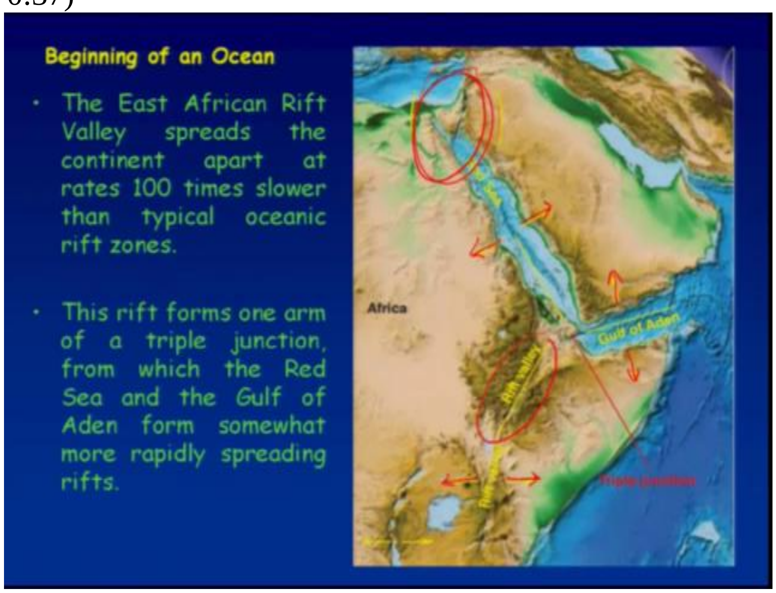
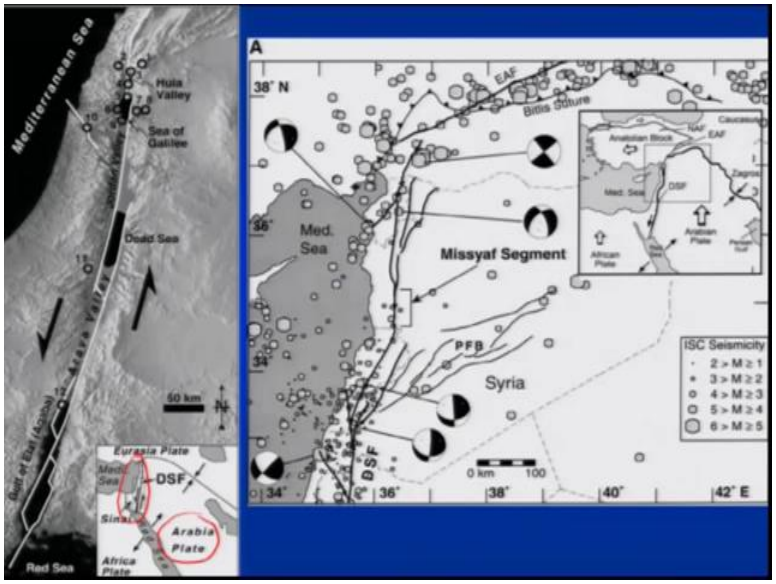
Earth Sciences for Civil Engineering
Professor Javed N Malik
Department of Earth Sciences
Indian Institute of Technology Kanpur
Module 1
Lecture No 5
Plate Tectonics and Continental Drift (Part-4)

Hello everybody, welcome back. During the last lecture, we talked about the plate tectonics. We were talking about the different types of plates plate boundaries in particular and we left this the triple junction part. Now let us move ahead and then talk about that what exactly is happening in the dead Sea region because of the triple junction and the plates which are moving apart one another.

(Refer Slide Time: 0:37)

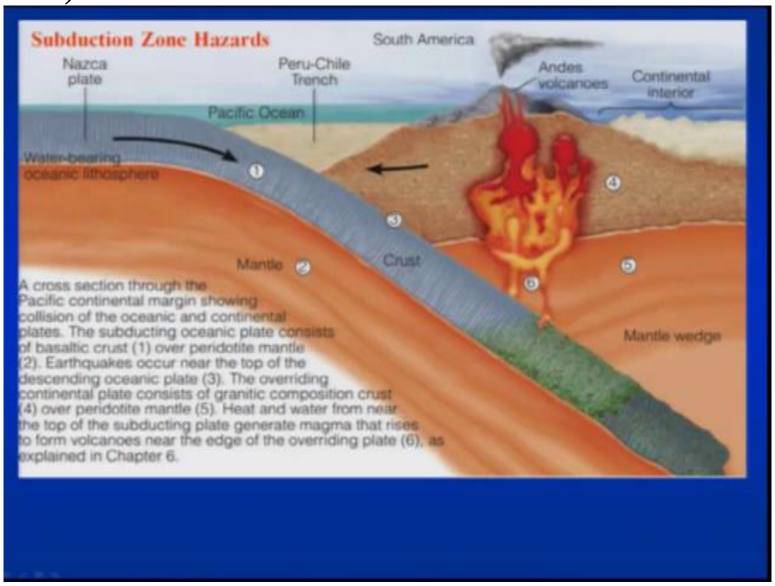




So this is the region which is opening up and there is a huge valley which has been created and because of that you are having the side slip motion. This is, we will talk about what is side slip and all that. But it is a lateral movement which is taking place in this region particularly because of the differential movement of the plates here. So this is the red Sea, we are having the Arabian plate which is moving in this direction and then African plate which is moving in the south-western direction.

And we are having this zone which is the dead Sea fault zone which is having an almost a left lateral movement here. So we will talk about this. But these are these type of zones which are which are seen on the Earth's surface and these are developed because of the differential plate motions on the earth.

(Refer Slide Time: 1:42)



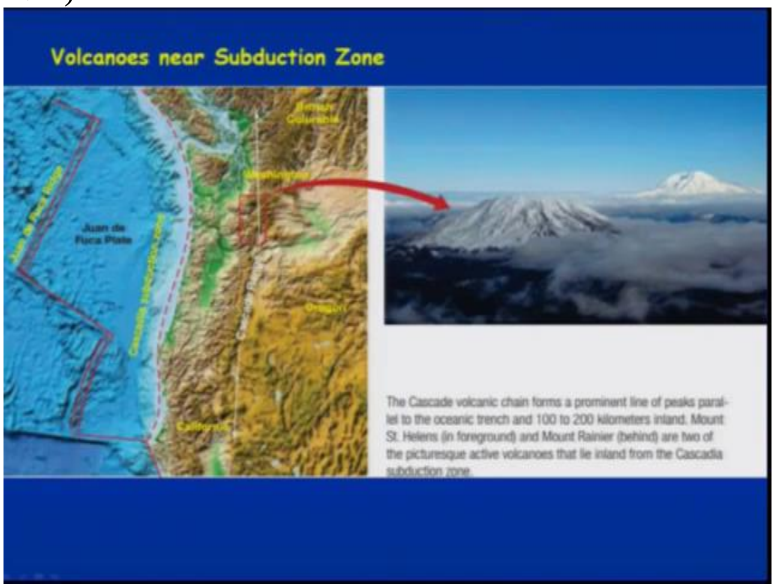
Now coming to the subduction zone hazard which is extremely dangerous and this type of zone is as I told on that day that this subduction zone is present along the south-eastern margin of Indian subcontinent that is the Andaman Sumatra Andaman subduction zone. And here basically what we see is that we will have the volcanic eruptions on the overriding plate and we will have a lot many like type of earthquakes which we classify usually the deep earthquakes or the shallow earthquakes or the intermediate earthquakes.

And hazard is tremendous because the hazard will not only will be not only because the earthquake, mega earthquakes which are above 9 magnitude or so but not always it will be 9 magnitude but these are the regions which are capable of producing the mega earthquakes on this earth’s surface and the largest one which occurred between the Nazca plate and the South American plate was the 1960 Chilean earthquake which resulted into the mega tsunami also.

And then so far if we take in terms of magnitude, that was the magnitude of 9.5. And then what we are having, the next one is most of the scientists, the scientific groups, they list the Sumatra Andaman earthquake of 2004 as one of the largest, the second-largest earthquake on this earth so far recorded and that was of magnitude 9.3. So we have the mega earthquakes and we have also the secondary effect which is what we call the tsunami generation from this. So this subduction zones are extremely dangerous in the sense if they are close to our subcontinent.

So definitely we have 2 types of subduction zones in India. We are having, in the eastern side we are having Sumatra Andaman subduction zone and in the western side we are having Makaran subduction zone. So we are being trapped from both the sides here in the sense.

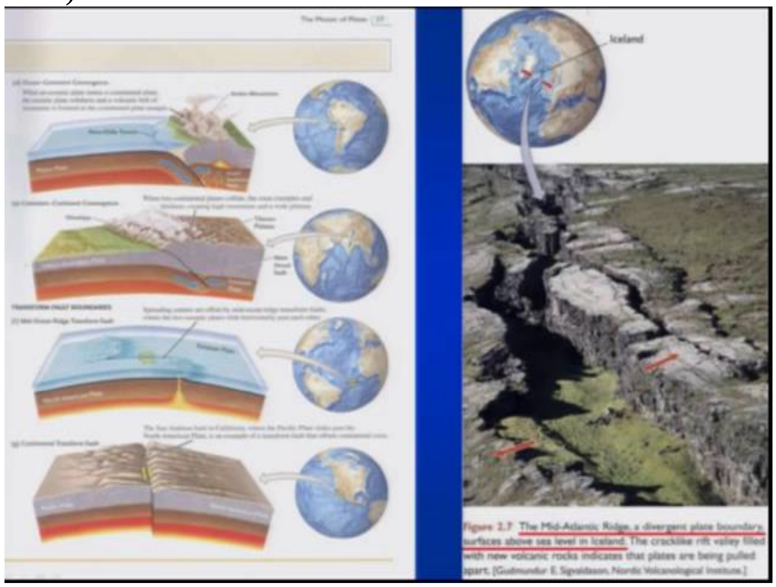
(Refer Slide Time: 3:53)



Then moving ahead, as I told that this subduction zones will have the, on the overriding plate mostly we will see volcanic eruptions. This is one of the examples from Cascadia which shows the mountain chain which comprised of several volcanic cones here. And this picture it shows the Mount St Helens. In the foreground, this is Mount St Helens and this one is your mount Rainier.

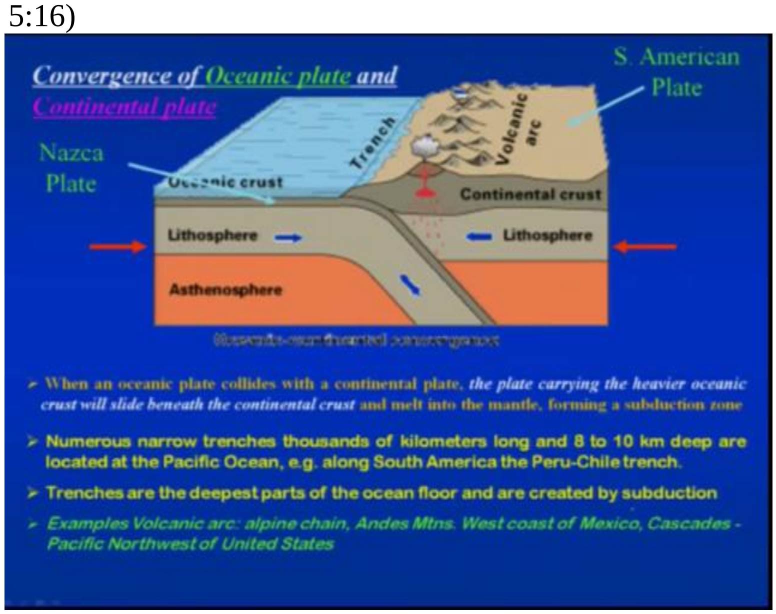
So a lot many active volcanoes you will be able to encounter along the along the plate boundaries if you are having the oceanic plate subducting below the continental plate.

(Refer Slide Time: 3:59)



And then along with that, the spreading centres mainly if you see on the earth's surface, the best example is there in the Iceland where the spreading centre is seen on the on the surface that is on the continent and passing through the mid-oceanic ridges coming onto the surface through oceanic part actually. So this is one of the best examples where we see the example of the divergent plate boundary on the earth's surface.

(Refer Slide Time: 5:16)



Then moving to another part that is the convergence of the oceanic and the continental plate, so we see there is a best example but this type of a configuration is seen in many places. So this is just to take an example that what we are having, the Nazca plate and South American plate we are having the volcanic eruptions on the overriding plates. And here what we see is I have already explained about that if we are having the plate which is subducting down then only we will be having the so we will have the melting of rocks and that will result in to the formation of magma and rising up to the surface and form of through the volcanic cones and all that.

So when an oceanic plate collides with the continental plate, the plate carrying the heavier oceanic plates. So the heavier one as we have learnt in the beginning also that the oceanic plates are the heavier plates as compared to the continental plates. So the heavier plates will subduct below the lighter ones. And when they reach the crust when it reaches the mantle region, it will melt and result into the formation of magma.

Now numerous trenches. Now this is the region which I also talked on that day that the junction of 2 plates is a marked by a deeper part which is termed as the trenches. And these trenches are seen at many junctions where we are having the subduction is taking place. And one of the best examples is the Mariana trench which is one of the deepest. So numerous narrow trenches thousands of kilometres long and about 8 to 10 km deep, this is what the Mariana trench is, is located at the Pacific Ocean.

This is along the this thing. And trenches are the deepest part on the earth's surface. As we have seen that the highest point on the Earth's surface is the Mount Everest and the deepest part on the on the ocean floor is the Mariana is along usually seen along the subduction zones. So examples are the volcanic arc, Alpine chain, Andes mountain and all that. So these are having the volcanic chain or volcanic arc we can say.

(Refer Slide Time: 7:40)

Now this is just to show the example that if you are having looking at the Andes Mountains then we have this is the trench portion we are having which is the, which marks the plate boundary between the 2 plates that is Nazca plate and the South American plate and we have the mountain chains which is the Indies along this coast. And this comprises of several active volcanoes.

(Refer Slide Time: 8:09)

So wherever we are having subduction zones, we will have the volcanic mountain chains. So I will just quickly move and try to show that couple of very good locations.

(Refer Slide Time: 8:21)

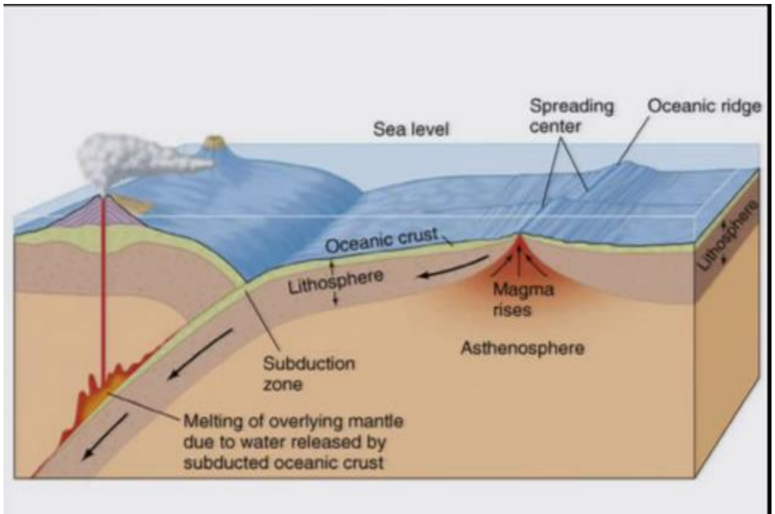
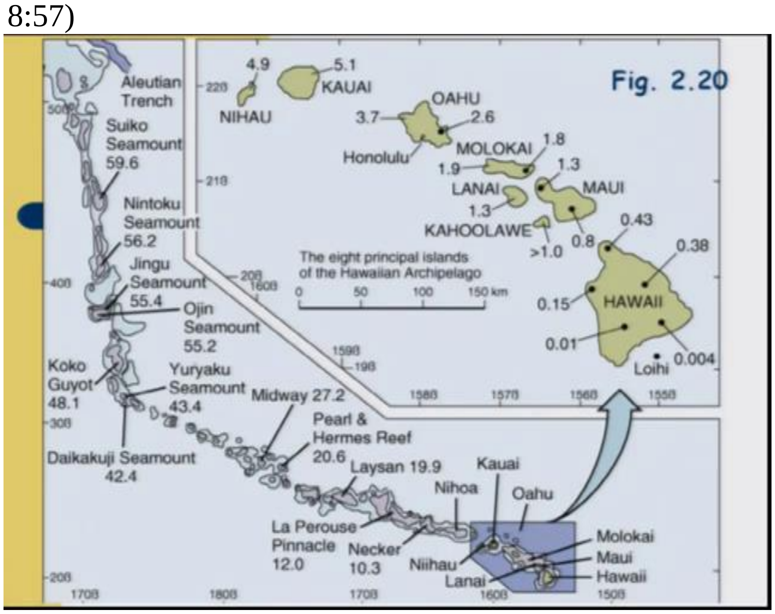


Fig. 2.8

This is what you see on the on the overriding plate, the volcanoes. This is from Chile. Some of the active volcanoes. And this is again showing the same, explains the same thing which we have been talking about that we have in the oceanic plane going down and we are having the…

But this is an example of the oceanic-oceanic plate. It is not the continental plate and again here, the heavier oceanic plate will subduct below the lighter one and the older ones will be comparatively heavier. The older oceanic plates will be comparatively heavier than the younger ones.

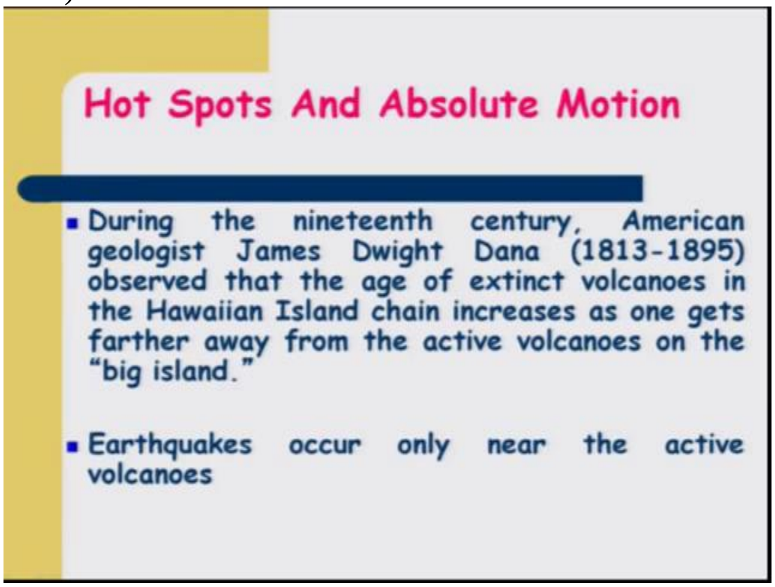
(Refer Slide Time: 8:57)



This is a wonderful example which explains about the movement of oceanic plate when it passes through or it is passed over the magma chamber. And the mountain chain the island chain which developed because of the formation of the volcanic cones and all that.

So this is one of the examples of Hawaii where it shows that how the oceanic plate moved above the magma chamber and whenever when it stayed at the above the magma chamber there was a volcanic eruption which resulted on the surface. But when it moved ahead, those volcanoes become dormant actually. So we have the chain of such volcanic cones.

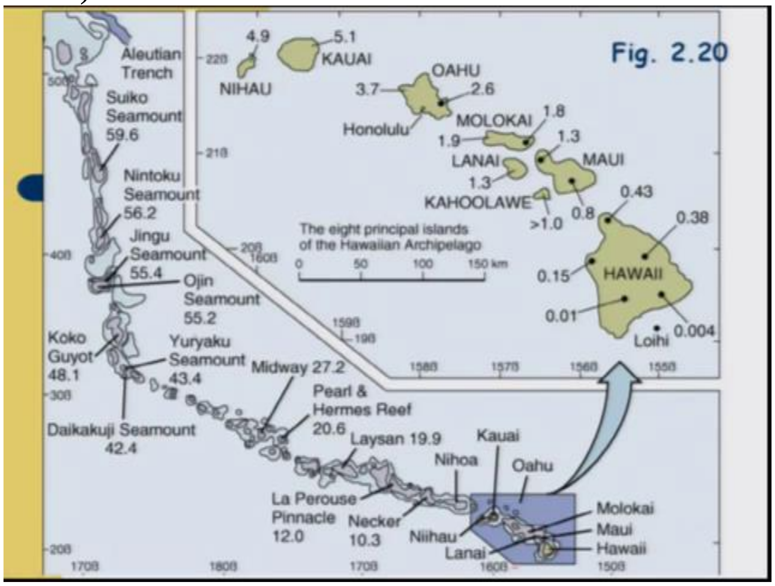
(Refer Slide Time: 9:46)



But this particularly what we call is the hot spots and the absolute motion because you can understand that when it moved because they have dated, the scientists have dated the rocks and they know that when exactly it was above the active magma chamber. So we say that there is hot spots and absolute motion.

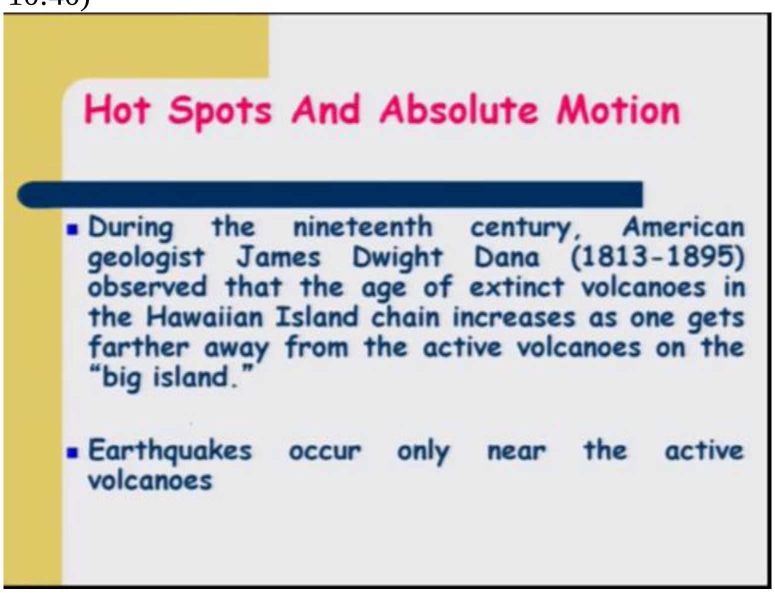
So during the 19th century, American geologist James Dana, he observed that the age of the extinct volcanoes so these are the dormant volcanoes which we are having, in the Hawaiian island chain increases as one gets farther away from the active volcanoes on the big Island.

(Refer Slide Time: 10:33)



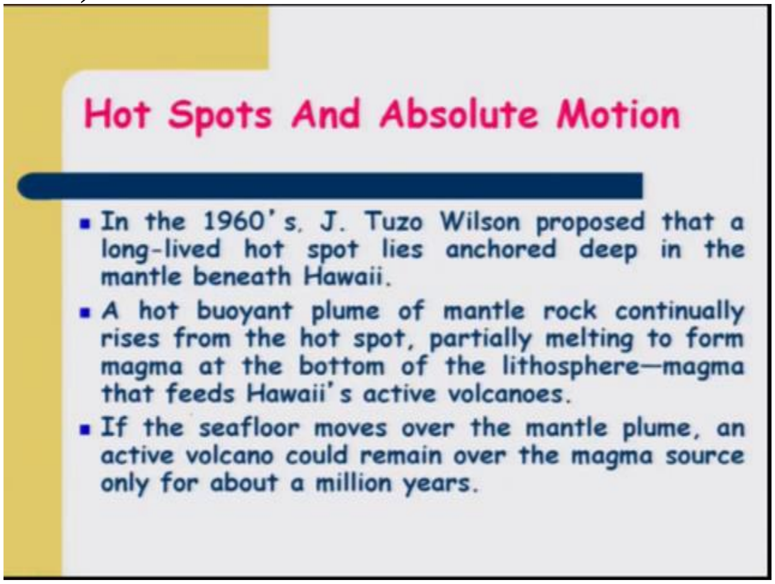
So these are the active ones here. We are having this is the active one. And if you move away, you are getting the older ones. And the earthquake occurs only near the active ones.

(Refer Slide Time: 10:40)



But if you move away from the active chambers, you will not be able to see even the earthquake occurrence also. And they are basically dormants, dormant volcanoes. So hot spots and absolute again that part.

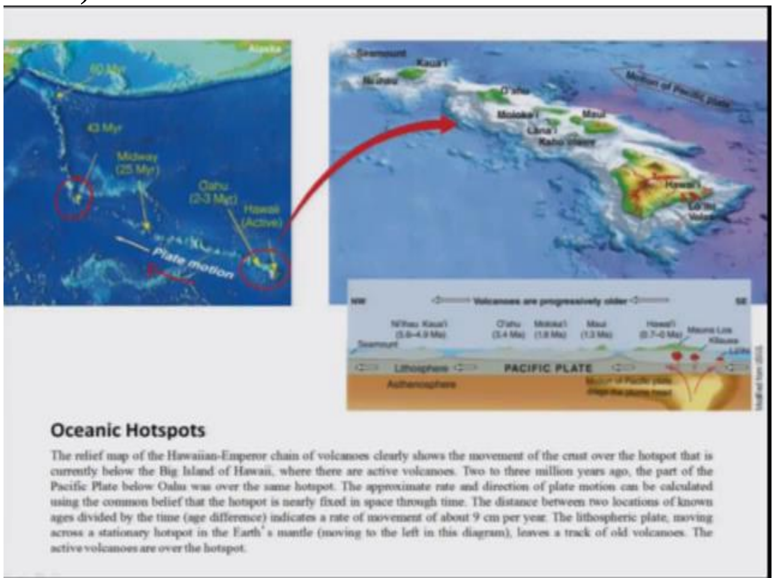
(Refer Slide Time: 11:01)



So this was been proposed and that the hot spot lies anchored deep into the mantle beneath the Hawaii. So this is the source for the volcanic eruptions and the magma which is coming up on the surface. So it says that there is a hot buoyant plume of mantle rocks ex-continuously rise rises from the hot spots. And particularly melting to form magma at the bottom of the lithosphere.

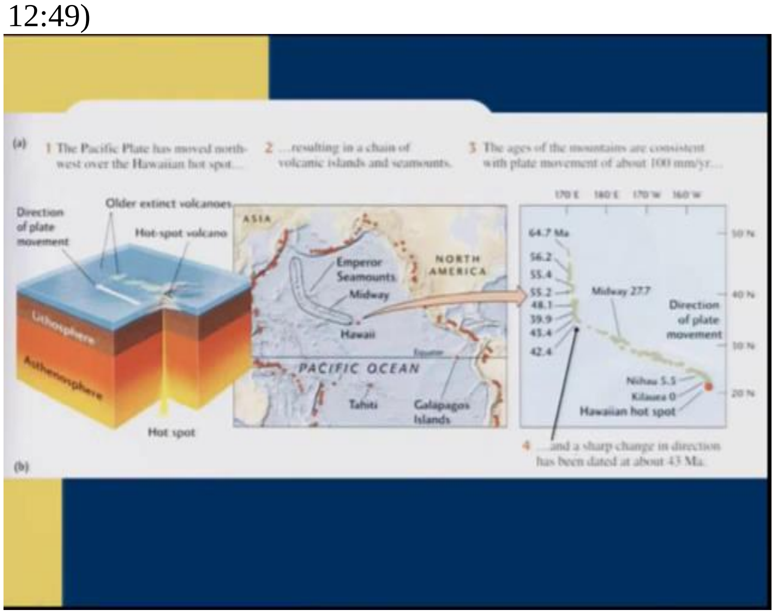
So this is what we also discussed in earlier part. So if the seafloor moves over the mantle plume this is important. So this is when we were talking about that it is sitting above the mantle plume. So if it moves above the mantle plume an active volcano can remain over the magma source only about a million years. So it remains because the motion is quite slow. So it remains for millions of years. But yes of course, that is quite a longer period for in…

(Refer Slide Time: 12:08)



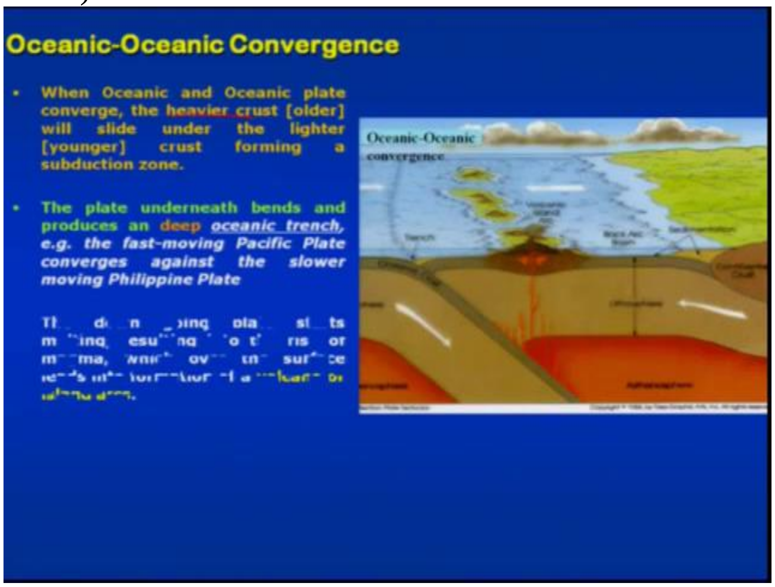
And then if you look, this is what they have tried to discuss about that there was a change in the plate motion direction actually. So when plate moved over the magma, active magma chamber but at some place, it changed the direction. So this was the time when the direction of the plate changed. It used to move in this direction that is in north-west. But this then it changed to almost towards the North north-west. So this is one of the best examples that explains that when exactly how we can know the plate motions also.

(Refer Slide Time: 12:49)



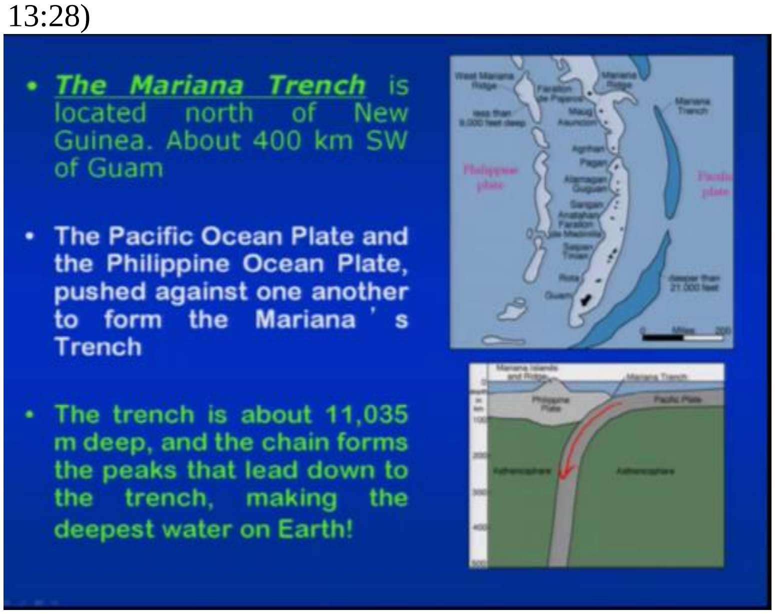
So this is what they say that at around a sharp change in the direction occurred at around 43 million years ago in this region.

(Refer Slide Time: 13:02)



Now coming to the oceanic-oceanic convergence, as the previous one we were talking about the oceanic continent. Here the heavier ones that is the plate underneath bends deeper that is the heavier plate will subduct compared to the overriding lighter plates.

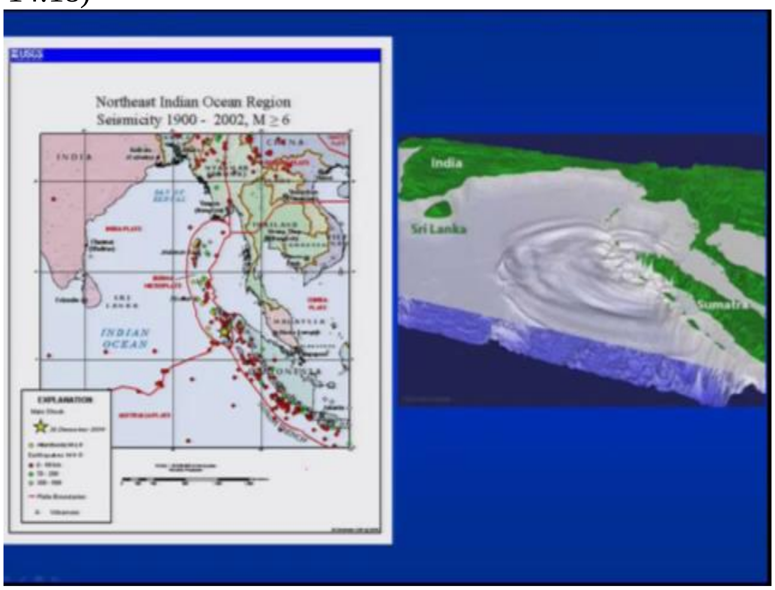
(Refer Slide Time: 13:28)



And this is the example of the Mariana trench where we are having the deepest ocean on the earth, which is almost like 11,000 metres deep. So here, this is basically related when we talk about the subduction zones, different type of subduction zones, we classify subduction zones as either the Mariana type subduction zones or we say there is another type of subduction zone where the plates are comparatively subducting shallower.

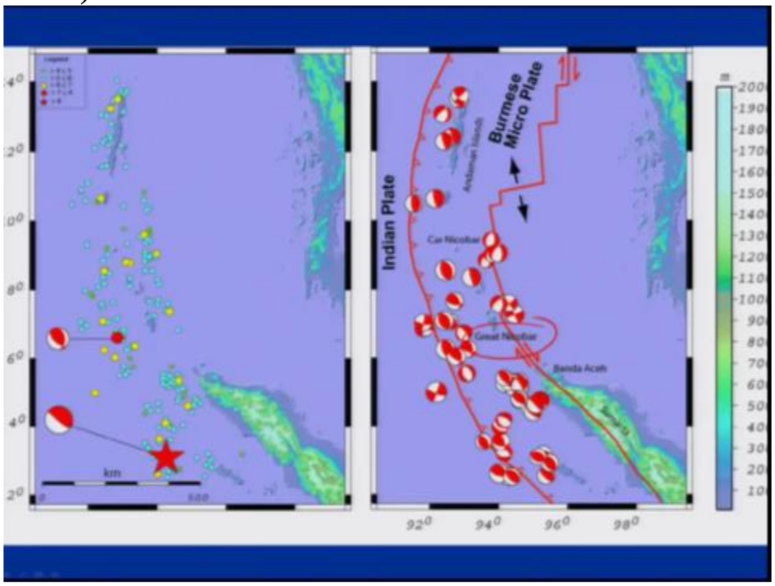
So this is one of the examples where the subducting plate is deeping or or subducting below at a greater angle resulting into the deepest part at the contact of 2 plates here.

(Refer Slide Time: 14:18)



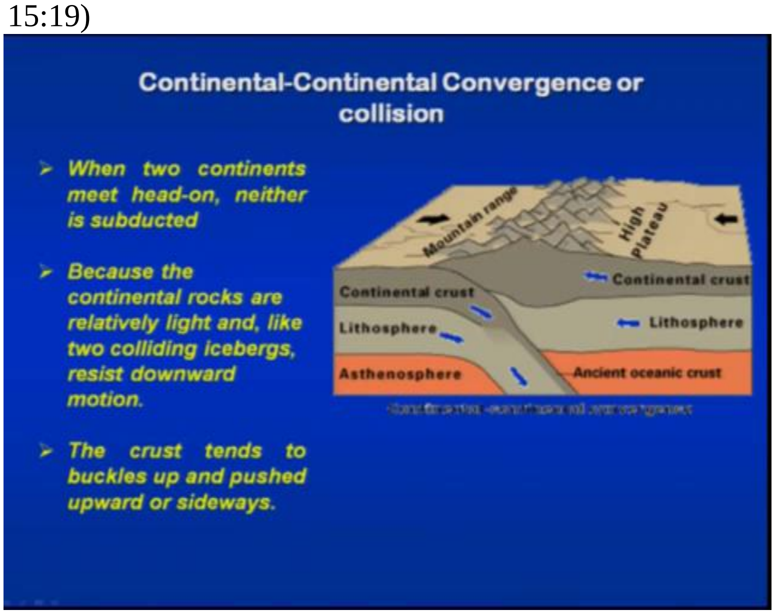
So this is an example what I was talking about that we also have the subducting plate which has resulted into the formation of the trench and which we call as Sumatra Andaman trench. And this was one of the source area for the 2004 Sumatra Andaman earthquake and the mega tsunami in that region which killed lot many people.

(Refer Slide Time: 14:50)



So this is the just to show that how the plate boundaries are seen close to the Indian subcontinent, this is the southernmost tip of the Indian subcontinent that is the Car Nicobar and then we move further, we get into the Andaman Islands and all that. And a lot many earthquakes which occur are aligned or they are oriented along the trench part.

(Refer Slide Time: 15:19)



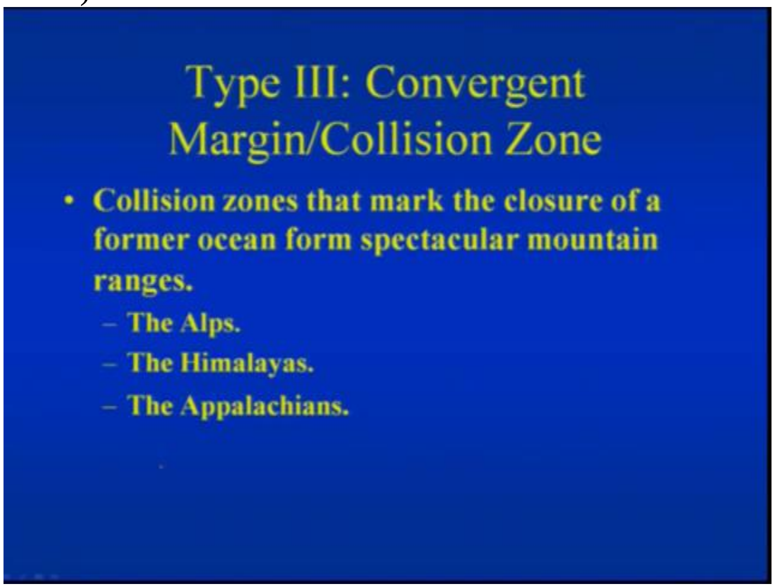
Now coming to the the final one that is the continental-continental convergence or collision. We are talking about the best example what we see on the author is the Alpine Himalayan mountain chain. And this is the example we will be talking about the Himalayan mountain chain which occurs. So here what we see of course the question comes that there is a subduction which has been seen here.

But then finally what we are having is the collision between the 2 plates. These are both are continental-continental. Both plates are continental. But in earlier times when they subducted, these plates subducted, it had an ancient that is an oceanic plate was ahead of it which subducted initially beneath the continental region. And finally when the time came that is the 2 continental plates came together, came near to each other, they collided and no more subduction is there.

But yes of course, we cannot say that it is completely collision but partial subduction is also seen in this region. So when 2 continental continents meet head-on, neither is subducted. Because both are having almost similar density and all that. So they are relatively lighter. So because the continental rocks are relatively lighter and like to collide. Like 2 icebergs they collide and resist downward motion.

So neither of them wants to go down because of their density. So they eventually result into the collision. And that collision what we see has a resultant into the crumbling of the rocks and rising up of the mountain ranges. And that is what we are looking at, the buckled up or pushed up material in form of the mega mountain chains like Himalayas.

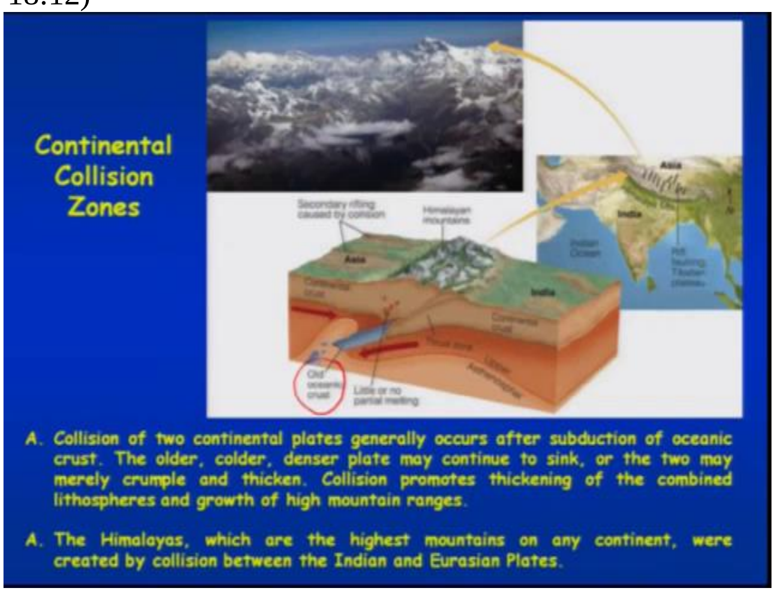
(Refer Slide Time: 17:17)



So type of convergent margins if you look at is the collision zones that marks the closure of the former ocean which were in front of them. So in terms of the Himalaya we see that there was a tetheancy region which closed down slowly and finally what we are looking at is the formation of the Himalayas. But before the Himalayas, we had of course if we talk about that there was not subduction.

So we had volcanic eruptions in this region and finally we lost kept keep losing the tetheancy region and now we are having the complete collision and crumpling of the material coming up on the Indian plate from the Eurasian side. So we have Alps, where Appalachians, we have Himalayas, these are one of the, there are few of the examples which talks about the collision zones on the earths surface.

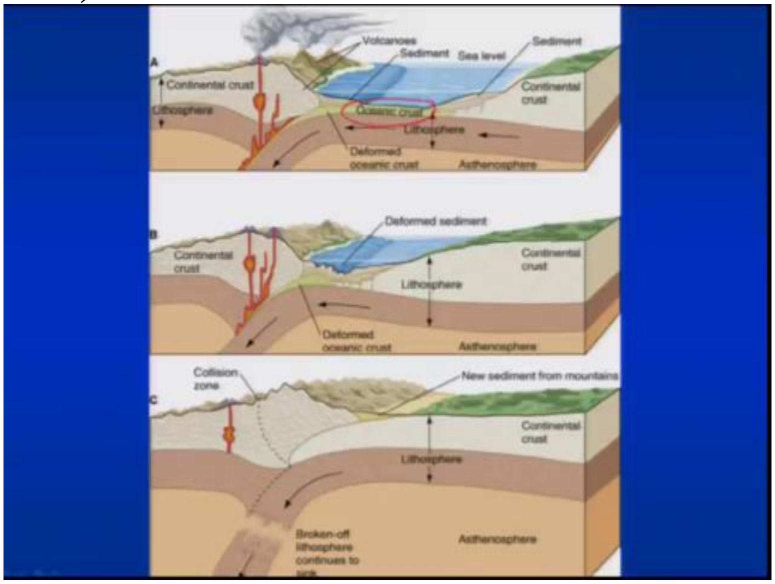
(Refer Slide Time: 18:12)



And continental collision is we have been talking about the Himalayan region. So if we see that it had an old oceanic plate before it subducted which resulted into subduction. So we had partially the melting of the rocks also and resulted into some of the volcanic eruptions also. Before but now also what we see that it is now no more feeding of the oceanic plate is taking place in this collision zone but now what we see is the crumpling of the material resulting into the formation of the rock wedge.

And this wedge is day by day it is rising up and we are having the higher Himalayas. So we see, the best example of collision on earth’s surface.

(Refer Slide Time: 19:09)

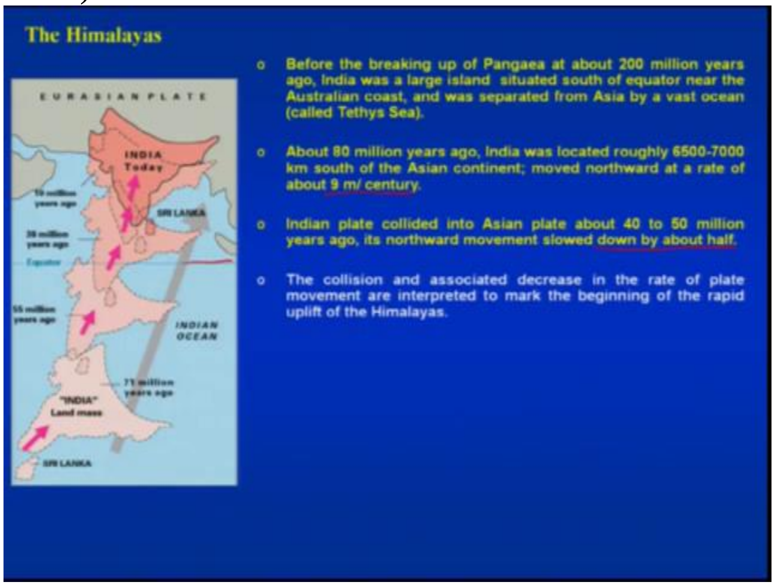


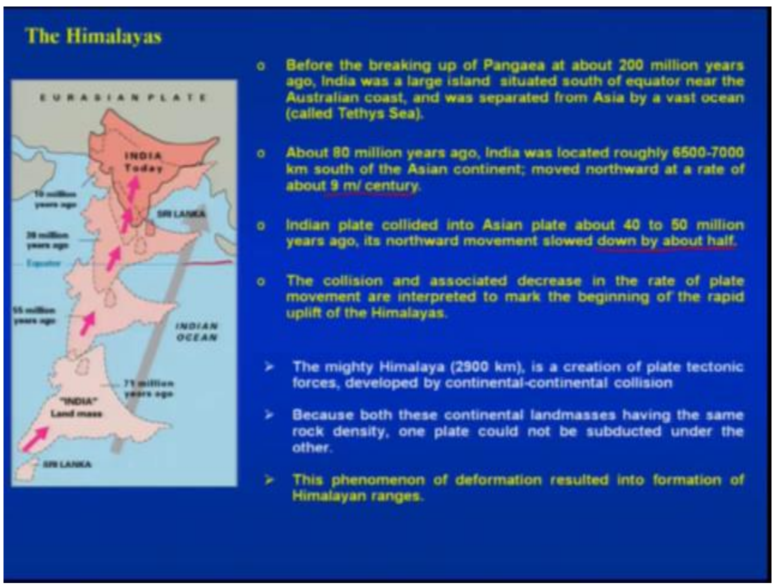
This is again a cartoon which explains that how it happened. So this is the 1st stage when we had like the oceanic crust which subducted below the continental one and then we had behind the oceanic crust we had the continental crust. And then slowly this area got deformed and it started closing up. So this is closing up of the tetheancy and finally this disappeared. So we do not see any ocean any more in this region but earlier there was an ocean which was a part of the oceanic crust.

And then finally what we see right now is the formation of Himalaya. So we have a topography and we have drainage. We have different climates. Like we have the seasons monsoon and all that and we have streams which are flowing down. And we are having the deposition in the Indo magnetic plain.

So we are having the fertile land which got developed after the collision and not before that. And now what we see that no more sinking of the oceanic plate takes place in this zone.

(Refer Slide Time: 20:23)





So if we look at the Himalayan part that how it evolved, as we discussed in the beginning that it was far south of equator. It was located far south of equator and it was in the form of the Gondwanaland. So before the breaking up of Pangaea at around 200 million years ago, India was a large island situated south of equator near Australia and all that. So slowly it moved.

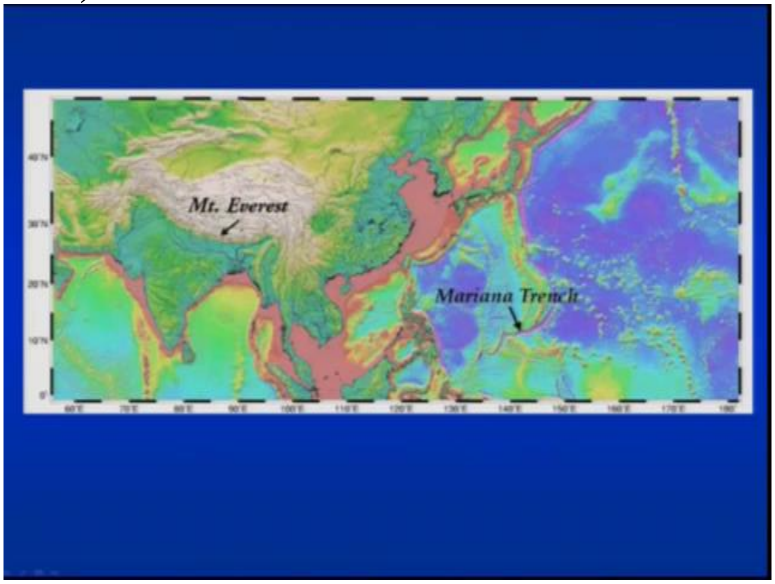
And about 80 million years ago, India was located roughly 6500 to 7000 kilometres south of the Asian continent. It moved at a rate of almost like 9 meter per century. This is very important. Just keep in mind what we are talking here. So it was, the speed was almost like it was moving at the rate of 9 meter per century. But at around 40 to 50 million years back, it is northward movement slowed down almost by half. It slowed down almost by half.

Now this was the time when the collision started. So this is the time when most of the geologists are taking into consideration that around 40 to 50 million years back the collision started. And that resulted into the slowing down or decreasing rate of the movement. And that interrupted the rate of movement. And that was the time or the beginning of the rapid uplift of Himalayas.

So the mighty Himalayas almost covering an area of East West if you take around 2900 kilometres is a knit creation of your continental-continental collision. So that is between the 2 plates, the Indian plate in the south and north we are having the Eurasian plate. Because both these continental landmass had almost same rock density. One plate could not subduct under the other one.

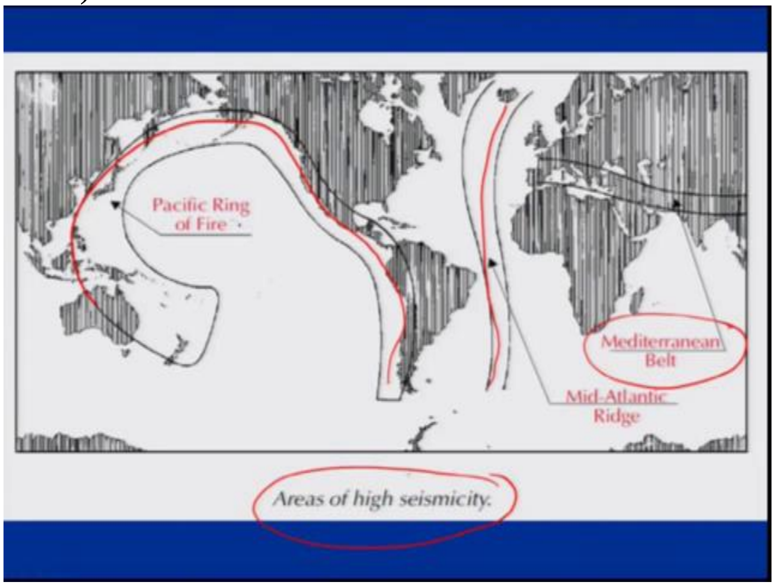
So this is one of the reasons which we were talking about the importance of the heavier plate and the lighter plates in terms of their density. So this phenomena of deformation resulted into the formation of Himalayan ranges.

(Refer Slide Time: 22:43)



So just move ahead, maybe this is all we have discussed. So finally if we look at so we have because of the plate motions and how the ocean floors and the continental floors were been sculptured because of the plate motion, we see the deepest part on the earth that is 11,035 metres and then we are having almost like 8800 metres high Everest on the earth's surface.

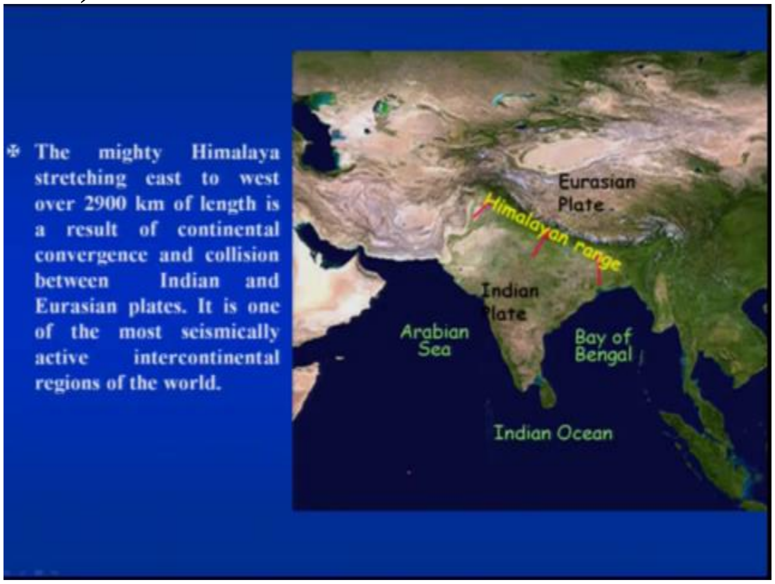
(Refer Slide Time: 23:16)



And in total if you look at the tectonic boundaries or the plate boundaries, we are having the ring of fire, we are having the midoceanic ridges which are running across the (inaudible 23:31) and then we are having the Mediterranean belt. This is the alpine Himalaya and chain and this is the area where we have the all active volcanoes which have been active.

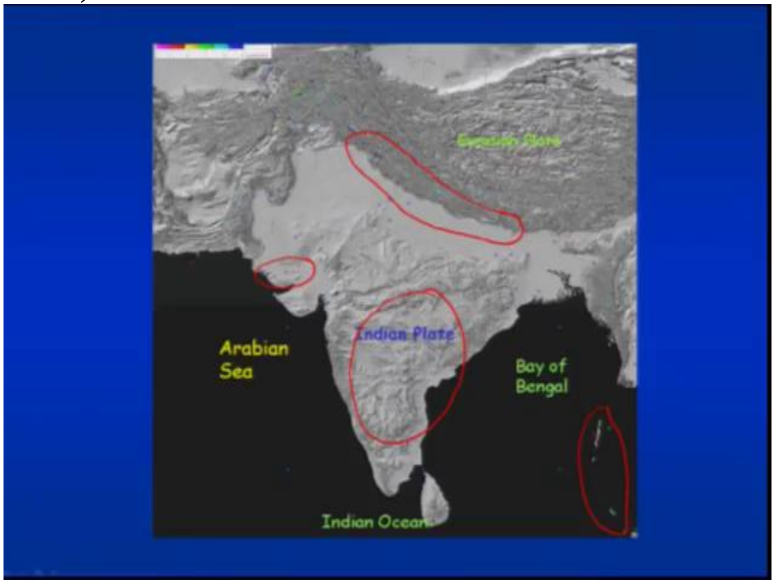
So this is the ring of fire, or the Pacific Ring of Fire we can say. So these are the major areas of high seismicity. So these are the hazardous areas on the earth's surface which triggers lot many earthquakes and volcanic eruptions and tsunamis and all that.

(Refer Slide Time: 24:01)



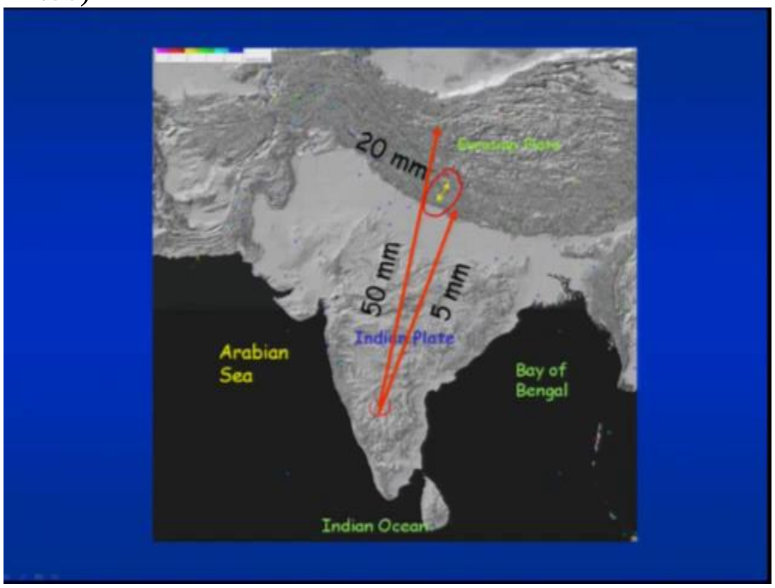
So in particularly if we take now coming to the Indian part, we have almost like this is the Himalayan front or Himalaya and range which is the contact between the Eurasian plate and the Indian plate.

(Refer Slide Time: 24:16)



Now as I was talking about that there will be relative plate motion which has been measured between these 2 plates and now with the help of a support of Ministry of Earth science we are putting a lot many GPS stations in the Himalayan region to understand the rate of deformation in this area. And we are having GPS stations also in this region, that is Andaman region and of course in the Kutch region. And relatively, we have couple of stations which are in the Indian plate part that is the peninsular part.

(Refer Slide Time: 24:58)

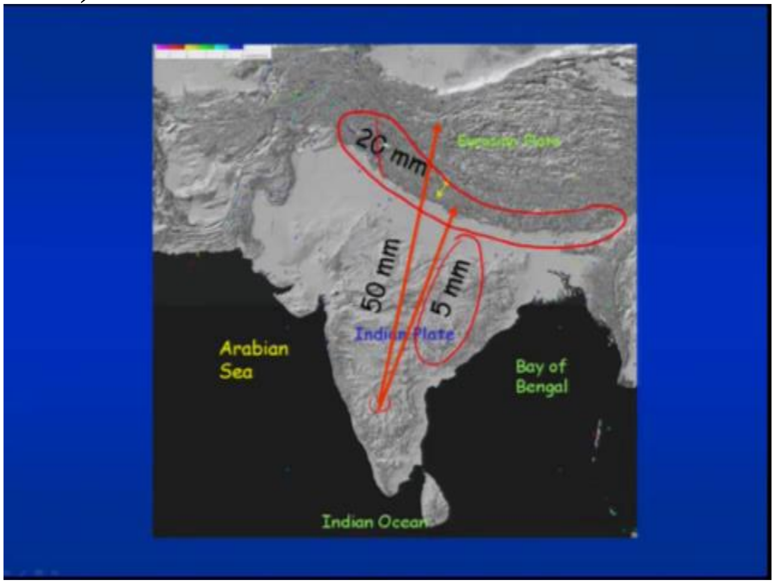


Now the studies have proved that the plate motions between the point here in the Bangalore and with respect to the Eurasian plate, it is almost like 50 millimetre. So the plate motion between the 2 is around 50 millimetre. And between this point and you are having the Himalaya in front we are having around 5 mm only. So 45 mm is still left out. Out of that, this region, that is the Himalayan zone is taking up almost like 20.

So as we were discussing about that the Indian plate motion, so if we take from the Bangalore part we are almost having like 50 mm which is between the Indian plate over here. That is the point between on the Indian plate on the southern side and the Eurasian plate is 50 millimetre and 5 millimetre only has been consumed across the plate and rest 20 mm has been consumed along the Himalayan front.

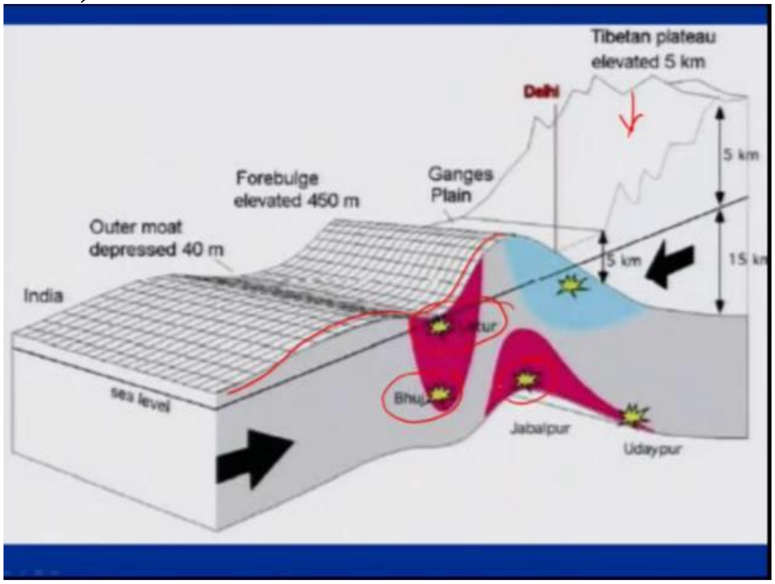
So this Himalayan range is taking up almost 20 mm and the rest what has been left out, 25 and half, half has been taken up by the Eurasian plate part. So based on this, what we can understand is the region along the Himalayan zone is comparatively like deforming much much faster as what we see in the rest of the plate. Hence, more hazard can be expected or is expected in the Himalayan region as compared to the rest of the Indian plate.

(Refer Slide Time: 26:48)



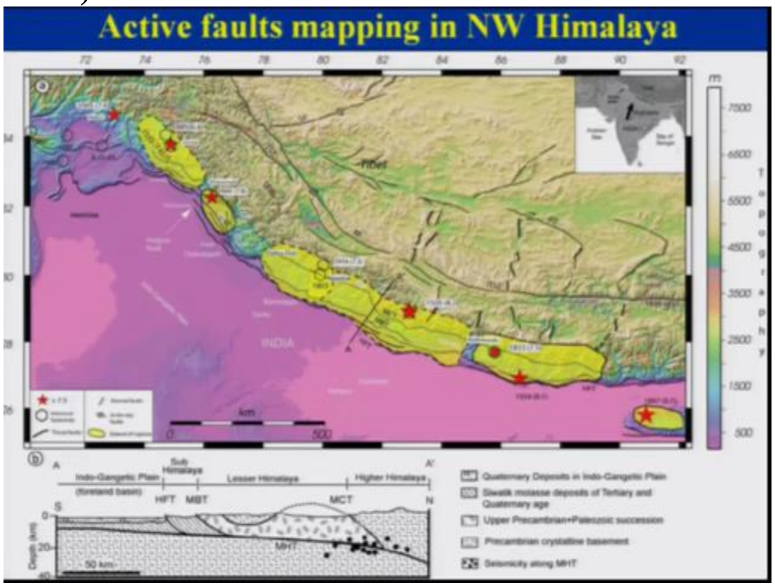
Now this is what it explains that how the whole Indian because we cannot say that only the Himalayan part over here is your like resulting into the deformation. But rest of the plate is also under deformation.

(Refer Slide Time: 27:00)



This explains, this cartoon explains that not only the Himalaya but also the rest of the Indian plate is getting flexed up. And that is one of the reasons why we had an earthquake in Bhuj, we had an earthquake in Lathur and all that. And also in Jabalpur. That is in the Indian plate, the peninsular side we see these type of earthquakes.

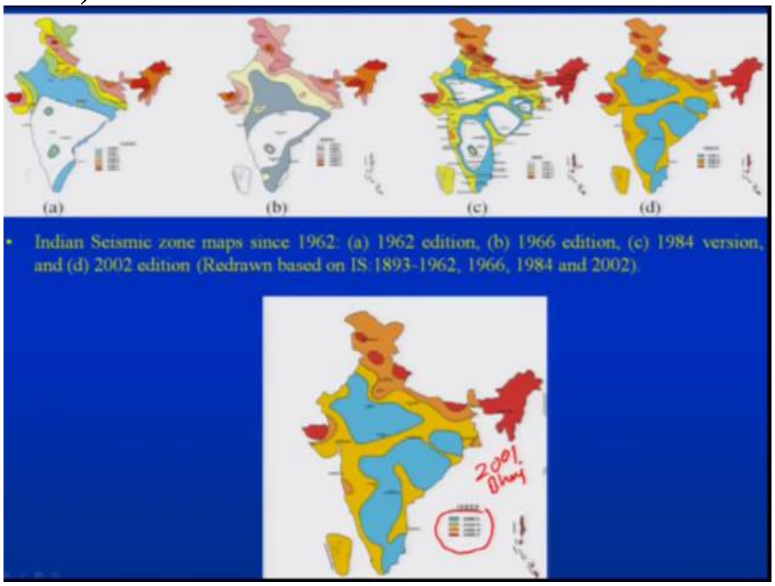
(Refer Slide Time: 27:26)



So this hazard remains in this region. So this we will be talking when we talk more about the faults and we talk more about the earthquakes and the ancient earthquakes and the present earthquakes in Himalayas and of course I will try to talk briefly about the recent earthquakes which occurred in 2015 in Nepal also. But in short, if we look at, we have the Himalayan front or the Himalayan region had several large magnitude earthquakes, devastating earthquakes in the past which occurred in Kashmir in 1555.

Then we have 1905 earthquake in Canada. Then we are having 1934 earthquake, these are all large magnitude earthquake. This 1934 is in Nepal, Bihar and all that. And then further towards the east we had 1950 earthquake of upper Assam. So we will talk in detail when we are talking about the earthquakes in Himalayan region.

(Refer Slide Time: 28:29)

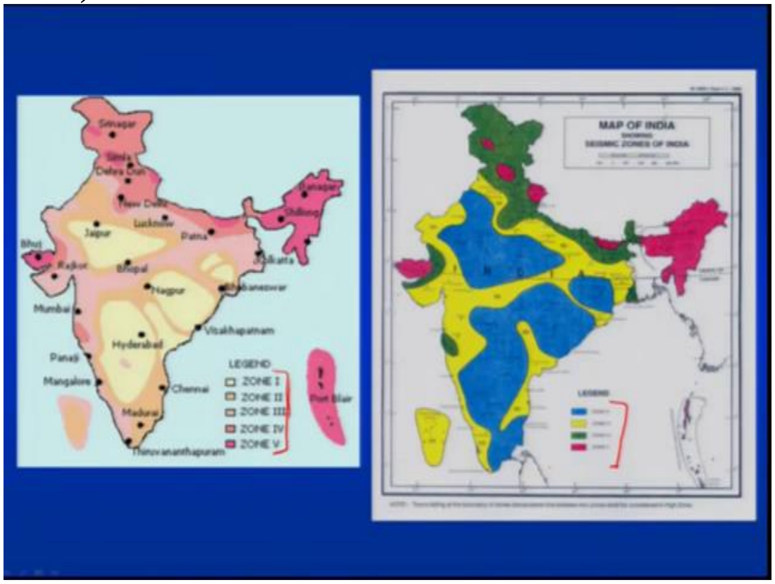


But in short if we look at in terms of the hazard, so based on these earthquakes which are known from the region like Kutch or maybe in Himalayan region as the data is coming up, we have been changing we have changed the seismic hazard map of India.

So this is the seismic zonation map of India which before 2001 we had 5 zone starting from 1 to 5. But now we are not having. We have already excluded the zone 1 and we are having from 2 to 5. So Indian seismic zonation map since 1962. So it was been revised at locations or the number of times when more data came in. And finally we see it was revised in 2000 after 2001 Bhuj earthquake.

And you can see here that we have only 4 zones starting from 2 and going up to 5. So because the Bhuj earthquake resulted into different intensity what earlier was been predicted or was assumed that this area will have this type of, this much of intensity from shaking. It was different which was experienced in 2001.

(Refer Slide Time: 29:53)



So if you look at this was this is an older one which had from 1 to 5 but now we are having from 2 to 5 only. So there is a change in that. So then this type of information is extremely important for civil engineers when we are taking into consideration that where we are going and constructing our structures. Either it is in zone 1 or it is in zone 5. Because that will vary based on the building cores in different areas.

So this is what I had to talk in this one. So thank you so much.