Geomorphology

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Lecture – 12
Weathering & Soil Formation (Chemical & Biological Weathering)

So friends welcome to this lecture series geomorphology and we are discussing about this chemical weathering mostly the oxidization process. So you know the oxidation process mostly oxygen is involved here and water is involved there. That means if you summarize in an environment which is moist and oxidized is more prone for oxidation as compared to dry air. So if you analyze the geological past of the geological history then you can say oxidation in certain geological times were more prone for development of iron deposits.

If you see this present day iron deposits which were dated back to 2.5 billion years ago. Then there were certain times in Precambrian rock reach in iron oxide are a widely distributed on the continents. Most of them they are dating back to 2.5 billion years and when our evolving atmosphere began to be oxidized to be fast. That is why our commercial deposits commercial iron deposits are mostly due to this oxidation.

So this is all about our oxidation process and now we will discuss another prominent reason for chemical weathering it is called carbonation. In first in oxidation oxygen was playing major role. Water and oxygen was playing major roles. Here carbon dioxide will play major role and in oxidation we have iron which was mostly affected or iron bearing rocks were mostly affected. In carbonation the carbonate bearing rock will be mostly affected.

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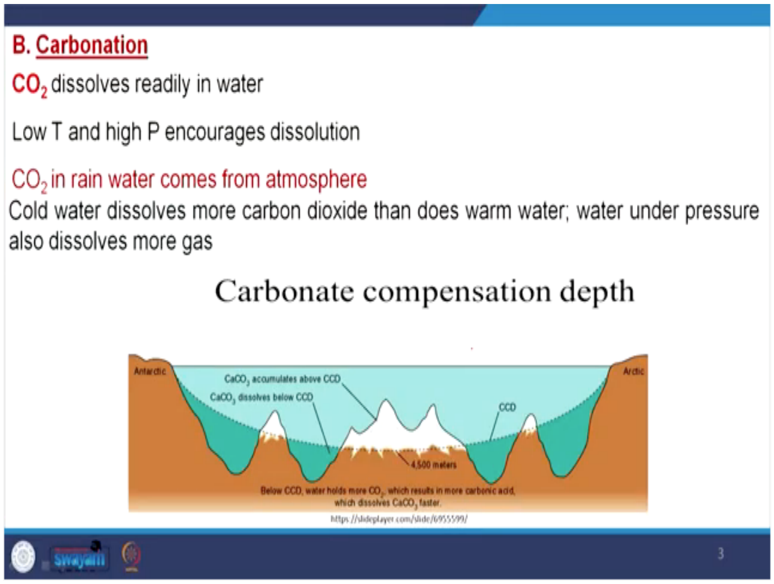

We know carbon dioxide it dissolves in water and it is form a weak acid which is called carbonic acid. Low temperature and high pressure encourage dissolution. Carbon dioxide in rainwater comes from atmosphere cold water dissolves more carbon dioxide than does warm water. And water under pressure also dissolves more gas. So you might have heard about this term calcium carbonate compensation depth which is an imaginary line imaginary level in this ocean body below which calcium carbonate will not be able to precipitate.

Because if you imagine there is a basin here and gradually we are going to more and more depth. So as we know more depth means more water pressure, water column depth is more or water column height is more. So that means more pressure at depth and we know here more pressure water under pressure dissolves more carbon dioxide. So that means water below is more acidic as compared to the surface near surface water.

So once the acidity of water increases more and more carbon dioxide is involved there. So that means the water at depth is more acidic. So that is why whenever this calcium carbonate precipitate from the surface. This acidic water reacts with that and finally it dissolves it out. So that is why up to this distance up to this depth this is average is 4,500 meter. Present day this CCD or calcium carbonate compensation depth in ocean body is about to 4.5 kilometer.

So below 4.5 kilometer the ocean water becomes acidic due to high content of CO2. That is why there will be no carbonate deposit below that level. So nowadays if you analyze those limestones, the dolomites that has expose to the surface we can say that those were nearly shallow surface deposits nearly shallow ocean depth deposits. Because at great depth the ocean water will be acidic and would not allow the calcium carbonate to precipitate.

So that means we want to say the water and carbon dioxide mixed together forming this carbonic acid and which has a major role or major reagent for dissolution of calcium carbonate rocks and it is a prominent way or prominent factor or weathering of rock mostly the carbonate rocks.

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Then vegetal material once vegetal material as decaying it produces carbon dioxide. If you see here carbon dioxide content in soil is 10 to 1000 time than as compared to the present atmospheric carbon dioxide content. Present atmosphere is composed of 0.03% of carbon dioxide. However this column soil column here the soil column it is rich in carbon dioxide. It is 10 to 1000 times more that means 30% of the carbon dioxide it is restricted within this soil profile soil surface.

Mostly those zones which is plant effected which is effected by plant roots from few meters from the surface from 4 to 5 meters from the surface. This soil pores they are mostly filled with CO2. Air that fills pore spaces in soil is greatly enriched in carbon dioxide by decay of humus. So here if you see these two figures association. This is the depth of soil profile and this is soil CO2 content. So that means once we are going deeper and deeper the CO2 content is increasing and increasing.

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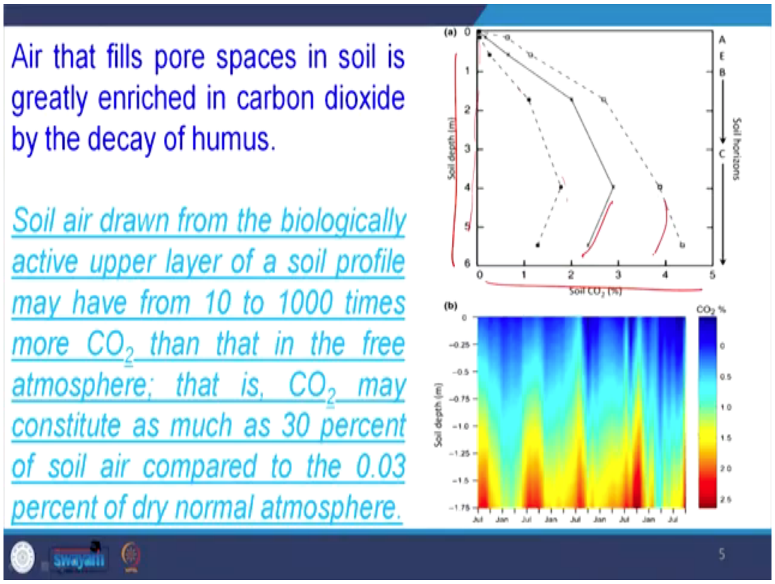

But after certain depth that it is decreasing because here the organic process of this humus is getting reduced. So up to that depth where up to which the humus or the effective of biological activities the effect of biological activities there up to that level the CO2 content gradually increases and it has been calculated that the CO2 content of that biological affected area or biologically affected layer or up to which this biological affect is there in a soil profile it contains 30% to 40% of this CO2 or carbon dioxide as compared to this general atmospheric content.

And very interesting to note it here that this content of carbon dioxide annually varies that means if you see the 2 parts of a year that means one is the summer part and other is the rainy part. Here if you see in July this is the scale is given. It is this red color is high content of 2.5% and this blue is nearly 0 or somewhat in between this scale varies. So here you see this is for one year, this is another year, third year, fourth year, fifth year like so.

So within a year if we confine ourself in July and January, in January the CO2 content of soil is less. However in July the CO2 content is more. Why? Because in July we have rainy season rainwater it percolates down. It takes organic matter from surface to the subsurface through this pore spaces. So that is why if were going down that means from surface to subsurface due to this percolation of organic matter through water through rainwater this CO2 content also varies.

But here in January this due to dry season there will be no raining and finally the organic matter they are restricted to the surface restricted to the near surface. That is why the CO2 content is different. So though the soil contains 30 to 40% of the carbon dioxide in a soil profile. But it is not same throughout the year. In rainy season the CO2 content increases and in the summer the CO2 content decreases.

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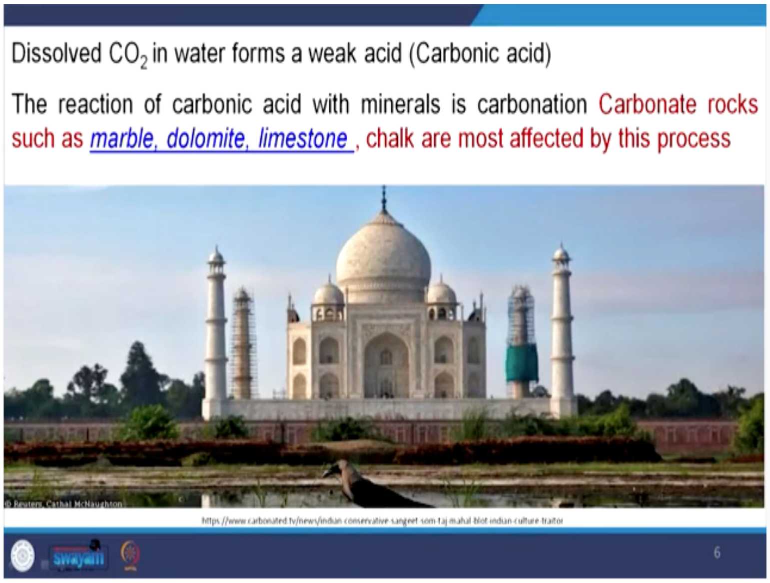

Then the dissolved CO2 it forms carbonic acids and its attacks the rocks like marble, the dolomites, the limestone, the chalk they are mostly affected. And that is why our famous Taj Mahal it is somewhat decolorize like this red color or grey color painting is grey color appearance is there due to this carbonation reactions. And this is some treatment is going on. Some treatment is going on to make this rock resistance or not reactive for the atmospheric CO2.

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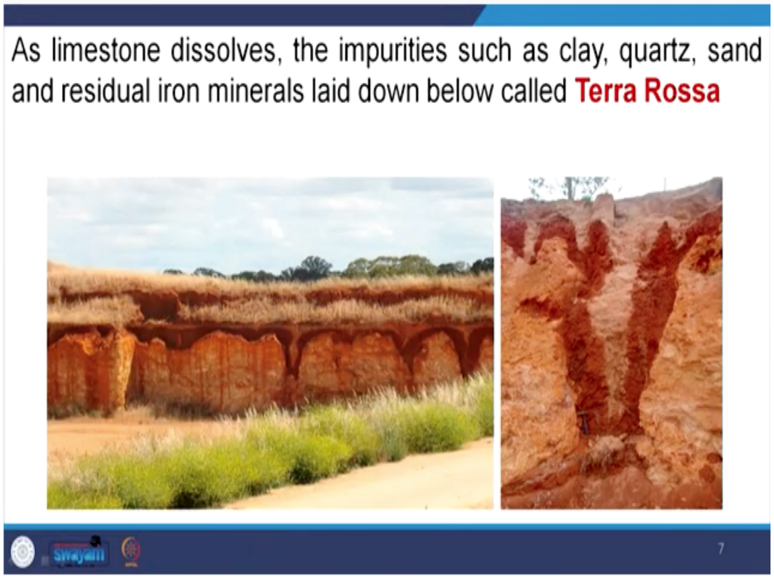

In the limestone area not only limestone is there within the limestone some impurities also there, some quartz is there, some other minerals is there, some iron content is there. So now if this type of impure limestone are allowed to react to this carbonic acid. This carbonate part will dissolve out and the remaining part or the residual will be mostly which is nonreactive to this carbonic acid it is mostly quartz, feldspar, iron oxide like that.

So those residual material which remain as resistant layer on the surface. This is called Terra Rossa. The geological term is Terra Rosa. So Terra Rosa mostly it is found in impure limestones. The limestone dissolves out or carbonate dissolves out due to reaction with the carbonic acid and the impurities or this minerals which was remain earlier it was a part of limestone that is now lying here undissolved.

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In limestone topography that are there is a particular type of topography geological term designed this is called Karst topography. Karst topography is a chemically reactive surface to the atmospheric CO2 and carbonic acid. So these type of irregular topography you see here this topography is not flat ridges, grooves irregular erosion like this. So this is called karst topography. So now if it is see this figure or this photograph the surface is very irregular.

Similarly if you take a cross section also this is a cross section. So that means if you see here these are hidden caves are there. Hidden hollows are there. So from this caves we can say there is some stalactite and stalagmite structures are formed. Stalactite and stalagmite this or this these are formed due to dripping of water from the surface of a cave. From the surface of a cave due to dripping of water some carbonate materials they looks like it is hanging as groups it is hanging like fingers like so.

So these are called stalactites. Here if you see in this figure these are the stalactites. Any limestone terrain you go you will find this type of hanging finger like even a column like this much column like materials they are hanging from the roof of this cave below the subsurface toward the surface. So this is called stalactite.

Similarly where the water is dripping down and is falling on the caves surface here with continuously dripping of water continuously accumulation of calcium carbonate. Some of these columns they are growing from surface up to upward these are called stalagmites. So stalactite which is hanging from the roof below. And stalagmite which is ranging from surface to upward. So this is stalactite this is stalagmite. So these are this typical structures typical features in carbonate terrain which is effected by chemical weathering.

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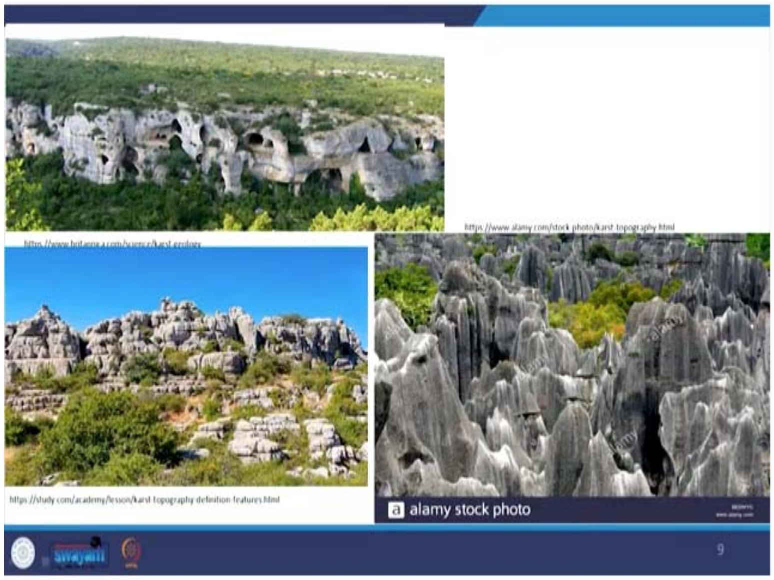

These are few other photographs of the karst topography very regular topography rugged surface and mostly it is by calcium carbonate.

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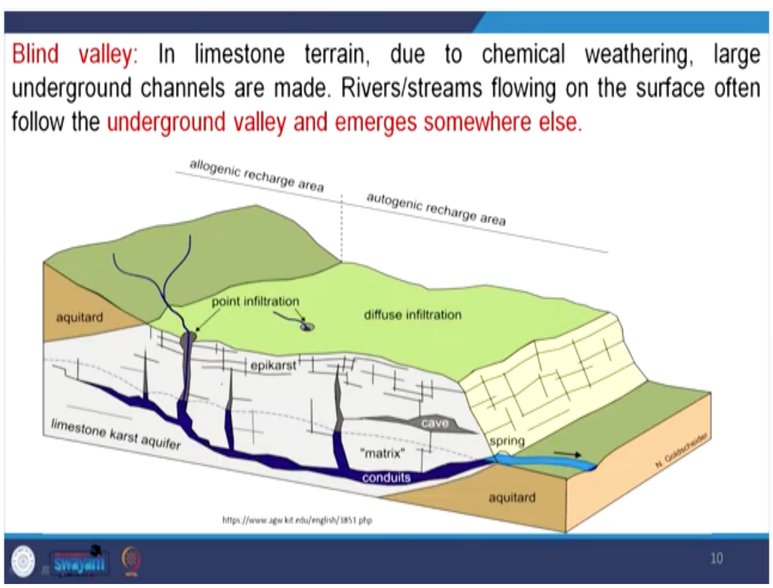

There is a very peculiar feature in karst topography or in carbonate terrain that is called blind valley. Blind valley means it is valley which is not looking who is blind. That means from the surface you cannot see. But there is a tunnel type. There are many tunnel like interlinked tunnel type features they are below this subsurface. So suppose a river is coming a stream is coming on the surface as the water is reactive to the limestone it dissolves the limestone and finally it goes down.

So this valley of this stream it looks missing from the surface. But there are many valleys lies in the subsurface. They mix they interconnected with each other finally river forms and river sometimes it comes out from the subsurface to surface. So from here now you see here this valley was looking up to here now in the surface the valley is looking here. In between this distance the valley is blind. That means in the subsurface.

The subsurface valley is continuing. The tunnels are interlinked. The natural tunnels natural caves they are interlinked. So this is called blind valley. So blind valley is a typical feature of karst topography that is found in the limestone terrain or in the carbonate terrain.

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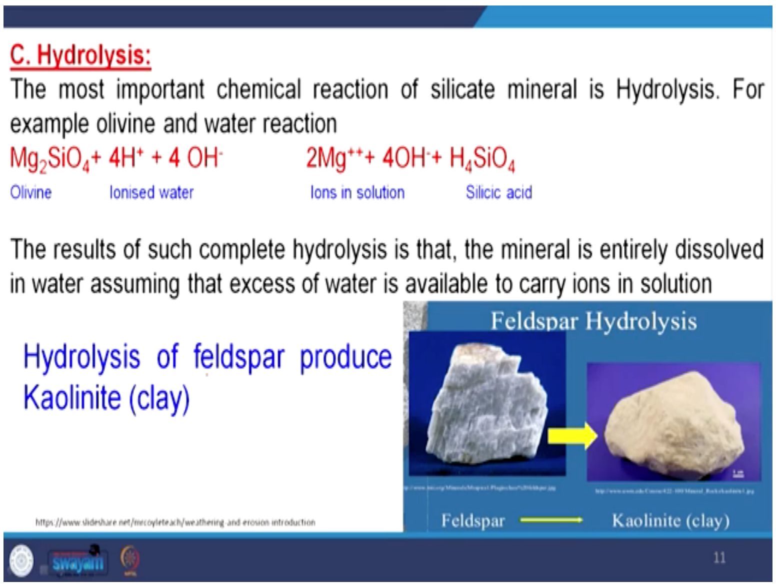

Then third type of chemical weathering it is called hydrolysis. Hydrolysis is for silicate rocks. For oxidation it is for iron bearing rock. Carbonation it is for carbonate bearing rock. Hydrolysis it is for silicate rocks. The most important chemical reaction is silicate mineral. Silicate mineral it is hydrolysis. Silicate mineral that means the minerals which are formed in the Bowens reaction series starting from olivine to quartz.

Similarly, starting from it is anorthite to quartz. So all those minerals which follow this Bowens reaction series of crystallization they are the silicate minerals. And hydrolysis plays major role in chemical reaction with this type of silicate minerals. For example if you see here olivine it is reacts with ionized water. So it is forming silicic acid and ion in solution and the silicic acid is very much reactive. It is the silicic acid it reacts with the surrounding and its chemically alters the rock.

The product is the mineral is entirely dissolved in water assuming that excess of water is available to carry out ions in solution. Hydrolysis it is feldspar produces kaolinite. If you see here this is feldspar and this is kaolinite and kaolinite is a clay. So many of this major clay deposit nowadays we are extracting where mining commercially. This was the product of chemical weathering.

So had weathering not been there clay we would not have been getting clay here. So that means I want to say weathering plays major role and deposition of minerals on the Earth's surface too.

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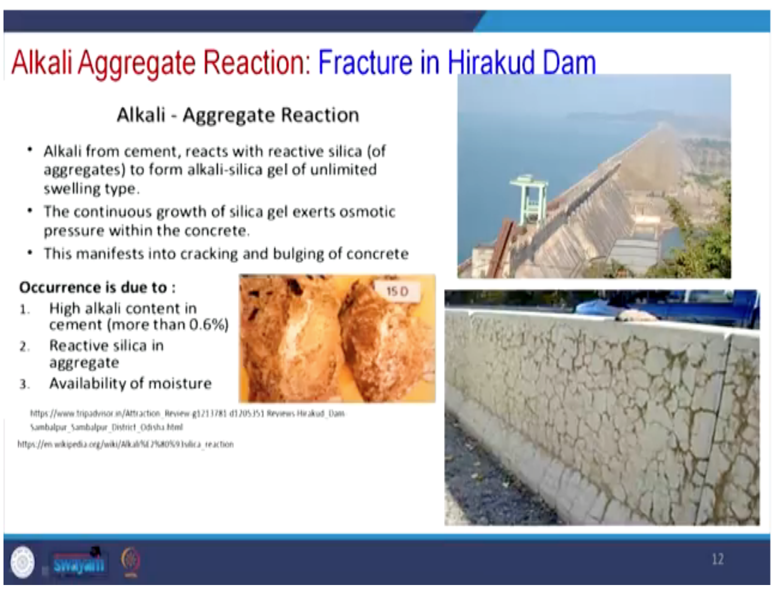

Then this type of hydrolysis is also sometimes plays very dangerous to the engineering structures. For example here alkali-aggregate reaction and fracture in Hirakund Dam. So that is why how what is this alkali-aggregate reaction? If you want to understand it if you see here alkali from cement reacts with reactive silica or aggregate form alkali silica gel unlimited swelling type. It has to be understood here.

So this alkali-aggregate reaction this swelling type that means whatever this product is that alkali silica gel is formed. That gel is unlimited swelling type. So now if suppose we have a concrete structure within the concrete structure we are using cements, we are using this chips, this broken rocks which is of silicates is not it? So that is alkali from the cement is reacting with this silicates. So it is forming this alkali silica gel.

So once the alkali silica gel is forming it is swelling the system. So this concrete is swelled up. So that means cracks are developed. So once cracks are developed that means water try to percolate. So that means again another chemical reaction starts due to water. So that means I want to say the alkali-aggregate reaction it is a prominent type of weathering and prominent type of threat to the major engineering architecture.

So here we are talking about the Hirakund Dam which is in Odisha. This due to this alkali-aggregate reaction this type of cracks are developed. And those cracks are very much threat to these major engineering structure and finally failures. Why it occurs? Due to high alkali content in cement more than 0.6%. So that is why during choosing a cement so the cement industries the geologist or the chemist which are involved in the cement industry they must be aware about this content of alkalis in their cement.

If you are not able to choose the right cement that means you are not going to develop an enduring structure of long life. Second thing reactive of silica in the aggregates. So whenever choosing the aggregates we must be very aware about what type of aggregates we are choosing? Then availability of moisture it is available especially in this type of environment where that the humid and most environment this availability of moisture is plenty.

Similarly near dam or a reservoir it is always reacting. It is always in contact with the water. So that means there is plenty of moisture is available and if the cement and this concrete or these chips they are reacting each other and moisture is provided by this water the reservoir water then the alkali aggregate reaction it moves fast and finally very fast. There will be cracks developed in the engineering structures. This is due to alkali-aggregate reactions.

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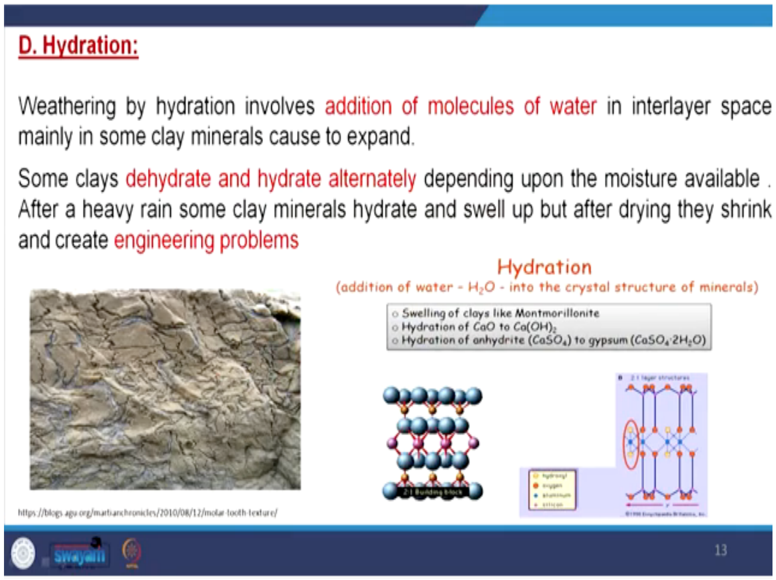

Then another type of chemical reaction it is called hydration. Hydration means it by addition of molecular water in the crystal structure mostly the clays. Mostly this clays dehydrate and hydrate alternatively depending upon the moisture available. After heavy rain some clay minerals hydrate and swell up and after drying they shrink down.

So alternative swelling up and shrinking down so it creates engineering problem. So this is hydration and dehydration. Hydration we are adding water where swelling up and dehydration were removing water we are shrinking down. So hydration and dehydration it creates engineering problems. Swelling and shrinking it creates cracks.

So that is why whenever we go for any major infrastructure development we must be sure that the basement or the base of this engineering structure the infrastructure does not have the swelling clays like montmorillonite, kaolinite all those are the swelling clays. So we have to remove them first and we have to go up to the fresh rocks. Otherwise we will be in trouble.

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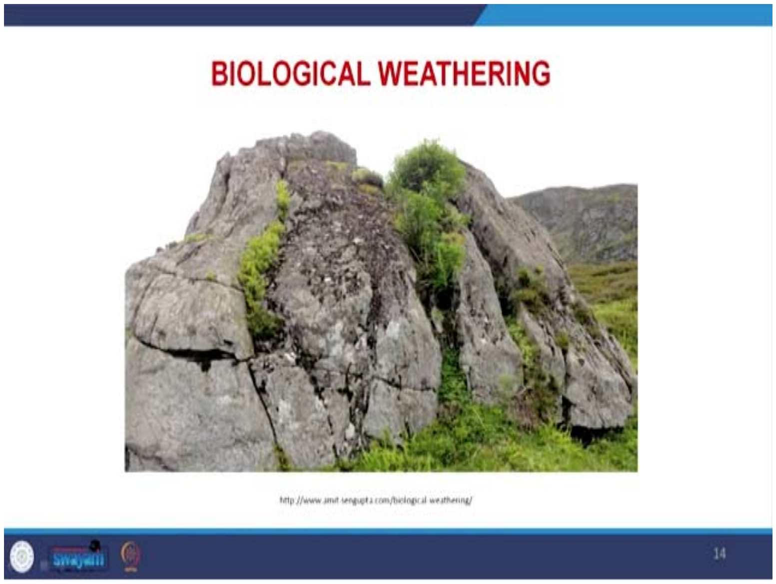

Then the third type of weathering it is called biological weathering. So far we are discussing this physical weathering or the mechanical weathering, the chemical weathering and here it is biological weathering. Here the biological factors like these plants, these fungus, these lichens, the human effect they are playing major roles in weathering of rocks. If you see here in this photograph there are vegetation along this cracks.

Once the vegetation grow up so this force or the pressure of the roots they again crack the rocks further cracks the rock. Similarly there will be fungus growth on the rock surface. The fungus growth also creates some reactive acids. So again it reacts chemically and chemical weathering takes place. So biological weathering sometimes the plants itself responsible. Sometimes the fungus they exert some acids they create some acids on the rock surface. So those acids they are chemically reactive and goes for chemical weathering.

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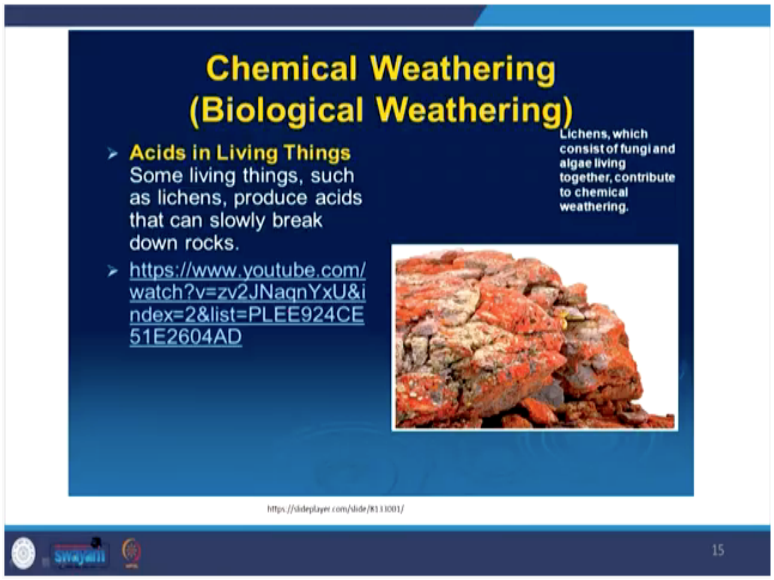

So chemical weathering and biological weathering that we are discussing here acids of living things. Living things means the lichens, the fungus they produce acids that can slowly break down the rocks. Now if you see here in the photograph. This is red color is the lichens. The lichens growth on the rock surface it is extracting some acid there and those acids it may be reactive to the surface or may not be reactive. But if it is reactive that means by some way it is helping chemical weathering on the rock surface.

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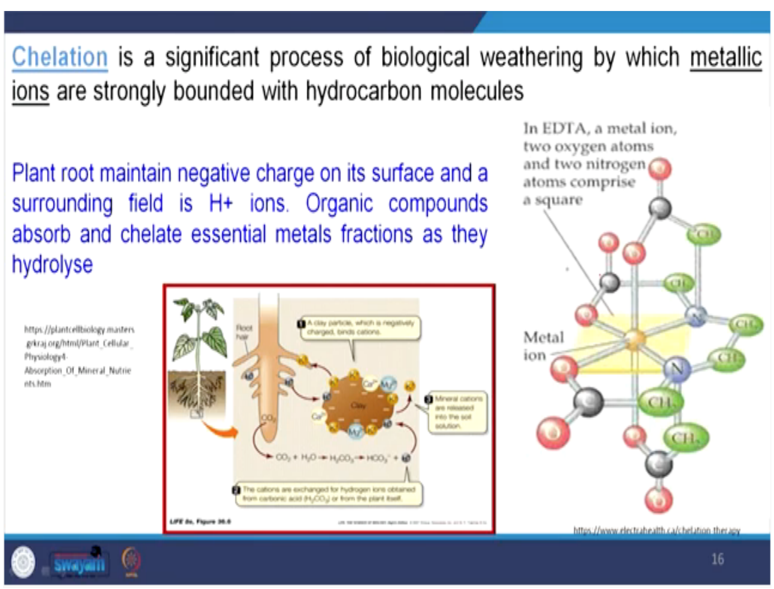

The most prominent type of chemical weathering is the chelation. Chelation is nothing it is the bond between the metal ions and hydrocarbons, metallic ions and hydrocarbons strongly bounded with hydrocarbon molecule with the metallic ions. Plant root remain negatively charged on its surface and surrounding field is hydrogen positive ion.

Organic compounds absorb and chelate essential metal fractions as they hydrolyse. So that means this plant root area or the rhizosphere this plant root area they are more prone for biological as well as chemical weathering as compared to the upper and lower part of the soil.

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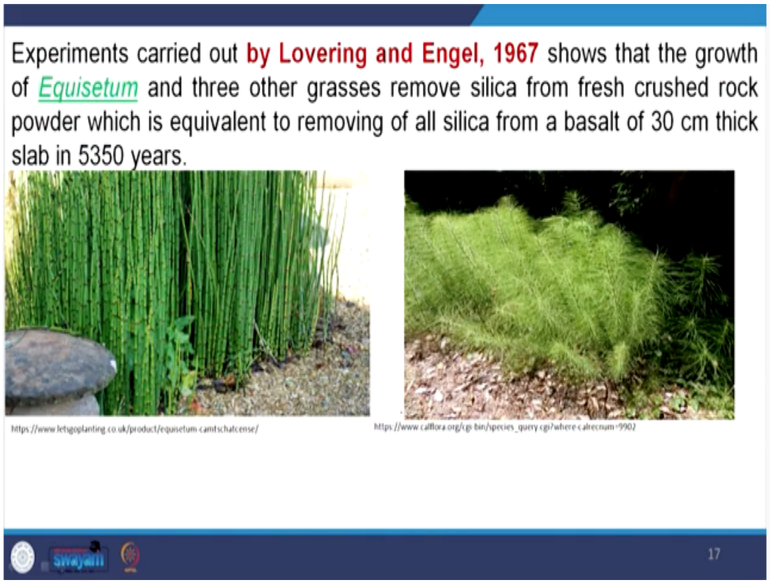

It was an experiment carried out this gentlemen Lovering and Engel in 1967. This experiment says 1 type of grass or plant that is equisetum and 3 other grasses remove silica from fresh crushed rocks and it is calculated that removing of all silica from basalt of 30 centimeter thick slab in 5350 years. So that means if we have 30 centimeter thick basaltic slab and we are allowing these plants to grow on it.

Within this 5350 years those plants are able to remove all those silicas from this basaltic slab. So now imagine if this type of weathering takes place. Silica is removed from the system then the remaining will be enriched there. So this is 1 type of biological weathering and is the most prominent type of biological weathering where the metallic ions are associated with hydrocarbon molecules.

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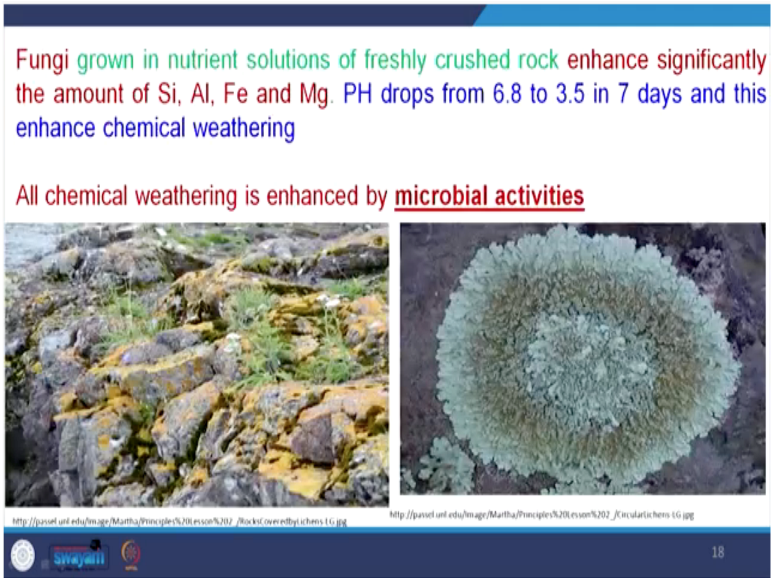

Fungi or fungus grown on nutrient solution on freshly crushed rock enhance significantly the amount of silicone, aluminium, iron, magnesium as the result pH drops from 6.8 to 3.5 in 7 days. Once pH drops that means the water becomes acidic and again it is promotes to chemical weathering. It enhance chemical weathering. So that means growth of nutrient solutions, growth of plants on the nutrient solution. It has 2 effects one is biological weathering and other is chemical weathering. So chemical weathering enhanced by molecular biological activities microbial activities.

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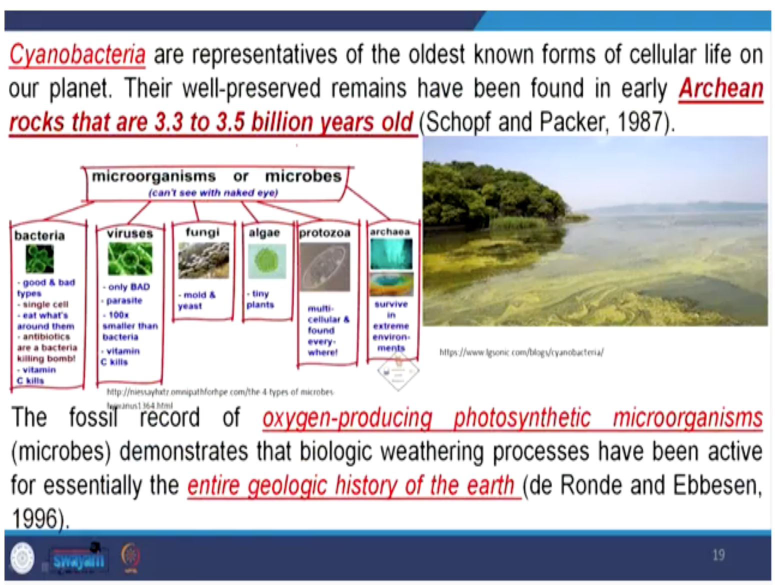

Cyanobacteria are the representative of the oldest known form of cellular in the Archean rocks. So now you imagine from this Archeans to present if cyanobacteria is working so that means by directly or indirectly it is reacting with the rock surface and weathering is continuously moving on from Archean to recent .

So the fossil record of oxygen reduced producing photosynthesis microorganisms demonstrate that biological weathering processes has been active for essentially the entire geological history. Why? Because we know from this Precambrian, from the Archeans we have those types of cyanobacterias are present. So those are removing this material pH is getting dropped. So this becomes rock becomes chemically reactive and chemical reaction and biological weathering, chemical weathering that is continuously going on from Archean to recent dates.

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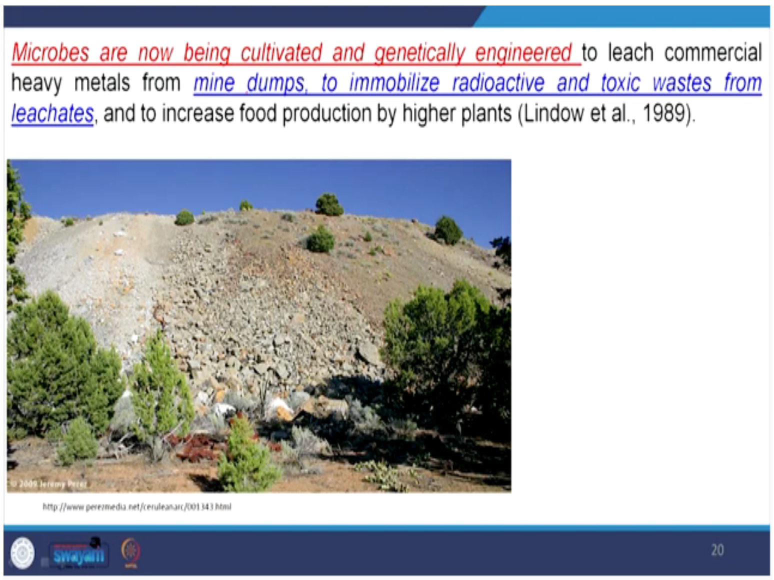

Microbes has positive effect. Nowadays we are using judiciously for these microbes for enrichment of metals in mining dumps. Because we know the mining dumps we are not able to extract the whole material in a dumps also, in a over burden also we have some metals. Now if you were allowed to grow these type of bacteria on this mining drops. So that means they will be removed your silica, they will be removed your unnecessary materials.

So this material which will be there as a residue that is you know metallic form. So now microbes are being cultivated genetically engineered to leach commercial heavy metals from the mine dumps to immobilize radioactive and toxic waste from leachates and to increase food production by higher plants. So that means we have genetically engineer some of these microbes for our benefits. So this is artificial biological weathering. We are genetically engineered. We are purposefully weathering these rocks for our own benefit.

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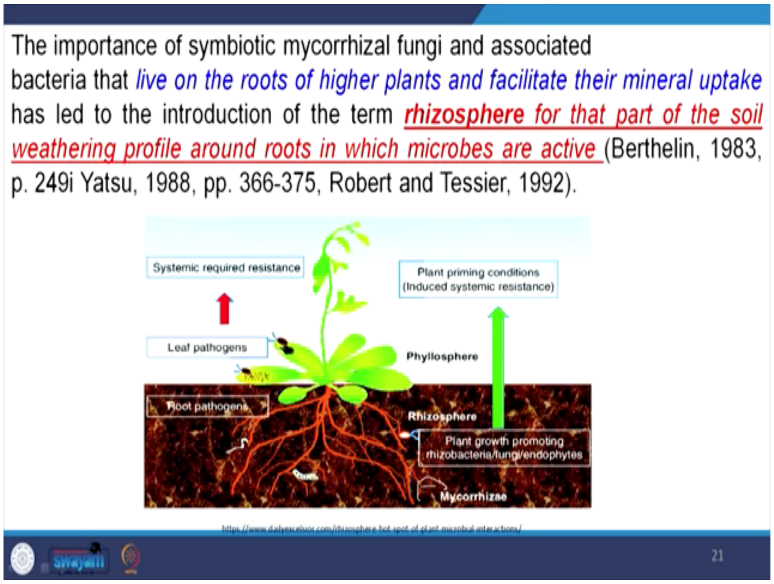

The importance of symbiotic mycorrhizal fungus and associated bacteria that live on roots of higher plants and facilitate their mineral intake has led to the introduction of this term rhizosphere for a certain horizon of soil weathering profile around which the roots in microbes are active. If you see here this is the soil profile and this is the root zone. This is called rhizosphere.

This is biologically active layer. This rhizosphere it is microbes are active. So microbes are active biological weathering, chemical weathering they are promoting. So this plants is able to take the necessary nutrients due to these type of weathering products. So this is all about this biological weathering. In the next class we will talk about the different type of weathering processes and their products for that it is I stop here. Thank you very much. We will meet in the next class.