Introduction to Engineering Seismology
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Lecture – 54
Seismotectonics of India

So vanakkam, we will continue our lectures. So last class we have been discussing about the Indian Seismicity, okay. We have been discussing about the some of the earthquakes how the damage distribution was reported to understand, what is the damage the extent? What is the radius it affect? What is the; this one? But we have observed that most of that that we do not have direct record, okay of the main shock, most of that what we discussed, okay even up to Killari earthquake, okay.

So, today class and then the subsequent classes we are going to talk about the tectonics of India. So, why tectonics of India, because we have to understand, where these earthquakes are origin, how it origin, so that; there are some of the parameters which is need to be considered or assumed further seismic hazard analysis will be obtained from these kind of tectonic settings, okay.

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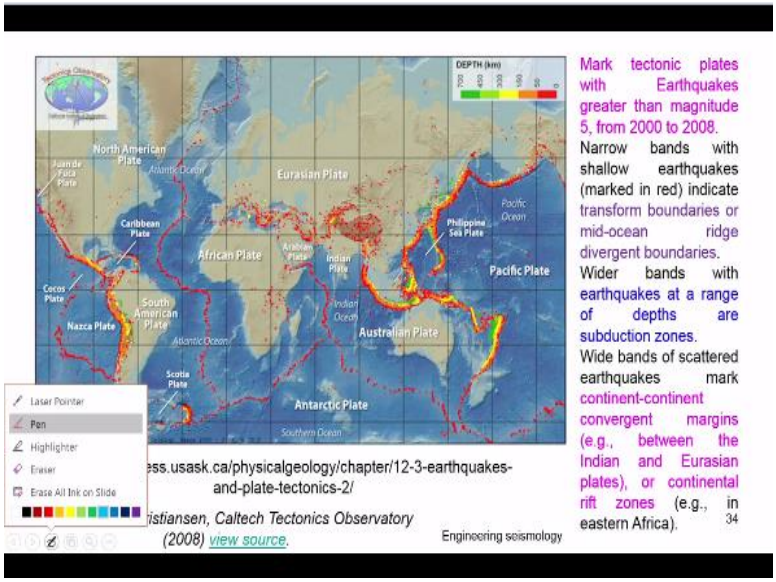

So if you look at the plate tectonics of the entire globe, so you can see; okay, so, this is the plate tectonics of entire plate. So, this is basically your Indian plate, correct. So, this is the entire

Indian plate, Indian; Australian plate you can see. This is the Eurasian plate. So, this information you can obtained basically from this website, okay. You can see the related publication, so that these maps are marketed.

So, here people have plotted the earthquake, okay, of the magnitude 5 and above from 2002 to 2008, okay, the above magnitude 5 for the 8 years. So, here you can see that; okay so, the depth up of the earthquake also mentioned. The red indicates 0 to 50, 50 up to 150, then followed by the yellow 300 and the green is 450 and 700 so where you can see the subsequently, the color composition of the; these events, which indicate here the depth of the earthquake occurring at this particular place, okay.

So, if you concentrate on the Indian region, which is very important for our discussion, okay. So, the narrow band, okay with the shallow earthquakes marked in red indicate that transformed boundaries or mid-oceanic ridges are divergent boundaries, okay. So, those are all the places where you get a very narrow, shallow focus of the earthquake, you can see, okay. So, this one, narrow band, there is no red.

So the wider band, okay; so with the earthquakes at a range of depth are subduction zones. So the wider band with a thicker band like this, okay these are all the thicker with a various depth of earthquakes are occurring in the subduction zones. So, wider band scattered earthquakes marked continental-continental, so this is the one where you can see the wider band, okay, it is happening in the continental-continental margin, okay.

So particularly, we have to concentrate on this place where Indo Eurasian plate and continental rift zone are exist in this area, okay, which gives plate tectonic evidence and the earthquake. You can see this earthquake most of the earthquakes are located in the shallow depth and few earthquakes over the particularly this area, okay. So the earthquakes on this location, and as well as this location where you have that slightly deeper earthquake, okay.

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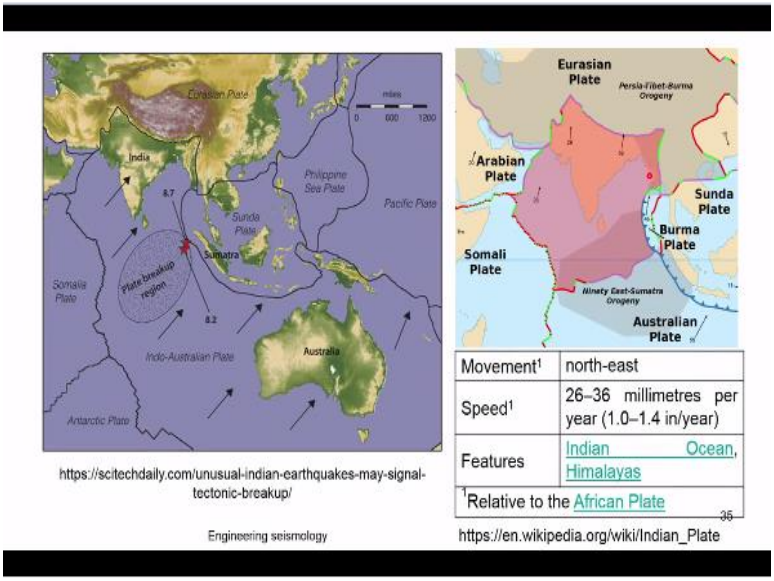

So you can see again, the plate tectonics in detail here. You can see this is the Indian plate. So the arrow indicates like how much the; it moving towards this one. And also here, you can also see the topography, okay, so like the mountains and this region and this is like the agriculture or the plane where lot of agriculture is taking place, okay. So, that this is the basically the separating, okay portion of the; your Australia and Indian junction plate, okay.

So, this is below the sea basically. So, where you can see there was even earthquake reported there, the arrow indicates here this one. So here also you can see the moment, okay, so, how the plates are moving. So, basically this is our Indian plate, okay. So, the entire plate is called us Indo Australian plate. The portion which comes separates, okay, this is the Indian plate. So, it is most actually northeastern part this plate moves northeastern part, okay.

The speed is given in millimeter per year. So, how much it moves, okay. By millimeter per year is mentioned as this one with related to the African plate, okay. It is not the actual movement what is taking place with reference to the African plate because a particular data was used or extracted here was actually somebody was writing the African plate kind of studies, they related how the Indian plate is moving with respect to their plate. So, that is how you can see the; this one. So, this example gives, okay, so how the; our plate, okay, a different portion how it behaves and moves the details about the; your plate tectonics.

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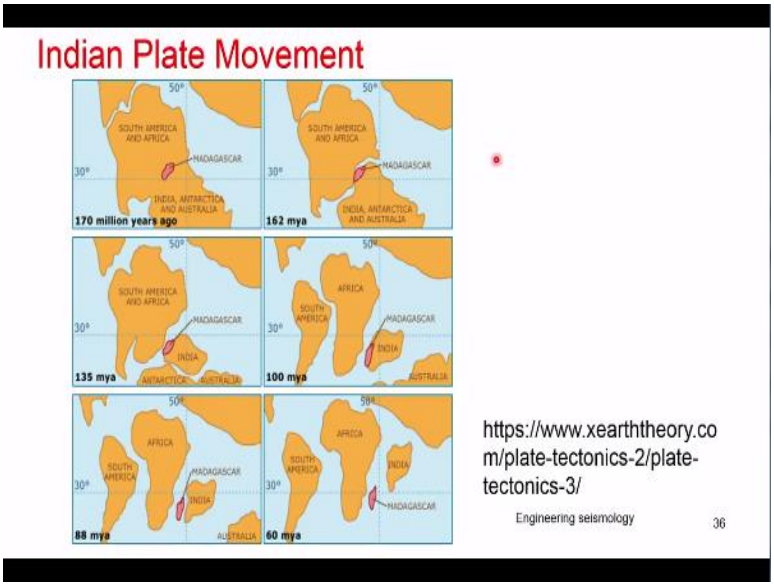

So, this you can even well relate with the; our continental drift theory, okay. So, we have seen that when we are talking about the continental drift, okay, theory. And then also how the different continents are formed? You can see that about 170 million years ago, okay, this was that island Madagascar Island you can see this is a South America and Africa together. And India, Australia and Antarctica are together.

So same plate, you can see this is the Madagascar region, okay. This is the South America and Africa. So, where the India, Australia and Antarctica are separated, where the Madagascar is in between, okay. So then it is; this was actually 162 million years ago. So, about 135 million years ago, so these three regions are completely separated. You can see South America and Africa. But still, those two are not separated.

Both the continents are together. The India and Madagascar are together. But, Antarctica and Australia were separated. Those are together, but moved from India. Then 100 million years ago, South America broken, okay, it does then separate Africa. India and Madagascar together and Australia was different. So, similarly the South America, Africa, Madagascar, India, so this is about 88 million years, 60 million years, so the Madagascar moved close to the Africa not anywhere close to India. So but, India is Island, okay.

So this evidence you can find from that this website where they have made a detailed discussion about that. So here you can understand that when I am talking about the history of southern India particularly, when I discuss about the India once it was the island, it is called as a Kumari Kandam, okay. So you can see that this was a island, okay where the origin Indians are; were there and even the some people Madagascar region and Africa, okay, so South America.

They are all together by the races, okay, by their appearance, okay, with their DNAs, because these are all together at some time. So the people who are lived on 170 million years ago, their genes are carried by the; even your present generation it has been proved people who are taken DNA test and proved that these are all people are sharing the similar DNA set up, okay. So, that is proved that. So, India was island about 60 million years, okay.

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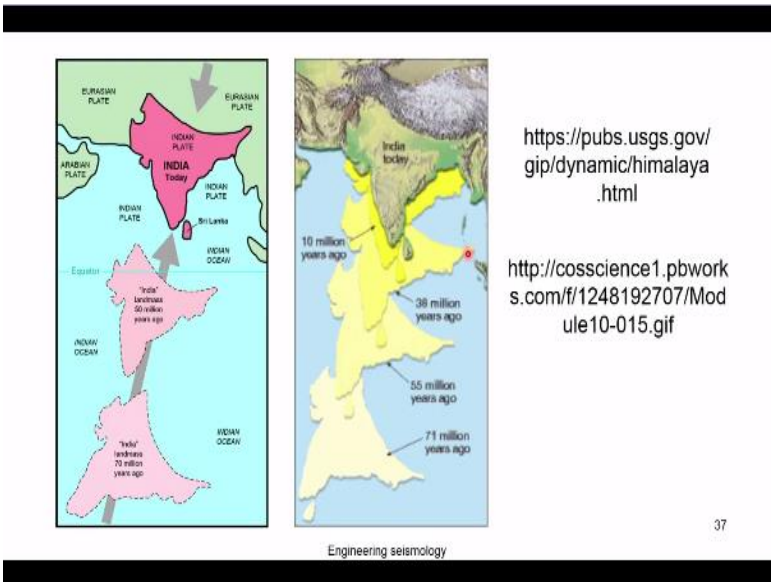

So, then basically, as we said that, so from the 60 million years, okay, so the India keep moving towards the northeast direction, okay. So you can see here, India land mass 70 million years ago, this is the land mass island. So, the India land mass 50 million years ago, okay, then actually before that there is no Sri Lanka, okay. The Sri Lanka was formed, okay, after 50 million years you can see.

So but even the maps they show together, but it is a graphical illustration, there is no detailed analysis kind of thing. Here you can see that, 71 million years, 55 million years, 38 million years,

10 million years and present. So this shows the India was continuously moving towards the northeast direction before hitting Eurasian plate, after hitting Eurasian plate the speed has been reduced that is what we discussed.

So it was earlier moving with the speed of 20 centimeter per year, now it is moving with the speed of 5 centimeter per year. So, that is what you can see. You can see the formation of the India where the India become Island, become a peninsula. Peninsula means three side water and one side land. Island means all the side you will have that water. So that was the evidence where you can see the geologically our terrain, okay.

Our land mass keep moved, tectonically keep moved, tectonically keep disturbed, okay. Tectonic forces are helping them to move, okay. That is what you can see from this kind of evidence under the theories.

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So the northward moving Indian plate first collide with the south edge of the Tibetan Eurasian plate. So, this continent-continent collision, okay, convergent boundary kicked-off the Himalayan Orogenic Process. So, that is a formation of mountain, okay Himalayan formation of mountain started by the Tibetan Eurasian plate by the Indian plate hitting leading edge of the plate oceanic crust carrying the India's subducted beneath the Eurasian plate.

The land mass continental crust collide and pushing up the land mass. The collision continues even today so based on the recent Global Positioning System, the India plate moves nearly 5 centimeter per year, about 2 inches growing in Asia, which is close to your nail growth. If you leave your nail without cutting 5 centimeter per year, it grows roughly. So, that much our Indian plate is basically moving.

However, GPS data also suggests that Tibetan plate pushes only about 3.2 centimeter, 1.3 inch into the Asia each year. So, both of them are hitting and then growing, okay. That is what is happening actually.

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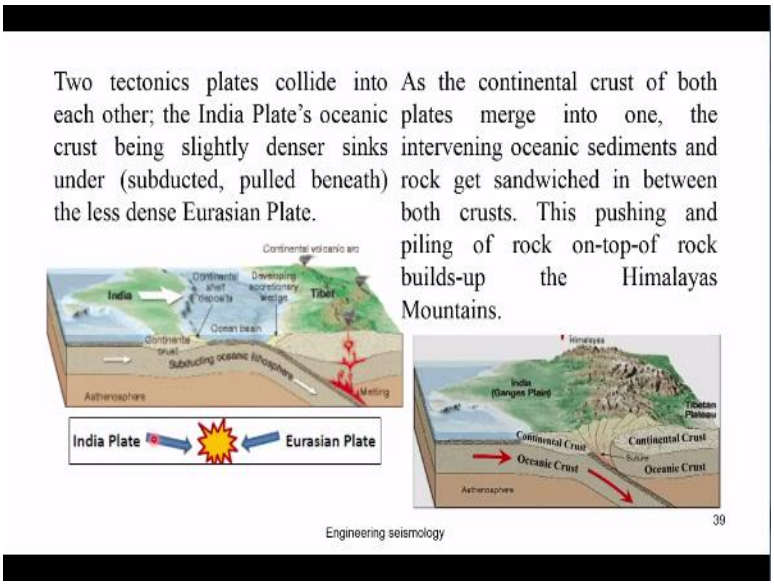

So this concept we can discuss that, as we told that so; the once the India was a island. So, the related land, okay, so, the Indian portion this is India. This is a portion which is sea-floor, okay, water and the sea-floor. So, this was keep moving like this, this is the typical graphical illustration of the before hitting the Eurasian pate. So, the two tectonic plates collide into each other. The Indian plate oceanic crust being slightly denser and sinks under the subducted to pull.

So this Indian plate basically is slightly denser, because of that, it gone down the; above this plant, okay, which was thin, which was above. So, as the continent crusts, both the plate merges into one, the intervening oceanic sediment and rock get sandwiched in between both the crust, okay. So, this is what happened here, both the crusts (()) (12:04) gets sediment.

And this pushing; pulling; the piling up rock on-top-of the rock behind the Himalayan mountains where the mountains are getting built up, you can see the mountains are getting built-up on this place. So this is; so that is the reason, there are many sea fossils, okay has been found in the Himalayan Hill even though Himalaya is the highest hill in the world, okay. You can find a sea fossil, sea fossil means you know fish type, okay turtle type or any other sea animal, okay.

Their fossil has been found in the Himalaya that clearly shows that the India was once island which is controlled by the; I mean surrounded by the sea that sea-floor due to hitting up that the sea-floor raising and that raises whatever the animals who are lived there and is died and buried that fossils are you know actually (()) (12:58). You can see the continental plate and then the oceanic crust goes (()) (13:03) crust, then the sea crust.

And all this the complex fracture, okay taking place, which building help to Himalaya to grow, basically this is the force which is taking place like this and like this, where it pushes, and then this is goes up, okay. So this is basically the continental-continental coalition, okay.

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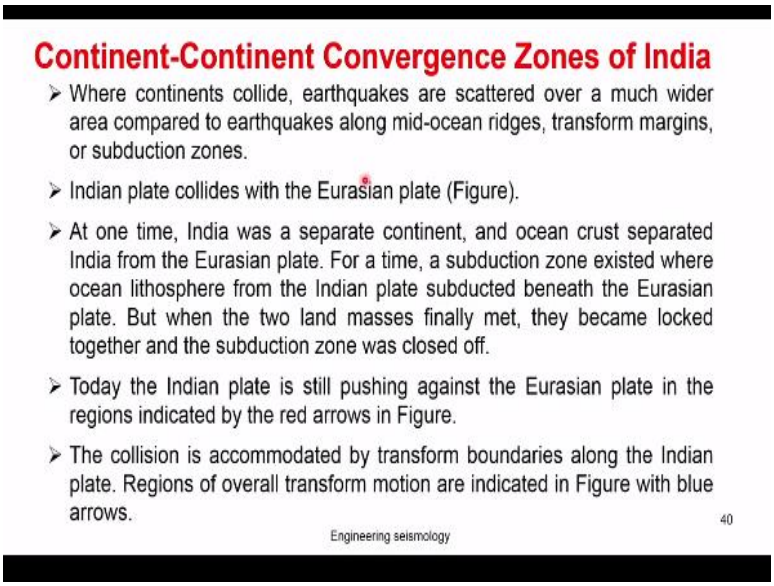

So these convergences the zones in the Northern Himalaya whereas continent collision earthquakes are scattered over a much wider area, which we have seen that compared to earthquake along the mid-oceanic ridges? So, that is the evidence, where you can see continent

to continent collision. So where the area of the earthquakes are wider, okay, because of the large land formation. Indian plate collide with the Eurasian plate, which we have seen.

At one time, the India was separate continent. Oceanic crust separated India and Eurasian plate. At a time, subduction zone existed where oceanic lithosphere Indian subducted beneath the Eurasian plate. But, two land mass finally met. They become locked together and the subduction zone was closed. So earlier, this Indian continent to continent close was subduction zone, okay under a sea.

But, when the two land mass are hit together, the subduction has disappeared it became a continent to continent convergence zone, okay. So subduction became a convergence zone in the geological age. Today the Indian plate is still pushing against Eurasian plate. The region indicated by the red arrows in the figure next, so there you can see how the; it is pushing. So you can see the here the earthquakes, okay. So the collision accommodated transformed boundaries along the Indian plate. Regions are overall transform motion indicated in the figure with the blue arrows, okay.

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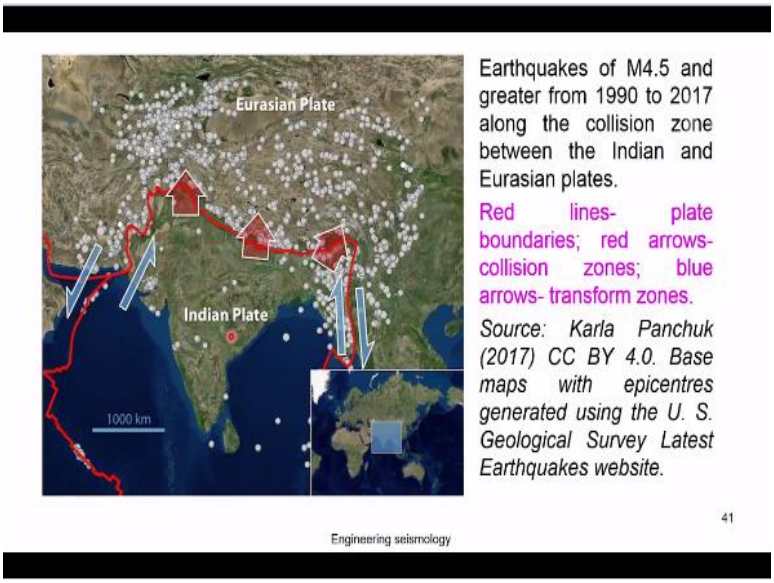

So this is basically; so the blue arrows. So, you can see here basically, this map. So, this is how the Indian plate pushing. And these boundaries, okay these are all the boundaries become a continent to continent subduction. And then now it become a; so, the more or less like the

convergence zone up action in these regions. But this joints, okay because of this action, this is becoming a transformed boundaries, okay.

The northeast and northwest of the plate boundary act in the action up transformed, okay boundary action. So, that we have to remember. The earthquake of magnitude 4.5 and above from 1990 to 2017, the researchers have plotted this. This was taken from this particular source. So, where the collision zone between the Indian and Eurasian plate you can see, the red line plate boundaries and red arrows collision zones, blue arrow transformed boundaries. You can see there, the wide distribution of the earthquake.

So when it comes to here, the distribution of earthquakes are almost like a thin kind of things when compared to this size here you can see the white distribution of the earthquakes in that region. So, they also marked some of the earthquakes, which you have seen in there previously. This is the area where this map is plotted you can see this, okay.

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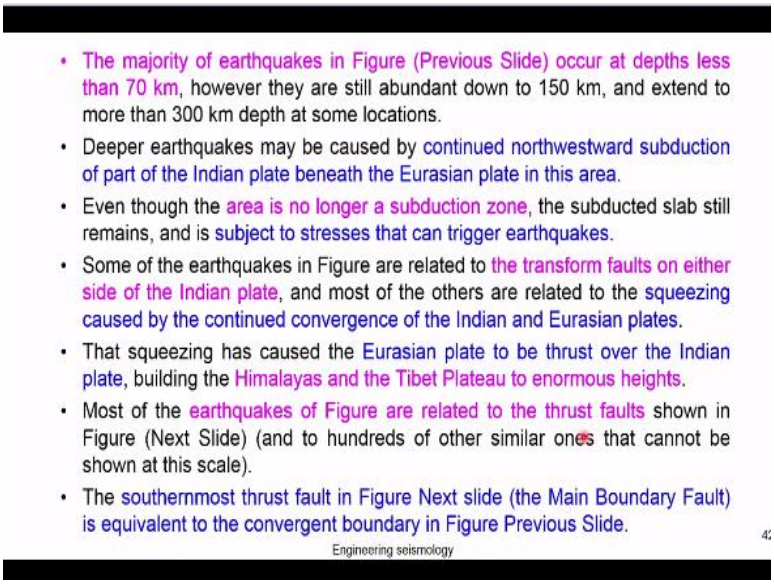

So the majority of earthquake in figure, okay occurs at the depths less than 70 kilometer. However, they are still abundant down to 150 kilometer and extend more than 300 kilometer depth at some locations, okay. The deeper earthquake may be caused by the continued northwestern subduction part of Indian plate beneath the Eurasian plate. So the deeper earthquakes are happening due to the subduction action at the Indian and the Eurasian plate.

So, which is occurs very rarely, because the subduction was almost was there long back, okay. Even though area is no longer subduction zone, subducted slab still remains and is subject to stress can trigger the earthquake. So, which; indicates that, there may be possibility of the subduction earthquakes also in this region. So, apart from that to crustal shallow earthquakes. Some earthquakes in the figure are related to the transform fault either side of the Indian.

So the both the side up India basically we have that transformed boundaries. Most of the other areas related squeezing caused by the continued convergence and the Indian Eurasian plate. The squeezing has occurred Eurasian plate to be thrust over Indian plate building Himalaya and Tibetan plates enormous height, okay. These are all hitting together and growing that's why Himalaya is keep increasing their height.

Most of the earthquakes figure are related to the thrust fault shown in the; this one and the hundreds of other similar ones cannot be shown in this case. The southernmost thrust figure next slide; main boundary to the convergent boundary of the previous slide.

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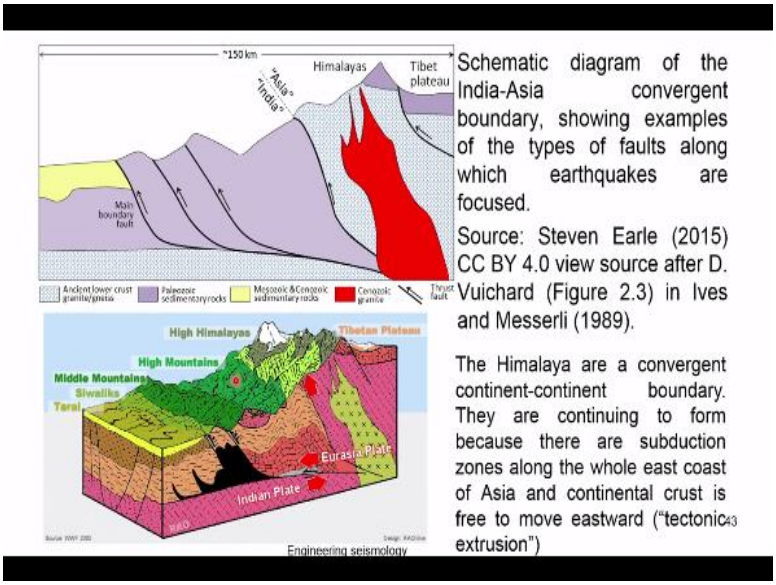

Schematic diagram of the India-Asia convergent boundary, showing examples of the types of faults along which earthquakes are focused.

Source: Steven Earle (2015) CC BY 4.0 view source after D. Vuichard (Figure 2.3) in Ives and Messerli (1989).

The Himalaya are a convergent continent-continent boundary. They are continuing to form because there are subduction zones along the whole east coast of Asia and continental crust is free to move eastward ("tectonic extrusion")

So you can see here, so how the thrust fault formed due to this action. How these earthquakes are oriented. So, the schematic diagram of India-Asia convergent boundary showing the example type of fault system the earthquakes are focused, okay. The fault system are here focused. So,

these are all helpful to identify your ground motion prediction equation, okay. What type of tectonic setting it has been developed?

Because, as we have seen that, the number of equation prediction equation developed for India is lesser when compared to seismic activity. So that if you want to use a equation developed elsewhere, how do you consider, okay. That is what is given. So, the Himalayan are the convergent continent to continent boundary. They are continued to form, because their subduction zone along the whole east coast of Asia continental crust is free to move eastern wards, okay. So, that is what it says.

So you can see there, the cross-section, typical cross-section represented by preparing a graphics figure. You can see the what are the; like Terai, Siwalika, Middle Mountain, High Mountain, High Himalayas, Tibetan plateau, the Eurasian plate and Indian plate, okay. How it moves, you can see here. How it moves? All those information you can get. So from this, it is very clear that, okay, our India is formed by hitting a two plate. So, is once it was a subduction zone, then now it is become a continent to continent divergence zone.

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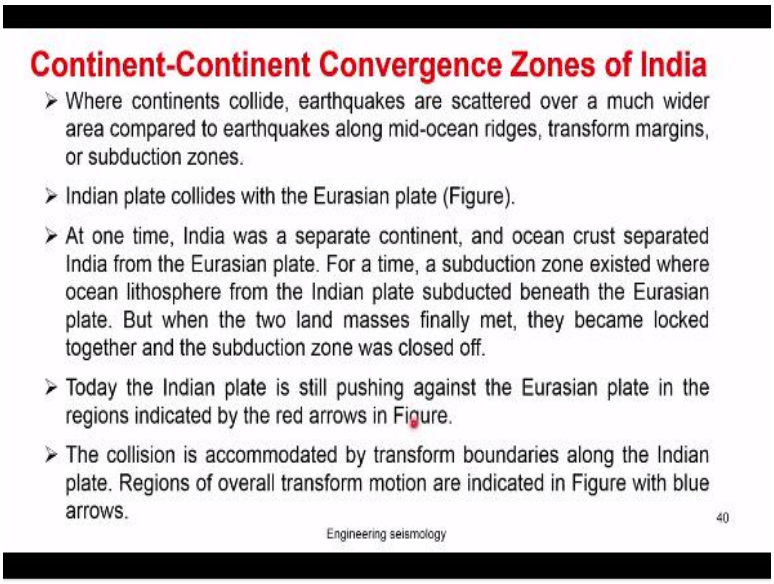

Convergence zone; continent to continent convergence. So there is a possibility of active shallow convergent zone earthquake as well as the subduction zone earthquake in the region. Generally, subduction zone earthquakes can occur very deep, okay. So that 350, 300 kilometer, because of

deep in nature, the seismic force released by these earthquakes are not much effect the cause damage. But at the same time, we should not ignore that, and then; but the earthquakes which is caused by the continent-continent.

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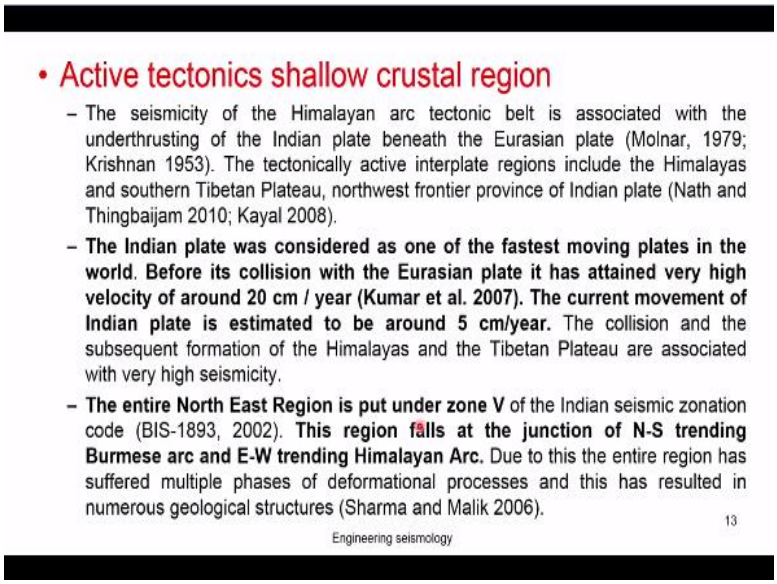

So convergent action which is your active tectonic shallow crustal nature, okay. So most of the fault in the region thrust fault, both the eastern western side we have the transformed boundaries so where the earthquakes can occur.

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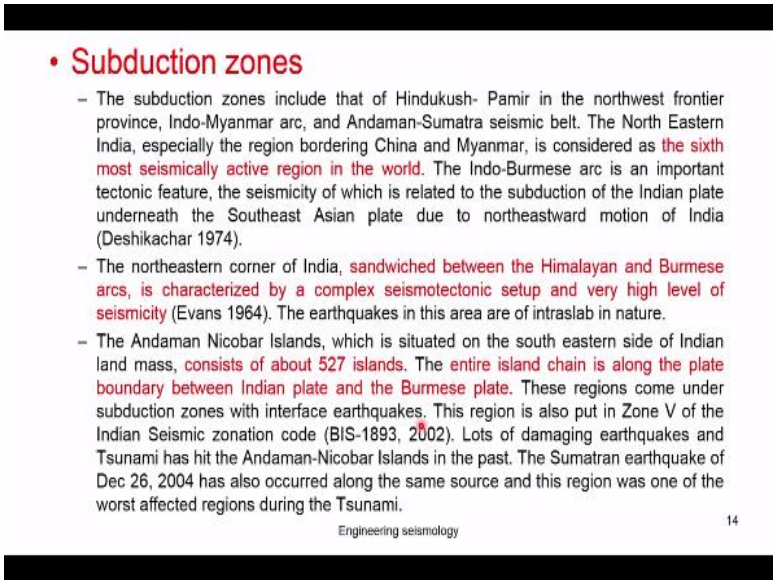

So this is about the; I am talking about the Northern India more on a Northern India. So I am not talking about the subduction zone of the Andaman and Nicobar area, because; that is also very

important, but the number of islands there was only so much cover. So our Indian land mass in this area was negligible so that because of that we are always here after talk about the Peninsular India and our Northern India and North West and North Eastern part of India and it is related tectonic activity.

So these are all we are going to discuss in the upcoming classes, okay. We are going to talk about more on our Indian tectonic this one particular the areas where you can see this part, okay. So, this region we will be discussing, and this region will be discussing, and this region. So what are the different geological studies are done? How the tectonic people try to understand? And we will try to also discuss about that.

Because, our most of the populations are located on this part, even though this subduction zone also part of Indians tectonics, but we do not give much attention, there only we will concentrate much on here. So, these settings will help you to identify what type of nature tectonic earthquakes are occurring? What depth it is occurring? What is the range of magnitude occurring? So, those are all the information you get from the tectonic settings. So we will discuss this further in the next class. So, thank you very much for watching this video. So I will meet you in the next class. Thank you.