Evolution of the Earth and Life
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Continental Drift

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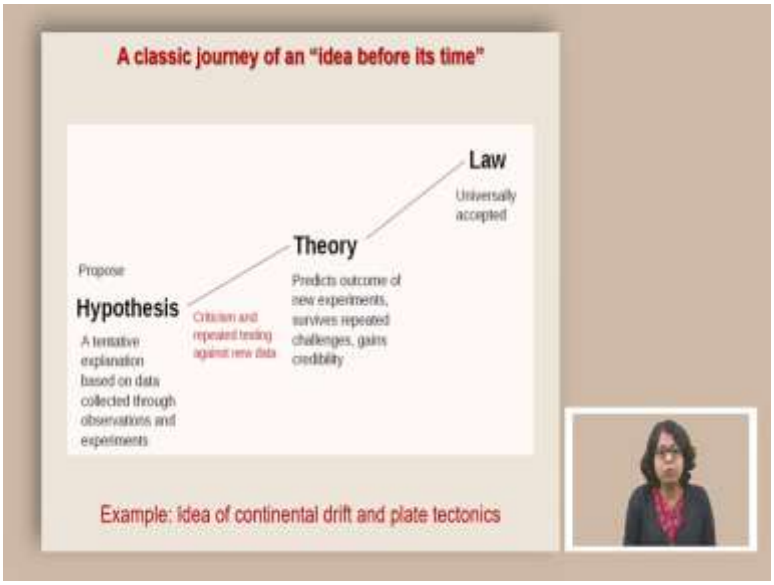

Welcome to the course of Evolution of the Earth and Life. Today, we are going to talk about continental drift, as we know that any idea in Earth science progresses through validation from observation and the path of this idea of continental drift and eventually plate tectonics also went through these layers of validation and testing. And it is an interesting journey of an idea before its time.

So, the framework suggests that any idea will start as a tentative explanation based on the data collected through observations and experiments. And that is what we call hypothesis, now hypothesis once framed it will go through rounds of criticism repeated testing of this idea and often incorporating theoretical results as well as experimental results.

Once all of these suggest this hypothesis to be correct then it progresses to become what is known as a theory. It is something which predicts the outcome of new experiments survives repeated challenges and it also gains credibility, for Earth Sciences, it is something which is predicting the new observations and it is getting validated by new observation. And from theory, once it is universally accepted in different situations then it progresses to become a law. The idea of Continental Drift actually started something of the sort where initially it was just a hypothesis.

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So, the idea that continents change their position with time is not really a new one. There are people as early in 1596 who observed that the coastlines of different continents are somewhat matching, the particular observation came from the continental margin of South America and Africa. So, somewhere around here and this margin. And a Dutch map maker Abraham Ortelius proposed that Americas were torn away from Europe and Africa and he said it in 1596.

He was the first one to write it down but at the same time he was not the last one, there were a number of researchers from different fields of geography, biology, who also noted that the shapes of the continents on opposite side of Atlantic Ocean specifically Africa and South America seem to fit together. And that gave rise to this idea that probably the continents are not fixed in their position, they change their position through time.

However, especially after 1596 the first time it was written in a scientific journal with a very clear claim came in around 1912 by a German meteorologist Alfred L Wagner, who proposed that the continents actually are drifting. Now he came up with this idea from various observations, we will go into that but his basic idea was that the continents are drifting and if we go back in time there would be a time when all the continents were together.

And he called this a large continent which were together making a large mass a supercontinent and he gave the name as Pangaea. He first gave a slightly different name but Pangaea was something that survived and that was the published proposal that there existed a supercontinent

long back in time and that is Pangaea and based on other evidences he also said that it began to break in Mesozoic.

So, that means we are talking about a time window between 251 million years to 66 million years, this is the time window of Mesozoic and he said that this is the time when this large mass started to break down and all the parts of this large mass after the breaking drifted away from each other and because they drifted away from each other they still retain the place where they initially broke from and hence they match the boundary.

And the present position of the land mass that we see today is basically a result of the fragmentation from the original large landmass and eventual drifting. He came up with this idea and he wrote this idea and he published a paper in 1912. And what were the sort of evidences that he gathered in support of this, one idea was very simple and which was I mean that claim was made even before as we saw by the Dutch map maker that the boundaries of South America and Africa is sort of matching and it if you rotate it somewhat it actually creates a single part of the land, so, that is one of them.

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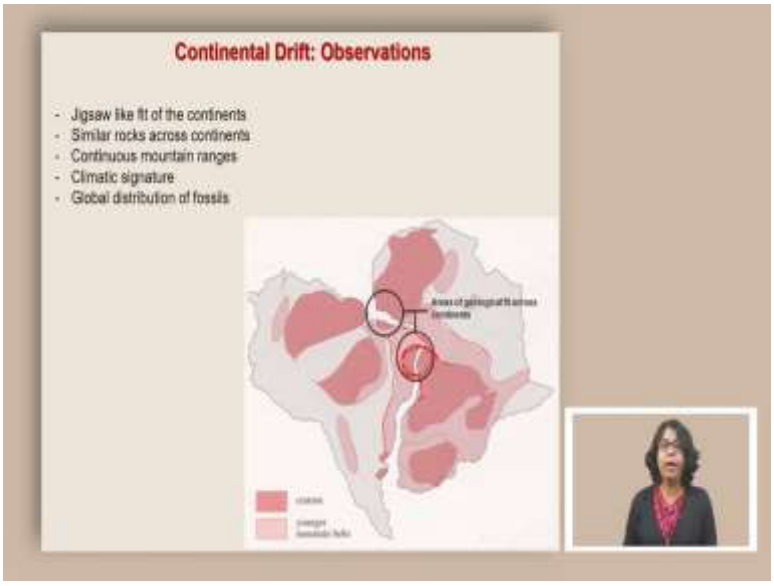

But he also started collecting evidences from other parts of the field of largely called Earth Science. Now he was a meteorologist. So, that means he studied climate and weather and therefore his expertise in geology was somewhat really limited but he contacted a number of geologists and he started probing into the rock record, the fossil record and other kinds of paleo

environmental record. And using all of these things he started to claim that the continents were together.

So, let us see what were the evidences that he was proposing, the first one as we saw was the jigsaw like fit of the continents. So, let us Focus primarily on South America and Africa because it is one of the closest fits but it is not just a mere fit it is also the rock types that we find across Atlantic. So, for example if you look at these two parts we find that there are similar rocks that we find in South America and in Africa. And it seemed to have a continuous boundary and these rocks are called cratons these are some of the most stable very old Continental Rock record.

And it is hard to explain, how you would find similar rocks across the big Atlantic forming with same kind of structures. So, when we say that these are the same type of rock, it is not only that they are a composition are the same it is how they are oriented that is what we are we call structure or how they formed how they basically arranged in the field they also show some sort of a continuity and that is one of the very perplexing fact of these rock distribution.

The second one is the note the old rocks but relatively younger mountain belts. And what he found that, after Consulting the geologists that the mountain belts that we find in the eastern part of South America seems to have a continuity in Africa but in the western part of Africa making them somewhat of a continuous pattern. And these are quite perplexing again as I said that they tend to share similar arrangement of how rocks are oriented and how they are placed in the field. So, it seems like that they formed together and then torn apart.

Now, people started giving other explanations such as that they formed independently probably it is just by chance because of which we are finding such similarities but it is not completely convincing because of the scale because of the really high continuity in terms of rock types, rock orientation, and also in terms of their age. Now there was another thing that he was quite certain about and that is the climatic signature. So, let us take a look at the climatic signature.

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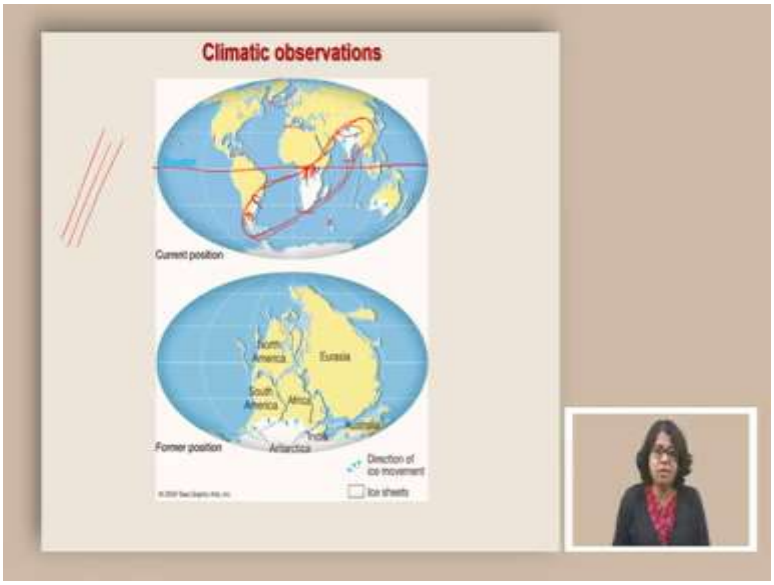

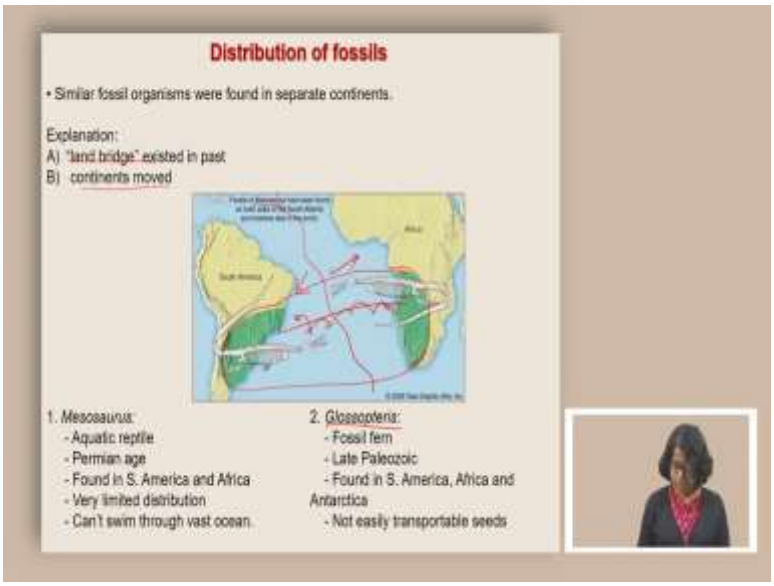

So, we are going to look at the modern day distribution of the continents. So, these are the current position and as we know that South America falls somewhere here. We can also look at Africa which falls somewhere here and if you look at India, it falls very close to the equator and Australia again somewhere close to the equator, if we are looking at the northern part.

Now this is the equatorial line and what it means that things around it are going to be generally warm and the climate that we can expect around it is going to be warm climate. Would you expect to find signatures of glaciers around these places? Well, the answer is yes, it can happen

simply if you have very high altitude if you have very high mountains you can have glaciers. I mean we can give an example of glaciers that we find in let us say Himalayas today.

But it is very hard to explain, how you can find really large scale glaciers all around these places which are tropical in nature. Now the question is how do we know that there were glaciers? Well, when the glaciers move they carry a lot of large rocks and as they are carrying large rocks those rocks grind the bedrock and therefore they leave some marks on the bedrock, using those marks it is possible to tell how big the glacier was, which direction it was moving, and from which central direction it was moving in what other directions.

If you put together all of these things, it basically shows that there were glacial rocks almost of the same time which are found in South America, in Africa, in India, in Australia, and they are showing somewhat of single diverging pattern, which means it is if you look at all the arrows of how the ice was flowing which direction the ice was going, it is going to show you as if they are separate, they are moving from a central point and in different directions, that is a typical signature of continental glacial movement, something that we find in let us say Antarctica.

Note for altitudinal glacier which simply goes down and moves in all kinds of different direction controlled by the topography of a specific spot. And when Wegener started looking at these paleoclimatic evidence, it was quite clear that probably these groups actually were not tropical these continents were not tropical throughout their history. Probably, there was a time when they were close to the polar region where you can expect to find large-scale continental glacier, another proof or supporting evidence came from a unlikely place. So, he was as part of his meteorological expeditions he was also looking at arctic.

And there were isolated Islands or in the Arctic where he was finding some of the rock records, which carried fossils and some of these fossils were plants. And some of the plants looked exactly like a tropical plant leaf. And it was very surprising, that how in these extremely cold polar climates you can have plants that resemble the tropical palm leaves or tropical plants and the fossils or the remnant of past life tells you something how the biology was, how the ecosystem was far back in time. And when he found those evidences he was convinced that probably these continents were not, where we find them today.

And therefore the climate that they experienced in the long past was different which can support a tropical life than what we see today. Now the moment he started looking into fossils, he realized that it requires more expertise in the study of fossils what we know as paleontology. So, he started contacting paleontologists too. And when he started interacting with the paleontologists he found that there are more evidences. One such evidence is that a small reptile mesosaurus they are found from South America and they are also found from Africa.

Now what was so great about mesosaurus, we are talking about reptile it could be so that they basically crossed the ocean, but it is not so, because all the times all the fossil record that we found of mesosaurus they are always associated with aquatic places, what we mean by that, they are fresh water habitats, they are from lakes and rivers and the groups which live in lakes and rivers they are adapted to fresh water. They cannot survive in salt water their bodies are not adapted to survive in salt water.

Now imagine this very small reptile crossing such a vast ocean of Atlantic to go to Africa and then spread its population there and thereby preserving their fossil is very unlikely, a better explanation would be that they were on the continental landmass when these two landmasses were together and they basically survived and eventually these landmasses split and moved in different direction carrying with them the remnants of these mesosaurus.

However, because it was so unusual at this point to think of continents moving people started coming up with other explanations such as a land bridge, what it argues is, there were land connection between them but not as a continent but probably smaller Islands which these organisms can hop and eventually go to these places again relatively complicated explanation and we do not really have a direct proof of these land bridge.

And second point is even with a some sort of a land bridge or island hopping, an animal has to survive prolonged period in the sea water, but because mesosaurus were known to be aquatic some people argued maybe they could swim a bit, but again from the Modern Biology we know that it is very unlikely that a group which is adapted to fresh water habitat to survive prolonged exposure in the ocean. So, that is one of the supporting evidences of Continental Drift.

The second evidence that he found or that he came across was a fern, its name is glossopteris and it is a fossil fern. It is found in South America, Africa, as well as Antarctica and it does not have

easily transportable seeds and then it becomes very difficult to explain, how you can get those same patterns of life in South America and Africa where the seeds cannot be transported, which are far away separated today.

Around the same time some people argued that probably, they arose independently and that is something that we know today that it is very very unlikely that two species of or I would say two populations with the same genetic composition that is what we call a species arose independently of each other. It is very unlikely, it is as unlikely as to find two non-identical twins to have the same genetic makeup.

So, we can reject this hypothesis saying that it is not possible to have two communities developing in without any connection between them to have the same species composition. Today, we know even more evidences which support that at some point they were linked together from the fossils.

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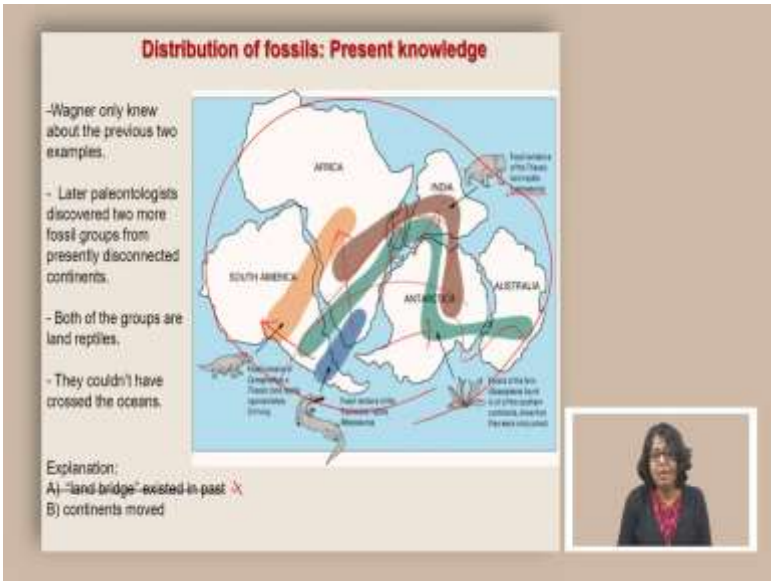

So, Wegener only knew about these two examples, but today we know two more land groups. So, for example there is a large land reptile called Lystrosaurus, which is found from Antarctica, from India, from Madagascar, from Africa. And this Lystrosaurus is not aquatic. So, it is not possible for it to basically cross all of these oceans that we find today.

And eventually land in different land masses, it is not also possible for it to Island hop or to go through land bridges and therefore it is the only suitable explanation would be that at some point

of time these continents were together, not only Lystrosaurus, we have another type of land reptile which is known as Cynognathus again that is found between South America, and Africa, there are other types of fossils also that are constantly emerging which is showing similarity between all of these land masses.

So, all of these things clearly shows that land bridge explanation does not work to show to explain these distribution of fossils. And therefore the only remaining explanation is that continents moved, there was a time when all of these continents were together that also explains why some of these continents are actually showing glacial signature, if this entire position of this entire continent was somewhat towards the pole then you can expect to have somewhat glacial atmosphere even in distinct places, which are now tropical.

And after the fragmentation, they moved in different direction, where we find them today. Even with all the supporting evidences, it this idea was not accepted. around 1930s it was completely rejected.

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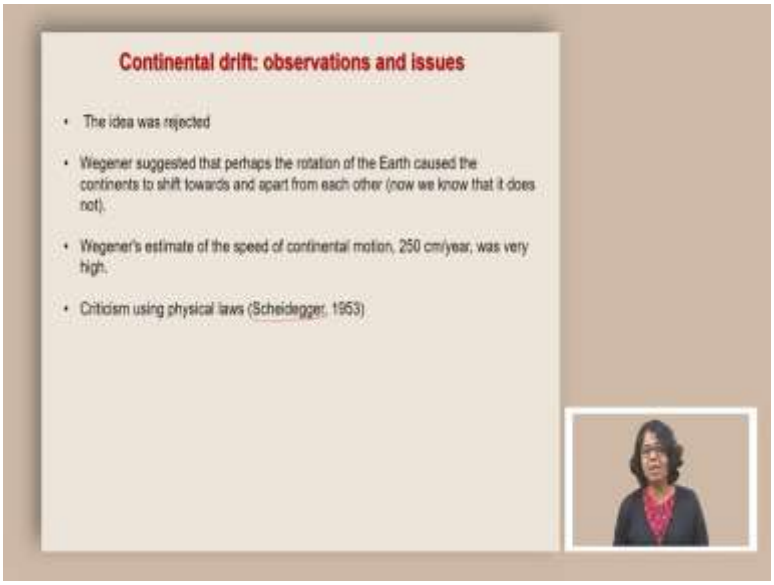

So, this is the evolution of an idea. So, it was a hypothesis but it was shot down, it was rejected because there was no suitable mechanism. So, Wegener primarily proposed that he found these observations, he found these evidences which all support the movement of the continent, but when he was asked how these continents would move he was not very clear about it, in fact one

of his suggestion was that the rotation of the earth caused the continents to shift towards and apart from each other but now we know that it cannot be true.

There has to be some other mechanism because the rotation of the earth cannot push these continents in different direction, if that is the case then we will expect to find only one such thing and also the force is not enough to move the continent. Second important aspect of it, is Wegener proposed that the estimated speed of the continental motion is 250 centimeters per year which is extremely high. And if that is the case then you can actually observe within human time scale how continents were moving.

But now we know that this rate is not correct, in fact the rate is much much lower, it is probably 2.5 centimeters per year instead of 250 centimeters per year and therefore we do not really see the continents move in our time scale unless we have very precise measurements. So, because Wegener's first idea of mechanism was completely flawed. And second what he estimated about the speed was absolutely incorrect and therefore could not be observed most of the scientific community, they thought that this idea is not correct and then they rejected this idea. In fact, it got these rejections from multiple sources.

So, one of the major criticism and the latest criticism came in 1953 where it was criticized based on physical laws where it was said that if Wegener's idea is correct or continents are drifting then it basically contradicts physical laws again going back to Wegener's initial idea that it is happening because of the rotation of the earth. And the physicists proposed, that if it is because of the rotation of the earth you will basically make all the continents come together and maybe form a large continent but that is not always the case we are also talking about fragmentation.

So, it really did not get supported, the second point was how would you push these large land masses. So, the idea of this is also in on, I mean without the understanding of how these continents are made of and what is beneath the continents, how thick the continents are, and what is inside below the crust and how crust and mantle interacts it is not really possible to explain the mechanism.

So, without a suitable mechanism even with all these convincing evidences supporting the continental drift it was rejected and this is how a hypothesis evolves first hypothesis was given it got some support from the evidences of observation but there was no mechanism which can

stand the test of the observations and hence it was rejected and we will see how it evolves after this.

So, during 1930s when Wegener passed away he did not see the acceptance of his idea it was rejected it was still among those ideas which just survived as an idea but then scientific community did not take it seriously.

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In summary, today we learned what is the idea of Continental Drift and how Wegener put together different sources of evidence that support the idea of Continental Drift. We also learned even with all the supporting evidences from paleoclimate reconstruction, from paleontology,

fossil studies, from distribution of rocks and mountains, it is not accepted as an idea because the mechanism was not clear.

So, all these observation supported the idea that continents are not fixed in one position probably they all were connected together forming a large continent and afterwards fragmented and drifted apart, this idea was not accepted, this hypothesis was not accepted, simply because it did not have a valid mechanism, that can explain how large pieces of land mass such as continents can move over vast expanse of the ocean as they observed at that point of time. Here are some of the resources that I used for this lecture. Here is a question that I would request you to think about. Thank you.