**Evolution of the Earth and Life**
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**Weathering and Erosions**

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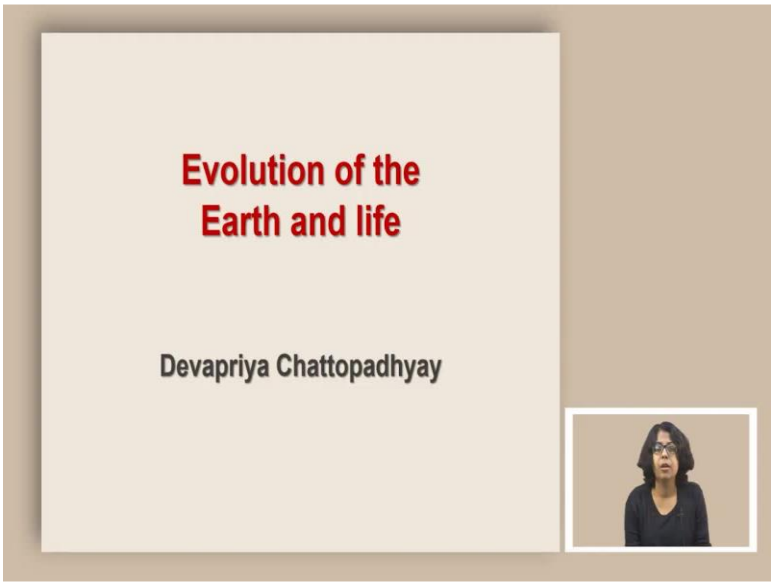


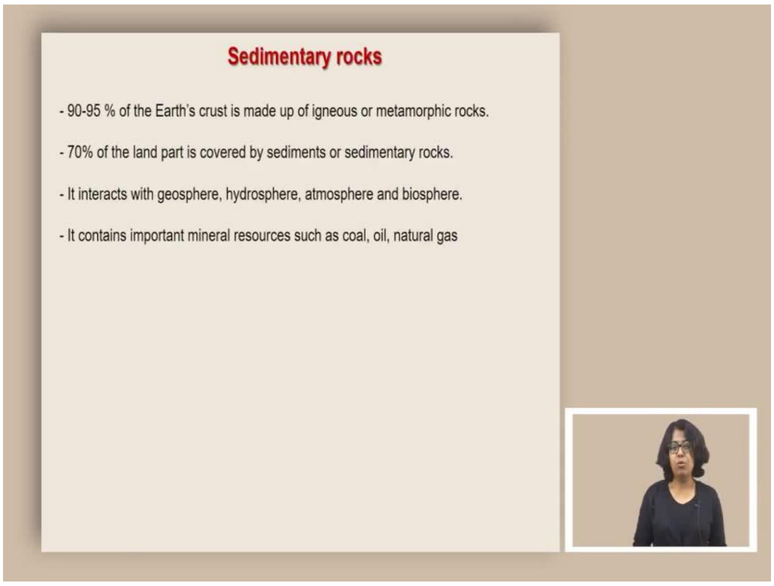


Welcome to the course evolution of the earth and life. Today we are going to talk about sedimentary rocks. When we talk about sedimentary rock in the context of the rock cycle, it is those rocks, which form from existing rocks, when those existing rocks get crushed down, or go into solution and eventually precipitate. 90 to 95 percent of the Earth's crust is made up of igneous and metamorphic rocks.

However, 70 percent of the land part is covered by sediments and sedimentary rocks. As a result, they interact with the other spheres, such as biospheres, atmosphere, hydrosphere and they retain the records of these interaction.

So when we try to reconstruct the history of the Earth and how the environment has changed over time or how biology has shaped the earth, one of the major sources of information is the sedimentary rocks and that is one of the reasons people are so interested in studying sedimentary rocks. Another important aspect is that sedimentary rocks contain one of the major energy resources such as coal, oil, natural gas, and in order to have a good understanding of sedimentary rocks also helps one to contribute in the prospecting of these natural resources. So before we talk about sedimentary rocks, let us first focus on sediments.

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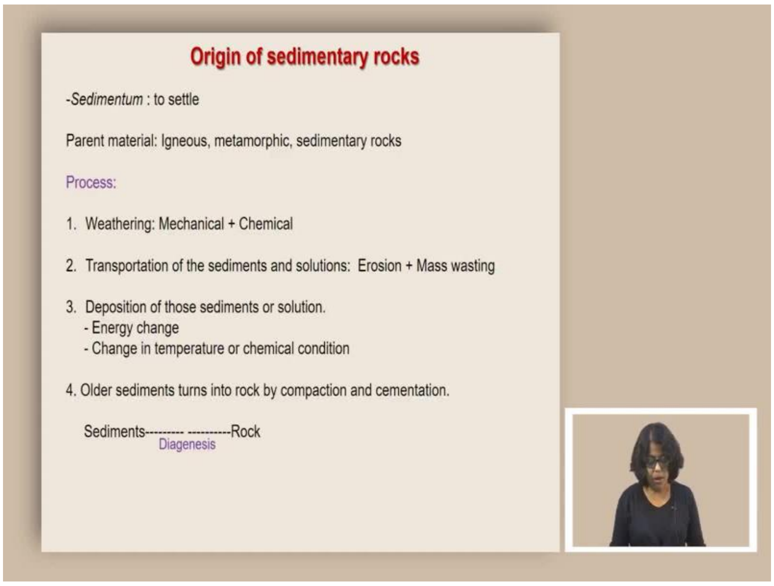


The sediments or sedimentary rock, the name actually originates from the word called sediment thumb, which means to settle. So anything which is settling down out of a liquid solution or getting their depositing because of the action of gravity, they are basically sediments. The parent material can be igneous rocks, metamorphic rocks, or any other sedimentary rocks. But once they are broken down into tiny pieces, and they are settling down, they are going to behave in a certain way and that is what characterizes the sediments or the sedimentary rock.

So the first process is to break down preexisting rocks. And this breaking down is generally called weathering, weathering can be mechanical or chemical. Once it weathered once it has broken down either through mechanical processes or through chemical processes, it needs to be transferred, it needs to be transported. And this transportation of sediments can be done in different ways and these ways include erosion when the materials are being transported by some medium, such as rivers or glaciers, so these are called erosion.

These materials these sediments can be transported either as particular sediments or it can also go into chemical solution, which is later transported by these mediums or agents such as rivers or glaciers.

But there is another kind of transportation which is called mass wasting and this transportation happens primarily because of gravity. Imagine a big pile of sediments at the slope of a hill and it finally topples down comes down below that is not really transported because of any agent like wind or river or glacier it is simply coming down because of the action of gravity. So a combination of factors such as what is the density of the material, how easily they can flow or viscosity, finally guides what is going to be the nature of the products which are coming down due to mass wasting.

Once things get transported, they will also finally settle down in a place of low relief, because always the movement tries to ensures that it finally goes to a place where it is the lowest relief to conserve the energy. So that the possession of the sediments can happen either if the energy changes or the change in the temperature or chemical condition.

So we are talking about two things. One is when things are getting transported as a physical component as small bits of preexisting rocks, in those cases, they are going to finally settle, if the energy condition changes, if the medium which is carrying them basically loses its energy then it will try to settle down.

The other process that operated for the settlement of sediments is the chemical process. So if something is in solution, then they are going to start settling down if the solution can no longer carry them, and that happens either if the temperature changes or the chemical composition of the fluid or surrounding changes and hence they start to precipitate out of the solution. So this is generally the framework of how from a solid rock we find sediments and eventually those sediments which get settled either from the chemical solution or from agent or transported due to mass wasting all of these finally settled down.

Once it settled down the older sediment turns into rock by compaction and sedimentation. So imagine something which is settling down and it generally settled down as a layer, but it is also overlain by newer and newer sediments and all these sediments create a large pressure and overburdening pressure, which will compact the sediments, there would be action of other solutions which are going through these sediments, which will also create cements that will bind these grains further.

So a combined process of compaction, cementation will eventually liquefy these sediments, where the sediments will convert to sedimentary rock. And the process through which it converts to rocks is called diagenesis.

It also will go through slightly higher temperature and pressure than what we can expect when the sediments are getting transported, but that temperature pressure will not be as high as what we can expect in metamorphic rocks or igneous rocks. So the general diagenesis temperature is never going to be more than 200 degrees centigrade, anything beyond that will fall in the realm of metamorphism.

So let us take an example of how exactly these sediments are getting transported and deposited. Let us take an example of Himalayas. So we know that Himalayas it is a high range of mountain and because of various reasons, such as the acting natural agents such as glaciers, the rivers that are coming out of Himalayas, it is also eroding existing rocks. As the river passes through the existing rocks it is going to crush the rocks and bring sediments into the river, the same thing happens for the glaciers too.

So at the end of the day, because of the weathering a lot of sediments are coming into rivers. And these rivers as they are coming down from Himalayas they go to the flat land, and they start depositing some of these sediments, but still there is a considerable amount of sediments in those rivers, such as Ganga and Brahmaputra. And then they keep on changing the elevation through which they are going down.

Finally, they meet the sea when they meet the sea that is the lowest part of the entire journey of the river and it does not have the energy to carry these sediments any longer. So it is going to deposit all these sediments in Bay of Bengal.

Now this process is operating over millions of years. So every year there is a layer of sediment which is being generated and eventually getting deposited in Bay of Bengal, and these sediments will create layer upon layer. Now, imagine the situation of the bottom most layer, it is already experiencing high overload of sediments on top of it and therefore, it goes to a relatively higher depth. When it goes to higher depth, it experiences slightly elevated temperature and because of the pile of sediments on top of it, it also experiences high pressure.

Accommodation of this slightly elevated temperature as well as the pressure starts to compact the rocks, the sediments at the bottom and these sediment grains will come close to each other, all the gaps will not be as big as they used to be. Moreover, some of the chemicals from the top may go through it and create glue like materials or cement that will make these sediments stick together even more.

Because of the compaction from the top and surrounding because of the temperature and these chemical actions now these sediments would be more compacted, it will basically look like a rock. So this is generally what the journey of sedimentary rock looks like starting from sediments to all the way compacted sedimentary rocks.

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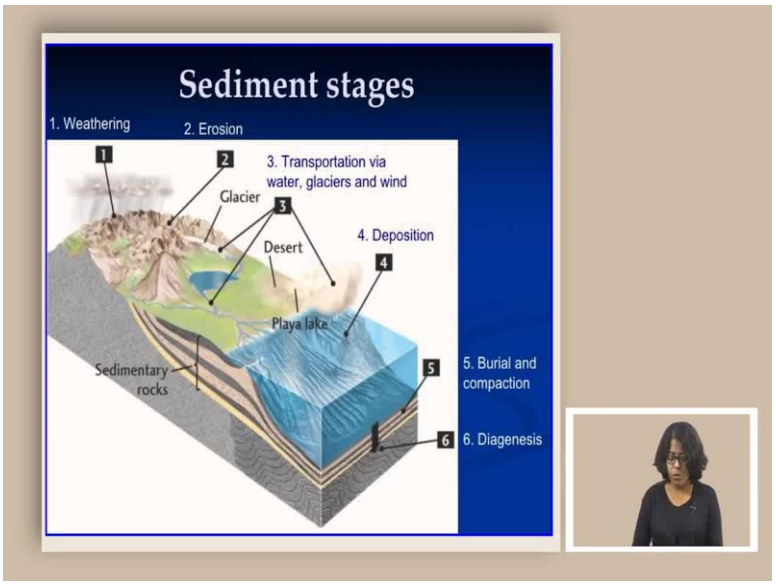


Now today, we are going to talk a lot about how these initial steps are done, how the weathering process starts. So as I mentioned before, that the sedimentary process actually starts from often from a high relief region, it starts from the high mountains and then eventually gets transported and finally get deposited in a low relief region. So the reason the rocks are breaking down is often because of certain physical and chemical processes. And all of these are part of something called weathering.

So the example that we gave of Himalayas, we can think of the rains. Whenever the rains coming down, they actually impact quite heavily on how much rock material is going to break down and with increasing rain, we can see that the input of sediment actually changes and these are observation that can be done even in modern day. So sedimentation, sedimentary rocks, or sedimentary processes, a great deal of it, we know from observing the present day processes.

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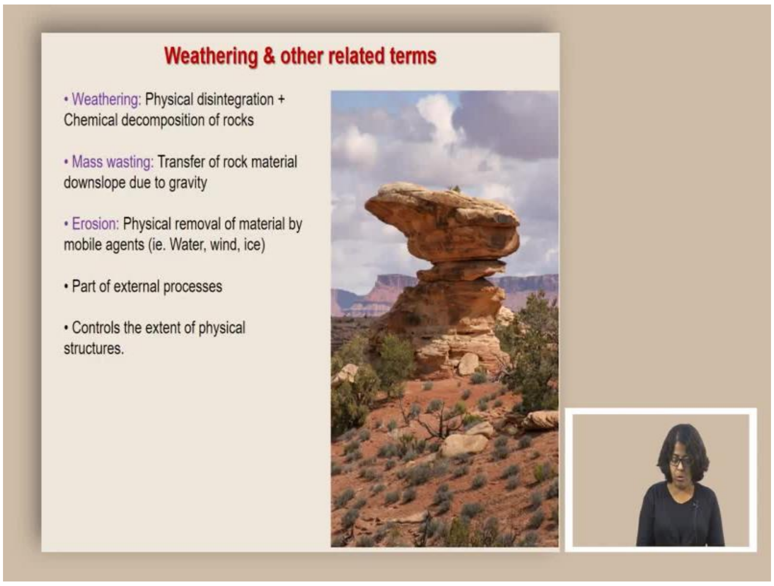


So now let us take a look at weathering and other related terms, we are going to define it and then look closely into how they are operating on earth surface. So weathering includes physical disintegration and chemical decomposition of rocks. The second term that we are going to use is mass wasting, which means transfer of rock materials downslope, primarily due to gravity. But another type of transfer can also happen through erosion, which basically means physical removal of material by mobile agents and basically transporting them. It can happen through water, through wind, ice, any of these things.

And all of these are happening at the uppermost part of the crust, so these are not really part of the deep earth processes, such as subduction and things like that. However, once these sedimentary rocks or sediments piled up in the ocean floor, they can eventually be consumed through subduction processes. But it primarily contributes this weathering, erosion, mass wasting and eventual sedimentation, all of these primary control the extent of physical structures that we see on the top of the surface.

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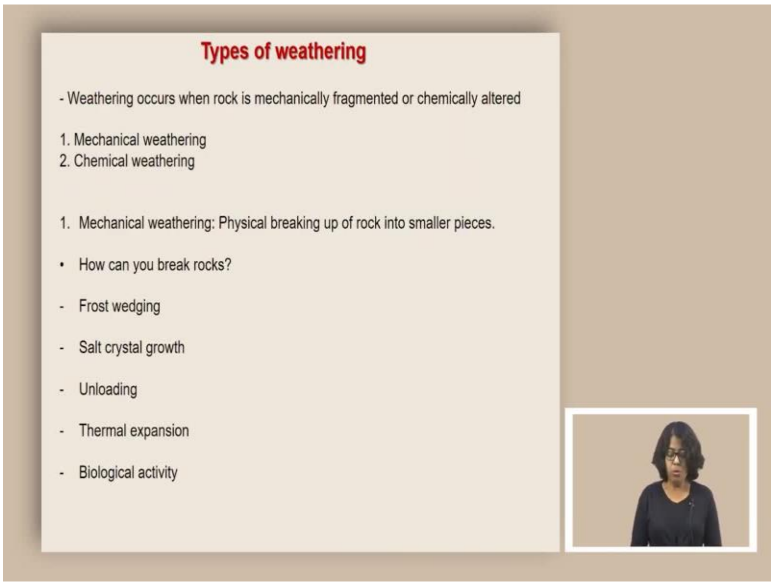


So as we said, that there can be primarily two types of weathering, the first one is mechanical weathering. And mechanical weathering basically means that you are physically breaking up the rock into smaller pieces. Now the question is, how can you break the rock? And there are different types of how you can break the rock naturally and these create different types of mechanical weathering.

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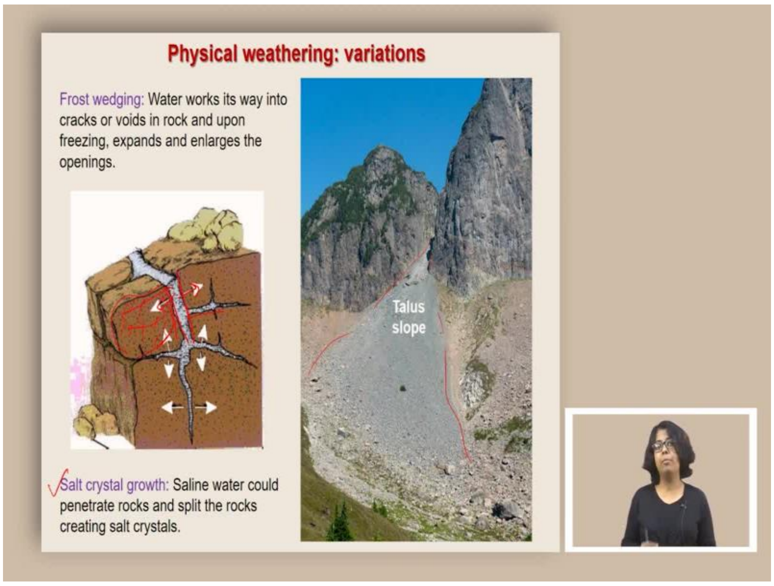


So the first one we are going to talk about is something which is called frost wedging. So imagine a situation where it is the temperature is quite cold. So in the whole year there will be times when the temperature is subzero and hence there will be development of ice and there will be times in the year when the temperature is above zero degrees centigrade and hence, you will not see ice. In those situations if water percolates through the rocks, they tend to their face depending on which time of the year you are looking at. So in colder times, it will convert into ice and during warmer times, it will simply be just water.

Now water expands in volume when it converts to ice and that is the reason we see that the icebergs actually float in water because their volume is actually higher than the same amount of water. So what will that mean in terms of the rocks? The same cracks which was percolated by some water and eventually freeze down will experience some pressure sidewise because the ice wants to occupy more volume, and therefore it is creating a stress on these walls.

So eventually, these walls because of the higher stress will break down and this happens even more because there are many cracks, tiny parts of cracks, which will be percolated by water and eventually increase the volume and crack it up.

So often what we see the result is the entire rock will break down and create smaller bits of rocks. And this is a very common phenomena in places where we see glaciers or there are enough water, and it goes from freezing to toying during different parts of the year. This is an example where you see the mountains and in between you see all these tiny pieces of rock which were created because of the frost wedging. And they create this slope, which is called a talus slope.

A characteristic feature of this talus slope, it is going to be completely made up of these tiny broken parts of rocks, it is not going to be completely rounded, it is going to be sharp, but there will be a lot and often at the vicinity of main mountains. A similar process can also take place instead of ice, it can happen if the salt crystals grow. So saline water could penetrate the rocks, and it can split the rocks creating salt crystals. Again the salt crystals end to take up more space and once it takes more space, it is going to create more stress on the surrounding rock breaking it down into smaller pieces.

We generally find this kind of weathering of salt crystal growth near the seaside if there are rock exposures and the moisture with a bit of salt or the water with a bit of salt percolates through these rocks and eventually produce salt crystals grows in volume grows in size and breaks down the rock.

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Another type of weathering is the unloading. So igneous rocks especially granites, when they are exposed, they are weathered in onion like fashion. So what I mean by that? Is often if you are walking on an igneous terrain, a large extended igneous terrain, you will often find that they have been weathered in a specific fashion where the outline is circular, but then you also find different layers almost peeling off at different times and that is what we meant by onion like fashion and these are called the exfoliation.

Now this happens because of unloading. If some things are were formed deeper underneath the Earth, where the pressure was very high, once you expose it to the surface, they tend to expand in volume, but this volume expansion is not equal at different layers and therefore, there are gaps between the layers through which the weathering takes place. And you see removal of materials in different parts.

This can happen at a very-very large scale if a big igneous body can be uplifted and eventually become unloaded because the pressure is much lower at the surficial condition. And this is an example of such a structure where you can see that the top rocks are getting peeled off compared to the rocks underneath and these are generally called exfoliation domes. Again, a common feature of igneous rock that are forming relatively deeper and then getting exposed at a superficial level.

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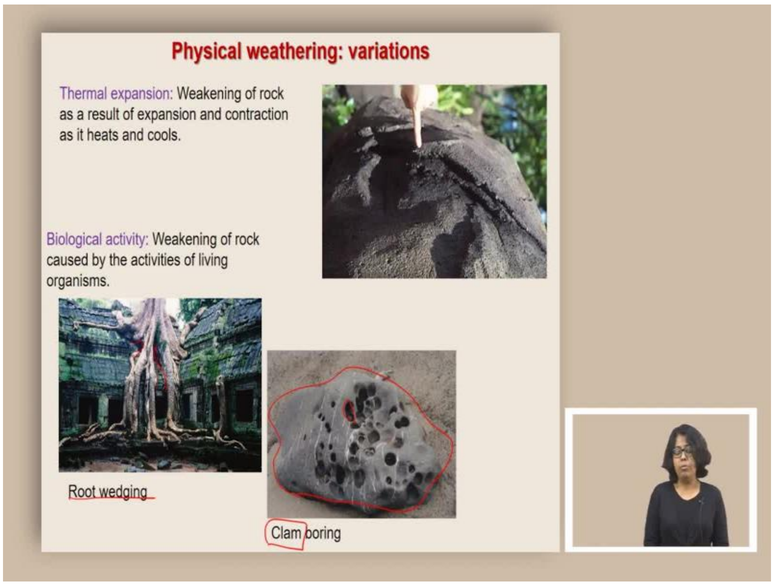


Other types of physical weathering includes thermal expansion. And it often includes rocks exposed in areas, which goes through quick change in temperature during the day and night. Then the rocks, rocks are poor conductors of heat, and they cannot really manage the expansion and contraction well and if there are rocks especially in desert like condition, where the temperature fluctuation during 24 hours is quite high, the nights are cold, and the days are quite warm the rocks find it difficult to expand and contract as a response to it. And often what we will find is weathering of characteristic, weathering of rocks as a result of these thermal expansion and contraction.

So far, we have been talking about primarily natural patterns or a biological patterns of physical weathering, but biology can play a very important role in terms of weathering. Biological activity are one of the major agents of weathering when it comes to rocks at the surficial level. It can be as simple as a bacterial colony creating a layer on top of the rock and thereby taking water and changing the chemical reaction, but it could also be a completely physical push that makes the rocks crack.

One of the clear example is the action of the roots and these are called root wedging. So this is an example from Southeast Asia where the roots actually created gaps in the temple. And these kinds of structures are breaking down because of the action of the roots. And it is not very unique, we do see such examples even in modern buildings, even in ancient rock records, everywhere if the root starts to penetrate, it creates, it tries to create more space as a result the surrounding rocks.

For example, places like here will try to break will break down eventually and these root actions are very important when it comes to surficial rocks along with the sediments on top. Because the plants tend to grow in the sediments, but if the sediment layer is very thin, then their root will also tie try to penetrate the rocks underneath and in that case, the rocks are going to experience these kinds of biological activity, eventually breaking them into smaller pieces.

The other way of biological activity contributing to the physical weathering of the rocks is when there are active organisms which drilled through the rocks and there are some marine organisms such as clams, which can do that.

So often in the shallow shell for sea shore, you may come across rocks like this, and especially if these rocks also contain a little bit of calcium carbonate they tend to focus on those areas, and then they use their body to drill through it, they have specific apparatus through which they can drill one sediment at a time very slowly, but they can create these kinds of holes in the rock and these are also examples of biological activity with primarily guiding the weathering process.

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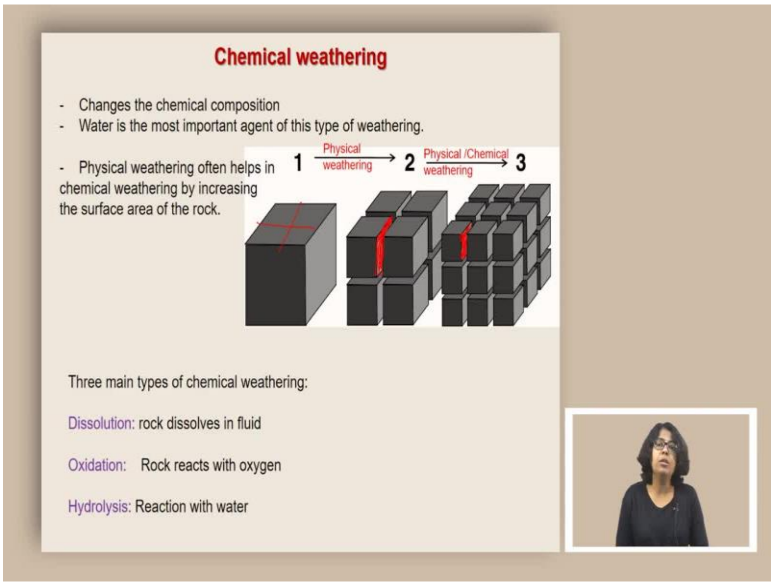


Now so far we talked about the weathering, in terms of physical weathering, but chemical weathering is almost equally important when it comes to the development or generation of sediments. So it primarily depends on change in the chemical composition and water is the most important agent of these kinds of weathering. And physical weathering and chemical weathering, they are not completely separated in terms of their processes, because one actually helps the other especially physical weathering often helps in chemical weathering, let us try to understand why that would be so.

Now rate of chemical reactions depend on the surface area at least in this cases where it is going into the reaction. So the exposed surface area is very important in terms of how quickly the reaction is going to take place. Physical weathering breaks down rock. Now, every time it breaks down rock it basically exposes more surface area which was not available to go into reaction before and every time it breaks down the overall surface area increases and therefore you are going to see increased rate of chemical weathering.

So over time, it has been seen that places where you see more physical weathering, if the conditions are the same and the necessary can conditions for chemical weathering is met, you will also find a high rate of chemical weathering. However, the requirement of physical weathering and chemical weathering are not always the same and we are going to see some of these are things that where we can expect higher chemical weathering versus where we are going to expect higher physical weathering. So there are different types of chemical weathering and we are going to discuss primarily three of them.

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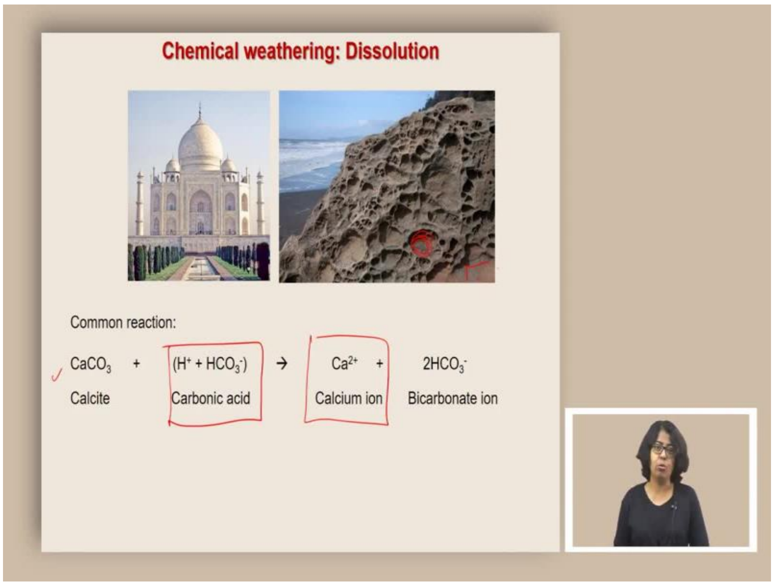


The first type of chemical weathering include dissolution and dissolution primarily means that the liquid the carrying liquid has the chemical composition which can dissolve part of the existing rocks and transport those ions in a chemical solution. So I have provided two example, the first example should be familiar Taj Mahal, it is made up of primarily calcium carbonate. And calcium carbonate is one of the minerals the mineral name is calcite, if you convert it to a rock, it can be either marble if it made gets metamorphosed, if it does not get metamorphose then it can be a limestone.

And this form of calcium carbonate is very-very susceptible to chemical weathering, primarily dissolution. The agent that dissolves calcium carbonate is any form of acid. Now the form of acid that is very commonly found in nature in the surficial condition is carbonic acid. The reason behind it is that carbon dioxide is quite available around us there is quite a high concentration of carbon dioxide, not with respect to the availability of nitrogen or oxygen, but there is a substantial amount of carbon dioxide.

Now carbon dioxide when it gets mixed with water, which can happen naturally in the surficial condition, it basically creates this particular type of acid, it is a mild acid, it is called a carbonic acid. So H plus HCO 3 minus. And once carbonic acid interacts with calcite, it is going to produce this calcium ion and then bicarbonate ion.

So that means this calcium carbonate or Calcite is going to disintegrate, the calcium ion is going to be carried by the medium and the bicarbonate ion is also going to be there. So where it used to be calcite, a solid mineral, you are not really going to find anything there because it is going to be carried out by the medium, primarily water and slightly acidic water.

And because of which you are going to find empty holes. These are structures which are generally called honeycomb structure. Again, it can happen for with the sand stones also, but it can develop because of the dissolution. So I have given only one example, where the calcium carbonate reacts with acid and eventually create these dissolution, but there can be other possibilities of other rocks reacting with different kinds of acids, and eventually getting dissolved and creating these kinds of structures.

And it is one of the major threats for buildings that are made up of calcium carbonate or marble, because, these acids are easy to produce and it can corrode the existing structure, especially if there are gaps in between along with the water, the moisture even can stay and corrode more.

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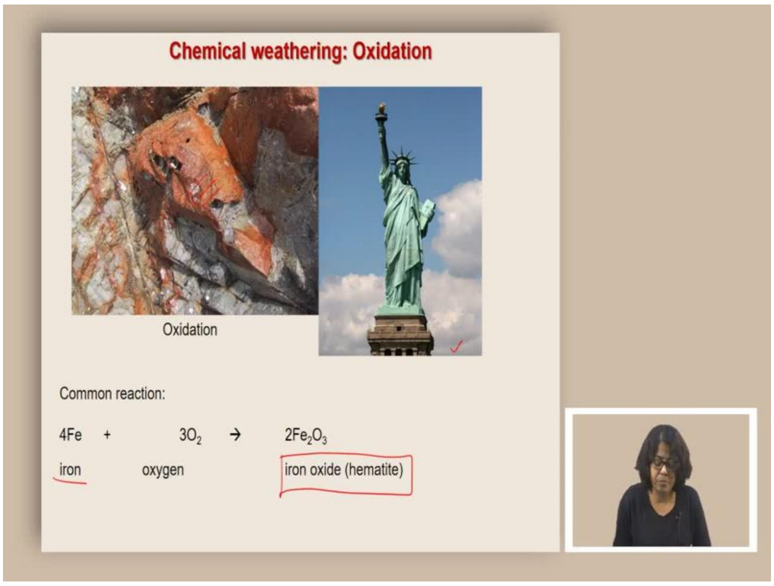


The second type of chemical weathering is the oxidation. So one of the common reaction is when we see iron getting rusted, but this rusting of iron can happen naturally. In nature, we have iron, there are iron ores, which are primarily concentration of Fe and when they react with oxygen, which is also available in nature, they basically form iron oxide and the mineral name is hematite.

So this reddish color basically showed the hematite portion of it and every time it converts to hematite, depending on whether it is a ferrous or ferric state, it will basically either be at that place or it can be flown. So the ferrous state is mobile, it does not precipitate out of water, it can be in water. Now, if you have very high oxygen concentration, it is not likely to be carried as a ferrous state for very long time. However, there can be patches where it gets converted to this ferric oxide state and it converts to hematite, eventually losing some of the initial material and that is how it is considered as part of weathering.

Another type of weathering of oxidation can happen with other odds, for example, this is a famous picture of the Statue of Liberty. So it has this greenish tinge, but this green tinge is actually a result of oxidation. So the green color is produced by the oxidation of copper and the original color was not this, the original color had a metallic color, it was not the green color, and the green color is actually the result of oxidation of the original metal.

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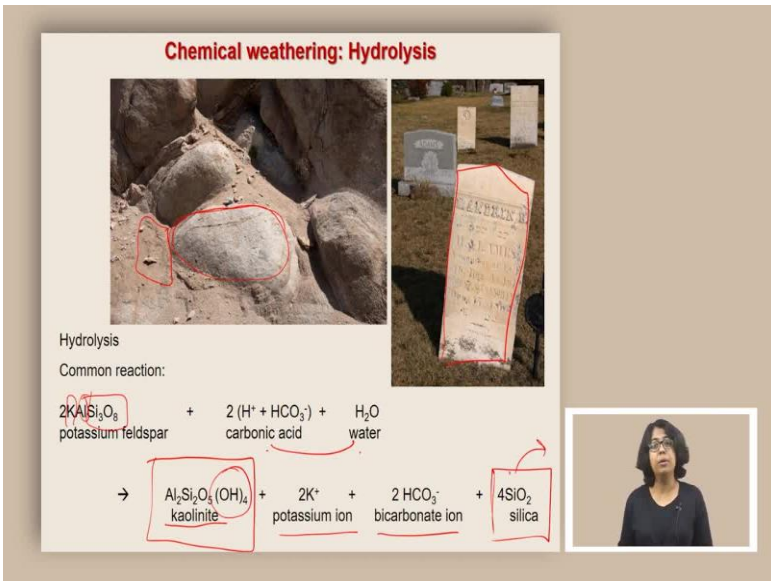


The third type of chemical weathering is hydrolysis. It is literally means eating up by water and it is one of the very common processes that we see around us. So the common reaction that is involved in it has some rocks and we are going to take this example of potassium feldspar. As we recall that all these minerals commonly found minerals on the crust, they are some form of silicate. So we have a silica tetrahedra.

Now how the silica tetrahedra is balancing and creating our structure makes different types of mineral. So there is a mineral where you have this silica tetrahedra but it is going to be balanced with other silica tetrahedra along with some potassium and aluminium. And this is the common chemical composition of potassium feldspar, one of the most common minerals on the surface of the earth.

Now these feldspars when they react with little acid again, as I am saying that acids are not so uncommon on the surface of the Earth, because of the interaction between available water and the atmospheric gases create carbonic acid, sulfuric acid, at times when you have the concentration of sulphur dioxide emitting from volcanoes.

So there are plenty of possibilities of development of acids, starting from very fine or very weak acid to quite strong acids. Even if we consider the weak acids such as carbonic acid found in nature and add water, then we see a very interesting reaction where the acid and the water when mixed with potassium feldspar at normal temperature and pressure, it forms another aluminosilicate with an OH part, and this is called kaolinite, we will come back to it what it means.

And then we have potassium ion released, we have bicarbonate ion released, and then we also have silica, because this is basically quartz. And it is one of the most stable parts, it is not going to break down further, unless the temperature pressure condition and the chemical fluid is very different. So this is going to stay along with this part of the thing. Now, let us try to understand what is this part? Kaolinite is a clay mineral. So by this reaction, the rocks, primarily rocks rich in feldspar, can convert to clay and that is one of the most common reactions that we see everywhere.

So let us take an example of these chunks of rocks, these are granites where you have a high amount of potassium feldspar or for that matter there can be any feldspar. And once it breaks down by the action of carbonic acid and water, what we are going to find are these weathered material, which is primarily composed of silica, and clay.

So we do find a lot of clay minerals as a weathered product of feldspar. This is also the reason if you have a granite tombstone, often these letters sort of get smudged after some point of time because they get weathered. And when they get whether they produce this clay, and silica and the original relief is not maintained because part of it gets filled up by this clay and the relief that was intended is no longer there, and therefore the lettering smudges over time.

So this weathering is very important, not only because we find them on the surface, it is also very common underwater. If you remember those places where we create the first oceanic crusts in mid oceanic ridges. So the mid oceanic ridges are places where there is enough water coming out and there is magma and it is convert into rocks and these rocks can also have feldspar and those feldspar are going to convert to these clay minerals, because they have all the required conditions, they have feldspar, they have some acids, they also have plenty of water converting to these kinds of kaolinite and other clay minerals.

So depending on what kind of potassium, what kind of feldspar you are looking at the final product of the clay is going to differ in composition, but this is a general pattern of the chemical reaction which is very common in nature.

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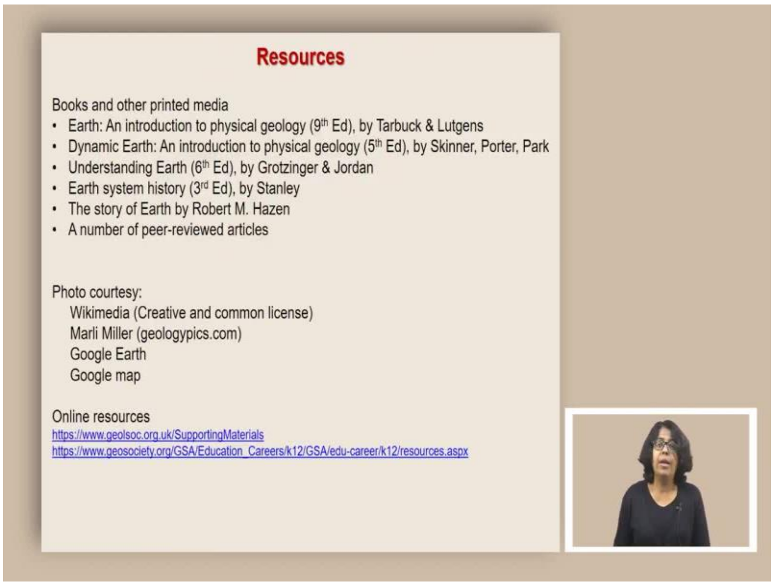


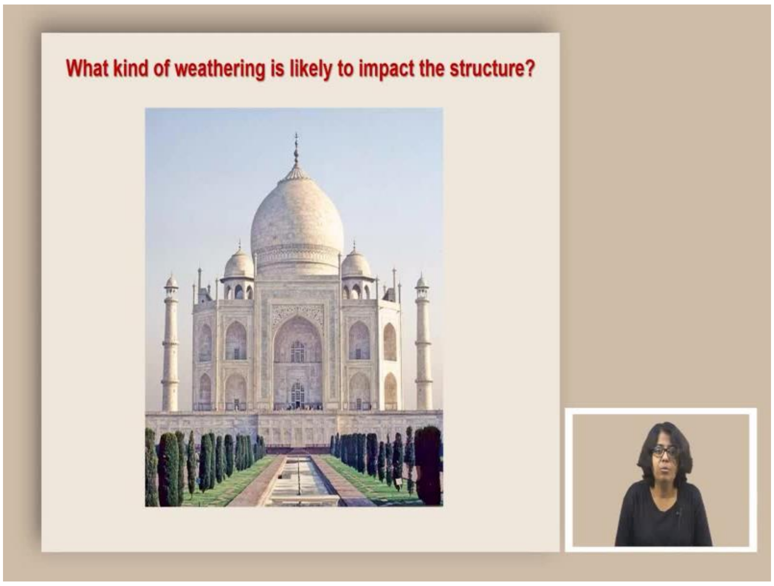


So let us recapitulation what we learned in today's class. So we learned how important it is to know sedimentary rocks because they are the record keepers of interaction between other spheres, especially atmosphere, hydrosphere, and biosphere. Sedimentary rocks gets produced from existing rocks such as metamorphic rock, igneous rock and other sedimentary rock and the process starts with weathering. Weathering means breaking down rocks into smaller particles that can happen by physical processes that can happen by chemical processes.

Once things are broken down, they can either get transported as a physical entity or in chemical solution and they get transported by agents either as wind, a river or glacier. In that case, we call these transportation mechanism as erosion. It can also change place by the action of gravity like a downslope of transportation in that case, it is called mass wasting. Once transported and once the energy condition or the chemical condition changes, they are going to precipitate or deposit that is the phase what we call sedimentation or sedimentary deposition.

One sediments get deposited, they get compacted, lithified, convert things into a rock. Depending on the composition or the environment of the place, it can be a physical weathering or chemical weathering. Generally what we find in colder areas, physical weathering dominates, in areas which is warm and has a lot of water these are conditions which increase the rate of chemical reaction. So these are the places where we find an increased amount of chemical weathering.

And a combination of physical weathering and chemical weathering finally leads to the production of huge volume of sediments, and these sediments eventually turn into rocks. So here are some of the resources that you can go through and these resources have been used to make the material there is also a question that you should think about. Thank you.