Engineering Geology

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Lecture - 13
Weathering

Hello everyone and welcome back. Today's lesson will be on weathering. We are going to talk about basically the evolution of different rock and soil minerals because of physical and chemical changes. That may actually alter their chemical and other characteristics, physical characteristics significantly. But before we take up the topic, we are going to look at the question set that was provided to you in the previous lesson.

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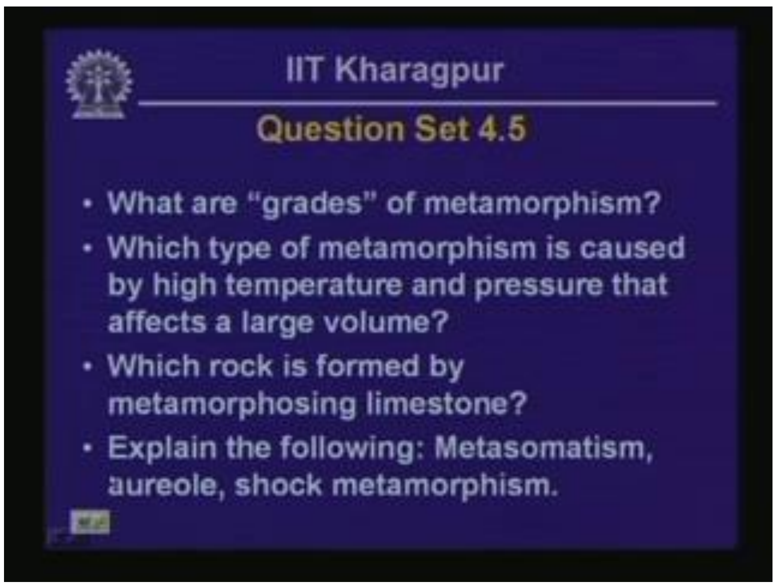

The first question was; what do you mean by grades of metamorphism? What is meant by the term grade is basically how mature is the metamorphism process in the sense that what kind of pressure and temperature is involved and how much of alteration of the parent mineral has been triggered by the metamorphism process.

For example, if the pressure and temperature regime is quiet near the ambient pressure and temperature near the surface of the earth; in that case, the alteration of the chemical characteristics is not very significant and what really happens is some hydrolysis of the parent minerals as well as some dissolution into weak acids that are available near the surface, so in that process, the characteristics, chemical characteristics of the parent mineral does not change very significantly.

Whereas, when very deep burial or extreme raise of temperature is occurring near the rock mass, then the rock, the minerals that is within the body of the rock mass, that gets baked and that alters, this alters the chemical characteristics of the mineral quiet significantly. What happens essentially is progressively more and more water is lost and other gases are lost from the mineral constituents and as result, there is a remarkable reduction in the percentage of hydrous minerals such as mica, clay minerals and other hydrous minerals such as gypsum that takes place as the metamorphism progresses.

So, when the metamorphism process becomes very matured, then you basically are left with none of those hydrous minerals and more of mineral such as pyroxene, amphiboles and pyroxenes and that process is given the name of grades. So, higher the grade of metamorphism you have got, less amount of hydrous mineral available within the rock mass; basically, that explains the term.

Then the second question that was asked was which type of metamorphism is caused by high temperature and pressure affecting a very large volume of rock mass? This type of metamorphism actually occurs some times in the regional scale and sometimes even in the continental scale and examples of these processes are the collisions between a tectonic plates that actually, that actually cover the surface of the earth and processes such as mount building near the plate boundary. So, these are the large scale process which subjects a very large area, very large volume of a rock to elevated levels of temperature and pressure. This kind of metamorphism, the kind of metamorphism that we are looking at in this particular case is called regional metamorphism.

The third question that was asked was which rock is formed by metamorphosis of limestone? And, the answer to this question is marble and this is the process to carry on with this topic. This is a process, if you recall the subject matter of previous lesson, the process involves is contact metamorphism in which a limestone body is intruded upon by a volume of magma and the rock which is in the periphery which is near the periphery of the aureole, that actually gets subjected to elevated temperature and pressure; not so much of pressure actually, temperature really and in that process recrystallization of calcite mineral takes place and that leads to the development of an interlocked, relatively more compact structure of the rock and the process that arises because of this is called, it generates volumes of marble. So, that is the answer to question number 3.

The fourth question that I asked was explanation of a few terms. The first term that I asked you to explain was metasomatism and process of or in order to illustrate the process of metasomatism, we want to look at the process of metamorphosis of say limestone formation.

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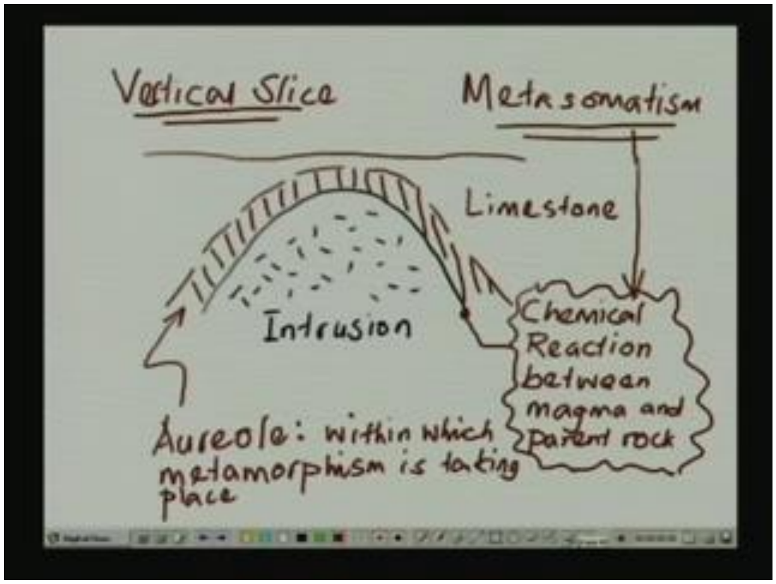

So, let us consider a mass of limestone getting intruded upon by a volume of magma. So, this is the intrusive and as a result what is going to happen is, so let us label this one; so this one is the limestone formation, limestone formation and this one here is the intrusion.

So, as a result what is going to happen is the rock in the immediate vicinity of the intrusion is going to be subjected, is going to be subjected to elevated level of temperature and this is going to, this is going to be more remarkable, the elevated level of temperature is going to be more remarkable near the boundary between the intrusive body and the parent rock mass. So, in this area, there are going to be a reaction, chemical reaction actually chemical reaction between magma and parent rock and in this case, the parent rock is limestone and the influence of the chemical reaction is going to actually decrease as one moves out from near the boundary between the intrusive body and the parent rock outward.

So, near the outer perimeter of the aureole and this actually also answers our next, the next part of the question; so this one here is the aureole within which metamorphism is taking place, metamorphism of parent rock is taking place. So, near the outer perimeter of aureole, the chemical reaction is going to be less prevalent than chemical reaction between magma and parent rock is going to be less prevalent than near the boundary between the intrusive body and the parent rock.

So, this particular this particular process of chemical reaction between the parent rock and the intrusive body is called metasomatism, this is called metasomatism and because of that many of the mineral, many of the chemical species that were absent in the in the original rock mass is going to be introduced in the system from the intrusive body.

What we are looking at actually in this; I should also explain what we are looking at. What we are looking at in this particular sketch is a vertical slice of an intrusive body. So, that actually explains the process at metasomatism and incidentally this also explains what is meant by the term aureole which was the next part of this particular question set.

Then the last term that I wanted you to do explain was shock metamorphism and what is involved in shock metamorphism is that the parent rock mass is subjected to ultra-high levels of pressures; not so much as rise of temperature but it is subjected to ultra-high levels of pressure and the pressure could be as much as say 2400 MPa or which is approximately equal to about 80 meter of crystal depth and under this kind of extreme stress environment, several different types of mineralogical changes triggered within the rock mass and as a result exotic minerals such as coesite and stishovite forms and because of the fact that this kind of metamorphism is triggered by impacts of very massive bodies such as meteorites, the presence of minerals such as coesite and stishovite is a ((… Refer Slide Time: 14:01)) sign of such meteorite impact. That kind of settles the question set and now we move on to the subject matter of this particular lesson.

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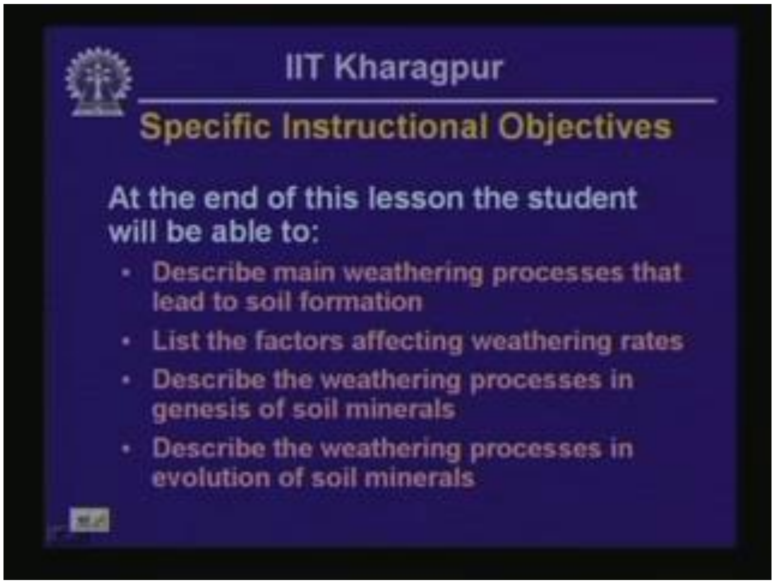

So first of all, the objective of what we are trying to learn in this particular lesson; after completion of this lesson, we would be able to define, we would able to define and describe weathering process that leads to the weathering of parent rock mass and leads to soil formation, we are going to able to list the factors that affect weathering rates, then we are going to be able to describe weathering processes that leads to the genesis of soil minerals and we also would be able to describe the evolution of these soil minerals because soil minerals can also be subjected to the weathering process and that will lead to the change of chemical and physical characteristics of the mineralogical composition. So, that is the list of objectives of this particular lesson.

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Now, we get on to the core subject matter. The first question that we need to answer is what is meant by weathering? So, we have to define the process. Weathering in a sense is disintegration or structural breakdown, physical structural breakdown or chemical alteration of rock and soil minerals. So, two processes are there; one is that you start with a big piece of a rock and because of the weathering process, the larger piece is going to be broken down physically into smaller pieces, so that is one part and the second part is that the chemical characteristics of the mineralogical composition of the rock mass is also going to change with the progress of the weathering process.

So, that actually makes it clear that the agents, the primary agents that instigate this kind of process would be; number 1 - mechanical processes and number 2 - chemical processes. So, we would have mechanical weathering and we would have chemical weathering as well.

Now, you cannot actually view mechanical and chemical weathering just by themselves and they always go hand in hand. In other words, because of mechanical weathering, large pieces of rock, they get broken down into smaller pieces and that triggers chemical, that actually accentuates or increase the rate of chemical reactions and in the process, chemical weathering also accelerates as a result of mechanical weathering.

And, the reverse is also true; because of chemical weathering, sometimes the mineralogical composition, the change of mineralogical composition leads to the change of volume of the crystal system that are within the rock mass and as a result, rock masses could be split by that process and that itself is going to lead to smaller pieces of rock and as result, what we get is an accelerated rate of mechanical weathering as well.

So, what you need to understand is that you cannot consider mechanical weathering and chemical weathering as separate entities and they are infact processes that go in hand in a mutually complimentary manner.

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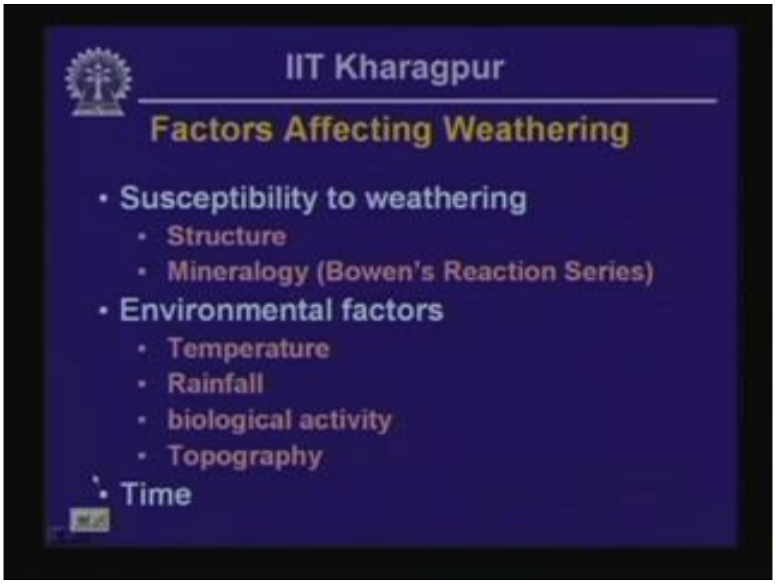

We are going to look at the details of the mechanical weathering and chemical weathering process as we continue with this particular lesson. Now, first of all, we want to look at the factors that affect weathering rate. So obviously, the rate of weathering, the primary consideration in deciding the rate of weathering is going to include whether the mineralogical composition of the rock mass is more, is inherently more susceptible to the weathering process.

In this connection, you should recall Bowen's reaction series and when I was, when I was talking about Bowen's reaction series sometime back, I was saying that if you are at one end of Bowen's reaction series, then the susceptibility to weathering is going to be very small in comparison with the susceptibility of the minerals that appear at the other end of the series and we are going to look at this issue in one of the, later on in this particular lesson as well. So, mineralogy is a very major driving factor in deciding what is the rate of weathering. Some, of the minerals are more susceptible to weathering such as olivine and some other minerals are relatively inert such as quartz.

Then the second thing that is important in this connection is the structure of rock mass itself. Some of the rock masses are more jointed in comparison with others. So, jointed rock masses are going to let entry of the agents of weathering deep within the mass. As a result, the rate of weathering is also going to accelerate. In comparison, if the rock mass is massive and there is no joint and if the mass is relatively intact, then rate of weathering is going to be much slower.

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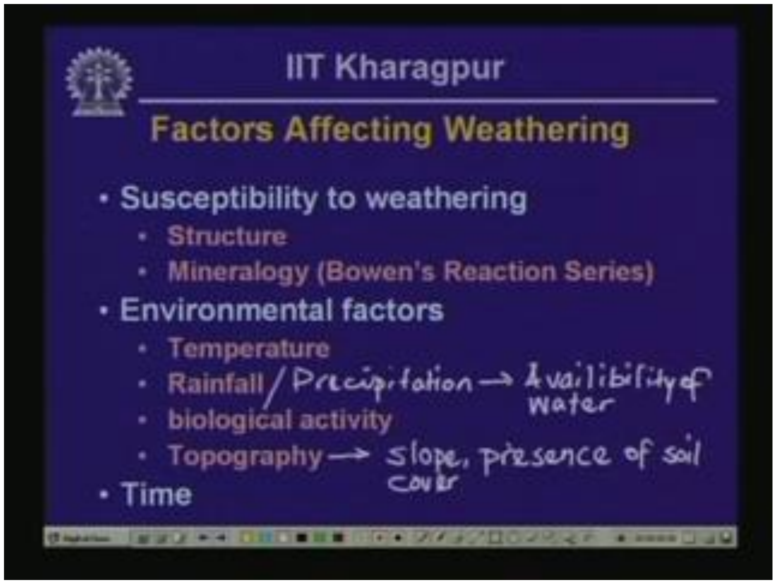

Then there are environmental factors such as temperature, rainfall or I should really say precipitation, precipitation, really I would like to say precipitation because precipitation, what we are looking at in this connection is the availability of free water because water is a major driving force of the weathering courses and then we have got biological activity that also is an agent that accelerates the weathering process.

Then we have got topography and also in this one, I would like to mention this involves slope and this also involves where there is any soil cover and finally you need to, the amount of weathering is going to be affected by time over which the rock mass is exposed to the weathering process.

So basically, these are the factors that you need to look at while deciding the weathering process. The influence of these particular items should be explained actually here. So for instance, if you elevate the temperature, then the chemical reactions that are typical of weathering process at shallow coastal layers within shallow coastal layers, the rate of those weathering reaction increases several fold. So, elevated temperature is an agent that accelerates weathering rate.

Secondly, the more the rainfall, more will be weathering because more water will be available - number 1 and also the secondary minerals that actually that actually or secondary minerals and other irons that are or which actually forms because of the weathering process, they are going to get readily carried away by run off, by the water that is going to flow out of the system and this process itself is going to accelerate the rate of weathering.

Then I talked about biological activity; what I mean by that is for example, development of forest cover, root penetration activity of powering animals and what happens because of this is the cracks are, the cracks open up because of this processes or deeper areas within the mass of rock that is subjected to weathering process, that gets or into that, the weathering agents such as water and air, they gain entry into those areas and as a result the weathering rate also accelerates because of biological activity.

And, biological activity actually makes available some other chemicals also deep within the mass of a, deep within the mass within which biological activity is going on such as in many cases biological activity makes available carbon dioxide deep within the mass of soil or highly weathered rock within which the biological activity is taking place such as root penetration.

Then topography; to explain that if the slope is steep, then the soil cover is going to get removed, run off will be quiet heavy and as a result, the minerals that develop because of the weathering process, they are going to get transported to other areas and the weathering process is going to get accelerated. The erosion as a result of steep slope can also work in a negative way because if erosion is taking place, then forest cover is going to, is not going to develop in that area and as a result, biological activity is going to be discouraged in that environment and that is going to decrease the rate of weathering.

So, there is there is a two way situation going on as far as topography is concerned and topography also is important because the slopes, the slopes can make larger quantities, larger amount of energy available from sun rays to a particular surface. As a result, weathering process can also get accelerated if the slope ways orients in a particular direction depending on which geographic region we are looking at. So, that basically explains the type of influence of these major factors that affect weathering rate.

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And, with that said, we want to get into what we mean by mechanical weathering and how these particular processes are triggered? So, as we have seen before, mechanical weathering involves breaking down of larger rock mass, rock volume into smaller pieces. So, the process involved in this case is number 1 - uplift and exfoliation.

You think about, if you think about jointed rock mass; if the jointed rock mass was at a great depth underground, in that case the joints are going to be closed because of the ambient pressure at that level and if because of some reason because of tectonic other processes, that particular rock mass is uplifted to a smaller pressure regime, in that situation the joints are going to open up and this is going to give entry of weathering agents within the rock mass and weathering process is also going to accentuate by this particular, by this particular processes.

Second thing is erosion; because of erosion, rock masses would be chipped by the agents of erosion, we will see more details about this thing just a little bit later. And then, temperature is another agent. Because of expansion, temperature can trigger expansion and contraction within rock mass and that will lead or that may lead to the breaking of rock mass and weathering of and weathering of the smaller pieces. Then, crystal growth such as salt wedging and frost action can also actually expand the volume within which the crystal is growing and as a result, the rock mass along that particular area within which the crystal growth is taking place is going to or it may, is going to it may breakdown into smaller pieces.

Colloid plucking is another agent of weathering. There are some colloidal entities, colloidal chemicals within the system and these colloids, they may shrink or swell depending on whether depending on whether they dry up or they become wet and this process is going to apply tension or expansive pressures around the, around the mass within which the colloid is present and that also is an agent of mechanical weathering. And finally, biological activities such as root wedging and burrowing; I explained what is meant by that is another instigator of mechanical weathering.

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Now, we want to look at the details of a very prevalent, very prevalent sequence of weathering process and this is uplift and root and frost action and this is a very significant instigator of mechanical weathering. What happens here is as I explained previously; pressure release cause volume expansion and opening up of cracks and separation, cracks separation and jointing. Then water may get into these cracks because they have opened up and this water actually may contain some salt or clay minerals or there might be some precipitation taking place and chemical reaction within this precipitates can actually lead to volume expansion and that is going to make the cracks even wider. As a result, the rock masses around the cracks are susceptible to breakage.

Also, there could be other types of crystallization within these cracks. For example, water can get in and this water can freeze up in cooler temperatures and because of the fact that the volume arise is more than the corresponding volume of water, that may also actually exhort expansive pressure leading the breaking of rock pieces rock masses that surround the joint within which the frosting is taking place.

There are other agents in this connection which can accelerate the process such as change in temperature and availability of certain minerals or chemicals.

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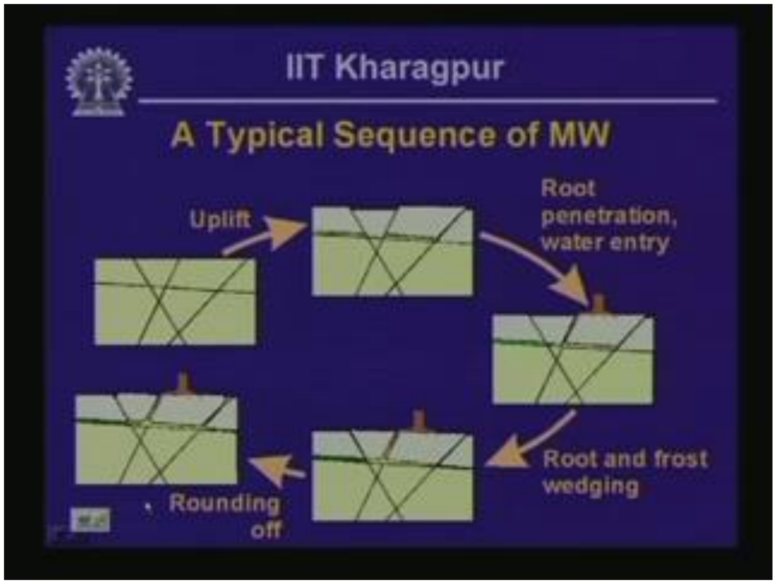

This particular slide actually shows you a number of small sketches. What we begin with here, this is actually in order to explain what is meant by the process of uplift and root wedging and other types of chemical wedging. So here, what we are considering is a piece of, is a mass of rock, jointed mass rock which was very deep underground and you can see as a result, the joints in this case, joints in this case are not open, they are all closed joints typically.

This is actually highly idolized, you can you can imagine that and then this particular rock mass is subjected to uplift and because of the uplift, what is happening is some of the joints, some of the joints are opening up, some of the joints are opening up because of pressure release and then what could happen actually is trees could grow, growth of vegetation can begin in due course of time, vegetation could grow in due course of time, then some chemical weathering agents can gain entry such as water and subsequently what could happen actually is the growth of the vegetation that could lead to wedging of some of the joints.

This particular area we are considering root wedging or the water that has entered the joints that can freeze up depending on the temperature and this may also actually lead to the opening up, further opening up of the joint and eventually what is going to happen is the sharp corners, the joints are going to be much more open finally and what you could end up with is pieces of rock in which the sharp corners are all rounded up and this particular situation may end up in extreme case in situation called spheroidal weathering. You will see an example of it later on.

What is happening in this case is that at all the corners, the area per unit mass of the rock is much larger. As a result, the weathering process wants to round it up so that the, so that mass becomes more and more inert from the weathering point of view because of the rounding of process, rounding of the corners, the amount of the area available will be smaller compared to the volume of the mass that is been subjected to weathering process.

And, what happens in this case? What we are, what we are interested or what happens because of weathering? Weathering always tries to stabilize, tries to stabilize and decrease and that can only happen if the amount of surface area available as a percentage of the volume is smaller than what it began with.

So, that explains the mechanical weathering process of this particular, actually this particular type of mechanical weathering process and that is not to say this is the only process that is responsible for mechanical weathering.

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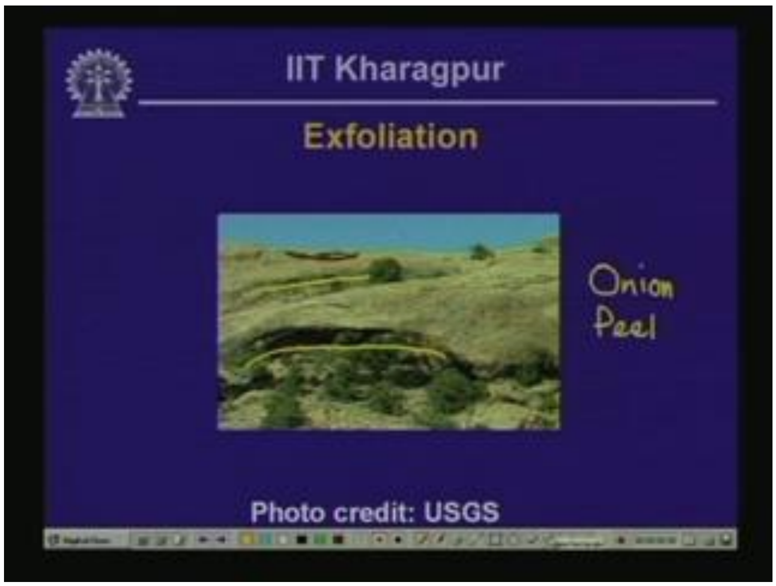

Some of the examples associated with this type of mechanical weathering; now here, what we see is actually is a weathering process which involve opening up of cracks because of uplift, an uplifted environment like what we discussed in the previous case and the cracks are visible here. This is a sandstone area that we are looking at, picture the sandstone area.

So, these are the cracks and you can see that these cracks are often parallel to the inherent bedding structure of this particular environment. So, for instance, sandstone formations are typically layered, you recall that they are sedimentary rocks and they are going to open up in layers that are parallel to the bedding plains and as a result, it appears or this kind of weathering also has got a similarity of for instance of an onion peel, onion peel. It has got an onion peel like appearance and really layers near the surface, they fall off as the weathering process continuous.

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Another example; this is an example spheroidal weathering and what we see here is a rounded off rock mass and as I explained in the preceding is that the ultimate, the aim of the mechanical weathering process is to make smaller and smaller area available for weathering exposed to the weathering agents as the time goes by as a percentage of volume and that would happen only when the pieces that comes into being as a result of the weathering process has got rounded corners.

And, this is an example in which we look at boulders of a rock which were formed because of spheroidal weathering as was explained in the cartoon that we looked at a few minutes back.

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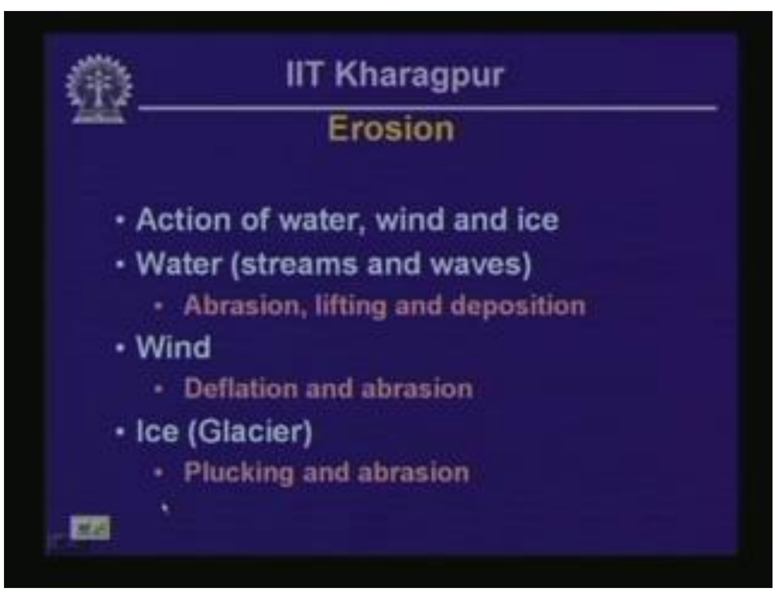

The second major agent that is responsible for mechanical weathering is erosion. Erosion essentially could be because of the action of water, wind or ice and water could be those in streams or they could be or the water could have water waves that could also act as an agent of weathering and what happens in this case is basically abrasion of the rock marks that is exposed to the action of water, lifting of small pieces of rock dislodged the action and deposition of these pieces elsewhere.

Second agent in this case is wind and wind also has got a very similar influence and this also plucks up the pieces from near the face of the rock exposed the wind and this process is called deflation and abrasion is the other action in which if wind carries a lot of floating debris such as fine particles of sand and silt, these things would act as agents of abrasion and they also are going to accelerate the mechanical weathering near the face, exposed face of the rock.

And finally, ice also could instigate weathering and the essential nature of the action is very similar to the action of water and wind. Here also, abrasion is one of the causes which is because of the small pieces of the rocks and other debris that is lodged within the mass of the ice itself that drops against the parent rock and because of that, small pieces of rock may get dislodged near this rock face and transported by the ice. So, these are basically the major process of erosion.

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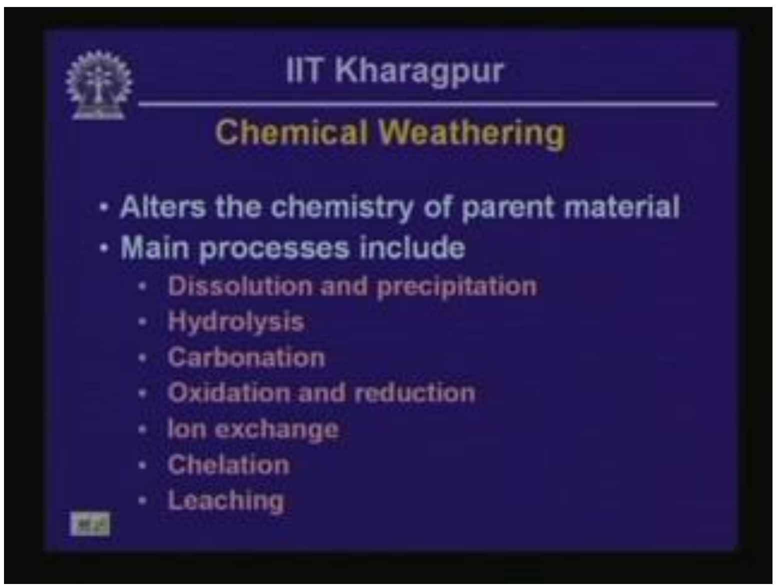

And now, we can get into the other major topic, major agent of weathering which is chemical weathering and what happens in this case is alteration of the chemistry of the parent material. In this case, several different chemical processes could be involved. Number 1 is dissolution and precipitation. The mineralogical compounds of rock mass can get dissolved because of or dissolved within the fluid that has been introduced to the rock mass and example of this one is dissolution of calcium carbonate or dissolution of calcite which we have seen in the previous lesson itself.

Then hydrolysis could be another major process of chemical weathering and I should give an example of hydrolysis just after I go through the list. Carbonation is another agent and we have already seen an example of carbonation in one of the previous presentation in which we looked at the formation of, formation of culinite mineral from the weathering of potassium feldspar.

Then oxidation and reduction is another major class of reaction that instigates chemical weathering, ion exchange, chelation and leaching. So, these are all different types of chemical reaction that all involved in the chemical weathering process. We want to look at an example of hydrolysis as I promised.

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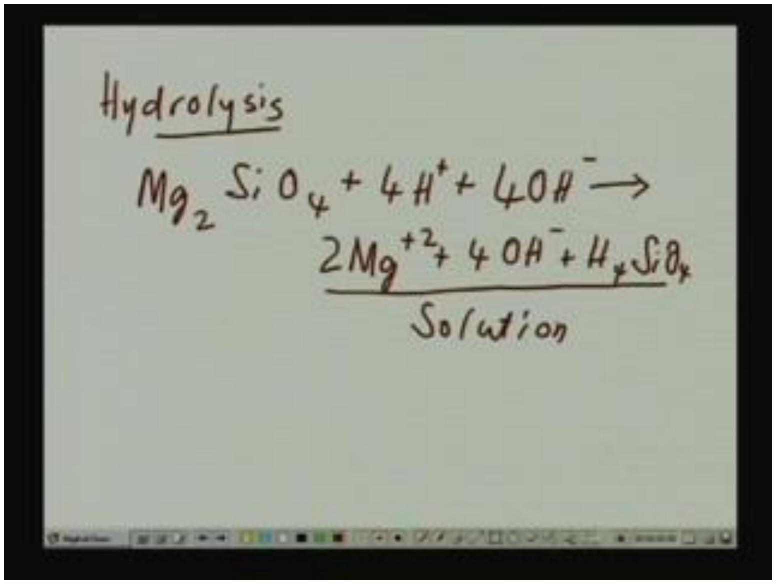

So, let us consider example of hydrolysis. So, want we want look at is weathering of olivine and olivine mineral that we are going consider is of this chemical formula. When that is subjected to hydrolysis, then you end up with release of magnesium ion and silicic acid and all of these things are going to be in solution. So, this is an example of hydrolysis and then let us consider an example of oxidation.

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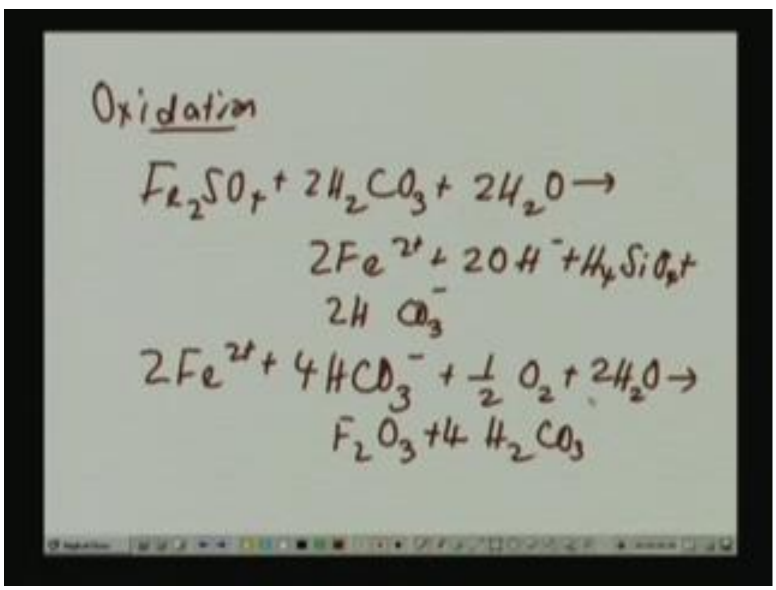

Let us consider an oxidation of ferrous sulfate. Actually, this one is HCO_3 minus and then you also have, this is a self-generating set of reactions in which one reaction actually instigates the other and what you end up in this cases is ferric oxide and carbonic oxide. Now, this is an example of oxidation processes and this is one of the very major reaction reactions that leads to the development of acidic oxide run out from sulfate containing rock. It would be natural or it could be because of dumping of sulfate contenting rocks.

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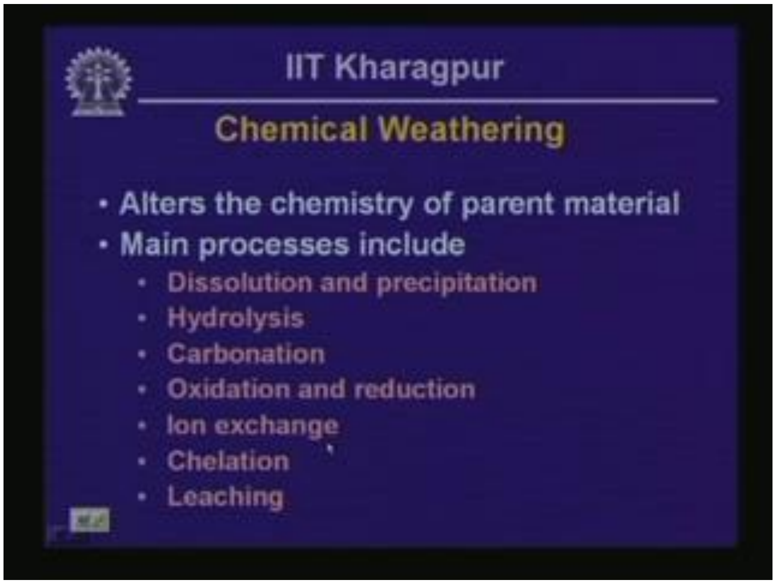

Now, the other set of or the other type of equations that I talked about in here was ion exchange. Ion exchange, an example of ion exchange is the transformation from elite to Montmorillonite by loss of potassium in the solution and up take of magnesium ions. Then, chelation is another class of reactions that takes metal ions in hydrocarbon chains and this is triggered mainly by biological activity. And leaching, this type of reactions also we have seen when we considered the weathering of kaolinite and in that kaolinite ended up formation of gibbsite and dissolved silica.

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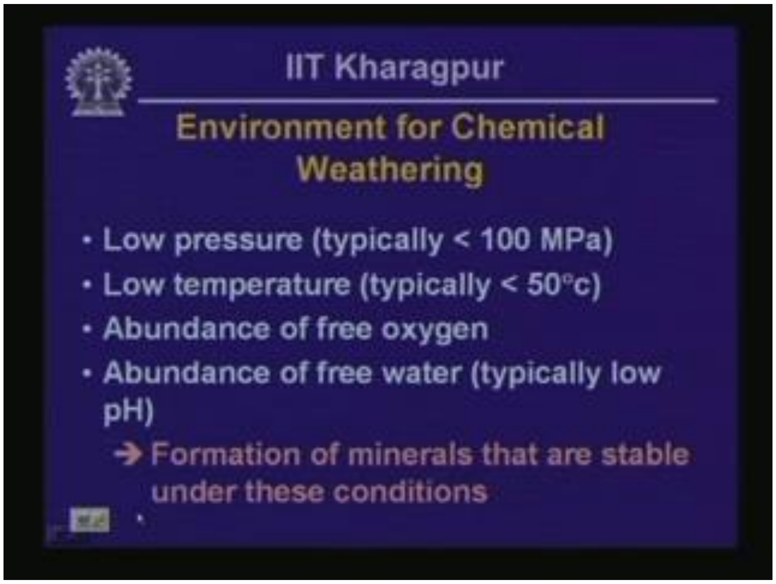

Environment for chemical weathering, these are typically low pressure, low temperature environment and as we have seen what we need is abundance of available free oxygen and free water. Now, this free water is also typically in low pH and you should really compare this particular environment, chemical environment with the environment that we considered previously when we were discussing metamorphic rock and there we would have large range of pressure, temperature as well as, as you down deeper, the water becomes instead of being acidic near the ambient conditions, it becomes more basic and also the salinity of water deep underground increase with depth. So basically, this is the chemical environment and you will form chemical species that are stable under those ambient conditions.

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So, what we look for is the mineral stability near surface. So, minerals formed at high pressure and temperature environment are least stable and this stability is on that order which is shown near the bottom of this particular slide and you should compare this particular list with the list that I provided earlier when I was discussing Bowen's reaction series and you would indeed see that there is a very close match with this series and the Bowen reaction series.

So, what we have here is iron and aluminum oxides, they most stable were as olivine that forms deep underground under very elevated temperature pressure environment, these minerals are least stable minerals.

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Now, we look at the weathering products of the nine most abundant rock forming minerals that we consider earlier. So, muscovite for example, because of weathering, it can lead to the development of illite clay mineral and kaolinite clay mineral; potassium feldspar or orthoclase can lead to development of kaolinite and in turn into the development of bauxite upon leaching and quartz; sodium plagioclase can also lead to development of kaolinite and quartz.

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Biotite mica can end up being chlorite minerals and chlorites can in turn get weathered and lead to the development of kaolinite clay, release of potassium and magnesium ions. Then we could look at the weathering of amphibole minerals. In this case, weathering product is again chlorite and kaolinite. Then pyroxenes, that also leads to the formation of chlorite and kaolinite and smectite. So, those actually are the most abundant mafic minerals which you may recall from the study that we did before on mineralogical composition of rocks.

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Now, we got two more actually, plagioclase and olivine. So, plagioclase weathering depending on the environment could lead to the development of kaolinite and llite and olivine mineral leads to the formation of smectite which may in turn and as well as chlorite minerals.

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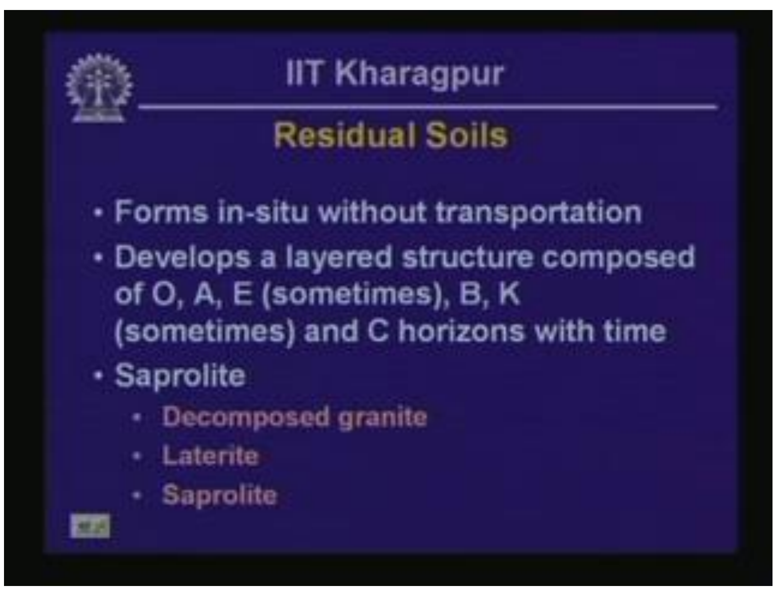

Now, that actually finishes the or we looked at the most abundant weathering action of most abundance rock forming minerals and now because of weathering, what we get actually is the thing called residual soil. Now, residual soils are those soils forms in-situ without any transportation of the soil particles and depending on the time which is allowed for the weathering process, a layered structure can be developed and this is composed of several different horizons and we are going to see what are those individual horizons. They could be O horizons, A horizons, E, B and K horizons as well as partly weathered and unweathered rocks composed of C horizons. Examples of residual soils include decomposed granite, laterite and saprolite.

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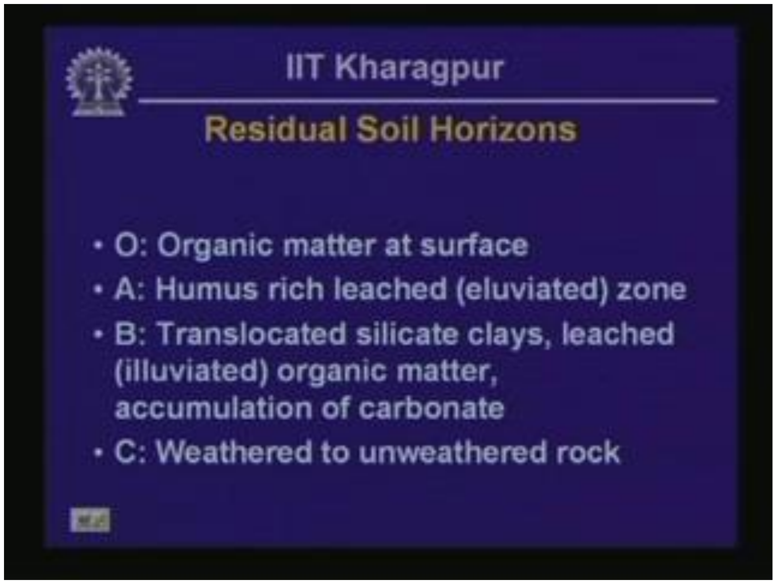

So, residual soils horizons; O horizon is the organic matter near the surface, it could be in a partly decomposed state. Then underneath A horizon, is basically mineral soil which is rich in partly decomposed organic matter. It is also depending on the weathering condition; it could be leached or illuviated. That means loss of mineral and mineralogical components out of this particular horizons is figured by the leaching action.

Then underneath A horizons, you could have B horizons and this is an illuvitated horizons that means here, the translocated silicate or the products of weathering of A horizons, product of leaching A horizon, that gets accumulated. Then finally, we have got a C horizon which is basically weathered to unweathered rock.

Sometimes between A horizons and B horizons, we could have another horizon in acidic soil environment and that is E horizon and above the C horizon, they are could be in some arid environment accumulation of carbonate minerals and that particular lawyer is called the K horizon.

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Now finally, in the final few slides, we are going to look at weathering of soil minerals because soil minerals can also get weathered chemically as the time passes and the major process is ion exchange and digenesis which occur at low temperature, low pressure environment.

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So, we look at the three most abundance clay minerals in this case. Kaolinite clay mineral can actually because of leaching, may end up in devolvement of bauxite ores or reaction with iron rich ground water could lead devolvement of the chlorite. From llite, we would actually get kaolinite and muscovite depending on weathering process that we are looking at.

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Then finally, smectite minerals can lead to the formation of kaolinite and llite depending on the weathering processes. Now, what is important to note here is that among all the three clay minerals, they are relatively stable in comparison to many of the rock forming minerals that we considered earlier and ambient temperature pressure conditions. But here also, the relative stability of these three minerals which are most abundance in clay layers, they are different and smectite minerals are the most unstable in comparison with the other to clay minerals; where s kaolinite minerals is the most stable.

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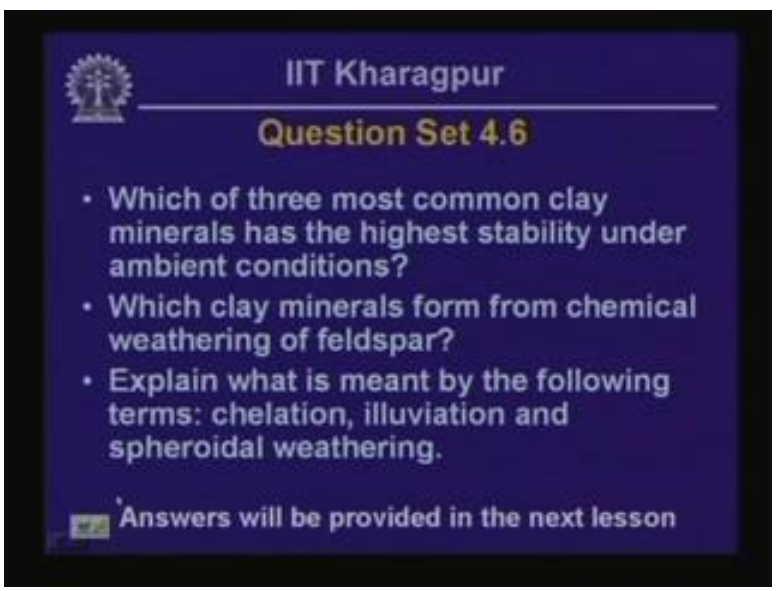

So, that kind of brings us to the end of the particular presentation and we close this presentation by this question set. Try to answer these questions at your leisure; let me read these questions out to you. The first one is which of three most common clay minerals has the highest stability under ambient conditions? The second question is which clay mineral is formed from chemical weathering of feldspar? Then the third question that I ask is, for you to explain the terms; chelation, illuviation and spheroidal weathering.

Try answering these questions and I will try to give you my version of this answer when we will meet you with the next lesson; until then, bye for now.

Thank you very much.

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Hello every one and welcome back to the new lesson of engineering Geology. Today we are going to talk about sediment transport and deposition. If you recall in the last lesson, we were talking about soil formation and we talked about some soil deposits which didn't get transported away from the location from where they were formed and today we are going to talk about soil deposits that are developed away from the location where they form and the process in between the in situ weathering and the deposition elsewhere involved, in this case is called transportation; we are going to look at the details of all different important processes involved in this.

But before we do that, we are going to look at the question set of the previous lesson, the question set is here.

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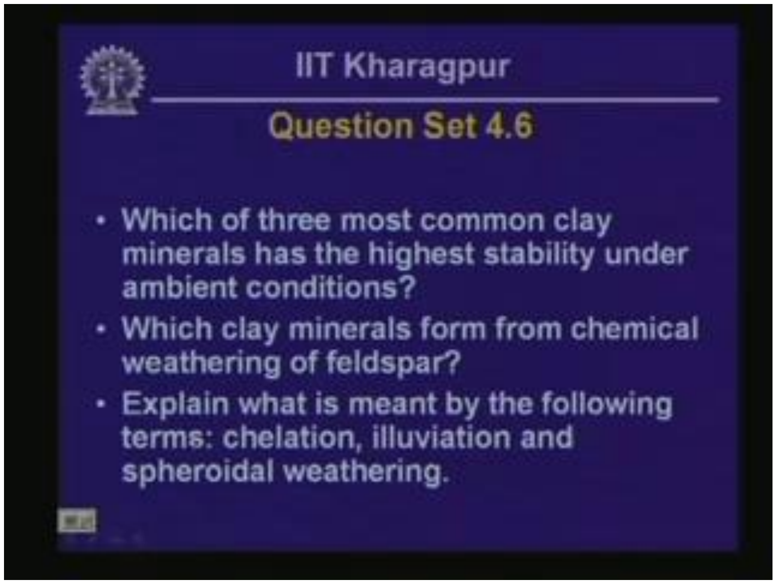

The first question was which of the three most common clay minerals has the highest stability under ambient conditions?