Evolution of the Earth and Life
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Detrital Sedimentary Rocks

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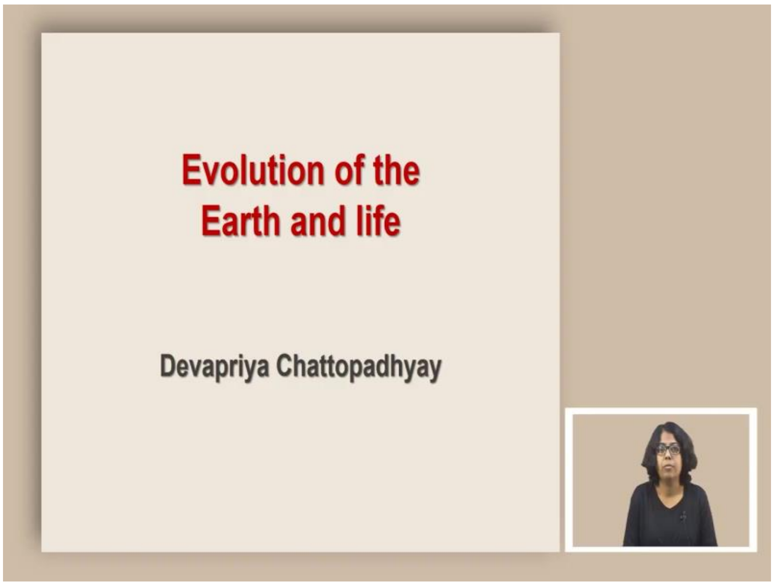

Welcome to the course evolution of the earth and life. Today we are going to talk about different types of sedimentary rocks. First let us try to see what kind of minerals we expect in sedimentary rocks?

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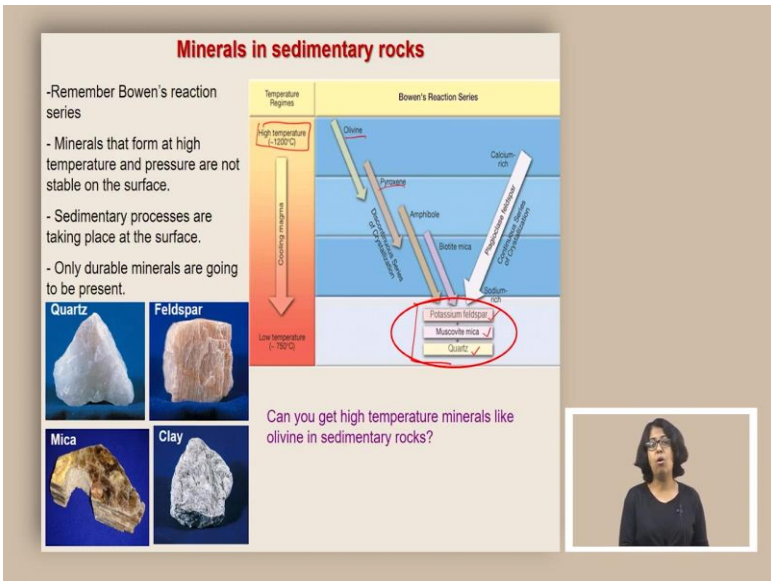

So, we have to start with Bowen's reaction series, because it actually tells us something about mineral stability. And if we know a little bit about mineral stability, then we can easily predict what kind of minerals we can expect in a sedimentary rock?

So, as you remember that Bowen's reaction series tells us that at high temperature minerals like olivine, pyroxene, these are stable. On the other hand, when we come to low temperature, the minerals that are more stable and the minerals that precipitate crystallize at low temperature are the quartz, mica and feldspar. So, we know that sedimentary processes are operating at very low temperature and pressure, because they are taking place at the surface.

And therefore, we can expect only the durable materials, durable minerals, which are stable at low temperature pressure to be found in sedimentary rocks. Now, the question is what happens when you break down on existing rock? Let us say we are breaking down our rock, which was formed deeper underneath and has a lot of olivine, pyroxene and these high temperature minerals. So, these kinds of igneous rocks once they undergo the weathering process, eventually what we will see that as the transportation gets longer, they stay longer duration on the surface of the earth, they get converted into minerals that are more stable.

So, we are going to see these things. But to start with, we primarily find these low temperature minerals making primary composition of sedimentary rocks. So, we are talking about quartz, feldspar, mica and clay and then there are some types, which will involve calcium carbonate and other chemical composition. But when we think about the minerals that we can expect, it is only a few, then the question is, then how can we find a variety of sedimentary rock and how can we interpret them in terms of telling us something about the environment?

So, that is the goal of the classification of sedimentary rock. And we will see how sedimentary rock classification is quite different from the classification of let us say igneous rock or metamorphic rock.

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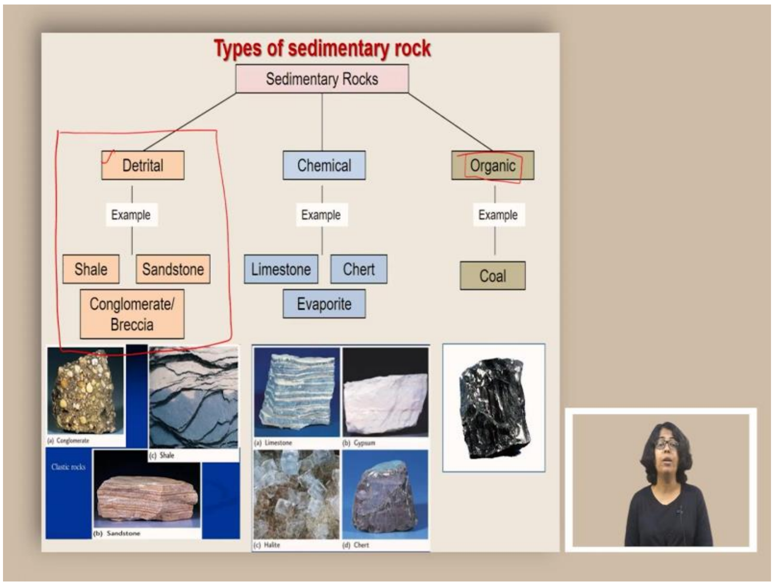

So, sedimentary rocks can be primarily divided into three types. The first one is called a Detrital sedimentary rock. These Detrital sedimentary rocks are primarily products of physical weathering and erosion or mass wasting. The chemical sedimentary rocks on the other hand are often results of chemical weathering. And then they can be carried by different agents and eventually precipitate.

There is another type of sedimentary rocks which are called Organic sedimentary rock. And these rocks are very important when we talk about energy resources. For example, coal is an example of organic sedimentary rock. So, now we are going to focus on this Detrital sedimentary rock.

So, this classification clearly does not tell you anything much about the mineralogy. So, what is the basis of the classification of sedimentary rock? So, we understood that it primarily depends on the process by which it is getting made. And we are going to focus on the Detrital sedimentary rock. So, Detrital sedimentary rock has three primary components. One is shale, one is sandstone and other one is conglomerate or breccia. So, let us take a look at what they are and how they are made up of and what do they tell us?

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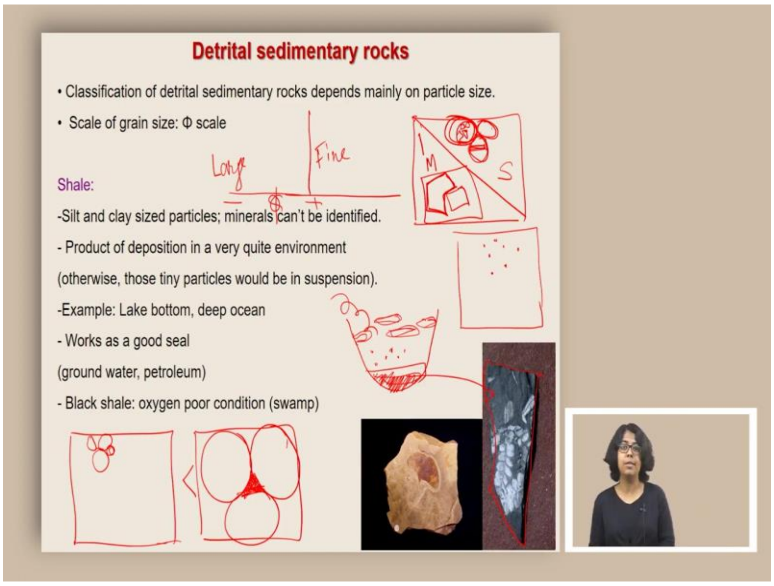

So, classification of Detrital sedimentary rocks depend mainly on particle size and particle size is the size of the grains. As we know that unlike igneous rock or unlike metamorphic rocks, in a sedimentary rock, we are not really talking about development of fine crystals or development of interlocking crystals. These are characters of igneous rocks and metamorphic rocks, where these crystals are growing, the crystals, the minerals are developing as they are cooling down or in some cases for metamorphic rocks as they are getting heated up and so on and so forth. In contrast, for sedimentary rocks, it is the grains that define the sedimentary rocks.

Now, when we are talking about grains, these grains can have different minerals because they are basically parts of older rock. But they can also be made up of the single mineral. But important thing to recognize is for igneous and metamorphic rocks, you are always going to find this kind of an interlocking texture, whereas for sedimentary rock, it is going to be grains and because these are grains, and these are remnants of other types of rocks, there would be gaps.

These gaps can be later filled up by cement, they can be later filled up by other minerals. But in a grain, you can have many minerals, you can have a single mineral, but you are less likely to expect such compacted situation that you see in an interlocking texture of igneous and metamorphic rock. So, that is one way to distinguish sedimentary rocks, when you are looking at it under microscope.

Now, because grain size plays a major role in identification of sedimentary rocks, we have to define the grain size. And the way we measure the grain size is basically measuring its diameter, but then it gets converted to a different scale, which is called a phi scale. So, the phi scale is in some sense, is taking the log of the diameter and then adding a minus in front of it. The reason is, that when we convert something, these kinds of measurements to log we also get a number, but we tend to or we would like to see the grain size which appear the most to be a positive number.

So, therefore, we designed the phi scale in such a way that rocks which are let us say made up of sandstone or shale, which are very, very fine grained, they get a positive number. And on the other hand, things which are we do not encounter very much in the nature, such as really big grains, really big grains such as glacially carried bolder those we do not encounter very often, those can be minus, so that is the design of the phi scale.

So, for phi scale, we will find large boulders to get the negative points and very fine grains to get a positive number. The other reason for this phi scale is to accommodate this huge grain size into one scale and that is achieved by converting into long. Because the long scale basically compresses the original scale, otherwise it would have been very difficult to float the diameters of a boulder which can be in the tune of let us say 500 meters, it can be that big to a micro meter, a micro centimeter or micrometer level, grain size of shape.

So, in order to accommodate all of these things in one scale, it has been converted to log and then just to have mostly positive number by the majority of the rocks which have smaller grain size, it has been added a negative when we are converting the diameter into phi scale. So, now we are going to talk about the first type, where we encountered the smallest grain size, they are generally called shale.

So, it is made up of silt and clay sized particle. And often the minerals cannot be identified because it is so small. So, when we are making our rock where the grain size itself is so small, it is often difficult to actually identify the minerals within the grain. And because they are so, tiny particles, it often gets produced in a very quiet environment. So, imagine a situation where you have a bucket of water and in that bucket of water, there are some large boulders and also you have mixed some mud in it. If you are shaking that bucket, everything goes into the water and you will see a muddy water.

But eventually you will see that these boulders which are slightly bigger in size, they are going to go down first and then if you are keeping the bucket really still and you will not be disturbing it for a very long time, eventually this mud will settle down very quietly. So, in order for this fine particle sized materials to settle down, it needs a quiet environment. So, wherever you see a deposition of these kinds of materials, it immediately tells you something about the environment that these particles have been in suspension. And the reason the suspended load or suspended material got precipitated is because it was a quiet environment.

The example could be lake bottom, deep ocean, where it is not being disturbed by the wave energy or any other biological activity. And then these suspended materials could settle down over a very long time and create layers with very fine grain size. It also works as once it converted to a rock it works as a very good scene that means because the grain sizes are so small that gaps between the grain sizes are also small.

So, it is a interesting thing to check that if you have the same area of these two squares, and you have small grain size versus very large grain size, where the gaps between the grain sizes would be maximum what you will find that if you accumulate all the spaces, these are the spaces which are called interstitial spaces.

If you add up all the interstitial spaces, it is always going to be higher in these then the if the grain size is smaller, the way to think about it is the smaller grain size tend to pack things and reduces the interstitial space.

Now, if the gaps in between the grains are smaller, nothing can escape through it. So, it will become a very good sealing material. That becomes important because it can create a reservoir. If it is above that liquid medium, let us say there is a pocket in the rock where there is water or oil and it is kept by these fine-grained materials eventually converting into rock. Those oil or rock cannot escape it gets trapped it gets capped by these shales.

So, therefore, it is also a good sealing material. And as geologists people have often focused on finding those places where things can be sealed very well because then they are the potential places to explore. Now, I have shown you two pictures where both of these have the composition the same composition in terms of the grain size, but the different colour, one is grey and the other one is black. The black shales indicate that they have quite a bit of carbon inside carbon particles, the reason they can have organic material in it is somehow those organic materials have not reacted with oxygen and converted into carbon dioxide.

And the only way it can happen is if the oxygen was not available, the oxygen was not as much as there should be in the open environment. And therefore, finding these black shales always indicate an oxygen reduced condition, a condition where there is not enough oxygen to they generally form in bottom of the lakes or swamps, because in the lakes, the only source of oxygen is from atmosphere.

Now, if there are lots of vegetation, lots of leaves and other vegetation on the top of the lake and it is a shallow lake. By decomposing these leaves, they take up enough oxygen as a result, things at the bottom which is far away from the atmosphere do not have as much oxygen in it.

This becomes a completely anoxic or sub-oxic environment. That is the places where if eventually, grain settle down, they will create a shale and the shale is going to be darker in appearance, because it will also have this organic material which has not been oxidized.

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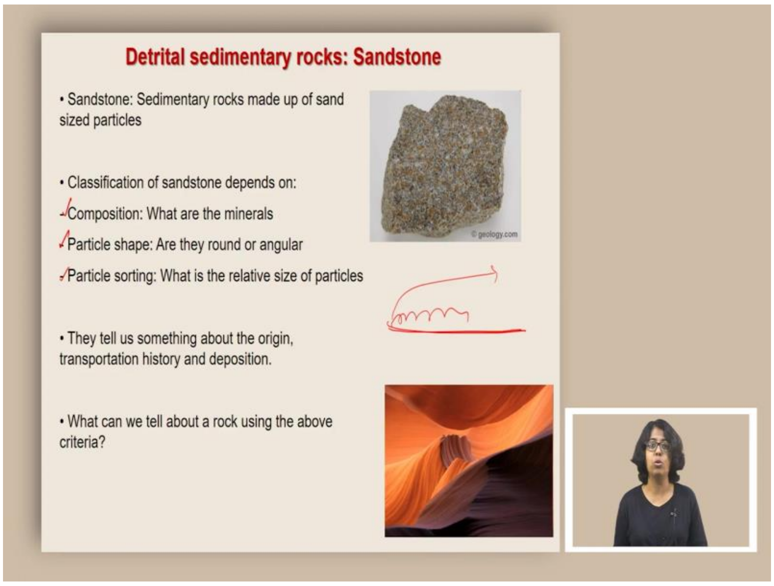

Now, let us look at slightly larger grains. So, now we are going to look at rocks that are made up of sand sized particles. Initially, we were looking at silt and clay sized materials. But now, we are going to look at Sand sized particles. These are particles which actually move, they cannot settle down from suspension, it is difficult for them to go to the suspended load, it actually gets carried by the action of the wind or river. And they basically get if this is the bottom of a river, these things basically move with the waves. And they can be carried near the ground, they can also be carried on the top, but they are not in suspension.

So, for them to settle down, it does not always require a very quiet environment, they can settle down if the wave energy or the current energy or the river energy slows down or goes down, they will simply try to settle.

Now, we can further subdivide the sandstone depending on number one composition, second is particles shape. And third is particle sorting. And these are extremely important things because it tells us something about the history of this rock. When was this rock developed? When were these sediments came together? How long did they get transported? When did they get deposited? All of these questions can be addressed by looking at composition, particle shape and particle sorting. So, we are going to focus on those aspects now.

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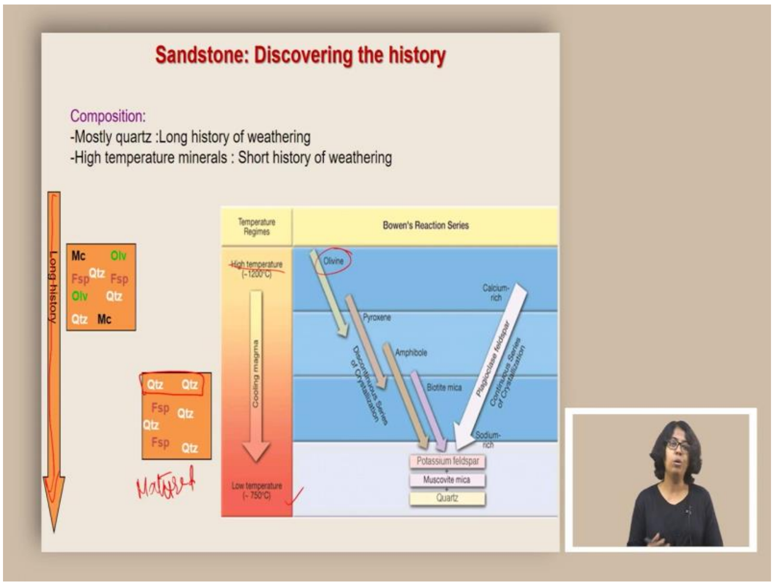

So, as I say that, if you remember the Bowen’s reaction series, the composition of the minerals tell us a lot. Now, if we start with a rock, which has mica, olivine, feldspar, quartz. So, that tells us that the original composition can have also high temperature minerals such as olivine. But, as it transports as a sediment, it is basically exposed at a high as at a surficial condition with low temperature and low pressure.

So, eventually it is going to break down, it is going to break down release its ions and eventually the remaining material is going to be only silica. So, that means the quartz, in fact feldspar also we have seen if certain types of feldspar can be converted into silica and also develop clay.

So, the longer the history of sedimentary rocks, you are less likely to encounter high temperature minerals. So, high temperature minerals immediately tells you that it is a short history of weathering. The Rock must not have been on the surface for very long, it has not gone through a long history of weathering that can be the only reason for developing or to have high temperature minerals in a sedimentary rock and this is also called mineralogical maturity.

So, this rock because it only has these low temperature minerals will be called matured. Because it has only low temperature mineral, it has gone through enough time of weathering and erosion and finally deposition. Because of it, it converted all the high temperature minerals into low temperature minerals.

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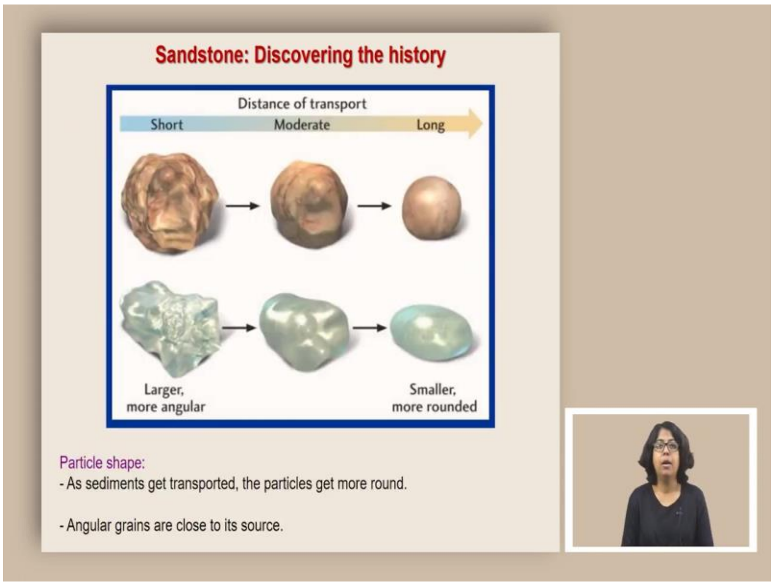

Another way of discovering the history of transportation and weathering for a sand particle is its shape. So, as sand particles gets transported for longer, it tends to lose its angularity, and it becomes smaller, and it basically loses its size too. So, it will become smaller and more rounded, as it transports more.

Once we have this idea, we can use it to reconstruct the history. So, if we find something which is angular and larger in size that immediately tells us that those sand particles have not been transported for very long. And it is close to its sources where those sediments were produced.

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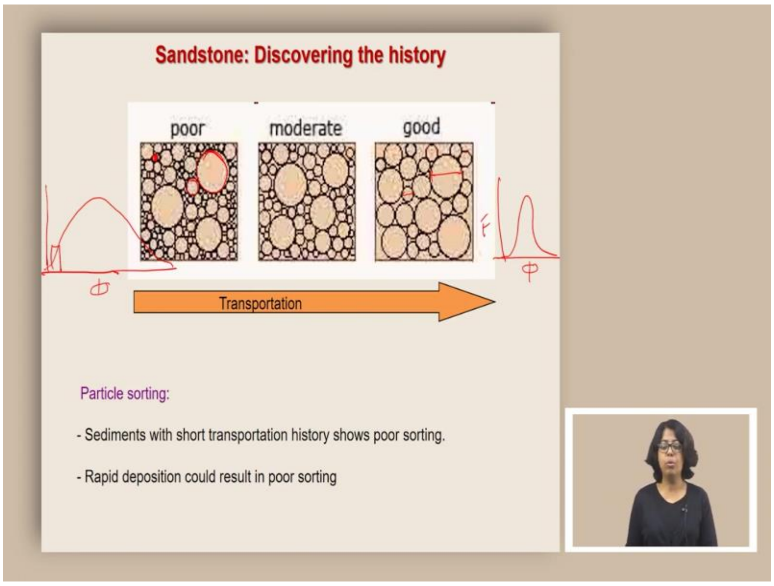

The other way of discovering the history is by looking at sorting, sorting basically means how sediments are mixed. So, what is their relative size to one another? So, let us take an example of this rock, or this pile of sediments, or how we are going to see the sediments under cross section in a sedimentary rock, that there are very small particles. And then there are very big particles too. And it is all mixed. So, if I have to draw that sizes of it, in terms of diagram, by counting how many small ones are there, and how many large ones are there, I am going to find something which is going to have a really long spread.

And these are the things which will basically tell us that it has a poor sorting. On the other hand, these are the things where all the sizes are pretty much the same, we do not really find something which is very small, and do not really find something which is extremely large. So, when I am plotting this, it is going to look something like this.

And again, I am talking about this as grain size, and this part of it is going to be frequency with which I am getting this grain size. So, good sorting basically tells us that it has transported for very long because natural process of transportation works like a sieve and the more transportation it has gone through all the small particles will basically all the different sized particles will be gone and eventually, we are going to get particles which are of the same size and sometimes same shape.

And therefore, the sorting is also a very good indicator of transportation. So, combining the size, shape and the sorting and mineralogical composition, we can get to this question, how long a particular rock has been transporting or how far it is from its source? And these are very important conditions that we would like to have an answer of. So, if we find a rock, which is very poorly sorted, it basically tells us that there has been a rapid deposition right after it was produced. So, we will take some example.

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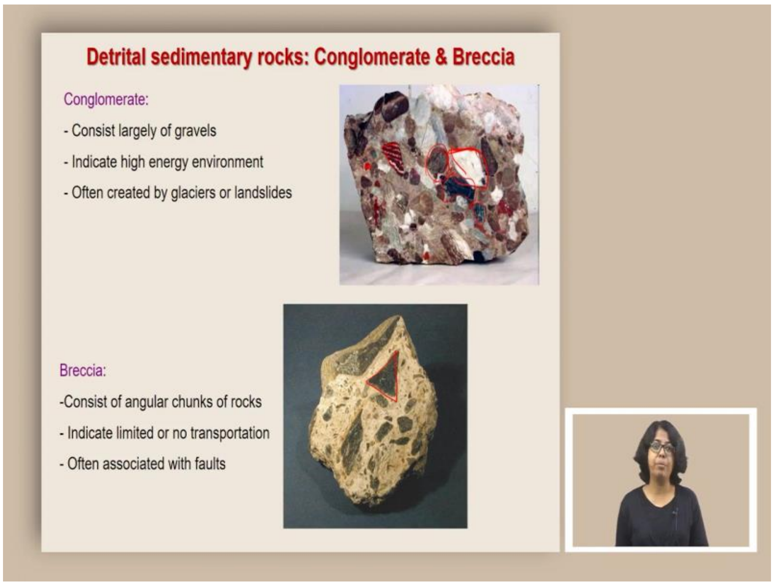

So, let us take a look at these two examples. These are also two of the types of Detrital sedimentary rock. So, we already talked about shale and sandstone. Let us now concentrate on these sedimentary rocks which are called conglomerate and breccia.

Now in conglomerate, it consists largely of gravels that means really large grain size. And because it is large grain size, and we also see some of the things are kind of angular and the other thing to notice is many of them are quite large. And there is quite a bit of contrast in terms of how small things are versus how large things are. And this basically tells you that it is poorly sorted, it has large size, it is not rounded.

Moreover, if you look at the colour patterns, it also tells you that you are encountering minerals that are high temperature minerals, and not all of them are low temperature minerals. So, it is mineralogically poorly matured, it is texturally poorly matured, and it is also compositionally, you can see a variation. So, all of these are telling you that they have been created in places and immediately caught deposited pretty much at the same place it has not gone through a very long transportation. Sometimes they are also produced by really large agents which has very high energy.

As a result, they are going to create a sediment mix, which is mix of very fine grains as well as very large grains. If the agent does not have that much energy such as wind, it cannot really carry materials of let us say this size. So, for wind, the sorting is always going to be very good and the grain size is going to be very fine. On the other hand, if we are looking at things produced by glaciers or landslides, we are going to find a lot of variation in terms of the grain size, they are not going to be Angular. And also, you can expect to find mineralogical immaturity.

The second one is a Breccia. So, it is somewhat comparable to conglomerate. But the important point to note is the grains are even more angular. And often it develops in places which are associated with vaults where a lot of sediments gets generated by crashing down and almost not transported for long distance they get generated and then they get deposited almost at the same time. And such short transportation history tells us we can conclude about these short transportation histories from these rocks, where we find poor sorting, larger grain size and angular fragments.

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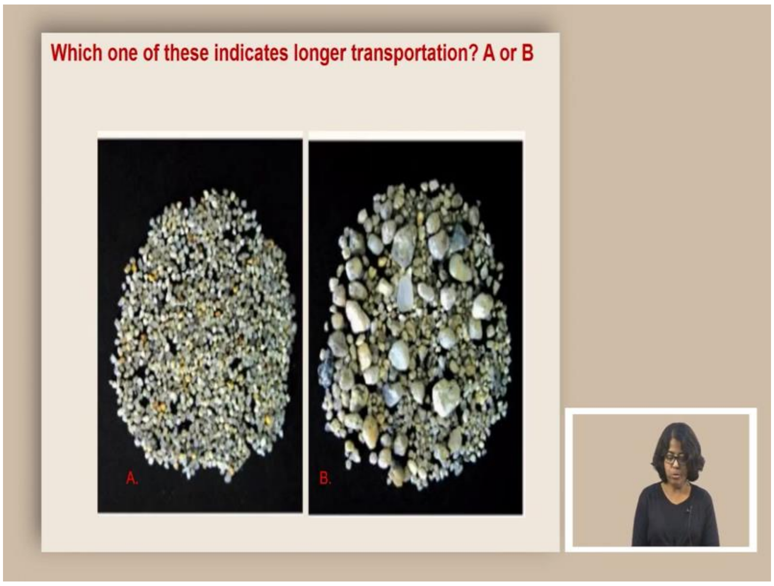

So, here are some resources. And in summary, today we learned different types of sedimentary rocks and how sedimentary rocks are classified. We also learn what kind of minerals we can expect in sedimentary rocks. Finally, we focused on the title sedimentary rocks and we learned how looking at their mineral composition, shape of the grain, size of the grain and sorting of the grain, we can tell about their transportation history. There is a question for you to think. Thank you.