Soil Science and Technology

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Lecture – 02
Weathering and Soil Formation

Hello friends. So, today in this Soil Science and Technology course, we are going to start a new chapter that is Weathering and Soil Formation and it is very much important for the point from the point of view of the soil development. So in the first lecture, we talked about what is soil, the definition of soil, the major functions of soil and also we talked about what are the major components of soil, what is a volume wise distribution of different components, what do you mean by mineral matter, what is the percentage of organic carbon or organic matter. And, what is soil air, soil water and what are the different sizes of mineral fractions, we talked about different sizes of sand silt and clay and how they differ in different types of physical and chemical properties. So from that lecture, we had an overview of different aspects of soil and today onwards we are going to start a new chapter that is weathering and soil formation.

Now, before going to before going in details about weathering and soil formation, you must know that soil, I mean the soil generally forms from rocks and rock is basically the precursor of any soil. So, it takes millions and millions of years to create one inch of soil and it generally occurs from rock. Now, there are 2 processes involved in the formation of soil from rock, these are weathering as well as pedogenesis. So, let us start.

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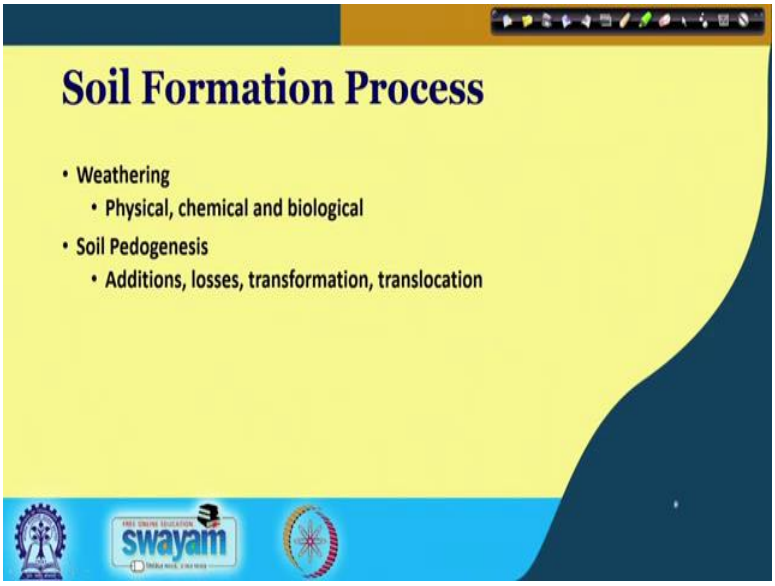

So, in this lecture we will be talking about both weathering as well as pedogenesis. Now weathering is basically is of 3 types, one is physical, another is chemical, another is biological, we will talk about them in details later on. And there is another process called soil pedogenesis, which is basically addition, losses, transformation and translocation of different components within the soil. So, unless these 2 processes occur, a soil cannot be developed. So, a soil formation is basically combination of these 2 important steps. So, let us first focus on what is weathering.

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Weathering is the disintegration and decomposition of rocks at the earth surface by different physical, chemical and biological activities. So, it involves both destruction and synthesis and; obviously, it is the precursor of pedogenesis. So, unless weathering stops, I mean weathering is although it is a continuous process, unless there is a considerable amount of weathering products the soil pedogenesis process cannot start. So, as you see in the definition weathering is basically, it is physical as well as chemical and biological. Now, the other name of physical weathering is mechanical weathering or disintegration and another name of chemical weathering is decomposition.

Now, biological weathering is a third kind of weathering, which is basically combination of both physical weathering as well as chemical weathering. And in case of physical weathering, please remember that there is only change in the size of bigger rocks to smaller rock fragments. So, there is no chemical changes. So, the chemical composition of the smaller fragments, which occurs through the physical weathering process has the same chemicals makeup as that of the original rock; however, in case of chemical weathering there will be a complete alteration of chemical characteristics from one form to another form. So, these are important aspects of physical and chemical weathering.

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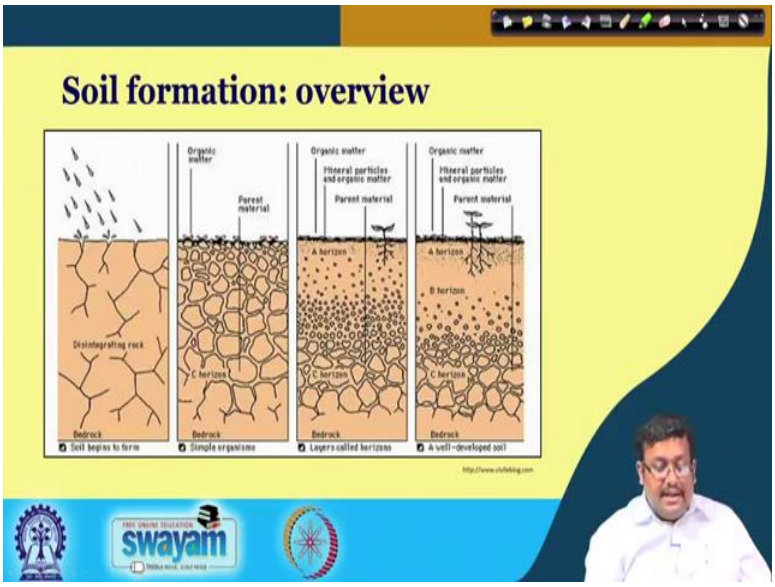

So, if you see in this picture, I have shown 4 panels which shows chronological events for soil formation as you can see in the first panel, the parent rock from which of the soil is formed is shown and which is acted upon by different you know by you know rainfall,

which is a physical force and these rainfall, I mean helps in physical breakdown of this of this rock to smaller fragments. So, as you can see here, these rocks you know the original parent bedrock, which is the disintegrating rock breaks down into these smaller fragments and these smaller fragments, we call them parent material.

Now, once this parent material is formed; obviously, there are some organic matter deposition at the surface, because of fresh litter fall as well as decaying plants and animal bodies. So, it creates a layer at the surface. And as we can see as the time goes on; obviously, there are some distinct horizon which are present in the soil. At the bottom, you will see the bigger fragments are there rock fragments are there and this is called C horizon and; obviously, some intermediate size fractions are there just above the C horizon and A horizon is basically, a mineral horizon and above the A horizon, there is an organic horizon or O horizon and; obviously, you know in the O horizon, you will see mixture of mineral particles and organic matter.

And; obviously, the C horizon will contain above mainly the parent material and in the final panel, you will see that a complete distinct you know horizonation has been formed in this soil, where you can see A horizon as well as B horizon as well as C horizon and at the top there is a completely developed O horizon. So, this is we call soil profile and unless this soil profile occurs in any soil, we cannot term that technically as a soil. And these you know formation of soil profile is dependent on you know both weathering as well as pedogenesis process, because not only weathering, but also different types of addition losses transformation and translocations are required for development of these horizons. So, let us see in details about the physical weathering in the next slide.

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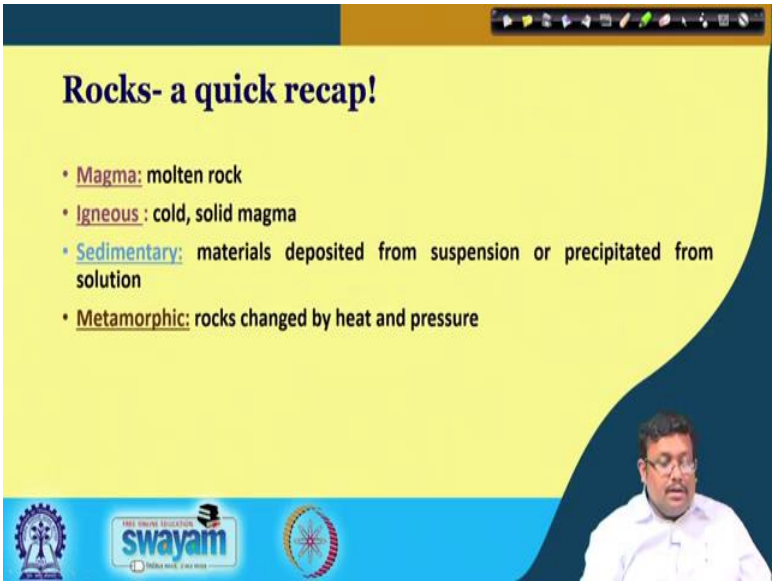

So, before going to the physical weathering let us make a quick recap of rocks and I am sure that you have already covered these things in your school. So, just to give you a quick recap before we go for weathering. Now magma you know, there is a molten rock whereas, igneous rock basically you know, it is a cold and solid magma and sedimentary rock basically, occurs from material deposited from suspension or precipitate from solution. Whereas, metamorphic rocks you know it basically, forms from change in heat and pressure and it is it all you know, it is an transform form of both igneous as well as sedimentary rocks.

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Now, in the next slide you will see some, I have given some pictures of igneous rock as well as sedimentary rock and metamorphic rock. To talk about some examples of igneous rock, you know granite and basalt, these are 2 important igneous rock and or I would say these are the 2 most prevalent igneous rocks over the surface and some example of sedimentary rocks are limestone, sandstone. So, these are examples of sedimentary rocks whereas, some examples of metamorphic rocks are Gneiss and then quartzite and then schist. So, these are some marbles. So, these are some examples of metamorphic rocks.

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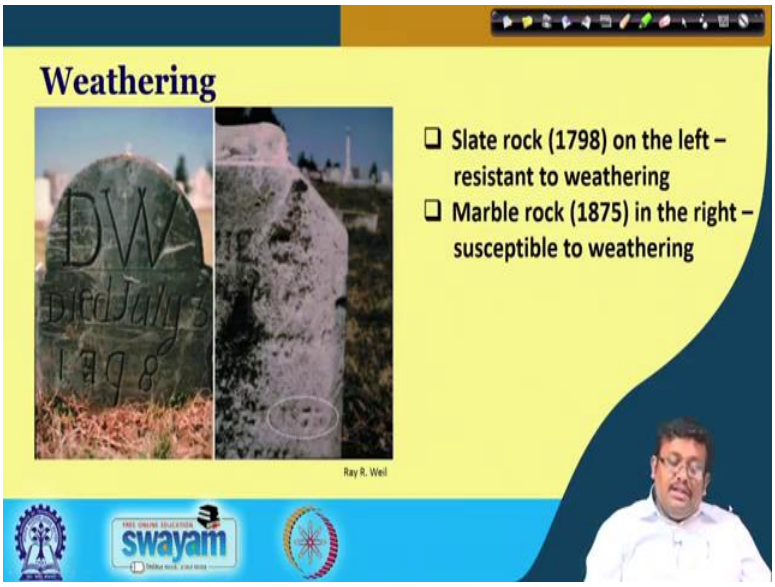

Now, all these rocks are precursor of soil formation and weathering basically occurs, it basically starts from this rocks. Now depending upon the chemical nature of this rock, they vary in their susceptibility to weathering; obviously, in this picture you can see that the left most, I mean the left most rock it is a slate rock, which we know in 1798 and it is very resistant to weathering as compared to the other rock, which is a marble rock, which is 1875 and which is basically susceptible to weathering. So, these 2 rocks that are present since, I mean 100 years apart, but you know depending on the chemical makeup and chemical nature of these 2 rocks, they differ in their susceptibility for weathering.

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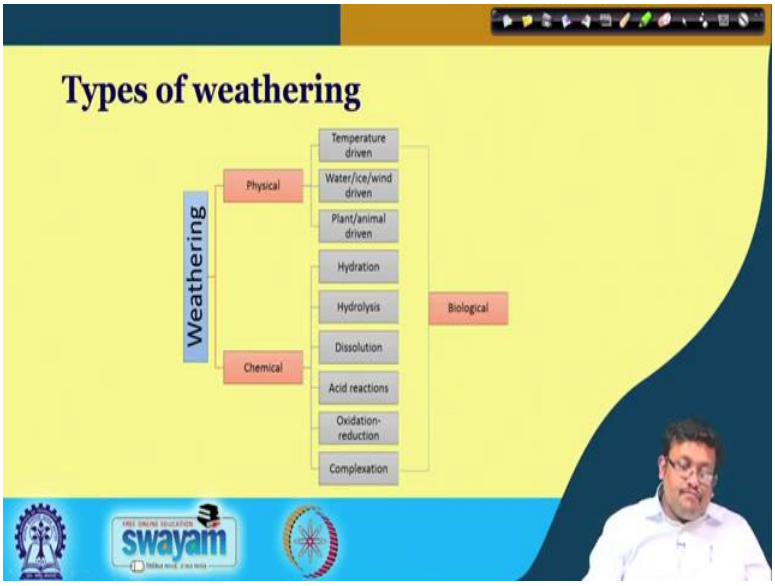

Now, let us see what are the different types of physical and chemical weathering or different process of physical and chemical weathering. Now as you can see, the physical weathering you know there are several forces of physical weathering. For example, it can be temperature driven, it can be water ice or wind driven or it can be plant and animal driven and in case of chemical weathering, it is basically, I mean characterized by several processes, these are for example, hydration, hydrolysis dissolution, acid reactions, oxidation reduction and complexation. So, all these processes are indispensable part for chemical weathering,

Now, as you can see biological weathering has I have already told you at the beginning of this lecture that biological weathering is basically a combination of both physical as well as chemical weathering, because biological agents like you know microorganisms and several microorganisms and plant roots can exert physical pressure. For example, the roots of the plants they can pry the rocks into smaller fragments and ultimately helps in physical degradation or physical disintegration as well as they can secrete some chemicals or acid along with some microorganism, which also can secrete some chemicals and these chemicals helps in change and altering the chemical nature of one mineral to another mineral. So, it is evident that the biological agents, you know helps in both physical disintegration as well as chemical decomposition.

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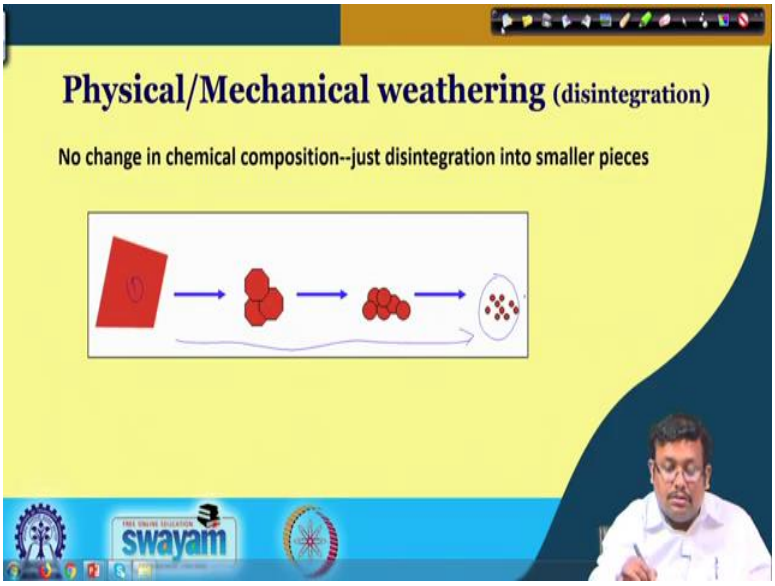

So, let us focus on physical weathering first. Now another name of physical weathering is mechanical weathering or disintegration and one of the major characteristics of physical and mechanical weathering is that there is no change in chemical composition, there is only just disintegration into smaller pieces.

Now, as you can see this rock we starts weathering and so this is stage 1 and ultimately as time passes ultimately, these bigger rock fragments converted into this smaller rock fragments or parent materials. Now this is an example of physical or mechanical weathering, because as you can see there is only creation of smaller pieces. So, the chemical nature of these smaller fragments will be same as the chemical composition of this bigger this is a primary criteria of physical weathering. So, there will be no chemical alteration only change in size. So, this is an example of physical weathering.

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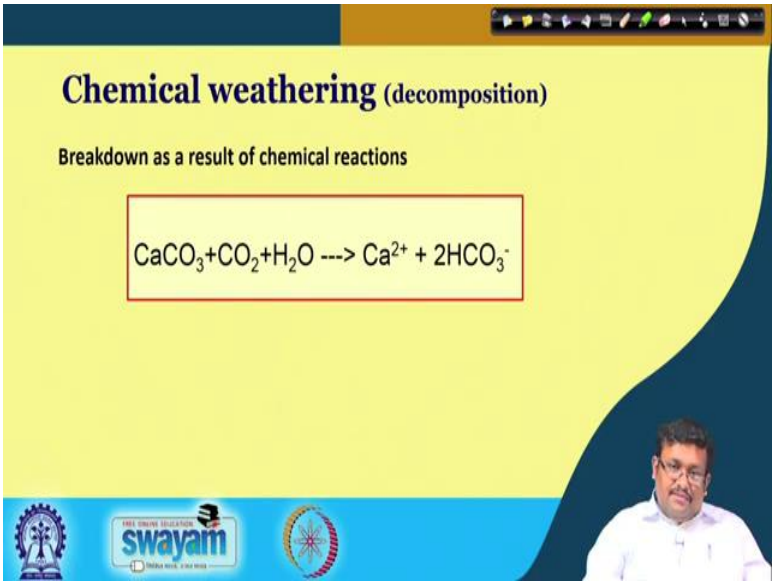

Let us see, what are the what is chemical weathering or decomposition. Now, in this slide you can see that, chemical weathering is characterized by breakdown as a result of chemical reaction. So, this is the major criteria for chemical weathering. Now as you can see here, the calcite or calcium carbonate or limestone as you know it is calcium carbonate, when it reacts with carbon dioxide and water inside this well now how this carbon dioxide comes? Basically, you know in the soil millions and millions of microorganisms are there like bacteria, fungi as well as you know algae and then protozoa, nematodes and due to their respiratory action as well as respiratory action from plant roots, there is the generation of carbon dioxide and; obviously, the partial pressure of carbon dioxide in the soil atmosphere is quite high.

And the and you know as compared to the atmospheric at the soil air contains 10 times higher carbon dioxide concentrations. So, when there is a high partial pressure of carbon dioxide, they reacts with the water vapour, which is present inside the soil and forms the carbonic acid and these carbonic acid basically, reacts with calcium carbonate and as you can see it changes into calcium ion as well as bicarbonate. So, there is a complete change in chemical nature. So, that is why it is called chemical weathering or decomposition; that means, change of composition ok.

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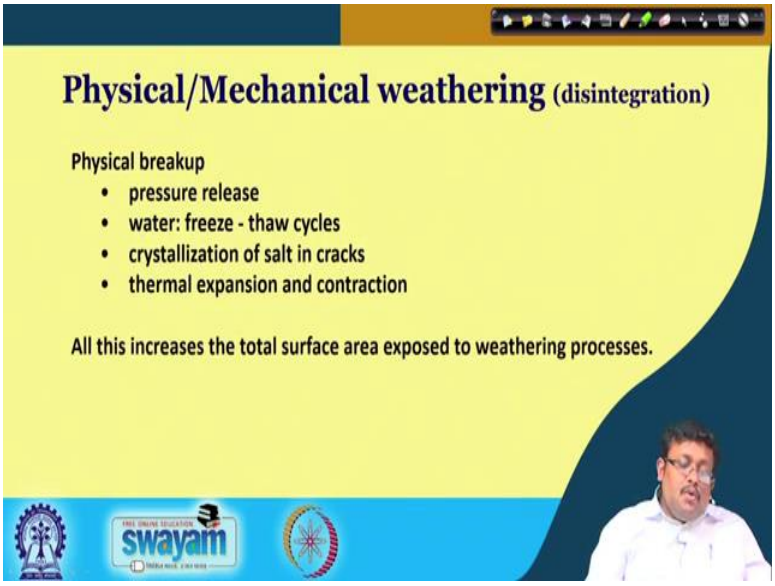

So, what are the you know what are the different aspects of physical breakup in mechanical weathering? Now; obviously, there are certain forces which are responsible first of all pressure release, second water due to its freezing and thawing cycles and crystallization of salts in the cracks as well as thermal expansion and contraction, these are 4 major processes in physical weathering, which participate in disintegration.

And all these increases the total surface area exposed to the weathering process. Now as I have told you that, due to the physical disintegration, the size of the particle goes down and as a result the size of the particle goes down; obviously, the reactive area, I mean the surface area, the total surface area also increases simultaneously and when the total surface area increases, it gives more opportunity for chemical weathering. So, these are 4 major process for physical disintegration.

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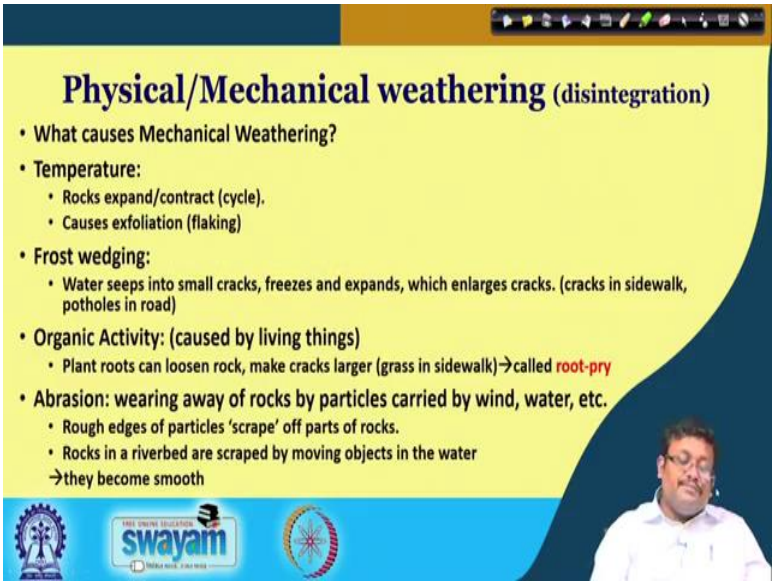

Now, let us see one by let us see them one by one first of all let us talk about temperature; obviously, as you can see that rock is as you know bad conductor of heat and in some extreme condition, when for example, when there is an hot climate I mean hot environment; obviously, there will be a temperature gradient present in the rock because, the outer surface of the rocks will be comparatively warm as compared to the inner core of the rock. So; obviously, there will be formation a there will be a formation of temperature gradient and when there is a formation of temperature gradient, there will be contraction and expansion and as a result of that due to the lower confining pressure a sheet of rock will break apart from the original rock and this is called exfoliation or flaking, I will show you the picture of exfoliation and flaking later on, but this exfoliation flaking is a major you know type of physical or mechanical weathering, which occurs due to the temperature variation.

Another important is frost wedging, now you know that water seeps into the small cracks freezes and then expands. Now, when water freezes to ice and you know it expands in volume and when it expands in volume, it enlarges the cracks in the sidewalks or holes in the roads and as a result it breaks apart this the rocks. So, this is an example of also physical and mechanical weathering, organic activity as I have already told you that plant roots can loosen the rocks and make cracks larger or grass in sidewalk, we call it root pry. Another important aspect of physical weathering is abrasion, which is basically wearing away of rocks by particles carried by wind and water and these rough edges of

the particle scrape of the parts of the rock. So, these are some major forces of physical weathering.

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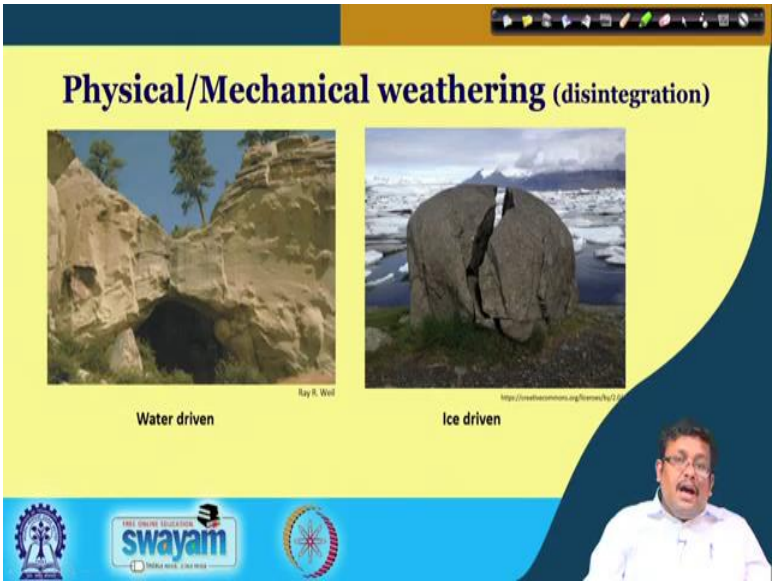

Now, in this slide you will see 2 examples of water driven physical weathering as well as ice driven physical weathering; obviously, in the second picture, you can see that the ice due to the formation of ice and it enlarged in you know it expands in volume and you know it gave a huge amount of tremendous amount of pressure, which breaks apart this rock. So, these are 2 examples of physical and mechanical weathering.

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Now, this one shows the example of exfoliation just like peeling an onion. So, you can see that the top layer of the rock breaks apart parallelly due to the contraction and thermal expansion and this is called exfoliation and the second picture shows the exfoliated domes in Yosemite Mountains of Sierra Nevada, which is situated in California State of USA. So, you can if you go there you will see this type of exfoliation occurs, I mean temperature mediated mechanical weathering.

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Now, this 2 picture shows the examples of frost wedging, now you can as I have already told you that water moves into these cracks and due to the lower temperature, it freezes and when it freezes it converts into the ice and these ice enlarge in volume and; obviously, exert a tremendous pressure and as a result, there is further breakdown of rocks.

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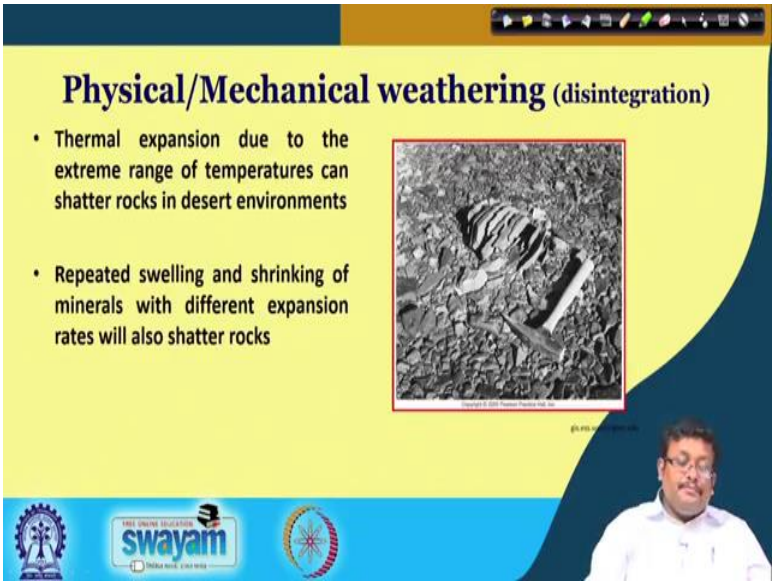

So, we call it frost wedging. Not only that, the thermal expansion due to the extreme range of temperature can shatter the rocks in desert environment, where there is an extreme climate and extreme temperature events can occur. For example, in the desert area, you will see that in the daytime there is a high you know very hot environment; however, in the night the air gets very much cold.

So, there is a extreme temperature environment, you know extreme temperature occurrences as a result thermal expansion occurs a thermal expansion of the rock rocks occurs and in the desert environment and; obviously, the repeated swelling and shrinkage of minerals with different expansion rates will also shattered rocks as you know that rock is composed of different types of minerals and based on the mineral internal, I mean mineral you know crystal chemistry, which I will talk which I will discuss later on you will see that due to the different types of swelling and shrinkage properties, different and different expansion it also shattered the rocks.

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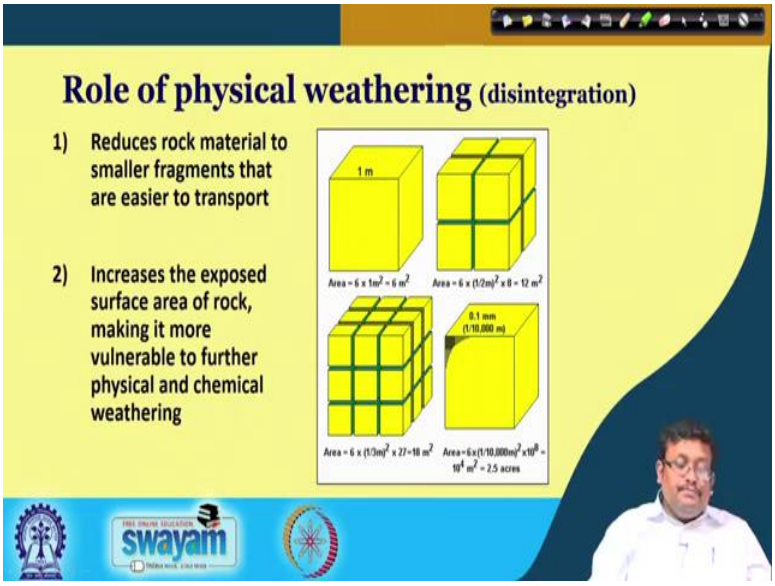

Now, why we need physical weathering, what is the role I mean of physical weathering? Now there are 2 major roles of physical weathering, first of all it reduces rock materials to smaller fragments that are easier to transport this is the first one, the second one you will see that, it increase it increases the exposed surface area of rocks making it more vulnerable to further physical and chemical weathering.

Now, as you can see here, we are having a cube with 1 meter of size and the total area of this surface area of this cube is 6 square meter and when we. So, if this is a parent rock from which soil is formed as you can see physical disintegration further, I mean decreases the size of the rocks and ultimately it will reduce to very small fragments. For example, in this case there is also another cube with the size of 0.1 millimetre. Now as you can see here, the total area goes to 10000 square meter. So, that is equivalent to 2.5 acres or 1 hectare of land. So, it can be easily you know seen that as a result of physical weathering, there will be several folds increase in surface area and when there is an increase in surface area; obviously, that will give more opportunity for subsequent chemical weathering ok.

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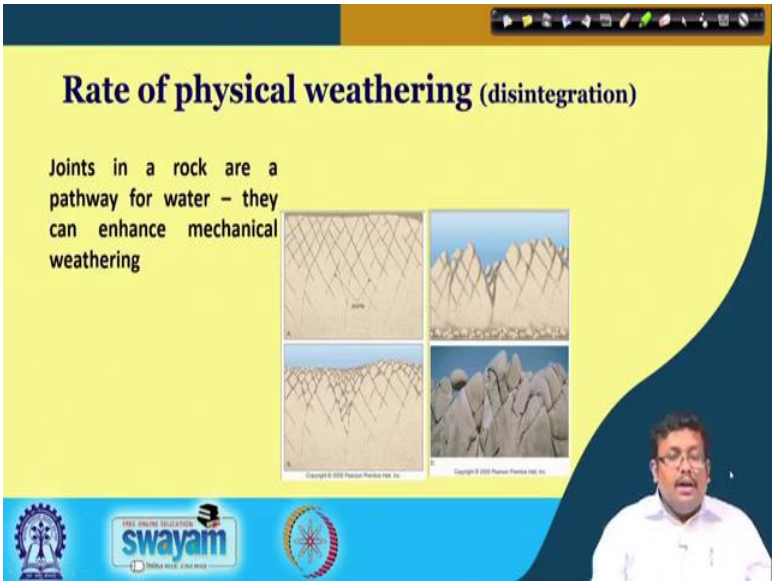

Also now you will see that rate of physical weathering or disintegration is different for different areas, I mean here you can see that a joint in a rock or a pathway, I mean here in this picture it is clearly evident that there are some joints in the rocks and water moves through these joints and these joints basically enhances the physical weathering. So, these are the primary sites, where physical weathering is more prevalent.

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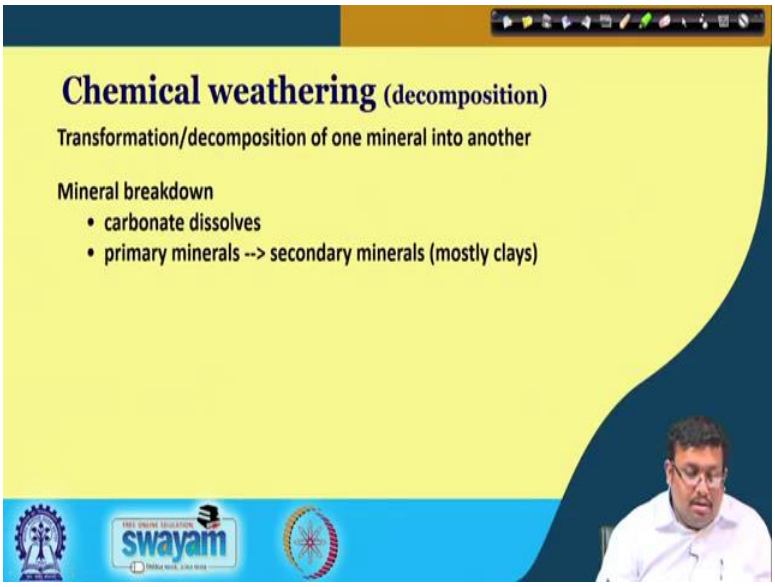

Now, chemical weathering now chemical weathering another name of chemical weathering is decomposition, because due to this type of weathering there is a complete

alteration of chemical nature of rocks that is why it is called decomposition. For example, mineral breakdowns like carbonate dissolves and primary minerals to secondary minerals. So, these are some examples of chemical weathering. Now let us also discuss about what is primary mineral and secondary mineral. Now primary minerals are the minerals, which are originally present in the rock from where soil are formed, now this is this primary minerals when undergoes chemical changes and converts to another type of mineral that is called secondary mineral.

Now, some example of primary minerals are quartz, feldspars, olivine, hornblende, etcetera where as some examples of secondary minerals are vermiculite, kaolinite, illite, we will discuss these secondary clay minerals in details, just remember that the most predominant primary minerals in that surface is quartz followed by feldspars whereas, these quartz and feldspars basic you know can be basically found in the sand and silt fraction that is why sand and silt are chemically inert in nature. Because, these sand quartz and feldspar are chemically inert and secondary clay minerals, secondary clay minerals, the other name of secondary clay mineral secondary minerals are clay minerals. And, these clay minerals can be found in the finest fraction of soil that is clay and these minerals are highly reactive and also these minerals show their implication in physical chemical and biological properties of the soil.

So, we will discuss in details about the different process of chemical weathering in our next lecture. So, to sum up in this lecture we have covered the definition of weathering and definition of soil formation or basic overview of soil formation and then I showed you how a soil form forms in different steps, then we talked about different you know aspects of physical weathering and chemical weathering, what are the major factors of chemical weathering physical weathering like temperature, like frost wedging and all these stuff. And, what are the roles of physical weathering and what is the difference between physical weathering and chemical weathering and we also talked about in brief about the biological weathering. So, let us wrap up here and in the next lecture, I will start from here and we will discuss about different processes of chemical weathering.

Thank you very much.