to break in given directions producing relatively plain surfaces. Now what happens is, when we talk about crystals they have a fixed arrangement of atoms inside. So, if we draw one such arrangement like this. So, here we are marking out where the atoms lie in this particular crystal.

Now if this is an arrangement and if you try to break this crystal then there will be certain planes along which breaking this crystal would be easy. Like this plane; because you have atoms in this particular plane. So if you, say, break the crystal at a plane that is parallel to this then it is very easy to break this crystal. But if you take a plane where you are getting a few atoms but not many. Something like this. Now in this case it will be difficult to break the crystal along this particular plane.

So, there are certain planes that are known as the cleavage planes along which it is easy to break the crystal. So, cleavage is the tendency to break in given directions producing relatively plane surfaces, because in this case you are breaking the crystal in such a manner that a plane gets created in which the crystal structure is maintained.

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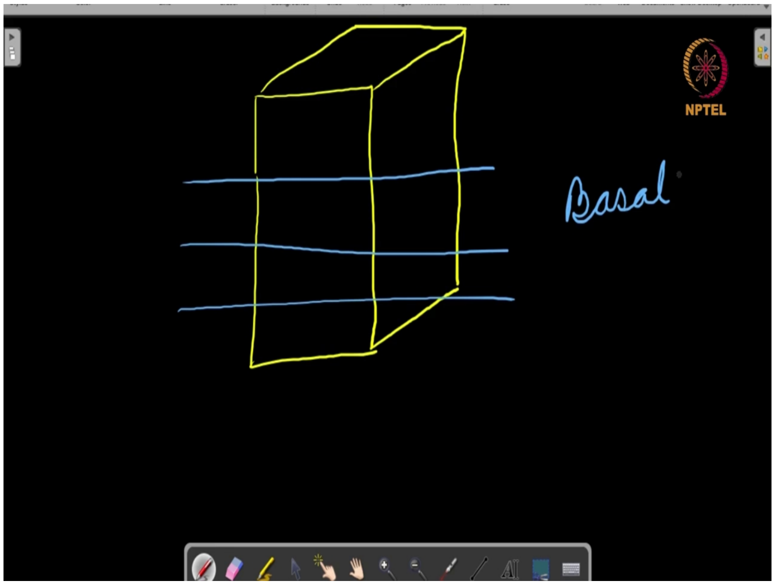

Now cleavage can occur in a number of forms. So, for instance you can have a basal cleavage in which case, say, you have this mineral block then it is easy to break the crystal parallel to one face. But if you try to break the crystal in any other direction it is very difficult. Now such a cleavage is known as a basal cleavage, that is, this is cleavage along a particular base. And this is very commonly observed in those minerals that have a sheet-like structure.

So, for instance if you consider graphite. Now in the case of graphite the carbon is arranged in the form of sheets. And so if you try to break a crystal of graphite it is very easy to break along these directions and the resultant surface will be a very smooth surface. But if you try to break the crystal in any other direction it will be very difficult. Another good example is mica. Now mica is also found in the form of sheets and it is easy to break the crystal along the direction of a sheet. But in other direction it becomes very difficult.

So, if you have a mineral and you find that it is breaking only in one direction, it does not break in any other directions in a cleavage plane that is resulting in a smooth surface then you can say that, okay the atomic arrangement in this particular mineral is in the form of sheets. And so this can help you identify the mineral, because there are very few number of minerals that have the atomic arrangement in the form of sheets. Similarly you can have other cleavage patterns. Another cleavage pattern that is very commonly observed is a cubic pattern.

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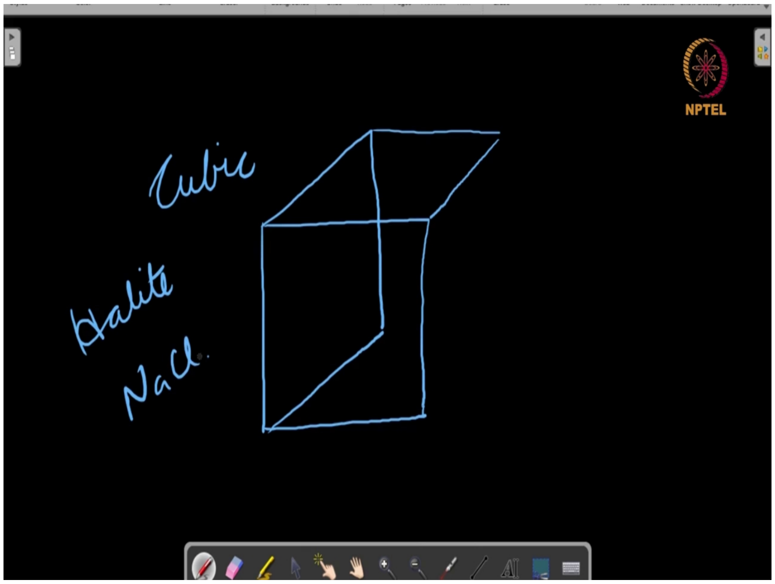

Now in the case of a cubic pattern you can break the crystal along this plane, or you can break the crystal along a 90 degree plane, or you can break the crystal in this 90 degree plane just like the three faces of the cube.

A very good example is halite which is nothing else, but your common salt, sodium chloride. So, if you take a crystal of sodium chloride and if you try to break it, then it will break and it will give rise to other smaller cubes. And all of these cubes will be having a very smooth surface. So, that is telling us that it is having a cleavage that is a cubic cleavage.

Another common cleavage is the octahedron cleavage which is found in diamond. So, by looking at the cleavage which is the tendency to break in given directions producing relatively plain surfaces you can identify the mineral, or at least get some idea of what this mineral could be.

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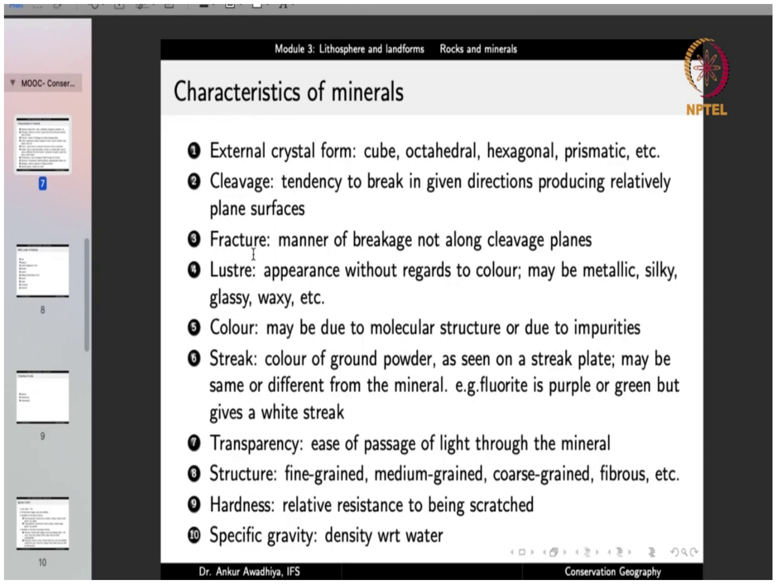

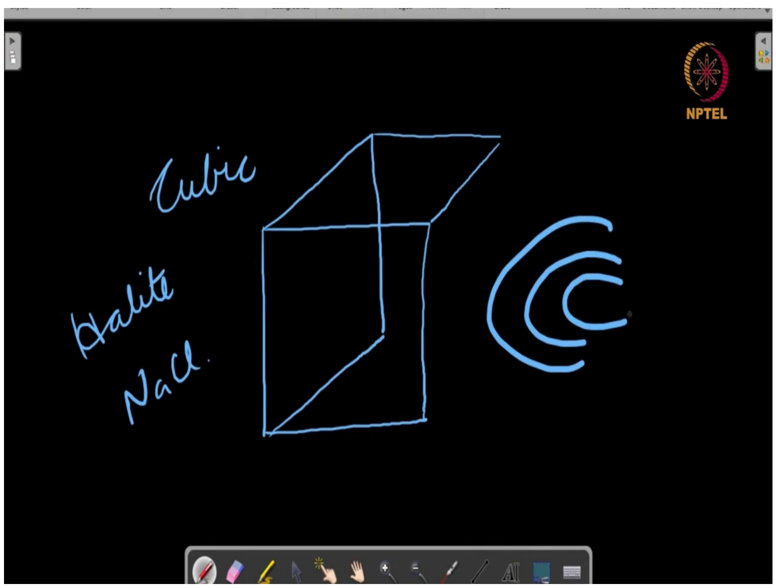

Another characteristic is fracture which is the manner of breakage not along the cleavage planes. So, if you apply force to a crystal and if it breaks in other direction as well; so you know about the cleavage directions but what happens when you break it in certain other directions; that can also give you certain information about the mineral. So, for instance when you break a crystal, and you, in another direction that is resulting in a fractured surface, now this surface will not be a smooth surface; because if it were a smooth surface we will call it a cleavage surface.

But when it is not a smooth surface it is a fracture, then it is possible that the mineral has been broken to result in a surface that is very uneven, something that looks like, say, a lump of Earth.

So, we will say that this has an earthy fracture. Or you can have situations in which it results in a very jagged structure. So, there are very sharp points somewhere. A jagged fracture is found, say, in case of naturally occurring metals such as silver. Or you can have a situation in which when you break it along a fracture surface you get the rings that are very similar to what you see in the case of a mussel shell.

So, we will call it a conchoidal fracture. So, you have different lines that go like this. Now this is a conchoidal fracture. So, by looking at the different kinds of fractures or the manner of breakage that is not along the cleavage planes you can have also have certain idea about what this mineral could be.

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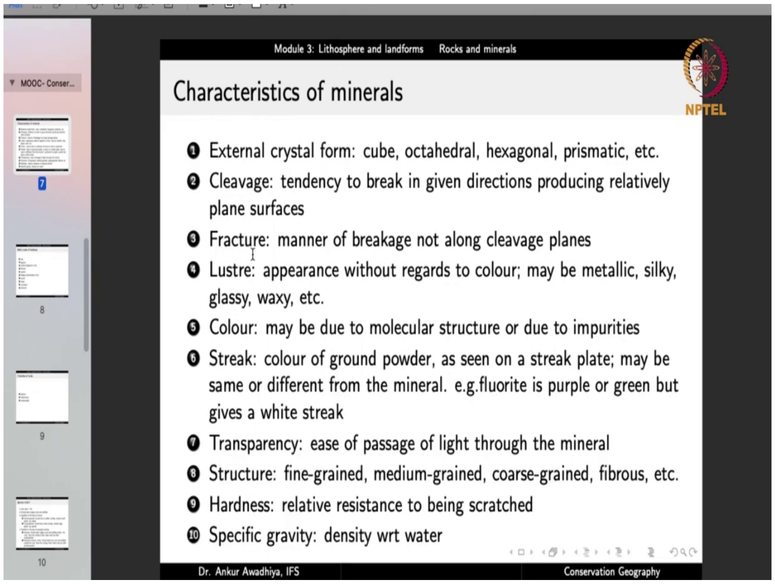

Another characteristic is the lustre of a mineral. Lustre is the appearance without regards to color. So, if you forget about what the color of the mineral is, what is the appearance like? Is it very shiny? So, if it is very shiny, it looks like a metal we will say that it is having a metallic lustre. Or if it looks like silk we will say that it has a silky lustre. If it looks like glass we will say that it has a glassy lustre or a vitreous lustre.

If it looks like wax that is it is having a bit of translucent sort of an appearance just like a wax then we will say that it has a waxy lustre. Now in this case we are not talking about the color. So, you can have a mineral that is having a waxy luster, but say, it is having a pink color or it is having a black color or it has blue color. But we are not talking about color now. We are only talking about the lustre, that is, appearance without regards to the color. So, if you look at this mineral does it look like a glass? Does it look like metal, shiny like a metal? Does it look like a wax surface? How does it look like? So, that is lustre.

Another characteristic is color. Now color may be due to molecular structure or due to impurities. Now by looking at the color, at times it is possible to identify the mineral. So, for instance, graphite will always look deep grey in color. But it is also possible that you have a mineral that shows different colors because of certain amount of impurities. And so color, it may help you, but it is not a very good characteristic to tell you about the mineral.

A much better characteristic is the streak. Now streak is the color of ground powder as seen on a streak plate. It may be the same or different from the mineral. Example fluorite is purple or green but gives a white streak. So, what happens in the case of streak is that you take a plate; and so you take a plate like this and you rub the mineral against it. And when you rub the mineral against it then the mineral will break down into a fine powder and you will get a line on the streak plate.

Now what is the color of that line? Now in a number of cases the impurities are present in a very tiny amount in a mineral. And so when you look at a streak line, you will get the color of the major constituents. And so a streak line or the color of the streak line can give you very important information about what the mineral is, irrespective of the slight amount of impurities that may be present in the mineral. So, for instance fluorite may be purple or it may be green depending on what are the impurities inside. But it always gives a white streak. So, streak is a much better indicator of the mineral.

Another characteristic is transparency. How much amount of light does this mineral permit to pass? Ease of passage of light through the mineral. Is the mineral transparent? Is the mineral completely opaque, in which case it does not permit any light to pass through it? Or is the mineral translucent which means that it permits some amount of light to pass but not all light? So, transparency also is a characteristic of the mineral.

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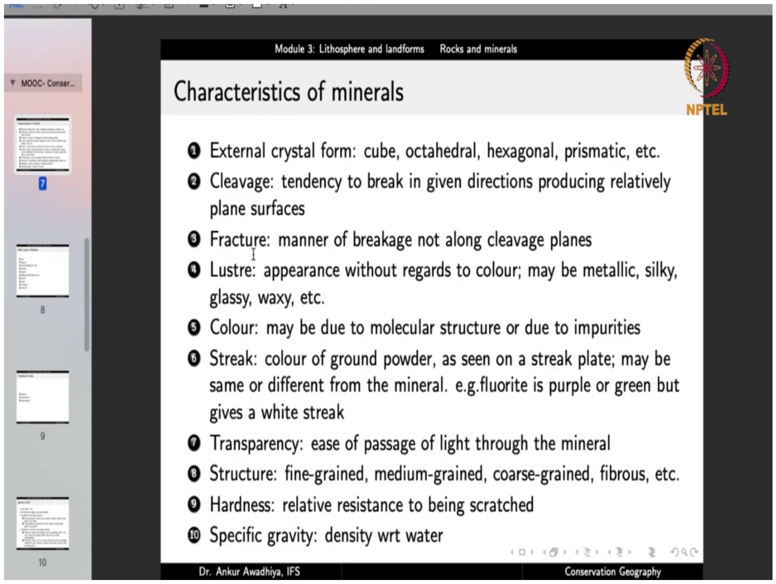

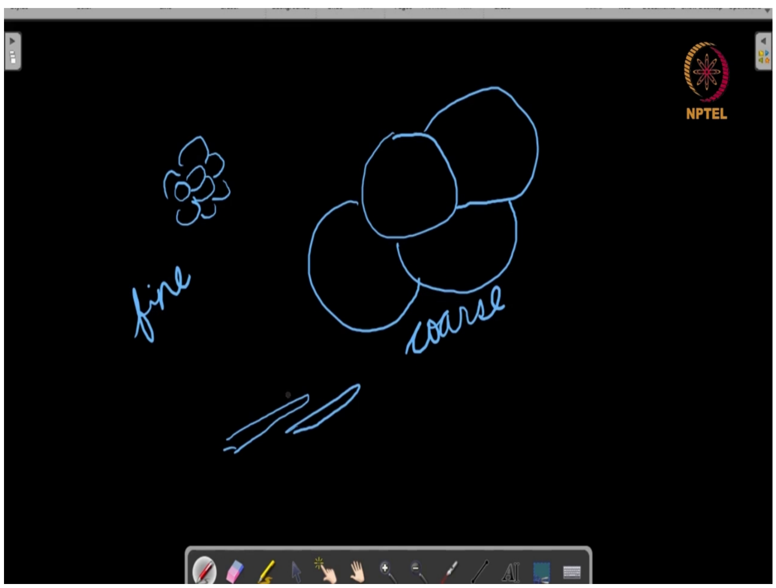

Structure; is the mineral fine-grained, medium grained, coarse grained, fibrous and so on? Now structure is typically looked at under a microscope. And it is possible that when you look at the mineral under the microscope you have very small grains inside the mineral. Or it is possible that you have very large sized grains.

Now this is a fine texture, this is a coarse texture. Or you can have grains in the form of needles. So, this is the structure of a mineral. Is it fine grained, medium grained coarse grained, fibrous and so on. But structure is typically difficult to identify under lab settings so we try not to use it that much.

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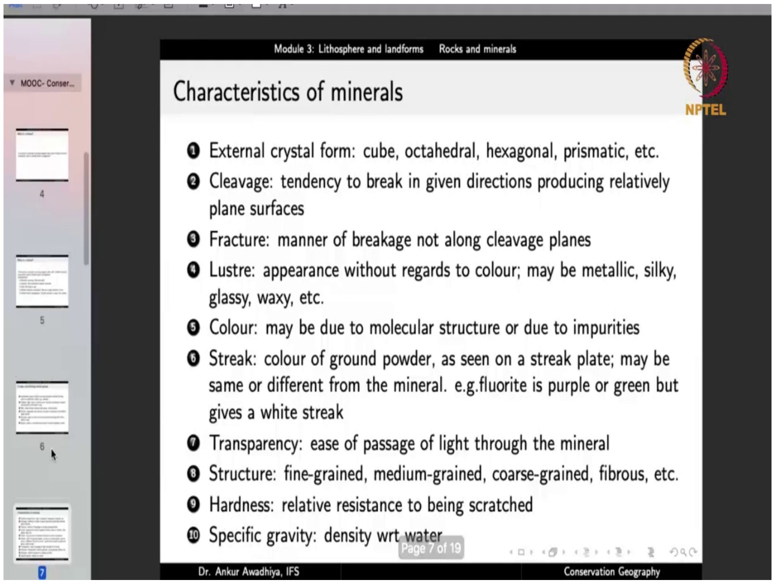

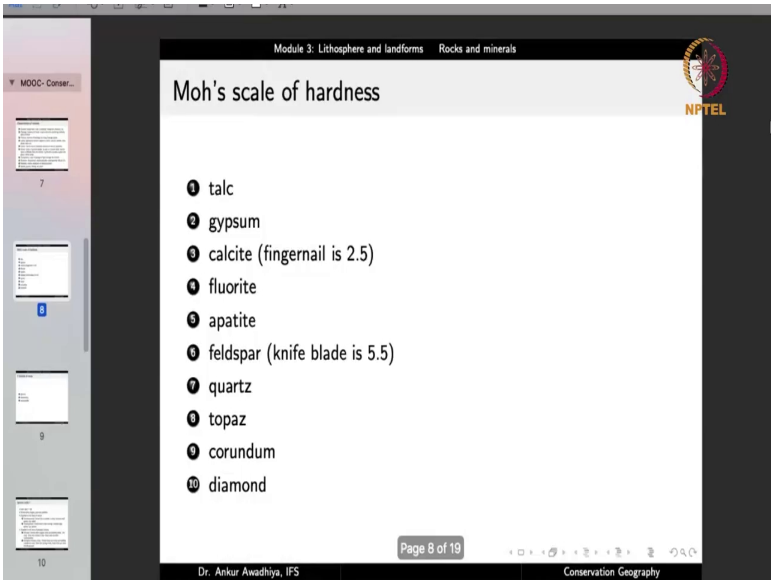

One characteristic that is easy to understand is hardness, the relative resistance to being scratched. So, hardness; ask the question, is the mineral hard or is it soft? Now how do you identify the hardness? You just take two minerals. One is your known mineral, one is the unknown mineral. Now using your known mineral if you try to scratch the surface of the unknown mineral then will the known mineral be able to put a scratch or not?

Now if the known mineral is able to put a scratch then it means that the known mineral is harder than the unknown mineral. Or in other words the unknown mineral is softer than this. And so you go with a softer material, you try scratch it again. And you will reach a point where you are not able to scratch the mineral any further. So, this will give you an indication about the hardness of the mineral. And typically we make use of Moh's scale of hardness.

So, these are certain minerals that are made use of. Talc is a very soft mineral and this has Moh's scale of 1. So, talc can be scratched by each and every of the minerals downwards, but it cannot scratch any of these down minerals. Gypsum can put a scratch mark on talc, but not on any of these others. Calcite is able to put a scratch mark on talc and gypsum, but not anything below.

Calcites hardness is very similar to that of a finger nail. Then fluorite, apatite, feldspar, now feldspar is close to a knife blade, so it is that hard. Quartz, topaz, corundum and diamond; and diamond is the highest mineral. So, diamond is able to put a scratch on all of these, but none of these are able to put a scratch mark on diamond. So, we can locate the hardness of the mineral.

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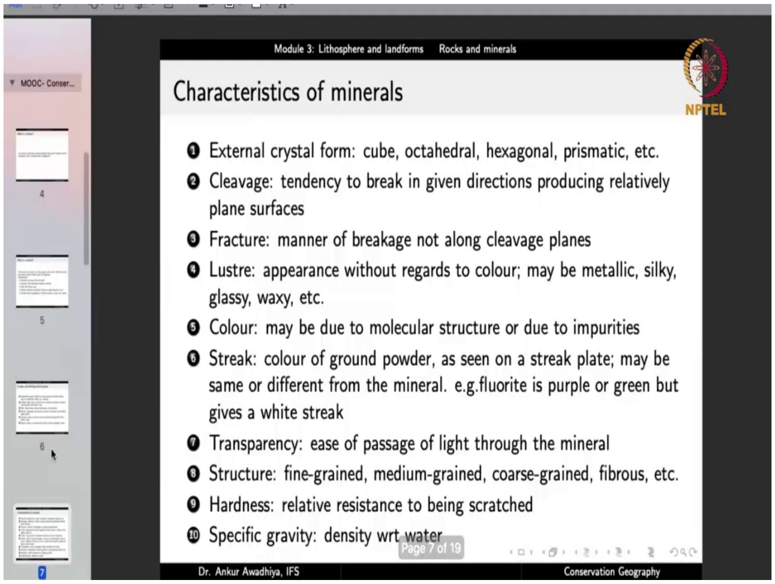

And we can also look at the specific gravity of the mineral, which is the density of the mineral. Is it a dense mineral or is it a light mineral? Now if a mineral is dense then it can give us two indications. One, it comprises of those elements that are heavy. So, it comprises of things like iron. Or it has a particular atomic arrangement, which permits a very close packing of the atoms. So, that per unit volume, much more mass can be accommodated. So, specific gravity is also another important characteristic of a mineral.

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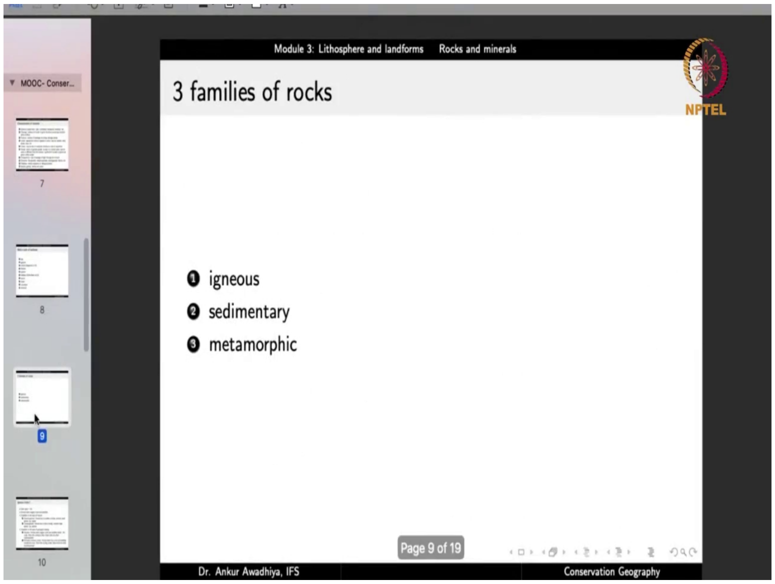

Now minerals make rocks and rocks are divided into three families. We have igneous rocks. We have sedimentary rocks, and we have metamorphic rocks. And now we will have a look at all of these.

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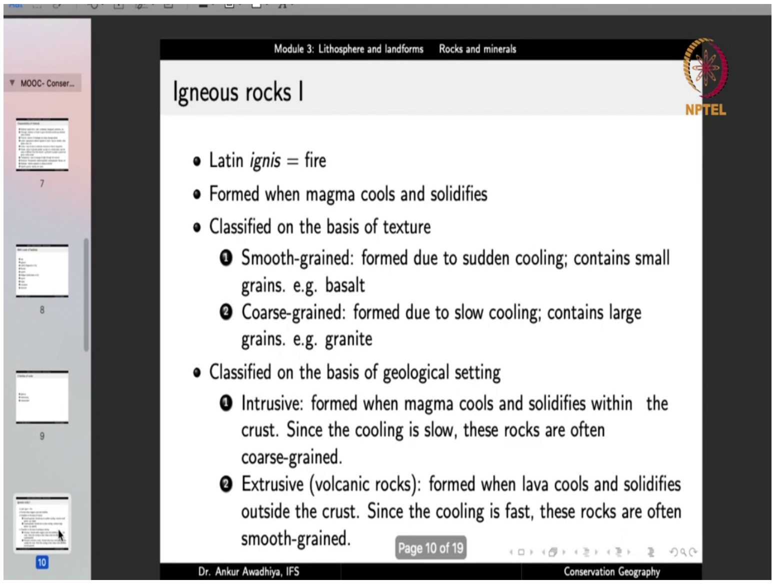

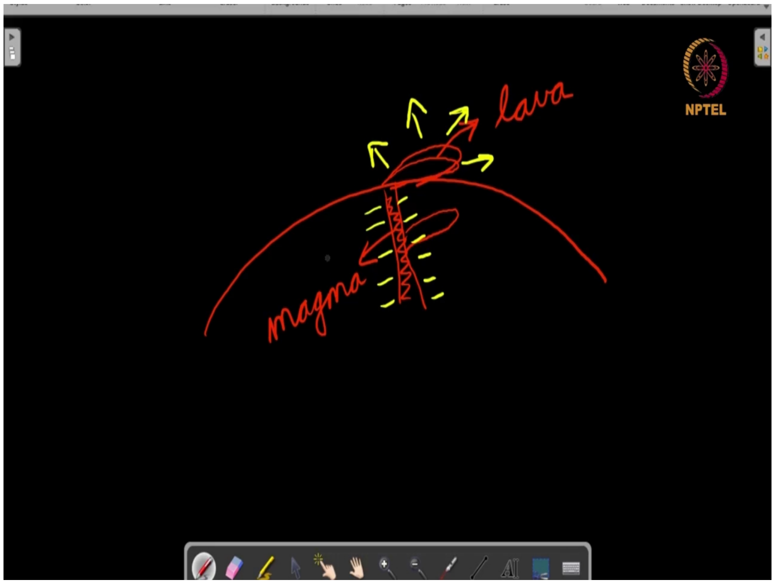

The igneous rocks are derived from the word root ignes which means fire. They are formed when magma cools and solidifies. So, igneous rocks were the first rocks to be formed. When the Earth began as a molten mass it solidified after sometime when it went through a cooling process. So, when the solidification of Earth happened the first rocks that got formed were the igneous rocks.

Now today also we find igneous rocks that are being formed especially in those areas where there is volcanic activity. Now as you remember in the case of volcanism there is a release of magma from the Earth's interior to the outside. Now when the magma is coming out, when it comes to the surface it becomes lava; but when it is coming out then too, it can get into certain intrusions beneath the Earth's surface and it can solidify there as well.

So, we can have a solidification of magma either on the surface of Earth or below the surface of Earth; that is if we consider the Earth and there is magma that is coming out from, say, this conduit, if magma comes out here and it solidifies then we say that this is a solidification of lava. But at the same time it is also possible that the magma solidifies somewhere here. Or it solidifies in the conduit itself. So, in this case we will have a solidification of magma. And in both the cases the rocks that get formed through the solidification process will be igneous rocks.

Now on the basis of their texture we can have smooth grained rocks or coarse grained rocks. Smooth grained rocks are formed due to sudden cooling and they contain small grains such as basalt. And smooth grained rocks typically form when the lava has come to the surface, because when once it has come to the surface then we can have a rapid release of heat to the surroundings.

It is typically surrounded by either air or water, and in both the cases air and water are very good media to take heat away from the surface. So, there is a very quick solidification. Now when there is a quick solidification, then the minerals that get formed, they do not have a very large amount of time to grow into large size crystals. And so the crystals that get formed are very small in size. Now small size will result in a smoother texture.

On the other hand when the magma gets solidified inside the Earth, then in that case, because it is surrounded by Earth on all sides, so in this case it does not get a medium to transfer the heat away faster. And so there is a slow cooling of the magma. If there is a slow cooling then the crystals have a lot of time to accrete matter and grow into larger size crystals. And if we have larger size crystals we will say that this is a coarse grain rock or a coarse textured rock.

So, on the basis of their texture we can have smooth grained rocks or coarse grained rocks. Smooth grained rocks are formed due to sudden cooling. They contain smaller grains. And coarse grained rocks are from due to slow cooling and they contain larger grains. A good example of smooth grained rock is basalt, because as we have seen before, in the case of basalt provinces, the basalt comes out. It has less viscosity. It spreads very fast.

So, there is a fast spread in a very large area. So, you have a very thin sheet of rocks that is getting formed. The surface area is large and so there is a very quick cooling. And so basalt typically is a fine grained rock.

On the other hand granite is formed due to slow cooling. Granite is much more acidic in composition as compared to basalt. It is very viscous in its formation. And so even if it comes out it will either grow into granite rock when it is below the surface, because it is very viscous so it will not come out to the surface. Or even if it comes out to the surface it will just accumulated there. And so there will be a coarse grained structure that gets formed. So, granite is a coarse grained rock.

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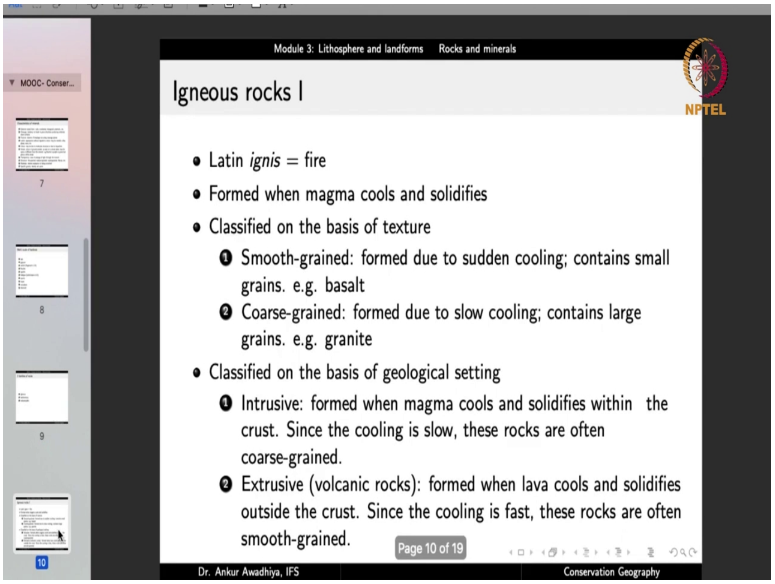

Now on the basis of their geological settings we can have intrusive and extrusive rocks. They are also very similar. Intrusive rocks are formed when magma cools and solidifies within the crust. And since the cooling is slow these rocks are often coarse grained. So, intrusive is when the cooling and solidification is happening within the crust. Extrusive rocks also known as volcanic rocks are formed when lava cools and solidifies outside the crust, that is, it has come out. And since the cooling is fast these rocks are often smooth grained.

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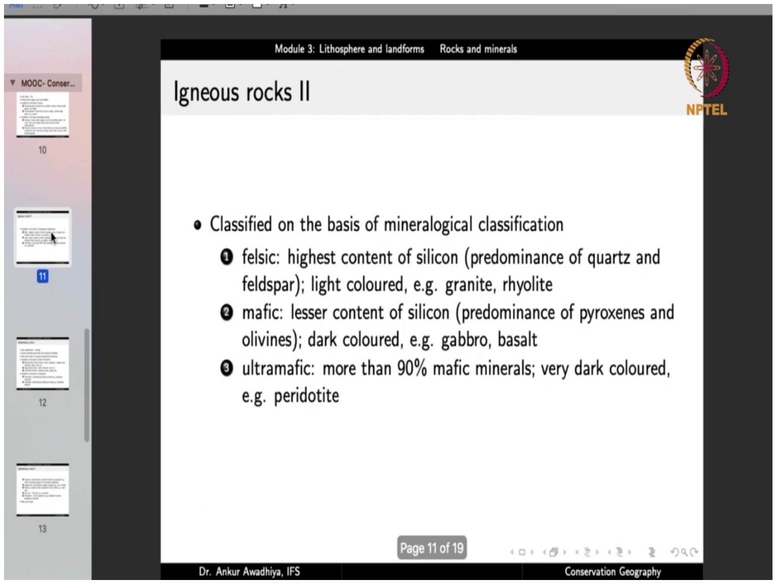

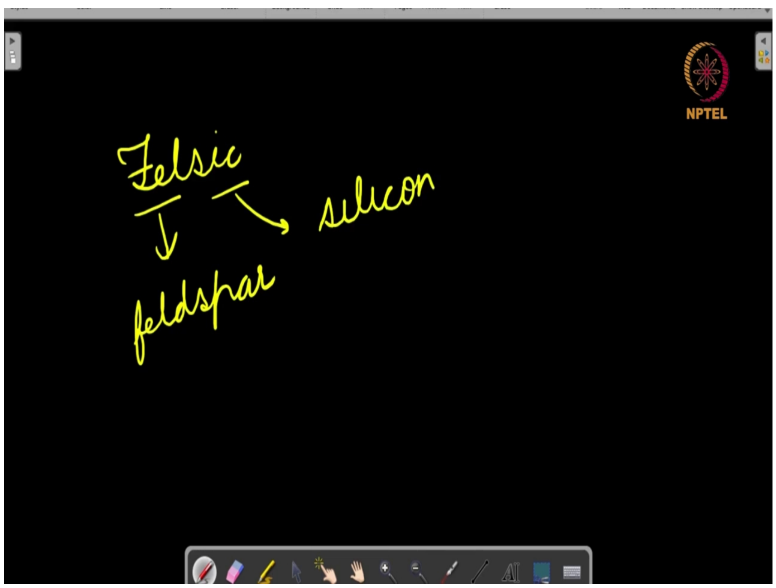

Now igneous rocks are also classified on the basis of mineralogical classification, that is, what are the kinds of minerals that we have inside. So, we have felsic, mafic and ultramafic igneous rocks. Felsic, the word is derived from, so you have felsic, fel is feldspar and sic is silicon or silisic. So, these are those rocks that have a high concentration or content of silicon and feldspar.

So, there is a predominance of quartz and feldspar. They are light in color. And good examples are granite and rhyolite. Mafic rocks, so the word comes from magnesium and fic is iron. So these have lesser content of silicon and so there is a predominance of pyroxenes and olivines.

They are dark in color. Example is gabbro and basalt. And ultramafic is more than 90 percent of mafic minerals. These rocks are very dark colored. Example is peridotite.

Now depending on the minerals that are inside we can also make a prediction about the properties of these rocks, because silica is typically the acidic constituent. And so if there is a rock that is very high in silica it will be an acidic rock. And silica also is a very viscous material. So, if a rock is having a lot of silica then it will be viscous rock, that is, the magma will be a very viscous magma. And so typically the magma will not get a chance to come outside of the Earth. it will get solidified in the process of coming outside.

And so typically we will find intrusive rocks that have a large concentration of silica. Because they are intrusive rocks they will typically also have coarse grains. And so what we are observing here is that the high silica rocks are; the example is granite and rhyolite. And as we saw in the previous slide the granite is a coarse grained rock. And a coarse grained rock is typically an intrusive rock.

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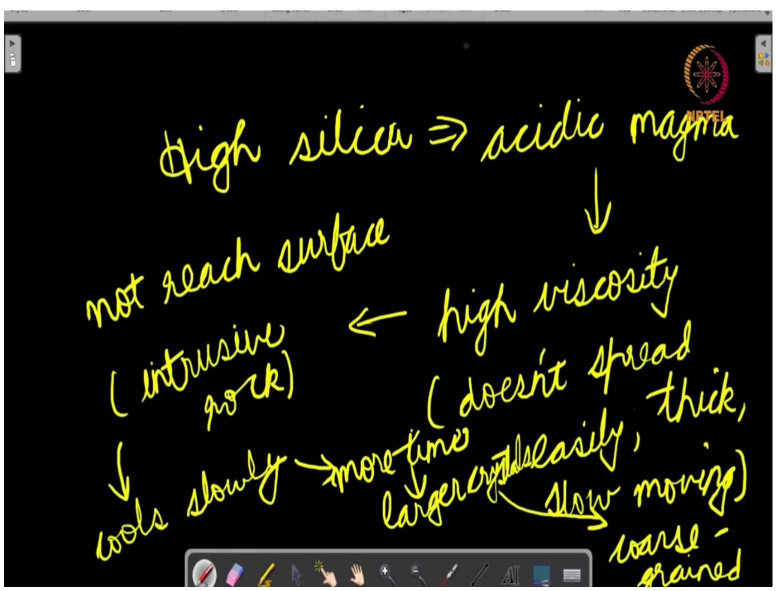

So, you can make a correlation. So, basically rocks with high silica content will be acidic rocks. So, let us write it like this. High silica, so these will be acidic magma and acidic magma has high viscosity which means that it does not spread easily. Now if it does not spread easily and it is, at the same time it is also… it is thick and it is slow moving.

Now with these properties, typically the magma will not reach the surface, which means that it will result in an intrusive rock. Now an intrusive rock has lots of time because it cools slowly. It cools slowly because it is surrounded by Earth. There is no medium which can easily transport the heat away from it. And if it cools slowly so it has more time. And more time means larger crystals, and larger crystals means that this is a coarse grained rock. So, high silica rocks are typically coarse grained rocks.

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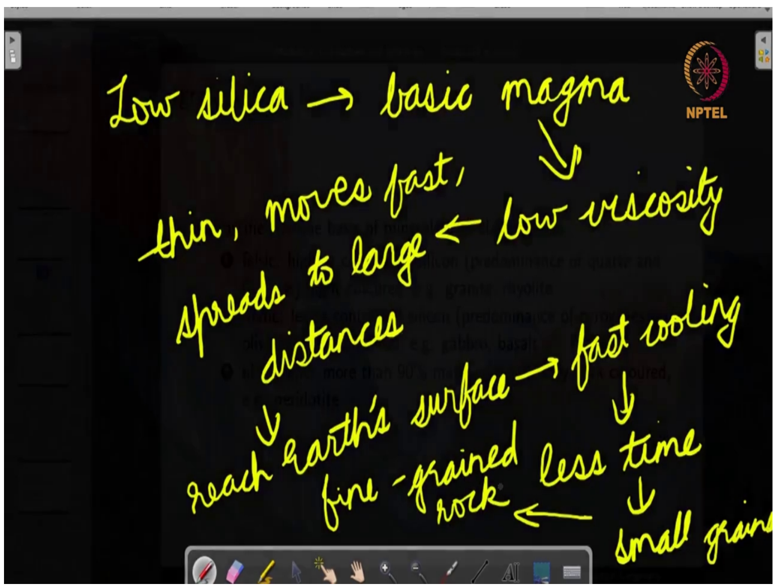

On the other hand if we have low silica then these are typically basic magmas. A basic magma has low viscosity, which means that it is thin. It moves fast and it spreads to large distances which means that typically it is able to reach the Earth surface. Now when it reaches the Earth surface there is a fast cooling. Why is there fast cooling? Because it will either come in contact with air or it will come in contact with water and the heat will be very quickly lost because of conduction, convection and radiation.

Now if there is fast cooling, so there is less time and less time means that the crystals are smaller in size. So, it has small crystals and small grains and so it is a fine grained rock. So, by knowing whether a rock is intrusive or extrusive or by knowing whether it is course grained or fine grained or by knowing its chemical composition we can make a number of predictions about the other properties of these rocks.

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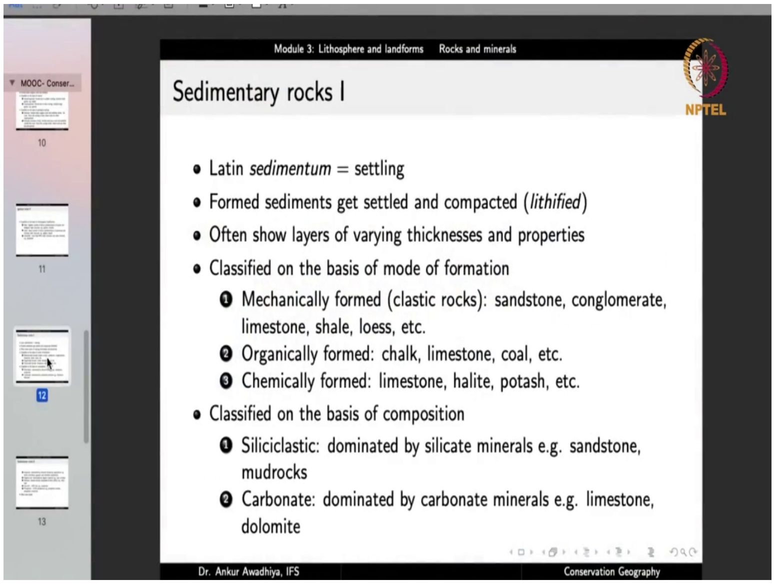

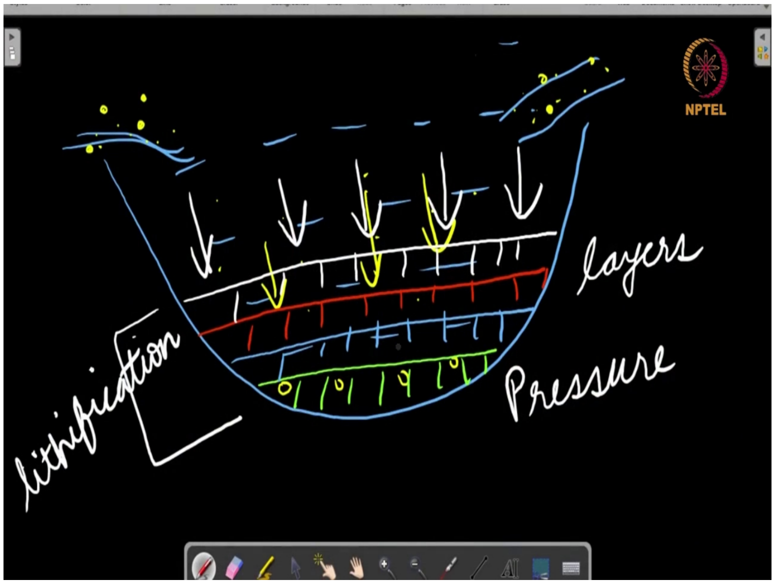

Now the next category of rocks is sedimentary rocks. The term is derived from the Latin word sedimentum which means settling. And they are formed when sediments get settled and compacted in a process that is known as lithification. Now lithification, lithos is rock and lithification means rock formation.

So, in this case the sediments are getting settled. They are getting compacted and they are converting into a rock. They often show layers of varying thicknesses and properties. And typically if we consider a big size lake or say, a water body like a sea and there is water that is being brought in through different streams into this area. Now these streams will also be bringing sediments with them or small pebbles or small pieces of rocks.

Now these sediments get into this water body. The rocks will settle down very quickly but the other segments will also settle down after some time because of the action of gravity. So, all of these sediments are settling. So, basically what will happen is we will get a layer of these sediments. Then after sometime we will get another layer of sediments. Then after some more time we will get yet another layer of sediments, and so on. So, what is happening in this process is that we are getting different layers.

Now all of these layers are also getting pressed from the top because of the weight of the water that is there on the top and the weight of all the previous layers that are there on the top. So, there is a good amount of pressure on these sediments. Now some of these sediments might also be having certain cementing properties, which means that there might be certain compounds that are able to stick these sediments together. So, you have sediments, you have a cementing substance and you have a lot of pressure. So, under the circumstances these layers will get converted into a rock in a process that is known as lithification that is rock formation. So, this makes a sedimentary rock.

Now on the basis of their mode of formation we can have mechanically formed rocks that are also known as clastic rocks. Mechanically formed means that they are being formed because of the pressure, the similar mechanism as we saw here. So, these will be referred to as clastic rocks or mechanically formed rocks good examples are sandstone, conglomerates limestone, shale, loess and so on.

But along with mechanical formation we can also have an organic formation. For example in the case of chalk or limestone. Now what happens in the case of organic formation is that there are certain organisms that make their own shells, organisms such as large number of mollusca species. Now when these organisms make their shell through a biological process, now this shell can also later be converted into a rock.

So, for instance, if you have a large area that is full of corals. Now when the corals die their exoskeleton remains. And now this exoskeleton is also getting pressed due to pressure. So, in that case if this exoskeleton gets converted into a rock later on then we will say that it is an organically formed rock or biological formed rock. So, good examples include things like chalk, limestone, coal and so on. Together with mechanical and organic formation we can also have chemical formation such as in the case of limestone, halite, potash and so on.

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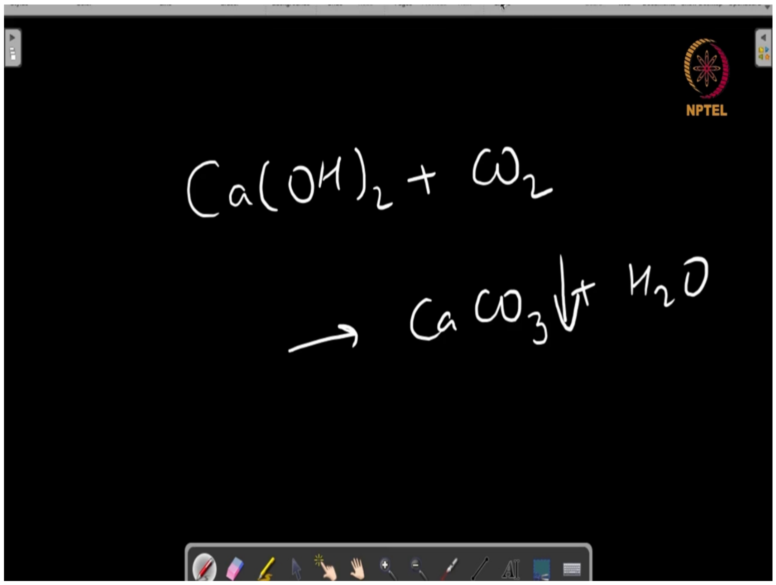

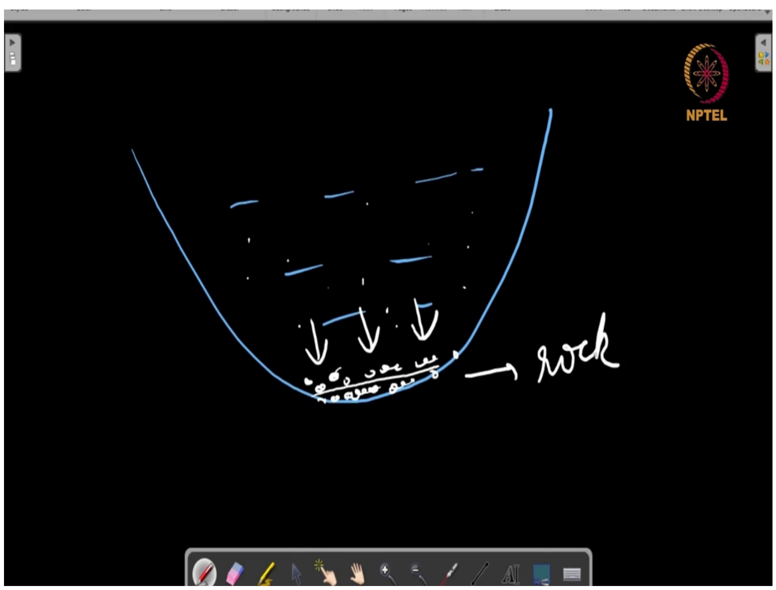

So, for example we can have a chemical reaction like calcium hydroxide coming in contact with carbon dioxide giving rise to calcium carbonate and water. Now in this case this calcium carbonate can get precipitated out. Now when you have a lake where you have different ions in the form of different salts and when there is a chemical reaction, this chemical reaction may result in the deposition of a certain layer of chemicals. Then later on there will be another layer that gets formed.

Now in this case these salts are getting deposited because of a chemical reaction. And once they are deposited next we will also be having the impact of the pressure. And this will result in the formation of a rock. So, in this case we can also have chemically formed sedimentary rocks that involve certain chemical reactions for their formation.

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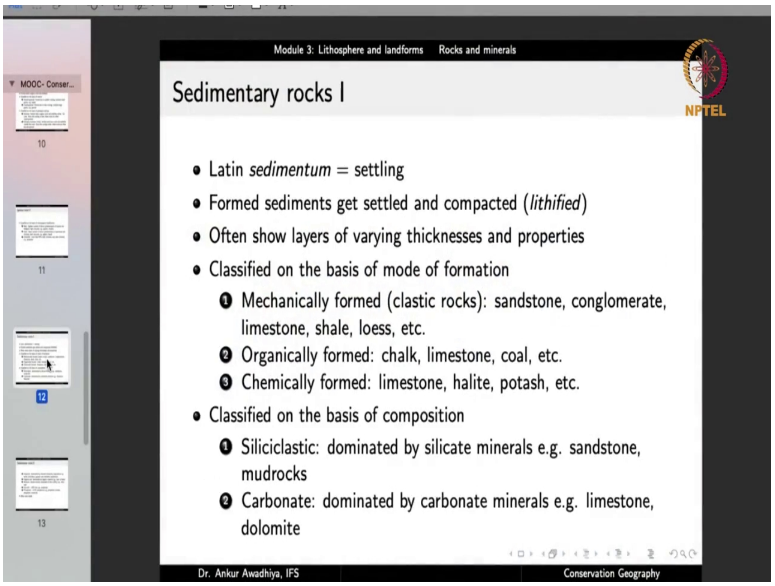

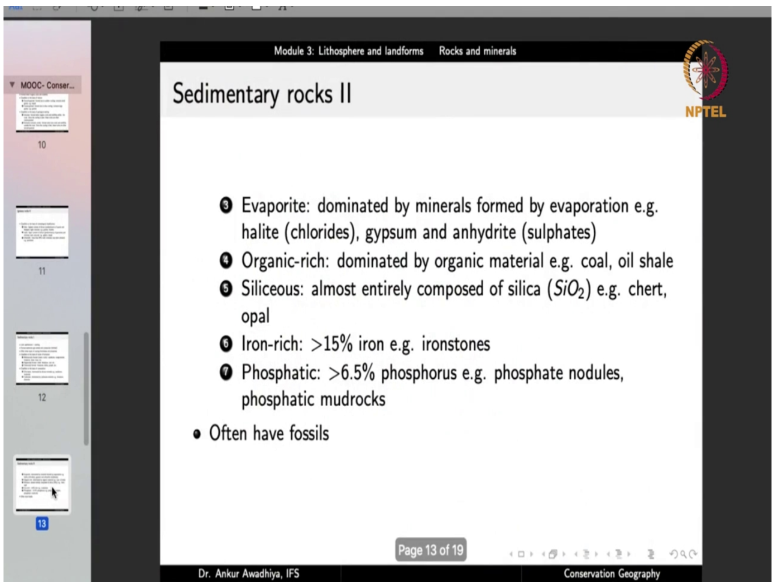

We can also classify sedimentary rocks on the basis of their composition. So, we have siliciclastic rocks. Now silici means that they are dominated by silicate minerals and clastic means that they are mechanically formed. So, siliciclastic rocks are dominated by silicate materials formed through a mechanical formation include things like sandstone and mudrocks.

We can also have carbonate rocks that are dominated by carbonate minerals like limestone, dolomite. So, these are different forms of calcium carbonate. So, we can have carbonate-rich rocks. Or we can have rocks that are evaporites that are dominated by minerals that are formed through evaporation. Example halite which is chlorides like common salt, sodium chloride, gypsum, anhydride; so gypsum and anhydride both are sulphates of calcium. So, we can have these rocks that are dominated by minerals that are formed through evaporation process in which the salts get concentrated, and after concentration they get precipitated.

We also have always organic-rich rocks that are dominated by organic materials such as coal, and oil-bearing shales. Or we can have siliceous rocks that are almost entirely composed of silica that is silicon dioxide. Example is chert and opal. Or we can have iron-rich rocks that have greater than 15 percent iron. Example is ironstone. Or we can have phosphatic rocks that have a good amount of phosphorus, greater than 6.5 percent. Example phosphate nodules and phosphatic mudrocks.

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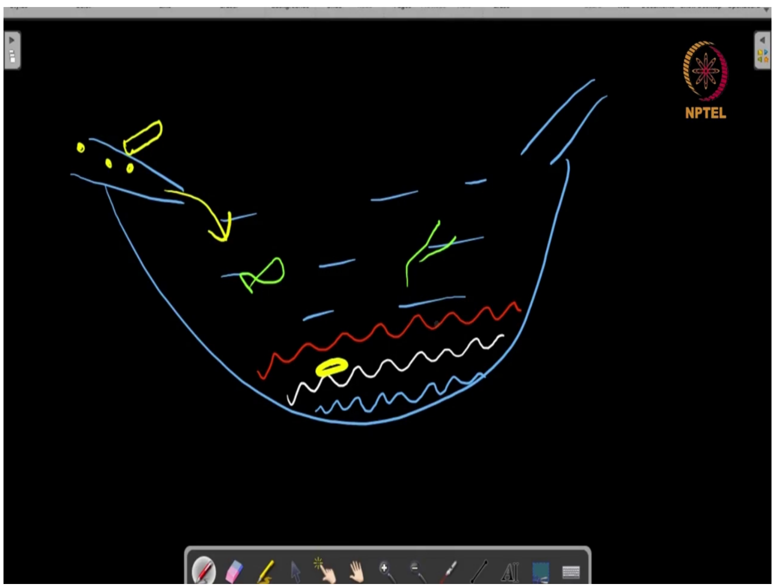

Now an important characteristic of sedimentary rocks is that they often also have fossils. Now why do they have fossils? Because in the process that they are formed… so you have a lake and you have streams that are bringing in sediments and these sediments are getting deposited in the form of different layers. But it is not just the sediments that gets deposited. There are also a number of organisms that are living in these water bodies.

So, probably they are certain fishes or there are certain plants that are growing here. Or there is certain material that is being brought by these streams, say, certain fruits or flowers or logs. So, there are being also brought inside and once they reach into this water body it is possible that they also settle down.

Now remember that a large quantity of this organic material will be eaten up by the organisms that are living in this water body. But it is possible that certain amount gets left out. Now that portion that gets left out, typically things like the skeleton of organisms, it will come down. It will settle down. And as soon as it gets settled here it will soon be covered by another layer of sediments.

Now once it is covered with another layer of sediments then it is cut off from the other biological organisms. So, it will no longer be eaten up by any other organism for food because the upper layer of sediments is now protecting this organic material. And when all these layers, through compaction, they get converted into a sedimentary rock, this organic material, say a fruit or a flower that is embedded in one of these layers, it also gets lithified, and it turns into a fossil. So, typically in the sedimentary rocks we find a large number of fossils.

Now it is also important to remember here that igneous rocks by their very nature, that they are formed out of molten material, they will not contain any fossils because the fossils will be destroyed in the process of making an igneous rock. But in the case of a sedimentary rock the fossils may be left intact. And so we typically find a large number of fossils in the sedimentary rocks.

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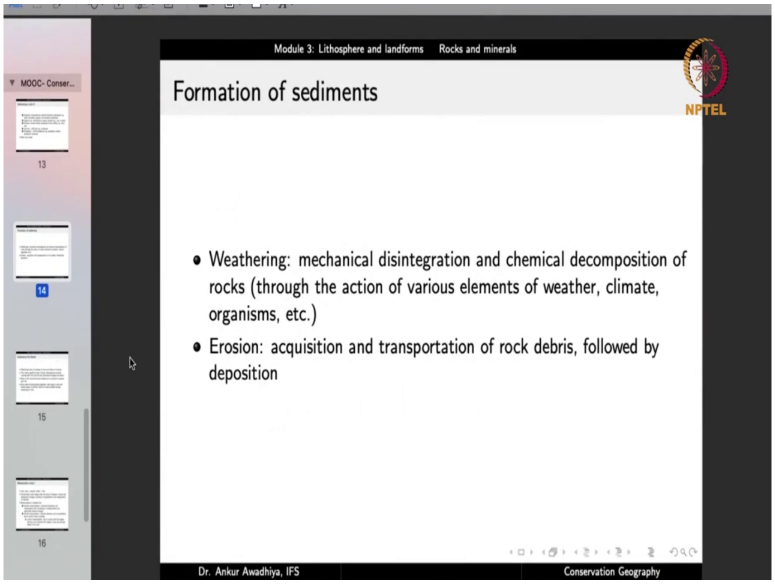

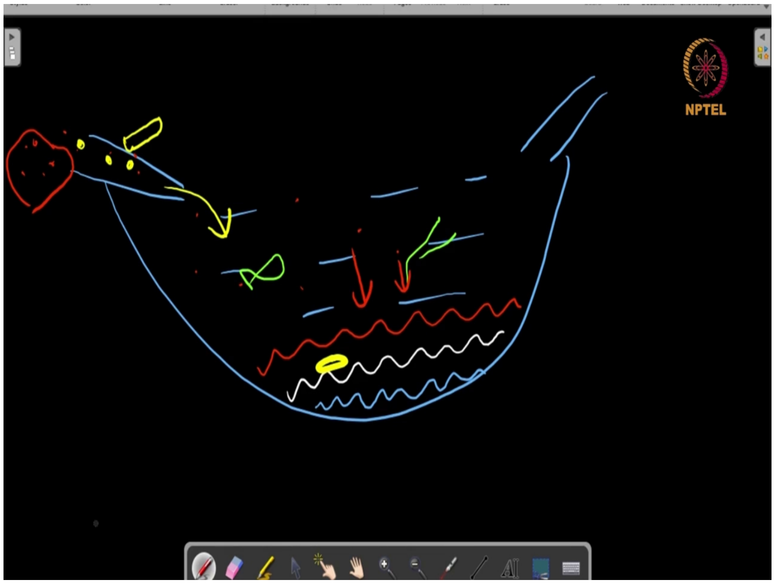

Now the formation of these sediments occur in two ways. We have weathering which is a mechanical disintegration and chemical decomposition of rocks through the action of various elements of weather, climate, organisms and so on. And also there is erosion which is acquisition and transportation of rock debris followed by its deposition. Now in the formation of sediments, what happens is that the existing rocks that are there on the planet, they undergo a disintegration process.

Now we will look at it in more detail in the lecture on soils, but in brief what happens is that because of processes like uneven expansion due to heat and cold or due to process such as crystal growth of salt or because of mechanical action of, say, wind and water the rocks slowly and steadily they get disintegrated. Now this process of disintegration is known as weathering. Typically it is also exacerbated by biological processes and by chemical processes.

Now once a rock is weathered it gets converted into smaller and smaller fragments. Now these fragments may be carried away to other locations by media such as wind and water. So, wind and water can carry these materials through the process of erosion. And once they carry them to another location they can also get deposited, which is what we observe in the case of these streams.

So, what we are saying here is that probably there was a rock somewhere. It got disintegrated into smaller fragments. And the stream carried these smaller fragments to this water body, and then these smaller fragments got deposited. So, this is the process of formation of sediments. There is weathering and there is erosion and deposition.

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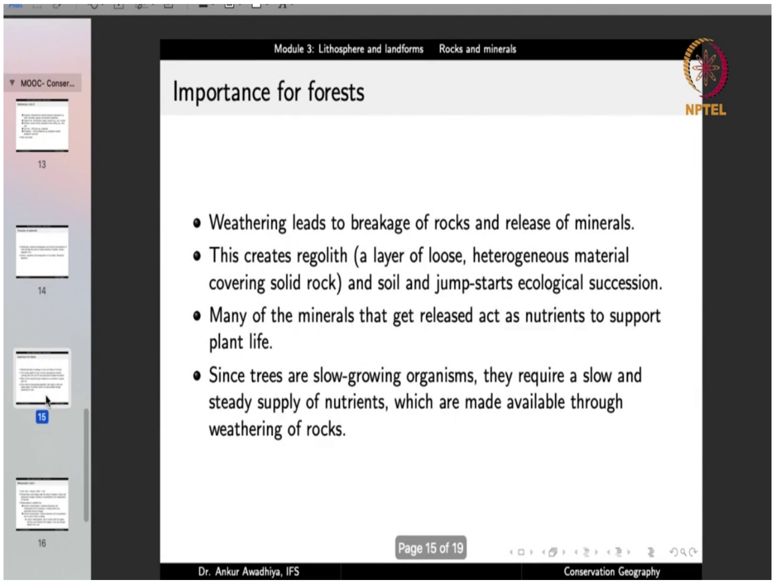

Now this process is very important for the running of biological processes. Typically it is very important for forest. Why? Because weathering leads to the formation of soil. Weathering leads to a breakage of rocks, release of minerals. Now a number of these minerals are also very important from the point of view of nutrition of plants, nutrition of animals. Now animals will get their food from plants or from other animals, but plants have to get their nutrients from the soil.

Now this process of weathering leads to the formation of soil. It leads to the release of these minerals so that they can be taken up by the plants. It also creates regolith which is a layer of loose and heterogeneous material that covers the solid rock and soil, and it jumpstarts the process of ecological succession. Many of the minerals that get released, they act as nutrients to support the plant life, and especially for trees because trees are slow growing organisms. They require a slow and steady supply of nutrients which is made available through the weathering of rocks.

Now because trees grow very slowly they require a slow and steady supply of nutrients. And this slow and steady supply of nutrients is made available through the process of weathering. So, when the rocks break, when the rocks get weathered the minerals become available for the plants.

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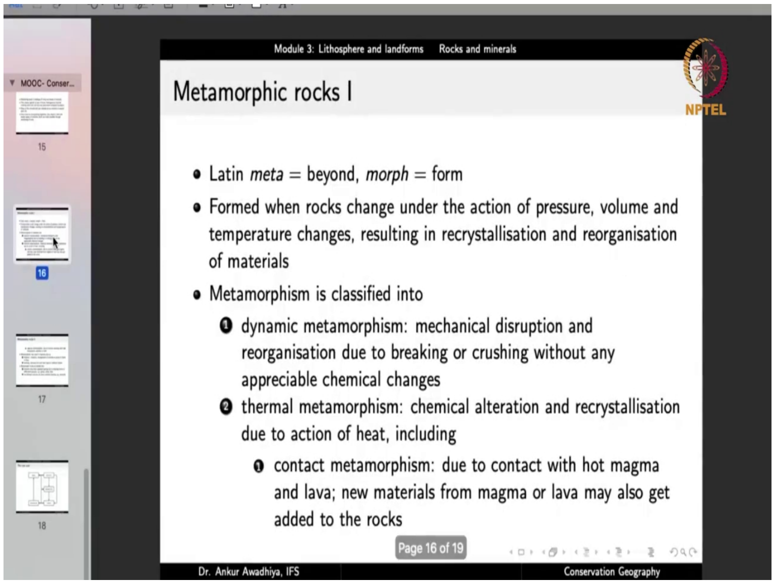

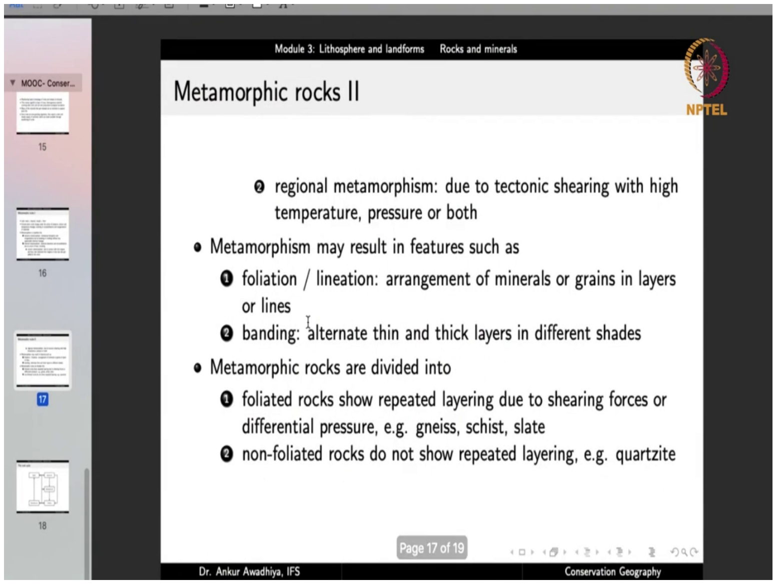

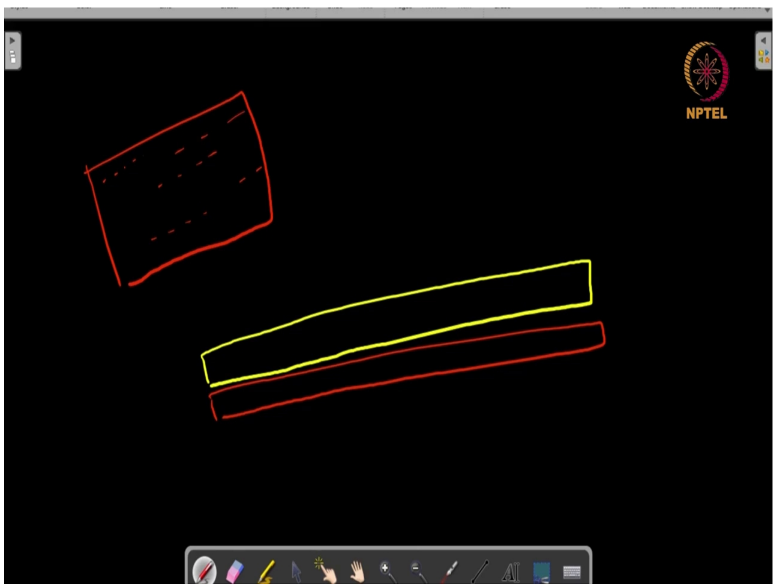

Now the third category of rocks is metamorphic rock. Meta is beyond, morph is form. So, these rocks are gone through a process which turns their form into something that is beyond what they were originally existing. So, it changes the form. And how does the form change? These rocks are formed when rocks change under the action of pressure, volume and temperature changes resulting in recrystallization and reorganization of materials.

That is, if you have an existing rock whether it is igneous, sedimentary or say another metamorphic rock and this rock is again put through a process in which it gets heated up. So, when it gets heated up some portion of it may get melted away. So, me of the crystals may start to grow again, or some other changes might happen, or this rock may get crushed so there can be a physical pressure that is crushing these rocks.

Now these changes of pressure or volume or temperature result in the formation of metamorphic rocks. It is classified into dynamic metamorphism which is metamorphism due to pressure, mechanical disruption and reorganisation due to breaking or crushing without any appreciable chemical changes. But what happens is that if you have a material and this material is getting impacted by pressure, so what happens is that the crystals that were inside the minerals, that were inside, they suffer a shear stress because of which they get arranged in layers. So, this is what happens in the case of dynamic metamorphism.

Thermal metamorphism is a chemical alteration and recrystallization due to heat. So, it can occur because of contact metamorphism where a rock gets in contact with hot magma and lava. And in this case some portion of the rock melts again or it undergoes certain chemical reactions because it is getting heated up. Now in this process the constituents from magma or lava may also get incorporated into the rocks.

Or we can have regional metamorphism, which is due to tectonic shearing with high temperature, pressure or both of these. So, we have looked at tectonic movement of plates. So, when there is a tectonic movement when two plates are colliding together or two plates are rubbing against each other, so there can be a huge amount of pressure and temperature that gets generated and because of that, a certain region of rocks may get metamorphosed. And this is known as regional metamorphism.

Typically metamorphism results in features such as foliation or lineation which is arrangement of minerals or grains in layers or lines or banding patterns which is alternate thick and thin layers in different shades. What is happening is that because of the shear stress, the minerals are getting arranged in bands, and because of that it looks like a structure which is having number of layers.

Now these layers are not the same as the layers as we saw in the case of the sedimentary rocks. Because typically in the case of sedimentary rocks we will have layers that are like this. They covers the whole region. So, these are the kinds of layers that we will find in sedimentary rocks. But in the case of metamorphic rocks what we will find is that there is say, a particular banding here, some banding here, some banding here and so on. But these are not continuous bands.

And metamorphic rocks are divided into foliated rocks that show these layering arrangements due to shearing forces or differential pressure, and non-foliated rocks that do not show these layers. So, foliated rocks include gneiss, schist and slate. And non-foliated rocks include things like quartzite.

So, in this way the metamorphic rocks can be formed through the action of pressure, volume and temperature changes on existing rocks. And these existing rocks maybe igneous rocks or sedimentary rocks or metamorphic rocks. We have also observed that in the case of sedimentary rocks they incorporate sediments from the existing rocks which may again be igneous, sedimentary or metamorphic rocks.

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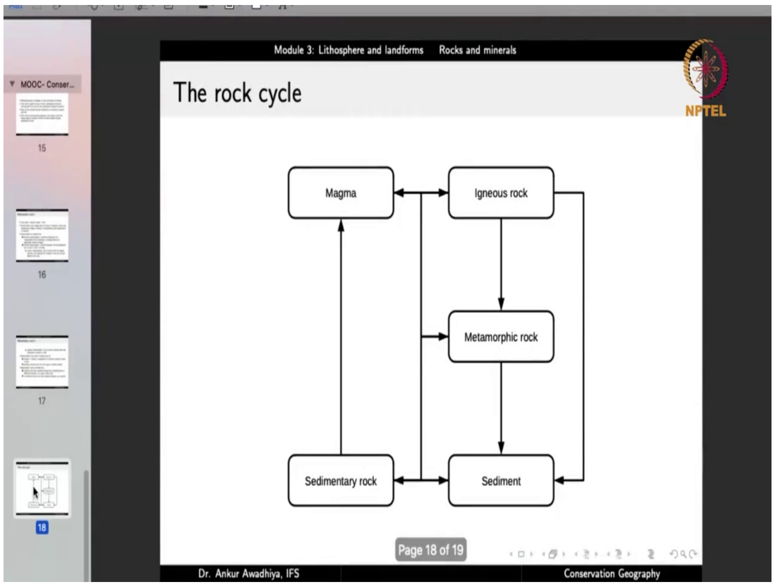

Now this brings us to the understanding that there is a rock cycle. Rocks are not static things. They are continuously going through changes. So, magma results in the formation of igneous rocks, but the igneous rocks can again melt back to form magma. The igneous rocks can, through the process of metamorphosis, convert into metamorphic rocks. But metamorphic rocks at the same time, they can melt back into magma. Igneous rocks can give rise to sediments. Metamorphic rocks can also give rise to sediments.

And these sediments can give rise to sedimentary rocks. But sedimentary rocks can also be broken and again release back the sediments. Sedimentary rocks can also undergo the process of metamorphosis and become metamorphic rocks. Or they may be molten back into magma and later on get converted into an igneous rock. So, the rocks are continuously undergoing changes. And this process goes on and on to change the material from igneous to sedimentary to metamorphic and so on and so forth.

So, that is all for today. Thank you for your attention. Jai Hind!