Soil Science and Technology

Prof. Somsubhra Chakraborty
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 03
Weathering and Soil Formation (Contd.)

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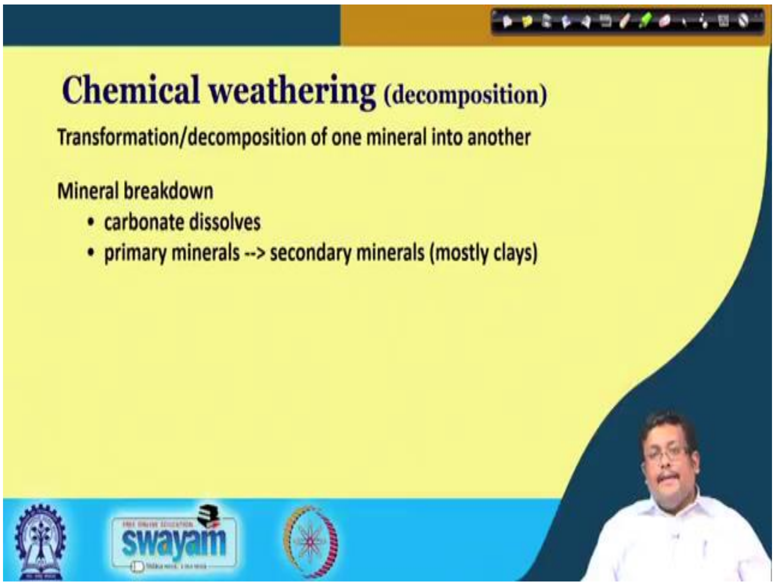

Hello friends, welcome to this lecture of Soil Science and Technology, I am Doctor Somsubhra Chakraborty from IIT Kharagpur. And in this lecture we will continue from the chemical weathering and in the last lecture, we have discussed about Weathering and Soil Formation. And we talked about what are the 2 major processes of soil formation, there we mentioned about weathering as well as pedogenesis and soil weathering is basically disintegration and decomposition of rocks by different chemical physical and biological activities.

And we talked about different types of weathering like physical or mechanical weathering then chemical weathering and as well as biological weathering, we talked about why we call physical weathering as disintegration, why we call chemical weathering as decomposition and why biological weathering is a combination of both physical weathering and chemical weathering. We talked about different factors which are responsible for physical weathering now remember that again, I am telling you that physical weathering only changes the size of rock fragments, it does not change the chemical composition of rock. The chemical weathering can only change the chemical composition of rock and that is why it is called decomposition.

So, we talked about exfoliation we talked about frost wedging, we talked about you know different other factors, which are responsible for physical weathering in the last lecture. And in this lecture, we will be covering different aspects of chemical weathering, what are the different processes of chemical weathering, I will show you some examples chemical of chemical reactions. And then we will see some examples of biological weathering and finally, we will go to pedogenesis and soil formation factors and different processes of pedogenesis.

So, let us start from chemical weathering. Now, in the last class, I have mentioned that chemical weathering is called decomposition because, it changes the chemical nature of the soil and some examples are carbonate dissolve dissolving of carbonates and conversion of primary minerals to the secondary minerals. I told you that primary minerals are present mostly in the rocks whereas, secondary minerals are mainly present in the clay fractions and some primary minerals like quartz are predominant in sand and silt fraction of the soil.

So, sand and silt are chemically inert in nature whereas, clay is chemically reactive, because of the presence of this secondary clay minerals and we will talk in details about the secondary clay minerals in their structure and their physical and chemical properties in the coming lectures. So, let us start with different processes of chemical weathering or decomposition.

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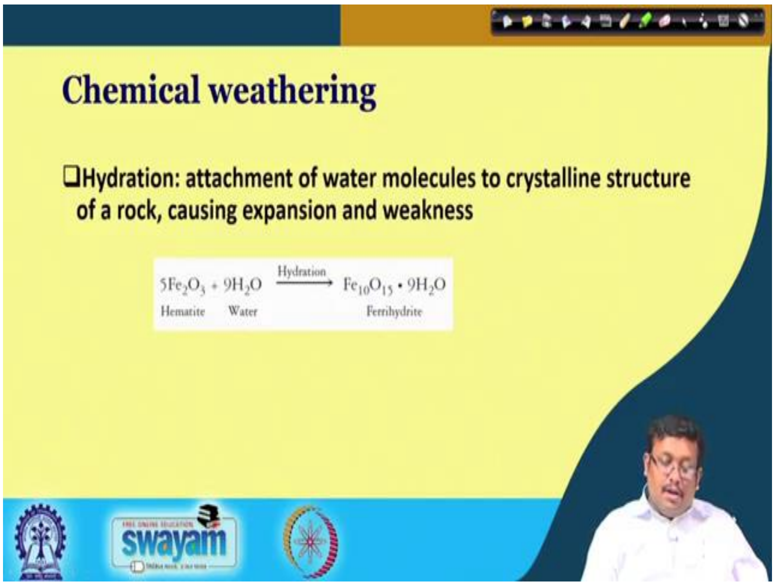

So, first process is hydration; now hydration is basically the attachment of water molecules to crystalline structure of rocks causing expansion and weakness. So, it is an important process of rock breakdown as well as change in their chemical composition as you can see from this chemical reaction, where hematite which is an important iron bearing mineral is reacting with water and as a result it creates due to the process of hydration, it creates ferrihydrite which is a completely new mineral.

So, this is an example of chemical weathering and when this type of we know chemical alteration occurs, there will be; obviously, change in their physical stability and when there is a change in physical stability or susceptibility to weathering there will be further breakdown of minerals.

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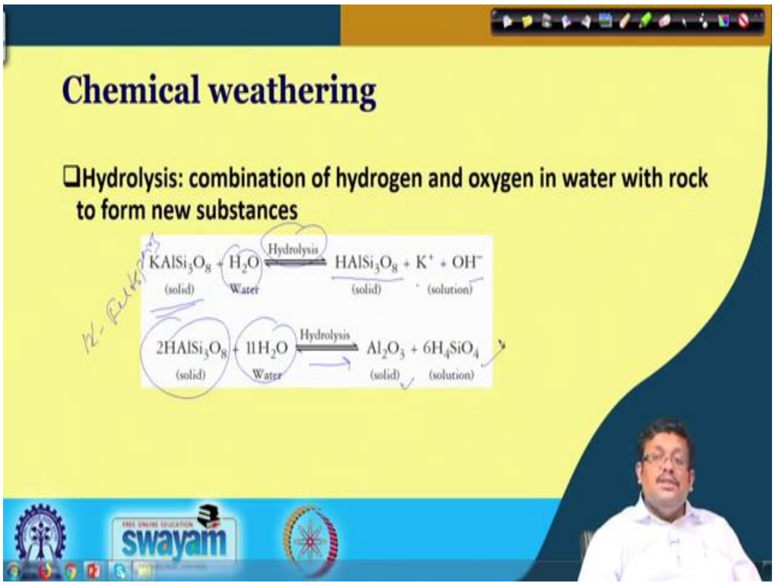

So, what is the next one? The next one is the most important that is called hydrolysis. It is a most important process of chemical weathering which says it is combination of hydrogen and oxygen in water with rocks to form new substances. So, as the name suggest hydrolysis mean lysis of water; that means, when water you know dissociates into H plus and OH minus it. And this when it dissociates to H plus and OH minus and these H plus and OH minus when it reacts with any mineral and changes its chemical nature that is called hydrolysis. For example, here you are seeing it is a potassium feldspar, it is potassium feldspar.

Now, when the potassium feldspar reacts with water and in the hydrolysis process it converts into this HALSi 3O8 and also K plus and hydroxyl. In this in the subsequently, you will see that this HAL 3 S i O 8 reacts with water in hydrolysis process to form aluminium oxide or alumina and silicic acid. So, you can see as a result of water breakdown and it is combination with potassium feldspars, we are getting 2 end products that is aluminium oxide and silicic acid. So, the chemical nature of the minerals as we already know is changed.

So initially, there is feldspars and ultimately we are getting aluminium oxides as well as silicic acid. So, this is an example of hydrolysis process.

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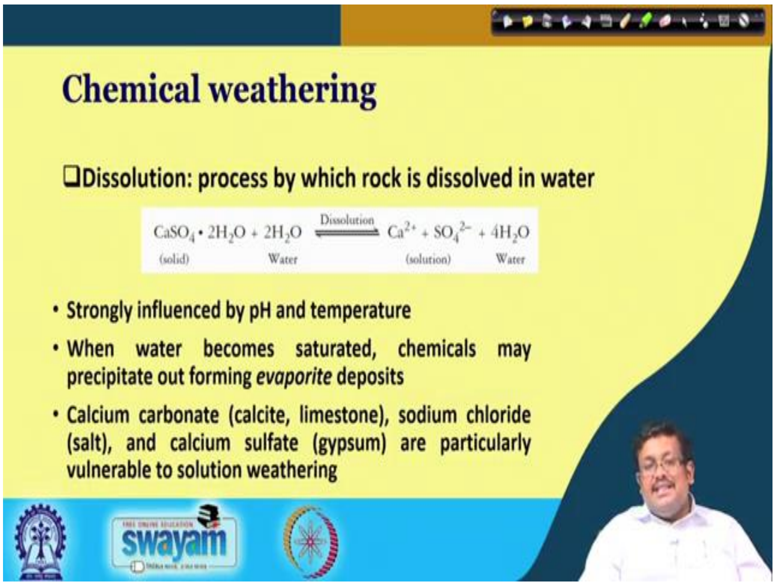

Now. the other process of chemical weathering let us see what are those dissolution. Dissolution is the process by which rock is dissolved in water. As we can see this is a calcium sulphate 2H2O; that means, it is a gypsum molecule, when it reacts with water it undergoes dissolution and ultimately forms this calcium ions, sulphate anions and water. So, this is an example of chemical weathering. Remember one thing that this chemical weathering is strongly influenced by pH and temperature. For example, in low pH condition that mean in acidic conditions, some minerals will you know will undergo different types of chemical changes.

So, that is why pH is a major factor for chemical decomposition and also temperature for example, in the with the increase of temperature, the rate of chemical reaction increases. So these 2, pH and temperature are the major factors for chemical weathering. And when water becomes saturated chemicals may precipitate out forming evaporate deposits, which is I mean you know you can see it in the salt affected soils due to the high evaporative demand when we know when the salt solution in the water moves through the soil and goes to the upper part of the soil and the water evaporates leaving behind only the salts and that forms a white crust of soil.

Now, if you go to Kutch areas of Rajasthan, you will find this type of soil and so, water initially was saturated, but due to the high evaporative demand water evaporated leaving behind these evaporate deposits. And calcium carbonates like you know the other names of calcium carbonate; obviously, calcite or limestone sodium chloride, which is a common table salt and calcium sulphate and gypsum are particularly vulnerable to solution weathering.

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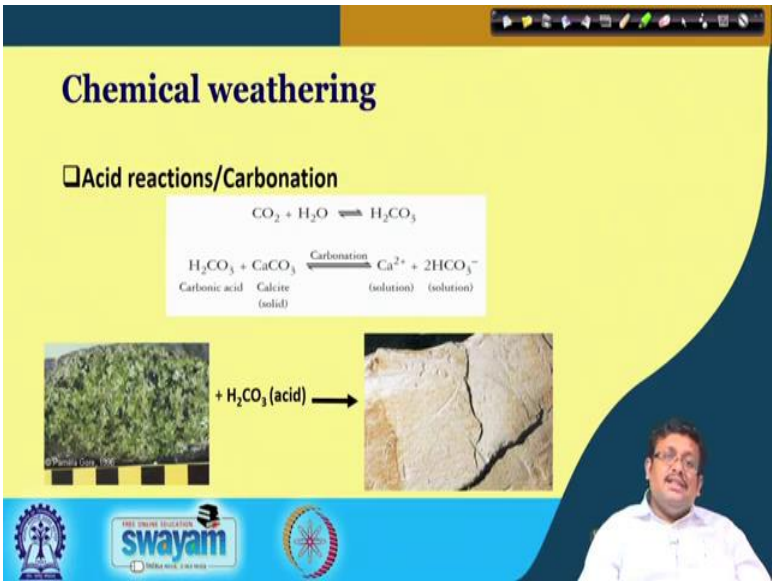

Another important process of chemical weathering is acid reaction or carbonation. Now, as I have already told you in the soil the partial pressure of carbon dioxide or the concentration of carbon dioxide is quite high due to the respiratory actions of micro and macro organisms. In the macro organism, different macro flora or macro fauna, in the macro flora; obviously, roots of the higher plants and in the micro organisms you know bacteria, fungi, algae and you know protozoa, nematodes are there. So, due to the respiratory reaction there is a you know there is a high amount of carbon dioxide in the soil air and this carbon dioxide when it reacts with water vapour in the soil it forms carbonic acid or H2CO3.

When this carbon you can see it reacts with calcite, which is solid and it changes the chemical composition to CA2 plus and 2HCO3 minus. So, this is an example of carbonation, because the mineral here is reacting with carbonic acid. So, one example of you know carbonation here, you can see there is a green colour mineral, which is basically olivine and when olivine reacts with carbonic acid it changes into other forms. So, this is an example of acid reactions or carbonation.

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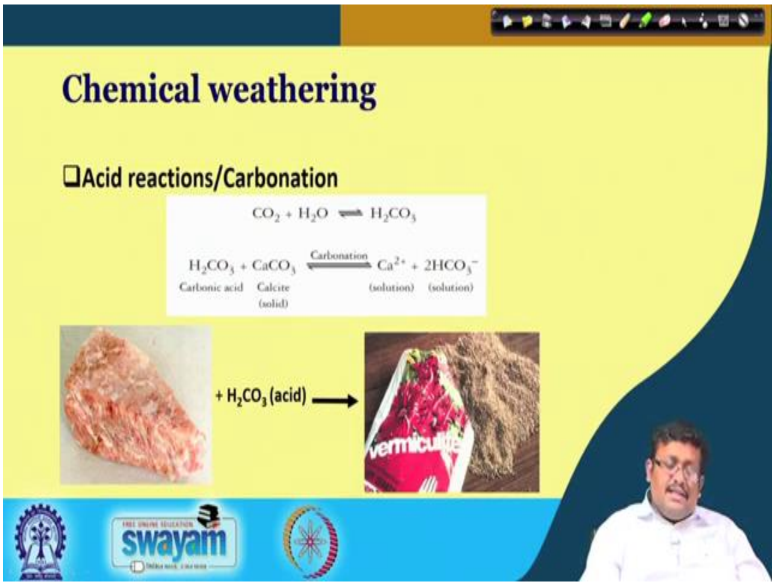

In the next slide, you will see feldspar is reacting with carbonic acid to form secondary clay minerals that is vermiculite and I will talk about vermiculite in details later on.

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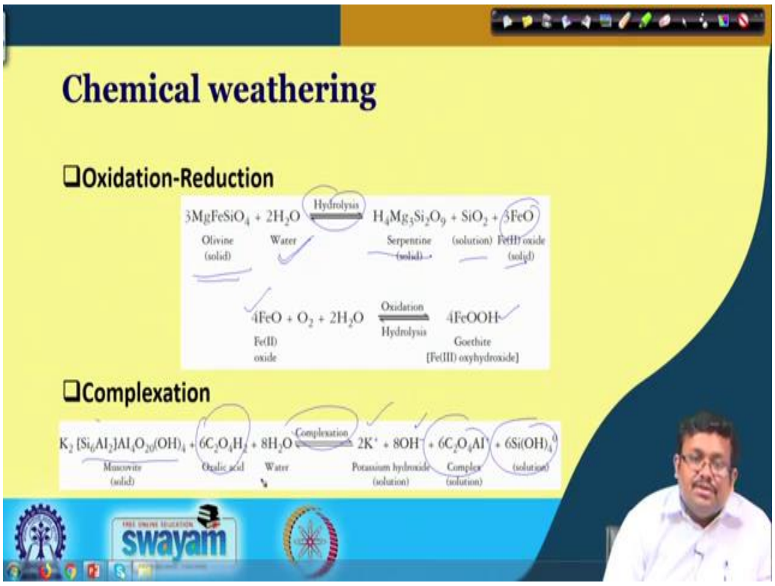

Another important reaction is called redox reaction or oxidation reduction reaction as the name implies, it is basically you know when one mineral oxidized to another form this is an oxidation and vice versa for reduction and so, you can see that olivine here, in the first step is reacting with water.

So, here it is an olivine which is a primary mineral, when olivine is reacting with water due to the hydrolysis process, it is forming another mineral called serpentine and apart from serpentine also there is some silica solution and ferrous oxides, which are solid in nature. And subsequently these ferrous oxides reacts with oxygen the or in other words it oxidized to form this goethite, which is another important iron bearing mineral. So, this is an example of oxidation or redox reaction and these type of reaction very frequently occurs in the soil due to chemical weathering.

Another important reaction is called complexation reaction. Now, as I have told you that there are millions and millions of microorganism present in the soil and also so, they secrets different types of organic acids, plant also secrets different types of organic acids through their root system. So, when so, this oxalic acid is an important organic acid, which is secreted by different microorganisms, our plant roots when these organic acids reacts with this muscovite, which is a solid mineral. It forms a complex and ultimately, it produces potassium ions, hydroxyl anions and a complex in solution and another compound, which is also remains in the solution. So, this is an example of complexation reaction. Now, this complexation also implies that chemical weathering is mediated by different types of biological agents, which I have already talked about.

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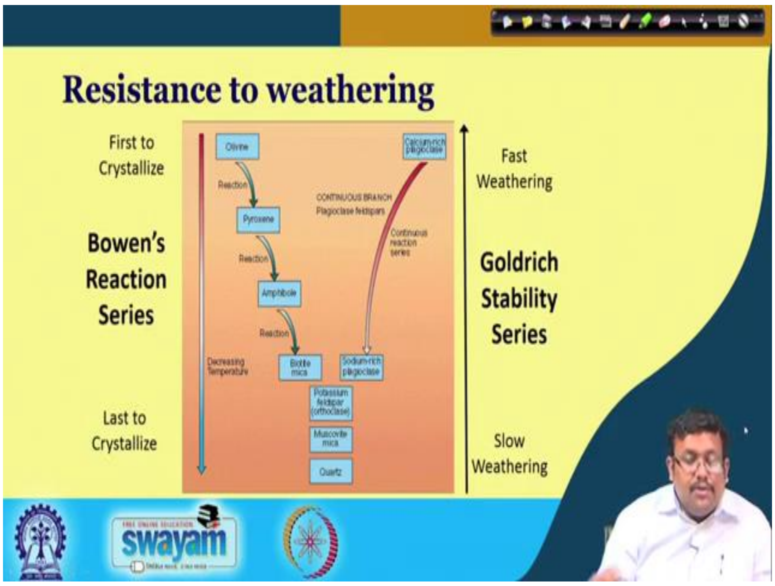

So, we have covered what the physical weathering, we have covered the chemical weathering, we have learned about different types of forces, which are responsible for physical weathering and we have learned about different types of process for chemical weathering. However, a question always comes to our mind that we have a you know we have a range of minerals, which are present in the earth's surface, how can we distinguish them based on their susceptibility to weathering, what are the criteria's?

Now, to show the stability of those mineral it is important to discuss about these Bowen's reaction series as well as Goldrich stability series. Now, Bowen's reaction series basically shows those minerals chronologically, which crystallized from molten magma or in other words, when there is a molten magma what which mineral will crystallize first and which mineral will crystallize second and so on so forth. This series is called Bowen's reaction series. So, as you can see from here, olivine is the first mineral which crystallizes from the molten magma followed by pyroxene, followed by amphiboles and then biotite mica, potassium, feldspars, muscovite mica and quartz. And similarly from calcium this rich plagioclase feldspars to sodium rich plagioclase feldspar, plagioclase feldspars it is a series of feldspars.

Now, as you can see this is the chronological list of minerals, which will crystallize from molten magma. And the Goldrich stability series is just opposite that is that says that the mineral, which crystallizes first in the Bowen's reaction series is most susceptible to weathering or inner in other words, the mineral which crystallizes last is very slowly weatherable. So, these 2 series I mean they are in opposite direction; obviously, according to these series we can say that quartz is very slowly, I mean quartz weathered very slowly whereas, this plagioclase calcium, rich plagioclase feldspar as well as olivine they weathered very fast. So, when there are 2 different rocks of different composition, if we compare their Bowen's reaction series or Goldrich stability series, it will be easy for us to predict which one will weather first.

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Now, this slide shows biological weathering, now biological weathering as I told you can be both chemical and mechanical in nature because, as you can see roots pry apart or splits apart, these rocks and root also produces acid that dissolves the rocks and there are some also burrowing animals. And you know different types of; different types of plant species, which can occur over the earth's over the rock surface and there may be some algae's and all these reacts on all these you know exerts pressure for physical and you know chemical breakdown of rocks. And although these macro organism essentially produces the physical forces for breakdown of the rocks, sometime these smaller micro organisms like micro flora, they exert you know they secrete some chemicals, which reacts with rocks and changes their chemical structure. So, this is an example of biological weathering.

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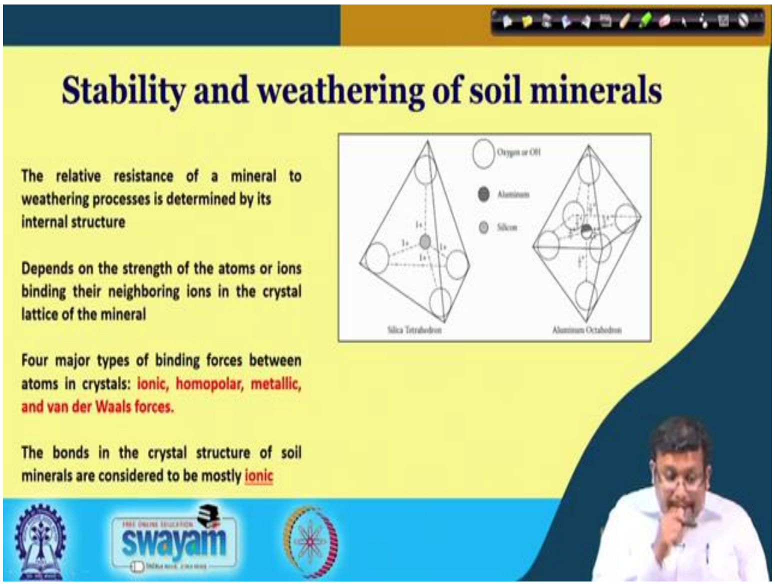

Now, one important thing comes to our mind that what is the reason behind the stability and weathering of soil minerals? So, to have a basic idea about the stability and weathering of the soil minerals, we need to have a good idea about crystal chemistry. Now, the relative resistance of a mineral to weathering process is determined by it is internal structure and depends on the strength of the atoms or ions binding their neighbouring ions in the crystal lattice of the mineral. And remember that there are 4 major types of binding forces between the atoms in a crystal, these are basically ionic, homopolar, metallic and Van der Waals forces. Although, you know this ionic force is the most important from the soil as far as the soil is concerned and the bonds in the crystal structure of the soil minerals are considered to be mostly ionic.

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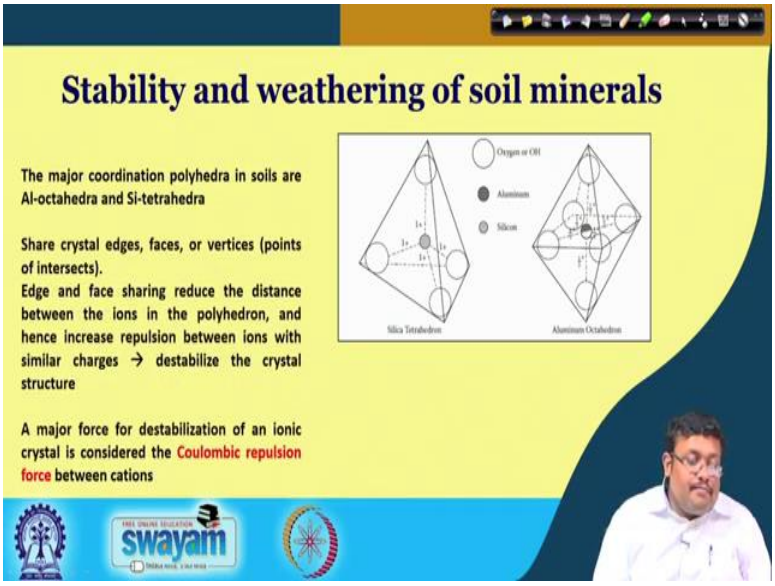

So, let us see what are the major coordination polyhedra in soils. So, there are 2 major coordination polyhedra in the soil, one is called silica tetrahedral, another is called aluminum octahedral.

Now, in the silica tetrahedra you will learn in details in the subsequent classes that these are basically the building blocks, these 2 are basically the building blocks of any soil, depending on their structural arrangement, depending on their arrangement, we can differentiate different types of chemicals and in the clay minerals their specialized arrangement has developed different types of clay minerals. Now this is called silica tetrahedron, now in the silica tetrahedra you can see at the centre, there is a silica atom or silica cation, which is surrounded by 4 equidistant oxygen atoms. So here, you can see a coordinates the coordination number of silica here is 4. Whereas, this is aluminium octahedron where a aluminium iron is surrounded by 6 hydroxyl anions. So here, the coordination number is 6 and these 2 are the major coordination polyhedra in soils and different arrangement and different sharing of these tetrahedron and octahedron give rise to different clay minerals and different other primary minerals.

Now, remember one thing that with these coordination polyhedral, these 2 types of coordination polyhedral, they share their crystal edges faces or vertices which are point of intersects. Now, when the edge and face sharing reduces the distance between the ions in the polyhedron hence, increase repulsion between ions with the similar charges;

obviously, there will be destabilization of the crystal structure. Obviously, when the similar 2 ions comes in close proximity come in close proximity; obviously, there will be repulsion and a major force for destabilization of an ionic crystal is considered the columbic repulsion forces between cations. So, this is why one mineral shows different susceptibility to weathering than other mineral ok.

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So, what are the major factors that affects weathering? I mean so, climate this is the prime factor that affects weathering and specially the temperature and moisture characteristics. Now, in case of chemical weathering, chemical weathering is most effective in areas of warm or moist climates and in those climates decaying vegetation creates different types of acid that enhances weathering. And these chemical weathering is least effective in polar regions because, in polar region water freezes into the ice. and if you remember all the important process in chemical weathering requires water you I mean in starting from hydration, from carbonation, from hydrolysis, all requires water for chemical reaction, but if water freezes into ice So, there will be no chemical reaction. So, that is why, it is least effective in polar regions and obviously, mechanical weathering is enhanced, when there is a frequent freeze and thaw cycles.

So, in a nutshell mechanical weathering is prevalent in extreme weather conditions whereas, chemical weathering is prevalent in moist and humid climate, I mean warm and humid climate.

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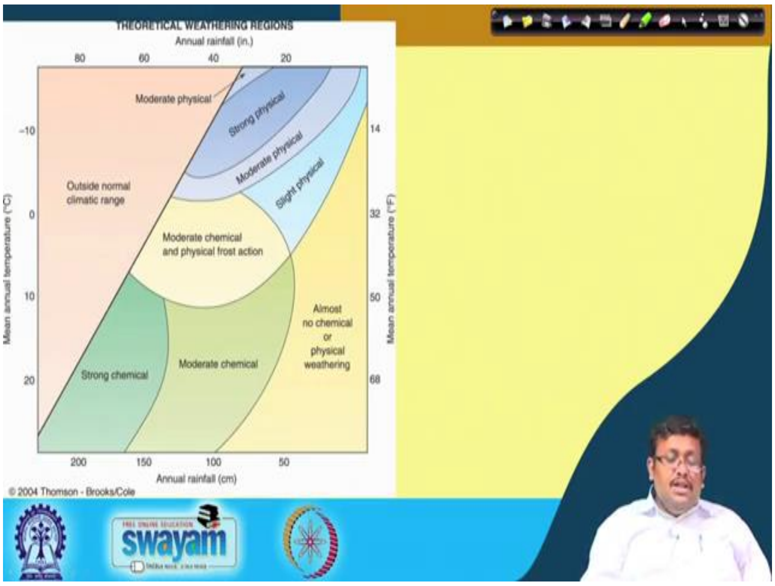

So, these graph basically shows in which region which I mean what weathering process is predominant. Now, in the x axis, you can see this is an annual rainfall it starts from 0 then goes to 50, 100, 150 and so on so forth into this direction. and in the in the y axis there is a mean annual temperature from minus 10 to 0 to 10 to 20 as we can see in this zone, where there is a high annual rainfall around 200 or more than 200 centimetre as well as 1, I mean annual temperature is also high, there will be predominance of chemical weathering. Whereas, when the annual rainfall goes down to below 150, there will be moderate chemical weathering and here weather is a low amount of annual rainfall, there will be almost no chemical weathering.

So, as you go from this area to this area; obviously, there will be moderate chemical and physical frost action because, it is nearby to this 0 degree centigrade, where frosting basically occurs. And when we go from this region to this region due to the extreme temperature, because of this minus 10 degree centigrade there will be strong physical weathering. So, this chart gives us an overview in which condition climatic condition or climatic I mean combination what I mean physical weathering or chemical weathering or other type of weather, I mean physical weathering or chemical weathering is prevalent. So, let us wrap up here in the next session or next lecture, we will talk about more about different factors of soil formation as well as different pedogenesis process.

Thank you.