Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture – 12
Plate Tectonics (Part V)

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So, welcome back. In previous lecture we discussed about the transform faults and the most notorious and dangerous transform fault other than the mid endogenic edges which are evident on the Earth's surface is your north Anatolian fault in Turkey and San Andreas Fault system and California.

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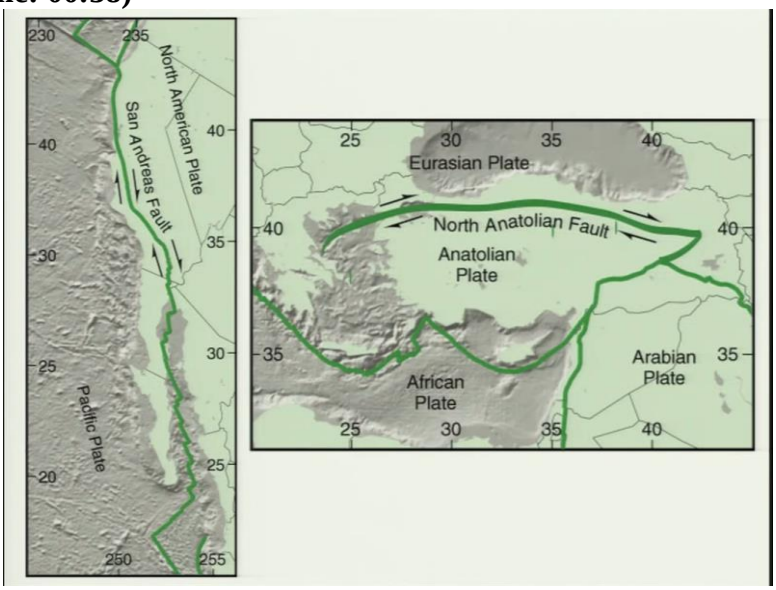

So, these are the 2 major fault system. Of course, there is one more, which is median tectonic line that exists in Japan and other one it is not so large as this 2 systems are, but they also exist and majors transform fault system in Himalayas that is an Karakorum fault system.

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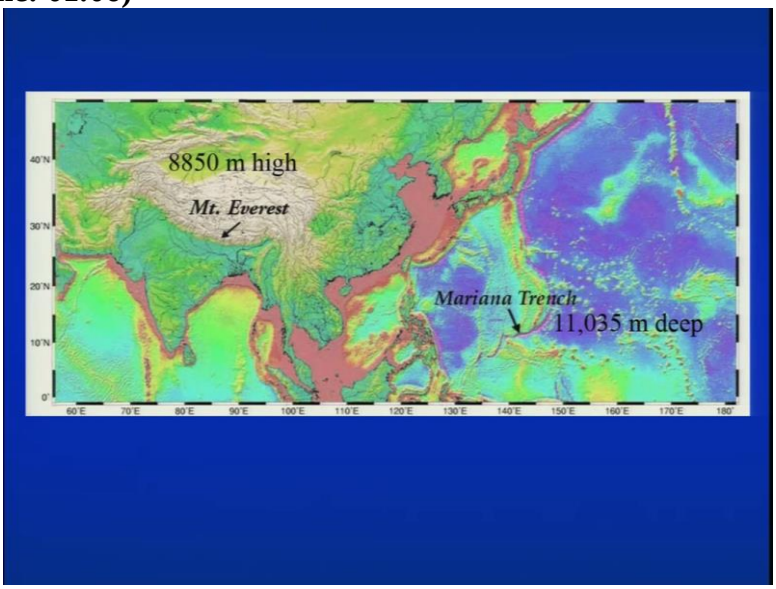

And now that the because of the plate tectonic movements and the ongoing active tectonisms, we have this 2 points, which are the tallest and the deepest one on the Earth's surface, that is Mount Everest almost like 8850 meters and the Mariana Trench deepest 11135 meters.

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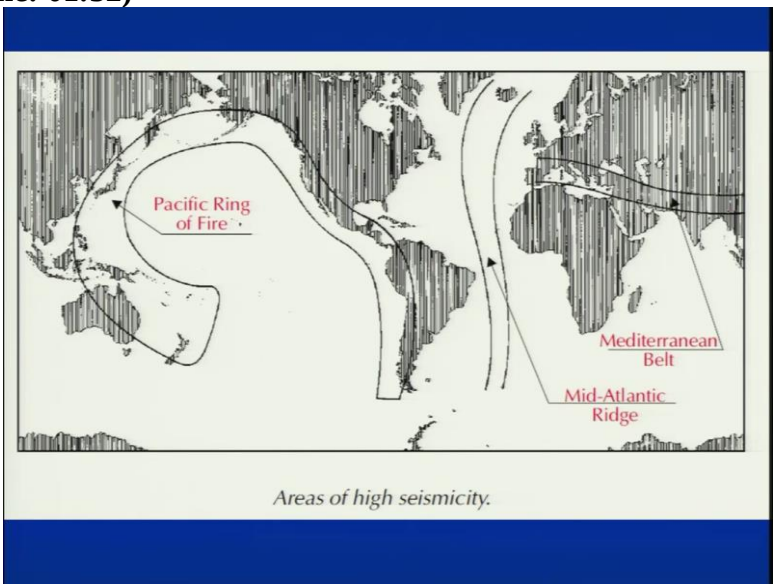

And other than that, what we have is the Pacific Ring of Fire, where as we discussed in the one of the lectures, that these are all along this boundary PC and the alignment of the active volcanoes and then we have the mid oceanic ridges, and the longest one is your mid Atlantic Ridge spreading centers and the mountain building activity which we see is the Alpine Himalayan chain.

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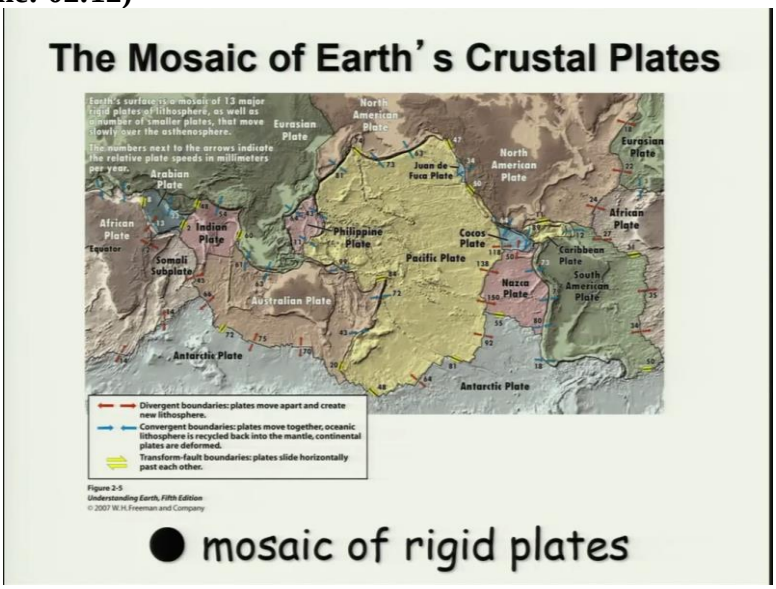

So configuration of the tectonic plates, if we take in total, then we have like at various locations with respect to the tectonic boundaries, we have divergent plate boundary, we have convergent plate boundaries and we have transform plate boundaries. So, as I was mentioning that we have this blue arrows, which has showing the direction opposite to one another is your conversion plate boundaries.

And with the red arrows are been shown as the spreading centers is the divergent plate boundary. And in between we have the transform plate boundaries. And the major one which I was talking about is the along the northern American plate and the Pacific plate and in some locations we have over here, as well as I was just mentioning about that we have in India also and that is the along the subduction zone.

So, if you come towards the north of the Sumatra Andaman subduction zone the Andaman region is showing the boundary which is almost likes the strikes the point whereas here we have collision, but there is one fault system which is which exist is showing the right lateral strike slip. Three type of boundaries we have divergent convergent and transform. This cartoon shows the location of different plate boundaries on the Earth's surface.

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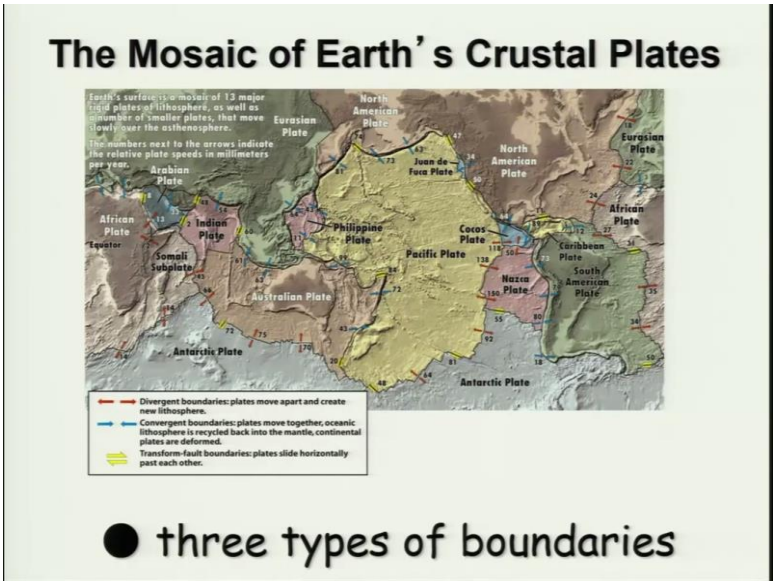

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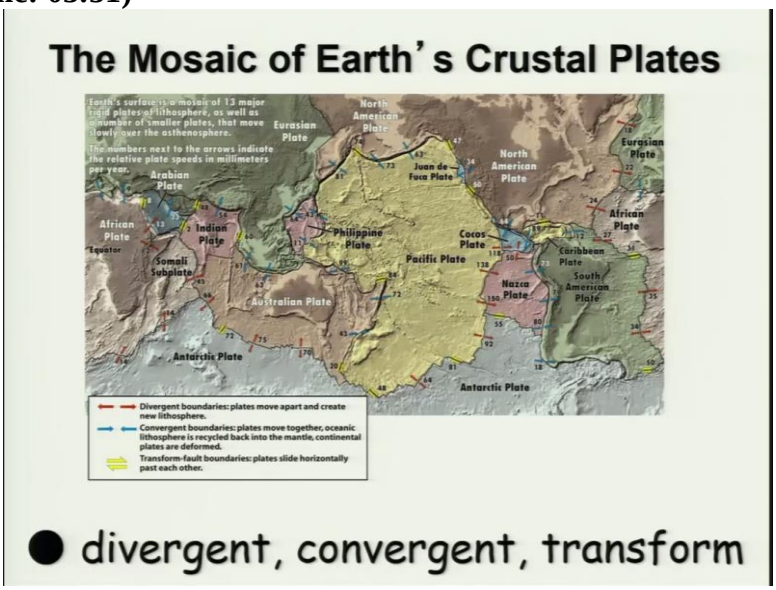

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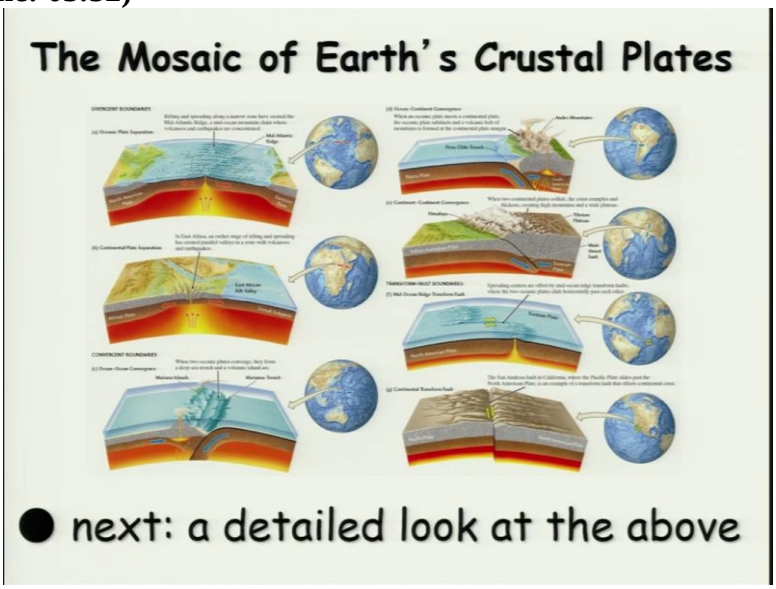

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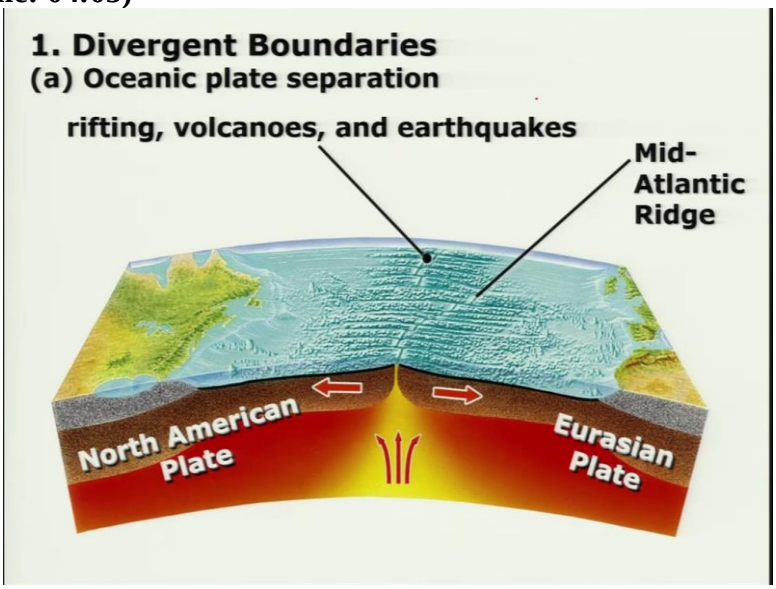

So, the detail one is the divergent plate boundary where we have the magma which is coming up and new crust is continuously forming along this one and in between what we have is the transform faults. So, these are all transform faults and this is your Trans divergent plate boundary. So, what landforms which will be associated with this type of plate boundaries that is the divergent plate boundary will have rifting where the 2 plates are moving away from one another, we will also see the volcanoes and along with that the associated hazard will be your earthquakes.

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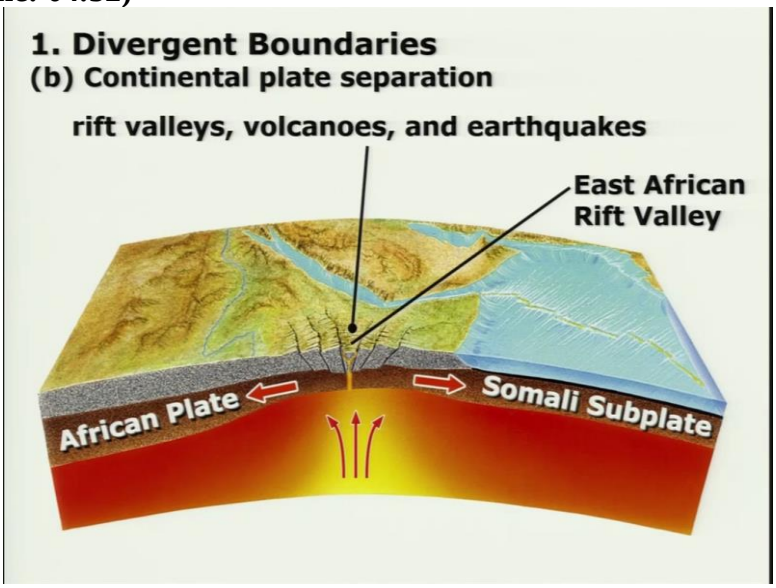

And coming to another one we have the rift valleys as we have seen the example of an African plate and we also discussed in brief the East African rift valley so see rift valleys volcanoes as well as associated earthquakes in such locations. So, the previous one was your

oceanic plate separation, the mid oceanic ridges and the best example is mid Atlantic and this one is continental plates separation both are categorized as divergent plate boundaries.

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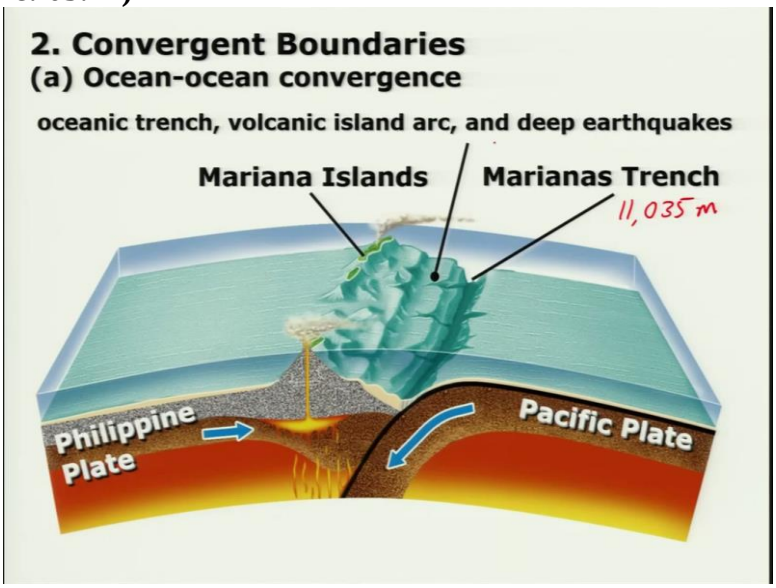

Then the prominent features which will develop between the 2 plates that is mainly during the conversion and boundaries is your trench and one of the best example that exists between the Pacific plate and the Philippine plate is your Mariana Trench. And the depth of this is almost around 11,035 meters. So, here again we will see the form the between the oceanic-oceanic convergence will see the formation of oceanic trenches. Volcanic Island arc on the overriding plate and we experience here gain the deep earthquake along with that will also experience intermediate and shallow earthquakes.

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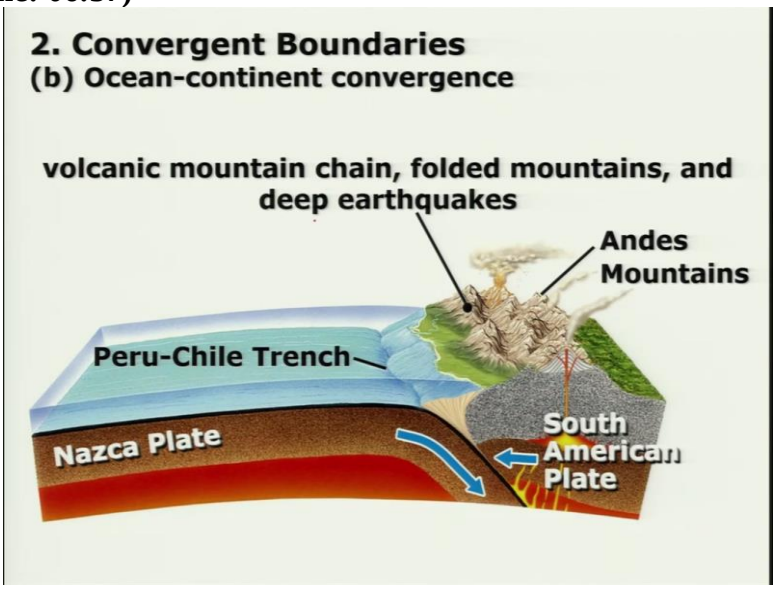

Then another part of the convergent plate boundary where we are having the ocean-oceanic and continental convergence. So, best example which has been given is the Chilean type of

trench we have the Nazca plate subjecting below the South American plate. So, on the land portion that is the continental portion again we see the formation of volcanoes and the best example between this 2 plates is your Peru Chile trench.

And on the surface of the overriding plate we have in this mountain. So, again we will come across the volcanic chain of folded mountains and deep earthquakes along with this as I told in the previous one will also have shallow and intermediate earthquakes. And this deep earthquakes are with respect to the depth at which they are occurring.

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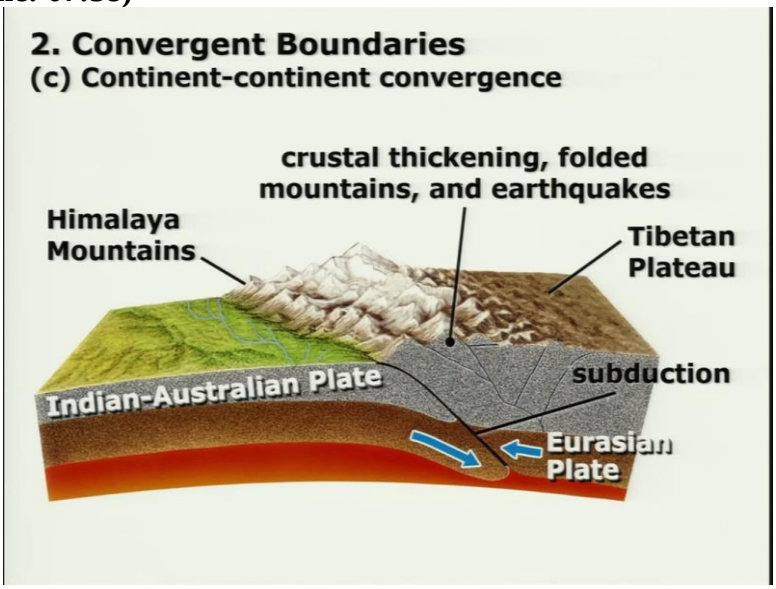

Then coming to the third one is the convergent plate boundary is the continental -continental convergence. The best example is Himalayas, where the Indian Australian plate or the Indian plate is subjecting below the Eurasian plate. But at present, what we see is just the collision between the 2 but the plate which subjected initially this boundary remains and we also termed this as an convergent plate boundary.

So, landforms here is what we see is mostly the crust thickening folded mountains and shallow earthquakes mostly because no plate is getting below this portion. So, we have mostly the shallow earthquake in this region. So, these are the important points that thickening of the crust years and then what we are getting is the rising of the topography that is the mountain chain folded mountain chain and the best example is here Himalaya.

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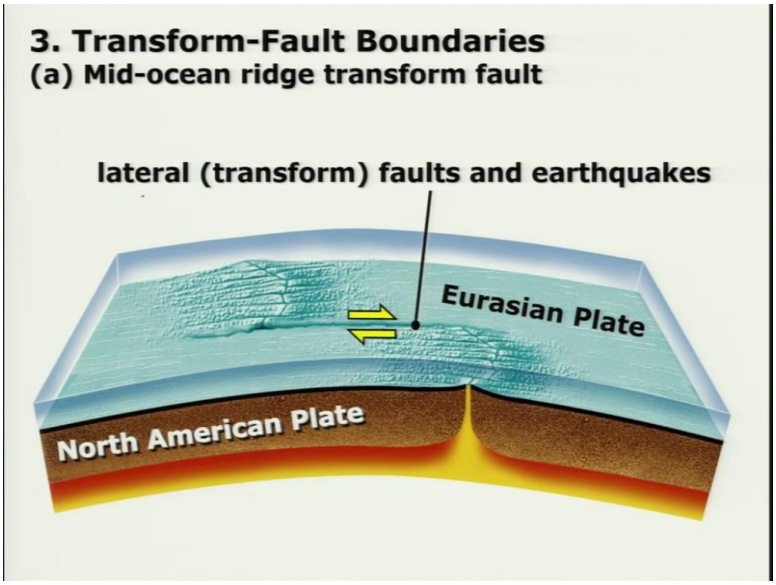

Then comes another one is the third one is the transform faults for the best example of transform fault as the Mid Atlantic ridge and mid oceanic ridges and in between you have the transform faults. So, which behaves like a it will there will be a moment in the lateral fashion and of course, the earthquakes will be all shallow earthquakes here.

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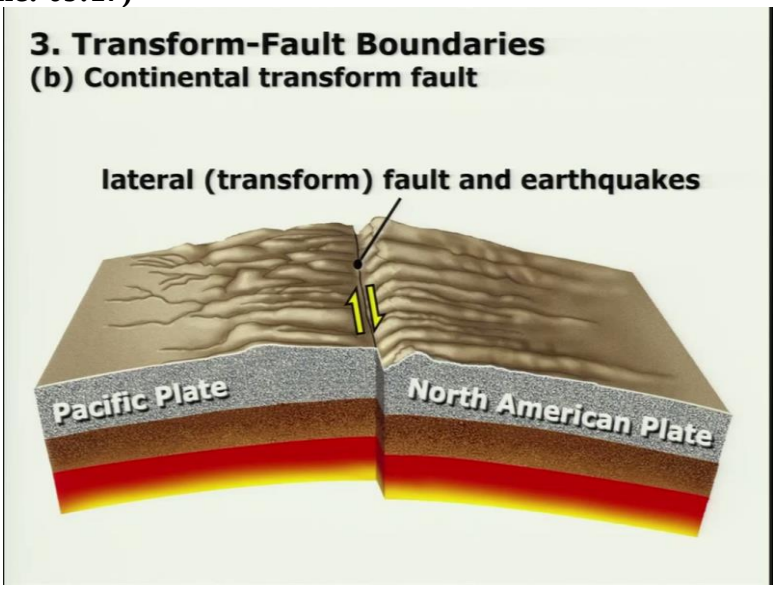

And others so, this is related to the mid oceanic ridges in the ocean part, but on the land, you have continental transform fault boundaries. And the best example which we were talking about is one of the notorious fault or the dangerous fault is the standard fault system which has formed between because of the deformation between the Pacific plate and the North American plate.

So, this plate is moving in this direction shown by this arrow and this portion of the plate on the on the left hand side of the plate boundary is moving away from us. So lateral transform faults as well as earthquakes. So here also again, we will see mostly the shallow earthquakes.

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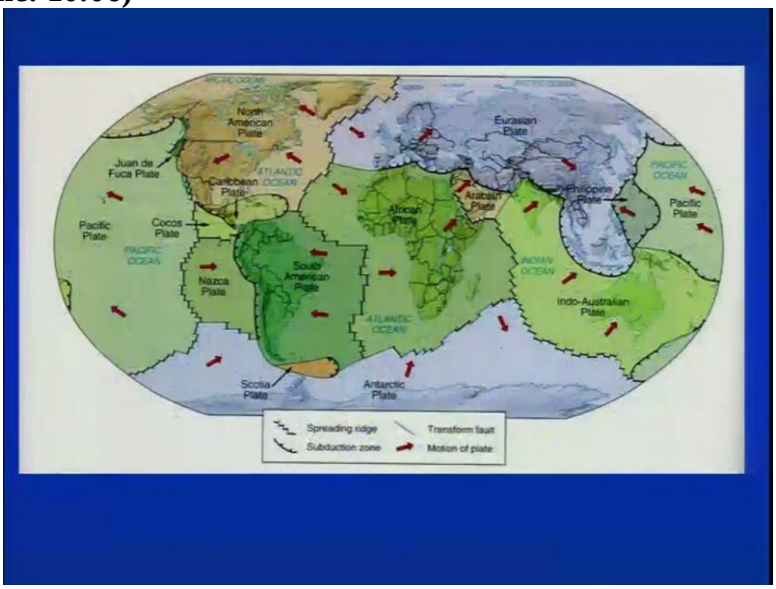

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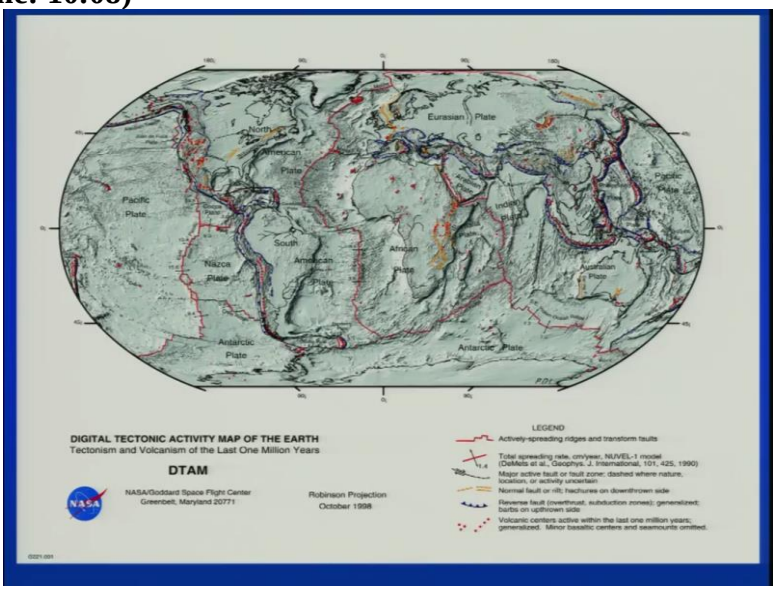

So there is an overall configuration of the plate boundaries and the important part which we should remember here is that depending on the different type of plate boundaries that exist between the respective plate, different type of earthquakes in terms of the depth will occur and the hazard which has been related to such plate boundaries will vary from place to place depending on the configuration of the plates. That is the pattern of the plate boundaries that exist on the Earth's surface.

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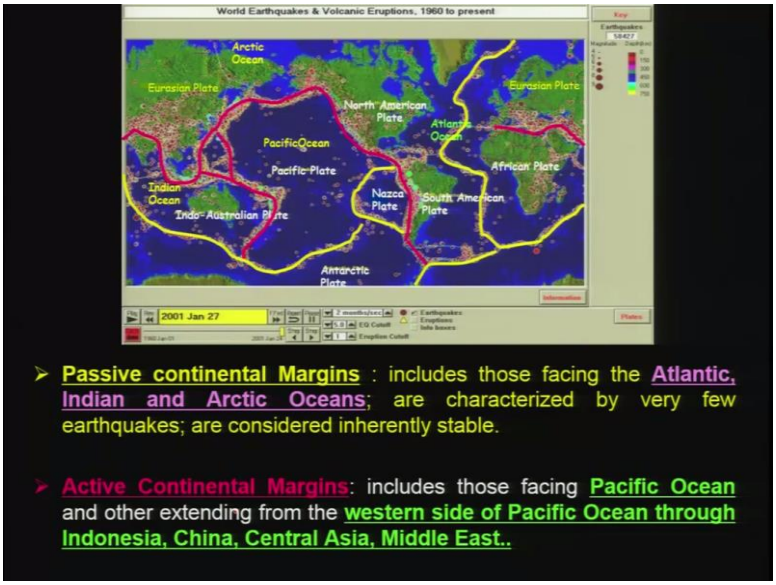

So, we discuss in the beginning that we have the all well aligned occurrence of the earthquakes along the plate boundary along with that we have also the alignment of the or the orientation of the distribution we could say that would be better at distribution of the volcanoes along the plate boundaries wherever we are having convergent plate boundaries where the new oceanic plate is sub ducting below the continental plate.

Now, this all plate boundaries marked in yellow are been classified as passive continental margins includes those facing the Atlantic, Indian and Atlantic, Indian and arctic oceans are characterized by very few earthquakes are considered inherently stable. So, these are the regions of course, they are the spreading centers here, but they are considered to be and passive continental margins.

Whereas, the marked with the red one all our active continental margins includes those facing Pacific Ocean or here and others extending western side of the pacific ocean through Indonesia, China, Central Asia and Middle East. So, these are all active continental margins which are responsible are the which are the areas which have triggered large and make earthquakes in past and even in the recent time.

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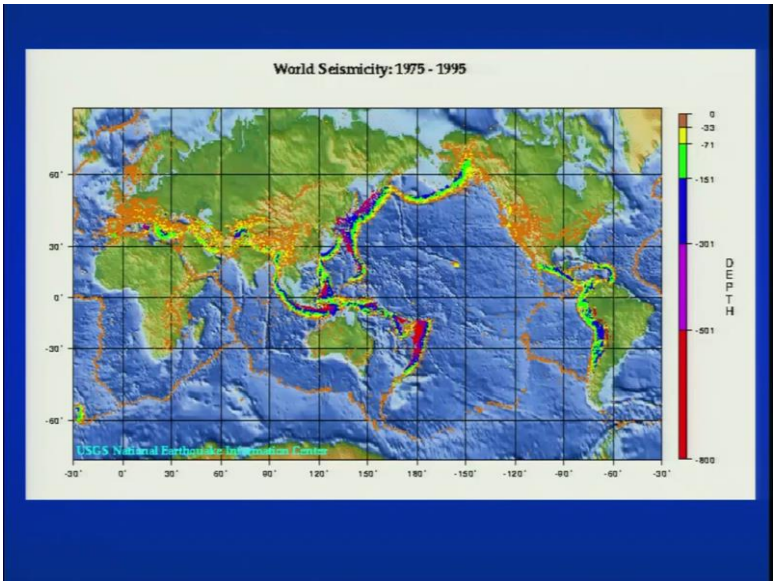

So, as I was talking about that the our worry basically is and that along with this plate boundaries, what different type of earthquakes with respect to depth will occur because this will be associated with what type of hazard we are going to experience.

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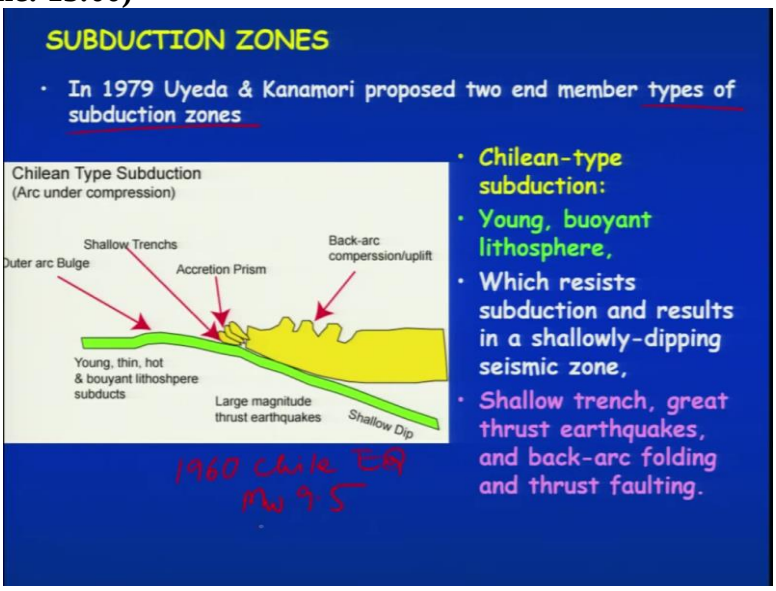

So, subduction zones basically are of 2 types which we have been classified in 1979 by Uyeda and Kanamori, they propose to end member types of subduction zone. So one is the Chilean type subduction zone. So, this is what we were talking about in one of the slide of convergent plate boundary that is between the oceanic plate and the continental plate that is Peru Chile subduction plate boundary.

So they are been classified as Chilean type subduction zone. Now in this what is been shown here is that you have an older oceanic crust within shallow depth. So, there are a few

important points which we should consider when we are classifying the types of subduction zones. So we have and shallow sub ducting plate which is going down with respect to the overriding plate here.

And the features which we will see on the surface is the back arc compression and uplift on the overriding plate in front of that we will see and the formation of the sediment secretion resulting into the formation of accretion prism and you will have shallow trench. So in the Chilean type will see the formation of shallow trench. The other one is the Mariana Trench, which is between the Philippine and the Pacific plate.

And since there is an and at the friction or the track is been confined to a very large area will also see a formation of bulge are that formation which will be experienced by the under thrusting plate and such plates which is we are classifying as an Chilean subduction zones are younger 10 hot and buoyant lithosphere subduction will occur so we have Chilean type subduction.
So we have young buoyant lithosphere which resist subduction and result in a shallow - dipping seismic zone. So we will have a very shallow-dipping seismic zone because the contact between the overriding plate and the under thrusting plate or the subducting plate will be in a very shallow nature and the area of contact will also be larger as compared to the others.

If you are having the sharp dipping sub ducting plate. Shallow trenches, great thrust earthquakes. So very large magnitude earthquakes will be experienced in this type of region and the best example of because this is the 1960 Chile earthquake magnitude 9.5. So one of the largest recorded or we can say that this was this is the only largest recorded earthquake on earth till date.
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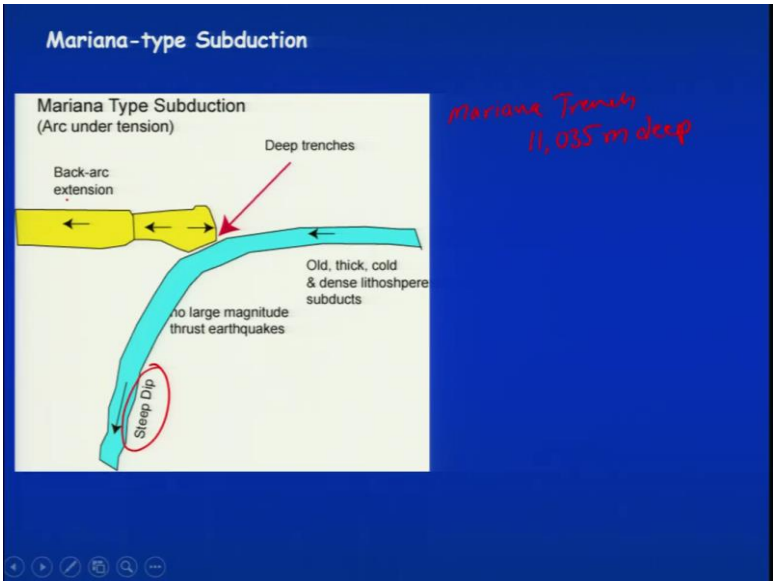

Now coming to another one is the Mariana-type subduction zone. So, hear that major difference is that there we are happy we are having the younger and thinner oceanic plate, but here we are having the older thicker and denser and those not those type of the plates that is in Chilean type is the lighter one compare to this. Now, the dip of this plate that is a subducting plate is steep.

And because the contact between the overriding plate and the subducting plate is not much as what we were looking at in the shallow type because in the shallow one what we were looking is at we are having a very wide area which has been covered. So shallow subducting plate will have a shallow dipping subducting plate will result into the shallow focused earthquakes.

But in this case, no large earthquake or no large magnetic thrust earthquake would be experienced. Whereas, other part is since the plate is steeply dipping. So have this will result into the formation of deep trenches and the best example is the Mariana Trench 11,035 meters deep. And the overriding plate will experience extension because of the pull of this subducting plate.

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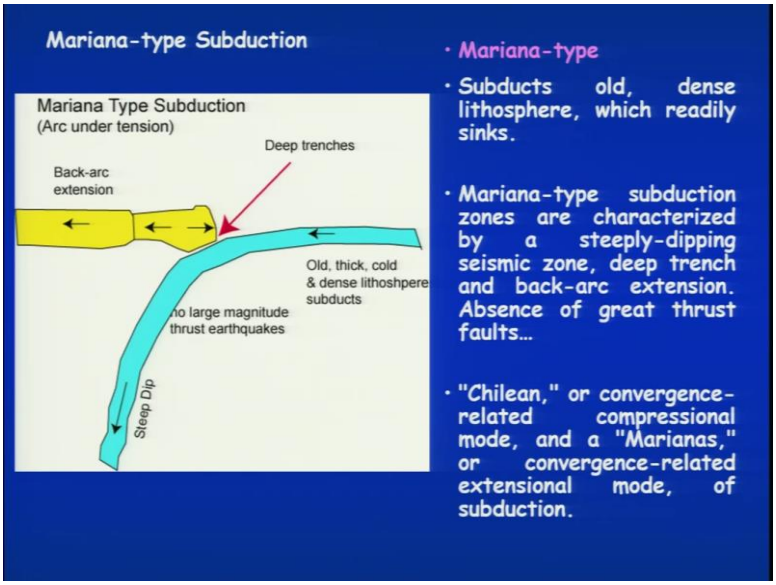

So Mariana Trench, or the Mariana type subduction zones, usually what we see as the sub ducts old, dense lithosphere, which readily sinks because of the older and thicker one or maybe can say the thicker as well as denser. So it will sub duct or has been pulled down in such a way that it will result into the steep dip. Mariana type subduction zones are characterized by steep dipping seismic zone deep trench back arc extension on the overriding plate an absence of great thrust falls.

So, this type of areas will not trigger large or great magnitude earthquakes so Chilean or the convergence related compressional mode and the Marianas or convergence related extensional mode of the subduction zone this is basically what we are looking at is the convergent plate boundaries. So, basic difference you should remember and this is everything is related to the seismic zone.

So we will have the absence of the great earthquake whereas in that, the other one that is Chilean one, we will have the presence of the greater of thrust falls and the earthquakes also and the best example of the Chilean type subduction zone that is in terms of the earthquake is your 1960 Chilean earthquake of magnitude 9.5.

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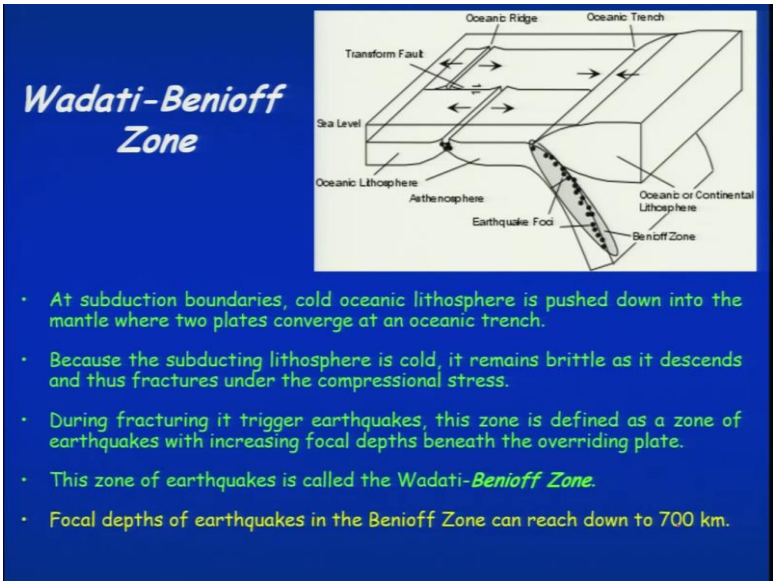

Now, this can be further explained with the help of this Wadati Benioff zone in basically, if you are having if we are talking about the different type of earthquake that is in terms of the focus of the earthquakes how deep they are occurring along the plate boundary. So, on the surface plate boundary as well as with the ocean which is sub ducting below will also result into the earthquakes.

So, at any subduction zone, usually what happens is the old oceanic lithosphere is pushed down into the mental where 2 plates converge at an oceanic trench. So, this portion is your oceanic trench and this is the convergence which has taken place because the subducting lithosphere is called it remains brittle in nature as it descends and thus fractures under the compression of stresses and this will be responsible.

This process will be responsible for triggering earthquakes. And so, during fracturing because, when they fracture, they will trigger earthquakes and this zone is defined as a zone of earthquakes with increasing focal depth beneath the overriding plate. So, increasing focal depth beneath the overriding plate, this zone of earthquake was been termed as, or are termed as Wadati Benioff zone.

Focal depths of earthquakes and Benioffs zone can reach down up to 700 kilometers. So, these are the deep earthquakes which are occurring. So you can imagine the subducting plate which is going down can trigger earthquake up to the depth of or at least up to the depth of 700 meters kilometers.

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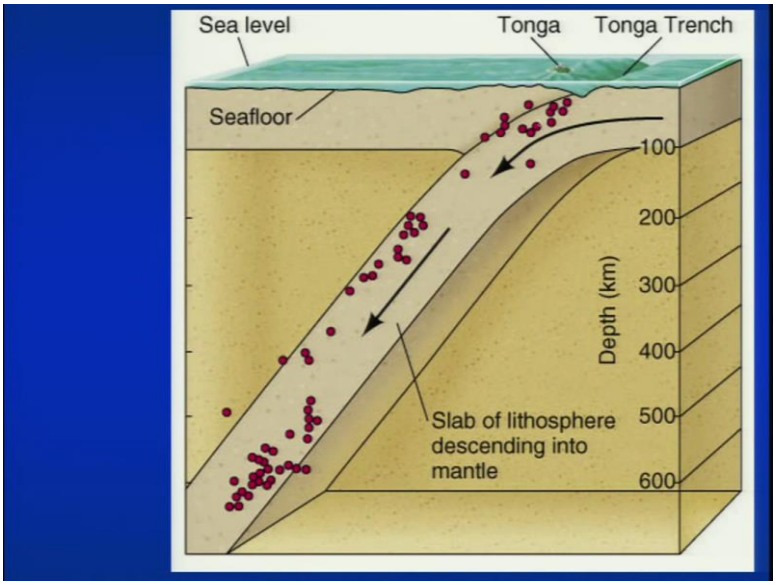

So, this is the same diagram which has been explaining that how the subducting plate will host the different type of earthquakes. These are the deeper earthquakes, which are going below 600 and around 700 kilometers. And then we have shallow earthquakes which can range less than even 100 kilometers. So, these earthquakes will be definitely dangerous.

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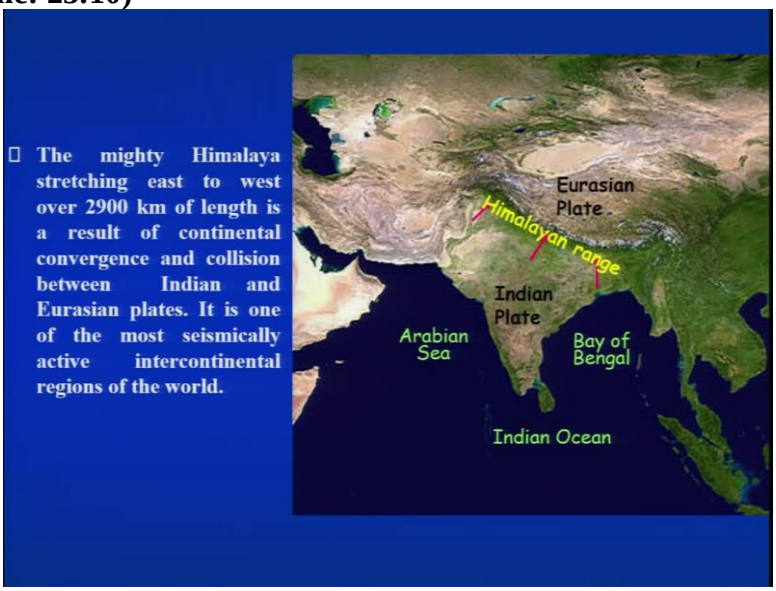

Now coming to the Indian part, as we have discussed that we have almost the mighty Himalaya was stretching from east to west over 2900 kilometers along this line here and this is one of the prominent plate boundary and example, which we have is the Himalayan range.

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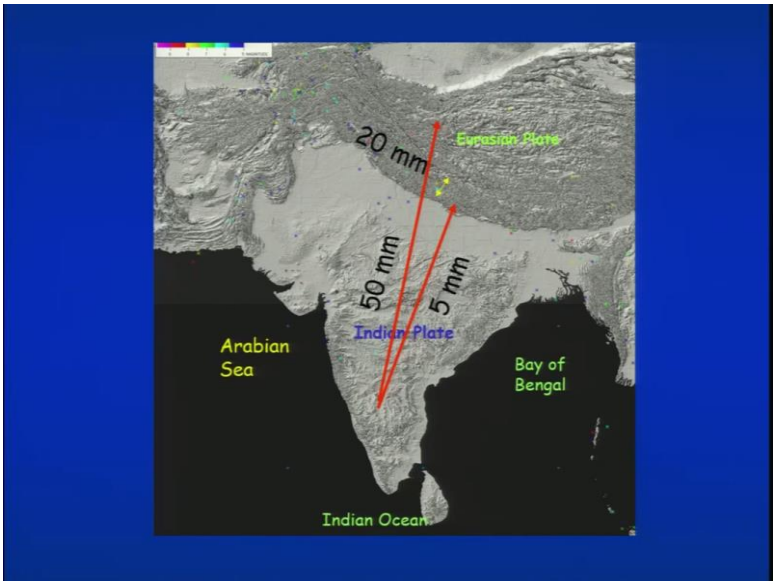

Now, this ocean which I am trying to explain is important for us in terms of the formation pattern, because this will like tell us that which area will be more active and which area is less active compared to the rest of the and the plate on. So, the Indian plate if you consider not the whole plate is colliding with the Eurasian plate, so, the boundary. That is the head-on collision which is occurring along this one is having more deformation as compared to the rest of the plate.

So, you cannot say that the rest of the plate is not under the compression but whole plate is under compression, but the rate of the deformation will vary from this region to this region. So, the based on the GPS measurements keeping this fixed point. And this is moving towards the north northeast direction and the direction of the Indian plate ocean the point from way from Bangalore towards the Eurasian plate.

It is around 50 millimeter and between this point and write up to the Himalayan front, it is consuming around 5 millimeter. So, still 45 is left out from this one. So, across Himalaya the deformation, what has been consumed is around 20 to 21 millimeter. So, this portion is more consuming more of the total deformation between the 2 that is the convergence rate. Hence, this will be the area of the hosting large amount of seismicity

Are higher seismicity and the number of earthquakes as compared to this one because the deformation is larger here and more amount of strain is been developing. So, this vary area will become the area of high strain and this region is the area of low strain. So, the recurrence

we between the 2 earthquakes will be larger whereas the recurrence between the 2 earthquakes will be lesser here because the deformation is higher as compared to this region.

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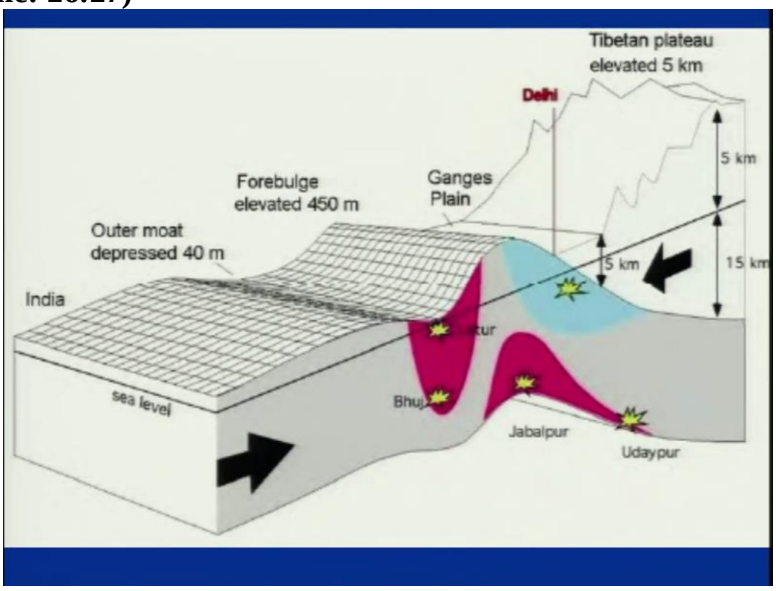

So, as I told that whole plate is flustering it is not the only the portion which is in contact with the addicted contact between the Indian plate and the Eurasian plate, only that boundary is active, but the whole plate in a sense is under deformation and this is one of the reason why we experience the earthquakes like and Latur and Bhuj in Jabalpur and so on.

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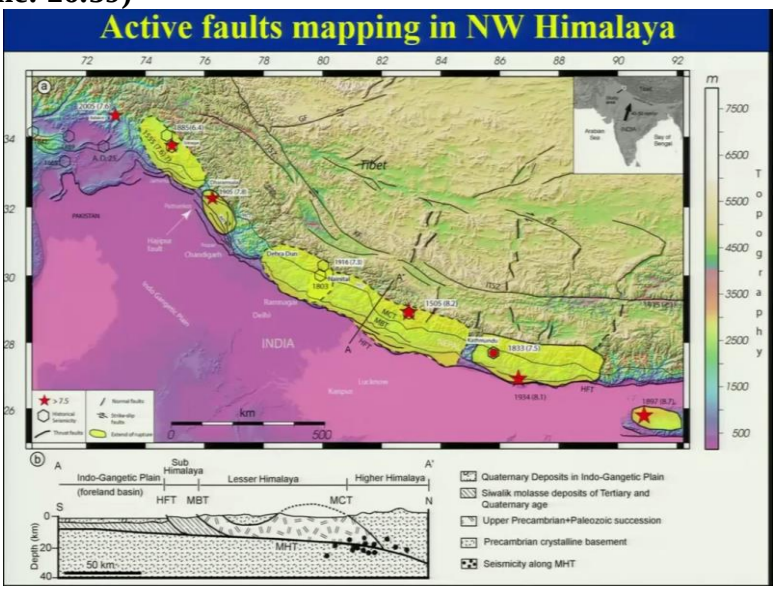

So, slowly we will move towards the part of the paleoseismology. But before we get into that the most important for us as that what is the pattern of distribution of earthquakes in this region that is the important one. For example, if we look at the Himalayan arc here, we have some that the in terms of the historical records, some information is available.

Which has been put we have put here like the mainstream or the historic earthquake of 2580 and 1869, 1842 and so on 1885 so for whatever the records that are available with us in historical Chronicles, we have tried to incorporate that and the best example which we have or the written records which are available was from the records of 20th century. That is the 3 major earthquakes which were been triggered.

In Himalayas were 1905 with the magnitude of 7.8. And we had 1916. And then another one major one was 1934. And are somewhere here that is in the eastern side that is in 1950, upper some earthquake. So the distribution of this false are important and that what we are going to talk about and what type of earthquakes and how many earthquakes. We have been experienced in the past.

Of course, as we have been talking right from the beginning that we will go up to 10,000 years for us it is important for the paleoseismic records. So, we will try to see that in the past 10,000 years how many earthquakes were been triggered along the individual fault and which fault is more active with respect to the another one. That is an another important part of this study. So I will stop here and we will continue in the next lecture.