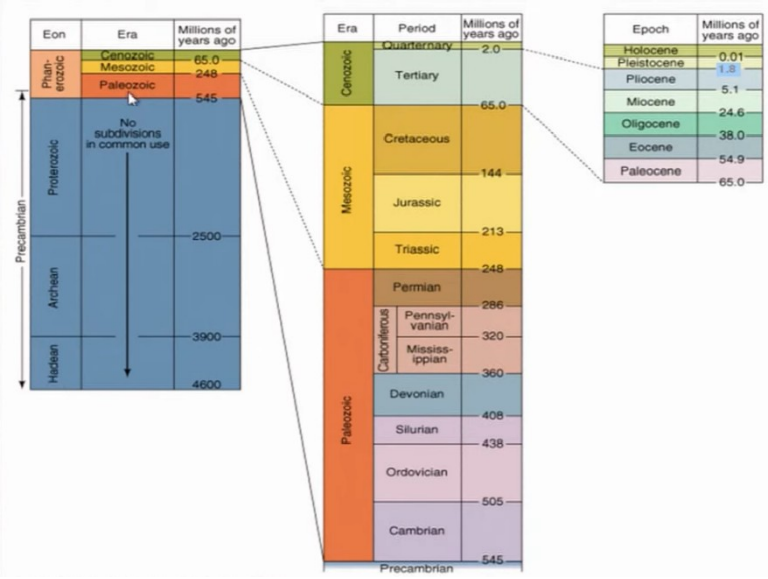
Geomorphic Processes: Landforms and Landscapes
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology – Kanpur

Module No # 03
Lecture No # 11
Interior of the Earth & Plate Tectonics (Part II)

Welcome back so in the previous lecture we discussed about mainly the interior of earth and we to some extend we talked about the plate tectonics what exactly it means is the driving force were we see the movement of plates different plates and because of the tectonic movement we have the different landscape and we also talked about the isostasy meaning.

Now talking in detail about the plate tectonics.

(Refer Slide Time 00:57)



We should have some idea about the background we should have some idea in background about the geological time scale. Now geological time scale quickly if we look at we discussed in one of the this slide in previous lecture with we were talking about the era period and then we talked about the epoch. And that was the slide which I was talking about this final figure. And so right now we are in Cenozoic era and period if we take, we are in quaternary period and further epoch if we take we are in Holocene.

So this is for what is the time scale but it goes back right up to like as old as you have in million years so from the onset of the earth's birth. So that is the what we have Precambrian and we have different eons and then we are getting into era's here. And then further era's what we saw or talk about is Paleozoic, Mesozoic and Cenozoic.

(Refer Slide Time 02:21)

So the plate tectonics mainly it started with the thought process of this gentleman Alfred Wegener who gave an idea about the continental drift. So looking to the outer boundaries of different continents is suggested that it is an very similar to the Jigsaw Puzzle. So in 1912 Alfred Wegener is German meteorologist proposed that the continents were all together like one piece and named that is Pangaea means all land.

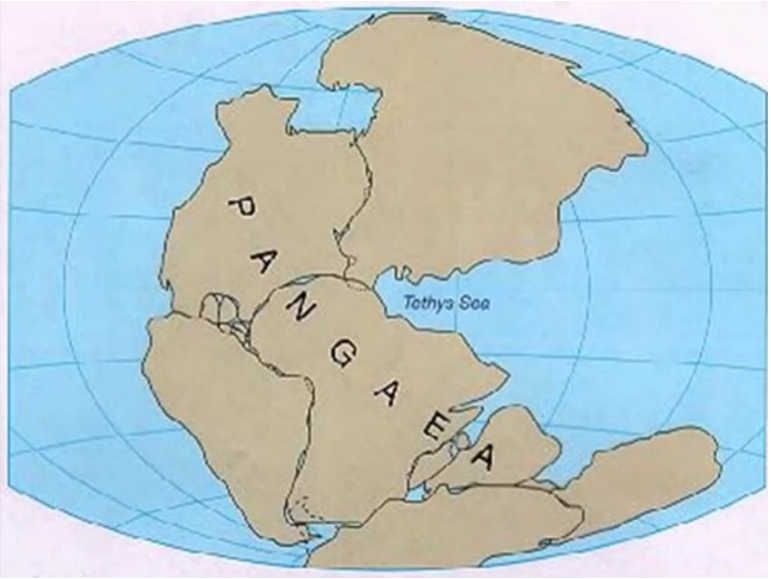
So it was one single land and that means that all continents which we see now were to were all together. Then the drifted apart and reached their present location and this theory was been termed as continental drift. Initially not all believed and this theory of continental drift and plate motion. But now we are sure, and it is one of the robust theory which was been proposed. So if we look at the earth globe, then what you see is the 2 continents the outer boundaries are very much similar that is Africa and South America.

So the line which is been shown here the red one this is the outer bond. So if you fit this and that is why it been said as a Jigsaw Puzzle. So if you if you fit this corner over here then it will fit exactly into this again. So this also suggests that the this 2 continent that is south America and

Africa were together in past geological time. And the moved apart and the landscape that is the ocean which was when formed at the later stage during the drifting of this 2.

Still they are moving away from one other and the crust which is this portion is the continental crust and the portion is closed to this is the oceanic crust. And similarly, you have on this side also. So this were together but now they are away from one another. So Alfred Wegener in 1912 gave the concept of continental drift and later on what we talk about the plate tectonics came in. So the whole landmass were was one. So one single Pangea and the all continents were together. So even in India was sitting south of the equator.

(Refer Slide Time 05:45)



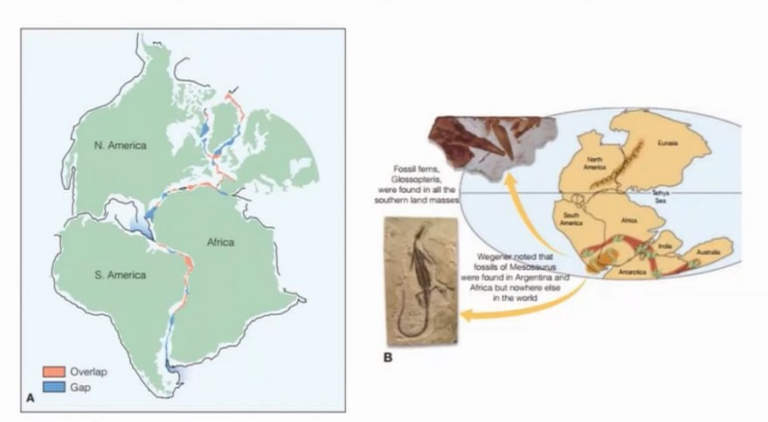
So all were together and this what we can say the Pangea the landmass of comprise of all continents was engulfed or encircled by a sea which was termed as Tethys sea. This is again a hypothesis in the and the theory which was given in the continental drift and the plate tectonics.

(Refer Slide Time: 06:11)

Figure 20.1 A

So the area north of equator was in named as Eurasia and south of equator was termed as Gondwana land. So the Gondwana land the India was a part of the Gondwana land and this was the again the portion of the Gondwana land. So the whole area if you look at the even the including the Australia, Antarctica, India, Africa and South America all were together they were south of equator. And north if you see they have not moved much but of course they have separated this is one is North America and Eurasia. So the Eurasia were we have the china and all that.

(Refer Slide Time 07:07)



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.

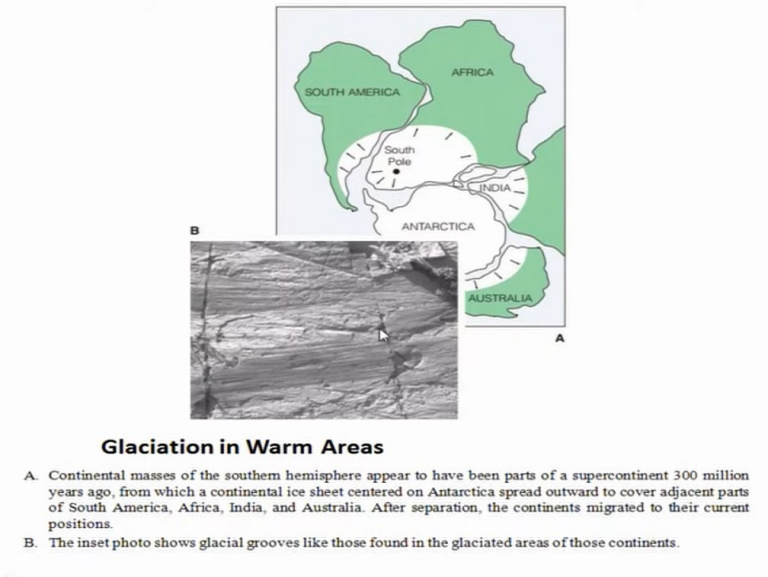
B. Some distinctive fossils and mountain ranges lie in belts across the Atlantic and Indian oceans.

Now that was not the only criteria which was enough to fulfill or to justify that this continents because the outer boundaries were together so they were they were together. But are the outer

boundaries fits are the similar to the one continent to another continent like South America and Africa and also the North America and the Eurasia so this continents were together. But also what they looked at is the floras and faunas and they identified that since this landmass was together they experience similar types of climate and the faunas are were also.

So the animal which were been identified were very much similar because of this similar environment or the habitat. So this is the another example which helped in understanding the that this **this** continents were together.

(Refer Slide Time 08:13)



Glaciation in Warm Areas

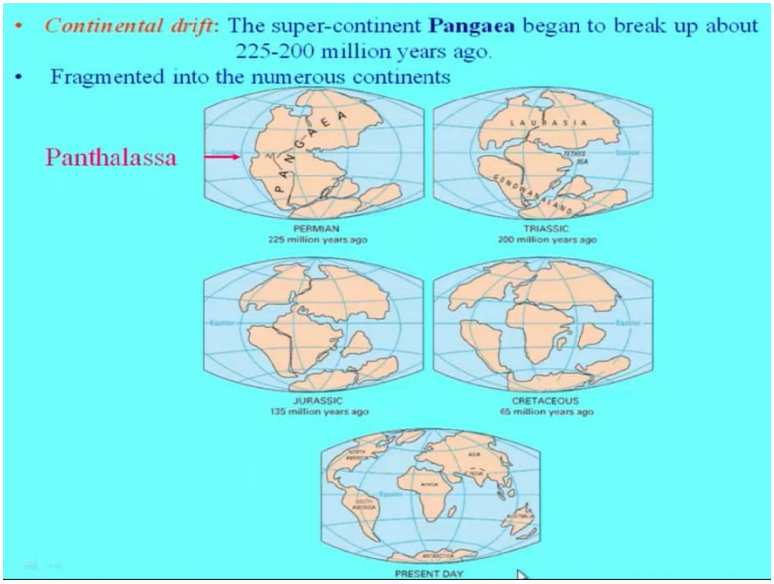
A. Continental masses of the southern hemisphere appear to have been parts of a supercontinent 300 million years ago, from which a continental ice sheet centered on Antarctica spread outward to cover adjacent parts of South America, Africa, India, and Australia. After separation, the continents migrated to their current positions.
B. The inset photo shows glacial grooves like those found in the glaciated areas of those continents.

Another example was the rocks which where been found from this portion of different continents were very much similar. So the glaciation in warm areas so this again helped the inset photo shows glacial grooves like those found in the glaciated areas. But now if we talk about the India are all even this region, we do not have the glaciers. But the initial time when the they were together the climate was different and this area was under glaciation.

So Australia, Antarctica, India then you are having the Africa which was experiencing and having the South Pole this whole area and even the South America this whole region shows the evidence of glaciation or the movement of glaciers during warmer periods. Because this type of striation or the features or the grooves you will be able to see in the glacial regions. And when the glacial moves it will result into the formation of such grooves. And we are talking about the

incoming lectures the glacial landscape you will come and you will able to understand about the how this features are formed when the glacier moves.

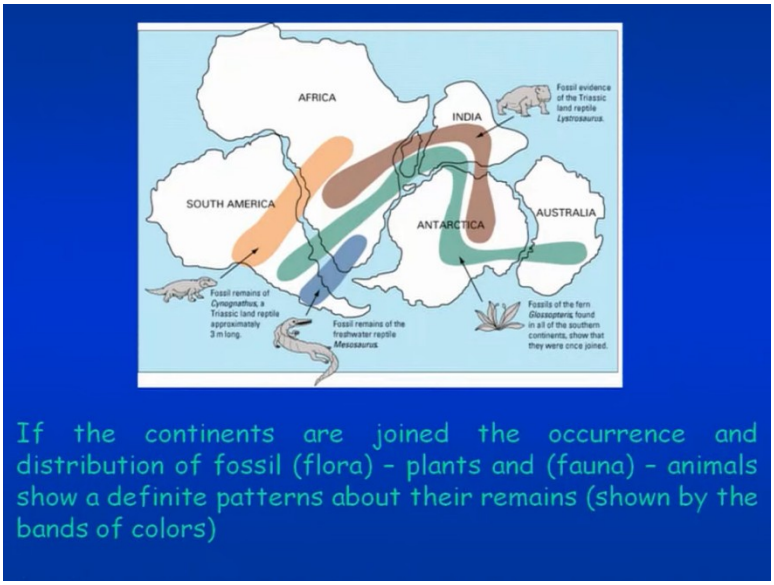
(Refer Slide Time 09:50)



So continental drift the super continent Pangea began to break at about 225 to 200 million ago. Fragmented into the numerous continents this is what it shows so it is started with they were together at around 225 million years ago and slowly they started drifting away from one another. And this drifting you can see that the India moved from south of the equator and it travels. So it traveled a huge journey and similarly other continents also drifted apart from one another and this is what we see the present day.

So you have the Eurasia which is been shown here and then the fragmentation of the Gondwanaland which is been shown here is been present situation what you would see is this one. And still these plates are in motion.

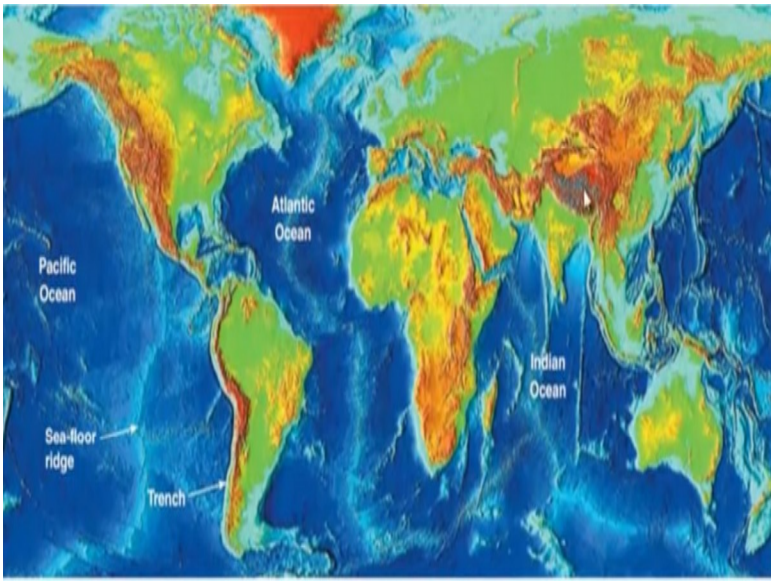
(Refer Slide Time 10:56)



So as I was talking about that they not only the rocks or the signature of the neglecter movement were enough and not only the boundaries which were matching that is Jigsaw Puzzle was enough to prove that this continent were together. But along with that the occurrence and the distribution of fossils and plants that is flora and fauna animals shows that they definite patterns about their remains as shown in the color bands here.

So this different animals and the floras they showed a very similar pattern in all this continents. So this also helped in proving that yes of course this continent experienced a similar climate once upon a time in the past in the geological past when they were together in the southern hemisphere..

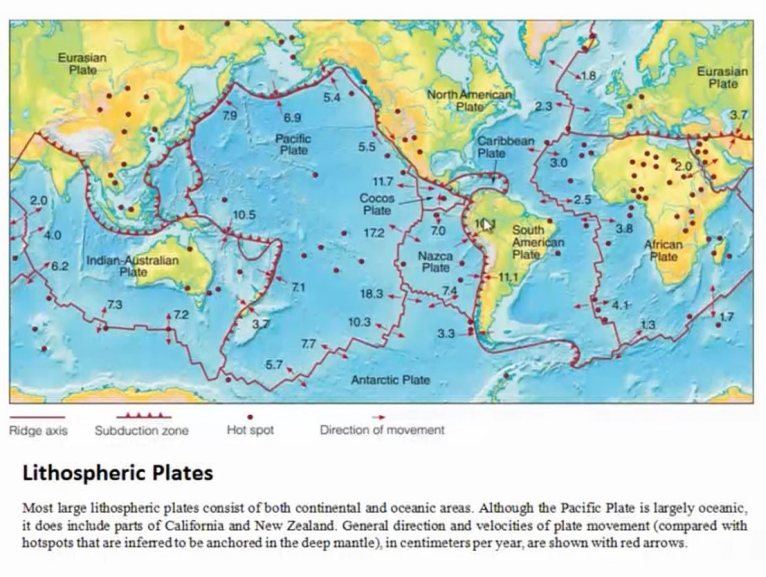
(Refer Slide Time 12:01)



So this is the present configuration which you can see here so you have the continental crust which is been shown in green and the darker portion of the of reddish or the brownish are the hilly elevated portions. Like here we have in this South America we have the mountains here along the North America and we have the mountains here in the and the South Africa and then we have the Mediterranean mountains and the Himalayas in this region.

And then finally we see what we have the china. So this is the and in the ocean part this all this mid oceanic ridges which keeps on moving some part from one another and keep adding the crust. Whereas this portion of the plate is subduct below the this the continent the continental crust. So we will talk in detail further of this portion so let see what we have more.

(Refer Slide Time 13:20)



Lithospheric Plates

Most large lithospheric plates consist of both continental and oceanic areas. Although the Pacific Plate is largely oceanic, it does include parts of California and New Zealand. General direction and velocities of plate movement (compared with hotspots that are inferred to be anchored in the deep mantle), in centimeters per year, are shown with red arrows.

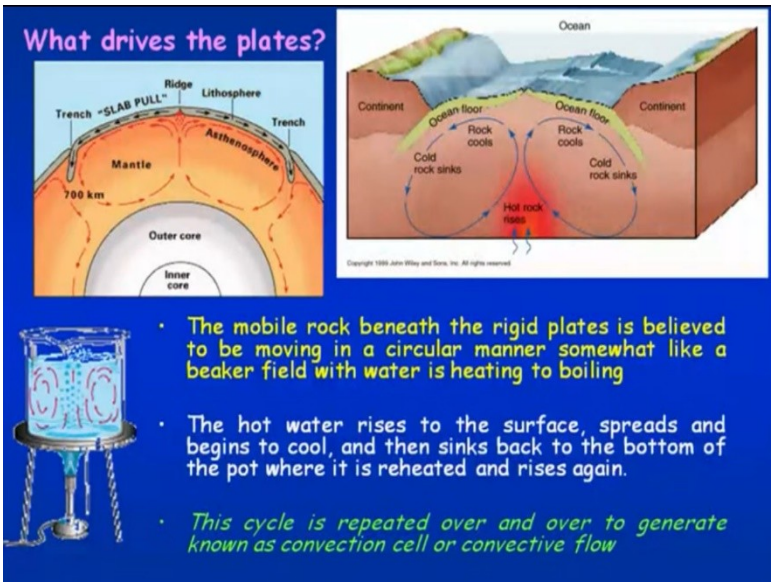
So this shows the arrows shows the movement of the different plate with respect one another that is towards it moves of away like what is been shown here. So this portion from this portion is 2 plates are moving away from one another. Whereas here the plate is colliding the 2 plates are colliding so one plate is moving in this direction and other opposite to (()) (13:50). So they are colliding with respective to one another and then this is what it is been termed as subduction zone. And then we have the location of hot spots were the plume activity is active and this arrows which are been shown in this direction of the of the movement plate movements.

(Refer Slide Time 14:14)

So we have like dozens of plates which are moving relative to one another and as we are talking in the previous slide that they collide that this is the subduct it goes one beneath the other plate

with respect to the other or they move away or they slide even pass by with respective one another. So one here this plate that is an pacific plate is moving in this direction and the north American plate is moving in this direction.

(Refer Slide Time 14:51)



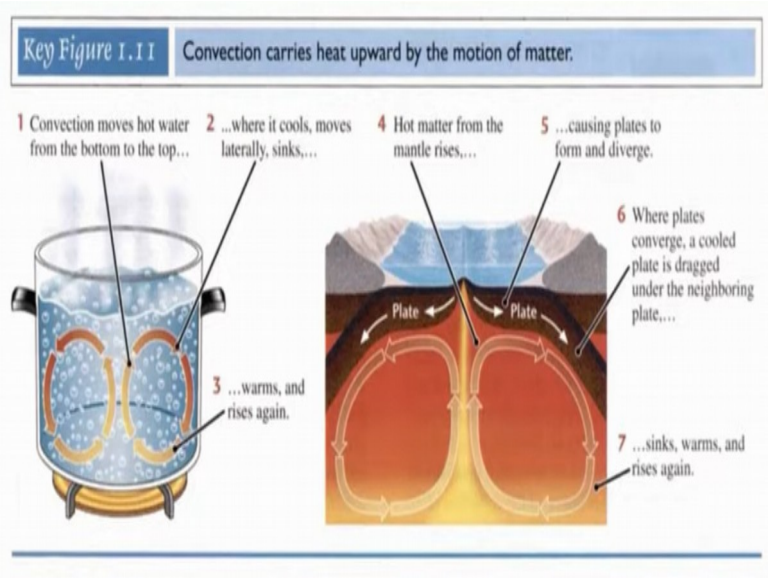
So what drives the plate as we have been talking about the convection currents are the most important player that moves the oceanic plate and the continental plate. So the convection currents which are developed because of the heat which is in transferred not only from the interior of earth but also because of the decay of the of the radioactive minerals or the rock which are comprised of the radioactive minerals they keep on adding the heat in these asthenosphere.

And asthenosphere being partial molten it will keep generating the convection current very much similar to what you see the figure here that if you are having a soap solution and if you if you keep heating the with the burner at the below and in the in the soap solution the beaker the hotter particles will come to the surface cool down and then goes back. And this is because of the convection currents which have been developed here.

So this is these asthenosphere is very much similar to this. So the hot water rises if you are having soap solution hotter as the ice on the surface spreads and begins to cool and then sinks back to the bottom of the pot where it is reheated and rises again. So similarly if you take in terms of the crust that is either it is oceanic crust or the continental crust it will go back in to the asthenosphere melt and will rises again back to the surface. So new crust is been added and crust

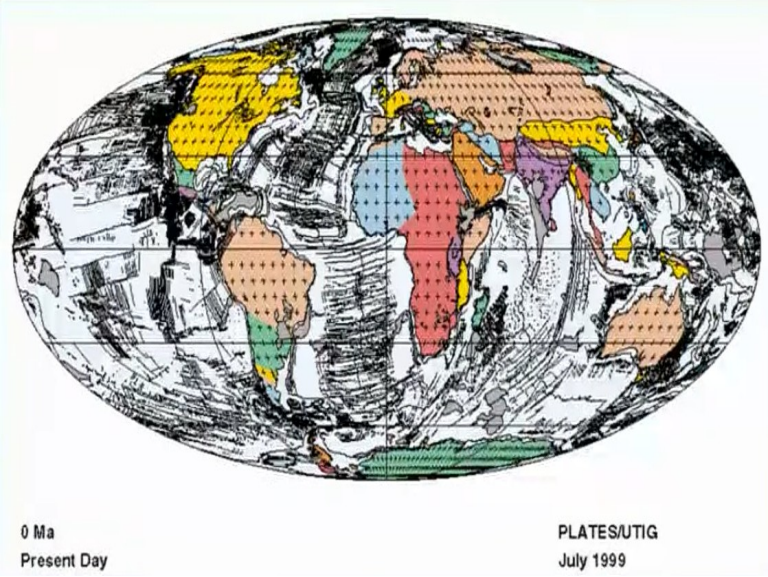
will be destroyed also. So this is this phenomena or the process is very much similar to what has been shown as in the in the soap solution in a beaker.

(Refer Slide Time 17:18)



So this you can you can remember that what is the reason for the movement of the plate and this is been shown here similarly. So we have the convection currents which are developed within the earth's surface and which is very much similar to convection currents which are developed or the convection more motion which is been developed in a hot water. When it is heated and if it is with the soap solution.

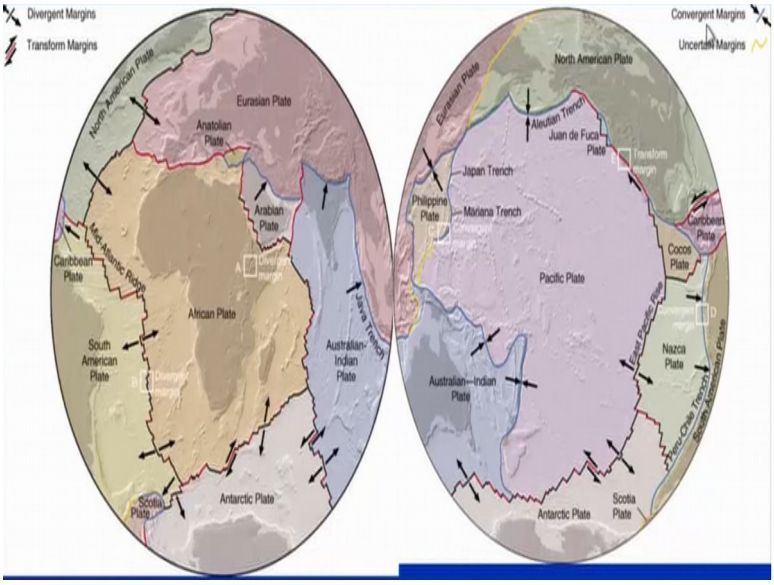
(Refer Slide Time 17:49)



So further with this understanding of the era period and the epoch please have a look at this were on this side it shows the time and the movement of the of the plates and you will able to see that as the plates are moving away from one another in between you see some horizontal line which are come up. Those are the signatures of the mid oceanic ridges. So I will if I just switch it back then you see that how the continents are going back into their original locations.

So and the on the left hand side you see the times scale which reduces. So 150 million years then 160 and then finally if you go back up to 200 or so. So they were together and then they were started moving. So I am just playing it again slowly and you can understand that how the different continents are moved away from one another and the India has finally reached that is in purple and collided with the Eurasia.

(Refer Slide Time 19:06)

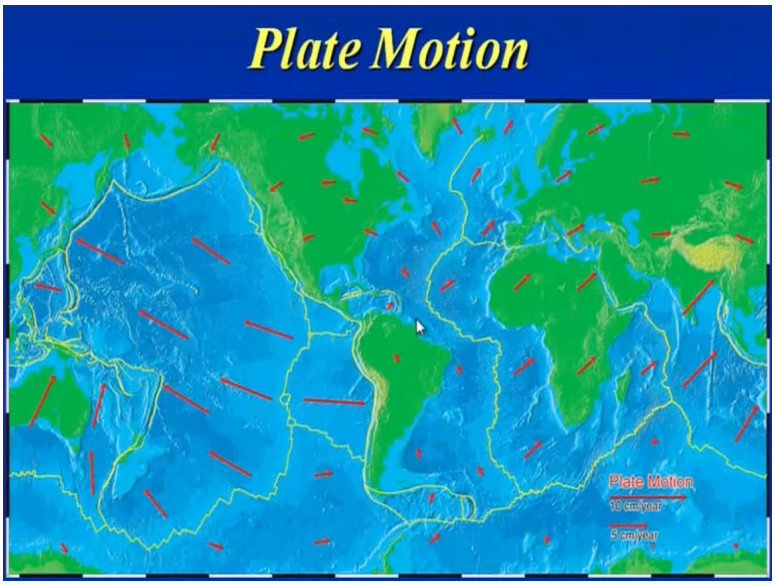


So this is what we see is the present configuration of with respective of the plates that is with the respect one plate and with the another one so we are having the and this arrows which had been shown here are the arrows of the direction of the movement of the plates. So as some places the plates are moving in opposite direction and some plate its plate places they are sliding past each other and some places they are subducting below one another.

So this is the portion and then we have what we can term this as an where they are sliding past each other terms are transform for margins were they are moving away from one another have been termed as divergent margins and then where there is not subduction one plate subducting

below or going below the another one and we termed this as an convergent margin over the subduction zones.

(Refer Slide Time 20:20)

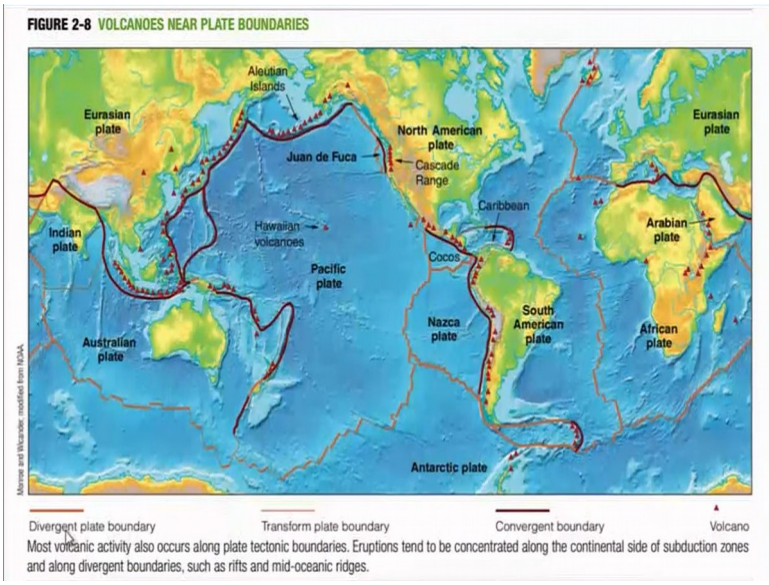


So plate motion this helped and this is has been done based on the GPS measurements ok. So all differential GPS have which are been put across the continents helped in understanding that how this plates are moving and what is the velocity of different plates. So the red arrows which you see here are the velocity arrows and the length here which has been shown is 10 centimeter and then or 10 centimeter per year and it smaller one is 5 centimeter per year.

So you can judge that the Indian part is almost more than 5 centimeter. So it is around 55 centimeter per year the Indian plate is moving towards Eurasia and north-north east direction. So these are the arrows with respect to north and the arrow length shows that how much is the movements. So this is almost like 50, 55 mm or but it is not same all along the front or the all along the collision zone here.

But it is it varies but maximum if you look at is around 55 millimeter that is 5.5 centimeter per year. And in some locations if you see they are almost like over here this is close to 10 centimeter that is 100 millimeter per year. So this plate motions were obtained from the GPS measurements which keep on monitoring and measuring the coordinates 24 7 and since the plates are moving so the coordinates keep changing.

(Refer Slide Time 22:26)



Now another important point which is which we should remember is the occurrence and the distribution of the earthquakes and the alignment of the earthquakes along a specific belt. So if you look at the cursor which I am moving here the earthquakes are been seen all very much aligned along the plate boundaries. So the red ones are the deeper earthquakes. So it shows here that the red ones are the deeper focus earthquakes and then we have the intermediate and the shallow.

So these are the plate boundaries where mostly we see shallow earthquakes. And shallow earthquakes are also been seen in were we are having the plate relationship between the Eurasian plate and the Indian plate. So we have shallow earthquakes we have shallow and deep earthquakes along the Sumatra trench. And then we have the shallow as well as deep earthquakes over here where we have the Nazca plate and we are having the South American plates. We have shallow intermediate and deep.

So we have all type of earthquakes here but as compared to this because the configuration or the relation is different over here if you compare with the Indian plate. So the Indian plate relationship is the collision. So initially it subducted but now it is the collision, so all are shallow earthquakes. But here the Nazca plate that is an oceanic plate is subducting below the South American plate.

Hence what we see is the shallow earthquakes at the contact but at the plate is going deeper towards the open continental plate it shows intermediate as well as deeper earthquakes. So, important part is that the seismicity or the earthquakes are very much aligned or follow the plate boundaries. That is the plate boundaries marked between the 2 plates and also the spreading center.

So these are all spreading center where we are having very shallow earthquakes. This is also again the spreading center between the 2 and this what I was talking about when the cartoon which was been shown in the previous slide where the continents started drifting from the southern hemisphere and in between we saw some black lines horizontal line which are coming in. These are all spreading centers which also shows the aligned occurrence of the shallow earthquakes.

There is similar figure which shows the plate boundaries and the bold lines and the distribution of volcanoes. So again, this is an important slide to remember that we have the different boundaries or the plate boundaries where we are talking about the divergent plate boundary, transform plate boundary, convergent plate boundary. And the previous slide we were talking about the distribution of the earthquake and in this the distribution of volcanoes ok. So volcanoes are been seen where we have the subduction zones.

That is 1 plate subducting below the another one. So this is the most important one so the maximum amount number of volcanoes if you see are been seen along the subduction zone that is in Sumatra in the areas of Taiwan, Japan and then you are having the North America and the South America as well as in some locations what we see in the Arabian plates. We have the location of the volcanoes that is in South Africa and all that. So I stop here and we will continue in the next lecture thank you so much.