Engineering Geology
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Lecture - 11
Sedimentary Rocks

Hello everyone and welcome back. Today we are going to study sedimentary rocks in lesson 4.4. Like we did in the previous lesson for igneous rocks; we are going to look at different processes in which sedimentary rocks form and what are their major uses and engineering issues involved with the sedimentary terrains. But before we start, we are going to examine the questions that were given in the previous lesson.

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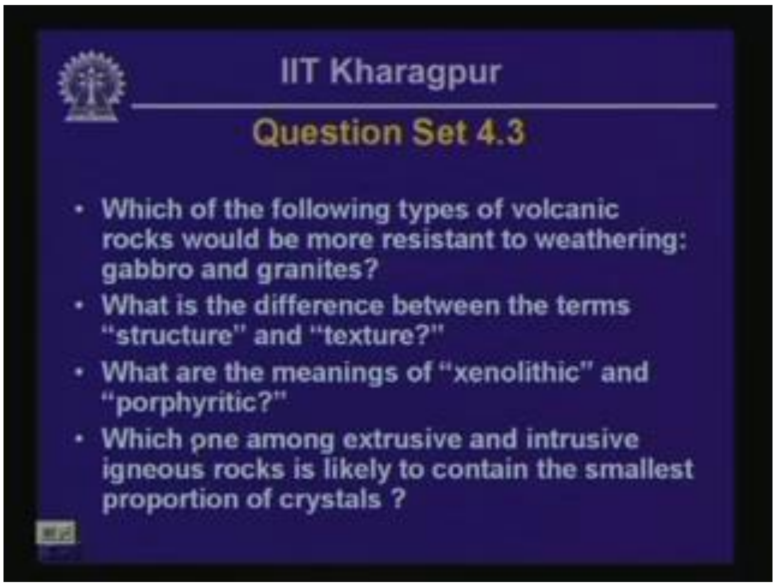

The first question that was asked was which of the following types of volcanic rocks would be more resistant to weathering; gabbro and granite? Now, if you recall the subject matter of last lesson, then gabbro is much more, it contains much larger proportions of mafic minerals in comparison with granites. As a result, you would expect that gabbro is more resistant to weathering sorry it is going to be more susceptible to weathering really in comparison with granite. But because of the fact that mafic mineral in general are more susceptible to weathering, chemical weathering.

But there are several other issues that also comes into consideration in this case, those issues include the joints and compact nature of these particular rocks and as a result, the susceptibility of a given piece of rock to weathering, chemical weathering is going to vary by a significant margin and that may sometimes over write the mineralogical considerations when we look at the susceptibility to chemical weathering.

Now, the second question that was asked was what is the difference between the words - structures and texture? Now, I indicated in the last lesson itself that by structure work we mean is the macroscopic characteristic of a rock mass; whereas by the word texture, we are really looking at a mineralogical or we are looking at a microscopic scale.

So, examples of structure, if you consider the examples that I gave in the last lesson; structures are governed by things like joint set or the lava form, lava forms that may end up being retained after solidification of the lava like different type of formation because of viscosity of lava like Pilo lava and other things. Whereas, the texture, the word texture, it signifies microscopic nature of the orientation or distribution of different types of mineralogical components within the matrix, within the matrix which is normally not crystalline and the orientation of these features within the matrix or it could be even distribution of gas bubbles that was there when the lava was in molten, partially molten state and the gas bubbles were forming because of escape of dissolved gases like vesicular texture or for that matter, we have phaneritic texture, aphanitic texture and so on and so forth.

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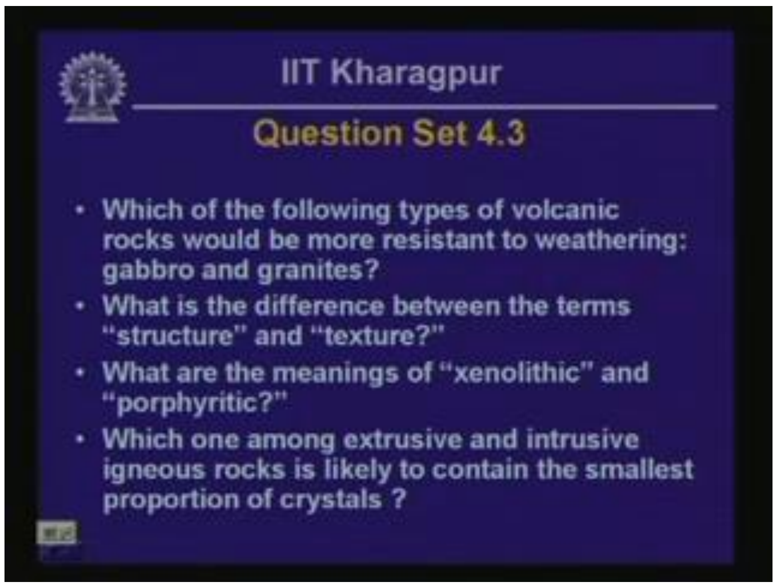

The third question that was asked was what are meanings of xenolithic and porphyritic? Now, xenolithic, by the word xenolithic what is meant is a foreign rock material, a foreign or a piece of rock really which is remnant of other types of rock that is included within a mass of volcanic rock and these xenoliths are normally, they often times they react with the parent rock which is the major proportion of the rock mass and give rise to a structure called reacting structure.

The other term porphyritic; that actually is a type of texture and if you recall a porphyritic structure is composed of minerals of different sizes, some of the minerals could grow very large in comparison with other minerals and if you recall actually, let me draw a porphyritic structure to actually jog your memory.

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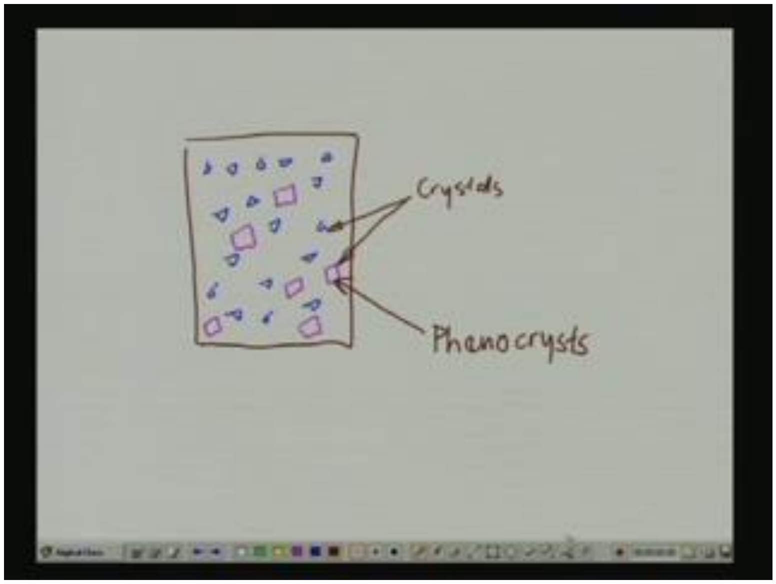

If you have got a mass of rock of say this size and most of the minerals may be are going to be of that nature, let us say there is a distribution of similar size crystals but then within the matrix, there will be some crystals which are quiet large in comparison with general crystal size. So, these are all rock crystals in this case, these are crystals and the larger crystals are known as phenocrysts.

Now, if you recall from what we discussed in the previous class, previous lesson; the size of mineral really is a function of how fast the lava is cooling. As a result, porphyritic structure, actually prophyritic texture it arises because of a variable cooling rate that may actually be encountered during the lava solidification and crystallization process.

The fourth question that I asked was which one among extrusive and intrusive igneous rocks is likely to the smallest proportion in crystalline matter? Now here, again as I indicated when I was answering the previous question, the cooling rate is the major consideration and if you have got a smaller cooling rate or the cooling rate is quiet slow, in that case the crystals are going to grow quiet large. Whereas, if you have got much larger, actually the cooling rate is much faster, in that case the crystal sizes are going to become very small.

And, you could actually extend that and for the fastest cooling magma, what you are going to end up with is a texture called glassy texture where crystalline matter is almost nonexistent and what you have got is a glass like matter, glass like solid. So, what we see then is for extrusive rock; since the cooling light is much faster and cooling normally as I mentioned takes place in the matter of few hundred days, so in this case, the faster cooling rate is going to end up being translated into smaller crystal size in comparison with intrusive rocks because they actually in this case, the magma solidifies at a much slower pace and the solidification process can prolong over as several hundreds of thousands of years.

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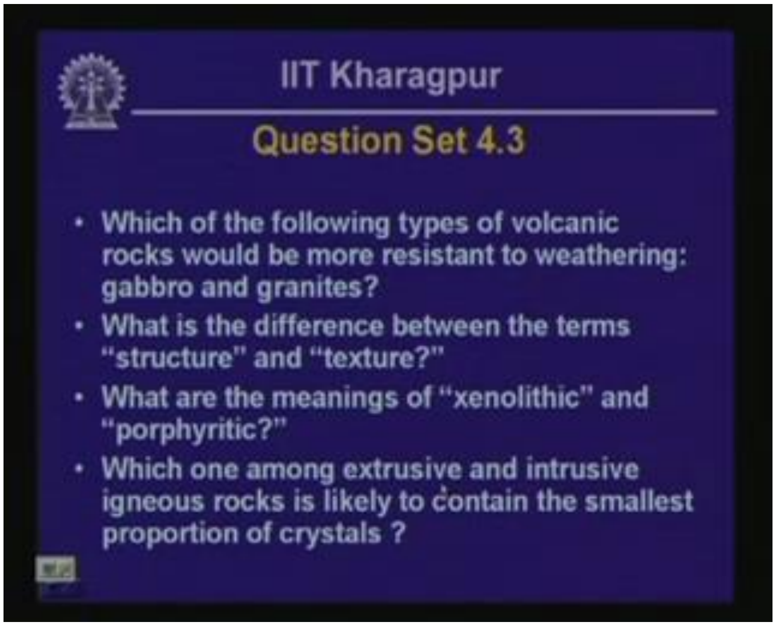

So, with that actually wraps up the question set and now we hop on to the subject matter of this particular lesson.

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What we are going to discuss here today is essentially origin, evolution and the processes involved in origin and evolution of different types of sedimentary rocks.

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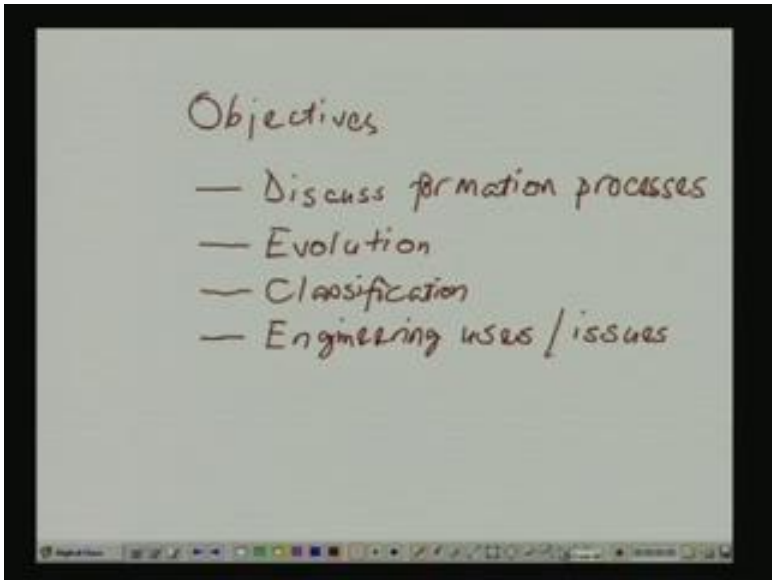

And also, we are going to look at, so the objectives here, objectives of this lesson would be, to be able to discuss formation processes of different types of sedimentary rocks, evolution of sedimentary rocks, classification of sedimentary rocks and then, we are going to consider engineering uses and issues that are relevant in sedimentary rock areas. So, these are the major objectives that we want to take care of in this particular lesson.

So heading back, what is meant by sedimentary rock; that is the first question that comes in mind. Sedimentary rock actually forms from disintegration, accumulation, compaction, consolidation and cementation of sediments which primarily form from the physical and chemical weathering of preexisting rock mass and actually, this solid matter would also be deposited because of organic activity or chemical activity, chemical deposition processes.

Now, sedimentary rock by far, it covers the largest proportion of the earth's surface or within the near surface layers which is a primary importance in engineering geology, the rock that is mostly abundance that is sedimentary rock; an approximately 70% of the area, continental area is covered basically by sedimentary rock. So, you can imagine that from engineering stand point, sedimentary rock is going to be going to be of greatest importance.

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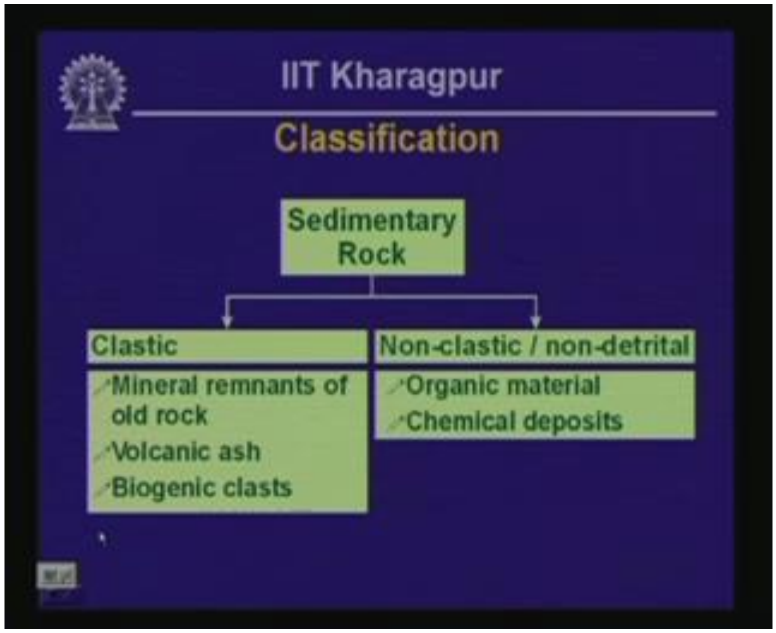

Now, the first thing that we do is try to classify sedimentary rock. Sedimentary rocks are primarily classified depending on whether they are mainly composed of detrital matter in which case, the type of sedimentary rock is called plastic rock, composed of detrital matter, these things are composed mainly of detrital matter and by that what I mean is fragments or mineral remnants of preexisting rock or volcanic ash or mineral pieces which may arise because of decaying organic matter. Like for example, shell fragments or other remnants of ((… Refer Slide Time: 14:50)) and so on and so forth.

So, this type of rock which is going to be, which is mainly or somewhat granular in nature that is going to be known as clastic rock; whereas, you could also have non clastic rock, non clastic is going to be composed of non detrital material and these things are mainly deposited because of organic activity or they could be chemical precipitate, chemical deposits like precipitates from saturated solution of some kind of chemical species. So then, we have got two types to content with primarily; one is detrital sedimentary rock or clastic sedimentary rock and the other one is non clastic or non detrital sedimentary rock.

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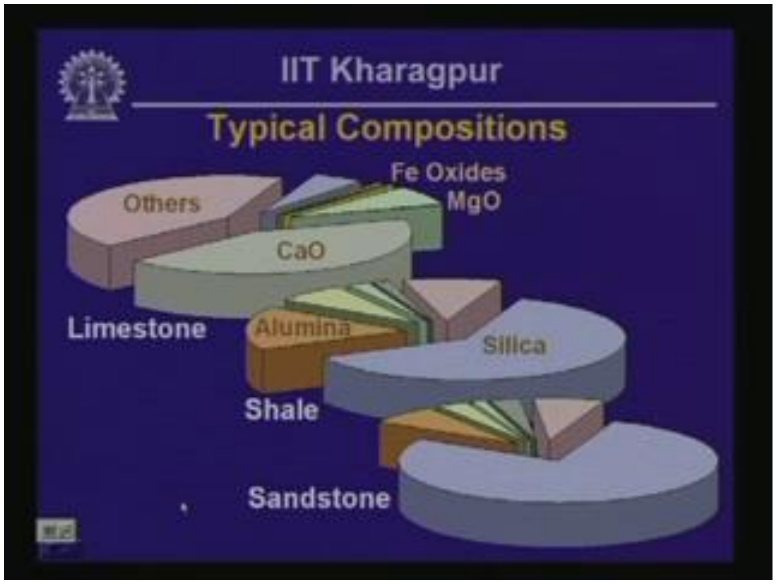

Now, we try to take a look to begin at the typical compositions of different types of sedimentary rocks. At the top left, we have got typical composition of limestone and here you can see, by far the largest proportion is that of calcium oxide and then there are several other oxides like iron oxides or magnesium oxide and other minerals, like there is a minor proportion of silica as well. By the way, all these pie charts shown here are color coded, so one particular type of color is used to denote a particular mineral species.

So, this one here is the silica, the orange color is used to denote alumina, the light yellow color is used to denote the oxides of iron, the light green color is used to denote oxides of magnesium, oxide of magnesium; so that is about it. Now, so this one here is a chemical, chemically formed; it is an example of chemically formed non clastic sedimentary rock and then at the middle, we have got an example of a mineral of a clastic sedimentary rock. This is basically it is called shale; basically forms from deposition, compaction and lithification of clay and here you can see the largest component, largest mineral component that is present within the rock mass is silica and then there is an abundance of alumina, oxides of iron and other chemical species as well.

So basically, most abundant component of this particular class of rock is silica and alumina and actually continues through to another clastic species of sedimentary rock called sand stone. As the name suggests, these type of rock actually forms from sand beds. When sand beds get deposited under pressure and become lithified and the rock that you get in that process is called sandstone and here also, the largest component like in the previous case is silica and then you have got a large proportion of alumina as well. But the proportion of silica in this case is typically larger than the proportion of silica in case of shale. So, you can see that there is a wide variety of sedimentary rocks that could be or that could that one has to come across as far as the mineralogical composition goes.

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A few pictures showing some of the abundant types of sedimentary rocks; on the left, the picture on the left shows a section of rock called conglomerate and this type of rock, you can see is composed of gravel and cobble size detrital matter. These are really fragments of preexisting weathered rock pieces. So, these are the gravels and cobbles and then these things are bounded, these things are binded basically by cementitious material, cementing agents which also in this case are of Siliceous variety, containing a lot of silica.

Now, at the centre here, the middle, we have got a picture of pink sandstone. In this case, the rock mass, actually the rock develops because of lithification of sand beds as it is evident from the picture there and on the right here, what you have got is you have got a limestone and also of interest in this case, here you have got a large fossil within the mass of limestone. Limestone actually, often times contain lot of fossil and that type of rock is called, how this type of rock is classified; we will discuss in more details as the lesson continues.

Now, the scale of these particular pictures is indicated at the bottom, just immediately below the pictures. So, in order to give you an idea about what is or what are the size of different types aggregates that form these rocks; with that said, we have to revert back to the presentation.

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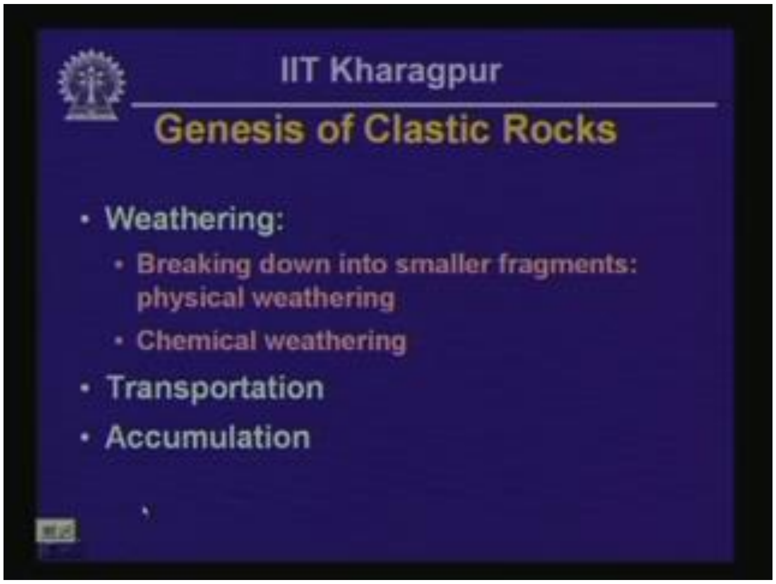

Now, what we look at is we try to look at the processes that are involved in the formation of clastic sedimentary rocks to begin with, then we are going to look at with processes after words that are involved in formation of non clastic sedimentary rocks.

So, to begin with clastic rocks; clastic rocks actually forms from physical and chemical weathering preexisting rock and they also form from deposition of biogenic matter and lithification of these detrital matter by some cementing agent. So, the process involved then; they include breaking down of the preexisting rock mass into smaller fragments and chemical weathering, then the second step in the formation process is transportation of these debris, accumulation and deposition of this debris.

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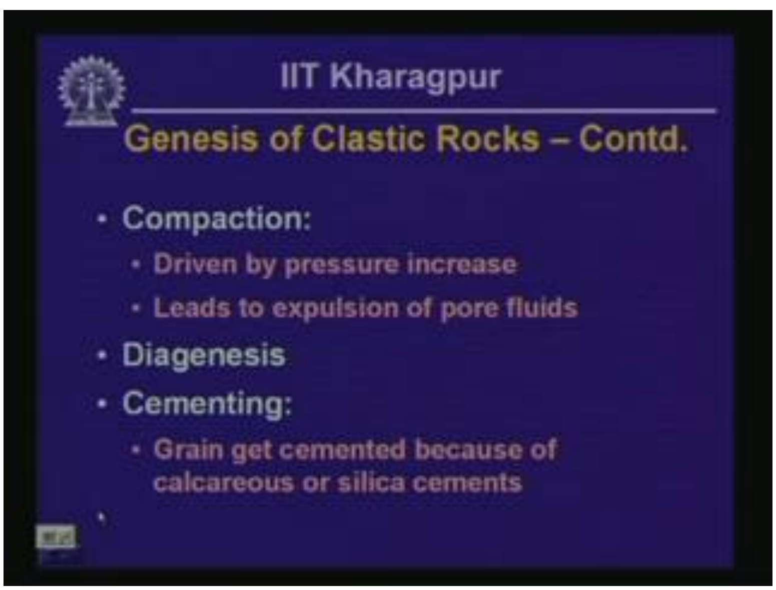

And once the clasts, they deposit and they actually get deposited underneath a heavy sediment load, on top of it; then what is going to happen is a process called compaction in which the inter-granular pore space becomes smaller and smaller and this leads to expulsion of pore fluids comprised mainly of air and water and following this or through this entire process, there could be an outgoing digenesis processes and we know from what we have done so for in this course, what is meant by digenesis.

Digenesis actually indicate chemical, physical or geometric alteration of the parent rock forming material and then finally, after all these or after the clastic matter goes through all these processes; what you are going to have is cementation and in this case the grains may get cemented because of deposition of calcareous or silica cements near the inter-granular contacts or in between the grains in between the clasts or the grains could be pressure welded leading to the formation of the clastic rock.

So, the formation process then begins with chemical or physical weathering and then the rock debris can actually be transported to another location and get deposited under pressure, accumulate and get deposited under pressure and then it get compact, it gets compacted under pressure and then finally, the material get cemented and what you get is a mass of clastic rock and the process of chemical weathering can actually proceed through the rock forming process as indicated on the slides.

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Now, we try to look at the types of clastic rock or an approach for classification of clastic rocks. You could classify clastic rock depending on the grain size that composes the major proportion of the clastic rock. So, if you have got very coarse grained or heterogeneous rock, it is called argillaceous, lutaceous or rudites. Examples for this type of rock is conglomerate, a picture of which we have already seen or you could have another type of rock which is called breccia and what is breccia is, breccia is in fact angular pieces of preexisting volcanic rock bound by a matrix of cementitious material.

Then, as the grain size becomes smaller, we could have erinaceous rock and these things are also composed of primarily coast grained material. By coast grain what I mean is the grains that are visible to naked eye and this coast grain material could be pressure welded or they could be cemented by silica or calcareous cements. Example of this type of rock is sandstone and finally when as the grain size becomes even finer, then we could end up with lutaceous rock or rutites as they are called; these things are fine grained rocks packed together with compaction. Example of that is shale which we have discussed to some extent in the preceding.

These are actually three classes of clastic rocks depending on the grain size and these terms, the terms rudite, areanite and lutite, these terms are also used for classifying non clastic rocks containing carbonates. For example, you could have calcirudite. What is going to or what we are going to mean by that is a limestone which has got coarse grain texture or you could have calciaranite which is of intermediate grain size, limestone again but on intermediate grain size, a calcilulite which has got a much finer grain limestone. This is important because the permeability of a rock mass or rock mass after weathering is affected to a large extent by the property, by the grain size of the primary component of the rock mass.

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So, a more refined classification of clastic rock: so here, what we do is we use a tool called ternary diagram and what is meant by ternary diagram is we are going to see in the next little bit. The first ternary diagram that we are going to consider is called a QFL diagram. What is meant by QFL really quartz feldspar and lithic. So, this looks at the mineralogical composition of the rock mass, we look at the relative abundance of the quartz component, feldspar component and rock fragments. So, if the rock is composed mainly of quartz, then we are going to call it quartz something; if it is containing most of feldspar, then they are called arkoses and if it contains fragments of preexisting rock, then these things, the rock, the sedimentary rock is going to be called lithic sedimentary rock.

Then after we actually classify according to the mineralogy, then we consider the texture of the sedimentary rock and in this case, we are going to use another couple of ternary diagrams depending on whether it is composed of very coarse segregates like gravels and cobbles or if they are composed of sands or final grains and finally we are going to give a name to particular type of sedimentary rock. The sizes of different types of texture is indicated here at the bottom of the slide, so by gravel what we mean is a clast that has got greater than 2 millimeter size. Sands on the other hand, will range from one - sixteenth of a millimeter to 2 millimeter and silts are going to be from one - sixteenth to 1 over 256, one - two fifty sixth millimeter.

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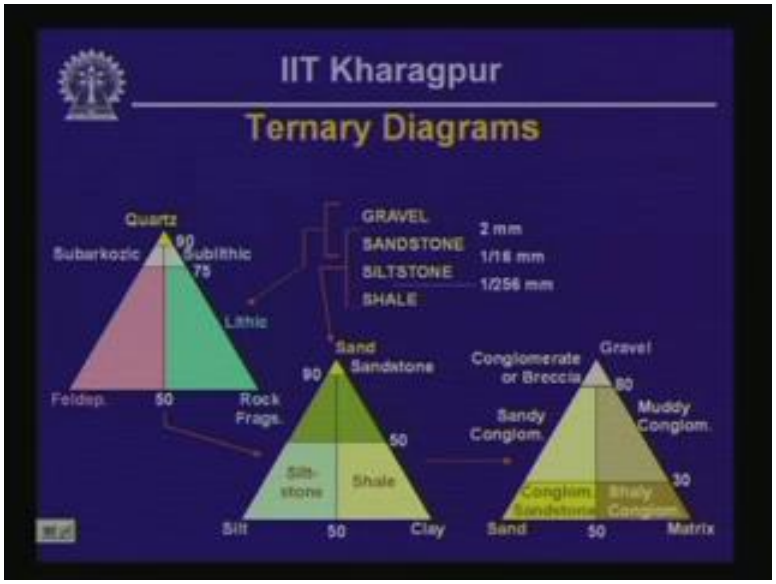

These are the ternary diagrams. So, what we said in the previous slide is that first we are going to, we are going to consider the QFL diagram. So this, here is your QFL diagram and what it is actually? It is a triangle and you plot the composition of a given type of rock on this particular triangle and if it actually plots to the left bottom, towards the left bottom portion of this particular diagram, then it is going to be called a Feldspathic rock and whereas if it plots near the bottom right, then the rock mass is going to be composed mainly of preexisting rock fragments; in that case, what we got is a lithic clastic rock.

Whereas, if the rock plots near the apex, near the top of the QFL diagram, then we have got a quartz rock and there are some intermediate areas within this ternary diagram in which case if it is on the left, near the left top center of this particular diagram out here, then we are going to call it subarkosic rock and if it is in this area, then we are going to call it a sublithic rock.

Now, you carefully look at the border lines that actually separate these different areas and the percentage that separate these areas are indicated along the edges of this particular triangle. For example, the differentiating line in between feldspathic and lithic rock type is at 50% composition of feldspar and 50% lithic. Whereas, the lines that separate sublithic from lithic is at 75% lithic fragment, lithic composition and the one that actually differentiates within sublithic and quartz is at 90% lithic composition, actually 90% quartz composition.

So, if you are near the top, then the rock is composed mostly of quartz. So along this particular edge, along the right edge, actually proportion of quartz increases, proportion of quartz increases; whereas as you climb down on the right edge, along the right edge of the QFL diagram, the proportion of the lithic fragment increases. Whereas, as you move along the bottom edge of this particular diagram, then the lithic proportion decreases and feldspar proportion increases and while if you actually climb up along the left edge of this particular diagram, then the quartz proportion increases and feldspar proportion decreases.

So, that in a nutshell is the QFL diagram and in addition to that what we have to consider are two diagrams that looks at the texture of these different types of rocks and what you have got on the middle ternary diagram is the composition by percent of different sizes of grains. If it composes of mostly of sand, then the rock is going to plot near the top of this particular diagram; whereas if it is composed mostly of silt, it is going to it is going to plot near the bottom left of this diagram; whereas if it is composed of clayey particles, then the rock is going to plot near the bottom right of this particular diagram.

Again, you have got some intermediate areas to consider in this case and I mean, the percentages of different components that actually differentiate this different classes are also indicated along the margin of this particular ternary diagram and finally, if you have got rocks that are composed to some extent by very coarse grain material like gravel or cobble size, then you are going to use the ternary diagram near the bottom right of this particular slide.

So here, what you have got is if the rock is composed mainly a matrix that is mainly a matrix, non-detrital non-clastic matter, then it is going to plot near the bottom right. Whereas, if it is composed of sand, then the rock is going to plot near the bottom left and if it is composed mainly of gravel size or coarser material, then the rock is going to plot near the top of this particular ternary diagram and how you are going to name these different types of rocks, that is also indicated there.

Let us take an example; for instance, if you have got a rock that plots at this location, so let us call it rock A. So, how do you or how you are going to classify or how you are going to name this particular rock? So, what we are going to do is we are going to look at the least abundant material first. So, in this case, the least abundant material is going to be quartz and then we are going to look at the next least abundant material and that in this case is going to be feldspar. So, this is going to be quartz, actually arkosic, feldspathic, lithic something.

So, this particular rock after we complete this step is going to be arkosic, feldspathic, lithic something and this something for finding out what is meant by this question mark, we have to go to the next step in which we are going to move over to the next ternary diagram. Let us say a rock A is composed mainly of sand grains and it plots near the top of the ternary diagram, top of the middle ternary diagram. So, this is the location where rock A plots on the central ternary diagram.

So, in this case what is going to happen, how we are going to name this particular rock is, we are going to call this one lithic sandstone. You should notice, so rock A in this case is arkosic, feldspathic, lithic sandstone. Now, what is actually, what is the meaning of this particular thing is that you first go into the QFL diagram, you try to classify the rock and then move over to the texture tract ternary diagram and try do actually complete the classification of the rock.

Now, in this case we use the ternary diagram near the bottom center of this particular slide but had it contained a large proportion of gravel or coarser size material, then we would have had to use the ternary diagram which is near the bottom right of this particular slide. So, lot of information on this slide and I am going to actually leave it up there for the next little bit in order to allow you to assimilate the different types, the different components of these ternary diagrams used in classification of clastic sedimentary rocks.

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Now, then we have to actually move over to the classification of non-clastic or we have to look at the genesis and types of non-clastic sedimentary rocks and as we have mentioned earlier, the non-clastic sedimentary rocks could form from chemical or biogenic processes and rock forming processes in this case includes in case of chemically formed rocks; precipitation, actually these are the primary processes involved – precipitation, evaporation or crystallization. In case of biogenic sedimentary rocks, what you have got is accumulation of biogenic material, burial and disintegration. So, these are the processes that actually involved mainly in development of non-clastic sedimentary rocks.

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First of all, we try to consider what is meant by or what are the different types of chemically formed rocks? In case of chemically formed rocks, if you recall, these rocks form primarily from evaporation, precipitation, evaporation and precipitation of matter primarily from inorganic processes although in this case, some biogenic activity could also catalyze the rock forming process.

Now, the types of rocks here include siliceous deposits, siliceous deposits formed mainly by evaporation of saturated silica solution. How these different types of silica solutions actually form in the aqueous form is going to be examined later when we look at chemical weathering. Examples of this type of rock include flint, chert and jasper. Then you have got carbonate deposits, these are primarily precipitates from carbonate rich water solution, carbonate which aqueous solution and examples of this class of rock includes limestone and dolomite.

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You could have ferruginous deposits, these deposits chemically formed from some iron ores and they are often times catalyzed by organic activities. Then you have got phosphatic deposits; sea water rich in phosphoric acid leads to the formation of phosphates, rock phosphates primarily through inorganic processes.

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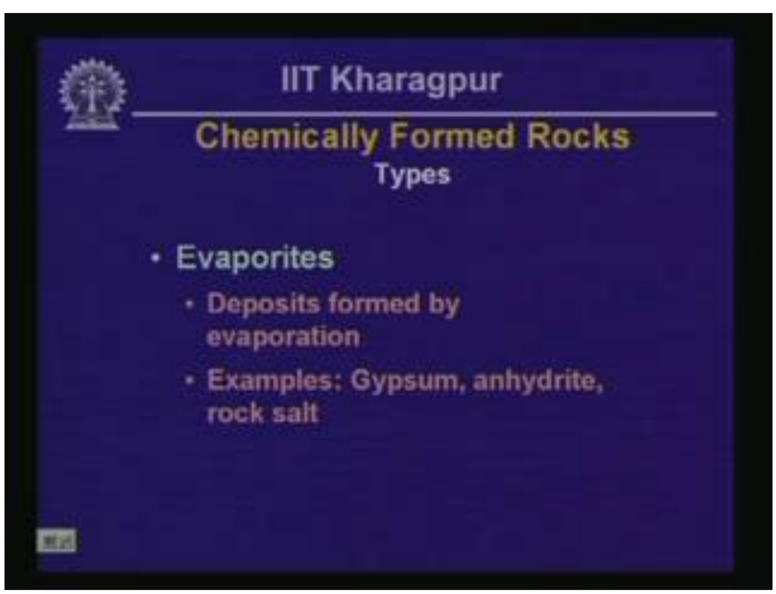

And finally, we have got evaporites which forms from evaporation of saturated solutions and the type of rock, the types of rocks that arises from this type of process include gypsum, anhydrite and rock salt.

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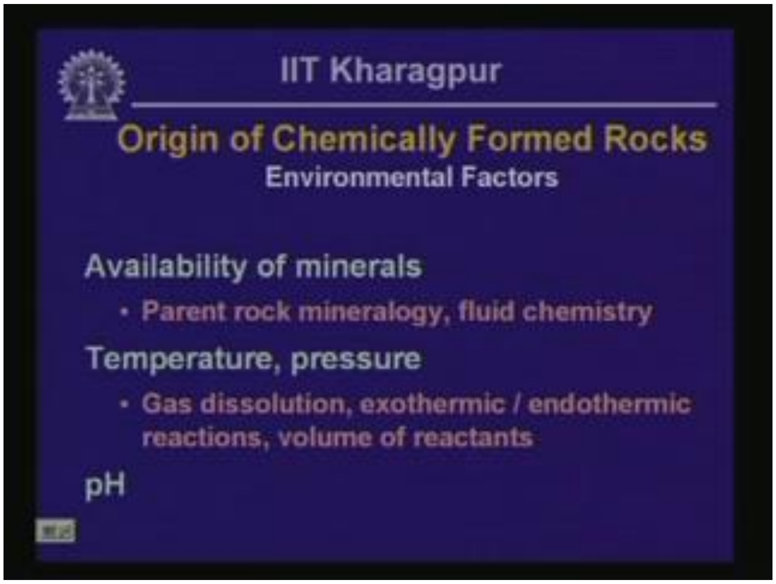

Now, the chemical processes that actually gives rise to the formation of chemically formed rocks are affected by a number of environmental factors. So, these rock formation processes actually accentuate or they might get impeded under some environmental conditions. What are those conditions? They include whether a certain type of mineral is available or not and here what is important is the mineralogy of the parent material as well as the chemistry of fluid.

Then the second thing that is important here is temperature as well as pressure. This actually affects the dissolution of different types of gases and they sometimes impede or catalyze exothermic or endothermic reactions or reactions in which the volume increases and also pH of the environment; what is the concentration of the hydrogen ion, that also is another important environmental factor that affects the chemical process.

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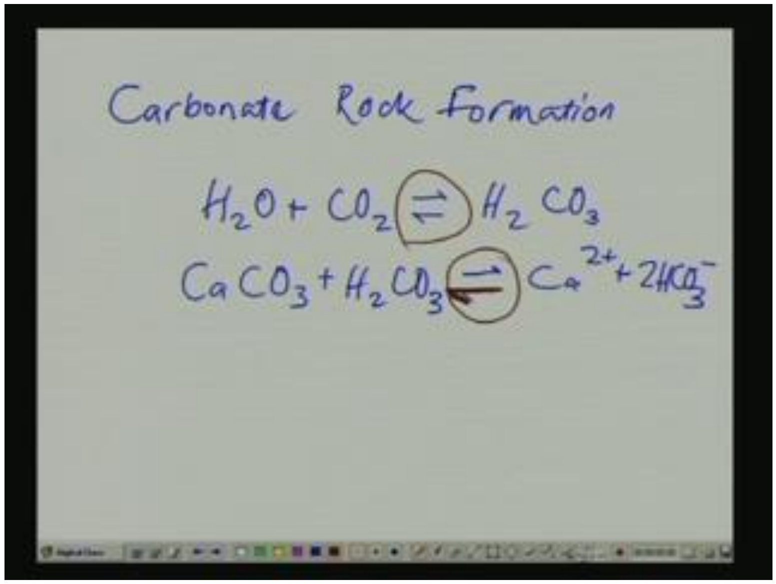

Now, we actually want to have a look, a quick at the formation process that leads to the development of carbonate rocks. Carbonate rock formation: so in this case, the chemical reactions that are involved include formation of carbonic acid by the dissolution of ambient carbon dioxide into water and reaction between calcite and carbonic acid giving rise to release calcium iron and release of different irons in the aqueous solution.

So, in this case you should notice, the reactions can proceed both ways and what happens actually is depending on the environmental condition, sometimes forward reaction gets accentuated or sometimes the backward reaction gets accentuated. For example, if you have got an elevated temperature, then dissolution of carbon dioxide in water actually is impeded and in that case, formation of carbonic acid is impeded. As a result, the reaction mainly proceeds, the bottom reaction mainly proceeds to the left and in this case, what you are going to have is this is going to lead the deposition of precipitation limestone.

Whereas if you have got a reverse environmental condition that means you have got a low temperature environment, in that case it is going to lead to the dissolution of limestone into aqueous solution.

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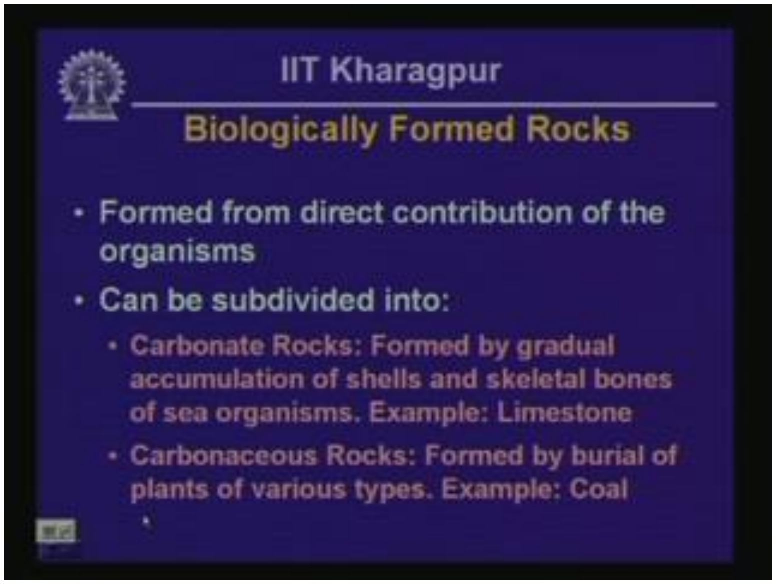

So, biologically formed rocks, they form because of direct contribution of biologic organisms and in this case, rocks can be subdivided into different categories. You could have carbonate rocks, this class of carbonate rocks actually formed by gradual accumulation of shells and skeletal matter and you could have carbonaceous rocks like anthracite or bituminous coal.

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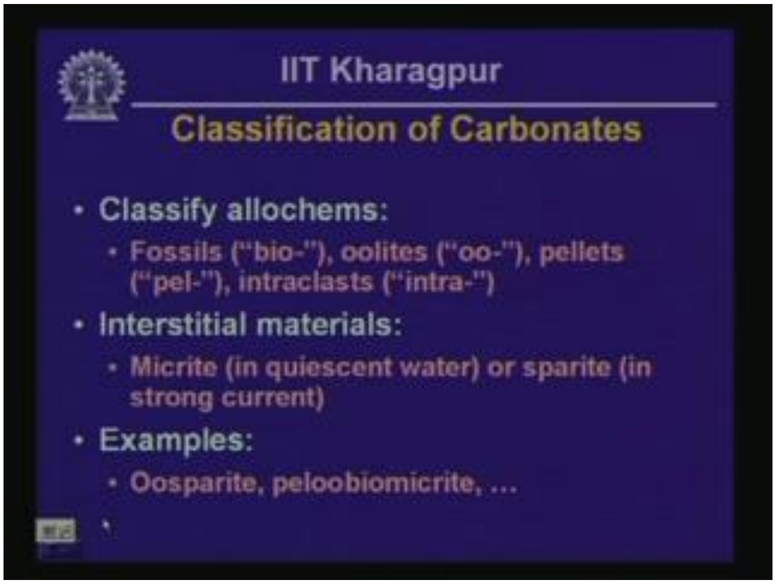

Classification of biogenic carbonate rock: in this case, the classifying scheme includes the naming of the allochems. By allochems what is meant is the clastic component, clastic component and you also need to have, you need describe the interstitial cementitious materials or the matrix. So, if the allochems contains a lot of fossils; in this case, the rocks will have a set of letters called bio or if it contains oolites which is actually chemical precipitate of calcium carbonate which looks like round nodules, in this case you are going to have a double O in the naming of that or it could have excreta of biogenic matter, in that case you will have a pel in the name of the rock or if it is intra-clasts, broken debris of preexisting rock, then you will have something by the name intra in the name of the rock.

Then you will have micrite, if the interstitial matter is mainly of micrite, formed of micrite, this is calcite cement formed in quiescent water or sparite, sparite actually is a pigment of a strong current environment, it is also of calcite, it is composed of calcite cement. Examples of this types of classification includes oosparite or peloobiomicrite or you could combine, you could have several different combination of this phrases as I indicated above.

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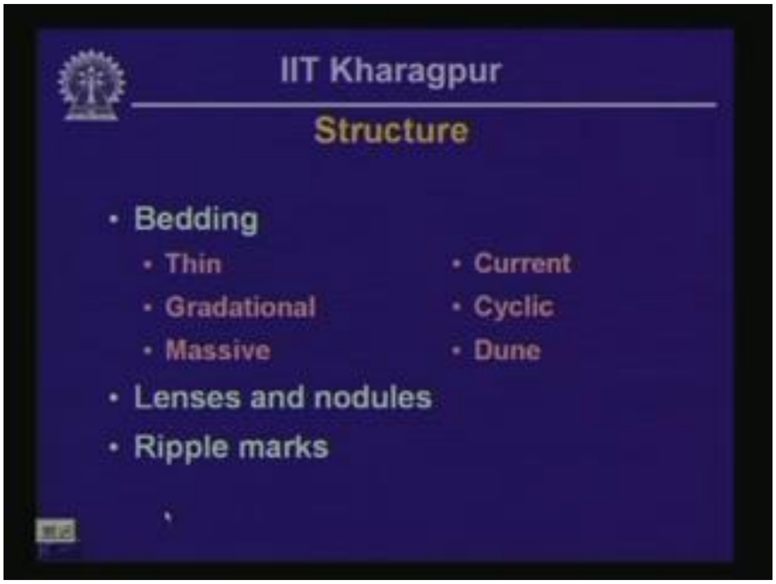

Then there could be several different structures of sedimentary rock. The main thing, the main structure type is bedding. The bedding could be thinly bedded, there could be thin laminations, thin laminate of different types of material or there could be a gradational layering or the sedimentary rock could be massive which does not show any bedding as such. These things, massive bedding is typical of clay stone or limestone, fine grained sedimentary rocks, whereas thin and gradational bedding is typical of coarser grain sedimentary rocks like sandstone. Then there could be ripple marks, lenses and nodules or there could be other remnants activity of water, flowing water like current, cyclic and dune. What we mean by these things; let me quickly explain.

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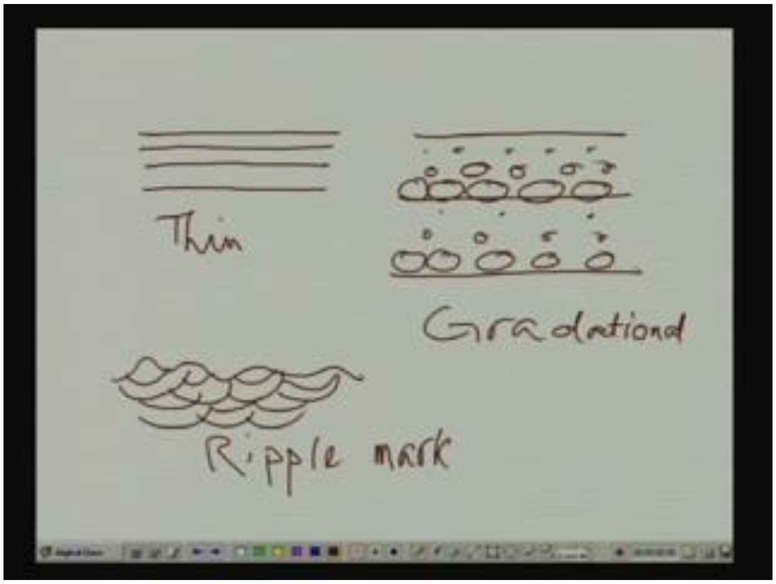

For example, thin bedding is going to be of this type, then you could have gradational bedding; in this case, within a particular bed, the gradation of the clastic matter is going to progressively change. So, you can see, what is meant by gradational bedding and this one is thin bedding, then you could have ripple marks, so within the structure of the rock, you have got marks of ripples of water activity. So, this is ripple mark and then in addition to it, there could be several remnants of biogenic and inorganic activities that might be on going during the lithification process like there could be remnant mud cracks or remnant cross bedding in fluvial environments.

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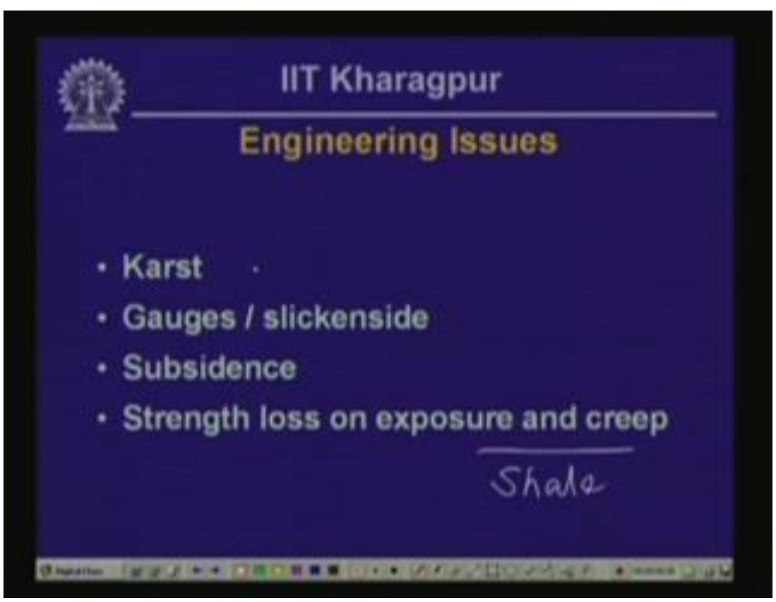

Then we look at the major engineering issues that affect the terrains underlained by sedimentary rock. Main problem here includes the terrains, limestone terrain, limestone terrain where portion of limestone can get dissolved in water leading to the development of karst topography and these types of areas are affected by subsidence because the over burden on top away hollow dug out by activity of water may actually subside.

Then there could be gauges and slickenside that may be developing at the inter-beds because of chemical weathering. All these things actually can lead to strength loss on exposure to air or environment and creep and this type of problem is a frequent problem in this case of shaley areas, shale terrains; so, this one is problem in case away limestone terrain, this is also a problem of karst areas. Finally, we look at the uses, engineering uses of sedimentary rocks.

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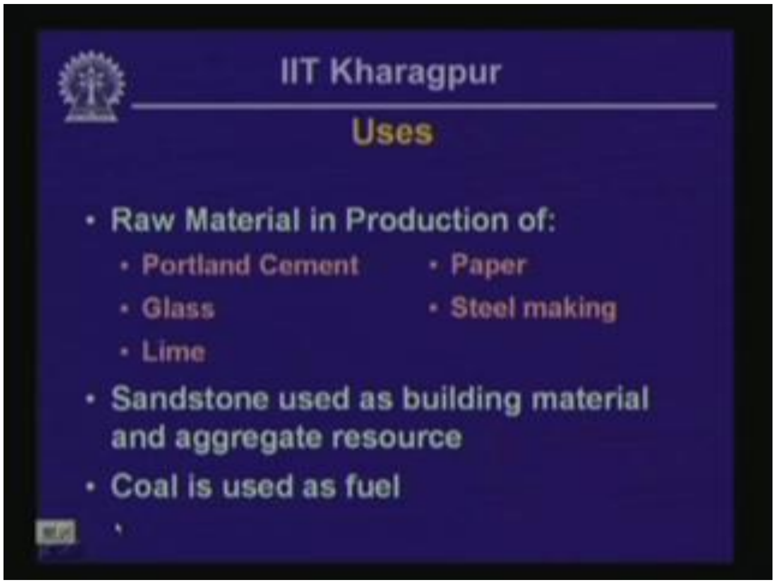

Sedimentary rocks are used in manufacturing of Portland cement, paper, glass and steel making; lime stone is a major ingredient in that case. Sandstone is a very major building material and aggregate resource and as you all know, coal is used as fuel.

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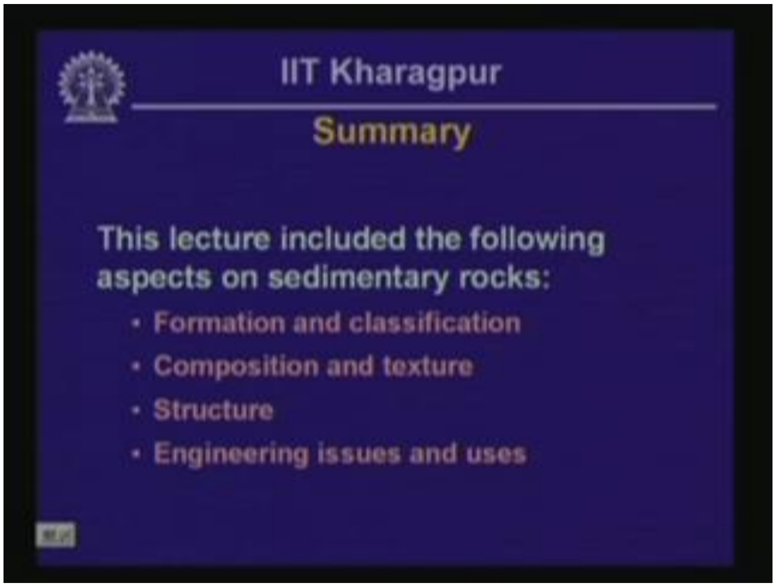

To summarize; this lecture included formation and classification of sedimentary rock, we looked at composition and texture of sedimentary rocks, we looked at structures of sedimentary rocks and we looked at engineering issues and uses and finally, we end this particular lesson with the question set. You try to answer these questions at your leisure.

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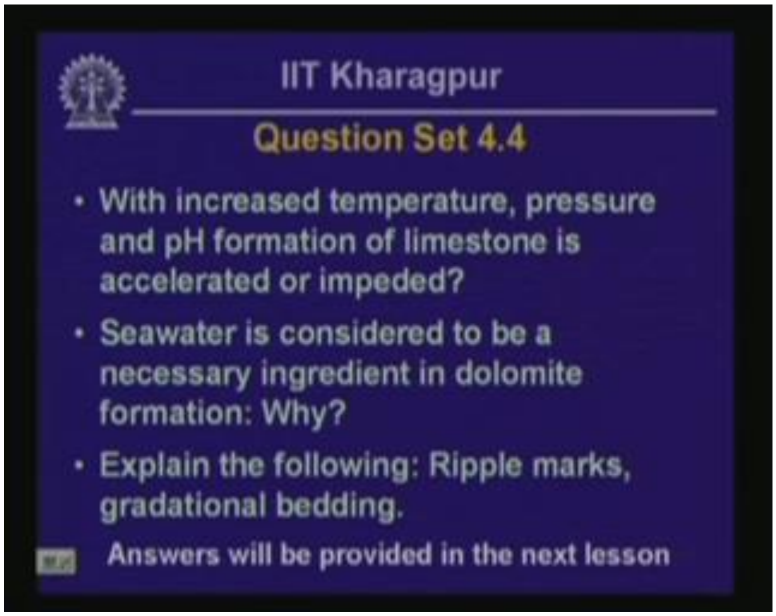

The first question is that with increased temperature and pressure and pH, formation of limestone is accelerated or impeded? Then the second question is, sea water is considered to be a major ingredient necessary for dolomite formation; why that is so? And, the third question is, explain the following terms: ripple marks and gradational bedding. Try to answer these questions and I will be providing you with answers when we meet for next lesson.

Until we meet, bye for now. Thank you.