Conservation Geography
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Module - 2
The Earth
Lecture - 6
Features on the Earth

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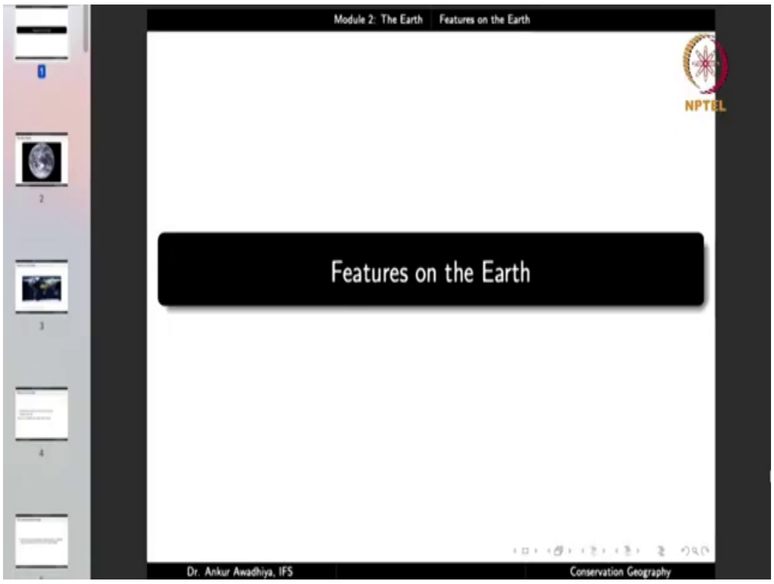

Namaste! We carry forward our discussion on the Earth. And in this lecture, we shall have a look at the features on the Earth. Specifically, where the continents and oceans lie. And where do they exist in the locations where they do exist.

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So, if we have a look at our planet from the space, this is how it will look like. This image is known as the blue marble. And it shows that the Earth is a spherical body that is primarily blue because it has lots and lots of water. So, essentially, all of these are the oceans here we can observe the continent of Africa. And a major chunk of the Earth is comprised of waters, this blue is water, and these white patches are the clouds.

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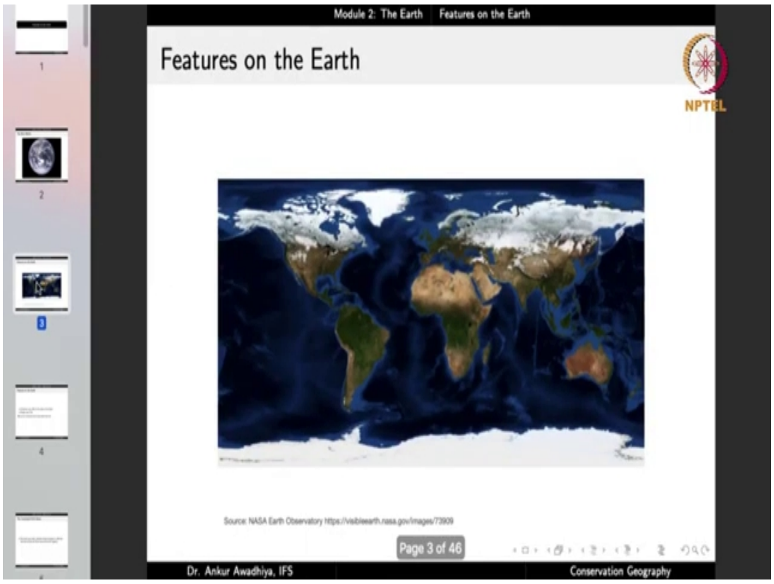

Now, if we made a map of the Earth, this is how it will look like. So here we can observe the different continents. So, we have North America, South America, Africa, Europe, Asia, Australia, and Antarctica. And between these continents, we have all these blue things which are water bodies, we have the oceans, and we have the seas.

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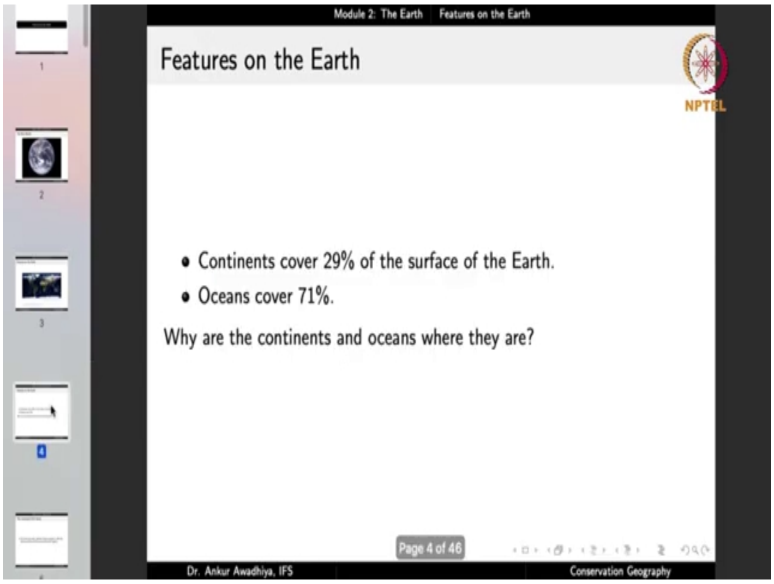

In fact, continents cover only 29 percent of the Earth's surface. Whereas oceans cover 71 percent. That is the majority of the Earth is covered by the oceans, and only a small fraction around one-third or less than one-third is covered by the continents. Now the question is, why are the continents and oceans where they are? And did they always exist in the locations where they exist now?

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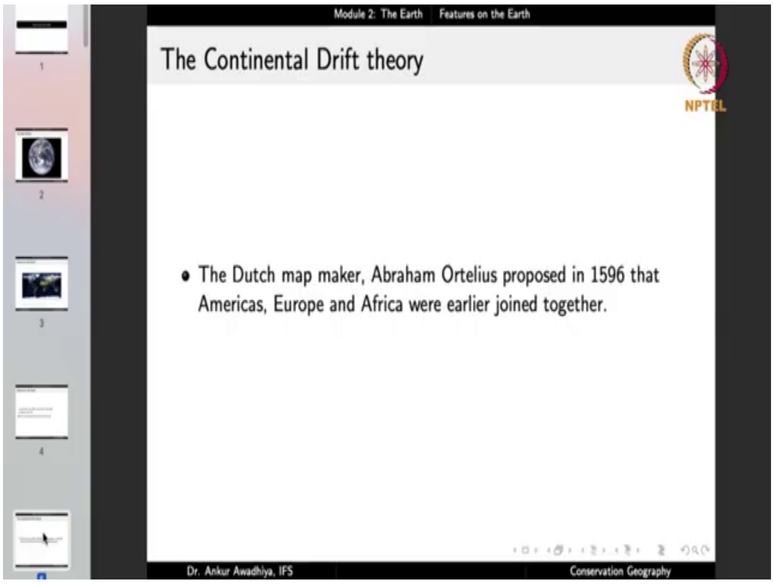

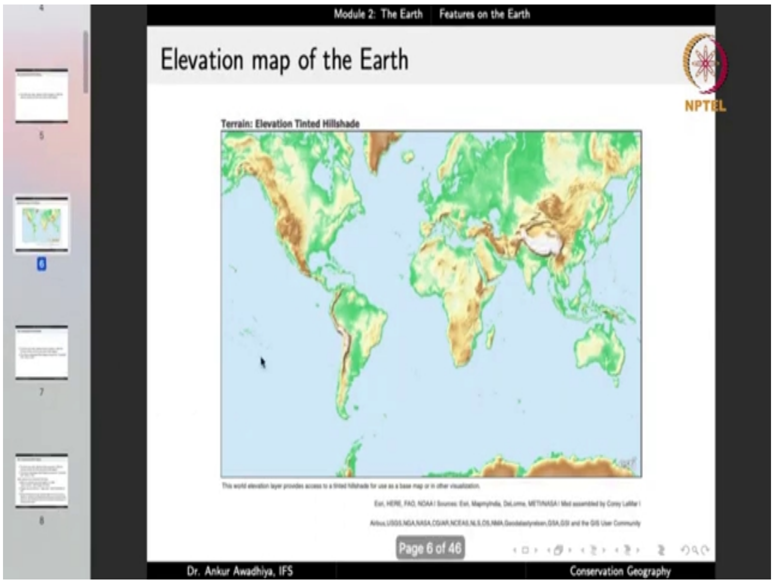

Now, in this context, the Dutch mapmaker, Abraham Ortelius, proposed in 1596, that Americas, Europe, and Africa were earlier joined together. Now, when he was making the map, he had a hunch that if we look at the East portion of South America, and the West portion of Africa, it looks like we can move this part and it will fit there.

Similarly, the portions in North America, they very well match some locations in Europe. So, he had this hunch that probably some time back in history, the Americas, Europe, and Africa, were all joined together, but he did not have a way to prove this.

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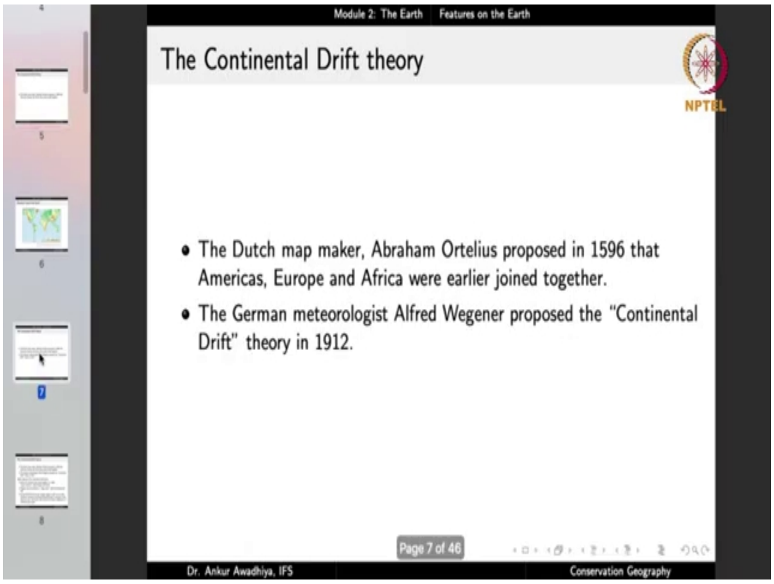

Later on in the year 1912, the German meteorologist Alfred Wegener proposed the continental drift theory.

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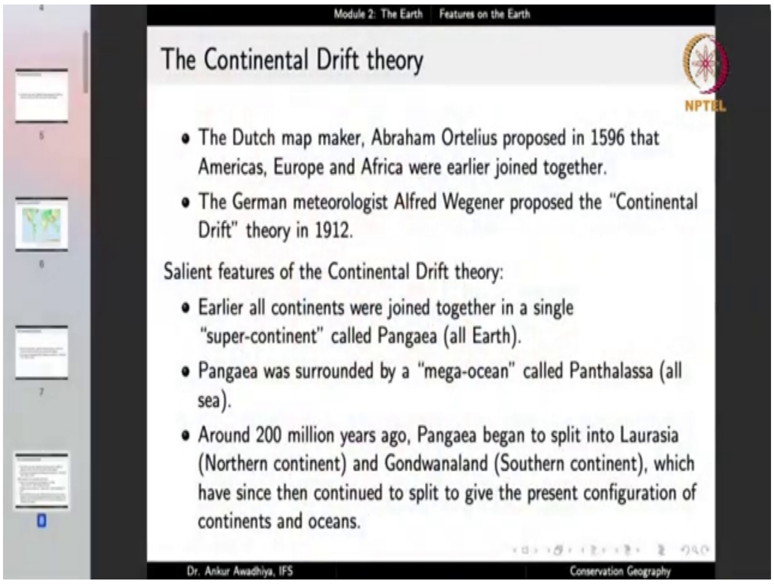

Now, the continental drift theory states that the continents move. So, Wegener built upon the earlier ideas, and he proposed that the continents can move and in fact, they have been moving and they have been moving in such a way that earlier all the continents are joined together. Later on, they broke and they are still moving and slowly and steadily they are taking up new locations.

So, he proposed that earlier all the continents were joined together in a single supercontinent called Pangaea. Now, pan means all, gaea is Earth, so Pangaea is all Earth. So, all the land masses were joined together in this super continent, which he called Pangaea. And the Pangaea was surrounded by a mega ocean called Panthalassa. Now, pan is all, thalassa is sea. So, it is all seas together. They are the Panthalassa.

So, he proposed that some time back in antiquity, all the continents were joined together, all the oceans were joined together, and then, later on, the continents broke apart. So, he proposed that around 200 million years ago, the Pangaea began to split. And when it split, it split into two parts. The northern part of the Northern continent was called Laurasia. And the southern continent was called Gondwanaland. And they have since continued to split to give the present configuration of the continents and oceans.

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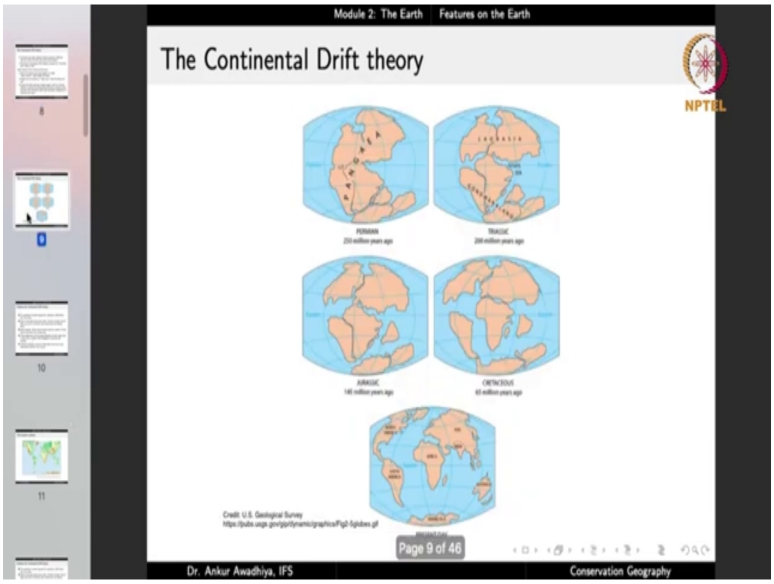

So, essentially, this is what Wegener proposed that a long time back, we have Pangaea, all the continents that are joined together. And here you can make out that we have the South America, we have Africa, we have North America, we have Europe, and so on. And then, later on, there was a split and it in the Triassic era, around 200 million years ago, it divided into two parts.

So, we have Laurasia, which is the northern continent, and Gondwanaland, which is the southern continent. Then in the Jurassic period, 145 million years ago, these carried on their movements, then the movement carries on in the Cretaceous period also, so Cretaceous 65 million years ago is the time when the dinosaurs became extinct. So, at that time, as well, the continents were moving, and this is the present configuration.

So, here you going to observe that India was moving, and this portion was called Tethysi, so India, it was moving, moving, moving, and then it collided with Eurasia, and now it is a part of Asia. So, this is what he had proposed. But how did he come to such a theory? He needed certain evidences, how do you prove that once upon a time, all of these things were joined together and later on they moved away from each other, they split, how do you prove that? So, he put forward a number of evidences.

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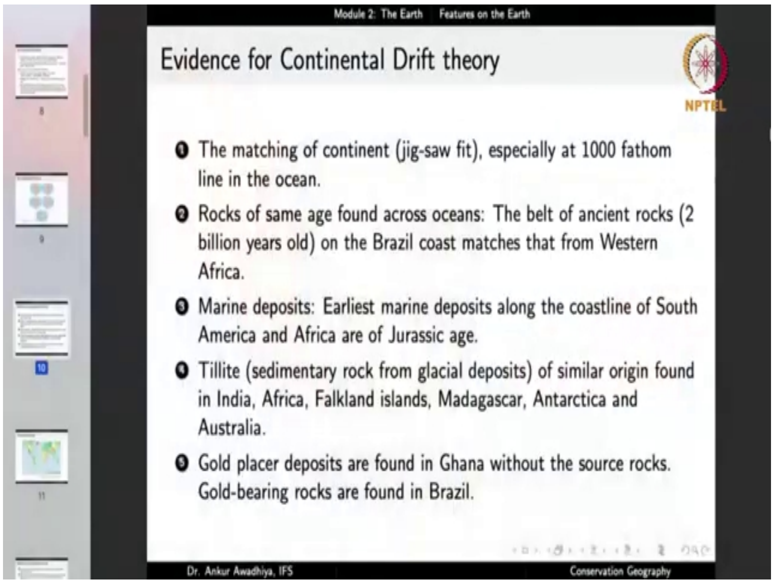

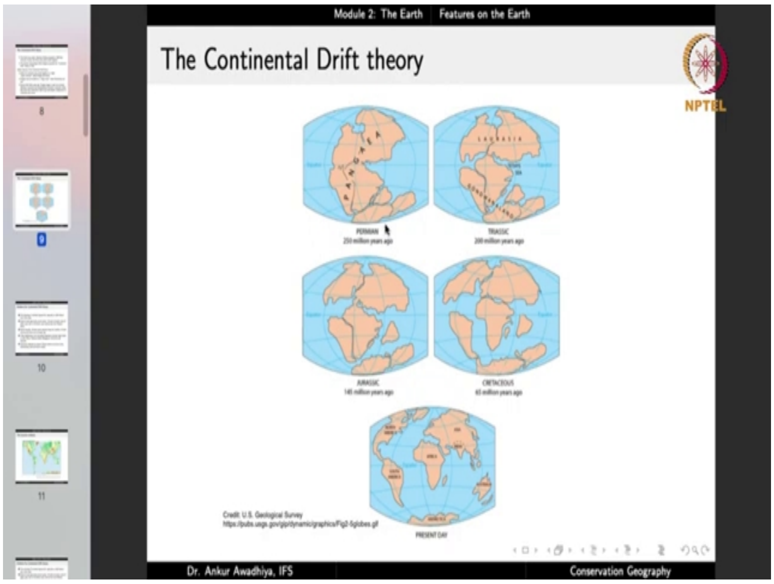

Some of the evidences are listed here. The first one is the matching of the continents, the jig-saw fit, especially at 1000 fathom line in the ocean. So, this is what we have observed before. Wegener also stated that because this nautch, can get into this nautch, so probably this, these are just pieces of a jig-saw puzzle, and because they can meet together, so probably once upon a time they were together.

But he gave more evidences than this, he found out that rocks of the same age are found across oceans. That is the belt of ancient rocks, around 2 billion years old, on the Brazil coast, match that from Western Africa. That is, the rocks that we have here in the land masses, and the rocks that we have here in the African landmass, they are very similar. Now, you cannot have a situation where these two locations which are separated by the Atlantic Ocean, they will be having the same configuration of rocks.

Now, that is not possible. That is only possible. When some time back in antiquity, they were joined together, then these rocks got formed. And then, later on, these continents drifted apart. So, this was one evidence for his theory. Another evidence is that of the marine deposits, earliest marine deposits along the coastline of South America, and Africa are of Jurassic age.

So, what he was proposing is that if you look at the Jurassic age. Now, before the Jurassic period, we have that the South America and Africa they are joined together. And around the Jurassic period, they began to split apart. And so, if there was, if these continents were together before the Jurassic period, you cannot have any sediments in the oceans that are older than this period. And this is exactly what we find today.

The sediments in the ocean bottoms, the earliest sediments are of the Jurassic era, you do not have any sediments before that time period. Which means that before the Jurassic period, there was no ocean or there was no water body, between South America and Africa. Because if there were a water body, then we would have had some sort of sediments.

Now, Wegener did not find out all of these clues by himself, but he looked at the published literature, he looked at what the other scientists had found out, and he used those evidences to put forth his own theory. So, this is another evidence that if you look at the ocean sediments between South America and Africa, there are no ocean sediments that are older than the Jurassic period.

Then, another evidence is that Tillite, which is a sedimentary rock from glacial deposits of similar origin, is found in India, Africa, Falkland Islands, Madagascar, Antarctica, and Australia. Now in India, today we have glaciers only in the very north of the country. But we do not have glaciers in other locations, but we can find glacial deposits in other locations as well.

Which means that probably India was in a location that was much more colder than where it is today. Similarly, these sediments called Tillite that are made from glacial deposits of similar origin. Now, similar origin means that they have come up through the breakage and weathering, and erosion of this same rocks or similar rocks. So, they are of the same origin.

Now, we are finding these sedimentary rocks of glacial origin. In all these different locations that are so far apart today, India, Africa, Falkland Islands, Madagascar, Antarctica, and Australia. So, probably sometime back in antiquity, they should have been together. So, if you look at this image in the Permian era, we will find that here you have India you have Africa, you have Madagascar, you have South America, in the Falkland Islands, you have Antarctica and all of these are together.

So, if these land masses were together, sometime in antiquity, then it is possible that you can have sedimentary rocks from the same origin or similar origin in all of these locations. But if you look at the configuration today, where these are so far apart, it is next to impossible to create sedimentary rocks of the same origin in these locations that are so far apart.

So, this is another evidence for the continental drift theory. Another is that the gold placer deposits that are found in Ghana are without the source rocks. Now, gold placer deposits are deposits of gold, that have accumulated in a place primarily through the river waters.

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So, what happens is that if you have these hills that are rich in gold, and you have rivers that are flowing through these, so they will be erosion and the sediments from this rock, they will be carried away, and probably they will be deposited here. So, these are known as Placer deposits. Now, today, the situation is that you have lots of Pacer deposits in Ghana. But you do not have the corresponding rocks, that would that are gold-bearing rocks, but you do find gold-bearing rocks in South America.

So, you do find gold-bearing rocks here. So, if both of these were joined together sometime in antiquity, then it is possible that a river that was flowing from this region to this region, it would carry the sediments from these rocks and deposit them here. So, the fact that we have gold placer deposits here without the source rocks, and the source rocks here is another strong evidence that sometime in antiquity, both of these continents were together.

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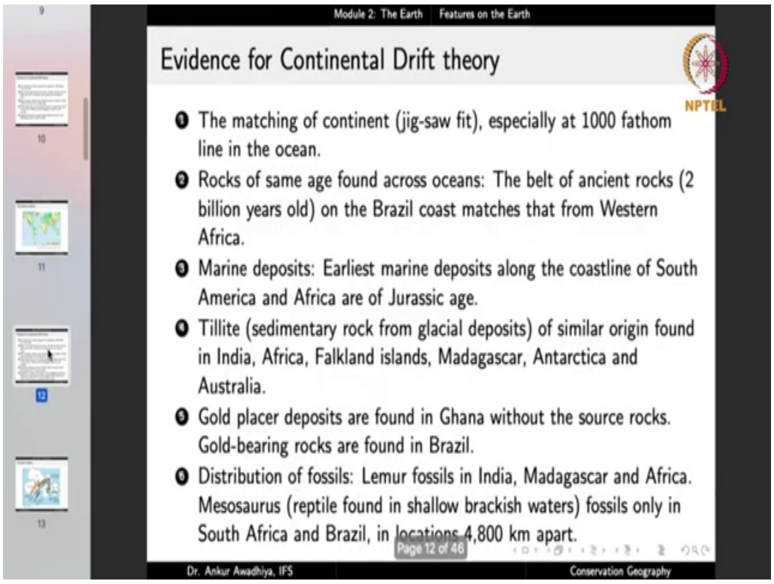

Another evidence is in the form of fossil records. So, we have the distribution of fossils, that shows that Lemur fossils are found in India, Madagascar, and Africa. Now, today, India is here, Madagascar is here, and Africa is here. And we do not find the fossils here. But you find the fossils of the same species here, here, and here. Now, that is not possible, because you cannot have an organism that has a range that is divided into these three portions, organisms generally tend to have a very contiguous range.

So, the presence of the species in the form of fossils in very different locations is another evidence that probably sometime in the past they were together. Similarly, we find

Mesosaurus fossils and Mesosaurus was a reptile that was found in shallow brackish waters. And these fossils are found only in South Africa, and Brazil, in locations that are today 4800 kilometres apart, that is, we find them here and we find them here.

Now, it is not possible for a species to be found only here and here. It is only possible if both of these locations were earlier together so that this species could have a range that encompassed Africa and South America. So, this is another strong evidence.

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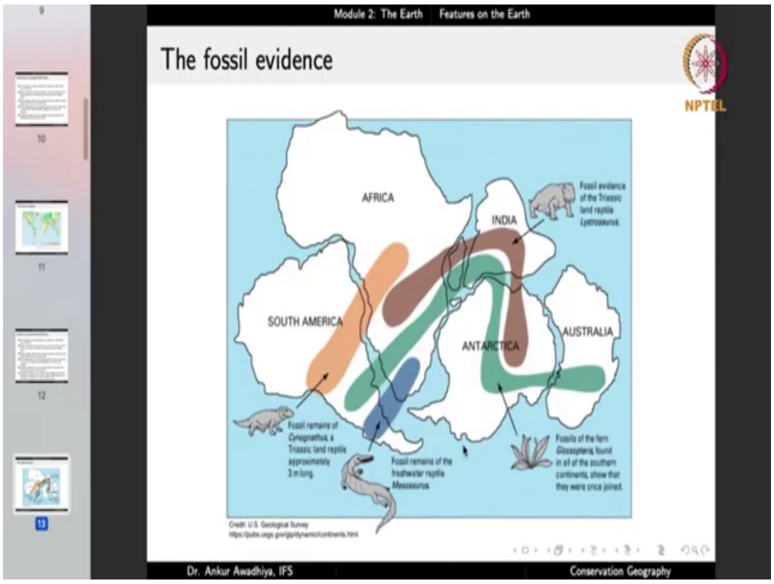

So, if these continents were joined together, sometime back then it is possible for us to have ranges like this. So, this is the range for a Triassic land reptile Lystrosaurus. So, the fossils are found in Africa, they are found in Madagascar, they are found in India and they are found in Antarctica. Currently, these locations are far apart, but during the Triassic period, these locations should have been together.

Similarly, we find fossil remains of Signothorus in South America and Africa telling us that okay, both of these locations should have been together. Similarly, we have other organisms that are having ranges like these. Now, the fact that we are having so many different evidences that point to the same thing that all these continents should have been together is next to impossible to refute.

It is very difficult to have all these things, such as having similar rock types or similar sediment types, or placer deposits, or fossils by any other means. So, when you have removed the impossible, whatever remains, however improbable, must be the truth. So, in this case, when we have removed the other possibilities, whatever remains, that is the continents should have been together. So, that must be the truth.

So, this is the continental drift theory that continents earlier were together later this split, and they are now in the current position. But then what causes these continents to move, because we are not talking about small masses, we are talking about large size continents. And Alfred Wegener was saying that these contents earlier were together and then they split apart and then they started to move.

The first question anybody would have asked him is, okay, what was the mechanism of this moment? Now, Alfred Wegener did not very well know what the mechanism was. He had even proposed that these continents were moving above the sea floors. So, they were essentially crushing the sea floor, just like an icebreaker ship.

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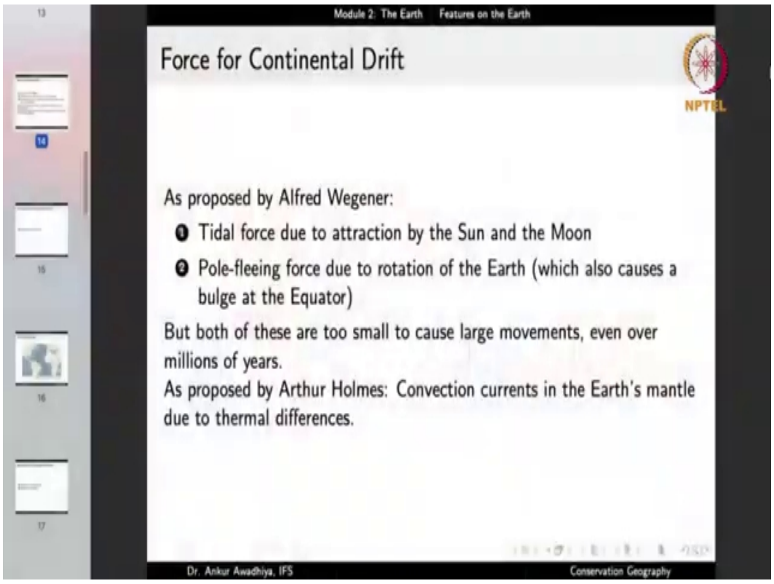

He proposed that there could be different forces such as the tidal force due to attraction by sun and the moon. But then the tidal forces a very small force. Or he said that it could be because of the pole fleeing force due to the rotation of the Earth, essentially a centrifugal force, which also causes a bulge at the equator. Now, scientists of the day calculated the amounts of these forces.

And they found that both of these are too small to cause large movements, even over millions of years. And so, it was very difficult for him to prove his theory that the continents were earlier together and they were then moving. The theory had to wait for a number of decades before we could find other evidences.

Now, in the meantime, we have a proposal by Arthur Holmes, who stated that convection currents in the Earth's mantle due to thermal differences could be one of the ways in which these continents move.

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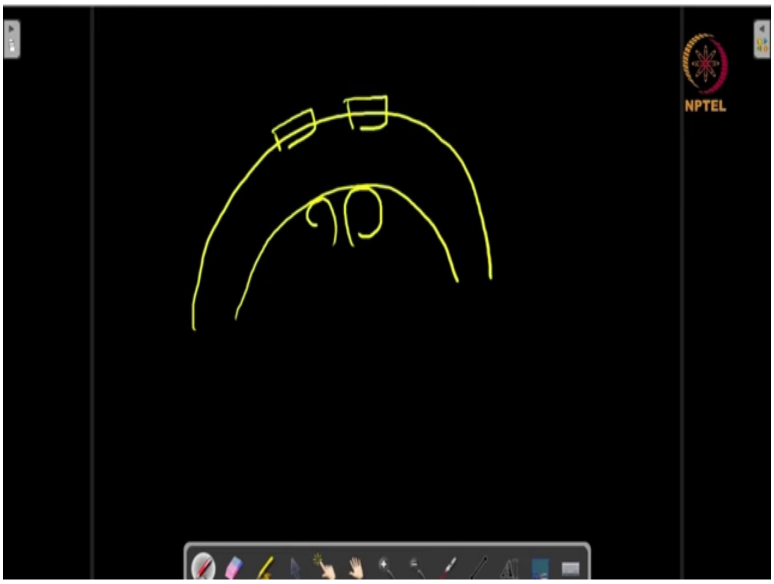

So, what he was stating is that, if you look at the Earth, and if we consider the mantle, which is semi-solid, we can have convection currents that go like this. Now, if we have these convection currents, then probably any continent that is on top of these, it will move along with the currents. So, this was one proposal, but it was very difficult to prove.

And in any case, for the continents as a landmass to move over another landmass in the form of sea floor is right next to impossible, because that would require a tremendous amount of force, tremendous amount of energy. So, this was one proposal. But again, this had to wait.

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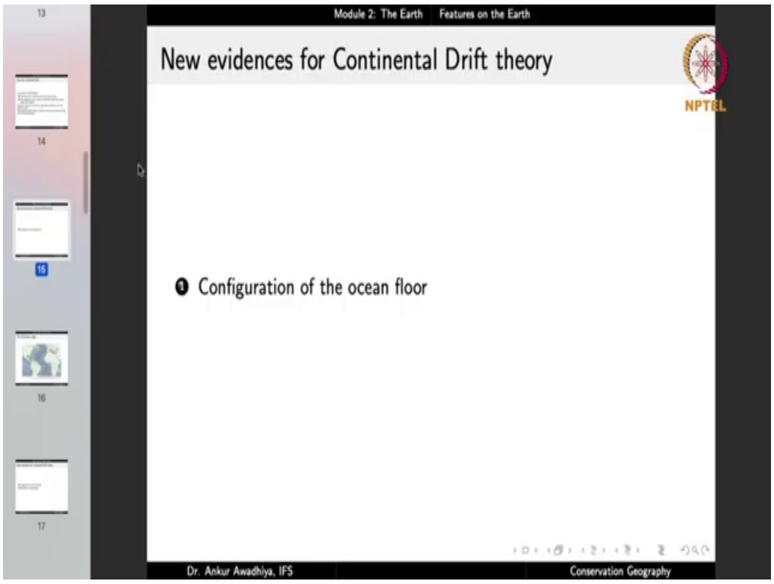

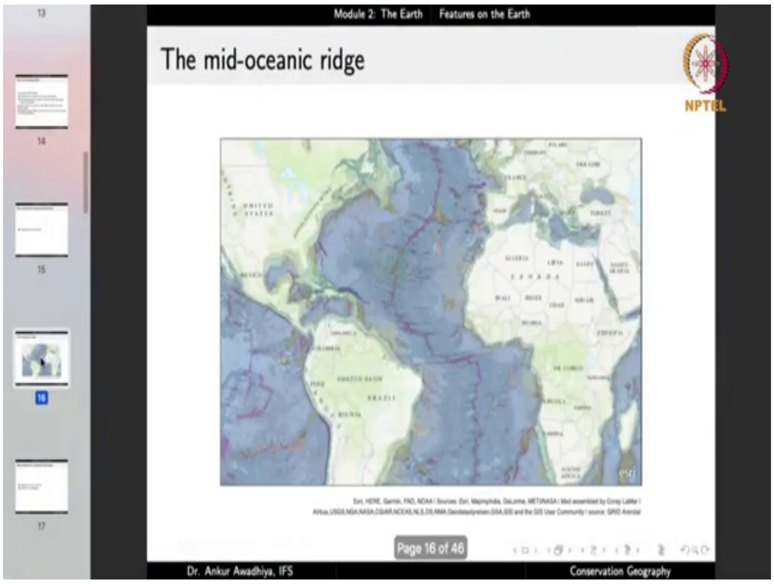

Now, in the waiting period, we got new evidences, we started to look at the configuration of the ocean floor. So, in the time of Wegener, we only knew that okay, there are continents and there are oceans and the oceans, for the most part, they must be a flatland, it must be a plain area. But later on, especially during the Second World War and later years, the ocean floor was also mapped.

And it turned out that the ocean floor is not a featureless plane, it has a number of different landforms, very similar to what we find on the continents as well. So, you have hills, you have valleys, you have planes, you have n number of different things. So, when the seafloor mapping was done, we came to know that okay, there are certain ridges, so there are ridges like this Mid Atlantic ridge.

Now, this Mid Atlantic Ridge, it runs roughly from the north to the south of the Earth in a continuous chain, and this is in the form of a mountain range. Similarly, at other locations as well, we have different features. So, one new thing that we got after Wegener is that the ocean floor is not a featureless plane, it has a number of different landforms. So, if it has different landforms, then there must also be a mechanism that is acting there to create these landforms to transform these landforms.

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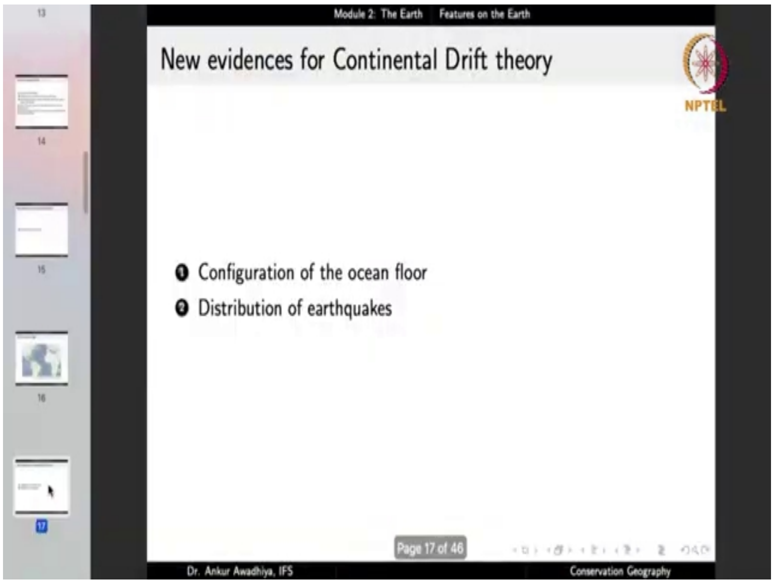

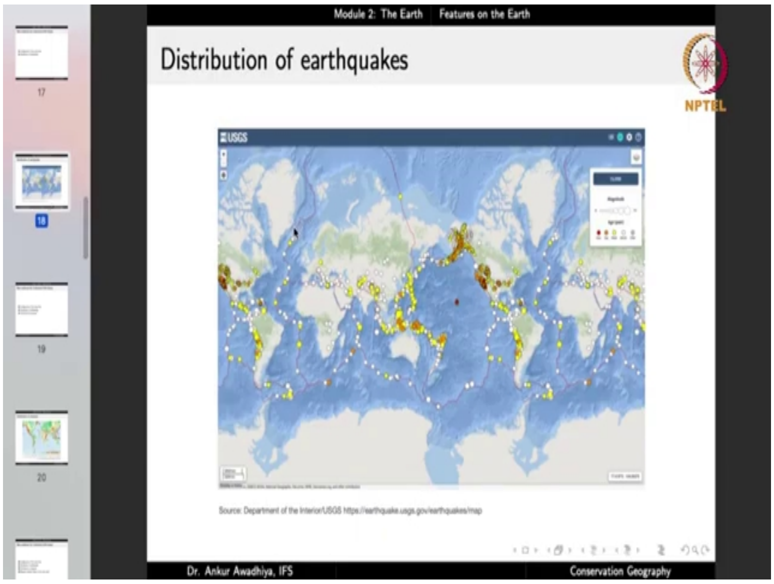

Next, we also came to know about the distribution of earthquakes. So, if you plot the earthquakes, this is how it looks like. Now, the important thing here is that we also get a number of earthquakes here on the Mid-Atlantic ridge as well, this purple line is the Mid Atlantic ridge and we can find that there are earthquakes right here, which means that these ridges or these landforms they are not a stationary thing, they are moving, they are dynamic things, there is something that is going on there.

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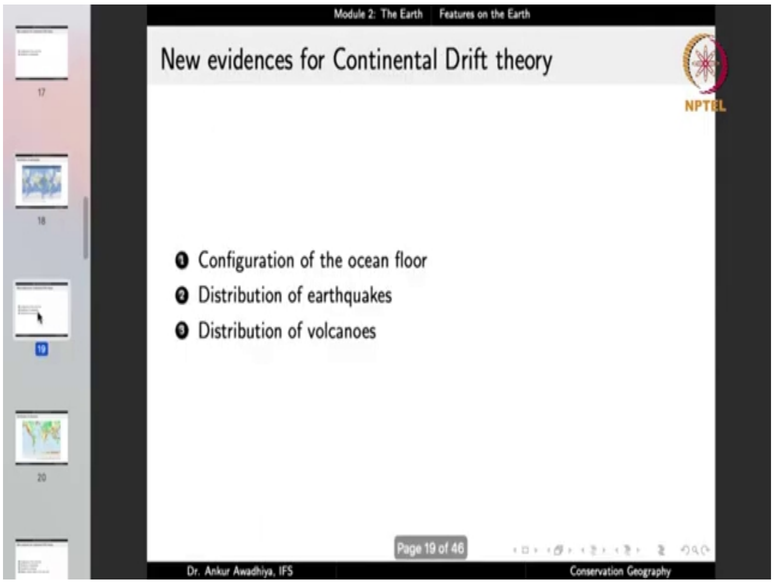

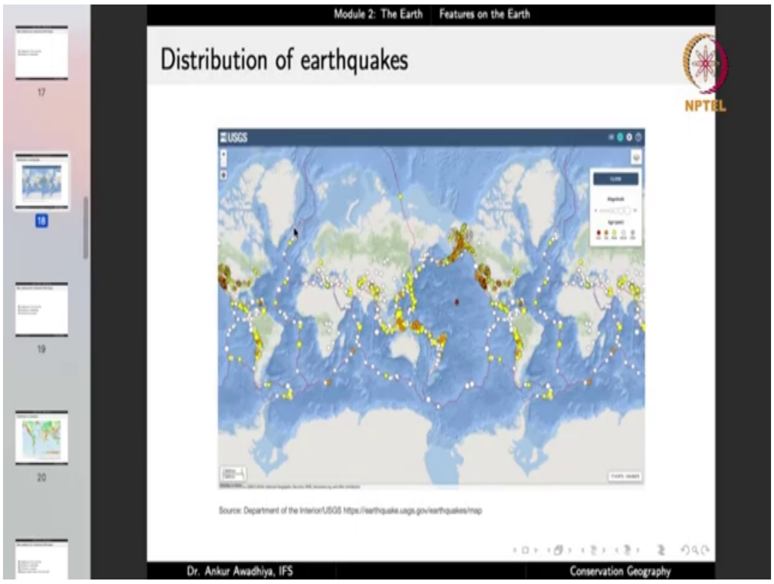

Similarly, if we looked at the distribution of volcanoes, here again, we will find a very similar thing that you have volcanoes that are along certain lines. Now, if you look at these lines, and if you compare them with the earthquake lines, so here we can observe that here in North America and South America, you have the western edge that is lined with earthquakes. If you look at this image, the western edge is also aligned with volcanoes.

Here we find a line right next to Japan, which is full of volcanoes. And if you look at the earthquake curve, yes, there is a line here that is showing a very high intensity of earthquakes as well. So, there is something that is going on these in these specific locations, because of which they are getting a very large number an intensity of earthquakes and volcanic eruptions.

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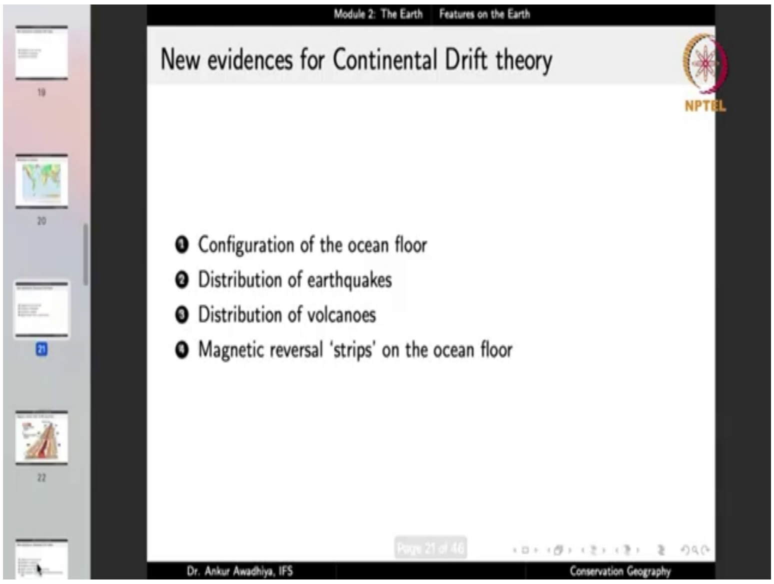

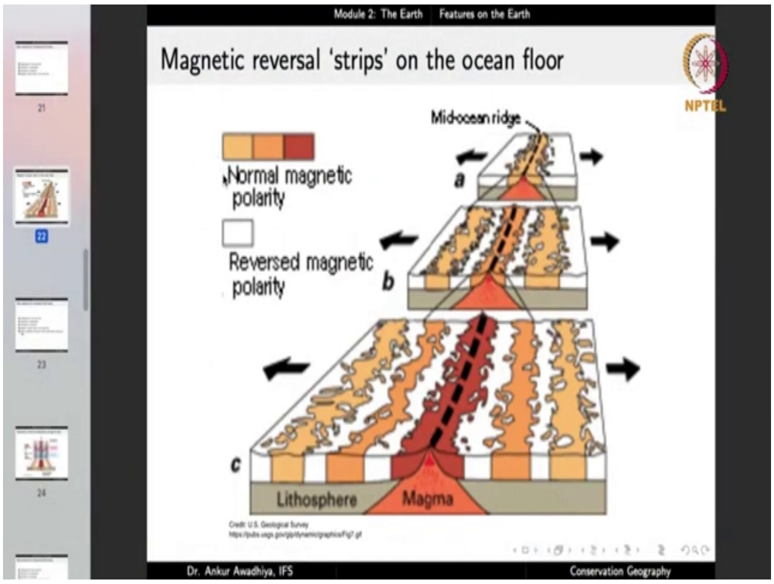

We also found magnetic reversal strips on the ocean floor. Now, this was not known in the time of Wegener. But later on, when magnetic surveys were done, it was found that different locations on the ocean floor they have different magnetic properties, different strengths, and directions of the magnetic field. So, this was another map that was drawn.

And in this case, what was found is that we have magnetic reversal strips on the ocean floor. So, that there in certain times the magnetic poles have the normal magnetic polarity similar to what we have today. And in certain other times, they have had a reversed magnetic polarity meaning that what is north became south and what is south became north.

Now, in different locations on the ocean floor, we found that there are places that showed normal polarity and there are places that show the reverse polarity, and maps for these locations were also made.

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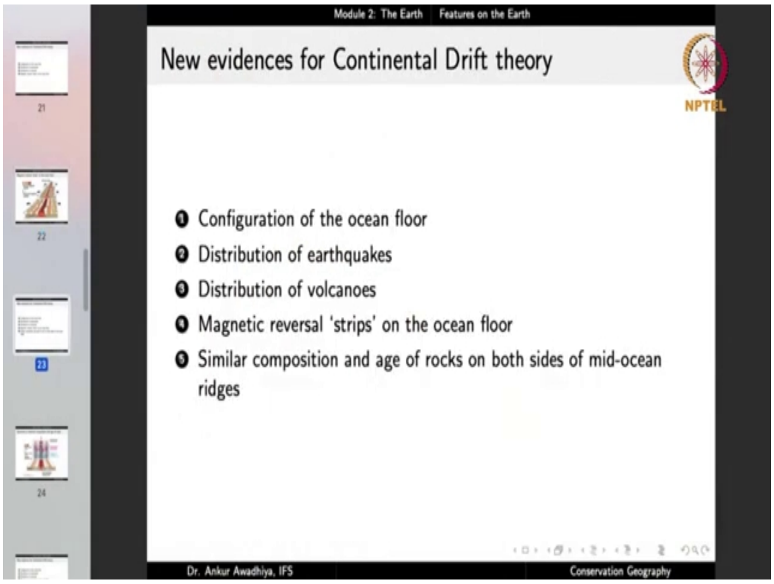

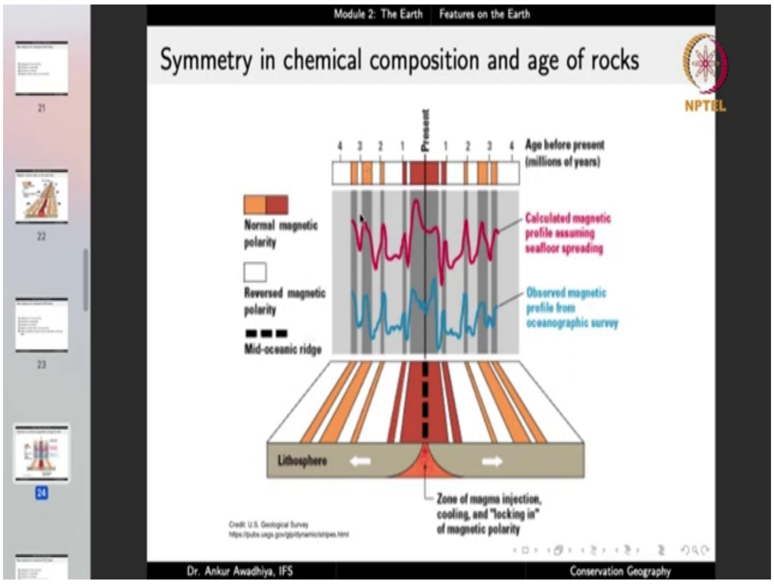

One other thing that was found is that there is a similar composition and age of rocks on both sides of the mid-ocean ridges, meaning that, if you have a ridge-like this at this location, then on both the sides, you find a symmetrical arrangement, the magnetic arrangement is also similar and the age arrangement is also similar.

That is, if this portion has normal magnetic polarity, then this portion will also be having a normal magnetic polarity of similar strength and direction. Similarly, these two will have the, will have similar magnetic properties, these two will have similar magnetic properties, these two will have similar magnetic properties, and so on, not just the magnetic properties, but they also have similar ages.

So, if this location is 1 million-year-old, this location is also 1 million-year-old. If this location is 4 million years old, then this location is also 4 million years old. Which tells us that there is something that is going on here that is resulting in a mirror arrangement. Anything that is there on the right you find a very similar thing that is there on the left.

Now, we did not have this information in Wegener's time because, in those days, we did not have the maps of magnetic fields in the ocean floor. We did not know about the mid-Atlantic ridges and the dating of the rocks on both the sides of the mid-ocean ridges that was also not done. But later on, when these were done, it was found out that we are having a very similar arrangement on both the sides.

Now, how can we have these similar arrangements? Well, one thing is that if something is formed here and then later on, this portion splits, so that half of it moves this side and the other half moves this side then it is possible. So, for instance, if this is the zone where magma is getting injected, it is cooling and it is locking in the magnetic polarity and if both these regions are moving in opposite directions, so this portion is moving to the left, this portion is moving to the right.

Now, in that case, when any rock gets formed here, then it will split into two parts, one will move to the left, one will move to the right. Now, because this rock was made at the same time, both the right and left parts were made at the same time. So, they will be having similar properties, they will be having similar ages they will be having similar magnetic properties.

Now, this is one way in which we can explain why we are having a symmetrical arrangement on both sides of the mid-ocean ridges. Another thing that we find is that, as you move away from the mid-oceanic ridges, the rocks get older. So, these rocks were made very long back, then these rocks were made, then these rocks were made and these rocks are the current rocks.

Now, had this with the information that you are having volcanic eruptions in this place, telling you that rocks are getting formed in this place by the cooling of magma. Add to it the information that you are having moments in these locations because you are getting earthquakes. And if you join all of these evidences together, then you will have to come to the same conclusion that these areas are tectonically active and they are spreading away from each other, creating new crust in this area. So, this is a new evidence.

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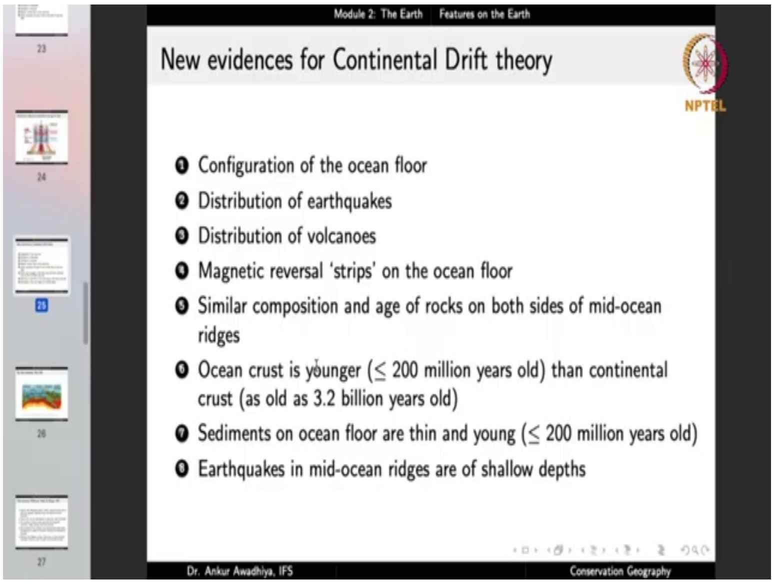

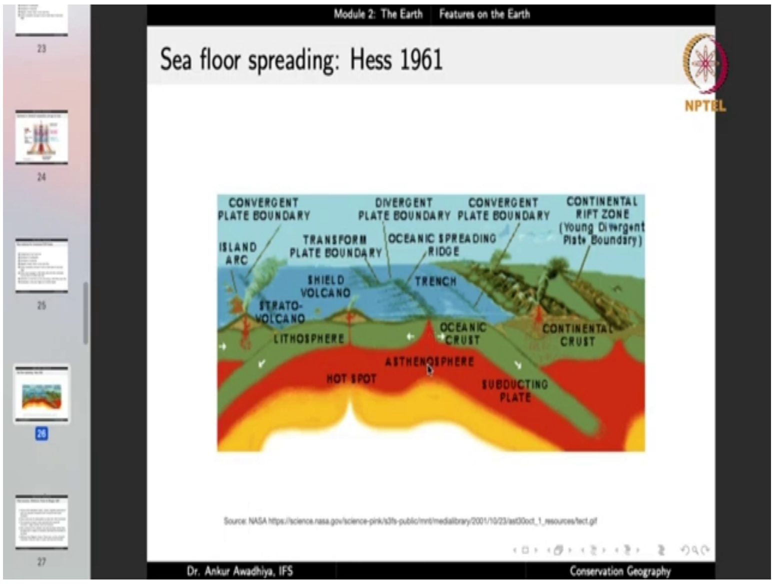

Also, it was found that the ocean crust is much younger than the continental crust. So, the ocean crust is always less than or equal to 200 million years old. We do not find any rocks in the oceanic crust that are older than this. But on the continental crust, we get rocks as old as 3.2 billion years old. Now, this tells us that the oceanic crust was formed later, the continental crust was formed earlier. So, the continental crust is older, the oceanic crust is younger.

Now, why is it younger, because it was made later. So, this information tells us that the oceanic crust are in the process of being formed. The crust are not the same since the beginning of the Earth, they are dynamic. They are not static. So, they are being formed and they are being formed where in the oceans. Because the oceanic crust is younger. There is very less crust formation in the continents.

Maybe in a few locations where you have volcanoes but majority of the crust formation is happening in the oceans. Another evidence is that the sediments on the ocean floor are also thin, thin, and young. You do not find any sediments that are more than around 200 million years old. Which means that before 200 million years, you do not have any oceanic crust that is existing today.

Which tells us that not only is the crust being made, but there must also be a process of destroying the older crust. And especially, the older oceanic crust. So, it is telling us that the Earth is not a static thing, it is a dynamic thing the oceanic crust is being formed and oceanic crust is also getting destroyed through some process. And another evidence is that the earthquakes in the mid-oceanic ridges are of shallow depths.

So, there is something that is happening right next to the surface. We are not talking about something that is happening very deep into the mantle or very deep in the core, but this is something that is happening near the surface. And putting all of these together Hess developed a model of seafloor spreading.

So, Hess said that in certain locations such as this location, there is the formation of the oceanic crust, because the magma comes out from this location and the crust on both the side is moving away from this location. So, the new crust will get formed and it will then spread on both the sides and this the older crust has to be destroyed somewhere. So, one mechanism is that the oceanic crust where it meets the continental crust, then the oceanic crust goes down.

So, this is a subduction zone, this plate is getting subducted down, it is getting downwards. Now, one way to understand this is that if you remember that the oceanic crust is having a greater density than the continental crust. And so, if you have the oceanic crust and if you have the continental crust, and if both of these are coming together, the continental crust will remain on the top and the oceanic crust will slowly go down.

So, this is what is being proposed as a mechanism for the destruction of the oceanic crust. Now, because it is going down and down here you have the mantle you have higher temperatures. So, after sometime this crust will get molten and it will become a part of the mantle. So, at in certain locations, the crust is getting formed in certain other locations, it is getting downwards and it is in a subduction zone and it is getting destroyed.

Now typically, where in these locations where you have the oceanic crust that is going down, you will also be carrying a lot of water and water-based minerals down into this area. Now, when it goes down, the solid portions melt. But the liquid portions they get vaporized when they get vaporized, they generate gas and gas leads to the creation of a great amount of pressure.

Now, these gases are released through means of volcanoes. So, in all the locations where we find these two-crust meeting together oceanic crust and the continental crust, creating a subduction zone will typically also find a number of volcanoes to release the gases that are being formed in these locations. And in these trenches, here we have the divergent boundaries because both of these sides are going away from each other.

But you can also have divergent boundaries in the continents in the form of rift zones. And a good example is the Rift Valley of Africa. Now, in the case of the Rift Valley of Africa, the continent of Africa is getting broken into two different parts. So, remember that earlier we had the Pangaea and it got broken into the Laurasia and the Gondwanaland.

Similarly, today, we can witness that in the Rift Valley of Africa, the continent of Africa is also breaking into two different parts. So, we can have rift zones in the continents as well. Then we can have volcanoes in other locations as well, it is not necessary that they should only be in the subduction zones. So, we can have certain locations that are hotspots where there is a plume of magma that is going upwards.

And this can also result in the creation of volcanoes. And wherever you have these crust that are going down, so in this location, you have only the oceanic crust that is going down and the continental crust is remaining steady. In this location, you have a continental crust that is moving towards the oceanic crust and oceanic crust is also moving towards the continental crust, so you can have n number of configurations.

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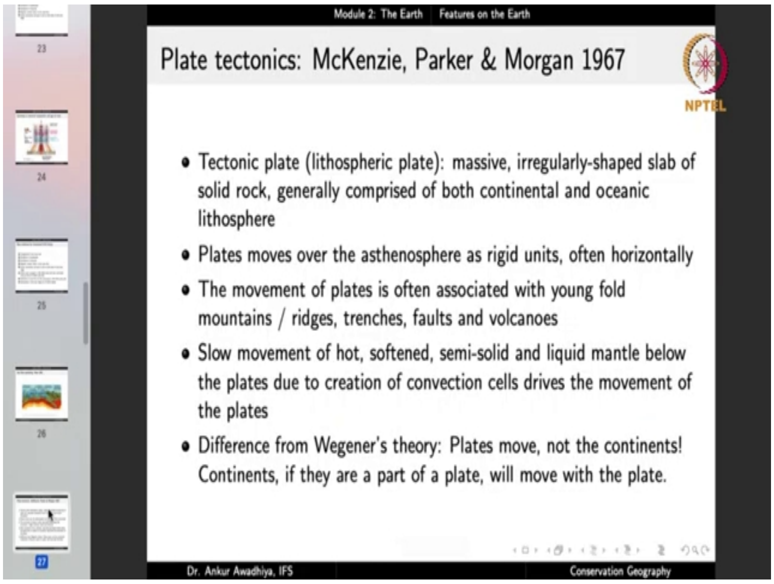

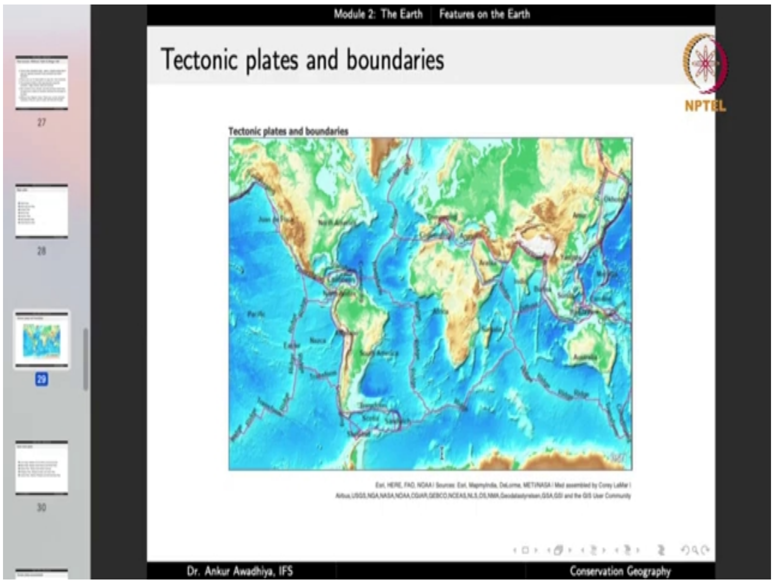

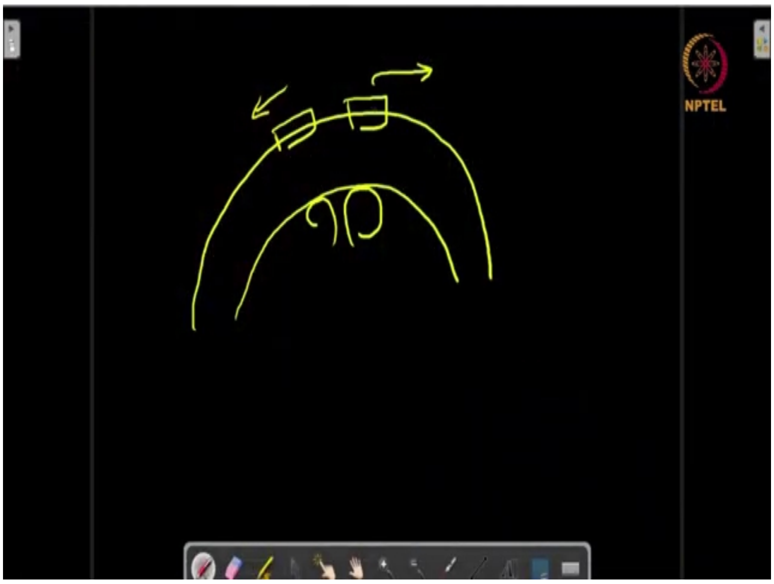

And this model was later further refined into the plate tectonic model by McKenzie, Parker and Morgan in 1967. Now, plate tectonics talks about tectonic plates, which are lithospheric plates, lithos is rock. So, this is the sphere of rocks. And this sphere of rocks that is the crust. It is divided into different plates. So, it is crust and maybe some portions of the mantle.

So, these are massive, irregularly shaped slabs of solid rock, generally comprised of both continental and oceanic lithosphere. Now here, you can note, a subtle difference between the plate tectonic theory and the Wegener's theory of continental drift. In the Wegener's theory, we saw that the continents are moving not the oceans, but the plate tectonic theory states that any plate can move.

And if there is a continent on the plate, then that continent will move, if there is oceanic crust in that plate, the oceanic crust will also move. So, it is not necessary that the oceans will remain as such and only the continent should move. So, the plates move not the continents, and the continents if they are a part of the plate, they will move with the plate.

So, tectonic plate is a massive, irregularly shaped slab of solid rock generally comprised of both continental and oceanic lithosphere. So, if you look at an image of a plate, so like this is the African plate. So, this is an irregularly shaped slab of rock that is having this portion which is the continent, and this portion which is the oceanic crust, and this plate is a solid mass and it can move as a single piece.

Now, plates move over asthenosphere, which is the semi-solid portion as rigid units often horizontally, so the plates move as rigid unit. So, this African plate will remain like this until it is destroyed or there is something that happens to it, but it will move as a rigid solid block. The movement of plates is often associated with young fold mountains or ridges, trenches, faults, and volcanoes.

And we will explore this in a short while the slow movement of hot, softened, semi-solid, and liquid mantle below the plates due to creation of convection cells drives the movement of the plates. Now, in the case of Wegener's theory, Wegener was at a lot to explain how is continents moved, but in the case of the plate tectonics theory, we took up the ideas of Hess to say that if there are any plumes that develop then it is not these continents that move but the plates that move over the semi-solid asthenosphere. So, now, we also have a mechanism of this plate movement.

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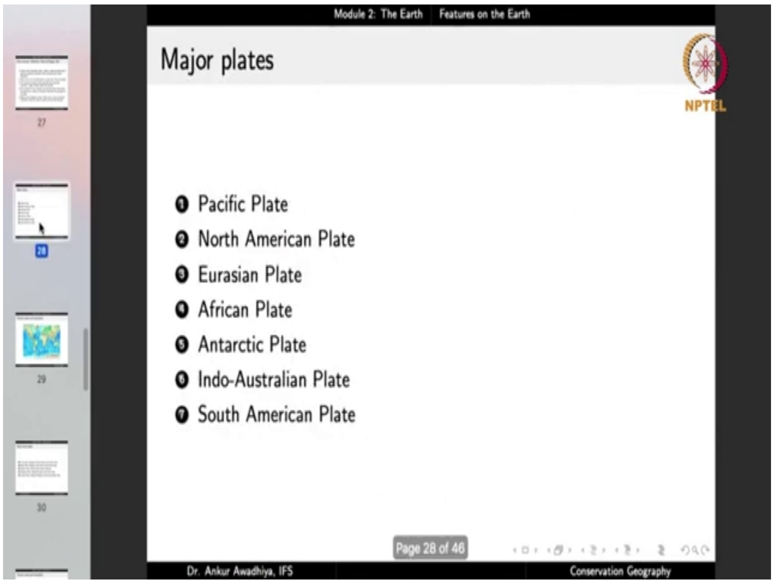

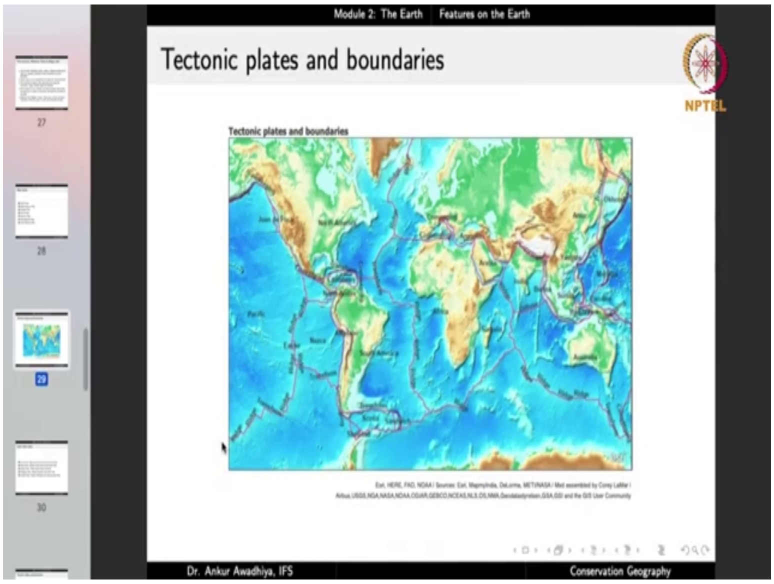

Now, what are these plates, we have major plates and we have minor plates, the major plates are the Pacific plate. So, here if you look at the Pacific Ocean, this large size plate is the Pacific Plate, then we have the North American plate. So, this is the North American plate, big size one then you have the Eurasian plate. So, Europe and Asia together, this is the Eurasian Plate, then we have the African plate.

So, this is the African plate then we have the Antarctic plate. So, this big portion is the Antarctic plate then we have Indo-Australian plate, it is sometimes divided into Indian and Australian plates, sometimes it is written together as Indo-Australian plate. So, here you have Indian plate and here you have the Australian plate.

Some researchers suggest that both of these are still connected together, some suggest that these are already divided into two portions, we are not very sure. And you also have the South American plate. So, this is the South American plate which has South America and it also has some portion of the Atlantic Ocean.

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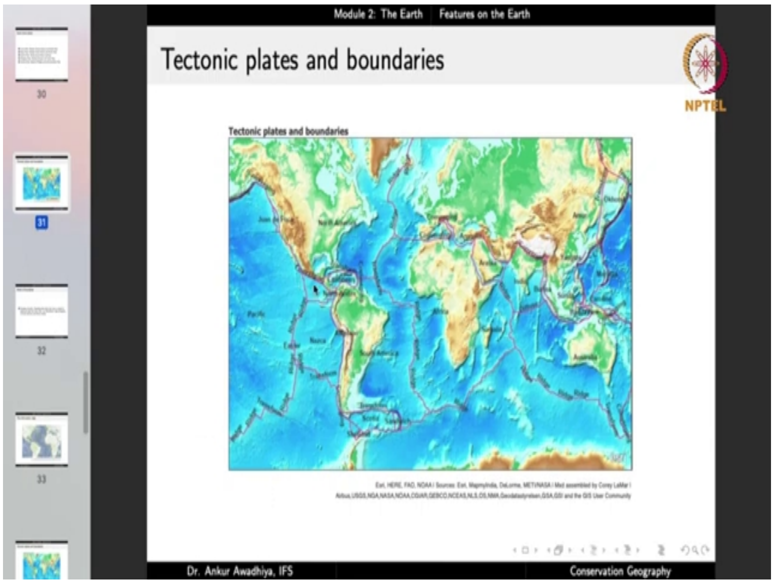

We also have a number of minor plates which are smaller size plates, like Cocos plate, Nazca plate, Arabian plate, Philippine plate, and Caroline plate. So, if when we talk about smaller plates, so like this is Arabia, this is the Arabian plate, very small in size. Similarly, here we have the Caribbean plate. So, we have major plates and we have minor plates.

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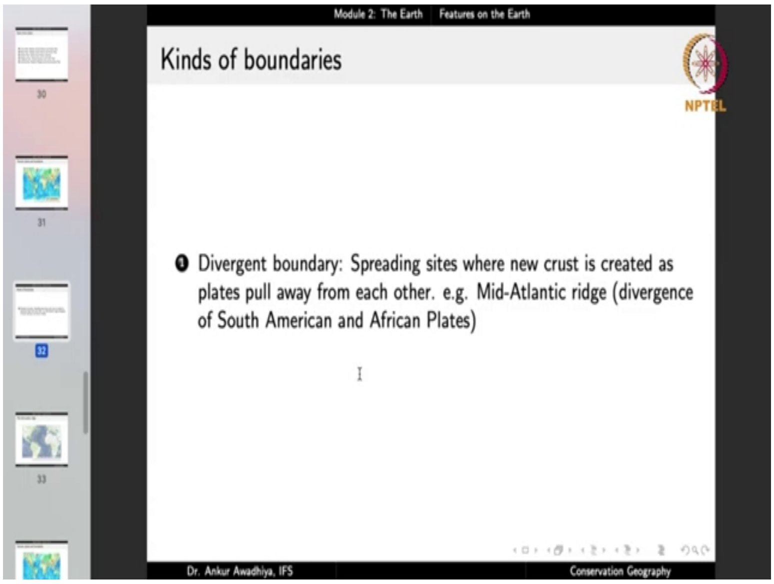

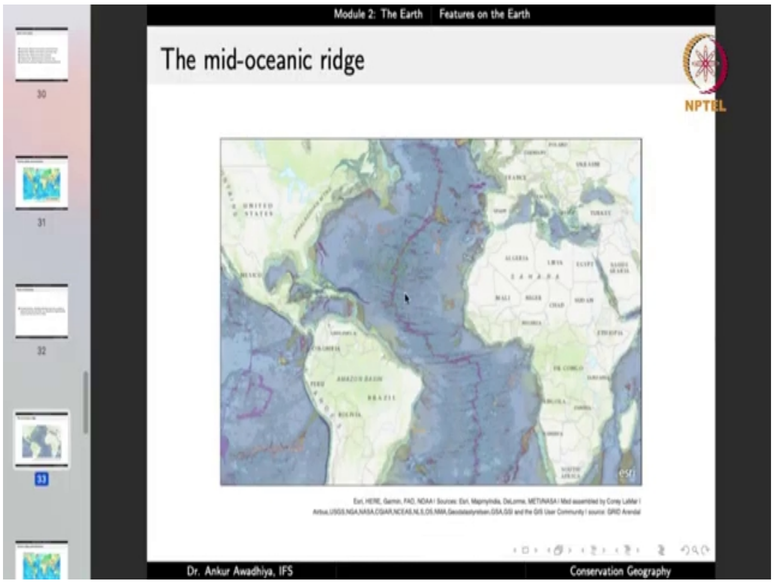

Now, between these plates, we can have different kinds of boundaries. The major boundaries include the divergent boundary, which are spreading sites, where new crust is created as plates pull away from each other, such as the Mid Atlantic Ridge, where we have a divergence of South American and African plates.

So, for instance, in the Mid Atlantic Ridge, so, this is the Mid Atlantic Ridge, here we are having divergence because this African plate is moving to the side and the South American plate is moving to the side. So, we have the divergence of South American and African plates, they are moving away from each other and such a boundary is known as a divergent boundary, we find a number of divergent boundaries along different ridges.

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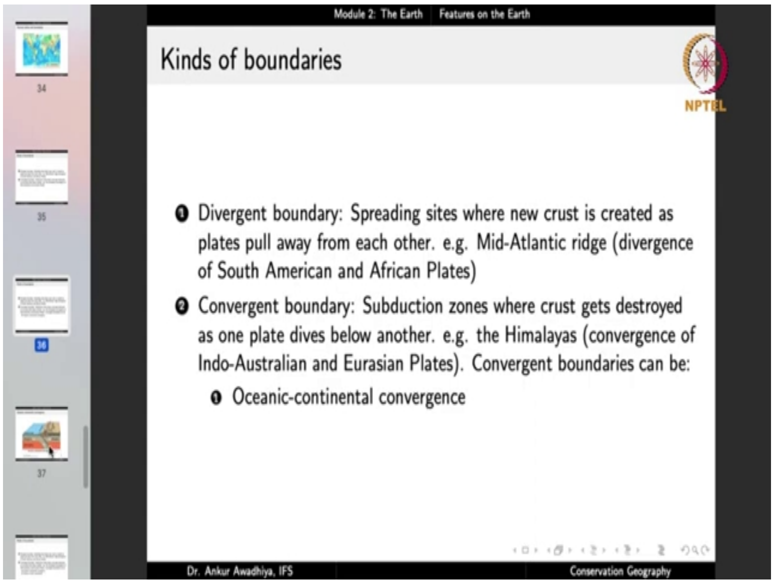

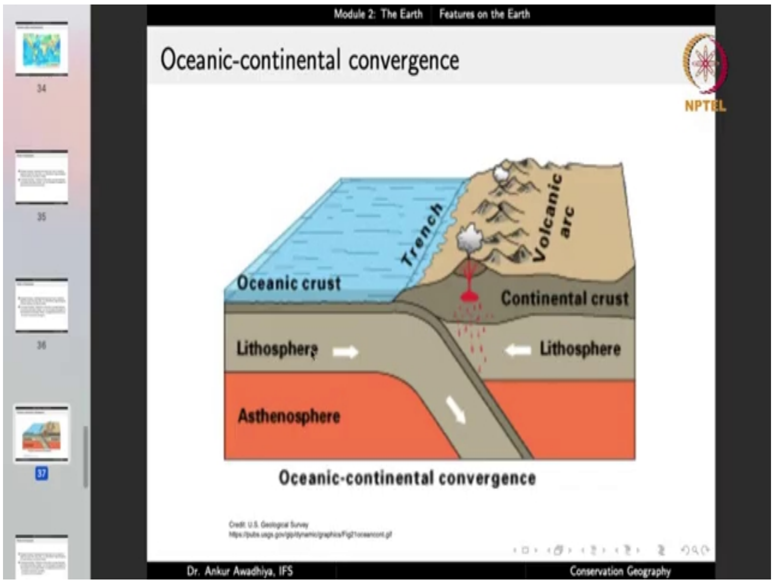

Another boundary is a convergent boundary. Now, a convergent boundary is a boundary where convergence happens meaning that two plates come towards each other. So, it is possible that one plate is static the other is moving towards it or it is also possible that both the plates are moving towards each other. But in both of these situations, there is a convergence, the plates are moving towards each other.

And convergence is often associated with subduction zones. Now in the divergent boundary, the crust was being created. In the convergent boundary, the crust is getting destroyed and it is getting destroyed because one plate moves below the other plate, it dives below the other great example is the Himalayas which is the convergence of Indo-Australian and Eurasian plates.

Now, it is a convergent boundary because India moved towards Eurasia and this happened because the Indian plate or the Indo-Australian plate moved towards the Eurasian plate. And when both of these collided together, it led to the formation of Himalayas. But because both of these plates move towards each other, and there is also a subduction, this is a convergent boundary. Now, convergent boundary can be of different types, we can have a convergence between oceanic and continental plates or oceanic and continental regions of the plates.

Now, one such example is here. Now, if you have the oceanic crust and when you have the continental crust, whenever you have a convergence, you will find that the oceanic crust because it is having a greater density, it will move down, it will dive down and it will get melted here and so there will be a destruction of the oceanic crust. And this will typically be associated with a volcanic arc, because the gases that get created or get released here, they have to be laid out. And they are laid out through these volcanoes.

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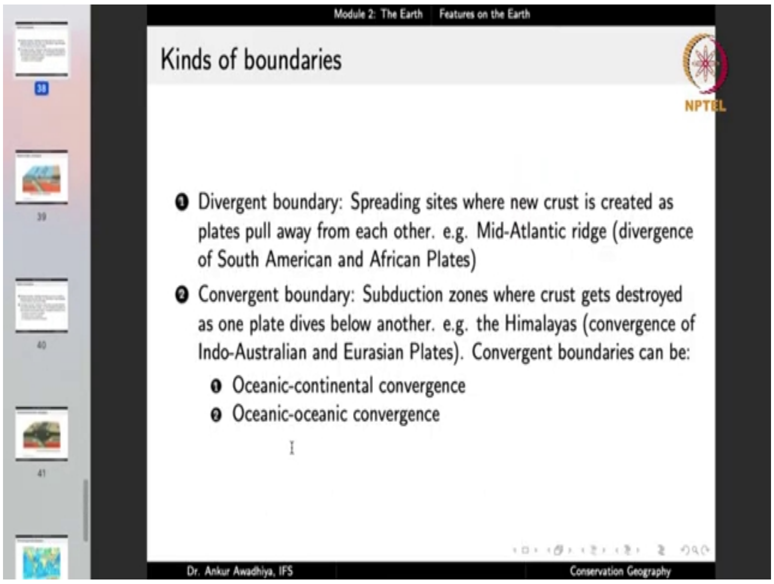

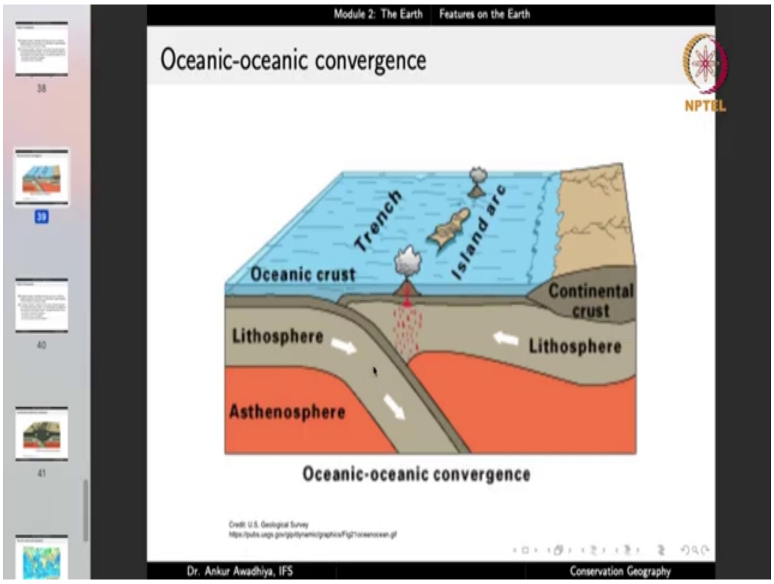

Another configuration is the convergence of an oceanic plate with another oceanic plate or oceanic region of a plate with another oceanic region of a plate. Now, once that happens, in that case, one of the portions will remain up, one of the portions will go down. And typically, here again, because you have a lot of water that is going down, here again, you will find a large number of volcanoes.

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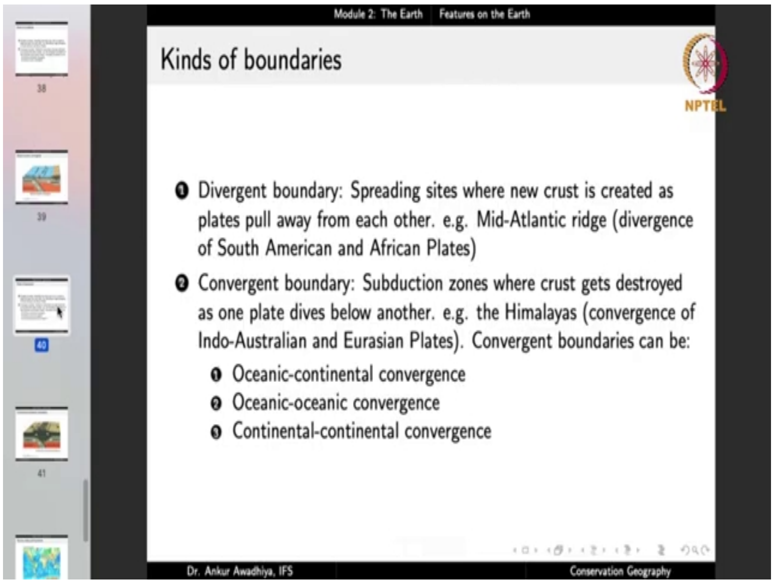

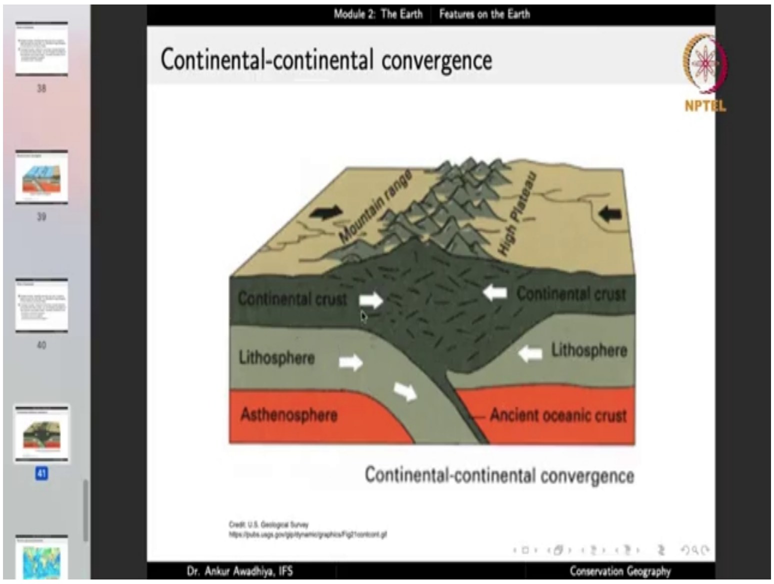

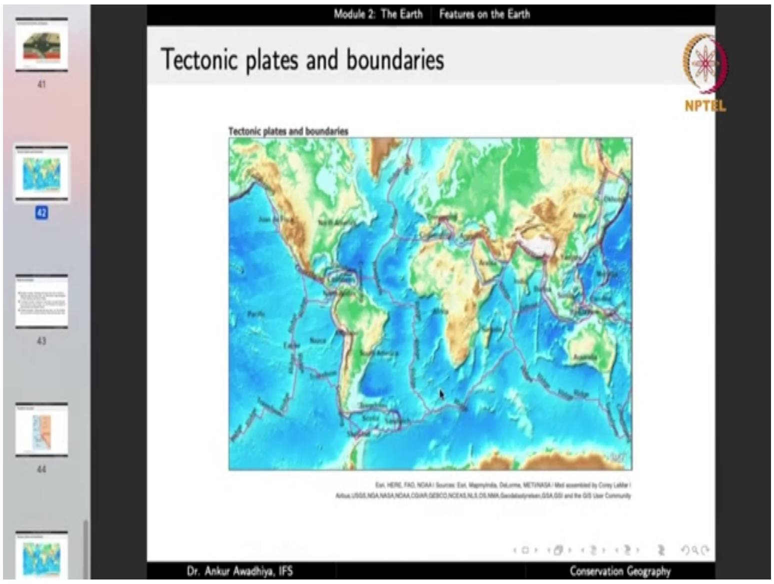

Another configuration is the convergence of continents with continents. So, you have continental areas that are converging with another continental area. A good example is the Himalayas. Now, what happens, in this case, is that here again as in the case of oceanic-oceanic convergence, one of the portions has to go down, the portion will remain up.

But what happens is that the continental crust it moves upwards. So, you will have the top portion that is coming together and it is rising like this, like the Himalayas and typically these are associated with young fold mountains. So, a continental-continental convergence will have young fold mountains and oceanic-oceanic convergence will have volcanoes and an oceanic-continental convergence will also have volcanoes.

In the case of continental-continental convergence, one of the plates will remain up the plate will go down. In the case of an oceanic-oceanic convergence, one of the plates will remain up the other will go down. In the case of an oceanic-continental convergence, the continental plate will remain up the oceanic plate will go down. So, these are the basic rules.

And we can observe that we have these convergences in a number of locations. One such convergence is here on the western coast of South America, which is why we have volcanoes here. Another convergence is here, right next to Japan. And here again, we will find volcanoes.

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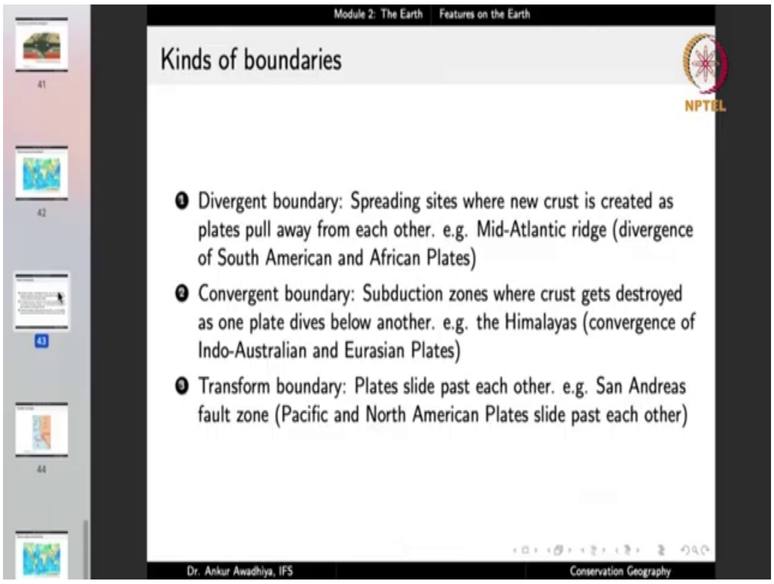

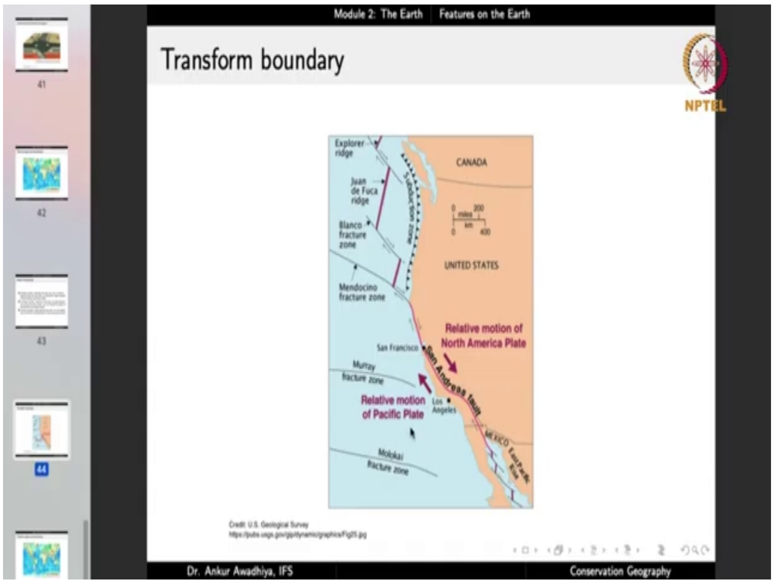

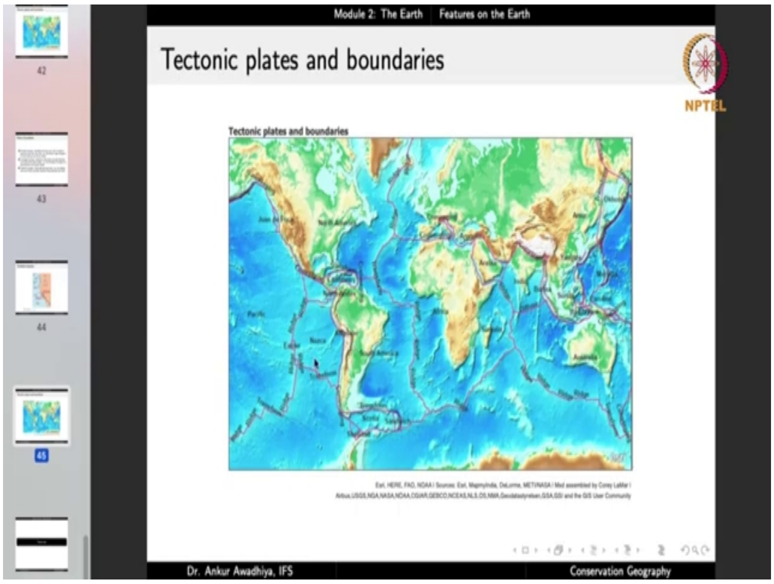

Another kind of boundary is a transformed boundary. Now, in the case of a transform boundary, the plates slide past each other. So, what is happening in the case of a transform boundary is that you have two plates that are together, none of them is going up or down, but they are just moving past each other. So, they are moving like this, past each other. So, this is a transform boundary.

Now, a transform boundary is typically associated with very massive earthquakes. Because the faults that get created in a transform boundary are typically very close to the surface. And so, you will find very massive, very destructive earthquakes. And a good example is the San Andreas fault zone, where the Pacific and the North American plates slide past each other. So, this is how it looks like.

So, here you have the North American plate, it is going like this in the southeast direction, the Pacific plate is going in the northwest direction. And so, this boundary between both of these plates, this becomes a transformed boundary. And this is associated with very massive and destructive earthquakes, like the Californian Earthquake. And in this way, we can look at the tectonic plates, their boundaries.

And we can make a sense of what the configuration of continents and oceans is today and how it is going to change in the future. So, we began this lecture by looking at the configuration on the Earth. And we saw that as much as 71 percent of the Earth's surface is covered by oceans, and only 29 percent of the Earth's landmass is covered with continents.

Then we saw that these oceans and these continents, they are dynamic things, they are not static. They have changed over time. Their configurations have changed through the course of history. Earlier, they were together later on this split, and they began to move. Now, while earlier speculations were made, such as that by Abraham Ortelius, but the first concrete theory was brought forward by Alfred Wegener in the form of continental drift theory.

Now, Alfred Wegener suggested that earlier, the continents were together in the form of one landmass called Pangaea. And all the oceans were together in the form of one great sea in the form of, in the name of Panthalissa. But later on, the Pangaea broke into two parts, the northern part became Laurasia, and the southern part became Gondwanaland. Later on, there were further splits.

And these continents kept on moving till we reach to the current configuration, and they are probably still moving. And he put forth a number of evidences to support his theory. Evidence is such as a very good jig-saw fit between the continents, especially when we look at the continents at 1000 fathom depths.

So, the boundaries match very well. Not only do the boundaries match very well, but wherever there is a match. The rocks on both the sides are also similar. Not only are the rock similar, but the sediments are also similar. Not only are the sediments similar, but it is also possible that we have source rocks in one location and placer deposits in other the location. Not only that, we also have evidences of common sedimentary rocks that got formed in both in two or more of these locations that are now very far apart.

We also have evidences of fossils that were found in these locations that are now very far apart, but earlier, were together. Now in this way, Alfred Wegener proposed that the continents move and when he was asked how do they move, he put forth two hypotheses, one is that they move because of tidal forces of the sun and the moon. And two is that they move because of centrifugal forces because the Earth is rotating.

Now, this is something that he called as the pole fleeing force. But when scientists calculated the amount of force that is required to move the continents, especially above and crushing the ocean floor, then it turned out that a very humungous amount of force and energy are required. Now, because Alfred Wagner was not able to prove the source of that force or that energy, so his theory, while it could explain a number of things, but it was not that much easily accepted.

Later on, people like Hess came up with a suggestion that probably it is due to the mantle plumes that the continents move. But over time, we also gathered newer evidences, we came to know that the oceanic crust is not static, it itself is moving, there is new, there is formation of new crust, especially in areas like ridges, the crust is not the same, the seafood is not a flat area, it also has a number of landforms. It also has hills and valleys and plains and whatnot.

And we also saw that the mid-oceanic ridges, they are having a parallel configuration or a symmetrical configuration of rocks on both their sides with similar edges, similar magnetic properties, similar compositions. And these came to be known because during the Second World War, and later, we were doing an extensive survey of the oceanic floors. These surveys go by the name of bathymetric service in which the depths of the ocean at different locations is figured out.

And also, magnetic surveys were done. The magnetic surveys were primarily done to ensure that when submarines go through an area they can easily be detected through changes in the magnetic field. The bathymetric surveys were done to know those areas where ships can get stranded. Because if the depth of the ocean is not great in a particular position, it is possible that a ship might collide there. They were also very essential to know the submarine routes that various military powers should be using.

So, this was an offshoot of the military research. But when we had these data, we came to know that okay, the sea surface floor is not a clean surface, there are a number of landforms. And by looking at the magnetic maps, we could see that okay, something fishy is going on here, because on both the sides, it looks like a mirror image.

Now, when we have these pieces of information, we can put them together to state that at certain locations such as the mid-oceanic ridges, the crust is getting formed. And how is it getting formed because the two oceans on two different sides, they are moving away from each other. And when these crust oceans are moving away from each other, there is a void that gets created.

And in this void, the magma comes it fills. And because they are moving away, then new magma comes it fills, then they are moving even further, new magma comes it fills, and so on. And whenever this new magma gets solidified, it stores the information about the Earth's magnetic field that was present at the time when the solidification happened. Now, in these locations, the crust is getting formed.

Another evidence was that if you move away from the mid-oceanic ridges, the rocks are older, if you move towards the mid-oceanic ridges, the rocks are younger. So, young rocks get formed at these locations and then they move away. So, that in the center you always have the young rock and far off you always have older rocks. So, we came to this understanding that okay, the crust is getting formed.

It is not that once the Earth solidified from the molten mass, it became a static thing. There are dynamic processes going on even today. But then the question was if new crust is being formed, but the total surface of the Earth is remaining the same, then what is happening with the excess crust and so we came up with another hypothesis that if there is, if we know that there is a formation of crust that is going on somewhere, at certain locations, destruction of crust should also be happening.

Now, this destruction happens in areas that are known as subduction zones. And a very good evidence for this is the fact that the oceanic crust at any location is not more than 200 million years old. The sediments are not more than 200 million years old, which means that all the older oceanic crust have been destroyed somewhere.

And typically, this destruction happens when two oceanic plates collide with each other or an oceanic and a continental plate collide with each other. Now, with this understanding, we next move to the theory of plate tectonics. Now, plate tectonics is the theory that states that the continents and the oceans they together are parts of a plate. A plate is a large-sized, irregularly shaped slab of rocks.

On certain portion of it, you can have continents on certain portion of it, you can have oceans, or you can have certain plates that are completely continental, certain plates that are completely oceanic. But these plates, more or less, they move as a unit, they move as a whole. Except in cases where these plates themselves break apart. Other than that, they will move as one piece.

Now, when you have a moment of these plates, then you can have different kinds of boundaries. You can have convergent boundaries where two plates come together, you can have divergent boundaries where the plates move away from each other, or you can have transform boundaries, where they slide past each other. Now, whenever you have such locations, you will get earthquakes.

And one way in which these plate boundaries were mapped was by looking at the locations of earthquakes and the locations of volcanoes. Typically, whenever there is a subduction of an oceanic plate or an oceanic crust, then the large amount of water that gets inside becomes vaporized, it has to come out and so there will be volcanic eruptions.

So, we can very easily find out those locations where these plates are going down into the asthenosphere. And similarly, in those locations, where we are having a divergent boundary or say a transformed boundary we will be getting earthquakes. So, by noting down these locations, we can figure out where these boundaries lie. And the plates have been mapped.

There are major plates, there are minor plates. And the movements of these plates determines the configuration of the continents and the oceans. So, they are very important when we talk about geography because they tell us the reason why we have a certain configuration and the reason why this configuration has been changing through time. So, that is all for today. Thank you for your attention. Jai Hind!