Evolution of the Earth and Life
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Lecture 28
Relative Age

Welcome to the course evolution of the earth and life. Today we are going to talk about relative deity. What I mean by that? Today we are going to try to understand what can we tell about the age of the rocks.

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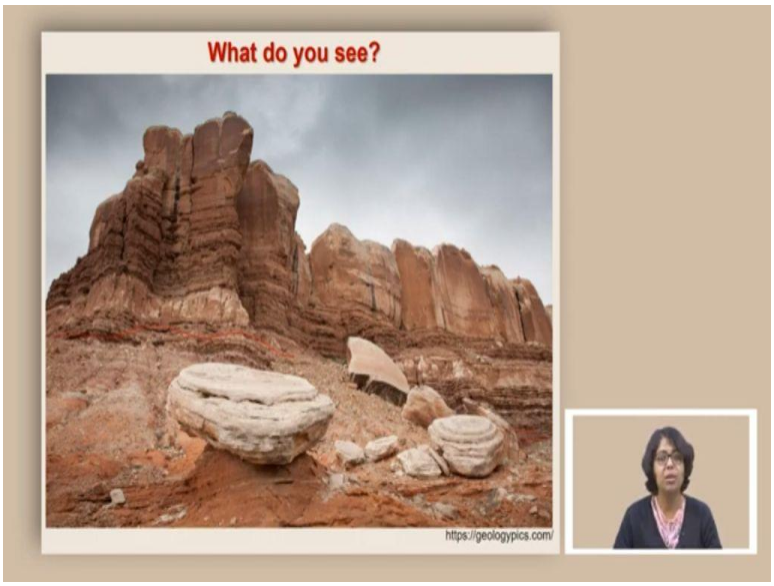

We will start with some pictures and I would like you to spend some time looking at the pictures. I am sure that you have gone out your home and you have seen rocks. Whenever you see rocks, you should try to understand how we can even try to think about the ages of those rocks and what we mean by ages of the rock. Now, when we look at this rock, there are different rocks some of them are lying around, some of them are stacked up. And when we look at these stacked up rocks, can we say anything about when they were formed?

And as it turns out, when we say when they were formed, it is not necessarily have to be a number. Let us take an example. Let us say that we are looking at two individuals. One, very young, so young that they could not walk, and then someone who is quite old, with crinkled faces maybe.

Now, we really do not know exactly what their ages are. But, still we can say the person with crinkled age face, probably is older than the one we talked about that could not walk, because they are so young. So, we still have not said anything about the absolute number of their age. But, we are still trying to have a comparison of their age and when they came onto the earth. The same can be done even for rocks and we will see it. Now, let us take a look at another picture.

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And this picture looks like this. Now, what is interesting in this picture is if you look at this picture, people see again rocks, but these rocks are slightly differently oriented. So, when you see these rocks, you will see that the patterns of these rocks are somewhat like this. But, when you look at the rocks at the top, they are arranged in some fashion like this. Thus, it tell you anything? But, this is again we are looking at observation. We are looking at the rocks that we can see outside and trying to figure out can we deduce anything about there nature, about how they were formed and when they were formed.

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The final picture is like this, where we do see some of the layering's, but sometimes these layering's are not continuous. We actually see some of these things which are at the top, again something which is something which looks like they got shifted. And then there are cracks which are going in between. Now, these were the observations that were made a long time ago, not with the exact same set of rocks, but with different parts of the world.

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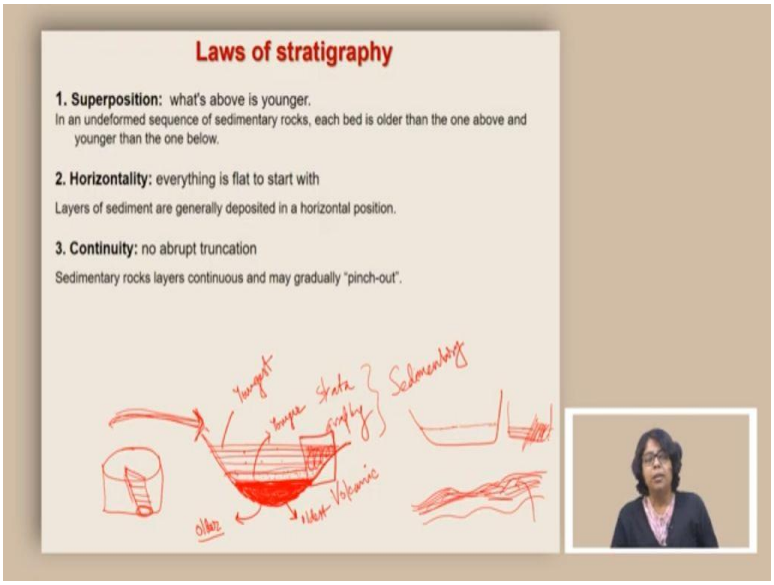

And people came up with very basic laws of stratigraphy. So, the idea of stratigraphy is strata, means layers, and graphy as we know, it means basically writing. So, it basically means the

writings in the layered rocks. And when we are talking about layered rocks, we are primarily talking about a particular type of rock, which is known as sedimentary rock. Now, these sedimentary rocks have this quality of creating layers upon layers. And when they create these layers upon layers, and then finally convert it to a rock, they actually tell us something about their relative age, and that is why we are using the term relative deity.

Now, is it only restricted to sedimentary rocks? Well no. If you have volcanic rocks where, let us imagine a lava flow, and that lava flow creates a rock and it completely solidifies. And then there is another lava flow which comes afterwards and again solidifies, so, there also you can have stratification. But, unlike the sedimentary rocks, these lava flows may have slightly different characters. And that is why in today's discussion, we will primarily focus on development of sedimentary rocks, and how we can figure out their relative ages. Now, let us try to understand how sedimentary rocks are formed.

We know that the source of sediments are often from the continents. So, the continents or the rocks that are exposed in the continent, they get eroded, and sometimes they get transported. And wherever there is a low energy area, they try to deposit all these materials that are cannot be carried any longer, and therefore, these layers of the sediments are forming.

Now, these layers of sediments are either forming by the agents which are carrying them, and basically depositing from the agent. So, it can be a river carrying sand, it can be a lake, which has got a lot of suspended sediments. Whatever is the process, these sediments are going to settle down with the action of gravity.

And therefore, you will find a pattern of them settling and creating these layers, we often call it a bed. Now, when that happens, they try to maintain this layer. And these layers are immediately going to tell you something about the relative age. How is that so? So, let us imagine a scenario where this particular place was empty to start with, and some sediments were being carried and they were deposited, so they made this particular layer. Now, once this layer was created, which completely covered up to this point, the sedimentation process did not stop it continued, and this entire part is filled up.

Once it is filled up, there was some time gap let us say, where sediment was not being carried to this spot. And therefore, these paths were still there, but it created this layer as we said, the next

layer which was created by the sedimentation process happened slightly later. And once it starts, again, it is going to create another layer. Now, for simplicity sakes, let us dot it up and simply saying that this has maybe a slightly different character. Now, what we can say very clearly even without knowing how long it took them to carry the sediments, how long it took them to transport the materials, and deposit the material.

We can very well say that this part, which formed below must be older than this part, which formed above it. So, why it is true always? Because unless this was formed, this could not have been deposited, and we can extend it on layers upon layers. So, unless things are disturbed, unless you are mixing it up, and by mixing it up, I mean, let us say there is another geologic process where this got mixed up, then this layering will not survive.

But, if you have a continuous layering, then this continuous layering actually tells you that it retains the information from when they were getting deposited. And if they were depositing in our region which was not getting disturbed, they will create this layer upon layer structure, and the bottom most part is going to be older compared to the subsequent layer.

And if we have to talk about the entire area, this would be the oldest part, and this would be the youngest part. And this idea is called the law of superposition, what is above is younger. So, in an undeformed sequence of sedimentary rock, each bed is older than the one above, and younger than the one below.

This law is very very old. 200 years, 300 years ago, people came across this idea primarily developed by the geologist in England and in Italy, where people observed this pattern and came up with this idea. The second idea was also connected to this is the horizontality. What it means that because we know that things are basically depositing under the action of gravity, to start with everything should be horizontal.

And the layers of sediments are generally deposited in a horizontal plane. So, if you see any deviation from horizontal plane that will mean that they might have been disturbed later. The third point is continuity, so there should not be any abrupt truncation. What do we mean by that? Let us imagine again the same area where things are getting deposited, it is very hard to understand, let us say where sediments are depositing. If in a normal condition, it is going to continue like this. There should not be any break because they are getting deposited by the action

of gravity. Now, if you find a rock section where the pattern looks something like this, so you have layer upon layer, but then there is a break.

And then maybe you do not really see any layers in this side that says that initially it has to be a continuous layer, and later, things got disturbed. And that is the reason we assume that continuity to be the original condition. So, now this are the basics of laws of stratigraphy. It is important to understand that these were very old laws, and they are mostly applicable to something which we call layer cake stratigraphy.

There are places where we do not find layer cake stratigraphy and then things get more complex. But for now, we are simply going to look at the laws which govern the layer cake stratigraphy. The reason it is called layer cake stratigraphy is quite obvious that if you look at a cake and you are going to cut a piece out of it, it is going to look something like this, where you are going to find the layers inside. And you can actually say that things which are at the bottom were the first things that you afford on a baking (tray). So, that is how we use this nomenclature of layer cake stratigraphy. Now, let us take a look at some more pictures.

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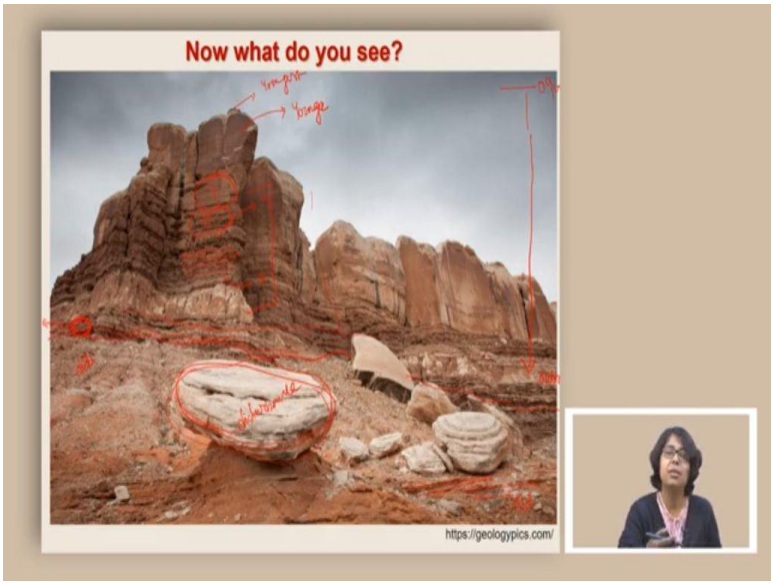

So, using the understanding that we simply talked about few minutes ago, we can now revisit this picture, and try to understand what it is telling us. So, what it is telling us? First of all, that there is a continuity and there is horizontality, so, all these layers are forming in a general horizontal

fashion. Second is, if you look at the layers they are sort of parallel to each other and you do not see abrupt breaks.

Using this, we also can say the things which are formed the layers, which have formed right here must have been folder, than the layers which are forming here. And this should be maintained for all kinds of this kind of rock sections, where you see this horizontality as well as continuity, because that means they have not been disturbed. And if I have to comment on the oldest rock and the youngest rock, probably, I will go at the bottom of this picture. I can still see these layers. And I am going to say that these at this in this picture, these rocks are the oldest. And then this rock at the very top is probably youngest.

And the age of the rock subsequent within that is progressively younging. So, you have the age if you actually know the age of this succession, you are going to find that the magnitude of the age is larger here and smaller here, if you are starting let us say from today. If we consider today as zero point, then as we are going deeper, it is showing us the older age. And this point if it touches this point, this is the youngest point. Now, it is also important to know that this relationship is not changing in between.

So, the same pattern can be talked about even in the middle of the rock. So, if we look at these layers, we can definitely say that this is younger and this is older compared to this one. So, every place you will look at, it will maintain this relationship that the part which is above is going to be younger, than the part which is below that.

Now, this is what we call the Law of superposition. And we also saw that if things are not disturbed, then it is also going to maintain the horizontality and continuity, we do not really see major breaks in between. Now, what about these rocks? Now, these rocks are actually falling down from somewhere here. And that is why we cannot look at these rocks, because these rocks will tell you a completely different age arrangement.

Why? Then, we should assume that the law of superposition holds true, because we are saying that the law of superposition will only be true, if the strata is undisturbed. Clearly, these rocks are formed by eroding some of the materials from here, and therefore these are a representation of disturbance. So, they were not in the same place where they were formed. And therefore, when we go to the field, then we have to make a decision about the age of a rock, young or old, we

never look at the boulders or pebbles which have fallen down from this section. We look at the existing complete rock which has not been disturbed and also it is not isolated. So, that is how we can look at or read the existing rock structure in the field.

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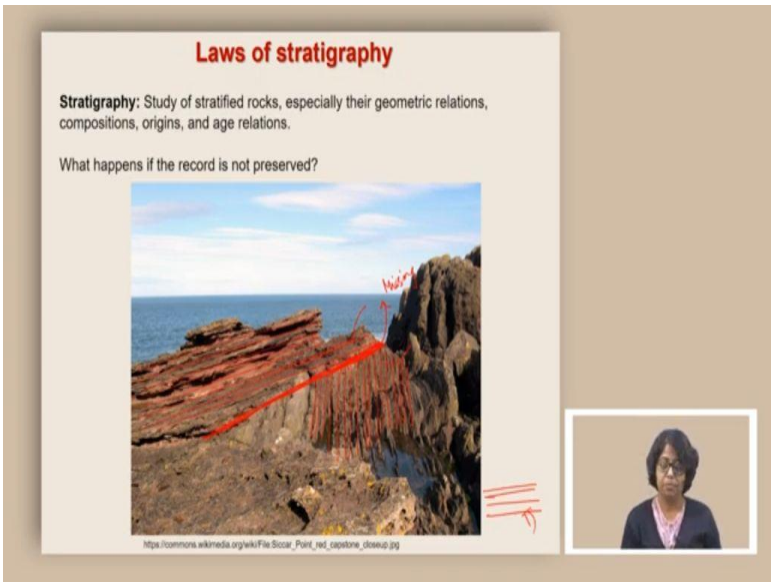

One more important aspect that people came across is it is not necessarily that you will always have this pattern of layered structure without any change. And in as I mentioned that stratigraphy is the study of stratified rocks, especially the geometric relationships, composition, origins and age relationships. Now, all of these depend on this understanding that all the rock record is preserved. What happens if the rock record is not preserved? And this idea came to the original or initial geologist or naturalist, when they started looking at the rock record. One of the very important point or place where people started studying stratigraphy was this Siccar point. It is in, as is a part of the British Isles.

And when we look at Siccar point, we see some interesting patterns. Now, let us take a look at, so this is Siccar point. And if you look at the rocks of the top, it shows you this orientation of this, and again these are sedimentary rocks. So, you can imagine these layers formed by depositing all kinds of sediments in this fashion, and initially it has to be a horizontal thing.

But, then when we look at the strata right below it, we find a different pattern. Unlike the top layer, the bottom layer has an orientation like this. And this orientation is very different from what we will assume to be the original orientation, because they are not horizontal. And this

question was asked by the initial geologist, including Hatton, who was often called the father of geology, that what exactly made these arrangements.

So, one of the understanding was that in order to have a change from the horizontal continuity to something like this vertical pattern, it has to change, so it has to get disturbed, so that the entire thing goes up. More importantly, once you rise it up, how do you again start depositing things horizontally? So, that is what people started thinking about.

Not necessarily, all the records are preserved. Maybe there was a situation where these were depositing at the bottom of the ocean, and then they became rocks, but then somehow, they got eroded. Part of it got eroded, and that is why you do not really see all the layers continuing. It is abruptly ending somewhere right here.

Now, the question is what erodes them and what we mean by completely missing a part of the history? And that is where people started to think about exactly how can you build this sequence. And this particular time, probably indicates a time where the rock record was built, but eroded and therefore we do not have that record and this line represents the missing record. And because the record is missing, we cannot really talk about how big was the record, unless we know something about the age of this part and the age of this part. And these missing records are often called unconformity.

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So, how can an unconformity develop? So, let us take us through from this cartoon diagram. So, sediments of the bed that owns the bed can be deposited in a low energy condition. So, for the simplicity, let us take it as the sediments are depositing beneath the sea or under the sea water. That is where a lot of sediment gets carried and they can deposit because under the waves, it is a low energy condition. And they are creating these layers, so, let us look at the A, B, C and D. This A must be older compared to D and they are creating these layered patterns. From the Law of superposition, we know that A must be older and D must be younger.

But then, this is the initial position. The second thing that can happen is the uplift above the sea level. And once it gets uplifted, then only it can get eroded if it is below the sea level, where no major agent is cutting down, and it is also below the level where any of these erosion is taking place. So, if the sediments are below the sea level, it is not going to get eroded.

So, in order to get eroded, things have to get exposed. And one way of exposing them is either by dropping the sea level or by uplifting the entire region. And there are plate tectonics processes which can uplift some of these places. And once it uplifted, the D is now exposed, and it can actually get eroded.

Because erosional agents are not operating at the same rate specially they can erode some of the paths faster compared to other paths. The original horizontality is not maintained often part of it gets eroded faster, and therefore, it will have a negative like a depression. And some of the paths are more resistant and hence it can have a positive impression, and then other paths are more flat.

So basically, because of this erosion, what do you have? You completely lost D, because D got eroded and probably part of C also. And the layer that you are ending up with is a layer C, where the record of D is gone, but the C has a very uneven contours. For uneven surface line, it is not the original horizontal strata that we started with. And what that means? That means we completely lost D.

Now, let us imagine that we also start getting another cycle of deposition, and that deposition can only happen if this entire block actually subsides under the sea, because then only the erosion will not take place. It is only going to be the position and deposition is creating another layer. We are calling that layer E. Now, exactly what is happening between let us say C and E? So, C was warmed long back, after that even D formed, deformed, then got eroded. And then again, E

started to deposit. So, the line between C and E, this particular line actually represents the deposition of D.

The erosion of D and then subsequent formation of E, so this disposition of D and the erosion of D is not recorded in the rock record. It is simply depicted by this line, which means this entire time that it took to form these things is not recorded. And that is why these layers, this particular boundary between C and E is representing an unconformity or a missing time. It can get even more complex where things can actually get folded. Once it folds, you can still have these layers. But, it is not maintaining or original horizontality, and therefore, you are seeing these kinds of patterns.

And once again, things changed where there is not much compression or deformation, and it goes under the sea. Again, some more layers started to form. And therefore, the change in terms of the depositional setting where it was complexly folded, unfolded, these were happening at a different time. And there must be a significant time difference, when it again comes back to the stage where it was depositing in a horizontal manner. So, this line also marks an unconformity. Now, depending on what kinds of layers we are seeing above and below, the unconformities can be classified even farther.

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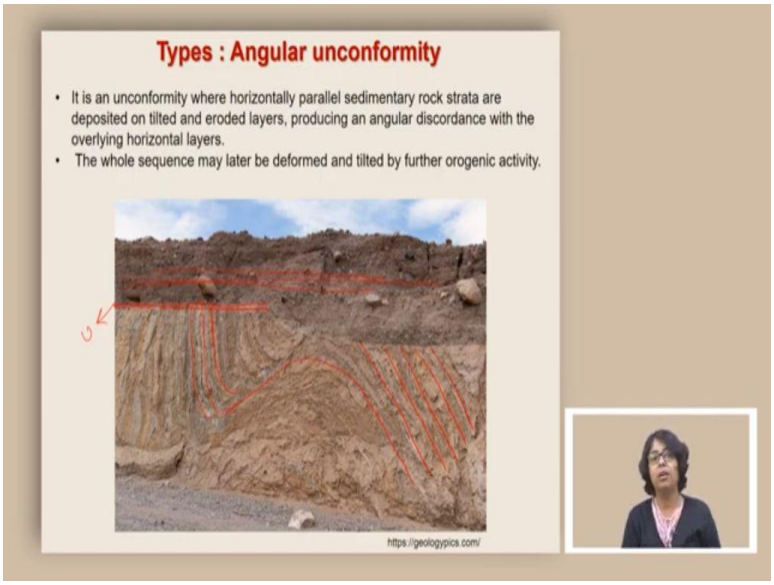

And angular unconformity is when the horizontally parallel sedimentary rocks strata are deposited on tilted and eroded layer. And they sort of result in an angular discordance and that is

why we call it an angular unconformity. So, if you look at this particular picture, you will see that the layers on the top, they are horizontally stratified. But, if you look at the layer just below this line, you are going to see that they are making folds, and the pattern of the folds are something like this.

So, these layers are making an angle, a very sharp angle with this overlying horizontal bed. So, this is clearly an unconformity, and this particular type of unconformity is called an angular unconformity. And it is, it can extend specially for a very very large area, where you can see this pattern. Now, if you recall the Siccar point. The Siccar point was also an example of an angular unconformity.

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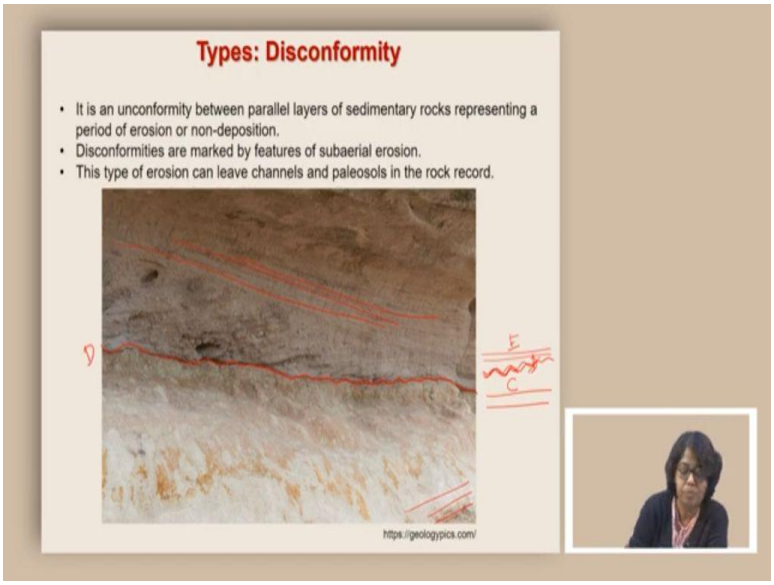

Another type of unconformity could be a disconformity. It is an unconformity between parallel layers of sedimentary rocks, representing a period of erosion or known deposition. Now, if you recall the development of the unconformity between E and C, you would have found that it was a time when the entire layer D got eroded. And because the erosional pattern took care of the entire D, but, part of C is also gone. And it is not a completely equally distributed erosion, some parts are eroded, more some parts are eroded less. And therefore, it is going to create a boundary between C and D, which is not perfectly horizontal.

It is not perfectly parallel to the layering above and layering below. And in this case, these kind of unconformities are called disconformity. So, now if you look at this picture, there is a layer

below and the layer has a pattern of deposition something like this. Now, if you look at the top, this layer also has a deposition or pattern which looks something like this. And between the two, there is this boundary, which is clearly a boundary which shows a gap in time, and it also shows an erosional mark, because there are some undulations. And these patterns are called the unconformity, which is created because of the erosional surface or a disconformity.

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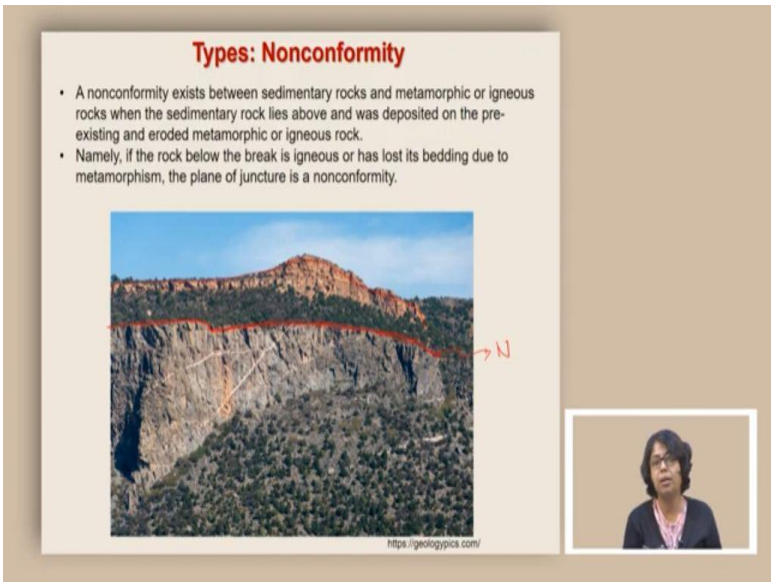

The last type of unconformity is called a nonconformity. Nonconformity exists between sedimentary rocks and metamorphic or igneous rocks. When the sedimentary rock lies above and was deposited on the preexisting or eroded metamorphic or igneous rocks. Why are we assuming that there is a time gap between the two? Because the conditions that are required for depositing the igneous rocks or to metamorphose the rock, it requires high temperature and often high-pressure condition. That is not where the sediments can deposit and form sedimentary rocks. So therefore, there must have been a substantial period between the two depositions.

And that is why the contact is called an unconformity, and in this particular case, it is called a nonconformity. So, let us take a look at this picture. So, this picture you can see that this part below of this part, it is a type of a metamorphic rock, and on top, there is this sedimentary rock. So, this part which binds or which demarcates the upper layer of this metamorphic rock, and the lower layer of the sedimentary rock is a type of unconformity, which is called nonconformity.

Now, these generally help us to understand the relationship between different rocks and how they are arranged in the field.

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And now if we go back to our previous observation, now we can understand that we see some of the layers of the rocks that are arranged in this fashion and if you look at the top rocks, it looks something like this. So, there is clearly a contact between these angular patterns and the pattern which is showing a horizontal deposition. And therefore, this boundary is an example of an angular unconformity.

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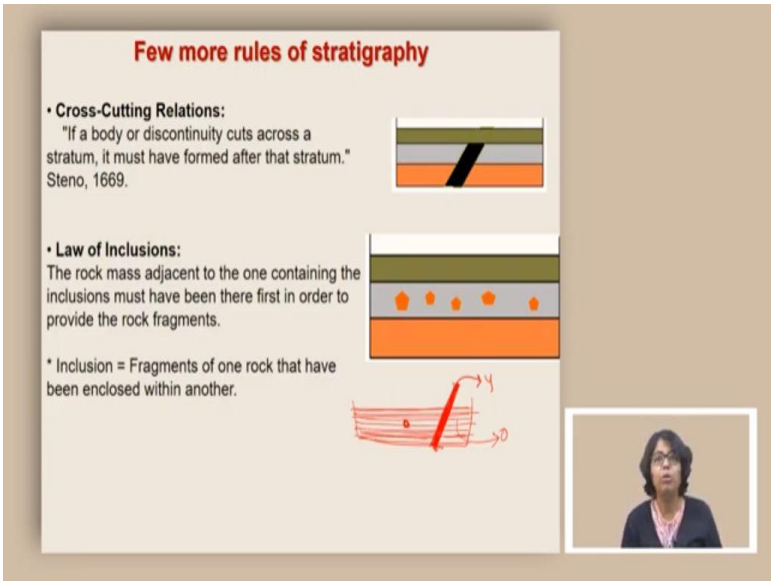

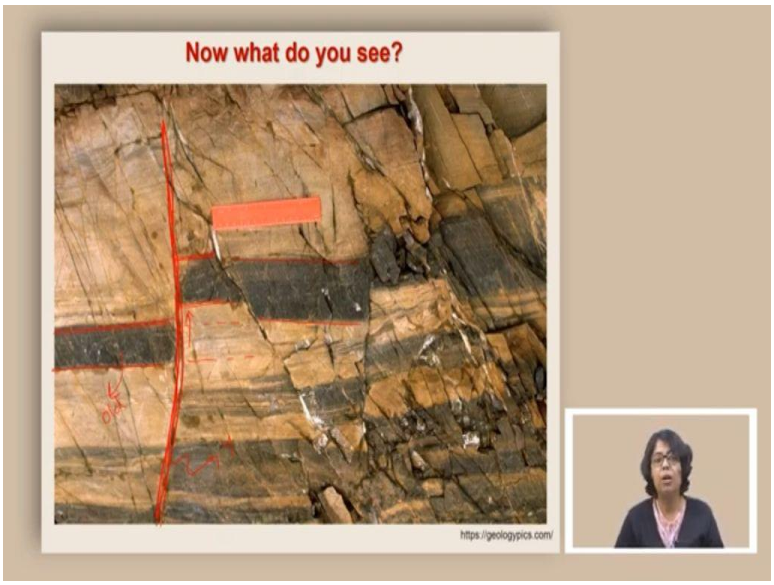

A few more rules of stratigraphy, it is called cross-cutting relationship. As we know that at the beginning, the relationship of the layers should be parallel, and they should be horizontal. If there is an abrupt break, that break must have formed after the deposition of the stratum. So, the way to imagine it is if you have a bucket or if you have a bowl, where you are pouring sediments and the sediments are creating these layers. There is no way you can disturb these layers from the beginning. And the only way you can disturb these layers is once the layers are formed.

So, let us say you put a part which cuts it in half. So, this part that you have put on must have come later than the deposition of these layers and then only you are going to cut it. And that is the whole idea of cross cutting relationship that the one that cross cuts it, must be younger than the events which produce these deposition.

The other idea is the law of inclusion, which means if you have this kind of formations, and within that, you find something like a piece of rock already formed rock which is not part of this. That rock fragment or that mineral or that fossil must have formed before the deposition of these sediments, because otherwise they could not be forming there.

So, that is the whole idea of law of inclusion. Now, we are going to look at the last picture and try to understand it. So, now we can see that these layers were the original layers, these layers we can see that there were some continuity, some horizontality to it, but it is not continuous. Now, they have shifted. So, with respect to this one, this one has shifted sort of up. So, what we can say? This part which cross cuts these layers, they have formed later.

So, initially it was actually a continuous layer, and because of this cross cut, they have moved to the layer up. So, this kind of cross cutting relationship must be younger compared to the deposition of the rock of this one. So, using these techniques, it is possible to figure out the rock record in terms of their relative ages.

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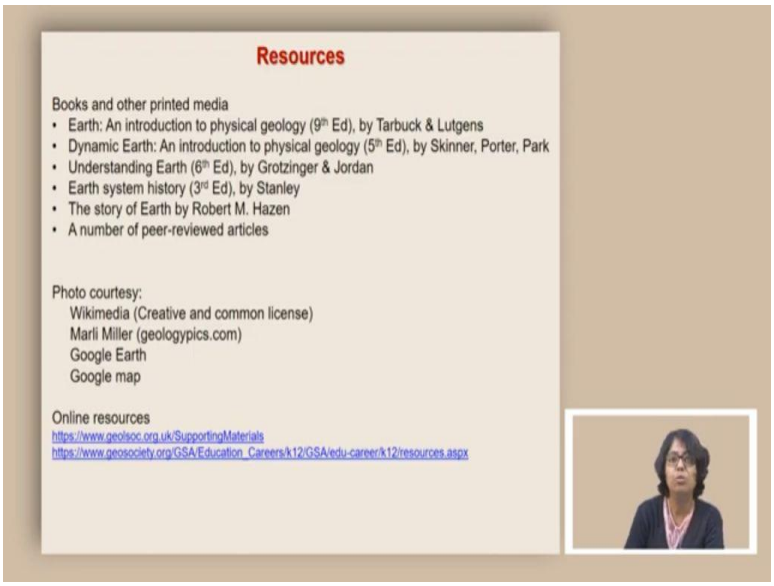

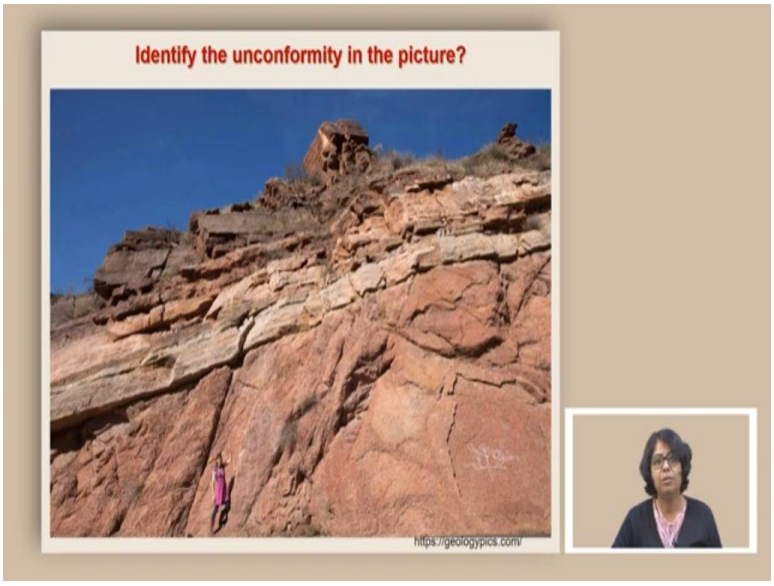

So, in summary, today we learned about the basic ideas of stratigraphy. What are the major rules of stratigraphy or laws of stratigraphy, including superposition, continuity and horizontality. We also understood how the unconformity is formed and what are the different types of unconformities one can expect in the field. We learned about the crosscutting relationships and

the rule of… We also learned about the cross-cutting relationship and the ages of the inclusions. Here are some of the resources that I used for making a slide and here is a question for you to think about. Thank you.