Earthquake Geology: A Tool for Seismic Hazard Assessment

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Lecture – 09
Plate Tectonics (Part II)

Welcome back so in previous lecture we discussed briefly about the interior of Earth and then we also talked about the isostasy and how are the plates different plates continental plate and the oceanic plate will be floating on the surface with respect to one another that is they are floating buoyantly in the asthenosphere. So we also looked at that the continental plate will be sitting quite higher as compared to the oceanic plate.

And the continental plate will have deeper roots because they are comparatively lighter with respect to the oceanic plate. Now moving further into the details for plate tectonics as I told that I will be bit quicker in this but of course the slides which we will be providing you will help you in understanding the overall process. And this part is important as I told in the beginning because this we are looking on the global scale the tectonic activity on the global scale.

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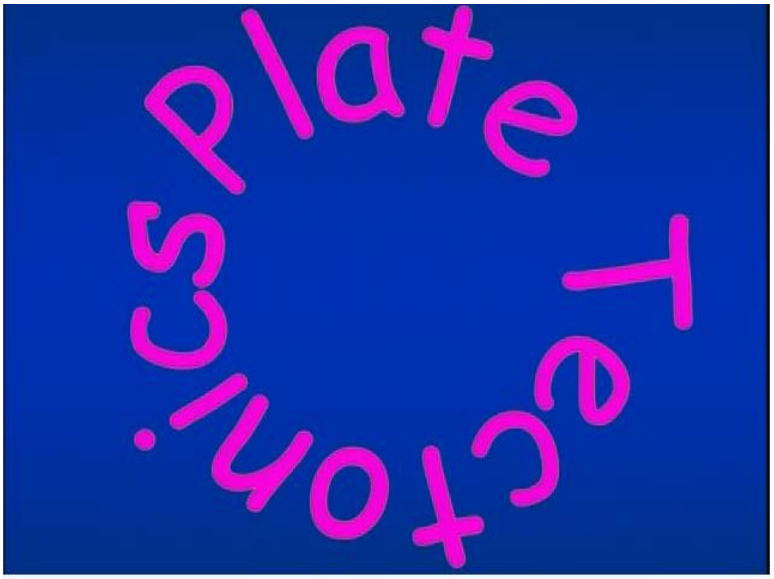

So coming to the plate tectonics.

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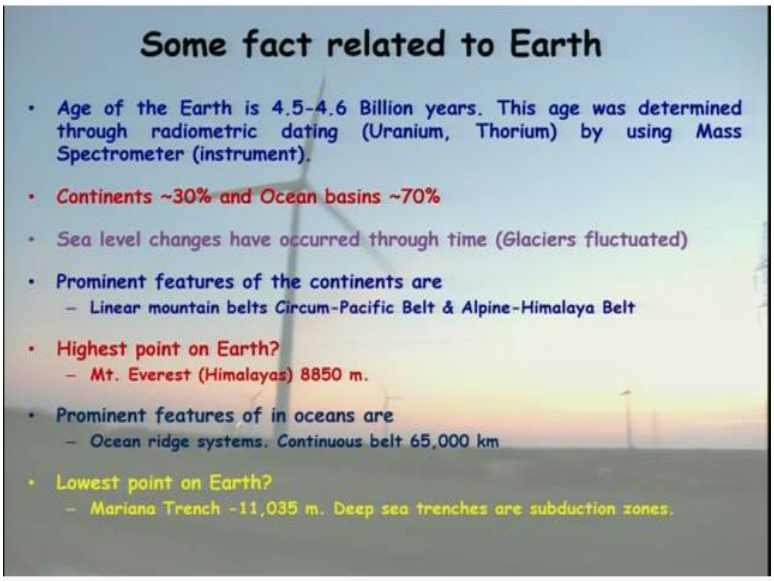

Before getting into the details of course the plate tectonics the continental drift has resulted into the overall globe or we can say the earth surface it has sculptured the Earth's surface in different forms and some of the facts which we would say that they are definitely related to the plate tectonic moments. These facts are related to the most elevated portion on the surface and the mostly deepest one along with that if we look at the view important points that we should remember is that the age of the Earth is almost like 4.5 to 4.6 billion years.

This was been gathered based on the uranium, thorium dating the radiometric dating and the overall continents okay. Either we talk about the continental plates or oceanic plate and the distribution of the continents is about 30% and the oceanic basin is almost 70%. So what we learn here is that most of the Earth's surface has been covered by your oceanic basins or ocean basin.

Then we also talk about that climate change of course this is related to that the sea level changes have occurred through the time and have resulted into the fluctuations of the glacial regions or maybe you can say the glacial limits. And the prominent features which you see because of the plate tectonics is the linear mountain belts, circum-pacific belt and alpine belt of Himalayas usually has been the most prominent one on the continent.

The highest point on the earth is the mount Everest the height is almost around 8850 meters where is the prominent feature of the ocean. Then we have the ocean ridges ridge system which continues for almost 65,000 kilometres. The lowest point on the earth is the Mariana Trench with an depth of about 11,035 meters. So we have like the landscape which has been formed on this globe because of the plate moments and then we have the highest point on the surface and the deepest one in the ocean.

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So with this if we look into the further detail that this person was the first to talk about the continental drift and at that time not many scientists believed what he is trying to tell us okay? So he suggested that the earth is as good as what we see based on the plate boundaries it is like an jigsaw puzzle. So in 1912 Alfred Wegener he was a German meteorologist, he proposed that the continents were all together like one piece and named them as Pangaea.

This means all land then drifted apart. So this continents or the landmass they drifted apart and reached their present location and the theory was termed as continental drift theory and as I told not many scientists believed what he said and what he wanted to that was of course an hypothesis. But he talked based on certain scientific parameters. Now if you see the globe here why it has been talked as in or say it as an jigsaw puzzle?

It was the boundary here which you see of this is your South America, so this is African plate and this one is South American plate. So if you fit this here it will exactly match the corners. Similarly, other plates are also showing some remnants of the outer boundary which matches with one another. So he that was what he suggested what initially all landmass was on existed here and then it started drifting.

And so this boundaries are indicative of the matching boundaries based on which it was been this was the first clue which people got that this probably were together. And in the beginning all continents were all together and that is what they termed as an Pangaea.

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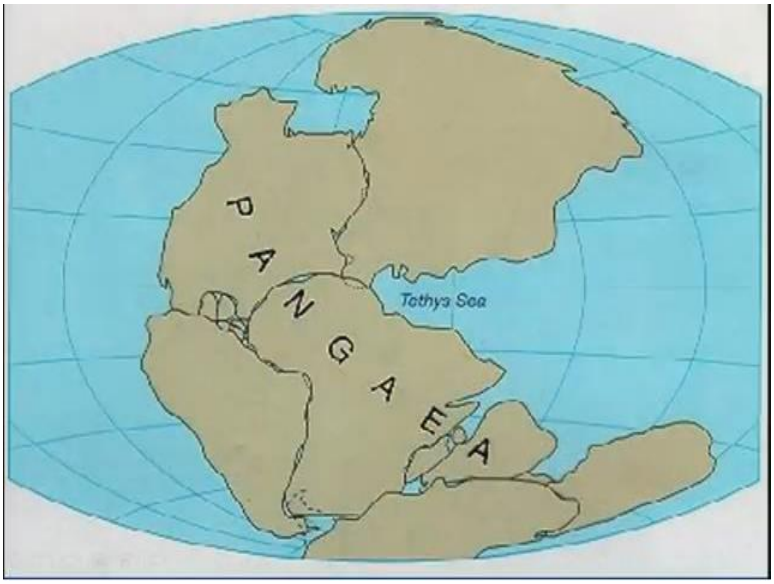

So moving quickly to the other part so this was not enough that is the matching the boundaries between the 2 plates. I was not enough to prove that they were once upon a time they were together.

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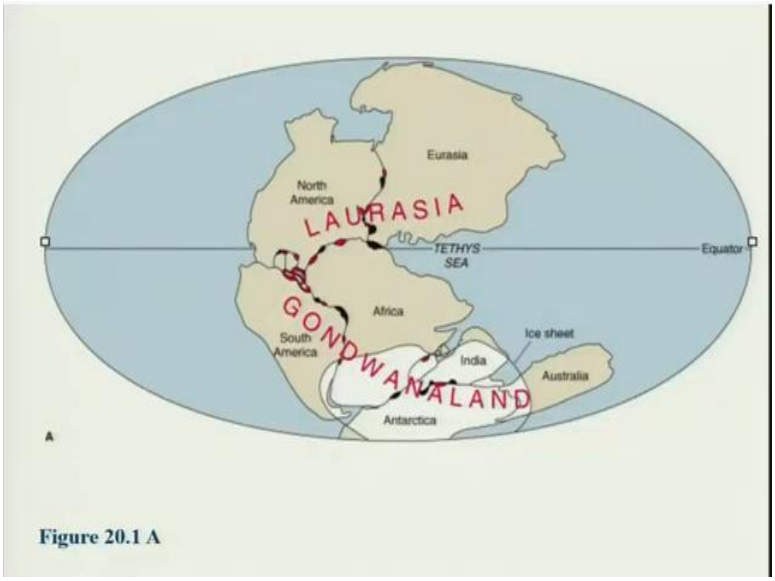

Figure 20.1 A

But of course then the geologists they started looking at more signatures that how we can prove or whether what has been thought that is the thought process is correct or not okay? So more theories came up and then they suggested that the landmass which we were together south of Equator were been turned as Gondwanaland which includes South America, Africa, India here, Antarctica and Australia.

And then the north of Equator was the Eurasia and the North American plate. So for us the this is the most important one because previously the India was located for far south of equator but now what we see is in the north.

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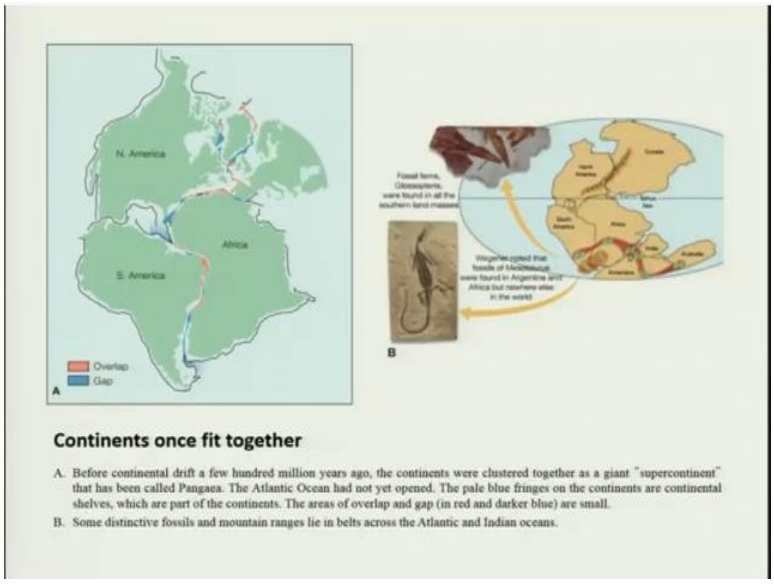

Continents once fit together

A. Before continental drift a few hundred million years ago, the continents were clustered together as a giant "supercontinent" that has been called Pangaea. The Atlantic Ocean had not yet opened. The pale blue fringes on the continents are continental shelves, which are part of the continents. The areas of overlap and gap (in red and darker blue) are small.

B. Some distinctive fossils and mountain ranges lie in belts across the Atlantic and Indian oceans.

So as I told that this was not enough that matching the boundaries that are the overlaps which were been looked at based on the when the outer margins that was not enough. So people started looking at the researchers started looking at whether if the same environment prevailed in this region then it must show some signatures of the environment and the flora and faunas. So they started looking for that and even the rocks okay and they found the similarity between that okay.

So they right now if you for example if you take India here and they try to see that what climate is here whether the same climate is existed existing here? The answer is no. But when they all were together that is in Gondwanaland then they were having almost similar climate.

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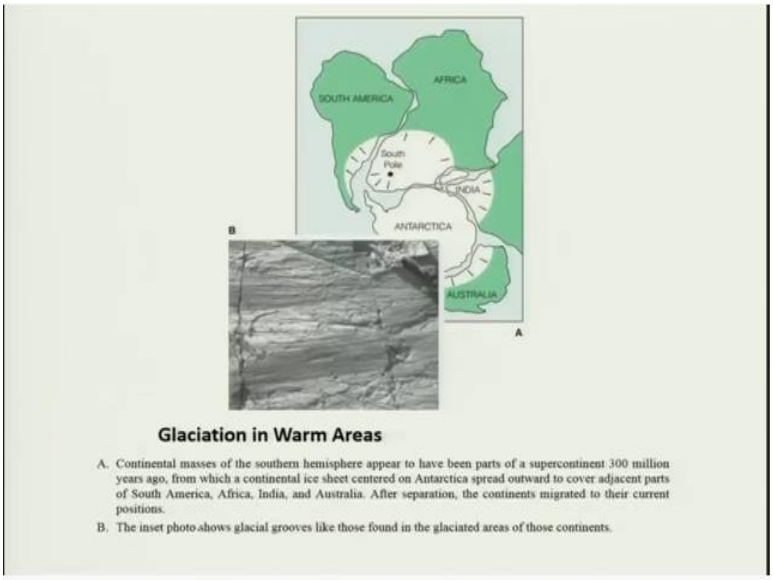

Glaciation in Warm Areas

A. Continental masses of the southern hemisphere appear to have been parts of a supercontinent 300 million years ago, from which a continental ice sheet centered on Antarctica spread outward to cover adjacent parts of South America, Africa, India, and Australia. After separation, the continents migrated to their current positions.

B. The inset photo shows glacial grooves like those found in the glaciated areas of those continents.

Further they also were able to identified because during that time also you had the glacial movements and all that. So this portions areas also experience the glacial moments or the glacial cover was there and large amount number of rocks were they indicated that they were glacial movements during that time. But right now there is no glacier in this portion of Indian subcontinent.

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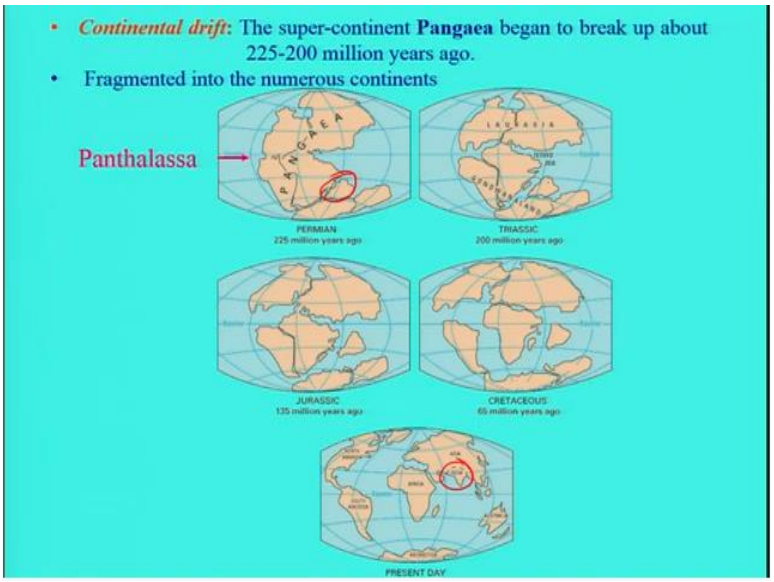

So along with the rocks and flora and fauna and other signatures like the outer boundary people started getting convinced about the theory of continental drift. So again the theory came up which suggested that is the same continental drift that the supercontinent Pangaea began to break around 225 million years ago and fragmented into numerous continents okay. So this is the time series diagram if you see what it starts from almost like Permian 225 million years ago.

And then how they separated out and finally what is we are having we see the present configuration. So India is setting much further north of the Equator. But if you see this one here it was located somewhere south of the Equator and one more thing that the researchers have named that the whole landmass were Pangaea whereas the southern one was Gondwanaland and they were classified as an Laurasia in the northern side of the Equator.

And the eastern portion of this land mass was been covered or engulfed by the sea Panthalassa and the sorry the western one and the eastern side was the Tethys sea and that is one of the reason why we say that we had Tethys sea this in the front of or the oceanic plate in the front of the Indian subcontinent in this continental plate and there was an closure of the Tethys sea when it collided with the Eurasia.

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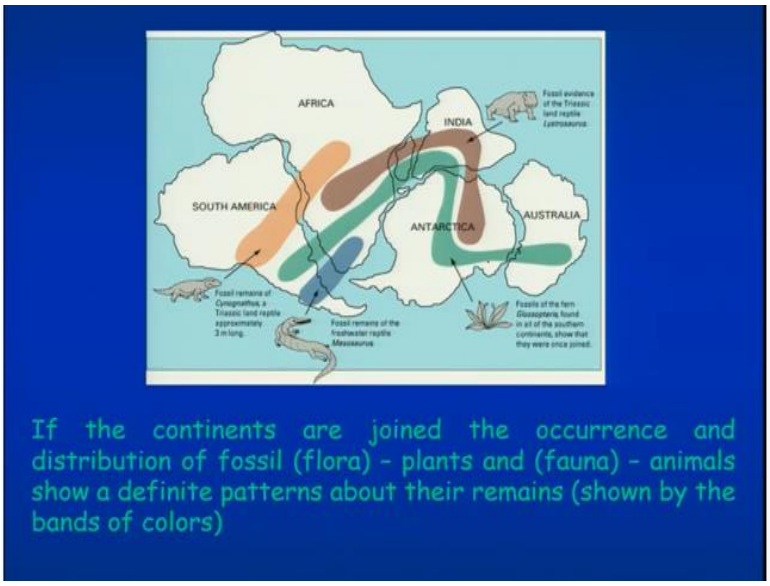

So this is the same one that only connecting or identifying the rock types were not so important were not the only points to be taken into consideration to prove that they were together along with the boundaries here the overlap between the boundaries of the 2 continent but also they looked at the flora and faunas which clearly indicated that these plates or the continents were together once upon a time that is almost like 225 million years back.

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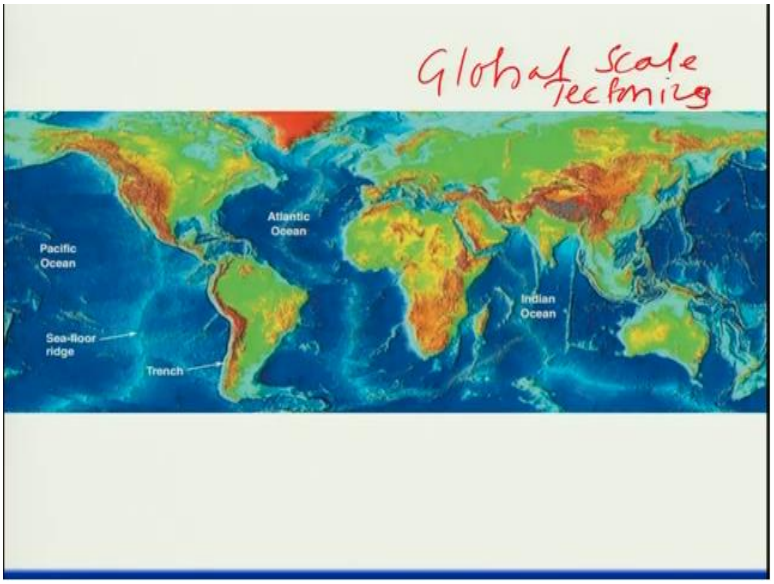

Now this is the present configuration of the distribution of the plates with respect to one another and the prominent features what we see along the plate boundaries are important for us to understand that what type of earthquakes? How deep? And how big will occur along this plate boundaries? And where exactly we are sitting from those plate boundaries. That part is most

important and when we get into the details of Paleoseismology**.** That is again what we are talking on we are talking of the global scale tectonics.

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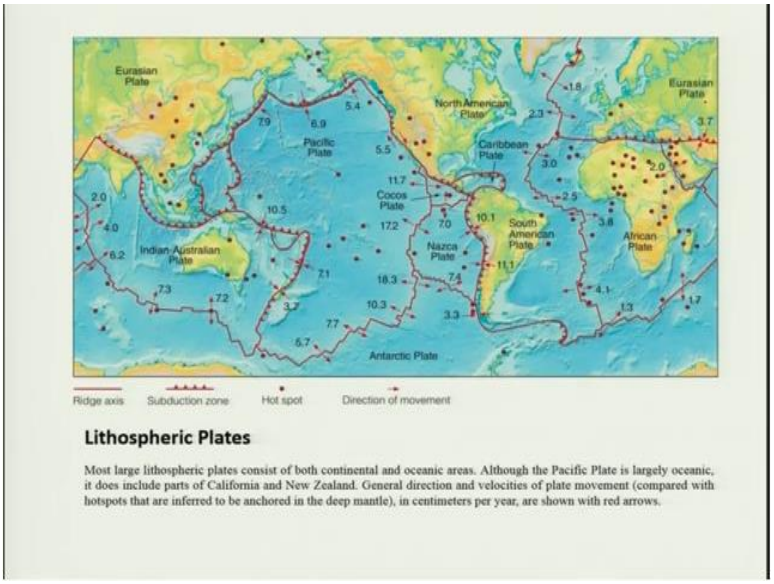

So this already I have shown this slide earlier. So we will quickly move to the further one. But in short these are all the plate boundaries and the moment or the type of the plate boundary either they are subducting or they are passing by with respect to one another or sliding pass by one another has been shown here and will come to this details hours later okay. So we have the collision zone here a subduction zone and then we are having subduction zone here. The major one which was responsible for triggering in 2004 Sumatra-Andaman tsunami is here and then in Himalayas many large magnitude earthquakes.

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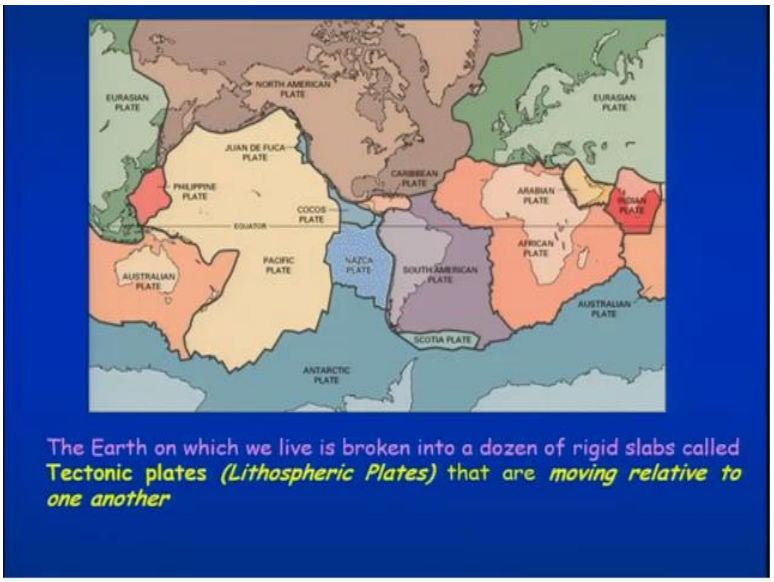

So we have more than a dozen of tectonic plates all over the globe with different configuration.

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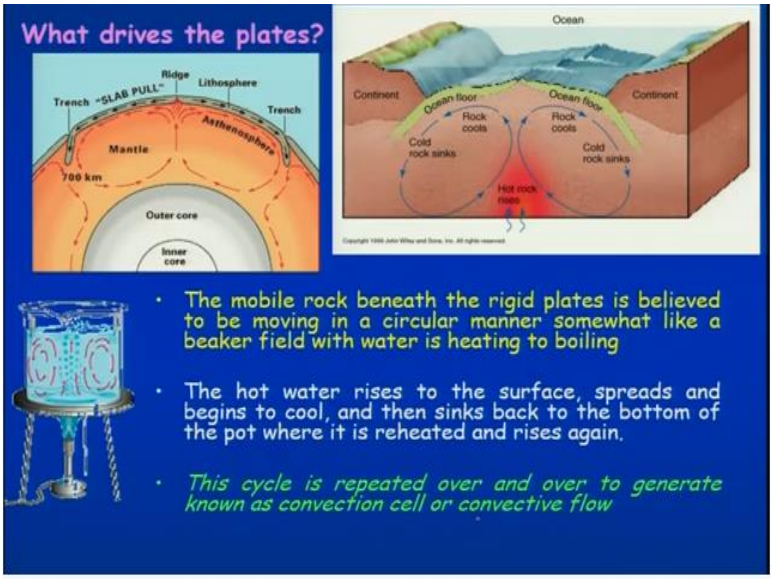

As I told in the beginning that for us interior of Earth is to some extremely important to understand that what exactly is the driving force behind the plate? And which unit or the layer of in the interior of Earth is responsible for the movement of the plates on the surface. So asthenosphere is partially molten and as we were talking about that there is a continuous heat which has been generated or which keeps generating the convection currents.

And this convection currents are responsible for driving the plates okay and bringing the hotter material on the surface and taking down the cooler one in form of either the lava itself or the

plates are subjecting below and getting melted again. And this can be well understood if you are having soap solution with the water with the beaker on a burner then the hotter ones will come on the surface cool down and again they will come down okay.

So this convection currents are similar to what we see here within the asthenosphere. This is responsible for rolling off the different plates neither it is continental plate or your oceanic plate. So this cycle is repeated over and over to generate which is known as convection cell or it is known as convection cell also the convection flow.

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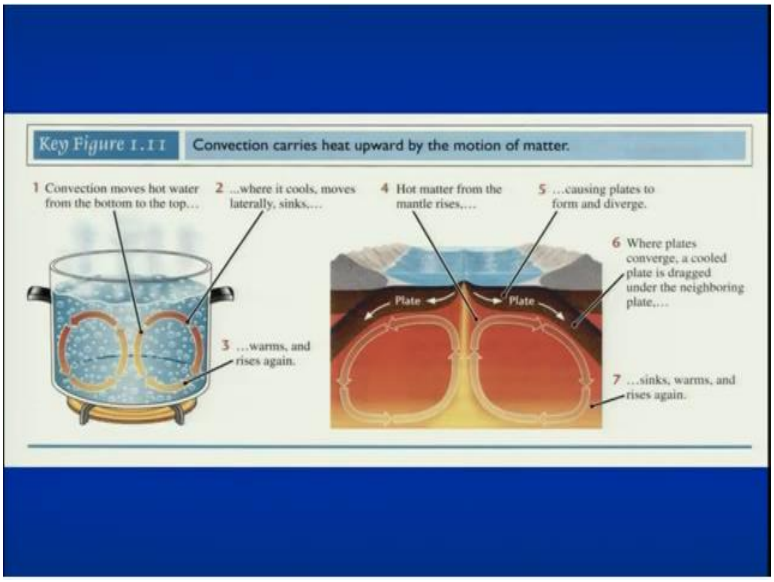

So the same example here. So when the soap solution of the matter cools down it is again goes back or sinks and further heated up and coming up to the surface and similarly this process is happening in the asthenosphere also.

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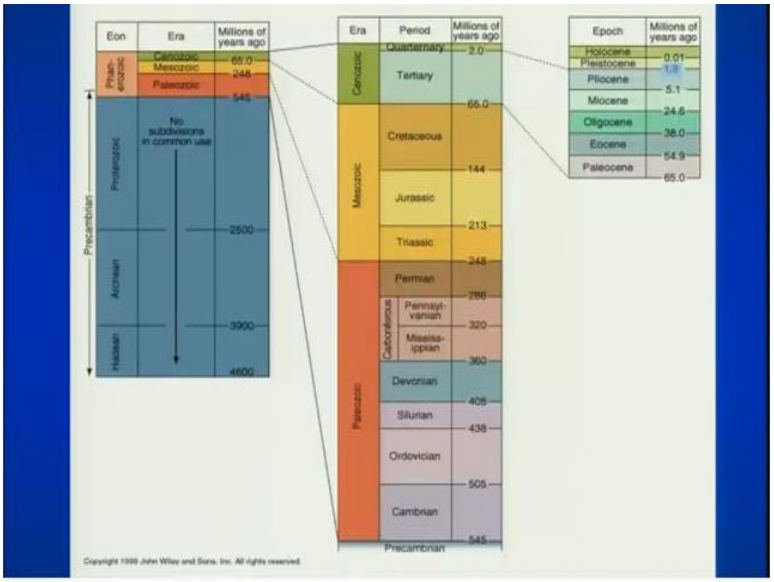

Now just to recall your point that because the next slide will show you that how things started moving at around 200 or 225 million years back and what we see the present configuration of the plates in present.

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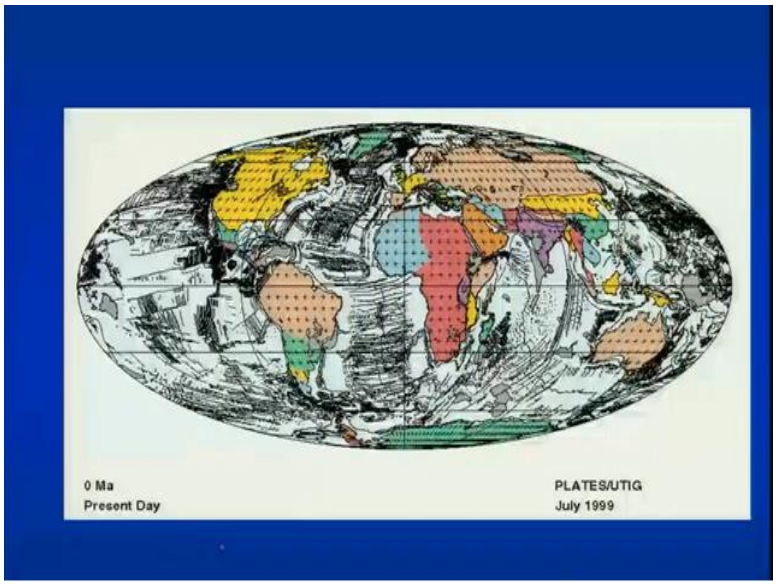

So there is a cartoon here and you have the age here which shows then how it started moving apart from a location but it was in the south as well as in the north here and as the plates started moving apart then the central portion started developing what we call the ridges the oceanic ridge right. So these are all spreading centers what we see here and finally what we see is the for us this is important the Indian plate which was located.

I will go back if you see slowly I am just moving back this map okay. So India is located here so this was like if you see the clock here it is 170 million years, then 180, 190 and then 200. So this was a part of your Gondwana and this is Laurasia and then started moving departed from the southern location and finally it collided with the Eurasian plate.

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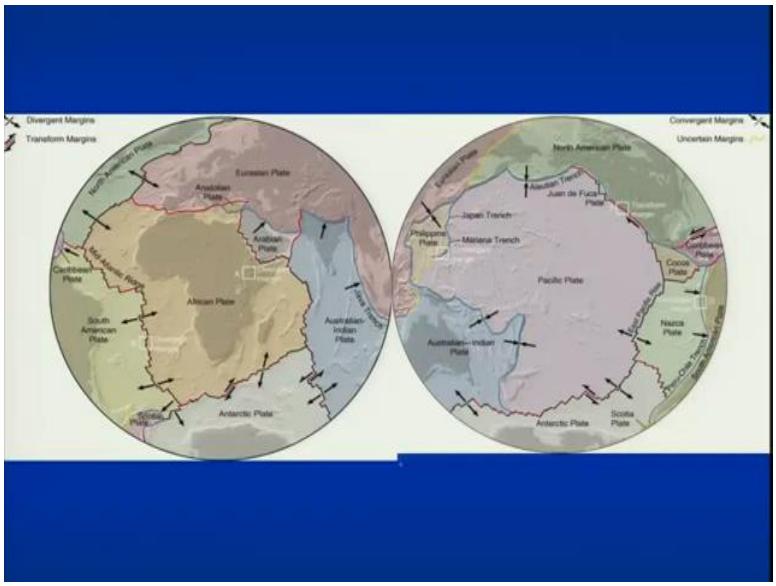

So if you unfold the globe and try to see the different type of boundaries then we have like divergent plate boundary with the 2 plates are moving away from one another. Then we are having transform margins or the transform plate boundaries where the 1 plate is sliding past one another as compared to this 1 okay. So this is Pacific plate is moving in this direction and the North American plate is moving in this direction.

So these are and similarly like here what we are having Caribbean plate and the North American plate. So at many locations you will have the transform plate boundaries and the divergent plate boundaries you will see or here what we were looking at where we have the African plate separated from the South American plate. So this is an portion of the Mid-Atlantic ridge okay. These are the spreading center this one and this is what we call the Mid-Atlantic ridge.

And then we have for us this part is extremely important this has been marked as an the subduction zone or the convergent margins okay where the plate is subjecting below the another

one. But here to some extent now what we can say and at present we have the collision which is going on between the 2 plates.

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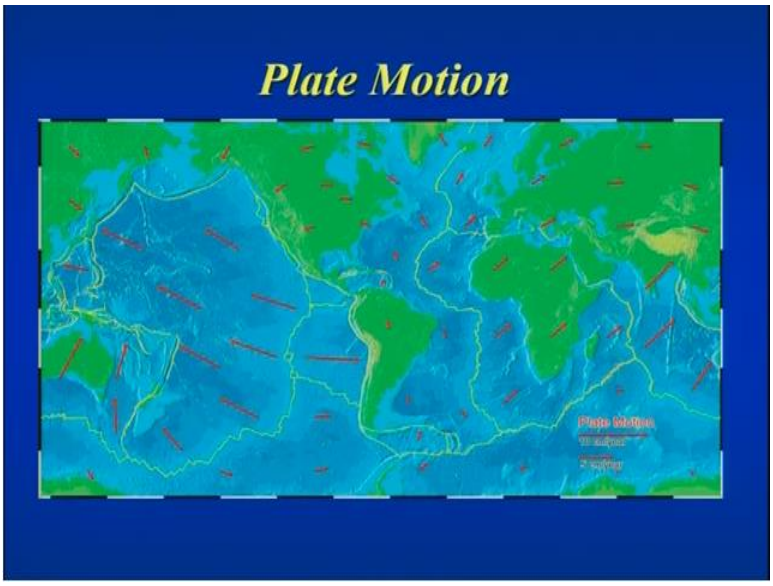

So plate motions we have been talking about that all these plates are moving at a particular velocity and this plate motion is now very well taken into consideration talking like in terms of the hazard related to the motion okay. Because more the plate motion more the deformation along the plate boundaries and can result into large magnitude earthquakes. So if you look at this is what shows that this is based on the GPS measurements.

So this arrow shows the velocity that is up to 10 centimeter per year and a smaller one has been given as an 5 centimeter just for a reference. So you can look at that this is almost 55 centimeter per year the Indian plate and then we have larger ones are here and this portions are all Mid-Oceanic ridges okay. And this one what I was showing here is your Mid-Atlantic ridge okay. So please remember this that the Mid-Oceanic ridge which lies between the African and the South American plate is your Mid-Atlantic ridge.

So this also helps in understanding that in which direction the plates are moving with respect to one another. For example, if you take here then it clearly shows that the Indian plate is moving in north east direction whereas the upper plate that is the part of the Eurasian plate towards the

China side and the Devonian side is moving towards east or south east and if you see here there are few more which are in the same direction but then it kept changing.

And then the boundary line between this 2 it will show that the plates are moving in different direction or almost in opposite direction okay and here to. Those 2 plates are moving in opposite direction. So they are drifting here what we see is colliding because this plate is going beneath this one, this plate is going beneath this one. So they are colliding and in some locations you will be able to find that they are just pass. So this is moving in this direction so here the movement is almost like transverse transform fall system.

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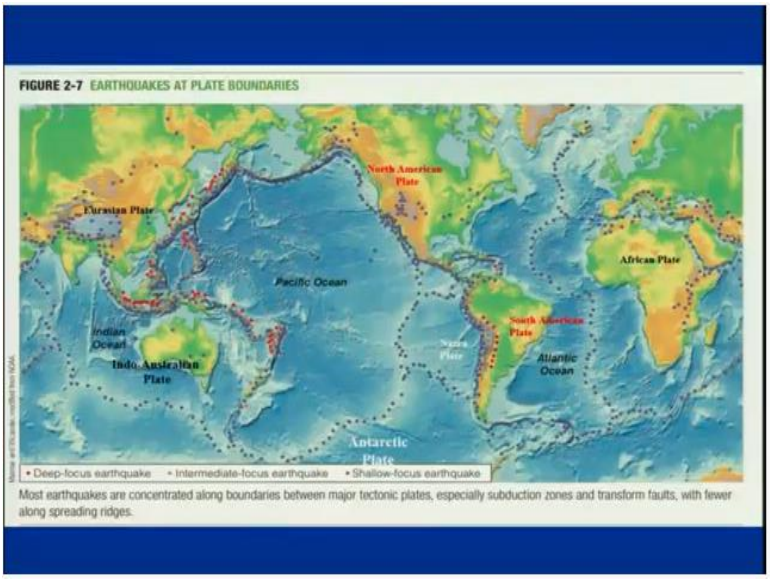

So as I told that for us it is important to know that what this plate boundaries are telling us that is on global scale then will come down to the regional and the local scale. But for us it is important whether the earthquake is deep focus earthquake we are going to experience or we are going to experience the intermediate focus earthquake or shallow earthquakes.

So if you look at the plate boundaries like here what we see is South American plate and then Nazca plate. There is an oceanic plate, there is an continental plate. So what we see the dots here the purple then we are having this brown and then we have the red one. So what we see here is that we have the shallow earthquakes, intermediate earthquakes and deep earthquakes okay. So all 3 were able to experience in this region.

That is the plate boundary that exists between Nazca plate and the South American plate. Similarly, not much of the activity has been seen here. But shallow earthquakes are been seen along this one and this is an important point which I will be showing you a clipping of this region where now this portion has started drifting or fracturing apart from one another okay. So there is an chances that not chances that we would say that it will take time to separate out this portion okay.

But it has the process already started. So this is an extensional regime where the 2 plates are moving up away from one another. Quickly coming to the portion here we have all mostly shallow earthquakes and the shallow earthquakes are more dangerous as compared to the deeper ones also. But when and mostly because the plates are the sliding past each other okay. So we have the transform plate boundaries here coming to this part of the Japan and all that.

And then coming down to the so here also they have mostly the shallow earthquakes. But in Japan we have the deeper ones also. So shallow, intermediate, deeper all and same remains the case where we talk about here that is the Sumatra-Andaman arc we have deep or shallow, intermediate and deeper one. Now I will just put an sketch here which will make things clear that if you take the plate which is going down and there is an overriding plate here.

So what we see is the earthquakes here. So we are having the earthquakes at the deeper part, we are having the earthquakes in the shallower one or the intermediate one. So these are the deeper one, shallower one and or intermediate and the shallower one okay. So these all 3 you will be able to see when you are having the subducting plate margins okay. So whereas in India the northern side mostly what we see is the shallow earthquakes.

Because mostly we are having the collision which is going on between the 2 plates that is the Indian plate and the Eurasian plate. So for us understanding the plate boundary is important because that will tell us that what type of deformation is going to be seen along these plate boundaries? And what type of earthquakes we will experience? Neither there is deep intermediate or shallower. So I will stop here and will continue in the next lecture. Thank you so much.