**Evolution of the Earth and Life**
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**Lecture 29**
**Correlation**

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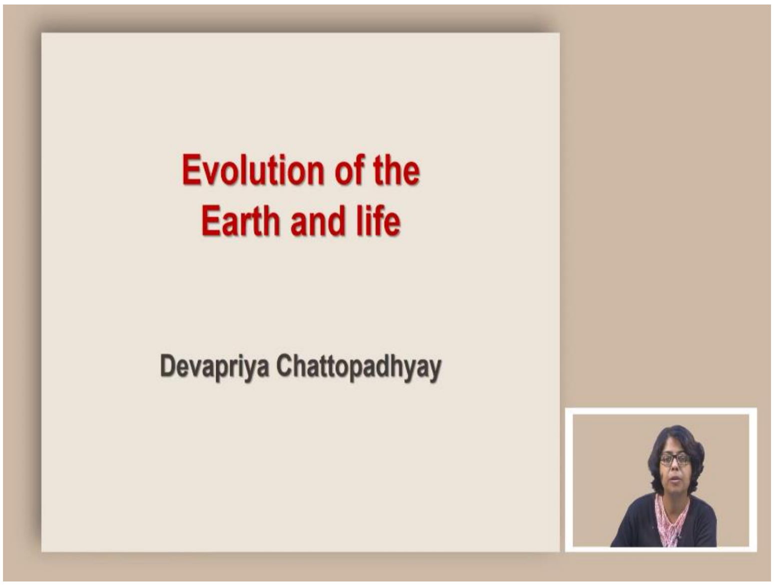


Welcome to the course Evolution of the Earth and Life. Today we are going to talk about correlation and geologic timescale.

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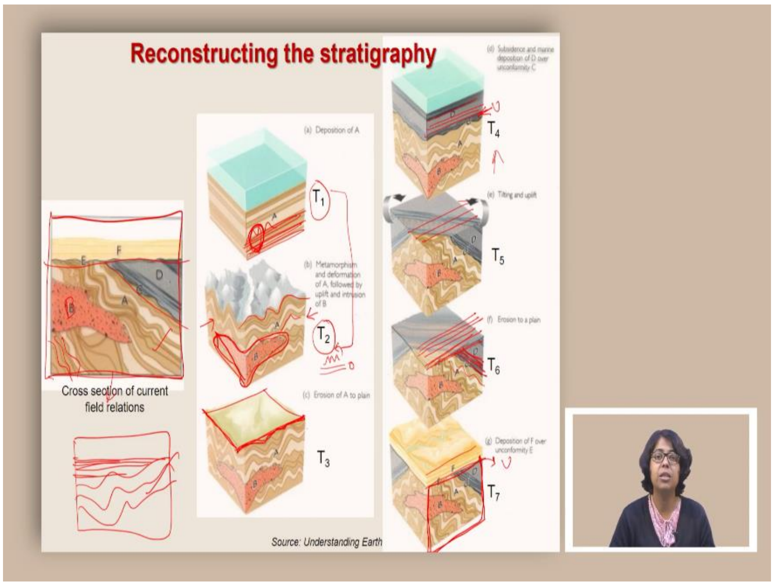


So, when we think about reconstructing the Stratigraphy, we understood that it has to start from the oldest strata. So, often the oldest strata forms by the deposition of the sediments in our horizontal fashion and creating these layers at a particular time, and let us call this time as

T1. Once it happens, then these sedimentary beds or sedimentary layers can go through different kinds of geologic processes, one such process could be a metamorphism and deformation.

So, this entire part of this rock can be complexly deformed, maybe by compression, it can also have intrusion of igneous activity, which is marked by B. Now, let us try to understand how it will affect the rock record and how would we relate it to time. So, this entire formation is happening at a time T2, which is younger than T1. We also learned that the moment we see A we would imagine that initially it was formed horizontally. So, horizontally, it was the initial state and then subsequent to it, the deformation happened.

So, if we have to age the events, we will say that the folding happened after the deposition of horizontal beds. And later, later to the folding, we have these intrusion of the igneous rock. Now, how do we know that this igneous rock is intruded after the folding, because if you look at it, we are going to use this cross cutting relationship that this intrusive actually cross cuts the folds. So, let us imagine a situation where the fold was not there.

It simply intruded in here, in that case, the subsequent folding will also fold this layer and you are going to see some evidence of folding or patterns of folding around this layer also, because we do not see that and we see that this intrusion actually cuts through the folding, that means the intrusion happened later than the folding itself. So, now up to this point, we can say that that the deposition was at the oldest time then the folding and then that in intrusion happened.

So, this is the sequence of timing and all of these are happening from T1 to T2. Now, let us look at T3 in T3. Let us imagine that this entire place is also getting eroded at the top maybe because it got exposed, got uplifted and that leads to erosion. And once it erodes, that means these folded parts are eroded and creates a layer which is kind of uneven. And now you have these folded patterns cut across and now if this goes down and have more deposition, then you can have again horizontal layers on top of this folded part.

So, there because you lost part of these sediments which were sticking up. This will basically indicate an unconformity in this particular type probably it could be an angular unconformity. Another thing that can happen after this is part of the layers got shifted or tilted or uplifted. So, tilting means that the entire thing is not going up as it is but it has an angle and if it has an angle so that means this part is going down and this part is coming up and there for the erosion that we are going to see are not going to be in the same plane. And therefore, this part is going to look something like this.

So, there was a deposition of D, but then you have tilted the block and removed this part. And in cross section, it will look these look at this folding. And then finally, deposition of this D. Now, the D clearly could not deposit at an angular fashion. So, that from this we can deduce that the D actually deposited in a horizontal fashion, but then got tilted and eroded. Finally, there can be another layer of deposition of F after an erosion, which we see here. And therefore, another layer which is F and in between we can have another unconformity.

When we see this entire thing in the cross section, that means we can go to a geologic field, and we can actually see all these rocks exposed. At the side, it often looks something like this, where we see these folded patterns, and then the layer of intrusive, and then there are all faulting's and there are unconformities. So, one way of looking at complex geologic history is to tease it apart and try to reconstruct the history back starting from the very horizontal, deposition of sediments. And that is what people do.

So, by now, if we look at a section like this, we can definitely understand within this section, which one is old and which one is young, but things get complicated, because we do not want to only decipher which one is old and which one is young only in this picture, but other pictures too, especially related to this picture. What do I mean by that? Let us imagine that we have a section like this in India. And we also have something of a similar section in China. And then we want to look at related to India, the section in China, how are they arranged.

So, if we have another section, where we also have layers and folding, and maybe some more depositional lines, we want to know this layer and this layer did they form around the same time, can we talk about these layers and these layers and compare them to D and talk about when they were forming. So, this gives us this question of correlation. The reason we are talking about correlation is because often the sections are not continuous, there can be subsequent geologic processes, which break things apart.

But still, we would like to know which layers are initially was continuous and which layers have the same age and therefore, we have to connect different sections which are not continuous and that is the whole coal of correlation. And in geology, correlation is one of the most important things when we are reconstructing stratigraphy.

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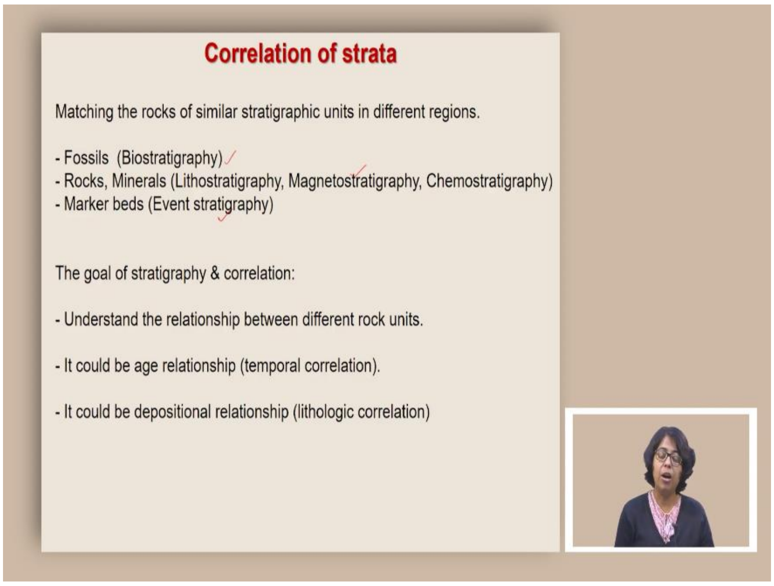


Correlation of strata basically means matching of the rocks have similar stratigraphic units in different regions. Now, it can be done through fossils, it can be done through rocks or minerals, it can also be done through very specific marker beds. So, we are going to talk about some examples of Biostratigraphy, Magnetostratigraphic and Event Stratigraphy, but there are different ways one can try to correlate between two strata which are not continuous.

The goal stratigraphy and correlation is to understand the relationship between different rock units, it could be age relationship, in terms of knowing which one is old and which one is young, when they are not connected. It could also be to understand the depositional relationship that means we want to know whether a particular environment particular depositional environment stayed in a particular place or not.

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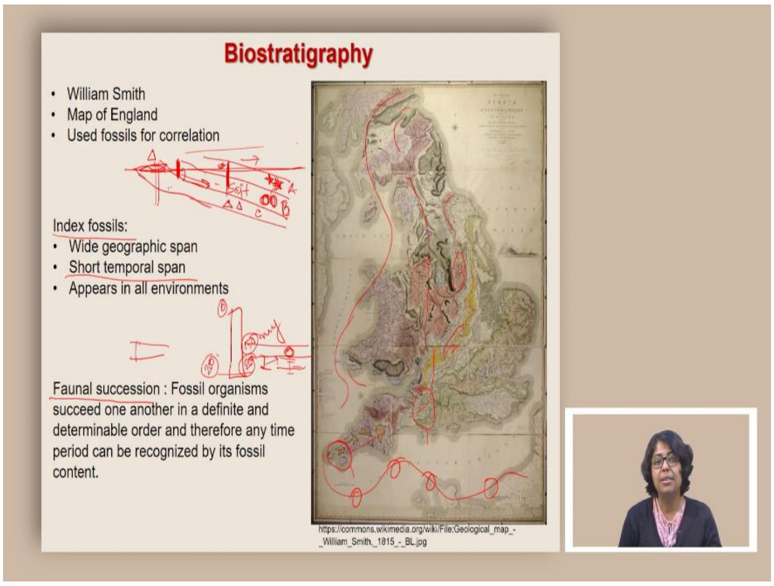


So we are going to talk about Biostratigraphy, Biostratigraphy means when the fossils are used to correlate strata fossils are the remnants of past organism or their activity. The first time somebody used it was William Smith, he was a British geologist. And he was the one who actually contributed to the first geologic map of England. It is often called as the map that revolutionized the world.

Now, what William Smith did, he started to look at the rocks and the associated fossils. And what he found that every rock has a very specific type of fossil assemblage to it. And if we track those rocks specially, often we find that we can predict how far do we have to dig to encounter particular strata, let us take an example. So, let us say we have these kinds of Strata. And we know through geologic processes, they can be tilted, they can be changing angles. And today's world is something like this. And there are parts of it, which is exposed, and parts of it, which is underneath.

When we look at the parts underneath, we really do not have any idea how far we have to go. And for William Smith, it was an important problem, because at that point of time, England was interested in digging tunnels for development of railways development of mining. So, every place had their own ways of digging a particular depth. Now, let us say there is a rock which is soft, and it makes much more sense to dig that rock and extend a tunnel, rather than going for very hard rocks. And what William Smith did was he observed some fossils in every Strata. And he could very well predict how the fossil assemblage is.

And once he knew that, he could see that if this particular rock is exposed here, this is the soft rock, they can dig only up to a point, and they will encounter this soft rock and then they can dig tunnels along this. But if the exposed rock shows this fossils, that means it does not matter how deep they dig, they are never going to encounter the soft rock. Because the soft rock is not there, it is actually above the soft rock.

On the other hand, if you are going in this direction, then encountering this fossil on the surface tells him that only if they dig a little bit, then they are going to encounter the soft rock. And these was very important information for the miners, because then they knew exactly how much depth they have to go. And this is the basic idea of creating a map, where just by pointing what is exposed, you are also giving information in terms of what is underneath.

So, initially, when this map the geologic map came about, it almost looked like a magic, because It is a map, which predicts not only what is on top, but Ii is also tells you that exactly what is underneath. So, in a geologic map, there is always the directions pointing of what is exposed, but also with some angle, it tells you that what are the Strata that are exposed at a particular angle. And if you know that angle, you can correctly predict what is underneath.

Things get a bit complicated if they are deformed if they have gone through multiple phases of erosion and conformities. But still, this was the first time someone used the indications the rock indications to predict correctly how far somebody has to go under to encounter a particular Strata. And this was so amazing because we could not really see what was underneath before digging. And this was the first map which tried to showcase that it is possible to predict the structure underneath the surface even without observe proving it, there is a nice relationship that you can follow, and you can predict what is underneath.

So, that was the time when William Smith came up with this idea of Faunal succession. Faunal succession argues that the fossil organisms succeed one another in a definite and determinable order. And therefore any time period can be recognized by its fossil content. So, just like as I said, that he observed that these, let us say the starfishes are always part of this rock called A, and these circular looking fossils are always part of this rock B. And this triangle looking fossil is always part of Part C. And because they have a predetermined order, it is easy to predict.

Now, the reason is, why do we expect to see such changes in the fossil? It is primarily because of the evolution. But there can be some overlaps too, and we will talk about it in a later part. But what kind of fossils do we really choose for these kinds of work? And William Smith, and farther other geologists also figured out that there must be some specific types of fossils, which are useful for this purpose, and they are called index fossils. Now, index fossils are fossils, which should have a very wide geographic span. Why is that important?

Let us imagine that some fossils are only found in this part of the world. If that is the case, then they cannot be correlated with paths which are here. But if there is a fossil, which is found here, here and all over the place, then those fossils can be marked, and let us say the Strata B can be extended all the way. And we will know every time that fossil appears, it is going to be the strata B, and we have a very good idea of the relative age.

The second important point is the short temporal span. Let us imagine a clock, which does not have a hourly division, it only has four divisions in our day, which will tell you either it is a morning, it is noon, it is evening. And it is night. That is not a very good clock compared to another clock, which has hourly division. So, what it tells you is whatever is your clock, it should have high resolution.

Now, imagine a fossil, that fossil, if it only has a very short duration during the entire time, that every time it appears, you can tell that, this is the small time where this fossil is found. And therefore, you can relate it to maybe a very small duration of time in terms of Strata. And then the next Strata contains another fossil, which also lives for a relatively short duration. If there is a fossil, which lived all the way maybe 200 million years ago, but still exist today.

Then, if you find a rock Strata, which has that fossil, you will be able to tell only that this rock Strata is anywhere between 0 to 200 million years, but not any further. But the example that I gave before, let us say there is a fossil which appears only between 200 million years ago, and 150 million years ago. That means every time you are encountering this fossil, you are going to tell that it is showing a particular type of rock, which formed between 200 million years ago and 150 million years ago.

Now, one more important thing to remember is when people identified index fossils or using the idea of Faunal succession, they really did not have any idea about the absolute. It is important to remember, however, that when William Smith and others were using the idea of

Faunal succession and correlating they had no idea about the absolute time. So, the examples that I gave 200 million years and 0 years versus 200 and 150 million years, they really did not know that.

But what they found was there are some fossils which are appearing in relatively smaller sections of the rock, smaller thicknesses of the rock. And then there are other fossils, which are found in different layers. And they decided that if there is a fossil, which is found in shorter interval, in only one layer of the Strata, they are more reliable than the fossils which appear in multiple layers through time.

The other important aspect about index fossils is that they should be appearing in different environment or large environment. So, if you know about a particular organism, which lives only in a small lake and never goes out of the lake, then it is not good for correlation because they are only going to be found in these small lakes. But let us imagine that there is an organism which lives in the ocean and the ocean is connected.

And that means every all oceanic sediments that are being deposited may have these animal remains in them, that is a much better way of correlating different types of rocks, which are forming in the ocean. So, generally, index fossils should have a wide geographic span, short temporal span and it should appear or it should have a large environmental tolerance, it should not be restricted to only small environments using that it is possible to start the correlation.

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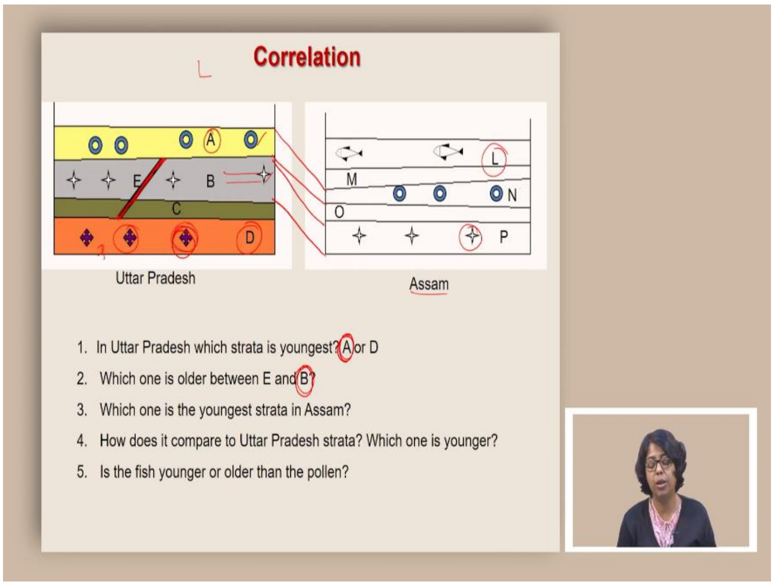

So, let us take a quick look at this hypothetical correlation pattern. So, let us say this we are looking at rocks Strata from Uttar Pradesh and another rocks radar from Assam and we are trying to correlate it. So, what we will also see that there are different layers A, B, C, D and E. And here It is L, M, N, O and P there are some fossils, some are doughnut shaped, some are star-shaped, some do not have it and some have these complicated star-shape.

So, what we can say at this point is we can start correlating it and try to answer the questions. So, the first question is in Uttar Pradesh which Strata is youngest? A or D. Now, as we know that the law of superposition tells us that these strata has to be younger than this strata, we will say that A must be younger than D. So, in this case, a is going to be the youngest. Now, the question is which one is older between E and B?

So, E is the cross-cutting relationship that we are saying and because cross cutting relationship happens after the formation of the strata, E has to be younger than the strata B. So, between E and B, B has to be older. Now, the question is which one is the youngest strata in Assam. So, again, we will use the same principle and say L is the youngest strata in Assam. Now, is the time to correlate how does it compare to Uttar Pradesh strata? Which one is younger?

So, now we have a strata called A which is younger in or youngest in Uttar Pradesh, and we have a strata L in Assam, which is the youngest in Assam. Now, how do they compare which one is older? Which one is younger? Or are they of the same age? Here, according to William Smith, if we connect the fossils, and especially those fossils, which are very specific to particular strata, that will help us to tell the relative age of discrete successions.

So, let us try to do that. So, we see these donuts shaped fossils present even in Assam in layer N. So, we can say that A is the same as layer N. And if we connect to that, that makes L as a younger strata compared to A. So, now if we have to compare A and L we are going to say that L is actually younger and A is older, So Assam strata at least the youngest strata of Assam is younger than the youngest strata of Uttar Pradesh.

It also tells us something about the age of the fossils to if we do this globally, it can also tell us which are the fossils, which are always appearing at the bottom and which are the fossils which are appearing at the top once we do all the correlation. So, in that case, we can actually say that let us say these are the pollens or even these can be considered as pollens, these pollens are always there in this strata and the fishes are only present in Assam, but we have seen that the fishes are present in layer L. And if we connect these strata to this one, we will see that P is actually younger than D. So, D is quite old, and these pollens are things which are quite old.

So, compared to these, and the fish, fish is younger. Using the same principle, you can connect completely discrete strata, which are which have some fossils. And what happens if there are strata which there which do not have fossils. For that we use different kinds of correlation techniques.

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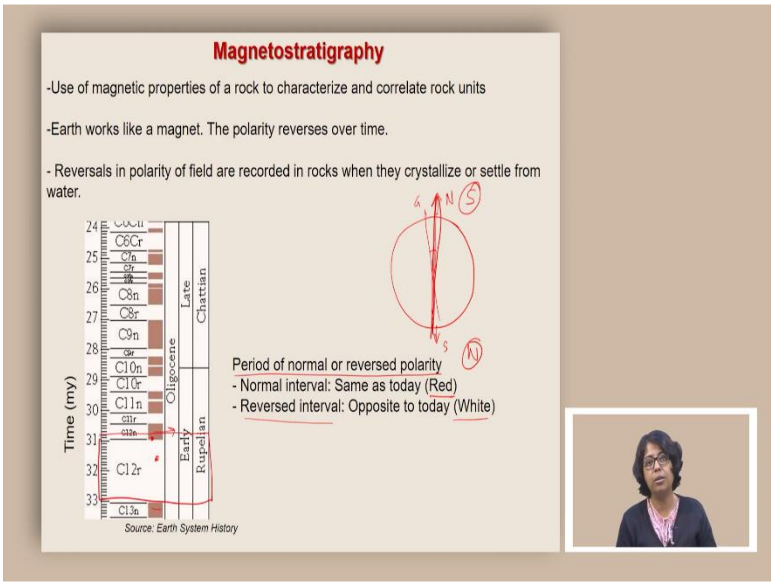


There is something called Magnetostratigraphy. So, it works on the principle that the earth works like a magnet, it polarity reverses once over time, and the magneto stratigraphy uses the magnetic properties of a rock to characterize and correlate the rock units. Now, sometimes, so if we think about today's Earth, we think the polarity is in the north, and this is the north and this is the south. And this also makes an angle with the magnetic north.

So, there is an angle between the magnetic north and the geographic north. But sometimes, in the past, this arrangement was not maintained, this North was actually south and the South was actually north. Now, if we decode those data are those Rock Records, it also adds to the chronology of the rock record.

So, the periods of normal or reverse polarity are indicated by we call something as normal polarity when it matches with the modern-day polarity of north of the top and south at the bottom of the globe. And reversed polarity is when It is the other way around. And then all the rocks can be characterized by this. And then we can find that there are times which are red, which basically means same as today.

But then there are some times which are white, which means they have reversed polarity. And using that it can even be found that how the rocks are and which one is connecting to the other. So if we have these kinds of patterns in another area, and if once you have figured out to a large extent, let us say up to this point, then you can figure out whether It is connecting to this part or this part. So, Magneto stratigraphy is also another valid method.

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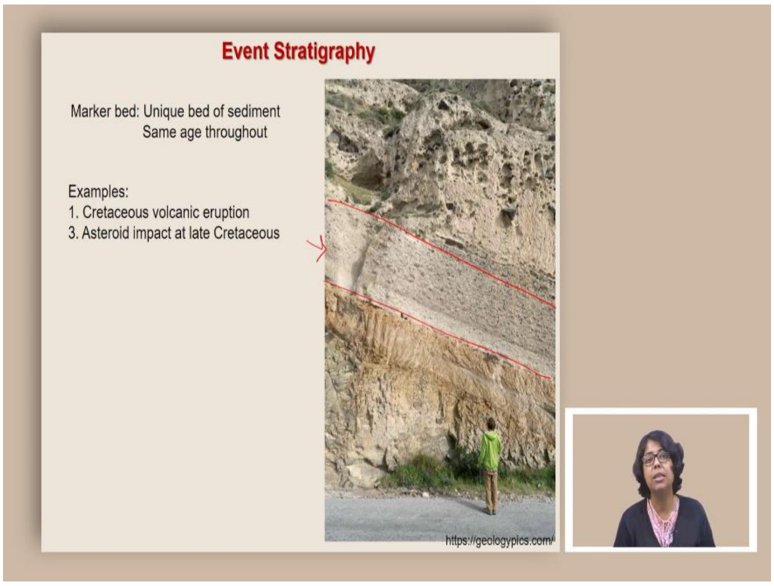


Another way of connecting different discrete points is by Event Stratigraphy. So this builds on the idea that there can be marker beds. These are unique bed of sediments, which cover a very large area, and therefore it the same age throughout what can be such geologic processes.

Let us say there is a volcanic eruption and there is an ash flow, ash because they are very fine in nature, they can be traveling with the air for a very large distance, and eventually when they fall out, it covers the entire globe in a relatively short time, geologically speaking. And that means this layer wherever you are finding is going to be of the same age and with respect to that the other parts of the layers can be figured out in terms of the age.

So, here is a picture where there is an ash bed, and this ash bed is fairly young. But let us say you find the continuity of these ash beds in other locations also, then It is possible to find those other locations and connect in terms of their relative age, keeping this as a marker bed, and this technique is called Event stratigraphy.

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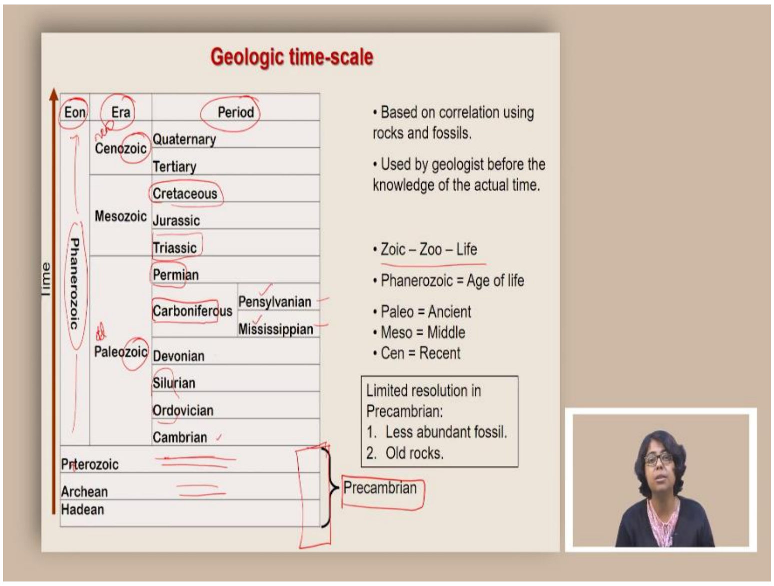


Using a combination of techniques such as these Events Stratigraphy, such as Magneto stratigraphy, such as the bio stratigraphy, and primarily the bio stratigraphy, people came up with Geologic time-scale. Geologic timescale is extremely important because this is going to be the vocabulary that we will use for the rest of the time. And these names are all has a story to tell. The structure of the Geologic time-scale is that it has been divided into major times, such as eons, then farther subdivisions era, and then smaller subdivisions called period. And once that is done, it has been subdivided even farther.

So, the first subdivision was Phanerozoic. Again, Zoo means life and zoic means a time with life Phanerozoic means It is the age of the life. The reason behind it is when people first understood the Phanerozoic they realize that this is the time above which or during which we find a lot of fossils, and below which we do not really find a lot of fossils, things have changed now, but because of this, the part below this used to be called Precambrian and above it used to be called Phanerozoic.

Now, it has been further subdivided. the Precambrian has been subdivided into Proterozoic, Archean, and Hadean. So, Hadean is the oldest Archean followed by Proterozoic, all making Precambrian. And then later, we find Phanerozoic. Within Phanerozoic, it can be divided into three era. Life which is old, life which is new, and life which is middle. So Palaeozoic, Mesozoic, and Cenozoic. Each of these types are further subdivided in terms of their characters, and therefore, they have been given different names.

These names are coming from some connection to where the rocks were found Cambrian comes from the old British Isle Cambrian, so that is where the rocks were exposed. Ordo, Silur. These are names of some of the original tribes from where these names came from. Devonian comes from Devonshire, where majority of these rocks are exposed. Carboniferous, has the name indicating a very high amount of carbon or coal. This is the time where the coal deposits are coming from. And this has been further subdivided based on two states of United States of America, Mississippi and Pennsylvania.

These are the places where many of these carboniferous rocks are exposed and they have different characters, and they have been arranged sequentially in terms of time. Permian comes from the name farm province, Triassic part of this Mesozoic comes from the idea that it has a three-part division and hence a triac division. Jurassic comes from the Jura mountains, and Cretaceous is primarily from the idea of chalk deposit.

So, this is the main structure of the geologic time-scale. It is important to recognize that when people first started developing this geologic timescale, they were because they were using only fossils, they could not subdivide. the Precambrian and Precambrian subdivision came later. Now, with the help of absolute time. We also subdivided it even further, but the time the expense of the time or the extend the time is really large for Precambrian, but it has not been resolved to very smaller or finer divisions because of lack of fossils.

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So, in summary, today, we learned about how we can look at correlation what are the different techniques of correlation? How can we connect rocks, which are not continuous using fossils using Magneto stratigraphy or using event beds? We also learned about the geologic time-scale and how the different names came about. And this geologic time-scale would be a very important factor for the entire course, because we will be using it again and again, to describe different events that took place at different parts of the time. Here are some of the resources that I used to make the slides.

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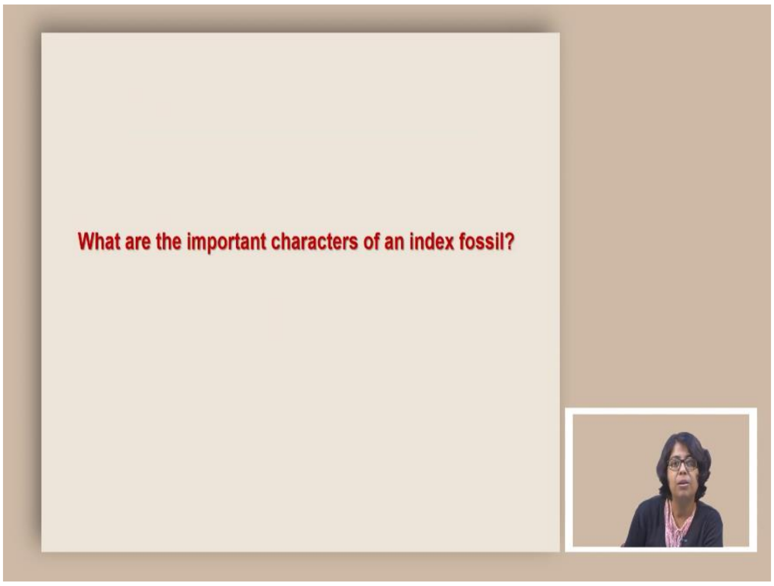


Here is a question for you to think about. Thank you.