Evolution of the Earth and Life
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Chemical and Organic Sedimentary Rocks

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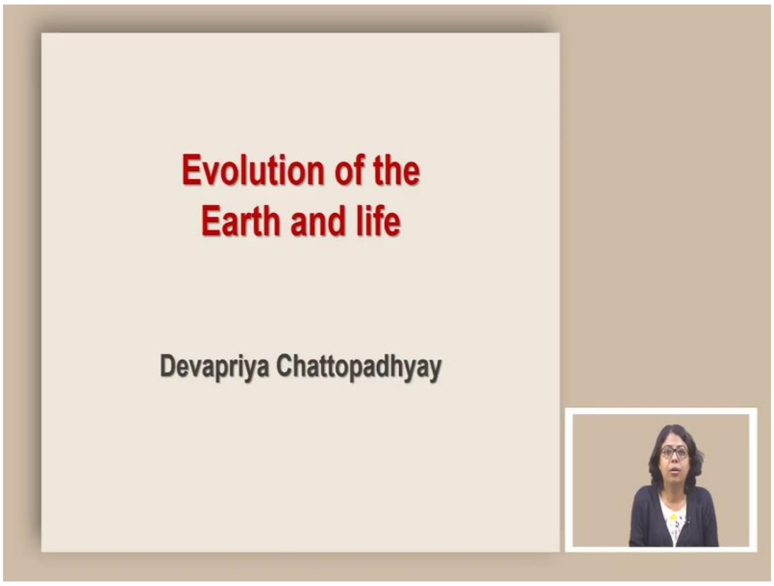

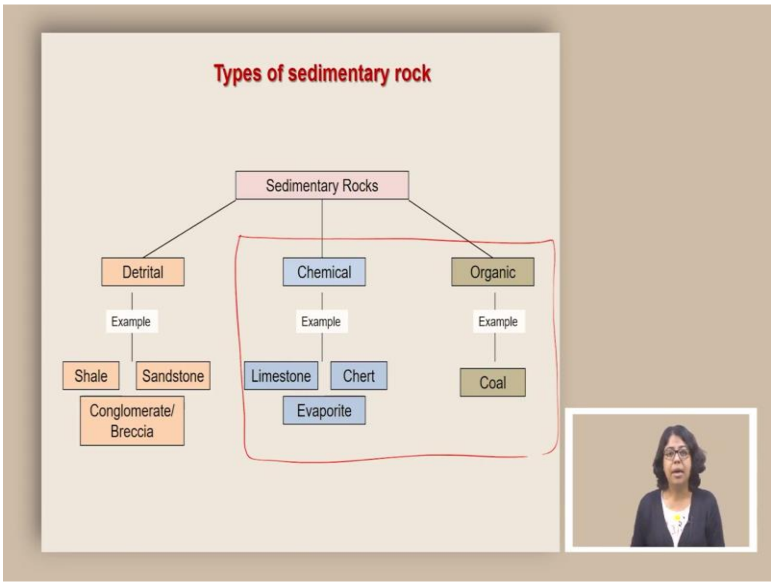

Welcome to the course evolution of the earth and life. Today we are going to talk about chemical sedimentary rocks and their classification. Sedimentary rocks can be subdivided into three major categories. One is Detrital sedimentary rock, second is chemical sedimentary rock, and the third one is organic sedimentary rock. Now, today, we are going to focus on this particular group.

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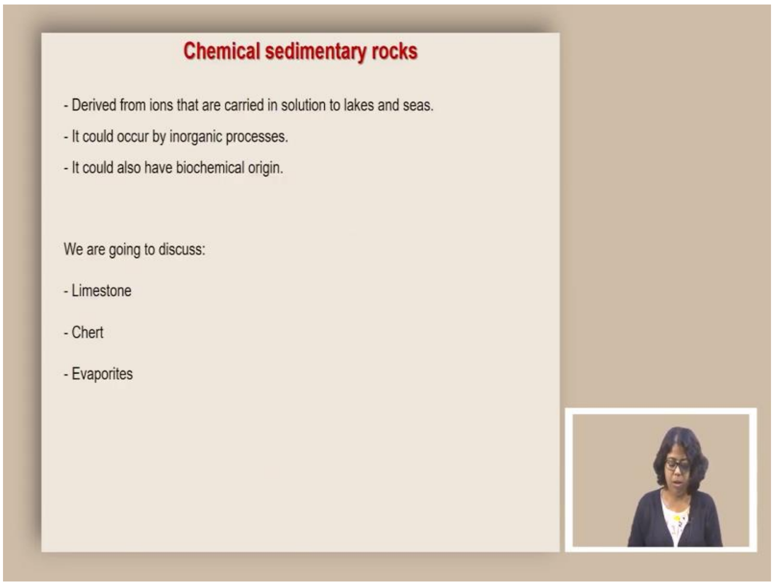

Now, if we look at the chemical sedimentary rocks, these are rocks that are formed from sediments, which are primarily produced by chemical weathering. So, they form from those ions that are carried in solution in to lakes and seas and they are carried by the rivers or any other agent which can keep the ions in solution. Now, the change in chemical condition of that agent primarily leads to the reposition of these ions and finally forming a sediment and eventually converting that sediment to sedimentary rocks. So, it can be developed completely through inorganic processes.

But as we will see that many of the chemical sedimentary rocks form because of significant involvement of life. And those are what is called the chemical sedimentary rocks of biochemical origin. So, today we are going to primarily focus on three types of chemical sedimentary rock, the first one is limestone, the second one is chert, and the third one is evaporite.

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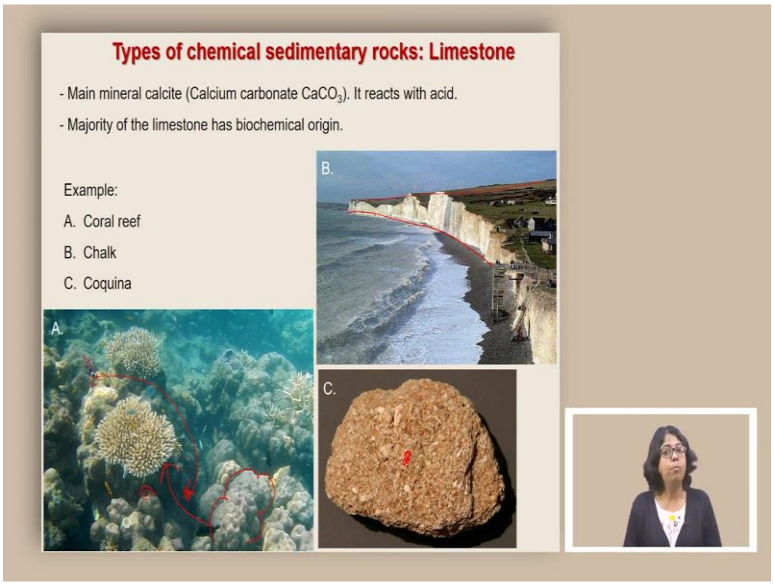

So, the main component of this particular chemical sedimentary rock what is called a limestone is calcium carbonate CaCO3, it reacts with acid. And the way it goes into solution is when the CaCO3 reacts with acid, slightly weak acid, often in the form of carbonic acid and eventually goes into the solution and gets transported. When it gets transported, it will continue getting transported till the environment around it changes. So, if the environment around it changes to a slightly alkaline condition, where it can no longer be in solution, then will start to precipitate and majority of these limestones has biochemical origin.

So, it is involvement of organism which creates these kinds of calcium carbonate. So, clear examples of these biochemically originated limestone, are coral reefs, chalks, coquina. So, let us take a look at what coral reefs are?

So, coral reefs are an accumulation of organisms, which has very hard structure, and they can create a hard surface for a very extended space. And those are generally called reefs. Now, these reefs these are, I mean, these calcium carbonate built up can happen through various organisms. We have given the example of corals but there are examples where these are created by clams such as oysters. In the geologic past, there were situations where it was created by other organisms.

So, these are simply the calcium carbonate built up, which happens in relatively shallow areas and primarily mediated by organisms. And these coral reefs are good places for increasing biodiversity. Because there are a lot of organisms which like to secrete calcium carbonate as they are skeleton, but they are not very good at extracting calcium ions from the seawater.

They often flock together and come closer to the reef because coral are very good at doing that, and therefore, they make the skeleton out of calcium carbonate. And when you have are proliferating reef, parts of these calcium carbonate also get dissolved in the water.

And that area will be super saturated with calcium carbonate, from which it is easier for those organisms, which are not very good at it, getting the calcium carbonate out of the water to make their skeleton. And therefore, coral reefs are places where you see a large accumulation of organisms which create their shales with calcium carbonate.

So, it is a system where one helps the other to grow their shales. And eventually, because they grow their shale there are other organisms which do not have shales, take shelter between them. And because they take shelter between them, there are other organisms such as fishes, which come to eat them, and it supports thriving biodiversity.

The second type of such biochemically originated limestone is something called chalk. This is a picture of England, near Dover. And if you see there are these white cliffs, and these cliffs are basically made up of chalk, which is a form of calcium carbonate, but this particular one is developed because of micro-organisms. Those organisms have they are shales made up of calcium carbonate, but because they are so tiny, that each of these shales can slide and therefore, it these rocks that are made up of their skeleton, these kinds of organisms are called coccolithophores.

These kinds of rocks are very easy to crush crumble, make a powder out of and that was the reason why, once you take a piece out of these rocks, you can rub it on top of a metamorphic rock which is called slate, and you will have a white streak. And that white streak is the chalk mark. And that is why it became very popular for reading and writing. Using this combination of rocks one is a metamorphic rock which is a slate and one is a chemical sedimentary limestone, which is chalk.

And this is quite extended, and which shows you the amount of deposition of these bio logical organisms and their skeletons, which created a mines of extent of these chemical sedimentary rock.

The third one is called a coquina. Coquina is a chemical sedimentary rock where various organisms which create their skeletons out of calcium carbonate can come together and form a rock in a loosely packed manner. So, it is not going to be as hard as a single coral colony. It is not going to be as soft as the chalk, but it will have a variety of hardness and softness, because there are some shales, which are hard, and then they are loosely packed. So, these coquina beds have a tendency of crumbling, and you can find individual fossils out of it primarily made up of calcium carbonate.

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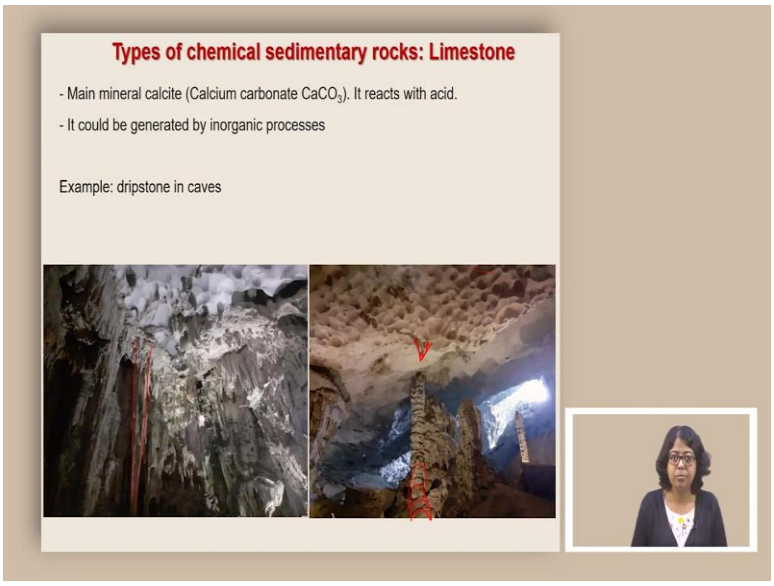

Now, limestones can also develop from completely inorganic processes. One such example is the dripstone that we find in caves. So, many minerals can be carried by water. But as I say that calcium carbonate is one of the major things that gets carried by water because it reacts with acid. So, if there is ground water, so let us say it rains and once the rain penetrates the ground level, it also mixes with certain layers which are slightly more acidic. Once the water penetrates through the surface, it is groundwater and it is slightly acidic. It will go through layers made up of calcium carbonate and dissolve them.

So, now you have a groundwater, which has enough calcium carbonate but because it is acidic, it can flow with this higher amount of calcium carbonate for quite some time. But then, if it comes to a place where there is not enough acid to keep it, or there are changes in other conditions such as oxygen concentration and things like that, then it will start to precipitate. And once it precipitates, it is the calcium carbonate, which will start to precipitate out of this water. And this forms these grip stones.

So, in the caves, it will start seeing one drop at a time from the ceiling of the cave. And because as it drips, part of it also solidifies, it will make this cone like pattern from the ceiling. But as it drops from the top, it is also building up at the bottom, again, calcium carbonate.

So, eventually, you will see some development of calcium carbonate solid calcium carbonate structures from the ceiling, as well as a buildup on the ground of that cave corresponding to those drips. And these are the combinations that we also called stalactites and stalagmites. They are commonly known as drip stones.

And they are excellent in terms of preserving some of the old records of how the groundwater behaved in certain times in the geologic past. Important thing to remember that these developments of limestone does not really require a direct involvement of biology, it is primarily developing through inorganic processes.

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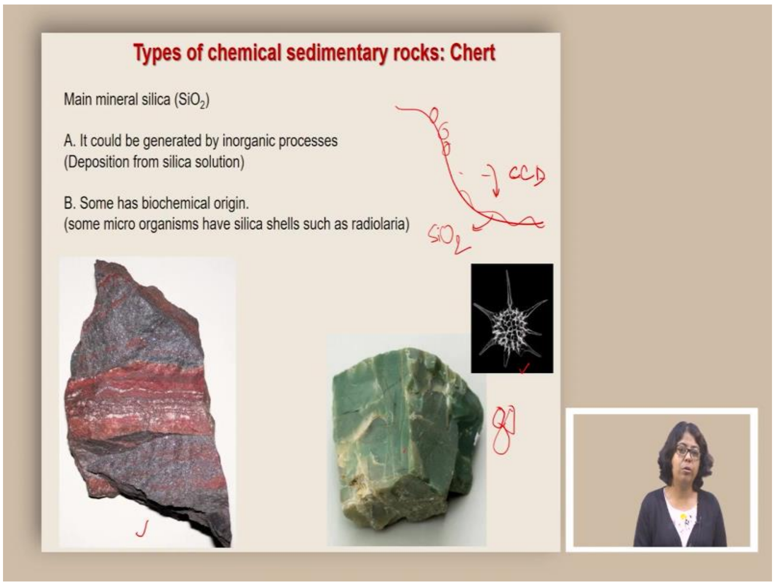

There are other types of chemical sedimentary rock and these primarily differ in the composition. So, so far, we have talked about calcium carbonate and their deposition, there can be other chemical sedimentary rocks, which are primarily made of silica SiO2. N

ow, we know that silica are not so easy to keep in the solution, because they do not dissolve so easily. However, if you change the condition of pH, as well as temperature, there is a particular chemical window during which it can dissolve in the fluid in water, you have to have the right balance of the pH as well as the temperature in certain cases, oxygen also plays a role.

So, if you are in that particular time and place where the water can dissolve silica, then the water actually carries a lot of silica in solution. And when the condition changes, it can start to precipitate. Now, again, chert also has two types of forms. One is produced by organic processes, where the skeleton becomes the part of a rock, another one where it is primarily inorganic process. So, there are organisms called Radiolaria, which can make their skeleton out of silica, they generally live quite deep in the ocean, a place which is below the level where the calcium carbonate can precipitate.

So, as we go down in depth in the ocean floor, there would be a point where the calcium carbonate will start to dissolve again, it has something to do with the overwhelming pressure of the water and the oxygen availability. So, as a result, the calcium carbonates can precipitate here and here, but the moment we go down below this level, a certain level of depth, it will start to go into the water solution again. And this is the level which is called CCD carbonate compensation depth.

So, anything which is below CCD will, if it has a calcium carbonate composition, it will go into solution and it will not precipitate. So, we find that organisms which are living above CCD, many of them have calcium carbonate skeletons, but the groups which live below CCD, if they have skeletons, they are not made up of calcium carbonate and one of the major group like Radiolarian they actually have a skeleton which is made up of Sio2 and that helps them to survive below the CCD level, they look something like this. And their skeleton is made up of silica.

Because they are microscopic, they are often not observed unless you have a good microscope and in fact, better even if you have a scanning electron microscope. So, they contribute to a development of a rock, which is called a chert, but it is a Radiolarian chert. And generally, it is always associated with a deep level of the ocean. Now, please remember that in many of these chemical sedimentary rocks, especially these kind of cherts, or you will find that if you take a section, you are not going to really see specific grain size because they are almost precipitating and binding together at the same time.

So, therefore, it will look very homogeneous and you will not find specific grains that we are so used to seeing in the Detrital sedimentary rock. Now, there can be another variety, where the silica deposition is happening because of inorganic processes and it can create such a banding of chemical precipitates, depending on oxygen availability, depending on the supply of silica and other things. So, you can have completely inorganic deposition of silica and that can also create a chert or Jasper depending on which subdivision you are talking about.

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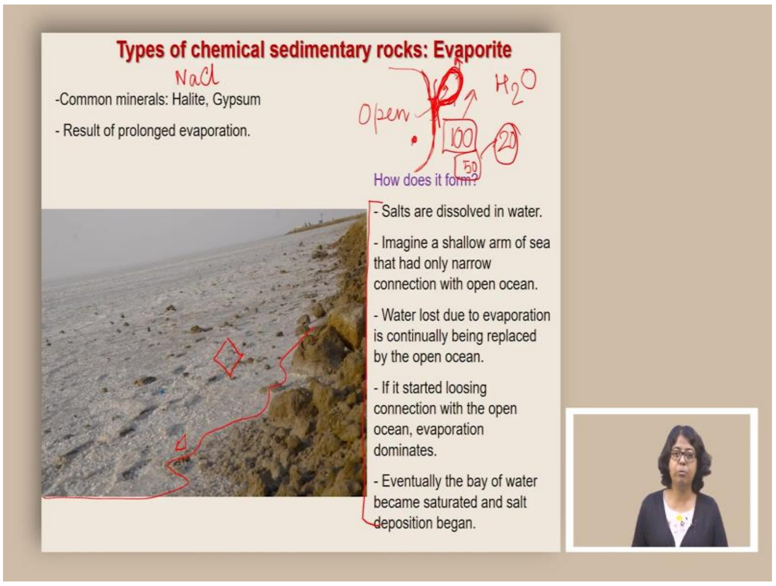

The third type of chemical sedimentary rock that we find in plenty in present day as well as in the geologic past is called an evaporite. And the common minerals that we find in these evaporites are halite, gypsum. Now, halite is actually the common table salt, so the composition is NaCl. The common theme that binds all the evaporate deposit is that they are the results of prolonged evaporation. And that creates these kinds of crystals as well as the final rock. Now, how does it form?

So, let us first start with a system where there is enough water. And there is also salt. For example, if you think about the ocean water, the ocean water actually has enough salt dissolved in the water. So, that can work as a source material. Now, imagine a shallow part of the sea that had only narrow connection with the open ocean. So, if I look from the top and try to draw a boundary, so let us imagine that there is an ocean where the boundary of the continent looks like this. And this is the open ocean, there is also a part which is sort of inland and the open water of the ocean also goes in there.

Now if it goes there, it cannot come back so easily with this to this open ocean. Moreover, the mixing of the water from here and the water of this part is not really happening very well. Now, there will be times when the water will reach this narrow place, and it will stay there for prolonged time because it is not getting mixed by waves and other energy. So, in these places, the water would be lost due to evaporation because it is continually being replaced by the water, but that water that when it evaporates, it will only take the water, the evaporated phase will not have the salt.

Now, it evaporate the water goes away. And the thing that is remaining behind is some water which is mixed with sodium chloride. Now, if we started with let us say 100 parts of water, and let us say 20 parts of sodium chloride, because this water is continually evaporating there will be a time when these 100 parts of water will become let us say 50 parts and this 50 parts will still have these 20 parts of sodium chloride.

So, with increasing evaporation, the proportion the relative proportion of sodium chloride will increase because it is not going into the evaporative phase. So, eventually it can happen that you will start finding this kind of increase in the evaporate concentration or sodium chloride concentration.

Now, the question is, is it enough just to have this kind of arm to create this situation? Well, sometimes it becomes even easier to form these evaporate deposit if this entire connection is lost. So, let us imagine that the open ocean has this small narrow area where it used to go inland.

But then the there was a development of the land itself, because of which this part becomes restricted. And this does not have any connection with the open anymore. In that case, whatever water whatever sea water went inside, will keep on evaporating. And that evaporation will only stop when there was no water, no water at all, the ground will only have this extremely high concentration of sodium chloride.

So, these kinds of situation happens when the connection with the open ocean is completely lost. And eventually the Bay of water became saturated and salt deposition starts. One example that we can find from India is in the western part, near Kutch, where you can find these salt flats.

So, eventually, if it completely loses its connection to the ocean, what we will find is a sediment which has development of salt crystals, the salt crystal creates very large smooth crystals, which you can see from a distance. So, this the entire region that you can see is actually covered with these salt crystals which are very clear white and can be seen from a distance. And if these sediments turn into rock, they will create our typical rock which will have this composition of sodium chloride.

Sometime sodium chloride crystals get replaced by other minerals, but they retain the shape of the crystal and this entire rock is called evaporite. And wherever we find the evaporite in the rock record, we can actually talk about this entire process just by identifying that it is an evaporite because this is the way of developing and evaporite through a geologic process.

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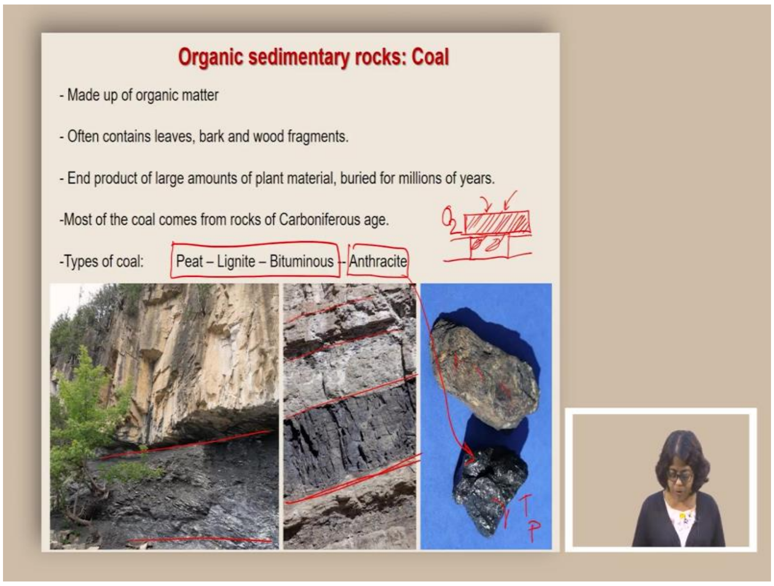

Apart from the chemical sedimentary rocks, there is another very interesting type of sedimentary rock which is called an organic sedimentary rock. Now, when we defined minerals, we categorically said that minerals should be inorganic in nature. However, now we come across a rock, which actually has quite a bit of organic origin, it is actually made up of organic matter. And therefore, sometimes, when coal are classified, we do not use the word mineral rather we call something like bio minerals. So, the example that we are going to talk about is coal.

It is made up of organic matter, it often contains leaves, bark and wood fragments, it is the end product of large amount of plant materials that are buried for millions of years. Now, let us try to understand how it can happen? When we are talking about plant materials. Once the plant dies, the first step that takes into place is the bacterial activity and they basically eat it up or decompose it.

So, the reason that we are finding some remnants of leaves bark and wood fragments means that they are somehow protected from the initial decomposition and to stop the initial decomposition there has to be some conditions one condition for stopping the bacterial decomposition is restricting the oxygen concentration.

Because if there is enough oxygen, then it also because they are primarily carbon, they convert to carbon dioxide and we ended up losing all the carbon. The second point is, if the entire part which has the coal which has the organic material like leaves and barks, they get covered by sediments, because they are getting covered by the sediments, the atmospheric oxygen or the bacterial activity cannot really penetrate and react to this organic layer. So, these are some of the ways how you can protect the organic layer from decomposing or from oxidizing and therefore, preserving the original concentration of carbon.

And most of the coal comes from the rocks of Carboniferous age, this is a particular time in geologic timescale and because of the higher degree of coal production or carbon heavy production of the organic material, it is called carboniferous.

So, there are four types of coal, these primarily shows you the increase in relative concentration of carbon. It starts with peat, then goes to lignite, then goes to bituminous and finally, anthracite. Now, these three the first three are part of the organic sedimentary rock. But this one because it requires significant involvement of temperature and pressure, this is actually metamorphic rock. So, this one is actually a metamorphic rock, whereas, the other types are part of chemical sedimentary rock.

So, if we go to the field, we will often see structures like these, these are basically the coal, it can deviate in terms of its composition in terms of how much carbon is there. So, it can vary between very low-grade coal such as peat where you can actually see some of the vegetation quite clearly, and the carbon percentage is going to be quite low to something which is more like a lignite, or bituminous which has slightly higher concentrations of carbon than peat. And in the rock record, you can see them as distinct layers, in contrast to other rocks such as shale, or sometimes even sandstone.

To finally produce a completely compacted type, which is the anthracite but again as I said that for anthracite, it requires a very high temperature and pressure, which is beyond the definition of sedimentary rock. As a result, anthracite coals are type of metamorphic rock, whereas peat, lignite and bituminous is the type which makes up the organic sedimentary rock.

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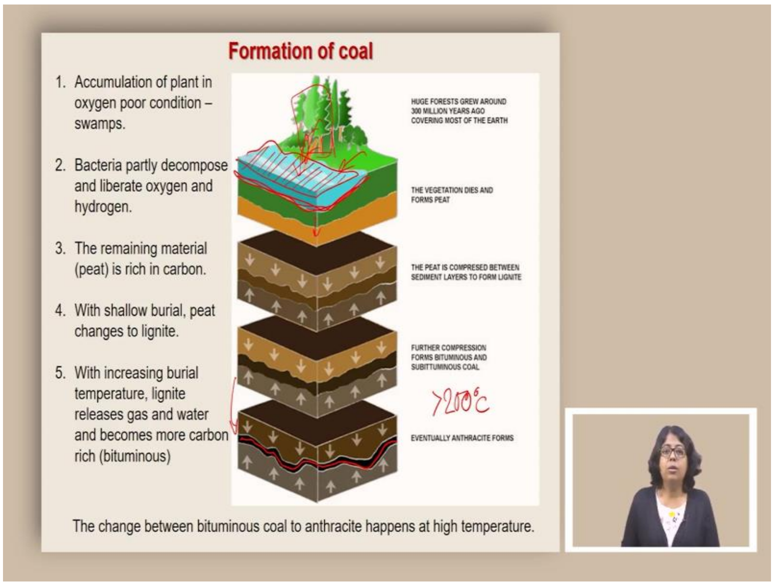

So, if we want to summarize how the coal forms, it starts with the accumulation of plants in oxygen poor condition and such condition can be in swamps. So, swamps are places where there is water and there is also the growth of vegetation. But because these vegetations are too much, this vegetation will eventually after their death, we will come back to this water they decompose.

Now, because it is only small part of the total vegetation. Their decomposition basically means that the top part of the swamp will become oxygen free, because all the oxygen that was available at the top part is already taken up because of the decomposition of this vegetation. And if this process continues, there can be a situation where the entire swamp is has only a very limited amount of oxygen and therefore, bacteria will partially decompose and liberate the oxygen and hydrogen. So, that means we are always retaining the carbon, but we are not really retaining the hydrogen or oxygen is already taken up by the bacteria.

The remaining material is therefore very high in carbon percentage because it already lost the other things. So, plants are primarily made up of hydrogen, oxygen, a bit of nitrogen and then oxygen. So, if you remove the oxygen if you remove the hydrogen, what is remaining is carbon and because you are still looking at the same material, the overall carbon percentage increases then this place is not really keeping the same geometry over time because there are more vegetation which is coming from the top and the vegetation which is already decomposed and heavy in carbon they are underneath.

So, they are going to be compressed by the overloading pressure of these vegetation the newer vegetation. So, this is when we are calling it a shallow burial. And this shallow burial will also involve sediments coming from the land. So, with sediment mixed with vegetation, and because of the weight, things are actually going down, this will all convert the speed into lignite. With increasing burial, the temperature also increases. The lignite releases the gas and water whatever is the remaining thing, and it becomes more carbon rich, and that is when the lignite converts into bituminous.

So, in a simple rule of thumb, as you are compressing things as you are going down deep with depth, it releases more materials except for carbon. And therefore, the coal that remains at the deeper part becomes really rich in carbon, and hence their grade increases. But from this part, for example, from the bituminous to anthracite, this compression actually requires higher temperature and pressure, which is part of the metamorphic realm, because it is definitely much greater than 200 degrees centigrade. And therefore, it is metamorphic rock that we already talked about.

So, this is a summary of how the coal can form starting from a vegetation again, indicating that if we find the coal in the geologic record, it actually tells us something about how, what are the processes that took place to form it?

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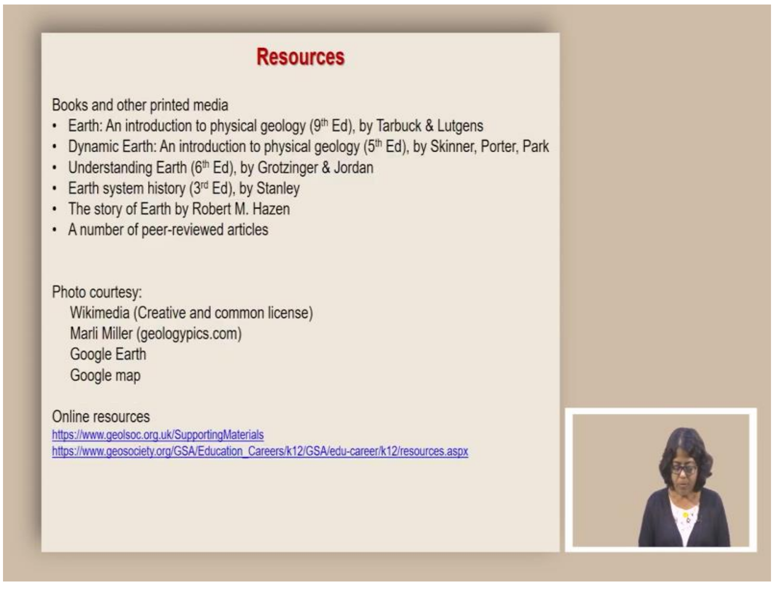

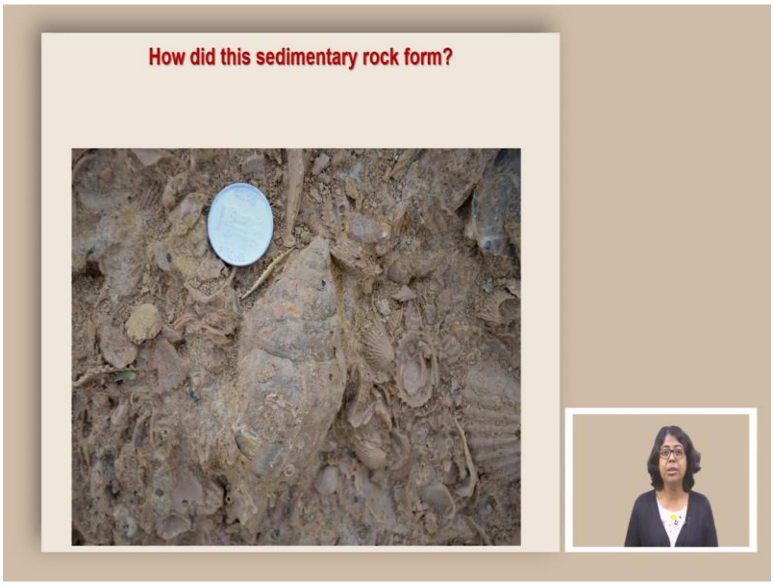

So, in summary, today, we learned different types of chemical sedimentary rock and organic sedimentary rock. We also learned that in chemical sedimentary rocks, many of the rocks can form by completely inorganic processes. However, many of the sedimentary rocks that are chemically originated actually have a biochemical origin rather than inorganic origin. Examples of such are coral reefs, limestones that we find in coral reefs, coquina, chalk, Radiolarian chert, and primarily these chemical sedimentary rocks are produced by chemical weathering.

We also talked about organic sedimentary rock and learn how the organic sedimentary rocks such as coal forms and what does it tell us about the environment where it formed? Here are the resources that are used to develop the content. And here is a question that you should think about. Thank you.