

Engineering Geology

Prof. Debasis Roy

Department of Civil Engineering

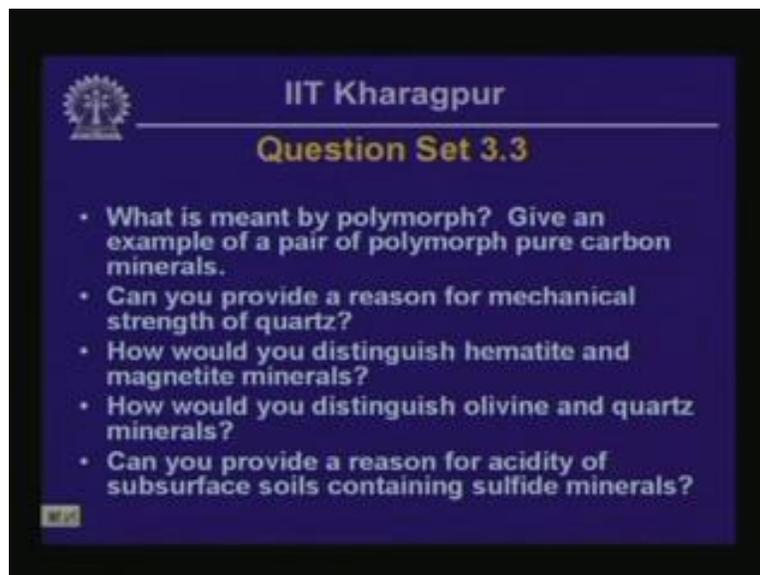
Indian Institute of Technology, Kharagpur

Lecture - 8

Origin and Types of Rocks

Hello, everyone and welcome to a fresh lesson on the engineering geology. Today we are basically going to talk about origin and types of rocks and also we are going to look at the different types of rocks that are commonly available, normally found across the country India. But before we actually proceed with the subject matter of today's lesson, we are going to consider the questions that were asked the last time when we met. This is the question set that you already have.

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The first question was; what is meant by polymorph and I also asked you to give an example of a pair of polymorph of pure carbon mineral. Now, polymorph is actually are a bunch of minerals which have the same kind of chemical composition or chemical formula but they have got different crystallographic geometry or different structure really.

Now, two common, two polymorphs of pure carbon mineral are graphite which is essentially a sheet, which has got a sheet structure like what we had for sheet silicates and then you have got diamond which is basically which has got a pair of tetrahedra which is composed of a pair of tetrahedral and it is a closed form structure. So, that is the answer or that gives you the answer of the first question.

Now, the second question that was asked was how you can explain the mechanical strength of the mineral quartz. Now, quartz as we have seen in the last presentation is composed of a three dimensional frame work structure of silicate tetrahedra and this can be cited as one of the fundamental reasons because that gives the strength of quartz mineral.

Now, the third question was; how you would distinguish between hematite and magnetite minerals? These two minerals as we have seen that they are actually oxides of iron and they are remarkably similar with respect to many of their properties except for the fact that hematite is weakly magnetic, whereas magnetite is very strongly magnetic.

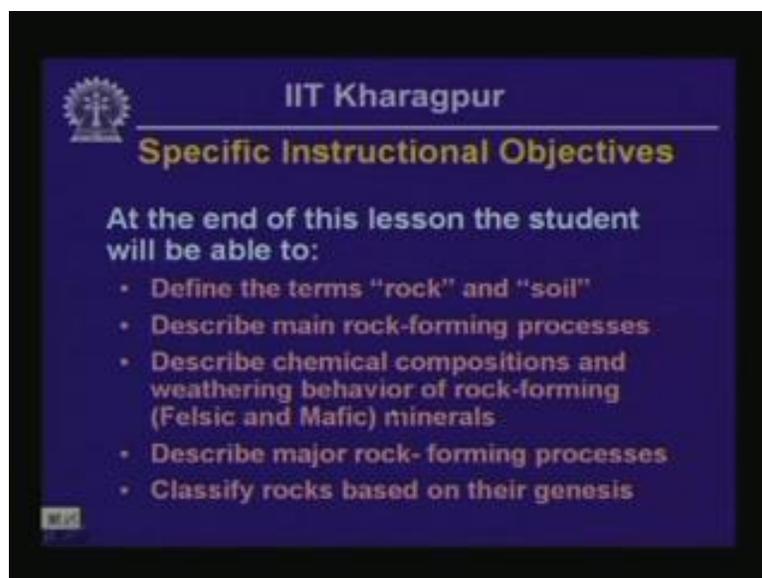
So, just by looking at the magnetite magnetic property of these two minerals, it could easily distinguish between hematite and magnetite minerals. Forth question was; how would you distinguish between olivine and quartz minerals? Again these two minerals are very similar in many of their characteristics. For example, the hardness of both olivine and quartz are very similar.

Now, one of the distinguishing characteristics emerge when you look at the, when you look at the unit crystals of olivine and quartz and what we see there is that both; actually quartz mineral has got a three fold symmetry, whereas the highest order of symmetry that is observed in a olivine mineral is a twofold symmetry. A quartz crystal, quartz unit crystal is basically trigonal crystal whereas olivine is of the orthorhombic family.

Now, we will see actually in today's presentation that olivine and quartz although there are similar in many respects, they are of two distinct family of rock forming minerals. Olivine is called mafic mineral, they are typically dark colored and heavier than the family to which quartz belongs. And, this is called felsic mineral, they are typically light colored mineral and they are of a little bit smaller unit rate and that also you can use as a distinguish characteristics of these two minerals.

The fifth question that was asked was how can you, how can you actually, can you give a reason for acidity of subsurface soils containing sulfide minerals? Now, what happens if subsurface soils contain lot of sulfide minerals is that this sulfide minerals, they get oxides in oxygen reach environments like aerobic environments near surface deposits for instance and then by the action of water, the sulfates get sometimes released as acids and that actually explains the reason for acidity in this kind of sulfide reach environment. So, that gives or that finishes the question set that was provided, that was given to you in the last lesson.

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Now, we move on to the subject matter of today's presentation. What we would learn in this particular lesson, a list of it is as follows; we will be able to define after we finish the lesson today, what is meant by the terms rock and soil, then we will be able to describe the main rock forming processes - geologic and chemical processes involved in formation of rocks.

Thirdly, we will be able to describe the chemical compositions and weathering behavior of main types of rock forming minerals - felsic and mafic as I just now mentioned when I was taking care of the previous days question set and then we are going to or we would able to describe major rock forming processes - and finally - major rock forming processes relevant to the Indian context and finally, we will be able to classify rocks based on their genesis. Let me correct this one here and what I meant here is in the Indian context.

So, that actually is in a nutshell are the list of the subtopics that we are going to cover in this particular lesson.

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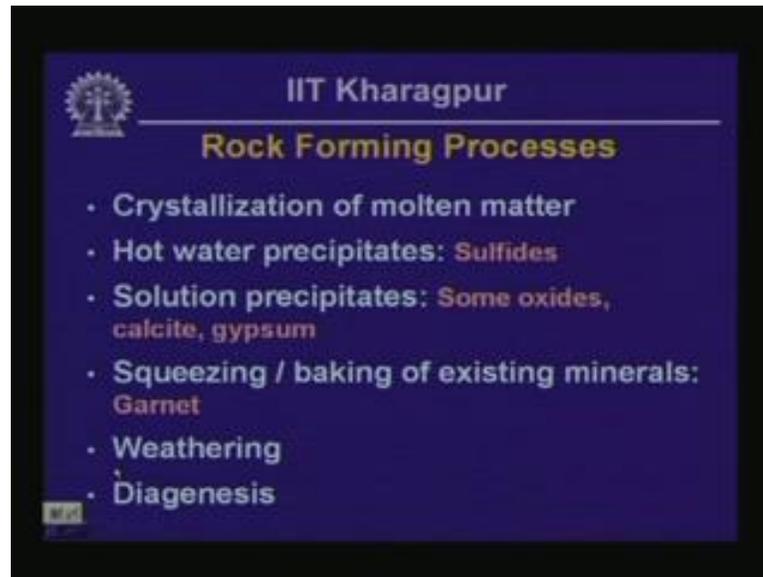


Now, with that said, we are going to look at the formal definition of the terms - rock and soil. These are two loosely used, these are two geologic terms that are often loosely used but when we want to formalize the concept, then what is meant by rock is essentially a massive natural aggregation of minerals, mineral grains which cannot be easily separated from each other.

What is meant by that is that in order to break a piece of rock, a relatively high amount of energy will be required; whereas if you compare the concept with the soil, soil particles are also in a sense the natural aggregation of mineral. But the grains, individual grains composing the soil mass can be separated from each other by relatively small amount of mechanical energy input and the processes involved in separating the soil grains, you could imagine that soil grains can be separated from each other relatively easily and you could separate the individual grains by simple processes like raining or pluviation of the soil mass, remolding and mixing of the soil mass with water and stirring.

So, these are the simple processes by which you could actually separate individual soil grains from other soil grains. Whereas for these processes, we will not be able to in general separate individual grains of rock from each other. So, that is actually the distinction between rock and soil which we are going to use in this course.

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Now, we get onto the common rock forming processes. What are the processes by which different types of rocks come into being? The first think that comes into mind is crystallization of partially molten matter. Now, what is partially molten matter? Say, underneath the surface of the earth, you get under pressure and temperature, the rock forming minerals exists in a partially molten state and this state, this particular state is called magma and when magma comes into contact with relatively colder mass because of some reason because of extrusion or volcanic activity or because of its being carried away in some other location at of colder temperature and lower pressure, then what happens? This partially molten material starts solidifying and they start solidifying in a sequential manner and that gives rise to a class of rock called volcanic rock.

Now, the second cause which we have indicated here, second rock forming processes which we have indicated here is the process of precipitation from hot water and the sulfide minerals, class of minerals which are chemically sulfide salts of different anions, many of them actually they get precipitated out of sulfide rich water which we were originally very hot and upon cooling, they get precipitated out of the water.

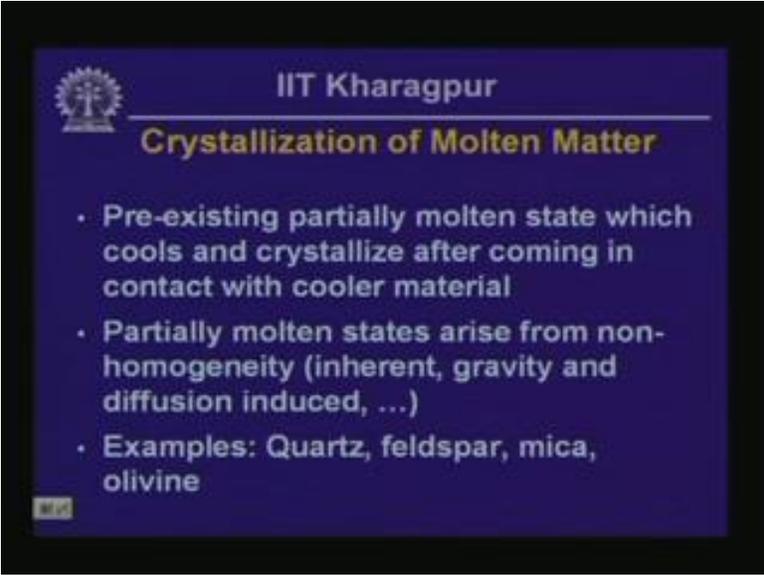
Now, the third rock forming process which we have indicated here is solution precipitates and some of the calcites carbonate minerals, oxides and gypsum; they get precipitated out of saturated solutions by inorganic and or biogenic activities. So, that is the third one, third most important rock forming process

and then we have got alteration of rock structure and this is really squeezing and baking of existing mineral. So, in that process, the identity of the original mineral or chemical characteristics of the original nature, that get salted and what you ended up with is a rock of different characteristics and one of the minerals that is formed in this manner is the granite group of minerals.

Then the forth one is weathering; pre exciting rock masses, they can get weathered and in that process different small pieces of rock, they may get mobilized by the action of water for example or by action of volcanic activity and get deposited once again and upon deposition, they might actually get buried underneath a deep very thick over burden and by the pressure that comes because of that the individual grains may get cemented once again and this process will gives rise to another class of rock and many of the sedimentary rocks actually originate from this type of activity.

So, to summarize this thing then, one of the major rock forming processes is crystallization of partially molten matter, then we have got different precipitation processes, hot water precipitates or precipitation from water solutions, then we have got squeezing or baking of pre exciting minerals, we have got weathering and deposition and cementation of pieces of pre exciting rock. These are the main classes of rock forming processes that are important.

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The image shows a presentation slide from IIT Kharagpur. The slide has a dark blue background with white and yellow text. At the top left is the IIT Kharagpur logo. The title 'Crystallization of Molten Matter' is in yellow. Below the title are three bullet points in white text. A small yellow box with the number '15' is in the bottom left corner.

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Crystallization of Molten Matter

- Pre-existing partially molten state which cools and crystallize after coming in contact with cooler material
- Partially molten states arise from non-homogeneity (inherent, gravity and diffusion induced, ...)
- Examples: Quartz, feldspar, mica, olivine

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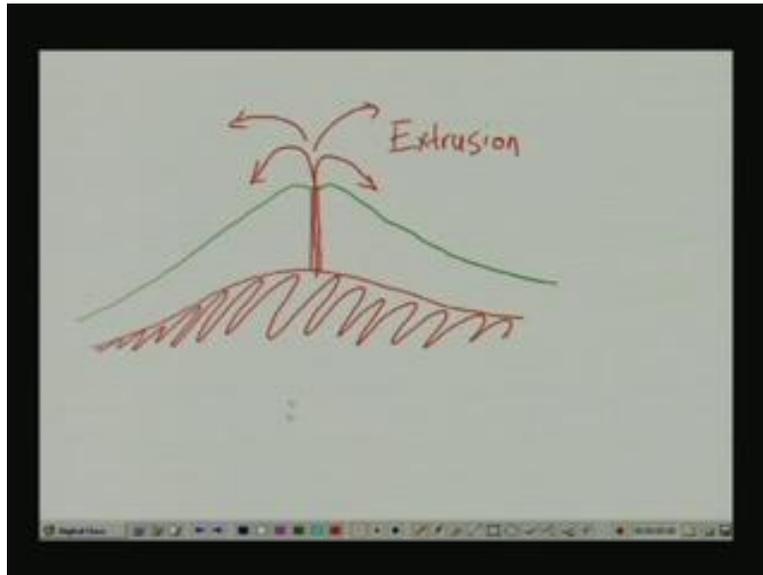
Then we look at the details of the crystallization process and a large volume, large amount of large proportion of rock on the earth surface within the crust of the geoid, a large proportion of the rock is formed in this process and what happens in this case? Pre existing partially molten rock forming minerals, they get crystallized as I indicated earlier when then come in contact with cooler material and that could happen for instance when a mass of partially molten magma gets ejected to the surface or comes in contact with water for example.

Then the second thing that happens, second thing that is important here is that partially molten state; how this partially molten state arises because you know by now from chemistry and other subjects that all the minerals have got a distinct temperature at which they melt. Then how come you have got partially molten material, partially molten? What is rational for existence of a partially molten of magma in partially molten state?

The reason why partially molten state occurs is non homogeneity or because of the fact that the magma is composed of several different minerals. This non homogeneity could be inherent non homogeneity or it could be driven by gravity or it could be induced by diffusion. Now, examples of rock that originate from crystallization of molten matter include quartz, feldspar, mica and olivine. Now, before I leave this topic, let me explain the main point here is the process that we indicated here in the first point that how partially molten magma actually cools.

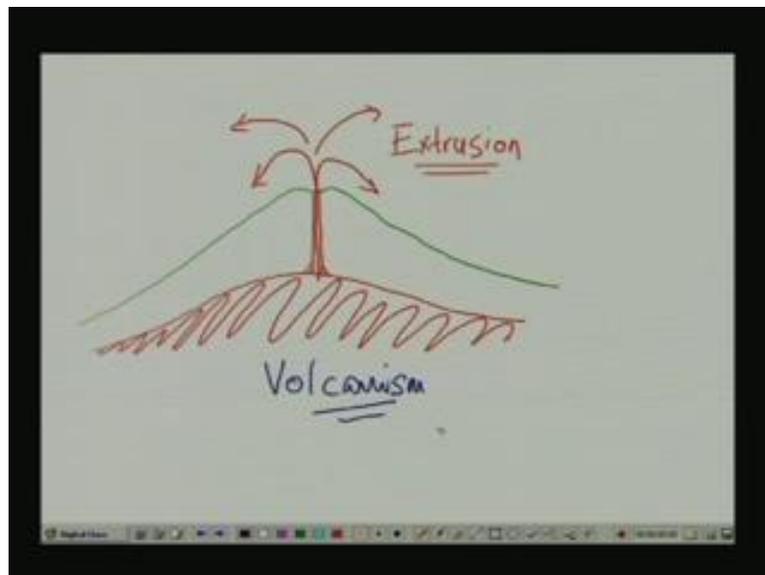
Now, let us consider a situation where you have got a magma chamber underneath a volcano and when the volcano erupts, the magma actually spews out and this process is called extrusion.

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This process of extrusion will bring the magma into a very cooler, in a relatively cooler atmosphere and the volume also is going to expand and in the process, the magma is going to cool down quite rapidly and you are going to get solid minerals separating out of the magma and that process is one of the processes involved in crystallization of molten matter. So, here we have seen the process of volcanism.

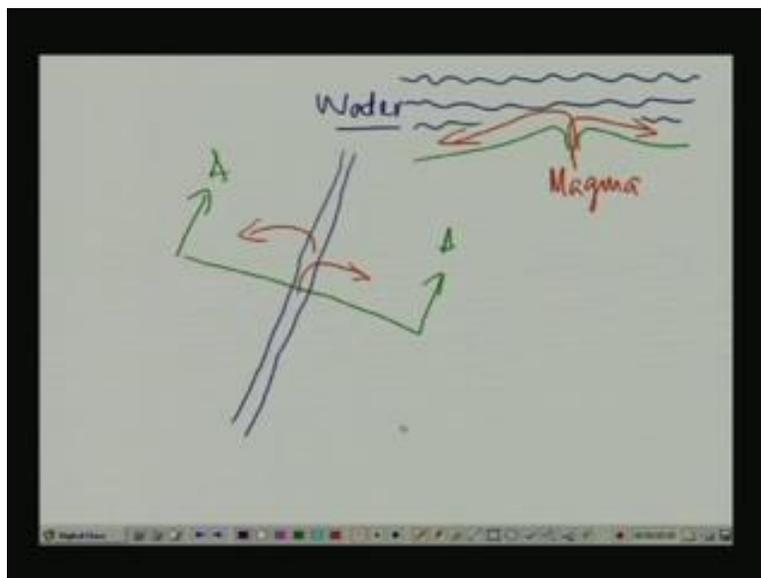
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The same process occurs underneath mid oceanic ridges, underneath the sea which is essentially a divergent boundary where individual plates that comprises the crust of the earth that actually diverges from each other. I will give you an example here; in the mid oceanic ridge what happens is you have got, we are looking at plan view in this case and let us say that is the mid oceanic ridge and the molten matter comes spewing out of the mid oceanic ridge and everything happens underneath the ocean.

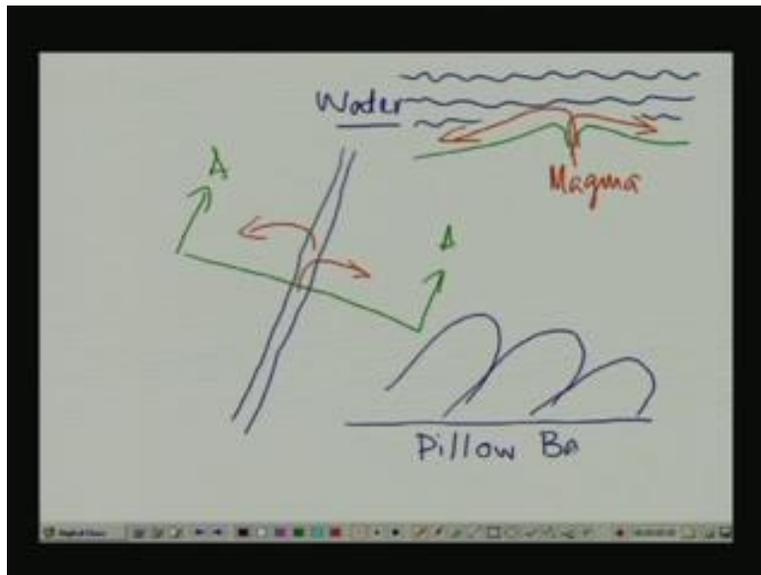
And in this process, the molten matter comes into contact with the water above it and in order to explain this one let us look a section here and here you have got a very similar situation as we have seen earlier in case when I was explaining volcanism. Here, the magma gets spewed out and here in this case, it gets spewed out underneath a body of water and when the magma comes into contact with water, then the magma solidifies and what you get is a type of rock known as basalt and often times what happens, this process actually makes the rock, makes the or gives the magma, partially molten magma after it comes into contact with water an appearance of pillow.

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And, the basalt that comes out of this process also retains the appearance of pillow and that type of basalt is called pillow basalt and pillow basalt has got an appearance which is kind of like this; so, pillow basalt has got an appearance of this type.

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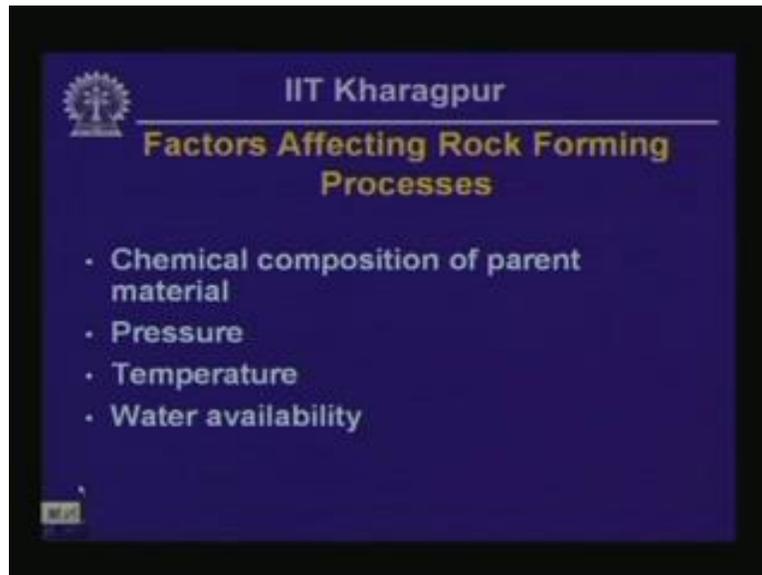


You can imagine that as the magma flows in this direction, this is what is going to happen, this is indeed what is going to happen intrusively because of increasing viscosity of the magma once it starts cooling down after coming in contact with water. So, that gives you an idea about how partially molten matter, partially molten magma cools down and crystallize after coming in contact with cooler material.

Now, extrusion is not the only process as we will see the later, as will see in one of the subsequent lessons of this series of lessons; there are other process also that can cool the molten partially or preexisting partially molten magma and another process that comes into mind is intrusion and the rock that comes out of the process intrusion is called basalt.

In this case, cooling rate is much lower than the extrusion process and consequently, the granular structure of the granite rock that actually comes from crystallization because of intrusion; the grains are larger than the grains of rocks formed out of extrusion process.

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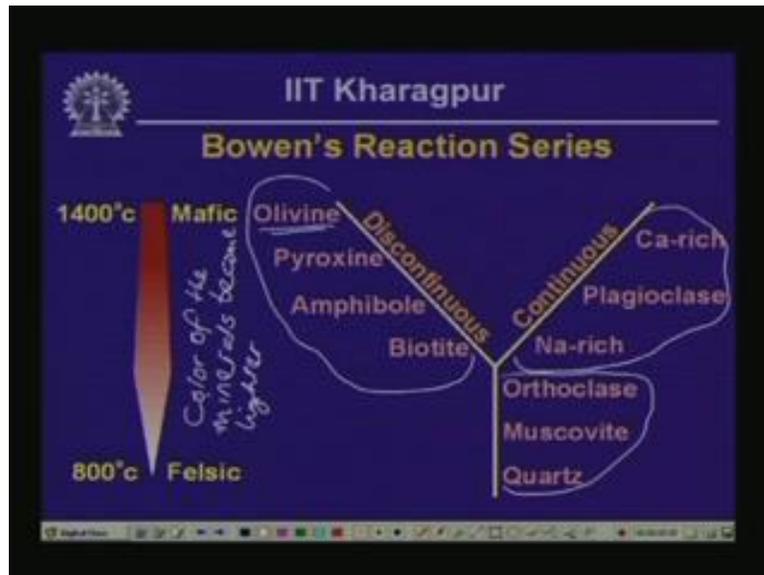


Now, the factors that affect the rock forming processes; these are the main factors that are listed here. The first one is the chemical composition of the parent mineral - parent partially molten or pre existing rock material, then the pressure at which the process is taking place, temperature at which the processes is taking place and whether during the rock forming process water was available or not or for that matter, whether there was any other type of mineral that was available in the vicinity while the rock forming processes was going on.

Why that is important is because if water is available, then many of the minerals might get hydrolyzed and alter their chemical characteristics and consequently the rock that is going or the rock that is going to be formed out of that processes may be different in characteristics compared to the situation in which water or other chemicals were not available.

So, what are important then? The chemical composition of the parent mineral, then pressure and temperature and the availability of water and other chemical constituents in the environment in which the rock forming process is taking place.

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Now, I indicated when I was talking about partially molten magma that the reason why partially molten magma occurs in the first place is because of non homogenic and Bowen is one of the earliest scientists who had a insight in this regard and what he came up with is a concept called a Bowen's reaction series in the early 1900 and that concept is still used in getting inside about the rock forming processes.

What Bowen proposed was the fact that minerals actually change their characters as the temperature comes down and there are two classes of minerals; one along the discontinuous series shown on the left here, these are the ones; this is the class of minerals on the discontinuous series and then you have got another class of mineral that form a continuous series as the rock forming matter becomes cooler and cooler.

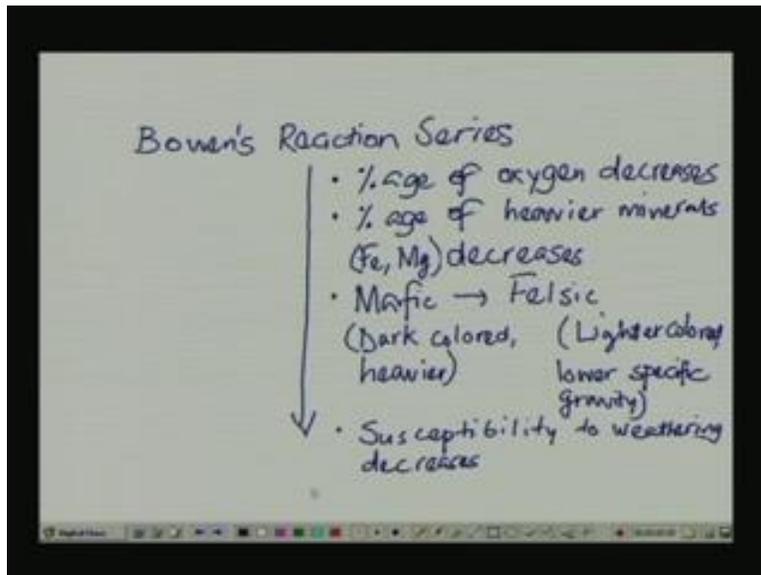
And then finally, when the rock forming magma cools further, then what happens is the two series, they actually ((... Refer Slide Time: 28:13) and what you end up with is another set of minerals; these things actually precipitate at a relatively smaller temperature. So, for example, if you consider temperatures like 1400 or 1600 degree Celsius, then you get olivine mineral solidifying out of the partially molten matter; whereas at those kind of temperatures, pyroxene mineral or amphibole mineral or biotite mineral, they are going to still remain in solution and on the continuous side what is going to happen is plagioclase feldspar is the one that is going to start precipitating out and initially at larger temperatures, the feldspars will be more calcium rich whereas when the temperature reduces, then

percentage of sodium is going to start increasing and when the two links ((... Refer Slide Time: 29:20)), then what we are going to get or what you are going to get, that crystallizes out of the partially molten matter are orthoclase, muscovite and finally quartz.

So you can see, this gives very important insight really. The precipitates that comes out of solution at higher temperature or the crystals that actually solidify at higher temperatures are essentially mafic minerals and the minerals that solidify at lower temperatures, they are essentially felsic mineral. So, the color of the minerals actually, color of the minerals become lighter and also you can, as I explained earlier is that mafic minerals are heavier than felsic minerals, so the second thing that occurs when temperature goes, temperature of the rock forming magma goes down is the percentage of iron and magnesium and such heavier elements, they actually go down.

Also, another thing that you might recall from the previous days presentation was that olivine has got, olivine has got the highest percentage of oxygen within the crystal structure whereas quartz has got the lowest percentage of oxygen in the crystal structure and this thing is very important actually, this concept is really very important because it give us some insight of understanding why in the first place magma occurs in a partially molten state and secondly, it gives the composition of different types or it gives as the idea about what is the formation temperature of different types of rocks and even as we will see latter on in this presentation, it will give as some insight about what is going to be the weathering characteristics of different type of rocks and we will see that as we claim down along the Bowen's reaction series or as the temperature actually falls, temperature of the magma falls, then the rocks that form from that magma are less and less susceptible to weathering. So, what we get then?

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Just to summarize, as we claim down along the Bowen's reaction series, then a number of things happen; percentage of oxygen reduces, percentage of heavier minerals, typically those composed of Fe iron or magnesium reduces. Actually, I should probably use the term decreases rather than reduces because reduction could be construed as a chemical process. So, let me use the term decreases.

Then there is a transition from mafic rock to felsic rocks. Mafic as I explained means dark colored and heavier that is pretty intuitive because the content of Fe and Mg decreases, so you would imagine that the color is going to become lighter and the mineral is going to become lighter as well. So, this one is lighter colored, lighter colored and lower specific gravity and finally susceptibility to weathering decreases.

So, this is a very powerful concept then and that helps us also to understand the rock forming process out of crystallization of partially molten matter; the chemical transition and some of the weathering characteristics as well.

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Then we want to look at the common main rock forming minerals that composes many of the majority of the rock mass there were available that are occurred on the earth's crust. Out of the 3000 known minerals, only 9 make 95% of the crust. So, this is very important statement here, this one is a very important statement; 9 of the 3000 minerals, they make 95% of the earth's crust. 4 of this minerals are felsic minerals, light colored minerals – quartz, muscovite, orthoclase and sodium plagioclase and 5 of these minerals are mafic minerals, they include biotite, amphibole or hornblende, pyroxene or Augite, olivine and calcium plagioclase

So, the silicate minerals that crystallize out of molten matter, 9 of them are of major interest in our case.

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Felsic Minerals

More susceptible to weathering

Quartz	SiO_2
Muscovite	$\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$
Orthoclase	KAlSi_3O_8
Na-Plagioclase / Albite	$\text{NaAlSi}_3\text{O}_8$

Usually more weathering-resistant than Mafic group

Now, the felsic minerals that form most of the rock masses that we consider that we saw in the last slide there, they are quartz, muscovite, orthoclase and sodium plagioclase or Albite and you can see that as we climb down on this particular table along this particular table, what we get are rocks, there are more and more susceptible to weathering.

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Now, rocks composed of quartz then, rocks that are composed of quartz, they are going to be more weather resistant, more weathering resistant, resistant to weathering; whereas, rocks that are composed of sodium plagioclase or Albite, they are going to be more susceptible to weathering and the chemical structure, chemical composition of these minerals are also indicated on column on the right and quartz as you all know, the chemical formula for that one is SiO_2 , muscovite mica is basically potassium calcium aluminosilicate, it has got some fluoride and hydroxyl also in that, then orthoclase is basically potassium, actually orthoclase is potassium aluminosilicate and sodium plagioclase is sodium aluminosilicate and the formulizations that if you have got or the formulas, chemical formulas for these minerals are indicated on the right.

So basically, we have seen also in Bowen's reaction series that oxygen abundance actually decreases as we climb down and quartz if you remember was at the bottom of the Bowen's reaction series and sodium plagioclase was up on the ladder, it has got more oxygen on its formula than the quartz mineral.

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Now, these are a few pictures of felsic minerals, how they appear really. So, quartz has got a trigonal crystal as I indicated earlier and muscovite is on the center top center; muscovite has got is essentially a mica, it has got a sheet like structure. Then orthoclase feldspar, it has got a structure that is shown on the right there, it is got a flesh like color, color of the flesh of animal for instance and plagioclase feldspar is on the bottom picture there. So, these are the appearance, physical appearances of the major

rock forming felsic minerals.

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The slide is a presentation slide from IIT Kharagpur. It features the IIT Kharagpur logo in the top left corner. The title "Mafic Minerals" is centered at the top in yellow text. Below the title, a blue box contains the text "More susceptible to weathering". A large, light blue arrow points downwards from this box towards a table. The table lists five mafic minerals and their chemical formulas. The minerals listed are Biotite, Amphibole, Pyroxine, Ca-Plagioclase, and Olivine. The chemical formulas are: Biotite: $K(Fe,Mg)_3AlSi_3O_{10}(F,OH)_2$; Amphibole: $Ca_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$; Pyroxine: $(Ca,Na)(Mg,Fe,Al)(Al,Si)_2O_6$; Ca-Plagioclase: $CaAl_2Si_2O_8$; Olivine: $(Mg,Fe)_2SiO_4$.

Mineral	Chemical Formula
Biotite	$K(Fe,Mg)_3AlSi_3O_{10}(F,OH)_2$
Amphibole	$Ca_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$
Pyroxine	$(Ca,Na)(Mg,Fe,Al)(Al,Si)_2O_6$
Ca-Plagioclase	$CaAl_2Si_2O_8$
Olivine	$(Mg,Fe)_2SiO_4$

We have got, if you recall, we have got 5 major rock forming mafic minerals and they are biotite, mica then amphibole, pyroxene, calcium plagioclase and olivine and in this case, what happens in general; as you climb down once again, as you climb down the table here, the table that is shown on your slide there, as you climb down the table, the rocks become more and more susceptible to weathering.

If you recall from the previous table, what we got there is rocks become more and more susceptible as you transit from quartz to muscovite to orthoclase to sodium plagioclase in case of felsic minerals. Right now, as you transition from biotite to amphibole pyroxene to calcium plagioclase to olivine, you are going to get rocks that a more and more susceptible to weathering.

Recall from Bowen's reaction series that olivine was appearing near the top of the reaction series and in this case I indicated there that if you are near the top of the Bowen's reaction series, then the rock that you are going to get is more susceptible to weathering while when you climb down when the formation temperature becomes smaller and smaller, then the rocks that come out of that process is less and less susceptible to weathering.

That pattern actually is more or less emerging out of the information presented on this stage and again

as I did in the last table comprising of the main felsic minerals, I have indicated the chemical formulas of the rock forming minerals, major mafic rock forming minerals on the column to your right there. So, this thing, the column right that gives you that gives you the chemical formula of these minerals and these are the minerals. So, that in a nutshell is a list of mafic minerals, the major mafic minerals that forms most of the silicate rocks.

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Now, these are the pictures, these are the pictures of rocks as they appear, rocks composed of mafic rocks as they appear. The one on the top left is Augite or pyroxene, the one in the middle is hornblende, then on the right top is biotite, bottom left is olivine and bottom right is calcium plagioclase. And, you can imagine, you can easily see if you compare these thing with the picture that I have shown earlier that in general, the appearance of these minerals are more dark in comparison with the major felsic minerals that form most of the silicate rocks.

So, mafic minerals as I indicated earlier are relatively dark colored and felsic minerals as you know are relatively light colored minerals and many of these minerals are composed of iron and magnesium as was evident from the chemical formula that was presented earlier.

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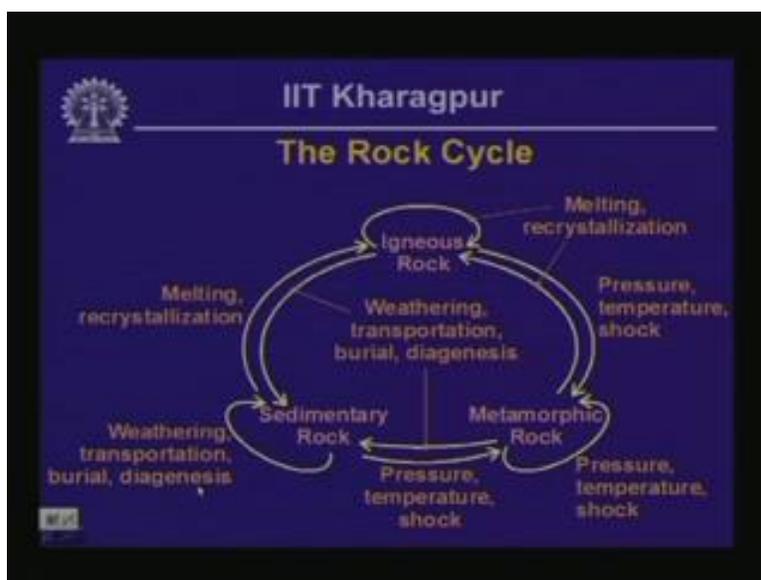
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Types

- Volcanic rock**
 - Intrusive (plutonic) or extrusive
- Sedimentary**
 - Weathering, precipitation (biogenic or inorganic), deposition, diagenesis
- Metamorphic**
 - Alteration of volcanic or sedimentary or metamorphic rocks because of pressure, temperature and shock

Now, the types of rocks include volcanic rock, sedimentary rock and metamorphic rock. So, volcanic rock actually are the class of rock that comes out of intrusive or extrusive volcanic activity, then you have got sedimentary rock which comes out of weathering, precipitation, deposition or digenesis, then you have got metamorphic rock that comes out of alteration of volcanic or sedimentary rocks or volcanic, sedimentary or metamorphic rocks because of pressure, temperature and shock.

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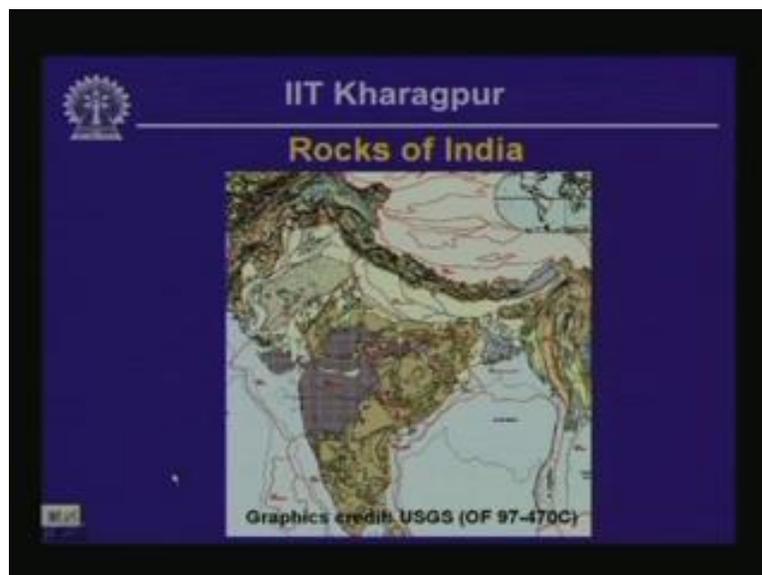


This slide here shows you the so called rock cycle and that gives you the interrelationship of different classes of rock as I mentioned in the previous slide and this formalizes the concept. So, igneous rock for instance, upon weathering, transportation and burial and diagenesis could give rise to sedimentary rock and sedimentary rock upon melting and recrystallization could give rise to igneous rocks.

Similarly, metamorphic rock upon the action of weathering, transportation, burial and diagenesis gives rise to sedimentary rocks; whereas sedimentary rock upon the action of pressure, temperature and shock would give rise to metamorphic rock and then metamorphic rock upon melting and recrystallization could give rise to igneous rock, whereas igneous rocks upon the action of pressure temperature and shock gives rise to metamorphic rocks and then there are loops that actually are self-contained.

So, igneous rock could actually melt and recrystallize and that gives rise to another igneous rock. Similarly, sedimentary rock could be weathered, transported, buried and cemented, that process would give rise to another type of sedimentary rock; whereas metamorphic rock, upon the action of pressure temperature and shock could yield another type of metamorphic rock.

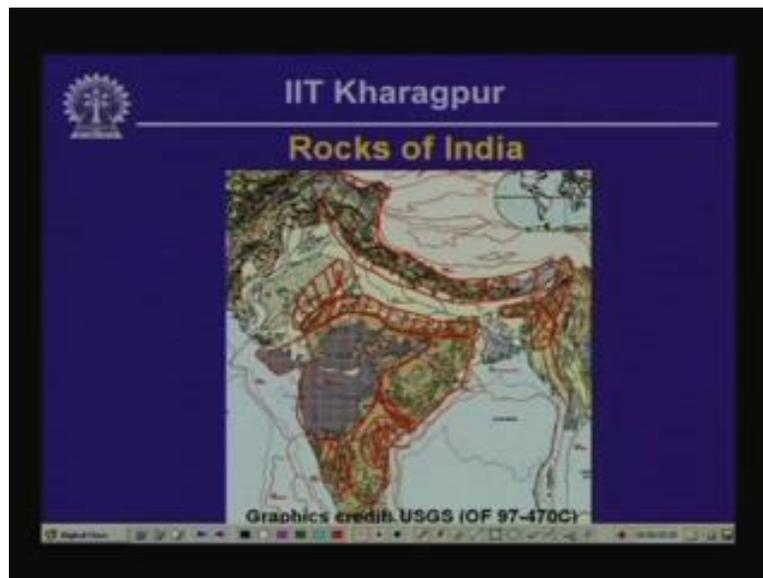
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Now, we consider the rock inventory that is available on different parts of our country. I got this map from United States geologic survey open file report 97 - 470 C and this is very large scale map, I had to

reduce it to present on the slide format and so it is not visible, so I am just going to quickly indicate on the map as what kind of rock type is available on what part of our country.

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Now, let us consider first the large mass that is visible here that is visible on this part with purple shade and this one essentially is the Deccan trap, essentially basalt that was found when there was a lava flow resulting from a divergent activity in this part of the tectonic plate. So, that is Deccan, a large part of Deccan plateau is underlain by basaltic rock and they have got, they have got sedimentary beds ((... Refer Slide Time: 50:41)) as well.

Then we look at another portion; let us consider this part here which is Eastern Ghats. Most of it actually is underlain by granites, very old granites and ((... Refer Slide Time: 51:10)) minerals. Except for the Godavari delta in this part, you have got sandstone and shale sedimentary rocks as well as over in this area that is called the Kudapa sequence, you have got sandstone, shale and limestone; this is also a sedimentary rock.

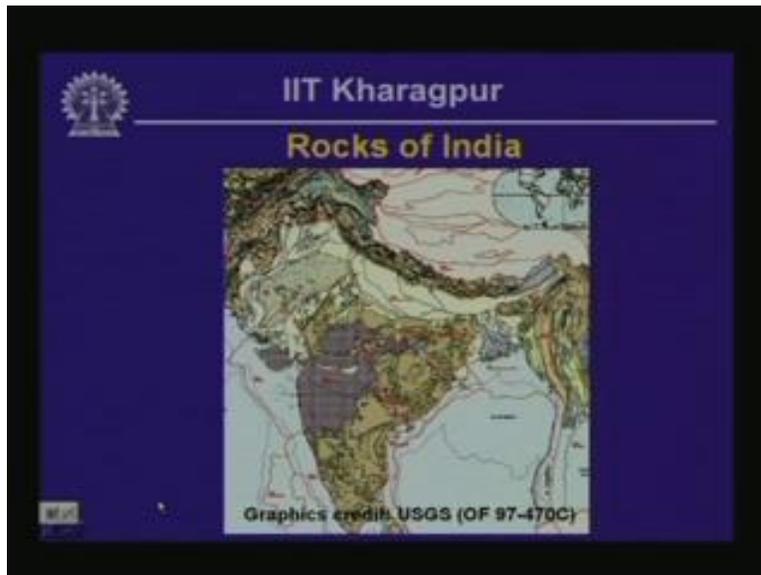
On the west coast in this area, granite, phyllite, schist, quartzite; this type of metamorphic and volcanic rock is found over in this area or the Vindians or the Vindhya ranges that is just to the south of the Gangetic plain, in that area, mostly sedimentary type of rocks are found including sandstone, limestone, shale and conglomerate.

Then in the Aravali hills, in this part, what is found is metamorphic rocks really composed of ((... Refer Slide Time: 52:41)) actually granite is also found there; granite, phyllite, schist, quartzite and in the Himalayan ranges to the north, it is a mix bag really where you could find granites, granitic intrusion flanked by different type of metamorphic and sedimentary sequences composed of sandstone, shale, quartz, conglomerates and conglomerates are found mainly in the southern fringes of the Himalayas and also you could find the limestone and dolomite and in the eastern Himalayas in the eastern part in this area; sandstone, conglomerate and shales, these are the major type of rocks that are found.

So, to recapitulate once again; in the Himalayas you have got mix bag where you could find all type of rocks – volcanic, metamorphic and sedimentary, whereas on the Aravali hills you normally find volcanic and metamorphic rocks, in the Vindhya we find mainly sedimentary rocks, on the northwest part of Deccan plateau mostly basaltic rocks are found, on the Eastern Ghats mostly granite and ((... Refer Slide Time: 54:36)), these are the different type of rock that are found expect for Godavari basin and the Kudappa area where sandstone and shales, sandstone and shales sedimentary rocks are found.

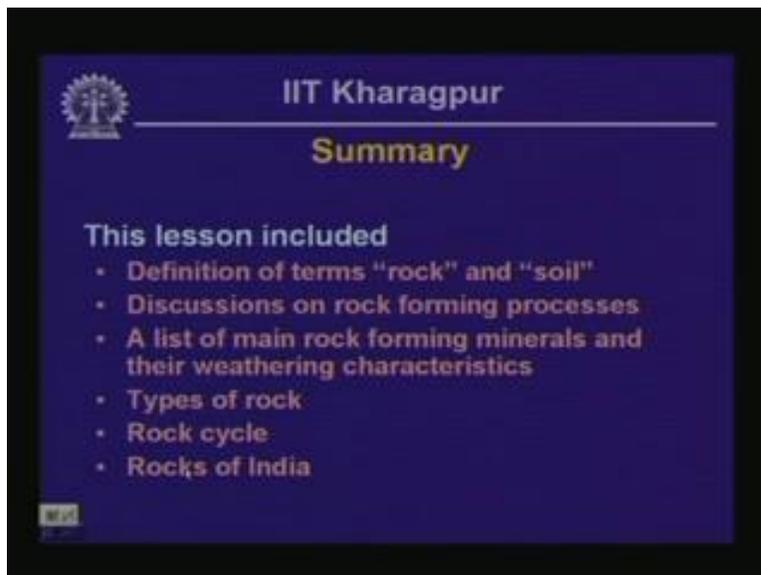
On the west coast, south of the Deccan trap, south of the basaltic area; we find an area rich with granite, phyllite, schist and essentially volcanic rocks and metamorphic rocks that generate out of volcanic rocks.

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So, that in a nutshell gives you the inventory of different types of rocks found across our country.

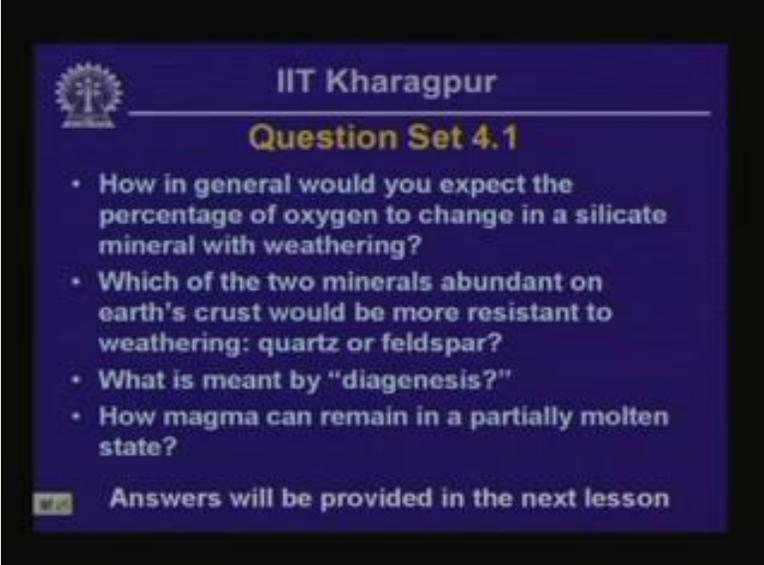
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To summarize the lesson then, what we learnt in this lesson includes the definitions of general terms like rock and soil, we had discussions on rock forming processes, we also looked at a list of main rock forming minerals and examined their susceptibility weathering characteristics or susceptibility to

weathering. We looked at different types of rocks - volcanic, metamorphic and sedimentary, looked at rock cycle and looked at rocks that are found in different parts of our country.

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The image shows a slide from IIT Kharagpur. It features the IIT Kharagpur logo in the top left corner. The text on the slide is as follows:

IIT Kharagpur

Question Set 4.1

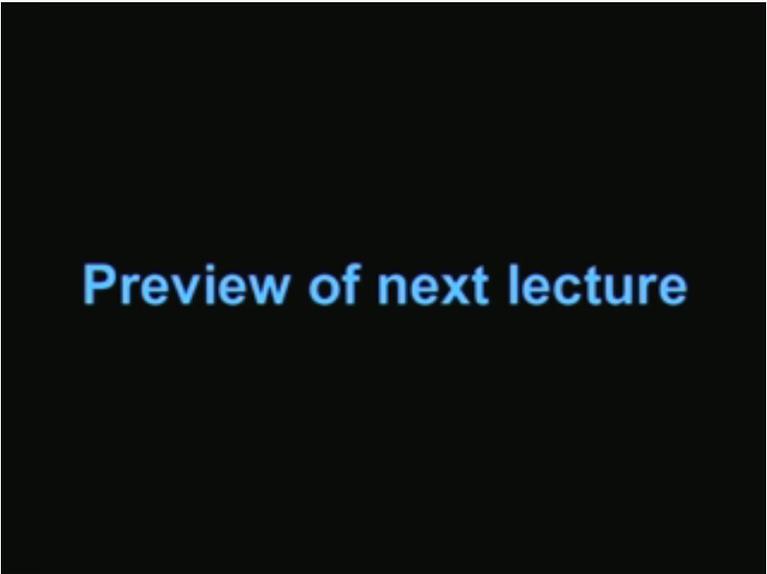
- How in general would you expect the percentage of oxygen to change in a silicate mineral with weathering?
- Which of the two minerals abundant on earth's crust would be more resistant to weathering: quartz or feldspar?
- What is meant by "diagenesis?"
- How magma can remain in a partially molten state?

Answers will be provided in the next lesson

That brings us to the end of this presentation. So, we close with the question set which you should try answering in your spare time. The first question is that how in general would you expect the percentage of oxygen to change in a silicate mineral with weathering? Second question is which of the two minerals abundant on earth's crust would be more resistant to weathering; quartz or feldspar? Third question is what is meant by diagenesis and fourth one is how magma can remain in a partially molten state.

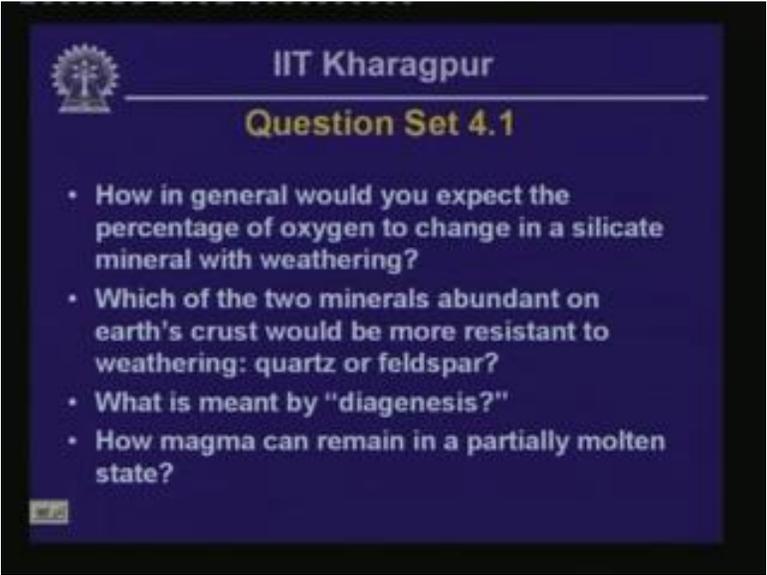
Try answering these questions; I will help you out with the answers when we meet in the next time. So, that ends this lesson and thank you very much for listening to me. So, until I meet you next time around, bye for now.

(Refer Slide Time: 57:08)



Hello everyone and welcome to this new lesson on engineering geology. Today we are going to discuss about types and origins of different types of, different soils that are found across the world and before we take up the subject matter of this lesson, we are going to look back at the questions that I gave when we are making the last presentation and the questions that are asked are on the slide here.

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The first question that I gave you was how in general would you expect the percentage of oxygen to change in a silicate mineral with weathering. So, what happens typically is that if you consider, if you consider the Bowen's reaction series, then you will find that the silicate minerals actually will have higher percentage of oxygen in comparison with silica near the top of the reaction series and as you come down, the oxygen percentage becomes smaller in comparison with silica, in comparison with the silica content. Now, to give you an example actually, the ((... - Refer Slide Time: 58:57 - ...)) these questions and I will try to give my take on these questions when I meet you the next time with the next presentation.